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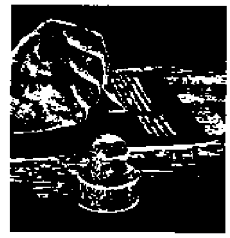

COASTAL ISSUES IN NEW ENGLAND

Regulations and Techniques for Dredging and Dredged Material Disposal Evaluation

Based on a R.I. Sea Grant Coastal Issues in New England Lecture
by 1991
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The Environmental Research Laboratory at Narragansett, R.I., is the Environmental Protection Agency's (EPA) center for marine, coastal, and estuarine water quality research. A major ongoing program at the laboratory focuses on the development of ecological risk assessment procedures to evaluate the potential impact of contaminated sediments on the marine environment. EPA, along with the U.S. Army Corps of Engineers (COE), has responsibility for evaluating and regulating dredging and dredged material disposal operations throughout the nation. Because, in some cases, dredged materials may be contaminated with anthropogenic pollutants, it is essential that these materials be evaluated to insure compliance with environmental regulations designed to protect our marine and coastal habitats.

With the passage of the Ocean Dumping Ban Act in 1990, the predominate material being disposed of in ocean waters is dredged material. This activity is regulated under two environmental statutes. They are Section 404 of the Clean Water Act (PL 92-500), which is the enabling legislation for disposal of dredged material in inshore waters within the territorial baseline; and Section 103 of the Marine Protection, Research, and Sanctuaries Act (PL 92-532), which governs the disposal of dredged material in ocean waters outside the territorial baseline. The on-site dredging activity is regulated under the National Environmental Policy Act (PL 91-190) and addresses water quality issues at the dredging site. The responsibility for these regulatory mandates falls on the Army Corps of Engineers, EPA, and individual states for Section 404 disposal within state waters.

This discussion covers some of the major types of dredging equipment and techniques used to excavate sediment and will include discussion of dredged material disposal options. The focus will be on the evaluative criteria and protocols used to assess compliance with the ocean disposal criteria. It will be useful to briefly discuss what dredged material is, and why it is important to manage it effectively.

Dredged Materials

As sediments are transported downstream and into the marine environment, hydrodynamic and geologic processes act to deposit these materials in deltas, bays, and coves. It is also in these areas that navigation channels, ports, and harbors are found. When sediments build up in these waterways and navigation becomes encumbered, it is necessary to dredge bottom sediments to allow for the safe passage of shipping. Dredged materials are those sediments removed from channels and harbors and transported for discharge on land or at sea. Over 25,000 miles of waterways and more than 400 harbors in the United States require annual maintenance dredging. This activity generates approximately 300 million cubic yards of dredged material that must be dredged and disposed of. This is important because our ports and navigable waterways play a vital role in the nation's economy and balance of trade. In 1992, global trade was estimated at some $3 trillion. It is further estimated that one in five jobs in this country is tied to the movement of goods and services through the nation's ports. Maintaining these waterways is also vital to national defense and for recreational use.

Dredged material encompasses a wide range of sediment types that vary in physical and chemical properties and degree of contamination. Anthropogenic contaminants enter aquatic systems through industrial and municipal effluent, nonpoint sources, combined sewer overflows (CSOs), and by atmospheric deposition. Many of these contaminants have a high affinity for particulate material. In time, these contaminants become associated with sediments by binding with the organic matrices of the sediment particles. Because of this potential for contamination and the concern that dredged materials may adversely impact water quality and aquatic species, the EPA and COE were tasked with developing an evaluative criteria for dredged material disposal. The criteria were published under Title 40 of the Code of Federal Register, Parts 220–228. They specify the use of bioassays and bioaccumulation tests as evaluative tools for assessing potential ecological impact in the aquatic environment.

The Excavation Process

There are primarily two dredging methods employed today. Suction dredging "vacuums" the sediments from channels using either hydraulic or pneumatic means, and mechanical excavation uses tools, such as buckets and backhoes.

The first type of dredge is the cutter-head or hydraulic dredge. This is a very common dredging technique used in the Gulf of Mexico. It has a powerful pumping system that vacuums up the sediment and pumps it through discharge pipelines either to adjacent areas outside navigation lanes, or onto barges for disposal at designated sites. The cutter-head has certain advantages. It can be used to excavate a wide range of material, including rocks; it can pump directly to the disposal site, saving transportation costs; and it can be used continuously. This dredging method is used quite often in areas requiring constant maintenance, such as the approach channels to the Mississippi River in the Gulf of Mexico.

Another type of dredge is the self-propelled hopper dredge, which also uses a vacuum suction technique. This dredge deposits the material directly into the hoppers on board a self-propelled vessel, which can then move to the disposal site for discharge. This type of dredge is amenable to open water and rough sea conditions. It can move quickly, under its own power, and therefore is used to deal with shoaling events following storms. The hopper dredge is economical for long-distance hauling and does not interfere with other traffic as does the cutter-head dredge, which often lays out miles of pipeline.

A third commonly used excavation technique is mechanical excavation that uses a clam-shell bucket. This type of dredge deposits material on barges that are towed to the designated disposal sites for discharge. Advantages of this process include the removal of a wide range of materials (such as construction debris), the ability to work in tight areas, and modification of the bucket to retain fine-grained material. This makes it more efficient for work in areas where contaminated material is excavated.

Ocean Disposal Alternatives

Upland and on-land dredge disposal are two alternatives to ocean disposal. These options offer many benefits—such as development of wetland and marsh habitat and beach nourishment, which is currently an important issue in many parts of the country experiencing recreational beach erosion. To restore beaches, clean (uncontaminated) sediment can be pumped directly onto the shoreline, assuming that the sediment has the appropriate physical characteristics. There are a variety of construction uses of dredged material as fill material and land cover, and there are also aquaculture applications. Examples of some of the aquaculture applications include using dredged material to build holding and grow-out ponds for the aquaculture of shrimp and catfish as practiced along the Texas and Louisiana coast. However, for all of these practical applications, the dredged material must be free of contaminants.

Dredged material that contains low levels of contaminants may be deemed suitable for confined aquatic disposal. This disposal option utilizes diked enclosures along the shore or sub-aqueous borrow pits and caps in aquatic environments. This type of sequestering depends, to a great extent, on the hydrodynamics at the disposal site and is only effective in low-energy containment areas. For dredged material that is determined to be contaminated, the most appropriate disposal option is complete physical isolation in facilities, such as confined disposal sites and containment islands.

Ocean Disposal

EPA and COE share responsibility for the dredged material ocean disposal program. The ocean disposal program for dredged material consists of three components. It begins with selection and designation of the disposal site. Sites are selected in accordance with specific guidelines for disposal of specific types of material. In the site designation process, limits of acceptability of

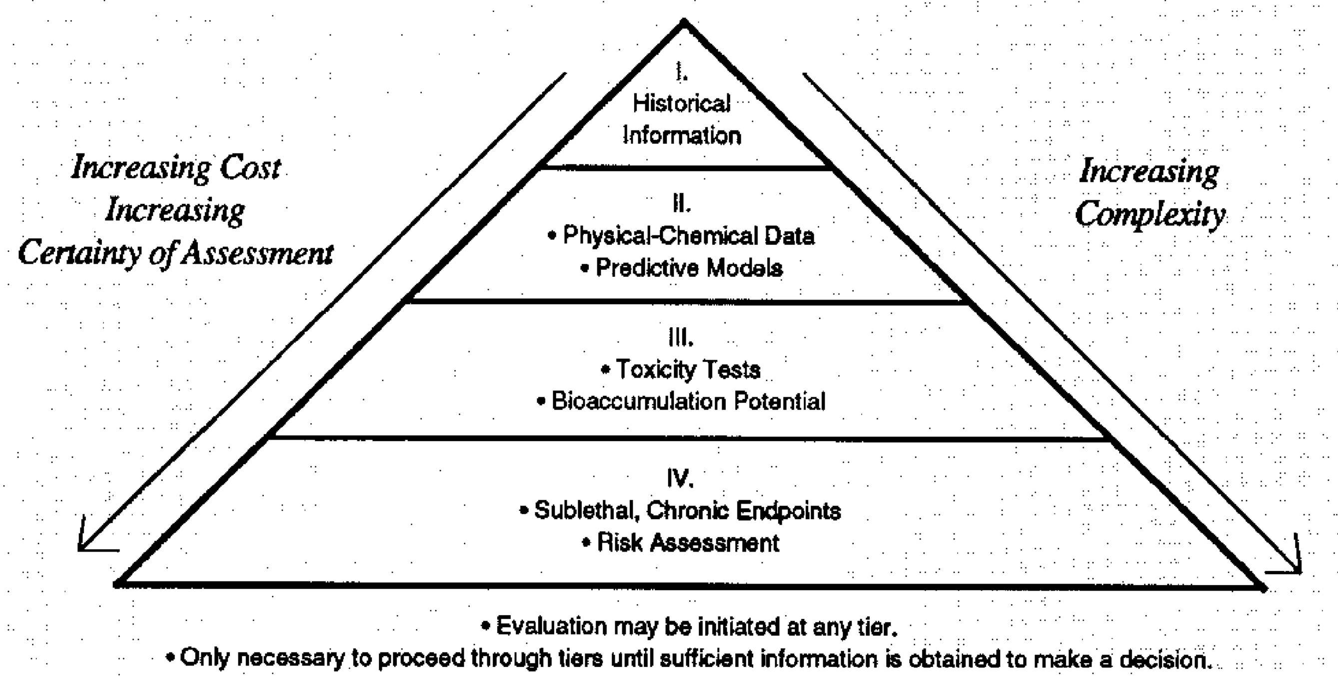

Figure 1. *Tiered testing approach for dredged material disposal evaluation.*

dredged material are defined for a given site. This step involves a detailed baseline study of the environs of the disposal site in which benthic and water column conditions are defined prior to disposal activity. The second element of the ocean disposal process requires a thorough evaluation of the specific dredged material considered for disposal. This is the permitting task and is accomplished with the use of the Green Book (see below). The third component involves site monitoring, which serves as the feedback mechanism to insure that the evaluative procedures applied are, in fact, maintaining the environmental integrity of the site as defined in the designation process.

Evaluative Protocol

In 1976, the COE and EPA were required to develop evaluative criteria and test methods for determining the suitability of dredged material for ocean disposal. This test manual, referred to as the "Green Book," provides the detailed information needed to assess dredged material compliance with the ocean disposal regulations. In 1991, the manual was revised to reflect new and improved evaluative protocols.

The Test Manual

The testing manual contains the pertinent sections of the ocean disposal regulation, an overview of the testing requirements, guidance on how to identify and evaluate contaminants of concern in dredged material, and selection of control and reference sediments. The manual provides a detailed tiered-testing procedure, which is a major improvement provided in the revised manual. Specific guidance is included for generating the information called for in the various tiers. The ultimate goal of the tiered approach is to determine if a given dredged material is in compliance with the limiting permissible concentration (LPC). The LPC of the liquid phase of a material, as defined in the ocean disposal regulations, is "that concentration, which after allowance for initial mixing, does not exceed applicable marine water quality criteria; or, when there is no water quality criteria, will not exceed a toxicity threshold 0.01 of a concentration shown to be acutely toxic to appropriately sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures." Compliance with the LPC is currently determined through the application of specific effects and bioaccumulation test protocols. These methods are outlined in the tiered approach described in the testing manual.

The Tiered Approach

The tiered approach is designed to proceed from simple, cost-effective evaluations, which take advantage of available information, to more complex and consequently more expensive ecological risk assessments requiring generation of case-specific data (Fig. 1). It is envisioned that the tiers may be entered

Dredged Material Analyses and Methods

Tier I - Characterization

Evaluation of Existing Information	Literature research
Geotechnical, Geochemical, and Hydrodynamic Data	
Biological Effects Data	
Spill Data	
Dredging History	

Tier II - Physical and Chemical-based Analysis

Benthic	
Grain Size	Sieving
Total Organic Carbon (TOC)	Combustion
Total Solids/Specific Gravity	Gravimetry
Organic Compounds	GC/MS
Metals	GC/MS
Miscellaneous (e.g., cyanide and asbestos)	AAS
Theoretical Bioaccumulation Potential (TBP)	Model
Water Column	
Organic Compounds	GC, GC/MS, GC/ECD
Metals	GC, GC/MS, AAS
Initial Mixing Dispersion Analysis	Model

Tier III - Biological Effects Testing

Benthic	
Toxicity Bioassays	96-hour & 10-day tests
Bioaccumulation/Availability Assays	10- & 28-day tests
Water Column	
Elutriate Toxicity Bioassays	96-hour test

Tier IV - Advanced Biological Effects Testing

Benthic and Water Column	
Chronic Effects Testing	
Case-specific Bioassays	Long-term exposure tests
Growth Analyses	
Reproductive Analyses	
Field Assessments	Field sampling

Figure 2. Information and testing requirements for the tiered approach.

at any point, providing the required information is available and that one proceeds through the tiers until sufficient data is developed to make a permit decision regarding LPC compliance (Fig. 2).

Tier I

Tier I is primarily an evaluation of existing data. However, in most cases, a chemical characterization of the dredged material will be required and must be generated if such data is not available. In some cases, the exclusionary criteria defined in the regulations may be invoked, thus obviating the need for further assessment. These exclusionary criteria relate to dredging activities far removed from any sources of contamination and also consider material, such as coarse sand and gravel, which are typically uncontaminated. In Tier I, it may be possible to establish that the dredged material under evaluation does not comply with the LPC (e.g., sediments from dredging site exceed hazardous waste levels). Sources of available information for Tier I evaluations include:

- "Selected Chemical Spill Listing" (EPA)
- "Pesticide Spill Reporting System" (EPA)
- "Superfund Reports" (EPA)
- STORET, BIOS, CETIS, ODES (EPA databases)
- NPDES permit records
- Previous permit evaluations
- Published scientific literature
- University research reports
- State environmental agencies

In the majority of dredged material evaluations, Tier I will typically indicate that further testing in subsequent tiers is warranted. However, in some cases a permit decision can be made in Tier I, thus providing a timely and cost-effective regulatory decision.

Tier II

Tier II is designed to take advantage of existing and developing predictive assessment models. It is envisioned that when sediment quality criteria are developed and adopted for regulatory use, they will be applied in Tier II as part of the permit decision process. Currently, there are a number of modeling approaches that are recommended for use in Tier II. These are the ADDAMS model, which provides predictive assessment of potential water quality impacts at specific disposal sites, and the TBP model, which is used to assess bioaccumulation potential of contaminants of concern associated with the dredged material. At present, the utility of the TBP model is limited because it only pertains to organic contaminants and does not address bioaccumulation potential of inorganic compounds. Consequently, Tier II cannot be used to fully determine LPC compliance for dredged material; however, Tier II is used to determine compliance with applicable marine water quality criteria.

Reference Sediment

The reference sediment is the key to the interpretation of the benthic toxicity and bioaccumulation tests. Results from treatments using reference sediment are compared to results from the dredged material treatments. This comparison is used to determine LPC compliance for the solid phase of the dredged material. Reference sediment is defined as a sediment that is substantially free of contaminants, is as similar to the grain size of the dredged material and the sediment at the disposal site as possible, and reflects conditions at the environs of the disposal site *prior* to disposal activities.

Tier III

In the majority of dredged material evaluations, Tier III laboratory testing will be necessary. The Tier III protocols consist of water column and benthic toxicity tests and whole-sediment bioaccumulation tests. As sublethal and chronic tests are developed, they will be incorporated in Tier III.

Tier III water column toxicity testing addresses the acute toxicity of both suspended and dissolved fractions of the dredged material remaining in the column, following a four-hour period to allow for initial mixing. The test recommended in the manual is a 96-hour acute toxicity test conducted with the mysid shrimp, *Mysidopsis bahia;* however, additional species are also recommended (Fig. 3). The LPC is defined as the concentration of any dissolved or suspended dredged material constituent, which, after allowance for initial mixing, exceeds 0.01 of the LC50 measured in the bioassay.

Tier III benthic tests are conducted to determine the potential for acute toxicity and bioaccumulation potential. The recommended test species for acute toxicity testing are benthic amphipods, such as *Ampelisca abdita* and *Rhepoxyinius abronious*. Amphipod toxicity is measured over a 10-day period. The LPC is not met if the toxicity measured in dredged material treatments

Water Column Bioassay Organisms

Crustaceans
- *Mysids
- Grass Shrimp
- Penaeid Shrimp
- Caridean Shrimp
- Blue Crab
- Cancer Crab

Fish
- *Silversides
- *Shiner Perch
- Pinfish
- Spot

Zooplankton
- *Copepods
- *Larvae
  - mussels
  - oysters
  - selected crustacean species

**recommended*

Figure 3. Recommended water column test organisms.

is statistically greater than the reference treatment and exceeds the reference treatment by at least 10 to 20 percent. The LPC is met if the toxicity in the dredged material is less than the toxicity in the reference sediment.

Species recommended for bioaccumulation testing include the bivalve, *Macoma nasuta*, and the polychaete worm, *Nereis virens*. Additional species listed in the manual are also considered suitable for toxicity and bioaccumulation testing (Fig. 4). Bioaccumulation potential of contaminants associated

Sediment Bioassay Organisms

Burrowing Polychaetes
- *Sand Worm
- Red-lined Worm
- Blood Worm
- Lugworm

Crustaceans
- *Infaunal Amphipods
- Mysids
- Grass Shrimp
- Penaeid Shrimp
- Caridean Shrimp
- Blue Crab
- Cancer Crab

Molluscs
- Small Clams

**recommended*

Figure 4. *Recommended benthic test organisms.*

with dredged material is evaluated by comparing residue levels in organisms exposed to reference sediment, to levels measured in dredged material treatments following 28 days of exposure. Dredged material residue levels are assessed by comparing 28-day body burdens to Food and Drug Administration (FDA) action levels for deleterious substances and to the concentrations measured in reference organisms. If FDA action levels are exceeded, the LPC is not met; additionally, if concentrations in dredged material treatments exceed reference treatment and the contaminants are of toxicological concern, the LPC is not met. It should be noted that interpretation of bioaccumulation results for ecological impact is a complex issue because the linkage of residue concentrations to biological and ecological impacts has not been established. Case-specific criteria that reflect local conditions are needed to enhance the interpretative framework for bioaccumulation test results. If residues are below FDA action levels and below reference residue values, the dredged material meets the LPC for the bioaccumulation endpoint.

Tier IV

Tier IV is designed to provide an ecological risk assessment approach for those situations that warrant the time and expense incurred by case studies. Tier IV tests consist of bioassays and bioaccumulation tests that account for long-term effects of exposure to dredged material. Tier IV methodology is primarily a research and development activity at this time. Ultimately, methods developed for Tier IV assessment will provide the required information to integrate long-term contaminant exposure and effects and thereby assess the ecological impact resulting from dredged material disposal in aquatic environments.

Conclusion

Maintaining the nation's ports and navigable waterways in an environmentally consistent manner is clearly a high priority of port authorities, state and federal regulatory agencies, and environmental interests. The tiered-testing approach provided in the Green Book attempts to utilize state-of-the-science evaluative procedures in a pragmatic and cost-effective way to provide the best possible approach for assessing the impact of dredged material disposal on the marine ecosystem. The efficacy of this rationale will become clear as monitoring programs generate information that will elucidate the impact of ocean disposal activities over time.

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