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Dredged Material Disposal in Coastal Wetland Environments: A review of the general ecology and environmental impacts of disposal on wetland ecosystems with recommendations for assessment procedures

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FOREWARD

Dredged material disposal in coastal wetland ecosystems can generally be regarded as environmentally degrading and therefore strict adherence to guidelines developed from a strong data base and assessment procedures are required from a resource management standpoint. As little as a decade ago, dredge and fill projects were largely unregulated activities and resulted in the complete destruction of large tracts of salt marsh and mangrove communities, extensive areas of productive subtidal bottoms including sea grass beds and the concommittant elimination of both economically and ecologically important aquatic populations. These activities, taken together, have been responsible for the loss of entire fishery resources and rendered many coastal areas, once valued for their recreational and aesthetic appeal, unfit. The anticipated development pressure along coastal areas throughout the United States in the coming years will certainly add to coastal resource management problems.

In this report, commissioned by the Office of Federal Activities, Environmental Protection Agency, we present a review of the technical information on the effects of dredged material disposal in coastal wetland ecosystems. Our emphasis has been to summarize the impacts of disposal on the physical, chemical and biological components of wetlands. For information purposes, we present current state and federal guidelines and a general discussion of wetlands ecology. Finally, using the above information, a detailed discussion of procedures for assessment of disposal impacts in coastal wetland ecosystems is offered.

The opinions and discussions offered in this report are those of the authors and do not necessarily represent the position of the Virginia Institute of Marine Science. However, through an intensive review within the Institute, we have incorporated many criticisms and opinions of earlier drafts and are indebted to the many persons outside the list of authors who contributed significantly to the report. We remain, nonetheless, responsible for its content.

ABSTRACT

The general ecology of coastal wetland ecosystems and the effects of dredge material disposal in these systems are reviewed. A summary of the physical, chemical and biological impacts associated with disposal are presented and discussed. The interaction within these three categories produces the system's response and because of a general lack of interdisciplinary studies cannot presently be quantified. Ecosystem modeling is suggested as a tool for interrelating the various impacts and producing a quasi-predictive capability.

As a minimum, marshes, sea grass beds, productive intertidal and shallow water areas are identified as requiring treatment within an EIS review if there is the potential for impacting these areas by dredged material disposal. Specific information and data requirements for assessment are discussed with these areas in mind. Adequacy of an EIS review should be judged according to the needed or required information and not simply that provided in the statement.

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CONTENTS

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CHAPTER I

INTRODUCTION

The history of dredging and filling in coastal wetland ecosystems began, in this country, with the first English settlers. However, the immense and varied values of these systems has not been recognized until recently. Consequently, guidelines controlling the alteration of these systems are still being formulated.

The federal government, through the National Environmental Policy Act of 1969, requires all government agencies to assess the environmental impact of any project expected to significantly affect the environment. Under section 309 of the Clean Air Act, the Environmental Protection Agency (EPA) reviews impact statements under this authority. The EPA's office of Federal Activities (OFA) has commissioned this report to provide the technical basis for review of proposals relating to dredge and fill projects in coastal wetlands. The principal objective is to improve both the quality and uniformity of the reviews.

To provide the technical information for such guidelines it is necessary to document the productivity and value of coastal wetland ecosystems, and present the currently known information on the alterations imposed by disposal of dredged materials on wetland ecosystems.

The scope of this report is limited to an analysis of dredged material disposal in coastal wetland ecosystems. It is intended to provide background information on the known impacts of dredged material disposal on the biota, water quality, and habitat quality of these ecosystems and to provide guidelines for assessing the probable impacts of disposal operations by presenting the types and amounts of information required for review. It is not intended to be a treatise reviewing all aspects of dredged material disposal operations, nor is it intended to be a critical review of the literature. (For a more complete discussion of the ecology of aquatic ecosystems, and activities occurring within them, see Darnell 1976).

Our discussion of the value and function of coastal wetland ecosystems draws heavily from the ecological literature on salt marshes and estuaries. Our information on the impacts of dredged material disposal on these systems is derived from published information, state and federal guidelines, and personal communication with researchers.

Unfortunately, there are broad gaps in our knowledge of wetland ecosystem function in general, and these gaps are magnified when dealing with disposal operations in particular. Many research efforts have been undertaken to fill these gaps, primarily through the Office of Dredged Material Research of the Waterways Experiment Station, U.S. Army Corps of Engineers. However, the results of these studies were not available for review or inclusion in this report, though they should be available within the next two years. We mention this so that the reader may be aware of the interim nature of this report.

We have presented this information in such a way that the field representatives of the permitting agency and those responsible for EIS review will be able to assess the probability of damage to a wetland ecosystem impacted by disposal of dredged material. Accomplishment of this objective has dictated the format of the report.

Chapter II describes the types and extent of disposal operations presently carried out in the United States, and the currently proposed guidelines for regulating these activities. The general guidelines for disposal of dredged materials in wetland ecosystems should be kept in mind when considering any proposal to dispose on these systems, and the federal guidelines are presented for this purpose.

Chapter III outlines the general ecological relationship among the various components of the coastal wetland environment while Chapter IV deals with the documented impacts of dredged material disposal on the physical, chemical and biological properties of wetland ecosystems. Chapter V presents methods of assessing probable damage to these systems by discussing the types and extent of information required for review of Environmental Impact Statements (EIS) related to disposal operations.

As appended material, we have included current state guidelines (January, 1976) for regulating dredged material disposal (Appendix A), and a list of state agencies and addresses responsible for activities in wetlands (Appendix B).

CHAPTER II

BACKGROUND

Deposition of dredged material in wetland ecosystems has resulted in severe impairment of a productive, valuable, and in some cases, non-renewable resource. Most dredged materials are derived from hydraulic dredging operations conducted in navigatable waters of the United States. Kirby, et al., (1975) reported that 291 million cubic yards of material are dredged annually by the Corps of Engineers. Dredging of existing channels accounts for 230 million cubic yards of this total, while the remainder is due to new projects. Not all operations, however, are large scale projects. For example, in Virginia in 1972, a new law designed to protect wetlands went into effect. In that year, approximately 160 applications were reviewed that proposed dredging in coastal wetlands. Of these applications, 147 involved dredging less than 50,000 cubic yards and 130 involved less than 10,000 cubic yards. In fact, almost 50% of the applications involved less than 1000 cubic yards. The result of such piecemeal destruction of wetlands is difficult to assess, but the cumulative effect is undoubtedly deleterious. As large scale disposal projects come under more severe scrutiny, such small scale projects may take on added significance.

Guidelines for the protection of estuarine wetland ecosystems have been drafted by private researchers, and state and federal agencies. The guidelines are usually intended to apply either to a broad range of cases or to specific instances. Private researchers generally suggest specific recommendations. These may provide accurate assessment of a particular type of project, but are limited in their range of application. A suggestion made for mitigating the effects of disposal in a northern marsh may not be applicable to a nearby open water situation or to a more southern marsh, for instance.

On the other hand, general guidelines, derived primarily from state and federal agencies, provide broad policy directives, but, while these guidelines are important, they give little information on assessment procedures to insure their implementation.

The type of broad guidelines which a disposal operation should satisfy are exemplified by the joint EPA-Army Corps of Engineers guidelines published in the Federal Register, Vol. 40 (173): Part 230, on September 5, 1975. These guidelines are:

1) Avoid discharge activities that significantly disrupt the chemical, physical, and biological integrity of the aquatic ecosystem.

2) Avoid discharge activities that significantly disrupt the food chain, including alterations or decreases in diversity of plant and animal species.

3) Avoid discharge activities that inhibit the movement of fauna, especially their movement into and out of breeding, spawning, feeding and nursery areas.

4) Avoid discharge activities that will destroy wetland areas having significant function in maintenance of water quality.

5) Recognize that discharge activities might destroy or isolate areas that serve the function of retaining natural high waters or flood waters.

6) Minimize where practicable adverse turbidity levels resulting from the discharge of dredged material.

7) Minimize discharge activities that will degrade aesthetic, recreational, and economic values.

The assessment procedures developed in this report should allow the investigator to determine if these general guidelines will be complied with, or to determine ways to minimize its deviation from the broad guideline.

CHAPTER III

GENERAL ECOLOGY OF COASTAL WETLAND ECOSYSTEMS

Coastal wetlands have been defined by various authors but in this report they include marshes, intertidal areas and shallow water estuarine habitats. This broad definition thus includes such diverse areas as salt marshes, mud flats, submerged grass beds, and subtidal, non-vegetated bottoms. Wetland ecosystems, although composed of relatively distinct topographic areas such as these, are highly interrelated systems due to the physical factors governing the distribution of these components, and as a result of the trophic structure of the salt marsh and estuarine ecosystem. The high degree of interdependence exhibited by the components of these various ecological habitats necessitates a holistic view of coastal wetlands for the evaluation of activities and processes occurring in them. Ultimately, the success or failure of management policies will depend on whether or not this over-all view is adopted. The holistic view, because of the extreme physical and biological complexity of wetland ecosystems, demands that the solutions to management problems be multidisciplinary in approach.

The material contained in this chapter is presented as an introduction to the general ecology of coastal wetlands and is intended to orient an EIS-reviewer toward considering this complex of aquatic ecosystems in its entirety.

WETLAND ECOSYSTEMS

If one were to approach a coastal area from the air at an initially high altitude, two distinct topographic features would be recognizable; 1) an area covered by water, and 2) an area appearing to be marsh, or land fringed by marsh borders. Depending on geographical location, the relative proportion of these two areas would vary. The distinction between the two areas would change as you approach. What initially appeared to be a definitive boundary between water and marsh would become a less clearly defined transitional area. The characteristic dendritic creek-drainage systems linking open water with marsh would be evident. It is via these relatively small creeks and natural channels that matter, energy, and nutrients are exchanged between marsh and estuary.

If one were to continue a general survey of the physical characteristics of a coastal wetland ecosystem, closer inspection may reveal several other distinctive features: 1) non-vegetated, intertidal areas, 2) shallow water bottoms, 3) grass flats or grass beds, and oyster reef communities which occupy intertidal or shallow water subtidal areas, and 4) deep water areas where the bottom is deeper than light supporting photosynthesis will penetrate.

These areas may, for classification purposes, be regarded as subsystems or units within the total marsh-estuarine ecosystem.

The extent and distribution of these areas within a given coastal system is dependent on both the physical characteristics of the area (e.g., tide, temperature, salinity, circulation patterns and geomorphology) and the biological and ecological characteristics of the populations found there. In these areas, the small-scale patterns of distribution, abundance, and dominance, within the biological community, are largely the result of physical-biological and biological-biological interactions.

For virtually all wetland ecosystems, several characteristic features and types of habitats exist;

I. Marsh

a. high marsh: intertidal areas vegetated by vascular plants and inudated by only extreme high tides and storm tides

b. intermediate marsh: vegetated intertidal areas inundated on nearly all normal tides

c. creek bank or levee marsh: vegetated intertidal areas inundated on all normal tides

II. Transitional

a. intertidal flats: intertidal, non-vegetated areas adjacent to creek bank or levee marsh or sand beaches

III. Estuarine

a. non-vegetated, shallow water areas: subtidal areas where light penetrates to the bottom; sediment characteristics vary greatly depending on local conditions but generally have a large sand fraction

b. grass flats or grass beds: subtidal, shallow water plant communities particularly characteristic of mid-Atlantic and Gulf coast estuaries; preferred habitat for many ecologically and commercially important fish and shellfish species; utilized extensively by migratory water fowl

c. non-vegetated, deep water areas: subtidal areas; bottom too deep for adequate light to penetrate for supporting plant growth; sediment characteristics highly variable depending on local conditions but surface deposits generally contain high silt-clay fractions

The distribution of these habitats ranges from relatively continuous, to extreme patchiness, within a given salt marsh-estuarine system. The contribution of each of these components to the overall system is not equal among the various categories. As a general rule, one finds that the distribution and concentration of ecologically important components are located near-shore or in shallow water habitats (including the intertidal areas) and occupy a relatively small proportion of the total area defined by the boundaries of the salt marsh and estuary.

For the purposes of this report, the above list of habitats will be considered the major components of wetland ecosystems. Each habitat will be briefly discussed in terms of its importance to the overall system and with regard to those factors having the most significant impact relating to dredged or fill material disposal operations. A detailed discussion of specific impacts due to dredged material disposal operations is presented in the following chapter.

MARSHES

Marshes are not only one of the more characteristic components of wetland ecosystems but are the most productive and ecologically important segments of the entire system. Marshes can be roughly grouped into one of four types, although many intermediate marsh types exist and more extensive classification systems have been proposed (e.g., Silberhorn, et al., 1974; Cowardin, et al., 1976). These basic types include:

1. high-salinity marshes

2. intermediate, or mesohaline marshes

3. brackish water marshes, or low salinity marshes

4. fresh water tidal marshes

Each type has a characteristic dominant plant community, relative size and distribution, and associated faunal community. The predominant factors controlling these systems are tidal amplitude, tidal excursion and salinity. The various groups can also be characterized according to such ecological measures as productivity, food web dynamics, and nutrient cycles. All the marshes, regardless of type, serve such important functions within the total system as erosion control agents, sediment traps, storm and wave surge buffers, water recharge areas, and wildlife habitats (both resident and transient). Most importantly though, they serve as the major producer of fixed energy for the entire ecosystem.

High salinity marshes are characteristic of coastal areas that are protected from intense and frequent wave action. The coastal barrier islands and embayments extending from Maine to Florida on the Atlantic coast and from Florida to Texas on the Gulf coast have extensive high salinity marsh systems dominated principally by one marsh plant species, _Spartina alterniflora_.

These marshes contribute 80 to 90% of their total production to the adjoining water body through the input of dead plant material. This material is degraded chiefly by bacterial action and eventually becomes incorporated into higher trophic levels. Because of the nature of this energy input to estuarine ecosystems, the trophic structure is generally termed "detrital-based". Secondary production in these ecosystems is directly dependent on maintaining plant detrital input. Human activities such as dredging and filling of marshes thus immediately reduces this input and may ultimately eliminate certain secondary producers through piecemeal reduction of total marsh acreage. Higher producers that could be affected include clams, oysters, crabs, and a variety of both ecologically and economically important fish species. High salinity marshes also provide both habitat and nesting materials for shore birds, small mammals, and migratory waterfowl.

Mesohaline and low-salinity marshes are characterized by a more diverse vascular plant community and generally fewer species of secondary producers. Wass and Wright (1969) reported that approximately four times as many fish species occur in seaside coastal areas than in riverine-brackish water marsh areas in Virginia. Functionally, the ecology of these areas is very similar to the seaside marshes. The trophic structure of these systems is detrital based but because of differences in salinity and sediment characteristics, species composition often differs from seaside marshes. The vascular plant community is usually dominated by more than one species of Spartina and might also include other species of grasses and sedges. These marsh types serve the very same function with regard to the adjoining estuarine ecosystem as in the seaside marshes.

Freshwater marshes have higher plant diversity than either seaside or brackish water marshes. The plant community is usually characterized by cattails (Typha spp.) while other common species include Arrow Arum (Peltandra virginica), Pickerel Weed (Pontederia cordata) and Arrowhead (Sagittaria supp.). These ecosystems are perhaps the least studied and understood ecologically of the marsh ecosystems. Production is variable but in some areas equals the productivity of seaside and brackish water marshes (Doumlele, 1976). The trophic ecology of freshwater marshes has not been well established but is known to provide habitat for muskrats, birds and some species of anadramous fishes. In addition, these marshes are preferred habitat for wintering waterfowl.

INTERTIDAL FLATS

Sand beaches and mud flats are characteristic transitional zones between marsh and/or upland habitats and the estuary proper. Sand beaches are extremely dynamic systems that are largely under the influence of such physical factors as exposure, tidal amplitude, and current. Ecologically, sand beaches are simple systems that contribute little production to the overall systems dynamics. They are, however, both a source and sink for eroding materials. Disposal of dredged materials in such an active physical area would probably result in dispersal of the material to adjoining areas. These areas of dispersal would likely include adjacent clam beds, oyster communities, and grass beds with their associated fauna.

The transition areas adjacent to marshes are generally mud flats. These intertidal areas support dense populations of infauna and epifauna that serve as prey organisms for many predatory invertebrates (e.g. blue crabs) and fishes (e.g. spot and croaker). Depending on the local depositional/erosional characteristics of an area, mud flats may also be areas of active marsh development. For many Atlantic coast marshes, mud flats support extensive intertidal oyster reef communities and clam populations. Mud flats also have well developed benthic algal communities whose production may equal 25% of the marsh vascular plant production. It is on these mud flat areas that many immature and juvenile fish species feed. It has been proposed that, for some organisms, greater than 50% of their caloric intake is derived from the benthic algal community growing on the organic-rich intertidal sediments. The benthic algae and the decomposition products of marsh vegetation have further ecological importance as sources of fixed energy and nutrients. These are exported, via tidal action, to the estuary, and significantly enhance both primary and secondary production. Since mud flats are both structurally and functionally related to the marsh ecosystem, activities that can influence the marsh have generally the same consequences for the mud flat.

ESTUARIES

As with the term "wetland ecosystems", estuaries have been variously defined by persons representing geological, physical, and biological disciplines. It is generally agreed however, that an estuary is a body of water where the river systems interact with ocean waters. Estuarine habitats are transitional between purely fresh water, non-tidal aquatic ecosystems and the sea. The factors governing the distribution of habitats, species, etc., are on the large scale physical in nature. These factors are generally related to salinity, tide, and circulation. It is impossible in a brief review such as this to deal in detail with the complexities of the estuary. That remains the subject of annual reviews and symposia. We present here a very brief discussion of those characteristic areas of the estuary that have been established as ecologically important segments of an extremely diverse system. Because the subject of this report is disposal of dredged material, the discussion is limited to benthic habitats. Chapter IV deals in detail with the impact of dredged material disposal in the water column.

Shallow water, subtidal habitats are defined as those areas where sufficient light penetrates to the bottom to support photosynthesis. The actual depth corresponding to this definition will vary drastically from area to area within an estuary as well as between different estuaries due to varying turbidity levels. These shallow water areas can be further classed as vegetated or non-vegetated.

Shallow water, non-vegetated habitats: These areas generally correspond to sediments having a high sand fraction and low organic content. They are well aerated with the redox discontinuity well below the surface. Characteristic faunal populations would include annelid worms, crustaceans, and one to several species of bivalve mollusks. These areas could include such economically important populations as clams, crabs and oysters. Many benthic feeding fishes use these areas as feeding grounds, preying primarily on the infauna, and moving from the area when not feeding. Sand beaches associated with these subtidal areas are also prime recreational areas and are used extensively by swimmers and boaters. They are also, unfortunately, a prime area for developers who destroy their original aesthetic and recreational value as well as their biological productivity, during construction.

Shallow-water, vegetated habitats: Submerged grass flats or grass beds are common along much of the East and Gulf coasts. Eelgrass (*Zostera marina*) predominates along much of the Atlantic coast while turtle grass (*Thalassia testudinum*) dominates Gulf coast estuarine grass beds. These grass beds are extremely diverse in faunal composition and support populations that are transient to the system. The grass beds stabilize sediments and serve as refuges for prey species, as well as being used directly as a source of food by many migratory waterfowl. Sea grass beds are also spawning grounds for many egglaying invertebrates and fishes. The common Bay scallop (*Aequipecten irradians*) is highly dependent on the maintenance of adequate grass beds for its survival. The actual number of organisms and number of species dependent on grass bed communities during various stages of their life history, although not well known, is presumed high. Nutrient dynamics within these submerged communities has not been well delineated, but the overall behavior of the community would indicate that grass beds export both nutrients and energy to other estuarine communities. They appear to be highly productive systems and extremely sensitive to human perturbations; especially sedimentation arising from dredging and/or disposal activities. Entire bay systems have been known to lose the majority of their grass beds to dredging activities. Concomittant with this loss has been the complete destruction of entire bay scallop populations and a lowering of both diversity and secondary production in many lagoonal systems. The grass beds are not only important trophically but add structural diversity to the overall estuarine system. From a holistic standpoint, this aspect may be more important for maintenance and stability of the overall ecosystem than trophic considerations. It would seem that an absolute requirement of an EIS would be an evaluation of probable impact on these habitats especially by evaluation of potential sedimentation problems.

Deeper-water estuarine habitats: These areas, by definition, are deeper than the depth to which adequate light to support photosynthesis will penetrate. The division between shallow water and deep water habitats, as mentioned earlier, is completely arbitrary. Some areas that would fall within the definitional boundaries for estuarine systems are extremely productive and others are not. Many productive shellfish grounds would be included in this category as well as some productive fishing areas. Ecologically, the importance of these areas vary and largely must be decided on a case-by-case basis. It is, however, within this category that the least productive and ecologically important areas exist. These would include deep water channels, anoxic basins and designated spoil disposal areas. Such nonproductive areas, excluding deep water channels, could be the types of estuarine areas where disposal operations may be carried out with little damage, as long as the impacts will be limited to them and not affect adjoining areas. It is extremely difficult to make general statements about the ecology of these areas except to point out that some are productive. For EIS reviews, sufficient evidence should be made available in the statement so no doubt exists as to the type of deeper water habitat to be involved.

SUMMARY

The general ecology of wetland ecosystems is viewed as a highly interactive system made up of various subsystems. Total system integrity depends on the maintenance of a continuous flow of both energy/matter and information from subsystem to subsystem. As we tend to simplify wetland ecosystems by selectively eliminating various components, the total system functions and productivity become impaired.

It is obvious from the preceeding discussion that the potential for adversely affecting wetland ecosystems by disposal of dredged and/or fill materials is an extremely complex managerial problem. We have identified what we believe to be a minimum number of habitat types that require the attention of EIS's. The reviewer of EIS's should require, as a minimum effort, assessment of these areas if they will be potentially impacted by disposal operations.

In the following chapters, we offer a summary of the known disposal impacts within these habitats and the methods of assessment we consider to provide the minimum information required for an adequate review.

CHAPTER IV

IMPACTS OF DREDGED MATERIAL DISPOSAL

A review of the literature on dredged material disposal reveals broad gaps in our knowledge of the effects on water quality, physical processes and biota. The systems parameters which are most often studied are generally those most easily studied, obviously impacted, or those which affect species of commercial importance. It is particularly difficult to find the interdisciplinary studies necessary to substantiate interactive effects. Since many potential and/or suggested impacts discussed in the literature are of an interactive nature, this is unfortunate. Nevertheless, a summary of known impacts coupled with a knowledge of wetland ecosystem ecology will allow a broad determination of probable impacts.

The impacts chapter is presented in summary form and is divided into the major headings: 1) water quality, 2) physical processes, and 3) biota, with a broad range of sub-headings under each.

1. Water Quality

a. Temperature

Apparently temperature is rarely monitored in connection with dredged material disposal operations. One study, however, reports no alteration of temperature (Gunter, 1969) while another reports a reduction of temperature fluctuations due to suspended sediments (Cairns, 1968).

b. Dissolved Oxygen

Dissolved oxygen depletion has been reported as a result of increased oxygen demand by sediments suspended by dredging and/or by natural currents during, or after dredged material disposal (Cronin, et al., 1967; Brown and Clark, 1968; Leathem, et al., 1973; Kaplan, et al., 1974; Maurer, et al., 1974). Oxygen concentrations are further reduced by a decrease in oxygen production from photosynthesis resulting from reduced light penetration caused by sediments suspended in the water column (Brown and Clark, 1968). However, if phytoplankton growth is stimulated by nutrients released from suspended sediments, the decrease in oxygen concentration may be negated since oxygen will be produced (Windom, 1973). Several investigators suggest that lowered dissolved oxygen due to suspended sediments is a temporary effect, lasting until sedimentation is accomplished (Cronin, et al., 1967; Leathem, et al., 1973).

Diking of disposal sites may prevent dissolved oxygen decrease by containing oxygen-demanding dredged materials and their associated anoxic water, alleviating the problem (May, 1974).

Dissolved oxygen reduction may also result when estuarine circulation becomes restricted, causing stagnant conditions to develop (Nelson, 1960; May, 1973a). Mortality of biota has resulted in cases of restricted bay circulation, although only one case has resulted from alterations produced by disposal of dredged material (May, 1973a). However, the potential conditions causing decreased dissolved oxygen; i.e. restricted circulation, reduced surface and tidal flow, and compartmentalization, have been reported by several investigators (Chapman, 1968; Sherk, 1971; May 1973b). Though research on the long-term effects of such modifications on biota are lacking, it is likely that they are not short-term.

c. Bacteria

Information on bacterial changes due to dredged material disposal is sparse. Present findings indicate that suspended sediments may act as a substrate for bacterial and fungal growth (Angino and O'Brien, 1967; Cairns, 1968; Ches. Field Station, 1968). The total bacterial count of a turbidity plume has been found to increase twofold due to suspension of sediment (Ches. Field Station, 1968). These increases are probably temporary but may nevertheless be highly significant in areas of shellfish beds and at times of shellfish harvests.

d. Viruses

We have been unable to obtain information on changes in water quality due to viruses after dredged material disposal.

e. Oil and Grease

Specific references to problems presented by oil and grease during dredging and/or disposal operations are apparently lacking in the literature. However, release of toxic materials from suspended sediments has been reported (Cairns, 1968; Sherk, 1971). Unfortunately, oil and grease are included in some estuarine sediments and may be implicated as one of the toxic materials released during a dredged material disposal operation.

f. Heavy Metals

Leaching of copper and zinc from suspended sediments has been documented (Cairns, 1968), but in general the problem of heavy metals associated with dredged materials is extremely complicated due to the complex chemical interactions involved. For instance, dredged materials containing heavy metals in excess of EPA criteria, do not necessarily increase metal release (May, 1974, Windom and Stichney, 1972). One of the more lucid explanations of the dynamics of metal species has been offered by Windom (1973). He states:

"Upon dispersion of these sediments in the overlying water the iron is oxidized and forms insoluble hydrated iron oxides. This material has a great ability to scavenge other metals such as zinc, copper, cadmium, and lead, decreasing their concentrations in the water column. Clay minerals and other constituents of the sediment may also scavenge metals. Upon deposition of their iron hydroxide floc, iron is again reduced. In this deposit, high in sulfide, the metals may be expected to remain even though the iron hydroxide floc has broken down. It has been found, however, that iron hydroxide flocculation efficiently scavenges organic complexes. If these are very stable, upon reduction of the iron hydroxide in the sediment, they may be released, leading to concentrations in excess of those originally present. The variations observed in the metal concentrations resulting from dredging activities may therefore depend primarily on the portion of the metals occurring as stable organic complexes. If a large part of the metals in the sediment are in the form of soluble organic complexes which have formed in the sediment, these may be irreversibly released upon dredging. Some of the metals released, however, may be in the form of metastable sulfides, which is probably the case for iron."

The potential for the inclusion of some species of heavy metals into the food web is readily apparent, but the overall result of this impact is poorly understood. There seems to be general agreement however, that the potential for this problem represents an adverse and unacceptable environmental impact. May (1974), has reported that diking of disposal sites is effective in reducing heavy metal contamination.

g. pH

We have found little information on pH changes associated with dredged material disposal. pH changes may be caused by inhibition or enhancement of phytoplankton growth. For example, an increase in phytoplankton growth has been found to increase pH (Windom, 1973). pH changes could also arise if the dredged material was contaminated with acid wastes. Again, diking the disposal site has been found to ensure that the pH of surrounding waters remained unchanged (May, 1974).

h. Toxic Materials

As discussed under other sub-headings, release of toxic materials due to resuspension of dredged material has been demonstrated (Cairns, 1968; Sherk, 1971). Possible toxins not discussed specifically in the literature with regard to dredged material disposal include pesticides, oil, radioactive wastes, and acids. Any of these, if present in the sediment, represents a potential source of water column pollution which may enter the food web of estuarine organisms.

i. Nutrients

High nutrient levels, particularly phosphorus and nitrogen, are characteristic of estuarine and many intertidal sediments, and are released when suspended by dredging activities or leakage from disposal sites (Gunter, et al., 1964; Cronin, et al., 1967; Gunter, 1969; Sherk, 1971; Windom and Stichney, 1972; Leathem, et al., 1973; Kaplan, et al., 1974; Windom, 1975). Ammonia appears to be released in significant quantities (Windom, 1972; Windom, 1975), while other forms of nitrogen and phosphate have also been found to increase in the vicinity of disposal sites (Cronin, et al., 1967). However, phosphate may be absorbed to particulate matter and precipitate, thus yielding no measurable increase in concentrations (Windom, 1973).

j. Salinity

Salinity changes due to dredged material disposal are also given scant attention in the literature. One investigator, however, reports that disposal of dredged materials has contributed to gross physical modification of water quality by altering circulation and salinity (May, 1973a; May, 1974).

k. Turbidity

There is no doubt that disposal of dredged materials results in conditions of high turbidity at least locally and temporarily (Gunter, et al., 1964; Brehmer, 1965; Angino and O'Brien, 1976; Chapman, 1968; Cronin, et al., 1967; Marshall, 1968; Ches. Field Station, 1968; Sherk, 1971; Leathem, et al., 1973; Bassi and Basco, 1974). The amount of water affected by increased turbidity will vary depending on the sediment size of the dredged material, and the current velocity at the disposal site. Increased turbidity may also be sporadic over a long time interval during periods of high run-off, especially from unconfined disposal sites, or leaking, diked, disposal sites.

l. COD and BOD

The oxygen depletion discussed in sub-heading (b), is the result of both the chemical and biological oxygen demand of the dredged material. Suspension of dredged materials in the water column will increase the oxygen demand of the water for the duration of the suspension time of the sediments. In addition, the circulation changes, discussed under sub-heading (b), cause oxygen depletion by allowing the build-up of oxygen-demanding substances in the estuary.

2. Physical Processes

a. Hydrologic Processes

The physical and chemical changes which affect estuarine biota can be brought about through altering the natural circulation of the water system. As noted by May (1973b), "The importance of adequate circulation to the assimilation capacity of estuaries must be recognized as being of foremost concern in planning future modifications in Mobile Bay as well as other bays". Various estuarine habitats have been seriously altered due to dredged material disposal, causing;

1. restricted circulation
2. reduced surface flow and tidal exchange
3. compartmentalization (Chapman, 1968; Sherk, 1971; May, 1973b)
4. increased shoaling (Chapman, 1968)
5. rearrangement of bottom sediment (May, 1973b)
6. gross physical modifications of water quality via circulation and salinity changes (May, 1973a; May, 1974).

Increases in suspended sediments are one of the most pronounced physical effects caused by disposal of dredged material. Loss of sediments from a disposal site results primarily from the local hydrological regime. Dredged materials released in open water, unconfined situations, have been lost rapidly and massively as a semi-liquid or mud density flow, affecting areas many times the size of the original site (Cronin, et al., 1967; Leathem, et al., 1973; Bassi and Basco, 1974). Increased turbidity conditions resulting from these activities are usually temporary, however. (Brehmer, 1965; Chapman, 1968; Cronin, et al., 1967; Marshall, 1968; Leathem, et al., 1973; Bassi and Bosco, 1974).

b. Sediment Alterations

Dredged sediments are often silty. Investigators have found greatly increased silt contents near disposal areas (Marshall, 1968; Leathem, et al., 1973; Bassi and Bosco, 1974; Kaplan, et al., 1974). Deposition in areas of sufficiently low current velocity prevents fine sediments from spreading, however the fine components of dredged materials (particles with a diameter less than 63 microns), may be resuspended and transported by tidal currents (Ches. Field Station, 1968; Leathem, et al., 1973; Maurer, et al., 1974).

Gross alterations in sediment composition have also been documented. For example, in one Florida disposal study, sediment composition was altered from 94% sand and shell to 92% silt and clay (Taylor and Saloman, 1968).

c. Erosion Control and Storm Protection

The value of wetlands in erosion control and protection from storm damage is well documented. Studies detailing erosion or storm damage caused by loss of wetlands through dredged material disposal are unknown to us. However, since the value of wetlands for these functions is well accepted, it can be inferred that loss of wetlands by any means, including dredged material disposal, will reduce or prevent wetlands from serving as erosion control agents and/or storm buffers.

3. Biota

a. Primary Producers

The effects of deposition of dredged materials on primary producers are of great importance since a disturbance at this level will be reflected higher in the trophic structure.

1. The principal source of salt marsh primary production is the macrophytic community, particularly members of the genus Spartina. Disposal of dredged materials on these grasses, and others in the marsh, results in the complete destruction of the community through burial (Marshall, 1968; Chapman, 1968; Kaplan, et al., 1974). Since most members of these plant communities are strictly intertidal, this particularly valuable habitat may also be lost by species replacement if disposal of dredged materials significantly increases the elevation of the marsh. (Nordstrom, et al., 1974; Kaplan, et al., 1974). Often the ecologically less desirable plant Phragmites communis invades and dominates such areas.

2. Another source of primary production in marshes is the benthic algae. The algae can contribute up to 1/3 of the primary production in marshes (Pomeroy, 1959; Gallagher and Daiber, 1974), and would be temporarily eliminated by burial if dredged material was deposited on or near marshes. In addition, the increased turbidity which accompanies disposal operations could also inhibit benthic algal production by reducing available light.

3. Grass flats are an extremely valuable subaqueous estuarine habitat which may be eliminated both by burial and by the sedimentation of materials suspended in the water column by disposal operations. (Sherk, 1971; Marshall, 1968; Odum, 1963; Taylor & Saloman, 1968).

4. Phytoplankton make up the final component of primary production in wetlands. The effects of dredged material disposal on this community are subject to debate and quite likely must be decided on an individual case basis. The chlorophyll a content of water taken near disposal operations and used as a measure of phytoplankton biomass, has been shown to increase by some authors (Kaplan, et al., 1974), while other investigators have reported no increase (Taylor & Saloman, 1968; Cronin, et al., 1967). Other researchers report that suspended sediments interfere with phytoplankton production by decreasing light penetration, limiting the depth to which phytosynthesis may occur (Marshall, 1968; Brehmer, 1965; Cairns, 1968; May, 1974; Odum & Wilson, 1962), while nutrients released during or after the disposal operation may cause increased phytoplankton production after turbidity subsides, (Cronin, et al., 1967; Kaplan, et al., 1974; Sherk, 1971; Copeland & Dickens, 1969).

b. Secondary Consumers

The obvious impacts on the primary producers are elimination, replacement, or reduction of primary production and the consequent reduction of energy/matter input to the system. Concurrently, there will be lowering of secondary production by other components of the system which depend either directly or indirectly on plant production.

1. Benthic communities

Benthic communities are more sensitive to environmental perturbations from disposal operations than other communities of secondary consumers (Maurer, et al., 1974). The limited mobility of benthic organisms renders them incapable of escaping burial by the deposited dredged material. Consequently, the effects of disposal on benthic communities may be quite dramatic, often resulting in complete destruction (Lunz, 1942; Brehmer, 1965; Cronin, et al., 1967; Cairns, 1968; Sherk, 1971; May, 1973a; Maurer, et al., 1974). However, a few highly mobile forms may escape burial if deposition does not exceed 20 cm. (Saila, et al., 1972). An overboard disposal operation in upper Chesapeake Bay resulted in a 71% decrease in average numbers of individual organisms, and an associated reduction of benthic biomass and number of species (Pfitzenmeyer, 1970). Increased numbers of *Mulinia lateralis* (Cronin, et al., 1967; Leathem, et al., 1973; Kaplan, et al., 1974), and *Macoma phenax* (Cronin, et al., 1967) have been reported at disposal sites, but Cronin, et al., (1967) attributes these increases to set of larvae rather than survival of the disposal operation by adults.

Apparently destruction by burial can be an acute but short term impact, though in Chesapeake Bay, a 1.5 year lapse resulted before pre-spoiling levels were restored (Pfitzenmeyer, 1970), and in a Florida operation, a 10 year recovery period was insufficient for re-colonization by invertebrates (Taylor and Saloman, 1968).

Aside from direct burial, benthic organisms may be indirectly affected by disposal operations through alteration of sediment composition, elevated levels of suspended sediments and settling of suspended materials.

Sediment composition largely determines benthic community structure. Consequently, alteration of the sediment composition has been reported to effect changes in the structure of the benthic community (Taylor and Saloman, 1968; Kaplan, et al., 1974). Taylor and Saloman (1968) found a dramatic reduction in numbers of polychaetes, mollusks, pink shrimp, and blue crabs following a radical change in sediment composition from 94% sand and shell to 92% silt and clay.

Elevated levels of suspended sediments clog the filtering apparatus of suspension feeders and cause mortality of their young. Slight increases in turbidity have been shown to increase the pumping rates of bivalves, probably due to mechanical stimulation of gill surfaces (Loosanoff, 1961), however, moderate to high concentrations caused adults to slow or entirely cease pumping (Loosanoff and Tommers, 1948; Cairns, 1968; Loosanoff, 1961). In addition, larvae and eggs of the American oyster, Crassostrea virginica and the hard clam, Mercenaria mercenaria, are severely affected by high turbidity (Loosanoff and Tommers, 1948; Davis, 1960; Loosanoff, 1961; Davis and Hidu, 1969), and oyster spat was reduced 30% in the vicinity of one Florida dredging operation (Lunz, 1942). Settling of suspended sediments also eliminates substrates for larval setting (Price, 1947), and smothers adult organisms (Brehmer, 1965; Marshall, 1968, Cairns, 1968).

2. Fish populations

Due to their higher mobility, the effects of disposal operations on fish populations appear to be caused mainly by subtle effects associated with suspended sediments and/or changes in sediment composition.

High turbidity levels have caused mortality of fish eggs and larvae (Bartsch, 1960; Brehmer, 1965), though in some cases these effects may be absent (Cronin, et al., 1967). Deposition of suspended sediments may also smother demersal eggs (Huet, 1965). Mortality of juvenile and adult fishes due to high turbidity has been reported by many investigators, using laboratory bioassay techniques, (Ingle, et al., 1955; Huet, 1965; Cairns, 1968; Servize, et al., 1969; Sherk, et al., 1975). Some fish can withstand high concentrations of suspended sediments through avoidance or other means, but are particularly susceptable to suspended sediments containing acids or alkalies which interfere with the production of protective gill mucus (Huet, 1965; Cairns, 1968). Juvenile fishes have shown various, and in some cases, high mortalities to suspended sediment concentrations occurring during dredging operations (Sherk, et al., 1975). Both wild and caged species of adult fishes, eggs, and larvae in the vicinity of a dredging and disposal operation exhibited no effects (Cronin, et al., 1967).

Changes in sediment composition also affect the distribution of fishes. After dredged material placement that altered sediment composition from 94% sand and shell to 92% silt and clay, all demersal fishes were eliminated, and the total number of fish species was reduced from 80 to 49 (Taylor and Saloman, 1968).

A more subtle effect and one not documented in short term investigations would result from the elimination of fish resources. The feeding relations among various fish populations is extremely complicated and changes with the various life history stages of the individual population. Elimination of the resource base due to dredged material disposal for any of the life history stages would thus affect total production by the population in the long term. For example, benthic algae, infauna and other components of the detrital system serve as feeding resources for forage fishes which in turn support, as prey, other fish populations. Thus, changes in marsh and shallow water productivity would indirectly affect predator species by reducing or eliminating their forage fishes.

c. Food Webs

The total response of a wetland food web to dredged material disposal is the result of the response of one or more communities to the disposal operation itself, or to one or more of the physical and/or water quality changes the operation induces.

1. Dissolved oxygen depletion resulting from suspension of oxygen demanding sediments may suffocate immobile organisms such as fish eggs and larvae, and benthic organisms, while driving away mobile organisms such as adult fishes and crustaceans. Long-term dissolved oxygen changes resulting from altered circulation have eliminated oyster beds (Galtsoff, 1959; Nelson, 1960), fish, shrimp, and blue crabs (May, 1973a), and oyster spat (Nelson, 1960).

2. To our knowledge, elevated bacterial levels have not been shown to have detrimental effects on organisms in the estuarine food web except possibly man. Elevated levels of bacteria, which could be chronic in cases of undiked or leaking disposal sites, may pose a threat to people at times or in places where shellfish beds are in contact with high bacterial levels.

3. Toxic materials may affect any part of the food chain directly or indirectly. Hydrogen sulfide potentially found in dredged sediment proved fatal to sockeye salmon smolts (10 minutes at a suspended sediment concentration of 1%, 14.7 C) (Servizi, et al., 1969). Sediments containing alkalies or acids may enable ordinarily harmless levels of suspended sediments to harm fishes by clogging their gills (Huet, 1965; Cairns, 1968). Heavy metals such as copper and zinc, have proven fatal to fishes (Cairns, 1968). Also, certain hydrocarbons, when associated with dredged materials, could be resuspended in quantities high enough to impair chemoteception in fish and crustaceans, thus not allowing the organisms to function normally in locating food, finding mates, and escaping predation (Saila, et al., 1972).

   Unfortunately, the indirect or longer term effects which may result from resuspended pollutants are often not studied. Pesticides, heavy metals, etc., present in some dredged materials, could be taken up by marsh grasses and transferred to other trophic levels which either consume marsh plants directly, or through the detrital food web which most marsh plants support. Since most heavy metals tend to adsorb on suspended sediments released in dredged material disposal operations, they could be taken up either directly by phytoplankton and secondarily enter other trophic levels by consumption or through filtration of suspended materials by benthic organisms such as clams or oysters. The degree to which such pollutants may cycle in this manner is largely dependent on the specific pollutant as well as the populations present.

Pollutants may be taken up by benthic organisms directly from sediments or by feeding on microbial populations associated with sediment particles. The benthos can then serve as a source of contamination for fishes and crustaceans feeding on the benthic populations. Mechanisms and amounts of uptake for some specific pollutants by estuarine organisms have been researched. Whether the effects demonstrated can be conclusively related to disposal of polluted dredged materials is not know.

Since the effects of at least some toxic materials are linked to suspended sediments which occur during and/or after dredged material disposal, the potential for adversely affecting estuarine trophic relations is present. Summarizing the impacts, at least in a predictive sense, is not possible because of the extremely complicated nature of both the physical-chemical and biological interactions possible. For the majority of situations, each case must be decided on an individual basis using local information.

4. Salinity changes effected by dredged material disposal alter estuarine food webs primarily by restricting or changing the natural circulation patterns. Reduced salinity caused by increased fresh water inflow, effects changes in community structure and causes mortality of sessile forms. Increased salinity can result in the same consequences and allow increases in predatory mortality by allowing invasion of areas by predators normally excluded by a low salinity barrier (Galtsoff, 1956). Salinity changes seem to be uncommon in dredged material disposal operations, but are a distinct possibility. When they occur, such changes can be expected to effect changes in community structure and function since some estuarine organisms have specific salinity tolerances.

5. By far the most serious effect of dredged material disposal operations results from the suspension of sediments during dredging and/or deposition. Chronic turbidity may result at disposal sites which are undiked or leaking. Increased turbidity may persist or be intermittent, depending on local hydrologic conditions. In addition to the extensive direct effects of suspended sediments on organisms (already discussed), there is a wide variety of indirect effects. These include;

    a) Grass flat production augments production from <u>Spartina</u> marshes as a food source and habitat for a variety of estuarine organisms. This function can be impaired or destroyed by high levels of suspended sediments (Odum, 1963; Marshall

1968; Sherk, 1971). Grass flats serve as spawning grounds for fish and shrimp and siltation during times of spawning eliminates eggs and larvae, as well as sites for future spawning. The effects are due both to elimination (burial) of grass beds and direct mortality of the associated fauna (Bartsch, 1960; Gunter, et al., 1964; Marshall, 1968; Sherk, 1971).

b) Suspended sediments also induce both positive and negative changes in phytoplankton production. High turbidities decrease phytoplankton production by reducing the euphotic zone (Odum and Wilson, 1962; Angino and O'Brien, 1967; Cronin, et al., 1967; Marshall, 1968; Brown and Clark, 1968; Cairns, 1968; Copeland and Dickens, 1969; Sherk, 1971). Dredged material disposal operations may also "fertilize" the water column by releasing bound or interstitial nutrients causing increased local phytoplankton production (Odum and Wilson, 1962; Gunter, et al., 1964; Copeland and Dickens, 1969; Gunter, 1969; Sherk, 1971; Kaplan, et al., 1974). A solution to this seeming contradiction has been suggested by Copeland and Dickens (1969), who suggest that there is an initial diminished fertility due to reduction of available light, but a later enhancement from redistribution and resuspension of nutrients from dredged materials. Diminished phytoplankton production of a prolonged nature will obviously reduce the production of secondary consumers in the estuarine community.

c) Enrichment of the water column with nutrients may result in blooms of algae which do not enter the estuarine food web or contribute significantly to maintenance of the ecosystem, e.g., blue-green algae. Increased production of these forms creates oxygen demands with death and represents a form of organic enrichment. Research has not demonstrated this consequence in wetlands, relating to dredged material disposal, but has certainly been a principal cause of oxygen depletion and fish mortality in other estuarine areas.

d) Suspended sediments eliminate benthic organisms by, 1) smothering (Galtsoff, 1956; Galtsoff, 1959; Brehmer, 1965; Marshall, 1968; Cairns, 1968; Sherk, 1971; May, 1973b), 2) decreasing filtration rate (Loosanoff and Tommers, 1948; Loosanoff, 1961), 3) killing larvae (Lunz, 1942; Loosanoff and Tommers, 1948; Galtsoff, 1959; Davis, 1960; Loosanoff, 1961; Davis and Hidu, 1969), 4) preventing settling of spat (Price, 1947), and 5) altering sediment composition (Taylor and Saloman, 1968).

Fish eggs and/or larvae are also killed by high levels of suspended sediment (Bartsch, 1960; Brehmer, 1965; Cairns, 1968; Servizi, et al., 1969), and adult fishes may die as a result of gill clogging (Ingle, et al., 1955), or be permanently driven from areas by changing the physical composition of the substrate (Taylor and Saloman, 1968). In addition, suspended sediments resuspend toxic materials effecting the changes previously discussed.

6) Physical alterations of estuarine circulation may produce conditions of altered salinity, reduced oxygen concentrations, and sediment changes which can potentially affect all parts of the food web. The impacts of these effects have been discussed in previous sections.

7) The extent to which terrestrial organisms utilize the marsh is not well known. Waterfowl use the marsh and estuary extensively, at least on a seasonal basis, and can be expected to be deleteriously affected by habitat changes due to disposal of dredged materials. Birds, such as marsh wrens, ospreys, great blue herons and marsh hawks, use the marsh and/or estuary as feeding and/or nursery areas, as do such mammals as raccons, mice, mink and muskrats (Teal and Teal, 1969; Wass and Wright, 1969). All of these animals will certainly be adversely affected by damage to wetlands.

e) Spawning habitats include grass flats, marshes, and estuarine shallows. These systems are used by such fish as croakers, _Micropogon undulatus_; spot, _Leiostomus xanthurus_; weakfish, _Cynoscion regalis_; silver perch, _Bairdiella chrysura_; black drum, _Pogonias cromis_; southern kingfish, _Menticirrhus americanus_; striped bass, _Morone saxatilis_; menhaden, _Brevoortia tyrannus_; American shad, _Alosa sapiddissima_; alewife, _A. pseudoharengus_; blue-black herring; _A. aestivalis_; hickory shad, _A. mediocris_, and obviously as sites for the spawning of other estuarine organisms, such as crabs, shellfish, polychaetes, etc. (Teal & Teal, 1969; Wass and Wright, 1969). Birds, such as the marsh wren, nest in the marsh proper (Teal and Teal, 1969). Destruction of such areas will create long term if not irreparable elimination of some nursery and spawning habitats. Siltation may not completely destroy a habitat, but may eliminate the ability of certain organisms to use the habitat, as previously discussed. Toxic materials also may not destroy a habitat per se, but may render it unusable and potentially lethal to some organisms.

f) Critical habitats are extremely difficult to define. For example, spawning habitats are critical for maintainance of a species but to identify critical spawning habitats for all species is not only an extremely difficult task but for many species an impossible one. Since many organisms are restricted to estuaries, including species of nearly every taxonomic group that are both ecologically and economically important, maintainance of the marsh-estuary system in general is imperative. Other organisms such as migrating fish and waterfowl require use of the ecosystem only during certain times of year, such as the fall waterfowl migration. For wintering organisms the estuarine system may be considered critical in the sense that the winter period is a period of great stress on reduced numbers, and even the relatively short term utilization of the ecosystem by these organisms is necessary for maintenance of the population. The problem of identifying and relating the effects of dredge material disposal to the destruction or severe impairment of critical habitats is further complicated by the dynamic character of species-habitat interaction. Some areas are used as spawning sites, feeding sites, or protection (refuges), and these areas can be different physical components of the estuarine system which change during the various life history stages of an individual species.

With such considerations in mind, a general list of habitats critical to the maintainance of estuarine life includes most if not all marsh areas, submerged grass flats, benthic areas of high productivity, especially shellfish beds, and many shallow water estuarine areas. Such broad documentation is all that is warranted by a review of the literature, and aside from these general areas, specific critical habitats must be determined in a site specific evaluation. The data available only allow a qualitative summary of potential impacts associated with habitat destruction by dredged material disposal.

SUMMARY

From the preceeding discussion, it is evident that the potential impacts of dredged material disposal are complicated and diverse. They range from short term changes (i.e. acute turbidity, local salinity-temperature variation, temporary reduction in dissolved oxygen) to longer term, irreversible impacts (i.e. circulation, substrate-sediment alterations, marsh elevation, chronic turbidity, habitat destruction). It is the principal objective of an EIS reviewer to identify and eliminate those impacts of an irreversible and biologically detrimental nature.

In the following section, we offer guidelines for general assessment procedures which we believe will certainly aid in accomplishing this objective.

CHAPTER V

ASSESSMENT OF DISPOSAL IMPACTS FOR COASTAL WETLAND ECOSYSTEMS

a. General

It is obvious from the foregoing that any disposal of dredged material in coastal wetlands will have an impact on the ecosystem. While there are techniques and operational procedures for dredging and filling which can alter the magnitude of potential impacts, it can generally be assumed that impacts will be environmentally adverse in nature. From the viewpoint of wetland ecosystems and the viability of the marine environment, the certainty of adverse impacts coupled with the uncertainty of the magnitude of effects leads us to the conclusion that dredged material should routinely be disposed of in fastland areas with proper procedures for containment. A primary objective in seeking alternative actions, therefore, must be a thorough search for upland disposal sites.

Unfortunately there are other considerations which sometimes dictate utilization of coastal wetlands as disposal sites. Those charged with either designing or reviewing wetlands disposal operations are faced with a lack of basic impact data in some scientific areas and therefore, an inability to quantify impacts. Consequently, those charged with assessing the impact of disposal operations must, from an environmental viewpoint, adapt a conservative bias by extrapolating and/or leaning toward the "worst case" type and magnitude of impact.

The review of a proposed disposal operation in coastal wetlands involves two basic interrelated steps; 1) an assessment of impacts, and 2) an assessment of operational procedures, including specific site locations, in order to reduce identified or suspected adverse impacts. The latter step can sometimes be expanded to include possibilities of developing environmental enhancement procedures to offset adverse impacts. Both steps require interdisciplinary considerations and it is the purpose of this chapter to guide the reviewer through the procedures.

b. Basic Information Requirements

In order to acquire a basic predictive capability, the assessor should have available the following information.

1. Environmental data

a. Physical

(1) Amount of dredged material in terms of cubic yards.

(2) Description of dredged material in terms of grain size distribution.

(3) Grain size distribution of soil/sediment in the disposal area.

(4) Description of bottom soils/sediments in adjacent or nearby waterways which may be affected by sedimentation.

(5) Hydrologic information pertaining to the disposal area and adjacent or nearby waterways. Data should include bottom configuration, water depths, current velocities, including net direction of flow, and tidal amplitudes. Data pertaining to historical flood levels and expected wave amplitudes is also useful.

(6) Elevation of the proposed disposal area.

b. Biological data

(1) Types and extent of vegetation in the disposal area and in adjacent or nearby areas which may be affected by sediment either directly or waterbourne.

(2) A description of the benthic community in the disposal area, if in the sub-tidal or intertidal zone, and in waterways which may be affected by waterbourne sediment. While all benthos are important, particular attention should be given to those of direct value to commercial or sports fisheries.

(3) A description of demersal resources in and near the disposal area. In view of the fact that we are considering disposal in wetlands, it is probable that spawning and nursery areas are nearby and these areas, if present, should be specifically identified and located. Again, particular attention should be given to those species of direct commercial or sport fisheries interest and to those which may be on endangered species listings.

(4) Listing of known or potential fauna with particular attention to nesting sites, species of trapping, hunting or fowling interest, and to species designated as endangered.

c. Chemical data

(1) The presence and concentration in the dredged material should be known for oils and greases, heavy metals, toxic materials, COD, BOD and nutrients.

(2) Existing or ambient water quality data should be known for the above as well as DO, ph, salinity, turbidity and coliform levels.

d. Weather and Climate

(1) Weather data should be sufficient to determine whether or not heavy rains or storms are likely to magnify sediment problems by contributing upland sediment, affecting the disposal area or by altering water circulation patterns.

2. Operational Data Requirements

Methods and techniques of dredging, containment and dewatering of dredged material and ultimate treatment of disposal areas can have a profound effect on the types and magnitudes of impacts of disposal in wetlands ecosystems. Indeed, operational techniques can sometimes be utilized to enhance various environmental amenities as a trade-off for those environmental amenities which are destroyed or degraded as a result of a disposal operation. In order to fully assess and/or take advantage of operational methods the assessor should have available the following data:

a. Method of Dredging

Most disposal operations of a size and scope requiring preparation of an EIS will involve dredging and disposal by the hydraulic method. Some projects may involve bucket or dragline methods. There may also be cases of dredging by hopper dredge but disposal in wetlands would be akin to the hydraulic method. A primary difference in methods is the amount of water being deposited in the disposal area in proportion to the material being deposited. Hydraulically deposited material vastly increases potential for sedimentation and consequently creates a demand for more comprehensive and stringent control measures at the disposal site. The dewatering process is also longer in duration thus delaying final treatment of the disposal area. Finally, disposal areas for hydraulicly dredged material usually necessitate larger areas than those required for bucket or dragline operations.

Hydraulic dredging has the advantage of being able to deposit spoil in an area remote from the dredging site. On the other hand, bucket and draglined spoil can be placed with precision but only within a distance of about 40 to 60 feet of the equipment.

b. Disposal Arrangements

The size, configuration and capacity of the disposal area must be known in order to correlate it with the amount and characteristics of the spoil and with the disposal method. The interrelationships will be discussed subsequently.

If the spoil is to be retained or confined, structural details must be known in order to assess the adequacy and integrity of containment measures. If the spoil is not to be confined, the environmental data requirements previously discussed will suffice. In cases where spoil is side-cast along the length of a dredging project, the physical area studied must be expanded accordingly.

c. Sediment Control

A confined disposal area as discussed above is a primary sediment control feature. Depending on the type of spoil and the method of dredging, however special attention may have to be given to control of sediment in water being returned to the marine environment from the disposal area. Necessary data for assessment include spillway design, rate and depth of flow of return water over the spillway, location of the spillway in relation to the point of discharge of spoil, rate of discharge of spoil (primarily in hydraulic operations), internal compartmentalization of the disposal area and retention time of water in the disposal area.

d. Timing

The time of year in which the operation is conducted must be known in order to specifically relate impacts to marine resources. Operations should be scheduled, for example, to avoid fish or shellfish spawning activities in nearby areas.

3. Exogenous Data Requirements

The assessor must be alert to those outside factors which may produce synergistic or additive effects. Some of these are:

a. Other activities in the general area which may increase ambient sediment loads in the affected waterway. The construction of a large housing development in the watershed is an example.

b. Other discharges in the area, such as sewage or industrial outfalls, which may complicate matters.

c. Ultimate uses of the disposal area. Uses can run a full gamut from industrial activities to development of a wildfowl sanctuary or creation of wetlands.

d. The effect of cummulative impacts such as repetitive use of the area for disposal or other activities which are destroying or degrading wetlands.

c. Assessment Guidelines

1. General

The array of information requirements and the multiplicity of interactions which can occur strongly suggest utilization of modelling techniques in evaluating specific projects. Even then, however, the lack of present knowledge in some areas precludes arriving at a definitive, quantifiable assessment. When added to the infinite variety of circumstances which can occur along the shoreline, plus various operational or engineering techniques which can be used, it is apparent that only very broad guidelines can apply for evaluating specific projects.

2. Dredge Spoil Characteristics

An analysis of the grain size distrubution of the dredged material is a key first step in evaluating potential impacts. Generally speaking, as grain size decreases potential problems increase. A medium grain size of 0.015 mm or greater approaches beach grade sand which is obviously less likely to be transported for considerable distances in the water column. It is usually "clearer" in terms of unwanted chemical or biological constituents, provides a better substrate for some commercial species of benthos if placed in the water column, can be more easily contained in place and, if placed in wetlands above mean high water, can be more easily spot-located in wetlands of lesser quality. In the latter case, the subsequent dewatering of spoil is greatly simplified which, in turn, facilitates preparation of the disposal area for whatever its ultimate use. Considering the ubiquity of shoreline erosion problems, there should always be an examination of adjacent shoreline areas with a view toward utilizing this grade of material for beach replenishment purposes or, in an even more positive tone, for creation of public beaches.

In the case of finer grained material, the evaluator must consider the wide ranging effects discussed in previous chapters. Every effort should be made to avoid open-water disposal or disposal at low elevations in the intertidal zone. Disposal areas should normally be above MHW (mean high water) with properly designed containment features to avoid sedimentation as spring or storm tides attack the area. As one proceeds from lower elevations to higher elevations, the necessity for and the complexity of containment devices decreases to the point where ultimately vegetated earthen berms may be utilized.

If the disposal area is to be used for other than creating wetlands or slightly modifying existing wetlands, the dewatering of fine grade soils can pose problems. The greater the depth of spoil material, the longer the dewatering process. As spoil drys from the surface downward, a typical occurance is the creation of a crust etched with deep cracks which, when filled with rainwater, can provide habitat for unwanted species such as mosquitos. These areas are also typically invaded by lesser value plant species. They have also been known to constitute a considerable hazard to humans who attempt to cross them and break through the crust into what is virtually quicksand. The evaluator will need to obtain an engineering assessment of these possibilities. If they exist in such a magnitude as to create problems, consideration should be given to enlarging the spoil area in order to reduce spoil thickness and/or treating the spoil through mechanical measures to speed the drying process. This subject area is currently being examined by the Corps of Engineers.

3. Disposal Area Soil Characteristics

Again, grain size distribution in the basic disposal area is a key to the potential magnitude of impacts. And again, engineering assessments are necessary to determine whether the overburden of dredged spoil is going to result in the shearing of underlying soil and consequent creation of mud waves which can raise the surface area of wetlands outside the spoil area to a point where they are no longer usable wetlands. Depending upon the depth of spoil (amount of overburden) and the nature of soil in the disposal area, this effect can extend for several hundred feet outward from the spoil area proper.

4. Vegetative Nature of the Spoil Area

There have been environmental values attached to the various species of vegetation typical of wetlands areas. These values are usually couched in terms of contribution to aquatic food webs, aquatic habitat, faunal food and habitat, soil stabilization and erosion buffering, ability to slow and absorb flood waters and ability to contribute to water quality. The composite value of any single segment of wetlands can be measured to some extent (vegetative productivity, for example) but is largely subjective at this point in our knowledge. In the case of a specific site, the subjective view can be enhanced by a careful consideration of the biological data discussed as an element of basic information requirements.

The environmental importance of submerged aquatic plants is well documented. Though there may be other factors affecting a specific site, beds of submerged aquatic plants should be avoided for use as spoil areas. There have been many successful efforts to create wetlands of emergent species but the same success, or even effort, has not been obtained with submerged vegetation. These subaqueous communities must be considered to be especially critical in the ecosystem.

An assessment of wetlands above mean sea level (MSL) may often depend upon the viewpoint of an evaluator, or group of evaluators, and an appreciation of what particular amenities are considered to be most important at the site in question. If protection of the purely aquatic system is desired, spoil areas in lower elevation wetlands (e.g. *Spartina alterniflora* or *Pontederia cordata*) should be avoided. The lower elevation marshes should also be avoided if shoreline erosion is a significant problem in the area.

Wetlands at higher elevations (above MHW) which are not flooded daily are often of more value than low marshes to a variety of wildfowl and terrestrial fauna. In some cases, disposal of spoil in these areas has resulted in increased wildfowl utilization once the spoil areas have become vegetated.

5. Chemical Considerations

The impact of chemical constituents is, indeed, a hazy area. Soil characteristics, as mentioned before, are vital in attempting to judge what concentrations might be released into the water column and the area which may be impacted. Hydraulic characteristics of the area will also affect concentrations through diffusion, dilution or flushing.

Where chemical constituents in fine grain soils exceed those limits contained in EPA water quality criteria, it must be assumed that proper containment of spoil is a particular necessity. The attention to containment details may be somewhat decreased as soil grain size increases and chemical constituents decrease, however, the proximity of biological resources must also be considered.

6. Physical Considerations

There are physical considerations other than those which relate more specifically to the nature of soil both in the dredged material and in the disposal area. The filling of wetlands obviously destroys or reduces floodplains. Whether or not this is of significant consequence at a specific site depends upon a number of factors not the least of which is the proximity of human development or uses which may be impacted. If the disposal area is large in relationship to the floodplain and there is development or agricultural activity in the vicinity, technical evaluation by hydrologists is prudent.

Deposition of spoil in wetlands will also affect hydraulic patterns. There will be some interaction with the physical changes in the bottom caused by the dredging separation. Determination as to whether or not there will be significant impacts on currents, circulation, flushing, salinity or tidal amplitudes is a matter for specialists. In major projects where major changes appear likely, attention should be paid to the effect of changed salinity or tidal amplitudes on the composition of vegetation in nearby wetlands. The prospects of inducing or aggravating shoreline erosion should also be examined.

7. Other Considerations

It has been indicated that potential sedimentation possibly accompanied by release of undesirable chemicals, cause problems associated with increased tubidity, and damage to the benthos. While not always associated with actual disposal operations, the utilization of sediment curtains should be considered around the scene of dredging and around any open water disposal areas. In some cases, they may be found to be useful secondary controls when installed outside of spillways discharging spoil effluents back into waterways.

The timing of a dredge and spoil operation can be adjusted to avoid those times associated with spawning and nursery activities of fish and shellfish resources.

d. Opportunities for Environmental Enhancement

1. General

All disposal operations in wetlands will have some adverse impact despite application of guidelines. Yet the maintenance of viable waterways will demand continued dredge and spoil operations and it is probable that wetlands will be used for disposal sites from time to time. While all available mitigating measures should be utilized, reviewer's of proposed projects can take a more positive view by considering possibilities for enhancing environmental amenities to at least partially offset damaging impacts.

2. Marsh Creation

There have been successful efforts at creating tidal salt and brackish vegetated wetlands on artificial fill. There has been less experience, but some success, in similarly creating tidal freshwater wetlands. The potential for artificially creating new wetlands should be considered as an alternative to destroying wetlands by filling. There are many factors to be considered, some of which are:

a) The value of existing benthic areas to be replaced by marsh as related to expected values to be obtained by a marsh.

b) The size of an available benthic area as related to spoil material available and final elevation of the proposed marsh surface to obtain vegetative species desired.

c) The probability of spontaneous vegetation by desirable species verses the possible requirement of seeding or transplanting.

d) The presence of toxic materials in the spoil which might leach into the waterway.

e) Containment measures in accordance with soil characteristics.

f) The physical regime and the ability of a new marsh to withstand erosion forces.

g) The impact of a fill in open water upon current and water circulation patterns as previously mentioned.

3. Marsh Alteration

Marshes can be altered, not destroyed, by either spreading a thin layer of spoil over the entire surface or by selectively spoiling in piles at various places in the marsh which will not interfere with tidal flushing. Depending upon the depth of the fill, the first method may make a low marsh less productive for the aquatic environment but may enhance its values for wildfowl and wildlife. The second alternative offers possibilities of maintaining some of the aquatic values while producing a variety of terrain attractive to wildlife and wildfowl.

4. Creation or Replenishment of Beaches

If the soil/sediment grain distribution of the dredged material is large enough (over .015 mm), consideration can be given to replenishing or extending existing beaches or to the creation of new beaches. Some considerations are:

a) Compatibility of grain size with existing beaches.

b) Erosion forces and patterns and net littoral drift. There may be a necessity to construct groins to contain the sand.

c) Accessability for recreational use.

d) The value of benthic areas to be covered versus recreational uses.

e) The presence of toxic materials in the spoil though sand is less likely to be contaminated than clays and silts.

f) The impact upon current and circulation patterns. This factor is particularly important if structures must be built to help retain beaches in place.

CHAPTER VI

SUMMARY

This report has reviewed much of the information available on the effects of disposal of dredged materials in wetland ecosystems. Federal, state and individually proposed guidelines and methods of assessment were reviewed.

Using existing state recommendations and the results of research efforts, general guidelines for the disposal of dredged materials in wetlands have been jointly proposed by the EPA and Corps of Engineers. These focus on protecting productive communities, minimizing long term effects, minimizing secondary impacts on communities physically removed from the disposal site, and suggest eliminating unnecessary activities. The report, with these general guidelines in mind, current research data, and our own experience, offers a scheme for review of EIS's involving dredged material disposal that we consider have the information requirements necessary for an adequate review.

As appended material, we include addresses of state agencies responsible for wetland protection and the current (January, 1976) criteria used by states for assessment of dredge and fill operations.

Based on the demonstrated productivity and value of wetlands as both a natural and national resource, and in view of the policies suggested by federal and state agencies and private investigators, we would recommend the following general guidelines.

1. <u>Certain areas within wetlands should be routinely deleted from consideration as a site for new commercial and private development</u>. We consider any disposal operation taking place on productive marshes, grass beds or productive shallow water habitats as environmentally degrading. We do not know of, and were unable to document through the literature review, any beneficial environmental effect of disposal on a marsh or submerged grass flat.

2. <u>In cases where deposition of dredged material is necessary, the operation should make use of existing sites and/or upland areas and in all cases deposition should be confined and revegetated to impede escape of material from the site</u>. Every precaution should be taken to minimize the area affected and to avoid significantly disrupting the natural hydrological regime of adjoining areas. Deposited material should have similar sediment properties (e.g. sand-silt-clay fractions, organic composition, etc.) as the site to be impacted.

Placement of confined material above mean high water does not necessarily remove the material from the wetland system. Both spring and storm tides and upland runoff will, with time, return the material to the system. Usually this occurs in an unpredictable manner both temporally and spatially.

3. Open water disposal of dredged material should be in areas of naturally occurring low biological productivity, both primary and secondary, and should be restricted to times of the year that would avoid periods of high biological activity and population recruitment. One of the major objectives of any management policy should be to eliminate the destruction of productive subtidal bottoms. A general statement as to what and where these areas are in the wetland ecosystem is difficult and has been identified only in general terms. However, intertidal mud flats, submerged grass beds and shallow bottoms as previously discussed, are generally considered the most productive estuarine habitats. Open water disposal should then specifically avoid impacting these areas. Since many estuarine species spend some stage of their life cycle as eggs, larvae or juveniles in the water column, disposal should be confined to times of the year which would avoid affecting critical life history stages of both ecologically and commercially important species. By choosing areas of low productivity and times of year least damaging to the resident community, the effect of open water disposal of dredged material can be minimized.

4. Disposal of untreated-polluted dredged material in wetland ecosystems is opposed. We are not presently capable of accurately predicting ultimate long term effects of the deposition of polluted materials in wetland ecosystems. Heavy metals in particular present a difficult case in point, due to the extremely complex biogeochemical cycles involved.

5. Lastly, we would encourage and support a "follow-up" monitoring program for dredged material disposal operations. Only by continual monitoring and study of both disposal operations and control areas can guidelines and assessment procedures be improved or revised. The practical implementation of guidelines and procedures is totally dependent upon such a program.

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APPENDIX A

CURRENT STATE GUIDELINES

State agencies have devised guidelines for the protection of wetland areas. These statements of policy range from general directives such as the suggested Environmental Protection Agency guidelines to very detailed summaries of policy such as the Virginia Wetland Guidelines (see Silberhorn, Dawes and Barnard, 1974).

In this chapter, we have summarized the state guidelines as they pertain to dredged material disposal operations occurring in coastal wetland ecosystems. State guidelines were obtained by contacting those agencies listed in Appendix B and are summarized in Table 1 from information made available to us.

The principal difference between federal guidelines and the state guidelines is primarily one of detail.

A total of 22 coastal states and Puerto Rico was reviewed. The answers to three basic questions other than specific guidelines regarding wetlands policy were sought to gather information concerning current assessment procedures. The three questions circulated were:

1. Does the state agency have guidelines specifically regarding operations in coastal wetlands?

2. Does the state agency have a legal definition of what constitutes wetlands?

3. Is there planned or pending legislation to redefine the coastal wetland system with regard to activities?

The response to these questions was varied; 70% of the state agencies surveyed have guidelines pertaining to dredge and fill in wetlands while only 50% have a legal definition for the wetland system. Twenty-five percent have planned or pending legislation to change wetland definitions and/or modification of existing procedures for the assessment of environmental impact due to dredge and fill operations. Three states (Alaska, Texas and Oregon) have submitted guidelines and methods of assessment for dredge and fill, but at the present time, these states have either failed to act on, or rejected the proposed legislation.

We strongly recommend the development of regional-federal policies and encourage states to implement programs within the federal guidelines. We also suggest that both state and federal guidelines be continuously updated and revised as new information becomes available.

The following guidelines were most frequently cited by the various state agencies and correspond to the column headings of Table 1:

A) The disposal of dredged material on valuable wetlands is opposed as an ecological and economic policy in most states. In general, no alterations of regularly flooded *S. alterniflora* salt marsh, deemed to be highly productive, will be permitted.

B) Dredged material should be confined to minimize the area affected.

C) Existing disposal sites should be used when possible.

D) Disposal should be alternated to opposite sides of the dredged channel and openings left of sufficient width and cross section between disposal sites to permit adequate water exchange.

E) Disposal material, at a new site, should be in water greater than 4 feet deep, and situated to minimize altered circulation to protect productive shallows.

F) Wherever possible construction shall occur on fastland. Commercial or private construction is construed to be an inappropriate use of wetlands.

G) All deposition of polluted dredged material should take place above mean high water, and be confined to minimize movement back onto surrounding marshes or into the adjoining body of water.

H) Insufficient information given to determine any general guidelines. However, this does not mean that the state has no policy regarding alterations of wetlands.

I) No reply.

In general, most states specified that any activity significantly altering the natural, physical or biological processes occurring in wetlands would not be permitted.

Disposal sites are required for authorized projects such as maintenance of navigation channels. In these cases, states have generally recommended upland disposal (at least above mean high water), the use of existing disposal sites, and the confinement of dredged materials.

In open water situations, recommendations center on confining or minimizing dredged material movement, preventing deleterious changes in water circulation due to disposal, and protecting the more valuable shallow areas from dredged material deposition.

TABLE 1

	A	B	C	D	E	F	G	H	I
Alabama	X								
Alaska								X	
California			X				X		
Connecticut									X
Delaware									X
Florida	X	X	X	X		X	X		
Georgia									X
Hawaii	X							X	
Louisiana									X
Maine	X			X			X		
Maryland	X						X		
Massachusetts									X
Mississippi									X
New Hampshire									X
New Jersey	X			X			X		
New York								X	
North Carolina	X	X		X		X	X		
Oregon			X					X	
Puerto Rico								X	
Rhode Island	X							X	
South Carolina								X	
Texas	X	X	X	X	X		X		
Virginia	X	X	X	X	X	X	X		
Washington	X	X		X			X		

APPENDIX B

RESPONDING STATE AGENCIES

ALABAMA, State of, Department of Conservation and Natural Resources, Marine Resources Division, P.O. Box 188, Dauphin Island, Ala. 36528.

ALASKA, Department of Natural Resources, Division of Lands, 323 E. 4th Avenue, Anchorage, Alaska 99501.

CALIFORNIA, The Resources Agency of, Office of the Secretary, Resources Building, 1416 9th Street, Sacramento, Ca. 95814 (Norman Hill, Asst. to the Secretary).

FLORIDA, Department of Environmental Regulation, 2562 Executive Center Circle, East, Montgomery Bldg., Tallahassee, Fla. 32031 (R. Fletcher, Environmental Specialist III).

HAWAII, Office of Environmental Quality Control, Office of the Governor, 550 Halekauwila St., Room 301, Honolulu, Hawaii 96813.

MAINE, Department of Conservation, State Office Bldg., Augusta, Me. 04330 (Barbara Singer, Bureau of Public Lands).

MARYLAND, Department of Natural Resources, Water Resources Admn., Maryland (Lester Levine, Chief, Wetlands Permit Section).

NEW JERSEY, Department of Environmental Protection, Div. of Marine Services, P. O. Box 1889, Trenton, N.J. 08625 (Thomas Hampton, Supervisor, Wetlands Section).

NEW YORK, Commissioner of Environmental Conservation, State Chamber of Commerce, N.Y.C. New York (or Office of General Counsel).

NORTH CAROLINA, Department of Natural and Ecomonic Resources, P.O. Box 769, Morehead City, N.C. 28557 (J.T. Brown, Division of Marine Fisheries).

OREGON, Division of State Lands, 1445 State Street, Salem, Oregon 97310 (Stanley Hamilton, Waterway Manager).

PUERTO RICO, Department of Natural Resources, P.O. Box 5887, Puerta de Tierra, Puerto Rico 00906 (Pedro Negrom Ramos, Secy.).

RHODE ISLAND, Division of Planning and Development, Veterans Memorial Bldg., 83 Park Street, Providence, R.I. 02903 (A.A. Zurlinden).

SOUTH CAROLINA, Water Resources Commission, P.O. Box 4515, 3830 Forest Dr., Columbia, S.C. 29240 (C.P. Guess, Jr., Exec. Dir.).

TEXAS, Coastal and Marine Council. P.O. Box 13407, Austin, Tx. 78711 (Howard Lee, Director for Programs).

VIRGINIA, Marine Resources Commission, 2401 West Avenue, Newport News, Virginia 23607

WASHINGTON, Department of Natural Resources, Olympia, Washington 98504 (A.N. Hansen, Division of Marine Land Management).