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SUMMARY
DEPARTMENT OF ARMY PERMIT
Application No. 9563 by
Nueces County Navigation District No. 1
To Construct A Deep Water Port
At Harbor Island, Texas In Nueces County, Texas

(X) Draft ( ) Final Environmental Statement

Responsible Office: U.S. Army Engineer District, Galveston
Jon C. Vanden Bosch, Colonel, CE
District Engineer
P.O. Box 1229
Galveston, Texas 77553
Telephone: 713-763-1211 EXT 301

1. Name of Action: (X) Administrative ( ) Legislative

2. Description of Action: Nueces County Navigation District No. 1 proposes to develop a multi-purpose deep-draft inshore port at Harbor Island, Texas. The proposed work covered by the application represents Phase I of a three phase development plan. The proposed work includes deepening the Corpus Christi Ship Channel, enlarging and deepening the inner basin to form a turning basin, redredging, deepening, and enlarging an existing slip and a docking basin, relocating the tributary channel to Aransas Pass, constructing three oil terminal docks, and filling both emergent and submergent areas to permit the construction of ancillary onshore facilities necessary to transhipp crude oil. The approach channel would be dredged to a depth of 80 feet below mlt for a distance of 10.59 nautical miles beyond the sea-ward end of the north jetty (-80 foot contour line). The jetty channel, 1.548 nautical miles in length, would be dredged to a depth of 76 feet. A 2,300 foot diameter turning basin would be dredged to a depth of 73 feet, and the docking basin 1,200 feet wide and 5,570 feet in length would be dredged to a depth of 76 feet. Approximately 98,000,000 cubic yards of sand and clay would be removed by hopper and pipeline dredges. About 60.8 million cubic yards would be removed with hopper dredges and placed in two offshore areas. The remainder of the material would be removed by pipeline dredges and placed within leveed areas having controlled spillways on Harbor Island and the immediate adjacent bay area, on San Jose (St Joseph) Island and on Mustang Island. The North Jetty and the channel to Aransas Pass would be relocated. Two docks would be constructed along the south basin line on 1,900 foot

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centers to accommodate ships ranging in size from 275,000 DWT to 500,000 DWT. Phase II and III of the overall plan will be subject to separate applications and public notices at some time in the future. Phases II and III would cover work from Harbor Island to the end of the existing Federally constructed channel at La Quinta and westward extension west of Ingleside, Texas.

3. a. Environmental Impacts.: The project would provide for unrestricted and safe use of low cost marine transportation, allow more efficient use of deep-draft vessels, and upgrade the well-being of the inhabitants and workers within the general project area (South Texas) through expansion of commerce and increased employment opportunities other than at the transhipment terminal on Harbor Island.

b. The project would result in adverse effects on the natural environment. These adverse impacts include the loss of 3,077 acres of wetlands of varying degrees of productivity, temporary removal of benthic life in the portion of the channel not now part of the Federal project and in the disposal areas, disruption of wildlife habitat and increased turbidity during construction.

4. Alternatives: The Corps of Engineers may only deny, grant or grant with conditions, the application before it. Project alternatives considered include those available to the Nueces County Navigation District No. 1 (the applicant), namely, offshore facilities such as single point mooring systems, sea islands, or piers offshore; alternate channel dimensions and configuration; alternate methods of construction; and no action.

5. Comments Requested:

Environmental Protection Agency
Department of Energy
Department of State
Department of Commerce
Department of Housing and Urban Development
U.S. Department of Agriculture
Department of the Interior
Department of Health, Education, and Welfare
Advisory Council on Historic Preservation
The National Wildlife Federation
Department of Transportation
Eighth Coast Guard District

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State of Texas, Budget and Planning Office
Coastal Bend Council of Governments
City of Port Aransas
City of Corpus Christi
City of Portland
City of Rockport
Texas Historical Commission
County Judge, Nueces County
Nueces County Navigation District No. 1
Sierra Club of Corpus Christi
Welder Wildlife Foundation
Sportsman's Club of Texas, Inc.
Water Resources Congress
League of Women Voters
Corpus Christi Chamber of Commerce
National Audubon Society
Corpus Christi Outdoor Club
Aransas-Corpus Christi Pilots
Coastal Bend Conservation Association, Inc.
Citizens for Estuarine Planning
Mayor of Aransas Pass
Mayor of Ingleside
County Judge, San Patricio County
Coastal Bend Council of Governments
South Texas Chamber of Commerce
Rockport Conservation Association Inc.
Citizens for Coastal Bend Progress
County Judge, Aransas County
The Coalition on American Rivers
Texas Committee on Natural Resources
Chamber of Commerce (Port Aransas Area)
M. H. Kuhn
Steve Rabalais

6. Draft Statement to EPA 31 July 1978
   Final Statement to EPA _____.

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DRAFT
ENVIRONMENTAL STATEMENT

DEPARTMENT OF ARMY PERMIT
Application No. 9563 by
Nueces County Navigation District No. 1
To Construct A Deep Water Port
At Harbor Island, Texas In Nueces County, Texas

1. PROJECT DESCRIPTION

1.01 Nature of the Proposal and Authority. The proposed action relates to an application by the Nueces County Navigation District No. 1 for a Department of the Army permit to construct a deep draft inshore port at Harbor Island, Texas, pursuant to Section 404 of the Federal Water Pollution Control Act amendments of 1972, Section 10 of the River and Harbor Act of 1899, and Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972. General policy for evaluating permit applications requires consideration of a number of factors including the effect of the proposed work on conservation, economics, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land use classification, navigation, recreation, water supply, water quality and, in general, the needs and welfare of the people. This environmental statement has been prepared pursuant to the requirements of the National Environmental Policy Act of 1969 to assist in evaluating the permit application. The material presented in this statement is drawn mainly from a report titled Effects Assessment of Candidate Navigation Plans for the Corpus Christi Bay area by Southwest Research Institute under contract with the Galveston District Corps of Engineers. Copies of the report are available for public inspection at the offices of the Galveston District, U.S. Army Corps of Engineers, Galveston, Texas.

1.02 History of the Project. By a Resolution of the House Committee on Public Works a study to determine the need and feasibility of modifying the Corpus Christi Ship Channel to accommodate vessels larger than those which can now transit the channel was authorized on 12 October 1972 (Senate Document No. 99, 90th Congress, 2nd Session). In June 1973, the Nueces County Navigation District No. 1 applied for a permit for a deepwater inshore port terminal at Harbor Island. The reason for local interests pursuing navigation

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improvements via both the permit and Federal authorization routes is that an immediate need exists for a deepwater inshore port to accommodate Very Large Crude Carriers (VLCC's) of up to 275,000 DWT capacity fully loaded, with a later requirement for handling bulk cargoes. The local sponsor and several oil companies supporting its effort consider that immediate needs can be met more quickly via the permit process and non-Federal investment. A public meeting held in September 1973 surfaced areas of environmental concern and economic need for the project. Action on the permit was then deferred pending the preparation of an environmental assessment report for the Federal Study. The environmental assessment report was prepared under contract by Southwest Research Institute, San Antonio, and completed on 20 February 1977. The environmental assessment report was intended to provide a basis for preparation of an environmental impact statement which was deemed necessary after the initial public meeting.

The following sections of the Project Description are based upon information officially submitted by the Nueces County Navigation No. 1 to the Corps of Engineers.

1.03 Purpose of Project. The purpose of this project is to provide public port facilities capable of accommodating Very Large Crude Carriers (VLCC's). These facilities would allow crude oil from the producing areas throughout the world to be transported to the energy-related industries located within the Coastal Bend area, the State, and the Nation at a cost saving as compared to tanker sizes which can presently enter the Port of Corpus Christi.

1.04 Corpus Christi has developed into a major refining center, to a large extent because of the past local availability of large volumes of crude oil. However, local crude oil production is rapidly declining, and these refineries are being forced to rely increasingly upon imported crude oil as a feedstock. For the most part, these local refineries process crude oil into petroleum products for major product distribution companies located elsewhere in the State and the Nation. Approximately 85 percent of locally produced products are destined for markets outside of Texas.

1.05 Since the Corpus Christi refineries generally have neither an assurred, owned source of crude oil supply, nor their own tanker fleets, nor their own proprietary markets

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to absorb the total refinery production, their continued functioning depends upon their ability to remain economically competitive. Any shutdown or reduction of the local refining capacity would result in a loss to the local economy and would not be in the national interest. As a result of a review made of the project, the Federal Energy Administration concluded in a letter to the Chief of Engineers that it (project) should be "considered as a potential national energy facility which would provide an incentive for expansion of existing refinery capacity." With rising dependence upon imported crude oil, marine transportation costs will play an increasing role in the competitive capability of Corpus Christi refineries, and the need for a deep draft port will become increasingly important. According to the latest figures from the refining industry in south Texas, the total capacity of these refineries as of January 1, 1978 was 694,000 BD (barrels per day). Planned refinery expansion will add to this present capacity. The growing refinery capacity coupled with an increased share of imports has served as the basis for the estimated throughput projections for the Harbor Island facility.

1.06 Recognizing the inherent difficulties in developing a precise throughput forecast in view of the uncertainities in feedstock sources and end markets typical of Corpus Christi refineries, it is, nonetheless, estimated that the imported crude oil volume which would be available to put through the Harbor Island deep draft inshore port would commence at 690 TBD ~~MBD~~ (~~million~~ thousand barrels per day) in 1980 rise to 870 TBD ~~MBD~~ by 1986, and continue at this latter level (or higher), through at least the year 2000. This projection serves as the basis for the economics of the project. The project would remain economically attractive at throughputs of approximately 25 percent less, and any increase in volumes would increase the attractiveness. It is planned that all the bonds for the project would be retired over the first 15 years of operation. 3/4/78

1.07 The primary use of the facility would be the receipt of crude oil imported in large tankers. It is not contemplated that either crude oil or petroleum products would be exported through the project facilities. Crude oil would be transferred from tankers, metered for custody transfer, go into surge tankage on Harbor Island, be metered again, and then be transferred by pipeline to refineries and terminals on the mainland. Some crude could also go to other areas by interconnecting pipelines, and small volumes

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could be transshipped by small coastwise tankers or by barges on the Intracoastal Canal.

1.08 The size of the tankers expected to use the project facilities would vary, since few large tankers are owned by the project participants. Most of these tankers would be chartered rather than owned by the participants. It is estimated that the number of tankers berthing at these docks annually would vary between 125 and 150 vessels. The size of the vessels that would be accommodated at the unloading berths could vary from 100,000 DWT to 275,000 DWT capacity fully loaded and would be capable of accommodating tankers up to 500,000 DWT capacity in a partially loaded condition.

1.09 Prospective project participants include:

Nueces County Navigation District No. 1
Champlin Petroleum Corp.
Southwestern Refining Company, Inc.
Sun Oil Company
American Petrofina
Coastal States Petrochemical Company

Other prospective users with refineries in South Texas include:

Tesoro Petroleum Corp.
Quintana-Howell Joint Venture
Sigmor Refining Co.
Saber Petroleum Company
Ingleside Refining Co.
Century Refining Co.
Tipperary Refining Co.
Gulf Coast Refining Co.
Rymal Refining Co.
U.N.I. Refining Co.

In addition to the foregoing companies, other crude oil users have expressed an interest in participating in this project. However, the full extent of their participation and use of the facilities cannot be identified at this time.

1.10 Over-View Of Project. Phase I of the Harbor Island Deep Draft Inshore Port consists of the facilities for an oil port intended to serve crude oil tankers up to a maximum size of 275,000 DWT fully loaded (1.9 million barrels), or vessels of up to 500,000 DWT partially loaded. The project as proposed includes dredging of an offshore approach channel, deepening of the present outer bar and jetty channels, dredging of an inshore turning basin in Lydia Ann

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Channel, dredging a docking basin to berth Very Large Crude Carriers (Figures 1, 2, 3, and 4) and relocating the Tributary Channel to Aransas Pass. The project would also include relocation of the North Jetty, construction of the docking facilities for the VLCC's (mooring and breasting facilities and unloading platforms), the surge tankage necessary to provide for a steady rate flow through the delivery pipeline system (considering the size of tankers, number of crude oil segregations, and average throughput volume), and the pipeline system for delivery of the crude oil to the participants in the project. The project would permit South Texas refiners to realize the transportation economies associated with large size VLCC's. The following aerial photo displays the project channel and disposal areas.

1.11 Dredging. As noted before, the proposed dredging activities include deepening and extension of the present approach Channel, deepening of the Jetty Channel, dredging of the docking and turning basins, and dredging of a re-routed portion of the Aransas Pass Channel to by-pass the new docking basin to the north. The approach and jetty channel work is considered offshore dredging, and the remainder inshore dredging.

1.12 The channel depths of the project are predicated upon the provision of maximum water depths to the project while still staying within the coastal waters of the State of Texas. Greater clearance under the vessel keel is required in the deep waters of the Gulf of Mexico to account for the effect of deep water swells; thus, as a practical matter channel depths can be reduced in sheltered waters and still provide the same operating safety to the tanker.

1.13 With respect to dredging, there are many options in the way the channel may be constructed. For instance, an ultimate channel side slope of 1:3 can be achieved by dredging a slope (which is difficult to control), or by making a "box cut" in which the bottom of the channel would be dredged to a greater width than required. The side slopes of the box cut would then be allowed to slough to the natural angle of repose. The final channel bottom width would the same in either case. Further, provisions can be made at the outset for advance maintenance by overdredging up to about 2 feet), and an allowance can be made for a specified amount of overdredging for which the dredges would be paid in accordance with the amount actually removed.

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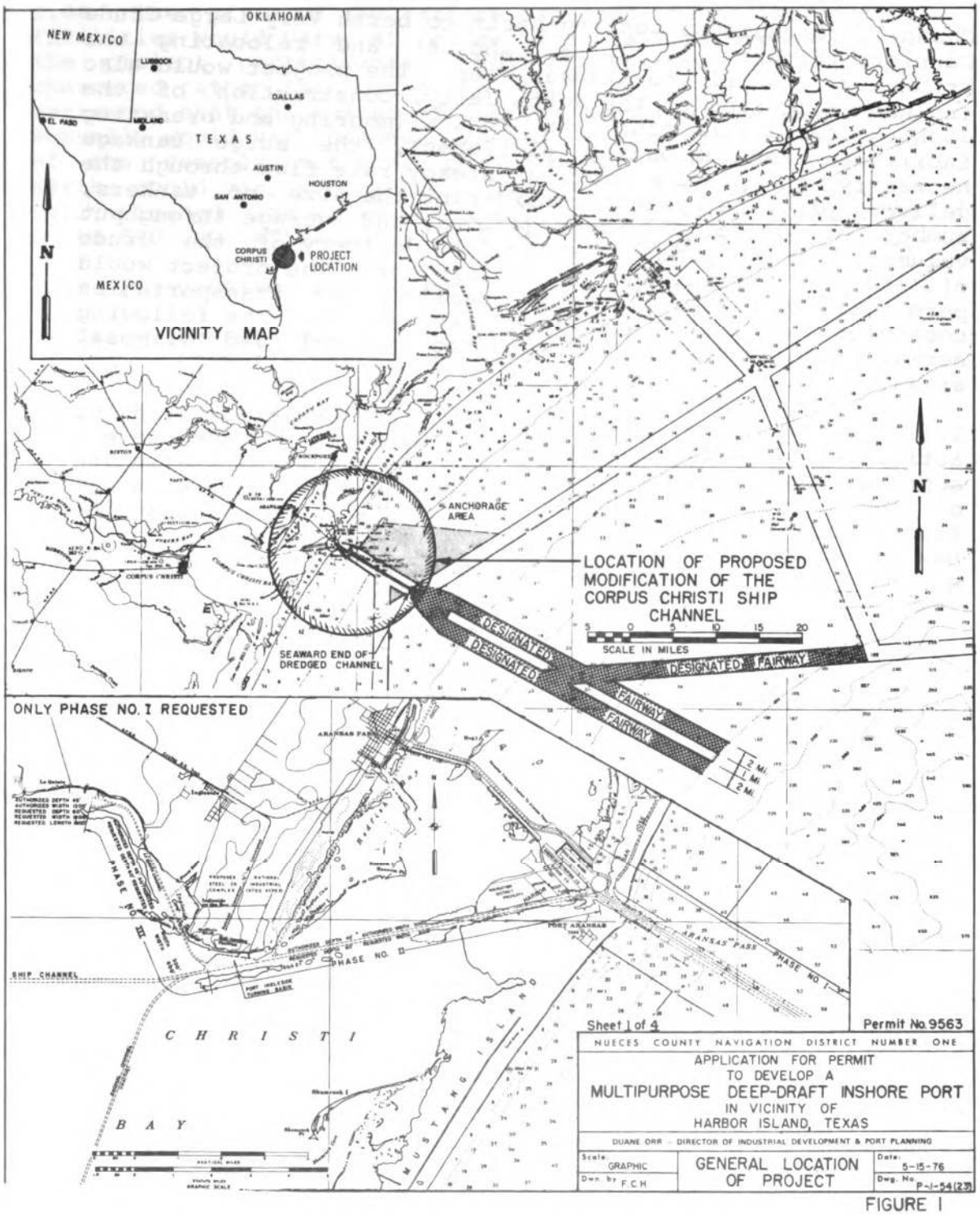

FIGURE 1

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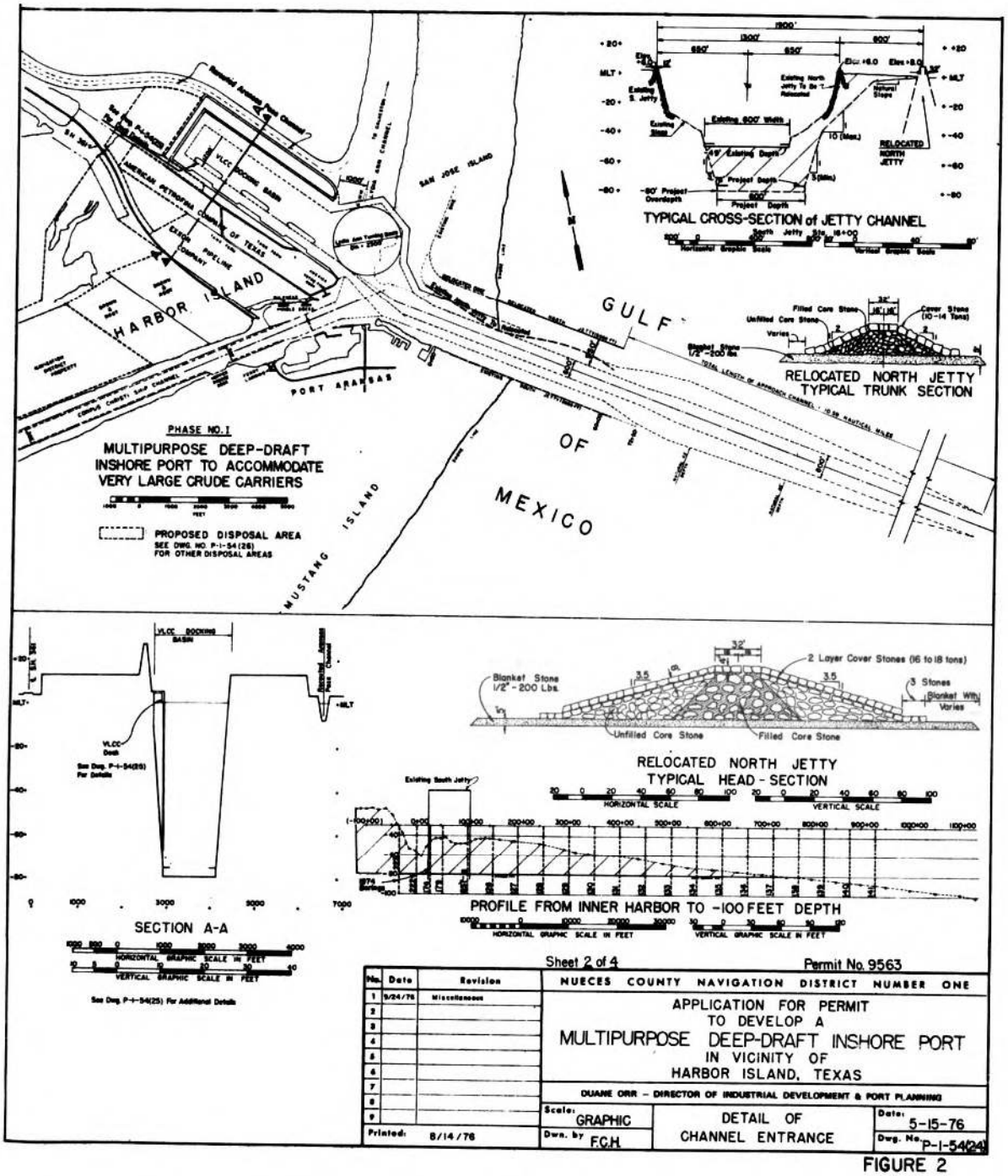

Sheet 2 of 4 Permit No. 9563

No.	Date	Revision
1	9/24/76	Miscellaneous
2		
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Printed: 8/14/76

NUECES COUNTY NAVIGATION DISTRICT NUMBER ONE

APPLICATION FOR PERMIT TO DEVELOP A MULTIPURPOSE DEEP-DRAFT INSHORE PORT IN VICINITY OF HARBOR ISLAND, TEXAS

DUANE ORR – DIRECTOR OF INDUSTRIAL DEVELOPMENT & PORT PLANNING

Scale: GRAPHIC | DETAIL OF CHANNEL ENTRANCE | Date: 5-15-76

Dwn. by F.C.H | Dwg. No. P-I-54(24)

FIGURE 2

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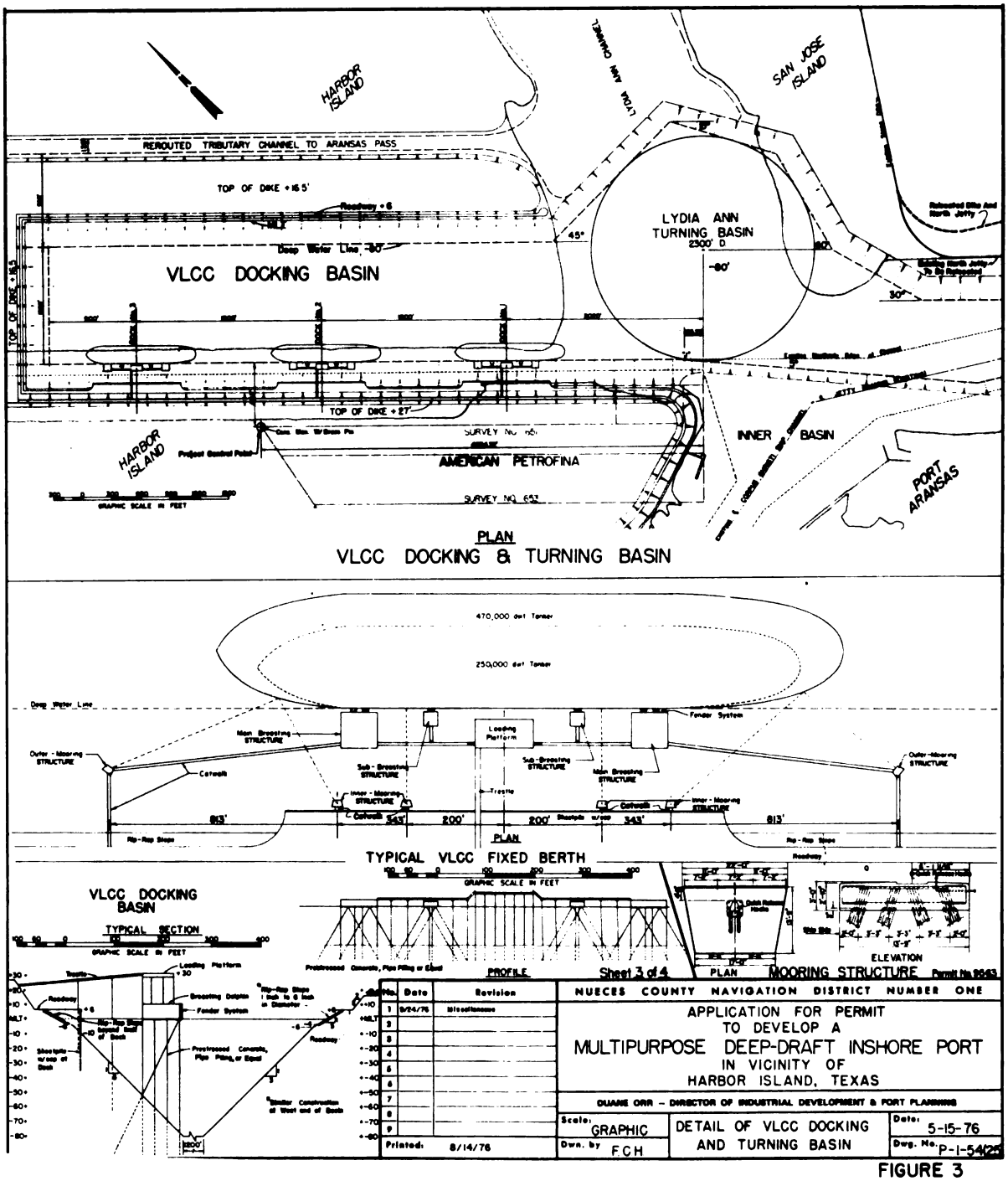

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APPLICATION FOR PERMIT
TO DEVELOP A
MULTIPURPOSE DEEP-DRAFT INSHORE PORT
IN VICINITY OF
HARBOR ISLAND, TEXAS

DUANE ORR – DIRECTOR OF INDUSTRIAL DEVELOPMENT & PORT PLANNING

Scale: GRAPHIC	DETAIL OF VLCC DOCKING AND TURNING BASIN	Date: 5-15-76
Dwn. by F.C.H		Dwg. No. P-1-54/25

FIGURE 3

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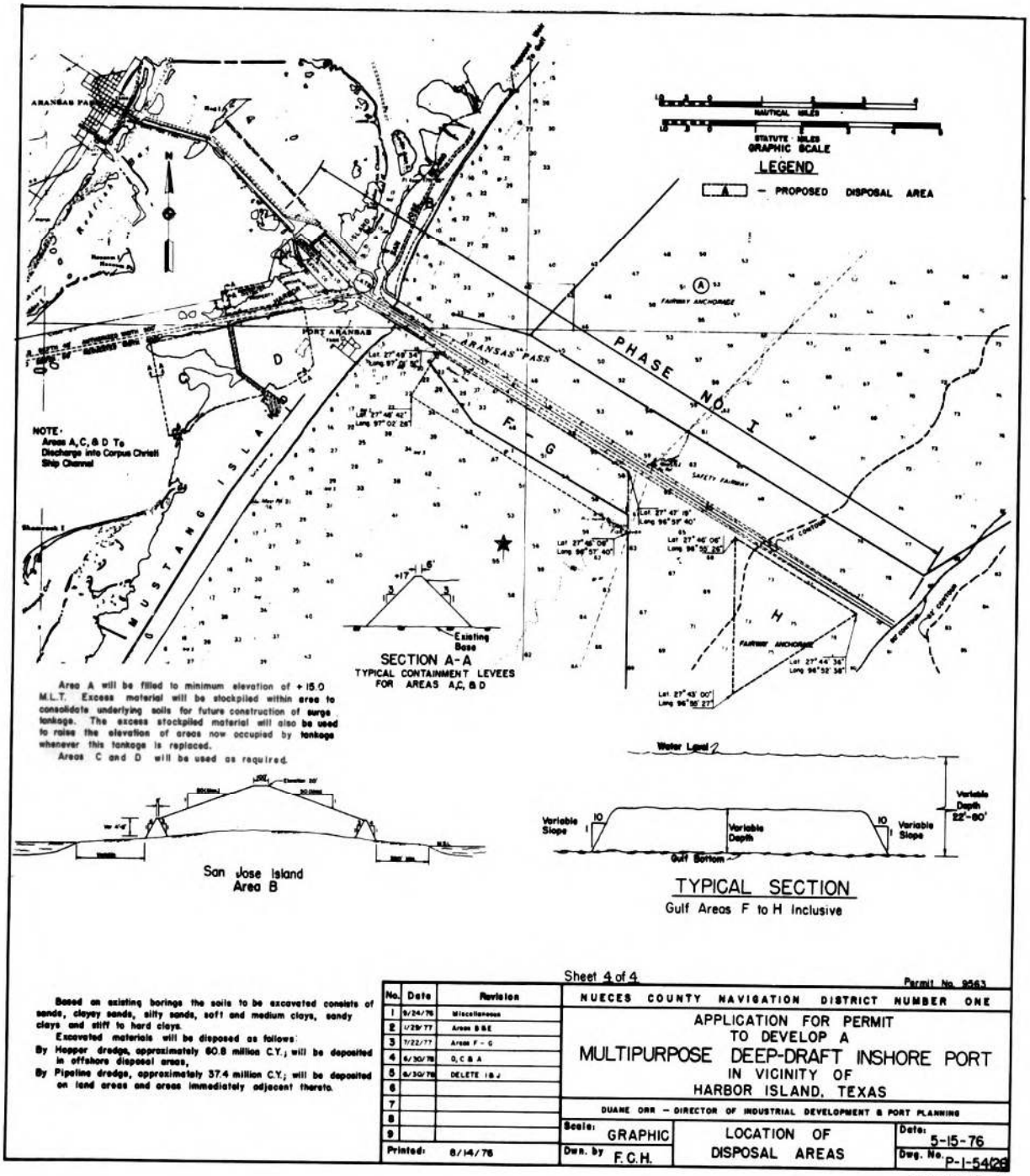

FIGURE 4

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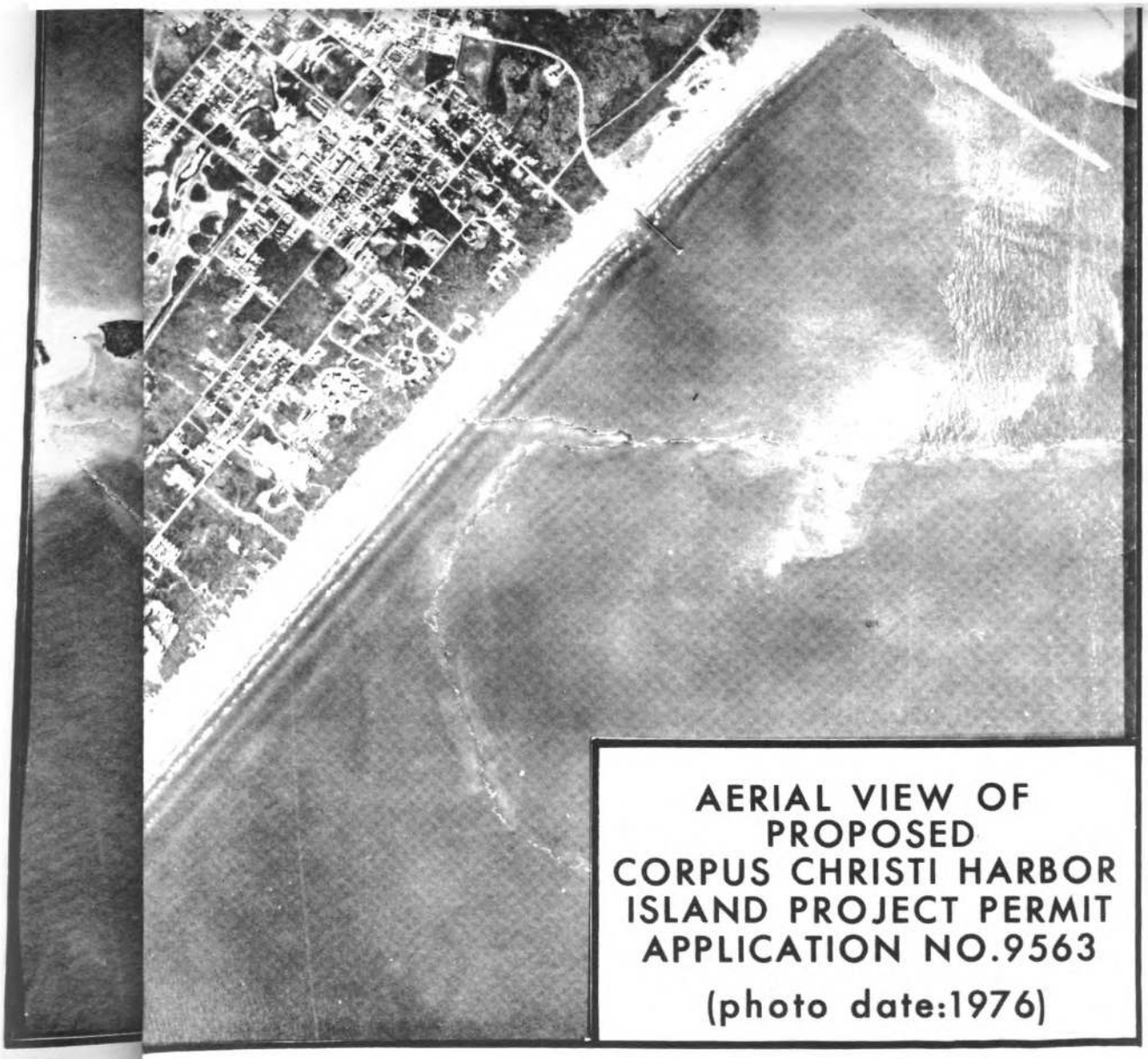

AERIAL VIEW OF
PROPOSED
CORPUS CHRISTI HARBOR
ISLAND PROJECT PERMIT
APPLICATION NO.9563

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1.14 For this project it is presently planned to allow the dredges to use box cut channels (overwidth at the bottom), to limit overdredging not benefitting the project (by making any overdredging for the account of the contractor), and to do no advance maintenance (so as to permit earlier utilization of the full project capabilities). A further option which the applicant may decide to exercise is deepening the channels and basins by depth stages to allow use of the project by smaller than 275,000 DWT VLCC's prior to full completion of the project. Maintenance dredging activities would probably commence shortly after the project was placed in operation so as to take advantage of the available equipment.

1.15 The Approach Channel would be approximately 10.59 nautical miles in length from the end of the North Jetty to the minus 80-foot underwater contour. The channel in this reach would be dredged 800 feet wide and 80 feet deep. The approximate volume of the material that would be dredged in constructing the approach channel is 47.3 million cubic yards. The Jetty Channel would be dredged to a depth of 76 feet. The maximum bottom width of the channel in this section would be 600 feet. The deepened Jetty Channel would follow the alignment of the present channel as it proceeds inshore to Station 15+00 on the South Jetty, at which point it would veer approximately 10 degrees northward. The present channel would continue to be maintained in its existing alignment and authorized depth. The approximate volume of the material which would be removed in the 1.4 miles of the Jetty Channel is 13.5 million cubic yards.

1.16 At the onshore terminus of the Jetty Channel, a 2300-foot diameter turning basin would be dredged in the Lydia Ann Channel. It would permit turning of fully loaded 275,000 DWT tankers, or partially loaded 500,000 DWT tankers. The project depth would be 73 feet. The approximate volume of material which would be removed in construction of the turning basin is 13.1 million cubic yards. The ultimate side slopes of the turning basin would be approximately 1 on 3. The docking (or harbor) basin would have a bottom width of 1200 feet at a project depth of 76 feet. The basin would accommodate three VLCC berths on the south side. The side slopes of the VLCC docking basin would be 1 on 3 with the slopes stabilized from 6 feet below mean sea level to 6 feet above mean sea level. A box cut would not be employed in the docking basin. Stone riprap, sheet piling, or concrete grout placed in a fabric envelope to form a monolithic structure could be used for this purpose.

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1.17 Levees for containment of dredged material would be constructed around the docking basin, along the re-routed tributary channel to Aransas Pass, and around the perimeter of the selected disposal areas. These levees would be constructed to 17 feet above mean sea level with a 6-foot crown width and 1 on 4 side slopes. A roadway would be constructed around the docking basin at an elevation of 6 feet above MSL. Along the south side of the docking basin and across the eastern end of the properties presently owned by Petrofina and Exxon, the dike height would be at +27 feet MSL. A small boat harbor would be constructed at the inshore end of the docking basin to serve the needs of the vessels employed in running ship lines and the oil-spill control program. To permit construction of the docking basin at the proposed location, the Aransas Pass tributary channel would be re-routed around the docking basin to the north. This channel would be 125 feet in width and authorized project depth. Enlargement of the Tributary Channel to Aransas Pass is scheduled to begin in the summer of 1978. The authorized improvements involve deepening the entire project from 12 feet to 14 feet and widening to 175 feet between mile 3.5 and mile 4.6.

1.18 Marine Facilities. The marine terminal, which would be of fireproof construction, initially would have two berths along the south shore of the dredged basin adjacent to the surge tank farm. The two initial unloading berths are designed to accommodate tankers ranging in size from 100,000 DWT to 275,000 DWT fully loaded and up to 500,000 DWT partially loaded. They would consist of unloading platforms, breasting structures, mooring structures, and shore-connecting trestles. Provision is made in Permit Application No. 9563 for adding a third berth at the west end of the basin to accommodate the same size tankers.

1.19 Unloading Platforms. The unloading platforms would be of steel jacket construction on steel pipe piling, or prestressed concrete piling construction, and would support the unloading arms, piping and ancillary equipment. Decks would be of monolithic concrete construction with curbs designed to contain possible oil spills and with drains to carry such oil spills and "slops", as well as water falling on the platform, to an onshore containment area. The following equipment will be on the unloading platform:

a. Unloading arms for transfer of crude oil.

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b. A central building housing storage, electrical gear, controls, etc.

c. Piping, manifolds, drain tanks and pumps.

d. Drainage gear and sumps.

e. Fire hydrants and hose cabinets, walkways and operating platforms, lighting and power accessories, and miscellaneous hoses and adapters.

f. Hand rails and stairs.

g. Walkways and catwalks.

1.20 Breasting Structures. The tankers berth against structures called breasting dolphins which must withstand not only the berthing impact from the ship but also the mooring forces resulting from wind, waves, and currents. Four major breasting structures would be installed, two on each side of the unloading platform. If needed, additional breasting structures could be added to accommodate smaller vessels. Each breasting structure would consist of large diameter, high tensile steel tubes driven into the basin bottom. Hard timber facing with rubber fenders, held in place by structural steel members, would cushion the tankers and allow the breasting structures to absorb the berthing energy. Each would contain mooring hook assemblies, an electric capstan motor, internal wiring and connections, and all accessories for a complete assembly. In addition, guard railings, an access ladder from the water, and landings for catwalks would be provided on each mooring structure.

1.21 Catwalks. Catwalks of steel girder/truss design with an open steel grating deck would connect the unloading platforms and breasting and mooring structures and would be supported at intermediate points by pile support bents. The catwalks would be equipped with handrails, lighting standards and carry electric cables to lights and capstans.

1.22 Trestle. The trestles connecting the loading platform to shore would be curbed concrete deck structures supported by steel pipe piles or prestressed concrete piles.

1.23 Operational Area. The portion of the work pertaining to the Operations Area would include the following facilities:

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a. An equipment building housing the following:

(1) Water pumps complete with piping, valves, manifolding and controls.

(2) Foam transfer pump controls and piping, valves and manifolding.

(3) Motor control center for onshore manifold motor-operated valves.

b. Foam receiving tank.

1.24 Crude Oil System. The crude oil system would include main crude piping, laterals and crossover manifold onshore; and pumps, valves, motor operators, and fittings as required for the system.

1.25 Terminal Facilities. Four metal flexible-joint 16-inch diameter unloading lines would be installed on each of the docks, and they would discharge into delivery lines to the terminal manifold and tankage. For the projected throughput volumes, a total of up to 13.4 million barrels of surge tankage may be required. Twenty tanks of 600,000- and 700,000-barrel capacity would provide this volume. Surge tankage where crude oil is stored before being piped overland to the refinery, in conjunction with a steady flow pipeline, is more economical than an intermittently operated pipeline capable of full tanker unloading rate. The surge tanks allow the tankers to unload at their full unloading rates, reducing expensive ship delay. Each tank would be approximately 60 feet in height and approximately 300 feet in diameter. Four tanks would be located within each fire wall area, and a common suction and discharge line would be provided for each two tanks. All tanks would have floating roofs and would be equipped with variable angle mixers and level and temperature gages.

1.26 The proposed project is primarily intended to serve the imported crude oil needs of refineries in South Texas. Approximately 85 to 90 percent of the crude oil volumes upon which the economics of the project are based would go directly to Corpus Christi refineries through the new pipeline system described in this impact statement. These volumes are based upon present and planned expansions of local refineries and their projected needs for imported crude oil. Local refineries have little or no domestic production. The refineries would accept the crude oil

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directly from the pipeline which would terminate in close proximity to the refineries located along the Inner Harbor of the Corpus Christi Ship Channel. It is estimated that approximately 10 to 15 percent of the throughput volumes would be delivered elsewhere, either by transshipment in coastal tankers and intracoastal canal barges or through existing marine terminal facilities, or by pipeline transport through existing pipelines. Should the project be the sole Texas port capable of accommodating VLCC's, it is quite possible that additional volumes would move through the port destined for Gulf Coast locations beyond South Texas. Depending upon the volumes and destinations, such movements might be either through existing pipelines or by new pipelines to meet the specific needs. In the absence of any present commitments, such additional movements and their magnitudes remain purely conjectural at this time.

1.27 Other Facilities. Other facilities at the terminal include the following:

a. Meters. Input to the surge tankage would be measured by turbine-type meters installed in parallel operation so that each bank would be capable of metering 100,000 barrels per hour per berth. Meter provers would be provided to verify accuracy of measurement.

b. Control System. A centralized control system would be operated from an office on Harbor Island in conjunction with the Harbor Master's office. Remote controls, records, and alarms would be displayed at this location. The control system would be computerized to continuously monitor and display all important phases of operation and the status of the system. It would include cathode ray tube video displays, teleprinters and push button keyboard controls.

c. Terminal Buildings and Offices. The main office housing the control center and management and administrative personnel would also be located on Harbor Island. Other space at the terminal would serve for offices and facilities for operating personnel, customs officials, environmental officer, pilots office, a public observation platform, and a laboratory. There would also be a small

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warehouse and maintenance workshop, as well as buildings for the Fire Company and the Corpus Christi Oil Spill Association.

d. Waste Water Treatment Facilities. Waste water treatment facilities would be provided as required to comply with environmental control standards. These facilities would include tankage water draw lines which would be connected into a closed sewer line system. The line would empty into a collection pond from which the contents would be processed through an oil separator and water treating facility. After necessary treatment, the effluent water would be contained in an aeration pond before release into natural water bodies. All surface water run-off from sensitive areas will be impounded and, if necessary, treated before release. Chemical treatment facilities would be provided for sanitary sewer systems serving the terminal buildings. Construction and operation of the treatment facilities will coordinate with the Texas Department of Water Resources and the waste water discharges will require EPA and State NPDES discharge permits.

e. Fire Protection. The proposed terminal buildings and tank farm would be protected by a system consisting of facilities for pumping and directing saltwater or foam to fires. Fire protection is described more fully in Paragraph 1.47 "Safety and Fire Protection." Fire walls around the tanks would be constructed 8 feet high with a 12-foot crown width. These embankments would also serve as a roadway to reach any area of the tank farm.

f. Communication Facilities. Communication facilities would include conventional radio and telephone service for ship-to-shore communications for the control center and communications between the control center and the operations within the terminal. Further discussions of the communications system are presented in paragraphs 1.47 and 1.60 "Safety and Fire Protection" and "Navigational Aids", respectively.

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g. Electrical System. The electrical system would include substations, switchgear, conduit runs, distribution transformers, motor control centers, lighting, etc., including standby emergency generators to provide electric power as required for safe and reliable operation of the facility.

1.28 Pipeline. A buried pipeline, designed to operate at constant throughput rates, would deliver the crude oil from the terminal to various Corpus Christi refining centers, as well as to interconnecting pipeline systems and other delivery points. The pipe will be API 5LX 52, 40-inch OD by 0.500-inch wall thickness. Where required, concrete coating would be applied to the pipe to maintain a negative bouyancy factor of 1.25. The pipeline design is in accordance with current D.O.T. "Minimum Federal Safety Standards for Liquid Pipelines" and ANSI B31.4. The pipeline from Harbor Island to Corpus Christi would be approximately 39 miles in length, and its route would generally follow State Highway 361 from Harbor Island to a point near Ingleside, Texas. It would then pass between Gregory and Portland, Texas, subsequently cross Nueces Bay, and then be routed into the Corpus Christi refinery area. The pipeline from the terminal to the delivery points would be monitored and operated from a control center on Harbor Island. The approximate pipeline mileages to points along the route would be as follows:

Approximate Mileage from Harbor Island	Segment
0-9	Harbor Island to Aransas Pass
9-12	Aransas Pass to Ingleside
12-15	Ingleside to Portland
15-29.5	Portland to Nueces Bay
29.5-39	Nueces Bay to Corpus Christi refineries including approximately 1-1/2-mile underwater crossing of Nueces Bay

Where these pipelines cross navigable waters, a Department of Army permit will be required. This permit application does not include the pipeline crossings.

1.29 Pump Station. There will be a single initial pump station for the pipeline system. The land required for the

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Harbor Island tank farm and pipeline pump station would be approximately 250 acres. A total of 9500 operating horsepower would be required by the pumping operation. Turbine-type meters would be installed to measure throughput volumes to the pipeline.

1.30 Types of Dredges. There are two basically different dredging concepts employed for the proposed project: the use of trailing hopper suction dredges for the offshore work and the use of cutter head hydraulic suction dredges for the inshore work. It is believed that use of these types of dredges would provide the greatest certainty of achieving the desired 2-year schedule for completion of the dredging work, as well as greater economy in terms of project costs.

1.31 Offshore Dredging. The desired 2-year schedule for completion, coupled with the 80-foot dredging depth and the anticipated wind and wave conditions in the open waters of the Gulf and in the Jetty Channel, form the basis for assumption of the use of trailing hopper suction dredges for this portion of the work. Such hopper dredges trail a large-diameter pipe and nozzle at an angle as they transit the channel, draw up material from the bottom by suction, and deposit the dredged material into hoppers on the dredge. For dredging to the proposed project channel depth, hopper dredges would normally operate with an underwater pump for greater efficiency and higher progress rates. When the hoppers of the dredge are filled with dredged material, the dredge would travel to the approved disposal site and place the dredged material within the designated area.

1.32 The material to be dredged in the Approach and Jetty Channels is predominantly sandy material which could readily be removed by hopper dredges. However, there is some material of a stiffer consistency which would reduce the dredging production rates. Until the extent of this latter area and the qualities of the stiffer material are better defined, it will not be possible to precisely define the offshore dredging fleet that would be necessary to meet the proposed schedule. However, it is anticipated that two hopper dredges of 12,000-cubic yard capacity would be required, and that possibly two 8,000 cubic yard or three 6,000 cubic yard dredges may be required to supplement the two larger dredges. It is anticipated that dredging operations would take place over the entire channel simultaneously. This would allow staged use of the channel, if applicable, and would be necessary to permit several dredging vessels to be employed. It is the intent to

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minimize the duration of the period of disturbance of the environment by dredging operations. Dredged material from the Jetty Channel and the Approach Channel would be placed in offshore disposal Areas F-G, along the south side of the Approach Channel, (Figure 4). At present, there is only one commissioned U.S. registered, privately-owned hopper dredge. It has a split-hull hopper with a 70-foot maximum working depth and 3,600-cubic yard capacity. It is understood that construction of one additional U.S. dredge with approximate capacity of 3,600, cubic yards will be completed during 1979. Two other dredges of 4500 and 8000 c.y. capacity are scheduled to be constructed. Only one dredge will have an 80-foot working depth. However, even if all three dredges could be dedicated full time to the proposed project, the schedule would be substantially extended, and the costs would be materially higher than if foreign dredges were utilized. Because of limited anticipated availability of U.S. registered dredges of requisite capacity and size, foreign dredges may have to be considered for performance of the offshore work. The applicant is aware of the legal constraints imposed on foreign dredges by 46 U.S.C. 292.

1.33 Maintenance dredging of the proposed Approach channel has been estimated by Southwest Research Institute (SWRI) to be 2 million cubic yards per year. However, because information concerning littoral drift and siltation rates is incomplete, this figure may vary significantly.

1.34 Inshore Dredging. The inshore dredging activities would include work on the turning basin, docking basin, and the relocation of a portion of the tributary channel to Aransas Pass. For this work, it is planned that U.S. registered hydraulic pipeline dredges would be employed. These dredges operate using "spuds" or anchors to maintain their position and advance to the work, and they dredge by means of a rotating "cutter head" at the end of a suction pipe in advance of the dredge. The dredged material is drawn up the suction pipe by pumping and is disposed of via pipeline to designated confined areas approved for filling. For dredging to the proposed project depths, it is likely that the dredges would be equipped with underwater pumps which would be used in conjunction with pumps on the dredge. For distant disposal areas, an intermediate pumping station, or booster pump, may be installed. The dredged material would be placed within approved leveed containment areas which would contain the solids. The effluent from such areas would flow over adjustable wiers with controlled rates of discharge and be discharged into either the Gulf (for the

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San Jose Island disposal area), or into the docking basin or the Corpus Christi Ship Channel (Figure 4).

1.35 The first step in the inshore dredging would be to construct the levees around the docking basin and around Disposal Areas A and B. It is probable that most, if not all, of the construction of the levees would be started using a dragline to place the material for a toe levee. The material dredged initially would be placed behind the toe levee. The upper portions of the levees would then be constructed by bulldozing portions of the initially dredged material into position and shaped with a dragline to form the balance of the containment levee.

1.36 There are three or four U.S. cutter head suction dredges in the immediate service area which are suitable for work on the proposed project. It is probable that three such dredges would be required to meet the schedule. Typically, these would be 30-inch size with 6,000 horsepower, and would have a supplemental underwater pump and also employ booster pumps to deliver dredged material to distant areas. Because of the need to employ multiple pieces of equipment, it is anticipated that work would proceed simultaneously and continuously on all of the inshore dredging areas. The timing of performance of portions of the work could be adjusted to reflect environmental conditions. Initially, emphasis would be on placement of select dredged material in portions of Disposal Area A in proximity to the docking basin and excavation of the portion of the docking basin where VLCC docks would be located, as well as upon relocation of the Aransas Pass Channel.

1.37 It is estimated that approximately 13.1 million cubic yards from the turning basin would be placed on San Jose Island to form a major portion of a levee 20 feet in height extending from the North Jetty to the existing dunes, located approximately 4 miles to the north. In addition, approximately 6.8 million cubic yards from the docking basin would be placed on San Jose Island to create the balance of the levee. The remainder of the estimated total of 24 million cubic yards from the docking basin would be disposed of in Area A, as well as the 300,000 cubic yards from the Aransas Pass tributary channel. The estimated total capacity of Area A, including the present Exxon and Petrofina properties, would be 23.7 million cubic yards, based on a final grade elevation of +15 feet MSL.

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1.38 Southwest Research Institute estimated the maintenance dredging in the inshore channels and basins at 1.6 million cubic yards per year. These volumes would be disposed of in the remainder of Disposal Area A until such time as the area had been filled to an elevation of approximately 15 feet; then other areas such as C and D would be used for subsequent disposal of dredged materials.

1.39 Jetty. The initial project plans call for construction of a full north jetty prior to removal of the existing north jetty. However, such a concept entails considerably more expense than either stabilizing the existing channel to deepen it, or a construction concept where by the new jetty could be constructed largely or in part from the materials of the existing jetty. Therefore, the jetty stabilization movement concepts continue to be studied and subject to the approval of the Corps of Engineers, may be modified in the final project. Such modifications would be required to meet Corps of Engineers criteria for maintenance of the integrity of the system and provide interim protection to vessel traffic during construction.

1.40 Marine - Docking and Shore Protection. The docking basin, after being dredged to its described configuration would have slopes from an elevation of -6 feet MSL to +6 feet MSL protected to prevent erosion as a result of tidal action, currents, waves and turbulence. The majority of the construction work on the ship berths would be performed utilizing barge-mounted cranes and specialized pile driving equipment. Equipment and facilities so installed would include installation of the jackets for the piers, driving the piles, installation of fenders and catwalks, fabrication of concrete forms, pouring of concrete, etc. Prefabricated modules (such as the jackets), units, forms, etc. would be used where possible to reduce the on-site construction operations to a minimum. Close control would be maintained over the construction operation to minimize the possibility of pollution from petroleum spills or debris from construction. A positive program would be developed and carried out. Containment and cleanup would be effected through use of temporary floating booms and patrol boats, as necessary. The booms would isolate construction areas, where practical, and the patrol boats would be employed for prompt response should remedial action be required. It is projected that the construction work on the ship berths would commence approximately 6 months after commencement of the dredging operations and would extend over a period of approximately 18 to 24 months.

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1.41 Terminal. Construction of terminal surge tankage would begin approximately 6 months after the placement of the land fill for construction. It is planned that such terminal tankage would be placed on land raised to a minimum elevation of 16 feet above MSL and suitably compacted to support the large floating-roof steel tanks. Suitable soil compaction would be achieved either by use of a surcharge of additional depth of fill material, or by use of vibratory compaction of the selected sand fill material. Soils tests would be made of the area to determine the pressure which the soils would support, and, if necessary, additional foundation measures such as concrete piles or support pads would be installed. All onshore construction work (including that of levee construction, tank erection, installation of piping, construction of buildings, electrical work, etc.) would be performed by standard methods of construction common to the industry with judicious precautions to ensure that disruptions to the environment are minimal. The initial 6-month period prior to commencement of terminal construction would be employed for placement of steel orders, delivery of the tank steel, the mill and plant fabrication operations, and mobilization of the construction effort preceding the jobsite fabrication of the tanks. The tanks would be started with a ring base, and then the curved metal plates would be welded in place in sequential rings until the tank was completed to the diameter and height required to contain the desired volume. Completion of the first tank would require aproximately 4 months from start of construction, and succeeding tanks would be completed at approximately 1-month intervals. The first 8 tanks projected for the initial throughput increment would be completed approximately 16 to 18 months after commencement of work on the project.

1.42 Pipeline Construction. The construction of the pipeline could be completed within a 1-year span. The actual work of construction of the pipeline itself would require approximately 4 to 6 months, and that of the pump station approximately 6 to 8 months. The pumping units would be of the "packaged" type in which the pump driver and the pump are mounted together, along with the necessary instrumentation and control, to form a complete functioning unit. This would permit factory testing for performance and minimize the onsite construction effort. The selection of either electric motor or turbine drivers would be subject to final design of the system. The pumping unit would function

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automatically in response to remote control from the operating center at Harbor Island. The units would be "fail-safe" in operation and would shut down in response to indicated "faults" in the operation of the system.

1.43 The land portions of the pipeline would be installed by means of a conventional pipeline operation. This would involve clearing and grading of the pipeline right-of-way, stringing of the pipe along the right-of-way in 40-foot (or 80-foot "double-jointed") sections, trenching of a ditch in which to install the pipeline, welding of the joints together, testing of the joints, and then lowering the welded sections of the pipeline into the ditch. "Tie-in welds" would be made in the ditch to join the lowered-in sections. Where the water table is near the ground surface, the pipeline would be of a minimum negative bouyancy of 1.25; This would be achieved, when necessary, by a concrete coating placed around the pipe. Such coating would be applied to the pipe joint sections prior to welding of the system and then the welded joints would be subsequently concrete-coated after inspection. A final hydrostatic test would be made of the pipeline as a whole prior to placing it in operation. The pipeline would subsequently be covered with soil, and the area restored to its original contour.

1.44 Water crossings, such as the Morris and Cummins Cut, the Intracoastal Waterway, and Nueces Bay would be crossed by means of a technique called "Underwater Pulling." In this technique, the entire length of the pipeline crossing would be welded together on the ground perpendicular to the direction of the waterway to be crossed and, for shorter crossings, it would be subsequently drawn across the bottom of the waterway by means of a cable pulling operation. For longer crossings, several long sections would be made up and these would be welded together and the crossing made in partial pulls corresponding to the lengths of the segments.

1.45 Operations. This section on Operations describes the marine operation, the terminal and pipeline operation, and has supplementary sections describing in greater detail the Safety and Fire Protection Systems, Aids to Navigation, and the Environmental Monitoring Program.

1.46 Marine Operation. Fully loaded 275,000 DWT tankers could use the Harbor Island Deep Draft Inshore Port, and larger vessels would be able to enter under favorable conditions or when partially loaded. The 275,000 DWT VLCC's would have drafts ranging up to approximately 70 feet loaded

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when entering the port, and approximately 40-foot draft in ballast condition when departing. All harbor pilots who would be berthing VLCC's would receive additional experience in handling VLCC's by training at a school having simulators of large ships and by interchange of operating information through the International Pilots Association.

1.47 Operational limits would be established for the port as a function of weather and sea conditions to assure safe operation at all times. The harbor pilot would board the VLCC's seaward of the entrance to the dredged channel. In the Approach Channel, the vessels would be under control of the harbor pilot and would proceed at approximately 8 knots. Entry would normally be under ebb tide conditions, preferably at the start of the ebb tide, and departure would be on any tide. By the time the VLCC reaches a point approximately 2 miles from the seaward end of the Jetty Channel, it would have slowed to 2 knots, and up to 4 tugs of approximately 3200-horsepower each would commence assuming control of the tanker. By the time the VLCC reaches the narrower Jetty Channel, the tanker would be under full maneuvering control by the tugs. A typical tug arrangement would be with one tug on each side of the bow, one astern, and one pushing on the side, the particular side depending upon the tidal forces. The number and size of tugs and towing arrangement would be determined by the professional judgment of the pilots. The pilot would be in full communication with the shore-side guidance system control, and with each tug by radio. Directions would be given to the tugs as needed to maintain the tanker in a mid-channel position en route to a location directly off from its assigned berth in the docking basin. One-way traffic would prevail in the Jetty Channel for all ocean-going vessels, including VLCC's. However, it should be noted that VLCC's in ballast could depart northward from the dredged entrance channel shortly after leaving the Jetty Channel, thus limiting traffic to one-way for only a short distance. Once within the Jetty Channel, the tugs would move the VLCC at less than 1/2-knot inside the docking basin to a location approximately 200 feet off of, and parallel to, a specified berth. The final approach to the berth would be made with a minimum of forward motion, and transversely at less than 1/4-knot. During these last maneuvers in the still waters of the docking basin, two tugs would push on the side outboard from the berth (starboard side) at the bow, and two at the stern. All pushing tugs would then hold the tanker while mooring lines were run to the mooring and breasting structures. Departing tankers would be maneuvered by four

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tugs in a similar manner as during the approach, but with the procedure reversed. Departure could be accomplished on any tide.

1.48 Oil Spill Control Operation. The oil spill control operation would be governed by the Department of Transportation, Sixth Coastal Region Oil and Hazardous Substances Pollution Contingency Plan and by an Oil Spill Contingency Plan developed for the project and approved by the EPA and the Coast Guard. It would be the intent of this plan that no oil would be permitted to escape into the navigable waters of the U.S. as a result of the operation of the Harbor Island facility. Protection procedures would be routinely employed to isolate each docked vessel. Individual booms would be employed around the tankers at each berth. For each berth there would be approximately 2,000 feet of back-fence boom and approximately 2,200 feet of boom that would be routinely deployed in the basin on the deep water side of the vessel. It would be secured by mounting hardware on the dolphins and platforms and deployed by a boom-tending boat. As an additional protection, a harbor boom would be available to close off the entrance to the docking basin. Two diesel-powered boom boats would deploy the harbor boom, which would be secured by mounting points on both sides of the basin entrance. Such a boom would be approximately 2800 feet in length and of heavy construction with a 3- to 4-foot vertical dimension. In addition to the harbor boom and back-fence booms, stowed boom packs would be maintained at the facility for deployment in an emergency. These would consist of approximately 4,000 feet of boom in 6 to 10 packages. Loading arms would have rapid emergency shut-off features which would be automatically activated by sudden pressure change in the loading lines and would limit the potential magnitude of oil spills. Unloading operations would be ceased in severe weather conditions, and tankers would vacate the berths for the open waters of the Gulf 12 hours in advance of expected hurricane conditions. Necessary equipment would be provided and stored on-site for rapid clean-up of any spill which might occur. The oil spill control operation would function under the direction of the existing Corpus Christi Oil Spill Control Association (CCOSCA). For clean-up purposes, an oil skimmer would be brought in as needed. In addition, sorbent materials would be provided at the facility for clean-up use in an emergency. Permanent weir-type openings would also be provided in the northwest wall of the basin, to assist in increasing the rapidity of clean-up in the event of a

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possible spill. It would be planned to place the weir so as to take advantage of the prevailing southeast winds. If wind patterns within the facility indicate efficiency of clean-up could be significantly improved, a permanent weir-type spill pool would also be provided in the southeast corner of the basin. Vacuum trucks, pumps, floating skimmers and sorbent materials would be provided by the facility for oil spill clean up purposes. Additionally, equipment of the CCOSCA and Coast Guard would be available for use in large spills occurring in the docking basin and adjacent waters.

1.49 Terminal and Pipeline Operations. After the tankers had been berthed, connection would be made between the four flexible joint metal loading arms on each berth platform to the manifolds of the tanker. It is projected that the typical tanker turnaround time would be 36 hours and the unloading time at the berth approximately 24 hours. This assumes tankers providing 125 psi at the rail and use of this pressure to fill the onshore surge tanks at rates up to 100,000 barrels per hour. The crude oil would be metered for custody transfer purposes after it leaves the tanker, and again at a later time by another set of meters before it enters the pipeline for delivery to refining centers. The centralized control system for the terminal and pipeline operations would be located in an office on Harbor Island. There, all remote controls, records, and alarms would be displayed for the benefit of terminal operating people. The control system would be computerized to continuously monitor and display all important phases of operation and present status of the system. It would include cathode ray tube video display, teleprinters, and push button keyboard controls. Based upon projected throughput, it is planned that two segregations of crude oil would be maintained initially within the surge tankage at Harbor Island. These two types of crude oil would be delivered to Corpus Christi refining centers in batches of an economic size, as dictated by requirements of the operating companies and efficient pipeline operations. The surge tankage at the Harbor Island terminal would permit delivery to refining centers and interconnecting pipeline systems at the average throughput rates of the system.

1.50 Safety and Fire Protection. A fully integrated safety and fire protection program is planned as an integral part of the Deep-Draft Inshore Port at Harbor Island. It would provide protection to the public, environment, discharging tankers, docks, surge tankage, pump stations, and ancillary facilities. An operation manual would be prepared, and all

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personnel involved in the port activities on Harbor Island would be thoroughly trained in operating procedures prior to commencement of operations. Such a manual would comply fully with U.S. Coast Guard regulations for Oil Transfer Facilities - including the latest published revision in the June 27, 1977 Federal Register under 33 CFR 154, 155 and 156 to harmonize with IMCO's International Convention for the Prevention of Pollution from Ships, 1973, and such other regulations as may be promulgated.

1.51 Codes and Standards. Safety and Fire Fighting Standards will comply with the following:

a. "Operations of Marine Terminals" National Fire Protection Association (NFPA) No. 307

b. "Piers and Wharves" (NFPA) No. 87

c. "Centrifugal Fire Pumps" (NFPA) No. 20

d. "Foam Extinguishing Systems" (NFPA) No. 11

e. "Sprinklers, Fire Pumps, and Water Tanks" (NFPA) Vol. 6

f. "Alarms and Special Extinguishing Systems" (NFPA) Vol. 7

g. "Portable and Manual Fire Control Equipment" (NFPA) Vol. 8

h. "Handbook of Fire Protection" (NFPA)

i. Applicable Coast Guard and other governmental Regulations

1.52 Alarm System. A fire and oil spill alarm system would be installed connecting discharging tankers, oil docks, tugboats, work boats, stations of the Refinery Terminal Fire Company, oil spill control office, security guard office, pilot office, Harbor-master's offices, Coast Guard Captain of the Port Office, and other shore stations.

1.53 Communication System. A VHF radio communication system would be installed to link equipment operating in the Harbor Island Port area. This system would provide communications between the tankers, tugboats, work boats,

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docks and the land based units, as well as the Harbormaster's offices on Harbor Island and in Corpus Christi, the fire station on Harbor Island, the Refinery Terminal Fire Company station in Corpus Christi, the Oil Spill Association, Coast Guard Captain of the Port office and other appropriate shore stations.

1.54 Surge Tankage. Each tank containing an inflammable liquid would be equipped with approved foam heads installed in accordance with applicable codes. Foam lines would extend from the foam heads to locations outside the fire walls adjacent to all-weather roads which would provide ready access for land-based fire fighting equipment. An adequate supply of foam and chemicals would be maintained in the port area for fighting oil fires, either aboard tankers or at shore installations.

1.55 Docks and Tankers. To the extent feasible, each crude oil receiving dock would be fireproof and designed to contain spills that may occur on the dock platform. Spilled oil would immediately flow into a "slop" tank located on shore. The dock platform would be equipped with a permanently mounted foam dispersal system which could blanket both the dock and manifold area of the tanker with foam. Operation of this system could be controlled either from the dock or from a remote station. Remote hydraulically-controlled monitors would be placed at appropriate locations on the mooring and breasting structures to blanket over the tanker dock. These would be equipped with either fog nozzles or foam nozzles and a foam proportioner that could supply either a fog or foam blanket over the tanker deck. Four inch fire hydrants, hoses, fog nozzles, and other Underwriter-approved equipment would also be installed. Dry chemical extinguishing agents would be maintained on the docks and at other approved locations throughout the port area.

1.56 Ancillary Facilities. The API trap into which oil received from the docks and from inside the fire walls and other sources would be pumped, would be protected by a permanently installed blanket foam system which could be activated by remote control in case of a fire.

1.57 Water Supply System. Fresh water for fire fighting would be provided by looped mains with standard fire plugs located at strategic points throughout the port area. A backup system using salt water would be installed. Electrical or diesel driven pumps would provide the

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necessary pressure. Salt water would be taken from either the docking basin or Corpus Christi Ship Channel through a pipeline taking suction below the water surface.

1.58 Electrical System and Controls. All electrical components and controls installed would comply with the applicable National Electrical Manufacturers Association (NEMA) Standards and the National Electrical Codes for the areas in which the equipment would be installed.

1.59 Onshore Fire Protection. A fire station with an adequate number of mobile fire fighting units and ample supply of foam and other chemicals would be maintained in the port area under the supervision of the Refinery Terminal Fire Company. The fire fighting capability maintained at Harbor Island would be supplemented by the fire company from its main station located in Corpus Christi. The Refinery Terminal Fire Company, a non-profit corporation with 29 years experience in providing fire protection for the Port of Corpus Christi and adjacent industrial areas, would furnish necessary fire fighting equipment and personnel to provide protection for the docks, tankage, pump stations and ancillary facilities situated in the Harbor Island Port areas, similar to that which it now provides in the Corpus Christi Port Area. The fire company would provide firemen on the tugboats whenever these boats were used as fireboats. Among the present members of the fire company are the Navigation District and most of the Harbor Island Participants. Backup capability for the fire company would be provided through liaison and cooperative agreement with the Corpus Christi Fire Department, U.S. Navy Fire Department, U.S. Coast Guard and other area cities. Each organization, upon request, can provide support to the others requesting assistance, thus providing significant additional capability to meet emergencies anywhere in the Corpus Christi Bay area.

1.60 Offshore Protection for the Docks and Tankers. No less than three tugboats, depending upon horsepower, would be required to maneuver and control the tankers while docking and undocking at the Harbor Island docks. Each tugboat would be equipped with the most current and efficient apparatus for fighting oil fires on tankers and on the water. Should the need arise, these boats could be operated as fireboats. Capability of these tugboats to fight oil fires would be equal to that of any fireboat. The tugboats, when in service as fireboats, would operate generally in accordance with an agreement recently entered

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into between the Navigation District and a company that maintains a new 3200-horsepower tugboat at the Port of Corpus Christi. Under the present agreement, the Refinery Terminal Fire Company provides the fire fighting personnel for the tugboat when it is operating as a fireboat. The fire company also provides and maintains 1000 gallons of foam on the tugboat in a tank built into the boat for this purpose. To have this service available in the port, the Navigation District pays a daily standby charge to the company for providing and maintaining permanent fire fighting equipment on its tugboat and an hourly rate when the boat is operating as a fireboat. It is contemplated that a similar agreement would be negotiated with the additional tugboats operating at Harbor Island.

1.61 Ballasting and Tank Washing Operations. Since the proposed project would only handle import of crude oil, no discharge of ballast water is anticipated. Ballast water will however be taken from the channel as the ship unloads. Tank washing would not be allowed in the project area.

1.62 Protecting the Public, the Environment and Port Facilities at the Deep-Draft Port on Harbor Island. Providing for the safety of the public, protecting the environment and the public port facilities on Harbor Island would be the responsibility of the Navigation District. Likewise, general supervision of the operation of the public docks would be a function of the Harbormaster acting for Nueces County Navigation District No. 1. Prior to commencing operations, applicable rules and regulations consistent with Federal, State and local laws would be adopted by the Navigation Commission to accomplish these objectives. For protection of the public, access into the properties would be controlled by cyclone fences and guarded entrances. Such security would be under the direct supervision of the Harbormaster's office, unless such authority is delegated to others. In the latter case, the Harbormaster's office would continue to have general supervision in the port area. For fire and spill protection, the Refinery Terminal Fire Company, the tugboats, work boats, pilots and Oil Spill Association would be available upon call by the Harbormaster's office. While discharge of a tanker is in progress, a "dock master" would be on duty on the dock at all times monitoring the operations. Readily available to him on the dock would be an emergency alarm system as well as a direct communication line between the dock, the center controlling the flow of oil into the surge tanks, and the ship's officer controlling

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the unloading operation mate onboard the tanker, to assure instantaneous response in case of an emergency while the unloading operation is in progress.

1.63 Navigational Aids and Their Use. Standard visual aids to navigation necessary for safe operation of the Harbor Island Deep-Draft Inshore Port would be provided as required. Such visual aids would include ranges, fixed structures, and buoys. They are described as follows:

a. Ranges. These are visual targets denoting the center-line and sidetracks within the navigable channel. The front and rear targets are differentiated by design and color. Sensitivity to direction is dependent upon the distance separating the targets. Visibility under normal conditions is dependent upon height and size. Ranges and lights with twelve mile visibility are available, and these are lighted at night and in times of poor visibility. Each light has its own unique characteristic.

b. Fixed Structures. These are bottom mounted and are used to denote position or limits and, in particular, turning points in the dredged channel.

c. Buoys. These are lighted and specially tight-moored with distinctive coloration and numbering and are used to denote position or limits along the seaward channel entrance.

1.64 Radio Positioning. Radio navigation devices may be grouped into those appropriate to the purposes of general aids to navigation and those of high accuracy and high stability for precision or controlled navigation. Supplementary aids to position-fixing are radar transponders which, when triggered by ship radars, emit a signal clearly identifiable on the radar screen. Present technology is available which can meet the operating needs of the facility; however, specific selection of systems or equipment would be made from that available just prior to the date the Harbor Island Deep-Draft Inshore Port would commence operation. Various types of radio positioning aids may be described as follows:

a. General Aids to Navigation. Already available in the Gulf of Mexico are "LORAN A" and "LORAN

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C" - which allow electronic determination of position by the intersection of two lines of position from two "Master-Slave" stations emitting synchronized electromagnetic wave pulses. The line of position is determined by measuring the time differences between the pulses from the paired stations. The vessel's actual position is determined from the intersection of two such position lines derived from inspection of the navigation chart upon which incremental lines of position are color-coded.

b. Precise Navigation Systems. The same principles described before are also used in approved, precise (Multi-user) navigation systems. Such systems are shorter in range and are so configured as to provide optimum accuracy and stability within the selected prime areas of interest. Several such systems are available, employing a mix of phase comparison and synchronized pulse techniques. On-board receivers provide instant and continuous read-out directly applicable to special pre-drawn charts. In addition, track plotter devices directly interfaced to the system can supply the Pilot and Ship Master with precise control during transit of the dredged channel. All units are duplicated to provide redundancy. Position accuracy of ±10 feet throughout the critical channel transit could be achieved if the system is properly configured.

c. Supplementary Aids. Suitably positioned radar transponders on shore, or on offshore structures, would emit a characteristically coded signal when triggered by the emission of X-band ship radars with horizontal polarization. Radar ranges from such fixed transponder stations could provide back-up in the event of catastrophic failures.

1.65 Communications. All deep sea vessels within port limits and all vessels involved in transiting the approach channel would be equipped with common ship-to-ship and ship-to-shore radio-telephone communications. From the relocated

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Aransas Pass Sea-buoy all vessels transiting the dredged channel would be under port directed Pilotage. All pilots would be personally equipped with portable radio-telephone transmitter/receivers and with portable navigation system receivers capable of direct plug-in to ship's power.

1.66 Approach Procedures. The following text describes the use of aids to navigation contemplated for this project. The following apply to the procedures relevant to the exercise of port control of inward and outward-bound traffic transiting the dredged channels:

a. The length of the dredged channel from the seaward end of the north jetty across the Aransas Pass Bar to Sea would be approximately 10.59 nautical miles.

b. The draft of conventionally loaded outward-bound vessels would not exceed 45 feet. Such vessels would leave the critical reach of the channel to the north approximately 3 miles seaward of the outer end of the jetties. Those outward-bound vessels sailing light would leave the channel 1 mile seaward of the end of the jetties.

c. For inward-bound vessels, absolute right-of-way would be provided. The critical section of the channel would be the inner 5 miles approaching Harbor Island. This part of the channel would require high candlepower, lighted, center-line range markers, established with a height and distance differential to provide adequate sensitivity in the inner 5 miles. Lighted side ranges in contrasting colors would also be provided.

d. The outer 5 miles of dredged channel, non-essential to either loaded inward-bound or outward-bound traffic with drafts less than 45 feet, would be limited solely to use by deep-laden inward-bound VLCC's provided with precise navigation control and continuous ship-to-shore communication.

e. The entrance to the seaward end of the dredged channel would be marked by a specially emplaced tight-moored, characteristically

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lighted buoy hereafter referred to as the relocated Aransas Pass Sea-Buoy. Such buoy would be equipped with a beacon transponder which would accurately indicate bearing and distance to the buoy on X-band shipboard radar.

f. A series of buoys with transponders and lights would mark the south side of the channel as necessary for the safety of navigation.

g. Pilot boarding of inward-bound VLCC's would take place in a 2-mile radius seaward of the relocated Aransas Pass Buoy.

Navigation by VLCC's to the vicinity of the seaward entrance to the Approach Channel (i.e., to the proposed relocated Aransas Pass Buoy) would be conventional from overseas ports to the anchorage area. Adequate radio positioning aids to navigation exist for this purpose through United States Coast Guard LORAN A and LORAN C systems, coupled with navigation charts, upon which the hyperbolic position lines generated by LORAN are superimposed. All VLCC's are expected to have receivers on board to avail themselves of such publicly available services to mariners. From the location of the relocated Aransas Pass Buoy (where the Pilot would board the VLCC equipped with a communication system and portable "Precise Navigation Receiver") to the critical 5-mile section, only inward-bound VLCC traffic would be permitted. From the Aransas Pass Buoy landward, the Pilot and Shipmaster would be provided with the requisite automatic, high-precision navigation capability to proceed. For the navigation of the approach and entrance to the channel, particularly during periods of low visibility and at all times in the interest of safety, an approach "High-precision, multi-user, hyperbolic navigation system" would be used. All units thereof would be duplicated and have automatic switch capability to assure round-the-clock operation. Battery power back-up would take over in the event of power failure.

1.67 Such a system would be established in optimum configuration to provide maximum accuracy of $\pm$10 feet on a continuous basis. The system would be installed well in advance of commencement of VLCC operations and would be extensively tested prior to operational use. With the addition of track-plotter capabilities, the entire dredged channel and surrounding areas could be mapped at expanded

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scale and such maps issued to all Pilots; the latter will be thoroughly trained in the operation/application procedures of both receivers and track-plotters. Verification of the navigational system would be performed prior to opening Harbor Island to VLCC's by operational tests conducted on lighter-draft vessels of the type presently entering and leaving the Port of Corpus Christi. Given such precision and procedures, the Pilot and Shipmaster could establish checks for Go/No-Go of entry from the relocated Aransas Pass Buoy into the Channel Entrance and farther, with established ability to assess drift, or crabbing, could enter the dredged channel at a speed consistent with safety and with initial heading satisfactorily established. At all times, and in particular just prior to entry of the dredged channel, the vessel would be provided with prevailing and predicted weather conditions applicable to transit via the communication system. Such precise weather data would be made available from the Port Harbormaster's office located at Harbor Island, where an automatic weather station would provide data for integration with U.S. Weather Bureau data. In this manner, local forecasts for "Pilots" would be current. Transit of the outer end of the dredged channel would, therefore, be assisted by Precise Navigation System and supported by Buoys and Transponders leading to clear vision of the center-line range markers, providing precision for navigating the inner five miles. In the event of low visibility or inclement weather, the Precision Navigation System would become the primary aid for continued entry and for inner channel transit. Reporting points for key locations would be established, e.g., channel entrance, transit, entry to inner five miles, and approach to Harbor Island. Safe speeds would be established in accordance with Pilot recommendations and vessel stopping power. Approach to ship berths and the actual berthing of the VLCC's would be by conventional, established procedures. However, in the case of VLCC's berthing would be aided by providing the pilot with the necessary pilot-controlled or vessel-installed Doppler-Radar devices to provide accurate distance measurement and rate of change thereof. The inner 5 miles of the approach channel and jetty channel would be open to all deep sea traffic on a one-way basis after the VLCC enters the docking basin. It should be noted that the adoption of these procedures for entry of VLCC's would in no way impinge upon the existing operating procedures for conventional vessels except when an inbound VLCC enters the channel. In such instances its right-of-way is absolute. During the time shipping is in, or in the vicinity of, the channels and basins comprising the Port of Corpus Christi,

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ships are required to guard VHF radio-telephone circuits and advise intended movements as required by law. Such controls are now exercised and would be maintained.

1.68 In conclusion, an exit of a VLCC would be treated as a special case similar to that of entry from the turning basin through the inner 5 mile critical section of the dredged approach channel. Since the VLCC would be light draft and lack maneuverability, channel right-of-way would be granted it and traffic alerted accordingly.

1.69 Environmental Monitoring Program. An environmental monitoring program would be carried on to monitor ecological conditions at various locations within the project limits during both the constructional and operational phases of the Harbor Island Deep-Draft Inshore Port. The purpose of the construction phase of the monitoring program would be to measure conditions prevailing immediately prior to, and during construction so as to permit minimization of harmful environmental changes, as compared to preconstruction conditions. The monitoring program carried on during early operation would be undertaken to evaluate the ecological changes in the project area attributed to development of the Deep-Draft Inshore Port.

1.70 During the construction phase of the monitoring program, particular attention would be given conditions in the vicinity of the dredges, the sites where dredged material is placed, effluent receiving areas, and those other localities which might be significantly influenced by construction activities. Air and water conditions, sediments, and living forms in the area would be periodically examined during the construction phase. If a particular physical, biological or chemical change were anticipated within the system, or if an unusual ecological condition were noted, a special sampling program would be undertaken. It would be planned to collect the data at intervals most appropriate to the ecology of the area immediately prior to, during, and subsequent to completion of construction activities. Locations, periods, and type of sampling would be planned to reflect the various stages and types of activities to be undertaken during the construction program. To make the monitoring program more meaningful, it would be planned to take successive measurements of water quality parameters, biological variations, air quality, noise levels, and sediment quality during similar periods of the year.

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1.71 During the early operational phases of the environmental monitoring program, it would be planned to continue the types of monitoring activities commenced during the construction operation, but modified to reflect significance of findings and the conditions arising as a result of operations. The principal changes anticipated as a result of the construction of the facility would be in the water sector because of the increased channel and basin depths involved; therefore, attention would be concentrated in this area.

1.72 Studies previously conducted in the channels adjacent to the confluence area by Southwest Research Institute (1974-1975), Texas Water Development Board/U.S. Geological Survey (1972 and 1975), Ned Smith (1975-1977), and the monitoring program planned for the construction phase of the project would provide baseline data by which environmental changes can be evaluated. Particular attention would be given to circulation patterns, oxygen content, and those primary water quality parameters that occasionally have cumulative characteristics in some channel sections such as heavy metals or nutrients.

1.73 Water Quality. It is planned to establish a series of sampling stations in the confluence region, docking area, turning basin, Jetty Channel, Approach Channel, and in the offshore disposal sites. Seasonal samplings and measurements would be made at various depths in the water column for such parameters as temperature, salinity, dissolved oxygen, total suspended solids, biological oxygen demand, nutrients, pesticides, current velocities, tidal conditions, oil and grease, total (Kjeldahl) nitrogen, and the heavy metals: zinc, mercury, cadmium and arsenic. Special emphasis would be placed on monitoring water movement during various tidal cycles and wind conditions. The water quality monitoring programs with regard to sampling frequencies, sites and parameters would be coordinated with the Texas Department of Water Resources and EPA Region VI.

1.74 Turbidity in the water column (total suspended solids) would be measured prior to and during both construction and operation; it is an important parameter in the geological prolongation of the estuarine system. During construction, measurements would be taken near the operating dredges, in the receiving waters of the return flow from the land disposal sites, and in the offshore disposal sites. Travel paths of disposal of dredged material, ponding basins, and

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discharge weirs for the land disposal sites would be carefully monitored with the intent of taking constructive action to minimize turbidity in receiving waters. Where feasible, larger disposal sites with greater potential distances over which the dredge material and waters could travel would be employed. The longer runs would permit a greater settling time for suspended sediments. In addition, the speed of the currents in the modified channel and turning and docking basin of the deep-draft port would be carefully followed to ascertain the extent of the flushing capabilities of the system.

1.75 With respect to the offshore disposal sites, turbidity studies would be made during construction, including transmissivity transects, to measure the distribution of the sediment plume in both horizontal and vertical directions. Samples would be taken after disposal trips by the hopper dredges and at various times during the seasons. Near-bottom current speeds and directions would be measured with the intent of detecting any significant directional changes which might materially alter migration patterns of shrimp caused by the sediments deposited at these sites.

1.76 Sediment Quality. Recent sediment core samples, representative of the virgin material to be dredged in the various sections of the project, show no unusual chemical levels except for one core sample which may be in error. Periodic sampling would be made at strategic locations in the disposal sites to detect any possible changes in such important parameters as heavy metals, chemical oxygen demand, and other important factors. The configuration of the sea floor in offshore disposal sites would be monitored during construction and operation by means of acoustic depth recording instrumentation in conjunction with precision navigation equipment.

1.77 Biological Monitoring. Both marine and terrestrial monitoring would be undertaken to evaluate the degree of biological changes caused by construction and operation of the deep-draft port, as well as recovery rates of the marine life in the areas of modification and the revegetation and repopulation rates of the terrestrial life forms of the land disposal sites. The present deep channels, such as the existing Jetty Channel and Outer Bar Channel, which have periodic maintenance dredging have relatively minor benthic populations. Preconstruction and operational monitoring data would provide a basis for comparative analysis which would assist in determining the mortality rates of benthos

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in disposal sites and the rates of recovery of such areas after deposition. Such data would also indicate whether benthos population found associated with certain phases of disposal activities had actually increased. Field studies conducted in the fall of 1975 by the Southwest Research Institute suggested both increased population and favorable diversity of organisms in the offshore disposal area utilized by the Corps of Engineers for the past 55 years. Before and during construction of the facility and the deposition of the dredged material, bottom trawls would be undertaken during periods of known migration of some of the more important sport fish and commercial species.

1.78 Where dredged material is placed on submerged land areas, which at their final elevation would be "wetlands", careful monitoring would be made of the rate of vegetation establishment. The results of programs currently underway along the Texas coastline which are intended to induce more rapid growth and plant cover over newly deposited sediments, barren lands, and shallow water areas would be applied to the areas around Harbor Island.

1.79 Air Quality Monitoring. Air quality would be measured at carefully selected key locations on the Harbor Island site and adjacent areas during both construction and operation. The test data would reflect the effects of heavy construction equipment used in the work. Photochemical oxidants and particulants and odors would be sampled and recorded. Samples would be taken under a variety of weather conditions to most properly evaluate the various activities. The Air Quality monitoring program would be coordinated with the Texas Air Control Board and/or EPA Region VI.

1.80 Noise. Noise level measurements would also be taken during construction and operation. Such measurements would be taken to determine if and when such levels could be objectionable under certain climatic conditions and activities. A Harbor Island meteorological recording station would be erected to supply information to establish local climatic variables. In conjunction with information on ambient noise levels in the Harbor Island area collected by Southwest Research Institute in 1975 and the data which would be acquired during construction, as compared to the values during operation, determinations could be made of levels of change in noise conditions and could be used as a guide to attenuate the noise level, if necessary, of any sector of the facility deemed to be detrimental.

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1.81 Ownership. The proposed Multipurpose Deep-draft Inshore Port is located on and adjacent to the Corpus Christi Ship Channel, a Federally Authorized Project. The Harbor Island Project, (Phase No. 1), is a joint and cooperative endeavor of public and private interests. However, it will be a public port operated as a division of the PORT OF CORPUS CHRISTI. The Project includes three basic elements: the marine facilities; the surge tankage; and the distribution pipelines. At the present time, final decisions have not been made as to the division of ownership and responsibility for operations between the public and private industry aspects for each element of the Project.

1.82 In any event, the marine facilities (channels, docks, basins, etc.) will be owned by the Nueces County Navigation District No. 1, a political subdivision of the State of Texas, and as such would be financed 100 percent by revenue bonds supported by throughput agreements from the participants guaranteeing sufficient revenue to meet annual bond payments and operation and maintenance costs of the phases of the project which the navigation district financed. Such bonds are typically of 15/20-year term and are amortized by payments of principal and interest over the life of the bonds. The interest rate anticipated is about 6-1/2 percent per annum.

1.83 The annual amortization on such bonds is approximately $105,000 for each million dollars financed on the shorter term bonds. The Navigation District would also receive a modest return, the exact amount of which would be dependent, in part, upon the extent of the responsibilities of the District in the ownership and the ongoing operation of the project. However, overall control of the Marine facilities will rest with the District.

1.84 The private industry aspects include the pipeline from Harbor Island to a terminus near the Port of Corpus Christi Inner Harbor and possibly the surge tankage and pump stations. Either one of two options might be employed to finance the capital costs of these facilities: 100 percent equity participation by those participants in the throughput commitments; or approximately 10 percent equity with the balance financed by bonds issued by the companies over a period of time ranging from 15 to 30 years and at interest rates of approximately 9 to 10 percent per annum. For 15-year bonds at 9 percent, the amortization payments for each million dollars of principal are approximately $125,000 per year. Such facilities would likely be subject to I. C. C.

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regulations and be limited to a 7 percent return on the I. C. C. valuation.

1.85 The capital costs, and the corresponding operating costs, are subject to considerable future definition. These costs depend upon the date in the future at which the facility would be constructed (escalation impact), final design refinements, more detailed information on soils to be dredged, and upon the conditions within the construction industry at that time. The estimates of capital costs must therefore be considered as preliminary and subject to future change. Similarly, the operating costs must be viewed by the same criteria. Table 1 presents order-of-magnitude 1978 first quarter costs, and Table 2 presents estimated typical unit costs of transhipment from the tanker to the Corpus Christi refining center corresponding to the presented capital costs and the 4th year of operation.

1.86 As part of its long-range master plan, the Nueces County Navigation District No. 1 contemplated a three phase project. Phase I, which is the project under consideration in this statement, calls for construction of an 80' channel to Harbor Island for the purpose of unloading crude oil from VLCC's. Phase II would accommodate OBO (ore/bulk/oil) vessels and dry bulk carriers. Phase II contemplates deepening the Corpus Christi Ship Channel to 60 feet and widening it to 600 feet from the inner basin at Harbor Island to and including the Port Ingleside turning basin, a distance of 8.3 nautical miles. The Port Ingleside turning basin would be enlarged to 60 feet deep and 600-2,000 feet wide (bottom width).

1.87 Public docking facilities are contemplated at or near the Port Ingleside Turning Basin for transferring dry bulk commodities and other cargoes directly from OBO vessels, dry bulk carriers, and other cargo vessels onto rail cars, intracoastal canal barges, (the intracoastal canal passes the Port Ingleside Turning Basin), or on to stockpiles on shore or into shoreside tankage. These facilities would also be available to serve industries located on National Steel Company and adjacent properties. Railroad tracks serving the proposed facilities and adjacent property would connect near Ingleside with a major railroad transportation network serving most states west of the Mississippi River.

1.88 Phase III would accommodate OBO vessels and dry bulk carriers. The modifications would include deepening and widening the La Quinta Channel and turning basin, and

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Table 1. Estimated Construction Costs of Phase I Harbor Island Deep Draft Inshore Port, 1977 a/

Item	Estimated Costs b/	
	(Millions of 1978 dollars)	
Marine Facilities		
Harbor	17.40	
loading platform		6.40
bresting dolphins		2.20
mooring dolphins		3.10
navigation aids and oil spill equipment		2.40
small boat harbor		0.30
slope stabilization		1.30
allowance for lands		1.70
Dredging and Jetty Relocation	190.20	
offshore		74.60
onshore		52.40
jetty straightening or relcation		57.00
allowance for lands		6.20
Onshore Facilities		
Terminal	119.20	
storage		91.10
support and control		5.50
other		22.60
Delivery	28.10	
pipeline		17.50
pumps and motors		10.60
Contingency and Engineering	76.40	
TOTAL	431.30	

a/ Bechtel, Inc. preliminary estimates, subject to approval.

b/ Estimated costs were given in 1978 dollars.

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TABLE 2

Estimated 4th Year

Direct Operating Costs*

	Cents/barrel
Fuel and Power	.56
Maintenance - Dredging	2.40
Marine Facilities	.34
Tank	.23
Oil Loss	.35
Manpower	.59
Benefits	.25
Insurance	.33
Ad Valorem Taxes	1.06
Other	.33
Total Direct	6.44

*700,000 barrels/day estimated system throughput - Marine Facilities, Surge Tankage and Distribution Pipeline.

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extending the channel westward along the north shore of Corpus Christi Bay with an appropriate turning basin at the head of navigation.

1.89 The channel would be deepened to 60 feet and widened to 600 feet; the approach flare of La Quinta Turning Basin would be lengthened and its width increased from 1,200 feet to 1,500 feet. A comparable depth and width would probably be requested for any justified westward extension of the channel beyond La Quinta with an 1,800 foot wide by 1,800 foot long turning basin at the head of navigation. Public port facilites are contemplated near the head of navigation on the La Quinta channel extension to accommodate cargoes transported in OBO vessels and dry bulk carriers up to 175,000 dwt capacity.

1.90 Issuance or denial of the permit application addressed in this statement should not foreclose or limit options with respect to other phases of the three phase project. Phases I, II, and III are financially and operationally independent of each other.

1.91 Relationship of Proposed Action to Federal Projects in the Area. Construction of the proposed project would affect the existing federally constructed Corpus Christi Ship Channel, Tributary Channel to Aransas Pass, and Gulf Intracoastal Waterway Lydia Ann Channel. Should the proposed project be constructed, Federal maintenance of the existing ship channel (entrance and jetty channels) would no longer be required since that portion of the channel would be deeper than the Corps of Engineers is authorized to dredge. Maintenance of the existing GIWW Lydia Ann Channel in the vicinity of the proposed project likewise would no longer be required.

1.92 The proposed action calls for rerouting the Tributary Channel to Aransas Pass, a federally constructed and maintained shallow draft navigation channel. Rerouting of this channel should not affect the Federal maintenance of the project. Enlargement of the Tributary channel to Aransas Pass is scheduled to begin in the summer of 1978. These authorized improvements involve deepening the entire project from 12 feet to 14 feet and widening the reach from mile 3.5 to mile 4.6 from 125 feet to 175 feet.

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2. ENVIRONMENTAL SETTING.

2.01 Physical Description. Harbor Island, the site of the proposed project, is located immediately northeast of Corpus Christi Bay in Nueces County on the Southern Texas coast, 180 miles southwest of Galveston and 132 miles north of the mouth of the Rio Grande. Corpus Christi Bay, the major bay in the area, is a large shallow body of water about 14 miles long in a northwest-southeast direction and is about 12 miles wide at its widest part (Figure 5). It is one of the deepest bays along the Texas Coast with natural depths of 11 to 13 feet. Mustang Island separates Corpus Christi Bay from the Gulf of Mexico on the east. Redfish Bay to the northeast, Nueces Bay to the west, and Oso Bay to the south are smaller arms of the main embayment. Laguna Madre, a narrow coastal bay, extends southward from Corpus Christi Bay.

2.02 The Corpus Christi Bay system is located in the coastal prairies physiographic region of the Texas Coastal Plains. Land elevations in the area range from 146 feet above sea level in the northwestern corner of Nueces County to sea level along Corpus Christi Bay. The southern and western shorelines of the bay have been cut back by wave action to form steep banks ranging in height from 15 to 35 feet. Most of the county lies on the nearly level coastal plain, while a much smaller area is composed of tidal flats and barrier islands. Soils characteristic of the coastal plain in this region are sandy or clay loams or saline clays. The tidal flats and barrier islands in the area consist of fine to medium grain sands.

2.03 Geology. Geologically the study area lies within the Gulf Coastal province of the United States, a segment of the Mesozoic-Cenozoic era coastal geosyncline of North America which can be traced from Newfoundland to Guatemala. The geosyncline, lens-shaped in cross section, exists in nearly equal parts beneath the water and adjacent to the shores. Along the western Gulf of Mexico, the geosyncline contains about 45,000 feet of predominantly arenaceous-argillaceous (sand-clay), marginal to shallow water strata, although calcareous materials predominate in the rocks of the Cretaceous Period.

2.04 Beneath the geosynclinal mass are Precambrian-Paleozoic era rocks of variable facies, structures, and degrees of metamorphism. The major sedimentary units are arranged in belts subparallel to the modern shoreline.

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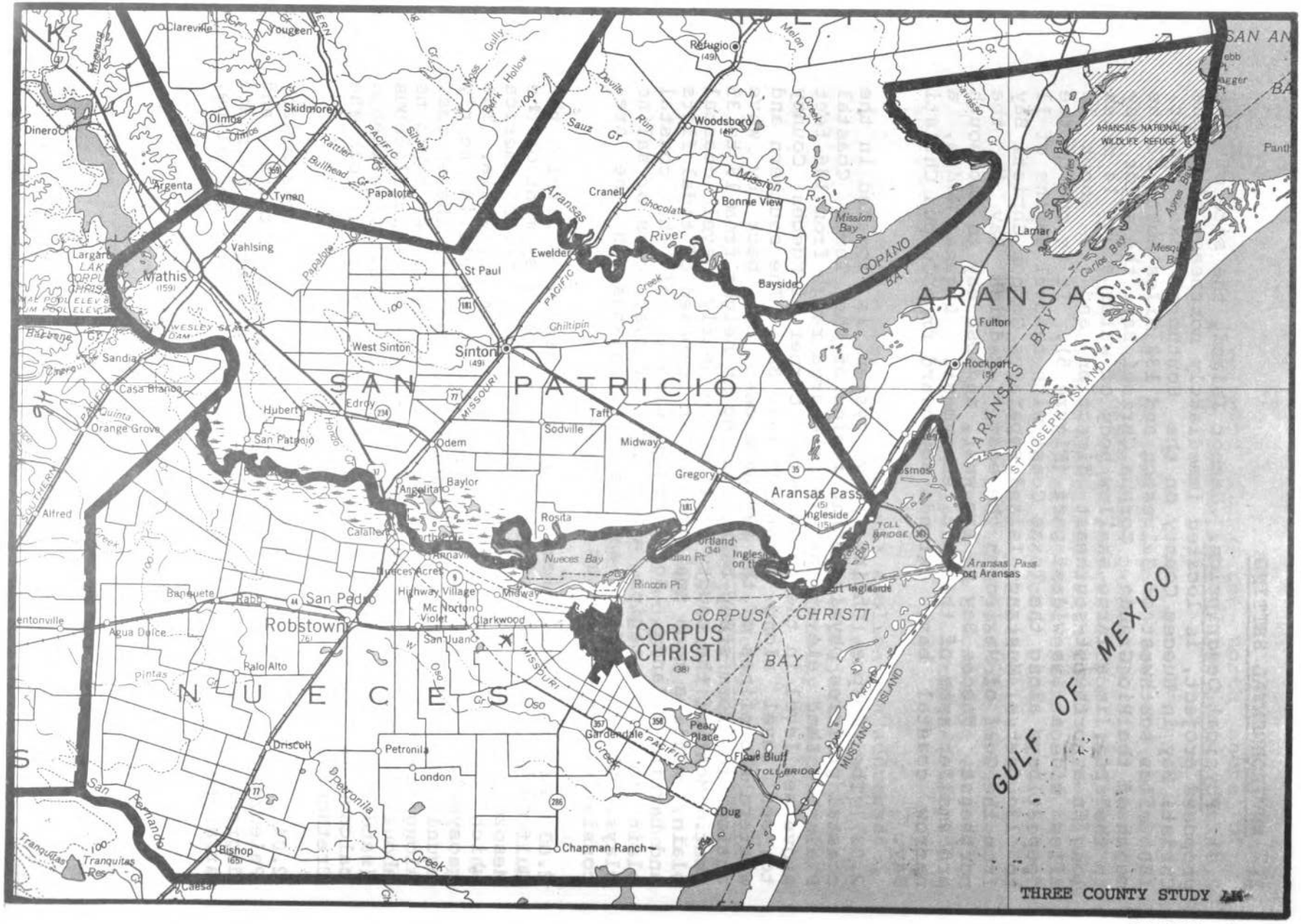

FIGURE 5

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Pleistocene and Holocene Epoch sediments, those of principal interest to this study, consist of widespread deltaic (fluviatile, marginal and marine) sediments. The fluviatile facies comprise alluvial terrace deposits flanking streams and their valleys with alluvial filling in the valleys. Marginal materials occur either as belts of deposits underlying the alluvial surfaces more or less parallel to the modern coast or in modern coastal marshes and deltaic plains.

2.05 A majority of the sediments of the Continental Shelf were formed as nearshore deposits during the post-Pleistocene sea level rise. These deposits are covered with fine grained sediments which are forming today. During the period of lowest sea level stand (about 300 to 400 feet below the present stand), sediments from rivers were carried across the exposed Continental Shelf. The major rivers, during the period of the lower sea levels, had increased gradients and cut deeply into the Pleistocene sediments (identified as Beaumont clays). The Nueces River, where it neared the sea level grade, meandered and formed relatively broad flood plains in the area of the present Nueces and Corpus Christi Bay. Filled Pleistocene epoch channels with depths of 50 to 60 feet are present beneath Nueces Bay and on the west side of Corpus Christi Bay and increase in depth to more than 100 feet on the east side of Corpus Christi Bay. Within the old river channel are many buried oyster reefs. They are especially numerous in the channel where depths are less than about 70 feet, but only a few reefs have been encountered on the old flood plain surfaces. Carbon 14 dating of the oyster shells from neighboring bays at depths of 70 feet give an age of 9300± 1300 years. The deposition in the bays presumably began during the time when glaciers were retreating and when the sea was considerably lower than it is at present. The sediments that fill the channel and surround and cover the oyster reefs are soft clays and muds which possess little impedance to high frequency acoustic signals thus allowing the delineation of these reefs. The depth of reef burial increases seaward. The most abundant area of channel reef development in Corpus Christi Bay is buried beneath 25 to 40 feet of bay bottom muds. Near surface and shallow buried reefs prevail in Nueces Bay.

2.06 The barrier islands, San Jose (Saint Joseph), Mustang and Padre, are outlying belts of sand separated from the mainland by Aransas, Redfish, and Corpus Christi Bays. The islands are approximately 1/2 mile in width and have nearly

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straight seaward margins in contrast to their irregular lagoonal shoreline. These barrier islands have three major divisions: an outer beach, a belt of dunes, and an inner tidal flat or marsh. On Mustang Island the average elevation above sea level of the dune area is 15 to 20 feet with some areas as high as 40 feet. San Jose Island is generally less than 5 to 6 feet in elevation except at the southernmost end where several points reach 20 to 25 feet.

2.07 The beaches of these barrier islands consist of clean, well-sorted fine or very fine sands. Locally, shells are numerous, but the beaches are smooth and hard-packed and consist predominantly of quartz sand.

2.08 The Continental Shelf off Port Aransas is covered with silty clay. The nearshore deposits change from sand on the barrier island and in the surf zone, through silty clay and sand-silt-clay, to a large offshore area of silty clay. According to Curray (1960), this area is one of the few on the modern shelves of the world showing the classic change from coarse to fine sediments in an offshore direction. It is also one of the few areas of the shelf where no major rivers empty into the Gulf. This is the area of convergence of both semi-permanent surface currents and the wave induced longshore current. These currents take the place of rivers in supplying sediment which is subsequently carried outward by seaward current and deposited on the shelf.

2.09 Climatology. The climate of the Corpus Christi Bay area is a product of the combined effects of the humid subtropical region to the northeast, the semi-arid region to the west and southwest, and the warm, moist, modifying influences of the Gulf of Mexico.

2.10 Temperature. Corpus Christi has an annual mean temperature of 72°F with average maximums and minimums of 81°F and 62°F, respectively. The warmest three months are June, July, and August with an average temperature of 84°F. The coolest three-month period is December through February with an average temperature of 59°F. Daily temperatures in the summer rarely reach 100°F near Corpus Christi Bay. However, a 100°F temperature was reached in August 1969 and September 1965, a 101°F temperature, the high, occurred in July 1964. Mornings are warm, and the daily maximum is reached by noon. The afternoons are more pleasant than the mornings, especially after the sea breeze begins.

2.11 Humidity. Relative humidity remains high throughout the year due to the nearness of the Gulf of Mexico and the

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prevailing winds that bring moist air inland from the Gulf. The humidity averages 75 percent daily over the year. The humidity reaches an average maximum of 86 percent at midnight and an average minimum of 64 percent at noon. The period of record for this information is 1931 through 1971.

2.12 Barometric Pressure. The annual average barometric pressure is 1016 millibars. The monthly mean sea-surface pressures vary from a minimum of 1014 millibars during the summer months to a maximum of 1020 millibars during the winter months. The record low of 99 millibars (29.29 inches of mercury) was recorded in September 1961 with the passing of hurricane Carla (Corps of Engineers, 1972).

2.13 Precipitation. Corpus Christi has an average annual precipitation of 28.34 inches, with the driest season in the winter months and the wettest months being September and May. June, July, and August are usually dry months, but large amounts of rainfall can be added by tropical storms. The wettest month on record was September 1967 with 20.33 inches, resulting mostly from a record maximum twenty-four hour rainfall of 8.76 inches during the month. Since 1931, the only two months to have no recorded precipitation were October 1952 and July 1957. The most precipitation recorded for any one year since 1931 was 44.35 inches in 1960, and the least was 14.66 inches in 1963.

2.14 Snow precipitation averages 0.1 inches per year. However, since records were begun in 1887, trace amounts of snow have fallen on the average of only one day every two years. The record maximum monthly snowfall of 1.2 inches in 1940 was not recorded at the weather station proper.

2.15 Texas A&M University has determined from meteorological data the annual rainfall probabilities at Corpus Christi: during 16% of the years, 20 inches or less may be expected; during 61% of the years, 20 to 30 inches fall; in 17% of the years, 30 to 40 inches fall; and in 6% of the years, the total is over 40 inches. May and September, with averages of 3 to 4 inches of rainfall, are generally the rainiest months of the year in the area, and the months from December through April and August are the driest. It is during the months when moisture-laden winds from the Gulf blow almost incessantly that rainfall is likely to be most substantial.

2.16 The Corpus Christi area has 280 to 320 frost-free days per year, and during the rest of the year frost is not an expected daily occurrence. The first frost usually comes about December 10, and the last about March 1.

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2.17 Winds and Waves. Two wind regimes dominate the Corpus Christi area. Persistent, southeasterly winds occur from March through September, and north winds occur from October through February. More important to bay processes than the occurrence of the prevailing wind direction, however, is the dominance of a particular wind as defined by its duration and speed. The dominance of winds from the Southeast quadrant and from the winter northers is even more pronounced than just the occurrence of their direction would indicate.

2.18 Southeasterly winds have a significant fetch across parts of Copano, Aransas, Redfish, Corpus Christi, and Nueces Bays and Laguna Madre. Shorelines of all bays in the Corpus Christi area are affected by waves and longshore currents resulting from the prevailing southeast wind. Waves generated by the southeast wind erode shorelines that face into the wind and transport sediment westward and northward. Wind stress on the water surface causes a lowering of water level along the bayside of barrier islands and flooding of low-lying mainland shorelines. The setup from these winds may raise the water level 1 to 2 feet above normal high tide.

2.19 From December through February strong northerly winds occur in the area. Rain with winds up to 50 miles per hour accompanies these sudden 24 to 36 hour long storms. These north winds generate intense wave activity in the larger bays which erode the south and west bay shorelines. West and south-flowing longshore currents are generated within the bays by waves approaching the shorelines from the north. Waves generated by the north winds resuspend some of the bay mud, part of which is moved through Aransas Pass and the Fish Pass. Resuspended mud in Aransas Bay is transported toward the south bay shore and southward and eastward through Lydia Ann Channel and Aransas Pass.

2.20 North wind stress on the water surface causes a lowering of water level along the north bay shore and a rise in water level along the south bay shore. At this time water level may be lowered as much as 2 feet below mean low tide in northern parts of bays. Parts of the southeast bay shores (baysides of San Jose, Mustang, and Padre Islands) are inundated by wind tides created by northers.

2.21 Coincident with the rise in water level along the southeast bay shores is a lowering of water level in the Gulf of Mexico, which results in higher ebb currents through the tidal inlets.

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2.22 Along the Gulf beaches, these northers eliminate breakers, and north winds transport sand from dune and beach areas into the Gulf of Mexico. Rains that accompany the northerly winds combine with increased river discharge to lower bay salinity.

2.23 The sea state in the Gulf off Corpus Christi is calm in the summer and fall and moderate during the winter and spring. Waves greater than 5 feet occur about 20 percent of the time during the year. High waves are precluded by the shallowness of the Continental Shelf. Large waves and swells lose their energy as they propagate into shallow water and "feel the bottom". Orbital water motions because of these bottom feeling waves keep bottom sediments in suspension and add to the littoral drift processes.

2.24 Hurricanes. The hurricane season for the Corpus Christi area is from June to October, with a concentration of occurrences in August. Carr (1967), determined that 6 hurricanes have struck the area during 1871-1963 period; 3 were hurricanes with winds over 125 miles per hour.

2.25 A fully developed hurricane consists of a well-defined circular area, throughout which the atmospheric pressure diminishes rapidly on all sides toward the center or point of lowest atmospheric pressure. Within the storm area the winds blow with great force, the velocity increasing toward the center; however, the direction is not toward the center but around the center in a counter-clockwise direction in the northern hemisphere. At the center is an area, usually 10 to 20 miles in diameter, throughout which relatively calm conditions prevail.

2.26 Tropical cyclones vary in size and intensity, from small storms accompanied by winds having velocities of about 30 miles per hour to hurricanes up to 600 miles in diameter and winds exceeding 100 miles per hour. Winds of hurricane velocity (75 miles per hour or more) may be felt over a width of over 100 miles in storms of large size and severe intensity. Occasionally tropical cyclones of small diameter and severe intensity do great damage over a small area. The tropical cyclone communicates its whirling movement to the water. If its progressive movement is slow the rotary winds act for a longer time upon the same water area, and more vigorous currents are set up around the storm center. As the storm approaches the coast the currents thus created "pile" the water up against the shore, causing extremely

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high water levels. When the storm is some distance from the coast, the first effect is a slow rise of the water in the section toward which the storm is moving. The greatest response to the storm usually occurs to the right of its path or track, the side in which the winds are directed onshore by the counter-clockwise rotation. The height of the storm surge depends upon the size and intensity of the storm, its forward speed, and the underwater topography. Great storms moving slowly in a direction nearly normal to the coastline develop very high storm surges and storm waves at the coastline. Severe hurricanes of large diameter have produced surges of 14 to 15 feet above mean sea level along the Texas coast. Usually the rise of the sea is gradual as the storm approaches the coast, but sometimes it comes swiftly. The tides or surges caused by hurricanes as they approach and then cross the coast are extremely variable, depending upon such factors as the size and intensity of the storm, the relative position of the point on the coast with respect to the storm path, the rate at which the storm mass approaches the coast, the Coriolis effect of longshore winds and currents, shoreline configuration, land and underwater topography in the storm path, and the barometric pressure profile between the storm's center and the periphery of the storm. A gradual rise in water surface levels brought about by wind surges moving radially outward from the storm can be observed along the coast more than 24 hours in advance of storm landfall.

2.27 Five of the most severe storms since 1900 with high storm surges were within approximately 70 miles of the project area. The storm of 13-14 September 1919 was among the most severe to strike the Texas coast during the 20th Century. Meteorlogical notes from the U.S. Weather Bureau station at Corpus Christi indicate that the station was within the radius of maximum winds as the center passed inland to the south near Sarita, Texas. The storm tide at Port Aransas was 11.5 feet above mean sea level, and the bay tide at Corpus Christi has been variously reported between 12 to 16 feet above mean sea level. The storm of 23-25 July 1934, which crossed the Texas coast near Rockport, produced storm tides of 5 feet and 1.2 feet above mean sea level at Port Aransas and Corpus Christi, respectively. The storm of 26-30 August 1942 crossed the coast at Port O'Connor, Texas and produced a bay tide of 3 feet at Corpus Christi. The storm of 24-27 August 1945 passed by Palacios, Texas and created maximum tides of 3.7 and 3.2 feet above mean sea level at Port Aransas and Corpus Christi, respectively. Hurricane Carla, the large storm of 8-13 September 1961,

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moved inland over the Port O'Connor-Port Lavaca area. The storm produced an estimated maximum storm tide of 9.1 feet above mean sea level at Port Aransas and a bay tide of 6.5 feet above mean sea level at Corpus Christi.

2.28 A hurricane may alter the shoreline significantly and damage or destroy man-made structures. Large waves accompanied by storm surges will erode beaches, dunes, and shore cliffs and damage structures. The peak winds and tidal surge will occur to the right of the direction (path) of the hurricane center. The surge may be capable of breaching the barrier islands and extensively invading and flooding low lying coastal areas. The Bureau of Economic Geology of the University of Texas (1974) reports the following expectations for storm surge heights at Mustang Island: 4 feet within 5 years; 6 feet within 10 years; 8 feet within 25 years; 10 feet within 50 years; and 11 feet within 100 years. From historical records, planning agencies consider the 15 foot contour in the Corpus Christi Bay area to be the design limit of flooding; however, high water marks above the 20 foot contour have been found at locations around the bays where wind set up was great.

2.29 Hurricanes, and thus their effects, vary in intensity and size, but several other factors also affect the severity of their impact upon the coast: bottom slope and profile of the inner shelf and shoreface; the position and degree of the astronomical tide cycle at the time of approach; the shape and orientation of barrier islands, deltaic headlands, passes and upper bay areas; vegetative cover in the area; and the angle at which the storm strikes the coastline. These factors determine how much of the storm-tidal surge will be dissipated upon striking land and how much energy will remain to affect the bay system.

2.30 The approach of a hurricane is marked by rising tides and increased wind velocities. Generally speaking the longer a storm remains offshore, the greater will be the storm surge. Storm tides or surges are higher in narrow, funnel-like bays than along the straight barrier or peninsula shoreline; local surges in these embayments have reached to 20 feet above MSL. Storm surges deposit sand and shell berms on beaches, push shelf sand onto the shoreface, erode fore-island dunes, and may breach the barrier island or peninsula through storm or washover channels.

2.31 As the storm moves inland, water setup in the bays during the storm's approach suddenly begins to drain gulfward through passes and storm channels. Heavy rains

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persist inland with intensive flooding along streams and poorly drained coastal prairies. Rainfall that accompanies some storms may exceed 30 inches over a period of 2 days. After the passage of a hurricane, reorganized bay and Gulf circulation rapidly seals the mouth of storm breaches in the barrier island, and waves begin to erode storm berms.

2.32 Other Significant Weather Occurrences. Atmospheric conditions are the best during the summer months, especially July. Annually there is an average of 104 clear days, 122 partly cloudy days, and 136 cloudy days. An average of 75 days out of every year have at least 0.01 inches of precipitation. Thunderstorms occur on an average of 32 days out of every year with the fewest occurring from November through February. May and September have the most thunderstorms with five each. An average of 30 days out of every year have heavy fog, occurring mostly from November through April.

2.33 Hydrology. Excerpts from the "Water Quality Management Plan for the Nueces Basin," June, 1975, are presented in this section (paragraphs 2.34 to 2.46) to provide a general hydrological description of the Nueces River basin. These excerpts were extracted from Sections B and F of the Plan. "The Nueces Basin Study" area encompasses 26,690 square miles of south central Texas. This area includes the entire drainage area of the Nueces, Frio, and Atascosa Rivers, the San Antonio-Nueces Coastal Basin which includes the Mission and Aransas Rivers, and approximately two-thirds of the Nueces-Rio Grande Coastal Basin. The coastal and estuarine waters from Refugio to Kennedy Counties are also within the study area.

2.34 Most of the Nueces Basin Planning Area can be classified as semi-arid, based on low annual rates of precipitation. Historically, both severe droughts and significant rainfall have resulted in wide climatic variation within this semi-arid region. (Semi-arid is the average condition of the entire basin.)

2.35 The average annual rainfall ranges from 28 inches per year along the immediate coastal area to 21 inches per year in the headwaters portion. Mean evaporation rates range from 30 inches per year at the coast to 60 inches per year at the headwaters.

2.36 The surface waters of the Nueces Basin Study area consist of one major water supply reservoir, two major rivers, five minor rivers, a multitude of creeks, ten

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coastal estuarine water areas, and a portion of the Gulf of Mexico. Associated with the watercourses and waterways of the basin planning area are the contributing land drainage areas.

2.37 Natural stream flow within the study area has been modified because of man-made activities and demands. Water supply reservoirs, flood prevention and soil and water conservation reservoirs, diversions for domestic, agricultural, and industrial needs, and modified surface drainage have resulted in a much different stream flow pattern from natural conditions.

2.38 The principal rivers in the planning area are the Nueces and Frio Rivers which rise on the Edwards Plateau, flow southeastward through deeply dissected limestone and then across the Balcones Escarpment into the broad Coastal Plain. Major tributaries rising on the Plateau are the West Nueces and Sabinal Rivers and Hondo Creek. Others originating on the Coastal Plain are the Leona and Atascosa Rivers and San Miguel Creek. Those originating north of the Balcones fault zone have sustained flows from the discharge of hundreds of springs that serve as outlets from the Edwards limestone aquifer underlying the Edwards Plateau. In crossing the fault zone, these streams lose their low flow and substantial amount of floodwater by percolation into the Edwards fault zone aquifer. As a result, stream flow in the Nueces River basin downstream from the fault zone consists almost entirely of flood runoff. The Nueces River has a braided channel through much of its course from Zavala County to its confluence with the Frio River near Three Rivers. This results in substantial loss of floodwaters from both in-channel and overbank flows. Stream flow in the Atascosa River consists mostly of flood flows in addition to an appreciable sustained flow from nonsurface source discharge.

2.39 Below Lake Corpus Christi, Nueces River stream flows result from controlled releases from the impoundment to meet the municipal and industrial freshwater requirements in the study area. The proposed Choke Canyon Dam, located on the Frio River four miles west of Three Rivers, is being sponsored jointly by the Nueces River Authority and the City of Corpus Christi. Presently in the early construction stages, this dam is designed to form a reservoir with a capacity of 700,000 acre-feet. Choke Canyon Reservoir would be operated in conjunction with Lake Corpus Christi to provide a water supply for the City of Corpus Christi and

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other Coastal Bend water users. Construction of the project is estimated to take 4-1/2 years.

2.40 The San Antonio-Nueces Coastal Basin has two minor rivers, the Aransas and Mission Rivers. Contributing to the Aransas River is Poesta Creek which flows through the City of Beeville. Another creek in the San Antonio-Nueces Coastal Basin is Chiltipin Creek which flows through the City of Sinton. None of the rivers and creeks within the San Antonio-Nueces Coastal Basin maintain streamflow.

2.41 The Nueces-Rio Grande Coastal Basin is drained by creek systems. Except during and after rainfall, many of these creeks have very low or no natural flow. In some instances, particularly in the vicinity of urban areas that have treated wastewater discharges, the only streamflow during dry periods is that of treated wastewater.

2.42 The most dominant hydrologic features of the lower basin study area are the many valuable and sensitive coastal water systems. Mesquite, St. Charles, Copano, Aransas, Redfish, Nueces, Corpus Christi, and Baffin Bays, and parts of San Antonio Bay and the Laguna Madre are major components of the Coastal water system. The majority of the sensitive ecological systems are found within the coastal waters.

2.43 In the Coastal estuarine waters, the return of treated industrial and municipal wastewater accounts for most of the "fresh water" inflow during dry, low-flow periods. Streamflow, urban runoff, treated wastewater return flow, and direct rainfall are the only sources of needed freshwater inflow in these coastal waters.

2.44 Irrigation of croplands and municipal and industrial supply are the principal water uses. Surface runoff reaching Lake Corpus Christi in Live Oak County supplies the Corpus Christi area with its municipal and industrial needs, while groundwater in the Edwards Aquifer furnishes the San Antonio area with the largest share of its needs in addition to meeting the irrigation and municipal requirements in Uvalde and Medina Counties.

2.45 The primary agricultural use of water within the Nueces Basin is for irrigation purposes, although livestock watering is another demand.

2.46 Water Resources and Wastewater Disposal. Corpus Christi Bay is located at the mouth of the 11,000,000 acre Nueces River basin. The economic activities associated with

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Corpus Christi Port affect Nueces, San Patrico and Aransas Counties. The largest city within the study area is the City of Corpus Christi. In 1970, there were approximately 285,000 people residing in these counties. These people required approximately 87,000 acre feet of freshwater each year to meet the demands of household and industrial uses; this averages 0.31 acre feet per capita per year, or approximately 280 gallons per person per day.

2.47 At the present time, almost all of the freshwater demands for the study area are met from regulated streamflow in the Nueces River basin. The average annual flow of the Nueces River is approximately 600,000 acre feet per year. However, the natural streamflow varies from no flow during dry seasons to as much as 141,000 cubic feet per second during flood periods. Surface impoundment is therefore necessary to insure that the freshwater demands of the area can be met under conditions of worst historical drought.

2.48 The regulation of flow in the lower Nueces River is accomplished by Lake Corpus Christi, located some 35 river miles upstream from the City of Corpus Christi's water treatment plants at Calallen. This 22,000 acre lake has been created by an earth filled dam extending approximately 50 feet above the valley floor. The normal operating level of the reservoir is 94 feet above mean sea level at which elevation the quantity of water contained behind the dam is approximately 270,000 acre feet. It has been estimated that should a repeat of the most critical drought period of record occur now, this volume of water would supply a firm yield of approximately 126,000 acre feet per year. Because of forecast future siltation, this firm yield is expected to decrease to 108,000 acre feet per year by the year 2010. Lake Corpus Christi has sufficient capacity to handle water demands approximately 40 percent greater than now occurring (1975) in the Corpus Christi area.

2.49 Several forecasts of future water requirements for the study area have recommended construction of additional reservoirs to handle anticipated future needs. The United States Bureau of Reclamation surveyed the Lower Nueces River Basin to determine a feasible location for a new reservoir to supplement Lake Corpus Christi. The Bureau's study recommended a 700,000 acre foot reservoir on the Frio River upstream from Lake Corpus Christi. This reservoir site is referred to as the Choke Canyon Reservoir. The Bureau estimates that a firm yield of 252,000 acre feet per year can be maintained during a repeat of critical drought

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conditions if Choke Canyon and Lake Corpus Christi are operated in combination.

2.50 Tides. Water level changes in the Corpus Christi System are caused by astronomical and meteorological influences. The yearly average of the astronomic tide change at Port Aransas ranges from about 2.5 feet below MLW to 1.7 feet above MLW. This variation is attenuated by the Port Aransas entrance channel, Lydia Ann Channel, and the Aransas Pass and Corpus Christi Ship Channels and decreases in magnitude westward to an average variation of about 6 inches at Port Ingleside and in Corpus Christi, Aransas, and Nueces Bays. Both diurnal and semi-diurnal tides are present in the system.

2.51 The tidal wedge produced by the combination of astronomic and meteorologic conditions proceeds inland from Port Aransas at varying rates dependent on the type of tide. Calculations by Smith (1974) indicate a 5+ hour passage from Port Aransas to Ingleside for a daily tide with a 3+ hour period for a semi-daily tide. Time lags of these magnitudes have been recorded during recent field studies. Southwest Research Institute (SWRI) personnel have observed a 7 to 12-hour variance between the arrivals of high tide and low tide within the zone. SWRI has noted that when a high tide enters Aransas Pass it takes from 3 to 8 hours to traverse the approximately 10-mile distance from Port Aransas to the Ingleside area, with most high tides taking 5-6 hours. The same high tide will reach the Redfish Bay and Mud Island stations in from 1 to 8 hours, but the average high tides traverse the 6 miles in 4 hours or less. Carrying capacity of the channels and the bay volumes have an influence on arrival times relative to the Gulf tides. Low tides also are delayed, but the lag time is reduced to 2 to 4 hours at Port Ingleside compared to the entrance channel at Port Aransas.

2.52 A study of a series of tide gauge data from Port Ingleside and from the mouth of Corpus Christi Inner Harbor suggests that a high tide traverses the 12 miles from Ingleside to Corpus Christi in less than 1 hour. Smith (1974) has calculated that the tide change takes only a few minutes to traverse the Bay from Ingleside to Corpus Christi.

2.53 The normal tidal movements in the channels produce currents with the normal speeds of 1 to 2 knots, but speeds at the surface of 3 knots and higher have occurred at the

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pass near Port Aransas under some conditions (not including tropical storms). A water "build up" of as much as 6 inches has been recorded during average diurnal conditions in the confluence area adjacent to the jettied channel due to the shape and size of the channels and the rise and fall of the Gulf water levels. Shepard and Moore (1960) show with data from a 12-month survey, conducted with the assistance of the University of Texas Marine Science Laboratory, that winds have an effect on the currents coming in the inlets. They indicate that the north winds are accompanied by stronger southeast currents flowing out of the pass and south winds by stronger northwest currents flowing into the pass.

2.54 Within the bays, excluding the channels, conditions vary considerably, and no well-defined permanent current patterns have been determined. Winds may be as important as tides in establishing the bay circulation. Water levels in the bays often change by as much as a foot or more as the result of winds, causing the water to rise on the lee shores.

2.55 Observations have been made that suggest that Laguna Madre to the south and Redfish and Aransas Bays to the north act as reservoirs for water entering at Port Aransas rather than suppliers of water to the Corpus Christi Bay system. Current and salinity measurements taken by the Marine Laboratory at the entrance to Laguna Madre demonstrate that a northward flow of water from Laguna Madre into Corpus Christi Bay occurs during sustained south component winds, especially during semi-diurnal tides.

2.56 The effect of wind produced oscillations in the shipping channels of the Bay system is poorly known, but tidal records do not indicate a significant change in tidal levels which can be directly related to wind direction. Smith (1974) has noted that a rise of water at the Ingleside station could take place as a result of an offshore wind or a decrease in magnitude of an onshore wind. Conversely, during an onshore wind, water levels at Port Aransas and Corpus Christi could rise, while temporarily lowering the level at Ingleside.

2.57 Because of the predominant wind directions, the water level effects due to atmospheric conditions are most pronounced in the northern and southern sectors of the bay. The east-west orientation and the near-center Bay location of the ship channel within the system places the principal tide recording stations (at Ingleside and Corpus Christi)

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approximately on a line of minimum water level change, which could in part account for the less-than-expected water level change caused by atmospheric forces.

2.58 The inflow and outflow of water via Aransas Pass is poorly documented with only two studies having been conducted by the U.S.G.S. Water Resources Division in conjunction with the Texas Water Development Board. The results of these studies are presented in Figure 6. It is apparent that large quantities of water enter and leave via Aransas Pass. The effect of different seasonal tidal conditions on the inflow-outflow regime is shown as well.

2.59 Currents. Southwest Research Institute acquired current and wind velocity measurements in the Corpus Christi Bay area from 1970 to 1973. Thirteen stations located to include major channels, areas of water exchange, and segments of the Bay system were sampled every two weeks. The measurements from these stations have been compiled into the four accompanying maps (Figure 7 thru 10). Since the Bay and its environs are affected by two primary tidal conditions, the maps were prepared to reflect diurnal and semi-diurnal tides. The maps prepared from the more abundant semi-diurnal data were considered to be most useful if based on wind direction and speed; thus, three separate maps were constructed depicting currents with winds of 8-18 knots from the northeast, 8-18 knots from the southeast, and 19+ knots from the southeast. Sufficient data were not available to compile the daily tides in more than one wind category (8-18 knots) from the southeast.

2.60 The four maps depicting baseline conditions utilize symbols to show the number of daily periods a specific station experienced a current flow from a particular direction. A compass rose subdivided into 16 segments illustrates the direction of current flow for both near-surface and the near-bottom waters. The current direction which comprises the greatest number of days of flow from a particular direction appears on the maps as a darkened cone radiating outward in the direction of flow. Average current speeds on the dominant segments are given in knots. Excluding the channel stations, where current speeds in excess of 1.5 knots are frequently encountered, currents at the Bay stations normally measure between 0.1 and 0.5 knots at the surface and rarely more than 0.3 knots in the bottom waters.

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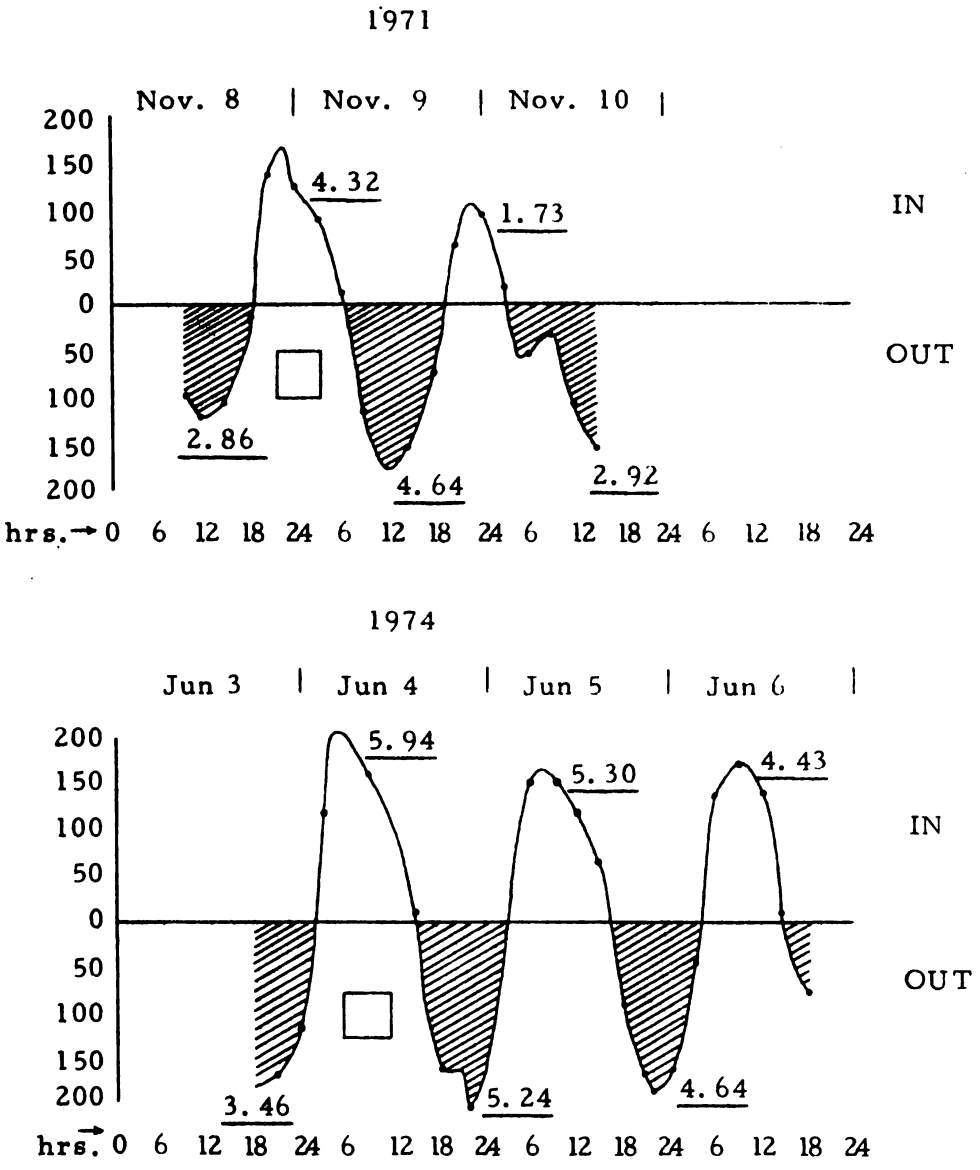

□ = 1.08 X 10^9 cu. ft. of water

2.34 = billion of cu. ft. of water in the inflow or outflow regime

(From U. S. G. S. Water Resources Division and Texas Water Development Board Data)

FIGURE 6 INFLOW AND OUTFLOW AT ARANSAS PASS

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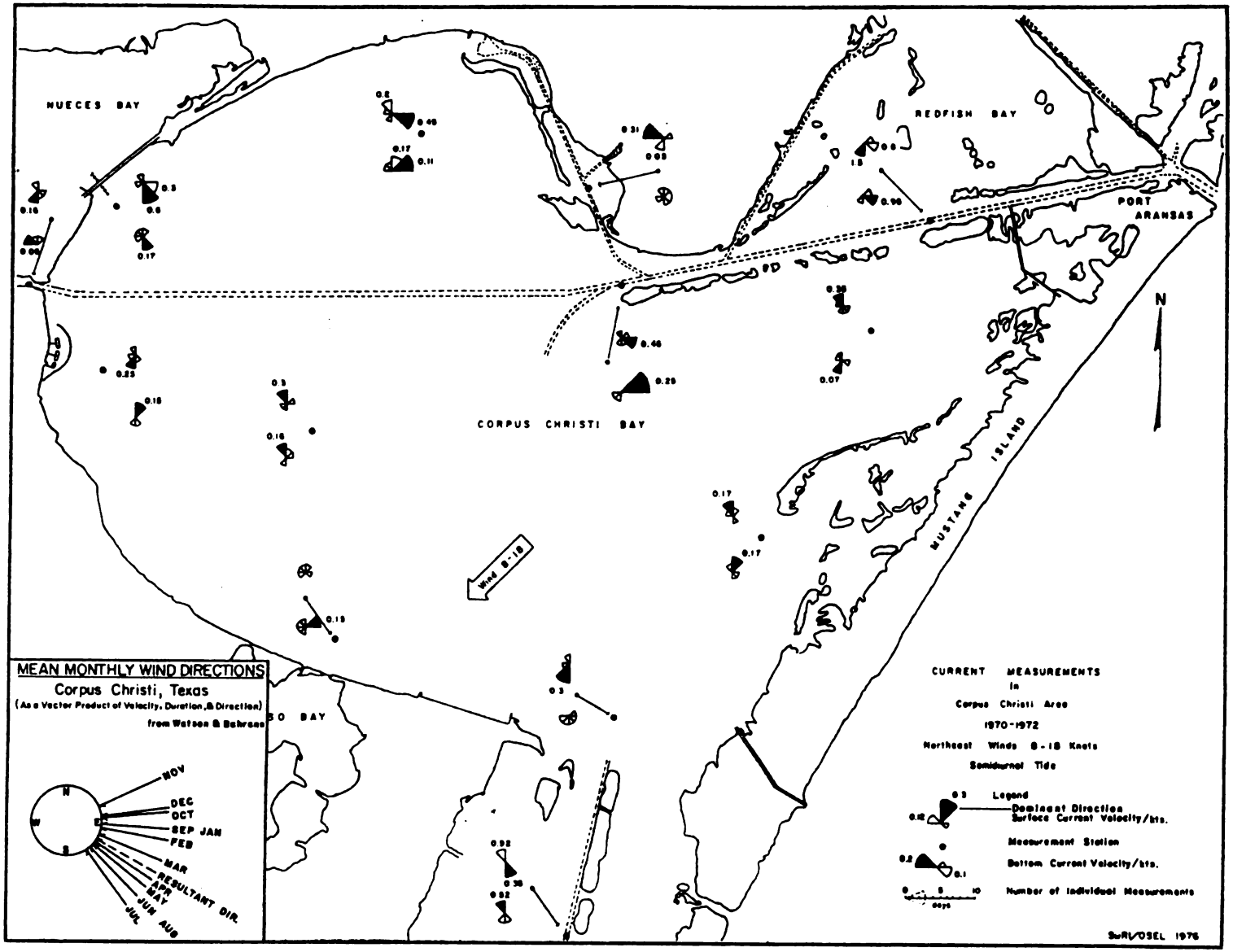

FIGURE 7. CURRENT MEASUREMENTS IN CORPUS CHRISTI AREA - 1970-1972
(Northeast Winds 8-18 Knots - Semidiurnal Tide)

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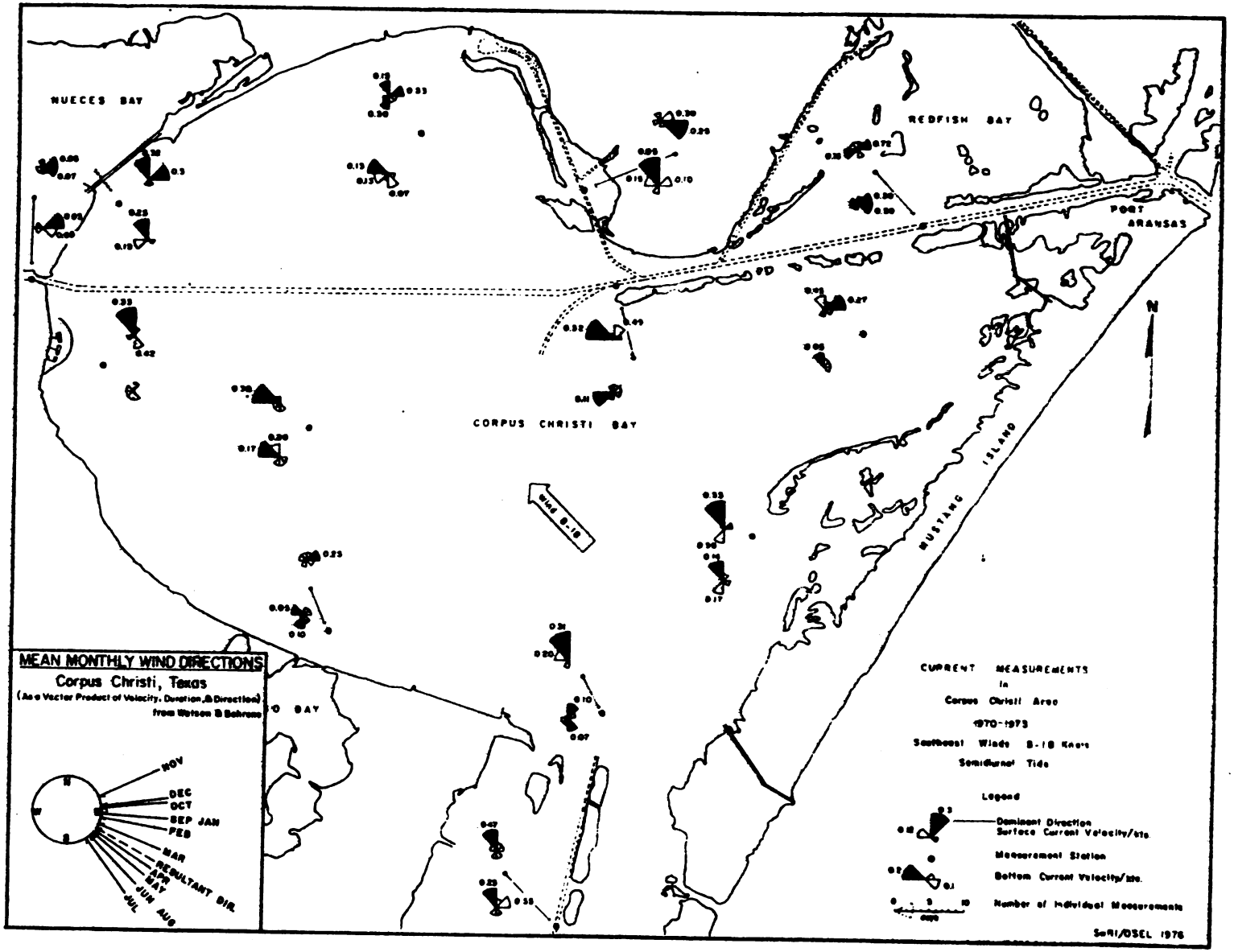

FIGURE 8. CURRENT MEASUREMENTS IN CORPUS CHRISTI AREA - 1970-1973
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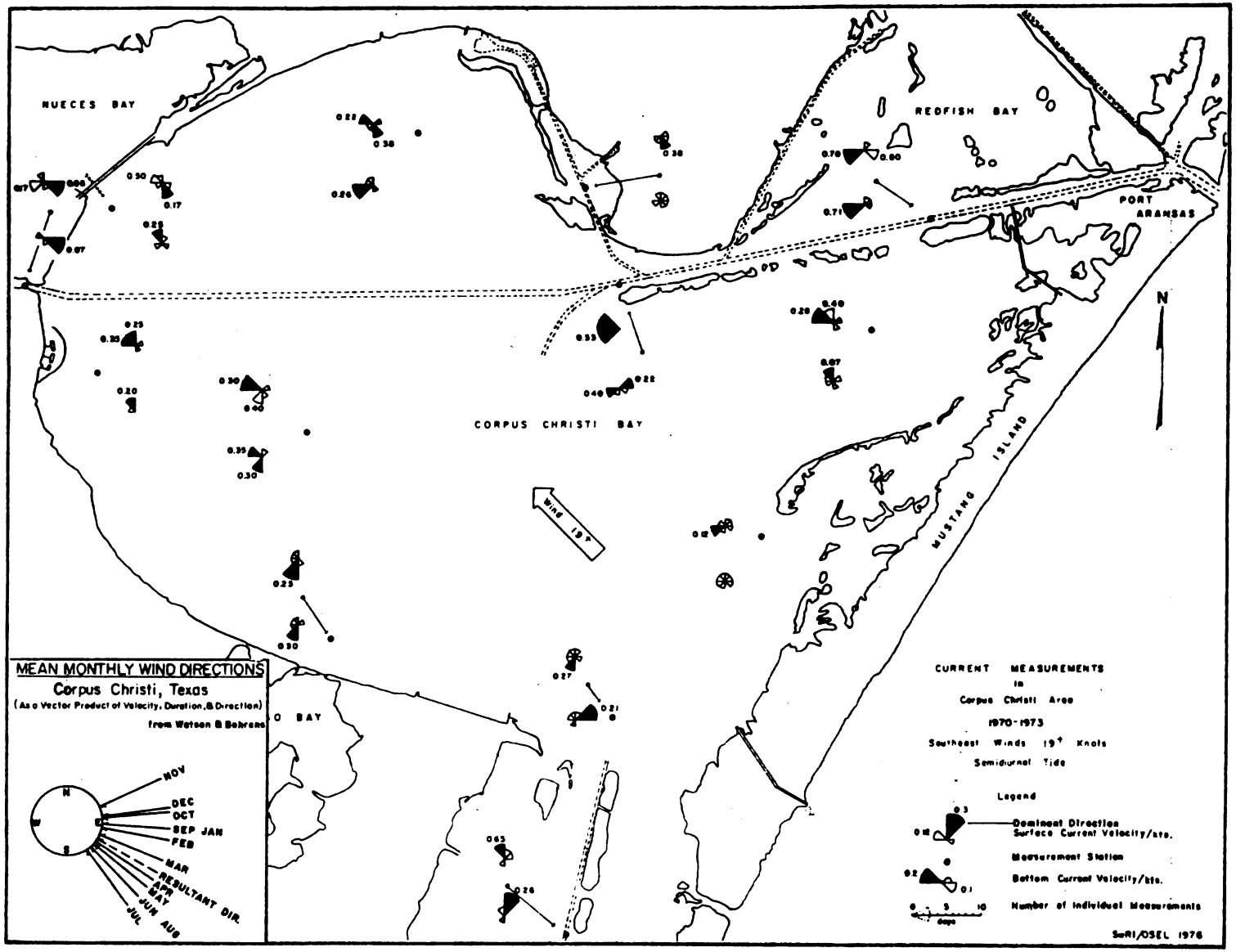

FIGURE 9. CURRENT MEASUREMENTS IN CORPUS CHRISTI AREA - 1970-1973
(Southeast Winds 19^{+} Knots - Semidiurnal Tide)

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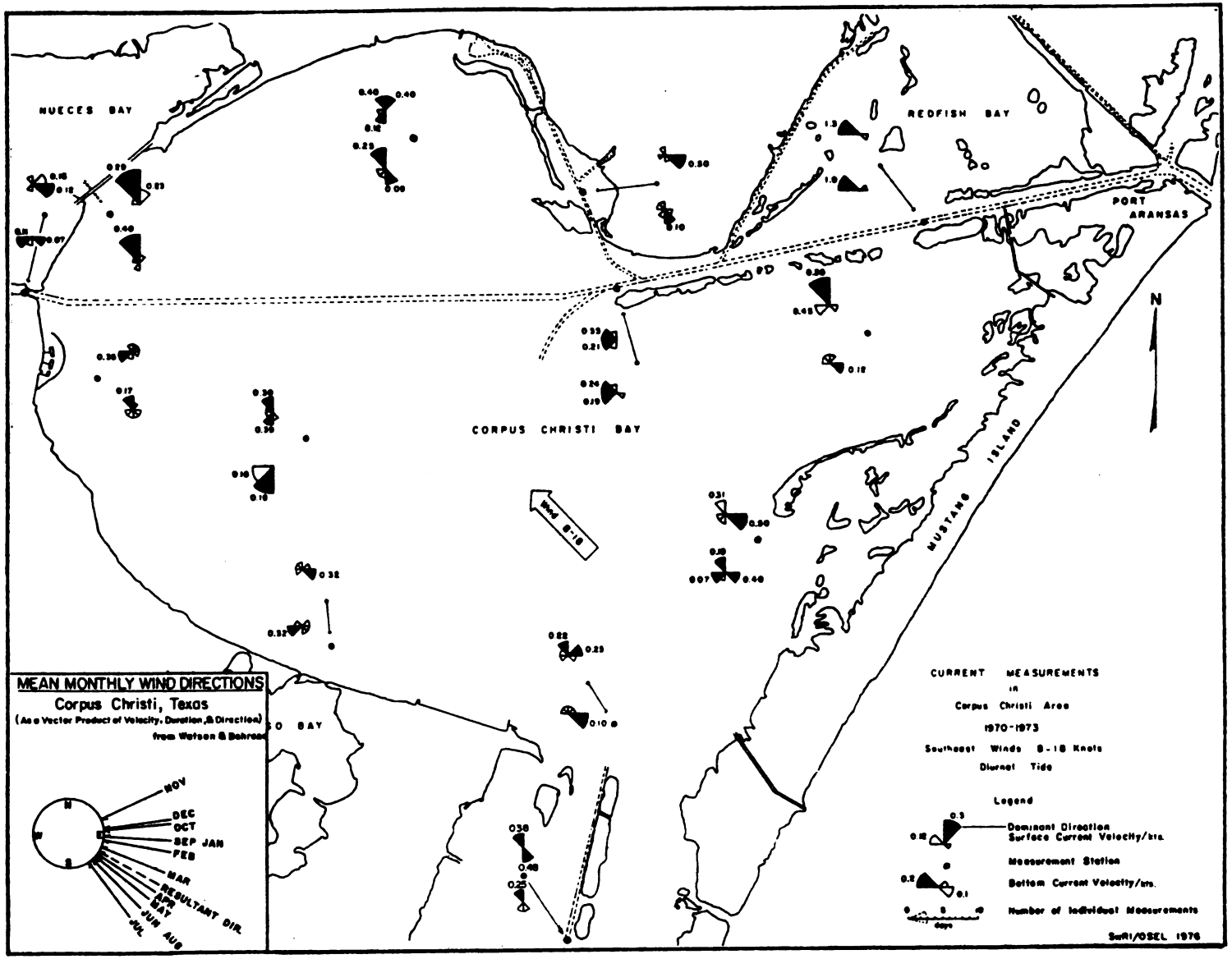

FIGURE 10. CURRENT MEASUREMENTS IN CORPUS CHRISTI AREA - 1970-1973
(Southeast Winds 8-18 Knots - Diurnal Tide)

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2.61 A series of four additional maps drawn from the limited, and only available, data compiled over a period of several years depicts what are believed to be the general circulation patterns in Corpus Christi Bay under different wind/tide regimes for both near-surface and near-bottom depths (Figure 11 thru 14).

2.62 In general, the southeasterly winds set up a northwesterly flow into North Bay where the waters abut the shores and are deflected both to the northeast and southwest following the configuration of the shoreline and eventually rejoin the northwesterly flow. The surface waters set up several gyrelike flows which persist, in each of the mapped wind speed regimes. The gyres occur in North Bay, in the Alta Vista Reef area on the west side of the Bay, and in the northeastern sector north of Shamrock Cove. Bottom water circulation in the bays follows the near-surface flow but may locally oppose the uppermost water movement, especially along the windward shorelines.

2.63 From the available data, northeasterly winds do not appear to set up the strongly discernable flow pattern expected. It is possible that the available data are too limited or the short period of the normal frontal passage does not afford sufficient time for the flow patterns to develop. Also, the measurements may have been made during the early part of the frontal passage.

2.64 The circulation on the continental shelf off of Corpus Christi is only partially understood. Nearshore there is a southerly moving current while farther offshore there is a northward moving current. Nearshore currents along the coast off the barrier islands are quite complex. The alongshore currents have a tendency to reverse every 50 miles or so. There is a fairly consistent reversal point that oscillates between Aransas Pass and the north end of Padre Island. The flow diverges to the north and south at this point. Smith (1974) has made both near surface current and bottom current measurements seaward of Aransas Pass and observed a bi-directual bottom current with a speed of about 0.58 knots at a depth of 36 feet.

2.65 Littoral Sediment Drift. Prevailing winds from the southeast develop wave trains that are translated into extensive breakers as the waves contact the bottom of the smooth, gently sloping inner shelf and shoreface. These wave trains result in secondary waves and currents that control deposition and erosion along barrier island beaches.

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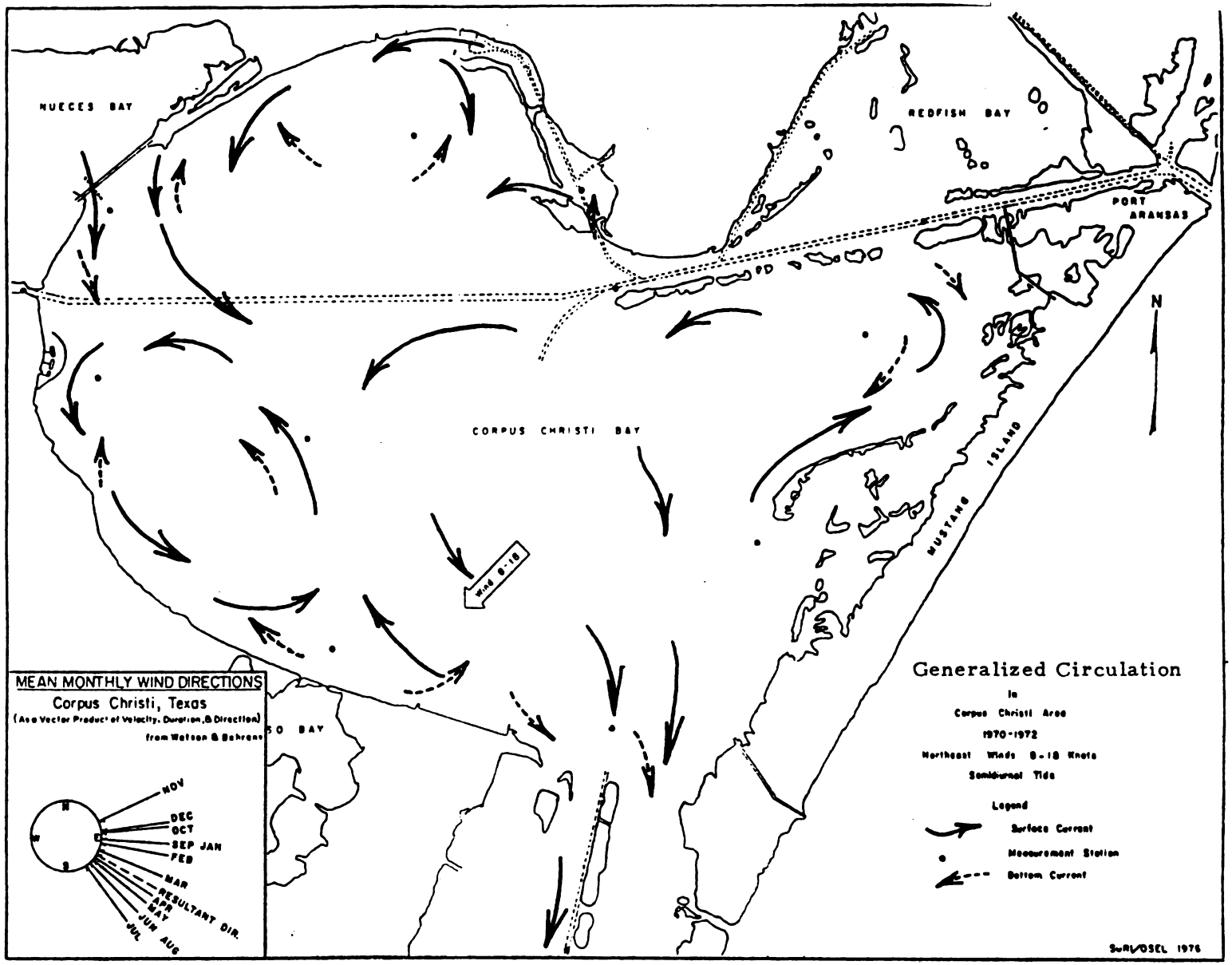

FIGURE 11. GENERALIZED CIRCULATION IN CORPUS CHRISTI AREA - 1970-1972
(Northeast Winds 8-18 Knots - Semidiurnal Tide)

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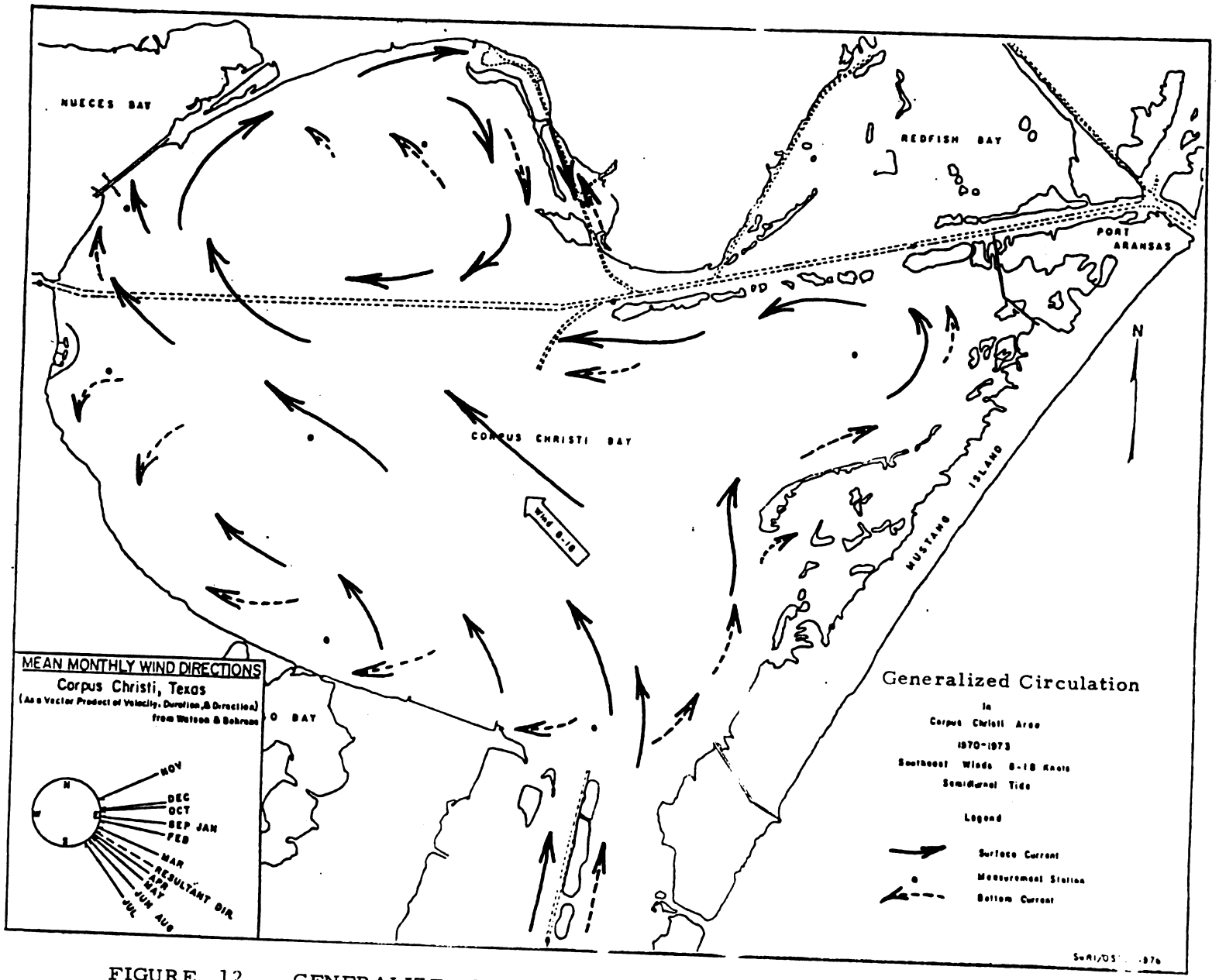

FIGURE 12. GENERALIZED CIRCULATION IN CORPUS CHRISTI AREA - 1970-1973
(Southeast Winds 8-18 Knots - Semidiurnal Tide)

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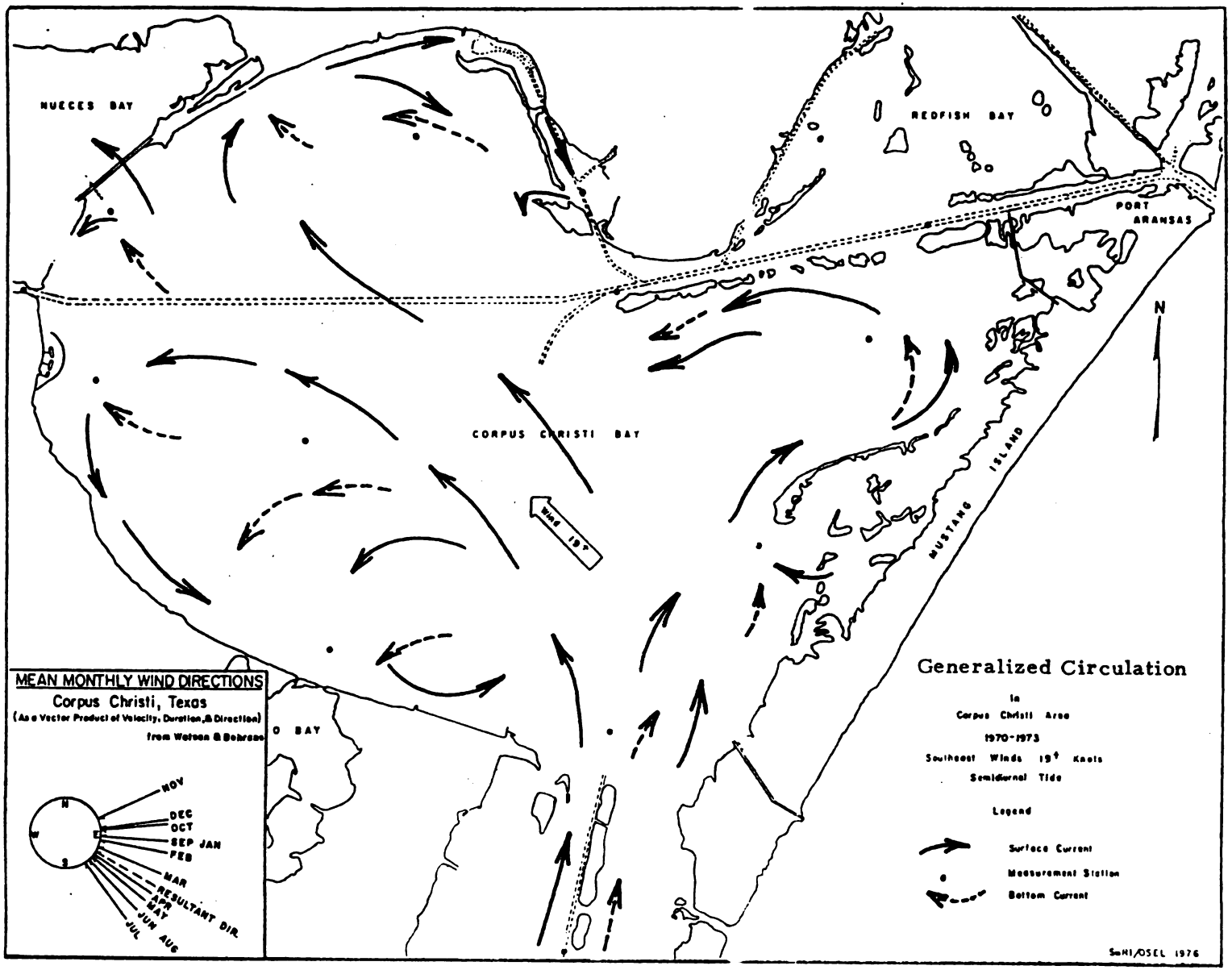

FIGURE 13. GENERALIZED CIRCULATION IN CORPUS CHRISTI AREA - 1970-1973
(Southeast Winds 19+ Knots - Semidiurnal Tide)

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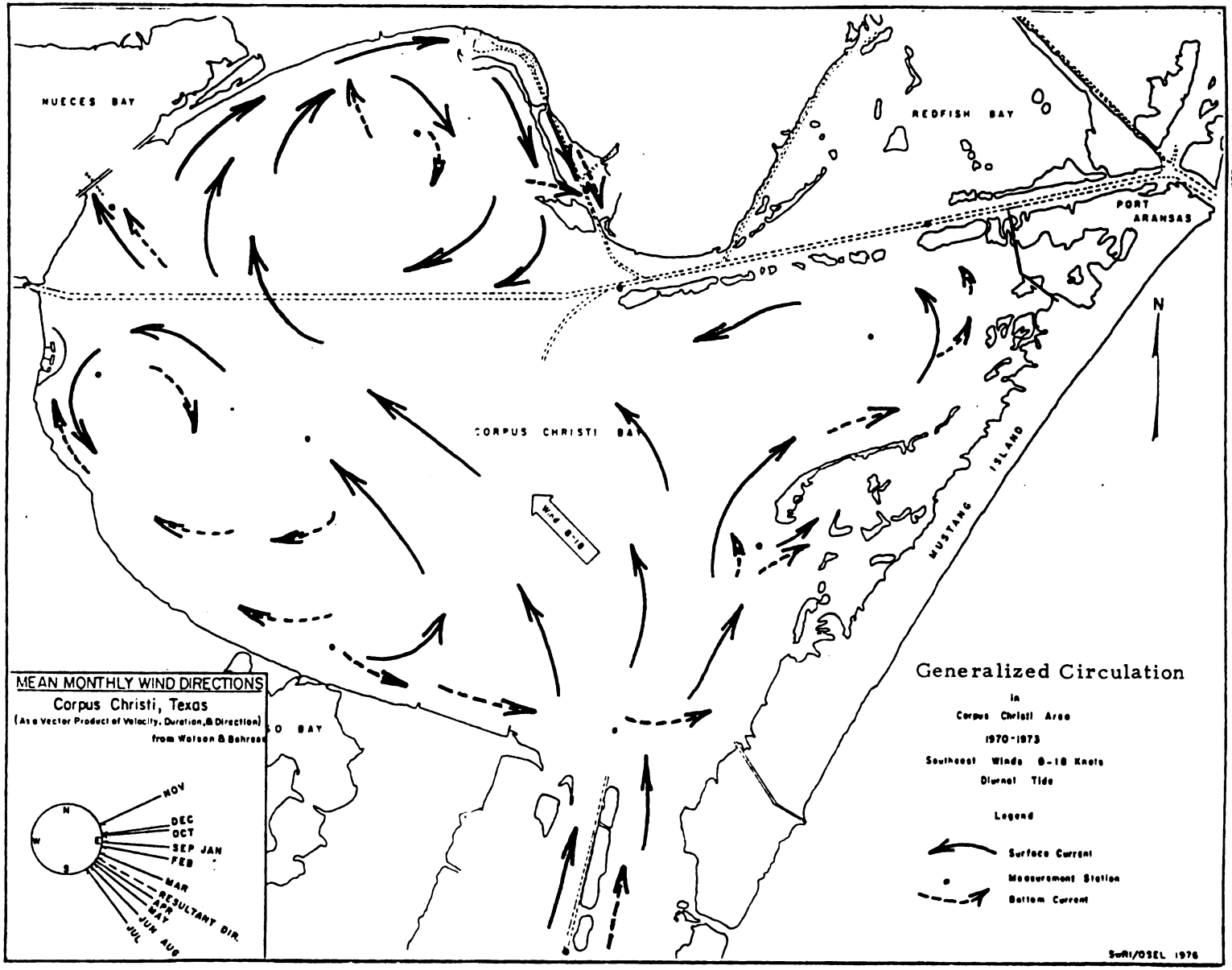

FIGURE 14. GENERALIZED CIRCULATION IN CORPUS CHRISTI AREA - 1970-1973
(Southeast Winds 8-18 Knots - Diurnal Tide)

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Wave crests oriented northwest-southeast move onshore where they strike the coastline at very low angles to the north and south along the coastal bend. Waves may break and reform three or four times across the broad shoreface, resulting in three or four lines of breakers and associated breaker-point bars of shell and sand that change size and shift position as wave size varies.

2.66 Because wave trains generated by the prevailing southeast winds cross the shoreface and strike the concave shoreline at low angles, net longshore drift occurs. Within the Corpus Christi area two opposing drift directions occur during the summer months. Along the south shoreline, drift is generally to the north, and along the northeastern part of the area drift is southward. Waves approach the shoreline almost at right angles in the region just north of Aransas Pass. In this area there is virtually no longshore drift component; this is the area of longshore drift convergence. Within the area of longshore drift convergence, there is sediment accumulation and short term shoreline accretion or equilibrium. Longshore drift direction shifts in compliance with the wind regime, and the net result of the interaction of the wind regime in the Gulf of Mexico with the orientation of the Texas shoreline is a net longshore drift convergence near the north end of Padre Island. Under the southeasterly wind regime, sediment continually moves onshore to the beach where swash removes the fine particles that are returned to deeper waters of the shoreface and inner shelf. Storms may also push large volumes of sand high onto the beach to produce storm berms, either to be eroded and redistributed or to be stabilized as beach ridges by vegetation.

2.67 If a sand supply is available from rivers located farther to the northeast and south, and from along the shoreline, and from the sea floor sources on the nearby inner shelf, the sandy beach and shoreface will slowly build seaward. If sand is in short supply, perhaps because little is available from rivers or from offshore, beaches will become sand-starved and will be composed of broken shell and rock fragments which constitute the dominant available sediment. Active shelly beaches are sand-starved and normally shift landward during their development due to the absence of sufficient sand nourishment.

2.68 Water and Sediment Quality. The navigation channels in the project area are subject to flushing action from tidal currents and have no apparent stagnation problems.

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However, in the inner harbor of the Corpus Christi Ship Channel and nearby Corpus Christi Bay, discharges of waste effluents from the industrial plants have resulted in water and sediment quality degradation. The effluent discharges are made under permits of the Texas Department of Water Resources and the Environmental Protection Agency. More stringent water quality standards and effluent regulations now in force may result in improvement of Inner Harbor conditions, but changes are expected to occur only very slowly.

2.69 The following paragraphs summarize data for salinity, temperature, dissolved oxygen, transmissivity, suspended solids, heavy metals, nutrients, and biological oxygen demand for the Corpus Christi area as a whole.

2.70 Salinity in Corpus Christi Bay has varied from 65 ppt in 1963, a year with a total of less than 15 inches of rainfall, to a low of 2 ppt following the heavy rains associated with hurricane Beulah in 1967. Within a yearly period salinities have ranged from a minimum of 8 ppt to a maximum of 43 ppt, and the average variation within a year is more than 20 ppt. The Bay areas with the most extreme variances in salinity are the shallower portions of north Corpus Christi Bay near the opening to Nueces Bay (because of fresh water inflow) and the southeastern portion of the Bay off the entrance of Laguna Madre (because of inflow of high salinity water).

2.71 Throughout the Corpus Christi Bay, the average bottom salinity is higher than the average surface salinity by 0.5 to 1 ppt, but greater variations are found in areas near sources of freshwater or highly saline waters and in the deeper waters of the ship channels. For example, La Quinta Channel shows an average salinity change of more than 4 ppt from surface to bottom water, while the change in the Corpus Christi Ship Channel averages about 2 ppt. Average salinity during the past 5 years in Corpus Christi Bay, including the channels, is 28 ppt.

2.72 Because of its shallow depths and proximity to the Nueces River, Nueces Bay has a wide variance in salinity. Low salinity levels occur during periods of heavy rainfall in the watershed while high salinity readings occur during periods of drought. Historical data are not as extensive for Nueces Bay as for Corpus Christi Bay, but salinity measurements ranging from 0 ppt to 54 ppt have been recorded during the past 20 years. A power plant located on the

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south-central side of Nueces Bay discharges large volumes of water from the Inner Harbor into Nueces Bay, tending to somewhat stabilize the Bay salinity. The overall average salinity in Nueces Bay since 1970 is 22 ppt, but an increase in averages of several ppt is expected with the increase in power plant discharge.

2.73 Historical salinity data in the Inner Harbor of the Corpus Christi Ship Channel over the past 10-15 years are insufficient in quantity and frequency to establish a reliable set of long-period yearly averages; however, data collected over the past six years shows a top-to-bottom average of 27 ppt. Extremes recorded were 48 ppt in 1963 and 10 ppt in 1968. Pre-1970 years with satisfactory salinity data for the Inner Harbor including annual range and regional rainfall measurements (illustrating the relationship between salinity and rainfall and the wide variance from year to year in the past) are as follows:

Year	Salinity Average(ppt)	Salinity Range (ppt)	Rainfall(in)
1946	29	25-36	34.1
1947	31	28-37	33.3
1963	37	32-48	14.6
1968	15	10-22	41.5

2.74 Salinity sampling coverage of Redfish Bay is meager, and data are not available for all seasons. However, on the basis of the available information, the average salinity for the Bay is estimated at about 25 ppt.

2.75 Aransas Bay salinity averages are calculated from the available seasonal samplings. These values are probably lower than normal due to a heavy upland rainfall. Data from Corpus Christi and Nueces Bays were affected by the same inflow of fresh water, but the larger number of measurements there provide a more statistically reliable average. The water column salinity average in Aransas Bay is 19 ppt which reflects the abnormally low readings measured during November of 1971 (10 ppt). If the November 1971 values are omitted from the average of the nine readings at each Aransas Bay station, an overall average salinity of 22 ppt results.

2.76 Dams constructed along rivers for municipal reservoirs will decrease the peak natural river flow of fresh water into the back bays, and increase the salinity particularly in the segment containing the river mouth. A large share of

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the reservoir water used in community activities (industry, yards, sewage, etc.) returns to the Bay system minimizing the salinity change. In addition, control of rivers may smooth peak inflows due to heavy upstream rainfalls.

2.77 Large industrial or utility plants can alter the salinity in a segment of the Bay system by drawing water from one water body and discharging into another body having a different salinity, such as from Corpus Christi Inner Harbor into Nueces Bay (normally of lower salinity), or Laguna Madre (usually higher salinity) into Corpus Christi Bay via Oso Bay. Depending on the time of year, rainfall, and climatic cycle, the overall effect on the salinity in the various segments of the Bay can vary, but generally the effect is one of moderation of the extremes experienced.

2.78 Opening of passageways to the Gulf or between two other segments also has a moderating influence on the salinity of the involved water bodies. Similarly, water circulation changes caused by island construction could alter the salinity of various bay segments. Variations in salinity in conjunction with the progressive deepenings of the Aransas Pass Channel and the Corpus Christi Ship Channel are poorly documented but no evidence of a noticeable salinity change in Corpus Christi and Aransas Bays is indicated by historical information.

2.79 Historical salinity values are displayed in Figure 15. Averages for the bay systems segments are given as well as values for individual stations.

2.80 Temperature. Temperature of the study area's waters is controlled by average insolation (incoming solar radiation). The surface waters approximate the atmospheric average with the winter months of record averaging from 56°F (13°C) to 59°F (15°C), with an extreme low of 50°F (10°C) while the summer months average from 82°F (28°C) to 85°F (29°C) with an extreme of 91°F (33°C). The deeper areas maintain cooler temperatures than the shallow areas in the summer time and warmer temperatures than the shallows in the winter season. During periods of cold weather the temperatures of the shallow bays and surface waters of deeper areas may approach 37°F (3°C), while during extremely warm summer conditions the same area's temperature may rise above 91°F (33°C). Occasionally, during strong northers such as in 1951, the shallow margins of the bays are exposed to freezing temperatures, and ice may form in the nearshore fresher portions. These extreme conditions persist only for short time periods.

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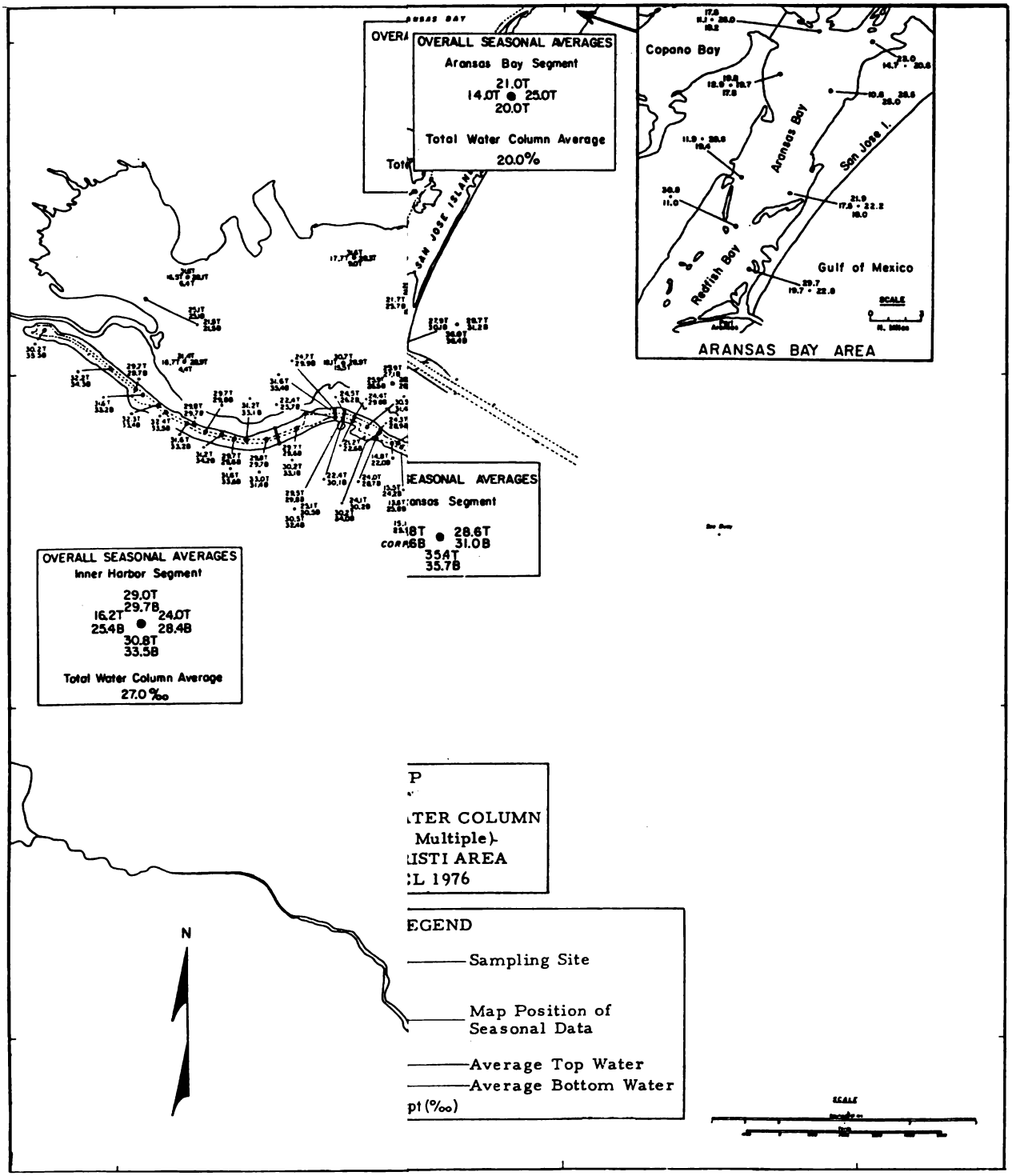

VATER COLUMN IN CORPUS CHRISTI AREA

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2.81 Temperature varies inversely with water depth in the summer months. In the winter months the reverse is true with temperature increasing with depth. Thus, the deeper channels are coolest in the summer, warmest in the winter and offer nektonic life forms a haven of retreat from the more variable conditions of the shallow water.

2.82 Man can influence water temperature in the Bay system on a local basis through the introduction of heated or cooled waters from industrial sites and treatment plants. Warmed waters used in cooling processes are added to the Inner Harbor, Nueces Bay, and La Quinta Channel, increasing temperatures slightly adjacent to the discharge sites.

2.83 Dissolved Oxygen. Dissolved oxygen (DO) is a measurement of the quantity of uncombined oxygen (expressed in parts per million) in a given water sample. Dissolved oxygen measurements have been taken in the Bay for at least the last 30 years, but were sporadic in time and space until the last 5-7 years of record. The quantity and quality of dissolved oxygen measurements are sufficient to allow the calculation of a diagnostic base condition, as well as to aid in the determination of possible temporal and spatial trends.

2.84 Dissolved oxygen data for the past years have been compiled from Federal, state, county and municipal agencies, industrial organizations, university publications, Southwest Research Institute files, and recent field studies to prepare the exhibits and information for this section. Figure 16 shows the long period average, yearly average, and the yearly range of dissolved oxygen in Corpus Christi Bay. Figure 16 indicates the general trend over several decades and shows a comparison of the rainfall and dissolved oxygen. It should be noted that during some years the high rainfall does not necessarily correlate with the high DO averages, but the broad yearly range suggests that periods of high DO are related to massive rains and low oxygen readings to high salinity periods (corresponding with low rainfalls). Another possible correlation which has not been verified is that between winds, rainfall and DO since high winds could increase DO levels.

2.85 The highest DO reading found for Corpus Christi Bay was 13.5 ppm (supersaturated), in the winter of 1973 in the Shamrock Cove area. Other similarly high supersaturated DO readings have been reported in Aransas Bay during the winter months of 1972 and 1973.

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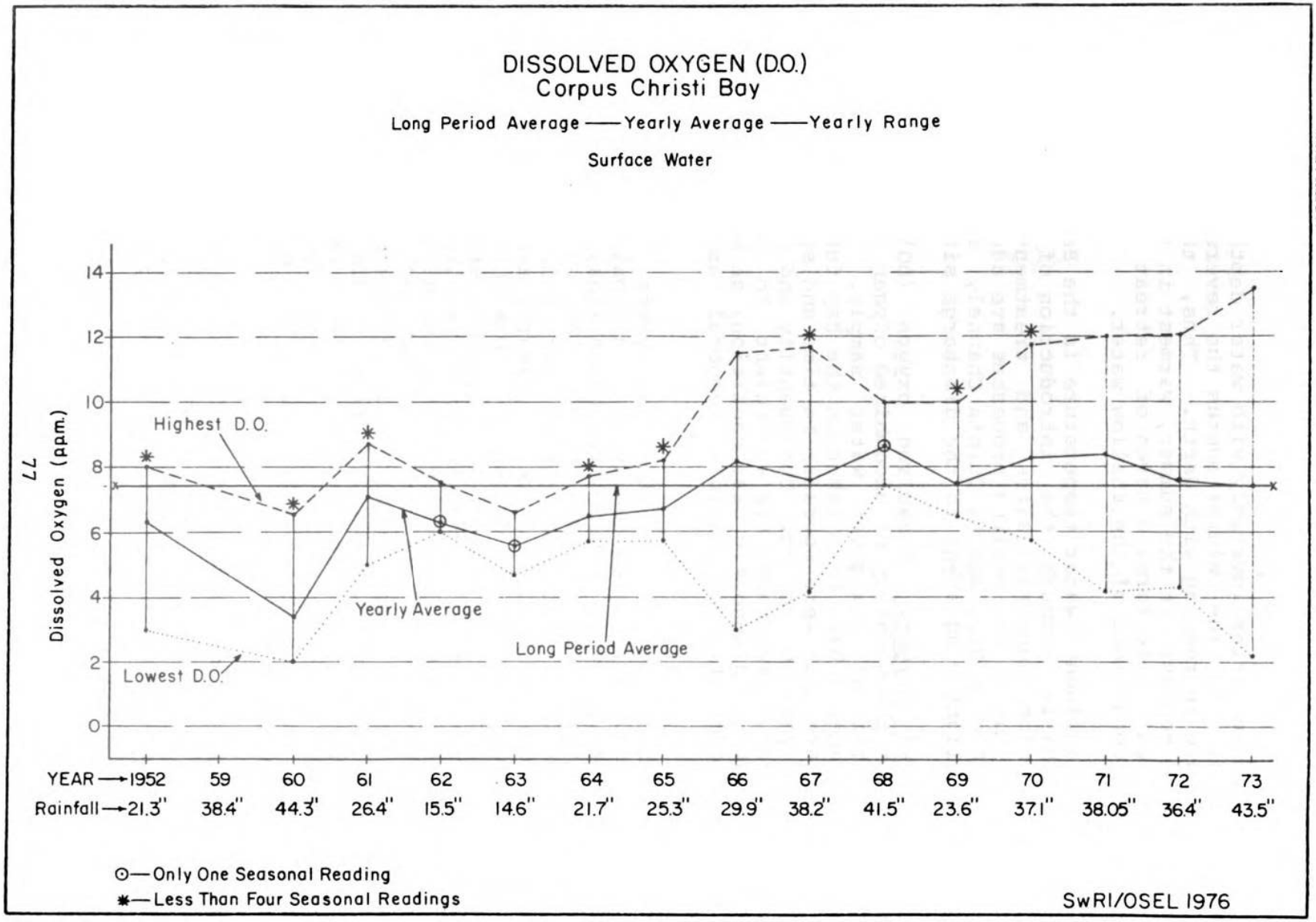

FIGURE 16. DISSOLVED OXYGEN (D. O.) IN CORPUS CHRISTI BAY

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2.86 Low DO values of near 1.0 ppm at the bottom have been recorded in the Inner Harbor in the summers of 1944, 1946 and 1970. Seasonal averages for Corpus Christi Bay are more moderate, being 6.7, 7.9, 8.6, and 6.8 parts per million in the summer, fall, winter and spring in the top water, and 5.1, 7.6, 8.5, and 6.0 on the bottom, respectively. The average annual DO value for the various segments of the system are:

Dissolved Oxygen in ppm

	Surface Avg.	Bottom Avg.	Water column Avg.
Corpus Christi Bay	7.5	6.8	7.1
Nueces Bay	7.7	-	8.0
Inner Harbor	6.4	3.5	4.9
Redfish Bay	7.3	7.3	7.3
Port Aransas Channel	-	-	-
Aransas Pass	9.1	-	-

Figure 17 shows averages for all of the available dissolved oxygen data in the Bay system. The average for each of four seasons and summary averages for each Bay segment are presented. The data suggest the Bay system has only a few areas that might be of concern because of seasonally depressed dissolved oxygen.

2.87 The western end of the Corpus Christi Inner Harbor has experienced low dissolved oxygen values in the bottom waters during the summer months. DO values below 4.0 ppm, which is considered by many to represent the lower limit of the DO range for marine animal life, tends to occur in areas of deep water having warm temperatures, high salinity, weak circulation, low wind speed, and high chemical and biological oxygen requirements.

2.88 A combination of all these factors may exist during the late summer months in the Corpus Christi area. The Inner Harbor, because of its landlocked nature, is more influenced by these conditions than other segments of the bay system, although La Quinta Channel turning basin is affected to a lesser extent. Warm water can dissolve less oxygen than cold, and saline water less than fresh water. Tidal ranges decrease in late summer thus reducing water exchange. Wind speeds also diminish during the summer months lessening the wave agitation, and the greater solar intensity increases plant and animal growth that demands a

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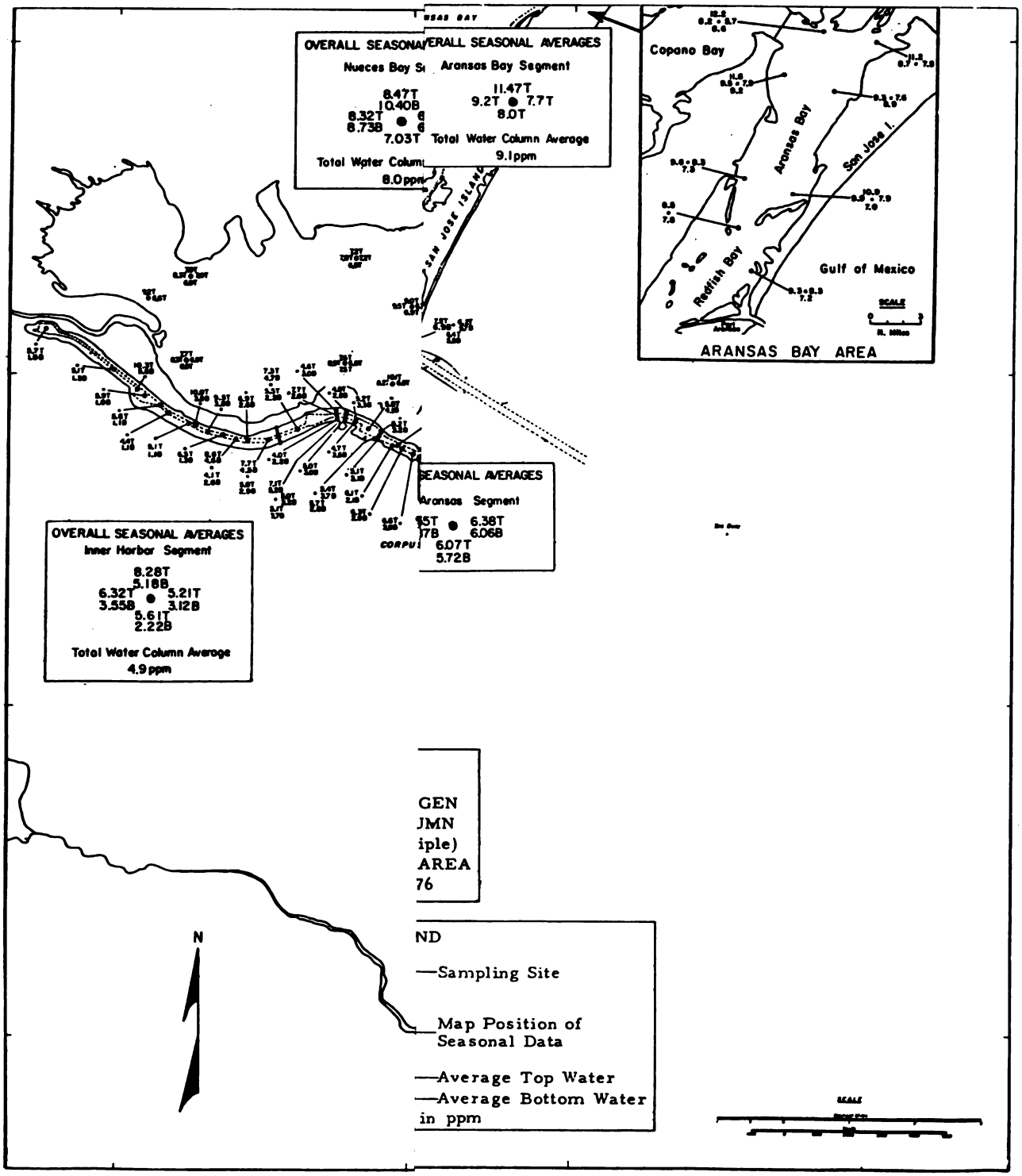

SSOLVED OXYGEN IN WATER COLUMN

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net increase in oxygen. In addition, oxygen dependent chemical reactions normally increase with temperature to deplete the available oxygen. Some investigators have concluded that turbidity increase in waters correlates with decrease in the dissolved oxygen. This does not appear to be a significant relationship for Corpus Christi Bay where the wave agitation of the shallow waters produces areation as well as turbidity. In the Inner Harbor where transmissivity values are usually high there is a lack of correlation with DO also.

2.89 Fish kills have not been more abundant in the Inner Harbor during recent years than in other segments of the bay system. Further, the annual fish kill experienced in the system does not seem to correlate with the period of low dissolved oxygen in the Inner Harbor or elsewhere in the system. Fishes that find the seasonal low oxygen content intolerable in the Inner Harbor apparently move upward in the water column or leave the area until higher levels of dissolved oxygen return.

2.90 The DO levels in the bay system apparently have not undergone serious modification by natural conditions or the activities of man over the period covered by reliable data. Lowering sufficiently the amount of chemicals and organic materials which utilize oxygen in the system could raise the dissolved oxygen levels during the summer months in a confined area such as the Inner Harbor. Since dissolved oxygen values during the winter months are satisfactorily within the prescribed limits and since man's discharges in the summer and winter months are of similar magnitude it is doubtful whether the change would be large enough to appreciably alter the low DO condition.

2.91 Increases in circulation and flushing action could have a moderating effect and may even tend to add oxygen to the system. Measurements of dissolved oxygen in the channel confluence area at Port Aransas have shown favorable levels at maximum depths.

2.92 Transmissivity. Transmissivity is a measure of the amount of light transferred through a liquid sample relative to an equal path length of distilled water taken as 100 units of transmission (i.e., 100%). Transmissivity values are an accepted means of determining the relative clarity of natural waters. Transmissivity involves both color and turbidity in the water column, i.e. a lower transmissivity indicates darker color or more particles in the water, while

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a higher value indicates lessening color and/or quantities of particulate matter.

2.93 Transmissivity measurements have been made for 10 to 15 years in Corpus Christi Bay, but only the last 6 years were readings frequent enough for analysis. Because the particulate material that occurs naturally in the water is a function of wind-generated agitation in the bay system, the transmisseometer readings reported here have been compiled into appropriate wind speed groups rather than seasonally. The wind groupings selected were 0 to 10, 11 to 20, 21 to 30, and over 30 knots (see Figure 18). Also affect transmissivity in the bay. Currents within the bay system. If currents are flowing unaided by the wind some particulate material will be entrained, particularly in the shear zone near the bottom. These current-induced particulate concentrations are small, however, and are dominated by particulates introduced by wind developed agitation.

2.94 Individual transmissivity measurements in the bay range from nearly 98 percent to 2 percent, but the average of all station transmissivity values for the column with less than 11 knots of wind is 62 percent (top water 69, bottom 55) and 19 percent (top water 19, bottom 19) with over 30 knots of wind. The extremes of average transmissometer values for the total water column at the different stations in the bay under the various wind categories are:

Wind Speed in Knots	Transmissometer
0-10	68-35
11-20	66-24
21-30	62-19
over 30	32- 1

Generally the top water values in the water column sampled average about 5 points higher (clearer) than bottom values.

2.95 Nueces Bay is more turbid than Corpus Christi Bay, primarily due to its shallow depth, about 3 feet in most places. In Nueces Bay the turbulence generated by wind induced waves is strong from the surface to the bottom, so that low transmissivities are found in the bay even during low wind velocities. Nueces Bay exhibits averages for the various wind groups as shown in Figure 19. The ranges of average transmissivity for the different wind speeds are:

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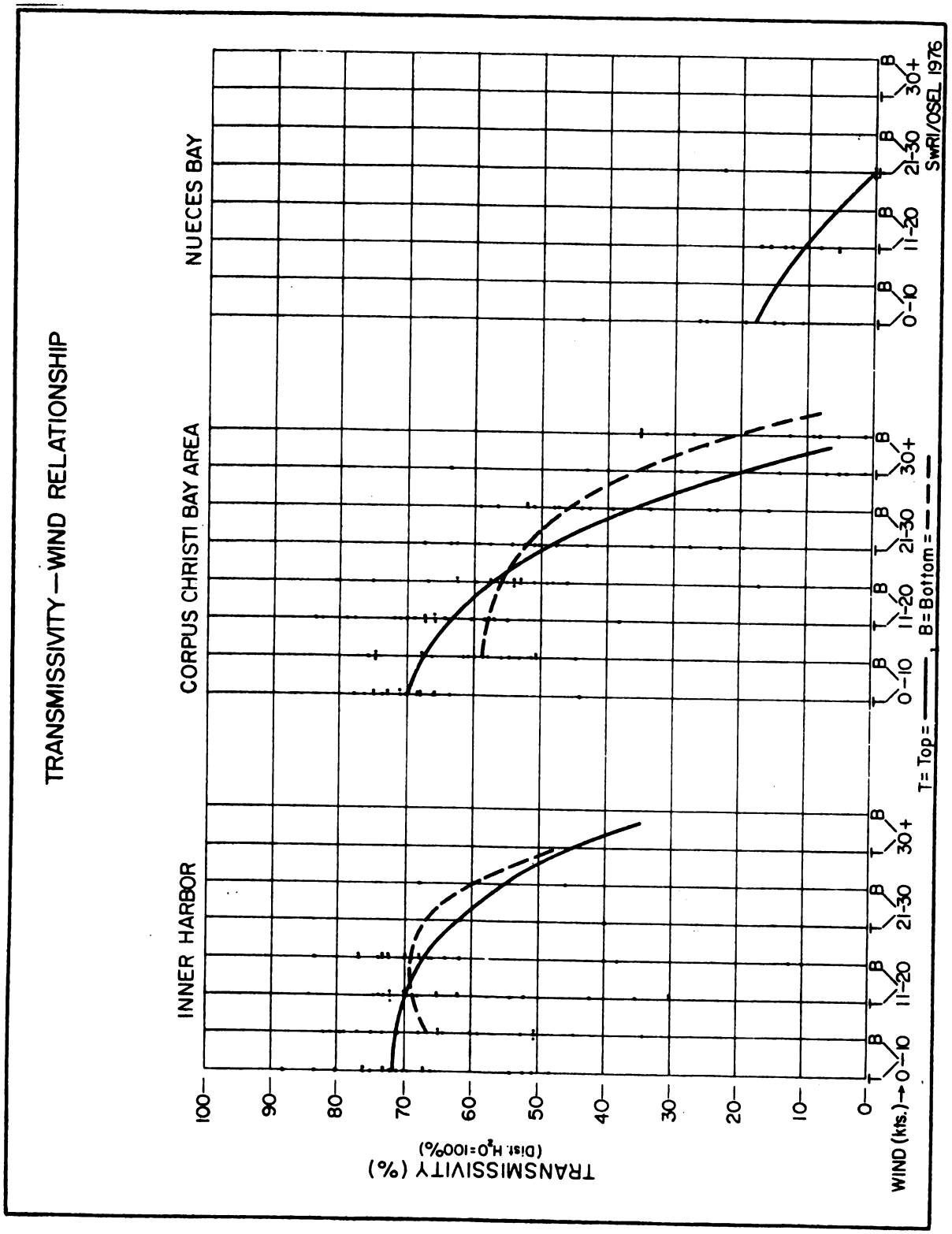

FIGURE 18. TRANSMISSIVITY - WIND RELATIONSHIP

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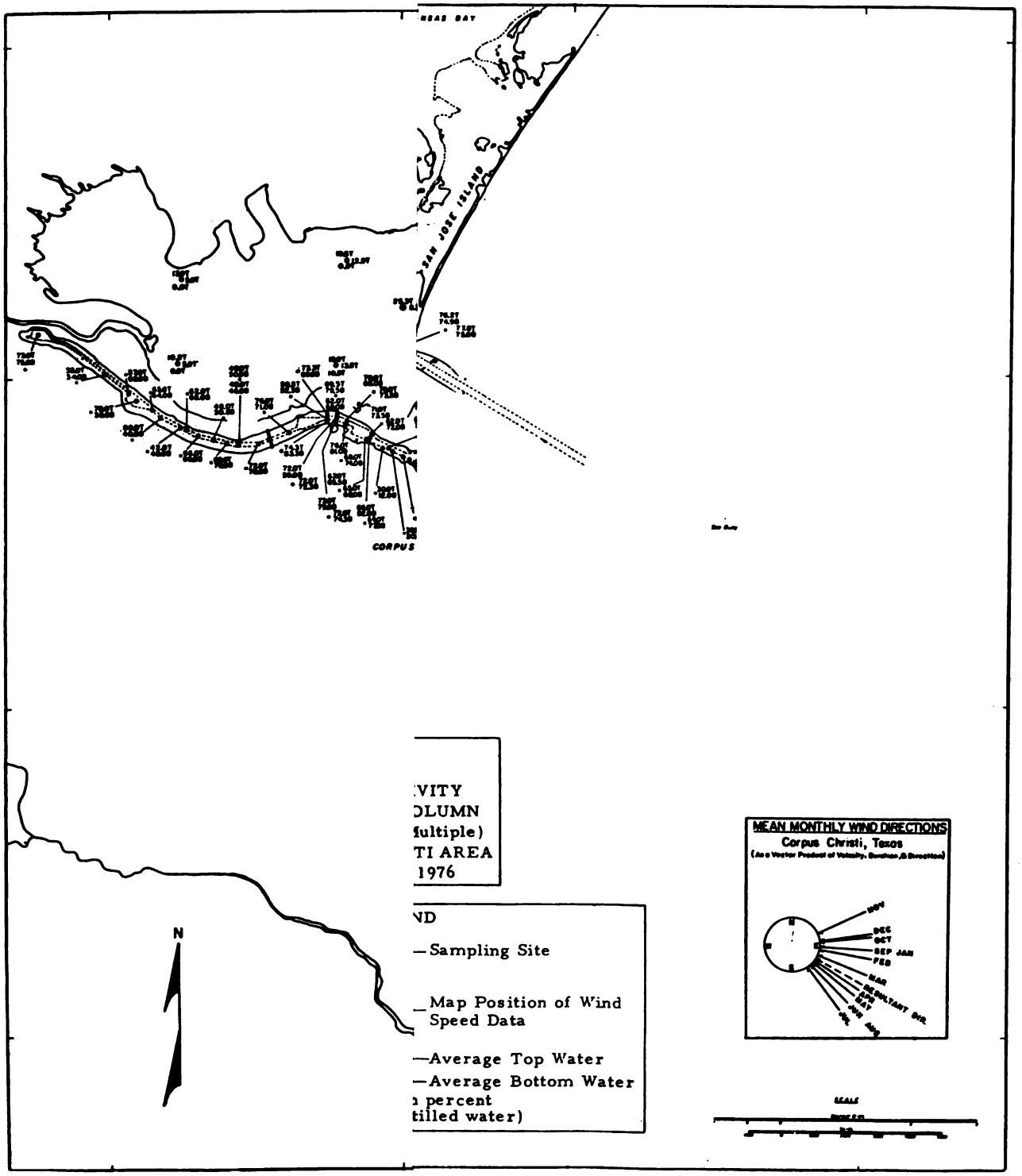

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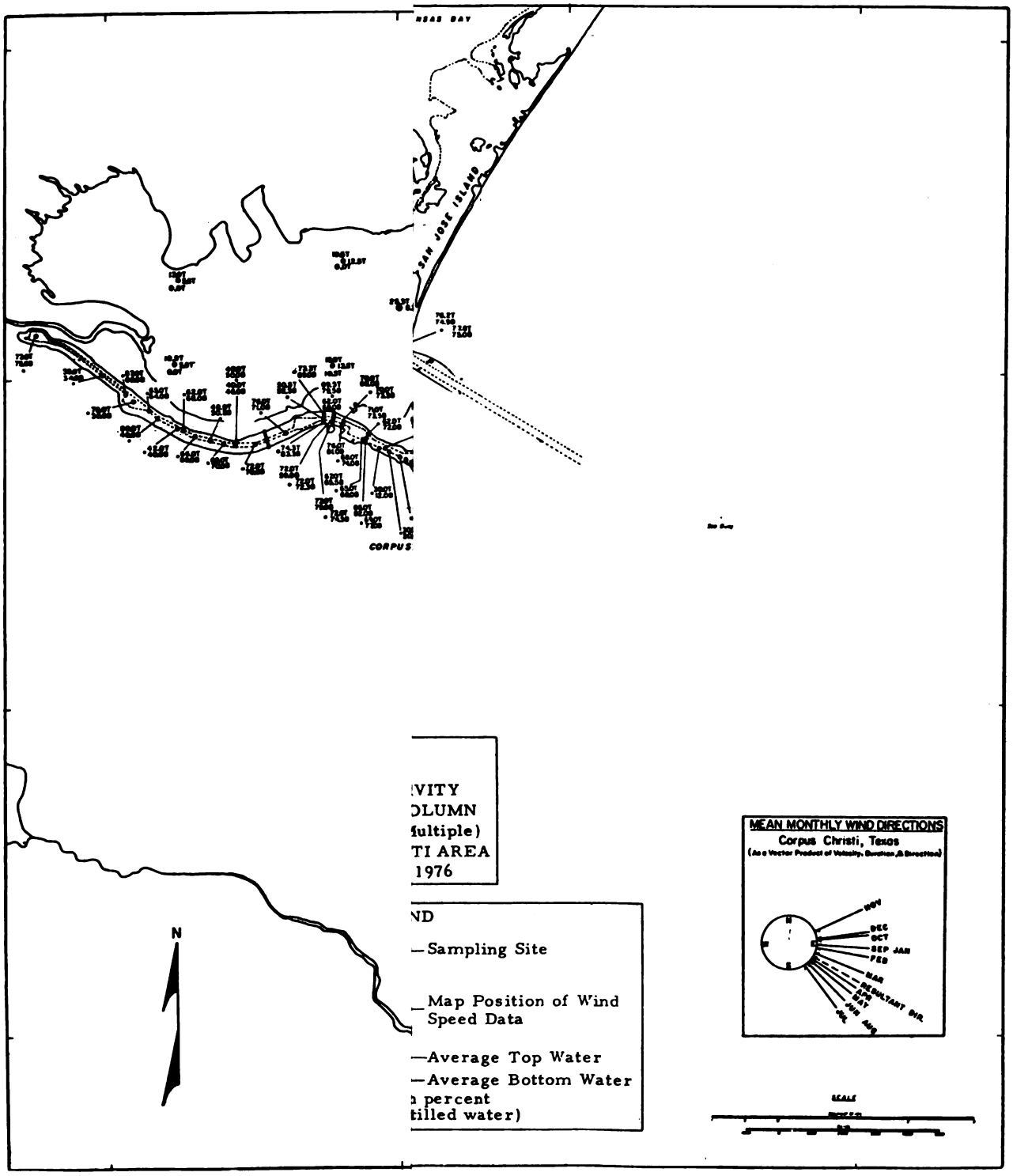

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Wind Speed in Knots	Transmissometer
0-10	26-11
11-20	16- 6
21-30	11- 0

2.96 The Inner Harbor Area is clearer than Corpus Christi Bay, with values rarely lower than 40 percent and averaging 61 percent under all wind conditions. The insensitivity of this area to wind action probably results from its secluded nature, depth, and its limited exchange with Corpus Christi Bay resulting from small tidal level changes. (See Figures 18 and 19 which show the relationship between top and bottom readings in the Inner Harbor, Corpus Christi Bay, and Nueces Bay).

2.97 The La Quinta Channel also exhibits the effects of a wind-sheltered environment in its high transmissivity readings. The La Quinta surface waters average 67 percent and the bottom 54 percent under gentle breezes, and during strong winds average 58 and 52 percent, respectively. The protection afforded by the flanking emergent islands allows the waters in La Quinta Channel to maintain a greater degree of clarity than the open bay waters.

2.98 The channel waters in the Harbor Island area maintain similar transmissivities to waters in the La Quinta Channel and the Inner Harbor, exhibiting a clearer quality than the open bays and are relatively little affected by increased wind velocities. The Harbor Island area has the highest average transmissitivity values encountered in the bay system. However, these values represent a fairly short sampling period and may not be representative.

2.99 The natural changes in transmissivity probably affect fish life. Those species that find the often highly turbid water conditions in the bays intolerable must migrate to the less turbid channels or to offshore locations during periods of high winds. Since waters of naturally high turbidity dominate the bay system, it is a reasonable assumption that most local species tolerate a wide range of turbidities and thus are able to survive in harsh conditions which develop periodically.

2.100 Vessel traffic, both from large ships in the channels and small craft in the shallower areas of the bay will "stir up" bottom sediments and temporarily decrease the water clarity. Agricultural plowing in the watershed has a

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pronounced effect on the suspended material carried into the bay waters following rainstorms. Increased silting of the bays from these upstream sources has contributed to the shallowing of the bay waters thus increasing the effects of the waves in disturbing bay bottom sediments.

2.101 No change in this parameter's average is anticipated through 1980, as the transmissivity (i.e. turbidity) of the system°s waters is dominated by the wind speed (relatively independent of direction). It is probable that only a major climatic change could cause a significant increase or decrease in seasonal averages. It is assumed that the transmissivity values as described herein are reasonable representations of baseline conditions.

2.102 Suspended Solids. Suspended solids (SS) is the quantitative mass measurement of particulate material suspended in water samples. Suspended solids are expressed as milligrams per liter or parts per million. Suspended solids measurements within the bay system are few in number. Average values from stations throughout the entire system range from 15 to 30 mg/l, with values as low as 2 mg/l being recorded in the ship channels and values as high as 160 mg/l in nearshore areas during periods of high wind velocities. During dredging activities values ranging from 200 to 500 mg/l have been recorded immediately adjacent to the cutterhead, and within the outfall near the point of discharge. The higher levels of suspended solids associated with dredging operations decrease rapidly away from points of discharge and reach ambient conditions within short distances (a few thousand feet), except where strong currents or wave action transport the particles and delay settling. These latter conditions normally occur in channels or in shallow waters along shorelines. Naturally occurring conditions in the bay system during periods of high winds often produce levels of suspended solids similar in magnitude to those in the plumes generated by dredging activities.

2.103 Suspended solids in the water column and the transissivity measurements are closely associated. Light scattering depends on the size and, to some extent, the nature of particles as well as the concentration. No simple, general numerical relationship between suspended solids and transmissivity has been established. No significant change in the ambient suspended solids in the water column of the bay system is expected in the near future.

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2.104 Heavy Metals. More than 2,500 analyses for heavy metals in the water and sediments have been made in the Corpus Christi Bay system over the past 5 years. The sample coverage is broad, including virgin Pleistocene outcrops, Inner Harbor, Nueces Bay, Corpus Christi Bay, Redfish Bay, La Quinta Channel, Harbor Island Channels (Lydia Ann, Aransas, Corpus Christi and entrance) and the Gulf of Mexico. Offshore sample stations have covered the dredged channel, undredged channel, disposal areas, and virgin sites. Maps have been prepared which display the areal distribution and average values for the four heavy metals of concern in the area. The data represented on the maps were compiled from more than 20 different field studies by 15 different investigators. Proposed criteria for heavy metals in water and sediment are as follows:

EPA PROPOSED SEDIMENT CRITERIA OF JUNE 1973 AND QUALITY CRITERIA FOR WATER OF JULY 1976

Sediment (mg/kg)		Water (Mg/l)	
Mercury	1.0	Mercury	0.001
Lead	50.0	Lead	0.05 (See note)
Zinc	75.0	Zinc	0.1 (See note)
Cadmium	2.0	Cadmium	0.005

Note: Proposed criteria of 1973 given because 96-hour LC50 to be determined through bioassay using a sensitive resident species.

2.105 Cadmium in Sediment. The cadmium content of samples of the Pleistocene clay outcrops on the north-side shore cliffs of Nueces Bay indicates a high background level in the virgin material (5.3, 5.3 and 6.8 Mg/Kg). Only one station in Nueces Bay and three stations, all in the ship channel, in Corpus Christi Bay showed higher cadmium levels than the onshore stations. However, a number of the samples from the Inner Harbor, especially at mid reach, exceed the EPA criterion and the values obtained from the outcrop. Analysis of sediment samples collected in the Inner Harbor for the summer months (July, August and September) are consistently 2 to 4 times lower in cadmium than those collected during the colder months (January, February and March). An explanation of this phenonmum is not available,

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but the removal of the cadmium from the sediments into the water column during seasonal changes in temperature, salinity, dissolved oxygen, pH, and other physicochemical factors has been suggested as a possible mechanism. However, as discussed in the next section (cadmium in the water column) higher cadmium levels have not been found in the water during seasonal periods of low cadmium levels in the sediments.

2.106 Sediments analyzed from Nueces Bay exceed the EPA criteria, including one at the mouth of the Nueces River. With the exception of four stations in the Corpus Christi Ship Channel and five stations in the North Bay near the dredged material from La Quinta Channel, Corpus Christi Bay sediments are within acceptable levels (Figure 20). Offshore in the Gulf no unusual cadmium levels were encountered in the channels or in the disposal areas.

2.107 There is no evidence to suggest a rise in the cadmium level in the sediments will occur in any of the Bay system. Planned confinement of material to be dredged from the Inner Harbor Island should reduce the possibility of spread of cadmium from this source into other bay areas.

2.108 Cadmium in Water Column. Cadmium content is considered an important measure of the quality of drinking water and has become a guide to the condition of all water bodies, including saline waters. A proposed criterion (Environmental Protection Agency in July 1976) is 0.005 milligrams per liter (Mg/l). In the Corpus Christi Bay system there have been about 130 analyses made for cadmium in the water column, and only three of these analyses have shown levels exceeding the EPA criterion. Because the ship channels, the Inner Harbor, and Nueces Bay are sites where a concentration of cadmium should be expected, samplings have been concentrated in these areas. Figure 21 shows the sampling locations and the average cadmium concentrations for each of four separate, 3-month periods.

2.109 There is no indication that cadmium in the water column will increase in the bay systems in the near future and no evidence to suggest an upward change due to known activities of the future.

2.110 Lead in Sediment. Values at the midway stations in the Corpus Christi Ship Channel Inner Harbor are

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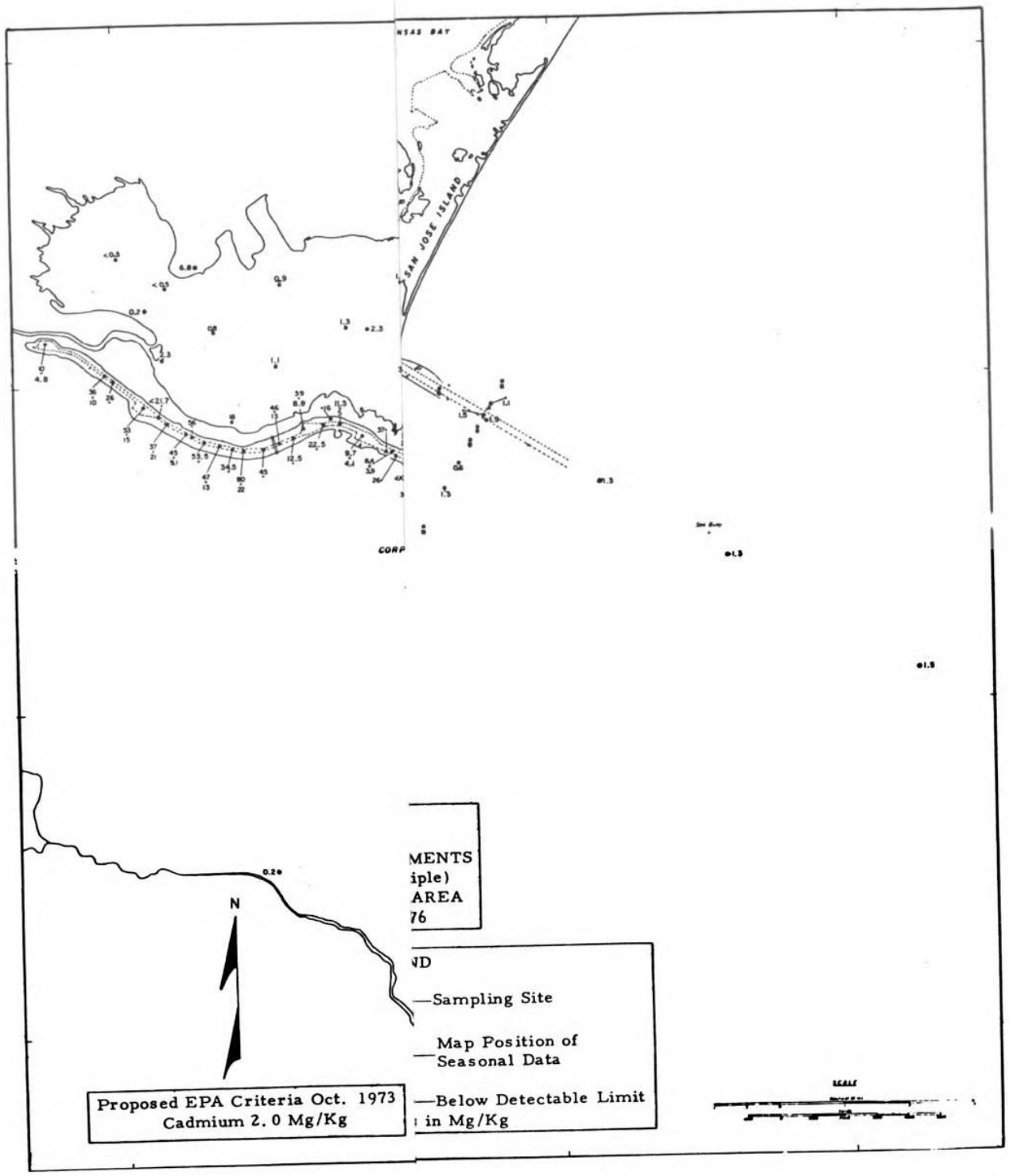

IN SEDIMENTS IN CORPUS CHRISTI AREA

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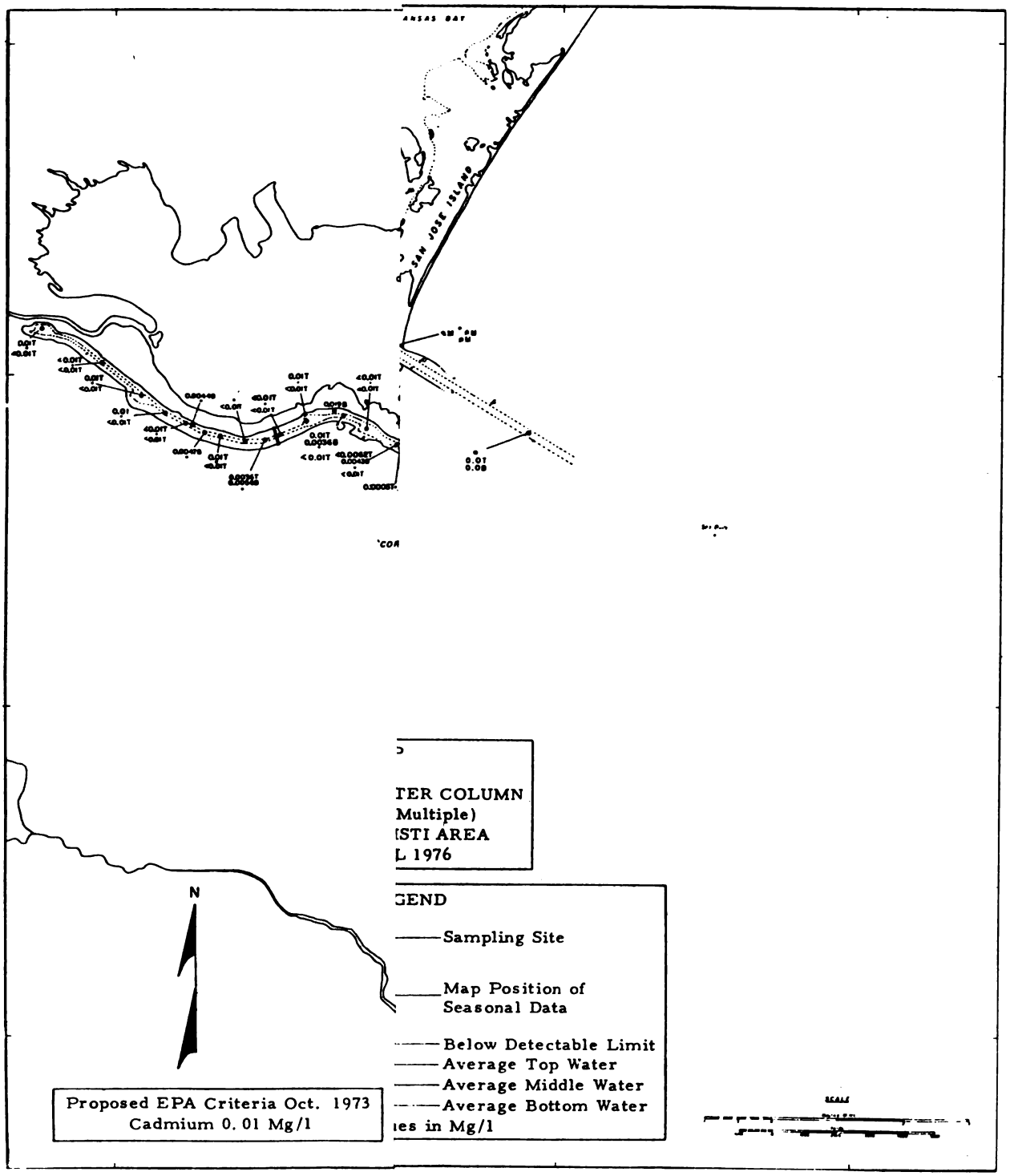

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considerably higher than the proposed EPA criterion of 50.0 mg/kg (Figure 22). Only two stations outside of the Inner Harbor exceed the criterion. All other segments of the bay system, including Harbor Island and the offshore, are below the limits.

2.111 Lead in Water Column. About 7 percent of the water samples analyzed show lead concentrations greater than the EPA proposed criterion of 0.05 ppm for lead in the water. Most of the higher values were recorded in the westernmost reaches of the Corpus Christi Ship Channel before it merges into the Inner Harbor, and in La Quinta Channel. The concentrations of lead in the water do not appear to be changing, and background levels are expected to change little in the future (Figure 23).

2.112 Mercury in Sediment. Mercury content in the sediments of the Corpus Christi Bay system has exceeded the EPA suggested limit of 1.0 ppm in about 9 percent of all the samples analyzed. Almost all the higher than acceptable readings occur in the central portion of the Inner Harbor. Mercury content of sediment samples follows the same general patterns as lead, zinc, and cadmium as its frequent natural associates. It is possible that the mercury containing sediments of the Inner Harbor may be dredged and redeposited. Removal of these sediments could eventually lower Inner Harbor mercury levels if no additional mercury is being introduced to the area. If the dredged sediments are confined, there should be little chance of the mercury content being redistributed in the bay's water or sediments. No significant changes are anticipated in mercury levels in the sediments (Figure 24).

2.113 Mercury in Water Column. About one-tenth of all mercury values reported in the water column exceed the EPA criterion level of .001 ppm. Most of the higher readings are barely over the EPA suggested levels but two stations have reported values nearly 10 times larger than the criterion level. No individual water station or bay system segment exhibits values which are high continuously. The high mercury levels in the water are ephemeral in time and widely varying in spatial distribution, with no pattern discernible. No changes are expected in mercury in the water (Figure 25).

2.114 Zinc in Sediment. The EPA proposed (October 1973) criterion for zinc in sediments is 75.0 mg/kg (ppm). Zinc concentrations in excess of the criterion have been found in

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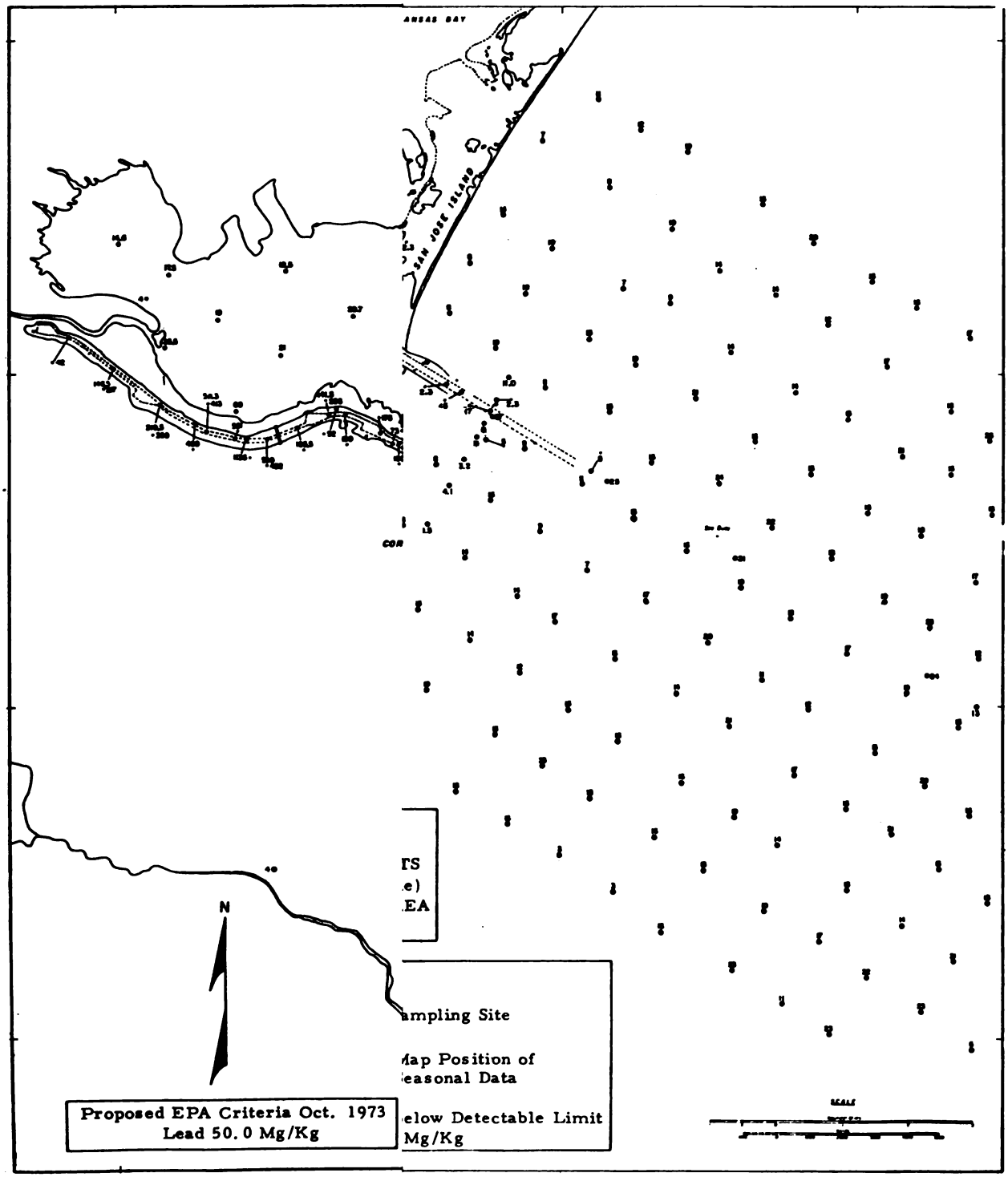

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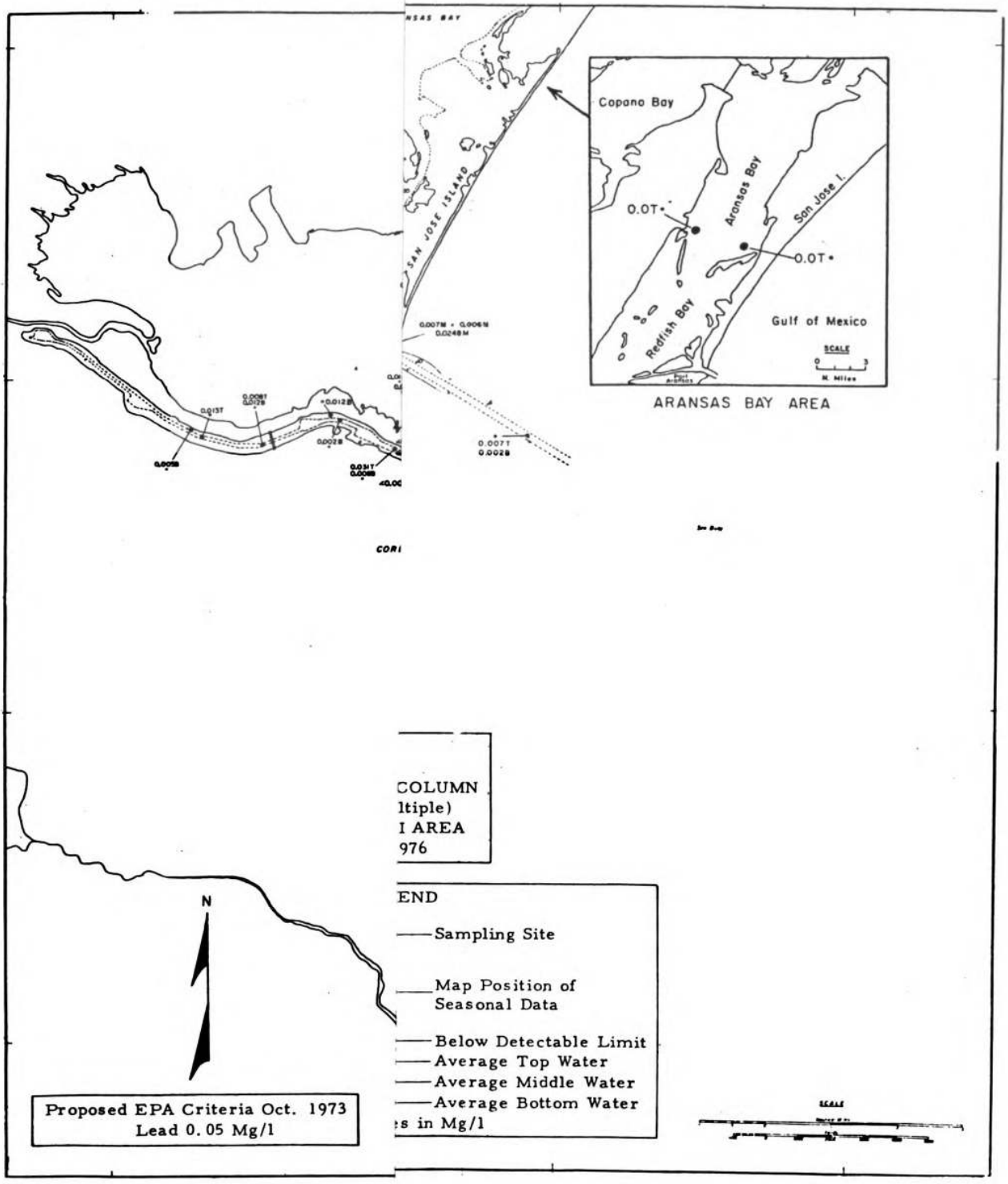

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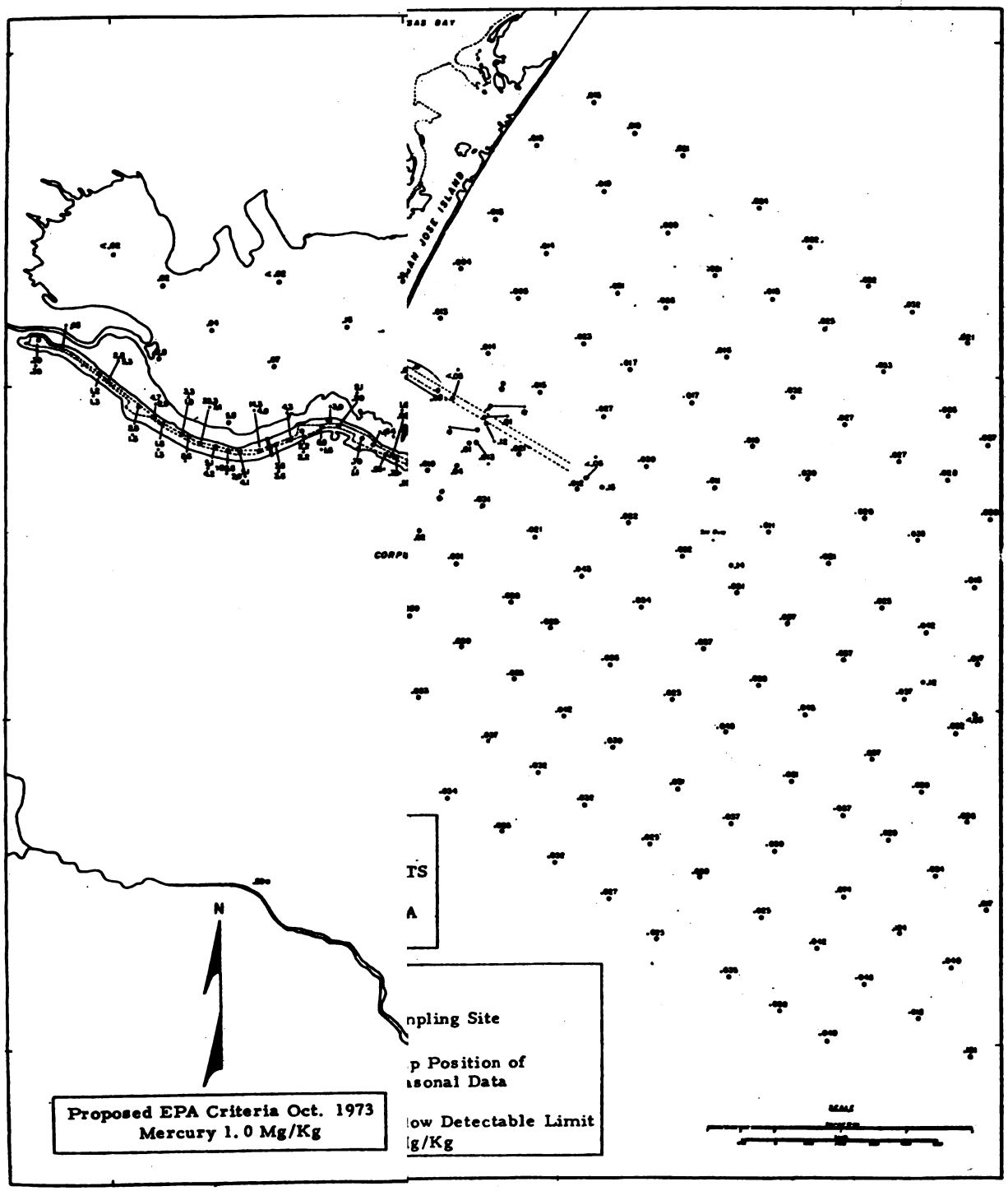

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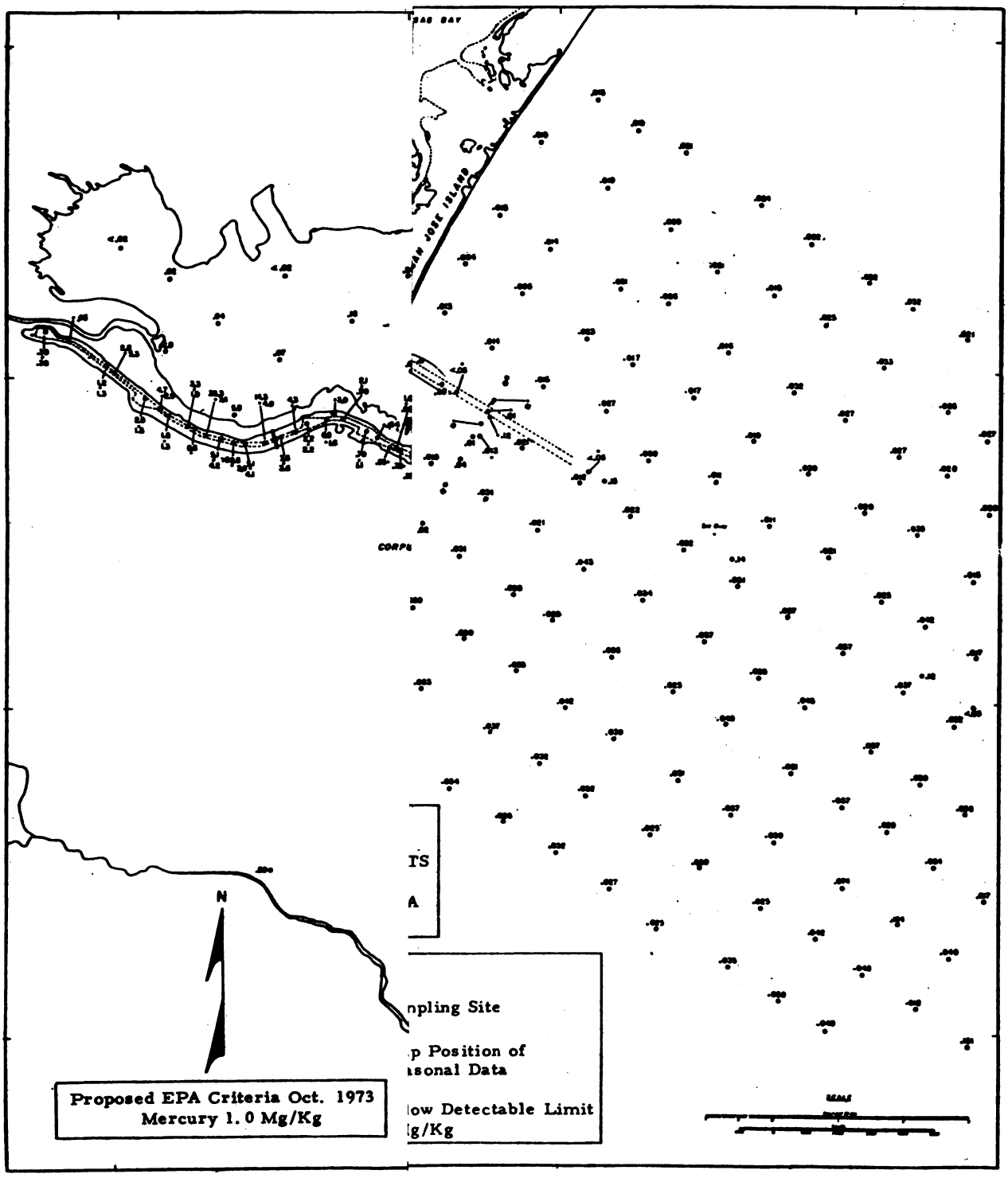

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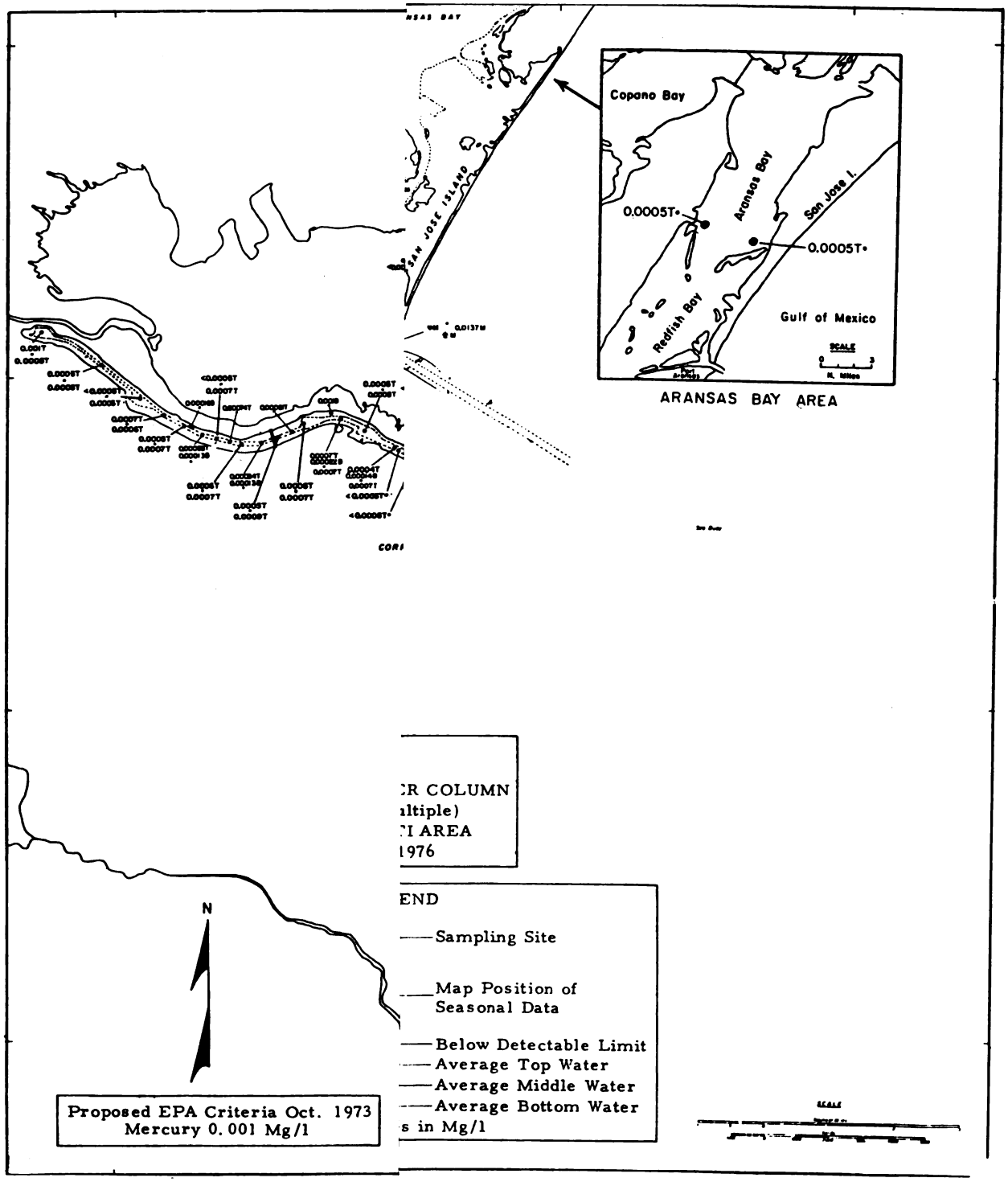

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the sediments of the Inner Harbor, portions of Nueces Bay, and in some parts of Corpus Christi Bay, such as adjacent to the entrance to the Inner Harbor and a few northern bay locations near La Quinta Channel (Figure 26). The natural Pleistocene clays in the area measure between 40.0 and 55.0 ppm zinc. The highly industrialized Inner Harbor shows the highest zinc values in the sediments. The pattern of zinc concentrations in the areas suggests that these higher concentrations may be due to transfer from the Inner Harbor. Because of the zinc values reported for Inner Harbor sediments, the placement of material dredged from the area has become controversial. Dredging in the Inner Harbor offers the possibility of reducing zinc values by removal of contaminated sediments; the time required for such dredging to have an observable effect on zinc levels is unknown. Zinc in the sediments of the Harbor Island area and in the immediate offshore area is not high.

2.115 Zinc in Water Column. Concentrations of zinc in the water column for the individual samples from the Corpus Christi Bay system have been found to exceed the EPA (October 1973) proposed criteria of 0.10 mg/l in about 14 percent of the samples. A majority of the excessive values occur in the area of the Inner Harbor and immediately bayward thereof. Averages compiled for individual stations in the Inner Harbor show zinc values at 5 of the 25 stations exceeded the EPA criterion with one value exceeding 0.4 ppm (Figure 27). The few analyses made in Nueces Bay show a low zinc level where a high level might have been expected due to a power plant cooling system transferring large volumes of water from the inner harbor to the bay. The highest values appear at stations in Corpus Christi Bay near the entrance to the inner harbor and along the Corpus Christi Ship Channel eastward. The typical averages in North Bay and La Quinta Channel are below the criterion. No obvious basis for the distribution of observed water column values was found. No changes are expected in zinc levels in the water column.

2.116 Nutrients. 'Nutrients' is an inclusive term for materials which stimulate plant growth and, for the purpose of the following discussion, include ammonia, nitrate, nitrite, orthophosphate, and total phosphorus. A certain level of nutrients is required to support life cycles in the bays, but excessive levels produce unbalanced plant growth. Data on nutrient concentrations, usually expressed in

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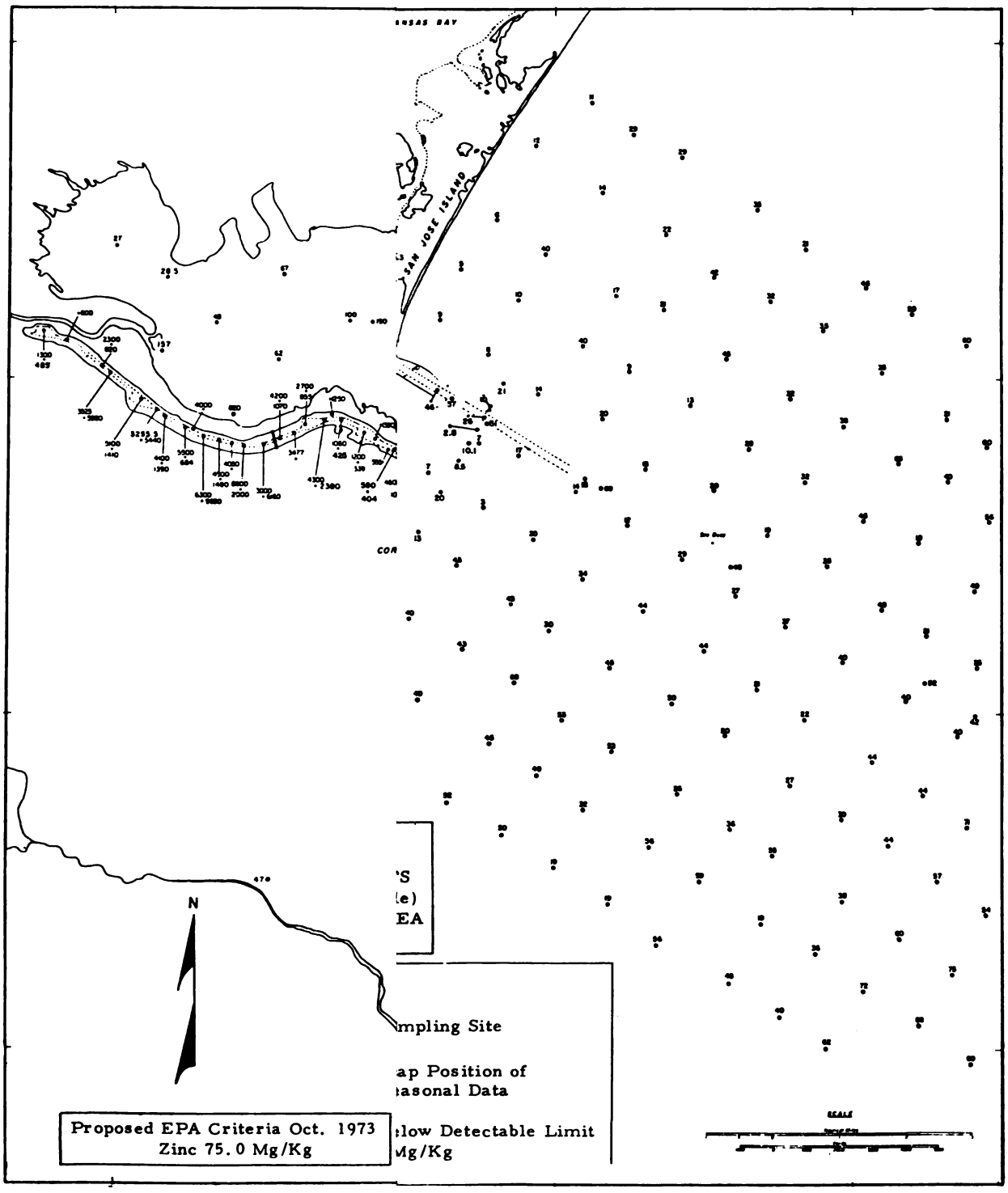

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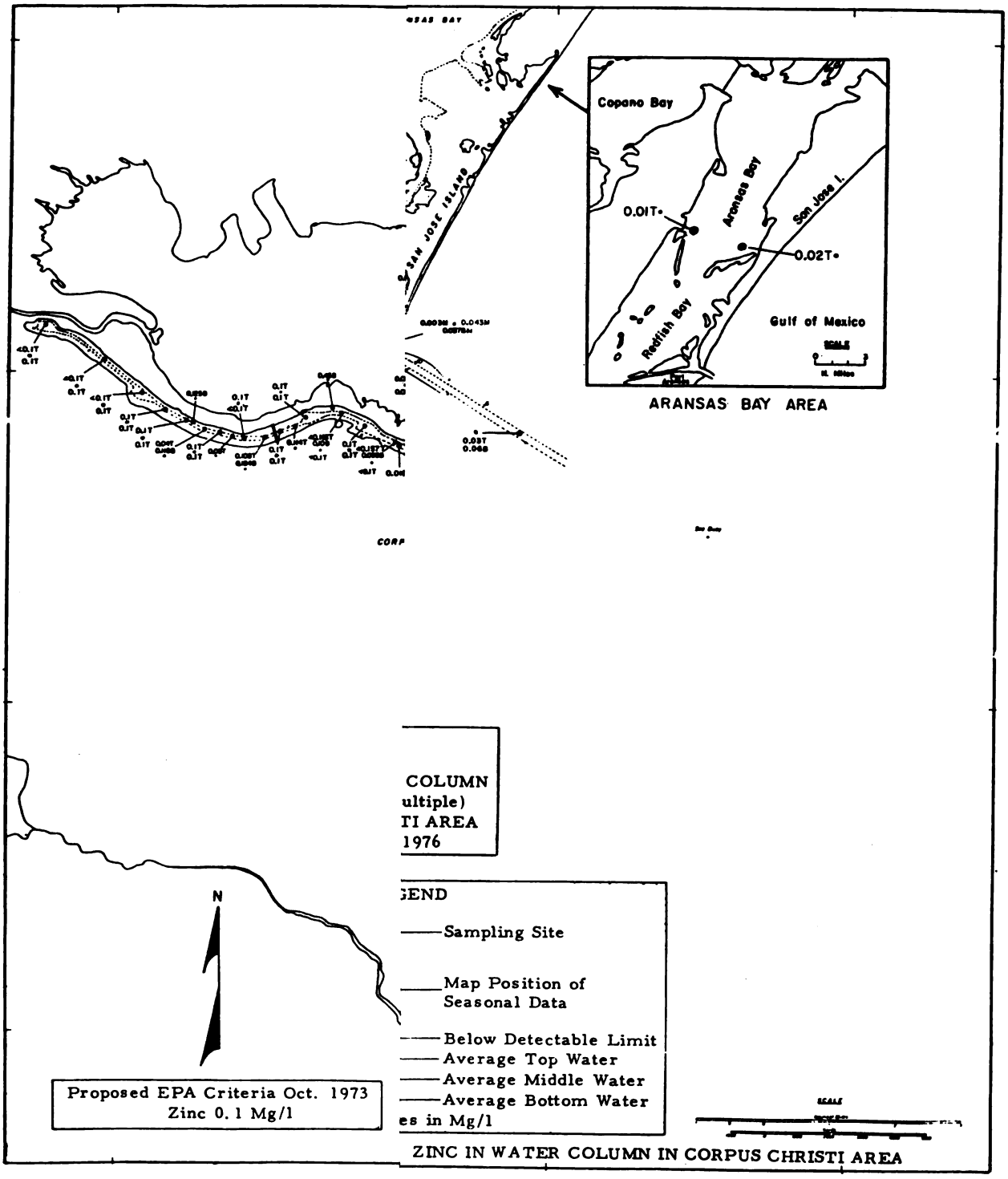

TER COLUMN IN CORPUS CHRISTI AREA

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mg/liter, are available from various research papers, as well as from ongoing data collections by the Department of Water Resources. Useful amounts of quantitative data have been collected since the mid-1960's, and the quality and quantity of the available data permit characterization of nutrient levels in the bay system.

2.117 Total nitrite concentrations in the system range from undetectable amounts to 0.18 mg/l, while nitrate concentrations vary from undetectability to .07 mg/l. The average nitrite concentration is .006 mg/l, while the average nitrate concentration is .03 mg/l. Nueces Bay exhibits the highest average nitrate and nitrite concentration in the system, probably due to the agricultural land runoff to the Nueces River. The average nitrite concentration in Nueces Bay is .014 mg/l while the average nitrate concentration is .04 mg/l. Corpus Christi Bay averages .002 mg/l for nitrite and .04 mg/l for nitrate.

2.118 Ammonia nitrogen in the system ranges from undetectable at various points in the system to 0.75 parts per million in the Inner Harbor. Corpus Christi Bay averages about .09 ppm, Nueces Bay about 0.17 ppm, the Inner Harbor about 0.4 parts per million, and Aransas Bay about .07 ppm. Averaging values over the entire bay system gives a value of 0.2 ppm. Levels greater than 0.4 mg/l are considered less than ideal. Only the inner harbor exhibits a tendency toward undesirably high ammonia levels.

2.119 Orthophosphate and total phosphorus are two of the nutrient components which have been measured in the bay system. The bay-wide average concentration for orthophosphate (expressed as phosphorus) is 0.08 mg/l, while the total phosphorus concentration averages 0.15 mg/l.

2.120 Average concentrations of orthophosphate and total phosphorus in the sediment in various areas of the system are as follows:

	Orthosphosphate	Total Phosphorus
Corpus Christi Bay	.02 mg/l	.05 mg/l
Nueces Bay	.05 mg/l	.07 mg/l
Inner Harbor	.19 mg/l	.43 mg/l
Aransas Bay	.04 mg/l	.06 mg/l

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2.121 Although Nueces Bay exhibits heightened nitrite-nitrate values and the Inner Harbor shows higher ammonia and phosphorus levels than the rest of the bay system, the system-wide distribution and quantity of nutrients is within acceptable limits.

2.122 Biological Oxygen Demand. Biological oxygen demand (BOD) is an expression of the relative oxygen requirements due to metabolic activity of organisms in water; it is determined by a bioassay procedure which measures the dissolved oxygen consumed by microbial life assimilating and oxidizing the organic matter present. It is expressed in mg/l. Nowhere in the bay system are biological oxygen demand values overly high. The averages for the various segments and the ranges reported are as follows:

	Range	Average
Corpus Christi Bay	0.65 - 2.3 mg/l	1.49 mg/l
Nueces Bay	1.36 - 3.7 mg/l	2.24 mg/l
Inner Harbor	2.75 - 8.2 mg/l	3.99 mg/l
La Quinta Channel	0.53 - 1.13 mg/l	0.99 mg/l
Aransas Bay	1.45 - 1.55 mg/l	1.51 mg/l
Harbor Island Area	0.49 - 1.75 mg/l	0.98 mg/l

2.123 The overall average of value for the system is 1.93 mg/l. The area which exhibits the highest BOD values is the Inner Harbor, which has the greatest potential effluent discharge from industrial, ship, and population sources. The BOD values are not too high, however, and by themselves present no problem in the Inner Harbor. Unless waters are very well mixed or aerated, there is usually a correlation between higher BOD, COD, and lower DO. The conditions which cause dissolved oxygen to be lowered in the Inner Harbor are probably related to the increased biologic oxygen demand values. At times, levels in the Inner Harbor have indicated anoxic conditions near the bottom.

2.124 It is reasonable to assume that the pattern of biological oxygen demand levels in the Inner Harbor's waters should continue. Actions which increase mixing of the water column in the Inner Harbor or increase water exchange with

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the bay system might improve oxygen levels in the Inner Harbor but at the possible risk of transferring heavy metals to the bay system.

2.125 Chemical Oxygen Demand. Chemical oxygen demand is a measure of the quantity of oxygen required to oxidize the organic matter in a sample, under specific conditions of oxidizing agent, temperature and time. The test gives an indirect measure of the organic material in a given sample. Within the bay system relatively few COD measurements have been made in the water, with slightly more made in the sediment. Average values are approximately 240 mg per liter (ppm) in the water with low readings of 20 ppm in the water, and 500 ppm in the sediment. COD values reported are as high as 900 ppm in the water and 216,760 ppm in the sediment (this high reading in sediment is an unlikely value especially considering its Gulf location). The quantity of chemically oxidizable organic material in the water and sediment primarily is a function of organic pollutants added to the system by local population, commercial, and industrial activities. The highest average COD values in the sediment occur in the Inner Harbor area with average values of about 50,000 ppm. This is to be expected as the area's greatest municipal and industrial loading is centered in the Inner Harbor. Although values are at a high level in the Inner Harbor, no increase in the levels are expected as future discharge and water quality regulation should be at least as stringent as at the present. The majority of the Bay system does not exhibit high level either in the water or sediment currently and levels are not expected to increase in the foreseeable future.

2.126 Oil and Grease. The quantity of oil and grease in the water and in the sediment is small. The levels range from 0.1 to 6.0 Mg/liter, averaging about 3.0 Mg/l in the water. No significant accumulations are evident within the water of the channels and harbors, and it is probable that background levels are low throughout the year. Possibly the oil and grease from point sources such as industrial sites and vessels, or from area wide runoff may temporarily raise levels undesirably, but these occurrences are not predictable temporally or spatially, and in the future are not anticipated to differ significantly from existing levels.

2.127 The concentration of oil and grease in the sediment ranges from undectectable to 6000 ppm, with the higher

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values found in the Inner Harbor area. High oil and grease values in the Inner Harbor can be expected because of the storm sewage runoff, the concentration of industrial activity, and vessel traffic. Elsewhere in the system, oil and grease quantities are low, with the overall average of measured values being about 800 ppm.

2.128 Pesticides. With the exception of data collected at the mouth of the Nueces River where it discharges into Nueces Bay, very little information exists on pesticides in the Bay system's waters. Low levels of various herbicides have been reported at the mouth of the Nueces, but no detrimental conditions have been observed. Elsewhere, levels of pesticides are below detection limits during most of the year. It is probable that water-borne quantities of pesticides increase after application on local crops, but data available do not show harmful effects.

2.129 pH and Alkalinity. The pH of the local waters varies from 7.2 (slightly basic) to 9.1 (basic) with an average of about 8.3. Seasonal variations are small. No significant deviations from the range and average as presented are expected.

2.130 Alkalinity is the acid neutralizing capacity of water. Only a few measurements have been made at scattered locations. The average alkalinity is about 118 Mg/l expressed as milligrams per liter of calcium carbonate, but because of the limited quantity of available data, no statistically reliable range can be established.

2.131 Air Quality. Pursuant to the Clean Air Act Amendments of 1977 (42 U.S.C. § 7401, et seq.), EPA, in order to protect public health and welfare, has promulgated certain primary and secondary standards for air pollutants which are to be attained, i.e., not to be exceeded, in each area of each state (see 40 C.F.R. Part 50). Such standards have been established for sulphur dioxide, particulate matter, carbon monoxide, photochemical oxidants and nitrogen dioxide (Table 3).

2.132 Pursuant to Section 107 of the Clean Air Act Amendments of 1977, EPA and the Texas Air Control Board have determined whether each area of the State of Texas is attaining or not attaining the required primary or secondary standards. Such determinations are set forth in the March 3, 1978 Federal Register (43 F.R. 9037-9038). The standards

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TABLE 3

FEDERAL AND TEXAS STATE AMBIENT AIR QUALITY STANDARDS

Agency	Pollutant		Primary	(PPM)	Secondary	(PPM)
Federal and Texas	SO_2	Annual	80	.03		
		24-Hour*	365	.14		
		3-Hour*	---		1,300	.5
Federal and Texas	Particulate	Annual**	75		60	
		24-Hour*	260		150	
Federal and Texas	CO	8-Hour*	10,000	9.	10,000	9.
		1-Hour*	40,000	35.	40,000	35.
Federal	Photochemical Oxidant	1-Hour*	160	.08	160	.08

*Not to be exceeded more than once per year.
**Geometric Mean

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for carbon monoxide, nitrogen dioxide, and sulphur dioxide are being attained and satisfied in Nueces County, San Patricio County and Aransas County; the standards for particulate matter and photochemical oxidants are being satisfied and attained in San Patricio County and Aransas County. Portions of Nueces County do not satisfy those standards (non-attainment) for photochemical oxidants and particulate matter. The project area lies in an area of Nueces County that is non-attainment for photochemical oxidants but is an attainment area for particulate matter.

2.133 Biotic Environment. The biotic environment within the potential area of influence of the project includes all marine and estuarine systems subject to project-related development and potential spill exposure. Because of the high uncertainty associated with the actual distribution of the oil spill impact potentials, the emphasis is placed on areas in proximity to the proposed construction and operation.

2.134 Vegetation. The productivity of Corpus Christi Bay is based on a plankton system since the deep and turbid water of the bay prevents growth of grass areas. Productivity in Redfish Bay and the southern reaches of Aransas Bay can be attributed to the shallow grass flats and saltwater marshes.

2.135 Most of the submerged and emergent marine vegetation is confined to the northeast (Redfish Bay) and southwest (Laguna Madre) margins of Corpus Christi Bay. These areas constitute grassflats and saltwater marshes which produce more in terms of species diversity and standing crop than any other estuarine zone in the project area.

2.136 The grassflats, which are much more widespread than saltwater marshes in the Corpus Christi Bay area (Figure 28), are characteristically composed of moderate to dense growths of turtle grass (Thalassia testudinum), shoal grass (Diplanthera wrightii), and to a lesser extent widgeongrass (Ruppia maritima). With the heavy growths of attached plants and animals, the total biomass represented by the grassflats is large. Sea grasses are important in coastal marine environments for several reasons. They fix inorganic carbon, much of which enters the food chain either by direct feeding of grazing animals or via decomposition as detritus. Estimates of production range from 15 to 1,500 grams (dry-weight) per square meter per year for turtle grass.

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FIGURE 28.

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Seagrasses provide shelter and a place for attachment of many small animals which normally form part of the seagrass community. The seagrasses also bind sediment, thereby increasing the stability of the substrate and the clarity of the water. Seagrass also plays an important role in the cycling of various nutrients and trace-elements in the marine environment. Seagrasses support a rich community of invertebrates and fishes. The Thalassia community is one of the richest known in the tropics, rivalling that of coral reefs in its diversity and numbers of animals (Thoraug, 1976).

2.137 The saltwater marsh, which is not as widely distributed as the grassflats in the bay area, is subjected to intermittent inundation by the tides (Figure 29). The dominant grass of the marsh is smooth cordgrass (Spartina alterniflora). Other less abundant plants include glasswort (Salicornia sp.), saltwort (Batis maritima), beach tea (Corton punctatus), saltgrass (Distichlis spicata), and sea purselane (Sesuvium portulacastrum).

2.138 The saltwater marshes are important resources because of their high productivity, the diversity of their biota, and their ecological sensitivity. Growth and decay of the vascular plants with these marshes is important in the nutrient cycle and for the development and maintenance of important food webs. Periodic flooding by the tides provides fresh inputs of minerals, which contribute to high vegetative productivity. Vegetation of the low marsh provides natural habitat for over-wintering migratory waterfowl. The major groups of primary consumers in the salt marsh include bacteria and fungi, meiofauna, snails, fiddler crabs, polychaetes, mussels, insects, birds, and mammals. Gosselink, Odum, and Pope (1974) have asserted that the total annual life-support value per acre of marsh-estuary is $4,100 and that the economic value as tertiary treatment plants can be valued in the tens of thousands of dollars per acre as compared to mere hundreds that accrue from byproduct uses.

2.139 Black Mangrove. Black mangroves (Avicennia germinans) grow on moist salty soils along beaches or on marshy islands. The black mangrove is a small, evergreen shrub with leathery, elliptic or oblong leaves. Its flowers occur in terminal clusters that are white with a yellow throat.

2.140 The black mangroves are well established at Harbor Island (Figure 30) with some mature individuals of this

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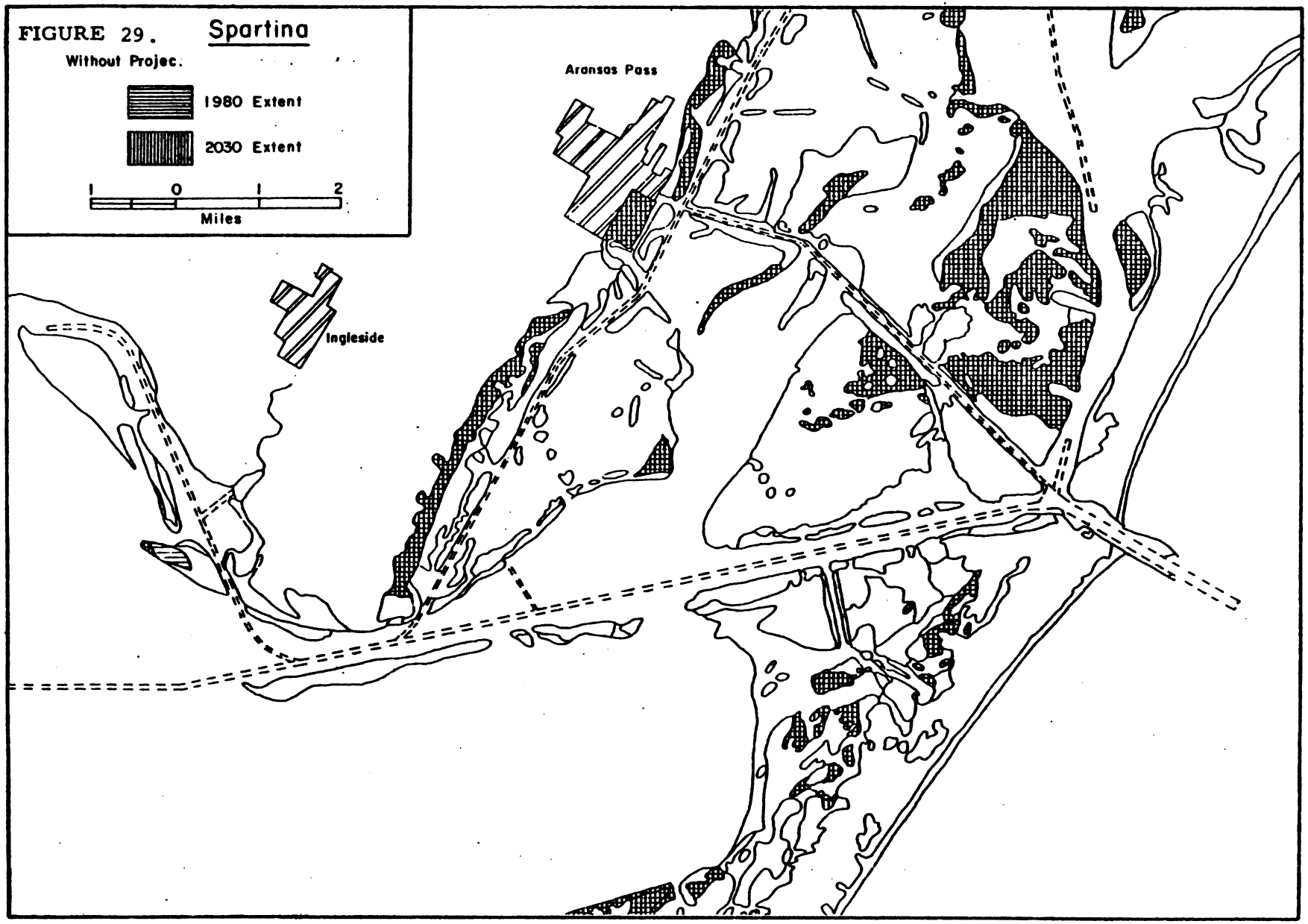

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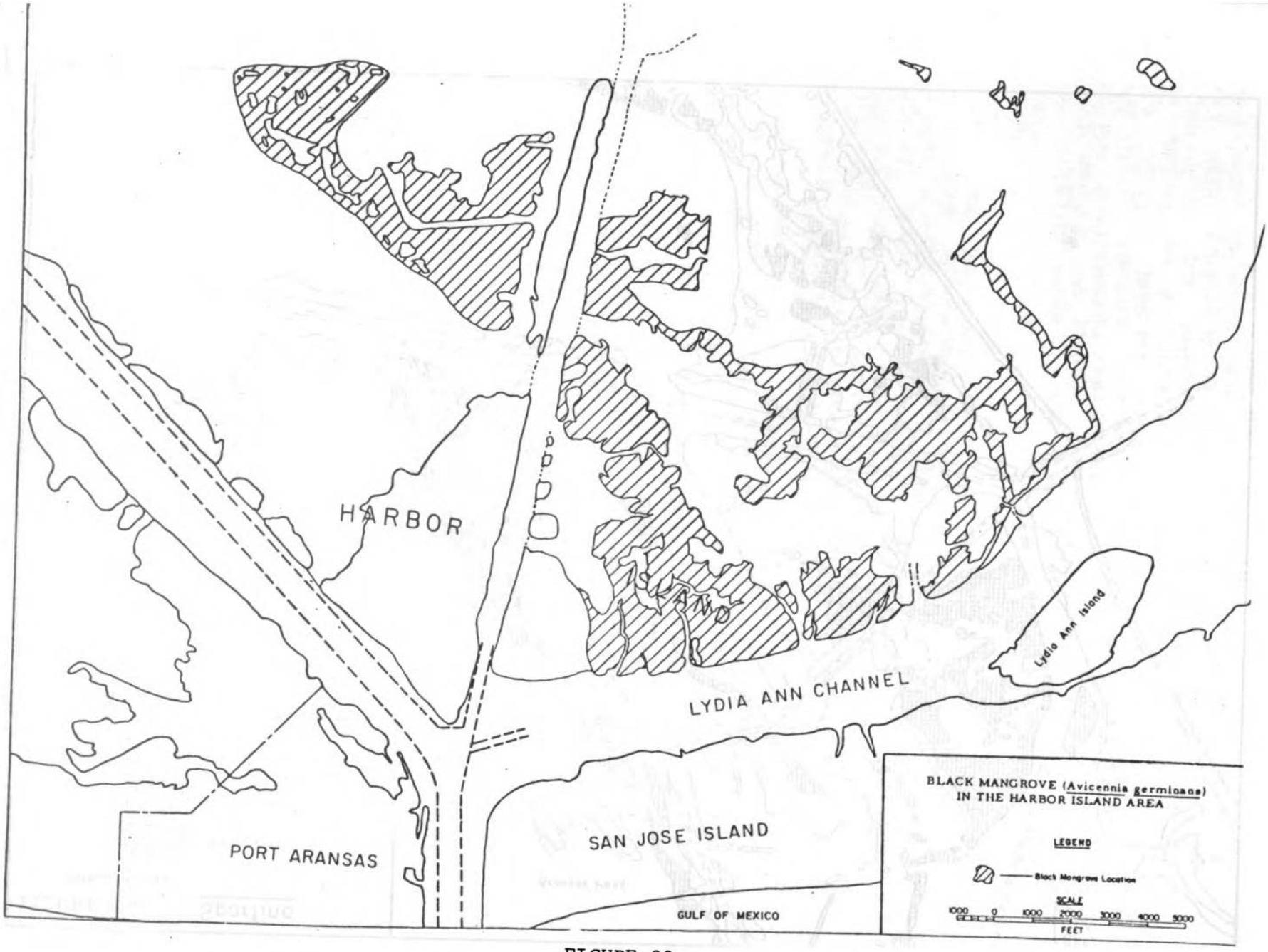

FIGURE 30

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shrub-like plant attaining a height of 4 to 5 feet near the Lighthouse of Lydia Ann Channel. Most individuals are less than 2 feet tall with some 3-4 year old and younger specimens being less than 1 foot in height.

2.141 At Harbor Island the black mangroves have invaded marshes that were previously all Spartina, displacing marsh vegetation. Additionally, seedlings can be found at scattered points in the Bay system with some individuals occurring at least as far south as Corpus Christi pass.

2.142 In the Harbor Island Area the black mangroves provide roosting places for the avian population. In addition, once the plants are firmly anchored and established they act to stabilize the soil, both with their root system and the wind cover effect of their foliage and branches. The mangroves are also of importance as detritus producers, principally through leaf fall. Some bark, root, and wood detritus does enter the water, but the magnitude of this input is unknown. Unlike roots and wood, leaves decompose rapidly into small particles which are easily transported by currents to detritus consumers.

2.143 Terrestrial Plants. Over 112 species of plants in the area could be considered non-marine. Common species in the study area are listed in Appendix A. Of these, four species are on the endangered lists (Texas Organization of Endangered Species); however, these are not within the areas of potential impact of the project. The endangered species include the hedgehog cactus, associated with brush or mesquite woodlands in the Coastal Bend; Kleberg's saltbrush, found near Alazan and Baffin Bay; a variety of ragweed, found in westernmost Nueces and in several areas of Kleberg County; and the rush pea, near Robstown and Petronila in Nueces County and also in adjoining Kleberg County. There are no known threatened or endangered plant species affected by the project.

2.144 Bay Plankton. The metabolism of Corpus Christi Bay and associated waters is based primarily on plankton (Odum and Wilson, 1962). These plankton species can be divided into phytoplankton (microflora) and zooplankton (Microfauna). Field studies indicate that the phytoplankton populations both inshore and offshore are dominated by diatoms; dinoflagellates and green algae are present in lesser quantities. Most phytoplankton studies have not

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observed the nannoplankton. Nevertheless, these minute nannoplankton probably comprise the bulk of the phytoplankton population.

2.145 Plankton populations increase or "bloom" in response to heightened levels of nutrients, such as nitrogen, phosphorus, and silicon, and increased light. Blooms occur when the length of daylight hours increases in the spring. In the fall, storms replenish waning nutrient levels, and blooms of plankton again become apparent. As the numbers of phytoplankters increase in response to a stimulus, the available nutrients are used up and the numbers of individuals subsequently decline.

2.146 Zooplankton levels parallel the phytoplankton numbers as the zooplankton graze on the phytoplankton. The zooplankton are important to the Corpus Christi Bay metabolism since they serve as the first step in the food web. These lower organisms are used as food by many pelagic organisms and fish. Dominant zooplankton include nauplii and copepods. Nauplii are the early larval stages crustaceans and are present during all seasons but are particularly abundant in the summer. The larval forms account for the importance of the estuarine waters as nursery grounds for many species of Gulf biota. Most of the larval species found in the nutrient-rich water of the bay system migrate to the Gulf as they grow and mature. The inlet at Port Aransas provides acess to the sea for the high nauplii numbers moving in and out of the Corpus Christi-Aransas system. Additionally, other species of crustaceans common to the bay system spend their early development as plankton, while other organisms live their entire life cycle as zooplankton (Oppenheimer and Gordon, 1972).

2.147 Gulf Plankton. The information on Gulf plankton provided in paragraphs 2.152-2.160 is excerpted from the draft Environmental Statement by Department of the Interior, on the proposed 1975 outer Continental Shelf Oil and Gas General Lease Offshore Texas.

2.148 Because there is little available data concerning the phytoplankton of the Texas shelf waters, the information being reported was taken primarily from El-Sayed et al., (1972). In addition, information from the few studies carried out in the eastern Gulf was reviewed. These publications include Baleeh (1967 a,b), Curl (1959), El Sayed (1967), Kabanova (1966), Marshall (1956), Odum and

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Hoskin (1956), Riley (1937), Simmons and Thomas (1962), and Steele (1964).

2.149 The diatoms and dinoflagellates are the major sources of primary production in the sea. Genera of neritic phytoplankton found in Gulf waters off Texas include Ceratium, Ceretulina, Hemiaulus, Guinardia, Biddulphia, Hemidiscus, Rhizosolenis, Thalassionema, Skeletonema, Chaetoceros, Gonyaulax, Asterionella, and others.

2.150 The animal plankters are called zooplankton. Zooplankton distributions and occurrences are also relatively continuous in pelagic waters. They are influenced by the same factors that affect phytoplankton distribution and occurrence. Inorganic nutrients and depth of the lighted zone are not as important to zooplankton as to phytoplankton, but these factors affect distribution and abundance in that greater availability of nutrients and light allow higher primary productivity and consequently a greater food supply for zooplankton.

2.151 Data on zooplankton for the Texas shelf waters is limited. Most of the zooplankton studies were restricted to certain groups of organisms and included only the inshore waters. Khromov (1965) studied the quantitative distribution of zooplankton biomass in the northwest Caribbean Sea and most of the Gulf of Mexico, and indicated a zone of low zooplankton density east of Galveston. Southwest of Galveston the nearshore density exceeded 0.5g/m3 in the shallow coastal waters with lower densities seaward.

2.152 James et al., (1972) extrapolated from the taxonomic studies of the eastern Gulf and the few Texas zooplankton collections which have been examined and concluded that Texas shelf waters are quite rich in the same zooplankton species found elsewhere in the Gulf, with representatives from many diverse biotic groups. Some of the more common and important members include the copepods, euphausiids, medusae jellyfish, ctenophores, mysids, chaetognaths, planktonic larval shrimp, crab larvae, pteropod and heteropod molluscs, worms, salps, and pyrosomes. Protozoans (one cell animals) such as foraminiferans and radiolarians may be locally abundant.

2.153 Organisms which are planktonic at all stages of their life cycles are called holoplankton. This term applies to

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both phytoplankton and zooplankton representatives. Examples from Texas are Calanus zooplankton, Physalia zooplankton, Chaetoceros phytoplankton, and Guinardia phytoplankton. Planktonic reproductive stages of species which in other stages of the life cycle live on the bottom or eventually become nektonic are called meroplankton. Examples are eggs (skate egg cases), larvae (barnacles), swarming stages (crustaceans), juveniles (fish, crustaceans, and echinoderms) or sexual alternates to vegetative states of a host of marine plants and animals. Tychoplankters are small, weakly motile, bottom dwelling organisms which are accidentally swept into suspension by turbulent water motion. Cumaceans (shrimp-like organisms) are regularly found as tychoplankters.

2.154 Benthos. Estuarine benthic organisms generally occupy a vital intermediate role in the food web. They transfer the energy stored in microorganisms (which they consume) to higher organisms which feed heavily upon the benthic community.

2.155 The composition of benthic faunal assemblages is often a good indicator of local conditions since those organisms are relatively immobile and incapable of relocation in response to stress. Salinity and substrate composition are usually key factors in determining local species distribution.

2.156 The benthics of the study area have been investigated at various times, but the work of Holland (1973) is most inclusive. Holland found over 331 species of benthics in the inshore study area. Peaks in populations appeared in December and March-April at many stations. After plotting the distribution of the common benthic species against certain hydrographic parameters, it was found that the temperature vs. salinity distribution was the most meaningful to explain the behavior of the benthic population. There appeared to be no correlation with temperature. Oxygen did not appear to be limiting. Most distributions were dependent upon salinity.

2.157 Offshore, Berryhill et al., (1975) investigated the distribution of benthics and found an interesting sample diversity with the Aransas Pass inlet as its focus (Figure 31). Also, Berryhill reported a positive correlation between heavy metal contents of certain benthic species and the heavy metal contents of the sediment in which they were found.

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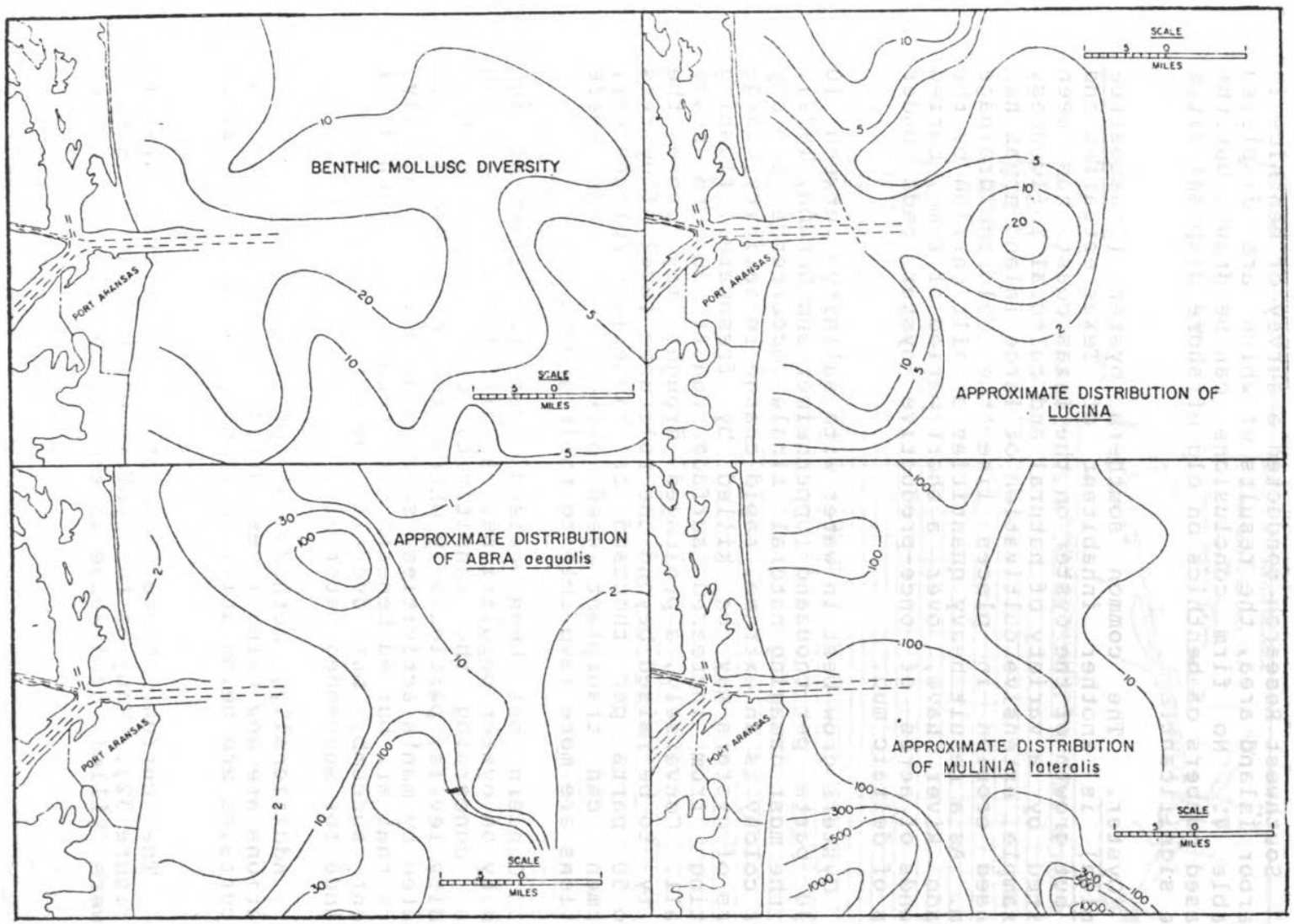

Figure31. BENTHIC DIVERSITY AND DISTRIBUTION

From Berryhill (1976)

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2.158 Southwest Research conducted a survey of benthics in the Harbor Island area, the results of which are displayed in Table 4. No firm conclusions can be drawn, but the increased numbers of benthics on old offshore disposal sites may be significant.

2.159 Oyster. The common southern oyster (Crassostrea virginica) is another inhabitant of Texas estuaries and bays, but growth of the oyster on the Texas coast has been inhibited by a variety of natural and cultural influences. For example, extensive cultivation of large inland areas has increased erosion in places like the Colorado drainage system. As a result heavy quantities of silt carried by the Colorado River have, over a short period of time, buried thousands of acres of once-productive oyster beds under layers of deltaic mud.

2.160 Oysters grow best in water with salinity between 10 and 30 parts per thousand (Oppenheimer and Gordon, 1972). Since the most damaging natural single occurrence to any oyster colony is an extreme, rapid change in salinity, large numbers of oysters may be killed by freshwater flushing resulting from increased surface runoff due to heavy rainfall. Conversely, a prolonged drought may cause the salinity to be raised beyond the tolerance level of oysters (40 to 50 parts per thousand or higher). Fortunately, oystermen can transplant seed oysters to areas where conditions are more favorable to their growth.

2.161 Concern has been raised over the effect of high turbidity on oyster populations. A difference of opinion exists concerning the sensitivity of oysters to high turbidity levels, particularly where the high levels are generated by man's activities, such as dredging. Generally, oysters that are buried beneath more than a few inches of sediment succumb, but overall, oysters seem to have a tolerance for suspended materials.

2.162 Additionally, methods of protecting live oyster populations are now being investigated, and devices such as silt curtains are being utilized along portions of the Texas coast.

2.163 The current oyster population in the study area is low (Figure 32). Many of the oysters which lived in Nueces Bay were killed by disease in the mid 1960's, and further

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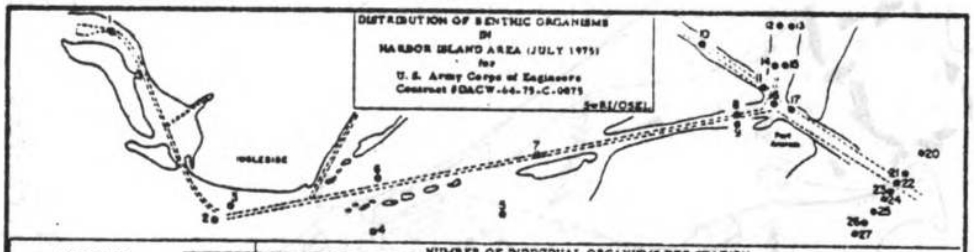
TABLE 4



ORGANISM	Station # →	*1	2	3	4	5	*6	7	8	9	10	11	12	13	14	15	16	17	20	21	22	23	24	25	26	27
Abra aequalis																										
Aglaophamus verrilli							1																			
Ampharete sp.																										
Amphipoda I																							2			
Amphipoda II																										
Amphipoda III																										
Amphipoda IV								3																		
Amphipoda V																										
Amphipoda VI								2																		
Amphipoda VII																										
Amphipoda VIII																										
Amphipoda IX																										
Amphipoda X							3																			
Anemone, cf. Paranthus rapiformis																				2						8
Ariciidae fragilis							8																			
Armandia agilis																										
Barmangaia brasiliensis																										
Brachioteuma caribaeum																										
Cerebratulus lacteus			1									11												2	1	
Clymenella torquata valida							4																			
Clymenella zonalis				2																						
Corbula dietziana				1																						
Cossura delta	19	1																		2						
Cumacea																										
Cumacea A																							1			
Diopatra cuprea					1																					
Diopia uncinata																										
Eocerosmus proximoglus																						2	1			
Gastropoda																										
Glycera americana																										
Glycinde solitaria																										
Goniadidae								4																		2
Grubea vittata				2																						
Hesionidae																										
Hemichordata		3						2																		
Hemipodia simplex																		35					24	2		
Hemipodus swanscombensis								3										6								
Lumbrineris impatiens																										
Lumbrineris sp.																										
Magelona rinkai														9												
Magelona reese																										
Magelona sp.																										
Mediomastus ambiseta																				3						
Mediomastus californiensis			1				1	5				3	1									2	1			
Microphthalmus sp.			2	3	1																			35	33	28
Mooreonuphis sp.											3															
Mulinia lateralis																										
Mysidopsis bigelowi																										
Nemertea cf. tubulosa										2																
Nemertea, ribbon head						5					2															
Nemertea, ribbon and purple head																								5		
Nephtys picta																										
Nephtys sp.																										
Nereis sp.													4											1	2	2
Nereis succinea							5										5									
Notomastus hemipodus																										
Nuculana concentrica																			10							
Odontosyllis enopla																										
Oligochaeta sensilia													2													
Onuphis eremita oculata																						3		9		
Orbiniidae																										
Paraprionospio pinnata			2																							
Parandalia sp.							2																			
Parapionosyllis longicirra																							17			
Parapodibius mutilicaudatus						26																				
Parapodibius socialis																										
Pectinaria gouldii																		10								
Pectinaria spinosa							3																			
Phascolion strombi			4	2																						
Pherusa arabiensis																										
Pionosyllis cryptica			2																							
Pista palmata																										
Polynoidae																										
Prionospio cirrifera			3																							
Prionospio pinnata	3	4																								
Prionospio steenstrupi						6				3	30	9	11	3					11		2		3	9		
Pseudocirrithoe arnbiseta									2													1	3	27	91	
Pycnogonida																										
Schistomeringos rudolphi							4																			
Sipuncula unidentified																							4			
Spiophanes fallacina			1																							
Spp. within																										
Sigambra tentaculata																							43	1		
Solen viridis																										
Spiophanes bombyx																										
Spio cernea																								26		
Squilla empusa																										
Sthenelais sp.																										
Tellina cf. iris				2																						
Terebellidae						2					2													4	3	
Thyrra cotagora			2																							
Xenosabra brevitelson						2																		5	4	
TOTAL ORGANISMS PER STATION →		23	3	26	9	3	63	38	5	5	11	38	17	21	3	1	49	2	17	8	3	15	101	208	83	16
Pearson Diversity Index →		1	2	2	3	3	3	3	3	4	3	3	2	2	1	0	2	1	3	3	2	3	3	3	3	2
Shannon-Wiener Div. Index →		0.5	1.0	0.8	1.3	1.0	0.4	0.7	1.6	1.5	0.8	0.4	0.7	0.4	0.9	0.0	0.4	1.0	0.7	1.0	0.9	1.0	0.9	0.5	0.9	1.0

*Grab Sample +4" Tube Sample NOTE: Grab and Tube Samples are not necessarily comparable.

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damage to the oyster beds resulted from hurricane Beulah in 1967. Parts of Corpus Christi and Nueces Bays and all of Redfish Bay and Oso Bay are now closed to commercial oystering due to bacterial contamination. The local oyster fishery is not thriving, but the Texas Parks and Wildlife Department is encouraging the expansion of oyster reefs in the area.

2.164 Estuarine Fishes. Species composition and life history relations of the Texas estuarine fishes are fairly well known. A few species, such as the bay anchovy (Anchoa mitchilli), appear to be year-round residents. Most of these fishes are seasonal transients derived from the fauna of the inner Continental Shelf, invading the coastal bays as juveniles during the spring and summer, feeding and growing as summer residents, and passing to the outside waters during the late summer and fall. Prominent among the seasonal transients are the menhaden, sea catfish, mullet, croaker, flounder, spot, seatrout, and red drum. Basically, the two types of fishes present in Texas bays are the commercially and recreationally important fishes and forage fishes which are fed upon by birds and other fishes. These shallow water fishes spawn on the inner Continental Shelf. The young make their way into the bays primarily during the spring months. After a summer feeding and growth period they then migrate to the outside waters where additional growth and reproduction occurs. Some individuals may overwinter in the inside waters and migrate to the outside during the following spring. Appendix B includes a list of fishes known to inhabit the Corpus Christi - Port Aransas region.

2.165 Commercial Shellfish. Three species of commercial shrimp are taken in Texas coastal waters: the white shrimp (Penaeus setiferus), brown shrimp (Penaeus aztecus), and pink shrimp (Penaeus duorarum). The brown shrimp is the most abundant and, therefore, the most important of the three since it essentially supports the shrimp fishery of Texas. Pink shrimp constitute less than one percent of the Texas catch. All three of these species spawn in the Gulf of Mexico on the Continental Shelf, and the young, aided by seasonal and tidal currents, migrate into the estuaries as plankton during the spring and summer months. Feeding, growth, and maturation take place largely in the estuarine nursery areas. In late summer and fall, many of the new adults move back into the Gulf waters. Some of the young

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may over-winter in the estuaries and pass outside in the spring. It is estimated that one-third of the brown and pink shrimp, and over one-tenth of the white shrimp caught off the Texas coast are reared in estuaries that rely on the Aransas Pass for a migration route to the Gulf.

2.166 The blue crab (Callinectes sapidus) is the only crab found in Texas waters that reaches a readily marketable size. Fertilized mature females tend to concentrate in the inner waters of the Continental Shelf for egg development. Eggs are hatched in the Gulf and eventually return to the bays as planktonic larvae. The planktonic larvae move into the nutrient-rich estuarine zone where they grow to maturity. Copulation takes place in the estuaries after which the females move back to the Gulf. The males, however, remain in the bays where they may continue to copulate with other maturing females. Egg-bearing females are most abundant in June and July. The crab fishery is important in both estuarine and Gulf waters.

2.167 Commercial Fisheries. At the present time, relatively small amounts of seafood products are commercially harvested from Corpus Christi Bay (Table 5). In 1973, for instance, it ranked last in oyster harvest for Texas, along with Sabine Lake and the upper Laguna Madre; it ranked fourth in shrimp production, far behind Aransas and Copano Bays in third place; it ranked sixth in crab production; and it ranked fifth in finfish production. The commercial landings of fish and shellfish in the Corpus Christi Bay area amounted to 1.89 million pounds, with a total dockside value of $1,058,211. There are several possible reasons for this low commercial harvest, one of which is probably the salinity gradient which affects migration habits. In addition, the laws concerning commercial harvest are more restrictive in Corpus Christi Bay than in other Texas bays, and the bay is not commercially fished as extensively as some of the other bays on the Texas coast.

2.168 Even though the Corpus Christi Bay area ranks low in fish and shellfish production, it is part of an extremely productive spawning and nursery area for much of the commercial fish and shellfish catches for the south central portion of the Texas Gulf Coast. The system contains several estuarine areas extending from Nueces Bay to the west, and Oso Bay and Laguna Madre to the south. The Corpus Christi Ship Channel and Aransas Pass serve as the primary

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TABLE 5
SUMMARY OF TEXAS LANDINGS
FOR 1973 - 1975

	1973		1974		1975	
Fish	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Croaker	13,200	809	12,300	727	6,900	690
Drum						
Black	220,200	28,519	201,100	34,893	205,700	38,407
Red (Redfish)	153,300	52,263	214,100	74,160	167,600	70,531
Flounders	17,500	5,358	37,800	11,152	56,300	20,221
King Whiting	-	-	-	-	100	3
Mullet	15,300	805	1,100	105	1,200	77
Pompano	400	180	500	225	800	335
Sea Catfish	14,900	2,042	10,000	1,180	16,400	2,397
Sea Trout, Spotted	156,700	52,419	178,100	60,563	129,900	53,431
Sheepshead	35,700	1,962	91,300	4,979	18	3,938
Unclassified for food	-	-	-	-	-	-
TOTAL FISH	626,700	144,357	746,300	188,022	664,200	190,054
Shellfish						
Crabs, Blue	41,100	4,569	326,300	44,339	125,700	20,981
Oyster Meats	-	-	-	-	1,000	1,335
Shrimp (Heads-on):						
Brown and Pink	372,100	145,376	154,900	41,852	399,700	118,432
White	849,900	763,877	320,300	308,486	531,400	582,718
Squid	200	32	-	-	-	-
TOTAL SHELLFISH	1,263,300	913,854	801,500	394,677	1,057,800	723,466
GRAND TOTAL	1,890,000	1,058,211	1,547,800	582,699	1,722,000	913,520

SUMMARY GULF COAST SHRIMP DATA
ANNUAL SUMMARY FOR 1973 - 1975

		1973	1974	1975
Grid Zone 19	Brown	5,834,492	4,779,471	6,712,688
	Pink	-	-	-
	White	3,269,298	2,301,099	1,545,304
	Total	9,103,790	7,080,570	8,257,992
	Total Dollar	17,277,179	10,219,042	18,187,600
Grid Zone 20	Brown	8,549,667	7,938,888	7,769,969
	Pink	775	3,137	555
	White	1,032,545	801,981	388,996
	Total	9,582,987	8,744,006	8,159,520
	Total Dollar	17,335,532	12,915,709	17,960,840
Grid Zone 21	Brown	6,993,975	5,502,797	6,215,611
	Pink	-	-	-
	White	245,207	155,011	79,913
	Total	7,239,183	5,657,808	6,295,524
	Total Dollar	13,088,088	7,617,973	12,586,759

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migration route from Corpus Christi, Aransas, and surrounding bays to the Gulf of Mexico. The annual shrimp landings for 1973, 1974, and 1975 from grid zones 19, 20, and 21 are included in Table 6.

2.169 Recreational Fisheries. The project area receives heavy recreational use throughout the year. Fishing activities are particularly heavy during the seasonal runs of flounder, spotted seatrout, red drum, and black drum. The Department of Commerce (1976) conducted a study of the recreational fisheries that exist along the south Texas coast from Port Aransas to Port Isabel. The study dealt with both onshore (fishing from jetties piers, and the beach in shallow waters) and offshore (fishing from boats in water depths of 6 - 600 feet) fisheries. Results of the study indicated the greatest amount of fishing effort, 61.6 percent of the total effort, occurred in the Mustang Island section of the study area. The study indicated a total of 424,932 man-days of fishing between 28 April 1975 and 24 April 1976, which resulted in an estimated value of $9,332,300.

2.170 Recreational fishing statistics are not available for the Corpus Christi area, however, Hefferman et al., (1976) conducted surveys of creel and pressure estimates for Aransas Bay system which included Mesquite, Aransas, Redfish, St. Charles, Copano, Mission, and Port bays. Results of the survey showed that during the period from 1 September 1974 through 31 August 1975 sport fishermen harvested 667,900 fish weighing 518,600 pounds with spotted seatrout comprising 49.6 percent or 257,300 pounds of the total harvest. Other fishes comprising the sport harvest included red drum, sheepshead, sand trout, gafftopsail catfish, and southern flounder. It is reasonable to assume that similar species would make up the sport catch in Corpus Christi Bay.

2.171 Marine Mammals, Birds and Turtles. The information in paragraphs 2.176-2.178 is excerpted from the draft Environmental Statement on Outer Continental Shelf Oil and Gas General Lease Sale Offshore Texas. (U.S. Department of Interior, 1975).

2.172 Several species of marine mammals, birds, and sea turtles constitute the wildlife species in the open Gulf. However, due to the difficulty in obtaining data, little is known concerning their populations. Available data

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concerning the mammalian fauna in Texas waters have been treated by Schmidly and Melcher (1974). The spotted dolphin appears to be the only mammal of any abundance in offshore waters with records of other cetaceans (whales, porpoises) being rather fragmentary. Caldwell and Caldwell (1973) also reported a scarcity of the marine mammals in the Gulf.

2.173 Woolfenden and Schrieber (1973) summarized data available on the Pelagic birds in the Gulf. Again, little data are available on the populations in the Gulf. Records of Lowery (1960) indicated that oceanic birds in Louisiana waters include shearwaters, jaegers, and petrels. It would be reasonable to expect these species occur in Texas waters also.

2.174 According to data from Rahn and Gelback (1972), four species of sea turtles occur in Texas waters. These include the leatherback, hawksbill, ridley, and green turtles. All but the green turtle are listed as endangered species. Little can be said about their distributions. They may be occasionally observed floating on the surface of the water and are susceptable to being caught by commercial fishermen. The few coastal observations and declining occurrences in trawl nets indicate a scarcity of the animals. Appendix C is a listing of terrestrial and marine mammals known to occur in the Gulf of Mexico.

2.175 Birds. The Corpus Christi estuary, which is located in the middle of the largest migration route in the United States, is an important wintering and breeding area for many species of waterfowl, shore and wading birds, and other migratory birds. The enormous expanse of beaches, coastal marshes, and mud flats supports a great diversity of shore birds, while the large number of adjacent shallow bays and grain fields creates an ideal habitat for waterfowl. Texas coastal waterfowl surveys, conducted annually in January by the Texas Parks and Wildlife Department, indicate that 50,000 to 60,000 waterfowl use the Redfish Bay - Harbor Island complex each winter. This situation provides for moderate hunting for waterfowl and a great amount of bird watching in the project area. Important species of migratory waterfowl which winter in the area are canvasback, redhead, lesser scaup, American wigeon, pintail, blue-winged and green-winged teal, shoveler, Canada goose, and snow goose. Shore and wading birds that nest on vegetated islands along the channels and obtain food from nearby shores and bays include heron, reddish egret, roseate

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spoonbill, gull, brown and white pelican, ibis, and tern. One of the major nesting colonies on the Texas coast lies just south of the Corpus Christi Ship Channel. This area, known as Pelican Island, was originally a continuous emergent bank of dredged material but has been reduced by storm tide erosion to five prominent mounds. Portions of these mounds are heavily vegetated and used as nesting sites by many coastal birds including the brown pelican, which is an endangered species. According to the U.S. Fish and Wildlife Service, brown pelicans now nest in this area between channel markers 21 and 25 on the Corpus Christi Ship Channel from about 1 March to 30 August. Appendix D includes a list of birds known to inhabit the Corpus Christi-Port Aransas region and information on their seasonal status, range, and abundance.

2.176 Terrestrial Mammals. There are 46 species of terrestrial mammals known to frequent the study area. A species list of the mammalian inhabitants of this region is presented in Appendix C. The species in the area include 24 differing species of bats, rats, shrews and mice. Larger species present are coyote, jack rabbit, raccoon, fox, white-tail deer and badger.

2.177 Reptiles and Amphibians. In the area, there are 53 different species of reptiles and 18 species of amphibians. Of the amphibians there are 15 species of toads and frogs, 2 salamanders species and 1 newt species. In the reptilian group are 11 turtles species (4 are seagoing), 14 lizards species, and 31 snake species. Lists of reptiles and amphibians known to inhabit the area are given in Appendix E and F, respectively.

2.178 Of concern to naturalists is the fate of the American alligator (Alligator mississippiensis) in Texas. The American alligator is found in limited numbers in the Aransas National Wildlife Refuge.

2.179 Rare and Endangered Species. The eastern brown pelican, the Arctic peregrine falcon, the southern bald eagle, and the whooping crane are endangered species that may be found in the Corpus Christi Bay area at some time during the year. Appendix G includes a list of rare and endangered species known to range in the project area.

2.180 The Arctic peregrine falcon migrates along the Texas coast, dwelling predominantly on Padre Island during the

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fall and spring. The southern bald eagle occurs sporadically along the Texas coast where it nests, but, in general, this species is removed from the marine environment. A flock of about 50 whooping cranes spends the winter in the Aransas National Wildlife Refuge which is approximately 20 miles northeast of Port Aransas.

2.181 According to the U.S. Fish and Wildlife Service, brown pelicans now nest along the Corpus Christi Ship Channel approximately 7 miles west of proposed docking basin. Brown Pelican Island, the area where these birds nest, was originally a continuous emergent bank of dredged material but has been reduced in size by storm tide erosion to five prominent heavily vegetated mounds. The Corpus Christi Outdoor Club, an affiliate of the National Audubon Society, studies and provides protection for these birds.

2.182 Socio-economic Setting. The three county study area, composed of Nueces, San Patricio, and Aransas Counties, lies in the Coastal Bend portion of Texas. The description of socio economic characteristics for this EIS is based upon information compiled for the three county area in the census and in planning documents and other available studies which have been made for the area. Data sources include reports from the Bureau of Census, Southwest Research Institute, Coastal Bend Council of Governments, cities, and other agencies.

2.183 The description of the socio economic setting for the Harbor Island port development consists of a description of the population density and distribution, economic setting, land use, community facilities, archaeologic and historic resources, recreational resources, and housing. Socio-economic estimates in Section 2 of this EIS are without project projections.

2.184 Population Distribution. The population is the study area is concentrated in the Corpus Christi Metropolitian area. The Corpus Christi area is sparsely settled, characterized by a concentration of people on the coast. To the west and northwest about 145 miles are the cities of San Antonio and Laredo and 225 miles to the northeast is Houston. With the advantage of its port facility, including the intracoastal waterway and deep ocean connections to other parts of the U.S. and world, Corpus Christi serves as a distribution center for the area to the south, southwest, and west.

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2.185 Coastal Bend Council of Governments (CBCOG) prepared population estimates for various planning periods through 1995 (Table 6) which have been approved by the State for planning purposes. Each of the cities in the study area (Table 7) shows a varying amount of growth through 1995 depending upon the amount of change expected by local authorities. The significant areas of growth are expected to be within existing urban areas and specifically in the cities of Corpus Christi and Portland and along the Rockport-Live Oak Peninsula. However, the major urban center in the study area is Corpus Christi with a 1977 estimated population of 222,374 people and a 1995 estimated population of 285,000. These estimates are based on the United States averages of projected changes.

2.186 Household size in 1970 ranged from an average of 2.97 in Rockport/ Fulton to a high of 4.69 in Gregory as compared to 3.17 for Texas and 3.14 for the U.S. By 1974 a declining birth rate led to smaller families nationally but there has been little change in the study area (Table 8).

2.187 Economic Setting. The economy of the three county economic (Nueces, Aransas, and San Patricio Counties) Study area is broadly based in manufacturing, agriculture and fishing. The development of improved port transportation facilities has allowed greater export of agricultural products from surrounding agricultural areas. The discovery of oil promoted a broad industrial base and aided in the development of industries such as oil refining, chemicals, and primary metals which also rely on port facilities. Military and civilian government employment is another major element in the economy in Corpus Christi. Commercial fishing and tourism complement the agricultural, industrial, and government base. All will continue to contribute to the long term economic growth in the region.

2.188 Employment in Economic Study Area. Steady growth in employment has occurred for the past 25 years (Table 9). Average annual growth between 1950 and 1960 was 2.62% and decreased to 1.73% between 1960 and 1970. The average annual increase in numbers of jobs was 1753 and 1458 for the two ten year periods respectively. Changes in the type of employment from agricultural to industrial reflects the increasing urbanization and development in the study area. The trend has been towards a decrease in farmers and farm managers and an increase in professional, clerical, craftsmen, and service workers.

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TABLE 6

POPULATION ESTIMATES AND PROJECTIONS (WITHOUT PROJECT)

TOTALS		1975	1977	1982	1985	1995
208 Area		289,225	297,100	332,100	352,800	425,450
Service Area		282,900	290,900	326,400	456,900	418,600
TWDB Counties 1/		317,800	327,450	351,425	365,700	417,200
Census Bureau 2/		307,900	-	-	-	-
Rockport-Live Oak Peninsula		9,700	10,000	15,555	18,888	30,000
Corpus Christi-Padre Island		217,162	222,374	240,000	250,000	285,000
Port Aransas	(P)	2,160	2,496	6,303	8,587	16,700
WCID #4	(T)	1,840	2,126	5,369	7,315	13,800
		4,000*	4,622*	11,672*	15,902*	30,000*
Robstown-San Pedro		16,000	16,160	16,968	17,477	19,225
Aransas Pass		6,434	6,709	7,170	7,488	8,544
Gregory		2,451	2,540	2,800	2,900	3,400
Ingleside		4,166	4,309	4,611	4,707	5,714
Odem		2,315	2,389	2,520	2,550	2,650
Portland		9,062	9,932	12,300	14,000	20,700
Sinton		6,032	6,219	6,540	6,600	6,850
Taft-Taft SW		5,550	5,650	6,260	6,350	6,550
Remainder of Non-Urban 208 Area		6,350	6,169	5,675	5,925	6,825

1/ TWDB estimates and projections are from TWDB Population Projections, November, 1976 for total county area, Aransas, San Patricio, and Nueces.

2/ Census estimates from Page 25, Series No. 637 for total county area, Aransas San Patricio, and Nueces.

* This figure represents both permanent (P) and tourist (T) population (excludes campers).

Source: Coastal Bend Council of Governments, 1977

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TABLE 7

1975-1977 POPULATION ESTIMATES

City	# of Elect. Connections* 1975	Persons Per Household 1975	Correction Factor	Number In group Quarters	1975 Pop. Estimate	1977 Pop. Estimate
Rockport-Fulton	2,751	2.70	0.8080	46	6,048	6,568
Corpus Christi	62,388	3.25	1.0510	4,060	217,162	222,374
Port Aransas	1,344	2.98	.5385	3	2,160	2,496
Robstown-San Pedro	3,775	3.93	1.0772	19	16,000	16,160
Aransas Pass	2,821	2.98	.7606	39	6,434	6,709
Gregroy	596	4.46	0.9220	0	2,451	2,540
Ingleside	1,662	3.30	0.7560	20	4,166	4,309
Odem	750	3.56	0.8670	0	2,315	2,389
Portland	2,806	3.48	0.9280	0	9,062	9,932
Sinton	1,895	3.24	0.9686	85	6,032	6,219
Taft-Taft SW	1,473	4.05	0.9303	0	5,550	5,650

*April 1, 1975

Source: Coastal Bend Councils of Governments, 1977

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TABLE 8

NUMBER OF PERSONS PER HOUSEHOLD

Place	1960	1970	% Change 1960-1970	1974
U.S.	3.33	3.14	-6%	2.97
Texas	3.36	3.17	-6%	2.98
Corpus Christi	3.36	3.42	-7%	3.25
Gregory	4.81	4.69	-2%	4.46
Ingleside	3.69	3.47	-6%	3.30
Odem	4.18	3.74	-11%	3.55
Portland	3.62	3.66	-1%	3.48
Sinton	3.68	3.41	-7%	3.24
Taft-Taft SW	4.10	3.90	-5%	3.71
Rockport-Fulton	3.31	2.97	-10%	2.82
Aransas Pass Port Aransas	3.39	3.14	-7%	2.98
Robstown-San Pedro	4.61	4.14	-10%	3.93

1960 and 1970 data obtained from the General Population Characteristics for 1960 and 1970. Bureau of the Census, Department of Commerce.

1974 data obtained from "Current Population Reports" Series Page 20, No. 266. Bureau of the Census, Department of Commerce, July, 1974.

Source: Coastal Bend Council of Governments, 1977

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Table 9. Changes in Employment Groups 1950 - 1970, Economic Study Area

	1950	1960	% Change 1950-60	1970	% Change 1960-70
Farmers/ Farm Manager/Workers	12,829	6,420	-50	3,055	-52.4
Prof./Kindred	5,419	9,211	+70	13,777	+49.6
Clerical/Kindred	6,990	10,930	+56.4	16,034	+48.7
Craftsmen/Kindred	10,195	10,781	+5.75	16,034	+48.7
Service Workers	7,814	10,276	+31.51	14,144	+37.6

Source: CB Council of Governments, 1977

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2.189 Labor force data (SWRI,1977) (Table 10) indicates that unemployment in 1970 was between 3.2 and 4.2% for the three counties. An estimated 17-25% of the families had incomes below the poverty level. Labor force projections (1970-2000) for the economic study area (Table 11) show large gains in labor force size in Nueces and Aransas counties. Recent labor force data (Table 12) shows that unemployment has increased to 6.6% in 1976 for the study area and that the total civilian labor force is estimated to be near 127,690 (Texas Dept. of Labor Statistics, 1976). Port related industries in the Corpus Christi standard Metropolitan Statistical Area (Nueces and San Patricio Counties) (SMSA) accounted for 41% of the non-farm income. First quarter estimated port-related non-farm earnings for 1972 were $310 million. Nearly 40% of total SMSA employment was port-related in 1972 (Ryan and Adams, 1972). In this portion of the labor force port-related employment is distributed between transportation and transportation services (100% and 85% respectively), manufacturing (68.7%), construction (37.2%), and several other industry groups (Table 13). Estimates of total tonnage of cargo made by Ryan and Adams (1972) show that nearly 27 million tons of cargo are handled every year through the port of Corpus Christi (Table 14). Composition of the cargo consists of crude and refined petroleum (9.37 and 9.45 million tons respectively), metals and ores (3.72 million tons), chemicals and related products (1.95 million tons), and agricultural products (1.79 million tons). Tonnage at the Port of Corpus Christi has steadily increased from its beginning until the present, making it the second ranked Port in Texas today. Total Waterborne Commerce for the Corpus Christi Ship Channel for 1977, was 60,699, 825 tons-this being more than twice the commerce handled five years earlier. Its influence extends well into the surrounding areas of the State as well as the Nation. These areas depend upon the port for shipping petroleum and agricultural products and the import of ores, chemical, and basic chemicals (Table 15). With respect to foreign commerce, aluminum ores and crude petroleum are first and second in imports and sorghums and basic chemicals ranked first and second in exports. Crude petroleum is first in domestic commerce receipts and crude, distillate fuel oil, and gasoline were top ranked in domestic shipments.

2.190 Major sectors of the economy include manufacturing, mining, agriculture, and fisheries, wholesale and retail trade, and government employment. Present and projected

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TABLE 10

ECONOMIC STUDY AREA
TOTAL EMPLOYMENT AND INCOME DATA, 1970

A. EMPLOYMENT DATA

COUNTY Cities over 5000 in Population	LABOR FORCE		EMPLOYED		UNEMPLOYED		PERCENT UNEMPLOYED	
	Male	Female	Male	Female	Male	Female	Male	Female
ARANSAS	1925	1035	1846	999	79	36	4.1	3.5
NUECES	59017	30917	52291	29014	1892	1682	3.2	5.4
Corpus Christi	51572	27798	45446	26052	1618	1525	3.1	5.5
Robstown	2261	1201	2107	1158	131	43	5.8	3.6
SAN PATRICIO	10579	5129	10073	4874	449	285	4.2	5.0
Aransas Pass	1451	614	1358	601	83	13	5.7	2.1
Mathis	1024	401	999	385	25	16	2.4	4.0
Portland	1859	958	1748	935	95	23	5.1	2.4
Sinton	1313	796	1230	760	78	36	5.9	4.5

B. INCOME DATA

1969

COUNTY Cities over 5000 In Population	Income				Income Less Than Poverty Level*	
	$0- $5,999	$6,000- $14,999	$15,000 & Over	Medium Income	Families	% Families Less Than Poverty Level
ARANSAS	1,088	1,084	263	$6,661	415	17.0
NUECES	19,166	29,136	8,737	$8,168	9,732	17.1
Corpus Christi	15,678	25,945	8,084	$8,468	7,694	15.5
Robstown	1,040	1,091	231	$6,616	675	28.6
SAN PATRICIO	4,552	5,403	1,195	$7,266	2,792	25.0
Aransas Pass	684	708	130	$6,583	290	19.1
Mathis	790	354	39	$4,532	563	47.6
Portland	234	1,254	359	$11,254	114	6.2
Sinton	595	637	141	$6,709	384	28.0

*Total income of family or primary individual is below the poverty level (ranged from $1,834 to $6,116 depending on conditions). Determined by weighted average of thresholds at poverty level in 1969 by size of family and sex of head, by farm and nonfarm residence.

Source: U.S. Census, 1970.

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TABLE 11

LABOR FORCE PROJECTIONS (WITHOUT PROJECT)
1970 - 2000

County	1970[1]	1975[2]	1980[2]	1990[2]	1995[2]	2000[2]
Aransas	2,960	3,491	4,023	5,520	6,484	7,448
Nueces	89,934	97,460	104,986	122,931	132,359	141,786
San Patricio	15,708	16,110	16,510	17,407	17,739	18,072
TOTAL	108,602	117,061	125,519	145,858	156,582	167,306

[1] 1970 Census for counties completely in the study area. Staff estimates for those counties partially in the study area.

[2] Projections based on 1970 labor forces-to-population ratio applied to Water Development Board Population Projections.

SOURCE: SWRI, 1977, Appendix C.

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TABLE 12

LABOR FORCE EMPLOYMENT (1976)

Corpus Christi SMSA (Nueces, San Patricio)	Civilian Labor Force	124,043
	Employment	115,716
	Unemployed	8,327
	% Unemployed	6.7%
Aransas County	Civilian Labor Force	3,647
	Employment	3,508
	Unemployed	146
	% Unemployed	4.0%
TOTAL:	Civilian Labor Force	127,690
	Employment	119,224
	Unemployed	8,466
	% Unemployed	6.6%

Source: Department of Labor Statistics, Dallas, Texas, April, 1976.
*Average for three months (January through March)

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TABLE 13

PORT-RELATED EMPLOYMENT IN THE CORPUS CHRISTI SMSA
First Quarter 1972

Industry Group	Employment	Percent Port-related	Number Port-related
Agriculture	4,580	0.0	0
Manufacturing	10,330	68.7	7,097
Mining	4,150	0.0	0
Construction	8,400	37.2	3,125
Printing and Publishing	710	37.2	264
Water Transportation	505	100.0	505
Transportation Services	650	85.0	533
Other Transportation, Communication and Utilities	5,310	37.2	1,975
Wholesale and Retail Trade	27,050	37.2	10,063
Banking	1,120	46.3	519
Other Finance, Insurance, and Real Estate	3,760	37.2	1,399
Services	18,080	37.2	6,726
Government	20,200	37.2	7,514
Total:	104,845	37.9	39,740

Source: (SWRI, 1977)

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TABLE 14

COMPOSITION OF CARGO
AT
PORT OF CORPUS CHRISTI
(IN SHORT TONS)

Category	Tonnage	Percent of Total
Petroleum		
Crude	27,152,396	44.8
Refined	21,359,664	35.2
Chemical & Related Products	3,240,298	5.3
Metals and Ores	4,848,383	8.0
Grain and Grain Products	3,452,437	5.7
Total Bulk Cargo	60,053,158	99.0
Total Cargo	60,669,825	100.0

SOURCE: Nueces County Navigation District No. 1
Statistical Information on Port Commerce for 1977

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TABLE 15

1977
MAJOR ITEMS OF WATERBORNE COMMERCE
AT THE
PORT OF CORPUS CHRISTI
(Thousand of Tons)

FOREIGN COMMERCE

Rank	Imports	Volume	Rank	Exports	Volume
1	Crude Oil	27,152	1	Grain & grain products	3,452
2	Metals & Ores	4,848	2	Other dry cargo	181
3	Molasses	41	3	Chemicals	52

DOMESTIC COMMERCE

Rank	Receipts	Volume	Rank	Shipments	Volume
1	Chemicals	689	1	Diesel & Fuel Oil	7,713
2	Crude Oil	356	2	Heating Oil #2	5,996
3	Naptha	21	3	Gasoline	4,761
4	Other dry cargo	14	4	Chemicals	2,233
			5	Crude Oil	1,667
			6	Jet Fuel	1,337

Source: NCND No. 1, 1977

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economic conditions (Table 16) indicate decreasing employment in mining (oil and gas extraction), agriculture, and fisheries. Gains have been projected in manufacturing and trade, finance, and related services. Parallel estimates of increases for earnings are shown in Table 16.

2.191 The following discussion of the local economy of the three county area is divided into manufacturing, agriculture, forestry and fisheries, mineral resources, retail and wholesale trade, tourism, and other related factors such as federal employment and institutions. The importance of the port has already been stated and the following information further explains the developing industrial base.

2.192 Manufacturing. Employment in the three county economic study area increased by 162 people between 1960 and 1970 (SWRI, 1977). In 1970 total employment was 11,086. Economic growth is dependent upon expansion of employment opportunities in the sectors of the economy which export products outside of the region. Growth in manufacturing is vital to increasing prosperity of the area (See Table 16, 17 & 18 for industries in manufacturing). There was little manufacturing in the Study area until the discovery of oil. The discovery of oil promoted a variety of industries. Among these were chemical and food processing plants, marine supplies, and others.

2.193 The rate of growth of the manufacturing sector leveled off in the sixties. New plants and expansions barely kept pace with the loss of jobs. Employment remained relatively stable from 1960 to 1970. Continued development of manufacturing plants in the study area increase employment in the future.

2.194 Major manufacturing employment is concentrated in Nueces and San Patricio Counties (Table 16). This is in petroleum and petrochemical processing and primary and secondary metals which depend upon port transportation facilities.

2.195 Key Industries and Their Growth. Major manufacturing forms in the economic study area are identified by location and product in Table 17. A major emphasis in manufacturing in the area centers around primary metals, chemicals, petroleum refining, and transportation. Ryan and Adams (1973) have analyzed the Corpus Christi with respect to the

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TABLE 16
EMPLOYMENT BY OCCUPATION GROUP

Occupation Group	Three Counties (Aransas, Nueces, San Pat.) Emp 1950	Emp 1960	Emp 1970	208 PLANNING AREA Emp 1977	Percent Unemp	Emp 1982	Percent Unemp	Emp 1985	Percent Unemp	Emp 1885	Percent Unemp
TOTALS	66,991	84,516	99,096	109,400	7%	121,200	6%	127,500	6%	151,400	5%
Professional & Kindred	5,419	9,211	13,777	15,644		17,574		18,615		22,255	
Farmers & Farm Workers	2,170	2,225	1,206	1,094		1,091		1,020		1,060	
Managers & Administrators	7,364	8,157	9,727	10,831		11,999		12,240		14,534	
Clerical & Kindred	6,990	10,930	16,034	18,598		20,604		21,803		26,041	
Sales Workers	4,982	6,166	7,465	7,658		8,726		9,053		10,900	
Craftsmen & Kindred	10,195	10,781	16,034	18,160		19,998		20,783		24,375	
Operatives & Transport Opers	9,951	12,384	12,766	13,128		14,544		15,555		18,622	
Service Workers & Private Household	7,814	10,276	14,144	16,629		18,422		19,508		23,315	
Farm Workers	5,732	4,195	1,849	1,094		970		893		908	
Laborers	5,657	6,345	6,095	6,564		7,272		7,905		9,538	

Columns may not equal total due to rounding

SOURCE: Coastal Bend COG, Interim Report 2, 1977.

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TABLE 17
SUMMARY OF PROJECTED SOCIOECONOMIC CONDITIONS WITHOUT PROJECT
Corpus Christi Study Area (1967 $). 1980-2030

	1980	1985	1990	2000	2010	2030
Population	308,200	319,690	331,600	347,450	363,110	390,680
Total Personal Income (000's)	1,997,000	2,337,000	2,734,800	3,792,600	5,021,800	8,141,000
Per Capita Income	6,479	7,310	8,247	10,916	13,830	20,838
Total Employment	121,500	126,170	131,020	142,800	149,880	163,010
Total Earnings (000's)	980,670	1,149,500	1,347,300	1,870,000	2,571,200	4,427,800
Earnings per Worker	8,071	9,111	10,283	13,095	17,155	27,163
EMPLOYMENT						
Agriculture, Fisheries, Petroleum Production & Construction	19,450	19,200	18,970	18,910	18,910	18,710
Manufacturing, Total	17,460	18,330	19,250	21,460	23,230	25,890
Chemicals & Allied Products	3,810	4,260	4,730	5,850	6,810	8,480
Petroleum Refining	2,270	2,350	2,420	2,590	2,670	2,670
Primary Metals	2,880	2,830	2,760	2,730	2,580	2,200
All Other Manufacturing	8,500	8,990	9,340	10,290	11,170	12,450
Transportation	3,370	3,400	3,540	3,610	3,770	4,020
Communications & Utilities	4,110	4,510	4,820	5,890	6,410	7,460
Trade, Finanace, Insurance, Real Estate & Services	60,670	63,670	67,070	74,380	78,610	87,150
Government	16,440	17,060	17,370	18,550	18,950	19,780

SOURCE: SwRI Derivation from OBERS Series E Projections, 1977.

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TABLE 18

PROJECTED EMPLOYMENT & EARNINGS,
COASTAL BEND COG, 1977
(WITHOUT PROJECT)

	UNEMPLOYMENT RATE			
	7%	6%	6%	5%
	1977	1982	1985	1995
Total Employment	109,400	121,200	127,500	151,400
Total Personal Income (In Thousand of 1967 $)	948,218	1,332,411	1,504,351	2,349,380
Total Earnings (In Thousand of 1967 $)	713,835	1,030,200	1,147,500	1,771,380
Agriculture, Forestry & Fisheries	18,774	24,519	24,098	30,645
Agriculture	16,347	20,902	20,081	24,976
Forestry and Fisheries	2,427	3,503	3,902	5,668
Mining	23,699	29,979	28,688	24,799
Crude Petroleum and Natural Gas	23,342	29,567	28,114	24,303
Contract Construction	50,847	72,526	78,260	147,733
Manufacturing	108,717	145,937	164,207	244,273
Food and Kindred Products	10,065	13,382	13,540	17,537
Textile Mill Products	S	S	S	S
Apparel & Other Fabric Products	1,114	12,043	16,639	25,508
Lumber Products and Furniture	1,324	1,957	2,066	3,011
Paper & Allied Products	S	S	S	S
Printing and Publishing	4,851	7,211	8,262	13,108
Chemicals and Allied Products	34,435	37,077	41,769	65,541
Petroleum Refining	20,980	30,268	32,589	46,233
Primary Metals	21,608	24,725	25,245	37,199
Fabricated Metals and Ordnance	4,112	45,123	7,115	11,337
Machinery, Excluding Electrical	2,855	3,915	4,361	6,377
Electrical Machinery & Supplies	971	1,442	1,721	3,011
Motor Vehicles and Equipment	S	S	S	S
Transportation Equip, Exclud Mtr Vehs	1,742	2,576	2,754	4,606
Other Manufacturing	4,390	6,799	7,917	12,577
Trans., Comm. and Public Utilities	49,205	87,429	101,393	145,962
Railroad Transporation	1,548	1,854	1,721	1,594
Trucking and Warehousing	8,723	12,878	14,344	21,965
Other Transportation and Services	9,066	26,785	31,786	37,553
Communications	10,872	16,895	19,737	37,553
Utilities (elec., gas, sanitary)	18,974	28,537	35,573	49,599
Wholesale and Retail Trade	126,991	193,163	213,320	314,583
Finance, Insurance and Real Estate	32,551	49,656	57,260	92,820
Services	110,409	191,823	221,353	366,853
Lodging Places and Personal Services	10,522	22,046	22,606	26,471
Business and Repair Services	22,100	39,457	48,425	82,546
Amusement and Recreation Services	1,742	10,806	12,967	15,234
Private Households	4,390	5,563	5,279	7,617
Professional Services	71,384	113,837	136,438	236,125

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TABLE 18 (CONTINUED)

	UNEMPLOYMENT RATE			
	7%	6%	6%	5%
	1977	1982	1985	1995
Government	175,461	229,735	258,647	423,183
Federal Government	67,265	82,416	91,685	159,247
State and Local Government	70,384	106,111	120,947	193,080
Armed Forces	37,919	41,308	45,900	60,227

S- Amount too small to calculate
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degree to which each industry category is "basic", that is the degree to which it essentially exports products to other regions in Texas and the U.S. In other words, a 100% basic industry would only serve markets outside of the local area. The greatest economic benefits within a region increase with increasing levels of export out of the region. For example, the primary aluminum industry prepares aluminum ore in Corpus Christi for further processing elsewhere in the United States. A list of some local industry categories, together with the ratio of basic character of each, is given below from the Ryan and Adams work:

Manufacturing	90% basic
Petroleum production	100% basic
Construction	10% basic
Transportation, communications and public utilities	25% basic
Wholesale and retail trade	15% basic
Finance, insurance, and real estate	15% basic
All services	10% basic
Federal civilian	85% basic
Military activity	100% basic
State and local government	10% basic

2.196 The world demand for petroleum is such that essentially full local production could be sustained without local markets. Certain industries will probably be affected by major changes in port capabilities and still others will tend to be dependent on the former's reactions to change. Accordingly, several major industry categories have been selected as being representative of the total effect which might be expected from each change in port facility configuration. In the previously cited work by Ryan and Adams, the degree of dependency within the manufacturing industrial category was estimated (on the basis of responses to a questionnaire) as follows:

Food and kindred products	10% port oriented
Chemicals and allied products	95% port oriented
Petroleum refining	99% port oriented
Stone, clay, and glass products	36% port oriented
Primary metals	100% port oriented
Fabricated metals	68% port oriented
All other manufacturing	81% port oriented

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2.197 Port dependency includes receiving raw materials or shipping finished or intermediate products through the port in international, national, or intracoastal trade.

2.198 For purposes of this study, four industries were selected as being "key" or "driving industries" in defining the probable impact of major change in port and harbor capability:

Chemicals and Allied Products
Petroleum Refining
Primary Metals
Transportation

Such major "port oriented" industries as are covered in the "all other manufacturing" category are felt to be dependent or can be assumed to depend on changes in the four selected. Transportation includes three important groups which will certainly be affected directly by changes in port activities: railroads, trucking and warehousing, and water transportation and transportation services. Accordingly, it is felt that analysis of changes within four industry categories, together with estimation of follow-on growths in secondary industry, will serve to approximate the overall and total economic effects concerning port development.

2.199 The Corpus Christi Study Area in Various Market Areas. A useful tool for testing the reasonableness of preliminary growth estimates in each industry is an analysis of the position of the Corpus Christi Study Area in the logical market area served by the industry category in question. It would be unreasonable to project growth which could not be supported by the market. Examination was made of three areas which the Study Area serves as a source of raw, intermediate, or finished material. These three areas match probable markets served from three different industry categories chemicals and allied products, petroleum refining, and primary metals. The nature of the chemical industry in the Corpus Christi Study Area is such that some products are sent all over the United States, but the bulk of production can be assumed to go as intermediate or finished goods within what might be broadly defined as the "Texas Gulf Coast". For statistical convenience, this area has been defined as including BEA Economic Areas 143 (Corpus Christi), 129(Austin), 140(Beaumont), 141(Houston), 142(San Antonio), and 144 (Lower Rio Grande Valley). Using this area for comparison of chemical production in the Study Area is felt to be a conservative test.

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2.200 Local petroleum refining distribution, while complicated by brand identification and individual company marketing practices in South Texas, can generally be assumed to be confined largely to an area defined as the "Corpus Christi Region," consisting of BEA Economic Areas 143(Corpus Christi), 142(San Antonio), and 144 (Lower Rio Grande Valley). Using this market is conservative in terms of reasonable certainity of demand for products of Corpus Christi industry. However this accounts for only about 15 percent of local production. The remaining 85 percent goes outside the state of Texas, principally to the east coast, and states served by the Mississippi River system.

2.201 Alumina production serves the entire nation. Accordingly, the State of Texas and the U.S. total alumina markets have been used for comparison of primary metals production. These comparisons are shown in Table 19, "Corpus Christi Study Area Position in Various Markets."

2.202 Data contained in Table 19 indicate that, for all three industries under inspection within any but its own region, the contribution of the Corpus Christi Study Area is not great enough to upset the market by major growth in the Study Area. For example, in 1990, doubling of the projected capacity or production output (directly proportional to total earnings in the industry category) would only raise the position from about 5% of the Gulf Coast to 15% and the extra growth account for a little more than one quarter of the projected growth for the entire area. Similarly, doubling primary metals output would hardly be noticeable in the State of Texas market, much less in the nation. Thus, the information in Table 19 serves as a check on growth assumptions.

2.203 Agriculture, Forestry and Fishing. The emphasis in agriculture prior to 1900 was on producing crops such as corn and vegetables. Since 1900 other crops and livestock have had a prominent role in agricultural products. Cotton and other crops such as sorghums (which is rotated with cotton), flax, guar beans, and truck crops have been grown in the area. Agricultural output in the area also includes livestock such as beef and dairy cattle, sheep, horses, and poultry.

2.204 Commercial fishing historically has supplied food for the Texas coastal areas. Improved transportation and

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Table 19

CORPUS CHRISTI STUDY AREA POSITION IN VARIOUS MARKETS
Comparison of OBERS Series E Industry Earnings (Millions of 1967 $)

	1970		1980		1990		2000		2020	
	Earnings	CCSA Percent	Earnings	CCSA Percent	Earnings	CCSA Percent	Earnings	CCSA Percent	Earnings	CCSA Percent
CHEMICALS AND ALLIED PRODUCTS										
Corpus Christi Study Area [1]	21	100.0	50	100.0	72	100.0	105	100.0	195	100.0
Corpus Christi Region [2]	62	33.9	93	53.3	135	53.8	194	54.0	352	55 4
Texas Gulf Coast [3]	508	4.1	836	5.9	1,358	5.3	2,078	5.0	4,107	4.7
State of Texas	672	3.1	1,120	4.4	1,800	4.0	2,741	3.8	5,390	3.6
U. S. Total	10,231	0.21	15,632	0.32	22,549	0.32	32,251	0.32	58,746	0.33
PETROLEUM REFINING										
Corpus Christi Study Area [1]	17	100.0	29	100.0	37	100.0	47	100.0	71	100.0
Corpus Christi Region [2]	29	59.0	37	77.2	49	75.3	63	74.4	97	73.0
Texas Gulf Coast [3]	461	3.7	605	4.8	772	4.8	978	4.8	1,477	4.8
State of Texas	530	3.2	695	4.1	883	4.2	1,116	4.2	1,680	4.2
U. S. Total	2,625	0.65	3,385	0.85	4,188	0.88	5,213	0.90	7,720	0.91
PRIMARY METALS										
Corpus Christi Study Area [1]	13	100.0	29	100.0	35	100.0	42	100.0	58	100.0
Corpus Christi Region [2]	43	29.8	77	38.2	101	35.0	127	33.2	187	31.3
Texas Gulf Coast [3]	149	8.7	209	14.1	264	13.4	325	12.9	468	12.5
State of Texas	291	4.5	413	7.1	525	6.7	649	6.5	935	6.3
U. S. Total	12,284	0.11	14,302	0.21	16,404	0.22	19,088	0.22	25,528	0.23

POPULATION COMPARISON (000's)

	Population	CCSA Percent	Population	CCSA Percent	Population	CCSA Percent	Population	CCSA Percent	Population	CCSA Percent
POPULATION										
Corpus Christi Study Area [1]	294	100.0	308	100.0	332	100.0	347	100.0	377	100.0
Corpus Christi Region [2]	2,111	13.9	2,107	14.6	2,230	14.9	2,298	15.1	2,458	15.3
Texas Gulf Coast [3]	5,446	5.4	6,028	5.1	6,809	4.9	7,379	4.7	8,395	4.5
State of Texas	11,254	3.6	12,167	2.5	13,580	2.4	14,633	2.4	16,607	2.3
U. S. Total	203,235	0.14	223,532	0.14	246,039	0.13	263,830	0.13	297,146	0.13

[1]Corpus Christi Study Area = Aransas, Nueces, San Patricio Counties (SMSA + Aransas County)
[2]Corpus Christi Region = BEA Economic Areas, 142, 143, 144 (Corpus Christi-Laredo, San Antonio, and Lower Rio Grande Valley)
[3]Texas Gulf Coast = BEA Economic Areas 142, 143, 144 + 129, 140, 141 (Corpus Christi Region + Austin, Beaumont-Port Arthur and Houston)

Source: OBERS Series E Projections

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refigeration allowed the fishing industry to expand, and it now forms an important sector of the economy.

2.205 A recent production decline has been experienced in both finfish and shellfish. The oyster harvest has had the greatest decline. Oyster, harvest has declined steadily during the last decade, while the crab harvest has increased Finfish fishery is showing a recent decline. Economic species include drum, flounder, and trout. There has been an increase in landings of shrimp and other finfish offsetting the decline in other landings. This offset has helped maintain the 1970 tonnage catch near that of the 1960 level. Even though production has seemed to stabilize, the Aransas Pass-Rockport area still ranks fifth in the nation in marine landings. The market value of marine landings has increased despite a relatively stable landing level. Income from 1960 and 1970 increased approximately $2 million, even though the landings decreased. The commercial fishing industry is subject to seasonal fluctuations in employment which makes employment data almost impossible to obtain.

2.206 Mineral Resources. Petroleum has done more than any other economic sector of this area to provide a stable economy. It has stimulated the development of petrochemical plants, oil field service firms, improved port facilities, and expansion in housing, retailing, and services. Petroleum and related minerals have become a dominant force of the area.

2.207 Oil and gas are the major minerals extracted within the study area and account for the majority of the minerals income. Oil and gas are found in every county of the study area and in offshore waters as well. Oil and gas production is also an important factor in the state's economy. In 1960 the basin study area's oil amd gas production was 9 percent of the state's production and this has increased to over 11 percent in 1970. As demand and income increase, it will become more advantageous to develop the offshore fields and reopen old wells to increase production, maintaining the oil and gas industry as one of the leaders in the economy. Values of mineral production, as well as ranking of the importance of oil and gas, are shown in Table 20. There are several mineral deposits in the basin that add to the economic base. Among these are materials such as oyster shell, limestone for roads, sandstone, sand and gravel, caliche, clay, bentonite clay, carbonate clay, salt, gypsum,

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TABLE 20

VALUE OF MINERAL PRODUCTION
($000's)
ECONOMIC STUDY AREA

	1960	1970	1971	In Order of Value - 1971
Aransas	10,266	13,340	15,083	Natural gas, petroleum, natural gas liquids
Nueces	67,682	94,717	95,609	Natural gas, petroleum, natural gas liquids, cement, lime, stone, and gravel
San Patricio	46,314	45,692	39,644	Natural gas, petroleum, natural gas liquids, stone, sand and gravel, clays

SOURCE: Texas Almanac

Ref: See U.S. Department of Interior. Mineral Yearbook 1974.

EMPLOYMENT IN MINING
ECONOMIC STUDY AREA

County	1960	1970	Change 1960-1970 Number	Change 1960-1970 Percent
Aransas	144	129	-15	-10.4
Nueces	2,564	3,253	+689	+26.8
San Patricio	687	959	+272	+39.2

SOURCE: U.S. Census Data

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uranium, asphaltic limestone, and crushed basalt. The value of mineral production and total employment in the three county study area is provided in Table 20.

2.208 Tourism. Early attempts to establish tourism as part of the area's economic base were unsuccessful. The program was ineffective due to either inadequate planning or financing, and/or discouragement by hurricanes. Representatives of the Corpus Christi Area Convention and Tourist Bureau estimate that 2 million persons visited the Corpus Christi area in 1977. The majority of these visitors participated in saltwater-related recreational activities along the 350 miles of shoreline in Aransas, San Patricio, and Nueces counties.

2.209 Tourism makes significant contributions to the economies of Aransas, Nueces, and San Patricio counties, according to the 1975 Texas Outdoor Recreation Plan, by Texas Parks and Wildlife Department. U.S. Census Reports from the 1967 Census of Business indicate hotel, motel, and camp receipts represented 13% of all retail trade receipts in Nueces County and 17% of all retail receipts in San Patricio County for that year. In addition, receipts collected from recreation and amusement business comprised nearly 9% of all retail receipts in Nueces County and almost 13% in San Patricio County. While seasonal housing represented only 1% of all 1970 housing in Nueces and San Patricio counties, seasonal housing comprised nearly 7% of all housing in Aransas County. Port Aransas, a small community of approximately 2496 permanent residents and about 2126 summer residents, (1977 estimate of COG) is almost entirely reliant upon tourism. The Port Aransas Chamber of Commerce reports that almost all of the community's retail businesses are based on tourism. Port Aransas city officials and the editor of the community newspaper report that Port Aransas receives over 1 million visitors per year, with an average visitation rate of 30,000 persons/summer weekend. Vehicle counts by the State Department of Highways and Public Transportation for the two main access routes to Port Aransas indicate that over 1 million vehicles rode to Port Aransas via the ferry on State Highway 361 in both 1976 and 1977. Over 3 million vehicles crossed the JFK causeway to the south of Port Aransas from the Nueces County mainland in both 1976 and 1977. While Port Aransas was not the only destination for all recorded vehicular traffic, these counts lend credence to the tourism reports made by the local Port Aransas residents.

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2.210 There are approximately 40-42 motels and 15-16 rental condominiums in Port Aransas. Receipts from the city's hotel and motel tax indicate that over $3 million in revenue was generated from room rentals during a one-year period. In addition to rental facilities, between 300-400 homes in Port Aransas are absentee-owned for seasonal recreational use.

2.211 Presently, the community as well as other sections of Mustang Island are undergoing growth as condominium developments gain in popularity. Another contributor to growth is the expanding year-round tourism as winter visitors increase in number. The changing profile of winter visitors is bringing added revenue to the community. With increased promotion of the South Texas area as a winter retreat for Canadians, local city officials report that 500-600 Canadians visited Port Aransas in 1976. The expanded winter tourism has a stabilizing influence 2.212 Recreation.

2.213 Tourist Related Employment. The effects of tourism are primarily found in the services industry, including motels, clubs, and restaurants. Table 21 illustrates the employment in major tourism service categories. Tourist-related income is also used to create jobs in construction, repair services, finance, real estate, and many others.

2.214 Other Economic Factors. Other factors affecting the area's economy are public institutions and government employment. Although not directly involved in the economic activities of the area, they serve as a quality index of the economy.

2.215 Federal Employment. The area's economy was broadened by the establishment of military bases and facilities (Table 22). Three Naval Air bases were established to train combat pilots. Corpus Christi was selected for the main Naval Air Station (NAS) with auxiliary fields at Kingsville and Beeville with a satelite field at Orange Grove. After World War II, the Corpus Christi base became the Navy's jet training and aircraft repair facility. The Korean conflict renewed activity at the Naval Air Stations. Kingsville and Beeville both became all-jet facilities during the conflict. After the conflict, the Navy closed its Overhaul and Repair Department, which affected the local economy. However, the Army opened the Aeronautical Depot Maintenance Center (now called the Corpus Christi Army Depot) at NAS Corpus Christi

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TABLE 21

TOURIST RELATED EMPLOYMENT

Nueces River Basin Study Area
1970

County	Total Employed	Eating and Drinking		Service Stations		Entertainment & Recreation Sycs	
		No.	%	No.	%	No.	%
Aransas	2,845	133	4.6	67	2.3	35	1.2
Nueces	81,305	2,275	2.7	2,455	3.0	602	0.7
San Patricio	14,947	475	3.1	542	3.6	85	0.5

SOURCE: 1970 Census

SOURCE: SWRI, 1977

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TABLE 22

MILITARY PERSONNEL AND PAYROLL
(Payroll and Budget in $ millions)

Facility	Personnel		Payroll	Budget
	Military	Civilian		
Naval Air Station, Beeville	2,000	360	20	6.5
Naval Air Station, Corpus Christi	2,800	1,000	27	12.0
Naval Air Station, Kingsville	1,960	200	20	5.7
ARADMAC U.S. Army Aeronautical Depot Maintenance Center (Corpus Christi Army Depot)	450	4,408	47	

SOURCE: Public Information Officer, Naval Air Station, Corpus Christi

Public Information Officer, ARADMAC

SWIR, 1977

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which offset the closing of the Navy Facility. The combined military and civilian employment in area installations is over 13,178 with a yearly payroll of $114 million.

2.216 Major public institutions located in the study area are primary and secondary schools, colleges and universities, hospitals, nursing homes, libraries, and museums. They provide a "quality index" which is often used to measure whether or not the basin cities are good places to live, work, and raise families. New residents, business firms, and industries are reluctant to locate where these institutions are not available or inadequate.

2.217 Employment in education in the Study Area in 1970 accounted for between 8 and 10 percent of the total labor force. The number of persons employed in schools, colleges, and kindred educational services totaled 16,061 according to the 1970 Census. There are 71 high schools, 57 junior high schools, and 190 elementary schools in the basin. This includes both private and public schools. These institutions are important to the communities in the basin because of the payrolls and purchases made in operating these facilities. Kleberg County had approximately 15 percent of its labor force in employment related to education. Since almost all schools receive state funds, these institutions become a source of income that is essentially basic in nature.

2.218 Economic Trends in the Study Area. Aransas, San Patricio, and Nueces counties form the economic study area. San Patricio and Nueces form the Corpus Christi Standard Metropolitan Statistical Area (SMSA) for which statistical information is aggregated. In 1975 the Texas Water Resources Board (TWRB) estimated the study area population at 317,800. Projections by TWRB for 1982 and 1995 show study area population growth to 351,425 and 417,200 people respectively. Currently the economy of the study area is based to a large extend upon the availability of port transportation facilities to serve the needs of agriculture and fisheries, petroleum imports and exports, minerals processing, and recreation. The area serves as a major trade center for southeastern Texas and is the second most active port on the Gulf Coast. Corpus Christi was ranked tenth in the nation (by tonnage) in 1974. This tonnage was transported on barges and ships in domestic and foreign commerce. About 70% of the cargo in the port of Corpus Christi is crude or refined petroleum, 14% is metals and

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ores, 7% is chemicals and related products, 7% is agricultural products.

2.219 The labor force within the study area is expected to expand with the population increase. Decline in agricultural and mining employment is expected to continue and is projected to be offset by increases in manufacturing jobs in the urban areas. All economic activities are projected to have increases in income, but the percent increases in agriculture and mining are expected to be considerably smaller than the others. Manufacturing, services, and government are expected to have the greastest increases in both employment and income. Earnings in the services industry are projected to increase at a faster rate for the whole area but this will primarily occur in Nueces and San Patricio Counties.

2.220 Future economic growth of the study area will be affected by many public and private sector decisions. Among these are the construction of a deep draft harbor in Corpus Christi and the building of an additional surface water reservoir in McMullen and Live Oak Counties. The deep draft harbor is one possible method of assuring an economic supply of oil for existing industries which are dependent upon oil.

2.221 Land Use. The three county study area covers 1795 square miles (Table 23). In this area population density varies from a low of 9.1 persons/acre in Odem to 21.0 persons/acre in Taft. Corpus Christi has a population density of about 120 persons per acre (CBCOG, 1977). These densities (Table 24) reflect the settlement patterns within the study area communities. Projections of residential, commercial, and industrial land use by the CBCOG are based upon existing land use and upon local anticipated growth. The development trends depend upon population growth and locally developed plans and goals. Such plans range from encouraging an expanded industrial base to promoting seasonal tourism. Based upon these considerations, CBCOG predicts an increase in commercial and industrial land use (Table 24). As the population increases, there will be a need for additional institutional land use (i.e., government lands, schools, libraries, and hospitals). The projections made by the CBCOG assume a constant level of use for range land, forest land, water and wetlands, and barren lands through 1995. New residential, commercial, and indutrial lands will be converted from lands now in agricultural uses. Growth trends in the Corpus Christi-Padre Island area

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TABLE 23

LAND AREA BY COUNTY
(SQUARE MILES)

County	Total Area
Aransas	270
Nueces	845
San Patricio	680
TOTAL	1,795

SOURCE: CBCOG, 1977

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TABLE 24

SUMMARY OF DESIGNATED LAND USE BY YEAR
(WITHOUT PROJECT)

	1977	1982	1995
URBAN			
Residential (+ Mixed)	36,864	39,589	46,403
Commercial	11,648	12,849	16,214
Industrial	9,792	10,898	13,591
INSTITUTIONAL	13,312	13,617	13,923
AGRICULTURAL	337,66	332,327	319,149
RANGELAND	67,008	67,008	67,008
FORESTLAND	6,208	6,208	6,208
WATER	201,344	201,344	201,344
WETLAND	20,608	20,608	20,608
BARREN LAND	23,360	23,360	23,360
TOTALS:	727,808	727,808	727,808

SOURCE: CBCOG, 1977

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include primary and secondary residential growth in much of the area. Padre Island Investment Corporation plans to develop 3,100 more acre of residential lands by 1995, while only 2500 more acres of residential lands will be developed in Corpus Christi. The majority of industrial land use is outside the city, and this trend is expected to continue with only about 720 acres more of industrial lands developed by 1995. In the Rockport-Live Oak Peninsula Area, residential and commercial growth will continue to spread northward along Highway 35. About 1919 additional acres of residential and 445 additional acres of commercial lands will be developed by 1995. Industrial land development is projected to increase from 142 acres in 1975 to 493 acres in 1995 and will center around expansion of light industry.

2.222 In Port Aransas, growth of residential lands will continue along the Gulf Beach area until approximately 1215 acres are developed by 1995. Commercial land use will reach 75 acres by 1995 and be concentrated in the central core of the city. Industrial lands will increase by only 98 acres to 340 acres by 1995.

2.223 Other cities will have slight growth in residential, commercial, and industrial land use through 1995.

2.224 Hospitals. Hospitals can be divided into two categories; non-general and general. Non-general hospitals, which are not available to all citizens, include rehabilitation centers, ambulatory hospitals, mental hospitals, a state school for the mentally retarded, and a pediatric hospital. All non-general hospitals are located in Nueces County.

2.225 General hospitals include all hospitals licensed to provide services that are available to all citizens. There are 18 general hospitals located within the lower basin planning area, and 10 general hospitals within the upper basin planning area. Including one long-term convalescent hospital, the basin study area has 38 nursing homes.

2.226 Libraries. Corpus Christi is designated by the State of Texas Library Plan as a major resource center for 21 counties. In the lower basin study area Class II libraries (serving 25,000 or more) are found in Alice, Kingsville, and Robstown. There are many smaller libraries in cities throughout the area, but these are limited and have small budgets.

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2.227 Archaeological and Historical Resources. Information for all known sites which may be affected by the proposed action was requested from the Texas Archeological Survey. It reported that no known sites of archeological value would be affected. A Search of the National Register of Historic Places indicates that there are three National Historic Places in the project area. These are the Mathis House in Rockport in Aransas County, the King Ranch in Nueces and Kenedy Counties, and the McGloin Homestead near San Patricio County. One additional place, the Aransas Pass Light Station in Nueces County, has been nominated for inclusion in the National Register of Historic Places. These areas will not be affected by the project.

2.228 Recreation Participation rates for recreational activities within the study area have been estimated by the Texas Parks and Wildlife Department and are presented in Table 25. These estimates show that Nueces County has the highest current and projected future participation rates of the three counties under investigation.

2.229 Participation rates by recreational activity, as presented in Table 26, indicate that sport fishing is the leading activity in the study area for the years 1970 and 1975. By 1980, however, swimming is projected to replace fishing as the most popular activity. Projections for recreational activity participation rates show water-related activities (i.e., boating, fishing, skiing, surfing, and swimming) dominating the recreational opportunities. Recreational activities, other than those water-related, should gain participants over time, comprising nearly 40% of all activity days by the year 2000.

2.230 An indication of sport-fishing popularity on Mustang Island in Nueces County is revealed in the 1976 Department of Commerce publication, Environmental Studies of the South Texas Outer Continental Shelf, 1975. Table 27, taken from this report, shows estimates of sport-fishing effort (number of persons fishing) and the gross expenditures generated from this effort during the period of investigation 28 April 1975 - 24 April 1976.

2.231 Most fishing effort occurred on fishing piers, as indicated in Table 27. Beach fishing ranked second in popularity, accounting for approximately 23% of all sport-fishing effort during the twelve-month study period.

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TABLE 25

Estimated Current and Future Recreation Participation Days Occurring in the Three County Study Area, 1968-2000
(Without Project)
(Million Activity Days)

	1968/1970		1975		1980		1990		2000	Total % Increase
Aransas County	2.6		3.8		5.2		6.8		9.4	
% Increase		+47%		+35%		+32%		+37%		+262%
Nueces County	10.0		16.5		23.9		33.3		47.9	
% Increase		+64%		+45%		+39%		+44%		+378%
San Patricio County	2.3		2.9		3.5		4.3		5.4	
% Increase		+27%		+21%		+21%		+26%		+135%

Source: Texas Parks and Wildlife Department, Texas Outdoor Recreation Plan, "Outdoor Recreation on the Texas Gulf Coast," Vol. V, 1975.

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TABLE 26

Current and Projected Participation Occurring in Three-County Area
1968/1970 - 2000 by Type of Activity (Annual Activity Days)
(Without Project)

	%	1970	Rank	%	1975	Rank	%	1980	Rank	%	1990	Rank	%	2000	Rank
Boating	7.9	1,173,800	5	7.4	1,723,000	5	6.8	2,226,700	5	6.9	3,050,700	5	6.8	4,291,200	6
Fishing	35.7	5,330,500	1	29.8	6,927,700	1	24.8	8,089,000	2	23.8	10,561,500	2	21.5	13,495,000	2
Skiing	1.5	220,400	10	1.0	232,200	10	0.8	243,800	11	0.6	259,800	10	0.5	282,300	10
Surfing	2.2	333,108	8	2.1	484,500	8	1.9	613,600	8	2.1	932,600	8	2.2	1,344,400	8
Swimming	22.4	3,342,900	2	28.2	6,557,600	2	29.3	9,569,600	1	28.8	12,827,500	1	29.6	18,568,300	1
Camping	9.7	1,442,400	4	9.8	2,279,200	4	9.0	2,927,800	4	8.0	3,547,400	4	7.0	4,349,600	5
Picnicking	10.7	1,598,400	3	10.6	2,465,300	3	16.4	5,363,300	3	15.9	7,054,300	3	17.0	10,657,700	3
Marsh Hunting	0.1	19,100	12	0.2	43,900	12	0.2	57,200	12	0.2	76,700	12	0.2	128,000	12
Sightseeing	2.1	306,800	9	1.8	417,300	9	1.5	489,000	10	1.4	652,300	9	1.4	842,500	9
Walking	3.4	511,700	7	4.3	993,500	6	4.7	1,542,600	6	6.5	2,906,100	6	7.5	4,722,000	4
Hiking	0.7	110,800	11	0.7	154,500	11	0.5	175,900	9	0.5	220,900	11	0.4	272,400	11
Nature	3.6	543,700	6	4.1	941,700	7	4.1	1,354,900	7	5.3	2,359,000	7	5.9	3,693,400	7
TOTAL		14,933,600			23,220,400			32,653,400			44,448,000			62,646,800	

Source: Texas Parks and Wildlife Department, Texas Outdoor Recreation Plan, "Outdoor Recreation on the Texas Gulf Coast," Vol. V, 1975.

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TABLE 27

Estimates of mean daily effort and total effort by section, fishing platform, and time of week in the study area, 28 April 1975-24 April 1976. (Without Project)

Section and fishing platform	Weekday			Weekend-day			Total effort (weekday and weekend-day	
	Mean daily effort	Total effort	(%)	Mean daily effort	Total effort	(%)		(%)
				Man-days of fishing				
Mustang Island								
Outboard	25.6	6,351	(2.7)	72.0	8,358	(4.5)	14,709	(3.5)
Inboard	48.6	12,055	(5.0)	173.9	20,176	(10.8)	32,231	(7.6)
Headboat	107.6	26,692	(11.2)	136.5	15,840	(8.6)	42,532	(10.0)
Jetty	145.1	35,995	(15.1)	221.3	25,674	(13.8)	61,669	(14.5)
Pier	212.6	105,464	(44.1)	308.9	71,656	(38.5)	177,120	(41.7)
Beach	211.0	52,335	(21.9)	382.2	44,336	(23.8)	96,671	(22.7)
TOTAL		238,892			186,040		424,932	

Source: U.S. Dept. of Commerce, National Marine Fisheries Services, NOAA Final Report - Environmental Studies of the South Texas Outer Continental Shelf, 1975, Vol I.

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2.232 The reported fishing effort generated over $9 million in gross expenditures for the one-year study period, as shown in Table 28. These expenditures represent money spent by anglers in connection with fishing including transfer costs for transportation, food, and lodging and durable costs for fishing equipment and special clothing. This figure is based on an estimated $11.36 gross expediture/man-day of saltwater fishing derived by the Department of the Interior in the 1972 publication, 1970 National Survey of Fishing and Hunting.

2.233 Housing. The housing mix in the study area varies from large single family homes to small frame houses to rental units and apartment houses. Approximately 58% of the housing is owner occupied, 37% is renter occupied. Ten percent of the housing stock is vacant and is available for purchase or rent. Rental units may be seasonally occupied during the tourist season. About 86% of the housing stock has been built since 1940; 83% is single family dwelling, 15% multi-family and 2+% mobile homes.

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TABLE 28

Estimates of the values of the fisheries by section, fishing platform, and time of week in the study area, 28 April 1975-24 April 1976.

Section and fishing platform	Weekday	Weekend-day	Total (weekday and weekend-day)	Total (expanded for inflation-8%/year)	Total expanded for night fishing
	----------Gross expenditures in thousands of dollars----------				
Mustang Island					
Outboard	72.1	94.9	167.0	245.4	245.4
Inboard	136.9	229.2	366.1	537.9	537.9
Headboat	303.2	179.9	483.1	709.8	709.8
Jetty	408.9	291.7	700.6	1,029.4	1,441.2
Pier	1,198.1	814.0	2,012.1	2,956.4	4,139.0
Beach	594.5	503.7	1,098.2	1,613.6	2,259.0
Subtotal	2,713.7	2,113.4	4,827.1	7,092.5	9,332.3

Source: U.S. Dept. of Commerce, National Marine Fisheries Services, NOAA Final Report - Environmental Studies of the South Texas Outer Continental Shelf, 1975, Vol 8.

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3. RELATIONSHIP OF THE PROPOSED ACTION TO LAND USE PLANS.

3.01 A variety of land uses exist in the vicinity of the proposed project site. Existing land use (1977) in the three county area includes 36,864 acres of residential (mixed), 11,648 acres of commercial, and 9,792 acres of industrial lands. (Coastal Bend Council of Governments, 1977). Projected changes in land use made by the Coastal Bend COG indicate a decrease in agricultural lands and an increase in residential, commercial, and industrial acreages through 1995.

3.02 The project site is located on Harbor Island. To the north of the project site is Saint Joseph Island, a privately-owned barrier island which extends from the north jetty at Aransas Pass to Cedar Bayou. The island is used for ranching and private recreation. A small portion of the southern tip of the island, adjacent to the Aransas Pass Channel, is owned by the Federal Government. Mustang Island extends from the Aransas Pass Channel to the Corpus Christi Pass, a distance of about 16 miles. The 16 mile long beach front is a very popular recreational center. Mustang Island has numerous beach homes and water-oriented recreational facilities.

3.03 Port Aransas is the only town on the northern end of Mustang Island. It is a tourist center, serving as the access to beaches and a base for sport and commercial fishing. Both State and Federal Agencies operate marine research centers in Port Aransas.

3.04 A causeway and ferry provide access to the northern end of Mustang Island at Port Aransas, while the John F. Kennedy Causeway provides access to Padre Island which is separated from the mainland by Laguna Madre. An elaborate hotel complex and canal frontage homes and apartments have been built on the north end of Padre Island. A few miles south of the John F. Kennedy Causeway is the northern entrance to the Padre Island National Seashore. The park is 80 miles long and is dedicated to preserving that portion of the island in its natural state for the public enjoyment. Each year its beaches provide recreation for many thousands of people. Presently, there are camping and picnicking areas, an observation tower, and a tourist center with additional facilities planned.

3.05 Harbor Island is located opposite the Aransas Pass inlet and separates Corpus Christi Bay from Aransas Bay.

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Most of the island is submerged or is honeycombed with small channels. Development on Harbor Island consists of the industrial port-related petroleum facility over a limited area opposite Port Aransas. There are a few fishing camps along Highway 36, which links Aransas Pass to Port Aransas. On the southeastern portion of Harbor Island, Exxon and American Petrofina have petroleum unloading docks and oil storage facilities. In addition, Brown & Root Inc. has a facility for the construction of offshore oil drilling platforms. The tributary channel to Aransas Pass bisects Harbor Island on the north side of Highway 36. An old lighthouse on the northeast end of the island is a major landmark and has been nominated for inclusion in the National Register of Historic Places.

3.06 Much of the area designated for construction of harbor facilities, surge tanks, and disposal area, is currently wetlands and undeveloped land that has been in industrial use since 1912. Various portions of the upland area serves as wildlife habitat, while the wetland areas are of importance to the marine and estuarine ecosystem. Construction of the project would result in removal of some terrestrial and aquatic habitat.

3.07 No significant displacement of population in the study area should result from construction of the proposed project. Secondary industrial and residential development is anticipated to occur but will probably be within the normal growth experienced in the study area. Estimates indicate that over the next fifty years, approximately 4 percent of the total agricultural acreage in Aransas, San Patricio, and Nueces Counties would be lost to other uses. The loss of this agricultural land is inevitable with or without the project and the land irreplacable, but the crop loss may be lessened by future technological improvements and the use of marginal land for agriculture. Similarly, a continuing decline in agricultural employment not related to the project is anticipated.

3.08 Temporary inflation of property values may occur in critically needed land areas. However, the value of such lands seldom drops to previous levels when use pressures are lessened. Development is expected to continue around Metropolitan and urban centers. Property values are expected to increase steadily throughout the region. The rate of increase will be greatest in the 1991-2000 span and will slow thereafter. Both residential and industrial development will give Corpus Christi and vicinity a broader

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tax base. The increased efficiency of water transportation would encourage existing industries to expand and new industries to locate in the area. Industrial growth would add employment, increase property values, develop satellite services, help diversify the area's economy, and generally enhance the economic well-being of the population in the area.

3.09 Dredge material disposal is planned for San Jose Island and areas west of Port Aransas. Plans for these disposal areas include future unspecified residential and recreational development or land reclamation for open space, however, this development will not be allowed until the areas are no longer feasible for use as disposal areas for maintenance materials.

3.10 Relationship of Proposed Action to Federal Projects in the Area. This project would affect the existing federally constructed Corpus Christi Ship Channel, Tributary Channel to Aransas Pass, and Gulf Intracoastal Waterway Lydia Ann Channel. Should the proposed project be constructed, Federal maintenance of the existing Corpus Christi Ship Channel (entrance and jetty channels) would no longer be required, since that portion of the channel would be deeper than the Corps of Engineers is authorized to dredge. Maintenance of the existing GIWW Lydia Ann Channel in the vicinity of the proposed project likewise would no longer require Federal maintenance.

3.11 The proposed action calls for rerouting the Tributary Channel to Aransas Pass, a federally constructed and maintained shallow draft navigation channel. This channel is used primarily by the shrimping fleet operating from the Port Aransas area. Rerouting of this channel should not affect the Federal maintenance of the project. Enlargement of the Tributary channel to Aransas Pass is scheduled to begin in the summer of 1978. These authorized improvements involve deepening the entire project from 12 feet to 14 feet and widening from 125 feet to 175 feet between mile 3.5 and 4.6. The proposed permit should not affect federal construction or maintenance of the Tributary Channel to Aransas Pass.

3.12 The State of Texas has not yet implemented an approved coastal zone management program.

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4. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION.

4.01 The proposed deep draft port would have far reaching social and environmental impacts on the entire project area. The proposed project would provide economic benefits in the region through improvement of marine transportation facilities. In turn, the developmental potential of the already major navigation dependent industrial complex, the employment and income associated with these industries, and, consequently the economic well-being of the inhabitants of the area would be enhanced. The beneficial effects of ocean-going commerce through the port would extend far beyond the local community and would make significant contributions to the economy of the state, region, and nation. The project would, however, have adverse effects on the natural environment. These adverse impacts include the loss of wetland areas, removal of benthic life in the channel and disposal areas, disruption of wildlife habitat, increased turbidity during construction, and other social and environmental impacts.

4.02 Effects on Water Quality. Some temporary water quality effects could be expected to result from construction and maintenance of the project, including increased turbidity and possible resuspension of pollutants. During dredging and disposal activities, increased turbidity would affect an area several hundred feet or more from the source. The significance of this effect depends on dredging time and methods used to control turbidities.

4.03 Adverse effects which could result from increased turbidity, include reduction of light penetration which results in lower photosynthetic activity and a reduction at the base of the aquatic food chain. Other effects which may result from increased turbidity include sedimentation in adjacent wetlands, smothering of some benthic organisms, and death of juvenile fish and shellfish by coating of gill tissues with sediment. The significance of these impacts depends on the length of dredging time and number and size of dredges. Should dredging be continuous in one location for the 2 years of anticipated construction time, the primary production in the immediate vicinity could be affected through a loss of photosysthetic activity.

4.04 Because of the nature of the materials and the lack of pollutants in the material to be dredged, no significant degradation of water quality should occur through resuspension of heavy metals, organohalogens,

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organosilicones, pesticides, or other constituents. Even if the sediments contain pollutants, little or no data exist to indicate that dredging and disposal of polluted sediments would cause a significant degradation in water quality. After several years of intensive study of this problem, laboratory investigations done in conjunction with the Corps of Engineers' Dredged Material Research Program have shown that most heavy metals in sediments are unavailable to the water column and that zinc, mercury, cadmium, and most other heavy metals are immobile and unavailable biologically. Lee (1976), in studying the results of elutriate testing, found only ammonia and manganese were released in sufficient amounts to become of potential concern with respect to acute lethal toxicity. All other chemicals released were in quantities considerably lower than the acute lethal limits for various forms of aquatic life. Lee concluded that concentrations of these contaminants in the water column would be rapidly diluted below the acute lethal limit and, therefore, present little or no hazard to aquatic life in the water column, either from acute lethal or chronic sublethal effects.

4.05 Other studies on the effects of water quality degradation from dredging have been made in recent years. These studies were generally made in the actual areas being dredged and reflect the naturally occurring influences of chemicals and materials present in bay areas. The results of most of these studies indicate that a portion of the pollutants contained in sediments may be resuspended in the bay waters immediately surrounding the point of disposal and that these pollutants are then rapidly removed from biological accessibility.

4.06 In pilot laboratory studies, Gustafson (1972) discussed the fallacies connected with turbidity and resuspension of sediments by dredging. He showed that suspended clays attract bacteria and remove oils, pesticides, sewage products (except nitrates), and metals from the water and demonstrated the probability that metals adsorbed to clays are not released when clays are resuspended and that organic molecules are not liberated in amounts sufficient to cause ecological concern.

4.07 Because of rapid settlement of dredged materials, volatile solids are of little importance to dredging situations unless they are high enough concentration to have already degraded water quality.

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4.08 The Galveston District Corps of Engineers has conducted numerous water quality monitoring programs in conjunction with dredging operations along the Texas coast over the past four years. The results of these programs have invariably shown that the only potentially harmful constituents normally entering the water column during dredging and disposal operations are nitrogen compounds. The Galveston District is not aware of any situation where the resuspension of heavy metals caused by dredging has been reliably demonstrated.

4.09 Every reasonable effort would be made to protect sensitive wetlands from increased turbidity during construction of the project. Wherever practical, cutter suction dredges and land based equipment would be used in inshore areas. These produce less turbidity than other types suitable for inshore use. Further, dredging would be minimized as much as reasonably possible during peak migratory movements. Disposal areas would be diked to reduce turbidity in adjacent waters and effluent from these diked disposal areas would be controlled by wiers.

4.10 For the forgoing reasons, it is believed that the dredging of the inshore portions of the channel and the contained land disposal operations would not have any significant adverse effect on water quality other than localized temporarily high turbidities. Nitrogen compounds released could aid in recovery and growth of vegetation near the channel.

4.11 The following paragraphs (provided primarily by Southwest Research Inc.) are devoted to the forecast of water quality components in the project area. The overall forecasting techniques are general in most cases, as the various components do not lend themselves to specific, quantifiable prediction. The forecast interval was 1980 through 2020. The 1980 forecast year was selected by SWRI as a projected construction date. Furthermore, any increase in pollutants which would otherwise occur as a result of secondary industrial or residential development would be regulated and controlled through adminstrative water pollution control programs. The 1972 Amendments to the Federal Water Pollution Control Act prohibit any discharge of pollutants to a navigable waterway (42 U.S.C. § 301a) unless the discharge is permitted by the Environmental Protection Agency through a National Pollution Discharge Elimination System (NPDES) permit, issued pursuant to 42 U.S.C. § 1342. Under such a permit, the discharge must meet

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the effluent standards established by the Act. The level of treatment, based upon technological capabilities, is set forth for both industrial sources and sanitary sewage treatment plants in 42 U.S.C. § 1311. If those technology-based effluent limitations are insufficient to protect a given waterway from water pollution, then EPA is authorized under 42 U.S.C. § 1312 to adopt more stringent effluent limitations for those sources which are causing the condition of pollution so as to

> ". . . assure protection of public water supplies, agricultural and industrial uses, and the protection and propagation of a balanced population of shellfish, and wildlife, and allow recreation activities in and on the water..."

Consequently, governmental regulatory programs are expected to preclude any significant water pollution as a result of secondary industrial or residential development which might occur as a result of this project.

4.12 Heavy Metals. The construction and maintenance activities should have little, if any, effect on the heavy metals content of the area's waters. Some sediment containing undesirable metals would be dredged and confined in the various disposal areas utilized.

4.13 If some fraction of heavy metal accumulation in the water and sediment does indeed result from the use of a waterway by vessels, then an increase in heavy metal content of the sediment, in particular, would occur in the new turning basin at Harbor Island.

4.14 It is possible that heavy metals content in the water and sediments offshore could increase due to the flushing effect of tidal exchange at Port Aransas. Levels offshore should not, however, approach inshore levels because of the long distance from the zones of greatest potential heavy metal concentration in the Corpus Christi Inner Harbor and along La Quinta Channel.

4.15 Pesticides. No effect on pesticide concentration is anticipated as a result of the Harbor Island Deepwater Port and its related activities, including population growth and industrial activity. Because of the additional water exchange in the system there may be a slight lessening of pesticide concentrations in the water in the system.

4.16 Suspended Solids. No overall change in the suspended solids is expected, though dredging operations could raise

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levels for short time periods in the vicinity of activities. No detrimental effect of dredged material disposal on baywide suspended solid contents is expected. A slight increase of suspended solids in the entrance channel, Lydia Ann, Aransas and Corpus Christi Ship Channel to Ingleside could develop due to expected velocity increases engendered by deepening and widening of the ingress-egress area at Port Aransas, but additional suspended particle quantities should pose no environmental hazard. The same mitigation measures used to control turbidity could act to reduce suspended solids levels.

4.17 Transmissivity. No appreciable long lasting transmissivity change should develop. During the construction period, considerable turbidity of a short duration and small spatial extent would be created, but there should be no long-term effects on transmissivity from one-time dredging and disposal. The maintenance dredging operations could produce turbidity (transmissivity) problems, but the activities and effects would be short-term and could probably be mitigated by preventive and controlling actions, such as silt curtains, bottom disposal of dredged materials, and other techniques.

4.18 Mitigation measures used to control turbidity will also act to improve transmissivity.

4.19 Nutrients. A small increase in nutrients delivered by the additional seawater flowing through the system might ensue, but the increase would be insignificant. There would be no increase due to the actual channel deepening and widening.

4.20 If pollution control laws are not enforced, nutrients derived from wastes could be added to the system by the burgeoning population and its concommittant industrial development. Estimates are that by 2030 Corpus Christi Bay nutrient levels could be about 2-1/2 times higher than the 1980 level, but still only reach 40 percent of Galveston Bay's 1980 level (Galveston Bay's 1980 level is viewed as the highest acceptable level for Corpus Christi Bay). Corpus Christi Bay's increase in nutrients, while advancing the bay toward unacceptable quantities will probably result in an increase in productivity in the bay system. However, once optimum levels of nutrients are obtained, additional increases may result in deterioration of aesthetic conditions.

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4.21 Temperature. A very small moderation of temperature range could develop due to the additional seawater available for mixing, but the magnitude of the change would be insignificant and would have no measurable effect on the biota.

4.22 Salinity. Salinity would be elevated slightly in the area of Harbor Island as the enlargement of the entrance channel (to 80-foot depth) would allow more Gulf water to enter the inshore system. Based on computer simulations conducted by SWRI, salinity in the Harbor Island area may rise as much as 5 percent from the 1980 base average of 30 ppt to about 31.5 ppt in 2030. Elsewhere in the Bay system very little effect on salinity would be experienced. Because the channels leading from Harbor Island to Corpus Christi Bay, Aransas Bay, and Redfish Bay would not be enlarged concommittantly, the exchange of water between the open Gulf and the inshore bays should be affected minimally. A change of less than 1/2 percent in salinity content might occur in the inshore bays, with the effects increasing as Harbor Island is neared. The reduction in salinity range would be greatest at Harbor Island and lessen away from the area. Effects of lessened salinity range should not be significant.

4.23 Dissolved Oxygen. No change in the overall average or in the 1980 base conditions should develop in Nueces and Corpus Christi Bays. The 80-foot deep Harbor Island Turning Basin and Entrance Channel would be an area of possible concern. Since the dissolved oxygen content generally decreases slightly with depth, values lower than 1980 contents would be expected in the deepened channels. Within the docking basin dissolved oxygen content could lessen additionally due to the confined nature of the basin. The lowest dissolved oxygen levels probably would be found at the portion of the docking basin farthest from the entrance channel. Due to the large opening in the configuration of the basin and the basin's nearness to the zone of maximum water exchange at Port Aransas, the dissolved oxygen values should stabilize above acceptable limits. It is probable that dissolved oxygen values at the bottom of the Harbor Island Turning Basin would be slightly higher than the 1980 base condition within the Inner Harbor (the 1980 Inner Harbor condition being the worst case condition in the various segments of concern).

4.24 Biological Oxygen Demand. The physical construction and existence of the Harbor Island facility should produce

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no effect on biological oxygen demand levels. A secondary effect related to the project is the development of industrial and population sectors. This could add organic waste pollutants to the system, particularly if proper safeguards were not initiated. With proper pollution control, however, biological oxygen demand levels should not increase.

4.25 Chemical Oxygen Demand. The construction, modification, and physical nature of the Harbor Island facility and its associated channel developments should not increase chemical oxygen demands. The associated population growth and industrial development could cause chemical oxygen demand values in the system to increase, particularly in La Quinta Channel area and the Inner Harbor, along which most new industry would locate. The 2030 chemical oxygen demand values would not be significantly higher than 1980 values if pollution control law enforcement is continued. The worst case maximum chemical oxygen demand change would be a doubling of 1980 base conditions. This would not constitute a threat to the biota of the bay water, though some localized effects on oxygen availability might be evident.

4.26 pH and Alkalinity. A slight increase in pH and alkalinity due to the influx of additional seawater could occur in the area of the Harbor facilities, but it should be smaller than both seasonal and isolated meteorologically induced fluctuations.

4.27 Oil and Grease. The levels of oil and grease in the Inner Harbor, La Quinta, and Harbor Island areas should be a function of the quantity of ship traffic through the area. Since overall traffic attributable directly to the project (number of vessels) would decline with the proposed project, it is assumed that oil and grease background levels would similarly decline. While land derived oil and grease pollution could grow proportionally with the growth of population, the projected 1980 oil and grease base is so low that it is probable that no adverse conditions would result from increased background levels of oil and grease in the study area.

4.28 Water Exchange. By opening the entrance channel to an 80-foot depth, additional water would be allowed to enter at Aransas Pass. The maximum estimated increase would be 10 percent at Aransas Pass with the water flowing out via Corpus Christi Ship Channel (handles 5.9 percent of

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increase), Aransas Channel (handles 0.3 percent of increase), and Lydia Ann Channel (handles 3.8 percent of increase).

4.29 Current Velocity. Current velocity should be affected positively in the channels at the confluence near Harbor Island. A 4 percent (± 2 percent) increase in speed is postulated within the entrance channel, but should average only 3 percent (± 1 percent) (Theoretical maximum speed in 1980 is 3.2 knots, should be 3.4 knots at most in 2030). Corpus Christi Ship Channel, Aransas Channel and Lydia Ann Channel should exhibit similar increases of about 5 percent in their maximum velocities and an average change of 3 percent (± 1 percent). These increases are quite small and relatively insignificant.

4.30 The Effects of the Proposed Project on Hurricane Surge. The SW Research Institute studies of surge were performed by utilizing the Bay Wind Surge model, namely the Standard Project Hurricane with a large radius to region of maximum winds and a slow speed of translation of hurricane center. The Standard Project Hurricane (SPH) is a hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations. It is further assumed that the SPH would approach a given project site from such direction, and at such rate of movement, as to produce the highest hurricane surge hydrograph, considering pertinent hydraulic characteristics of the area. The distance from the hurricane center to the point of maximum wind velocity is called the radius of maximum winds. The slow speed is about 4 knots, and the large radius is about 19 nautical miles. Peak surge varied less than 0.3 feet with the addition of channel modifications and disposal sites in the Southwest Institute simulations.

4.31 A utilization of the Standard Project Hurricane model with a large radius to region of maximum winds but moderate speed of translation (about 11 knots) was made for the project location. An improved channel entrance and a simulated barrier on the coastal islands resulted in the model peak surge of the back bay near Corpus Christi to fall about a half foot and peak surge behind the barrier island to decrease almost one foot.

4.32 A comparison by SWRI of the As-Is versus proposed Project conditions for a slow speed hurricane using

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numerical models indicate a minimum project influence on peak surge elevations. This is due to the long time period of inflow to the bay thus minimizing the effect of the increased flow area. The surge hydrographs indicate a gradual rise and fall of surge heights. In the back bay, the surge has a faster rate of rise and peaks higher than in the forebay. There is no indication of development of a rapid or steep wave movement out of the Bay. The results of these studies indicate that storm surges which would result from channel enlargement for SPH would have negligable effect on the surrounding bay systems. The following table indicates the expected changes in Surge Elevations (in feet) with and without the project.

	With Project	Without Project
Corpus Christi	16.3	16.6
OSO Bay	15.1	15.5
Port Aransas	11.5	11.5
Ingleside	14.3	14.5
Portland	5.7	5.9

4.33 The project should provide additional protection against storm induced high water in several areas. The stabilized dike on San Jose Island (disposal area B) should help protect the Aransas Pass -Rockport area from storm surge and the broad levee at the west side of area D would help protect Port Aransas from back surge and to confine storm waters to the Corpus Christi Channel.

4.34 Oil Spills. Near-shore and inshore marine oil spills occur from several sources. These include groundings or collisions of ships, loading and unloading accidents at terminals, rupture or leakage of submerged pipelines, and accidents at onshore facilities very near the water. Although accidental oil spills are spectacular events and attract the most public attention, they constitute only about 10 percent of the total amount of oil entering the marine environment. The other 90 percent originates from the normal operation of oil-carrying tankers, other ships, offshore production, refinery operations, and the disposal of oil-waste materials. The following percentages for 1969 sources of direct oil pollution are based on Revelle, et al. (1972):

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Tankers	24%
Other Ships	23%
Offshore Production	5%
Refinery Operations	14%
Oil Wastes	25%
Accidental Spills	9%
	100%

Oil spills from loading activities are in general easier to control and clean up than spills from vessel accidents. In addition, application of known technology and good practices can virtually eliminate major loading spills.

4.35 Oil Spill Risks Analysis. A. H. Beyer and L. J. Painter developed a method for determining the potential for oil spills from tankers. The technique provides a worst case estimate since it does not account for continuing improvements in technology, operation procedures, and safety measures. Only cargo spillage from casualties such as ruptured cargo tanks from collisions, structural failures, grounding, etc. are considered. Cargo-transfer related spills are not amenable to this prediction.

4.36 Bayer and Painter (1977) compiled information from the literature on world-wide tanker casualty spills during 1969-1972 (Table 29), and determined that such spills could be expected to occur within 50 miles of land, on an average of once in every 1000 vessel port-calls or about once in every 50 vessel years of operation. The average size of these casualty spills (within 50 miles of land) was 7100 bbl and the average spill rate was about 87 bpmb (bbl per million bbl) transported. Using this information they developed a technique for spill predicting. Table 29 contains a summary of historical spill parameters for predicting future tanker casualty spills by any of three exposure variables, number of vessel port calls, volume of cargo transported, and number of vessel-years of operation. Using an exposure variable from table 29 the mean spill size, and the spill size distribution must be determined to make future spill projections. The projections include such information as spill recurrence intervals, spill probability and average annual spillage.

4.37 For this project, only volume of cargo transported, and number of vessel-years can be used as exposure variables since the number of Port calls (trade routes) have a great

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Table 29. Historical parameters for predicting tanker casualty spills within 50 miles of land

Exposure Variable	Spill Frequency Mean	Spill Frequency Basis	Spill Size Mean (Bbl)	Spill Size Basis	Generally Suitable for Use When:
Number of Port-Calls	0.92×10^{-3} spills/ port-calls	1969-1970 world-wide spills < 50 miles from land and 1969-1972 spills at 7 major U.S. ports	7,100	1969-1972 world-wide spills < 50 miles from land	The tanker fleet, total volume of cargo, and trade routes are known
Volume of Cargo Transported	12.9×10^{-9} spills/ bbl transported	1969-1972 world-wide spills < 50 miles from land	7,100	Same as above	The total volume of cargo is known, but the tanker fleet and trade routes are uncertain.
Number of Vessel-Years	20.3×10^{-3} spills/ vessel-years	1969-1972 world-wide spill < 50 miles from land	7,100	Same as above	The tanker fleet is known, but the total volume of cargo and trade routes are uncertain.

SOURCE: Beyer and Painter, 1977

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deal of variability. Using these exposure variables to compare the proposed project with the as is situation the following predictions in spills per year result:

Exposure Variable	Without Project	With Project
Number of vessel-years	10.46 spills/year	2.5-3.0 spills/year
Volume imported	.278 spills/year	3.81 spills/year

4.38 It is important to recognize that the information used in this analysis was derived from international historical statistics and hence does not reflect the higher degree of regulatory control of ship design and operations of U.S. flag carriers. Further, the estimates do not reflect recent pollution control regulations.

4.39 Accidental releases occurring in ship to shore transfers are the second major source of oil pollution from waterborn crude transport. These spills result from human error or from mechanical failure of transfer equipment. U.S. Coast Guard (1971) determined that 0.00007% of the oil handled is spilled. Porricelli et al., (1971) suggested a larger volume of 0.00015% spilled. Using the Porricelli value and an assumed 870,000 bbl per day volume, or 317 x 10^6 bbl annually results in 476 bbl spilled annually by unloading operations. This estimate of terminal spillage is based solely on the volume of crude oil transferred and not upon transfer frequency. Quite obviously, frequency will have a bearing on the general conditions at terminal locations as the number of connects and disconnects and transfer pump starts and stops present opportunities for human error and equipment failure. Thus, it can be argued that the total amount of oil spilled from these operations should be proportional to the number of transfers, rather than to the total volume. It should be noted that larger crude carriers employ larger piping sizes and increased transfer pumping rates. Therefore, although the frequency of terminal spills may decrease with the use of larger vessels the severity will likely increase in proportion. The total net discharge may also increase since total volume unloaded at Harbor Island would increase with the proposed project.

4.40 Oil Spill Movement Analysis. As part of the environmental assessment, SWRI (1977) used a non-computerized approach in predicting oil spill movements and

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computerized approach in predicting oil spill movements and the following discussion outlines the results of that approach.

4.41 Investigations were conducted to evaluate the non-computerized techniques available for oil slick movement and their predictive capabilities. Sources which had investigated the spread of oil on a water surface, the direction and speed of oil on a water surface, the direction and speed of movement, and the maximum attainable size were comprised of three principal investigating teams: Fay and Hoult (1971), Fannelop and Waldman (1971), and Wang and Tayfun (1973). Thus, combining the slick size and spreading formulas developed by Fay and Hoult (1971), and Fannelop and Waldman (1971) with the slick movement and direction formula developed by Wang and Tayfun (1973) an estimate of the overall slick movement processes was made. The formula developed by Wang and Tayfun (1973) is based on an overall slick movement composed of 56% of the water current speed and 3% of the wind speed in a direction to the right of the wind (due to the Coriolis effect).

4.42 Applicability of the Approach. The investigation of the applicability of the non-computerized approach addressed both inshore and offshore considerations. Therefore, a somewhat modified approach to the offshore oil spill movement predictions was required. The influence of water current drift was neglected and wind drift was assumed to be the prime influence. This is a reasonable approach for the offshore Texas area since the majority of water movements in the Gulf are thought to be induced by the prevailing wind patterns. Under this assumption, the movement of an oil slick from an offshore spill site was investigated under the following conditions:

The oil spill was considered as a single point release of 10,000,000 gallons.

One release point was considered, this being the proposed SPM location in the vicinity of coordinate 27° 33'N, 96° 53'W, approximately 7 nautical miles offshore.

The oil slick movement was evaluated for four different wind directions which (with other forces) would tend to move the slick towards land areas. These directions are N, NE, E, SE. A continuous velocity of 25 knots was used for a

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period until that time at which the oil slick reached shore.

The oil slick movement trajectory was computed for every four hour time increment from start of spill until land fall occurred.

Under the above stated conditions, the following parameters were estimated: trajectory for each given wind direction, time for the oil slick to reach shore, size of each oil slick at any given time increment, point at which the oil slick will first reach shore, and area of inundation by the oil slick for each given condition.

4.43 The results for the predicted oil spill movement in the offshore area are shown in Figure 33. Several observations can be made for each of the spill paths depicted. A summary of these observations is presented in Table 30. It appears that an oil spill occurring at the offshore location could reach land in as little as 22 hours. This condition exists with an East wind. The potential areas of inundation, except for that portion of Padre Island below Baffin Bay, are in most cases prime recreational areas for South Texas inhabitants.

4.44 Next the applicability of the oil spill movement predictive approach was investigated for the inshore area. The necessary inputs relating to water current speed and direction were generated by the Texas Water Development Board°s (TWDB) tidal hydrodynamic computer model. The complete oil slick drift rate formula developed by Wang and Tayfun (1973) were used. The oil slick drift and spreading was evaluated for two different spill locations in and around the Harbor Island area. The locations were chosen to analyze the implications of the effect of tidal variances and to recognize the potential effects of oil spreading into Redfish, Corpus Christi, and Aransas Bays. These sites will not be accessible to a VLCC; however, the problem was purposefully approached in this manner to adequately evaluate the effects of oil spills on all three of the major bay areas mentioned. The analytical techniques do not lend themselves to use in channels or constricted areas. Therefore, oil coming through channels was treated as coming from a psuedo-source where the channel opens to the bay. This approach covered the environmentally significant areas both adjacent to and removed from the proposed Harbor Island

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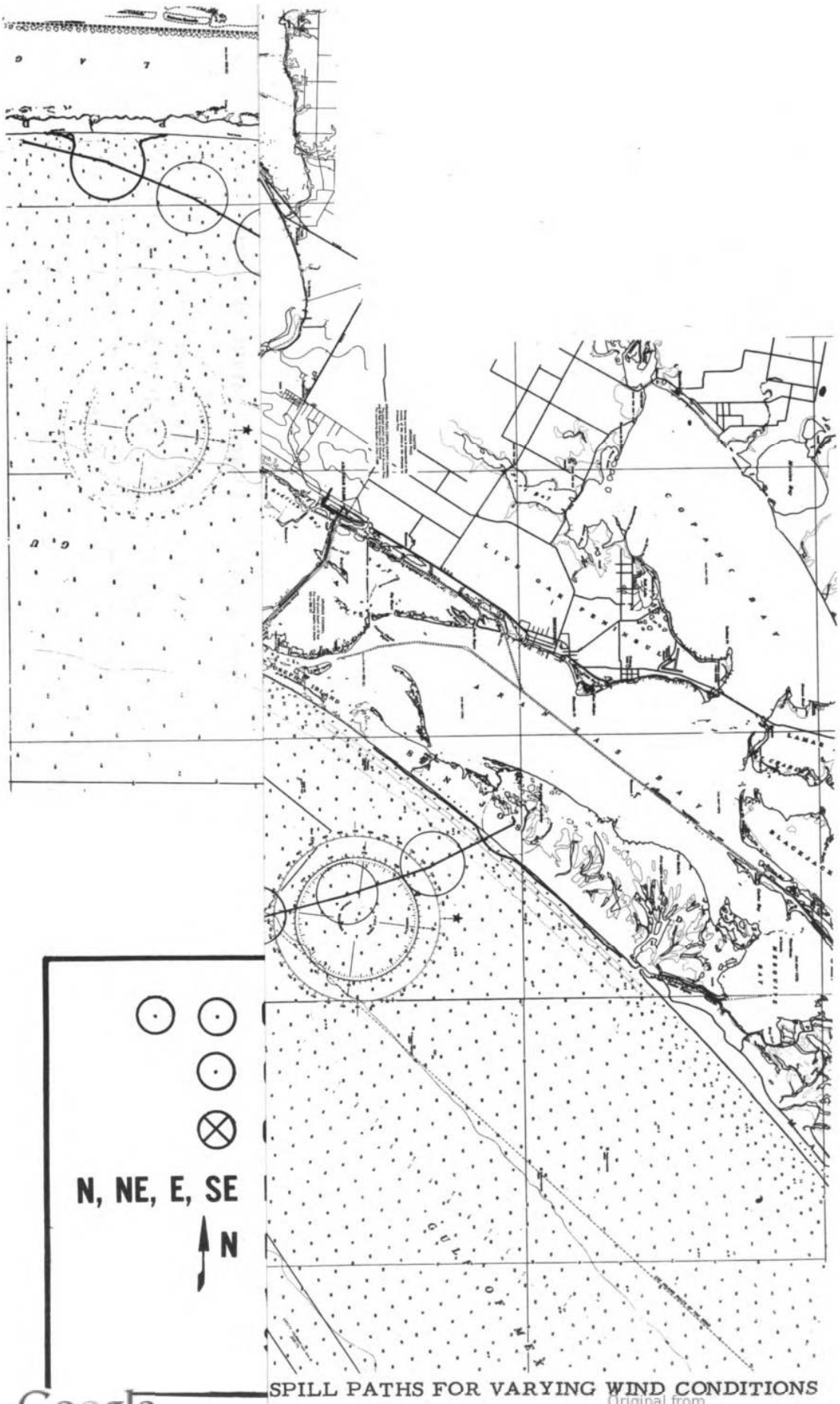

SPILL PATHS FOR VARYING WIND CONDITIONS

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TABLE 30

SUMMARY OF OFFSHORE OIL SPILL MOVEMENT OBSERVATIONS

Spill Wind Condition	Approximate Time to Reach Shore	Estimated Maximum Spill Diameter	Point of Oil Spill Shore Contact
North	44 hours	2.5 nautical miles	Padre Island shoreline several miles below Baffin Bay.
Northeast	26 hours	2.0 nautical miles	Padre Island shoreline seven miles south of John F. Kennedy Causeway
East	22 hours	2.0 nautical miles	Mustang Island shoreline in line with Shamrock Cove
Southeast	34 hours	2.25 nautical miles	San Jose Island shoreline three miles north of Mud Island.

SOURCE: SWRI, 1977

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VLCC off-loading terminal. For the inshore deep water port at Harbor Island, the movement of an oil slick was investigated under the following conditions:

The spills consisted of single releases of approximately 1,000,000 gallons.

Release points were located at the following locations:

.. In the Corpus Christi-Aransas Pass Channel, near the vicinity of Point of Mustang.

.. In Lydia Ann Channel near the vicinity of Lydia Ann Island.

Water current velocities determined by the Texas Water Development Board's hydrodynamic model were used in estimating the oil slick movement.

The oil slick movement was estimated for a release at the start of an incoming tide and at the start of an outgoing tide and for the four most probable wind conditions over any given year, N, NE, E, and SE, at a continuous velocity of 25 knots. The simulation produced data points at four hour increments from the start of the spill until the time the oil slick was assumed beached or moved to the offshore area.

4.45 By conducting the oil slick movement analysis under the above stated conditions the parameters estimated included trajectory for each given wind condition and tidal prism, approximate time for the oil slick to reach any ecological and economically important areas, and areas inundated by the oil slick for each given condtion.

4.46 The results of inshore area investigations are presented in a series of spill path illustrations. Figures 34 and 35 provide information on the potential movement of an oil spill occurring near Lydia Ann Island at incoming and outgoing tides, respectively. Both figures show the almost immediate contact of the spill with surrounding natural land forms or other obstructions. It appears saltwater marshes and grass flats are the areas potentially affected by the movement of the oil spill. The estimation of spill spread is hindered by the immediate beaching of the spill. The spill configuration will be greatly modified by its contact

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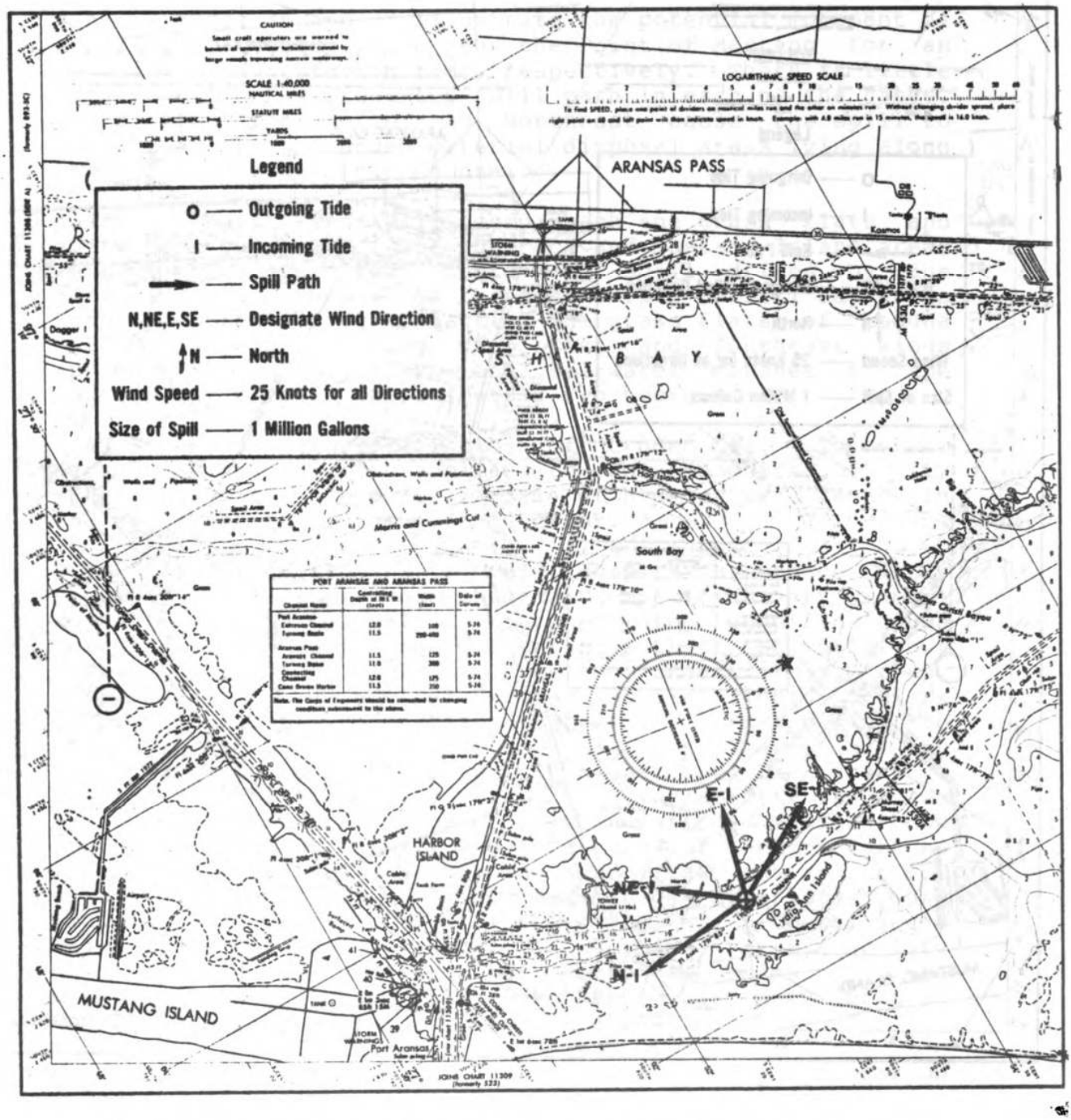

FIGURE 34 HARBOR ISLAND OIL SPILL ENTERING ARANSAS BAY VIA LYDIA ANN CHANNEL (INCOMING TIDE)

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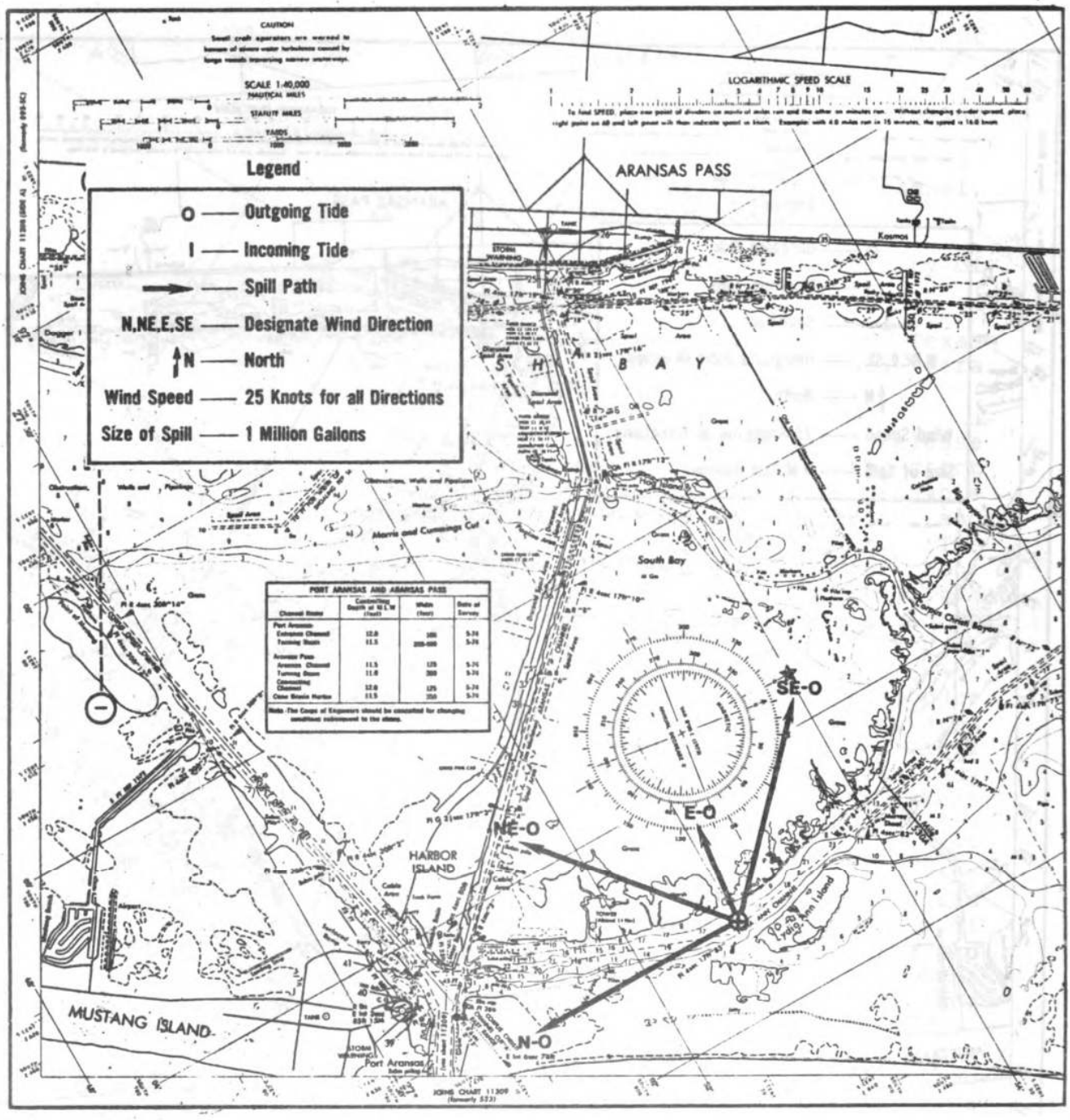

FIGURE 35 HARBOR ISLAND OIL SPILL ENTERING ARANSAS BAY VIA LYDIA ANN CHANNEL (OUTGOING TIDE)

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with the natural land forms near Lydia Ann Island. Similar results are obtained whether the spill is released at the start of an incoming or outgoing tide.

4.47 Figures 36 and 37 illustrate the potential movement of an oil spill taking place near the Point of Mustang for an incoming and outgoing tide, respectively. There is little difference in the predicted spill path in each of the cases. Winds from the North and Northeast cause the spill to contact existing dredged material disposal areas lying along the Corpus Christi Ship Channel.

4.48 The North wind spill could reach the grass flats and saltwater marshes of the Shamrock and Mustang Island areas in a little over four hours. A spill driven by the Northeast wind heads for the open Corpus Christi Bay areas with the potential of contacting the grass flats of Laguna Madre. Spills occuring with East and Southeast winds approach the grass flats and saltwater marshes of the Redfish Bay area in approximately two hours.

4.49 General Characteristics of Crude Oil. The term petroleum (crude) is applied to the deposits of oily material, usually composed largely of hydrocarbons found in the upper strata of the earth's crust.

4.50 Crude petroleum is a very complex substance whose physical appearance and chemical composition vary widely, depending on its course. Variations are found in crude petroleum not only from different parts of the world, but also from different fields in the same area. Thus, crude may appear as a yellowish-brown mobile liquid, a black viscous semisolid, or anything between. Corresponding to this variation in appearance is a similar range in physical/chemical properties, such as specific gravity, boiling point, volatility, etc. This variability is caused by the different proportions of the various hydrocarbons contained in the crude, the occurrence of nonhydrocarbons (e.g., sulfur, nitrogen, vanadium, etc.), and the amount of dissolved gas in the oil. These characteristics are important not only in terms of the type of processing to which the crude will be subjected and the number and quality of the products obtained, but also in terms of the commodity's impact on the environment (U.S. Army Corps of Engineers, 1972).

4.51 Table 31 presents data on the primary hydrocarbon fractions of a characteristic Mideast crude, with physical

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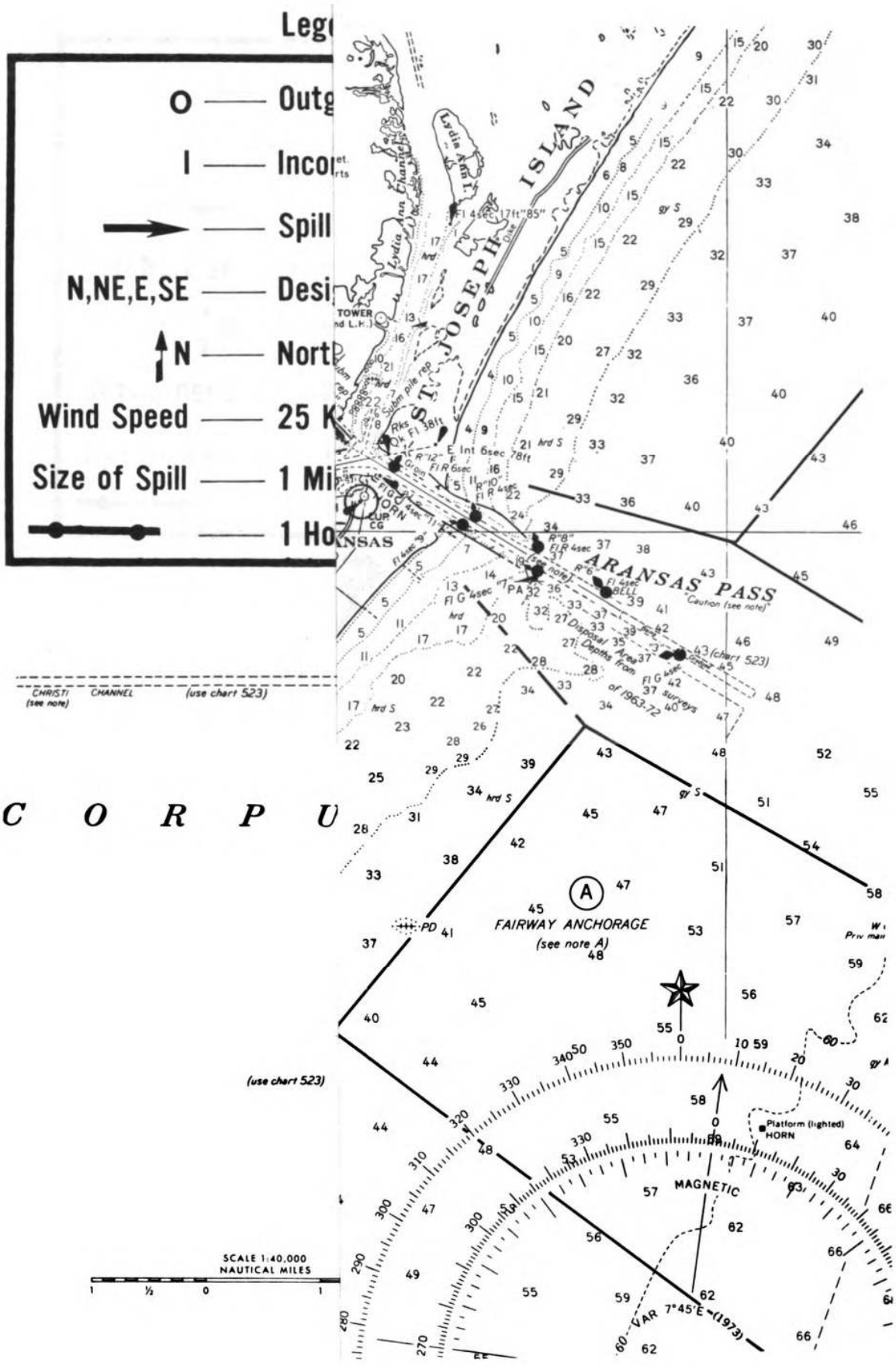

NG OIL SPILL (OUTGOING TIDE)

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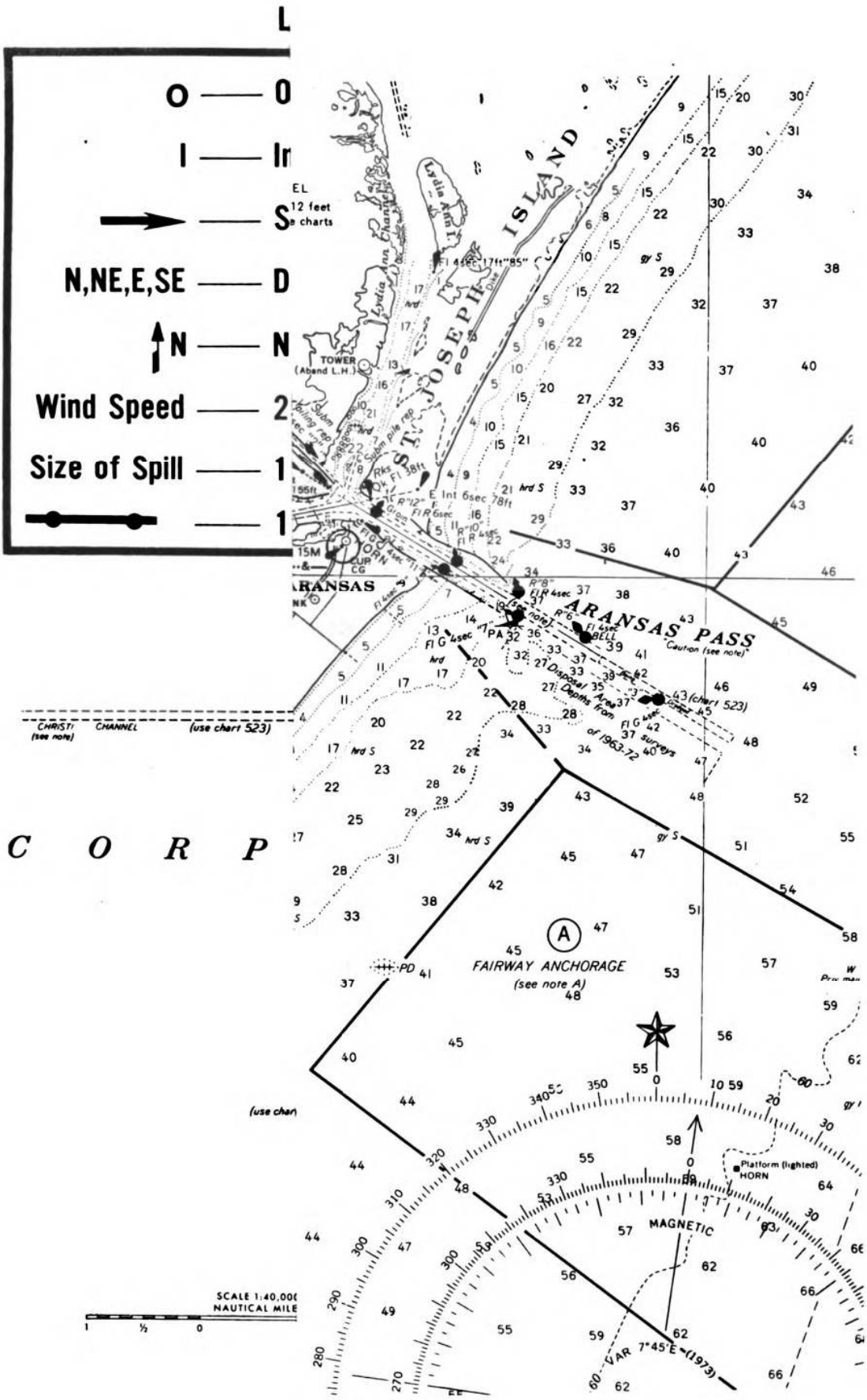

ING PHENOMENA

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TABLE 31

CHARACTERISTIC MID-EAST CRUDE FRACTIONS

	Light Gasolines	Naphtha	Kerosene and Gas Oil Distillate	Distillate	Residuum	Cumulative Overall Composition
Viscosity, S.U.S. @ 100°F	35	35	36.8	85	250	
Tbp range, °F	122-208	210-399	401-620	622-797	800†	
Gravity, Sp. G.	0.700	0.785	0.850	0.890	0.965	
Sulfur, wt %	0.07	.16	0.97	2.3	3.2	Vol %
Paraffins	8.2	11.3	12.4	6.1		38.0
Ring Cycloparaffins	1.6	4.1	3.5	3.9		13.1
Alkyl benzenes	0.2	3.7	1.4	0.6		5.9
Indans		0.1	0.7	0.2		1.0
Dinaphthenebenzenes			0.4	0.2		0.6
Naphthalenes			0.3	0.1		0.4
Acenaphthenes – Acenaphthylenes			0.5	0.7		1.2
Anthracenes, Phenanthrenes			0.2	0.7		0.9
Pyrenes, Chrysenes				0.4		0.4
Benzothiophenes, Naphthobenzothiophenes			0.9	2.5		3.4
Yield, vol % of total crude	10.0	19.2	20.7	15.4	34.7	
Yield, vol %, cumulative	10.0	29.2	49.9	65.3	100.0	65.3

Source: Martin, et al., *Proc. of 6th World Petroleum Congress*, 1963.

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properties and chemical constituents listed for each. The composition data are that given by Martin (1963) of a 29 API gravity Iranian crude from the Darius Field.

4.52 Table 32 presents data on the chemical and physical properties of a characteristic Mideast crude.

4.53 Phases of Oil. The fate of oil spilled on the sea surface is determined by a number of physical, chemical, and biological factors. Part of the oil evaporates into the atmosphere, part dissolves in the water column, part may be emulsified and become suspended in the water column, and part may precipitate and sink to the bottom. The oil on the surface, in addition to that which is emulsified or precipitated, is subject to degradation. Thus, the five major mechanisms by which oil may be removed from the surface of the sea are evaporation, solution, emulsification, precipitation, and degradation (James et al. 1972).

4.54 Evaporation. Crude, being a complex mixture, will evaporate initially by loss of the lower boiling ends, such as gasoline and naphtha fractions, and later, of successively higher boiling fractions. The evaporative process which occurs is a complex function of film thickness, wave action, wind, temperature, type of oil, etc. In general, the fractions which evaporate early in the life of a slick are the most toxic (James et al. 1972). The important role of evaporation in removing oil from the surface of the sea was demonstrated in a study conducted during the "Torrey Canyon" spill. The study (Smith, 1968) indicated that 25 percent of the oil, by volume, was lost in the first few days.

4.55 Solution. The amount of the various fractions of crude that go into solution is important in assessing impacts because oil in solution is in direct contact with the marine organisms in the water column and because the low boiling aromatic fractions, which are the most soluble and volatile, also appear to be the most toxic (James et al. 1972). The equilibrium solubilities of a few of the more toxic (acute cellular) species in each type of major chemical class are listed below:

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TABLE 32

CHARACTERISTIC MID-EAST CRUDE
CHEMICAL AND PHYSICAL PROPERTIES

Gravity[6]	0.8654
Viscosity[6], S.U.S. @ 100° F	57.0
Pour Point[6], °F	–5.0
Surface Tension[6], Dyne cm^{-1}	24.0
Sulfur[6], wt %	2.24
C_4 + lighter, Vol %	2.0
Carbon Residue[12], wt %	10.9
Ash[12], wt	0.04
Water[12] wt %	nil
Nickel[12], ppm	93.0
Vanadium[12], ppm	129.0
Nitrogen[12], wt %	0.58
Metalloporphyrin[7], ppm	152.0
Porphyrin metals[7] as Vanadium, ppm	14.0
Asphlatenes[5], wt %	1.6

Temperature Boiling End Point of Product[6]

°F	Volume % of Crude Cumulative
150	6.6
200	10.7
250	15.6
300	21.2
350	24.3
400	29.1
450	33.9
500	38.4
550	43.0
600	47.8
650	53.2

Source: *Oil and Gas Journal*, April 1963.

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Species	Solubility (ppm)	Species	Solubility (ppm)
hexane	140	phenol	82,000
heptane	50	pyridine	indefinite
nonane	10	aniline	36,000
benezene	820		
toluene	470		
naphthalene	300		

4.56 Clearly, the paraffins are the least soluble. The aromatic hydrocarbons have moderate solubility, and the functional derivatives have high solubilities.

4.57 Emulsification. Sea conditions, the type of oil, and weather are the major factors in determining the amount of emulsification (James et al., 1968). A turbulent, choppy sea causes a much higher degree of emulsification than a calm or rolling sea (Murray, 1970).

4.58 Berridge et al. (1968) points out that some crude oil emulsifies readily at sea, forming rigid stable water-in-oil emulsions which can contain up to 80 percent water, having a film thickness of 1mm. Such emulsions are stiff, yellowish-brown in color, and since the Torrey Canyon incident have become widely known as "chocolate mousse". The formation of an emulsion slows down the tendency of a slick to spread, and emulsified oil below the surface may move in a different direction than the slick because of subsurface currents.

4.59 Precipitation. Nelson-Smith (1970) has shown that the phenomenon of sinking may occur by two mechanisms; concentration of residue after prolonged periods of exposure and by suspended matter.

4.60 Concentration of residue results in a higher mean molecular weight, thus causing the specific gravity to increase. Fresh crude has a density of 0.855, but through evaporation of the lower boiling fractions up to gas oil distillate the specific gravity quickly increases to 0.934. Upon further exposure, possibly 20 to 50 days, the residue may have a specific gravity of 1.03, resulting in sinking.

4.61 Where there are large quantities of suspended matter, it may be incorporated into the oil, increasing its tendency to break up and sink. However, increasing salinity reduces the rate of sedimentation. Removal methods for crude have

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been tried by spreading powder or fine granular solid of high true density over the oil patch to mix with the oil, adhere to it, and sink it. Normally, it was found that after several months under water, the sunken mass was still mobile and could be released by agitation.

4.62 In general, little oil is deposited on the bottom of the sea unless the sea is rough and silt particles are present (James et al. 1972). In the Chevron spill, samples of soil taken directly beneath the platform from which the spill occurred never contained concentrations of oil higher than a few parts per million (Mackin, 1972).

4.63 Degradation. Microbiological degradation is the ultimate fate of all oil left in the sea, but such degradation entails a severe oxygen requirement and a supply of other nutrients, such as nitrogen and phosphorus, for the degrading bacteria.

4.64 Little is known about the rate of such degradation, but it is known that no single microbial species will completely degrade any crude oil. Bacteria are highly specific, and several species are probably necessary to decompose the numerous types of hydrocarbons in crude oil. During decomposition, intermediate products are formed, and different species of bacteria and other microorganisms may also be required to attack the decomposition products (Zobile, 1969). The oxygen requirement of microbial oil decomposition is large, and oxidation would be slow in areas where previous pollution had depleted the oxygen content. Even when oxidation proceeds rapidly, depletion of the water°s oxygen content by the active microorganisms may have harmful secondary ecological effects. Unfortunately, the most readily attacked fraction of crude oil - the normal paraffins - is the least toxic. The more toxic aromatic hydrocarbons - especially the carcinogenic polynuclear aromatics - are not degraded rapidly under natural conditions in seawater.

4.65 J. W. Smith (1968) observed the fate of oil lying on the sea bed, and found that the natural biological degradation of oil in the sea, especially when the oxygen content is high, is much more rapid than was at first believed. Based upon rates at which marine bacteria have been ovserved to oxidize various types of mineral oils under controlled laboratory conditions, and upon information of the abundance of bacteria in the sea, oil might be oxidized

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in the sea at rates as high as 100-960 mg/m^3 per day, or 36-350 g/m^3 per year. These figures are estimations, but nevertheless, do indicate that microbiological degradation is a highly important factor in weathering.

4.66 However, it should also be noted that oil is poor in nutrients and large populations of bacteria acclimated to the oil are required to effectively degrade the material. These populations would not be available for large spills.

4.67 Physical Impacts of an Oil Spill. For the Corpus Christi area, offshore spills under common wind conditions could result in inundation of extensive areas of the barrier island beaches. Oil reaching the beaches would make them uninhabitable for most living things and would destroy their appeal for human use. If the amount of oil is not too great the impacts would be temporary and the beach would recover in a short time. Biological and chemical breakdown of the oil combined with wave action can be very effective. The recovery of the biota would take a much longer time.

4.68 If the oil reached the beaches in quantity, the sands could become saturated with oil and recovery would be slow. The beach may appear cosmetically clean in several weeks and yet remain oil saturated below the surface. As the oil ages, asphalt compounds are left which can leach into the water or surface on the beach for months. The subsurface biohabitat may not recover for years. It has also been reported (Marx, 1971) that oil tends to make beach sand "quick" and can accelerate sand loss. Beach oriented recreation is of great economic importance in the project area and even temporary pollution of the beaches would therefore have great adverse impact.

4.69 For inshore spills, the areas affected would depend on the wind conditions and the point of spill. Due to the presence of cargo transfer activities and the maneuvering of vessels in confined areas, the area of highest oil spill risk is the Harbor Island area with its adjacent channel approaches (this includes the Corpus Christi Ship Channel to Ingleside). Because of the confined nature of the docking basin and relatively low exchange of water with the bay system, oil spills in this location should be more easily controlled through confinement and cleanup actions than in an unconfined area. Additionally, the basin would be closed off by a floating oil fence barrier when unloading operations are taking place and individual oil fences would

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be placed around each vessel. In the channels of the Harbor Island area, however, moderate currents and tidal exchanges between the bays and the Gulf occur. Spills in this area have the potential for emerging into the three adjacent bays: Corpus Christi, Redfish, and Aransas. However, vessel time in these limited reaches is small and the VLCC's would be under full tug control while in these areas. Heavily used recreational beaches in the city of Corpus Christi and the Rockport vicinity are points of concern regarding inshore oil spills. Another major concern is the productive breeding and nursery areas of Aransas and Redfish Bays. Oil spills which contact public recreational beaches are the most noticeable and offensive to the public.

4.70 Biological Impacts of Oil Spills. The ultimate impact of oil on the biota of a region depends not only on the effect of oil on individual organisms, but also on the changes that would occur in species, populations, communities, and ecosystems as a result of effects on individuals. Unfortunately, one of the least understood and most difficult aspects of the problem to deal with is the effect on the higher levels of biological organization. A literature review by Moore et. al.,(1973) has provided some clarification of effects of oil on individual organisms.

4.71 The effects of oil (from any source) on individual organisms may be categorized as: immediate (acute) lethal toxicity; sub-lethal disruption of cellular level processes, causing disruption of behavioral patterns (death may follow, but not immediately and usually indirectly, if at all); lethal and sub-lethal effects of coating organisms with oil, which does not interfere with cellular activities, but which mechanically interferes with organism activities such as respiration, feeding, and locomotion; incorporation of hydrocarbons in organism tissue, which may cause tainting, and/or accumulation of high boiling-point polycyclic aromatic hydrocarbons in the food chain; alterations in habitats caused by deposition of oil on substrates such as rocks, sand, and mud. Different types of compounds in oil are responsible for causing these various effects. The lower-boiling (b.p. 250°F), high-solubility, aromatic compounds are the primary cause of immediate toxicity, behavorial disruption, and tainting. Coating and habitat alteration result from the tarry residue components.

4.72 Due to weathering processes the particular individual response listed above which can be expected in any

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particular case is highly dependent upon the time elapsed since the spill occurred. The lower-boiling, high-solubility components of an oil slick can be expected to be lost in the first three days following the spill release. The acute toxic and other effects associated with these materials would be most significant immediately after the spill occurs. If the slick is thick or oil combines with sediment and silts, however, even these volatile components can persist.

4.73 In addition to dependence on oil composition, the effects of spilled oil also varies due to the different biological sensitivities of various types of organisms. For example, gastropods are apparently much less subject to acute toxicity than crustaceans. Also, sessile organisms, such as mussels, are highly subject to effects of coating, whereas fish are not because of their mobility.

4.74 Another source of confusion in assessing the biological effects of oil is the lack of dependable experimental and field observation on the toxicity and other effects of oil on marine organisms. It is difficult to evaluate the toxicity of this complex mixture. A variety of techniques have been tried. In some experiments, oil is floated on the water in the test container. The concentration is derived from the quantity of oil and the total quantity of water; this is clearly not the concentration to which the organism has been exposed. In other experiments, extracts of oil with hot water or with various solvents are added to the test jar, without identification of the oil fraction being tested. In still other cases, care has been taken to produce a fine emulsion of oil in sea water more representative of the actual concentration to which the test organism is exposed. Considering the differences in the meaning of "concentration" in these tests, and the variation in sensitivity of the test organisms, it is not surprising that the ranges of toxicity that can be found in the literature vary by several orders of magnitude.

4.75 Studies of the toxicity of oil have been reviewed by Clark (1971). Mironov (1971) carried out toxicity studies by comparable techniques using a variety of marine organisms. In testing 11 species of phytoplankton, he found that cell division was delayed or inhibited by concentrations of crude oil (unspecified type) ranging from 0.01 to 1000 ppm. He also showed that some copepods were

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sensitive to a 1 ppm suspension of fresh or weathered crude oil and of diesel oil. Freegarde et al. (1970), found the larvae of Balanus balanoides and adult Xalanus copepods maintained in a suspension of crude oil ingest, without apparent harm, droplets of oil that later appear in the feces. Mironov (1967) found 100 percent mortality of developing flounder spawn at concentrations of three types of oil ranging from 1 to 100 ppm and increased abnormality of development at longer periods of time in concentrations as low as 0.01 ppm. In contrast, other experimenters have found that concentrations of several percent are necessary to kill adult fish within a few days (Chipman and Galtsoff, 1949; Griffith, 1970).

4.76 Finely dispersed droplets may be ingested by filter-feeding organisms and thus become an integral part of the marine food chain. Some of the oil may pass through the gut in the feces of these organisms, but Blumer et al., (1970), have shown that it can pass through the gut wall and be incorporated in the organism's lipid pool. Dissolved within the fatty tissues of the organisms, even relatively unstable hydrocarbons are preserved. They are protected there from bacterial attack and can be transferred from food organism to predators and possibly to man.

4.77 Should an oil spill occur near shore, or an oil slick be brought to the intertidal zone and beach, extensive mortality of marine organisms would occur. When the Tampico Maru ran aground off Baja, California, in 1957, about 60,000 barrels of spilled diesel fuel caused widespread death among lobsters, abalones, sea urchins, starfish, mussels, clams, and hosts of smaller forms (North, 1967).

4.78 In West Falmouth, Massachusetts, a relatively small oil spill occurred within a few miles of the Woods Hole Oceanographic Institution in September 1969; since then, biologists and chemists of the Institution have studied the effects of introducing fuel oil into the coastal waters. Studies of the biological and chemical effects of this spill were continued after the event (Hampson and Sanders, 1969; Blumer, 1969; Blumer et al., 1970; Blumer and Sass, 1972). Immediately after the accident, massive destruction of a wide range of fish, shellfish, worms, crabs, other crustaceans and invertebrates occurred in the region. Bottom-living fish and lobsters were killed and washed ashore. Dredge samples taken in 10 feet of water soon after the spill showed that 95 percent of the animals collected

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were dead and the other 5 percent were moribund. Much of the evidence of this immediate toxicity disappeared within a few days, either because of breaking up of the soft parts of the organisms or because the organisms were buried in the sediments or dispersed by water currents. Careful chemical and biological analyses reveal, however, that not only has the damaged area been slow to recover but the extent of the damage has been expanding. A year and a half after the spill, identifiable fractions of the source oil were found in organisms that still survived on the perimeter of the area.

4.79 In the crude oil spills from the wreck of the tanker Torrey Canyon and the Santa Barbara oil-well blowout, oil reached the beaches in significant amounts at varying times after release. The oil may thus have been diluted and modified by evaporation or sinking before it reached the beach. In the Santa Barbara spill, many birds died and entire plant and animal communities in the intertidal zone were killed by a layer of encrusting oil, often 1 or 2 centimeters thick (Holmes, 1967). However, in the case of the Torrey Canyon, the deleterious effects have been attributed more to the detergents and dispersants used to control the oil than to the oil itself (Smith, 1968).

4.80 The catastrophic ecological effects of the oil spills of the Tampico Maru (Baja, California) and the Florida (West Falmouth) appear to be more severe than those reported from other oil spills such as the Torrey Canyon (Salty Islands) and the Santa Barbara (California) blowout. The Tampico Maru and the Florida accidents both released refined oils (in one case, diesel oil; in the other, No. 2 fuel oil) and both occurred closer to shore than either the Torrey Canyon or the Santa Barbara accidents, which released crude oil. The differences in the character of the oil and the proximity to shore may account for the more dramatic effects of the first two accidents, but it is clear that any release of oil in the marine environment carries a threat of destruction.

4.81 Planktonic algae are killed throughout the water column by oil but oil's toxicity is reduced rapidly with time. Due to its short reproductive cycle, phytoplankton of an open water area may recover quickly as the oil dissipates. However, if an oil slick is thick enough to obstruct light penetration, photosynthesis will be reduced and the combined effect of increased oxygen demand and

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reduced oxygen production will increase the mortality of all living things in the area. The decaying of dead organisms will then increase the oxygen demand and produce a snowball effect capable of removing all available oxygen from the water column. If such conditions occur in the bay areas of the project the biota of the bay could be killed.

4.82 With the possible exception of a major spill associated with hurricane winds, the adverse effect on vascular plants would be confined to wetland communities. Most wetland plants have shown a relatively high tolerance for crude oil. However, sufficient oil to heavily coat the vegetation would kill the plant parts above ground and continued exposure would kill the roots. If the root structure survives, as has generally been the case in past oil spills, the plants would recover. However, during the period that the vegetative parts of the plants are absent, the marsh would be more exposed to erosion by wave action and may be reduced in area by the time the plant cover has reestablished. The temporary loss of food and shelter provided by the marsh plants, especially during spring and early summer, would have much greater impact on marsh - dependent species such as commercial shrimp than on the plants themselves.

4.83 If they become coated with oil, the marsh dwelling mammals would die of exposure, but generally the greatest adverse impact on them would be the disruption of their cover and food supply.

4.84 Petroleum would also present a hazard to avian forms. Not only would some of these forms be affected by the immediate presence of oil, but also they may feed upon marine life which has ingested and stored oil. The diving birds which spend most of their life at sea would be most prone to death from oil pollution, but any bird that would feed from the sea or settle on it would be vulnerable. In oil-matted plumage, air is replaced by water, causing loss of both insulation and buoyancy, and oil ingested during preening could have toxic effects.

4.85 Hartung and Hunt (1966) fed oils directly to birds by stomach tube and later analyzed, through autopsies, the pathological and physiological effects. The lethal dose for three types of oil ranged from 1 ml to 4 ml per kilogram (ml/kg) when the birds were kept outdoors under environmental stress. The experimenters concluded that a

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duck could typically acquire a coating of 7 grams of oil and would be expected to preen approximately 50 percent of the polluting oil from its feathers within the first few days. Enough of this could easily be ingested to meet the lethal dosage of 1 to 4 ml/kg. Thus, birds that would not die immediately from exposure to cold or by drowning as a result of oil pollution, succumb later from the effects of ingestion. The vulnerability to these lethal results is considerably increased by their inability to recognize oil as a threat. Birds appear to make little or no effort to avoid oil slicks.

4.86 The disruption of feeding due to loss of food or its unavailability would result in rapid starvation for birds unless other feeding areas were readily available. The high metabolic rate of birds requires frequent feeding. The brown pelican which nests in the immediate project area, for example, would starve in about three days if deprived of food. Oil intrusion into the marsh during nesting season would be lethal to nestling birds for all of the above reasons.

4.87 Adult finfishes in open waters would generally avoid oil concentrations. However, they may ingest oil contained in copepods or other food organisms, and this oil could be incorporated into their body tissue. The larvae of fishes are much less tolerant.

4.88 Since most fishes of the area are estuarine dependent during part of their life and many are marsh dependent, it is reasonable to conclude that oil entering the estuary and especially the marsh area would be very destructive. The secondary effects would extend back out to the outer edge of the continental shelf causing a reduction in fishes available to the sport and commercial fisherman.

4.89 Oils sink because of increased specific gravity with weathering and the accretion of heavy debris or sand into the oil. Sinking of oil has also been experimentally achieved by scattering talc or chalk on the oil, causing it to agglutinate into globules of density greater than sea water. Sunken oil tends to kill bottom fauna before even the motile bottom dwellers have time to move away. Little is known about the rate of degradation of oil in bottom sediments, but it is known that some fractions will persist for over a year (Blumer, 1969).

4.90 Shellfish are among the most sensitive marine organisms to oil pollution, especially in their larval and

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juvenile stages. Oil intrusion into the estuaries and marshes during spring and summer months could cause extensive mortality. Adults that survive may become tainted with the flavor of oil and become unmarketable.

4.91 Those crustaceans such as shrimp and crabs that are motile enough to avoid oil in toxic quantities may be so disoriented by the aromatic constituents of oil as to have their behavior altered to a lethal degree. Most of them depend on chemoreceptors to find food, mates, and habitat. These sensors detect indicator substances in quantities as small as a few molecules and this detection is obscured by oil.

4.92 Zooplanton would be affected by exposure to oil in a similar manner to the phytoplankton and would be killed by the resultant drop in dissolved oxygen. In the open sea this loss may be replaced in a short period by rapid reproduction and by immigration from surrounding areas. In the estuaries, the population of zooplankters would require much longer to reestablish resulting in a more significant loss to the food web. Reductions in this base could reduce production in important commercial and sports fish and shellfish.

4.93 Fire and Explosion Hazards. Since crude oil and petroelum products are combustible by their very nature, proper precautions are always mandatory to prevent fires or explosions with resulting loss of facilities and possible human life. Over many years, extensive work and long experience have made it possible to develop adequate safeguards to prevent disastrous incidents of this type.

4.94 The operation of tankers carrying combustible-liquid cargoes has been plagued by a comparatively large number of explosions which have resulted in the total or near-total loss of the ship involved and, in some cases, loss of life. Ever since December, 1969 when three very large crude carriers (VLCC) exploded at sea within a period of twenty days, the menance of cargo-tank explosions has been the subject of numerous research efforts by governments, universities, oil industry, and shipowner associations, as well as individual firms and fleet operators. The three tankers involved in the December, 1969 explosions were all over 200,000 tons dwt, and included the Marpessa (Shell Tankers BV), the Mactra (Shell Tankers UK), and the Kona Heakon VII (Norwegian).

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4.95 From these studies have emerged some fundamental facts which are now universally accepted. The principal suspected, and only clearly identified cause of most explosions in cargo tanks (other than those due to collisions and/or other obvious causes), is the spark ignition of fuel-air mixtures due to the high electrostatic charge densities generated by the washing jets used on the tanks. The most probable electrostatic spark-generating mechanism is known as the "water slug" theory. This theory postulates that dimensionally large "water slugs" created by the washing machine can receive induced electrostatic charge in high electrostatic field areas of the tank. The presence of the field is due to the existence of electric charges in the cloud of droplets stripped from the washing jet. The energy of the spark created between the water slug near its impact with the tank structure, has been proven to be sufficient to ignite a proper mixture of air and hydrocarbon gases (Van Weerd and Laar, 1973).

4.96 The turbulence created by the washing machine jet(s) is the principal cause of the nearly homogeneous electrostatic charge density that appears inside of a tank being washed by any method, including washing machines. The level of charge density normally reaches a value of 107 and 108 Coulombs/m^3. Its polarity may be either positive or negative and, frequently, experiences a complete reversal during the washing cycle. No parameter effectively controlling the level and/or polarity of the charge built-up has been clearly identified, including washing water temperature, pressure, presence of additives, detergents or oil mixtures, tank size or shape, conditions of the tank surface, etc.

4.97 This knowledge, as well as a large volumn of interesting data generated by the many researchers in this field since 1969, has lessened the continuing danger of cargo-tank explosions.

4.98 Rapid and uncontrolled combustion (i.e., an explosion) is only possible when three elements are present aboard a tanker. These elements are fuel, ignition, and oxygen. Remove any one of these and explosion cannot occur. In tankers, fuel will always be present in the form of cargo, and despite every care in choice of materials and equipment, it is impossible to eliminate all sources of ignition. Such sources include static electricity, radio transmission,

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impact sparking, electrical faults, friction, spontaneous combustion, and irresponsible human actions. Thus, there remains only the third factor -oxygen. To support combustion, a hydrocarbon/air mixture must have a content of at least 12 percent of oxygen by volume. Atmospheric air contains 21 percent, which makes it highly dangerous in tankers. But, if the air is replaced by an inert gas containing less than the critical 12 percent of oxygen, there can be no combustion.

4.99 The foremost justification for installing an inert gas system aboard a tanker will always be that of safety. All owners, now having to pay $50-75 million for a 250,000 ton dwt vessel, have to seriously consider the financial risk involved in operating a tanker with a flammable atmosphere within its tanks. An initial investment in the order of $500,000 to $750,000 for an inert gas system is obviously a reasonable step to protect this large capital investment and the lives of the men who operate that investment.

4.100 Fire Protection Concept. Fire protection services for the Harbor Island deepwater port facility would be provided by the existing Refinery Terminal Fire Company (RTFC) and the described facilities and concept are based on the recommendations of the (RTFC). The facilities would conform to the National Fire Protection Association (NFPA) Code and to the regulations of the U.S. Coast Guard and would provide protection to onshore tankage and to VLCC's at the docks.

4.101 Applicable Facilities. The fire protection concept proposed for this project is based upon the services and facility necessary for a deepwater port for VLCC's, of which a typical tanker vessel would transport 2-1/2 million barrels of crude oil. The applicable surge tankage which would be served would be approximately 15 million barrels in tanks up to about 600 to 700 thousand barrels in capacity which would be up to 300 feet in diameter and 60 feet tall. A basic parameter in designing fire-protection facilities is the area of the petroleum surface in tanks when conflagration must be controlled. The largest Exxon tanks presently on Harbor Island hold 153,000 barrels, and are 140 feet in diameter by 60 feet high. Fina has 80,000 barrel tanks on Harbor Island, measuring 120' x 42'. However, four refineries around the Corpus Christi Inner Harbor presently use 30,000 barrel storage tanks (216' x 46'), and one

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refiner has tanks containing 500,000 barrels (281 x 48'). These tanks have floating roofs and are equipped with foam chambers. (RFTC) has the technology and is equipped to control fires in these tanks.

4.102 Foam System. Based upon the installation of NFPA-approved foam chambers on each tank, the NFPA recommends 0.1 gpm/ft2 of surface, or 7000 gpm to control a fire in tanks of this diameter. Additional pumping capacity would be required for ground foam lines and cooling of adjacent exposed facilities. To meet these needs it is planned to provide facilities and equipment capable of producing 10,000 gpm of foam solution. This equipment would be backed up by the additional equipment of the RTFC in the Corpus Christi area.

4.103 Fire Water System. Salt water fire mains would provide 12,000 gpm of seawater at 150 psi to suitably located hydrants. When not in fire use, the lines would be purged and filled with freshwater. This would be supplemented by sea water wells fed by gravity conduits from which pumper trucks could draw a water supply. Prepiped turrets would be provided at each dock through which foam could be directed to reach the length of the VLCC°s.

4.104 Mobile Units. Six mobile units are planned to protect the Harbor Island terminal; it is assumed that they would be housed in a building in the Aransas Pass-Ingleside area. They would be accessible at all times to the RTFC driver-operators and the RTFC-trained firefighters. The RTFC would provide regular maintenance for these units and each unit would be operated weekly to assure capability of immediate response. It is planned that the Harbor Island mobile units would be identical to units now operated by the RTFC in the Corpus Christi area and that they would include the special design features incorporated in these units. The six units would include four 1000 gpm foam pumpers carrying 1000 gallons of foam concentrate and two 5000-gallon foam concentrate tank trucks with 3000-gpm proportioners which mix a concentrate with water to produce foam.

4.105 Back-up Equipment. The fire equipment and personnel of the RTFC in Corpus Christi would also be available to support Harbor Island - including foam pumpers and tank trucks. Further, the tug boat available to the RTFC which

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is equipped as a fire boat would also be available to fight any fires which might occur aboard vessels at Harbor Island.

4.106 Air Quality. Air quality in the project area would be affected by construction and operation activities and industrial development which would result from project implementation. During construction, air emissions, primarily nitrogen oxides, carbon monoxide, and hydrocarbons, would be generated temporarily from the operation of heavy construction equipment, trucks, dredges, and process machinery. In addition, dust from the movement of machinery over the exposed soil surface temporarily would increase the level of particulates.

4.107 Sources of air emissions resulting from operation of the project would include evaporation from storage tanks, evaporation from transfer of crude oil and fuel, combustion products from process machinery and marine vessels, and accidental small spills and leakage.

4.108 Hydrocarbon emissions are of particular environmental concern because they combine photochemically in the atmosphere with nitrogen oxides to form photochemical smog.

4.109 Although not part of the proposed project, the participants in the project contemplate construction of additional surge tanks, as a result of the project, to contain hydrocarbon. The participants plan to locate these surge tanks on the south side of the docking basin on Harbor Island. This location is in Nueces County which has been designated as a non-attainment area by EPA for photochemical oxidants emission. The surge tanks will incorporate the lowest achievable emission rate (LAER) but are still expected as a group to emit in excess of 100 tons per year of hydrocarbon into the atmosphere. The surge tanks, if required by current EPA regulation, could be located on the mainland, in Aransas County, along the pipeline leading from the docking basin to the receiving refineries. Aransas County has been designated as an attainment area by EPA for photochemical oxidants.

4.110 Secondary industrial development in the three county area which may result from the proposed project would affect air quality. A "worst case" assessment of the effects of secondary industrial development upon sulphur dioxide and particulate matter levels was prepared by Southwest Research Institute (SWRI 1977). In general SWRI concluded that

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projected industrial growth would not produce excessive sulphur dioxide emissions based on current standards. Particulate from "worst case" secondary industrial development emissions could exceed current standards from 1980 onward.

4.111 However, the implementation of the provisions of the Clean Air Act Amendments of 1977 (Public Law 95-95) will insure that no significant adverse air quality impacts will result from primary or secondary industrial development. In areas where the national ambient air quality standards for particular pollutants are not now being attained or are exceeded in the future, the implementation of the offset policy under Section 129 of the Amendments will insure that there will not be an increase in total emissions of any non-attainment pollutant despite additional emissions of that same pollutant from major new facilities, which demonstrate attainment of the ambient air quality standards by either 1982 or 1987. In those areas where the standards for particular pollutants are being attained, Part C of the amendments provides for control of emission from new facilities so as to prevent significant deterioration of air quality, including the violation of any national ambient standard.

4.112 Effects on Odors. The disposal of materials on land may result in the release of objectionable odors formed by the decomposition of vegetation and the organic materials from the channel bottom. The odors would be in the form of hydrogen sulfide. This temporary localized air quality effect should be eliminated by natural processes within two or three months. Concentrations of the gases evolved are not expected to be sufficiently high to present a health problem or to damage property. If necessary, odors could be controlled in the leveed disposal area by chemically treating with a proprietary product containing essential oils and deodorized kerosene. The product manufacturer advises that all the essential oils are on the GRAS (Generally Regarded as Safe) list of chemicals approved by the U.D. Department of Agriculture for use. If needed, the mixture of essential oils and deodorized kerosene in a 1 to 4 ratio could be applied over the area at a rate of 0.5 gallons per acre. The frequency of application could vary from once every 2 days to once every 10 days depending on the severity of the problem.

4.113 Industrial growth in the area as a result of the deep draft channel may increase odors in the area. Although EPA

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has no established standards governing odor, it is an area of concern. Most modern refineries are relatively odor-free, although even best available control technology will allow some hydrogen sulfide (H2S) emissions from the stacks. Studies have shown the H2S may be detected in the one to 1000 range. Similar low concentrations could result from other sulfur compounds as well. If incineration is the last step of control, these gases could be almost completely destroyed. Whether incineration would be used as the final step depends on the type of gas scrubbing the particular refinery would employ for sulfur removal.

4.114 Noise Effects. Predicting the exact impact of various sounds on populous areas presents a difficult problem. While the prediction of sound propagation and attenuation mechanisms has at least reached usable form, the response of people to sound has been unpredictable to date except in very specific situations or in large statistical averages. This non-predictability of subjective response is attributable to the fact that below the point where sound is physically injurous to the auditory apparatus the net psychological pre-conditioning of the subject becomes the controlling factor in the hearer's response.

4.115 With this in mind, it is important to realize that any established annoyance criteria can only serve as an approximate guide in predicting annoyance in a different situation. It is possible that even if the noise source produces lower sound pressure levels than the ambient or background noise levels, it may still produce annoyance because of unpleasant frequency components.

4.116 Many different pieces of construction equipment will be used during various stages of construction activity (e.g., excavation, concrete work, tank erection, and others). Since each piece of equipment generates its own characteristic sound, the effect of construction on the neighboring communities will be different during the different construction periods. Table 33 shows approximate noise levels of typical day to day activities, while Table 34 lists noise levels which should result from the different types of construction equipment to be used. In general, most construction activities, except for dredging activities, will be restricted to day time operations. The noise from dredges is observable in this area where the only other noise is produced by commercial and pleasure boats.

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TABLE 33

APPROXIMATE NOISE LEVELS OF TYPICAL ACTIVITIES

INDOOR NOISE LEVELS	DECIBELS	OUTDOOR NOISE LEVELS
	140	THRESHOLD OF PAIN
	130	Pneumatic riveter
Oxygen torch	120	
	110	Elevated Train
		Jet flyover at 1000 feet
Rock and roll band	100	
		Farm tractor
		Lawn mower at 3 feet
Boiler Room	90	Motorcycle at 25 feet
Food blender at 3 feet		
		Diesel truck, 40 mph at 50 feet
Garbage disposal at 3 feet	80	
		Lawn mower at 100 feet
Shouting voice at 6 feet	70	
		Car, 50 mph at 50 feet
Normal speech at 3 feet		
	60	Heavy traffic at 300 feet
Average business office	50	
Average residence		Bird calls
	40	
Library		
	30	
		Quiet rural area at night
Broadcasting studio		
	20	Rustling leaves
	10	
	0	THRESHOLD OF HEARING

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TABLE 34 CONSTRUCTION EQUIPMENT NOISE LEVELS

	Typical dBA level at 50 ft
Earth moving:	
Loader	78
Back hoe	82
Grader	86
Truck	88
Materials handling:	
Concrete mixer	82
Concrete pump	82
Crane	82
Stationary:	
Generator	77
Compressor	81
Impact equipment:	
Wrenches	85
Jack hammer/drill	89
Pile driver	100

Source: "Noise Impact Assessment Report, Pittston Refinery, Eastport, Maine," prepared for U. S. EPA, Region I, September 1976.

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Studies in Mobile Bay with an oyster dredge indicate that the noise level on the dredge MALLARD was recorded in the range of 100 decibels in the engine room and 80 decibels on the upper decks. Noise levels of the operating dredge were 60 decibels at a distance of 2,000 feet. (U.S. Army Engineer District, Mobile, Alabama, Draft Environmental Statement on "Permit Application by Radcliff Materials, Inc., Dredging of dead-reef shells, Mobile Bay, Alabama, October 1972). Noise levels from pipeline dredges are not expected to differ significantly from those of a shell dredge, and, therefore, no significant adverse effects of noise levels are expected to occur from pipeline dredging. The temporary nature of the construction activity, together with the limited nighttime construction operations, tend to somewhat alleviate the impact of construction noise in the surrounding community.

4.117 Figure 38 presents the overview of the proposed Corpus Christi Port facility with the location of plants denoted by the letters Table 35. The concentric sound attenuation isolines are plotted with a range of attenuations from 30 to 60 dBA. These isolines connect points where the sound level produced by the plants would be as an example, 30 dBA below the individual plant boundary line sound level.

4.118 Comparison of the results of model use with the general guidelines for community noise and annoyance levels provides a means of probable impact assessment when information is available on specific source locations, sound levels, specific receptor locations, and existing ambient noise levels.

4.119 Because of the wide range of human hearing, sound levels are expressed by a logarithmic relative scale "in a ratio" to a standard intensity level. It is difficult for the average person to grasp the meaning of such a scale from abstract concepts. Because it is logarithmic, linear comparisons of decibel levels cannot be readily made. For example, a noise pressure level of 130 decibels is 10 times as great as one of 120 decibels and 100 times as great as a noise pressure level of 110 decibels. A better feeling for the measurement scale can be obtained from values relating to common experience. Based on published typical noise levels, and some prior measurements (SWRI 1975) in the area, typical current noise levels could be expected as shown in Table 34.

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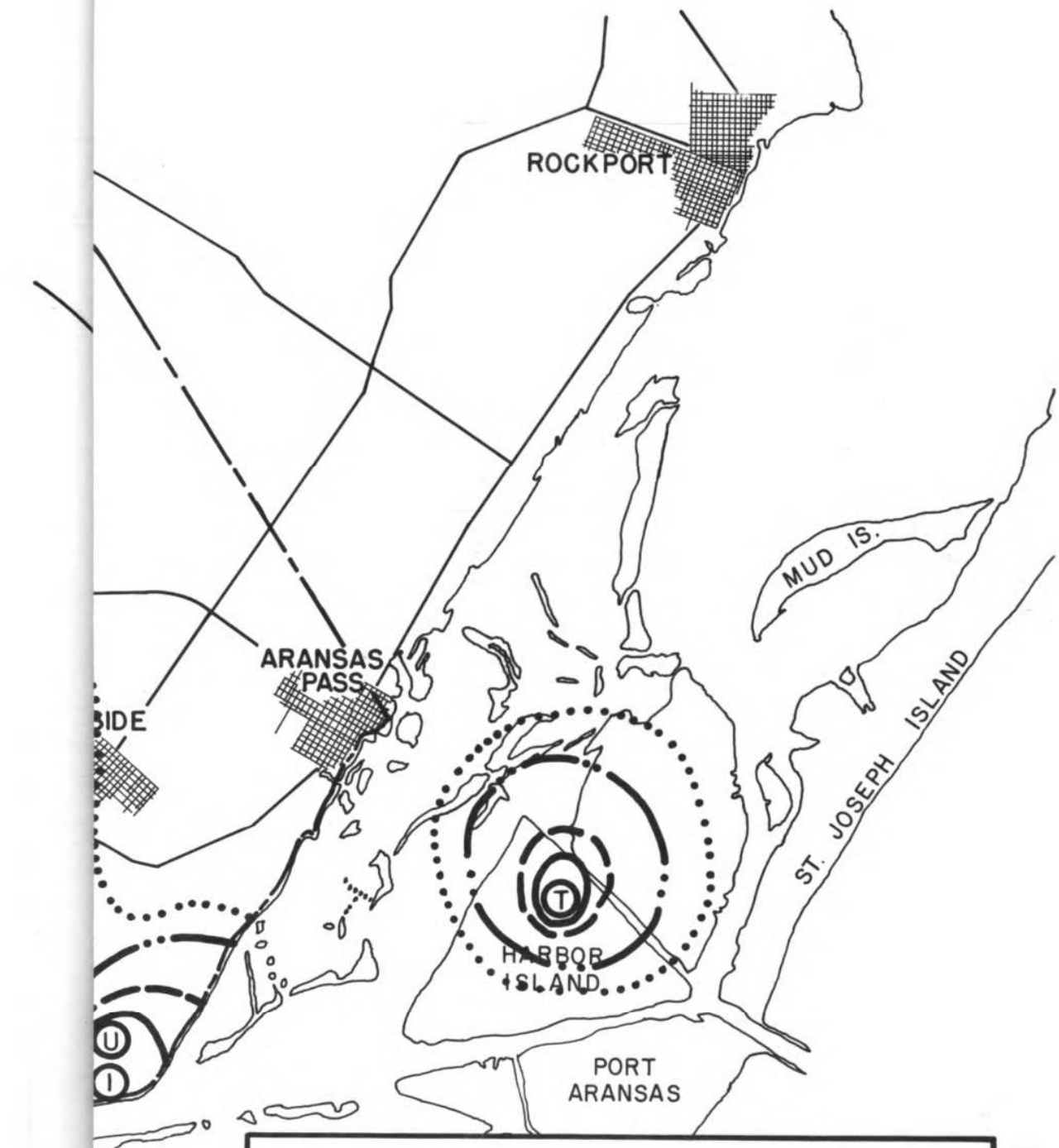

FIGURE 38

SOUND ATTENUATION CONTOURS

INDUSTRIAL PLANTS-PROJECTED YEAR 2030

ATTENUATION CONTOURS (dBA)

- 30 dBA
- 40 dBA
- 50 dBA
- 60 dBA

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TABLE 35

PROJECTED INDUSTRIAL GROWTH

(See figure 38)

Identification	Type	Capacities		
		1980	Without Project 2030	With Project 2030
A	Refinery[1]	70	150	200
B	"	185	300	300
C	"	41	100	100
D	"	119	180	200
E	"	65	100	100
F	"		200	300
G	"	50	180	180
H	"		180	240
I	"	10	60	60
J	"			320
K	"		160	200
L	"			200
M	"			200
N	"			200
O	"			100
P	"			100
Q	"			100
U	Blast Furnace or Sinter/ Scrap Furnace[2]		2	4
W	Bauxite/Alumina Plant[2]	5	11	41

[1] Thousands of barrels per day, 365 days per year.
[2] Millions of tons per year

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4.120 The isolines shown in the noise attenuation map (Figure 38) are presented in terms of attenuation or noise reduction values. They are useful in any study of industrial noise in this area. In addition, because of the conservative nature of the mathematical calculations used to produce the contours, all values are "worst case" or conservative estimates of the problem and impact areas.

4.121 Since differing industrial developments will each have differing impacts, the map (Fig 38) is intended as a tool for interpretation of possible noise pollution given, specific industrial plant sites.

4.122 For assessment purposes, a simple situation can be based on assumed 2030 locations of industries as shown on Figure 38. To be unnoticeable to an average listener, noise from industrial sources would have to be attenuated to about 20-25 dBA for quiet rural receptor areas, to about 30-40 dBA for residential areas, and to 40-50 dBA for light commercial-city areas. If the hypothetical sources shown in Figure 38 all have boundary line noise levels of 80 dBA (high for refinery and petrochemical plants), there could be a slightly noticeable increase in noise levels in the rural areas between Ingleside and Gregory with little or no noticeable increases in the San Patricio County urban areas as presently located. For urban areas near plants located along the Corpus Christi Inner Harbor, noticeably increased noise levels would be expected only within a few blocks distance of the industrial sites. With any industry or traffic activity there are usually occasional sudden peaks above the average sound levels (due to horns, whistles, venting, machinery impacts) which can prove annoying to some who hear. These sounds are often amenable to control by modifying equipment or routine operation and maintenance practices.

4.123 Effects on Benthic Organisms. Dredging and disposal operations associated with construction of the project would have varied effects on bottom dwelling organisms. These effects include removal and destruction of the benthic organisms existing in the areas to be dredged, coverage of those organisms existing in the disposal areas, and disruption to organisms in areas adjacent to the dredged channel. Most of the areas to be dredged have previously been dredged and have few benthic organisms.

4.124 Maintenance dredging would probably be performed every year, a frequency which could prevent benthic

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recolonization of the dredged areas commensurate with the productivity of surrounding undisturbed areas. Numerous studies have been made in recent years on recolonization of dredged channels. Ten years after dredging of Boca Ciega Bay, invertebrate recolonization of canal sediments (92 percent silt and clay; 3.4 percent carbon) was negligible. None of 49 fish species caught in these canals (as compared to 80 species in undredged areas) was demersal, apparently because of the lack of benthic food organisms on or in the canal deposits (Taylor and Saloman, 1968). Rogers and Darnell (1973) have demonstrated that dredge cuts reduce the population of small benthic (meiobenthic) animals to about one-third of their former levels, and that recovery is only about 80 percent complete a decade later. This study further indicated that modifications of the particle structure of the sediments was probably the prime causative factor for the slow rate of recovery. Pfitzenmeyer (1970) also concluded from the dredging and disposal studies in Chesapeake Bay that because of the instability of bottom sediments, the benthic biomass in the channel may remain low, even though recovery from dredging began soon after dredging operations had ceased.

4.125 Materials deposited in the disposal areas during construction would cover approximately 7000 acres of Gulf bottom and 2910 acres of inshore wetland and bay bottom. Bottom dwelling organisms in these areas would be covered and perish. The Gulf areas should recolonize and be improved as habitat. Date from offshore disposal areas used for maintenance dredging of the Sabine Neches Waterway, Galveston Channel, and Freeport Harbor have shown no adverse impacts on biological communities. The inshore areas, however, would be removed from tidal influence and no longer support benthic life.

4.126 As discussed in Paragraph 4.03, some sediment suspended by the pipeline dredge may be carried by the tides and deposited on adjacent wetlands and bay bottoms, affecting benthic populations. Some organisms may be destroyed, but most would not be covered deeply enough to cause death.

4.127 Effects on Shellfish. The disposal of dredged material would result in the burial of all oyster reefs existing within the boundaries of the disposal areas. Except for a few scattered oysters, the largest

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concentration would be in disposal area C (Figure 4 & 39). However, scattered oysters extend south along the back side of Mustang Island, almost to Shamrock Island (Personal communication, Jim Nolke). All oysters within the disposal area would be permanently buried. A few small scattered oyster reefs also exist among the tidal areas of Harbor Island (Figure 39). Some reefs would be physically removed by the realignment of the Channel to Aransas Pass. Also, some reefs near the dredging activities could be affected by siltation. However, the siltation should not be significant enough to cause death. The other major oyster populations in the Corpus Christi Bay System are not close enough to the project to be directly affected by it.

4.128 Effects on Wetlands. Wetland habitat in the Harbor Island area is diversified, with sizable stands of several productive types of wetland plants such as Spartina anterniflora and Avicennia germinans (Black mangrove), and submerged grasses such as Halodule and Thalassia. Wetland areas both provide shelter and support a rich community of fish and wildlife, increase the stability of the soil, reduce shoreline erosion, and are important in the nutrient cycle.

4.129 Changes that would be brought about in wetland areas as a result of the Project are highly significant with respect to any evaluation of the environmental impact. A detailed analysis of habitat areas has been developed for this EIS of both those areas to be utilized by the project and the total areas in the immediate regional system in which the project is to be located. The presented analysis permits an evaluation of the impacts on habitat by type and location within the project area as compared to the habitat within the regional system in which the project is located.

4.130 Wetlands have been defined in the Federal Register, Department of the Army, Engineers Corps, Vol. 42, No. 138, Tuesday July 19, 1977, pages 37128 and 37129. In summary, wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient enough to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Further, the "High Tide Line" (HTL) is considered the shoreward limit of wetlands in Coastal areas, such as Harbor Island. The HTL term has been defined as a line or mark left upon tide flats and beaches that indicates the

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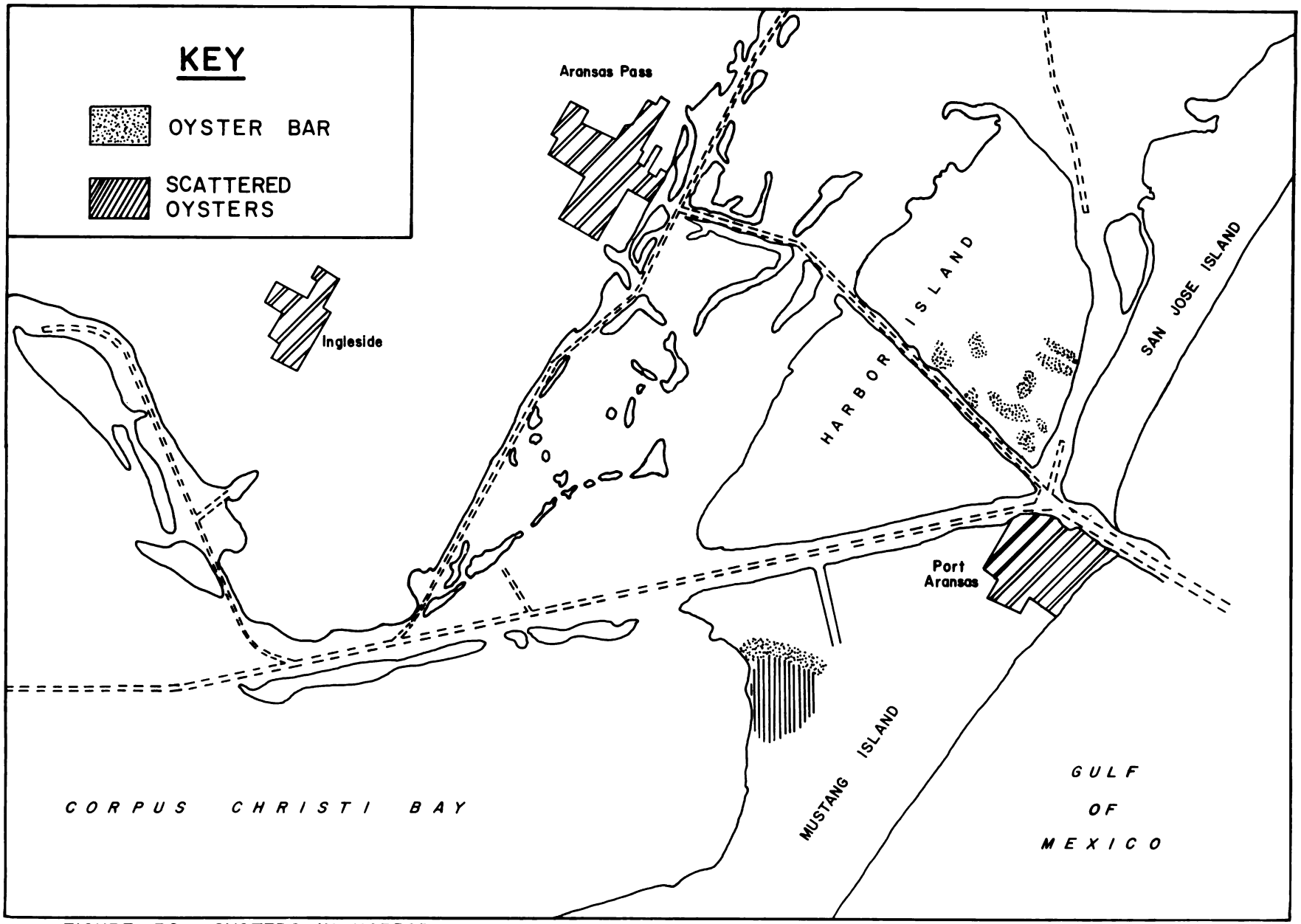

FIGURE 39 - OYSTERS IN HARBOR ISLAND AREA

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intersection of the land with the water's surface at the maximum height reached by a rising tide. While wetlands are intended to include areas covered by spring high tides and other high tides that occur with periodic frequency, they do not include those areas that are covered by tidal waters resulting from storm surges, hurricanes, or other intense storms.

4.131 A study was conducted in late 1977 and early 1978 to confirm the wetland boundaries and vegetative characteristics of the Harbor Island Project area in conformance with the Federal Register definitions. The identification and summarization of habitat and Biotope areas was derived from a detailed descriptive survey of the Harbor Island area based on the preliminary aerial survey map produced by the Texas A&M University Remote Sensing Center (Benton et al., 1976), as well as a recently constructed detailed topographic map compiled by Tobin Aerial Surveys for the Harbor Island Project. The former map and its vegetation descriptions were verified by a series of ground traverses taken through representative areas of special importance to the Project. A summary of information derived from the foregoing data is presented in Figure 40.

4.132 As noted, the patterns of vegetation shown on Figure 40 were classified by Biotope, using the description in Oppenheimer and Gordon (1972). A Biotope is a region which is uniform in environmental conditions and in the populations of animals and plants for which it is the habitat (Webster). The Biotopes in the areas shown on Figure 40 list the species of plants or other characteristics of dominance; including minor types of organisms and characteristics labeled "others". These data were statistically validated and field checked during the development of the plant inventory map.

4.133 Tables 36 and 37 were also drawn from the same data as figure 40. Table 36 compares the various environmental zones in the Bay Complex served by the water exchange through the Aransas Pass Inlet (Figure 41) and those zones influenced by the Harbor Island Project. Table 36 also summarizes the various subdivisions of the wetlands and uplands, indicated their vertical limits, lists the habitat characteristics and Biotope units, and shows the acreages involved in each category. Specifically, these latter data were compiled from aerial photographs, charts, and ground

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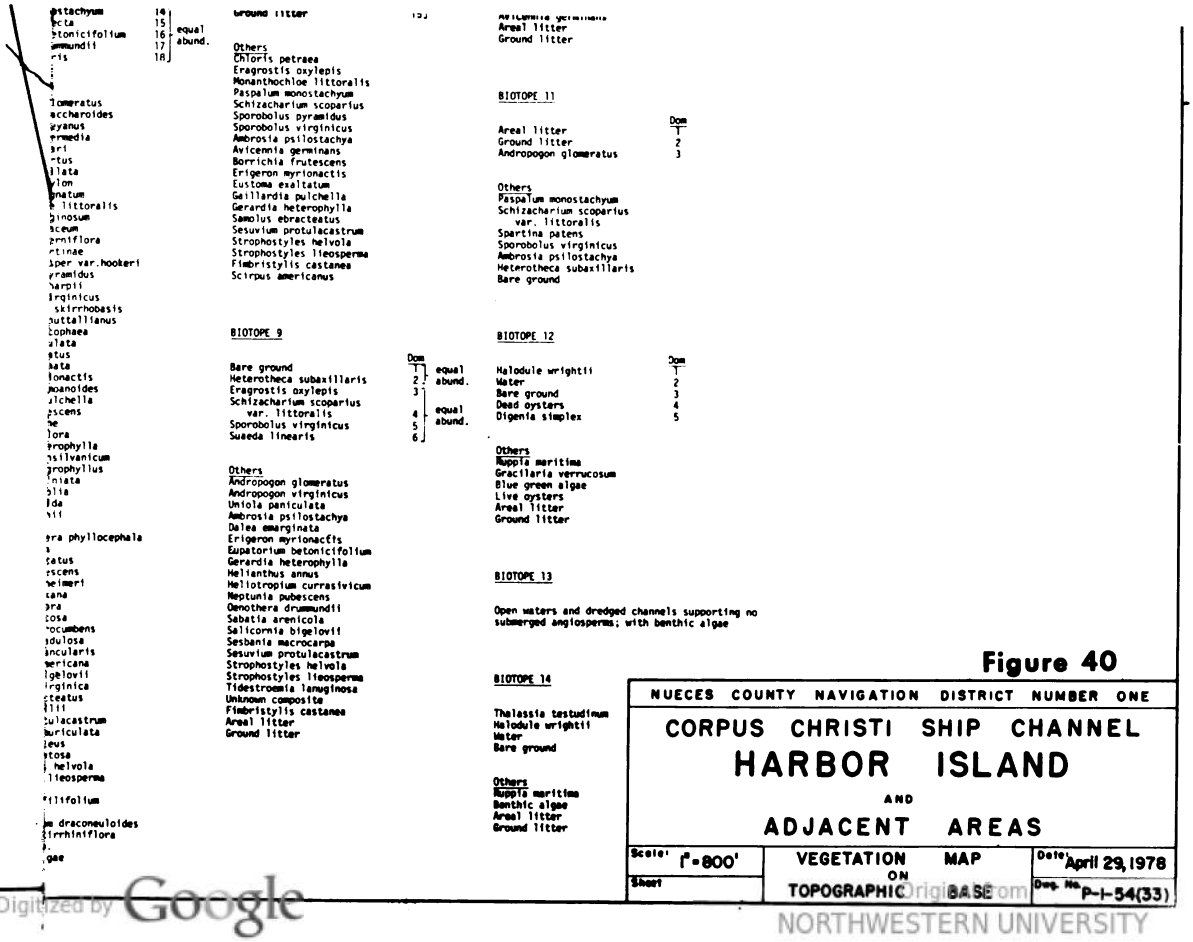

stachyum 14
cta 15
tonicifolium 16 equal
mmundii 17 abund.
ris 18

lomeratus
accharoides
yanus
rmedia
ari
rtus
llata
ylon
gnatum
littoralis
ginosum
aceum
rniflora
rtinae
per var. hookeri
yramidus
harpii
irginicus
skirrhobasis
uttallianus
cophaea
alata
atus
ata
lonactis
oanoides
ulchella
scens
ne
lora
rophylla
nsilvanicum
rophyllus
niata
olia
lda
nii

era phyllocephala
a
tatus
scens
neimeri
cana
ora
cosa
rocumbens
dulosa
ancularis
ericana
lgelovii
irginica
cteatus
llii
ulacastrum
uriculata
leus
tosa
helvola
lieosperma

ilifolium

m draconeuloides
irrhiniflora
.
gae

Ground litter 15

Others
Chloris petraea
Eragrostis oxylepis
Monanthochloe littoralis
Paspalum monostachyum
Schizacharium scoparius
Sporobolus pyramidus
Sporobolus virginicus
Ambrosia psilostachya
Avicennia germinans
Borrichia frutescens
Erigeron myrionactis
Eustoma exaltatum
Gaillardia pulchella
Gerardia heterophylla
Samolus ebracteatus
Sesuvium protulacastrum
Strophostyles helvola
Strophostyles lieosperma
Fimbristylis castanea
Scirpus americanus

BIOTOPE 9

	Dom	
Bare ground	1	equal
Heterotheca subaxillaris	2	abund.
Eragrostis oxylepis	3	
Schizacharium scoparius var. littoralis	4	equal
Sporobolus virginicus	5	abund.
Suaeda linearis	6	

Others
Andropogon glomeratus
Andropogon virginicus
Uniola paniculata
Ambrosia psilostachya
Dalea emarginata
Erigeron myrionactis
Eupatorium betonicifolium
Gerardia heterophylla
Helianthus annus
Heliotropium currasivicum
Neptunia pubescens
Oenothera drummundii
Sabatia arenicola
Salicornia bigelovii
Sesbania macrocarpa
Sesuvium protulacastrum
Strophostyles helvola
Strophostyles lieosperma
Tidestroemia lanuginosa
Unknown composite
Fimbristylis castanea
Areal litter
Ground litter

Avicennia germinans
Areal litter
Ground litter

BIOTOPE 11

	Dom
Areal litter	1
Ground litter	2
Andropogon glomeratus	3

Others
Paspalum monostachyum
Schizacharium scoparius var. littoralis
Spartina patens
Sporobolus virginicus
Ambrosia psilostachya
Heterotheca subaxillaris
Bare ground

BIOTOPE 12

	Dom
Halodule wrightii	1
Water	2
Bare ground	3
Dead oysters	4
Digenia simplex	5

Others
Ruppia maritima
Gracilaria verrucosum
Blue green algae
Live oysters
Areal litter
Ground litter

BIOTOPE 13

Open waters and dredged channels supporting no submerged angiosperms; with benthic algae

BIOTOPE 14

Thalassia testudinum
Halodule wrightii
Water
Bare ground

Others
Ruppia maritima
Benthic algae
Areal litter
Ground litter

Figure 40

NUECES COUNTY NAVIGATION DISTRICT NUMBER ONE

CORPUS CHRISTI SHIP CHANNEL

HARBOR ISLAND

AND

ADJACENT AREAS

Scale: 1" = 800'	VEGETATION MAP ON TOPOGRAPHIC BASE	Date: April 29, 1978
Sheet		Dwg. No. P-1-54(33)

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TABLE 30

ACREAGES OF LOCAL COASTAL HABITAT ZONES

Zones	Habitat Characterized By	INFLUENCED BY WATER EXCHANGE THROUGH ARANSAS PASS INLET FROM KENNEDY CAUSEWAY TO CEDAR BAYOU* (Nueces-Corpus Christi-Redfish-Aransas-Copano-Mission and St. Charles Bay including bay margins)			ALTERED BY HARBOR ISLAND PERMIT APPLICATION NO. 9563 (Harbor Island-San Jose Island-Mustang Island and adjacent shores)			
		Corpus Christi Nueces	Aransas Copano	Total Acres	Harbor Island	San Jose Island	Mustang Island	Total Acres
Deep Water Zone More than 3.5' (Biotope 13**)	Water Plankton Shellfish Fish	83,330	105,943	189,273	23	0	32	55
Shallow Water Zone from 3.5' to MLT (Biotope 12	Water Bare Sand Halodule Thalassia	18,894	10,131	29,025	319	0	916	1,235
Tidal Zone from MLT to HLT (Biotope 1-2-14)	Shore Margin Spartina Avicennia	7,990	33,107	41,097	151	0	164***	315
Infrequently water covered zone from HTL to Plus 2 (Biotopes 8-10)	Sand, Mud, Blue green Algal Flats Distichlis	9,160	3,835	12,995	208	18	1,246	1,472
Highland Above Plus 2 HTL (Biotopes 3-5-7-7A-9)	Bare ground Woody-Vegetation Grasses	30,876	10,874	41,750	155	1,971	791	2,917
Total of Wetlands & Uplands				314,140				5,994

* See Index Map Figure 41
** See Vegetation Map Figure 36
*** Includes Fresh Water Marshes

MLT = Mean Low Tide
HLT = High Tide Line

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TABLE 37

HABITATS INFLUENCED BY PERMIT APPLICATION NO. 9563*

(In Acres)

Zone	Deep Water More than 3.5'	Shallow Water 3.5' to MLT	Tidal Area MLT to HTL	Infrequently covered HTL to Plus 2	Highland Above Plus 2' HTL
Habitat Characterized by	Water Plankton Shellfish Fish	Water Bare Sand Halodule Thalassia	Shore Margin Spartina Avicennia	Sand, Mud, Blue-green Algal Flats Distichis	Bare Ground, Woody Vegetation, Grasses
Relative Aquatic Productivity	High*** (Net Productivity (1200 lbs,C/acre-yr.)	High*** (Net Productivity (1800 lbs.C/acre-yr.)	High*** (Net Productivity (1500 lbs.C/acre-yr.)	Low*** (Net Productivity (300-600 lbs.C/acre-yr.)	None*** (Net Productivity (1100-1700 lbs.C/acre yr.)
Biotopes**	13	12	1-2-14	8-10	3-5-7-7A-9
	Acres	Acres	Acres	Acres	Acres
Realigned Tributary Channel	0	15.4	34.7	15.6	6.6
Docking Basin	0	9.7	22.9	68.4	81.1
Disposal Areas					
A-1	22.9	23.4	32.1	9.8	3.7
A-2	0	23.5	7.4	11.6	17.4
A-3	0	0	4.2	32.8	26.7
A-4	0	114.9	49.6	69.3	19.6
A-5	0	132.5	0	0	0
C	0	906.7	41.1	405.5	376.7
D	31.5	8.8	123.1****	840.3	413.9
B	0	0	0	18.0	1971.0
Total Acres	54.4	1234.9	315.1	1471.3	2916.7

* Excluding 7000 acres of Gulf Bottom used for disposal of dredged material
** From vegetation map (Figure 36)
*** Productivity data taken from Kier and Fruh, 1977
**** Includes fresh water marshes

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FIGURE 41

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observations in the Aransas-Copano Area and from the NSF-RANN report (1974) for the Nueces-Corpus Christi Area.

4.134 The five definitive environmental habitat zones of Table 36 may be described as follows:

(A) The deep water zone includes all water depths greater than 3.5 feet and is characterized by water, plankton, shellfish, fish, and benthic organisms. It is mapped as Biotope 13 on the vegetation map (Figure 40). The primary productivity from this zone is from the suspended phytoplankton.

(B) The next zone is the shallow water zone extending from the 3.5 foot water depth to mean low tide (MLT). Except during unusual drops in sea level, such as might be caused by severe storms in other areas of the Gulf or exceptionally strong "Northers" coincident with low tide level, this zone is continuously covered with water. This is a submerged grass community characterized by water, unvegetated (bare) sands, seagrass such as Halodule and Thalassia and is mapped as Biotope 12.

(C) The intertidal zone lies between mean low tide and the high tide line (HTL) as described in the Federal Register. It is regularly covered or saturated with surface or ground water and is characterized by Spartina alterniflora and Avicennia germinians (black mangrove) communities and associated plant species (Biotopes 1, 2, and 14).

(D) The next zone is characterized by extensive sand, mud, and blue-green algal flats that are at or above the high tide line and may be inundated or saturated with surface or ground water. Such plants as Distichlis, Salicornia, Batis, Spartina, etc., typically grow in depressed areas and on small mounds. In areas where fresh water may stand for a few days or weeks after a rain, the flats are covered with blue-green algae. During dry periods between rains or infrequent storm surges, the algae becomes dormant and the surface changes to curled-up patches of dry algal mat. This zone between the HTL and plus 2 feet has been mapped on figure 40 as Biotope 8 and 10.

(E) This uppermost habitat zone includes the highlands above plus 2 feet HTL and is characterized by bare ground, woody vegetation and upland grasses (Biotopes 3, 5, 7, 7A, and 9).

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4.135 The influence area of the Aransas Pass Inlet extends from approximately the Kennedy Causeway at the south, northward to Cedar Bayou, the northeastern limits of Aransas Bay (Figure 41). The area includes Nueces, Corpus Christi, Redfish, Aransas, Copano, Mission, and St. Charles Bays and their shoreline margins. The total wetland acreage in the influence area has been calculated to be about 27,390 acres, as compared to a total of 3077 wetland acres in the total area to be occupied by the Harbor Island Project.

4.136 Table 37 presents a detailed breakdown of the wetland habitats to be altered by the Permit Application No. 9563 on Harbor Island itself - including both private and public lands, but excluding those lands presently utilized for transhipment facilities. The value of "productivity", in pounds of carbon/acre/year, has been shown for each of the habitat zones. All the areas are considered high in terms of aquatic habitat productivity. It is generally assumed that the variation in productivity is insignificant between the wetland zones, as the methods for determining such values are not precise. The uplands contribute little carbon to the surrounding aquatic habitat or wetlands. The sandy-silty soil absorbs the byproducts of microbial degradation and the carbon-nitrogen cycles take place in situ (Oppenheimer, 1977). Only during hurricane or major storm action is the carbon transported to the wetlands and made available to the aquatic food web. The productivity data are taken from a report of Kier and Fruh (1977).

4.137 A sea grant funded project is presently being conducted by the University of Texas Marine Laboratory at Port Aransas to identify the most appropriate plants and methods to enhance and reduce the time required for revegetation of dredged materials. The findings of this work are expected to be available and to be used for a vegetation/revegetation program as part of the Project.

4.138 Construction of this project would result in varied effects on wetlands of the project area including the physical removal by construction of the turning basin and realignment of the Tributary Channel to Aransas Pass, sedimentation in adjacent wetland areas associated with the actual dredging, and covering the wetlands in the proposed inshore disposal areas. Approximately 167 acres of wetlands would be physically removed from the project area by construction of the turning basin and realignment of the channel to Aransas Pass. The major wetland type affected by

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this aspect of the project is the black mangroves of the north Harbor Island area.

4.139 The Nueces County Navigation District has estimated construction of the inshore portion of the project would take approximately 2 years of continous dredging to complete the project and that pipeline dredges would be used. Pipeline cutter suction dredges are the least hazardous from an environmental standpoint, since the dredged material is taken up by pumps, producing limited turbidity. The turbidity that is produced, however, would be carried by the tides and currents and some may eventually be deposited on the adjacent wetlands. This effect could be significant if dredging is continuous in one location and could result in some damage to the wetlands. Turbidities would occur only as long as dredging is under way. Additionally, maintenance dredging would be accomplished annually.

4.140 One of the most significant effects on the wetlands as a result of the project would be from the proposed disposal operations. The use of disposal areas A, C and D, would result in a total loss of the wetlands in these areas (Figure 40). A breakdown of the habitat type in each disposal area is included in table 39. The loss of the higher productivity areas would result in lowered primary productivity, permanent loss of nursery grounds for marine species, and loss of wildlife habitat. However, new habitat would be created for terrestrial species. Wetlands play an important role in providing detrital material, a basic source of energy to the consumers of the estuarine system. Equally important to such first level consumers are the benthic organisms and epiphytic algae of this zone. Loss of the wetlands could result in a reduction in the numbers of sport and commercial fish, crustaceans, and mollusks, as well as larval, post larval, and juvenile fishes and crustaceans. With respect to wildlife, the dredged terrestrial uplands would reduce nesting and resting habitat for birds and other terrestrial wildlife. Establishment of terrestrial vegetation on the disposal areas could restore a part of the value to wildlife.

4.141 Enlargement of the entrance channel at Port Aransas would increase the cross sectional area and subsequently increase the tidal range in the project area. Changes in tidal range would be greatest at Harbor Island and decrease with distance away. By increasing tidal ranges, areas not previoulsy inundated by normal daily tides would now be

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periodically flooded, in effect creating additional wetland areas. The result of this would be a change in plant species from those which are only occasionally flooded by abnormally high tides to species able to tolerate daily tidal inundation. This could be expected to increase the extent of wetland vegetation in the project area, but, because of the many factors which affect plant growth, quantification of the increase in wetlands is not practicable.

4.142 To the greatest extent practical, offshore and upland disposal areas would be used to avoid loss of productive wetlands. New channels are aligned along existing channels and previously dredged waterways to minimize wetland loss. Wherever practical, land based equipment would be used to reduce the impact on wetlands. The locations of disposal areas were selected, in part, to displace areas of low productivity rather than the more valuable areas of high biological productivity.

4.143 During construction and maintenance dredging, state of the art equipment and procedures would be utilized to the greatest extent practical to minimize turbidity and siltation impacts on surrounding wetlands. To further reduce these turbidity and siltation impacts, the disposal areas would be diked and the effluent would be controlled by weirs draining into water areas of low sensitivity such as the naturally turbid surf zone of the Gulf or the docking basin or Corpus Christi Channel. Construction of the dike on San Jose Island and stabilization by vegetation would help protect the wetlands on the inshore side of the island from the continuing encroachment by blowing sand from the open beach.

4.144 Where practical, disposal areas would be contoured to provide proper terrain and saltwater circulation for establishing new desirable wetland habitat. Area D is a candidate for such a program. The displacement of wetlands by disposal areas would be partially offset by stabilization and revegetation programs to provide nesting and resting habitat for terrestrial species. In all cases, however, these area would be used as disposal areas until there use is no longer economically feasible.

4.145 Effects on Fishery Resources. Turbidities, excavation activities, and filling of wetlands, would have an effect on the fishery resources of the project area.

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4.146 High concentrations of extremely fine particles, can cause asphyxiation of juvenile fish and shellfish by coating of their gill tissues. Turbidities, which would result from the dredging and disposal activities would have the effect of inhibiting phytoplankton activity in limited areas near the dredging operations. These turbidities would occur only while dredging is under way. Reduction of photosynthetic activity results in a corresponding reduction at the base of the aquatic food chain. This loss could be projected up the food chain. The loss which would occur may be in part compensated for by increases in productivity following resuspension of nutrients and aeration of sediments and organic matter. Increases in productivity have been reported immediately following dredging. (Odum and Wilson, 1962; Odum, 1973; Virginia Institute of Marine Science, 1967). Mackin (1961) reported that the distance to which materials are carried away from a dredge is a function of the current velocity, specific gravity of the solids, grain size and shape, and flocculation of the grains at the time of transport. His observations of turbidity drift showed that there is a decrease in suspended matter and diminution in turbidity due to a rapid deposition of suspended material and dilution. For example, Mackin observed that in waters having an average current velocity of 0.25 knots and dredging material discharge having a net weight specific gravity of 1.7, only 0.1 percent of the total material removed in the dredging operation remained in suspension outside a radius of 100 feet from the dredged material discharge point. Fine material was lost in the natural turbidities at distances over 1,000 feet and had the same effect on the environment as materials put into suspension by natural conditions, such as is observed in most Texas bays. He also noted that during his control study, turbidity in one secondary bay caused by shrimp trawlers on one day was greater than that produced at a distance of 300 feet from the dredge discharge. Cronin, Gunter, and Hopkins (1971) found when turbidity increase is of short duration and the amount of siltation is low, the effects are generally insignificant. Odum (1963), however, noted serious effects up to about 1300 feet (1/4 mile) east of a dredging site in Redfish Bay. Odum noted the Thalassia beds were covered with 12 inches of soft silt and that no plant growth occurred on that surface by the next year. Odum suggested that Redfish Bay was shallower than the bays reported on by Mackin and that this shallowness may have been part of the cause for the different effects in the two areas.

4.147 The Aransas Pass inlet is extremely important to the fishery resources of the entire coastal bend region.

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Studies have documented the large numbers of invertebrate and vertebrate organisms that use the pass for movement in and out of the bay systems. Copeland (1965) estimated the biomass produced in the bay area served by the Aransas Pass inlet at 11.65 x 107 kg/year. Estimates indicate that one-third of the brown and pink shrimp, and over one-tenth of the white shrimp caught off the Texas coast are reared in estuaries that rely on the Aransas Pass inlet for a migration route to the Gulf. Marine fish of sport and commercial importance which use the inlet as a migration route include red drum, black drum, croaker, seatrout, flounder, sea catfish, and menhaden. The blue crab, the only readily marketable size crab found in Texas waters, mates in low salinity waters of the estuary, and the eggbearing females move into the Gulf for egg devalopment. The larvel stages develop into young crabs in the Gulf and the latter migrate through the pass into the upper reaches of the estuaries.

4.148 The migration of marine species in and out of the estuary is extremely important to their life cycles. Many of these migrations occur during very early and delicate stages of life. During construction of the channel these migrations could be affected. The magnitude of this effect would be dependent on the time of year, number, size, and location of dredges, and length of dredging time. The dredging should not preclude the passage of larval, juvenile, or adult marine organisms through the channel; however, those organisms approaching too close to the dredge suction pipe may be entrained in the pipe and pumped to the disposal area where they would be either buried in the sediment or consumed by birds.

4.149 Juvenile fish occur in the pass year round. However, the number of juvenile immigrations is greatest during November and March. The fewest juveniles occur during the month of May through July. The majority of gulf spawned blue crab juveniles immigrate from July through September. Brown shrimp post-larvae generally immigrate from mid-April to mid-June with a major peak during September and October. Some adult fish generally emigrate in the fall with decreasing temperatures as do the majority of adult white shrimp. The majority of adult brown shrimp emigrate from mid-June through mid-July.

4.150 Low levels of dissolved oxygen in the bottom waters of the inshore reaches of some deep channels may occur at

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times when mixing of tidal action is inadequate. Should such anoxic conditions develop, they probably would be limited to backwater areas of low current and would not be likely to affect migrating animals since they tend to move with tidal currents. The strength of the tidal movements and lack of stagnation near the pass is indicated by the bottom scour of some 15 feet below dredged depths in that area and favorable bottom measurements of dissolved oxygen made on numerous occasions by Southwest Research Institute.

4.151 Fishery resources in the area might also be enhanced by increasing the opening to the Gulf. Previous deepening of the entrance channel has decreased the extremes of both salinity and temperature which otherwise would occur in the bays. It is possible that channel enlargement could again improve biological productivity. Southwest Research Institute estimates the overall salinity change would increase less than 2 ppt. The salinity change would decrease with distance away from the pass. This change should not be significant enough to be noticed in sport and commercial catches in the area.

4.152 Impacts on fishery resources would be minimized as much as possible by utilization of existing disposal areas that are already disturbed and where new areas are necessary, selecting them to avoid biologically sensitive locations such as spawning areas, critical habitat, etc. Potential effects on migratory movements can be reduced by minimizing dredging in the jetty channel as much as practical during peak migratory movements. The utilization of state of the art equipment and procedures as much as practical to minimize turbidity and siltation impacts and diking disposal areas and controlling effluents to reduce project impacts as fishery resources.

4.153 Effects on Wildlife. Disposal of dredged materials would cover vegetation of value to wildlife, and excavation of the docking basin and realignment of the Channel to Aransas Pass would also eliminate wildlife habitat. However, new habitats could be established and, by employing revegetation, dredged material stabilization techniques would in part compensate for losses of existing vegetational cover. Sea Grant studies in several localities of the Corpus Christi area to determine appropriate plants to stabilize dredged material, improve productivity, and enhance the aesthetics of the area are now in the second

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year (Oppenheimer, 1978). Use of low productivity terrestrial habitat such as the unstable sandy areas on San Jose Island for disposal followed by a stabilization and revegetation program should increase the value of these areas for terrestrial wildlife. Other effects on wildlife which would result from construction of the project include increased development and human activity in the immediate area, and the possibility of secondary industrial development.

4.154 Use of disposal areas A, C, and D and realignment of the Channel to Aransas Pass would alter approximately 3077 acres of wetland areas (Table 39). These areas are used extensively by fish-eating birds and waterfowl. Texas Coastal Waterfowl surveys, conducted annually in January by the Texas Parks and Wildlife Department, indicate that 50,000 to 60,000 waterfowl use the Redfish Bay - Harbor Island complex each winter. These waterfowl feed on the shoalgrass and widgeongrass of the wetlands and on the benthic organisms associated with it. Also, large populations of shore and wading birds utilize the area extensively for nesting, feeding, and resting. The diversity and abundance of the specific foods now existing in the area would be reduced. Select vegetational planting of productive foods for wildlife could be established on the modified lands. This may alter the numbers and kinds of birds that populate the immediate area and would promote other bird populations and furnish different functionary uses for current wildlife populations.

4.155 Construction and operation of the proposed project would also affect the wildlife resources of the area. Noise associated with dredging and facility construction would cause some forms of wildlife to temporarily leave the area for adjacent areas. Once construction ceased, some wildlife would return, and the vegetated disposal dikes would provide noise and visual shields around much of the tank farm and docking facilities.

4.156 The changes that would result from industrial and urban developments associated with the project activities would adversely affect wildlife populations. However, projected locations of new industrial and urban complexes indicate that the land that would be utilized for new development and expansion is of minimal value to wildlife populations or is currently being used agriculturally. The animals which periodically utilize this land, such as

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rabbit, deer, quail, dove and others, would be forced to reestablish their range, with a possible ultimate reduction in their total numbers.

4.157 Effects on Rare and Endangered Species. The proposed project should have no direct effect on any rare or endangered species, except possibly the brown pelican. Disposal of dredged material could disturb areas used for feeding by the brown pelican. No areas designated as critical habitat for endangered species are located in the areas to be affected by project construction.

4.158 Gulf Disposal Operations. Materials removed from the entrance and jetty channels by hopper dredge would be discharged in a designated open water disposal area in the Gulf of Mexico. This disposal operation is subject to the Ocean Dumping regulations (40 CFR 220-227) established by the Environmental Protection Agency pursuant to the Marine Protection, Research, and Sanctuaries Act of 1973. Section 227.13 b (1) of these regulations states that dredged material may be excluded from evaluative procedures and considered environmentally acceptable if it is composed essentially of sand and/or gravel, or of any other naturally occurring sedimentary materials with particle sizes larger than silts and clays. Table 38 shows that the materials dredged during previous maintenance dredging of the existing Federal project were essentially sands. Materials from the deepening are clays and sandy clays and cannot be considered acceptable on the basis of grain size analysis alone. However, results of tests on samples recovered from borings made along the entire length of the channel revealed no significant contaminants in the virgin sediments (Table 39). These materials are virgin sediments that have not previously been dredged and have never been exposed to any significant amounts of pollutants. Because of the lack of pollutant sources within a reasonable distance of the offshore dredging site and the relatively high quality of water and sediment throughout the channel, it is concluded that the materials to be disposed of in the Gulf are unpolluted and, therefore, acceptable for ocean disposal. Additional information on the sediments to be dredged is included in Appendix H.

4.159 Part 228 of the Ocean Dumping regulations establishes criteria for the initial selection of ocean disposal sites and for the management of the sites after designation. It also establishes the requirement to evaluate the total

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TABLE 38

ARANSAS PASS OUTER BAR AND JETTY CHANNELS
MECHANICAL ANALYSIS OF MATERIALS TO BE
DEPOSITED IN OFFSHORE WATERS 1/

1970 - 1973

Station	% by Dry Weight Sand or Larger	MIL-STD-619B Classification		Date Sampled
180+00	33	Clay, sandy	(CL)	Aug 73
165+00	46	Clay, sandy	(CL)	Aug 73
165+00	41	Clay, sandy	(CL)	Aug 73
155+00	56	Sand, clayey	(SC)	Aug 70
145+00	83	Sand, silty	(SM)	Sep 72
145+00	88	Sand, silty	(SM-SP)	Jun 71
110+00	93	Sand	(SP-SM)	Jan 73
85+00	78	Sand, silty	(SM)	Sep 72
80+00	96	Sand	(SP)	Jan 73
75+00	92	Sand	(SP-SM)	Jun 71
72+50	73	Sand, clayey	(SC)	Aug 70
65+00	95	Sand	(SP-SM)	Jan 73
60+00	98	Sand	(SP)	May 71
56+00	99	Sand	(SP)	Sep 72
55+00	98	Sand	(SP)	Aug 70
50+00	95	Sand	(SP-SM)	Apr 73
50+00	96	Sand	(SP)	Jun 71
45+00	99	Sand	(SP)	Sep 72
45+00	98	Sand	(SP)	May 71
40+00	96	Sand	(SP)	Apr 73
40+00	97	Sand	(SP)	Sep 72
40+00	99	Sand	(SP)	Sep 72
35+00	98	Sand	(SP)	May 71
35+00	97	Sand	(SP)	Jun 71
30+00	96	Sand	(SP)	Apr 73
28+00	96	Sand	(SP)	Apr 73
26+00	99	Sand	(SP)	Sep 72
25+00	96	Sand	(SP)	May 71
24+00	98	Sand	(SP)	Jan 73
16+00	94	Sand	(SP-SM)	Aug 70
10+00	96	Sand	(SP)	Sep 72

1/ Samples were taken directly from hopper dredge bins and are representative of the materials being dumped during maintenance dredging of existing project

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CORPUS CHRISTI SHIP CHANNEL
RESULTS OF TESTS OF BOTTOM SEDIMENT

TABLE 39

Test Results for All Items Reported on Dry Basis, Milligrams per Kilogram

Boring No.	Date Sampled	Depth	Arsenic As	Cadmium Cd	Chromium (Total) Cr	Copper Cu	Lead Pb	Mercury Hg	Nickel Ni	Zinc Zn
76-106	30 Jun 76	3.8 - 20.0	1.4	0.52	3.7	4.2	3.7	< 0.1	4.2	8.1
76-106	30 Jun 76	26.0 - 37.5	1.4	0.24	4.8	16.0	8.6	< 0.1	5.7	12.0
76-106	30 Jun 76	37.5 - 48.0	12.0*	0.38	4.4	5.5	5.7	< 0.1	6.1	13.0
76-106	30 Jun 76	48.0 - 68.0	4.1	0.22	4.9	5.6	6.7	< 0.1	4.9	9.6
76-107	15 Jun 76	30.0 - 36.0	5.1*	0.25	9.6	11.0	14.0	< 0.1	10.0	22.0
76-107	15 Jun 76	36.0 - 41.0	1.9	0.69	3.4	5.7	7.8	< 0.1	6.4	7.3
76-107	15 Jun 76	45.0 - 62.0	1.1	0.22	5.2	3.8	4.9	< 0.1	3.6	8.3
76-107	15 Jun 76	62.0 - 70.0	13.0*	0.47	13.0	5.9	16.0	< 0.1	16.0	29.0
76-108	24 Jul 76	11.2 - 28.0	2.0	0.25	2.7	2.5	4.0	< 0.1	3.5	9.0
76-108	24 Jul 76	28.0 - 37.5	2.5	1.1	4.4	6.2	8.4	< 0.1	7.0	4.4
76-108	24 Jul 76	55.0 - 62.5	3.0	0.22	4.8	5.7	8.3	< 0.1	5.3	10.0
76-108	24 Jul 76	62.5 - 75.0	2.9	0.25	9.2	7.5	6.5	< 0.1	8.0	18.0
76-109	1 Jul 76	2.2 - 10.0	2.7	0.49	5.4	6.9	5.9	< 0.1	6.9	13.0
76-109	1 Jul 76	10.0 - 31.0	1.2	0.21	4.2	4.2	4.2	< 0.1	4.2	7.8
76-109	1 Jul 76	41.0 - 61.0	8.2*	1.1	7.6	6.7	12.0	< 0.1	10.0	17.0
76-109	1 Jul 76	61.0 - 81.0	2.2	0.64	4.9	15.0	10.0	< 0.1	7.3	11.0
76-172	25 Sep 76	48.5 - 49.0	<1.0	< 0.5	3.0	2.0	<5.0	< 0.1	6.0	19.0
76-172	25 Sep 76	54.0 - 57.0	3.5	< 0.5	<3.0	3.0	<5.0	< 0.1	5.0	20.0
76-172	25 Sep 76	65.0 - 67.0	6.4*	< 0.5	14.0	15.0	15.0	< 0.1	17.0	61.0
76-173	25 Sep 76	42.0 - 42.5	1.7	< 0.5	10.0	4.0	5.0	< 0.1	5.0	25.0
76-173	25 Sep 76	45.0 - 47.5	12.0*	< 0.5	10.0	13.0	10.0	< 0.1	20.0	53.0
76-173	25 Sep 76	52.5 - 56.0	<1.0	< 0.5	<3.0	2.0	<5.0	< 0.1	< 2.0	6.0
76-173	25 Sep 76	82.0 - 84.0	3.1	< 0.5	<3.0	3.0	<5.0	0.1	5.0	14.0
Environmental Protection Agency VI Guidelines for Determining the Acceptability of Dredged Sediments Disposal			5.0	2.0	100	50	50	1.0	50	75

Asterisk "*" indicates average of two or more results that exceed EPA Guidelines.

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CORPUS CHRISTI SHIP CHANNEL
RESULTS OF TESTS OF BOTTOM SEDIMENT

TABLE 39

Test Results for All Items Reported on Dry Basis, Milligrams per Kilogram

Boring No.	Date Sampled	Depth	Arsenic As	Cadmium Cd	Chromium (Total) Cr	Copper Cu	Lead Pb	Mercury Hg	Nickel Ni	Zinc Zn
76-174	24 Sep 76	43.5 - 44.0	<1.0	<0.5	5.0	3.0	<5.0	0.1	6.0	21.0
76-174	24 Sep 76	55.0 - 59.0	<1.0	<0.5	10.0	8.0	11.0	0.1	14.0	40.0
76-174	24 Sep 76	70.0 - 72.0	3.1	<0.5	11.0	5.0	10.0	<0.1	10.0	27.0
76-174	24 Sep 76	76.5 - 79.0	<1.0	<0.5	<3.0	2.0	<5.0	<0.1	2.0	11.0
76-174	24 Sep 76	80.0 - 81.0	<1.0	<0.5	5.0	5.0	6.0	<0.1	5.0	11.0
76-175	23 Sep 76	52.5 - 53.0	2.6	<0.5	11.0	6.0	15.0	<0.1	12.0	43.0
76-175	23 Sep 76	55.0 - 65.0	5.2*	<0.5	11.0	10.0	10.0	<0.1	14.0	48.0
76-175	23 Sep 76	68.0 - 73.0	1.7	<0.5	10.0	12.0	10.0	<0.1	14.0	36.0
76-175	23 Sep 76	74.0 - 78.5	5.9*	<0.5	10.0	12.0	12.0	0.1	14.0	42.0
76-176	23 Sep 76	62.5 - 63.0	5.2*	<0.5	19.0	14.0	11.0	<0.1	19.0	64.0
76-176	23 Sep 76	67.5 - 82.5	4.5	<0.5	10.0	7.0	8.0	<0.1	13.0	34.0
Environmental Protection Agency VI Guidelines for Determining the Acceptability of Dredged Sediments Disposal			5.0	2.0	100	50	50	1.0	50	75

Asterisk "*" indicates average of two or more results that exceed EPA Guidelines.

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CORPUS CHRISTI SHIP CHANNEL
RESULTS OF TESTS OF BOTTOM SEDIMENT

TABLE 39

Boring No.	Date Sampled	Depth	Moisture Content % Dry Wt	Total Solids % byWt	Total Volatile Solids % by Wt	Test Results for All Items Reported on Dry Basis, Milligrams per Kilogram					
						Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Organic Carbon	Oil & Grease	Chemical Oxygen Demand
76-106	30 Jun 76	3.8-20.0	32	76	1.1	120		110		230	3,660
76-106	30 Jun 76	26.0-37.5	22	82	2.0	75		65		< 100	1,910
76-106	30 Jun 76	37.5-48.0	25	80	2.3	50		40		< 100	1,640
76-106	30 Jun 76	48.0-68.0	22	82	2.2	135		50		< 100	2,020
76-107	15 Jun 76	30.0-36.0	33	75	3.1	370		310		< 100	11,800
76-107	15 Jun 76	36.0-41.0	27	79	1.1	90		70		< 100	1,330
76-107	15 Jun 76	45.0-62.0	19	84	1.6	100		90		< 100	1,500
76-107	15 Jun 76	62.0-70.0	25	80	4.9	320		310		< 100	1,390
76-108	24 Jul 76	11.2-28.0	32	76	0.9	970		935		930	1,860
76-108	24 Jul 76	28.0-37.5	27	79	0.7	< 15		< 5		410	1,090
76-108	24 Jul 76	55.0-62.5	22	82	2.0	50		15		450	2,360
76-108	24 Jul 76	62.5-75.0	43	70	2.0	80		70		320	2,070
76-109	1 Jul 76	2.2-10.0	39	72	1.5	300		290		730	10,900
76-109	1 Jul 76	10.0-31.0	32	76	1.1	180		155		620	4,700
76-109	1 Jul 76	41.0-61.0	28	78	4.3	470		445		340	2,420
76-109	1 Jul 76	61.0-81.0	25	80	2.9	110		100		610	1,410
76-172	25 Sep 76	48.5-49.0	24	76	1.6	259		246		205	4,180
Environmental Protection Agency VI Guidelines for Determining the Acceptability of Dredged Sediments Disposal					8.0	1,000					50,000

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CORPUS CHRISTI SHIP CHANNEL
RESULTS OF TESTS OF BOTTOM SEDIMENT

TABLE 39

Boring No.	Date Sampled	Depth	Moisture Content %Dry Wt	Total Solids %by Wt	Total Volatile Solids % by Wt	Test Results for All Items Reported on Dry Basis, Milligrams per Kilogram					
						Total Kjeldahl Nitrogen	Ammonia Nitrogen	Total Organic Nitrogen	Total Organic Carbon	Oil & Grease	Chemical Oxygen Demand
76-172	25 Sep 76	54.0-57.0	21	79	4.5	65		62		130	408
76-172	25 Sep 76	65.0-67.0	26	74	6.6	227		222		195	1,880
76-173	25 Sep 76	42.0-42.5	28	72	2.1	374		354		235	8,780
76-173	25 Sep 76	45.0-47.5	26	74	4.3	195		190		115	960
76-173	25 Sep 76	52.5-56.0	21	79	0.5	34		32		270	160
76-173	25 Sep 76	82.0-84.0	18	82	0.8	24		22		250	1,210
76-174	24 Sep 76	43.5-44.0	24	76	1.9	256		244		270	2,810
76-174	24 Sep 76	55.0-59.0	32	68	3.8	474		465		260	14,300
76-174	24 Sep 76	70.0-72.0	31	69	2.9	221		214		400	9,000
76-174	24 Sep 76	76.5-79.0	21	79	1.5	34		33		210	1,630
76-174	24 Sep 76	80.0-81.0	17	83	1.4	188		180		155	568
76-175	23 Sep 76	52.5-53.0	39	61	3.4	750		740		370	12,700
76-175	23 Sep 76	55.0-65.0	37	63	4.6	365		358		95	22,200
76-175	23 Sep 76	68.0-73.0	25	75	1.9	217		213		250	8,580
76-175	23 Sep 76	74.0-78.5	24	76	3.9	257		252		30	9,910
76-176	23 Sep 76	62.5-63.0	53	47	6.6	709		687		85	22,100
76-176	23 Sep 76	67.5-82.5	29	71	1.3	237		226		210	9,190
Environmental Protection Agency VI Guidelines for Determining the Acceptability of Dredged Sediments Disposal					8.0	1,000					50,000

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stress on the marine environment at the disposal site. The regulation states that disposal site selection will be based on historic uses of the site and on historic knowledge of the impact of disposal in areas similar in physical, chemical, and biological characteristics. The proposed Gulf disposal area F-G is fundamentally the same area used for maintenance of the existing Federal project except that it would have to be substantially enlarged. Disposal area H, however, has never previously been used for disposal. Data from offshore disposal areas used for maintenance dredging of the Sabine Neches Waterway, Galveston Channel, and Freeport Harbor have shown no significant adverse impacts on biological communities. The Chief, Marine Protection Branch, Environmental Protection Agency has been furnished information concerning ocean disposal site designation. Pertinent correspondence on the site designation request is included as Appendix H. Appendix H also includes an assessment of the proposed offshore disposal sites.

4.160 Effects on Population. Population estimates prepared by the Coastal Bend Council of Governments (CBCOG) show that growth will occur throughout the area but will center in Corpus Christi, the Rockport-Live Oak Penninsula, and in Portland. During the 34-month construction period about 4,134 construction related jobs would be required. Of these jobs about 1451 would be within the study area. Estimates of indirect and induced jobs due to construction are estimated to be as high as 4,642 jobs by the Texas Department of Water Resources.

4.161 Assuming an average household size of 3.0 the construction-related population would be 4,353 people. It is anticipated that about 60-80% of these families would already live in the study area and that 20-40% would move into the area from other cities.

4.162 Other secondary impacts during the construction phase would be in the area of housing and community services for the estimated 900-1800 families moving into the area.

4.163 Operation of the deep water port would generate long-term gains in employment at the marine facilities and at refineries both in and out of the study area. Gains in employment (jobs) were estimated to range from 2000-4000 for the study area based upon varying throughput schedules for refineries (Texas Department for Water Resources, Appendix I.) The population growth estimated for the Rockport-Live

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Oak Peninsula and Corpus Christi areas is expected to be 33,181 people between 1977 and 1982 (CBCOG, 1977). Induced growth by the project is estimated to be between 15% and 30% of the estimated or manned growth and does not appear to be a significant effect.

4.164 Effects on the Economy of the Area. Development of port facilities at Harbor Island would stimulate economic activity in the study area due to construction expenditures (short-term) and contribute to an increase in petroleum refining activities. Cost savings would also be realized by refiners from shipping imported oil in larger vessels. The construction phase, lasting over 34 months, is expected to cost $430 million (Table 1.) The project would require 5,477 man years of labor at a direct annual gain of 1451 jobs. About $260 million would be spent in the study area, $92 million spent in other areas of Texas, $79 million spent in the rest of the nation during construction. Household incomes (direct, indirect and induced) are estimated at $107 million for the study area and $85 million for the rest of Texas. The primary and secondary impacts of a deepwater port development on Harbor Island would have a strong positive influence on the local economy and contribute to a diversified economy with a broad industrial base.

4.165 The impact resulting from actual construction of the facility is a short-run benefit to the economy of the region, state, and nation that occurs only during the estimated 34-month construction period. The long-term economic benefit would come from the ability of the refining industry to increase its production and assist in supplying national energy markets. To meet the anticipated demand over the next 15 years American refineries will necessarily process imported oil shipped in larger tankers to realize cost savings.

4.166 Approximately 166 million barrels of foreign oil at a value of $1.8 billion (1977 dollars) flows through the port of Corpus Christi.

4.167 Effects of varying throughput schedules without the project and with low, medium, and high throughputs was prepared by Exxon, Incorporated for the TWRD. Future imported crude throughputs in local refineries is estimated to be 200.75 million barrels annually in 1980 and to increase to 262.8 million barrels by 1990 without the proposed Harbor Island facility. Low range estimates with

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the proposed facility for 1980 and 1990 are 251.85 and 317.55 million barrels annually, respectively. High throughput estimates as a result of the project could be 438.0 and 912.5 million barrels annually in 1980 and 1990, respectively. Increases due to the project range from a low of 51.1 million barrels annually in 1980 (low estimate) to a high of 649.7 million barrels annually in 1990.

4.168 Increased refining production would mean an increase in the value of refinery output to about $2.2 million by 1980. The current capacity of area refiners is approximately 200 million barrels per year. The Harbor Island project would increase refinery expansion significantly above present expansions planned for completion in 1982. Value of refinery output is projected to reach $2.87 billion by 1990 without the project.

4.169 The low-case project-related refinery output is estimated at $2.8 billion by 1980 and $3.5 billion by 1990. There would be a net gain of 1119 additional project-related jobs and a total of 5,512 jobs generated in the region. This is the lowest effect the project would be expected to have.

4.170 If rapid expansion occurs in Harbor Island facilities, the throughput could reach an estimated 2.5 mb/day by 1990. Refining capacity could reach four times the present level, resulting in employment of over 10,000 in the refining sector and an additional 9,000 employees in other sectors of the regional economy. The total economic output would be $7.9 billion larger than the output without the facility.

4.171 Effects on Land Use. Projected land use was determined for each community (by CBCOG) in the "208 planning area" portion of the three county study area. Population changes and projections of the economic growth in the study area formed the foundation for predicting land use changes. Residential and commercial use is projected to expand through 1995 within the cities in the study area. Agricultural lands are expected to provide expansion capability for growing cities in the area. Industrial areas are projected to increase from 9,700 acres to 13,600 acres between 1977 and 1995. Growth in residential , commercial, and industrial lands are expected to occur around existing urban centers without the creation of new cities.

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4.172 Industrial facilities (petroleum tank farm and marine facilities) exist on the southeast portion of Harbor Island across the Corpus Christi Ship Channel from Port Aransas. Project construction plans indicate a widening and deepening of the existing Aransas Pass Channel, relocation of the channel to the northeast. A 377 acre increase in industrial lands on the northeast edge of the Aransas Pass ship channel would present by the project. Related to projected changes in land use prepared by Coastal Bend COG in cooperation with cities in the 208 planning region, this represents approximately 10% of the increase in industrial land use predicted to occur by 1995. According to the Coastal Bend COG the majority of industrial development is anticipated to occur in the Corpus Christi area. Smaller increases are anticipated for Ingleside and Port Aransas.

4.173 Dredged material disposal is planned for San Jose Island and existing disposal areas along the Corpus Christi Ship Channel immediately west of Port Aransas. Secondary long-term effects of disposal are the creation of uplands which can be developed into residential, commercial, recreational or industrial sites. The extent or type of development on these disposal areas cannot be determined at this time. Project-related impacts by dredge material disposal areas, and docking basin and habitat type are shown in Table 39.

4.174 Effects on Recreation. The project area receives heavy recreational use thoroughout the year. Recreational activities in the area include fishing, swimming, surfing, picknicking, camping, and bird watching. Most of these activities should not be significantly affected by the project. Construction activities in the port area of Harbor Island could temporarily displace some mammals and birds. Dredge material disposal on inland areas could also displace temporarily some bird species. Bird watching would be affected to some degree by these construction activities. Fishing is heavy during seasonal runs of flounder, spotted sea trout, red and black drum. Annual channel maintenance as well as construction-related dredging and disposal which would increase turbidity could reduce the sport fish catch in the immediate vicinity of the dredge. Recreational boating in the project area may be affected during the 34 month construction phase. Boating may also be affected during those hours every 2-3 days when the VLCC is moving between the channel and the dock. During construction, dredge pipelines may interfere with recreational boating.

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Maneuvering of the VLCC's in the channel may produce localized waves or currents hazardous to small boat operation.

4.175 The proposed work should have no direct or indirect adverse effects on recreational use of the Federal or State recreational and wildlife management areas in the project vicinity. Demand for recreational activity is expected to increase over 1970 levels by 260% in Aransas County, 378% in Nueces County and 135% in San Patricio County.

4.176 Recreational use of shoreline areas may be affected by oil spills. Navigation and safety operations proposed as part of the project mitigation measures are aimed at reducing the potential for any oil spills. Equipment as well as a contingency plan required by the U.S. Coast Guard at the facility are geared to immediate response for any size leakage or spill. Project design also includes a control tower (similar to an airport control tower) for positive visual control of VLCC's.

4.177 Effects on Archeological and Historical Resources. A search of the National Register of Historic Places indicates that there are three National Historic Places in the project area. They are the Mathis House in Rockport in Aransas County, the King Ranch in Nueces and Kennedy Counties, and McGloin Homestead in San Patricio County. These areas will not be affected by the project. In February 1977, Mr. F. R. Hollard Jr. nominated the Aransas Pass Light Station for inclusion in the National Register of Historic Places. The lighthouse is approximately one mile from the proposed project facility and should not be affected.

4.178 An evaluation of archeological resources in the area of the proposed project conducted by Thomas R. Hester was performed for Southwest Research Institute. Results of that evaluation showed that the proposed channel modifications would not have any direct impact on archeological resources the project areas. The report recommended that an archeologist be present whenever widening cuts are made into major islands or the mainland since it is possible that some buried and previously unknown resources could be discovered.

4.179 An archeological survey of the Tributary Channel to Aransas Pass, Texas conducted by Kenyon L. McDonald of the University of Texas at San Antonio, Center for Archeological Research, included an appraisal of archeological and

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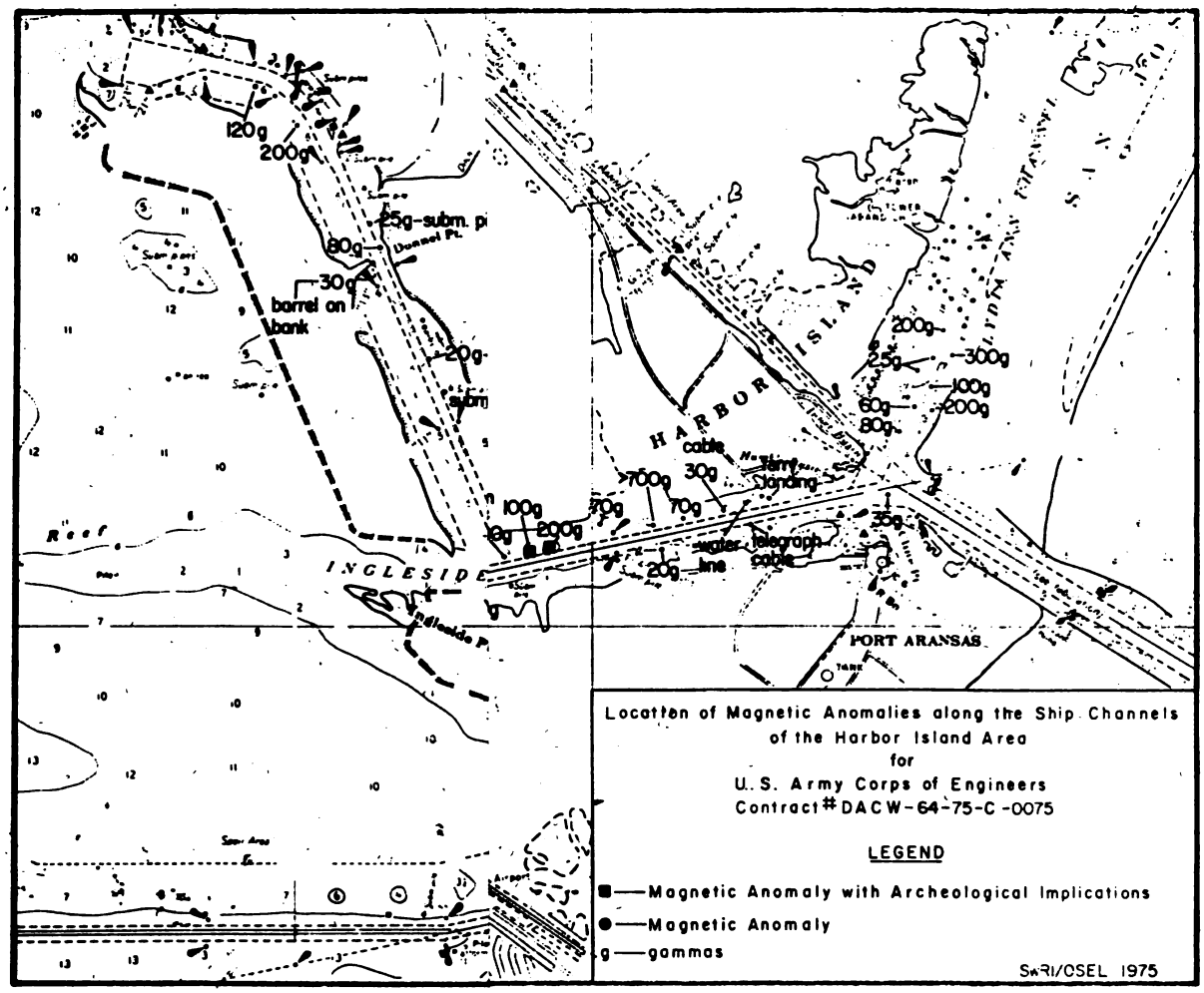

ATION OF MAGNETIC ANOMALIES ALONG THE CHANNELS OF THE HARBOR ISLAND AREA

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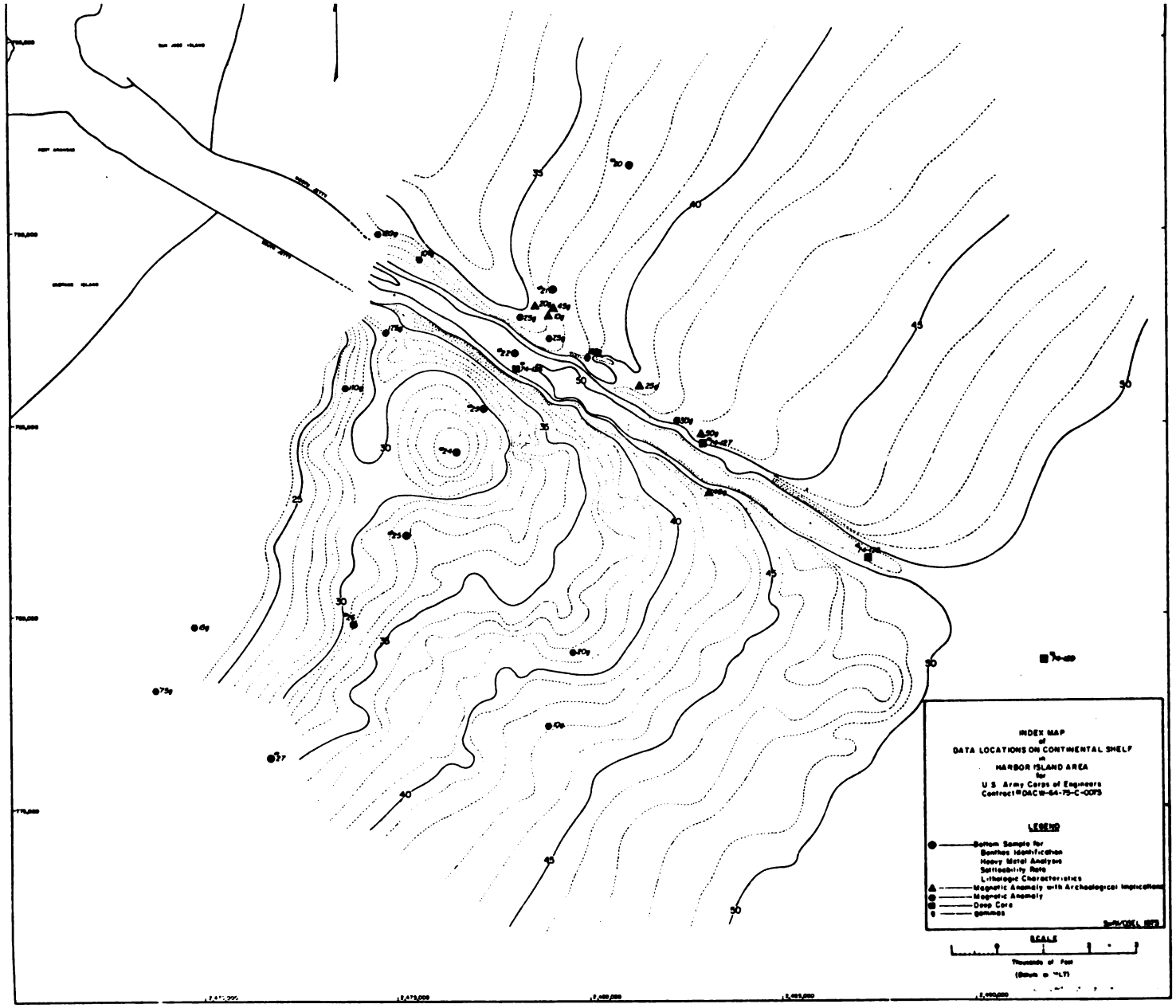

DATA LOCATIONS ON CONTINENTAL SHELF IN HARBOR ISLAND AREA
Figure 43

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TABLE 40

COMPARISON OF PROJECTED AND SUPPORTABLE POPULATIONS WITH RESPECT TO AVAILABLE FRESHWATER

Year	Projected Total Population	Predicted* Supportable Population (thousands)
1980	308,000	520-780
1985	320,000	520-780
1990	355,000	500-750
2000	534,000	440-700
2010	671,000	430-690
2030	713,000	400-630

*Assuming percent population in manufacturing as shown, and completion of Choke Canyon Reservoir.

Source: SwRI 1976.

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historical resources of the area to be affected by the proposed action. McDonald's report included a review of the archeology in the project area and six specific survey sites which are to be utilized as disposal areas for the tributary Channel to Aransas Pass. Results of the survey revealed no surficial evidence of aboriginal or historical remains. The report recommended that if during the course of channel modification, any articles that may be of archeological significance are seen in the dredged material, work should be stopped and qualified archeologists consulted. The report also noted that particular care should be taken in modifying North Harbor Island because this locality may be the least disturbed of all the survey areas and may possibly hold buried archeological resources.

4.180 Southwest Research Institute, under contract with the Corps of Engineers, conducted magnetometer surveys of the inshore area to be affected by the Harbor Island project. The survey results show no significant magnetic anomalies in the inshore area which could have archeological implications Figure 42. Several significant anomalies were located outside the area to be affected by construction of the project. SWRI also conducted magnetometer surveys in the offshore area and found no magnetic anomalies with archeological implications in the area to be affected by the project Figure 43.

4.181 Demands on Water Resources. Southwest Research Institute developed a water resource planning model for forecasting future water demands in the Corpus Christi area as a result of the proposed project. The results of the application of the water resource planning model showed a range of supportable populations of approximately 400,000 to 630,000. This is lower than the projected population of 713,000 in the year 2030. The chronology of growth was examined in order to determine when the water demand would exceed the planned water resource. Table 40 provides the total population, the manufacturing population, and the corresponding supportable populations. The incompatibility of water resource demand and supply observed could begin as early as the years between 1990 and 2000 if the worst demand/conservation situation occurs. Figure 44 provides a comparison of forecast water demands with existing governmental water plans for the Corpus Christi area. It can be concluded that the prediction of water demands is consistent with the projections of other governmental plans, that is, additional water supplies beyond the Choke Canyon Project will be required.

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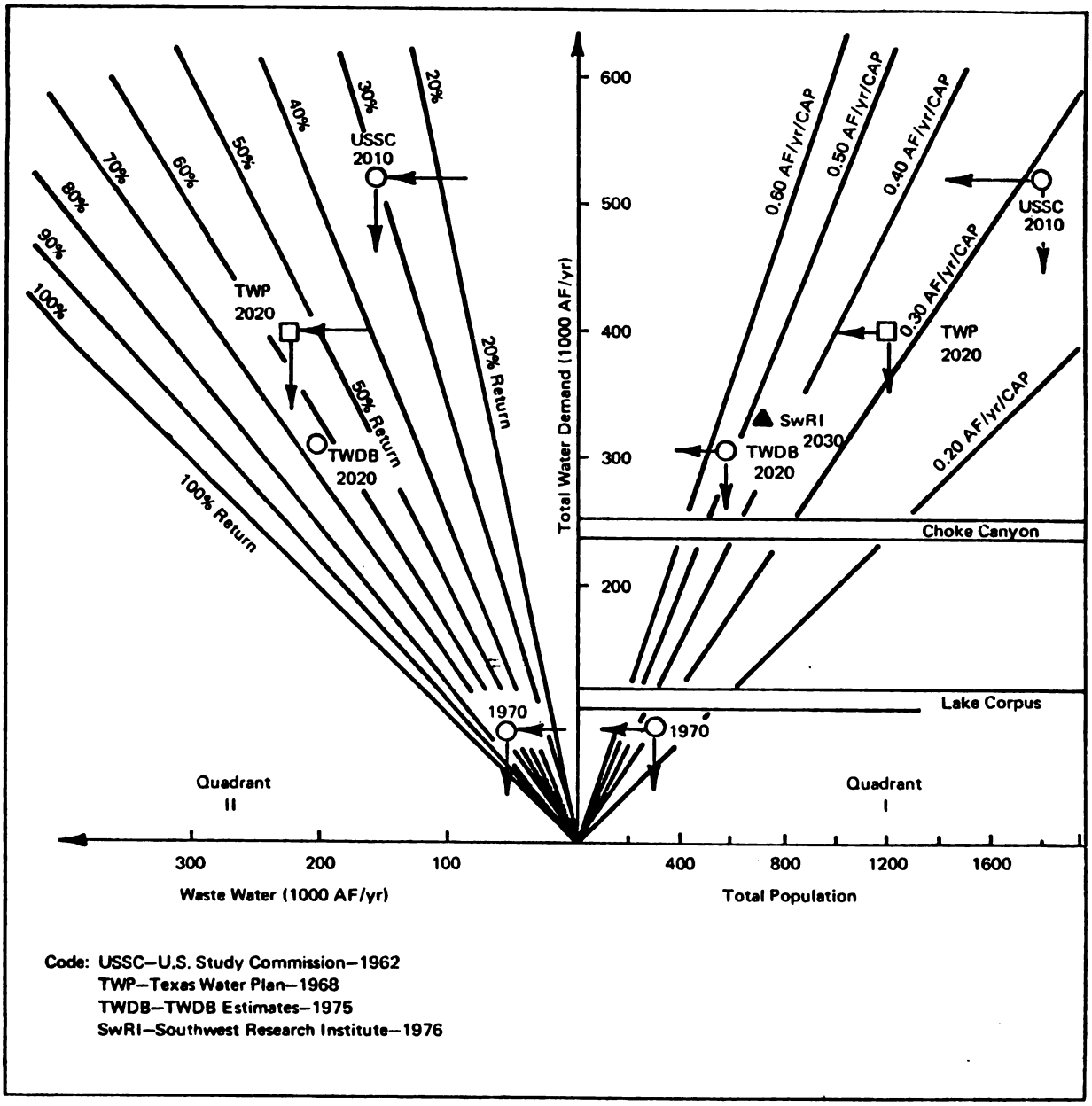

FIGURE 44 COMPARISON OF WATER REQUIREMENT WITH EXISTING GOVERNMENTAL PLANS

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5. ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE PROPOSED ACTION BE IMPLEMENTED.

5.01 Loss of Wetlands. Construction of this project would result in varied effects on the wetlands of the project area including the removal of wetlands by construction of the turning basin and realignment of the Channel to Aransas Pass; sedimentation in adjacent wetland areas associated with the actual dredging; and covering wetlands in the proposed inshore disposal areas. Approximately 167 acres of wetlands would be lost from the project area by construction of the turning basin and realignment of the channel to Aransas Pass. Of the several wetland types affected by this aspect of the project, the black mangroves of the north Harbor Island area are most important. One of the most significant effects on the wetlands as a result of the project would be from the proposed disposal operations. The use of disposal area A, C, and D, would result in a loss of the wetlands in these areas to the estuarine system. These areas contain about 2910 acres of wetland area. The loss of these areas would lower primary productivity, reduce nursery grounds for marine species, and reduce wildlife habitat. With respect to wildlife, the loss of wetlands would result in a reduction in nesting and resting areas and food sources. Establishment of terrestrial vegetation on the disposal areas could restore some wildlife habitat area.

5.02 Loss of Benthic Organisms. Dredging and disposal operations associated with construction of the project would have varied effects on bottom dwelling organisms. These effects include the removal and destruction of the benthic organisms existing in the previously undredged areas, coverage of those organisms existing in the disposal areas, and some disruption to organisms in areas adjacent to the dredged channel. Maintenance dredging would possibly be performed every year, a frequency which would prevent benthic recolonization commensurate with the productivity of surrounding undisturbed areas. The bottom of the inshore portions of the docking basin could, at times, be low in dissolved oxygen because of inadequate mixing and tidal action resulting in low benthic populations.

5.03 Materials deposited in the disposal areas during construction would cover approximately 7,000 acres of Gulf bottom and 2,910 acres of inshore wetland and bay bottom. Bottom dwelling organisms in these areas would be covered and perish. The Gulf areas should recolonize and may improve as habitat. The inshore areas, however would be removed from tidal influence and would no longer support benthic life.

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5.04 Effects on Fishery Resources. Turbidities, excavation activities, and filling of wetlands, would all have an effect on the fishery resources of the project area. Turbidities, which would result from the dredging and disposal activities would reduce photosynthetic activity in the vicinity of the dredge which would correspondingly reduce the base of the aquatic food chain.

5.05 Large numbers of marine species migrate in and out of the estuaries through Aransas Pass. Prolonged dredging in the entrance channel may affect these migrations. The magnitude of this effect is dependent on the time of year; number, size, and location of dredges; and length of dredging time. The dredging should not preclude the passage of larval, juvenile or adult marine organisms through the channel; however, those organisms approaching too close to the dredge suction pipe may be entrained in the pipe and pumped to the disposal area where they would be either buried in the sediment or consumed. The loss of 3,077 acres of wetlands in the project area would adversely affect the fishery resources of the project area. As discussed in Paragraph 4.132, the wetlands in the project area play a significant role in providing detrital material, a source of energy to the first level consumers of the estuarine system. The loss of this basic energy to the food chain may reduce the number of sport and commercial fish, crustaceans, and mollusks. The loss of protection and food that the wetlands provide for larval, post-larval, and juvenile fishes and crustaceans would also have an effect on the fishery resources. The significance of these changes is unknown.

5.06 Loss of Shellfish. The disposal of dredged material would result in the burial of oyster reefs existing within the boundaries of the disposal areas. Except for a few scattered oysters the largest concentration is in disposal area C. However, scattered oysters extend south along the bay side of Mustang Island, almost to Shamrock Island. All oysters within this disposal area would permanently be buried. A few small scattered oyster reefs also exist among the tidal areas of Harbor Island, and some of these reefs would be physically removed by the realignment of the Channel to Aransas Pass.

5.07 Effects on Wildlife. Disposal of dredged materials would cover vegetation of value to wildlife, and excavation of the docking basin and realignment of the Channel to Aransas Pass would elimate an equivalent area of wildlife habitat. Other effects on wildlife which would result from construction of the project include increased development and human activity in the immediate area and secondary

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industrial development. Noise associated with dredging and facility construction would drive some forms of wildlife out of the area and into adjacent areas with relatively little human activity. Once construction has ceased some wildlife could return to the area; however, numbers and diversity of animals might not be as high as formerly.

5.08 Effects on Water Quality. Some water quality effects could be expected to result from construction and maintenance of the project. These effects include increased turbidity and possible resuspension of pollutants. During dredging and disposal activities turbidities would affect an area which could extend several hundred feet or more from the source. The significance of this effect depends on dredging time and methods used to control turbidities. It is anticipated that approximately 2 years of continuous dredging would be required. Maintenance dredging would be accomplished annually. Turbidity barriers are often effective in controlling the spread of turbid water around a pipeline dredge, and the use of leveed disposal areas with spillways, if properly maintained, can effectively reduce the amount of suspended sediment returned to the bay system. In the offshore waters where hopper dredges would be used, no method of controlling turbidity exists. Water quality effects resulting from secondary project development should not be significant.

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6. ALTERNATIVES.

6.01 General. The alternatives available to the U.S. Army Corps of Engineers for action on permit applications are more limited than those for Federal projects undertaken directly. The Corps of Engineers may only deny, grant, or grant with conditions, the applications before them. A Federal agency does not have the latitude on permit applications which it has on its own projects to develop alternatives. Also, an understanding of the basis for the project as submitted is important to determine the relative impacts of possible alternatives so that a decision regarding the Federal action to be taken is made with knowledge of reasonable alternatives. Therefore, this section discusses the alternatives available to the Federal government, and to the Nueces County Navigation District No. 1.

6.02 Alternatives Available to the Federal Government. The only alternatives available to the Corps of Engineers are to simply grant the Nueces County Navigation District No. 1 its permit as requested, deny the permit, or grant it with conditions. By granting the permit, the applicant would be allowed to construct the project as described in Section 1 of the statement. Denial of the permit would essentially be adoption of the no action alternative.

6.03 No Action. This alternative would be to deny the permit application and allow no action to be taken on construction of the deep port facilities by the applicant.

6.04 In the absence of a deeper channel that would allow an increase in the efficiency of ocean-going cargo movements through Harbor Island, cargo movements would continue in smaller, shallower-draft vessels, the size of which would be limited by the existing Federally authorized project depth of 45 feet. As the commerce through the port continues to increase and the average size of ocean-going vessels increases through obsolescence and attrition, an increasing number of ships would have to either light load or call at other ports. Beyond a certain size, highly loaded vessels would be restricted from the Port of Corpus Christi either because of width, draft, or height. The economic growth of the area would probably be slow and the lack of the transport benefits of a deep channel might discourage long-range industrial growth and cause a decline in the local refinery industry if it became less competitive with other areas. This competitive posture is particularly significant since greater than 85 percent of the production of local refineries is consumed outside of the state of Texas.

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6.05 The no action alternative would result in a savings in resources (labor, material, and money) needed to construct the project. Additionally, potentially adverse environmental effects (discussed in Section 4) associated with the construction of the project would be avoided.

6.06 Granting the Permit with Conditions. Another alternative available to the Federal government is to grant the permit with conditions or restrictions. This action would essentially serve to modify the project so that it would be more socially and environmentally acceptable. These modifications could include alternate methods of dredging and disposal, and other structural and non-structural changes to the project including operational constraints. Such action may make the project no longer economically attractive.

6.07 Some structural and non-structural changes may negatively affect navigational safety. For example, the channel, turning basin or docking basin could be realigned to avoid a particularly environmentally sensitive area. Location and arrangement of surge tankage, levees, docks, and other facilities associated with the project could be modified if it were believed the project would be more environmentally sound. Other requirements which could be imposed including operational changes and more strict environmental monitoring requirements.

6.08 Various Types of Dredges Available. Dredges are generally divided into two categories--mechanical and hydraulic. The major types of mechanical dredges are dipper dredges, ladder dredges, and bucket dredges. Hydraulic dredges include hopper dredges, pipeline (or cutter suction) dredges, and side casting dredges.

6.09 Environmentally, hopper and pipeline dredges are the least hazardous since dredged material is taken up by pumps, producing only limited turbidity, and deposited in a controlled manner onto prearranged disposal sites. Dipper and bucket dredges have a dragging or scooping motion which causes high turbidity and scatters dredged material.

6.10 Dipper Dredge. The dipper dredge is basically a power shovel, such as is used for earth excavation, which has been mounted on a barge. It has the advantage of being capable of excavating hard materials such as blasted rock or loose boulders that cannot easily be removed by other types of dredges. Most such dredges do not excavate more than 60 feet in depth. The barge, which serves as the work platform for the power shovel, has spuds to anchor it in the work

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area while operating. Two spuds are used at the forward end to stabilize the dredge, and a single spud is centered at the stern of the barge.

6.11 Ladder Dredge. The ladder dredge is so named because of its chain of buckets passing over and under a long steel frame or ladder. This ladder is usually mounted in the middle of the dredge and extends toward the front of the barge. The operating depth of the ladder can be altered to suit the channel depth being excavated but is limited by design considerations. Larger dredges in this class use buckets of approximately 2 cubic yard capacity and can operate at depths of 100 feet. Dredging with the ladder dredge is accomplished by forcing the teeth of the buckets into the material to be excavated. The dredge is set up over the cut with an anchored cable set out ahead to pull on and side cables placed to either side to stabilize the barge while working. The ladder dredge is advantageous for dredging varied types of material at greater depths in a comparatively confined location. Disposal of the material from such a dredge presents a problem. No large marine ladder dredges are available in the United States.

6.12 Bucket Dredge. The bucket dredge is so named because it utilizes a bucket to excavate material to be dredged. The type bucket utilized (clamshell, orangepeel, or dragline) often can be changed to suit the job conditions and material to be removed. Different size buckets can be employed by the same dredge, again dependent on the character of the dredged material. Buckets holding up to 15 cubic yards are currently in use. The bucket dredge is mostly used to remove material in confined areas, such as around docks and piers, or where small amounts of material are to be dredged and placed on nearby areas. It is generally not economical for large scale excavation projects unless nearby disposal areas are available.

6.13 Side Casting Dredge. The side casting dredge evolved from modification of hopper dredges to provide overboard discharge of dredged material. Under certain conditions this type of dredging is feasible and by far the most economical means of providing and maintaining channel depths. These dredges can be designed for side casting only, or the conventional hopper dredge can be equipped to provide the capability for side cast dredging. All of this equipment is self-propelled with the discharge of the dredged material usually accomplished through a boom pipeline alongside the dredged channel. Side casting dredges are particularly effective in locations where the littoral currents do not return a significant amount of the

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dredged material to the navigation channel. The side caster can handle the same range of material that a hopper dredge can. Its ability to maneuver in the channel makes this dredge particularly useful in opening shallow inlets to the ocean. Side casting dredges range in discharge pipeline size from 12 inches to 26 inches.

6.14 Hopper Dredge. The use of hopper dredges to construct the entire project and dispose of the material at sea is a possible consideration. However, the economic use of hopper dredging requires disposal areas in reasonable proximity to the area to be dredged and the ability of the dredge to move fully over the dredging site. Hopper dredges are not designed for, nor can they be operated, so as to remove emergent land masses efficiently nor can they operate in small confined areas or dredge in corners or alongside docks.

6.15 Because of the time involved in transporting the dredged material to an offshore disposal site, the time required construct the entire project by hopper dredge would be considerably longer than by the proposed methods. Disturbance or removal of the bottom dwelling organisms would be the same as would occur with pipeline dredging. Localized turbidity and water quality problems in the immediate area of dredging would also occur with hopper dredging but would be prolonged because of the longer time required. The minor effects on air quality caused by hopper dredge exhaust would be comparable to those caused by a pipeline dredge. Use of a hopper dredge would eliminate the adverse environmental effects of disposing the dredged material in bay and wetland areas, but would require more disposal offshore. Use of a hopper dredge would not permit the restoration of the southern end of San Jose Island.

6.16 Alternatives Available to the Applicant. Several alternatives are available to the applicant which would provide the same end result of importing large quantities of petroleum at a cheaper price. These include offshore facilities and alternate modes of importing crude oil. The development of deep draft tanker loading and unloading facilities in some offshore waters may be subject to the legal constraints imposed by the Deepwater Port Act of 1974, which governs the construction and operation of oil terminal facilities located beyond the territorial sea. Such facilities constructed outside the seaward boundary of Texas would be subject to this Act.

6.17 Offshore facilities. Offshore terminals have been developed in many parts of the world for loading and

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unloading crude oil and other bulk materials. Pipeline transshipment to shore is generally more economical than dredging close to shore, and reduces harbor congestion.

6.18 Five alternate systems in use today are the conventional multiple-point buoy mooring, single point buoy mooring, single anchor leg mooring, sea islands, and trestle or causeway-connected piers. The acceptability of these systems depends on engineering considerations at a particular site. Where offshore storage is preferred, construction of an artificial island may, under certain conditions, be desirable. The criteria for these types of facilities are discussed separately below. In addition, there are many variations of these facilities including floating breakwaters which could provide for integral storage within the breakwater structure itself, and enclosed harbor and terminal complexes.

6.19 Conventional Buoy Mooring. This mooring system uses a number of mooring buoys to maintain the tanker in a given position and orientation. Flexible hoses connect the vessel to an underwater pipeline which is used to carry the crude oil from tanker to a tank farm on land. Multiple point mooring facilities have been in operation for years in many parts of the world. However, because tankers are essentially restricted to two orientations (180° apart), this system is limited to sites where prevailing winds are longitudinal to the berth or, at least, to locations where strong winds are not expected broadside to the berth.

6.20 This facility can become untenable in beam or quartering winds greater than 25-35 miles per hour. Limiting current conditions are normally one knot for beam or quartering currents and two knots or more for head currents. In addition, 100,000 DWT appears to be the limiting size for multi-CBM moorings.

6.21 Single Point Mooring Buoy (SPM). This mooring system consists of a flat cylindrical floating buoy with its vertical axis held in position by a multi-leg system of anchors and chains. The buoy has a central piping manifold topped by a single or multiple-product swivel and mooring ties, the former connected by under-buoy hoses to a submarine pipeline. A turntable on top carries pipes from the central swivel to the side of the buoy where they connect to floating hoses and then to the tanker manifold. The tanker is usually moored to two nylon hawsers running from the buoy turntable to the bow of the ship. This permits the tanker to berth into prevailing winds and to move with changes in wind and/or current direction while at berth. Such mooring operations usually require a launch for

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line running and hose handling. When launch operations are required, berthing is generally halted by six-foot seas. There is presently no way of controlling or containing a spill which occurs at an SPM in the open sea such as the Gulf of Mexico. Unloading operations take place in the open, unprotected sea, in contrast to the sheltered condition of an inshore port.

6.22 Due to the vessel approach requirements, for the same required water depth as for the proposed inshore facility the SPM would have to be located farther offshore from Corpus Christi, thereby probably requiring a permit from DOT for its construction.

6.23 Despite some drawback SPM's have been employed at offshore locations where sea and weather conditions may be severe. Currently proposed practices for SPM's suggest ceasing of offloading in 12-foot seas and berth abandonment in 15-foot seas. Berthing operations have limitations similar to CBM's and require a 4,000-to 5,000-foot clear radius around the buoys for approval, and for vessel survey. As the tanker unloads, ballast water is taken on to maintain a safe and stable draft.

6.24 One problem experienced with SPM's is a tendency of tankers to creep towards the buoy during calm weather and slack tide. This can lead to possible overrunning of the buoy and fouling of the buoy mooring chanins or submarine hoses by the tankers' bulbous bows. Floating hoses are particularly susceptible to vessel damage, particularly at night, and to wave damage in heavy seas. Turntable sticking and subsequent wrapping of hoses around the buoy can also cause damage. Further, in spite of the fact that pressure drop sensitive devices and volume flow measurement can be employed to detect leaks of sufficient magnitude, potential exists for fairly substantial leaks and spills to be undetected if they occur in the underwater portion of the system, particularly if unloading is being done at night. SPM's require a high degree of maintenance, particularly in the hose systems.

6.25 Single Anchor Leg Moorings (SALM). The single anchor leg mooring is a modification of the SPM system. The hose and product swivel mechanism of the SALM is located on the sea bed. The buoy floats on the water and is anchored to the bottom by a single chain. Should the bow of the vessel strike the SALM while berthing or drift while berthed, the buoy would be pushed aside and submerged without materially affecting the hose and product swivel mechanisms. However the system still suffers from the vulnerability of the

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floating hoses the potential for unobserved leakage, and the inability to contain spills should they occur. This system has been installed at two locations in depths of 85 and 140 feet and can be designed for mooring tankers exceeding 500,000 DWT. Mooring and berthing limitations with this system are similar to the SPM.

6.26 Single Point Mooring Pier. This facility consists of a pylon or tower fixed to the sea floor with a long swivel-mounted semi-submersible floating arm, which has a floating tower at its end. The tanker moors at the bow to the tower, permitting it to feather into the wind, seas, and current and to assume a line of least resistance. The oil moves from the vessel's manifold through a short hose to the floating structure and into the submarine pipeline. This facility is relatively expensive to install, costing two to five times as much as a monobuoy. The floating arm may be vulnerable to sea conditions. However, it has a much higher capacity than a monobuoy, as its hoses are shorter and they flex only where connected to the tanker manifold. In addition, single pile moorings endeavor to eliminate the monobuoy's major disadvantages (i.e. hose vulnerability and system maintenance) by replacing flexible elements with a rigid truss structure.

6.27 Piers. Piers, like sea islands, are fixed structures. This type of docking facility is usually placed close to an existing shore or artificial island. Cargo is carried ashore either by a trestle-or causeway-supported pipeline for liquid or by conveyor for dry material from the mooring facility. Since the ship is moored at a fixed berth, tugs are required for safe berthing. Waves which prevent tugs from completely controlling the operation will stop berthing at the facility. Construction of a breakwater to shelter the docking area permits the facilities to be used in much higher seas. The cost of a breakwater must be weighed against the cost of shut-down during adverse sea conditions. This type of system does not appear feasible inasmuch as a pier would have to extend in the Gulf approximately 11 miles to accomodate the same size vessels as the proposed project. If the pier were shorter, dredging would be required. Also, in all cases a breakwater would, in all probability, be required.

6.28 Sea Island. A sea island is a fixed structure to which a vessel is moored and which keeps the ship restrained in position and orientation. Fixed structures are usually used where prevailing winds are parallel to the berth or where strong broadside winds are expected infrequently.

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This system permits installation of several all metal loading arms allowing high oil transfer rates. Ships may dock at both sides of the sea island concurrently, and can easily be fueled or bunkered. Surveillance of the oil transfer can easily be conducted by trained personnel. For other mooring systems, these personnel would have to operate either from aboard the tanker or from special launches, an inconvenience if the facility is some distance from shore. The oil is transferred to shore via a submarine pipeline. Fixed berths require tugs to berth tankers safely and require more shelter from waves than do SPM's or CBM's. Therefore, wave conditions that preclude tugs from maintaining complete control of the operation will stop berthing. Similarly, wave height and direction will affect the vessel when moored. A tanker can remain moored in higher waves from the bow and stern than it can from the quarter or beam. Beam and quartering currents, along with or apart from beam and quartering winds, will also have an affect on a berthing tanker and a moored tanker.

6.29 Impacts of Monobuoy Systems. Monobuoys or floating-type structures will normally have little direct impact on the marine environment. Of the alternatives considered, these structures offer the least potential damage to the environment. Since monobuoys displace only a small area, they will not significantly affect current or circulation patterns other than in the immediate area. Since only a very small area is needed for anchorage of a monobuoy, there will be little impact upon the bottom habitat and its associated biotic communities. Like artificial islands, monobuoys will probably attract finfishes, but in much smaller numbers. In general, impacts of monobuoys on the marine environment and its associated biota will not be of great importance. However, the loading hoses require frequent replacement and since part of the hoses and the submarine pipeline are not visible from the surface, the possibility of a large and undetected oil spill during unloading is greater than with a system which is fully exposed to view and in which oil spills could be contained. It is not practical with the present state of the art to contain a spill at an open sea monobuoy.

6.30 Artificial Island. This is probably the most expensive type of deep water port facility. However, its versatility is practically unlimited. An island would probably be built by placing a rock fill dike around its perimeter; hydraulic fill would then be pumped in and compacted to form the island. Simultaneously, a stone revetment would be built around the outside perimeter of the dike. The revetment would be protected with precast

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concrete armor units massive enough to remain stable under severe sea conditions. The island size would be determined by the types of material shipped through the facility. A marginal pier or sea island to handle the actual berthing would be attached to the island. The island could be used for the unloading, storage, and transshipment of both liquid and solid commodities. Limitations of the artificial island are similar to those of the marginal pier.

6.31 The impacts of artificial islands with breakwaters are primarily related to water movement; however, certain segments of biota will definitely be impacted. The exact nature of impacts on water movement will depend upon the size and shape of an island and its location in the Gulf. A structure, such as the typical artificial island and breakwater, will act as a barrier to waves and will alter current and water circulation. The exact mechanisms of change to these parameters is not known. Several factors, such as water depth, location within the Gulf, and tidal influences, determine how circulation patterns will be influenced.

6.32 The direct impacts of an artificial island in the Gulf on marine organisms would primarily be related to destruction of bottom habitat. Benthic organisms existing at the site will be destroyed by dredge and fill operations. Removal of materials, such as sand for island construction, will affect the resident biota of the borrow area.

6.33 Some benefits may be derived from the construction of an artificial island. In the case of finfishes, an artificial island may create a desirable habitat where none existed before, increasing the concentration of certain species. The face of such a structure, often constructed of rock with holes and irregular surfaces, provides shelter and feeding areas unlike those of the surrounding marine habitat.

6.34 Floating Islands. Floating superports are impracticable because of their high cost (investment and maintenance) and sensitivity to sea conditions. Breakwaters can be built around these facilities to increase utilization but only with significant investment cost increases. Additionally, the floating superport concept has never been employed, even though extensive design studies have been performed. In general, these studies indicate the feasibility of modular concrete, or prestressed concrete, construction with offshore assembly and the applicability of the islands for offshore use. Moorings would be massive, and some sort of flexible connection still would be required

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in the cargo connection between island and submarine pipeline. Articulated mechanical arms, however, could provide for fluid cargo transfer to the island from a ship moored alongside. The impacts of such as system would probably be similar to those resulting from an SPM.

6.35 Submarine Pipeline Impacts Which Would Result from Any Offshore System. Submarine pipeline impacts in open water areas consist primarily of disruption of bottoms and alteration of water quality from construction activities. Benthic organisms in the area where the pipeline is laid will be destroyed or displaced. However, after the line is laid and covered with soil, benthic organisms will recolonize the area.

6.36 Water quality problems associated with pipeline construction are similar for those described for dredging; however, due to the much smaller amount of bottom disruption required for a pipeline, these problems are much less severe. The primary water quality problem associated with pipeline construction is increased turbidity in the immediate construction areas. These impacts are temporary, lasting only during the actual construction period.

6.37 Pipeline construction impacts in bay-estuary systems are similar to those discussed for the open Gulf area; however, since bay-estuary systems are more productive than open Gulf areas, the magnitude of impact would be greater. Also, impacts on water quality in bays and estuaries during pipeline construction would generally be more severe due to lower flushing rates. Of particular importance in bay systems are grass flats. Pipeline construction through these areas can seriously affect the vegetation and associated faunal assemblages by physical destruction and smothering from siltation. Pipeline construction through highly productive marsh ecosystems poses the most serious environmental threat related to pipeline construction. Some of the most serious impacts include (1) disruption of drainage in the marsh system, (2) physical and physiological destruction of marsh vegetation, and (3) loss of habitat for wildlife. These impacts can be minimized if the pipelines are covered with soil and the area allowed to revegetate. Some of the less serious impacts of pipeline construction through marshes include increased turbidities and BOD loading in surrounding water areas; however, these conditions are temporary, lasting only during the construction period.

6.38 Impacts of pipeline construction through upland areas consist primarily of destruction of vegetation and

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associated wildlife habitat along rights-of-way and disruption and erosion of soils. Impacts of denudation of the vegetative coverage in pipeline rights-of-way vary with the particular plant coverage in the area. For example, destruction of high quality bottomland hardwood vegetation would have a much greater impact than destruction of pasture vegetation along a pipeline right-of-way. Problems associated with soil erosion often occur most extensively during pipeline construction and the period required for establishment of vegetation.

6.39 Direct Shipment by Small Vessels. The use of small tankers (less than 65,000 DWT) and light loading of medium sized tankers is currently the primary mode of importing crude oil into the Gulf of Mexico. Harbor Island on the Corpus Christi Ship Channel is the only U.S. Port on the Gulf of Mexico that can accommodate vessels with draft up to 44 feet. Medium sized tankers of the 80,000 DWT class can be partially loaded to stay within draft limits of 44 feet. Although some of the benefits of the larger ship size are obtained, partial or light loading larger tankers cannot be a long-term solution to the problem of draft limitations in ports. The obvious disadvantage of continuing usage of small vessels is the higher cost of transportation. With the scrapping of the older vessels, fewer tankers will be available to transport the needed volumes of curde oil.

6.40 Congestion at the principal oil ports is expected to increase as more small tankers are used to deliver the expected increase in U.S. oil import requirements. If larger vessels are used, one tanker of the 150,000 DWT class would be required each day or a VLCC of the 300,000 DWT class every other day for every one million barrels per day of imports. Vessels of the 50,000 DWT class would require three tankers each day. The increase in small vessel traffic would increase the probability of collisions and other vessel casualities and associated oil spills.

6.41 Lightering. Lightering is a method whereby crude oil from VLCC's is transferred at sea directly to smaller vessels for delivery into existing ports. The technique was developed several years ago by major oil companies for deliveries to ports with insufficient draft and has become common practice. It requires good seamanship and good weather and wave conditions and is a relatively high risk operation. However, no major oil spills associated with lightering are known to have occurred. A bill is presently being considered by the U.S. Congress to regulate ocean lightering. Lightering is presently being used to some extent to import oil to Gulf Coast and other U.S. ports. In the Gulf, lightering requires off loading the entire tanker

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at sea because present docks and/or channel widths are inadequate to serve such vessels. Occasionally, tankers less than 120,000 DWT are offloaded only to the point where the draft of the larger vessel will allow it to enter port and complete unloading.

6.42 The primary advantage associated with lightering results from the economic utilization of VLCC's for the majority of the ocean journey. The major disadvantages of lightering are that it is unsafe to conduct this operation in rough seas, it would tend to cause congestion near approaches to existing harbors if used on a large scale, and the double handling of the cargo is more expensive than direct shipment. Delays will result primarily when seas are too rough to conduct the transfer operation. Also, it will increase the potential for an oil spill and will not avoid the problem of port congestion by small ships. Environmentally, lightering a VLCC by offloading part of its cargo into a lighter vessels is somewhat similar to the offshore buoy systems discussed in previous sections since the two vessels are secured to each other and transfer is by hose. However, weather conditions do affect this type of operation. The volume movement, or traffic, of the smaller lightering vessels, however, has greater potential for environmental impact than the project or offshore systems because of the increased traffic and potential harbor congestion. If the volume of crude oil projected to be imported in 1985 actually results, the movement of this much oil will require the equivalent of 2000 tankers of an average 70,000 dwt or 200 VLCC's of 200,000 dwt. (Texas A&M, 1972)

6.43 Transshipment. Transshipment is a method whereby crude oil from ULCC's(Ultra Large Crude Carriers) is first transferred to a land based facility and then later transferred to shallower draft vessels for delivery. Transshipment has some of the advantages of lightering at sea, such as partial usage of VLCC economy, but it avoids the environmental hazards of vessel to vessel exchange of oil at sea and the scheduling problems associated with large-scale lightering-at-sea operations. However transshipment does not alter the congestion problem associated with the use of a large fleet of small vessels at the final destination port.

6.44 In spite of the latter, transshipment is currently used from terminals in the Caribbean with deepwater, such as Aruba, Bonaire, Curacao, and the Bahamas, directly to U.S. ports on the East Coast and in the Gulf of Mexico.

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6.45 Since ULCC or VLCC economy is used only for part of the trip, and since unloading, storage and reloading are expensive, transshipment is inherently more costly per ton of crude oil delivered, than direct ULCC or VLCC delivery to destination. It has been estimated that transshipment may add as much as $0.40 to the cost of a barrel of oil transported from the Persian Gulf to Texas, as compared with direct shipment in VLCCs. An added disadvantage of transshipment is the location of terminals in a third party country, a situation that may entail a security risk for the United States.

6.46 Alternatives Developed in the Federal Study. As part of the ongoing federally authorized study, two alternate plans have been developed which would satisfy most of the requirements of the applicant and be much more environmentally acceptable. One plan calls for the same harbor configuration as that requested by the applicant; however, disposal of dredged materials would be on San Jose Island and offshore Gulf areas. There would be no disposal in wetland areas except that needed for construction of the docking basin. Materials dredged during maintenance of the channel could be deposited on San Jose Island and in the Gulf disposal areas. This plan would result in the loss of only approximately 167 acres of wetlands as compared to 3,077 acres in the proposed project. Some minor terrestrial habitat of value to wildlife would also be lost. Surge tanks would be located on high ground or mainland areas. This plan would reduce most of the impacts that would result from the physical construction of the proposed project such as filling wetland areas and loss of terrestrial habitat. Most of the other impacts associated with the proposed project as discussed in Section 4 would be applicable to this alternative. The other plan which is being considered in the federal study calls for the same harbor configuration as that requested by the applicant except that it has been relocated southwestward such that the Tributary channel to Aransas Pass would not require relocation. Environmentally, this plan would be the preferred inshore plan since no wetland area would be affected and the terrestrial habitat that would be lost has already been disturbed and is of little value to wildlife. This plan would also utilize San Jose Island and the Gulf for disposal of dredged material for both construction and maintenance dredging. Surge tankage would be located on mainland areas. This plan would, however, require the relocation or loss of 31 oil storage tanks, 3 crude oil receiving docks, and other facilities associated with the unloading process. Such a configuration may increase navigation problems and affect the safety of vessels while docking and turning. There would be no physical loss of any wetlands or loss to the

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biological community associated with these wetlands. Most of the other impacts of the proposed project (as discussed in section 4) such as turbidities from dredging and disposal activities and removal of benthic organisms in the dredged acres would be the same for this alternative.

6.47 Modification of the Proposed Plan. The applicant could modify the proposed project in other ways to make it more environmentally acceptable. For example, reducing the channel depth from 80 to 60 feet would reduce the amount of dredged material to be removed and disposed by about 50 percent. While this type of plan has several advantages environmentally over the proposed plan, most of the economic benefit of transporting in large tankers would be lost and the remaining economic benefit would not provide sufficient incentive for the commitment to throughtput agreements by the oil companies. The project then could not be financed with non-Federal funds. Reducing the channel depth would slightly reduce the amount of water exchanged through Aransas Pass as compared to the 80 foot channel and lessen the change in the overall salinity in the bays. Since less dredged material would need to be disposed of, less wetland area would be lost by filling. It may also be possible to dispose of all the dredged material offshore, depending on compliance with EPA's Ocean Dumping regulation (40CFR220-228). Locating the surge tankage on the mainland would preclude the filling of additional wetlands on Harbor Island. Reduction of channel depth would, however, decrease the per barrel savings which would be gained by an 80 foot channel. Modifications to the proposed disposal plans could significantly affect the environmental consequences resulting from the proposed plan. Generally, disposal of dredged material in areas other than wetlands would be an improvement and hopper dredging and offshore disposal in other areas of the Coast have been shown to improve Gulf bottom as habitat.

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7. THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY. The local short-term impacts resulting from the proposed project would occur mostly during the construction phase of the project. These impacts include increased turbidities during dredging and disposal operations, loss of benthic organisms, coverage and removal of vegetation, increased noise levels due to construction equipment, and disruption to wildlife. The proposed project would improve marine transportation facilities of the Corpus Christi area and long-term benefits would accrue from the savings in transportation costs. There would be a long-term reduction in productivity resulting from loss or disruption of valuable estuarine nursery areas. Lowered overall productivity in the channel and disposal areas would continue as a result of maintenance dredging of the channel. Other long-term adverse effects associated with this project include the introduction of new and continuous sources of air, water, and noise pollution to the area as a result of secondary industrial development. However, the pollutant emissions should be kept to a minimum with strict enforcement of State and Federal laws. Another adverse effect will be the exposure of this environment to a possible oil spill, fire and/or explosion hazard.

7.01 Other long-term effects associated with this facility would be beneficial, including increased employment, tax revenues, and investment in the area.

7.02 All of the above mentioned impacts, both adverse and beneficial, have been discussed in detail in Section 4.

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8. ANY IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE PROPOSED ACTION.

8.01 The labor, capital, and material resources expended in the planning and construction of this project represents irreversible and irretrievable commitments of human, economic, and natural resources.

8.02 A permanent loss to the natural environment would result from construction of the proposed project. This loss includes wetlands, terrestrial habitat, and undisturbed bay and Gulf bottoms. The operation of the harbor will permanently affect the character of the Harbor Island-Aransas Pass area. That area, which presently handles small commercial fishing boats, petroleum barges, and ocean going tankers, would be handling large ocean-going ships.

8.03 The operation of the port represents the commitment of the community, region, and state to accept the risk, however small, that an accident such as oil spill, collision, or explosion could affect all or portions of the estuarine system in the area. Thus, the port may represent a commitment to an industrial activity which could result in the suppression or even elimination of an unrenewable resource - the estuary.

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9. COORDINATION.

9.01 History of Events. As a result of the application for a Department of Army Permit to construct the proposed project by the Nueces County Navigation District on 20 June 1973, a series of prescribed actions were initiated by the Galveston District, Corps of Engineers. These actions are required prior to the issuance of a permit. This authority emanates from two Federal laws; Section 10 of the River and Harbor Act of 1899 and Section 404 of the Federal Water Pollution Control Act of 1972. Section 10 requires a permit prior to obstruction or alteration of any navigable waters in the United States and Section 404 authorizes the Secretary of the Army to issue permits for discharge of dredged or fill material into navigable waters. Section 404 also authorizes the administrator of the Environmental Protection Agency to prohibit or restrict the use of any defined areas as a disposal site after he determines that the discharge of such materials would have an unacceptable adverse effect on municipal water supplies, shellfish beds, or wildlife areas.

9.02 Following the receipt of a permit application by a Corps of Engineers district office, preliminary evaluations relating to the impact of the proposed work on the public interest are made. This includes the assessment of the economic, social, and environmental effects, as well as the legal, navigational, and engineering considerations. Based on the assessment, four general types of determinations are made. They are as follows:

a. Adequacy of the engineering data and procedural information as presented in the permit application.

b. Necessity for additional environmental data for the preparation of an EIS, based on the magnitude of the proposed work.

c. Identification of appropriate city, county, State, and Federal agencies; local, regional and national shipping, business and conservation organizations for distribution of related permit information.

d. Procedures for notifying the public based on the type of proposed work and degree of public interest.

9.03 Following these determinations, a public notice is issued to interested agencies, organizations, and individuals. Normally 30 days is provided for interested parties to express their views. Depending on the level of

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response to the notice, determinations are then made to provide further opportunity for expression of public interest.

9.04 A similar sequence of events has led to this stage of the permit process. On 12 October 1972 the Corps of Engineers was authorized by a resolution of the Committee on Public Works, United States House of Representatives, to consider modification of the existing project at the Corpus Christi Ship Channel to provide for increased depths and widths in the entrance channels from the Gulf of Mexico to a deep draft port in the vicinity of Harbor Island. On 20 June 1973 the Nueces County Navigation District applied for a permit to construct the proposed project. On 20 and 21 September 1973 a public meeting was held in Corpus Christi on the permit application. The meeting was attended by hundreds of individuals representing both public and private concerns. Numerous statements both for and against the proposed action were received. A record of the meeting is available for public review in the Corps of Engineers, Galveston District office. At the meeting it was announced that an environmental impact statement on the proposed project was required. In July 1974, the Navigation District expressed concern over the complexity of the permit activity and over the possible duplication of effort in impact statement preparation. Based on these concerns, they requested that the permit be placed in an inactive category. In March 1975, the Corps of Engineers awarded a contract to Southwest Research Institute for the preparation of an Environmental Inventory and Effect Assessment of the Candidate Navigation Plans for the Corpus Christi Bay areas. Southwest Research submitted the final report in February 1977.

9.5 On 2 November 1977 a public meeting was held in Corpus Christi for the Federal project. The purposes of the meeting were to present information and to obtain views and public preferences on alternative plans developed by the Corps of Engineers and to request comments for consideration in the final development of a recommended plan. The meeting consisted of three parts and was designed to encourage an open expression of views and information from all interested parties. Part I was an introduction of the study and format of the meeting. Part II was conducted in a work group format in which participants had an opportunity to express their views and concerns and discuss the study findings and the alternative plans with members of the District staff. In Part III, the most important items were summarized and discussed and some of the more pervasive questions raised in the work groups were answered. Formal oral statements were

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then heard from those who desired to address the assembly. Following a break, the meeting was reconvened to conduct a work group session for those who couldn't attend during the day and to continue to hear oral statements from those who desired to address the assembly. At the meeting, statements of support for Deepwater Inshore port were received from Congressman John Young and Jim Wright, Senator John Tower and Lloyd Bentsen and Texas Governor Dolph Briscoe. The following represent those issues perceived by the meeting participants as being the most important:

The effects on the environment and ecology caused by a navigation project and project-induced developments.

Navigation safety associated with the use of larger vessels.

The effects of increased ship traffic on the environment.

The problem of oil spills.

The effects of increased ship traffic on shore and beach erosion.

The land use changes in the project area as a result of a deepwater port.

The effects of dredging and associated disposal of the dredged material.

The social and economic advantages and impacts of a deep port on the local and regional areas.

Long term and short term effects of turbidity and salinity changes on sport and commercial fishing.

Future economic benefits in terms of proven oil reserves.

Increased susceptibility to hurricane surges.

The effects of other deepwater ports on proposals for the Corpus Christi area.

An effective resource utilization plan for the local and regional areas.

The recognition of the full potential of the ship channel at the currently authorized project depth.

Each person also was given an opportunity to rank the six alternatives in terms of acceptability. Generally, the

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results of this ranking in order of preference was Plan 4, the multi-purpose port facility; Plan 1, the "no-action" plan; Plan 2, the offshore monobuoy; Plan 3, the Harbor Island port; Plan 5, the onshore port; and Plan 6, the offshore island. This ranking indicates only the preferences of those participating in the work groups.

9.06 On 10 June 1976 the Nueces County Navigation District reactivated the permit application to construct a deep port at Harbor Island. On 22 February 1977 a public notice on the reactivated permit was released (Appendix C) with a request that comments be submitted on or before 24 March 1977. Over 3,800 letters and petitions have been received in response to the notice. Almost all of the responses have objected to the proposed project because of environmental, social, economic, or aesthetics reasons. There have also been numerous requests for a public hearing. A public hearing on the proposed permit is scheduled after circulation of this draft Environmental Statement.

9.07 Governmental Agencies. Copies of this draft statement will be circulated to the following Federal, State, local agencies and citizens groups for review and comment.

Environmental Protection Agency
Department of State
Department of Energy
Department of Commerce
Department of Housing and Urban Development
U.S. Department of Agriculture
Department of the Interior
Department of Health, Education, and Welfare
Advisory Council on Historic Preservation
The National Wildlife Federation
Department of Transportation
Eighth Coast Guard District
State of Texas, Budget and Planning Office
Coastal Bend Council of Governments
City of Port Aransas
City of Corpus Christi
Texas Historical Commission
County Judge, Nueces County
Nueces County Navigation District No. 1
Sierra Club of Corpus Christi
Welder Wildlife Foundation
Sportsman's Clubs of Texas, Inc.
Water Resources Congress
League of Women Voters
Corpus Christi Chamber of Commerce

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National Audubon Society
Corpus Christi Outdoor Club
Aransas-Corpus Christi Pilots
Coastal Bend Conservation Association, Inc.
Citizens for Estuarine Planning
Mayor of Aransas Pass
Mayor of Ingleside
County Judge, Aransas County
The Coalition on American Rivers
Texas Committee on Natural Resources
Chamber of Commerce (Port Aransas Area)
M. H. Kuhn
Steve Rabalais

All comments received will be considered in preparation of the final statement.

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