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EVALUATION OF THE U. S. ARMY CORPS OF ENGINEERS' DECISION-MAKING PROCESS FOR SELECTION OF DREDGED MATERIAL DISPOSAL SITES

BY

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Abstract

This study evaluates the decision-making process of the U. S. Army Corps of Engineers (COE) as it applies to the selection of land or open-water disposal sites for sediment from dredging projects planned by the COE. The study seeks to illustrate:

1) the structure of the COE decision-making process as provided for in laws, regulations, and COE policies;
2) the operational, economic, and environmental variables that might influence COE decision-making;
3) how the New England Division of the COE makes decisions on disposal sites for dredged material through consideration of operational, economic and environmental objectives.

The study finds that the COE decision-making process, with respect to dredged material disposal, is structurally complex and bureaucratic in nature. It is characterized by the interaction of numerous laws, regulations, federal agencies, and public and private interests. The process is designed to accommodate potentially conflicting interests and objectives.

There are many potentially important variables involved in the decision-making process. The possibility of conflicts between operational, economic and environmental objectives requires flexibility in decision-making. Because the potential environmental effects of
dredged material disposal are still poorly understood, the environmental objective is the one most easily compromised.

Based upon the quantitative evaluation performed in this study, the operational economic and environmental variable groups that were examined appear to have little or no influence on disposal site decision-making in the New England Division (NED) of the COE. This suggests that, in practice, the NED decision-making process is loosely structured, project specific, and highly subjective in nature. That finding is probably a function of the complex nature of both the dredged material disposal problem and the decision-making process.

It is difficult for the NED decision-makers to objectively assess the same set of variables in each disposal decision. The diversity of potentially important variables, and the variability of project conditions make the application of broad-scale decision rules impractical. The decision-making process must be flexible enough to accommodate the special considerations of each project. As a result, disposal site selections must be made on a project-by-project basis, and are ultimately subjective in nature.

The findings of this study raise an interesting issue in terms of the COE's environmental regulatory requirements. The New England Division does not appear to be making an attempt to exclude or restrict all potentially contaminated dredged material from open-water disposal. It seems that dredged material is excluded from open-water disposal only if it obviously violates current regulatory standards. Little effort is
made to restrict the discharge of material that may be marginally contaminated, so long as it complies with the regulations.

If these findings reflect the policy of the New England Division, that policy may or may not be justified in light of the uncertainty surrounding the potential adverse environmental impacts of dredged material disposal. The issue of contention is that, even though such a policy fulfills the regulatory requirements, it does not fully conform to the intent of Congress as expressed in the legislation.
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CHAPTER 1

Introduction

The goals of this study are two-fold. One goal is to develop a general understanding of the dredged material disposal issue, and the COE's decision-making process with regard to selecting land or open-water disposal sites for dredged material from federal dredging projects. These topics are discussed in chapters 2-4. The second goal is to evaluate the results of disposal decisions made by the New England Division (NED) of the COE to determine the extent to which certain groups of variables are incorporated into the decision-making process. This more specific objective is addressed in chapters 5 and 6. Chapter 7 presents conclusions concerning both objectives.

Historically, the Army Corps of Engineers (the COE) has maintained and expanded the navigable waters of the United States for the purposes of enhancing resource development and furthering "national economic efficiency" (Mazmanian and Nienaber, 1976, 229). In so doing, the COE has dredged and disposed of about 300 million cubic yards of sediment annually (Boyd et al, 1972, 6; Hart, 1983, 27). Disposal of this enormous volume of material is becoming an increasingly complex issue as an increasing number of conflicts arise between environmental, economic, social and political goals.

The COE's role as the maintainer of the Nation's waterways became labyrinthine in the early 1970's when its regulatory authority over
disposal of dredged material was expanded. Previously the COE's regulatory responsibility, under the Rivers and Harbors Act of 1899, included all dredging operations, but only those disposal operations that might interfere with navigation. Under its new mandate (see section 2.2, herein), the COE was required to consider the potential environmental impacts that disposal of dredged material might have on United States waters. The COE's regulatory authority now covers land disposal, where it affects the waters of the United States, and all open-water disposal of dredged material. The COE's regulatory mandate establishes it as the permitting agency for proposed private dredging projects, and requires that the criteria used to evaluate private disposal plans also be applied to federal disposal plans.

The justification for the Legislature's expansion of the COE's regulatory role lies in the findings of the ocean dumping report of the Council on Environmental Quality (CEQ) (Marine Protection, Research and Sanctuaries Act, Legislative History, 4238), which suggested that the COE is in the best position to regulate activities over which it has operational responsibilities (Council on Environmental Quality, 1972, p. v). Several intertwined arguments have been voiced in support of that position. First, the COE is the most knowledgeable and experienced government agency in terms of the economic and environmental considerations related to dredging and dredged material disposal. As such, it is regarded as the agency most qualified to make decisions pertaining to the disposal of dredged material (Miller, 1973, 67). Second, Congress presumed that regulation of dredged material
disposal should be an extension of the authority over dredging permitting already granted to the COE via Section 10 of the Rivers and Harbors Act of 1899. Such comprehensive authority would seemingly allow the COE to perform its dredging operations without unreasonable restrictions (O'Halloran, 1982, 757). Finally, given the COE's jurisdiction under Section 10, it was deemed appropriate to include regulation of discharge of dredged material into navigable waters within the COE's authority in order to avoid confusion (Power, 1977, 522).

The situation in which the COE is both regulating and being regulated, creates an apparent conflict of interests which was recognized by the CEQ (1970, 31) in its report to the President. Some observers have argued that operational responsibilities and regulatory functions should be separated (Miller, 1973, 65) in order to avoid any conflict of interests within the agency that might compromise its effectiveness as a regulatory authority (O'Halloran, 1982, 757). Wilson and Rachal (1977, 3) suggested that government agencies are ineffective in modifying the behavior of other government agencies. If this is so, can we expect regulation to be effective on an intra-agency level? Some political-economic theorists (Baden and Stroup, 1981, 5; Miskanen, 1971 and 1975) have asserted that, in general, government agencies strive to expand the scope of their activities. Assuming this assertion is correct, and if we further assume that agency expansion is constrained by regulation, can we then expect that the COE will regulate its dredging and disposal activities irreproachably?
In its role as grantor of permits for private dredged material disposal, the COE is acting as a pure regulator. The functions of the COE as "regulator" of its own disposal practices may be more inclined toward management than pure regulation. The distinction between these terms lies in the application of the regulations to a particular type of dredging project, i.e., federal versus non-federal. In applying the regulations to a non-federal dredging project, the COE, as a pure regulator, evaluates the proposed disposal on the basis of a fixed set of parameters, and either grants or denies a permit based on that information. As a "manager" of federal dredged material disposal, the parameters could be adjusted throughout the planning and evaluation processes in order to achieve the optimal management solution within the established regulatory constraints. In the management situation, proposals could be incrementally modified and reconsidered throughout the decision-making process, rather than being submitted "in batch" and either accepted or rejected.

The alternatives available to the COE for disposal of dredged material fall into basically two categories: land disposal and open-water disposal. Within each of these broad categories are a variety of sub-alternatives, described in section 3.2, which may be desirable or necessary for certain types of sediment or certain dredging projects. The variables involved in selection of a disposal alternative are numerous, and to a large extent are specific to the location and the job being considered. Some generic groups of these variables, which might influence the selection of a disposal alternative, include
technical and economic feasibility; social acceptability; political resistance; environmental conditions at a proposed disposal site; and the chemical and physical characteristics of the sediment. Within each of these groups are numerous individual variables which may receive varying degrees of emphasis depending upon the conditions of particular choice situations. Some variables may be exclusive to specific situations, while others are comprehensive.

In its role as the regulatory agency responsible for dredged material disposal, the COE is confronted with the task of identifying the variables relevant to a particular choice situation, and then weighing those variables to arrive at an acceptable solution. While the COE may be required to consider certain variables by explicit legal or physical conditions, the significance of many other variables may only be implied by less tangible forces in the decision-making process.

McFadden (1975 and 1976) describes government agency decision-making as a balancing process, where some objectives are weighted more heavily than others. For each COE decision, certain variables may be given greater consideration than others in the balancing process. The question that arises from this balancing of objectives concerns the manner in which the numerous variables are incorporated into the decision-making process. Because many aspects of the decision-making process are difficult or impossible to quantify, the determination of the optimal solution may become a subjective exercise. Given the subjective nature of the decision-making process,
it is difficult to make an objective assessment of the COE's regulatory effectiveness. It would be useful, however, to understand how the decision-making process explicitly and/or implicitly considers the various influencing variables.
Decisions made by the COE concerning the choice of land or open-water disposal alternatives for dredged material are guided by an extensive legal/regulatory structure. That part of the structure pertaining to open-water disposal is primarily determined by federal legislation. These laws explicitly address the issue of dredged waste disposal, and require the institution of criteria for regulation of open-water disposal of that material. The part of the legal structure controlling land-based disposal is much less concrete in the sense that no federal laws expressly address the issue of dredged material disposal on land, and no federal regulations exist to that end. There is an indirect federal legal structure that controls land-based disposal through administrative procedures and regulation of the constituents and by-products of dredged material. Appendix A lists and describes the federal legislation pertinent to dredged material disposal decisions, and the major laws are discussed below.

2.1 Land Disposal

The legal structure regulating land disposal of dredged material is, for the most part, grounded in state and local laws and ordinances (New England River Basins Commission, 1981, 6). The bases of the state-local legal structure are environmental protection laws, and land
use control laws (Cole and Brainard, 1978, 4-5). At the federal level, the laws in appendix A, with the exception of the Marine Protection, Research and Sanctuaries Act of 1972, may be applied to land disposal as described. Of those laws, the National Environmental Policy Act of 1969 (NEPA), and the Coastal Zone Management Act of 1972 (CZMA) are the most influential as administrative requirements. The Resource Conservation and Recovery Act of 1976 (RCRA), and the Federal Water Pollution Control Act of 1972 (FWPCA) may be important in regulating certain constituents of dredged material and its by-products, respectively, when land disposal is planned.

2.1.1 The Coastal Zone Management Act

The significance of the CZMA is that it was designed to give states greater control over activities occurring within their coastal zones. One of the major provisions of this act allows those states having an approved coastal zone management plan to require that any federal activities directly affecting their coastal zone be consistent with the objectives of the state plan. In order to implement a land-based disposal operation, in a state with an approved coastal zone management plan, the COE must first ensure that the activity is consistent with that state's plan. Once compliance with the plan has been established the activity is subject to public review and certification by the Department of Commerce (Cole and Brainard, 1978, 25).
2.1.2 The National Environmental Policy Act

NEPA was enacted during a nationwide environmental movement for the purpose of establishing a national environmental policy that would promote efforts to prevent environmental damage and encourage harmony between man and his environment. What the statute effectively did was to require every federal agency to assess, and report on, the potential environmental impacts of their proposed actions. The NEPA complicated dredged material disposal decisions by requiring that an environmental impact statement (EIS) be prepared, and a public hearing be conducted, for each proposed action. Additional complications, related to dredged material disposal, which arose as a result of NEPA are cited by Bradley (1976, 43) as follows:

1) The requirement to consider the best disposal practices (economically and environmentally);
2) The need to find beneficial use for dredged material;
3) The need to know physical and chemical characteristics of the material; and
4) The need to determine what techniques and types of equipment could be employed to minimize environmental costs.

2.1.3 The Resource Conservation and Recovery Act, and the Federal Water Pollution Control Act

Land disposal of dredged material is affected by RCRA if the material contains any substances that are considered to be hazardous waste by the Environmental Protection Agency (EPA), or if the material will be harmful to human health. Not all land disposal operations are
necessarily affected by the Act. Land disposal of dredged material is affected by the FWPCA only when the proposed action includes marsh filling (Sec. 404); or if leachate, runoff, or effluent from a land disposal area will enter navigable waters (Sec. 402; Bradley, 1976, 46).

2.2 Open-water Disposal

In contrast to land-based disposal, the legal structure for open-water disposal is almost entirely federally oriented. Open-water disposal in navigable waters, within the territorial sea, may be restricted or prohibited by state law (Mugler, 1983, 41), but the primary authority remains at the federal level. In New England, the only state where open-water disposal is not allowed is Rhode Island, which has no designated disposal site. The Clean Water Act of 1977 provides for state assumption of control over dredge and fill permitting, but little progress has been made in that regard. Currently, only Michigan has an approved permit program, and that program is limited to "unnavigable" waters. The COE retains jurisdiction over navigable waters and adjacent wetlands (Bureau of National Affairs, 1984, 958). Rhode Island has an experimental permit program similar to Michigan's, but it has not yet been fully implemented.

The Federal Water Pollution Control Act Amendments of 1972 (FWPCA), and the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA) are the primary forces behind open-water disposal
regulation. The CZMA and NEPA also apply to proposed open-water disposal operations in the same manner that they apply to proposed land disposal operations. Ocean disposal, beyond the limits of state jurisdiction, may be influenced by the 1984 United States Supreme Court decision regarding the consistency provision of the CZMA in California v. Secretary of Interior (see Bureau of National Affairs, 1984, 1571), but the implications of that decision are unclear at this time.

In addition to the federal legislation, there is the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Dumping Convention). This convention is an international treaty signed by the United States in London in 1972.

2.2.1 The Federal Water Pollution Control Act

The objective of the FWPCA, as expressed by Congress, is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. This Act has jurisdiction in the "navigable waters of the United States", which includes most of the internal waters of the U.S., as well as the territorial sea out to three miles (33 CFR Part 323.2).

The FWPCA applies to "any addition of dredged material into the waters of the United States" (33 CFR Part 323.2(j)). Section 301(a) of the Act makes discharge of any pollutant from a point source unlawful unless a permit is obtained. Section 404 makes it clear that dredged materials are a pollutant subject to the provisions of the Act.
(Bradley, 1976, 46), and establishes the Secretary of the Army, acting through the Chief of Engineers, as the permitting authority for disposal of dredged material. Dredged material disposal permits issued pursuant to this Act shall be referred to as 404 permits. Proposed disposal operations are to be evaluated according to criteria provided for in Section 403, and all permits granted are subject to veto by the Administrator of EPA under Section 402(a)(1).

While the result of the FWPCA is a permitting program which regulates open-water disposal of dredged material, some observers contend that Congress it to be a temporary program which would be terminated at a time when advancing technology had overcome the need for open-water disposal (Webb and Holmes, 1976, 97).

2.2.2 The Marine Protection, Research and Sanctuaries Act.

In the MPRSA, Congress declared it the policy of the United States to "prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities or the marine environment, ecological systems or economic potentialities". This Act authorizes regulation of the transportation of dredged material with intent to dump it in ocean waters. Ocean dumping is defined as the disposition of material into "open seas lying seaward of the baseline from which the territorial sea is measured" (40 CFR 220.2(c) and (e)). Generally, discharges of materials from an outfall structure are excluded from jurisdiction under this Act because they are regulated by the FWPCA. However,
dredge pipelines are not considered "outfalls", and are regulated under the MPRSA when the discharge occurs beyond the baseline (Marine Protection, Research and Sanctuaries Act of 1972, Legislative History, p.4244).

Legally, disposal of dredged material within the territorial sea is subject to the provisions of both the MPRSA and the FWPCA. However, in practice the MPRSA is applied to disposal beyond the baseline, while the FWPCA is reserved for regulation within the baseline. The reason for the precedence of the MPRSA in the overlapping area is the more stringent environmental standards of that Act. For the same reason, a 1980 amendment to the MPRSA required that the criteria established pursuant to Section 102(a) of the Act be applied to dumping from any federal project in Long Island Sound (Marine Protection, Research and Sanctuaries Act, 1980 amendments). Long Island Sound is within the baseline, and would otherwise be under the authority of the FWPCA.

Like the FWPCA, the MPRSA designates the Secretary of the Army as the permitting authority for ocean disposal of dredged material (Section 103(a)). The act also establishes criteria by which proposed disposal operations are to be evaluated (Section 102), and grants the Administrator of EPA veto authority over all permits issued (Section 103(c)). The MPRSA requires "case-by-case evaluation of ocean dumping proposals, with dumping approvals to be granted only when there has been an affirmative showing of no unreasonable degradation" (Kamlet, 1976, 54). Despite the seemingly stringent regulation of ocean
dumping established by the MFRSA, Congressional intent in enacting this law has been interpreted by EPA as allowing ocean dumping as an acceptable alternative for waste disposal so long as there is not "unreasonable degradation" (Smith, 1979, 246).

2.2.3 The London Dumping Convention

The London Dumping Convention was adopted in 1972 with the intent of controlling pollution of the sea by dumping through international action. Section 102(a) of the 1974 amendments to the MFRSA, requires that domestic ocean dumping criteria "apply the standards and criteria binding upon the United States under the Convention, including its Annexes" (Kamlet, 1976, 55).

The Parties to the London Dumping Convention pledge themselves "to take all practicable steps to prevent the pollution of the sea by dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea" ("Convention...", 1972, 627). Annex I of the Convention, the so-called "black list", identifies substances, such as cadmium and mercury, that are strictly prohibited from ocean disposal except when contained as trace contaminants in other material (e.g., dredged material). "Trace contaminants" are only vaguely defined as those occurring in small quantities. The materials listed in Annex II may be disposed of in the ocean only by special permit. Permits shall be issued only after careful consideration of the factors set forth in
Annex III ("Convention...", 1973, 628). The regulations that resulted from the MPRSA closely reflect the provisions made in these annexes for restriction and prohibition of materials, and for the establishment of permitting criteria.

2.3 Comments

The objectives of the London Dumping Convention, the FWPCA and the MPRSA clarify the desire of the international community, including Congress, to protect open-water environments from potential degradation due to disposal of waste material. The language of the MPRSA, in particular, expresses that objective when it states that the policy of Congress is to "prevent or strictly limit" ocean disposal of potentially degrading materials. All three of these documents specifically refer to dredged material as a potential contaminant whose disposal in open water should be restricted.

These documents do provide for some flexibility in the regulations by allowing open-water disposal where it produces "no unreasonable degradation", or where other methods of disposal are not "practicable". This author interprets that language to mean that Congress intended open-water disposal to be a secondary, rather than a primary, alternative. Alternative methods of disposal should be used whenever technically feasible, even if they are more costly than open-water disposal. Demonstration of "no unreasonable degradation" should be used for granting permission to dump in open-water only
after all the alternative methods have been evaluated, and found to be infeasible.
CHAPTER 3
Dredging and Dredged Material Disposal

In order to understand how the COE makes decisions with regard to dredged material disposal, it is first necessary to discuss the basic functional inputs that may influence those decisions. Functional inputs, in this context refer to the technical, economic and environmental variables that are internal to the decision-making process. The potential socio-political influences are beyond the scope of this study, and are therefore excluded from this group of factors. The functional inputs to be discussed here include dredging and disposal methods currently employed by the COE; sediment characteristics; economic considerations; and the short- and long-term environmental impacts resulting from dredged material disposal, both on land and in the water.

3.1 Dredging Methods

There is a wide variety of dredging equipment employed by the COE nationwide, either directly or through private contractors. The choice of a particular type of equipment is largely job-specific, and is subject to many variables (see for example, COE, 1983). It is important for the reader to understand the nature of the interaction between the use of a particular dredging method and the selection of an appropriate disposal site.
For federal dredging projects in the New England region, the COE relies primarily on hydraulic cutterhead dredges and mechanical bucket dredges. Hopper dredges are occasionally used in New England, and sidecast dredges are infrequently used. For a detailed discussion of dredging equipment and techniques see COE (1983) and Boyd, et al (1972).

3.1.1 Cutterhead Dredges

The cutterhead dredge is a hydraulic dredge that churns up bottom sediment using a rotating head on the end of a boom that is extended into the bottom sediment from a vessel. A suction pump aboard the vessel draws a sediment-water slurry up from the bottom by way of a pipeline. The slurry is pumped to a nearby land or water disposal site, or onto a barge. Barges are rarely used in transporting this type of dredged material because of the inefficiency associated with the high water content of the material. In most cases the slurry is pumped through a pipeline to a land disposal site where the sediments are dewatered. The slurry may also be pumped to a nearby open-water disposal site where it is discharged directly into the water column. This method causes a high degree of dispersion of the sediment in the water column.

The use of hydraulic dredging may be limited by the distance to the disposal site. Generally, the maximum distance the slurry may be pumped without the aid of a booster pump is dependent upon many factors, including the sediment characteristics and, for land disposal,
the topography. Increases in slope decrease the distance that dredged material may be pumped. Sediment characteristics may preclude the use of hydraulic dredging in some cases. For instance, consolidated clays cannot be dredged economically using this method (COE, 1983).

3.1.2 Bucket Dredges

The bucket dredge is a mechanical dredge that uses a clamshell, or bucket, affixed to a crane boom, to scoop sediments from the bottom. The sediment has a relatively low water content and usually remains in a fairly consolidated mass. This method minimizes the dispersion of sediment in the water column.

The sediment is placed in a barge, or scow, and is usually transported to an open-water disposal site, where it is dumped through the bottom doors of the barge. It is possible to transport the barge to a location near a land disposal site, where the sediment is mixed with water and pumped out as a slurry. However, this technique is generally not very cost-effective.

3.1.3 Hopper Dredges

The hopper dredge is a hydraulic dredge which is generally used for fairly large jobs in deep water. The dredge uses a pair of cutterhead booms to remove the sediment from the bottom, and a suction pump to convey it into hoppers in the hold of the vessel. When the vessel's hoppers are full it merely transports the sediment to an open-water dumpsite and discharges it through bottom doors. Initially,
the sediment has a high water content similar to the slurry produced by cutterhead dredges, but the supernatant water is usually allowed to overflow the hoppers, thus reducing the water content of the material. The sediment, however, is much less consolidated than that resulting from bucket dredging. The degree of dispersion of sediment in the water column is intermediate between pipeline and barge disposal methods. Supernatant overflow may be a water quality concern where the dredged material contains potential contaminants.

3.1.4 Sidecast Dredges

The sidecast dredge is a variation of the cutterhead dredge which discharges the sediment from a boom extended sideways from the vessel, rather than pumping it through a pipeline. Disposal from this type of vessel is, of necessity, performed in open-water. There is a high degree of dispersion of sediment associated with this method.

3.2 Disposal Alternatives

For the purposes of this study, the disposal alternatives used by the COE have been identified as either upland or open-water disposal. In reality, there are several sub-alternatives within each of these categories. In the 1970's, concern over the environmental effects of dredged material disposal, and the realization that there may be beneficial uses for those materials, spurred research into innovative methods of disposal. As a result, there are a variety of disposal methods currently being used (COE, 1983; Oceanic Society, 1982; and
Boyd et al, 1972). Although this study recognizes only land and open-water disposal, the reader should be aware of some of the more common alternatives available within these two categories. On a legal/regulatory level, these techniques do not alter the decision-making process. However, their potential impact on the environment makes them important in developing a management strategy for dredged material disposal.

3.2.1 Unconfined Open-water Disposal

Unconfined open-water disposal of dredged material has traditionally been the most common method of disposal used by the COE. This type of disposal operation is regulated by both the MPRSA and the FWPCA. The appeal of the open-water disposal method is due primarily to the ease and cost-effectiveness of the operation. There is very little technical preparation associated with open-water disposal, and transportation to open-water sites tends to be relatively inexpensive.

Transportation of dredged material to open-water sites may be accomplished by either vessel (e.g., barge or hopper dredge) or by pipeline. The precise behavior of dredged material in open-water is job-specific and dependent upon sediment and disposal site characteristics. After the dredged material has been released into the water column it generally settles to the bottom where it forms a mound. The extent of mounding will depend upon current conditions around the disposal site, and the method of disposal employed. The finer portions of the sediment tend to remain suspended in the water column longer
than the coarse fraction, and may be dispersed by currents to varying degrees. Sediment discharged by pipeline generally tends to be dispersed more as a result of the unconsolidated nature of the material.

3.2.2 Confined Open-water Disposal

Dredged material that may be contaminated, and is considered potentially harmful to the aquatic environment, may be "contained" in the water after disposal. The idea of containment is to protect or isolate the dredged material from the overlying water column and biota to prevent dispersion and biological uptake of contaminants. At this point in time, these techniques are still largely experimental and their effectiveness has not been demonstrated conclusively. Legally, projects using these disposal methods are still subject to the provisions of the MFRSA and the FWWCA.

A relatively simple containment technique, which has been used on an experimental basis, is to cover, or "cap", the contaminated sediment mound with coarse-grained clean material, usually sand, in order to isolate the contaminated sediment from the water column. The quantity of clean material required to form an effective cap may be several times the volume of contaminated material deposited. This clean material may be dredged from a less contaminated section of the same project, or from areas remote from the project site. If the material is dredged specifically for the purpose of capping, there may be a
significant added cost to this method depending upon the volume of material needed and the distance it has to be transported.

Another experimental method of containment is the construction of subaqueous dikes as retaining walls into which the sediment is dumped. Depending upon the level of contamination and the local current conditions, the material may or may not be subsequently capped with cleaner material. Dikes would most likely be constructed of clay sediment because of its cohesive properties, and its relative impermeability. The cost of this method probably would be high.

A technique comparable to diking is to dispose of contaminated sediment in bottom depressions or subaqueous mining pits. Theoretically, the sides of the pits will act to retain the contaminated sediment. Further protection could be afforded by capping the depression with cleaner material. This method would be considerably less expensive than constructing subaqueous dikes.

3.2.3 Habitat/Island Creation

Habitat and/or island creation are disposal techniques that have been looked upon favorably in recent years because some observers believe they may actually enhance, rather than degrade, the environment (COE, 1983; Boyd, et al, 1972). The basis of the concept is to construct a retaining structure, usually in shallow water, up to or above the water surface, and to deposit the dredged material within the structure. The material would most likely be hydraulically dredged and transported by pipeline. When disposal operations have been completed,
the resulting islands may be planted with marsh grasses or other vegetation. The islands may then serve as breeding grounds, nesting areas or other beneficial habitats. Two disadvantages of these techniques are the potential for passage of contaminants from the sediment into the food chain via plant uptake, and the finite nature of the marsh/island as a disposal site once it has been vegetated. These methods are also subject to the provisions of the FWPCA, and possibly the MPRSA.

3.2.4 Marsh Filling

In contrast to habitat creation, marsh filling has fallen into strong disfavor recently. This method involves merely pumping hydraulically dredged material into a marsh, which may later be used for development or other purposes. This method is regulated under the FWPCA. Growing concern over the loss of valuable wetland areas has reduced the use of this method to virtual non-existence.

3.2.5 Upland Disposal

Upland dredged material disposal may be either confined or unconfined, depending upon the level of contamination of the sediment. Sediment usually must be pumped to upland disposal sites via pipeline, and therefore requires hydraulic dredging. Sediment may be offloaded from barges directly onto disposal sites, but this is generally a less efficient method than pipeline transport. Relatively clean material may be disposed on open land, but, because it is clean, it may have
much more beneficial uses. Some of the beneficial uses of dredged material include mine reclamation, landfilling, and soil enhancement.

When the sediment is to be used for beneficial purposes it is often stored temporarily at a nearby site, and subsequently transported inland by truck or rail. The cost of disposal at an inland site may be high if the dredged material must be transported long distances.

Disposal of contaminated dredged material on land generally requires the use of containment dikes. The sediment is pumped into settling ponds within the retaining structure, where the sediment is allowed to settle out for a period of time while the supernatant water is drained off. Care must be taken to ensure that the runoff water is not contaminated.

Upland disposal is subject to the provisions of the FWPCA to the extent that runoff waters or leachate may impact the waters of the United States.

3.2.6 Beach Nourishment

Beach nourishment is a process by which clean, usually coarse grained sediment is pumped onto a beach to improve the quality of the beach or restore an eroded shoreline. The grain size of the sediment must be compatible with that of the sediment already on the beach.

Whether beach nourishment should be considered upland or ocean disposal is subject to debate. While the disposal site is, in fact, on land, the sediment is in contact with the aquatic environment periodically. However, any material that would be considered suitable
for beach nourishment is probably sufficiently coarse-grained that it is acceptable for open-water disposal under the current criteria. For the purposes of this study, beach nourishment is considered a form of land disposal.

3.3 Sediment Characteristics

The physical and chemical characteristics of the dredged material to be discharged have both indirect and direct effects on the selection of a disposal site. The indirect effect is associated with the influence that the physical characteristics of the sediment have on the type of dredging equipment used in the operation, and on transportation costs (State of Connecticut, 1982, 6). The direct effects are largely a result of the level of contamination of the sediment and its physical stability. For reasons to be explained shortly, dredged material from maintenance projects is often more polluted and of poorer quality from an engineering standpoint than that from new-work projects (Boyd, et al, 1972,13).

There are a variety of substances, that may be associated with dredged material, which can cause environmental degradation. They include, but are not limited to: biostimulants (e.g., nitrates and phosphates); heavy metals (e.g., mercury, cadmium); petroleum hydrocarbons; and persistent synthetic and organic materials (e.g., PCB, DDT). The potential effects of these substances on the environment are largely determined by the physical and chemical characteristics of the sediment.
3.3.1 Physical Properties

Boyd, et al (1972, 21) identify grain size, moisture content and plasticity as important engineering properties because they determine disposal characteristics such as turbidity, settling rate, shear strength, compressibility and permeability. Of these three properties, grain size is the most important because it is a determining factor in moisture content and plasticity. The engineering properties of the sediment may be particularly significant in land disposal operations. Fine-grained material poses land disposal problems because it is generally very compressible and very weak. As a result, fine-grained material may be of limited beneficial use on land.

From an environmental standpoint, grain size is important in open-water disposal operations because, according to Kester, et al (1983, 10), "it determines the conditions under which sediment will be resuspended or deposited, it determines the basic habitat available for benthic organisms, and it determines the surface area-to-volume ratio of the solid phase which is important in chemical exchange processes with the aqueous phase." Fine-grained material tends to result in greater water column turbidity, longer suspension time, and a larger dispersal area than coarse-grained sediment.

3.3.2 Chemical Properties

A report by the COE (1983, 4-1) cites the important chemical parameters of dredged material as pH, oxidation-reduction conditions,
salinity, amount and type of clay, organic matter content, amount and type of cations and anions, and the amount of potentially reactive iron and manganese. These properties largely determine what fraction of a chemical constituent may be potentially available for release to the water column in open-water operations or as leachate in upland operations. The clay content and oxidation-reduction conditions are the most important of these factors since most of the contaminants in sediments usually remain dissolved in the sediment interstitial water, become absorbed or adsorbed to sediment particles and/or become involved in complex sediment oxidation-reduction reactions (COE, 1983, 4-3). Organic matter content is important in that it retains water, may cause temporary oxygen depletion when deposited in water, and may produce objectionable odors on land (Boyd, et al, 1972, 23).

COE research (1983, 4-2) has indicated that fine-grained sediments have a high potential for retaining contaminants such as heavy metals, volatile solids, and organohalogenes (PCE, DDT, etc.) because they often contain a large proportion of clay particles, organic matter and retained water. However, according to the COE, these same properties may also tend to retain the contaminants within the dredged material after it is deposited, thereby preventing their release to the environment. The same COE report suggested that coarse-grained sediment is usually low in organic matter and clay content, and tends not to accumulate contaminants unless a contamination source is nearby. However, the report warned that coarse
sandy sediments that are contaminated pose the greatest potential for release of contaminants to the environment.

Material dredged from maintenance dredging projects is generally composed of organic matter and fine-grained sediment, such as silt and clay, from surface runoff, and sludges from municipal and industrial sewage (Boyd, et al, 1972, 21). More than half the material dredged in New England has a high organic content (Boyd, et al, 1972, 23) and nearly all of that is from maintenance projects.

3.4 The Economics of Dredged Material Disposal

Historically, decisions regarding land or open-water disposal have been based largely on economic considerations, with disposal sites being selected near enough to the dredging site to minimize disposal costs (Boyd et al, 1972, 5). However, with increased regulation there has arisen the need to balance environmental costs with the potential cost savings associated with a particular disposal option.

Although transportation costs are often an important economic factor in selecting a disposal site (Kester et al, 1983, 24), land disposal may not be the favored alternative, even when it minimizes transportation costs. Bakalian (1984, 253) suggested that the unquantifiable nature of the adverse environmental effects of ocean dumping invariably favors that alternative when it is compared to land disposal in coastal cities where land is at a premium. Supporting this notion, Alden and Young (1982, 567) commented that often the only areas available for disposal around highly industrialized estuaries are
wetlands that "should be preserved for environmental reasons"; leaving open-water disposal as the only viable option.

The costs associated with dredged material disposal fall into essentially three categories, which may or may not be accounted for in site selection decisions. These are operational costs, regulatory costs, and externalities.

3.4.1 Operational Costs

Operational costs are those expenses incurred as a result of the disposal operation itself. For open-water disposal, these include primarily transportation costs. For land disposal, they may include land acquisition costs, dike construction costs, and materials handling costs, as well. The unit costs for either land or water disposal are dependent upon the following conditions:

1) the type of plant and equipment employed;
2) the type of dredging performed (i.e., quantity and quality of material);
3) location and accessibility of the disposal site with respect to the dredge site;
4) the distance to the disposal site (Conner, 1979, 2-14; State of Connecticut, 1982, 30).

For land disposal sites there are several additional factors acting to determine cost. Unlike water-dumped dredged material, which may be transported by vessel or pipeline, the dredged material dumped on land may only be transported by pipeline. The cost of pumping
dredged material upslope increases as the gradient increases, and, as a result, the general topography of the land affects the cost. Even on flat terrain, there is a maximum distance which dredged material can be pumped through a pipeline without the aid of booster pumps. Disposal sites greater than that distance from the dredge site will require additional expense. There will also be additional expense if the material has to be rehandled (e.g., by truck, rail, etc.) before it reaches its final destination (State of Connecticut, 1982, 4).

Land acquisition costs may add substantially to the expense of land disposal in some areas. The location of the disposal site with regard to residential, recreational or biologically productive areas, and the general trends in population growth (Pope, 1976, 399) surrounding a disposal site have an affect on land values. Open land in densely populated areas or biologically productive wetlands may be prohibitively expensive sites for dredged material disposal.

Since the cost efficiency of using one or the other mode of transportation may vary substantially for a given project, the selection of a disposal site may have a significant impact on the final cost of the operation. For example, if the logistics of a particular operation are such that open-water disposal is much preferable to land disposal in economic terms, then all other things being equal, open-water disposal should be selected. If land disposal had to be selected in this case because of political, environmental or other constraints, the costs might be expected to increase markedly.
A major problem in attempting to delineate the incremental cost associated with open-water or land disposal is that it is very difficult to differentiate the relative importance of dredging and disposal costs (Conner, 1979, 2-12). This problem is manageable for mechanical dredging, where dredging and disposal are two relatively distinct operations. In this case, the cost of disposal is primarily associated with towing the barge, and the operation of the dredge constitutes most of the dredging cost. In fact, industry sources have estimated the cost of barge disposal as forty-five to sixty percent of the total cost of dredging, and an independent estimate suggests that it may be as much as seventy-seven percent of the total cost of dredging in New York City (Conner, 1979, 2-19). Even so, barges are generally considered the most economically efficient means of transporting bulk material like dredged sediment (State of Connecticut, 1982, 6).

For hydraulic dredging operations, dredging and disposal are a continuous system for which a cost breakdown is nearly impossible. Therefore, when comparing open-water and land alternatives it is not enough to merely consider the differences in transportation costs. The costs of the dredging operation itself must be considered as well.

3.4.2 Externalities

The externalities associated with dredged material disposal include the cost that is imposed upon society by marine or terrestrial environmental degradation, and the associated loss of resource
utilization (Kester, et al, 1983, 24). While externalities have not always been accounted for in evaluating proposed disposal projects, they are a valid part of costs and should be included (Pope, 1976, 398). Some of the externalities created by dredged material disposal, as cited by Pope (1976, 405), include:

1) impacts to adjacent land, including alteration of drainage and degradation of aesthetics;
2) displacement or impairment of business activities;
3) alteration of land-use patterns;
4) loss of land or water amenities;
5) increased municipal/industrial water treatment costs;
6) impairment of fishing; and
7) loss of recreational value.

In economically or biologically valuable areas, the external costs of dredged material disposal may be very high. In less valuable areas, the improvement of land through dredged material disposal may create social benefits rather than social cost. The cost of transporting the material for beneficial uses may be high, but those costs should be compared with the cost of destroying productive natural systems (Pope, 1976, 404) or using economically valuable land when making decisions.

3.4.3 Regulatory Costs

Regulatory costs are those attributable to activities required by dredging regulations (tangible costs), and those administrative costs
resulting from application of the regulations (intangible costs). These costs are usually high in comparison to the actual costs of dredging operations (Boerger and Cheney, 1976, 412), and are extremely difficult to delineate. According to Boerger and Cheney (1976, 412), the reasons for high tangible and intangible costs include:

1) Too many agencies involved;
2) Poor agency coordination;
3) Lack of properly defined procedures;
4) Lack of time limits within which agencies must act;
5) Questionable criteria; and
6) Inherent uncertainty in the regulatory process.

The tangible costs may be justified by the reduced social cost (environmental benefit) derived from improved disposal practices (Cable and Pearson, 1976, 353). For the same reason, some intangible costs may also be acceptable, but ideally they should be minimal.

3.5 Potential Environmental Impacts

The potential environmental impacts associated with dredged material disposal are best described in terms of the biological effects resulting from physical and chemical parameters. The physical and chemical characteristics of dredged material may have some direct adverse impact on environmental quality, but it is primarily through their effects on the biology that these characteristics may be linked to the human environment. It is difficult to measure the adverse impacts of increased water turbidity or release of contaminants to the
the bathymetry of the disposal site by the accumulation of a sediment mound.

Increased water column turbidity from dredged material disposal is a function of the degree of sediment-water contact. Unconsolidated sediment has a high degree of sediment-water contact, and therefore a high dispersion rate. Pipeline discharge of dredged slurry maximizes the sediment-water contact and may have significant turbidity effects if the discharge occurs in the same place for a long period of time (Boyd, et al, 1972, 41). Hopper dredge and barge disposal minimize sediment-water contact and therefore have lesser turbidity effects. The effects of turbidity at a given location largely depend upon the grain size of the sediment being discharged, the local current conditions, the distance from the discharge point, and the time that has elapsed since the discharge. Generally, the increased turbidity associated with dredged material disposal dissipates shortly after the operation is complete (COE, 1983, 4-12). There may be some reduction in biological productivity, particularly of phytoplankton, at the discharge site as a result of reduced sunlight penetration, but water quality degradation from suspended sediment is considered minimal (COE, 1983, 4-11).

The benthic effects of sediment discharge include the physical burial of benthic organisms and the alteration of benthic habitat by dredged material. These effects may be aggravated if the sediment is of a different quality than that of the substrate. These short-term impacts may vary in degree. The deposition of sediment can destroy a
predicting long-term effects associated with transmission of contaminants through the food chain.

One of the most significant conclusions drawn from the DMRP was that there are few if any biologically significant short-term environmental quality effects associated with chemical contamination of sediment that would be discharged at most open-water disposal sites (Jones and Lee, 1978; COE, 1983). One COE report concludes that "the intermittent nature of the dumping operation and the relatively rapid dispersion of any released contaminants at the disposal site creates a situation where the likelihood of significant toxicity or bioaccumulation of sediment-associated contaminants is small" (Jones and Lee, 1979, 7). The studies did not suggest that short-term effects do not exist, nor did they preclude the possibility of significant long-term effects.

Where significant short-term effects do occur they usually impact benthic and epibenthic organisms which are in close contact with contaminated sediment for longer periods of time than water column organisms (Brannon, 1978, 27-28). The effects on water column organisms have generally been negligible in test cases (Brannon, 1978, 26). Bioassay experiments conducted by Alden and Young (1982, 567) using dissolved material, fine suspended material and suspended solid phases from highly industrialized estuaries showed that where significant lethal effects were observed, the toxicity was mainly associated with suspended solids which tend to settle out of the water column in a relatively short period of time.
Although the short-term impacts of open-water disposal of contaminated sediments appear to be small, there is little evidence upon which to judge the long-term water quality impacts of the biostimulants (nitrates and phosphates), and toxins (heavy metals, pesticides) that may be associated with these sediments (Boyd, et al, 1972, 42). These impacts are difficult to quantify because of extensive mixing and dilution in the overlying water (Brannon, 1978, 11), and inadequate knowledge of the long-term fate of such contaminants.

Oxygen depletion in the disposal site environment is a potentially serious short-term impact that may be associated with even relatively clean sediments. Organic matter in fine-grained sediment is easily released upon mixing (Boyd, et al, 1972, 42) and may reduce the dissolved oxygen levels in the vicinity of the disposal site. Pipeline disposal operations generally cause the greatest oxygen depletion problems (COE, 1983, 4-11) because of extensive sediment-water contact. The extent of the area affected and the gravity of the problem are, again, a function of the volume of material discharged and the current conditions at the disposal site.

3.5.2 Land Disposal Impacts

Not nearly as much research has been done on the potential environmental impacts of land disposal of dredged material as has been done for open-water disposal. A rather important aspect of land disposal, from a management point of view, is the aesthetic impact.
Having a mound of dredged material deposited in one's backyard is generally not a very pleasant sight. That ugliness multiplies rapidly if there is a powerful odor emanating from the organic matter in the sediment.

The physical impacts of land disposal are similar to those of open-water disposal. Wildlife habitat may be destroyed by deposition of sediment, particularly in marshlands. Also, runoff from settling ponds and exposed sediment piles may cause turbidity and siltation problems in local watercourses.

There is potential for serious effects from chemically contaminated sediment on land even when it is in confined disposal areas. Contaminants may be transported to the surrounding environment by leaching into groundwater, release of contaminants into effluent during disposal, surface runoff of contaminants in dissolved or suspended particulate form, or plant uptake directly from sediment.

Some observers have argued that there is greater potential for release of contaminants, particularly heavy metals, from sediment disposed on land than from that disposed in open-water (State of Connecticut, 1982; Brannon, 1978, 12). Their contention is that most contaminated sediment is dredged from reducing environments and that disposal in a similar environment, such as quiescent open-water, will maximize retention of contaminants (COE, 1983, 4-2).

Brannon (1978) cites studies which suggest that the physical/chemical properties of dredged material are altered by drying, resulting in the release of more leachate when the material is mixed
with water. It has been proposed that dredged materials deposited in aerobic upland environments oxidize and become strongly acidic as they drain, thereby increasing the potential for release of heavy metals (COE, 1983, 4-2; State of Connecticut).

Table 1- The Degree of Potential Water Column Impact Associated with Various Techniques of Disposal *

least damaging 1) Mechanically dredged sediment; barge disposal.

2) Hydraulically dredged sediment; hopper disposal.

3) Hydraulically dredged sediment; pipeline disposal (variable point discharge) in open water.

4) Hydraulically dredged sediment; pipeline disposal (fixed discharge) in open water.

most damaging 5) Hydraulically dredged sediment; pipeline disposal into a confined land disposal area with a supernatant detention time of less than a day, where overflow is discharged to nearshore waters.

* Assuming equivalent dredged material and environmental conditions.

Source: Jones and Lee, 1978, 8.
Chapter 4

Evaluation and Decision-making

Chapters 2 and 3 discussed a variety of factors that influence the decision-making process of the COE regarding disposal of dredged material from federal dredging projects. The goal of this chapter is to elucidate the procedures and the agents through which those factors are administered to arrive at decisions on land versus open-water disposal. Because the COE has maintained that, in general, the environmental impact and the economics of the disposal operation are the functional factors in selecting disposal alternatives (COE, 1983, 2-6), those factors are the focus of this evaluation. While the COE has recognized the fact that the selection of disposal alternatives may be influenced by public opinion and/or agency regulations (COE, 1983, 4-30), the objective of this study is not to assess the impact of socio-political forces on the decision-making process. The study makes no attempt to account for these socio-political forces, neither in terms of their direct influence nor their influence on the functional factors.

The ecological testing and evaluation procedures described in sections 4.1 and 4.2 are part of a larger process which is diagrammed in simplified form in figure 1. This process is essentially the same as the "regulatory maze" of private dredged material disposal permitting, which was illustrated by Smith (1979), except that no
permit is issued for federal projects. In all its glory this process involves over forty major interlocking steps (Bokuinewicz and Minsch, 1982, 1145).

Where federal disposal operations are concerned, there are basically three levels of participation in the process—federal, state, and local. At the federal level, the process is controlled primarily by the COE and the Environmental Protection Agency (EPA), with supporting participation from the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS). At the state level, there is participation from environmental protection agencies, wetlands commissions, and water pollution control commissions. Local participation comes into play primarily in land disposal cases where local zoning, and health and safety ordinances may restrict available options (New England River Basins Commission, 1982, 5). Some observers have suggested that this inter-agency involvement in the planning process has created a system which has no clear objectives, causes conflict among interest-maximizing agencies, and does not follow a uniform methodology of application (New England River Basins Commission, 1982, 8; Boerger and Cheney, 1976, 409).

In figure 1, the initial step in the process is the determination of need for a dredging project (New England River Basins Commission, 1982, 3), which obviously then creates a need for disposal. This initial determination may be the result of an impairment to navigation, a request from local interests or other factors (Mazmanian and Nienaber, 1979, 16).
Figure 1 Overview of the Corps of Engineers Decision-Making Process
Sources: Francinques, 1984; Smith, 1979; 33 CFR Part 230.
The second step in figure 1 involves inter-agency meetings between the federal, state and local agencies mentioned above. The COE becomes the lead agency for the project, but this interactive effort continues throughout the planning and decision-making processes. Through this effort, potential disposal options and available sites are identified. The third step in figure 1 involves preliminary selection of probable disposal sites from the potential sites that have been identified. At this stage of the process there generally is no formal economic or environmental analysis of potential sites. Preliminary site selections are based on qualitative evaluations of the availability and suitability of sites, and technical feasibility. Only sites specifically designated by EPA may be used for open-water disposal unless the Administrator of EPA grants special permission for use of an undesignated site.

Some alternatives may be eliminated because they are obviously unsuitable based upon environmental, economic or technical conditions. For example, sites may be eliminated because of their value as natural habitat, nonconformance with local land use regulations, or the excessive cost that might be involved in transporting sediment to the site. In some cases, the choice between open-water or land disposal may become apparent in these early stages of evaluation. For instance, all land disposal options may be eliminated as being too costly or technically unfeasible. If this happens, the remainder of the decision-making process is aimed at determining the suitability of the material for open-water disposal. Should the material be found
unsuitable for open-water disposal, the project may need to be modified and reconsidered.

After preliminary site selection has been made, the COE must perform an environmental impact assessment in accordance with NEPA. An environmental assessment (EA) is a brief document which should provide enough information on the proposed action, and its environmental effects, to the Division Engineer so that he can determine whether or not a full-scale environmental impact statement (EIS) is required. If it appears that the project might have a significant environmental effect, then the complete EIS process must be carried out. Preparation of a Draft EIS (DEIS) is the first step in the process. Public interest review, including federal agency review, public comment, and public meetings or hearings, must be conducted throughout the process. If an EIS is not required, the EA is sufficient to fulfill NEPA requirements. Interagency review usually occurs as a part of the EA process, and, although not required by law, a public meeting may be held even when an EIS is not called for (33 CFR Part 230).

Before a final site selection can be made, the material proposed for disposal must be evaluated in terms of its compatibility with a proposed disposal site, and its compliance with regulatory criteria. For land disposal (see figure 1), the material must be evaluated according to RCRA, Section 402 of the FWPCA, and other "optional procedures (see section 4.3, herein). For open-water disposal, the material must be evaluated according to Section 404 of the FWPCA when disposal is to occur within the baseline, and according to Section 103
of the MPRSA when disposal is to occur seaward of the baseline (see section 4.2, herein).

Supporting permits, such as state water quality and wildlife permits, may also need to be considered in evaluating dredged material (Smith, 1979, 250). Certain states may have their own criteria for evaluating dredged material, for example, the Connecticut classification system represented in table 2. Under this plan, dredged material is classified according to its pollution potential, with Class III being the most "potentially degrading". According to the Connecticut policy, class III material shall not be disposed of in open-water unless it is capped with cleaner material. Class I material is considered clean,
and acceptable for either beach nourishment or open-water disposal. Class II material may be discharged at any of the three designated disposal sites in Long Island Sound (New England River Basins Commission, 1980, 17-18).

The evaluations conducted up to this point in the process may eliminate many or all of the alternatives in either disposal category. If both options are still available at this point, the final selection of land and open-water sites is made by the COE and other concerned agencies. The final choice between land and open-water disposal may require consideration of many of the same factors considered in the preliminary evaluation, but in much greater detail. Formal studies may be made of engineering and economic feasibility, and the environmental disposal site conditions for each alternative.

The environmental impact assessment process must be completed before a final site selection can be authorized by the Division Engineer. The full EIS process requires a Final EIS (FEIS), and a public meeting or hearing. An EA merely requires a Finding of No Significant Impact (FONSI) to complete the process.

If the evaluation procedures indicate that the material is not considered acceptable for disposal at the proposed site, the COE may modify the proposed project and repeat certain parts of the procedure; postpone the project for future consideration; or terminate the project entirely. Revision and reconsideration of the project may occur throughout the course of the decision-making process. Generally, the ecological evaluations of the material do not have to be repeated when
new sites are being considered unless the appropriate evaluations were not conducted the first time, or if a long period of time has elapsed since the previous evaluation.

4.1 Evaluation Procedures for Open-water Disposal

The first guidelines for regulating open-water disposal of dredged material based on environmental concerns were promulgated by the EPA in 1971. Prior to that time only the Rivers and Harbors Act of 1899 controlled dredged material disposal, but that Act regulated disposal only to the extent that it interfered with navigation. The 1971 guidelines, known as "the Jensen Criteria", were based on the bulk chemical content of the sediment with respect to seven chemical parameters. Those parameters included the bulk chemical content of total Kjeldahl nitrogen, volatile solids, oil and grease, mercury, lead and zinc; and the chemical oxygen demand (COD) of the material (Brannon, 1978, 8). The dredged material was designated as "polluted" if the threshold levels of any of those seven parameters were exceeded, and "unpolluted" if all seven parameters were within the specified limits. Polluted sediment was not allowed to be dumped in open-water.

The advent of the MPRSA and the FWPCA in 1972 brought rise to new sets of comprehensive guidelines which required ecological evaluations based on elutriate tests, bioassays and bioaccumulation tests. The elutriate test is used to estimate the contamination potential of the liquid phase of the material. Bioassays and bioaccumulation tests estimate the bioavailability of substances to the environment. These
evaluative procedures are described in section 4.3 of this chapter. The guidelines also required that factors, such as the availability of alternative disposal sites, and the potential impacts on other ocean uses, be considered in the decision-making process.

4.1.1 The MPRSA Regulations

The current regulations (40 CFR Part 227, revised as of July 1, 1984) controlling ocean dumping of dredged material, promulgated in accordance with the MPRSA, are illustrated in Figure 2. According to Section 102 of the Act, decisions to ocean dump dredged material can only be made 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" (40 CFR Part 227.1). These criteria may be waived by the Administrator of EPA if, in the opinion of the Chief of Engineers, "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" in the regulations (40 CFR Part 227.2(b)).

In figure 2, the first major step in the evaluation process is the determination of potential environmental impact. Part 227.5 of the regulations lists materials which are absolutely prohibited from ocean dumping including high-level radioactive wastes; materials used in radiological, chemical or biological warfare; materials of uncertain composition and properties; and persistent synthetic or natural
materials that might remain in suspension. Constituents excluded from ocean dumping in greater than trace amounts are organohalogen compounds; mercury; cadmium; oil of any form; and known or suspected carcinogens, mutagens or teratogens.

According to 40 CFR Part 227.6 (b), "these constituents will be considered to be present as trace contaminants 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." The determination of contamination in greater than trace amounts shall be based upon the results of bioassay and bioaccumulation tests on the liquid, suspended particulate and solid phases of the material, and upon the chemical content of the liquid phase in comparison with EPA marine water quality criteria (40 CFR Part 227.6 (c)).

Under Part 227.13(b), dredged material may be excluded from technical evaluation (see figure 2) if the material meets one of the following criteria:

1) The material is composed primarily of coarse-grained sediment larger than silt and is from a high energy environment;

2) The material is to be used for beach nourishment and is of a grain size compatible with the material on the receiving beaches;
3) The material is substantially the same as the substrate at the proposed disposal site, and the proposed dredge site is remote from historical sources of pollution.

If the material does not meet the screening criteria, it is subject to the multiphase bioassay, bioaccumulation test and elutriate test (figure 2), with consideration given to the degree of initial mixing at the discharge area. If the EPA water quality criteria are met, and there is no evidence of statistically significant contamination after allowance for initial mixing, then the material is judged environmentally acceptable.

After the technical evaluation has been completed, and if the material is still considered acceptable, there are several qualitative criteria which must be met. The "need for ocean dumping" must be assessed in terms of the availability of alternative disposal sites (40 CFR Part 227.16). If there are no "practicable" alternative locations or methods of disposal, the process moves on to the next step. Practicable alternatives are defined in Part 227.16(b) by their availability "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."
Figure 2  Ecological Testing and Evaluation Procedures Under Section 103 of the MERRA
Reproduced From: Environmental Effects Laboratory, 1976, 12.
The impact of the proposed dumping on "esthetic, recreational and economic values" must be assessed in terms of their potential for affecting recreational use and values of the ocean waters, inshore waters, beaches, or shorelines; and potential for affecting the recreational and commercial values of living marine resources. This determination shall be based upon the characteristics of potentially affected areas, visible characteristics of the material, water quality considerations and presence in the material of pathogens, toxic chemicals, or other material that might adversely affect human well-being or living marine resources.

Consideration must be given to the potential for "long-range impact on other uses of the ocean" that might result from each proposed disposal operation. This evaluation shall be made of the disposal site itself and of potentially affected areas with respect to commercial and recreational fishing, commercial and recreational navigation, actual or anticipated exploitation of living and non-living marine resources, and scientific research.

Finally, the material proposed for dumping must be assessed in terms of its potential affect on the disposal site management responsibilities of the COE and EPA. These responsibilities include regulating the times, rates and methods of disposal and quantities and types of material to be disposed of, and conducting monitoring and site evaluation studies.
4.1.2 The FWPCA Regulations

The guidelines for regulation of discharge of dredge and fill material were first issued in 1975 in accordance with the FWPCA. The current regulations are based upon the revised guidelines published in the Federal Register (Vol. 45 No. 249, Wednesday, Dec. 24, 1980), except for the ecological evaluation guidelines, which are still based on the 1975 guidelines (40 CFR Part 230.61, note).

The basic tenet of these guidelines is a general presumption against open-water discharge of dredged material "unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact either individually or in combination with known and/or probable impacts of other activities affecting the ecosystems of concern" (40 CFR Part 230.1(C)). Nevertheless, these guidelines are generally more flexible than the ocean dumping guidelines of the MPRSA. There is an "adaptability clause" in the regulations, which is designed to eliminate unnecessary testing and simplify the evaluation process (40 CFR Part 230.6).

Part 230.10(a) states that "no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences." In other words, an alternative to open-water disposal should be selected unless it is infeasible or it would cause greater adverse environmental impact. The limits of "practicability" are arbitrary.
Also prohibited are any discharges which may violate any applicable state water quality standard or any applicable toxic effluent standard; modify a critical habitat or threaten any species considered endangered under the Endangered Species Act of 1973; or violate any of the sanctuary protection requirements of the MPRSA (40 CFR Part 230.10(b)). Finally, no discharge shall be allowed "which will cause or contribute to significant degradation of the waters of the United States". Effects contributing to significant degradation include those that adversely affect human health or welfare; aquatic life or wildlife; ecosystem diversity, productivity and stability; and recreational, aesthetic and economic values (40 CFR Part 230.10(c)).

Part 230.11 requires that factual determinations be made of the potential impacts on physical, chemical and biological characteristics of the aquatic ecosystem; special aquatic sites; and human use characteristics, e.g., water supplies and fisheries. The determination of these potential effects must consider the physical substrate of the disposal site; water column turbidity; contaminant load and availability; aquatic ecosystem structure and function; disposal site considerations including the extent of the mixing zone; and cumulative and secondary effects on the aquatic ecosystems.

The procedures for ecological evaluation, required under Parts 230.10 and 230.11, are illustrated in figure 3. The testing guidelines are based on the 1975 interim final guidelines, but have been condensed and simplified. EPA is currently revising these testing guidelines (40 CFR Part 230.61 (note)).
Figure 3 Ecological Testing and Evaluation Procedures
Under Section 404 of the FWPCA
The "general evaluation", illustrated in Figure 3, includes a preliminary determination of the potential contamination of the material based upon the character of the sediments, the depositional environment, and the proximity and availability of potential sources of pollution (40 CFR Part 230.60). However, even if this screening procedure produces evidence of contamination, the material may not require further testing if constraints are available to reduce the level of contamination or to contain contaminants within the disposal site. Not all of the tests described in the guidelines are required for every proposed disposal operation. The guidelines emphasize that the testing requirements are determined at the discretion of the permitting authority (COE and EPA) as the situation dictates.

If further testing is deemed appropriate, the material may first be evaluated in terms of its potential chemical-biological interactive effects (40 CFR Part 230.61(b)). The water column effects may be evaluated using an elutriate test which takes into account specific disposal conditions and site characteristics, and/or bioassays if they are considered to be of value by COE or EPA (40 CFR Part 230.61(b)(2)).

When it is considered useful by COE or EPA, a comparison may be made between the characteristics of the dredging site, and those of the disposal site. An analysis of the bulk chemical content of sediment from the two sites may be used to determine if markedly different chemical concentrations exist. Comparison of biological community structure may be conducted using biological indicator species to
evaluate stresses, and sensitive species representative of different substrate types for possible bioassays.

Physical tests may be conducted to assess the potential effect of discharge of dredged material on physical substrate characteristics at the disposal site. Any or all of the physical tests illustrated in figure 3 may be conducted.

Also affecting the final site selection is a requirement of consideration of "actions to minimize adverse effects" (40 CFR Part 230.61 Subpart H). These actions may concern the location of the discharge, the nature of the material, potential post-disposal control, and method of dispersion, among other things. These actions affect disposal site selection to the extent that they may dictate conditions of the disposal operation, which, in turn, may constrain site availability.

Based upon the criteria listed in 40 CFR Subparts C-F, including the evaluative procedures described above, a factual determination must be made of the potential short-term, and if possible long-term, effects of a proposed discharge of dredged material on the physical, chemical and biological components of the aquatic environment (Part 230.11). From the factual determination the COE must make a finding of compliance or non-compliance with the restrictions on discharge put forth in the regulations (Part 230.12). If dredged material is found not to comply with these regulations the project must either be cancelled or modified in some manner so that it is in compliance with all regulations.
4.2 Evaluation Procedures for Land Disposal

There is no federal legislation which applies directly to land disposal of dredged material, therefore there are no established guidelines for regulating these operations. However, the Resource Conservation and Recovery Act of 1976 (RCRA) and the FWPCA may apply to land disposal of dredged material in certain cases.

Subtitle C of RCRA establishes a program for hazardous waste management with EPA as the permitting authority. Any dredged material considered hazardous by EPA would require a permit (40 CFR Part 267.64) for land disposal under this Act. The criteria for identifying the characteristics of hazardous wastes are presented in Subpart B of 40 CFR Part 261.

For those cases in which effluent or runoff from land disposed dredged material is expected to enter the "waters of the United States", there are testing procedures established under the FWPCA. Section 402 of the FWPCA compels the EPA to promulgate effluent limitations, and to require testing for certain constituents of pollutants to be discharged in internal waters. As a part of the National Pollutant Discharge Elimination System (NPDES) (40 CFR Part 122), any pollutant for which there is an established effluent standard, pursuant to Section 402 of the Act, must be chemically tested according to established analytical methods (40 CFR 136).

There are also procedures for analyzing the potential effects of land disposal of dredged material (figure 1) which are "optional" in the sense that they are not required by law. The importance of these
procedures lies in their usefulness as a management, rather than a regulatory, tool. The distinction between regulation and management, in this context, was discussed in chapter 1 (herein). The procedures include bioassays, elutriate tests and other forms of chemical analysis which may be conducted in order to assess the potential uptake of contaminants by plants and animals in and around the disposal site, as well as any potential water quality effects from effluent, runoff or leachate (Francinques, 1984, 2).

4.3 Ecological Testing Procedures

There are essentially three testing procedures currently used by the COE to assess the potential adverse ecological effects of contaminated dredged material. These procedures are used to evaluate the total chemical content of the material, the potential for release of contaminants to the water column, and the potential for adverse effects on the biota.

4.3.1 The Bulk Sediment Test

The simplest of the analytical procedures is what shall be referred to as the "bulk sediment test". This test measures the absolute quantity of specific constituents in the sediment to be disposed of. This test is no longer required by law, but is often used as a means of generally characterizing dredged material.

Originally, the bulk sediment test was the basis for the "Jensen Criteria" of 1971, which were used to regulate open-water disposal of
dredged material (see section 4.2, herein). However, the Jensen criteria were determined to be inadequate because they, and the bulk sediment test, don't take into account the biological availability of contaminants or their natural background levels.

The bulk sediment test has been widely criticized as an inaccurate, and possibly overly conservative approach to testing (Kamlet, 1983, 37; COE, 1983, 4-3). Because this test only measures the mass load of contaminants in the sediment, it gives no indication of the potential for release of contaminants to the environment, or the potential for biological uptake of contaminants. For instance, available literature indicates that there is little relationship between the bulk heavy metal content of sediment and its impact on water quality during dredging and dredged material disposal (Lee et al, 1975, xxvii).

The characteristics of the sediment, the disposal operation, and the disposal site all affect the potential release of contaminants to the environment. As a result, evaluation of the environmental impact of disposal operations based on bulk chemical content is suspect. For that reason, the bulk sediment test was eliminated as a legal requirement, but it is still used as a general indicator of pollution potential.

4.3.2 The Elutriate Test

The elutriate test is an attempt to estimate the potential release of contaminants to the aquatic environment during open-water disposal
operations, or as a consequence of supernatant overflow to the water column during confined land disposal operations. The test was originally designed to simulate disposal conditions during a hydraulic dredging operation with a contaminated sediment. However, it has been adapted to evaluate mechanically dispersed material. Because there is less mixing in the dumping operations, the test may overestimate contaminants released from mechanically dispersed material. Because the increased aeration that occurs on the disposal site represents a detailed examination of one of the mixing procedures.

The elutriation test is used to assess the potential for release of contaminants to the water column during disposal for only short periods of time, but

A major fault of the elutriate test noted by one author (Brannon, 1978) is that, generally, the release of contaminants to the water column during disposal occurs for only short periods of time, but
the EPA water quality criteria, to which those releases are compared, are designed for chronic exposure conditions. Because organisms probably would not be exposed to contaminants for long periods of time, the test tends to be environmentally conservative when the results are compared to the EPA standards. There are also indications that the test tends to overestimate the magnitude of contaminant release observed in the field.

Despite its apparent drawbacks, Brannon finds the elutriate test to be a useful predictor of the potential for long-term net release of contaminants from sediments. Another author (Kamlet, 1983, 37) considers it inadequate because "it may not detect the effect of chemical contaminants in dredged sediment on benthic animals", and it may not account for all of the complex factors that govern sediment-water exchange rates.

4.2.3 Bioassay/Bioaccumulation Tests

The potential biological effects of open-water disposal of contaminated dredged material are estimated through bioassay and bioaccumulation tests on appropriate sensitive organisms. The procedures manual for Section 404 evaluation offers little guidance for bioassay evaluations because, at the time it was written, those techniques were still being developed (Environmental Effects Laboratory, 1976, C7). As a result, the procedures manual for Section 103 evaluation is the primary guide for bioassay procedures. According to the Section 103 manual, bioassays are to be conducted on the liquid,
suspended particulate, and solid phases of the dredged material to
determine the potential for mortality to disposal site organisms caused
by the dredged material in general, or by specific constituents of the
dredged material. Bioaccumulation tests indicate the degree to which
specific constituents are accumulated in the tissues of the test
organisms.

**Liquid and Suspended Particulate Phases.** The liquid phase of
dredged material is defined as the filtered supernatant derived by the
elutriate procedure. The suspended particulate phase is represented by
the unfiltered supernatant. There are two criteria by which liquid and
suspended particulate phase bioassays are judged. Under the first
criterion, the procedure requires comparison of the mortality produced
in selected test organisms by different concentrations of the liquid or
suspended particulate phase in relation to the mortality of untreated
controls (Kamlet, 1983, 39). A statistically significant increase in
the 96-hour mortality of test organisms in one-hundred percent test
medium, as compared to the appropriate control, may indicate
unacceptable adverse impacts. Tests in which control mortality equals
or exceeds test organism mortality are considered to be indicators of
no-effect, and no statistical analysis is required (EPA/COE, 1977,
D10).

In cases where a statistically significant increase in mortality
is evident, the second criterion is the "limiting permissible
concentration" (LPC). The LPC in bioassays is defined as 0.01 of the
acutely toxic concentration of the liquid phase after allowance for
initial mixing (EPA/COE, 1977, 9). The 0.01 factor is used to account for sublethal effects and bioaccumulation of contaminants. The acutely toxic concentration is determined by the concentration of the liquid phase that is lethal to fifty percent of the population after a 96-hour exposure period. The fifty percent mortality concentration is plotted as a function of time at the four, eight, twenty-four, forty-eight, seventy-two and ninety-six hour points on the time scale. A dilution curve, which takes into account mixing zone characteristics, is plotted at the same time intervals and is compared to the mortality-concentration curve. If the concentration on the dilution curve exceeds 0.01 of the acutely toxic concentration, the LPC, at any point on the time scale, the criterion for safe disposal has not been met. This biological determination of the LPC may be used in place of EPA water quality criteria, or to assess the contamination potential of those constituents of the dredged material not contained in the EPA criteria.

**Solid Phase.** The purpose of the solid phase bioassay is to determine the adverse effects that might be experienced by benthic organisms living near the boundaries of the disposal site. The primary criterion for this test is the survival of several benthic species in the test material relative to their survival in a reference sediment control (EPA/COE, 1977, F1). Individual causative agents cannot be identified with this procedure.

The procedure for solid-phase bioassays differs somewhat from that of the liquid phase test in recognition of the fact that the
potentially affected organisms are in close contact with the sediment for long periods of time. The procedure requires that three to five species of appropriate sensitive benthic organisms, representative of filter-feeders, deposit-feeders, and burrowers, be established in reference sediment in a test aquarium and a control aquarium. A layer of test sediment is placed in the test tank, and a layer of reference sediment is placed in the control tank in such a way that they cover the organisms in their respective tanks. The test is conducted for ten days under carefully controlled conditions of aeration and seawater flow-through.

At the end of the ten day period, the surviving organisms from each tank are counted and compared. If there is a statistically significant increase in mortality of test organisms over control organisms, the dredged material may not be ocean dumped. The statistical analysis may be based on total mortality of all species combined, or it may be based on individual species mortality if increased sensitivity is desired. The Section 103 manual states that "there is a general feeling among many scientists that differences between control and treatment survival of 10% are necessary in most cases before predictions of probable impact can be made" (EPA/COE, 1977, P11). Based on that statement, the COE's practice has been to consider as environmentally unacceptable only those test cases in which there is an absolute difference of ten percent or more between control and treatment survival (Kemlet, 1983, 48). This is referred to as the "ten percent factor". Additionally, if there is greater than ten
and other suspected carcinogens, mutagens or teratogens. A separate analysis is made for each constituent and each animal species.

Laboratory bioaccumulation assessment generally takes a month or more to complete and does not account for mixing and sediment transport conditions at the disposal site. It is therefore preferable to use the field sampling procedure whenever possible.

4.3.4 Issues Related to Biological Testing Procedures

Kamlet (1983) has cited a number of contentious issues related to bioassay/bioaccumulation tests. The practice of using the combined total mortality of all species as a criterion in the solid phase bioassay has been criticized because it does not protect species of above average sensitivity. The ten percent factor is decried because it lacks any substantial justification other than "a general feeling among scientists". The COE's sediment sampling procedures, and the use of field assessments of bioaccumulation are also called into question. In summary, Kamlet suggested that perhaps the current testing procedures fall too heavily on the side of promoting ocean disposal.

4.4 Comments

A report by the New England River Basins Commission (1982, 2) suggested that the COE's planning and decision-making process for dredging should, ideally, provide a mechanism for setting priorities among projects, and for identifying, screening, and managing disposal sites. However, increasing competition for both terrestrial and marine
resources has engendered a corresponding need to carefully balance objectives to allow for the widest range of uses of resources, and to "produce maximum economic benefits with acceptable environmental impacts" (Bokuniewicz and Minsch, 1982, 1145).

In managing dredged material disposal, Congress, the EPA and the CCE have attempted to balance objectives, with the end result being a decision-making process that is complicated and subjective. The testing and evaluation procedures established pursuant to the MPRSA and FWPCA impart a sense of objectivity to the decision-making process. However, that objectivity has been diffused by guidelines that are often compromised by flexible standard and the delegation of discretionary authority to EPA and COE. As a result of that subjectivity, one might expect the COE decision-making process to produce unpredictable results.

Some of the comprises in the guidelines were pointed out in subsections 4.1.1 and 4.1.2 (herein). Examples of flexible and subjective standards which have resulted from the MPRSA include: the determination of "trace" contaminant levels through the use of bioassay results, and definition of "practicable" alternatives as those available at "reasonable incremental cost". The discretionary authority of the EPA and the COE are exemplified by the ability of those agencies, under the FWPCA, to determine testing requirements according to the specific conditions of a project.
Chapter 5

Methods for Quantitative Assessment

The preceding chapters of this thesis have discussed various aspects of COE decision-making, and the dredged material disposal problem. The intent was to illustrate the formal COE decision-making structure, and the variables that influence it with regard to dredged material disposal. The remainder of the thesis is a quantitative evaluation of the decision-making process as it functions in the New England Division of the COE. The objective is to determine how certain variables influence the selection of land or open-water disposal sites in the New England region.

McFadden (1975, 402) suggested that an understanding of any decision-making process may be achieved either by studying the internal workings of the process itself, or by studying the decisions resulting from that process. In a government agency, he asserted, it may be difficult to obtain candid information on the workings of the process, so the decision results are likely to be more revealing. The remainder of this study examines the decision-making process of the New England Division (NED) of the Army Corps of Engineers (COE) using a model similar to McFadden's. The model evaluates the results of decisions on the selection of land or open-water disposal sites for dredged material from federal dredging projects.
New England was selected as the region to be evaluated in order to minimize institutional and spatial variation in the data, while achieving a data base large enough to yield meaningful results. According to Maass (1959, 16), COE divisions tend to be rather autonomous authorities. Expanding the scope of the evaluation beyond a single division might introduce institutional differences in decision-making into the analysis. There may still be some degree of spatial variation within the New England region, but the loss of definition seems justified in light of the size of the data base available. Reducing the area to be evaluated, to a single state, for instance, would greatly reduce the number of projects that could be included in the data base.

The period of the study was designed to minimize temporal variation in the methods of evaluation used by the NED in the decision-making process. Only projects evaluated by the NED between July of 1977 and the end of 1984 were included in the data base. July of 1977 was the date of issuance of the procedures manual for Section 103 of the MFRSA (EPA/COE, 1977). This study assumed that any project report, environmental assessment or other record, concerning open-water disposal seaward of the base line and issued after that date, was written in accordance with the MFRSA guidelines. Documents concerning open-water disposal landward of the base line were assumed to be in accordance with 1975 interim final guidelines for Section 404 of the FWPCA (Environmental Effects Laboratory, 1976). The end of 1984
represented the end of the period through which the necessary NED records were generally available.

This study evaluates the COE decision-making process at the recommendation level, immediately prior to consideration by the Division Engineer. No assumptions are made about the final outcomes of the projects under consideration. The objective of the study is to assess the selection of disposal sites for dredging projects, not the implementation of those projects. The decision result for each project represents, as closely as possible, the method of disposal initially recommended for the project, before it was submitted for approval. Some of the projects included in the study have, in fact, been cancelled or postponed. Nevertheless, a disposal site decision was made for those projects, and it is that action which is of interest in this study.

The study assumes that the NED maintains, and makes available, records on all projects that have been formally evaluated. If this is true, then the data used in this study should represent all of the projects that have been formally evaluated during the period in question. Projects that have been ruled out prior to formal evaluation are not included in this study.

The data were obtained through an extensive search of information kept on file at the NED in Waltham, Massachusetts. A list of federal dredging projects considered and/or conducted during the period in question was compiled from project reports and environmental assessments kept on file in the Navigation Branch of the NED. The
information recorded from this source included the location of the project; year of the last available report; proposed disposal site (open-water or land); type of dredging project (maintenance or new work); type of dredging equipment employed (mechanical or hydraulic); volume of material proposed for disposal; and the results of ecological evaluations if they were available.

The Regulatory Branch provided the results of bulk sediment, elutriate, and bioassay/bioaccumulation tests to verify the data found in the environmental assessments, or to serve as the primary data source when other data sources were inadequate. The MEF examines a large number of variables in the various ecological tests. To facilitate analysis, only certain significant variables were included in this study. Table 3 lists the variables for which data were compiled from the ecological test results.

Grain size was selected for analysis because of its importance in the determination of engineering feasibility and environmental quality (see chapter 3, herein). It also plays a key role in the screening procedures for ocean disposal under the MPRSA (see chapter 4, herein). The MEF measures grain size in terms of the percentage of fine particles (silt or clay) in the sediment.

The bulk sediment content, elutriate release and bioaccumulation of several substances were included in the evaluation because they have special significance as potential contaminants. Cadmium, mercury and petroleum hydrocarbons were considered significant potential contaminants because they are specifically restricted by the ocean.
disposal guidelines; PCB and DDT are controversial and commonly recognized persistent organic contaminants; and volatile solids content may create environmental degradation through biological and chemical oxygen demand.

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Bioassay results on the three phases of dredged material were included because they are the primary legal criteria for ocean disposal evaluation under the MPRSA (see chapter 4, herein).

The records of the Engineering Branch provided information on the unit cost of dredging and disposal for individual projects. All of the data discussed above were available to the NED decision-makers prior to evaluation of each disposal site choice. In contrast, the cost data are based upon the lowest bid received for individual projects from private contractors after the decision had been made. As a result, these data can not be included as a priori decision variables, but do provide a means of assessing the relationship between cost and choice of disposal site after-the-fact.

The cost information has other limitations as well. Because of the continuous nature of a dredging and disposal operation, it is difficult to separate the cost of disposal from the cost of dredging (chapter 3, herein). Therefore, the combined cost must be considered in the analysis. It is likely that only an unknown portion of the cost differences between projects is attributable to differences in disposal site selection. As a result, any cost differences which appear in the results are merely approximations of the potential cost differences associated with land or open-water disposal.

The primary analysis of the data was completed using two methods. The first method employed a logistic regression model (LOGIST) to evaluate the explanatory value of several quantifiable variables in the decision-making process. The LOGIST procedure relates a vector of
independent decision variables to a dependent variable representing the decision results. The procedure estimates the proportion of the decision-making process that is accounted for by those decision variables. This procedure is explained in greater detail later in this chapter. The second method involved a qualitative assessment of those variables that were less amenable to quantification. It is the author's contention that a qualitative evaluation of these variables is more meaningful, and certainly simpler and more understandable, than attempting to fit the data into the regression procedure.

This study was concerned with three groups of variables that might influence the selection of a land or open-water disposal site: operational, environmental, and economic.

The variables evaluated under the operational heading included volume of material, grain size of the material, and whether hydraulic or mechanical dredging equipment was employed. Volume and grain size are quantitative data that were analyzed using the LOGIST procedure. The type of equipment employed are qualitative data that were evaluated by merely comparing the frequency of occurrence of each variable class in the two disposal categories.

Bulk sediment, elutriate, and bioassay/bioaccumulation test results were evaluated independently for their influence as environmental variables. The bulk sediment variables grain size, cadmium, mercury, volatile solids, and petroleum hydrocarbons were analyzed using the LOGIST procedure. The bulk sediment variables PCB and DDT were evaluated qualitatively due to lack of sufficient data.
The scarcity of data points for these variables would have reduced the number of observations included in the analysis to a level that would render the results meaningless.

Elutriate and biological test data were also evaluated qualitatively. Initially, elutriate concentration data were compiled for five variables representing cadmium, mercury, petroleum hydrocarbons, PCB, and DDT. These data appeared to be complete enough to allow for quantitative evaluation, but the COE collected the data under two different, and irreconcilable, formats. Prior to 1980, the elutriate data were recorded in units of ug/l or mg/l, which are absolute measures of concentration, while post-1980 data were recorded as parts per million (ppm) or parts per billion (ppb), which are relative measures of concentration. This change corresponded with a change in the format of the EPA water quality criteria in 1980. Because the elutriate test results were not comparable, their evaluation was limited to a frequency-of-use comparison between land and open-water disposal. Bioassay and bioaccumulation results were not used in the regression analysis because the results could not be quantified in a way that would be useful in a LOGIST model. Their evaluation focused on the frequency of use of these tests, and the frequency of negative test findings, as defined in subsection 6.2.4, herein.

The type of dredging performed (maintenance or new-work) was evaluated as a qualitative environmental variable. Because sediment from maintenance dredging projects may have greater potential for
degradation than sediment from new-work projects (Boyd, et al, 1972, 13; see section 3.3, herein), the type of dredging performed may be an important environmental variable in decision-making.

The cost variable was evaluated using LOGIST, but because of the nature of the data, the results are not directly comparable to those from the other LOGIST analyses. The cost data represent the cost of dredging and disposal per cubic yard of material, in 1984 constant dollars. The years in which the costs were incurred were determined from the COE's Annual Report of Civil Works Activities for each year. To arrive at constant dollar values, the actual cost was inflated from the year in which it was incurred to 1984 levels. The annual inflation rate was estimated from the annual Construction Cost Index, as reported in Engineering News-Record.

The logistic regression model uses a maximum likelihood approach to relate a vector of independent variables (BXn), for the nth observation, to a dummy dependent variable (Yn), in this case a binary variable having values (0,1). Since the dependent variable can only take on two values, the regression function is not linear, but is a sigmoid curve with non-normally distributed residuals (Walker and Duncan, 1967, 169). Let

\[ BXn = B1*Xn1 + B2*Xn2 + \ldots + Bi*Xni \]

be the vector of independent variables for the nth observation, where

\[ B = (B1, \ldots , Bi) \]

is the vector of regression parameters. Consider a regression model

\[ Yn = BXn + Un, \]
where the dummy variable $Y$ is defined by $Y = 0, 1$. The likelihood function for this model is

$$\ln = \prod_{i=1}^{n} F(-BXn) \prod_{i=1}^{n} (1 - F(-BXn))$$

(Maddala, 1983, 22),

where $F$ is the cumulative distribution function for $U$. The probability that $Yn = 0$ is $(1/1 + \exp(BXn))$, and the probability that $Yn = 1$ is $(\exp(BXn)/1 + \exp(BXn))$. Regression parameters $B$ are estimated by maximizing the likelihood function over $n$ observations. Maddala (1977; 1983), Cox (1970), and Harrell (1984) examine this model further.

Applications of the logistic regression model have been demonstrated in biostatistics (Walker and Duncan, 1967, 67), econometrics (Maddala, 1983), and other social sciences (Magidson, 1978, 27). The model used here is the LOGIST procedure on the Statistical Analysis System (SAS) computer package. Application of the model is explained by Harrell in the SAS Supplemental User's Guide (1984).

The LOGIST procedure on SAS automatically eliminates observations with missing values from the regression. To evaluate the predictive ability of a model, LOGIST calculates an $R$ statistic, which is similar to the multiple correlation coefficient. According to Harrell (1984, 183), "$R$ has a value of 0 if the model is of no value and 1 if the model predicts perfectly, and $R^2$ is the proportion of log-likelihood explained by the model".

The procedure also performs a chi-square test to judge the statistical significance of the derived $R$-value for each model. In
this study, the probability (P) must be less than alpha = .05 in order for the R-value to be considered statistically significant.

The function of the LOGIST procedure in this study was to relate decision variables from the operational, environmental and economic categories, to disposal decisions in order to determine the extent to which those variables are employed in decision-making. A close relationship between the independent (decision) variables and the dependent variable (results) indicates that the decision variables have a high explanatory value (R^2), and might be considered important in NED decision-making. Consider a simple example, where dredged materials discharged on land have high bulk levels of cadmium, and those discharged in open water have low bulk levels of cadmium. The variable for cadmium content will have a high explanatory value (R^2). If the variable is statistically significant at the derived R-value, then it is likely that bulk cadmium level is an important decision variable. This finding might suggest that potential environmental contamination from heavy metals is an important consideration in selecting a disposal site, and that the NED favors land sites for those materials.

In applying LOGIST to the problem at hand, the dependent variable (disposal type) was designated as 0, for land disposal, or 1, for open-water disposal. Land disposal included any form of upland disposal, as well as beach nourishment and marsh filling. Open-water disposal included ocean, river, or harbor disposal of any kind, including capping and marsh creation. The results of the LOGIST procedure were used to indicate the explanatory value of the independent variables in
each model in decision-making, both as a single array and as discrete
groups of operational, environmental and economic variables. This
study is concerned more with the impact of combinations of these
variables than with their individual impacts. The variables used in
the LOGIST analysis were selected for their importance as
representatives of their groups, not for their individual importance.

The values assigned to the independent variables in the LOGIST
analysis of bulk sediment test results represent the mean of the
concentrations of those substances in all sediment samples tested for a
given observation (dredging project). For example, cadmium (CD)
concentration was recorded for fifteen sediment samples from Boston
Harbor. The mean of those fifteen samples (4.33) was used as the value
for CD in one of the forty-four observations entered into the
regression. The statistical validity of these mean values varies
greatly among observations because the number of sediment samples taken
for each project varies. However, this analysis is concerned not with
the validity of the numbers used to make the decisions, but with the
results of decisions based upon those numbers.

At this point, two qualifying statements on the interpretation of
the data are in order. First, the standard deviations of the data
representing the variables volume, grain size, and volatile solids
exceed the mean values for those variables. This suggests that those
data are not normally distributed. All other data sets appear to be
normally distributed. Second, as with any regression procedure, the
results of LOGIST may be biased by the exclusion of potentially
significant variables. The conclusions drawn from the LOGIST results should be considered in light of the non-normality of some of the data, and the possibility that potentially significant variables were excluded from the analysis.
CHAPTER 6

Analysis

6.1 Hypotheses

Earlier chapters of this thesis (2-4) attempted to illustrate the complexity of the dredged material disposal issue, and the decision-making process of the COE. Based upon those discussions, the following hypotheses have been developed.

1) The NED decision-makers must incorporate a large and diverse array of potentially important variables into a system that is characterized by bureaucracy to begin with. In such a complex system, there is little chance that any small array or small groups of variables will substantially influence the decision-making process. One or more of the variable groups may have a noticeable impact on decision-making, but they will not account for a majority of the process.

2) The cost of dredged material disposal has, historically, been important in COE decision-making (see section 3.4, herein). However, the increasing involvement of other variables, including environmental considerations, has overshadowed the importance of the direct cost of disposal.
Consequently, cost should not be highly regarded in the decision-making process.

3) The operational variables are expected to show a strong relationship with disposal-type. The grain size of the sediment should be a decisive variable because it is a key factor in determining the type of dredging equipment employed, and how the material will react during and after disposal. Coarse-grained material should be favored for land disposal because it is more amenable to hydraulic dredging, and is more stable on land than fine-grained material (see subsections 3.1.1 and 3.3.1, herein). In addition, coarse-grained material is often used in beach nourishment, which is a form of land disposal for the purposes of this study.

The volume of material should influence disposal site selection because suitable land disposal sites are generally scarce, particularly in industrialized areas where the volume of material to be dredged may be large and land is valuable (see section 3.4, herein). Open-water disposal should be favored for large volumes of material. Individually, volume should have less impact than grain size, but the combination of the two should substantially influence disposal decisions.

The type of dredging equipment employed (hydraulic or mechanical) should affect disposal site decisions because
mechanically dredged sediment is most efficiently disposed of in open water, while hydraulically dredged sediment is most efficiently disposed of on land (see section 3.1, herein).

4) The environmental impacts of dredged material disposal, both on land and in open water, are still largely uncertain. There is little agreement among the scientific community on whether open-water environments are more or less sensitive to potentially contaminated dredged material than are land environments (see section 3.5, herein). To the best of the author's knowledge, the NED had not taken any official position on the subject during the period of the study. However, Congress' intent, when it enacted the MPRSA and FWPCA, was to keep potential contaminants out of the open-water environment whenever feasible (see subsections 2.2.1 and 2.2.2, herein). No comparable set of laws pertains specifically to land disposal of dredged material.

Interpretations of Congressional intent differ, and so, the mandate restricting open-water disposal is rather loosely implemented by the regulations that resulted from the legislation. Congressional intent is reflected in the regulations issued pursuant to the FWPCA, which require a general presumption against open-water disposal unless it can be demonstrated that the material will not have an adverse environmental impact (see section 4.2.2, herein). However, that goal is compromised by the flexibility of the
regulations. In effect, the regulations (see chapter 4, herein) reflect the uncertainty surrounding potential environmental impacts by prohibiting open-water disposal only when adverse short-term biological effects are demonstrated.

There are essentially two scenarios the NED might be expected to follow with regard to environmental regulation of dredged material disposal. The first scenario is one based on Congressional intent, where the NED would favor land disposal for those dredged materials containing higher levels of potential contaminants, such as cadmium and PCB, irrespective of the question of bioavailability. Under this scenario, bulk sediment data would show a strong relationship with disposal site selection, as would elutriate and biological test data. Land disposal would be favored for fine-grained material which might contain high levels of potential contaminants. The second scenario is a system which is based on a nominal adherence to the regulations. Under this system, biological test results would be the only decision criterion, and the bulk sediment and elutriate test results would have little or no influence on decision-making. There would be little or no favoritism of disposal sites based on environmental data.

From a policy perspective, the NED should be following the first scenario based on Congressional intent. If that is the case, the bulk sediment, elutriate, and biological test
results will be relatively important factors in NED decision-making. Sediment containing higher levels of contaminants and having greater potential for release of contaminants to the aquatic environment will be disposed on land.

The type of dredging performed should also be an important environmental variable in NED decision-making. If it is true that sediment from maintenance dredging projects has greater potential for degradation than sediment from new-work projects, then one would expect maintenance dredged material to be disposed of in the less sensitive environment. If Congressional intent is used as the criterion for judging the sensitivity of environments, then land disposal should be favored for maintenance dredged material.

6.2 Results

6.2.1 All Variables

A logistic regression was used to test the hypothesis that the operational, environmental, and economic variables determine disposal site selection. The LOGIST procedure was applied to a model of disposal type (land or open-water) as a function of the volume of material; the grain size of the material; the bulk chemical content of cadmium, mercury, petroleum hydrocarbons, and volatile solids; and the
cost of dredging and disposal. The results of the analysis are presented in table 4.

These results may have been biased by the omission of biological and elutriate test variables, which are believed to be significant variables in the overall decision criterion. Bias might also have been created as a result of accidental omission of other potentially significant variables.

The procedure produces an R-value, which is an estimate of the ability of the decision variables in the model to predict decision results (disposal-type). The value of $R^2$ is an estimate of the proportion of the log-likelihood of the results that is explained by those variables. The values of R and $R^2$ are indicators of the extent to which the variables being examined are incorporated into the decision-making process by the NED. High values of R and $R^2$ for a group of variables suggest that the NED considered that group to be important in decision-making.

Because this analysis deals with groups of variables, a high explanatory value ($R^2$) for a particular group (e.g. "all variables" or "operational variables") is expected only if all of the variables in observations associated with land disposal choices have values that are distinctly different than the values of the same variables in observations associated with open-water disposal choices. For example, the model of all variables will have a high $R^2$ if volume is always low for land disposal observations, and high for open-water disposal observations; bulk cadmium content is always high for land disposal
observations, and low for open-water disposal observations; and-so-on for all variables in the model. The value of $R^2$ is reduced as that distinction becomes blurred for any or all variables in the model.

When performed on all variables, the procedure revealed an $R$-value of 0.51, where $R = 0$ indicates the model has no predictive value and $R = 1$ indicates the model predicts perfectly (see chapter 5, herein). Squaring the $R$-value for the model revealed that twenty-six percent of the log-likelihood of the decision results was explained by this group of variables. The value of $P$ for this model indicates that the derived $R$-value is statistically significant at alpha = .05.

<table>
<thead>
<tr>
<th>Model</th>
<th># of Obs.</th>
<th>$R$</th>
<th>$R^2$</th>
<th>$P &lt; .05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Variables:</td>
<td>24</td>
<td>0.51</td>
<td>0.26</td>
<td>yes</td>
</tr>
<tr>
<td>All Variables except COST:</td>
<td>39</td>
<td>0.33</td>
<td>0.11</td>
<td>yes</td>
</tr>
<tr>
<td>Economic Variable:</td>
<td>26</td>
<td>0.0</td>
<td>0.0</td>
<td>no (.25)</td>
</tr>
<tr>
<td>Operational Variables:</td>
<td>42</td>
<td>0.41</td>
<td>0.17</td>
<td>yes</td>
</tr>
<tr>
<td>Environmental Variables:</td>
<td>39</td>
<td>0.33</td>
<td>0.11</td>
<td>yes</td>
</tr>
</tbody>
</table>

During the procedure, twenty of the forty-four observations introduced into the analysis were deleted due to missing values. Despite its apparent statistical significance, the high number of
deletions calls into question the reliability of this estimate of explanatory value. When the cost variable, which caused fifteen of the deletions, was dropped from the model, the procedure revealed an R-value of 0.33, or eleven percent of the log-likelihood. Because the individual R-value of the cost variable was zero, its elimination from the analysis should not have changed the R-value of the model substantially. The fact that the R-value for the model was reduced from 0.51 to 0.33 by removal of the cost variable suggests that the deleted observations had an important impact on the model. Therefore, the explanatory value of the model is probably closer to the eleven percent estimate based on thirty-nine observations than the twenty-six percent estimate based on only twenty-four observations.

6.2.2 Economic Variables

The impact of economics on disposal site selection was tested with a logistic regression on the model of disposal type as a function of cost. LOGIST deleted eighteen observations due to missing values. The remaining twenty-six observations were split equally between land and open-water disposal. The procedure produced an R-value of 0.0, indicating that dredging and disposal costs had no relationship with disposal site selection. This finding does not meet the criterion for statistical significance. When considering this finding, the reader should bear in mind the number of missing values in the data set, and the fact that the costs represent actual costs for private contractors, not expected costs for the job.
6.2.3 Operational Variables

The hypothesis that the volume of material and the grain size of the material determine disposal site selection was tested with a logistic regression model of disposal type as a function of volume and grain size. In the procedure, two of the forty-four observations were deleted due to missing values. Of the observations included, eighteen were land disposal choices and twenty-four were open-water disposal choices. The regression for the model produced an $R$-value of 0.41. Squaring the $R$-value to obtain an estimate of explanatory value revealed that this model explained only seventeen percent of the log-likelihood of the results. This $R$-value was statistically significant at alpha $= .05$. Again, the omission of potentially significant variables in the decision model may have biased these results.

The hypothesis that the type of equipment employed affects disposal site selection was tested qualitatively. Among the forty-two observations for which the equipment-type was indicated, mechanical dredges were recommended on twenty projects, and hydraulic dredges were recommended for the remainder. In nineteen of the twenty mechanical-dredge projects the proposed disposal site was an open-water site. In all nineteen of the proposed projects in which the NED recommended a cutterhead-and-pipeline hydraulic dredge, the suggested disposal site was on land. In only three of the projects did the NED
propose hydraulic dredging and open-water disposal: two would have used hopper dredges, and one would have used a sidecast dredge.

6.2.4 Environmental Variables

To test the impact of the bulk chemical content of dredged material on disposal site selection, a logistic regression was performed on the bulk sediment data using a model of disposal site selection as a function of grain size and the bulk chemical content of cadmium, mercury, petroleum hydrocarbons and volatile solids. The procedure revealed a model R-value of 0.33, indicating an explanatory value of only eleven percent when R is squared.

The value of P calculated for this model indicates that the derived R-value is statistically significant. This finding only represents the explanatory value of the bulk sediment test as a decision factor, not the entire environmental category. Bias may have been created by the omission of potentially significant variables in the model.

It was rather difficult to evaluate the effects of the bulk sediment content of PCB and DDT on disposal site selection because only about half of the observations contained values for those variables. The results of table 5 show the maximum and mean concentration of PCB and DDT to be higher in material intended for open-water disposal, but the number of observations included in those statistics is small. It should also be noted that the standard deviation is substantially
larger than the mean value for both PCB and DDT, indicating that the data are not normally distributed.

Table 5 Summary Statistics for Bulk Sediment Content of PCB and DDT.

<table>
<thead>
<tr>
<th>PCB Content (PPB)</th>
<th>Land</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Range</td>
<td>0-2750</td>
<td>0-4023.33</td>
</tr>
<tr>
<td>Mean</td>
<td>399.9</td>
<td>530.0</td>
</tr>
<tr>
<td>Median</td>
<td>4.5</td>
<td>19.9</td>
</tr>
<tr>
<td>S. D.</td>
<td>961.3</td>
<td>1132.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DDT Content (PPB)</th>
<th>Land</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Range</td>
<td>0-101</td>
<td>0-580</td>
</tr>
<tr>
<td>Mean</td>
<td>37.7</td>
<td>57.3</td>
</tr>
<tr>
<td>Median</td>
<td>28.5</td>
<td>3.8</td>
</tr>
<tr>
<td>S. D.</td>
<td>40.2</td>
<td>165.2</td>
</tr>
</tbody>
</table>

The impact of elutriate and biological test results as environmental variables in NED decision-making was tested by evaluating the frequency with which they were used to arrive at disposal decisions.

Elutriate tests are optional procedures under both the MPRSA and the FWPCA, and were not employed as evaluative techniques on all of the proposed projects. The test was used in sixteen of the twenty-four cases (67 percent) in which open-water disposal was the suggested
disposal method, but in eight of those cases only a few constituents
were examined. An elutriate test was performed in only four of the
twenty projects (20 percent) in which land disposal was selected.

Bioassay tests are known to have been performed in seventeen of
the forty-four proposed projects (39 percent). In all but one of those
projects (Pawtuxet River), the proposed disposal site was an ocean
site. However, seven of the twenty-four proposed open-water disposal
operations were not subjected to bioassays of any type. In six of
those cases the material was excluded from further testing by the
sediment screening procedures of the MPRSA; the seventh (Cohasset
Harbor) was subject to the provisions of the FWPCA, in which bioassays
are optional.

Appendix B identifies those projects which showed negative
results in any phase of the bioassay before dilution. In this context,
negative results for liquid and suspended particulate phases are those
showing a statistically significant reduction in survival rate in one
or more test species in one or more sediment samples. A negative
result in the solid phase is one in which there is a statistically
significant reduction in the combined survival rate of all species in
one or more sediment samples.

The liquid phase showed negative results in nine of sixteen cases
(56 percent), while the suspended particulate phase showed negative
results in seven of sixteen cases (44 percent). The solid phase showed
negative results in only three of seventeen cases (18 percent). After
allowance for initial mixing, none of the liquid or suspended
particulate phase tests showed negative results, while two of the solid phase tests (Pawtuxet River and Norwalk Harbor) turned out negative.

Bioaccumulation tests were performed in eleven of the forty-four projects studied (25 percent). The NED proposed open-water disposal for all of those projects. Negative results for a bioaccumulation test shall be defined, for the purposes of this study, as a statistically significant accumulation of a substance in one or more species in one or more sediment samples. Appendix B indicates that negative findings resulted from at least one of the five substances examined in nine of the eleven observations (82 percent) in which the test was conducted. In none of those cases did a significant finding alter the decision to discharge in the ocean.

A qualitative comparison was used to test the hypothesis that the type of dredging performed has an effect on disposal site selection. The hypothesis assumes that maintenance dredged material is potentially more degrading to the aquatic environment than sediment from new-work projects. Eleven of the forty-four proposed projects that were studied were for new-work dredging. Dredged material from six of those new-work projects (54 percent) was to be discharged in open water. Open-water disposal was also chosen for eighteen of the thirty-three proposed maintenance projects (54 percent).
6.3 Discussion

6.3.1 All Variables

The first hypothesis in section 6.1 stated that no small array or small group of variables would account for a majority of the decision-making process. The results of this analysis strongly support that contention. This analysis revealed almost no general relationship between the decision variables examined and the final decision results. From the LOGIST analysis of "all" operational, environmental and economic variables, it seems apparent that these variables account for only a small proportion of the decision-making process. When analyzed as groups, the operational variables seemed to explain the greatest proportion of the results. The environmental variables were somewhat less important, and the economic variable, with qualifications, had no impact. However, even the degree of explanatory value attributable to the operational variables (seventeen percent) only accounted for a small proportion of the decision-making process.

This analysis included relatively few of many possible variables which might have influenced dredged material disposal decisions in New England. Within the operational, economic, and environmental categories of variables, there may have been other variables that were equally, or more, representative of a particular category than the ones included here. This is especially true of the economic group, which is rather poorly represented in this analysis. An expansion of the economic aspect of the analysis should, ideally, include estimates of
social costs and administrative costs. Realistically, it would be extremely difficult to derive those estimates for even one or two projects, let alone forty-four projects.

On a larger scale, there are a variety of other groups of variables that were not accounted for in this study. Social conditions, interaction with other agencies, interest group pressure, political influence, and public interest are some of the other potential forces in decision-making. Within those groups there may be many individual variables operating. The failure of the variables examined in this study to explain the decision results implies that some, or many, of these other variables are important in the decision-making process.

6.3.2 Economic Variables

The second hypothesis in section 6.1 stated that the cost of dredging and disposal will have little value in decision-making because of the increasing involvement of other considerations. As expected, the economic category, represented by the cost of dredging and disposal, was insignificant in the decision criterion. One possible explanation for that finding may be the deficiency of the cost data set. However, the root cause may be that the direct costs of dredging and disposal represent only a small part of the total economic situation. If land acquisition costs, social costs of environmental degradation, and other factors could have been incorporated into the economic variable category, the explanatory value of that category in
the decision-making process might have been greater. Given the complex
nature of the current decision-making process, the direct costs of
dredging and disposal have become inconsequential.

6.3.3 Operational Variables

The third hypothesis in section 6.1 stated that the operational
variable group should have substantial explanatory value in NED
decision-making, primarily because of the importance of grain size as
an engineering characteristic of dredged material. The low explanatory
value of volume and grain size in the LOGIST evaluation suggests that
these operational variables had very little influence on disposal-site
selection. One possible interpretation of the low explanatory value of
grain size is discussed in subsection 6.3.5. The low explanatory value
of volume as an operational decision variable may be due to a lack of
upper or lower restrictions on the volume of sediment that may be
dumped in open water. While land disposal may be restricted to
relatively small volumes of sediment due to the scarcity of available
land, open-water disposal is not, conversely, restricted to relatively
large volumes of sediment.

Qualitative comparison of equipment-type with disposal site
selection revealed a high degree of correlation. The prevalence of
open-water disposal with mechanical dredging may be explained by the
ease and efficiency of barge transportation to open-water sites. The
difficulty and added expense that would be associated with rehandling
barge-transported dredged material for land disposal tend to discourage
decision-making. This hypothesis is based on the legislative objective of keeping potential contaminants out of the aquatic environment. The environmental variables included the type of dredging performed (maintenance or new-work); bulk sediment test results including content of cadmium, mercury, petroleum hydrocarbons, volatile solids, PCB and DDT, and grain size; frequency of elutriate testing; and frequency of bioassay/bioaccumulation testing.

Land disposal should be the preferred method for maintenance dredged material because it is believed to have greater potential for contamination than sediment from new-work projects. When evaluated comparatively, the nearly even division between the frequency of land and open-water disposal, for both new-work and maintenance dredging projects, suggests that the type of dredging to be performed had little correlation with disposal site selection. Based upon these data, there did not appear to be favoritism of one disposal environment over another for maintenance dredged material. Either the NED did not find maintenance dredged material to have greater potential for environmental degradation, or the distinction in ecological sensitivity between land and open-water environments is unclear.

The bulk sediment test results had little explanatory value as environmental variables in the decision-making process. The LOGIST procedure produced an $R^2$ of only eleven percent for the model which included the variables grain size, cadmium, mercury, petroleum hydrocarbons and volatile solids. From the analysis of PCB and DDT content in dredged material (table 5) one might surmise that open-water
disposal is favored for those sediments containing relatively higher concentrations of PCB. However, that conclusion is dubious in light of the weakness of the statistics. The sparseness of the data suggests that they were considered important variables only on a project-by-project basis, not as a general rule.

Under the "Congressional intent" scenario, the low explanatory value of the bulk sediment test results is surprising. This finding suggests that the NED is following the scenario of nominal adherence to regulations, rather than Congressional intent, in pursuing its environmental regulatory objectives. The NED may be using these test results as a means of generally characterizing dredged material, but they do not appear to be an important decision factor. After being widely criticized as an inadequate indicator of potential environmental degradation, the bulk sediment test has been deemphasized as a decision criterion.

Despite the fact that potential contaminants may not be immediately available to the biota, their mere presence should inspire caution. If the NED were attempting to keep potential contaminants out of the aquatic environment there would probably be a much stronger reliance on bulk sediment data, irrespective of the question of bioavailability. In that case, the LOGIST results for bulk sediment data would show a much stronger relationship with decision results because the more heavily contaminated sediment would be disposed of on land.
The frequency-of-use of the elutriate test suggests that it is employed primarily in cases where open-water disposal is proposed. Since elutriate tests are not legally required for either land or open-water disposal, this relationship may indicate greater environmental concern where open water is the proposed disposal environment. On the other hand, since elutriate tests are not necessary for clean sediment, these data may suggest that land disposal sites are more often the recipient of the apparently clean material. This notion is supported by the observation that thirteen of the twenty land disposal choices involved beach nourishment, a procedure which usually requires clean sandy material capable of passing the preliminary screening procedures.

The fact that bioassay/bioaccumulation tests were performed almost exclusively for ocean disposal choices is probably a consequence of the requirements for bioassays under the MPRSA. In six of the open-water disposal cases which did not include bioassays, the material was excluded from further testing by the MPRSA screening procedures; the seventh, Cohasset Harbor, was subject to the regulations of the FWPCA, which do not require a bioassay.

The data on bioassays and bioaccumulation tests suggest that the biological tests were performed only when required by law after the decision had been made to discharge the material into the ocean. This finding, again, illustrates that the NED is only nominally adhering to the regulations, rather than following Congressional intent. The biological tests, and possibly the elutriate test as well, seem to
function primarily as a means of providing justification for ocean disposal decisions under the jurisdiction of the MPRSA. With one exception, negative findings in these tests had no influence on the final decisions. If these tests were being conducted prior to disposal decisions, there would likely be several occurrences of biological testing on material that was disposed of on land. Only one such occurrence appears in the data. Bioaccumulation tests were performed only on material destined for ocean disposal. In all nine cases where negative bioaccumulation results were indicated, the decision to discharge in the ocean stood despite the test findings.

The criteria established under the MPRSA require prohibition of ocean discharge only for those materials which produce negative bioassay results after allowance for initial mixing. This is a rather subjective and environmentally liberal standard which should be applied cautiously. Should the ecological test data raise any doubt about the suitability of the material for open-water disposal, "Congressional intent" suggests that judgements should be environmentally conservative. Regardless of the results after dilution, any negative bioassay or bioaccumulation finding is an indicator of potential environmental degradability which should prompt an extra measure of caution. Yet, in all but one of the seventeen cases of negative bioassay results before dilution, the decision remained in favor of ocean disposal.

Negative bioassay findings after dilution do not necessarily guarantee that a decision in favor of ocean disposal will be altered.
Under the assumption that bioassays are conducted only on dredged material intended for ocean disposal, it is interesting to note the two cases in which significant negative bioassay results appeared after allowance for initial mixing. Both the Norwalk Harbor and Pawtuxet River sediments were evaluated with bioassays. Consequently, we will assume that the material from those projects was intended for ocean disposal. The Pawtuxet River sediment resulted in a significant negative finding on the solid phase. Given that the final decision favored land disposal, we might conclude that the decision was altered as a result of that negative finding. In the Norwalk Harbor case, a bioassay performed on two sediment samples in 1978 resulted in a negative finding on the solid phase after allowance for initial mixing. This would seem to preclude ocean disposal as a viable option. In 1979 the bioassay was repeated on four samples, and the results proved to be positive. The later positive finding apparently prevailed over the earlier results, and the decision remained in favor of ocean disposal.

In the case of the Pawtuxet River project, the bioassay regulations seem to have performed as a check on an ocean disposal decision. However, this is the only example where a negative bioassay has obviously influenced a disposal decision. The end result of the Norwalk Harbor evaluation provides that decision with the appearance of legitimacy, but the means employed to reach that end raise some questions.
- If the second bioassay had resulted in a negative finding, would the test have been repeated until it produced positive results?
- Is the Norwalk Harbor project an example of external forces dictating the manner in which evaluative procedures are carried out?

Further evidence of possible inadequacies in the application of biological tests is found in the five ocean disposal cases in which bioaccumulation tests were not performed, even when it appeared that they were required by law. In those five cases, bioassays were performed and they suggested some potential adverse impacts before dilution, but there was no record of bioaccumulation tests having been performed. The regulations issued pursuant to the MPRSA prohibit constituents of dredged material from the marine environment when there is the "possibility of danger associated with their bioaccumulation in marine organisms" (40 CFR Part 227.6(b)). Under those regulations, evaluations of bioaccumulation potential should have been performed and could have been cause for denial of ocean disposal.

Because bulk sediment tests do not account for bioavailability or natural background levels of substances in the marine environment they were phased out as a decision criterion in the ocean disposal regulations. The current regulatory guidelines rely on biological testing as the primary criterion for restricting ocean disposal of dredged material (see section 4.2, herein). The manner in which biological tests have been applied and interpreted raises questions.
about their value in decision-making. It is difficult to imagine that a test as subjective, and as easily manipulated, as the bioassay could be useful as a regulatory decision-making criterion. Based on the Norwalk Harbor project, and other evidence presented above, it apparently is not. The biological tests seem to have very little impact on decision-making, despite their legal/regulatory mandate as a primary decision criterion.

This finding might suggest that the biological testing procedures only nominally fulfill the regulatory requirements. Their primary function appears to be to corroborate decisions that are driven by other forces. When one considers the subjectivity inherent in the interpretation of biological test results, their value, even at this low level of application, is doubtful.

The reasons for the negligible value of the environmental data in the NED decision-making process are essentially three-fold. First, there are some basic scientific uncertainties about the potential adverse environmental effects of dredged material disposal. As a result, the EPA and the COE are unsure of the validity of avoiding open-water disposal as an environmental objective. Second, as a result of EPA's uncertainty, "Congressional intent" was interpreted as allowing open-water disposal unless a definite showing of potential short-term degradation is made. The regulations for determining potential degradation rely on biological tests that are subjective, and may be too environmentally liberal. Third, the biological testing procedures may not always be adequately applied in all cases. The
Norwalk Harbor evaluation, and the apparent omission of bioaccumulation tests in five ocean disposal cases, are examples of the questionable application of biological testing requirements.

6.3.5 Additional Comment

It is interesting that the LOGIST analysis showed both the operational and the bulk sediment variables to be generally inconsequential factors in decision-making. One reason for this situation may be that grain size is an important variable in each category. As a characteristic of dredged material, grain size suggests different disposal solutions depending on whether it is considered in operational or environmental terms. For operational reasons, discussed in the third hypothesis in section 6.1, coarse grain size should be favored for land disposal, and fine grain size should be favored for open-water disposal. However, if "Congressional intent" is used as a criterion, the environmental mandate from the legislation, specifically the MPRSA, favors just the opposite situation. Although its long-term effects are uncertain, fine-grained sediment has greater potential for contamination, which should make land disposal the favored alternative. This legislative mandate with respect to grain size is evidenced, in part, by the ocean disposal regulations, which require extensive testing of fine-grained material, but allow disposal of coarse-grained material in the ocean without such testing.

Since there is no clear rule for disposal of dredged material based on grain size, the end result of trying to combine the
conflicting operational and environmental objectives is a set of decisions with no pattern based on operational or environmental variables. The flexibility of the regulations allows the operational objectives to be balanced with the environmental objectives, thereby creating a muddled decision pattern. A clear pattern might emerge if one, or the other, of the objectives were to be given undisputed predominance in the decision-making process. This, however, is not a viable option. Considering the highly variable and complex nature of the dredged material disposal problem, it can not be firmly stated that one objective is predominant in every case. Consequently, decision-makers must continue to attempt to balance objectives.
CHAPTER 7

Conclusions

There seems to be little or no relationship between the operational, environmental and economic variables examined in this study, and the results of dredged material disposal decisions made by the New England Division of the Army Corps of Engineers. Since these variables are not explaining the decision results, then there must be other forces driving the decision-making process. An analysis of this nature can only deal with a limited number of variables, but the issue of dredged material disposal is a complex one that is subject to a diverse array of influential forces. As a result, the complexity of the decision-making process is suggested as one rationale for the lack of association between the variables examined and the decision results.

As the complexity of a system increases, it becomes increasingly unlikely that any individual or small group of independent variables will explain the results. The Holcomb Research Institute (1976, 5) delineates various types of environmental systems into four classifications, one of which they describe as "highly complex and unpredictable". As a decision-making system, the COE's regulation/management of dredged material disposal appears to fit into this class.
Bauer (1968, 56) observed that "there is a sophisticated modern approach to decision-making that is based on formalizing one's judgements, however subjective they may be and however tenuous the information may be, with the view of reaching the best decisions that can be made on the basis of this imperfect knowledge." This reality was recognized by Congress, EPA and COE when the system was formally developed. The implementation of the COE's current system of decision-making is related to Bauer's observation. It is not a "batch" processing of hard data in an objective manner, but a subjective balancing of multiple objectives.

The subjective nature of the process, and the lack of any obvious and recognizable decision rules, are inevitable consequences of the complexity of the issue, and the legal/regulatory framework within which the NED must operate. In such a complex system, it may not be possible, nor even desirable, to methodically assess all of the variables objectively. As a result, there is an ingrained flexibility in the system, which allows for the balancing of multiple objectives. Examples of that flexibility are seen in the open-water disposal regulations that resulted from the MPRSA and FWPCA.

Through a process of incremental adjustments to internal and external forces, similar to Lindbloom's (1959) process of "successive limited comparisons", the COE narrows the field of alternatives until it finds the disposal option that is most desirable for all parties involved in a particular choice situation. Lindbloom described this process as it applied to long-term policy-making, but it applies
equally well to short-term decision-making. His was a process of "successive approximation to some desired objectives in which what is desired itself continues to change under reconsideration" (p.111). He noted, as a failure of the incremental approach, the accidental and unsystematic exclusion of factors (p.110), but defends the approach as a valid one (p.113). The unsystematic operation of the NED's decision-making process is evidenced by the lack of correlation between decision variables and results.

The NED's decision-making process is essentially one of judgement, where there are no obvious rules for accommodating all the influential forces. Some of the information entering the system is objective data, but the majority of it is not. There are so many variables involved that the objective data entering the system is often inconsequential, and the end result becomes a subjective decision.

As objective data, the negligible influence of the environmental variables is particularly provocative because it raises the question of the relevance of the data collected to assess dredged material, and of the regulatory system itself. From the evidence presented in the analysis in chapter 6, it does not appear that the NED is using environmental data to carry out the legislative objective, as expressed in the FWPCA and the MPRSA, of eliminating contaminants from the aquatic environment. Instead, it seems that environmental data are used primarily as a means of nominally adhering to the regulations for open-water disposal in accordance with the FWPCA and the MPRSA. This conclusion is supported by the lack of impact that environmental test
results had on disposal decisions. Environmental test results, particularly from biological tests, affected decisions only when those results indicated an obvious violation of regulatory standards, regardless of the fact that they may have indicated the presence of potential contaminants that could have adverse long-term environmental impacts.

If these data have only a minor influence on the final decisions, does their involvement contribute anything more than complications to an already intricate process? Eliminating the environmental data collection and evaluation steps would certainly streamline the process, but that would not be an acceptable simplification. Regulations and data lend an air of objectivity to the process, which, though it may be pretentious, provides a means for lawmakers and regulators to procedurally justify their actions.

In chapter 1, a distinction was made between management and regulation, where management was defined as a dynamic process and regulation as a static process. Based upon that definition, the NED seems to be managing, rather than regulating, its own dredged material disposal operations. The process is punctuated by regulation when ocean disposal is proposed, but it is merely a legal formality that has little active impact on the decision results. This management system, which is characterized by subjective decision-making and regulatory justification, is complex and unpredictable. As such, it is susceptible to potentially biased influences, and the possibility of environmentally "risky" decisions. If the NED were performing a purely
regulatory function, the output from the decision-making process might be more predictable, but not necessarily better.

Despite its inconsistency, the subjective decision-making process is the only reasonable approach to the dredged material disposal problem. Although it does not perform particularly efficiently, the advantage of the COE's management system is its flexibility. Purely objective decision-making requires a relatively small and uniform set of variables. The dredged material disposal problem does not meet that constraint. Given the uncertainty surrounding the potential adverse environmental effects of dredged material disposal, the subjective process allows disposal decisions to be tailored to specific project and disposal site conditions. Application of a purely objective decision-making process might cause the decision-makers to ignore a variety of potentially important variables.

The problem with the current system of decision-making is that it does not fully comply with the objectives of the FWPCA and the MPRSA. Either the dredged material disposal regulations, and the COE decision-making process, need to be aligned with those objectives, or the objectives need to be redefined and clarified by Congress. The solution may require some of each. It is unreasonable to expect absolute prohibition of open-water disposal of dredged material. Yet, within the subjective decision-making process, a slightly more conservative and objective approach to the ecological evaluations might be the basis for greater consideration of the potential long-term environmental impacts. Until there is stronger evidence of the
presence or absence of long-term impact, it would be wise to proceed cautiously with regard to open-water disposal.
Appendix A

Federal Environmental Legislation Pertinent to Dredged Material Disposal
Federal Water Pollution Control Act
Amendments of 1972 (P. L. 92-500)

Section 404 of this Act requires permits, issued by the Corps of Engineers, for disposal of dredged material into navigable waters and adjacent wetlands landward of the boundary of the territorial sea. A state-issued water quality permit may also be required under Section 401 of this Act. The Act directly affects open-water disposal, including island and marsh creation, occurring in lakes, rivers, harbors or other waters if they are within the limits of the territorial sea. Land disposal is affected if the proposed action is marsh filling (Sec. 404) or if leachate, runoff, or effluent from upland disposal of dredged material will enter navigable waters (Sec. 402; Bradley, 1976, 46).

Clean Water Act of 1977 (P. L. 95-217)

Section 67(g)(1) of this Act grants states the right to establish a Section 404 permit program for the discharge of dredged material if the state's proposed program is approved by the Administrator of EPA. Section 67(r) exempts federal dredged material disposal operations from regulation by federal or state 404 permit programs if the following conditions hold:

1) The proposed operation is specifically authorized by Congress;

2) An environmental impact statement has been prepared in accordance with NEPA; and/or
3) The EIS has been submitted to Congress before any discharge has occurred and prior to authorization of the project by Congress.

If a proposed federal disposal operation does not qualify for exemption under this statute, the Corps' choice of disposal options, in a state with its own permitting program, may be constrained if that state's standards are more stringent than federal standards.

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

Section 103 requires permits, issued by the Corps of Engineers, for the transportation of dredged material for the purpose of dumping it into ocean waters. The Act affects any proposed federal ocean disposal operation which is to occur seaward of the baseline.

**Coastal Zone Management Act of 1972 (P. L. 92-583)**

Requires that federal activities, directly affecting the coastal zone of a state with an approved coastal zone management plan, be consistent with the state plan. Virtually all of the Corps' disposal operations are affected by this Act. Both land and open-water disposal alternatives are equally affected.

**National Environmental Policy Act of 1969 (P. L. 91-190)**

Requires federal agencies to prepare environmental impact statements and hold public hearings on proposed actions. All of the Corps' disposal operations require an environmental assessment and
public hearings under this Act. The Act applies equally to land and open-water disposal alternatives.

**Endangered Species Act (P. L. 93-205)**

Designed to promote the conservation of endangered and threatened species and the habitat upon which they live. Land disposal operations are affected by Section 7, which requires federal actions to be conducted in a manner that does not threaten habitat of listed species (Cole and Brainard, 1978, 36).

**Fish and Wildlife Coordination Act (P. L. 85-624)**

Requires that wildlife conservation be considered on equal terms, and coordinated with, other features of water resource development programs. Proposed land disposal operations must meet these requirements. If any disposal operation will result in impoundment, diversion or deepening of any body of water, the Corps must consult with the U.S. Fish and Wildlife Service (Cole and Brainard, 1978, 37).


Designed to insure safe disposal of waste on land, and to regulate management of hazardous waste. Land disposal of dredged material is regulated by this Act to the extent that open dumping might be harmful to human health. Also, if the dredged material is considered hazardous waste by the Environmental Protection Agency (EPA), the Corps is required to obtain a permit from EPA and provide
extensive information on the characteristics of the waste material, the dumping schedule and the characteristics of the dumpsite (Cole and Brainard, 1978, 34).

**National Flood Insurance Act of 1968 (P. L. 90-448)**

Provides for federal flood insurance to occupants of areas designated as flood hazard areas, and encourages state and local governments to establish land use guidelines for designated areas. A land disposal operation is subject to the provisions of this Act if the proposed activity is to take place in a designated flood hazard zone (Cole and Brainard, 1978, 38).

**Wild and Scenic Rivers Act (P. L. 90-542)**

Allows for designation of certain valuable rivers and their immediate environments as special protection areas. A disposal operation proposed within one of these designated areas is subject to the provisions of this Act (Cole and Brainard, 1978, 39).

**The National Historic Preservation Act (P. L. 93-205)**

Requires the Corps to coordinate with appropriate state preservation officers and preservation organizations to determine the potential effects of Corps actions on significant cultural resources (33 CFR Part 230.25(a)(1)).
Estuary Protection Act (P. L. 90-454)

Requires the Corps to submit EA or EIS on proposed projects affecting estuaries to the Department of Interior for review (33 CFR 230.25(a)(6)).
APPENDIX B

Raw Data

Legend:

W  open water disposal
L  land disposal
H  hydraulic dredge
B/S bucket and scow dredge
M  maintenance dredging
NW new-work dredging
LIQ liquid phase bioassay
SP suspended particulate phase bioassay
SOL solid phase bioassay
Y  yes, the test was performed
N  no, the test was not performed
ND not done
+ denotes negative test results

Notes:

1) An empty cell in the matrix of biological test results denotes a positive finding. Elsewhere in the table, an empty cell indicates no data was available.

2) Cost data are estimates of 1984 dollar value.
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<th>Project Location</th>
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<th>Disp. Type</th>
<th>Dredge Type</th>
<th>Work Type</th>
<th>Volume (CY x 10^3)</th>
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**Note:** The data in this table were compiled from the records of the U. S. Army Corps of Engineers, New England Division, Waltham, Mass. Sources included project reports and environmental assessments from the Navigation Branch; computer printouts of bulk sediment and elutriate test results, and handwritten records of bioassay/bioaccumulation test results from the Regulatory Branch.
Appendix C

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<td>RCRA</td>
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References


Environmental Effects Laboratory, 1976, "Ecological Evaluation of Proposed Discharge of Dredged or Fill Material Into Navigable Waters: Interim Guidance For Implementation of Section 404(b)(1) of Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972)," Miscellaneous Paper D-76-17, (Vicksburg, Miss.: U. S. Army Waterways Experiment Station).


