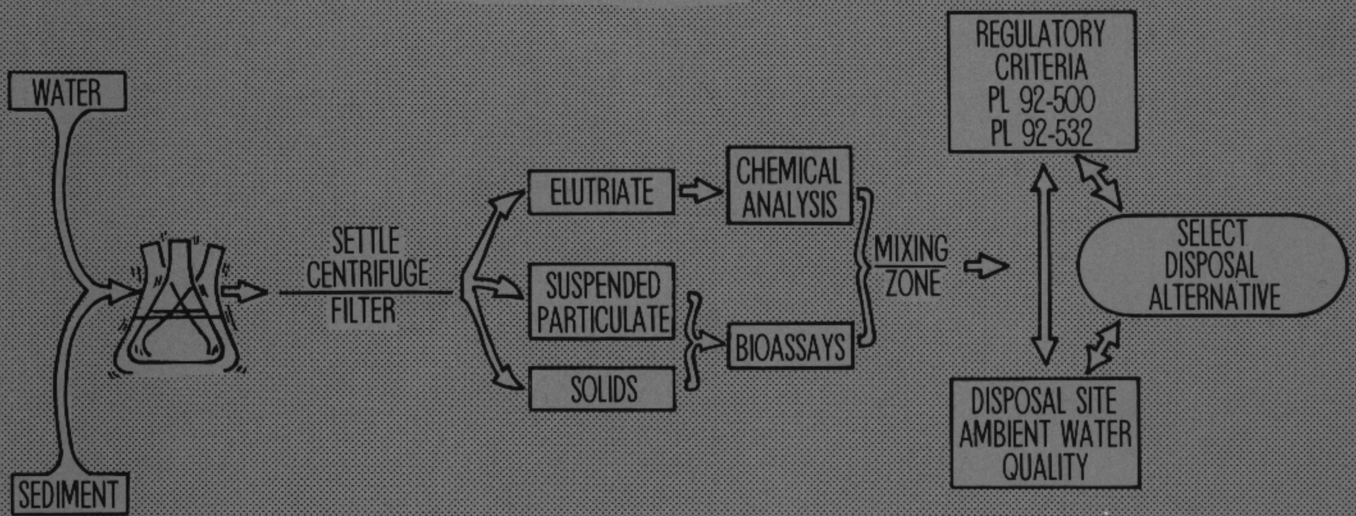
SYNTHESIS OF RESEARCH RESULTS

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT DS-78-6

EVALUATION OF DREDGED MATERIAL POLLUTION POTENTIAL



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THE DMRP SYNTHESIS REPORT SERIES

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This report synthesizes data from the U. S. Army Engineer Waterways Experiment Station, Dredged Material Research Program (DMRP), Task 1E. Task 1E consisted of seven research projects (work units) that investigated the pollution properties of dredged material and procedures for determining their potential for effect on water quality and aquatic organisms.

The short-term impact of dredged material on water quality and aquatic

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organisms is related to the concentration of chemically mobile, readily available contaminants rather than the total concentration. The Elutriate Test, which measures concentrations of contaminants released from dredged material, can be used to evaluate short-term impacts on water quality. The only constituents generally released from dredged material are manganese and ammonium -N. Elevated concentrations of these constituents, however, are of short duration because of rapid mixing and are of low frequency due to the intermittent nature of most disposal operations. The short-term chemical and biological impacts of dredging and disposal have generally been minimal.

Longer term impacts of dredged material on water quality have generally been slight and can be evaluated by means of the Elutriate Test and analysis of the mobile forms of sediment contaminants. No significant long-term increase in water column contaminant concentrations has been observed at any aquatic disposal field site.

The greatest hazard of dredged material disposal is the potential effect of the material on benthic organisms. Most dredged material has not proven particularly toxic. Some dredged material, however, can be extremely toxic or of unknown toxicological character. Benthic bioassay procedures are now available which can identify this toxic dredged material.

PREFACE

This report synthesizes the results of the Dredged Material Research Program (DMRP) Task 1E, Pollution Status of Dredged Material. The DMRP is sponsored by the Office, Chief of Engineers, U. S. Army, and is being managed by the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The objective of Task 1E was to develop techniques for determining the pollutional properties of sediments and their potential for effect on water quality and aquatic organisms. This report is based on the reports of the following DMRP work units:

Work Unit No. 1E03. Contract Report D-74-1, "Literature Review on Research Study for the Development of Dredged Material Disposal Criteria," by G. Fred Lee and Russell H. Plumb, Jr., University of Texas at Dallas, Richardson, Tex. Contract Report D-75-4, "Research Study for the Development of Dredged Material Disposal Criteria," by G. Fred Lee et al., University of Texas at Dallas, Richardson, Tex.

Work Units No. 1E03A and B. Technical Report (in preparation), "Field Testing and Verification of Dredged Material Disposal Criteria," by G. Fred Lee et al., University of Texas at Dallas, Richardson, Tex.

Work Unit No. 1E04. Technical Report D-76-7, "Selective Analytical Partitioning of Sediments to Evaluate Potential Mobility of Chemical Constituents During Dredging and Disposal Operations," by James M. Brannon et al., EL, WES.

Work Unit No. 1E06. Technical Report D-77-3, "Biological Assessment of the Soluble Fraction of the Standard Elutriate Test," by Peter J. Shuba, Joe H. Carroll, and Karon L. Wong, EL, WES.

Work Unit No. 1E07. Technical Report (in preparation), "The Long-Term Release of Contaminants from Dredged Material," by James M. Brannon, Russell H. Plumb, Jr., and Issac Smith, Jr., EL, WES.

Work Unit No. 1E08. Technical Report (in preparation) "Biological Assessment of Methods to Predict the Potential Environmental Impact of Open-Water Disposal of Dredged Material," by Peter J. Shuba et al., EL, WES.

This synthesis report was prepared by Mr. James M. Brannon, EL, under the general supervision of Dr. Robert M. Engler, Manager of the Environmental Impacts and Criteria Development Project, and Dr. John Harrison, Chief of EL.

Directors of WES during the report preparation were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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EVALUATION OF DREDGED MATERIAL POLLUTION POTENTIAL

PART I: INTRODUCTION

Background

1. Sediment contamination has generated increasing concern that dredging and disposal of these sediments may adversely affect water quality and aquatic organisms, focusing attention on open-water disposal. Moreover, the Corps of Engineers (CE) has dredged an average of 290,000,000 m^3 annually, approximately half of which is disposed of at open-water sites.

2. The development of specific criteria and guidelines for evaluating and projecting the pollution potential of dredged material is legislatively assigned to the Environmental Protection Agency (EPA) in consultation and conjunction, respectively, with the CE. The enactment of Public Law (P.L.) 92-532 (the Marine Protection, Research, and Sanctuaries Act of 1972) and P.L. 92-500 (the Federal Water Pollution Control Act Amendments of 1972) gave responsibility to the CE to regulate the transport and disposal of dredged material and to actively participate in developing testing guidelines and criteria for regulating dredged material disposal. The focal point for the research on these procedures was DMRP Task Area 1E.

Scope of DMRP Task 1E

3. Initial investigations were primarily concerned with further developing, refining, and field testing dredged material disposal criteria currently in use. These included investigations of the Elutriate Test (test for mobility of chemical constituents) and initiation of development of sediment bioassay procedures. Related criteria development research centered on field testing and verification of recently developed procedures.

4. Related investigations developed specific methodologies. Selective extraction techniques were developed to show the location of the various chemical constituents within sediments. These were followed by long-term leaching studies. Liquid (solution phase) bioassay studies were conducted using algae, bacteria, and protozoa. Finally, benthic (bottom organism) bioassay procedures were developed for predicting the effects of depositing contaminated sediment on or near benthic animals.

5. Sediment samples were obtained from throughout the continental United States (Table 1). This wide range of samples (pristine sands to highly contaminated sediments) ensured that the methods and criteria developed would be applicable throughout the United States.

6. Results of DMRP Tasks 1A, 1D, and 1C, in addition to results of Task 1E have provided a sound technical basis for development of more meaningful and implementable regulatory criteria. Task 1A (field studies) verified the short- and long-term biological, chemical, and physical impacts of open-water disposal. Task 1C provided information on the short-term mobility of chemical constituents caused by open-water disposal and longer term release after the material settles to the bottom. Task 1D provided data on physical and chemical processes that affect biological uptake, utilization, and longer term effects of chemical constituents upon aquatic ecosystems.

Chronology of Dredged Material Criteria Development

7. Prior to about 1970, the only regulatory control of dredging, construction, and related activities was under Section 10 of the River and Harbor Act of 1899. In the late 1960's, concern over possible environmental problems increased. Concern over dredged material disposal was initially greatest in the Great Lakes region and resulted in the request of the Federal Water Quality Administration (FWQA, predecessor of EPA) that the U. S. Army Engineer District, Buffalo, initiate studies on the chemical characteristics of selected Great Lakes harbors. The harbor sediments were analyzed using methods developed to

Table 1

Locations of Sediment Sampling Sites of the Task 1E Work Unit Investigations

Work Unit No.	Type of Collection Site	Sampling Locations: Water Body	Sampling Locations: City, State
1E03	Freshwater	Trinity River	Dallas, Texas
	Estuarine	Mobile Bay	Mobile, Alabama
	Estuarine	Houston Ship Channel Turning Basin	Houston, Texas
	Estuarine	Bridgeport Harbor	Bridgeport, Connecticut
	Freshwater	Ashtabula River	Ashtabula, Ohio
	Estuarine	Port Aransas Diked Disposal Area	Port Aransas, Texas
	Estuarine	Tule Lake Ship Channel	Corpus Christi, Texas
1E03A and B	Estuarine	Duwamish River - Elliott Bay - Puget Sound	Seattle, Washington
	Estuarine	San Francisco Bay - Mare Island - Rodeo Flats	San Francisco, California
	Estuarine	Oakland Harbor	Oakland, California
	Estuarine	Los Angeles Harbor	Los Angeles, California
	Estuarine	Galveston Bay Entrance Channel - Galveston Channel - Texas City Channel	Galveston, Texas
	Estuarine	Houston Ship Channel	Houston, Texas
	Estuarine	Port Lavaca	Port Lavaca, Texas
	Estuarine	Mobile Bay	Mobile, Alabama
	Estuarine	Apalachicola River	Apalachicola, Florida
	Estuarine	Wilmington Harbor	Wilmington, North Carolina
	Estuarine	James River	Virginia
	Estuarine	Perth Amboy Channel	New York, New York
	Estuarine	Bay Ridge Channel	New York, New York
	Estuarine	Newport Harbor	Newport, Rhode Island
	Estuarine	Norwalk Harbor	Norwalk Connecticut
	Estuarine	Stanford Harbor	Stanford, Connecticut
	Estuarine	Foundry Cove	New York
	Estuarine	Menominee River	Menominee, Michigan
	Freshwater	Upper Mississippi River	St. Paul, Minnesota
	Freshwater	Waterways Experiment Station Lake	Vicksburg, Mississippi
1E04	Freshwater	Ashtabula River	Ashtabula, Ohio
	Estuarine	Mobile Bay	Mobile Bay, Alabama
	Estuarine	Bridgeport Harbor	Bridgeport, Connecticut
1E06	Estuarine	Bridgeport Harbor	Bridgeport, Connecticut
	Freshwater	Ashtabula River	Ashtabula, Ohio
	Estuarine	Galveston Harbor	Galveston, Texas
	Estuarine	Arlington Ship Channel	Mobile, Alabama
1E07	Estuarine	Pensacola Bay	Pensacola, Florida
	Estuarine	Mobile River	Mobile, Alabama
	Estuarine	Mobile Bay	Mobile, Alabama
	Estuarine	Buttermilk Sound	Georgia
	Estuarine	Brunswick Harbor	Brunswick, Georgia
	Estuarine	Terry Creek	Georgia
	Freshwater	James River	Windmill Point, Virginia
	Estuarine	Bridgeport Harbor	Bridgeport, Connecticut
	Estuarine	Branford Harbor	Branford, Connecticut
	Freshwater	Hudson River	Upper New York
	Freshwater	Ashtabula River	Ashtabula, Ohio
	Freshwater	Milwaukee Harbor	Milwaukee, Wisconsin
	Estuarine	Duwamish Waterways	Seattle, Washington
	Estuarine	Columbia River	Oregon
	Estuarine	Miller Sands	Oregon
	Estuarine	Oakland Harbor	Oakland, California
	Estuarine	Houston Ship Channel	Houston, Texas
1E08	Estuarine	Duwamish River	Seattle, Washington
	Freshwater	Bailey Creek	Hopewell Virginia
	Freshwater	James River	Windmill Point, Virginia
	Estuarine	Bay Ridge Channel	New York, New York
	Estuarine	Long Island Sound	New York
	Freshwater	Small stream into Mississippi River	Vicksburg, Mississippi

characterize municipal and industrial wastes rather than sediments. Consequently, many harbors were shown to have been erroneously characterized.

8. The earliest guidelines or criteria proposed for dredged material, based on results of the Great Lakes survey, were promulgated in 1971 by the EPA and were commonly called "the Jensen Criteria." In the same year, the Corps of Engineers issued Engineering Circular 1165-2-97[1] which stated that the dredged material disposal criteria formulated by the EPA (Jensen Criteria) should be applied to sediments dredged from all U. S. waters. Seven chemical parameters with numerical concentration limits were specifically mentioned in the total-sediment (Jensen) criteria and included chemical oxygen demand, total Kjeldahl nitrogen, volatile solids, oil and grease, mercury, lead, and zinc contents. The numerical limits were total concentrations based on a dry weight of sediment. If the concentration of any of the seven constituents exceeded the numerical limit specified for that constituent, the material was classified as polluted and was not acceptable for open-water disposal. Although the criteria were not limited to the seven parameters for which numerical limits had been established, implementation of the criteria was restricted almost exclusively to them.

9. General opposition to the Jensen Criteria has developed with time as technical weaknesses or flaws have become apparent. The procedures did not take into account the location of contaminants in the dredged material, did not address the potential availability of contaminants to organisms, and did not consider natural levels of the same constituents. The procedures prescribed for use with the criteria provided only an inventory of the total amount of each constituent contained in the sediment. This inventory accounts for only the mere presence of a contaminant and does not measure potential biological availability or chemical mobility.

10. P.L. 92-532 and P.L. 92-500 directed that the EPA develop regulatory criteria and guidelines in consultation and conjunction, respectively, with the CE. Criteria implementing Section 103 of P.L.

92-532 regulate the transportation for dumping of dredged material in ocean waters, and guidelines implementing Section 404 of P.L. 92-500 regulate dredged and fill material discharge in inland waters. Both Federal and private projects would be regulated using the same criteria and guidelines.

Ocean dumping

11. Final regulations and criteria controlling ocean disposal of dredged sediments[2] were published by the EPA on 15 October 1973 in the Federal Register. The procedures (criteria) for assessing the suitability of dredged sediments for ocean disposal consisted primarily of the Elutriate Test in place of total sediment analysis. This procedure adequately addressed short-term water quality impacts but not the longer term benthic impacts. Bioassays were recommended only in general terms.

12. P.L. 92-532 further required that the criteria for ocean disposal be updated at least every 3 years. The first updated criteria, in effect at this time (1978) were published in the 11 January 1977 Federal Register.[3] These criteria account for provisions of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and reflect recent legal challenges by the National Wildlife Federation as to the adequacy of the 1973 criteria.[4] The Convention bans the ocean dumping of materials containing other than traces of certain contaminants. Contaminants on the prohibited list are considered to be present in trace quantities when the dumping of dredged sediments containing these contaminants will not cause significant undesirable effects.[3] The most recent meeting of the Convention (1977)[5] proposed that dredged material be exempted from these testing requirements.

13. The potential for undesirable impacts of dredging and disposal and determinations of trace contaminants are assessed in the ocean dumping criteria by means of bioassays of the liquid, particulate, and solid phases along with chemical analyses of the liquid phase. The impact of chemical constituents is addressed by comparing their concentrations with appropriate water quality criteria after taking initial mixing into account.

14. The 11 January 1977 criteria[3] also require by 1980 a thorough physical, chemical and biological assessment of all ocean disposal sites prior to their designation as "final" and acceptable dump sites. Until that time actively used ocean sites are listed as "interim" sites.

Inland disposal

15. Interim guidelines for implementation of P.L. 92-500 were published in the 5 September 1975 Federal Register.[6] The guidelines require the permit applicant to consider physical effects (especially impact on wetlands), chemical-biological interactive effects, and to conduct a thorough site selection review. Assessment of chemical water column effects is by means of the Elutriate Test. The District Engineer may also specify that the applicant conduct water column and benthic bioassays on a case by case basis. He may select total sediment chemical analyses or benthic community structure analyses when reviewing alternative sites for potential selection.

16. A recent area of concern surrounding P.L. 92-500 disposal criteria has not been the disposal guidelines per se but rather the extent of the Corps' jurisdiction. The Corps initially interpreted its responsibility under P.L. 92-500, Section 404, to include only the historically navigable waters of the U. S. However, in March 1975, the U.S. District Court for the District of Columbia in National Resources Defense Council v. Callaway, ruled that the responsibility of the Corps to regulate the discharge of dredged or fill materials extended to all waters of the U. S. The Corps has proceeded to implement the court order under a three-phase program which has gradually extended the Corps' permitting authority to cover all waters of the U. S. The final phase of the Corps' permitting authority went into effect in 1977. Amendments to P.L. 92-500, enacted in 1977, have slightly altered this authority. All phases of the regulatory program can revert to states (at the request of the governor) that have ongoing, EPA approved regulatory programs. The regulatory guidelines, however, remain basically unchanged.

PART II: LITERATURE REVIEW

17. This part contains results of non-DMRP studies pertinent to criteria development. Detailed literature reviews are presented in the respective DMRP Task 1E reports.

Evaluation of Short-Term Water Quality Impacts

18. Non-DMRP work has been limited and centered primarily on the Elutriate Test. Bricker[7] concluded that the mere presence of a constituent in sediment did not indicate that adverse effects would occur by dredging that sediment. He also concluded that the Elutriate Test provided the most realistic, presently available assessment of the effects on disposal site water quality.

19. Investigations[8,9,10] have shown that Elutriate Test results depend primarily upon the oxygen status of the test mixture during the procedure. Greater amounts of trace metals and orthophosphate are released if dissolved oxygen is depleted during the test procedure.

20. Agitation time is also a factor affecting Elutriate Test results.[9] Agitation of sediment-water mixtures for periods substantially greater than the half hour called for in the Elutriate Test procedure may overestimate the concentration of released constituents. Sly[10] showed that most Great Lakes dredged material disposed of in shallow (< 20 m) water would not disperse as it fell through the water column. From these and other results, Sly[10] concluded that only those chemical processes and reactions with rates lasting a few minutes or, at the most, a few hours appear to be significant during open-water discharge.

Evaluation of Long-Term Water Quality Impacts

21. Long-term water quality impacts associated with continuous contaminant releases are difficult to quantify because of extensive mixing and dilution in the overlying water. An additional confounding

factor is the effect of inputs of materials into the disposal site water column from sources other than dredged material. Knowledge gained on the long-term effects of dredged material disposal on water quality has therefore been mainly qualitative. Sly[10] reported results showing high fish densities in the water column overlying recently deposited dredged material in the Great Lakes. The dense fish populations were attributed to a continuing source of available food from the dredged material. Dense fish populations were not seen 12 to 18 months after disposal, implying that food availability from the sediments had decreased.

22. Mudroch[11] demonstrated that sediment leachates derived by mixing air-dried sediments with water showed higher releases than leachates derived from the same sediments that had not been air-dried. Mudroch and Zeman[12] confirmed changes in the physicochemical properties of dredged material subject to drying which further enhanced release. Sly[10] suggested that the summarized studies[11,12] indicate that upland disposal, in which the material is subject to aerobic leaching, represents the most severe condition under which longer term release of contaminants may occur. He also concluded that long-term release of contaminants from sediments disposed of in open-lake sites where they may remain largely unaffected by wave action is controlled by ambient physicochemical and biochemical processes.

23. The previous discussions help point out that long-term effects of disposal in open-water sites are poorly understood. It is possible, however, that long-term impacts of dredged sediments upon the disposal site water column can be quantitatively predicted.

24. Lee and Plumb[13] compared the standard Elutriate Test results of Wagner on taconite tailing with results of a long-term taconite tailings leaching study conducted by Plumb. The Elutriate Test results for taconite tailings were in good agreement with those for the long-term taconite tailings leaching study.

Dredged Material Bioassays

25. Bioassay studies conducted using dredged material have been limited in number and scope. For criteria development, two general types of dredged material bioassays are of interest: those addressing water column effects, and those concerned with effects on benthic organisms.

26. Water column bioassay work has entailed limited numbers of organisms and methods of bioassay water preparation. Emerson[14] used benthic polychaetes and sediment extracts of varying sediment-water ratios. Hoss et al.[15] used sediment extracts made from seawater and marine sediments to determine the effects of soluble compounds released from the sediments on larval fish. Their major finding was that the sediment-water ratio used in preparing the extract was important in test organism survival.

27. Benthic bioassays have been even more limited than water column bioassays. Gannon and Beeton[16] conducted benthic bioassays and sediment selectivity tests. Their results are questionable because dissolved oxygen depletion caused by high sediment oxygen demand may have caused the death of test organisms rather than any substances that may have been present in the sediments.

28. The previous studies have indicated that suitable bioassay procedures have not been forthcoming because of minimal work in the area. These studies have also shown that benthic bioassay procedures that eliminate sources of test organism mortality other than from sediment contaminants are a needed regulatory tool.

PART III: REQUIRED REGULATORY TESTING PROCEDURES

Marine Protection, Research, and Sanctuaries Act of 1972 (P.L. 92-532)

29. The criteria for ocean disposal require bioassays on the liquid, particulate, and solid phases of the sediment, along with optional chemical analyses of the liquid phase, unless the sediment can meet stringent criteria for exclusion from testing. The liquid phase is the filtrate from the Elutriate Test procedure, a vigorous leach of four parts water from the proposed dredging or disposal site with one part sediment from the proposed dredge site. The particulate phase is the unfiltered liquid portion of the Elutriate Test mixture remaining after 1 hour of settling. The solid phase includes all material settling to the bottom in 1 hour.

30. The bioassays required by the criteria allow prediction of potential environmental effects on aquatic organisms during and after dredged material disposal. This procedure also allows for evaluation of "trace contaminants," "significant undesirable effects," and bioaccumulation as required by the International Convention[4] and current regulations.[3] This direct determination of biological effects is much more meaningful than attempting to infer biological effects from the chemical makeup of the sediment.

31. The criteria recognize that the ocean environment is physically dynamic, has an assimiltative capacity, and that materials dumped into it will be mixed and diluted. The initial mixing required by the criteria as an allowance for mixing known to occur in the field is the dispersion or dilution of the liquid, suspended particulate, and solid phases that occurs within 4 hours after disposal. The criteria allow the use of a number of methods to estimate initial mixing. The preferred method requires using good field data (relevant to the proposed disposal operation) in an appropriate mathematical model for adequate prediction of initial mixing and dilution. If field data relevant to the proposed disposal are lacking, field data obtained for a material of

similar characteristics may be used. Theoretical oceanic turbulent diffusion relationships may be used to estimate initial mixing. However, the state of the art of dredged material dispersion theory does not allow for routine use of this method for adequate prediction of initial mixing processes. None of the previously discussed methods involving models are feasible until the models under development are verified.[17] Consequently, as an interim measure, the release zone method of estimating initial mixing is currently used. This method assumes that the liquid and suspended particulate phases of the dredged material will be evenly distributed at the end of a 4-hour initial mixing period over a column of water in the immediate vicinity of the dumping barge or scow.[18]

32. Bioassays are required on the liquid, particulate, and solid sediment phases prior to proposed activity regardless of the mode of dredging and disposal. When the dredged sediment is from an obviously contaminated area the most meaningful approach should place more emphasis on the water column for continuous discharge pipeline disposal, whereas less emphasis should be placed on the water column during scow or barge dumping because of their intermittent nature. Where the probability of adverse environmental effect is remote, conducting the entire battery of bioassays may be unnecessarily expensive and burdensome to the permit applicant. Flexibility for regional variations would be desirable.

Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500)

33. The guidelines for implementing Section 404 of P.L. 92-500 call for evaluating the physical effects, chemical-biological interactive effects of dredged material disposal, and require a site selection evaluation. The thrust of the physical effects guidelines is preventing degradation or destruction of wetlands by filling operations and changing the bathymetry of open-water disposal sites such as to adversely effect circulation patterns. The guidelines for chemical

evaluation provide for the District Engineer's selecting appropriate testing procedures. The EPA Regional Administrator may require testing beyond that recommended by the District Engineer on a case-by-case basis by stating what further analyses are needed and how the results of the analysis will be of value in evaluating potential environmental effects. Tests which may be conducted to evaluate chemical-biological interactive effects include the Elutriate Test and water column and benthic bioassays. For site selection evaluation inventorying total concentrations of sediment constituents and analyzing community structure may be of value.

34. The guidelines provide for using the mixing zone concept only when constituents of concern are released in the Elutriate Test or if any effects are found during liquid-phase bioassays. The size of the mixing zone is based on a case-by-case evaluation of each proposed disposal site. There is presently no widely accepted model for predicting the plume shape and size for all types of dredging operations. Consequently, a simplified approach (assuming complete mixing of the dredged material at the disposal site and conservative behavior of chemical constituents measured in the Elutriate Test) is used to estimate the maximum portion of the total aquatic environment considered necessary for the proposed discharge.[19] This volume can then be compared to the actual water volume available for mixing.

35. These guidelines permit the District Engineer to tailor the testing procedures to achieve maximum environmental protection without unnecessary testing. However, the testing procedures and guidance for interpreting test results are less specific than desired, reflecting the state of the art at the time the criteria were written. Total sediment analysis, one of the testing procedures, has shown no direct relationship to water quality alteration and effects on benthic organisms. Community structure analysis may assist in selecting the most biologically appropriate disposal site but in practice has never been used to predict the effects of a proposed discharge. This analysis has been generally restricted to determining the occurrence of changes in species

diversity as a consequence of some environmental perturbation. Whether this change is good or bad is a subjective determination.

EPA-CE Criteria Development Coordination

36. The present state of the art does not allow completely objective criteria, test procedures and other decision-making guidance for either Section 103 of P.L. 92-532 or Section 404 of P.L. 92-500. Provisions are therefore present in both Public Laws whereby periodic review and updating are possible as more implementable and meaningful tests are developed.

37. Corps research is closely coordinated with the EPA under the auspices of the EPA/CE Technical Committee on Criteria for Dredged and Fill Material.[20] Specifically, the committee (a) coordinates ecological research activities of the two agencies to avoid duplication, develop joint projects, and exchange research results; (b) promotes the application of current research results in revising criteria and guidelines when appropriate; and (c) develops both interim and longer term implementation and procedural manuals.

PART IV: DISCUSSION

Contaminants Associated With Dredged Material

38. The geochemical form of a contaminant in dredged material will determine to a great extent the impact of disposal on water quality and aquatic organisms. The mere presence of a contaminant does not mean that an adverse impact on water quality or aquatic organisms will occur. The contaminant may be present in any number of geochemical forms that render it more or less chemically immobile and biologically unavailable.

Unavailable phases

39. Metals and nutrients are naturally occurring components of all sediments. Sediments may also contain these constituents from contamination sources. Metals and nutrients will therefore always be found at various concentrations in dredged material, whether contaminated or not. In most cases, the majority of naturally occurring metals will be in the crystalline lattice of minerals and will be essentially inert and biologically unavailable.[21] Trace metals associated with parts of the dredged material other than the mineral crystalline lattice can also be essentially immobile and biologically unavailable. Metals associated with crystalline Fe and Mn oxides in dredged sediments are an excellent case. For example, most sediment As is usually associated with these highly crystalline Fe and Mn oxides[21] and is chemically immobile and biologically unavailable. This form of As will therefore have minimal impact upon the environment during dredging and disposal.

Potentially available phases

40. Metals, nutrients, and organics in sediment interstitial waters or adsorbed to the cation exchange complex and trace metals associated with poorly crystalline, amorphous Mn and Fe oxides are the most mobile and potentially available contaminants in dredged material.[21,22] Chemical tests, such as the Elutriate Test procedure, which measure these mobile forms of contaminants are useful for evaluating the potential for water quality impacts during dredging and disposal.

Organics

41. Chlorinated hydrocarbon pesticides and PCB's, unlike heavy metals and nutrients, do not occur naturally in dredged sediments. The presence of these constituents is due solely to man induced contamination. This is not to imply that the total amount is mobile and available, however. On the contrary, they are usually tightly bound to the sediments. Consequently, only limited amounts of sediment-bound chlorinated hydrocarbon pesticides and PCB's are present in the sediment interstitial water.[22] Only chemical tests which measure the amount of mobile, potentially available organics should therefore be used to evaluate the potential environmental impact of these constituents.

Interpretation of Short-Term Chemical Impacts

Chronic exposure criteria

42. Assessment of the potential release of contaminants from dredged material can be made by the Elutriate Test. Evaluation of the significance of any release is a more difficult problem. The 11 January 1977 Federal Register[3] specified that the EPA water quality criteria[23] should be used to judge the significance of chemical contaminant releases from ocean-disposed dredged sediments. The 5 September 1975 Federal Register[6] specified that estuarine and inland water disposal should conform to "appropriate" water quality criteria. The EPA water quality criteria,[23] however, are conceptually intended to protect aquatic organisms from continuous exposure to biologically available forms of contaminants for a significant portion of their lifetime. This factor creates the evaluation problem because almost all disposal operations are intermittent and do not result in chronic exposure situations.[24] This is especially true for disposal operations from hopper dredges or barges. In the case of pipeline disposal operations, it is conceivable that continuous exposure of sedentary organisms could occur for the duration of the operation although even this extreme situation would not provide exposure for a significant portion of the organism's life. Consequently, disposal operations must be assessed on a

case-by-case basis to determine if chronic exposure criteria giving a "worst case" estimate or criteria based on shorter exposure times should be used.

Intermittent exposure

43. There are presently no valid water quality criteria for the short-term exposures usually encountered during disposal operations. The chronic exposure criteria (EPA water quality criteria[22]) specify concentrations of chemical constituents which, if maintained indefinitely, would not impair the propagation of fish and other aquatic life and would allow recreation in and on the water. Concentrations considerably greater than those specified in the chronic exposure criteria can be allowed for short periods of time (3 days or less) without having a significant adverse effect on water quality at the disposal site. Before an adverse impact to an organism at the disposal site will occur, the exposure time and chemical concentration must exceed the critical concentration-time of exposure relationship for the respective organism-chemical combination.

Concentration-time of exposure relationships

44. An example of the importance of the concentration-time of exposure relationship was demonstrated by Mattice and Zittel[25] in a review of the impact of chlorine on aquatic organisms. The chronic safe level of chlorine for marine organisms is 0.01 mg/ℓ.[23] They determined that, for marine organisms of all types tested, the acute safe level of chlorine for a 100-minute exposure was approximately 0.03 mg/ℓ. For 10 minutes of exposure, the safe level for acute toxicity was approximately 0.06 mg/ℓ, while for 1 minute of exposure the safe level for acute toxicity was 0.15 mg/ℓ chlorine. This illustrates that decreasing the time of exposure to toxic chemicals significantly raises the tolerance level.

Mixing (impact) zones

45. The lack of appropriate water quality criteria based on both concentration and time of exposure has led to using mixing zones for disposal in navigable waters[19] and estimating initial mixing in marine waters[18] to simulate the dilution of released constituents that occurs

in the field. Such procedures should be used until bioassays are developed that reflect the concentration-time of exposure relationship at a respective disposal site.

Short-Term Chemical Impacts

Metals

46. Manganese. Investigations of a variety of sediments (Table 1) have shown that Mn is the only metal released in substantial quantities during the Elutriate Test and aquatic disposal.[21,24,26,27] Manganese, however, is generally not toxic and is a required micronutrient. The EPA water quality criteria[23] state that the safe chronic exposure level for the protection of consumers of marine mollusks is 100 mg/ℓ. However, tolerance values reported for freshwater aquatic life range from 1.5 to 1000 mg/ℓ.[23] The slightly elevated Mn concentrations (much less than 1.5 mg/ℓ) found in disposal site waters minutes following disposal were well below a critical tolerance level.[24,28]

47. Manganese release could pose a potential problem if pipeline disposal were continued for a prolonged period at one site and if the dissolved Mn plume were constantly drifting into an area containing marine mollusks. In practice, however, pipeline disposal would probably not result in any increases in water soluble Mn concentrations. Schubel et al.[29] found no discrete plumes of dissolved Mn during field evaluation of pipeline disposal at Morgan City, La., Corpus Christi, Tex., and Apalachicola, Fla., even though considerable quantities of Mn were released during the Elutriate Test. Even though Mn release was predicted, rapid initial mixing during disposal resulted in no discernable Mn plume. From this point of view, the Elutriate Test is a very conservative index of the potential for release.

48. Other metal releases. The consistent release of trace metals other than Mn has not been observed during the Elutriate Test.[21,24,26,27,29,30] Transitory releases (a matter of minutes) of mercury (0.01 to 0.05 ppb), lead (< 40 ppb), cadmium (0.08 to 2.5 ppb), and nickel (5 to 20 ppb) have been observed on occasion in the field.[24,28] Iron is usually

released initially in much higher concentrations than metals other than Mn. However, released Fe is subject to very rapid oxidation and precipitation in the water column.[30] Precipitation of iron oxides will then tend to remove other metals and orthophosphate from solution.[21,26] This rapidly occurring "scavenging" results in the removal of most other soluble constituents from the water column.

49. Large releases of Zn have been observed during Elutriate Tests run under oxygen free conditions.[21] However, these large, consistent Zn releases have not been observed by others[26,27] conducting aerated Elutriate Tests on similar sediments; this would be the usual case in disposal operations.

50. Releases of trace metals other than Mn during disposal by barges and hopper dredges have been found to be minor and of limited duration.[28] Such releases should not exert any short- or long-term adverse effects on water quality or aquatic organisms at a disposal site. Even in continuous discharge pipeline disposal, Schubel et al.[29] found no plumes of dissolved metals significantly greater than background levels in areas where sediments contained elevated levels of most metals. Trace metals in the disposal plume were associated with particulate matter and were rapidly removed from the water column.

Nutrients

51. Nitrogen. Ammonium-N (NH_4-N) has shown consistent release from dredged sediments during the Elutriate Test,[21,26,27,31] discrete aquatic dumps,[24,28] and continuous pipeline discharge.[29] These releases could degrade water quality and adversely affect aquatic organisms. Continuous discharge of dredged sediments releasing large quantities of NH_4-N may be hazardous to aquatic life if alkaline pH conditions exist at the disposal site where the nontoxic NH_4-N can be converted to very toxic NH_3-N. The percentage of NH_4-N present as NH_3-N must be determined before the impact of nitrogen releases can be evaluated.[23]

52. Results of field tests where disposal occurred in discrete dumps showed that potentially hazardous concentrations of NH_3-N are of short duration and infrequent. For example, during Texas City dump No.

2 in the Galveston disposal site, NH_4-N concentrations as high as 1.86 mg/ℓ were observed.[30] Conversion of NH_4-N concentrations[23] indicates that NH_3-N concentrations reached 0.06 mg/ℓ. This relatively high concentration of NH_3-N persisted for not more than two minutes before declining to a level of less than 0.025 mg/ℓ. In all, the NH_3-N safe chronic exposure level of 0.02 mg/ℓ was exceeded for only 12 minutes. It is unlikely that such a short exposure would result in harm even to immobile organisms exposed for the entire 12 minutes or to aquatic organisms swimming through the plume.

53. Continuous release of NH_3-N during pipeline disposal may be hazardous to aquatic organisms if exposed to levels greater than 0.02 mg/ℓ for a significant portion of their life cycle. Schubel et al.[29] found average NH_4-N concentrations ranging from 0.11 to 0.34 mg/ℓ near the outfall of various pipeline disposal operations. No temperature or pH data were given, but, assuming a worst case of 20^oC and pH 8.0, even the highest average NH_4-N concentration would not exceed the chronic exposure level for un-ionized ammonia. Scattered NH_4-N concentrations as high as 3.25 mg/ℓ were observed, which exceed water quality criteria for NH_3-N. Because of the concentration-time of exposure influence, these occasional, transient elevated concentrations of ammonium-N, even under conditions where a sizeable percentage is present as un-ionized ammonia, should not exert any significant impact on water quality.

54. Phosphorus. Orthophosphate-P has not exhibited consistent release patterns during the Elutriate Test,[21,24,26] discrete aquatic dumping operations,[24,28] or pipeline disposal.[29] Release of orthophosphate-P is highly site-specific. Elutriate Test results[21,24,26] indicate that sediments high in ferrous iron in a mobile form (as is usually the case) are unlikely to release orthophosphate-P during aquatic disposal.

Organics

55. Burks and Engler[22] concluded that chlorinated hydrocarbon pesticides and PCB's are rapidly sorbed from aqueous solutions. Other results[26] have shown that this behavior is generally the case for chlorinated hydrocarbon pesticides during the Elutriate Test. However,

releases of PCB's ranging from 1.3 to 6.9 times the concentrations in the receiving waters have been found in some Elutriate Tests. Somewhat contrary to the review presented by Burks and Engler,[22] the release of PCB's was found to be not related to the sediment total PCB concentration but to the oil and grease content of the dredged material.[24] Sediments low in oil and grease appeared to release the largest quantities of PCB's.[24]

56. Behavior of chlorinated hydrocarbon pesticides and PCB's during aquatic disposal by hopper dredge or barge is similar to their behavior during the Elutriate Test.[24] Dredged sediments from sites containing the highest oil and grease content tended to release the least chlorinated hydrocarbon pesticides and PCB's into the water column. Even though some dredged sediments contained high levels of chlorinated hydrocarbon pesticides and PCB's, no significant release of these materials into the water column was observed during disposal.[26] The laboratory PCB release was not detected in the field due to rapid mixing and dilution of the very small quantities released. Consequently, the release of chlorinated hydrocarbon pesticides and PCB's into the water column during dredging and disposal had little short-term impact on water quality.

Longer Term Water Quality Impacts

Field evaluation

57. Sediments are an almost irreversible sink for trace metals, chlorinated hydrocarbon pesticides, and PCB's.[13] There is very little evidence, pro or con, that these compounds become mobile once they are associated with the sediment. Consequently, the DMRP has focused on quantifying and predicting the long-term magnitude and significance of contaminant releases on water quality.

58. No significant long-term elevations of organic contaminant concentrations have been observed in disposal site waters following disposal of dredged material.[28] It should be cautioned, however, that the magnitude of contaminant releases at some field sites is difficult

to assess because of contaminant input from other sources, natural variations, and rapid dilution of released constituents.

Laboratory evaluation

59. Long-term leaching. Although it appeared initially that the magnitudes of contaminant releases in the field were minor, work[27] was initiated to assess in the laboratory the magnitude, predictability, and potential of long-term contaminant releases from settled material to the overlying water column.

60. Long-term laboratory studies were conducted with 32 dredged material samples representing broad geographical and pollutional variation. Under chemical conditions likely to prevail at aquatic disposal sites, total organic carbon, orthophosphate-P, and Zn exhibited the most consistent net releases to the water column. However, the magnitudes of the releases were such that no impact on the disposal site water column would be detected in a field investigation.[27] Some toxic metals such as As, Cd, Pb, and Hg showed virtually no long-term (8-month) net release. In general, the magnitudes of long-term contaminant releases under laboratory conditions from the sediments studied were such that little impact on water quality would be expected in the field.[27]

61. Relationship to Elutriate Test. The Elutriate Test showed considerable utility as a predictor of the potential for long-term net release from sediments.[27] Long-term net releases of As, Cu, Pb, Hg, total organic carbon, and orthophosphate-P were directly related to their respective net releases during the Elutriate Test. Releases of constituents such as Zn which were not related to their releases in the Elutriate Test were directly related to their respective concentrations in mobile sediment phases such as interstitial water.

62. Results[27] from certain sediments incubated under both agitated and quiescent conditions indicate that mechanical agitation will not appreciably enhance long-term net mass releases. However, one sediment suspension from Oakland Inner Harbor, Calif., when incubated under aerobic, agitated conditions, exhibited a marked drop in pH from near 8.0 to 3.6. The acidic condition was accompanied by a high net release of trace metals. The same sediment, incubated under aerobic, quiescent

conditions similar to those found at open-water disposal sites, did not lower the overlying water pH and did not show significant metal release. Such a sediment, if disposed of in an upland and drained disposal site, could oxidize, become acidic, and pose a potentially severe environmental hazard.

63. Manganese and ammonium-N exerted no long-term effects on water quality.[27] At the end of 4 months of incubation, Mn and NH_4-N which were released in large amounts during the Elutriate Test and presumably when the leaching columns were prepared, were usually present in lower concentrations than in the initial disposal site waters. These results indicate that Mn and NH_4-N were being actively removed from the water column.

64. These long-term release studies showed that, except under unusual circumstances, deposited dredged material should have limited impact on disposal site water quality. This conclusion is supported by other investigations.[22] Benthic and epibenthic organisms which are in intimate contact with deposited dredged sediments are much more subject to long-term impacts than water column organisms.

Biological Impacts

65. Chemical tests performed on sediments prior to dredging and disposal are an attempt to indirectly predict the potential for ecological impact of the disposal operation. Task 1E of the DMRP was primarily concerned with developing methods for directly assessing the ecological impact of open-water disposal. Direct assessment of dredged material disposal impacts by means of bioassays and bioassessments that reflect conditions at the disposal site are the only means by which regulatory decisions can be scientifically defended at this time.

Short-term water column effects

66. The short-term biological impact of dredging and disposal operations on aquatic test organisms typically has been negligible. Shuba, Carroll, and Wong[31] investigated the effect of the filtered elutriate (liquid phase) on various aquatic organisms. An inhibitory

effect on algal growth was found only in one case. The inhibition was in a "worst case" test with no dilution by disposal site water and simulated conditions inside a barge, hopper, or pipeline rather than the water column. Both liquid and suspended particulate phases prepared from kepone-contaminated Bailey Creek, Va., sediments were toxic to sensitive freshwater Daphnia (water fleas) when undiluted with disposal site water.[32] The soluble and particulate phases of Perth Amboy and Bay Ridge, N. Y., sediments also showed some toxicity to the estuarine copepods Acartia tonsa, grass shrimp larvae (Palaemonetes sp.), and adult opossum shrimp (Mysidopsis sp.) when tested with little or no dilution of the sediment preparations.[32] No toxicity was observed when the bioassays were conducted with elutriate preparations mixed with disposal site water at concentrations representative of field conditions. Consequently, this form of bioassessment gives a very conservative (worst case) estimate of the toxic nature of sediments.

67. Lee et al.[24] reported that laboratory bioassays with unfiltered elutriates (suspended particulate phase) showed very little toxicity to aquatic organisms even with limited dilution. Daphnia or grass shrimp survival for 96 hours in the laboratory without significant mortality was observed in the equivalent of a settled discharge from a dredging operation.[24]

68. Previous results have shown that the soluble and particulate phases of dredged material released during the Elutriate Test exhibited little toxicity with minimal or very conservative mixing and initial dilution. It is highly unlikely that the toxicity which occurred with no mixing or with 50 percent mixing in one isolated instance would be observed in the field. These conditions occur inside the dredge pipe or hopper and barge bin. The intermittent nature of discrete dumping operations and the relatively rapid dispersion[24,28,33] of released contaminants renders short-term acute toxicity or bioaccumulation by aquatic organisms unlikely in most cases.

Short-term bottom organism effects

69. The impact of dumping on benthic and epibenthic organisms may possibly be more pronounced. These organisms are in close contact with

deposited sediment for long periods of time in contrast to the relatively short exposure of water column organisms.

70. Benthic bioassay results indicate that some highly contaminated sediments can exert an adverse effect on benthic and epibenthic organisms that survive burial or recolonize a site after disposal. Shuba et al.[32] found some degree of toxicity to freshwater grass shrimp (P. kadiakensis) during benthic bioassays following 6 days of exposure to Bailey Creek, Va. sediments. Kepone concentrations increased in the tissues of test animals dying during the first 4 days of exposure. Benthic bioassays also showed that select sediments from the Bay Ridge Channel in New York City were toxic to opossum shrimp (M. bahia); sediments from areas of Perth Amboy Channel in New York City were toxic to grass shrimp larvae; and Vicksburg, Miss., sediments, subject to sewage and chemical plant contamination, were highly toxic to the adult grass shrimp.

71. Lee et al.[24] evaluated the accumulation of chlorinated hydrocarbon pesticides and PCB's by aquatic organisms from several aquatic disposal sites. Even in sediments containing very high concentrations of these compounds, none of the organisms in the monitored sites exhibited elevated body burdens. Shuba et al.[32] did note bioaccumulation of kepone (a chlorinated hydrocarbon), although, without toxicity to the Asiatic clam. Kepone concentrations in the clam tissues reached a high of 150 ppb after 7 days of exposure and then decreased substantially during the remaining 17-day exposure period for animals exposed to the highest sediment concentrations.

72. Extensive benthic organism contaminant uptake and accumulation studies with dredged material were also conducted under DMRP Task 1D "Effects of Dredging and Disposal on Aquatic Organisms." In general, no clear trends of uptake or accumulation of heavy metals were shown. However, uptake of chlorinated hydrocarbon pesticides, PCB's, and volatile or midmolecular weight oil and grease compounds by benthic organisms were not observed. Results of these studies are discussed in much greater detail in another synthesis report.[34]

Summary

73. Results to date indicate that the short-term impacts of dredging and aquatic disposal on water column organisms are minimal. Dredged material disposal may, however, exert an adverse impact on benthic and epibenthic organisms after deposition at the disposal site. Dredged material of unknown character or of known contamination should therefore be tested prior to disposal to evaluate potential adverse effects on benthic and epibenthic organisms. Benthic bioassays are available and are designed as 10-day toxicity tests.[18] Long-term (multi-year) biological impacts of deposited dredged sediments on benthic and epibenthic organisms are largely unknown. Consequently, continued monitoring of aquatic organisms at selected disposal sites should occur for several more years and are required in the ocean disposal regulatory program.

Testing of Potential for Ecological Harm

74. Testing of dredged material prior to disposal is required under both P.L. 92-500 and P.L. 92-532 to estimate the impact of disposal operations of other than "clean" materials. Consequently, DMRP research has been concentrated on developing and evaluating the Elutriate Test, water column and benthic bioassays and biological assessments, and the total sediment chemical analysis procedures.

Elutriate Test

75. Factors affecting reproducibility. Lee and Plumb[13] conducted a review of factors which could affect sorption-desorption of contaminants during the Elutriate Test. They concluded that the Elutriate Test is a potentially useful method for evaluating the short-term impact on water quality during aquatic disposal. Lee et al.[26] indicated that the oxygen status and solid-liquid ratio during the test procedure are the most important factors that influence results. They recommend that the Elutriate Test be conducted by stirring with compressed air when the suspension would otherwise be anaerobic (oxygen-free) during the process. Aeration better simulates the environmental conditions

during disposal operations at most open-water aquatic disposal sites and is allowed if it is known that anoxic conditions (zero dissolved oxygen) will not occur at the disposal site.[18,19]

76. Utility of test. Comparison of Elutriate Test and field results indicates that the Elutriate Test is environmentally conservative, tending to overestimate the magnitude of contaminant release observed in the field.[24] The Elutriate Test projected an environmental safety margin when considering the protection of water quality and marine organisms. In addition to its usefulness in predicting short-term water quality impacts, the Elutriate Test, alone or in conjunction with interstitial water analyses, can project long-term releases of As, Cu, Pb, Hg, total organic carbon, and orthophosphate-P from resettled sediments.[27]

77. Summary. The Elutriate Test is a valuable tool in assessing short- and in some cases long-term constituent releases from dredged sediments. No other chemical test has been able to demonstrate comparable utility. Consequently, the Elutriate Test should be used in assessing these potential impacts.

Total sediment chemical analysis

78. Validity. Lee and Plumb[13] concluded that using sediment total chemical analysis to assess short- and long-term impacts of disposal is technically unsound and unlikely to result in any level of environmental protection. Results of other studies conducted under the DMRP[21,24,26,27] have consistently verified their conclusions.

79. Utility. Bulk sediment concentrations of contaminants are usually unrelated to their respective concentrations in the elutriate and other sediment extractions.[21,24,26] Furthermore, Brannon et al.[27] demonstrated that total chemical concentrations in sediments cannot predict long-term net releases of chemical constituents from sediments. Other results[34] showed that total sediment analysis cannot predict uptake and accumulation of contaminants by various aquatic organisms.

80. Summary. Bulk sediment analysis has not proven useful for predicting either the chemical or biological impacts of dredged material

disposal. It does, however, possess some limited utility if geographical distributions or inventories of sediment constituents are needed.

Water column bioassays

81. Soluble phase. Bioassay procedures for dredged material were for all practical purposes nonexistent at the beginning of the DMRP. Therefore, development of suitable dredged material bioassay procedures has been a principal objective of the program. Early efforts centered on developing water column bioassays with later emphasis on benthic organism bioassays.

82. Shuba, Carroll, and Wong,[31] using solution-phase bioassays and a variety of test organisms and elutriate concentrations, found that algae respond well and show promise for use in regulatory testing. Bacteria and protozoans were found unsuitable for use in bioassays. Development of an algal bioassay was refined[32] to the point where it was incorporated into dredged material disposal regulatory criteria.[23]

83. Suspended particulates. Bioassays have also been developed for evaluating the impact of suspended particulates released during dredging and disposal.[24,32] This bioassay is suitable for a large variety of aquatic organisms, and the procedure is presented in detail in the Implementation Manual for Section 103 of P.L. 92-532.[18] Algal bioassays are not recommended for use in the suspended particulate phase.[19] Zooplankton were recommended as a test species for suspended particulate bioassays in place of algae.[19]

84. Summary. Relatively simple and implementable bioassays have been developed for assessing the impacts of disposal on water column organisms. The bioassays are conducted under static conditions and limited dilution with extrapolation to field dilution. Detailed procedures are presented in appropriate implementation manuals.[18,19]

Benthic bioassays

85. Dredged material benthic bioassay procedures were not available prior to the DMRP. Shuba et al.,[33] Swartz et al.,[35] and Prater and Anderson[36] initiated the development of practical benthic bioassay procedures which have been used in the implementation of dredged material disposal criteria.[18] The benthic bioassay procedures

approximate conditions found within or at disposal site boundaries and are useful for evaluating biochemical effects. The procedures measure the combined chemical impact of the dredged material and does not determine the biological effect of specific constituents in the material.[18] Shuba et al.[32] demonstrated that a number of different organisms can be used in the benthic bioassay to determine their sensitivity to contaminated sediments.

86. The procedures are basically toxicity tests and do not measure subtle sublethal effects. It is difficult to relate quantitatively the magnitude of a difference between exposed and control test animals in the laboratory to an actual effect in the field. Before this can be done, additional field verification is needed to determine the consistency and variability of benthic bioassay procedures.[32]

PART V: SUMMARY AND RECOMMENDATIONS

Summary

87. The mere presence of chemical constituents in dredged material does not imply that adverse environmental impacts will occur as a result of dredging and aquatic disposal of that sediment. The constituent may be present in a chemically immobile, biologically unavailable form. The impact on water quality and aquatic organisms is related to the concentration of mobile, readily available sediment contaminants rather than the total concentration.

88. The short-term impacts on water quality can be evaluated by the Elutriate Test. Field studies have generally shown the test to be a conservative procedure, generally overestimating releases observed in the field. This characteristic is desirable from a regulatory standpoint as a safety factor to ensure no adverse impacts.

89. In general, the only sediment constituents consistently released into the water column are manganese and ammonium-N. Manganese is relatively nontoxic, but the portion of ammonium-N present as unionized ammonia can be toxic if elevated concentrations persist at an alkaline pH for an extended period of time. Releases of these contaminants would, however, exert minimal impacts under the conditions usually encountered at aquatic disposal sites. Elevated concentrations of the constituents are of short duration because of rapid mixing and are of low frequency due to the intermittent nature of most disposal operations. Pipeline disposal, despite its continuous nature, does not generally appear to exert an adverse impact upon water quality or aquatic organisms. The short-term impacts of dredging and disposal have generally been minimal.

90. Deposited dredged material has not demonstrated long-term biochemical impacts on water quality. Physical effects dominate long-term impacts. No significant long-term increase in water column contaminant concentrations has been observed at any aquatic disposal field site. Laboratory studies indicated that the release of

contaminants from sediments to water in the laboratory are too small to exert significant impacts on water quality. In many cases, the sediment acts as a contaminant sink by accumulating constituents from the overlying water. The longer term net release of many contaminants can be evaluated by means of the Elutriate Test and analysis of the mobile forms of sediment contaminants.

91. The short-term toxicity due to dredging and disposal is minimal. Extensive studies conducted on the soluble and suspended particulate phases of contaminated dredged sediments have shown that limited toxicity occurs only during worst case situations that do not exist in the field. Bioassay procedures have been developed to consider dilution that occurs in the field and assess water column biological impacts prior to dredging.

92. Most dredged material has not proven particularly toxic to benthic and epibenthic organisms. Some dredged material, however, can be extremely toxic or of unknown toxicological character. Benthic bioassay procedures are now available which can identify these toxic sediments. The long-term sublethal effects of dredged material disposal on species diversity and density at field sites are not well known and are subject to continuing study.

Recommendations

93. Bulk sediment analysis has not demonstrated the ability to predict either the chemical or biological impacts of dredged material disposal, and therefore should not be used in any major aspect of dredged material disposal criteria. If geographical distributions and inventories of sediment constituents are needed, it may be of value.

94. The Elutriate Test should be used to predict the short- and long-term water column chemical impacts.

95. Existing water column bioassays are static procedures that simulate the worst case concentration-time of exposure relationships found in the field. These bioassays should then be interpreted in light of dispersion and dilution that occur during dumping.

96. The reproducibility and variability of current and projected benthic bioassay procedures should continue to be evaluated with respect to estimating the relationship between laboratory results and field impacts. Benthic bioassays should be refined to the point where potential chronic impacts can be accurately evaluated.

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