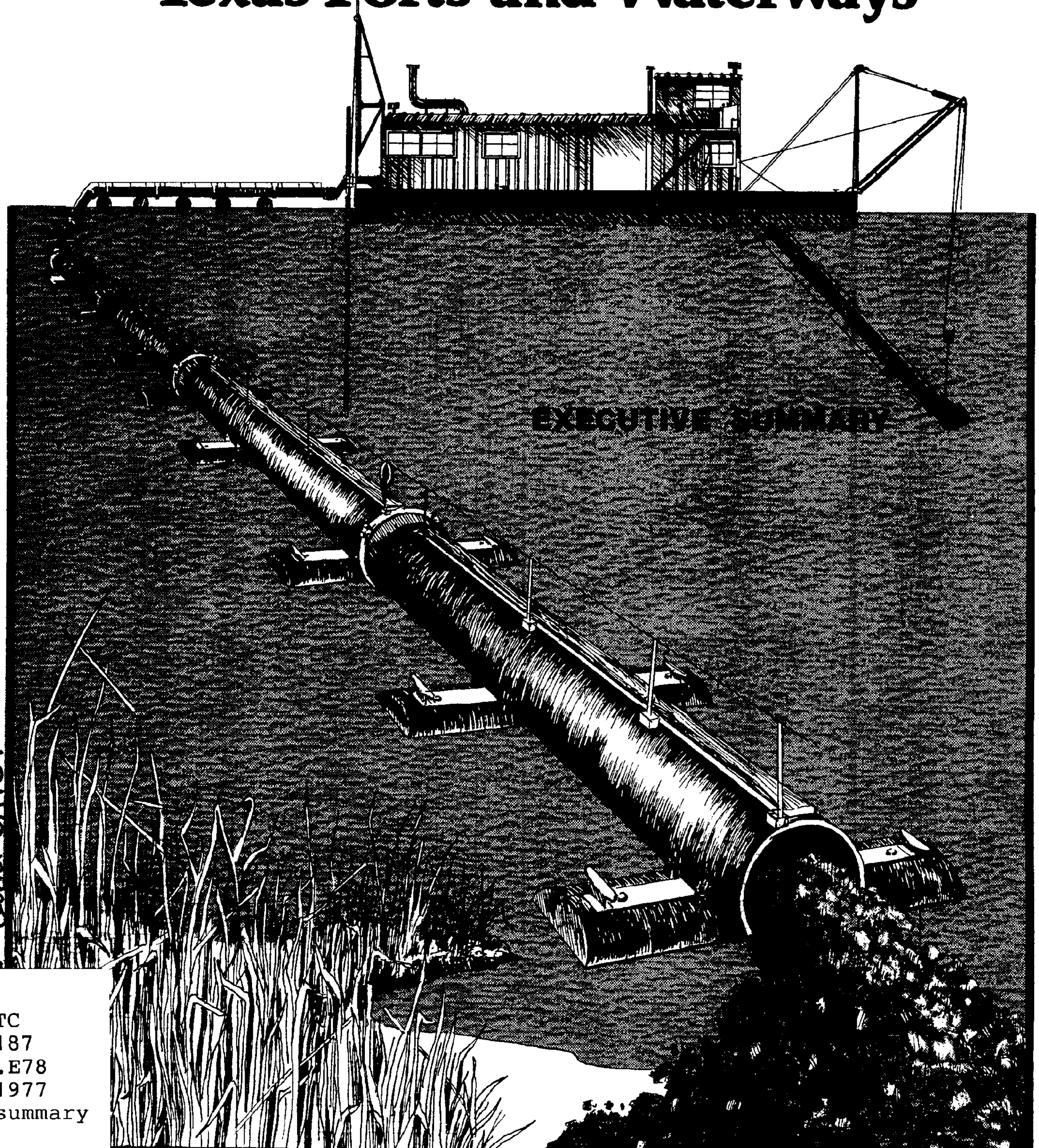
A Study of the Placement of Materials Dredged from Texas Ports and Waterways



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A Study of the Placement of Materials Dredged from Texas Ports and Waterways, February, 1977

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A STUDY OF THE PLACEMENT OF MATERIALS DREDGED FROM TEXAS PORTS AND WATERWAYS

EXECUTIVE SUMMARY

by

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December 1976

This study was funded in part through financial assistance provided by the Coastal Zone Management Act of 1972, administered by the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration

INTRODUCTION

The majority of dredging in Texas is presently undertaken by governmental agencies to support navigational interests in both waterways and harbors. Lesser dredging activities that occur within the private sector include the dredging and maintenance of channels, turning basins, marinas, and other coastal facilities. The material dredged can be described as either maintenance material or virgin material. Virgin material is generally composed of emergent or submergent soil which has not previously been dredged. Maintenance material consists of silt, sand, clay, or other particles which have been deposited from an overlying water column into an existing dredged waterway or harbor. Once these materials have been dredged, they must be placed in designated disposal areas. The selection of disposal sites can be a complex process involving various environmental and economic considerations. The objective of this study was to provide information relevant to minimizing the environmental impact of necessary navigational improvements and evaluating the trade-offs associated with navigational development. To achieve this objective several work elements were defined.

The specific tasks performed during this study were:

(1) a literature search to identify recent and relevant work on dredged material disposal and identification of ongoing or projected work with which coordination should be established;

(2) a determination of historical and projected volumes of materials dredged, or to be dredged, from the ports and waterways of Texas;

(3) an evaluation of the criteria relevant to determining the pollution potential of materials dredged from Texas ports and waterways;

(4) an evaluation of the capability of designated disposal sites to accommodate the projected volumes of dredged materials;

(5) the identification of beneficial uses of dredged materials, including means of enhancing such uses in Texas;

(6) an evaluation of the economic and environmental costs and trade-offs associated with navigational developments in Texas; and

(7) the identification of benefits and costs associated with alternatives to Texas' present navigational program.

The results of this study are presented in two volumes. The results of tasks (2) through (7) are in Volume I and the results of task (1), the literature search, appear in Volume II. The accomplishment of these tasks establishes a means of developing a disposal plan for Texas which includes parameters and criteria for determining the types of disposal sites acceptable, unacceptable, and marginal for the disposal of dredged material.

LITERATURE SEARCH

Both published and unpublished literature and data relevant to dredged material disposal were gathered and reviewed. Indexed summaries of more than 320 reports were prepared and are presented in Volume II. The report summaries are categorized as follows: (1) open-water disposal, (2) littoral disposal; (3) land disposal; and (4) economics of disposal. Additionally, the final section of Volume II identifies ongoing and projected work of the U. S. Army Corps of Engineers (USACE) Waterways Experiment Station, Vicksburg, Mississippi. Coordination with these programs will facilitate the development of a sound disposal plan for Texas.

VOLUMES OF DREDGED MATERIAL REMOVED ANNUALLY FROM TEXAS PORTS AND CHANNELS

All available records of new work and maintenance dredging along the Texas portion of the Gulf Intracoastal Waterway (GIWW), its tributaries, and the various deep-water ship channels from the Sabine-Neches Channels to the Brownsville Ship Channel, were analyzed to determine historical dredging frequencies and volumes in Texas. The present and projected annual volumes of material dredged, along with historical dredging frequency, were determined for each two-mile reach of Texas' channels.

Presently, nearly 49 million cubic yards of federal and nonfederal maintenance material are dredged annually in Texas. When existing channels are expanded to congressionally authorized dimensions, more than 55 million cubic yards of maintenance material will be removed annually from Texas channels. The congressionally authorized new work will produce an additional 89 million cubic yards of virgin dredged material. If all authorized new work is completed within the next ten years, nearly 400,000 acre-feet of disposal space will be required to accommodate both the new work and maintenance volumes removed from Texas waterways during that period.

Nearly half of the annual maintenance material is removed from channels in the Houston-Galveston and Freeport-Bay City areas. More than half of the congressionally authorized new work will be performed in the Corpus Christi and Kingsville areas. Another one-third of the new work will take place in the Houston-Galveston and Freeport-Bay City areas.

The majority of dredging in Texas is federally sponsored and administered by the USACE, Galveston District. Federal maintenance dredging removes more than 40 million cubic yards annually from Texas ports and channels. Quantities dredged by nonfederal interests, however, are more difficult to ascertain because records of private dredging activity are not separately maintained. Based on partial records, private concerns presently dredge nearly eight million cubic yards annually. It is anticipated that new work will increase this annual volume to about 13 million cubic yards. These are considered conservative estimates of nonfederal dredging volumes. Accurate records of nonfederal dredging may be obtained through a study of the files of the Permit Section, USACE, Galveston District. The results of such a study, coupled with current knowledge of federal dredging activities, would provide an accurate description of the distribution of dredging volumes in Texas.

POLLUTANTS AND POLLUTION POTENTIAL OF TYPICAL DREDGED MATERIALS

To minimize environmental risks during dredging and disposal operations, various considerations are necessary prior to the selection of a disposal site. The pollution potential of typical dredged materials can generally be determined by considering the chemical and physical properties of the material and the physical, chemical, and biological characteristics of the potential disposal site.

Critical Environments

To evaluate the potential effects of dredged material disposal, it is necessary to identify the sensitive or critical ecosystems which might be adversely affected by that disposal. The Texas Parks and Wildlife Department (TP&W), under separate contract with the Texas Coastal Management Program, nominated critical habitats along the Texas coast. These critical environments are available in map and matrix form from the General Land Office and may be used in evaluating alternative disposal sites. To supplement these critical environment designations, a matrix was developed to show the types of critical habitats known to exist in each two-mile reach of Texas ports and channels.

Further, for purposes of facilitating alternative disposal site evaluations, a set of overlay maps was prepared for use with Bureau of Economic Geology (BEG) environmental atlases of the Texas coastal zone. Included on these overlays are designations of the two-mile reaches of Texas waterways which contain polluted sediments, receive problem quantities of dredged material, have open water or otherwise incompletely confined disposal areas, and/or have a history of fish kills. These overlays, when placed over BEG maps of environments and biological assemblages, allow a partial integration of the problems associated with dredging and disposal in Texas.

To minimize environmental risks when considering alternative disposal sites, the area to be affected by the proposed dredging and disposal should be accurately predicted and the critical or sensitive environments within that area precisely located. During the course of this study, efforts were made to locate a central source of published and unpublished reports which deal with the coastal ecosystems of Texas. No such source was found. To facilitate identification of sensitive environments, it is suggested that some entity be established to obtain and centralize all published and unpublished reports concerning the coastal environments of Texas.

Chemical Pollution Potential of Dredged Materials

The sediments of Texas channels vary widely in chemical composition, and studies have shown that certain of these sediments contain and release chemical contaminants when they are resuspended.

The release of chemical contaminants from dredged sediments can have various adverse effects on receiving waters and the organisms which inhabit those waters. The release of heavy metals, pesticides, and other substances can increase the concentrations of these materials in the water to toxic or sublethal harmful levels. Nutrient releases, primarily the release of nitrogen and phosphorus compounds, can lead to increased microscopic plant growth and upset the oxygen balance of the receiving waters. The release of oxygen-demanding materials can reduce the dissolved oxygen content of the waters, thus causing organism avoidance of the area or, in extreme cases, organism mortality. These factors and others associated with the aquatic disposal of dredged materials constitute a potential threat to the stability of some coastal ecosystems.

To assess the potential impact of the disposal of contaminated materials in aquatic environments, important chemical, physical, and biological information is required. This information includes:

(1) contaminants present, or likely to be present, in the sediments to be dredged;

(2) quantities of contaminated sediments to be disposed of;

(3) the increase in concentration of these contaminants;

(4) the ecosystems anticipated to be in the area affected by the discharged material; and

(5) the response of these ecosystems to the increased concentrations of the contaminants.

Once this information is available, a site selection methodology can be developed to minimize environmental risks attributable to the disposal of contaminated material.

CHEMICAL CHARACTER OF SEDIMENTS

To chemically characterize the sediments of Texas' major ports and waterways, pertinent literature and data bases were collected and analyzed. The data analysis was performed by first segmenting the major waterways into two-mile reaches. The literature and other data sources were then searched to locate sediment chemistry data for each of the reaches. The bases for determining the contamination of sediments were the U. S. Environmental Protection Agency (EPA) screening levels for contaminants in the sediments of Texas waterways. If the concentration of a contaminant in a sediment sample exceeded the screening level for that contaminant, the two-mile reach from which the sample was taken was considered to be polluted by that contaminant.

The sediments in the deep-water ports of Texas are contaminated to varying degrees by heavy metals, nutrients, pesticides, and other contaminants. Sediments in the more remote channels are generally characterized by a lack of sediment chemistry data. No sediment chemistry data were found for two-thirds of the channel miles of Texas. For the waterways from Port Arthur to the Bay City area, 58% of the channel miles were lacking sediment chemistry data. For the area from Port Lavaca to Brownsville, no sediment chemistry data were found for 74% of the channel miles. To obtain more sediment chemistry data, it is suggested that results of future sampling and research programs of the Texas Water Quality Board, the BEG, the USACE, and other governmental and private interests be monitored and utilized. There is a need for more sediment chemistry information or some other means of identifying "polluted" sediments in order to minimize environmental risks in the evaluation of proposed disposal sites.

QUANTITIES OF POLLUTED DREDGED MATERIALS

Since there are no sediment chemistry data available for approximately two-thirds of the channel-miles of Texas, estimates of quantities of polluted maintenance material are necessarily conservative. Based on available data, nearly 45% (11,300 acre-feet) of the maintenance material disposed of annually during federal dredging along Texas ports and waterways is polluted. Nearly 80% of this polluted material is dredged from four channels: the Sabine-Neches Waterway; Galveston Harbor and adjacent channels; the Houston Ship Channel; and the Matagorda Ship Channel complex. Nearly 40% (4,300 acre-feet/year) of the polluted federally dredged material in Texas is presently disposed of in unconfined open-water sites.

There is insufficient information to determine the quantities, origin, and fate of privately dredged polluted materials. Since a significant quantity of the material dredged annually is dredged by private interests, and much of it is likely to be polluted, determination of the origin and fate of these materials is essential to the minimization of environmental damage during private dredging and disposal operations. Also, the quantities and distribution of all polluted dredged materials will be useful in determining the need for pre-disposal ecological evaluations of proposed disposal sites.

EFFECTS OF CONTAMINATED MATERIAL DISPOSAL ON AREA ECOSYSTEMS

A literature and information search was performed to determine current knowledge on the adverse effects of contaminated material disposal on area ecosystems. These effects will generally be water quality changes and the associated responses of aquatic organisms to such changes. Water quality alterations during disposal operations can result from changes in the concentrations of nutrients, heavy metals, organic toxins, and/or oxygen-demanding materials. At present, few generalizations can be made regarding the probable effects of contaminated material disposal on aquatic environments.

Available literature suggests that increases in contaminant concentrations as a result of dredging and disposal operations will generally be site-specific. Certain procedures are available to evaluate the potential water quality changes and biological responses resulting from dredging and disposal at a particular site. The EPA and the USACE jointly developed the Elutriate Test to predict water quality changes at proposed dredging and disposal sites. This test involves the mixing of sediment with overlying water to simulate the water quality of the discharge from a dredge.

Current EPA regulations outline an ecological evaluation procedure to assess the potential impacts of dredging and disposal operations. An interim guidance manual has been prepared by the USACE that includes specific tests that may be used in the ecological evaluation of a proposed dredging operation. Algal growth studies may be used to evaluate an algal community's response to increased nutrient concentrations. Bioassays can be performed to determine how toxic substances in the dredged sediments may affect sensitive aquatic organisms at a proposed disposal site. Other chemical, biological, and engineering evaluation techniques are also provided in the EPA guidelines and the USACE guidance manual.

Outlined below are specific findings of this phase of the study and some possible courses of action that may be taken to minimize the risk of environmental damage due to the dredging and disposal of contaminated sediments.

Nutrients

Findings -

(1) The duration of nutrient releases and the magnitude of phosphorous releases appear to be site-specific.

(2) The release of large amounts of nitrogen in the form of ammonia may depend solely on sediment concentrations of ammonia.

(3) Lower dissolved oxygen levels during dredging and disposal will likely be accompanied by higher phosphorous and ammonia releases.

(4) Nutrient releases during dredging and disposal operations can adversely affect receiving waters by stimulating excessive algal growth.

(5) Nutrient releases from dredging and disposal operations can indirectly disrupt the oxygen balance of the receiving waters.

(6) There are inadequate sediment chemistry data to generalize on the nutrient content of the sediments in Texas' waterways.

Possible Courses of Action -

(1) More sediment chemistry data should be collected so that all channel areas contaminated by high sediment nutrient concentrations can be identified.

(2) Sediment chemistry and elutriate testing should include analysis for ammonia.

(3) Elutriate and bioassay testing should simulate the proposed type of disposal, including retention time for confined sites and anticipated duration of disposal for all sites.

(4) If the predicted area of effect at a proposed discharge site includes a critical aquatic environment, a shallow or poorly circulating area, or an area with a history of oxygen-depletion fish kills, then environmental risks could be minimized if:

    (a) sediment chemistry and/or elutriate tests were performed to approximate nitrogen (including ammonia) and phosphorous releases;

    (b) nutrient-laden materials were not discharged into these areas during May through September unless algal assays indicated that no significant increases in algal growth would occur;

    (c) ammonia-rich materials were not discharged into these areas unless elutriate tests and/or bioassays indicated that ammonia releases would be non-toxic; or

(d) an alternative site were selected.

(5) Studies are needed in Texas of "worst case" type dredging and disposal operations (e.g., warm summer temperatures, poor circulation in shallow receiving waters, high sediment nutrient levels, relatively large quantities of material, and above average duration of discharge) to draw some conclusions on the potential detrimental effects of nutrient-contaminated material disposal.

Heavy Metals

Findings -

(1) Although the heavy metal concentrations in the sediments do not necessarily relate to the quantities of metals released upon sediment resuspension, they are the most widely available data which allow a preliminary assessment of the relative pollution potential of the materials to be dredged.

(2) Iron, manganese, and nickel appear to be consistently released upon sediment resuspension and warrant evaluation prior to dredging and disposal.

(3) The release of most metals during disposal operations will apparently depend to varying degrees upon local water conditions, sediment type, and the predominant chemical and physical conditions during mixing and resettling.

(4) Although the reliability of the Elutriate Test in predicting the magnitude and duration of metal release is presently unknown, it appears to be the best available means of making such predictions for both open-water and confined disposal.

(5) The apparent variability of metal releases during disposal operations makes it impossible to generalize the potential biological effects of metal-contaminated material disposal.

Possible Courses of Action -

(1) More field and laboratory study is needed to determine the potential toxicity or bioaccumulation that might occur during metal-contaminated material disposal. Such studies should include short-term metal uptake studies on oysters.

(2) If the predicted area of effect of a proposed dredge discharge includes oyster beds or other critical aquatic environments, environmental risks could be minimized if:

    (a) sediment chemistry analysis and elutriate testing were performed prior to discharge to approximate increases in metal bioavailability;

    (b) bioassays were performed to predict the acute toxicity and/or short-term bioaccumulation that might occur due to resuspended metal-contaminated material;

    (c) bioassays simulated the anticipated conditions of the proposed discharge (e.g., dissolved oxygen levels, temperature, salinity, pH, etc., of the affected receiving waters; the physical condition and life stage of sessile organisms in the potentially affected areas; and the duration of discharge); and/or

(d) no discharge of metal-contaminated material occurred at the proposed site.

Organic Contaminants

Findings -

(1) There is insufficient information to generalize the potential water quality or biological effects of pesticide- or PCB-contaminated material disposal.

(2) Water concentrations of pesticides and PCB's are apparently high enough at present in Texas bays to cause bioaccumulation and concentration of these materials in estuarine organisms.

(3) Short-term exposures to low concentrations of pesticides can cause significant biomagnification in oysters (Crassostrea virginica) and clams (Rangia cuneata).

(4) The simultaneous occurrence of oil and grease with pesticides and PCB's in sediments may increase the bioavailability of pesticides and PCB's upon dredging and disposal.

Possible Courses of Action -

(1) More study is needed to evaluate the potential toxicity or bioaccumulation that might occur during the dredging and disposal of pesticide- or PCB-contaminated sediments.

(2) If the predicted area of effect of a proposed dredge discharge includes shellfish beds or other critical aquatic environments, environmental risks could be minimized if:

   (a) sediment chemistry analysis and elutriate testing were performed prior to discharge to predict increases in pesticide or PCB bioavailability;

   (b) bioassays were performed to predict the acute toxicity and/or short-term bioaccumulation that might occur due to the resuspension of materials contaminated by pesticides or PCB's;

   (c) bioassays simulated the anticipated conditions of the proposed discharge including water quality of the receiving waters, the life stages and physical condition of sessile organisms in the predicted area of effect, and the duration of the effects of the discharge; and/or

   (d) no discharge of pesticide- or PCB-contaminated material occurred at the proposed site.

Oxygen-Demanding Materials

Findings -

(1) Based on the limited literature available, dissolved oxygen levels are significantly depressed only in mudflows that occur on the bottom.

(2) Organisms unable to avoid the affected areas would be subjected to the combined stresses of low dissolved oxygen levels and very high turbidities.

(3) If the duration of these conditions were sufficient, mortality of organisms could be expected to occur in the areas of mudflows.

Possible Courses of Action -

(1) More study is needed in Texas bays to evaluate the effects of dredging and disposal on dissolved oxygen concentrations. Studies should include the pipeline disposal of sediments high in oxygen-demanding materials that enter a shallow bay during periods of warmest annual water temperature.

(2) The results of such studies may be used to approximate the oxygen levels that should be maintained in the performance of elutriate tests.

Physical Pollution Potential of Dredged Materials

Dredged material disposal can create physical pollution problems to the extent that the materials are either dumped or accumulated to cause environmental degradation. The detrimental effects are primarily mechanical in nature. For example, the disposal of dredged materials can blanket productive terrestrial or benthic habitat areas, and spoil mounds can deflect normal water currents in bays and estuaries. The extent of the impact of disposed sediments on the environment is determined by a number of interrelated factors involving the nature of the sediment and the stability of the disposal site. The physical aspects of dredging and disposal considered during this study are:

(1) the physical character of the sediments in Texas waterways;
(2) the physical effects of land disposal;
(3) the physical effects of aquatic disposal on area ecosystems; and
(4) the interactions of aquatic disposal with circulation patterns.

Physical Character of Sediments

The physical properties of dredged material, such as particle size, permeability, plasticity, etc., can provide insight as to the possible uses and engineering constraints of the material. However, adequately detailed soil analysis data on channel sediments have not been collected for most of Texas' waterways and ports.

A problem encountered with the existing physical data on Texas' channel sediments is the lack of uniformity in classification. No standard method is used to identify and classify dredge spoil materials. The Unified Soil Classification System considers particle size, relative amounts of the various sizes, and characteristics of the fine grains, etc., and provides a standard method for classifying dredged materials. This system also allows an evaluation of the specific potential uses of dredged materials, e.g., the relative value of materials in the construction of embankments or foundations. If such a system were used in Texas, dredge spoil might be used more in construction and development projects.

Physical Effects of Land Disposal

The disposal of dredged material on land may have a number of direct and indirect impacts on area ecosystems. Productive vegetation and wildlife habitat may be covered and permanently eliminated, drainage patterns may be altered, and contaminants contained in sediments may harm plants and grazers. Texas coastal soils, vegetation, and wildlife, including sensitive species, serve as a point of reference in the assessment of the potential detrimental impacts of land disposal.

Dredged material disposal on land preempts natural habitat and can alter natural drainage patterns, with consequent detrimental impacts on adjacent marshland. Heavy metal concentrations in dredged material do not appear to present a problem at the present time.

The impacts of sediment disposal on land can be minimized by the selection of relatively unproductive sites where drainage and sheetflow are not significantly altered. Biologically productive areas and areas that are otherwise ecologically important should be avoided. Specifically, the following steps may be taken as a means of minimizing environmental risks in evaluating land sites:

(1) The affected areas must be accurately defined. This includes not only the primary disposal site but also the area of secondary impact, such as the area affected by altered drainage

or increased sedimentation caused by erosion of the spoil pile.

(2) The critical environments in the affected area should be defined, and the probable impact of the proposed action on those resources should be carefully assessed as prescribed by EPA regulations and the USACE guidance manual.

(3) If such an assessment predicts detrimental impacts to critical environments, or if less biologically productive areas are available, an alternative site should be selected.

Physical Effects of Aquatic Disposal on Area Ecosystems

The physical effects of aquatic disposal can include: (1) impairment of the water column; (2) covering of benthic (bottom dwelling) communities; (3) changes in bathymetry; and (4) modification of substrate composition. The effects on the water column are those associated with direct destructive effects on nekton and plankton, reduced light transmission, and aesthetic values. The effect on benthos is essentially the covering of benthic communities with subsequent changes in community structure. Significant change in bathymetry can alter natural circulation patterns, while substrate modification may affect the exchange of constituents between sediment and overlying water.

To minimize risks of environmental damage at a proposed site due to the physical effects of dredging and disposal operations:

(1) the area of ultimate sediment transport and deposition (affected area) must be predicted;

(2) the affected area should be defined and quantified in terms of duration of suspended solids increases, bay bottom surface area ultimately covered, and the probable depth of sediment deposition at all points in the area;

(3) the changes in circulation, salinity, temperature, and sedimentation patterns as a result of (2) should be predicted;

(4) the critical environments in the affected area should be defined;

(5) the effects of (2) and (3) on (4) should be evaluated using the methods described in this report and EPA and USACE regulations and guidelines.

If these evaluations predict destruction of or detriment to critical or sensitive environments, an alternative site should be sought.

Interactions of Aquatic Disposal with Circulation Patterns

Two factors of central importance in evaluating the adverse environmental consequences of dredged material disposal in aquatic systems are: (1) the effects of water circulation on the material and (2) the effects of the deposition of the material on water circulation. Definition of the former will provide an approximation of the area to be directly affected by sediment redeposition following disposal at a site. A description of the latter allows an identification of the area that will be indirectly impacted by disposal at a site.

In the evaluation of a potential aquatic disposal site, the most desirable data set would be a long-term record of current velocity. This, however, is rarely, if ever, available. Therefore, the recommended approach is to evaluate the probable currents in the vicinity of the spoiling operation on the basis of the overall circulation of the bay, expected wave action, and any local influences, such as proximity to a freshwater inflow, to tidal passes, or to a dredged channel.

The greatest weakness of this approach is the present state of knowledge of the circulation of the Texas bays. Although these bays have been studied for years, some since the mid-nineteenth century, only scant attention has been given the current patterns. Considering that a knowledge of bay circulations is central to evaluating the distribution of pollutants, the effects of hydromechanical alterations of the bay systems, and the problem of spoil movement, the meager information presently available is unfortunate. Therefore, to minimize environmental risks associated with dredging and disposal, our primary recommendation is that studies be instituted to remedy this lack of information. The character of these recommended studies is outlined below:

(1) All available information should be assembled and compiled on the Texas bays, even though this data set will be sketchy.

(2) Recording sensors should be instituted at key positions in the Texas coastal zone. These sensors should include recording current meters and meteorological towers. The data from these systems, together with that of existing recording tide gauges, will provide a base with good time continuity.

(3) A sequence of carefully executed 3-4 day measurement programs should be performed to provide

circulation pattern data sets of good spatial continuity under a wide range of external conditions.

(4) The overall data program will make better use of its resources by concentrating on specific bay systems rather than by dispersing men and equipment widely along the Texas coastline.

(5) As the data base develops, parallel analytical studies should be instituted to evalute the data, to apply the data in formulating a quantitative picture of bay circulation, and to identify and specify special experiments that may be required.

(6) Results of such studies should be used in predicting the areas to be affected by proposed alternative disposal sites. The physical and chemical character of the materials transported should be evaluated against the critical environments in the affected area.

Because of the central importance of bay circulation to the programs of many agencies, the possibility of a joint effort is suggested to take advantage of the combined resources of all of these agencies.

ACCOMMODATION CAPABILITIES OF PRESENT DISPOSAL SITES

The new work and maintenance dredging materials are placed in designated disposal sites. During this study a determination was made of the yearly federal maintenance volumes placed in each disposal site on the Texas coast. Also, the annual maintenance material deposition rate for each site was calculated, based on the present acreage of each site. Nonfederal dredging activities were not included in these calculations because information on the origin and fate of these materials is not presently available. Thus, some disposal sites near centers of private dredging activity will likely be receiving material in excess of the projections derived during this study.

Another criterion that will determine the capability of a site to accommodate the volume of material designated to be placed in it is the pollution potential of that material during and after placement. Presently, EPA regulations are such that the preclusion of disposal at a site can occur only after the USACE District Engineer has evaluated the economic impact on navigation and anchorage which would occur by failing to use the proposed site. Thus, it is not possible to determine from the pollution standpoint which sites may or may not be used in the future.

For the Texas coast there are 102,040 acres of available disposal area for federal hydraulic cutterhead dredging. The projected annual volume of dredging, including that by private interests, to be placed in these areas is approximately 33,000 acre-feet. Over a 10-year period, this amounts to an additional average placement in all available disposal areas to a depth of 3.3 feet. Many of the disposal sites will be subjected to lighter use while others will accumulate many times this depth of material. The latter areas will be problem areas in that they will require additional disposal acreage.

During the next 10 years 250,000 acre-feet of disposal space will be required for only the federal hydraulic cutterhead new work and maintenance projects. The main channel of the Gulf Intracoastal Waterway (GIWW) accounts for about 25% of this total, while the eight deep-water channels account for over 60%. The most critical channels in terms of shortage of disposal capability will be Galveston Harbor, Texas City Channel, and Freeport Harbor, where the average material depth in the disposal areas is to be increased by more than 15 feet within the next 10 years. These rates can be used to determine when the available areas will be depleted only if the quantity of material already placed in the disposal sites is known and if the maximum depth to which material may be placed is determined. Neither of these parameters is available because the site-specific field studies necessary to determine them have not been conducted. Such studies would be costly in terms of money and manpower, but the results of their achievement are essential to the development of a comprehensive dredged material disposal plan.

The results of this phase and other aspects of the study are summarized on overlay maps of the Texas coast. These overlays pinpoint potential problem areas with regard to disposal site accommodation capabilities in each two-mile reach of the major ports and channels of Texas.

Possible courses of action which would facilitate determination of the accommodation capabilities of existing disposal sites are listed below.

(1) The locations of nonfederal dredged material disposal sites should be determined. This may be accomplished by examination of the files of the Permit Office of the USACE, Galveston District, and by inquiry of the appropriate individual private entities.

(2) Site-specific surveys should be undertaken to determine the condition of each dredged material disposal site in Texas. These

surveys should determine the height and condition of existing levees and the elevation above base of material presently in the site.

(3) Sufficient soil samples should be taken from each dredged material disposal site to determine the engineering constraints on future levee heights.

BENEFICIAL USES OF DREDGED MATERIALS

Dredged material disposal has long been recognized as an environmental problem for a number of physical, chemical, biological, and aesthetic reasons. Objections to dredged material disposal sites include: unnatural appearance of the disposal materials and retention structures, great size of the area covered, visual incompatibilities with adjacent natural and manmade environments, disturbing odors, visible turbidity of the adjacent waters resulting from suspension of dredged material, interference with existing and proposed land use patterns, and intangible effects, such as the public connotation of confined dredged material disposal facilities as being derelict lands. For these and other environmental and economic reasons, beneficial uses of dredged materials are being sought.

As part of this study, an information and literature search was conducted to identify some beneficial uses of dredged materials and the costs associated with such uses. The USACE Waterways Experiment Station, Vicksburg, Mississippi, was the source of most of the information obtained. Some general beneficial uses of dredged materials, such as lawn sod production, Christmas tree production, and agricultural production, have been studied in other states. In Texas two beneficial uses of dredged materials are being studied. These are (1) the use of spoil on Bolivar Penninsula to create marshland, and (2) the use of a confined disposal site near Freeport to culture shrimp for commercial food purposes. Generally, however, few uses of typical maintenance material have been found that are economically feasible.

If a comprehensive disposal plan is to be developed for Texas that includes beneficial uses of the material as an option, certain information must first be obtained. This information includes:

(1) a uniform classification of the physical and engineering properties of the sediments in major Texas channels,

(2) a detailed geographic distribution of the annual volumes of materials dredged in Texas,

(3) the chemical composition of the sediments in major Texas channels, and

(4) the cost of conveyance for the various types of material encountered.

COSTS AND TRADE-OFFS ASSOCIATED WITH NAVIGATIONAL DEVELOPMENT

In the development of a disposal plan for Texas, a detailed breakdown of the costs of the various aspects of dredging and disposal is needed. Such a cost breakdown will allow a comparison of economic and environmental costs when future disposal areal requirements become available. Available cost breakdowns were obtained for various dredging and disposal operations in different regions of Texas.

The findings of this portion of the study and some possible courses of action to obtain the necessary information to evaluate environmental and economic trade-offs are:

(1) The average costs for federal hydraulic dredging and disposal have increased from 50% to over 200% for deep-draft and shallow-draft channels, respectively, from 1965-1975.

(2) Hopper dredging costs have risen about 50% during that period.

(3) Present costs for federal dredging range from $0.30-0.45/cubic yard regardless of the type of dredge used.

(4) Dredging costs are highest in heavily developed areas (e.g., Houston and Freeport) and lowest in areas employing open-water disposal (e.g., the Matagorda Ship Channel and the open-bay portion of the Houston Ship Channel).

(5) Nonfederal dredging appears to cost roughly twice that of federal dredging.

(6) Insufficient information is available to provide adequate cost breakdowns for evaluating economic and environmental trade-offs.

(7) To obtain detailed cost breakdowns for dredging and disposal on the Texas coast it is suggested that a confidential survey be conducted to determine the bidding practices of dredge contractors who perform work for the Galveston District of the USACE.

BENEFITS AND COSTS OF ALTERNATIVES

In this section of the report the beneficiaries of dredging and those bearing the social and economic costs are identified. The discussion pertains to the three alternatives of increasing, accommodating, or restricting navigational development in Texas. The direct and indirect costs which accrue through the implementation of each alternative are defined and discussed, including those which can be attributed to government at its various levels, to the natural environment, to commerce and free enterprise, and to society.

The direct cost of maintenance, rehabilitation, and new work on the GIWW and tributaries in 1970 was approximately $19.4 million. This represents a federal expenditure, the cost of which is ultimately borne by the taxpayers. Environmental "costs" are attributable to navigational development to the extent that dredging, dredged material placement, increased industrial wastes, oil spills, and water pollution have detrimental effects in the coastal environment.

The GIWW directly contributed $1.4 billion to the Texas economy in 1970. The major components of this contribution were revenues paid by the water transportation industry and the cargo value received by deep-draft ports. Industrial development stimulated by the maintenance of the GIWW in Texas is responsible for generating about 20 percent of the Gross State Product. Expanding the navigational development of the waterway may not necessarily cause a corresponding increase in industrial growth. Conversely, curtailing development of the waterway would inevitably cause a corresponding economic decline.