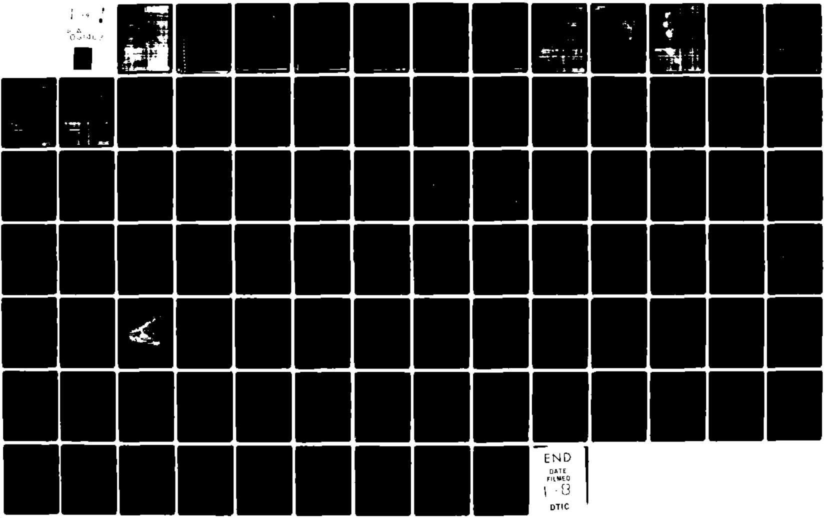
AD-A091 403   LITTLE (ARTHUR D) INC   CAMBRIDGE MA   F/G 13/10
GULF COAST DEEP WATER PORT FACILITIES STUDY. ENVIRONMENTAL ASSE--ETC(U)
APR 73   DACW38-73-C-0027
UNCLASSIFIED   ADL-C-75018   NL



END
DATE
FILMED
1-8
DTIC

6282

LEVEL

GULF COAST
DEEP WATER PORT FACILITIES STUDY

Environmental Assessment

a report to

U.S. DEPARTMENT OF THE ARMY
VICKSBURG DISTRICT CORPS OF ENGINEERS

1 APRIL 1973

(6

Gulf Coast Deep Water Port Facilities Study

ENVIRONMENTAL ASSESSMENT

a report to

U.S. Department of the Army
Vicksburg District Corps of Engineers
Vicksburg, Mississippi 39180

prepared under

(15) Contract No. DACW 38-73-C-0027

(11) 1 April 1973

(14) ADL-C-75018

(12) 94

Arthur D. Little, Inc.
Cambridge, MA.

208850

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENT

This study is the result of a coordinated effort by a number of people, under the direction of Gerald R. Schimke, Project Manager. Principal contributors are mentioned in the Acknowledgment of each volume.

Within Arthur D. Little, Inc. (ADL), Frederic March contributed substantially to development and application of the ranking methodology; Dr. Philip J. O'Brien was responsible for analysis of the water resources; and Robert E. Brooks, Jr., did the oil pollution probability analysis.

The contributions of our consultants – Dr. George L. Clarke, Harvard University; Dr. Bostwick H. Ketchum, Woods Hole Oceanographic Institution; and Dr. Stephen Moore, Massachusetts Institute of Technology – are acknowledged with thanks. Drs. Ketchum and Moore have been particularly helpful in making unpublished manuscripts available for our use in this work.

Three subcontractors – TerEco Corporation, Bryan, Texas; Bio-Oceanic Research, Inc., New Orleans, Louisiana; and the State University System of Florida Institute of Oceanography (SUSIO), St. Petersburg, Florida – collected and prepared the information presented in Appendices A, B, and C.

I. SUMMARY

A. PURPOSE

The purpose of this report is to provide environmental information and analysis which will help the Corps of Engineers decide on the most suitable location(s) for deep-water port development in the Gulf of Mexico.

B. SCOPE AND APPROACH

The Corps of Engineers asked Arthur D. Little, Inc. (ADL) to study the marine environment in all its pertinent dimensions, define dissimilar hydrobiological [illegible] of the Gulf Coast, and rank the regions as to their vulnerability to deep-water port development.

The scope of the study is broad and regional in nature, and *not* directed toward specific site selection. Geographically, the study encompassed the Gulf of Mexico, from Brownsville, Texas, to Tampa, Florida; the estuaries, shoreline, and open ocean; and considered both local and Gulf-wide effects of deep-water port development. Technically, the study was limited to investigation and assessment of existing information on the biotic and non-biological resources and human activities within the area of concern. Under the terms of the contract, no new research or field studies were undertaken.

To accomplish this task in a meaningful time frame, ADL sought local expertise from three groups in the Gulf area. The combined team researched the literature and current investigations and drew correlations to define dissimilar zones based on current environmental characteristics. Based on this existing environmental information, 27 dissimilar hydrobiological zones throughout the Gulf were defined, and are shown in Figure 1. Nine locations, currently under consideration, were ranked according to relative response to the environmental perturbations expected to result from deep-water port development. These locations are shown in Figure 2.

[illegible]

1. Hydrobiological Zones

Environmental information sufficient for the definition of broadly dissimilar hydrobiological zones currently exists. (See Appendices A, B, and C.)

- On a broad scale, there is more difference in zonal characteristics [illegible] perpendicular to the shore than there is in going from one [illegible] to another parallel to the shore.
- On a smaller scale (more appropriate to specific site studies) there is a considerable variation in existing environmental conditions within some zones.

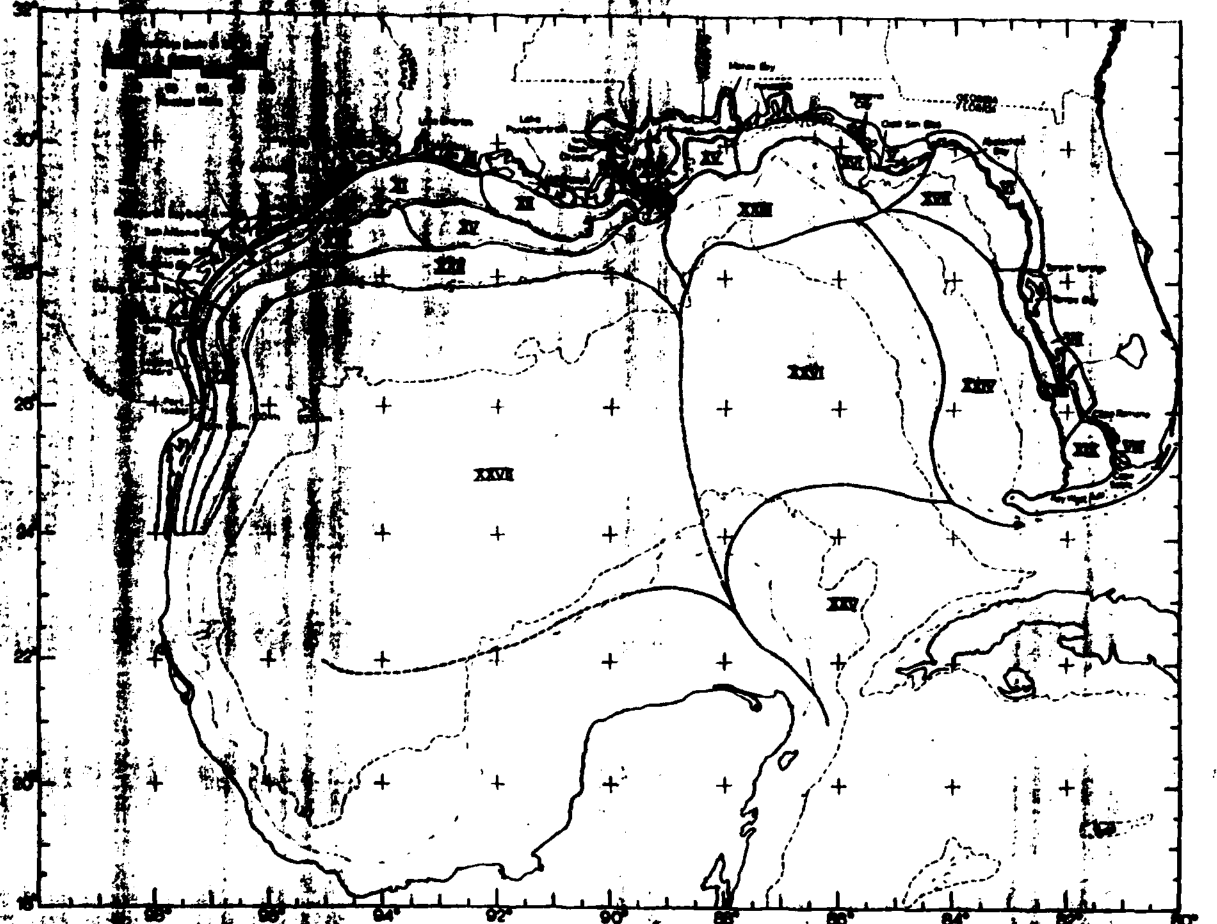


FIGURE [illegible] DISSIMILAR HYDROBIOLOGICAL ZONES—GULF OF MEXICO

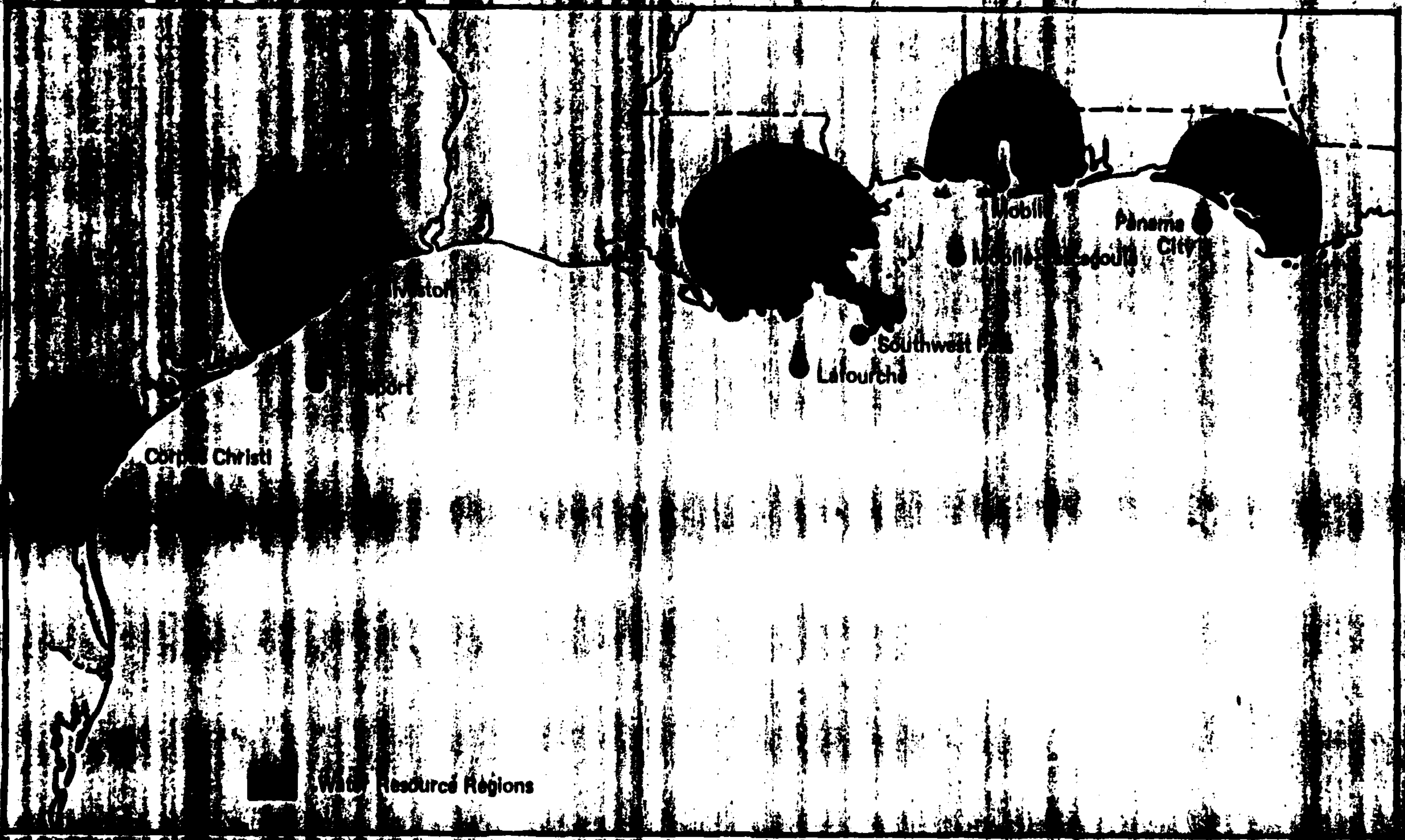


FIGURE 2 NINE POSSIBLE DEEPWATER PORT LOCATIONS

2. Adverse Environmental Impacts

Regardless of the location selected for deep-water port development in the Gulf, both local and distributed adverse environmental impacts will occur. The nature and severity of these impacts will vary from zone to zone and this variation forms the basis for determining each zone's relative suitability for such development. The main activities leading to environmental impact are:

- petroleum port-related industrial development in the coast zone (persistent water use and waste stress);
- dredging to bring deep-water channel (e.g., circa 75 feet) to the coastline (erosion, aquifers, marine and estuarine water quality, biota);
- periodic accidental spills of petroleum (biota and water quality); and
- terminal construction (local effects on biota and water flow characteristics).

3. Zonal Use Sensitivity

The character of the zones shown in Figure 1 differ from one to another, depending on the predominant use to which mankind has put them. Thus, current *uses of some zones* would appear to make them more sensitive to deep-water port development than others. Based on man's current commercial, recreational, and conservational uses of the land, and the adjacent sea, we have listed the coastal zones in order of *increasing* sensitivity to port development.

Sabine Lake to Calcasieu Lake (Zone III) – least sensitive
Atchafalaya Bay to Mobile Bay (Zone IV)
Port Isabel to Baffin Bay (Zone I)
Corpus Christi Bay to Galveston Bay (Zone II)
Pensacola to Cape San Blas (Zone V) – most sensitive

4. Water Resources

Secondary development associated with deep-water ports will require adequate water resources. Based on the quantity and quality of available surface and groundwater, and flood and drought potential, the five water resource areas shown on Figure 2 are listed in order of *decreasing* suitability for development:

Mobile, Ala.	very suitable for deep port development
New Orleans, La.	very suitable for deep port development
Panama City, Fla.	very suitable for deep port development
Freeport-Galveston, Tex.	moderately suitable for deep port development
Corpus Christi, Tex.	not suited for deep port development

5. Storm Potential

Based on National Climatic Center statistics, the following six locations are listed in order of *increasing* probability of tropical storm and hurricane occurrence;

Corpus Christi, Texas
Galveston, Texas
Offshore Freeport, Texas
Mobile, Alabama
Panama City, Florida
New Orleans, Louisiana and Offshore Mobile, Alabama
Offshore Southwest Pass and Lafourche, Louisiana

6. Zonal Impact Ranking

On the basis of deep-port-induced environmental change ("Impact") we find the following relative ranking for the nine zones examined:

Lowest Impact	Moderate Impact	Highest Impact
Mobile-Pascagoula (Offshore)	New Orleans	Mobile Bay
Panama City (Offshore	Freeport (Offshore)	Corpus Christi Bay
Southwest Pass (Offshore)		Galveston Bay
Lafourche (Offshore)		

This ranking reflects the rapid onshore to offshore changes in environmental character, and the extreme vulnerability of the inshore environment to the adverse effects of dredging and accidental oil spills.

Freeport is more vulnerable than the other offshore zones, primarily because of the anticipated water use and waste discharge stress which secondary industrial development would place on an already stressed environment.

New Orleans is less vulnerable than other inland zones because many potentially adverse factors are confined mainly to the Mississippi River, and do not directly impact the most vulnerable resources.

7. Overall Environmental Ranking

Considering the current zonal use patterns, water resources, and storm potential along with the impact scores, we conclude that offshore Mobile-Pascagoula is the most environmentally suitable region for deepwater port development. Southwest Pass and Lafourche rank second, because of their proximity to (and the high probability of major damage to) the adjacent marsh land. Because of the high conservation/recreation value placed on the Florida coastal zone, the offshore Panama City location ranks third, along with New Orleans and offshore Freeport.

Mobile Bay, Corpus Christi Bay, and Galveston Bay follow, in that [illegible] our analysis, these locations are listed in order of increasing vulnerability:

Mobile-Pascagoula (Offshore)

Southwest Pass (Offshore)
Lafourche (Offshore)

Panama City (Offshore)
New Orleans
Freeport (Offshore)

Mobile Bay
Corpus Christi Bay
Galveston Bay

8. Oil Pollution Impact

Although many worthwhile studies have been made to assess the effects of past oil pollution events on the natural environment, a high degree of uncertainty still exists in the analysis and interpretation of these studies. Furthermore, because the composition of the imported crude oil differs from typical Gulf crudes, and the magnitude of potential accidents (e.g., 14,000 tons) is many tens of times greater than anything yet experienced in the Gulf, past studies are not wholly applicable. Thus, the capability to quantitatively predict the probable impact of future hypothesized oil pollution events in the Gulf of Mexico is low.

9. Turbidity Impact

Broadly applicable definitive studies of biotic response to increased turbidity associated with dredging or supertanker operations are not available. Studies are needed before a high degree of confidence can be placed on quantitative predictions of probable effects of increased turbidity.

10. Ocean Currents

Definitive studies of the ocean currents in the coastal region of the Gulf of Mexico are lacking, so that any predictions of oil spill or suspended sediment transport must be viewed as tentative.

11. Supplemental Studies

The present study provides a partial documentation for the requirement that "all prudent and feasible" alternatives be considered. However, the findings regarding environmental impacts for any particular project considered here will have to be supplemented by specific site studies at the feasibility level.

12. Deep Water Location

We conclude that deep water terminals in the Gulf of Mexico should be located in naturally occurring deep water to ameliorate, as much as possible, the direct adverse effects of dredging, and the associated problem of spoil disposal.

13. Minimum Pollution Risk

We conclude that an oil offloading terminal should be located offshore in a region where prevailing currents and winds minimize the risk of shoreline pollution so that oil spills do not reach and pollute the vulnerable intertidal areas, especially marshes, in the event that one occurs inspite of preventive measures.

14. Further Study of Deep Dredging

We conclude that if a decision is made to further consider an inland location, then a more detailed environmental analysis should be conducted.

II. INTRODUCTION

A. NEED FOR DEVELOPMENT

The marine environment has served man for many years by providing: food, moderating influences on climates, inexpensive means of transportation, assimilation of a wide range of man-made wastes, and a recreational playground for a broad spectrum of individuals. It is only recently that events and observations have occurred which indicate that man's activities may be of such scope and magnitude as to cause wide-spread damage to the sea.

It is clear that the people of the United States find the coastal zone an attractive place to live. It is equally clear that this coastal zone contains some of the most biologically productive areas of the Earth, and plays a critical role in the maintenance of our fisheries. A conflict exists between preservation of the coastal zone for its own intrinsic value, and development for rather more short-term benefits to mankind. There are already many different development proposals for this valuable, and possibly fragile, portion of the United States.

In recent years many different factors – including a generally rising level of affluence in America, population growth, and the regulation of low-grade fuel consumption to affect a cleaner environment – have contributed to what has become known as the "energy crisis," which is the projected deficiency between U.S. demand for energy and the domestic supply. On April 25, 1972, Senator Mike Gravel of Alaska opened hearings "to examine the prospective benefits and risks of deep-water port developments in the United States" with the following comment:

> "The United States, once self-sufficient in domestic oil supplies, is fast becoming import dependent. Although U.S. oil imports presently constitute 27 percent of our total oil supply, some sources predict the United States will import over 50 percent of its oil supplies by 1985. Massive projected increases in oil imports, as well as other bulk goods, require serious consideration by the Congress of the adequacy of American ports and terminal facilities and of our maritime policies to meet future requirements.
>
> "The most expedient and economical way to transport this volume of oil is with supertankers; tankers of greater than 100,000 deadweight tons, capable of carrying in excess of 2 million barrels of oil. Western Europe and Japan already depend overwhelmingly upon supertankers of 100,000 to 300,000 tons, and much larger tankers of up to 1 million tons are being built or designed. However, ships of this size require offshore transport facilities, or harbor and channel depths substantially greater than are now available in the United States."

This study addresses the problem of identifying the most suitable locations (least harmful to the marine environment) for new deep-water ports in the Gulf of

Mexico. We first hypothesized the nature of port development, and then assessed possible environmental impacts which might arise.

B. DEVELOPMENT CHARACTERISTICS

Deep-water port development acts as a stimulus to the economy of the region in which it takes place. Transportation savings associated with deep draft ships are such that industries are rapidly attracted to the area, drastically changing the nature of the landscape.

Foreign experience (ADL, 1971) has shown that if a port can accommodate deep draft ships, the transportation routes change so that many different bulk commodities can be handled, even if the port was initially developed to handle only a single commodity (e.g., petroleum). Primary and secondary support industries associated with each commodity grow in the region, and without restrictive controls contribute their share to a general decline of environmental quality. The details of this process are complex and depend on many factors, including the existing infrastructure of the specific location in which the development takes place. For the purpose of identifying the most suitable region for deep-water ports, we do not dwell on these details, but have simply selected a representative commodity and examined the environmental impacts from this perspective.

A recent study has shown that petroleum is the commodity which would allow the greatest economic benefits from transportation savings associated with deep-water port development (Nathan, 1971). For the purposes of this study, then we define deep-water port development to encompass both construction of an oil offloading terminal and development of refineries and petrochemical plants to process and distribute finished products.

The study focuses on the estuaries, shoreline, open ocean, and man's related activities in these areas. Therefore, the development practices which affect these entities are of most concern to us. We are particularly concerned with construction, maintenance and operation activities in the marine environment, potential accidental oil spills, and the stresses which will be placed on water resources through increased demand and pollution loading.

C. ASSUMPTIONS

In this study, we have assumed that petroleum will be brought into the Gulf in tankers of 250,000 DWT that require 75 feet of water for safe operation. In the Gulf, this depth is typically found from 4 to 40 miles offshore, but is not available in any existing Gulf ports. Extensive dredging will be necessary to bring such depths to an existing port.

Initially, we intended to rank each dissimilar hydrobiological *zone* in the Gulf as to its environmental vulnerability to deep-water port development. However, these zones tend to be long, narrow, and oriented parallel to the coastline – a configuration well suited for ranking on-shore zones against offshore zones, but unsuitable for discriminating between zones along shore.

Assumptions related to *sites* in nine different zones under consideration for deep-water port development were specified by the Corps of Engineers for this study. Our efforts were thus devoted to assessing and ranking the *regions* around these nine *sites* according to their environmental suitability for such development. The sites and the accompanying oil import and processing assumptions are shown in Table 1.

TABLE 1

TERMINAL SITES, IMPORTS, AND PROCESSING ASSUMPTIONS

Terminal Location		Terminal Size	
Inshore	Offshore	Low Level	High Level
Marginal Pier	Artificial Island or Single-point Mooring	5.35 MM bbl/day terminal 5.35 MM bbl/day throughput 340 acre storage	10.7 MM bbl/day terminal 9.7 MM bbl/day throughput 680 acre storage
Corpus Christi		●	
Galveston		●	
New Orleans		●	
Mobile Bay		●	
	Freeport	●	●
	Bayou Lafourche	●	●
	Southwest Pass		●
	Mobile-Pascagoula	●	●
	Panama City		●
		Case 2	*Case 1*

Source: U.S. Army Corps of Engineers

1. Port Configuration

Three alternative terminal configurations were used for this study.

- *Marginal Pier* (Onshore) – A 75-foot-deep channel would be dredged from the 75-foot contour offshore to a bay shore location where sufficient land is available to establish both an offloading pier and the requisite storage capacity. This assumption presupposes that the terminal will be located within an estuary, and may be built on or over existing marsh land.

- *Artificial Island* (Offshore) – An artificial island (with a 680-acre surface storage area) would be constructed on the shelf in 70 feet of water, and would cover 760 acres of bottom. A two-mile-long breakwater covering an additional 45 acres of bottom would also be set in place to protect the island and the mooring. We assumed that 70 feet of water would be selected, to both minimize dredging (under the current assumptions) and to facilitate possible future expansion to accommodate ships of deeper draft.

- *Single-Point Mooring* (Offshore) – A cluster of single-point moorings would be installed around a central platform, in 75 feet of water, connected by pipeline to storage facilities located ashore. In this configuration, only a small amount of dredging would be required to excavate a trench for the pipeline, and then bury it.

2. Operations

The Corps of Engineers suggested that we assume two oil importation rates – 5.35 and 10.7 million barrels per day. These rates would average three and six Very Large Crude Carrier (VLCC) calls per day, respectively. The larger volume is confined to the offshore terminal alternatives. We assumed that, in shallow waters, the propwash and wake of such large tankers would cause a significant increase in turbidity; though, as described later, this is an area where the state-of-the-art does not allow a definite prediction of specific effects.

- *Dredging* – For the case of the marginal pier, we assumed that maintenance dredging would be necessary on a continuous basis, because of the depth and extensiveness of the required channels. Table 2 summarizes the dredging requirements for each of the four inshore sites, with 1000-foot bottom width at 75 feet below mean low water.

- *Oil Spills* – Oil spill statistics have only received serious attention for a short time. During the last four to five years, mechanisms for collecting data have been improved, reporting requirements and procedures have changed, and tanker sizes have increased. With the advent of larger tankers, and a growing public awareness of the magnitude of potential spill damage, future changes such as vessel traffic control systems may come about and alter the validity of oil spill size and frequency assumptions. The assumptions shown in Table 3 were provided by the Corps, and are based on recent Coast Guard statistics. These statistics suggest an offloading spill rate of one barrel per million barrels for daily operations.

3. Secondary Effects

As stated above, the secondary effects of port development are complex, and depend on the nature of: existing infrastructure; natural resources of a region; and local policies regarding land use, water use, and pollution control. We assumed that new refinery and petrochemical complexes would have to develop to process imported oil. (Appendix D.V presents details of such secondary growth.)

As directed by the Corps, we further assumed that only 9.7 million bbl/day would be processed locally, even though 10.7 million bbl/day would be imported under Offshore Case 1. Table 4 summarizes the secondary impacts and expected increased burden on the environment due to the factors shown in Appendix D.V.

TABLE 2

ASSUMED DREDGING REQUIREMENTS
(1,000 foot bottom width at 75 feet below mean low water)

Channel Location	Construction (1,000 cubic yards)		Maintenance (1,000 cubic yards)		Easements (1,000 acres)	
	Inshore	Offshore	Inshore	Offshore	R/W	Spoil
1. Mobile:						
Inner Bay	198,900		5,700		0	11
Open Gulf		65,900		9,100	0	0
2. Baton Rouge to Gulf:						
Southwest Pass	238,700		71,600		0	32
Head of Passes to New Orleans	426,600		128,000		0	57
New Orleans to Baton Rouge	1,692,400		507,700		0	227
3. Galveston Harbor*	175,000	259,000	1,300	4,400	1.626	0.374
4. Corpus Christi†	72,400	48,000	409	781	0.180	0

---

*Includes 2,000-foot-radius turning basin, approximately 11.1 miles inland from Gulf shore.

†Includes 2,000-foot-radius turning basin, approximately 2.7 miles inland from Gulf shore.

Source: U. S. Army Corps of Engineers.

TABLE 3

OIL SPILL ASSUMPTIONS

Throughput (million bbl/day)		Spill Size (Tons)	Spill Frequency (Once in ...)
Inshore	5.35	500	16 years
		14,000	48 years
Offshore (Case 1)	10.70	500	8 years
		14,000	26 years
Offshore (Case 2)	5.35	500	12 years
		14,000	40 years

Source: U.S. Army Corps of Engineers.

TABLE 4

IMPLIED SECONDARY IMPACTS

Factor	Volume of Oil Processed Locally (million bbl/day) 5.35	9.7
Refinery (250 thousand bbls/calendar day)		
Number needed	21.5	38.5
Land Use	18,300 acres	34,300 acres
Employment	13,600	25,100
Petrochemical Complex (10^9 pounds of ethylene per year)		
Number needed	31.0	76.5
Land Use	6,100 acres	15,900 acres
Employment	156,000	381,000
Residential Implications (at 1.7 children/family)		
Total Population	600,000	1,470,000
Land Requirements	57,000 acres	135,000 acres
Potential Air Pollution (million lbs/day)		
Particulates	0.65	1.16
Hydrocarbons	0.80	1.47
Oxides of sulphur	1.35	2.43
Oxides of nitrogen	1.90	3.40
Potential Water Pollution (thousand lbs/day)		
Total Dissolved Solids	2,100	3,800
BOD_5 (present technology)	57,500	105,000
BOD_5 (advanced technology)	20,000	36,000
Oils (present technology)	37,500	68,000
Oils (advanced technology)	12,000	21,800

Sources: Arthur D. Little, Inc., et al., Appendix D.V.

III. NATURE OF ADVERSE ENVIRONMENTAL EFFECTS

A. TERMINAL CONSTRUCTION

Rounsefell (1972) has recently reviewed the potential ecological effects of offshore construction activities and the installation of physical structures. He concludes that there is slight danger from most construction programs. The major threat is the placement of an artificial island too close to estuaries, which could affect water circulation. (Appendix D.I contains an outline of the possible environmental effects provided by Rounsefell, 1972.)

The process of construction and development depends heavily upon the locale. Dredging, filling, blasting, spoil and waste disposal, water flow diversions, and so forth, are closely related to the physical characteristics of a particular spot. In his discussion, Rounsefell *specifically eliminated from consideration* any effects of the *deep* dredging or blasting which would be necessary to establish a deep water terminal near shore in the Gulf. It is likely, however, that in the Gulf the primary environmental effects of terminal construction are related either directly or indirectly to dredging and disposal of the resulting spoil.

B. DREDGING

The direct effects of dredging and spoil disposal are loss of habitat, disturbance of the bottom, redistribution of sediments in ways which may be harmful to living organisms in the sea, and alteration of the natural current and wave patterns. A changing erosion and sedimentation pattern can be the result of an altered wave and current regime. Increased turbidity during both initial and maintenance dredging are very likely to have adverse effects on the biota. The effects are complex and only partially understood.

In the estuaries and the coastal zone, generally, the impact of dredging is both more complex and more severe than it is in more seaward zones. In the inner zones, dredging may interfere with stable equilibria of coastal circulation patterns, chemical composition of estuaries, and transport of solid materials. Biotic communities are most productive in the coastal and estuarine zones. Dredging will impact such communities by direct removal or burial under spoils, and indirectly by altering the relatively delicate vertical and horizontal stratifications of salinity, materials transport, and bio-mass distribution. Moreover, dredging in these coastal zones can adversely impact a number of present human uses of the environment, including fishing, and the maintenance of freshwater supply systems. Freshwater supply systems may be threatened by saline intrusion in previously fresh river zones, by saline seepage into aquifers contiguous with the river, and by the dredging into permeable strata under saline waters permitting the seepage into landward aquifer systems.

These effects are extremely difficult to quantify, since neither accurate models of biotic communities, nor the data to support these models are available. Also, aquifer systems are generally poorly understood, since their accurate mapping requires a project of major proportions. Changes in vertical and horizontal stratifications of velocity, sediment movements, temperature, and chemical composition are similarly difficult to predict. Although we believe that these effects may be minimized by proper selection of equipment and by timing the dredging to correspond with periods of minimal vulnerability, we assume that adverse effects occur whenever dredging occurs. (The contemplated effects are discussed more fully in Appendix D.)

The range and variability of environmental impacts associated with dredging and spoiling in the Gulf coastal zone are great, and precise analysis is difficult. To rank the zones, our analysis of these impacts considered the following factors to the limit of available data:

- Dredging volumes and spoil disposal requirements;
- Existing coastal processes and sediment regime equilibria;
- Natural turbidity and chemical balance;
- Effects of currents on redistribution of sediments resuspended by dredging operations;
- Spatial and temporal distribution of benthic communities, and their vulnerability to dredging activities;
- Probability of re-establishment of original benthic communities, and associated time scales;
- Estuarine vulnerability to salinity regime alteration; and
- Vulnerability of aquifers to saline intrusion.

In general, dredging and spoil disposal may adversely affect a wide variety of environmental parameters, and there is no evidence that deep dredging (> 75 feet) will *benefit* the environment.

C. SUPERTANKER OPERATIONS

Tanker operations may directly affect the environment in two ways:

- Increased hazards associated with navigation; and
- Environmental changes caused by scouring, turbulent mixing, and wave generation.

In either case, the traffic intensity must be relatively high to pose a serious threat.

The increased navigation hazard stems from the increased size of the supertankers which reduces their maneuverability and clearances in confined waters. These effects will be felt by all vessels operating in the same area as the supertankers. In addition, the wake generated by a very large ship may be a problem to small craft in areas of intense recreational boating, especially to those with inexperienced operators.

Increased navigation hazard increases the statistical probability of the occurrence of oil spills due to groundings and collisions. For the purposes of this study, our assumptions regarding oil spill magnitude, frequency, and impact are covered separately because of the importance to the natural environment of this aspect of port development.

Increased turbulence, scouring, and wave generation will act to erode and transport sediment, increasing the turbidity of the water and possibly affecting the biota adversely. Quantitative figures on actual amounts of sediment suspended in this manner are unavailable. Appendix D.IV presents an assessment of the state of knowledge about velocities in tanker wakes. Although it is known that benthic fauna can be adversely affected by overloading of their systems with sediment, definitive studies are unavailable. In any case, it is likely that these effects, associated with continuous tanker operations – of lesser magnitude than effects associated with either original and maintenance dredging – will affect the entire channel length. Direct comparison of either with the suspension of sediments by natural causes such as tidal cycles has not been conclusively made; extremely wide variations of solid content of water volumes due to natural causes have, however, been observed and measured. While evidence exists for possible adverse effects due to supertanker operations, in addition to accidental oil spillage, it is not clear that such effects would be significant.

D. OIL POLLUTION

In assessing the probable impact of oil spills originating from a particular site (which is to be compared with another site on the same basis) it is necessary to understand several different aspects of the problem:

- Physical dynamics of the environment, and the transport mechanisms of oil on water are needed to predict where and how fast the oil will travel, and how fast it is likely to spread – detailed knowledge of area water currents and wind conditions are prerequisites;

- Chemical composition and changes in oil characteristics due to weathering, vertical mixing and dissolution in the water, and combination with sediments in the water and on the bottom;

- Considerable detailed knowledge of the biota in potentially affected areas;

- Response of biological organisms, populations, and communities to a particular oil, in a particular stage of weathering, during a particular season in which the oil happens to spill; and
- That the "impact" is a probabilistic result of combining many joint and conditionally probable events.

1. Physical Dynamics

In any oil spill there are at least three factors which must be considered to determine the probability that the spill will reach any given point (in particular, a shoreline area). These three are the spreading of the oil caused by gravitational, surface tension, and buoyant forces; the direction and magnitude of the ocean current in the area of the spill; and the direction and magnitude of the wind in the same area.

Spreading determines the areal extent and width of path of a slick before contact is made with the shoreline. Calculations show that after three days, an instantaneously released 14,000-ton spill of typical Middle East crude oil will attain a radius of approximately 1 nautical mile. (As discussed in Appendix D.IV, three days is significant in that most of the acutely toxic, low-boiling crude fractions have evaporated or been dispersed in the water column within that duration.) In calculating the probability that oil will reach various points on the shore within a three-day period after the spill, we therefore assumed the distances from the spill site to various shoreline points to be one nautical mile less than true distance.

In our calculations, we have used the generally accepted approximation that the path of the oil can be determined by adding the current vector to a vector equal of 0.03 times the wind speed (in the same direction as the wind).

Definitive studies of the ocean currents at the level of detail required for site selection do not exist for any of the prospective deep-water port sites. The information varies between sites as to detail and completeness. It is known that the currents vary with the season at all sites, but detailed descriptions of this variation exists at none of the sites. The available information (Appendices A, B, and C) was examined, and our generalized assumption about the seasonal current regimes at each offshore site were specified. In subsequent calculations we assumed the currents to be constant in the specified direction for three days.

Whereas the spreading of the oil and ocean current are considered to be fully determined (by month), no such assumption can be made for the wind. (This statement reflects the availability of wind data that is considerably more detailed than current data for comparable locations.) Our calculations assumed that each site has a distinct monthly distribution of wind velocity by direction and speed (NOAA *Environmental Guide*, 1972). We also assumed that the wind speed and direction remains constant for at least three days following a spill release. While this is a somewhat unrealistic assumption, it certainly provides an upper bound to the probabilities that a shoreline point will be reached, because shifts in the direction of the wind result in a zig-zag path for the spill, instead of the straight line path assumed in these calculations.

The detailed calculating procedure which accounts for the effect of a constant ocean current and the probability distribution of winds is described in Appendix D.IV. The results of our calculations are presented in three forms. In Figures 3 through 7, the probability densities per mile of shoreline are displayed for the various possible spill sites. The perpendicular distance from any point on the shoreline to the curve gives the approximate probability density per mile for that point. These densities have been calculated for different times during the year, since some locations have distinct seasonal current changes and all have seasonal wind patterns. On these figures is also displayed the "Total Shoreline Probabilities" that some point on the shore will be hit and the "Shoreline Mileage," the length of shoreline which has a probability density greater than 0.0001/mile of being affected.

In Figures 8 through 12, the "Three-Day 0.90 Probability Curves" are presented. A straight line drawn in any direction from the spill site to these curves represents the limiting distance (with 0.90 probability) that the spill could travel in three days if the wind blew constantly in that direction (i.e., there is only one chance in ten that the spill would get beyond this point in three days).

The third type of exposition (Figure 13) shows the seasonal variation of the Three-Day Total Shoreline Probabilities for each of the five sites.

2. Chemical and Physical Characteristics

Appendix D.IV presents some pertinent physical and chemical facts about crude oil, and the basis for our assumptions as to the composition and weathering properties of the Middle Eastern crude to be imported into the Gulf. Briefly, crude oil is a complex combination of chemical compounds, many of which have known or suspected adverse effects on living organisms. The immediate, acute effects appear to be highly correlated with the low-boiling fractions which are largely lost through evaporation and dissolution during the first three days following a spill. Persistent effects are thought to be related to low concentrations of compounds which remain in the high-boiling and residual fractions of the crude. It is thought that Middle Eastern Grade, with its high asphaltene content, has a propensity to form emulsions of the "chocolate Mousse" variety, encountered during the Torrey Canyon accident.

3. Biological Response

Over a span of time, the effects of any oil spill appear at the surface, in the water column, on the bottom, and in the intertidal zone where the sea bottom and the sea surface meet. In addition, flooding due to storm tides can carry oil far inland on low-gradient coasts.

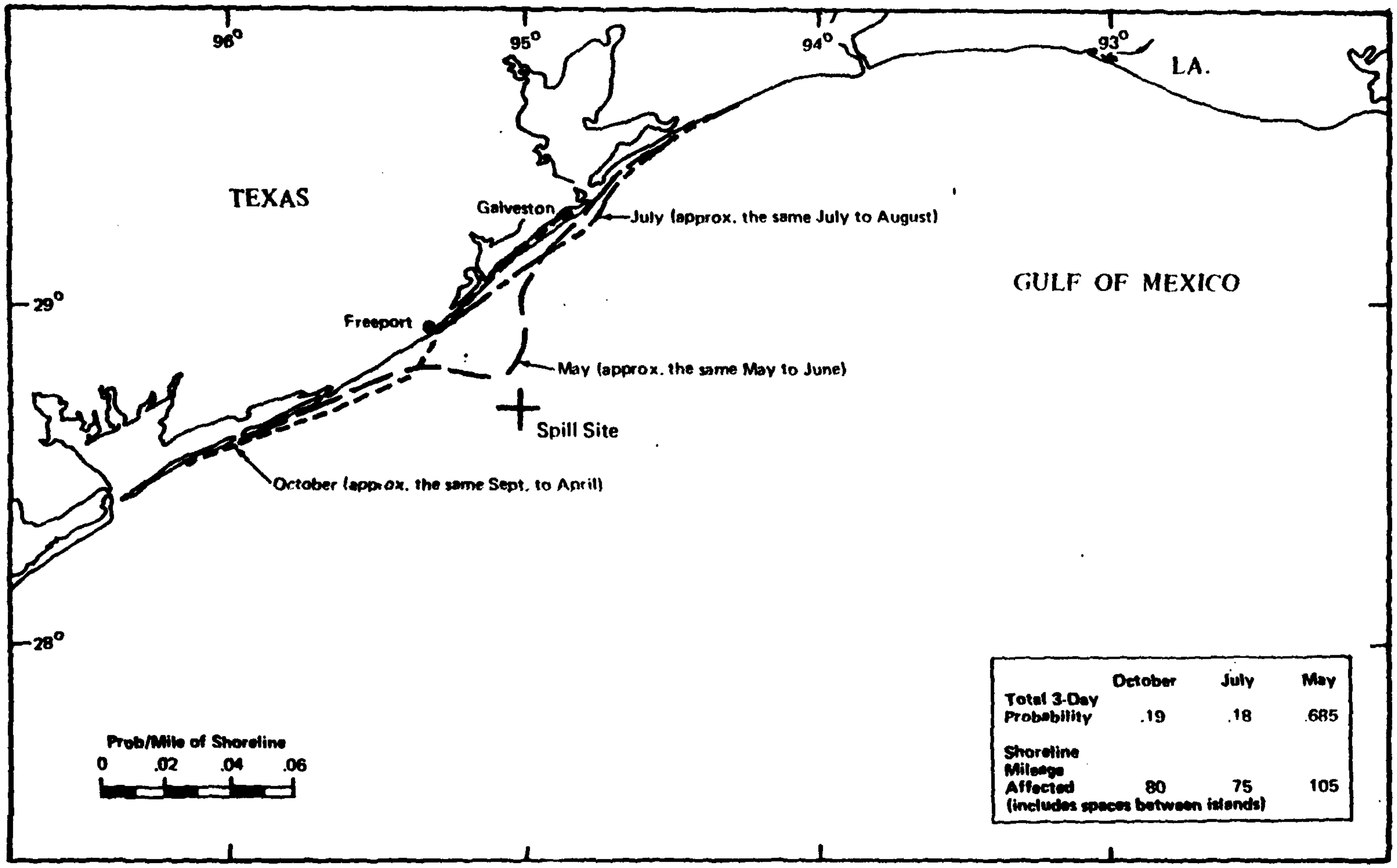
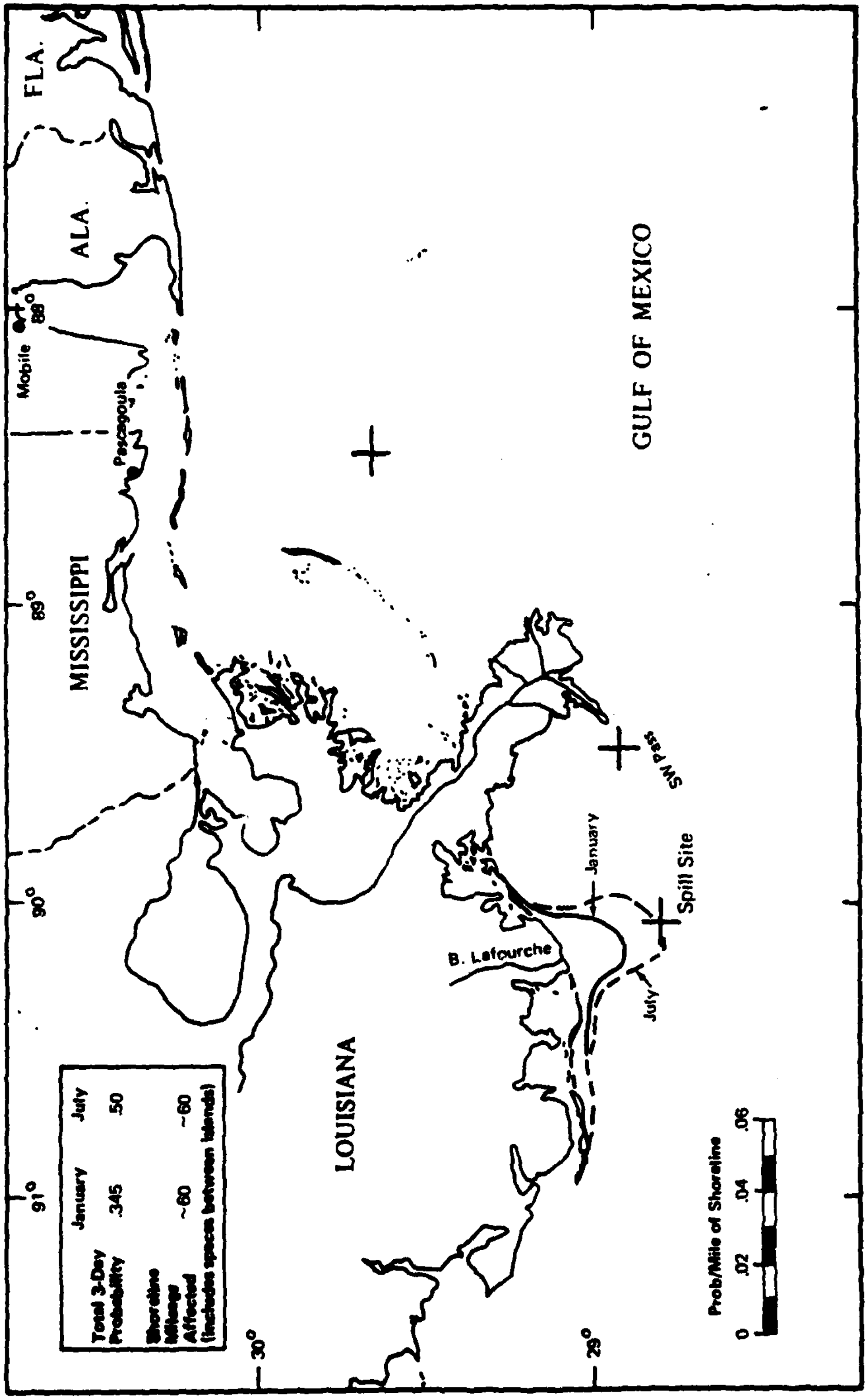


FIGURE 3 SHORELINE PROBABILITY DENSITIES FOR GALVESTON–FREEPORT SPILL SITE



	January	July
Total 3-Day Probability	.345	.50
Shoreline Mileage Affected (includes spaces between islands)	~60	~60

FIGURE 4 SHORELINE PROBABILITY DENSITIES FOR LAFOURCHE SPILL SITE

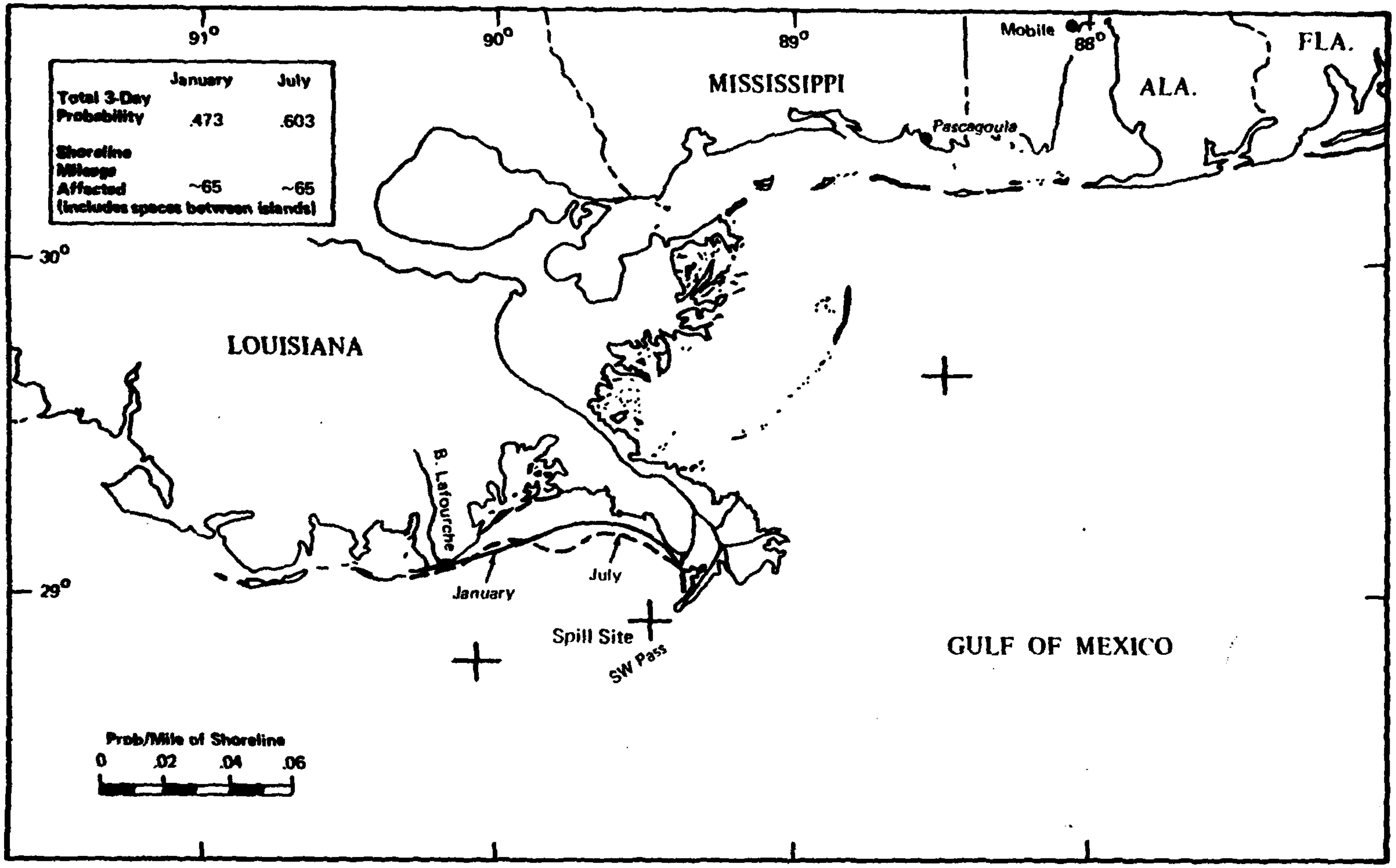


FIGURE 5 SHORELINE PROBABILITY DENSITIES FOR SOUTHWEST PASS

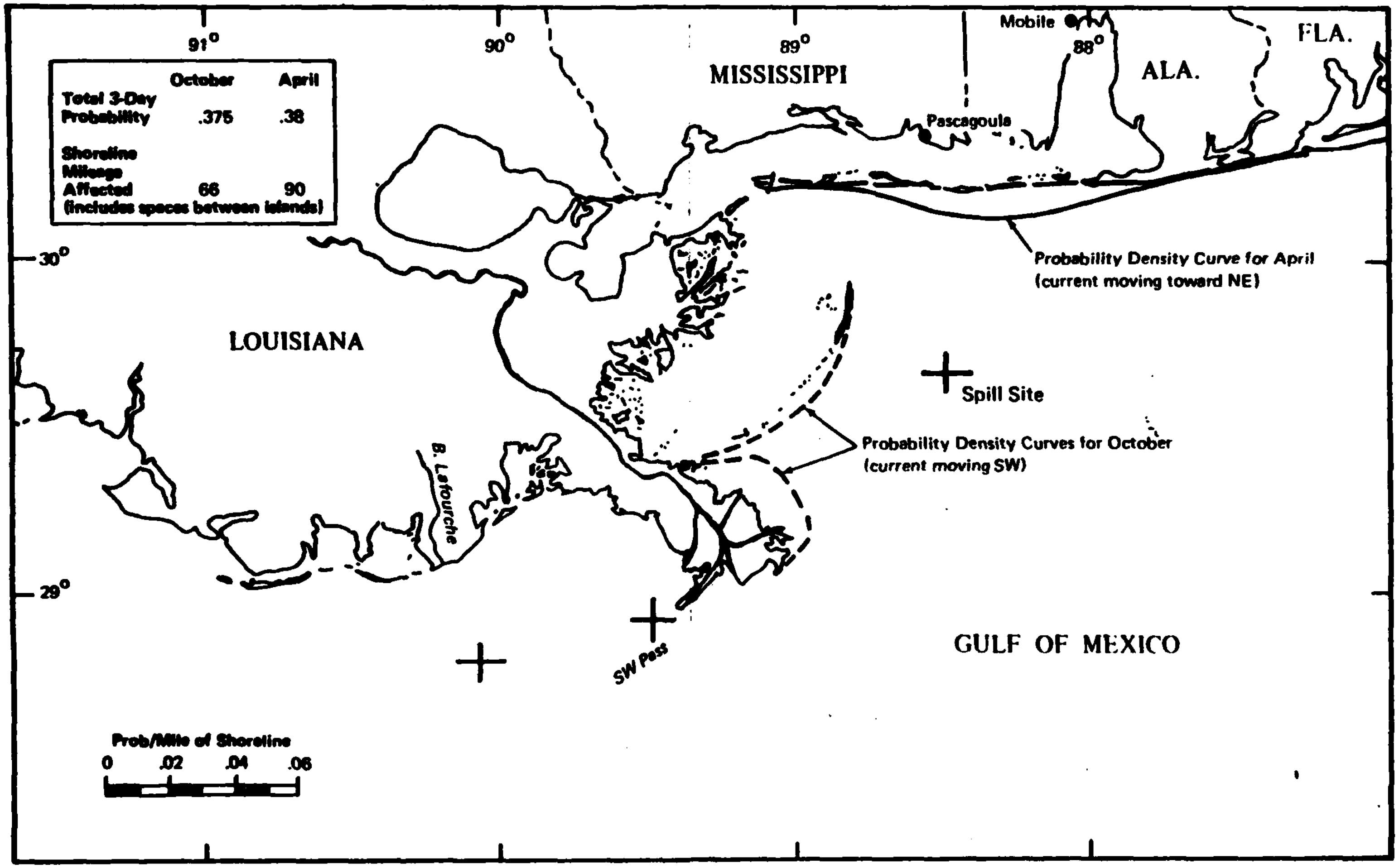


FIGURE 6 SHORELINE PROBABILITY DENSITIES FOR PASCAGOULA–MOBILE SPILL SITE

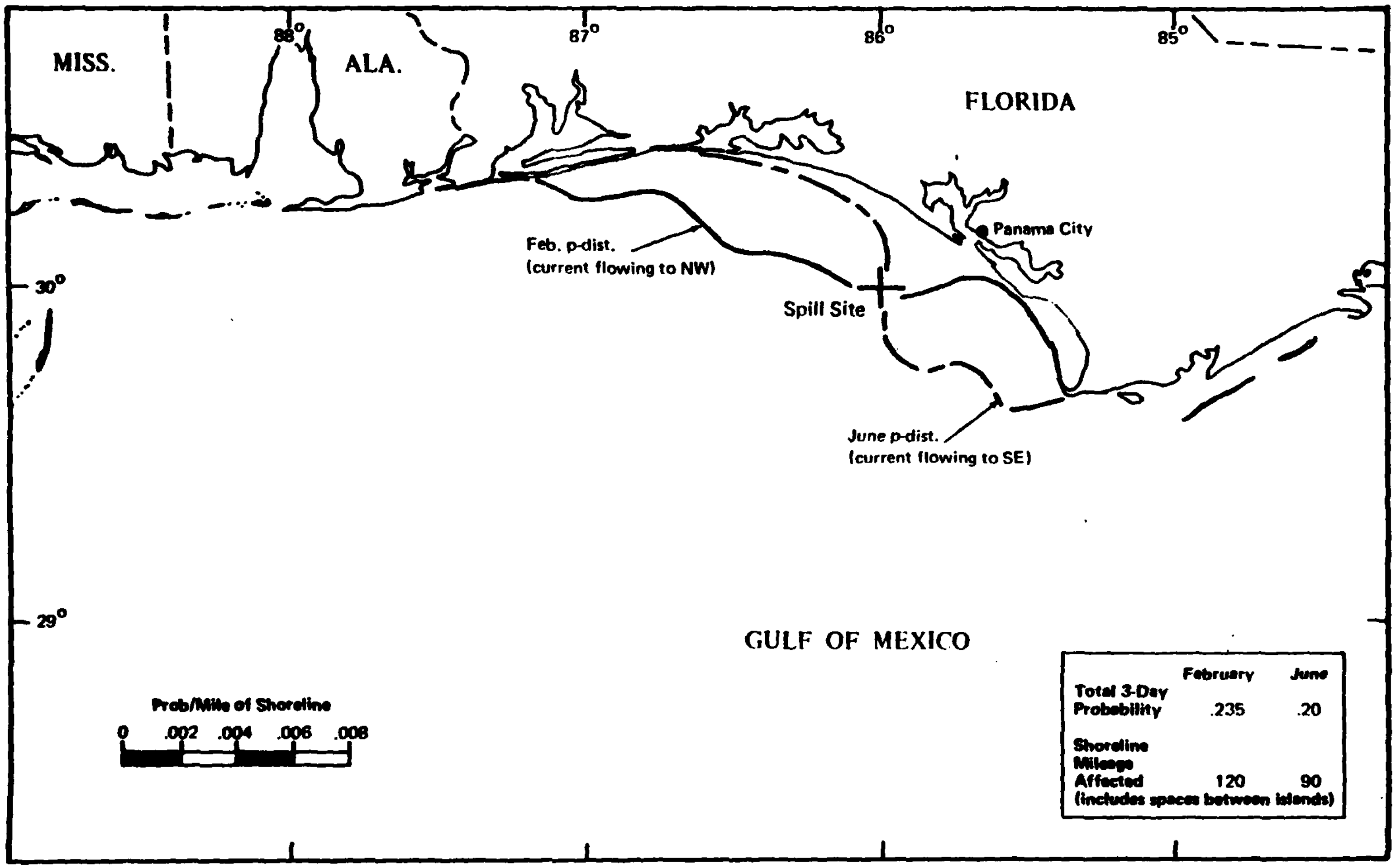
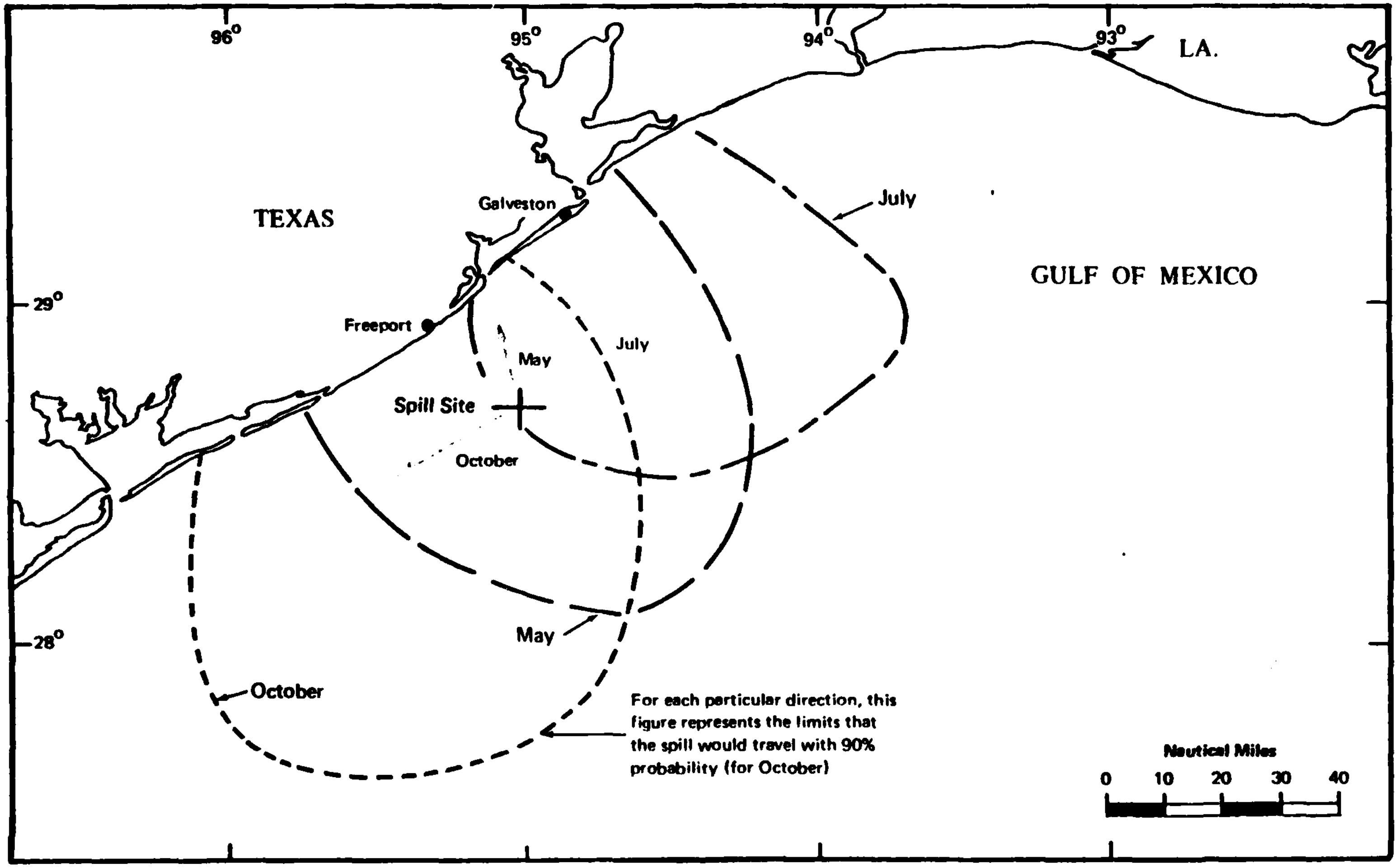


FIGURE 7 SHORELINE PROBABILITY DENSITIES FOR PANAMA CITY SPILL SITE



For each particular direction, this figure represents the limits that the spill would travel with 90% probability (for October)

FIGURE 8 THREE-DAY .90 PROBABILITY CURVES FOR GALVESTON–FREEPORT SPILL SITE

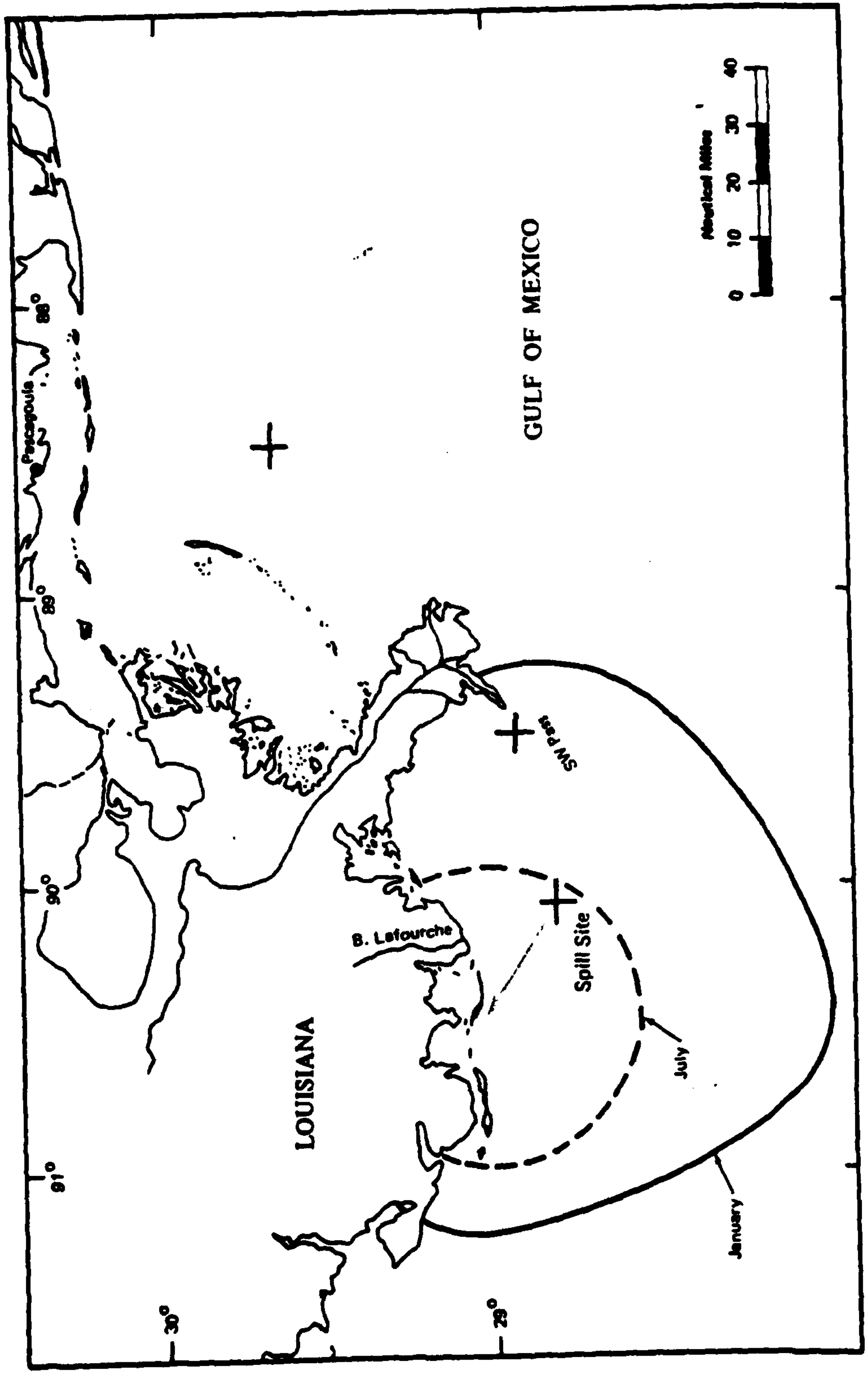


FIGURE 9 THREE-DAY .90 PROBABILITY CURVES FOR LAFOURCHE SPILL SITE

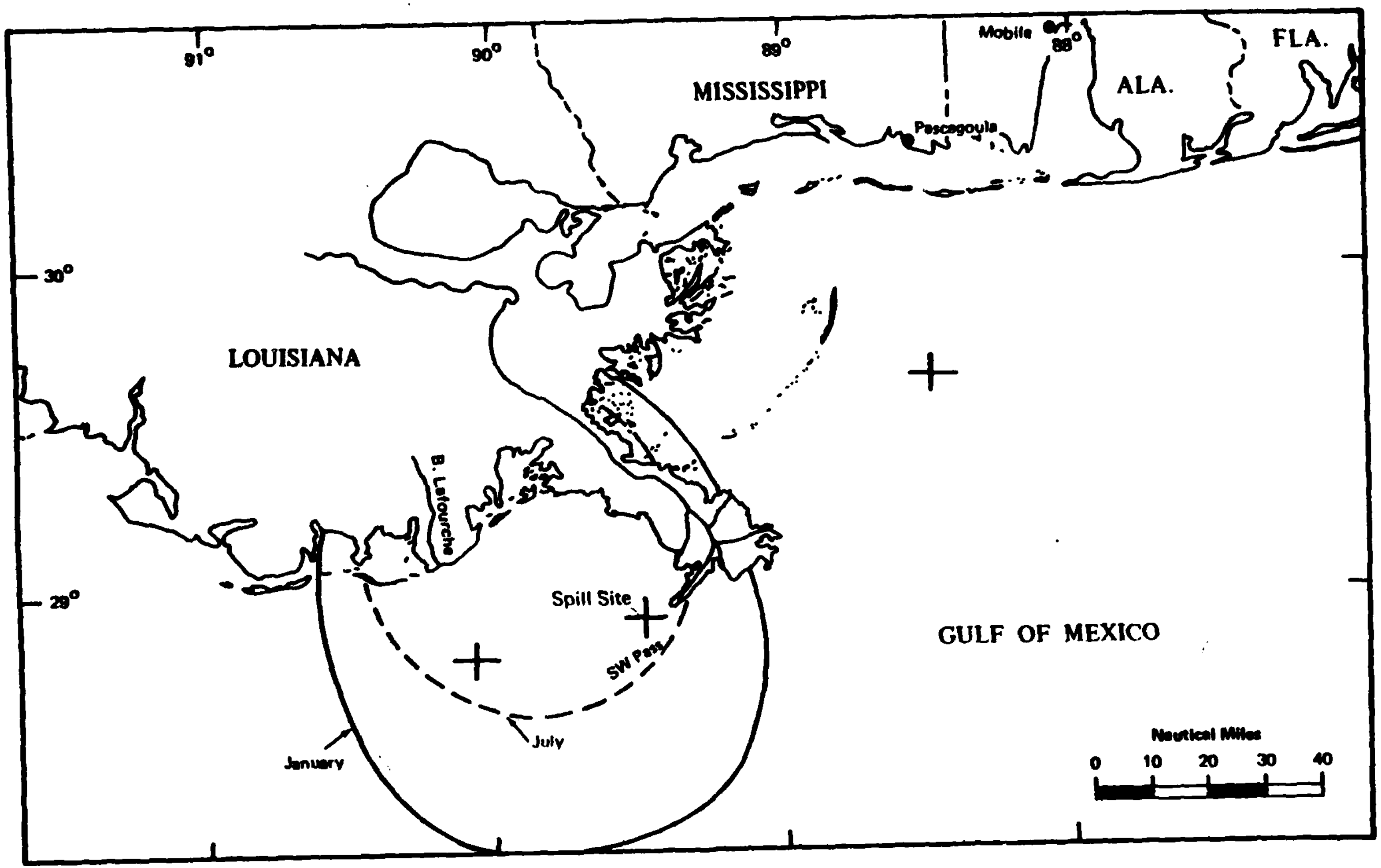
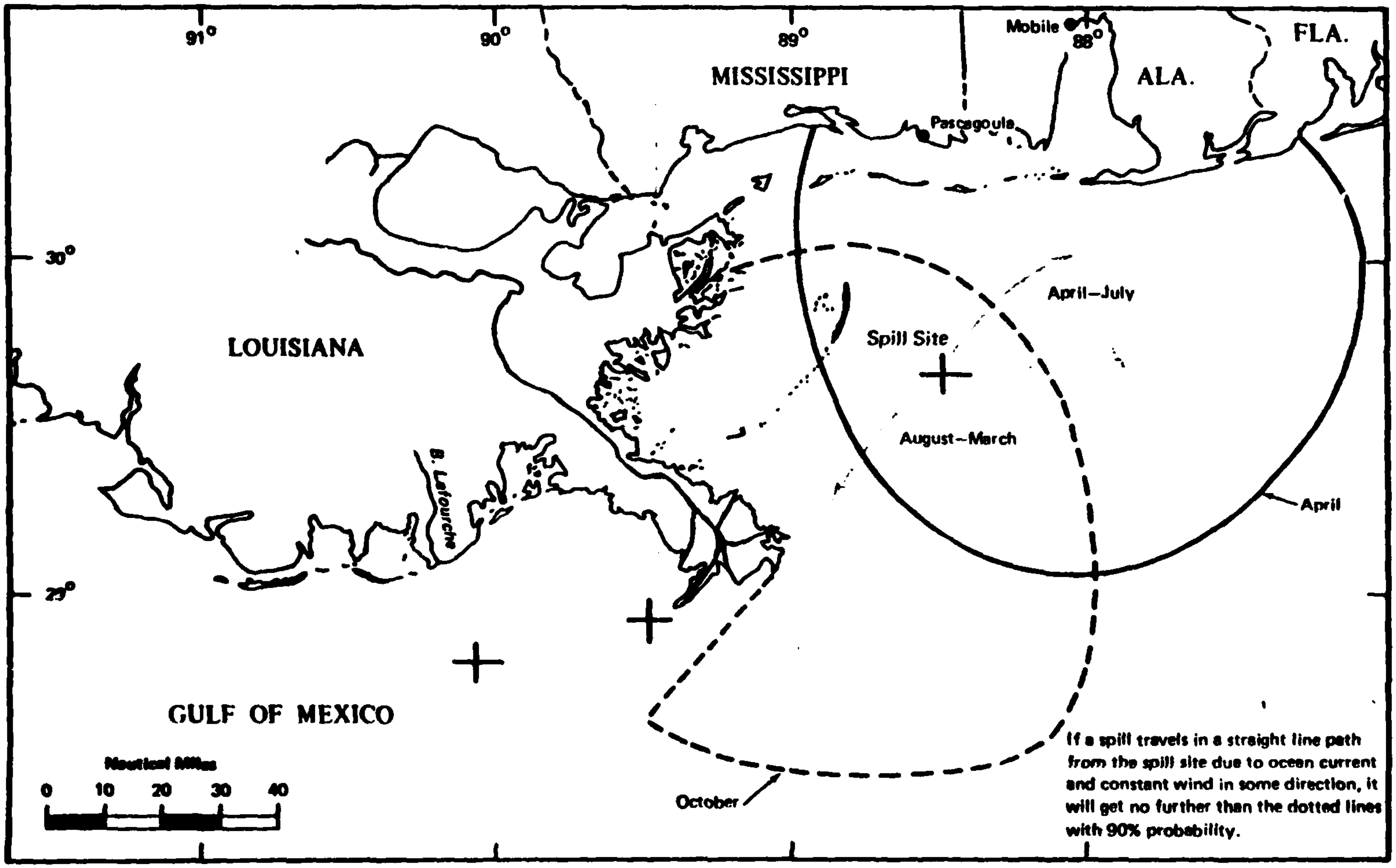
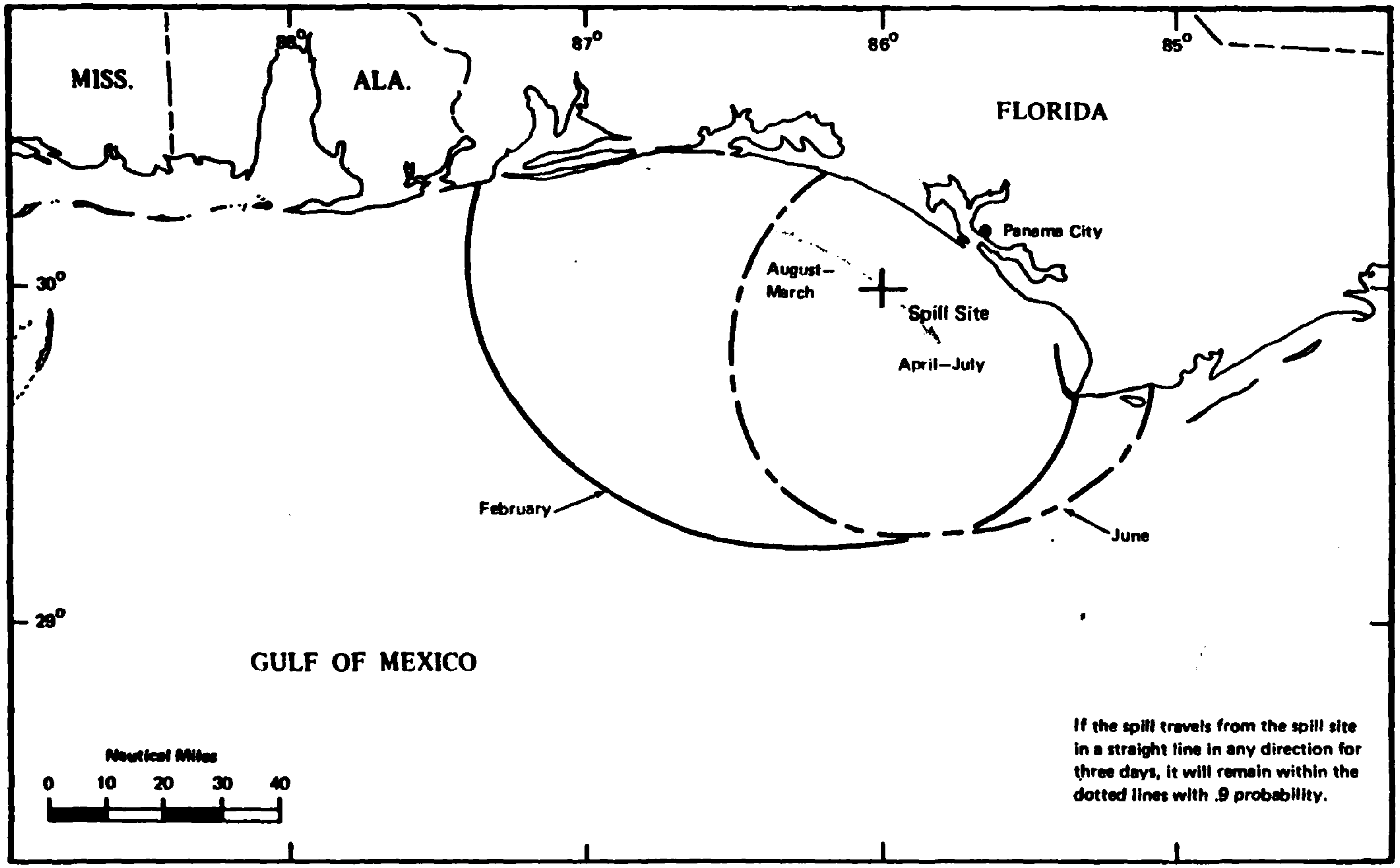


FIGURE 10 THREE-DAY .90 PROBABILITY CURVES FOR SOUTHWEST PASS SPILL SITE



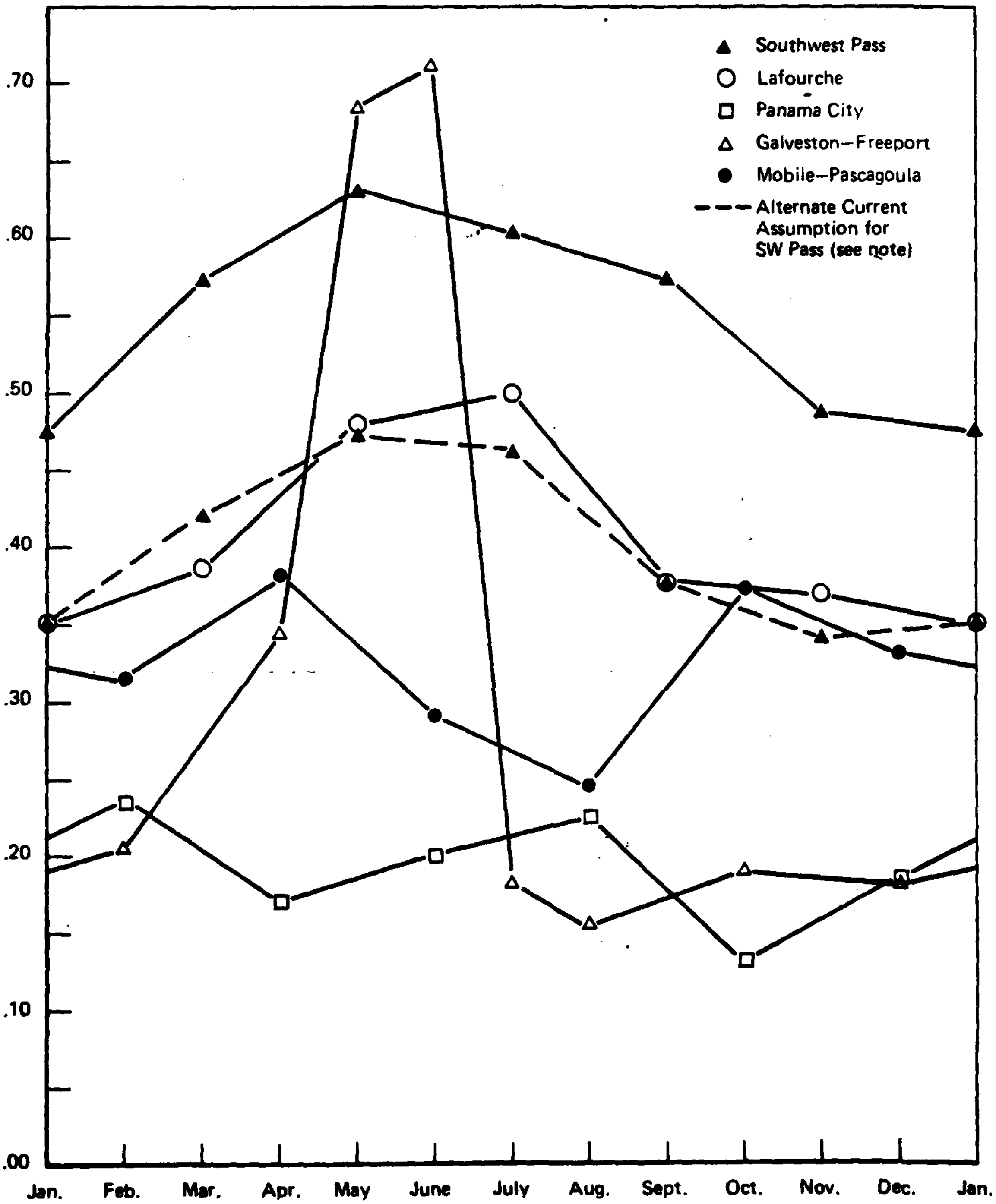
If a spill travels in a straight line path from the spill site due to ocean current and constant wind in some direction, it will get no further than the dotted lines with 90% probability.

FIGURE 11 THREE-DAY .90 PROBABILITY CURVES FOR PASCAGOULA–MOBILE SPILL SITE



If the spill travels from the spill site in a straight line in any direction for three days, it will remain within the dotted lines with .9 probability.

FIGURE 12 THREE-DAY .90 PROBABILITY CURVES FOR PANAMA CITY SPILL SITE



Note: Alternate current assumed to be in same direction at 5.3 nautical miles per day.

FIGURE 13 TOTAL SHORELINE PROBABILITIES FOR FIVE POSSIBLE SPILL SITES BY MONTH

Floating oil or oil residues adversely affect floating plant and animal life and surface plankton, as well as all the forms of marine life which feed or live in this layer. In addition, heavily contaminated areas or continuous slicks have serious effects upon the bird populations which feed in or inhabit this region, and may affect marine mammals living in or transiting such waters.

The dissolved oil fractions beneath an oil spill are more short-lived, because normal dilution rapidly reduces the toxic concentrations. The exact effects upon planktonic and nektonic populations are difficult to assess for two reasons: first, there is uncertainty in the prediction of oil concentrations beneath the slick, and second, there is uncertainty as to the effects of various concentrations on plankton.

The residues that sink to the bottom form long-lasting deposits, with some further small amount of leaching of soluble components, and cause a long-term effect upon the benthic populations. Further seaward, in deeper water, the dispersion of such residues becomes greater, so the effect on a local area becomes less serious. In general, it appears that the sub-surface effects of a spill become less severe in the bathyal zones and, conversely, are most severe in the neritic waters of the littoral and sub-littoral zones.

When a slick is driven ashore, the aquatic life in the intertidal zone is affected most seriously. The motion of the water surface permits the entire zone to be covered with a film of oil. The cover of oil may have serious mechanical and chemical effects upon the organisms in this region. The film of oil stops the liquid and gaseous exchanges, between biota and environment, and inhibits material exchange across the sediment/water interface, while the toxic components absorbed or ingested may have lethal effects. In some instances, such components may be accumulated in the food chain. While a slick lies along the land, the dissolution of soluble components continues with polluting effect upon the shallow water, with globules possibly sinking to the bottom. Particularly in shore zones with small gradients, the affected intertidal zone may be extensive and the contamination of sub-surface water and bottom will be more pronounced.

Inasmuch as the littoral zone and the associated wetlands and estuaries are the breeding ground of many species of fish and crustaceans, as well as the breeding ground and feeding area for a variety of avian and mammalian forms, the effects of oil spills on these regions are particularly severe. The ecological chain of dependencies is highly complex in the littoral zone and the effects of a major disturbance may spread far out to sea and over extended time periods. An assessment of the effects of oil spills from the biological viewpoint must consider both the initial and the secondary situations caused by the spill.

The time dependence and the complexity of the ecosystem in the littoral zones requires that an assessment of the effects of oil spills be analyzed by considering a typical oil and selected organism whose response is known. The total effects must be extrapolated from known factors and knowledge of the general food-chain relationships in the area. In the areas further offshore, the relationships are somewhat simpler, but here also total effects can be estimated only by examination of typical and known responses. Appendix D.IV discusses some of the above mentioned effects in more detail.

4. Spill Magnitudes and Frequencies

As has been discussed, there are many uncertainties concerning petroleum's impact on the environment. Since public attention has only recently been drawn to this issue, statistics and hard facts relating to most aspects of the problem are either difficult to obtain or non-existent. In addition, because of increased public concern, conditions which represented the norm only half a decade ago are changing significantly, thus altering the significance of some of the available statistics. Within the past three years, the U.S. Coast Guard has taken on new responsibilities in this regard. Therefore, we would expect that within a few years, definitive statistics will be available.

Foreign experience indicates that very low levels of accidental discharge of tanker-borne materials can be achieved by employing the newest technology and a vigorous program of education and enforcement (Dudley, 1971). However, this does not happen automatically and in setting forth the amount of accidental discharges to be expected in a U.S. superport operation, one should plan to err on the conservative side. Our basic assumptions (provided by the Corps of Engineers), set forth in Section II.C, and Table 4, are based on recent Coast Guard statistics that reflect past operating procedures and do not accurately portray the level of cleanliness which can be attained with proper enforcement. The assumptions are adequate for the purpose of ranking one location against another in this survey level of assessment, because their shortcomings are applied equally to all locations.

We should point out, however, that the criterion in our scoring system that determines whether or not an effect is persistent is based on recovery time and recurrence interval. Thus, the assumption that a 14,000-ton spill may occur once in 48 years is correct in a statistical sense, and a transient effect can be defined as one from which the environment recovers in less than 12 years. However, the assumption provides no information as to the frequency at which 13,000-ton, or 5,000-ton, etc., spills may occur, and hence the total impact of all spills is not evaluated or taken into account. The effect of the stated assumptions is thus to err on the side of *underestimation* of the oil-spill effects persistence.

It is also appropriate to point out the relative magnitude of the oil importing activity contemplated for a deep-water port in the Gulf. As directed by the Corps of Engineers, we assumed import volumes from 5.35 to 10.7 million bbl/day. The total amount of oil and condensate produced in offshore Louisiana since the inception of the Outer Continental Shelf leasing program in 1954 amounts to about 2 billion barrels (C.O.E., EIS, 1972). In other words, an amount equal to the total amount of crude oil produced from some 5,100 producing offshore Louisiana wells will be handled through a single terminal in a little over one year at the lower assumed volume, one-half year at the high end of the range. Analyses of adverse environmental impacts associated with well blow-outs clearly bear limited relevance to assessment of the impacts of a major accident involving a Very Large Crude Carrier. However, the only data relating to the response of Gulf biota to oil spills deals precisely with this aspect of the problem, which is several powers of ten smaller than a spill of 14,000 tons, for example.

E. SECONDARY EFFECTS

The effects on the marine environment of regional industrial development are in the form of land use, water use, and increased pollution loading. *Land Use* is a function of both physical characteristics, and of regulations and other institutional controls created by man. There is enough land within a 100-mile radius of any presently considered site to physically support the secondary industrial development associated with a deep water terminal. In some cases, such development could degrade the environmental quality if institutional controls prove insufficient. The extent to which they are sufficient depends on the people's wishes, as reflected in regional zoning regulations, taxation, etc. The extent to which possible degradation may occur is strongly related to public pressure, so we have noted only the amount of land required for various levels of oil importation.

A region's capability to support growth depends on the availability of an adequate water supply, for both domestic and industrial use. Thus, one measure of a region's environmental vulnerability to the secondary effects of port development is the extent to which it can provide enough reserve water capacity to support such development. Pollution of fresh waters by industrial and domestic wastes can adversely affect the estuaries into which they flow. A much more intensive study is needed to completely evaluate these effects – we only calculated the magnitude of the various effects. To do so, it was necessary to relate the projected quantities of oil which will be imported through the Gulf to the water, space, and employment requirements of the refineries and petrochemical industries needed to process the oil.

In Appendix D.V, we summarize the secondary effects outlook for a range of potential import volumes to the year 2000. Starting with projected oil volumes, we determined the required processing capacity and associated employment and land-use factors. Based on current and advanced technology, we then calculated the air and water pollution load associated with such development. The following water use factors are applicable: each 100 MB/CD refinery requires an intake of eight million gallons of water per day; each "typical" (one billion pounds of ethylene per year) petrochemical complex requires twenty million gallons per day; domestic water utilization is 60 gallons per capita per day. The results must be interpreted in light of the following four considerations:

First, the indirect (suppliers) and induced economic and environmental effects were not quantified. However, previous work for the Council on Environmental Quality indicates that the permanent employment multiplier on the Gulf Coast is approximately 4.2 (excluding construction requirements).

Second, our analysis of the impact upon the Gulf Coast industrial base did not include an assessment of the necessary additional job requirements in heavy and light construction trades.

Third, in our assessment of the impacts generated by increased petrochemical activity, we included only the primary portion of the industry. Such operations, which will locate in close proximity to new petroleum refinery activity, include producers of ethylene, vinyl chloride monomer, etc. We have not included an assessment of the impacts generated by the installation of new derivative or end-use petrochemical operations. Such plants, while purchasing the output of primary petrochemical operations, do not all locate near the primary producers. Location decisions for end-use activities are more heavily influenced by two factors – transportation and market economics, and labor costs. While all factors are critical, each plant type in this sector of the petrochemical industry assesses its relative importance differently. As a result, not all of the derivative petrochemical activity would grow up on the Gulf Coast. However, given the Gulf Coast's production advantages, a substantial share of the activity would remain on the Gulf Coast. If derivative petrochemical operations do develop in the area, then all impacts quantified could very well increase by as much as 100%.

Finally, the addition of almost 10 million barrels per day of new refinery capacity, and the creation of multiple new petrochemical complexes, would act as magnets attracting other industries and producers to locate their activities on the Gulf Coast. The tremendous growth implications for this area under the deep water terminal hypotheses are sufficient to surpass any "critical mass" level necessary for attracting new industry to a locality. With the creation of large-scale industrial activity, major markets for many speciality producers will grow large enough to attract new plant locations, and in some cases make re-location economical. Such an impact could generate further economic activity and environmental effects in an area already receiving stimulation capable of transferring it into a very dynamic and rapidly industrializing economy.

To conclude, we calculated the magnitude of the changes which can be expected to accompany deep-water port development. By considering only refining and petrochemical industries, we calculated a *minimum* expected effect. Well-thought-out regulations and controls can partially ameliorate the effects of any projected future development, but experience has shown that rapid growth and regional development has been correlated with environmental degradation and increased pollution loading in the past (McNulty, et al., 1972).

F. STATE-OF-THE-ART

There are many limitations on environmental assessment such as the one undertaken here. Some are discussed in Section IV, others are implied or specifically stated in this section and Appendix D. Due to the nature of the problem, one can always identify areas where "it would be nice" to have more data or information before coming to a conclusion. But the reasons for the lack of information differ, depending on the particular place and circumstances at the time. In some cases, basic information has not been collected in a particular geographic region, or in a particular disciplinary area. In other cases, the basic data may exist, but the connecting link relating it to another kind of information is missing, or only partially understood.

Therefore, Table 5 presents our assessment of the state-of-the-art concerning the topics addressed by this study. "Factors" lists basic types of data and knowledge which are necessary before an assessment of effects and impacts is possible. "Interactions" lists the connecting links between "factors" or between the "factors" and various environmental responses. "State-of-the-art" lists our judgment of the relative adequacy of the data. Marks in more than one column on the right indicate the range of available information.

TABLE 5

BASIC DATA VALIDITY RANKING

Information Type		State-of-the-Art		
Factors	**Interactions**	**Inadequate**	**Marginal**	**Adequate**
Physical and Biological Resources			x	x
Human Activities			x	x
Characteristics of Construction Operations				x
	Effects of Constructions on Resources and Human Activities		x	
Character of Dredging Operation			x	
	Effects of Dredging	x		
Character of Tanker Wake		x		
	Effects of Tanker Wake	x		
Ocean Currents		x	x	
Wind				x
	Spill Trajectory Mapping			x
Characteristics of Oil			x	x
	Prediction of oil concentration in water		x	
	Oil's Effect on Biota		x	
	Food Chain Implications of Oil	x		
Oil Import Volumes			x	
Oil Related Industrial Development			x	
	Effects of Industrial Development	x	x	

Source: Arthur D. Little, Inc.

IV. METHODOLOGY

The present study was conducted at the survey, or most general, level of assessment. Alternative projects, offshore and onshore, were considered for the entire U.S. shoreline of the Gulf of Mexico. The conclusions are therefore general in nature, and consistent with such a level of analysis.

A. IMPACT MATRIX

1. Philosophy

It is desirable to have a defendable quantitative basis for comparing the environmental impacts of alternative projects. If all impacts could be reduced to a common denominator, with equivalent units, then each alternative could be ranked in terms of a single composite score. We considered two general approaches: the dollar basis; and the weighted significance basis. As will become clear in the following discussion, neither approach could be completely implemented within the framework of the present study. The chosen ranking system can best be called an unweighted impact score, because it stops short of weighting the various environmental impact scores.

a. Dollar Basis

In this system, the significance of environmental impacts is measured only in dollars. The components of cost are:

- commercial losses,
- recreational losses,
- project costs to minimize adverse effects, and
- conservation losses.

Commercial losses include all commercially valuable present uses of the environment that would be foregone as a result of the project. The major elements in the Gulf of Mexico would consist primarily of fishing and tourism, but would also include loss of agricultural production, and the commercial value of any enterprise which would have to be displaced as a result of the project. The commercial losses associated with a major oil spill would also fall into this category.

Recreational losses pertain to that component of recreational activity which is not already accounted for under commercial losses. The known quantity here would be number of recreation days foregone because of the project; directly because of actual expropriation of recreational resource, or indirectly due to impairment of the quality of remaining resources. This cost may include both actual travel cost, and the value of time spent in traveling.

Project costs to minimize adverse effects include the costs of all structures, structural changes, and operational activities whose major function is to eliminate or minimize some adverse environmental impact. For example, the cost of an emergency spill control system, including monitoring and response capabilities. would fall under this category.

Conservation losses include the natural habitats and the species that inhabit them, to the extent that they have not already been accounted for under commercial and recreational losses. Methods for evaluating this class of losses have not been generally treated in the literature.

In our view, the dollar basis is a most effective decision tool in project planning, and can be readily integrated with a comprehensive benefit-cost valuation in both the project framework and any wider regional economics framework. However, this approach clearly requires considerable data, appropriate to the feasibility level of study. A survey-level study simply does not permit adequate precision in estimating all of the costs.

b. Weighted-Significance Basis

This approach has appeared in various forms in the literature (Stover, 1972; Leopold, et al., 1971), and has been applied at both the survey level and at the pre-feasibility level of analysis. By its very nature, it is a limited tool, because it substitutes a high degree of subjective judgment for quantifiable impact measurement. Nevertheless, it can provide a useful framework for environmental analysis and can aid in identifying environmental impacts in a comprehensive manner.

The approach is characterized by a matrix format which displays in outline form a system of cause-and-effect relationships. The first causes are the various components of the construction process and of the operating characteristics of the project. Each of these causes results in direct change in some attribute of the environment (physical, biological, etc.). Such changes in turn cause other changes in the environment, such as the propagation of effects brought about by physical change, alteration of habitat causing alteration in biotic communities, and propagation of effects through the food chain.

One may also consider within this framework a number of secondary causes. For example, the implementation of a single project may constitute an attraction for other forms of human development, such as increased urbanization or regional development. These secondary causes in turn impact the environment in a variety of ways.

Clearly, the analysis can be quite complex, as one attempts to model the endless variety of cause-and-effect relationships, and the relationship between primary and secondary causes. Analysts have constructed very simplified models of these relationships, but a common problem is the difficulty in defining a set of collectively exhaustive, yet mutually exclusive, categories of environmental impacts. A second problem has been reducing the categories to some common denominator that permits comparing the impacts of alternative actions.

The simplest model merely includes a list of causes, both primary and secondary (for example, as column headings), and a list of environmental entities (as row headings) that can be impacted either directly or indirectly as a result of any of the causes. Each intersection of the matrix then represents a complex cause-and-effect relationship. Characteristically, two quantities can be entered into each box of the matrix that provide useful summary evaluations. These include:

- magnitude of impact score (defined in terms of space and time, without reference to importance), and
- significance of impact score (defining the importance, or consequences of the impact).

The first number represents the best judgment of the analyst on a uniform scale (say between 1 and 4) of the magnitude of the impact. This judgment is supported by some degree of backup analysis, typically a combination of order-of-magnitude quantitative determinations and a number of qualitative arguments. The second number represents the significance of the impacted entity, and is supported by some backup evaluation of the relative social, economic, or ecological importance of the entity. The two numbers can be combined to provide a weighted-significance score. The sum of such numbers in a given matrix represents a composite score reflecting all impacts and their relative significance.

Other models could be postulated. For example, one could provide one matrix which translates causes into a set of physical impacts only. This matrix then provides a description of the changes in habitats of various species. A second matrix could translate the habitat changes into a set of impacts upon the various species that depend upon the habitat. A third matrix could then translate the results of the first two matrices into impacts measured in social, economic, and conservation terms. One might also proceed by starting with a matrix relating primary causes to secondary causes. The combined action of both sets of causes could then be analyzed in an analogous manner. Clearly, there are opportunities for various configurations.

Our original intention was to use the simplest model discussed above, and to score each project on a weighted-significance basis. However, because of the geographic diversity within the project area, number of variables considered, and non-uniformity of available information, we could not arrive at a mutually agreeable basis for scoring significance. Therefore, the ranking analysis was limited to scoring only the relative magnitude of the impact in the matrix. Considerations of relative significance or importance of these impacts is treated through appropriate discussions, rather than by actual scoring.

A major advantage of the matrix approach is that it provides a format for organizing data and concepts, and for discussing in more specific terms, the perceived differences in environmental impact. It also serves to make subjective judgments explicit, so that the decision maker has an understanding of factors relating to uncertainty and to value judgment. Finally, it serves to identify the need for further and more refined inter-disciplinary study.

By themselves, comparative scores have little intrinsic importance. However, they *do* become useful within the context of the subsequent discussions, and to the extent that they add perspective and understanding of the complex underlying phenomenon.

2. Scoring Criteria

The scoring system we adopted is related to the following definitions pertaining to the nature of potential environmental impacts:

Term	Definition
Insignificant –	The effects of an activity are such that properly applied current technology can confine the spatial distribution to the immediate area of the activity, *and* the scale of the activity is small – *or*, the activity has essentially no effects on the current environment.
Transient –	Known significant effects of the activity occur only during the activity; or the recovery time is < 25% of the time interval between projected occurrences at any one location.
Persistent –	Effects of the activity are known to be significant, continuous, and lasting over time; or the recovery time from known, significant effects is ⩾ 25% of the time interval between projected occurrences at any one location. (See Section III.D.4.)
Local –	Effects of a single occurrence are observed in < 25% of an estuary's water and shoreline, and along less than 10 miles of contiguous shoreline. Effects on land are felt over a contiguous area of less than 5 square miles.
Large Scale –	Effects of an event are observed in ⩾ 25% of an estuary's water, along 25% of an estuary's shoreline, or uniformly over 10 contiguous miles of shoreline. On-land impact is felt over a contiguous area of more than 5 square miles, or the combined impact of smaller-scale activities influences a similar area.

The following impact scores are related to the above definitions as follows:

Score	Attribute
0	No significant impact
1	Local and transient impact
2	Local and persistent impact
3	Large scale and transient impact
4	Large scale and persistent impact

Ideally, the above scale consistently represents increasing levels of seriousness of impact. Because of the definitions, however, it is possible that an impact scored as 2 may actually be more serious than one scored as 3. For example, an oil spill that may be judged to *permanently* damage only nine contiguous miles of coastline would be scored as 2, local and persistent. Another oil spill that damages eleven miles of coastline, but whose effect is judged to be *not permanent* would be scored as 3, large scale and transient. Most likely, the first event is more serious, yet scores lower.

In actually scoring impacts, we were alert to this possibility, and all matrices were examined for relative consistency following the scoring process. The theoretical difficulty noted above did not appear to pose a serious problem within the order-of-magnitude framework that was adopted for scoring impacts. Thus, we believe, a score of 3 does represent, within the limits of our judgment, a more serious impact than a score of 2. As an alternative scheme, we could have judged both categories of equal impact and scored them each as 2.5. However, we retained the scoring system, just defined, to make our assessment more explicit.

3. Impacting Activities

In considering a list of impacting activities ("causes" as employed in the previous discussion), we have identified the major categories that could be assessed in a manner permitting meaningful distinctions to be made among the various projects. Many important potential causes are thus treated in the aggregate, or not treated at all, because the information available did not permit an adequate relative judgment to be made regarding the impact.

These major impacting activities are organized as follows:

I. PORT CONSTRUCTION
  A. DREDGING
  B. SPOIL DISPOSAL
    1. ON LAND
    2. ADJACENT TO CHANNEL (in open waters)
    3. AT SEA
  C. FACILITY CONSTRUCTION
    1. ARTIFICIAL ISLAND
    2. SINGLE POINT MOORING
    3. ON LAND
II. OPERATIONS
  A. PETROLEUM SPILLS
    1. 14,000 TONS
    2. 500 TONS
    3. MINOR DAILY
  B. EFFECTS DUE TO SUPERTANKERS
  C. MAINTENANCE DREDGING

- D. SPOIL DISPOSAL
  - 1. ON LAND
  - 2. ADJACENT TO CHANNEL (in open water)
  - 3. AT SEA
- III. SECONDARY DEVELOPMENT
  - A. WATER USE
  - B. WASTE DISPOSAL

4. Impacted Entities

The list of impacted entities to be considered followed the rationale of selecting major categories within which distinctions as to level of impact could reasonably be made at the survey level.

The major impacted entities are organized as follows:

- I. NON-BIOLOGICAL
  - A. COASTAL AND BOTTOM FEATURES
  - B. LAND FEATURES
  - C. GROUND WATERS
  - D. SURFACE WATERS
  - E. MARINE AND ESTUARINE WATERS
- II. BIOTIC
  - A. BIRDS
  - B. FISHES
  - C. SHELLFISHES
  - D. PLANKTON
  - E. MARSHES

C. DETERMINING IMPACT SCORE

To implement the scoring system, the following steps were taken. All the available data, including Appendices A, B, and C, were examined. Special studies were made concerning the impacts of tanker operations, oil spills, and of dredging; and the results were summarized in Appendix D.

Several meetings were held in which an interdisciplinary team consisting of ADL staff and outside consultants jointly scored impacts, and discussed the criteria used. Two independent teams of evaluators then scored the same project to test reproducibility. Wherever inconsistent scorings appeared, they were discussed to further refine the scoring criteria and the basis for subjective judgment.

Finally, the interdisciplinary team examined the data for each project, discussed the rationale for scoring, and noted the dominant features of environmental impact in each case.

In addition to preparing a scored matrix for each project, a brief summary evaluation of the perceived environmental impacts was written. These summaries are presented in the Zonal Analysis section of this report, together with the scored matrices.

Each scored matrix was compared to the others to insure the most consistent application of subjective judgment.

D. RANKING METHOD LIMITATIONS

A number of general limitations for this type of analysis have already been discussed in the first two parts of this section. To fully understand and properly interpret the work that is presented, it is important to also consider a number of limitations that are specific to the analytic framework that was finally employed.

1. The General Nature of the Data

Data assembly was limited to available published sources. The survey did not include any field studies to obtain raw data. The original data had already been collected and analyzed by a variety of individuals, each pursuing his own purposes. Therefore data on the Gulf Coast region varied considerably in quality, detail, and quantity, depending upon the source. In some instances, there was considerable data relevant to the purposes of those who performed the studies, which was *not* germane to the immediate task of comparing alternative projects at the survey level. Thus, the process of filtering data from various sources, in an attempt to arrive at some uniform data base for ranking projects in different regions of the Gulf, proved to be both time consuming and not completely satisfactory. Of necessity, the analysis of environmental impacts in certain zones has proceeded from a less-developed data base than in certain other regions.

An important limitation in the survey was the emphasis on shoreline and oceanographic data, with detailed analysis of landside data, or secondary effects, specifically de-emphasized. This question merits special comment.

Secondary development by its very nature is often characterized by a cumulative progression of local environmental impacts, no one of which necessarily causes a large-scale or long-term effect, but which taken together *can* have serious implications. Moreover, the potential for large-scale and permanent adverse impact is often a function of various institutional and other constraints that can be applied to the development process. Land-use and zoning policies which include environmental protection criteria are often the determining factor in the nature and magnitude of environmental impacts associated with development. The structure of local government and the consciousness of the citizenry together with state and Federal laws and policies, may be the most important factor shaping the impact of development upon the environment. Thus, a true perception of the impacts must be predicated on some perception of the institutional structure that will evolve for managing environmental protection in a region that will experience major economic growth. Clearly, such predictions fall outside the scope of the present study. However, in certain instances the evaluation team felt that there were some distinguishing environmental features that would make the region particularly vulnerable to the pressures of secondary development. The most significant of these was water availability, when development would exert strong pressures upon a demonstrably limited regional capacity for supplying water without serious environmental stress.

2. Subjective Judgments

The ranking of various environmental implications of a project is not related to hard and fast quantitative criteria. Guidelines for ranking were, of necessity, generalized, and considerable professional subjective judgment was required. As previously indicated, two interdisciplinary teams of analysts were assigned to independently evaluate one of the locations to establish the extent to which independent assessors would converge on uniform criteria for ranking. For the most part, a satisfactory convergence was obtained, suggesting that the criteria as defined would reasonably lead independent evaluators to score impacts similarly. However, there were instances in which perceptions of impact among individuals was sufficiently different under the same criteria to require considerable discussion and examination of additional material before agreement could be reached as to scoring of impact.

One of the issues requiring subjective judgment was the concept of local versus large-scale effects. The criteria for distinguishing local from large scale were adequate for the oil spill impacts, but less satisfactory for other types of impacts, including those of secondary development. In effect, independent criteria for making this distinction had to be developed for each project alternative studied. This required considerable subjective consideration.

3. Complex Interactions

Theoretically, when one component of the environment is disturbed there is a propagative effect. For example, dredging in estuaries can alter bottom shape, which in turn alters sediment movement equilibria; the combination of effects alters water circulation and salinity distributions, which in turn impact the estuarine biota. Impacts upon estuarine biotic systems can adversely affect species, whose life cycle is partially linked to the estuarine system.

An ideal ranking scheme might have followed an interactive model. For example, the impact of oil upon water quality would become an input to the direct impact of altered water quality upon various biotic forms, which in turn produce impacts through the food chain. The ranking scheme actually employed, however, treated each major form of impact directly, with interactive aspects being implicitly considered in the ranking process rather than explicitly indicated. Thus, the ranking scheme does not generate a set of numbers that have a clear functional relationship to physical and other environmental phenomena.

This in turn impacts other ocean species in the life cycle and so on. Ideally a ranking scheme would take into account the various ways in which environmental impacts propagate and would to some extent provide a measure of ecological multiplier effects. However, while these interactive features are understood in general terms, the details of many of the interactions are poorly understood, and considerable additional data and research will be required before interactive models can become useful.

V. STUDY RESULTS

A. REGIONAL CHARACTERISTICS OF HYDROBIOLOGICAL ZONES

In providing the framework for this study, the Corps of Engineers recognized several essential facts:

- The nature of the coastal and marine environment is not uniform throughout the Gulf of Mexico;
- There was no current broad-scale description of the Gulf suitable to the task of assessing the relative environmental vulnerability (to deep-water port development) of one region to another;
- There have been major changes (due to construction of the intracoastal water way and industrial development) in the margins of the Gulf which render some of the older investigations of questionable validity; and
- Existing data is dispersed, and not all geographic areas are investigated with equal thoroughness in all the necessary disciplines.

Figure 14 shows the 27 dissimilar hydrobiological zones produced by the combined efforts of ADL and three subcontractors. (Information for any of the shaded regions may be found in the designated appendix.) Boundaries of areas south of the Mexican border and south of Tampa Bay were designated, because these portions of the Gulf are likely to affect, or be affected by superport development at locations between Brownsville, Texas, and Tampa, Florida.

The map (also shown as Figure 1) represents the distillation of a vast amount of supporting scientific data. To develop the zonal boundaries, the three subcontractors and ADL examined in sequence the physiography, climatology, physical oceanography, biology, and demography of the Gulf. Within each of these broad disciplines, the designated boundaries between dissimilar regions were designated. Where appropriate, the disciplines were divided into categories (e.g., benthic algae and benthic invertebrates within biology). Finally, the boundaries for each discipline were superimposed upon each other to delineate the dissimilar hydrobiological zones.

Variations occur even within zones. Part of the variation reflects the presence of small areas within a broad region which are not characteristic of the overall region. Another part of the variation is attributable to a gradation of characteristics from one end of a particular zone to the other end of the same zone. We have attempted to designate the boundaries in a way that assures more variation between zones than within zones.

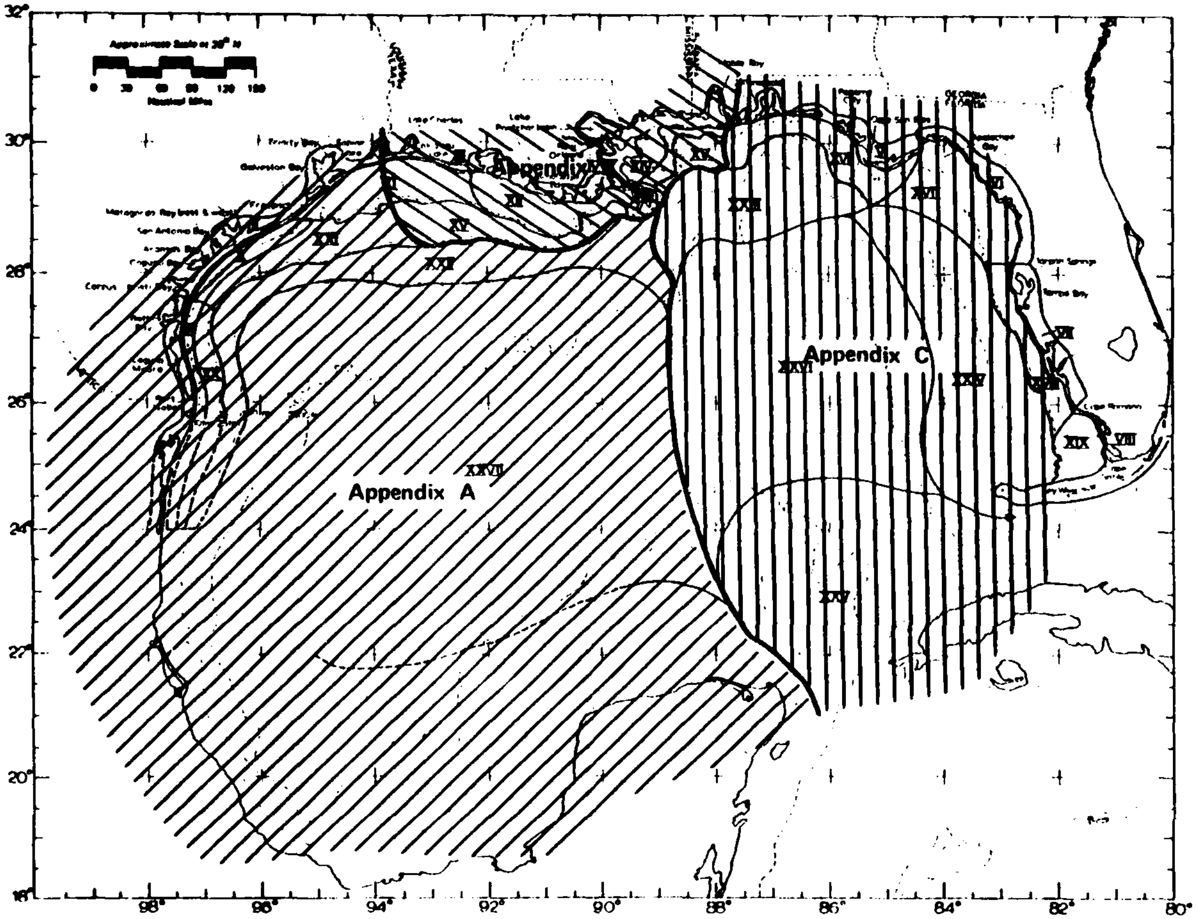


FIGURE 14 SUBCONTRACTOR ZONAL STUDY RESPONSIBILITY

The boundaries between the zones are convenient artifacts which have been designated for the purpose of assessing regional vulnerability to deep port development. All boundaries in the natural world are in fact areas of transition. Characteristic species of one region fade out and overlap with those of another region as the "boundary" is crossed. Tides periodically inundate the area as one crosses the land-sea "boundary," and the mangroves and salt marshes make it difficult to establish the "shoreline." Rather than being a single, distinct boundary, geological faults are often associated with zones of transition.

The "boundaries" between the dissimilar hydrobiological zones are subject to these effects. Because many characteristics of the environment have been considered in establishing these boundaries one must interpret them with care. While the regions are dissimilar, the specific location of the boundary lines must be viewed with caution.

1. Environmental Data Base

Once the boundaries of the dissimilar zones were defined, each of the three subcontractors described and documented the characteristics of each zone within his geographic purview. The studies described in Appendices A, B, and C, account for a significant portion of the environmental data upon which our assessment is based.

2. Relevant Environmental Factors

There are significant differences between adjacent bays throughout the Gulf, and hence a good deal of small-scale variability as one proceeds along the Gulf perimeter. However, in the broad view, change along the Gulf's perimeter is much more gradual than change perpendicular to the shoreline. Hence, the nature of the environmentally important physical forces, the biota, and man's activities change much more rapidly as one proceeds from the land across the shore and to sea than they do parallel to the shore. (This observation is distinctly evident in the shape of the dissimilar zones.)

The Gulf of Mexico has a surface area of approximately 619,000 square miles, and is connected with the Caribbean Sea by the Yucatan Channel (100 miles wide and 1000 fathoms deep) and with the Atlantic Ocean by the Florida Straits, which is less than 100 miles wide and only 440 fathoms deep. Thus, the combined width of both channels is less than two percent of the Gulf's perimeter, not considering bays and islands. The characteristics of the Gulf in general, and of the western Gulf in particular, are partially attributable to the fact that both of these connections with the parent Atlantic are confined to the southeastern sector.

The northern perimeter of the Gulf is characterized by a broad, shallow continental shelf, bisected by the Mississippi Delta. The Mississippi River is the largest single source of fresh water runoff and sediments in the Gulf, and has had a profound influence on the nature of the environment along the north central coast. Indeed, most of the Louisiana coastline owes its existence to relic Mississippi Deltas.

The overall relief of the coastal zone is low throughout the region. Sea level in the Gulf is rising (Hicks, 1972) causing the shoreline to gradually recede in those places not directly under the influence of a major sediment source.

Barrier islands protect the lagoons and bays of Texas, eastern Louisiana, Mississippi, Alabama, and northwestern Florida. The bays of the Louisiana coast are relatively open to the Gulf.

a. Limestone Karst Land

A region of highly soluble limestone and dolomite exists along the eastern Gulf coast from a point about 60 miles west of Panama City to just north of Tampa Bay. Limestone Karst terrains are particularly vulnerable to environmental stress associated with man's activities.

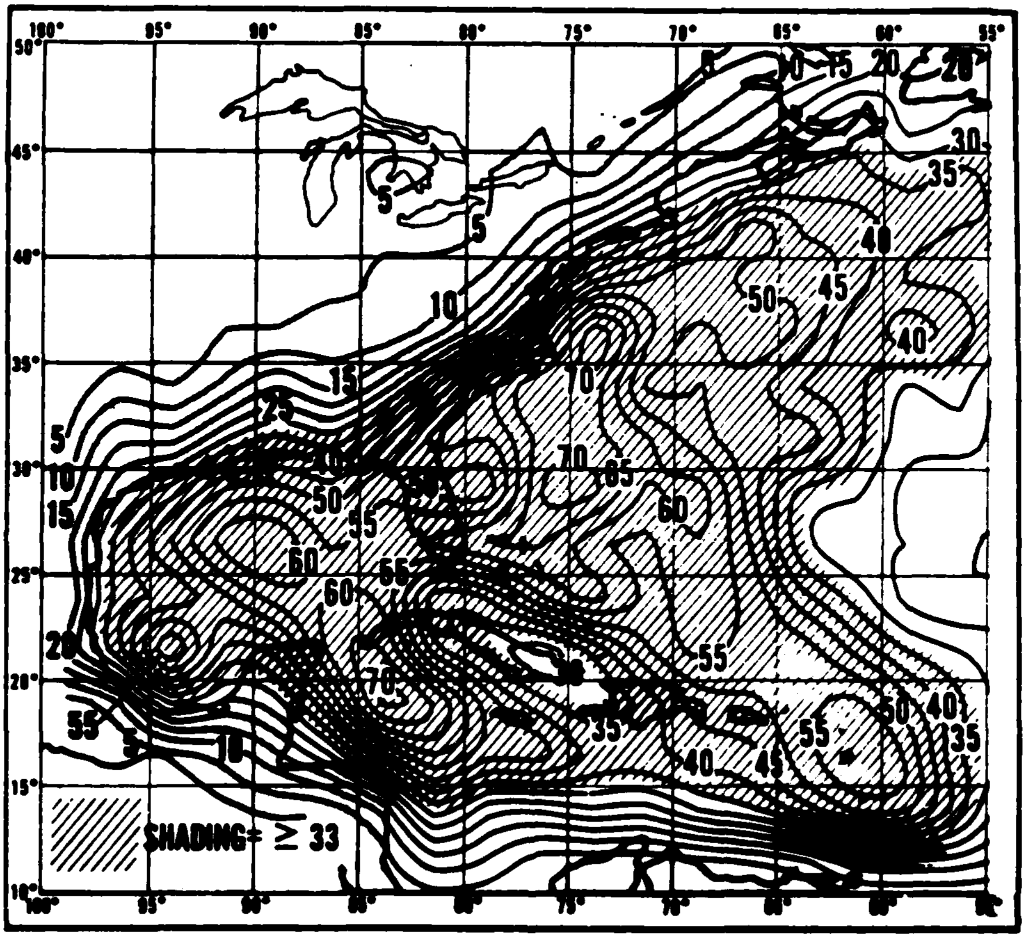
The Karst itself is developed by rock solutioning, along pre-existing fracture zones, by percolating water which becomes a weak acid as it penetrates the residual soil mantling the bed rock. Because of variability in bed rock composition and soil conditions, the soil layer developed on bed rock in Karst terrains is extremely variable in thickness and structural competence. Core borings for foundation design have to be carried out with extreme caution since misleading results are common due to unrealistic application of refusal depth criteria.

The behavior of groundwater in Karst terrains is also significantly different than in alluvial materials. Sink hole development in Karst terrains is a dynamic process that occurs at rapid rates compared with most other geological phenomena. The sink holes become direct conduits to the water table and, as such, are potential point sources of groundwater pollution. Finally, groundwater moves rapidly in carbonate Karst aquifers and, as a result, pollutants can spread areally much faster than if they were contained in a porous media such as sand.

As a result, construction of major facilities in Karst regions demands much more extensive and detailed site investigation work than is required to safely site a similar facility in a more geologically stable terrain. The structural integrity of surface structures, and protection of groundwater aquifers, are at stake.

b. Hurricanes and Tropical Storms

Tropical storms and hurricanes are relatively common occurrences in the Gulf of Mexico. Figure 15 shows that between 1886 and 1968 distinct differences in hurricane occurrence frequency were observed along the Gulf Coast. The Texas coast would appear to be less subject to such storms than other areas considered in this study. Table 6 summarizes these differences.



Source: *Mariners Weather Log,* NOAA, 15(5), September 1971, pg. 273.

FIGURE 15 NUMBER OF TROPICAL STORMS AND HURRICANES PASSING THROUGH 2½° LATITUDE–LONGITUDE SQUARES, 1886–1958

TABLE 6

TROPICAL STORMS AND HURRICANES, 1886-1968

Location	Number Observed
Corpus Christi, Texas	28
Offshore Freeport, Texas	35
Galveston, Texas	30
Offshore Southwest Pass and Lafourche, Louisiana	50
New Orleans, Louisiana	45
Mobile, Alabama	40
Offshore Mobile, Alabama	45
Panama City, Florida	42

Source: *Mariners Weather Log*, NOAA, 15(5), September 1971, pg. 293.

c. Water Resources

The development of a deep-water port facility in the Gulf of Mexico implies significant new demands on the selected area's water resources. Such demands can be met only by increased development of surface and groundwater reservoirs. The current study did not include a detailed analysis of the Gulf Coast water supply situation, but reviewed some available data.

For convenience in discussing Gulf Coast water resources we divided the coastal area shown in Figure 15 into the following five areas:

Corpus Christi, Texas,
Freeport-Galveston, Texas
New Orleans, Louisiana
Mobile, Alabama, and
Panama City, Florida.

(1) Surface Water. The surface water situation on the Gulf Coast is dominated by the presence of the Mississippi River conveying, as it does, 478,029 cubic feet of water per second and 516,900,000 tons of sediment per year from its 1,228,900-square-mile drainage area. Its flow exceeds, by orders of magnitude, the flow of other Gulf discharging rivers. The Mississippi is a continental scale feature, compared with the regional to sub-regional nature of other drainage systems. The Nueces River, discharging into Corpus Christi Bay, for example, has a drainage area of 16,000 square miles and an annual average discharge of 840 cubic feet per second. In these terms, the Mississippi represents a line source of water sufficient in quantity for any foreseeable deep-water port development which could be related thereto.

Table 7 summarizes values for several parameters related to surface water supply quantity, quality, and reliability.

TABLE 7

SURFACE WATER[1]

	Runoff		Water Quality (ppm)		Flood Potential[5] (cfs x 1000)		Drought Vulnerability[6]
Area	No. of Inches	Coefficient of Variation[2]	Dissolved Solids[3]	Suspended Sediment[4]	Mean Annual	10 Year	
A	0.5-1.0	90	>1800	280-2000	7	20+	MR
B	10-15	65	350-700	280-2000	9	20+	HR
C	25-30	45	100-350	< 280	10-15	15	HR
D	30+	45	<100	< 280	10-12	20	HR
E	25-30	50	<100	< 280	8	12	HR

(1) Values listed in Table were interpolated from small scale maps and hence are order-of-magnitude estimates.

(2) [Standard deviation of annual runoffs ÷ their arithmetic mean] x 100,
Example: Site A Annual runoff can be expected to be within 90% of the average in about 2/3 of future years. Runoff is least stable in streams with high coefficients of variation.

(3) Data based on analyses made from samples collected during low flow periods.

(4) Average annual quantity of sediment ÷ average annual stream flow.

(5) To be comparable, floods in different regions must be produced from drainage areas of the same size and have the same frequency of occurrences. Data represent flood discharge from a 300-mile-square drainage basin during mean annual and 10-year flood.

(6) (HR) = Humid region: vulnerable chiefly to short droughts.
(MR) = Marginal region: vulnerable to short and long-term droughts.

Source: *The National Atlas of the United States of America*

Review of the surface water data indicates that:

- There are large volumes of water east of, and including, the New Orleans area, whereas values decline westward from that point to a low in the Corpus Christi area. Note also that the flow at Corpus Christi is much more variable than the flows farther north and east. In this analysis, runoff is considered a measure of undeveloped water resource capacity.
- Dissolved solids and suspended sediment load are good indicators of overall water quality. By this criteria, Corpus Christi (> 1800 ppm dissolved solids and 280-2000 ppm suspended sediment) has the poorest water quality of the regions under consideration. Mobile Bay area and Panama City are significantly better in quality.
- The flood potential on a mean annual and 10-year basis is least in the Panama City area and relatively most hazardous at Mobile and New Orleans.
- Drought vulnerability is greatest in the Corpus Christi area and lower (i.e., subject only to short-term droughts) elsewhere on the Gulf Coast.

(2) Groundwater (U.S.G.S., 1971). Groundwater is a significant resource in the Gulf Coastal zone from Texas to Florida. It occurs in this area in two aquifer types:

- alluvial sediments (unconsolidated sand and gravel), and in
- carbonate rocks (limestone and dolomite).

The alluvial aquifers are principally coastal plain sands, locally including gravel. They extend from Brownsville to a point 60 miles west of Panama City where carbonate rock (limestone-dolomite and locally gypsum) becomes the major aquifer. The carbonate zone extends east and south to Tampa Bay. South of Tampa Bay coastal plain sands overlie carbonate rocks.

Groundwater development problems in the Gulf Coast can be generalized as follows:

Alluvial Aquifers

- Salt water encroachment due to over-pumpage, and
- Surface subsidence due to over-pumpage;

Carbonate Aquifers

- Salt water encroachment due to over-pumpage,
- Potential structural building problems in carbonate terrains, and
- Extreme vulnerability of aquifers in Karst terrains to pollution.

Corpus Christi. Groundwater aquifers in the Corpus area are for the most part poorly productive and saline. The area offers little opportunity for significant increases in groundwater availability.

Galveston-Freeport. Aquifers in the Texas City-Galveston area have been subjected to over-development. Water levels in deeper wells declined as much as 100 to 110 feet prior to 1948. Salt water encroachment was induced by this development and groundwater withdrawals caused land subsidence of more than five feet in the period 1942-59 at places in Texas City and lesser amounts at progressively greater distances from the centers of heavy pumping. This overpumpage clearly established the safe yield of the aquifer. If production levels of that period were repeated, similar overdraft and encroachment problems would result.

New Orleans. Much of the shallow water as well as that at intermediate depths is somewhat saline, extending southeastward from St. Landry Parish to New Orleans. In 1960, about 42 million gallons per day was pumped in the New Orleans area. Up-dip, in the direction of aquifer recharge, industrial use at Norco (a refinery center) reached pumping 19 million gpd in the early 1960's. There has been some encroachment of salt water at New Orleans.

Mobile. The coastal plain, in which Mobile is located, is the largest groundwater area in Alabama. Quality of water is good except in an area around Mobile Bay where salt water encroachment has occurred due to overpumping. The encroachment occurred as a result of over-umping in the downtown area during the 1941-1945 period. Pumping has since decreased, but the flushing is not complete and therefore groundwater development is limited. Groundwater is used to supply 121 of 123 municipalities on the Alabama Coastal Plain, with the exception of Tuscaloosa and Mobile.

Panama City. Carbonate and coastal plain sands underlain by carbonates are two aquifer types in the Panama City area. Near the coast, saline water encroachment is possible if careful water management is not employed. Basically, the area has large volumes of groundwater available. Surface supplies are extremely large. According to Water Supply Papers 1800 (p. 249) "In Escambia and Santa Rosa Counties alone the flow of fresh water in streams is more than 7-1/2 billion gallons per day."

(3) Implications. Based on water resources information in terms of surface and groundwater, quantity and quality, levels of flood potential and drought vulnerability, the five designated areas are ranked as follows:

Mobile, Ala.	very suitable for deep port development
New Orleans, La.	very suitable for deep port development
Panama City, Fla.	very suitable for deep port development
Freeport-Galveston, Tex.	moderately suitable for deep port development
Corpus Christi, Tex.	not suited for deep port development.

3. Man's Use of the Environment

Man's use of the environment along the U.S. coastline of the Gulf of Mexico may be viewed in terms of three major dimensions: commerce, recreation, and conservation. Within the category of commercial use a distinction is made between uses that depend upon the maintenance of a high degree of environmental quality and those that are relatively insensitive to environmental quality. Within the former category we include fishing, tourism, and vacation home developments. The latter would include port activities, oil wells, and general industrial activities.

Fishing is an important industry along the entire coast. *Fisheries of the United States, 1970,* lists the following catch statistics:

Louisiana	$62.0 million
Texas	53.5 million
Florida	40.2 million
Mississippi	11.9 million
Alabama	10.8 million

Since fish catches are recorded only at the port of entry, it is not possible to determine the Gulf locations of these catches without an extensive survey of the fishing industry. However, it is clear that a substantial portion of this $178.4 million per year industry (measured as the dockside price of fish) depends upon the maintenance of a high-quality environment along much of the coastal zone.

Tourism related to the Gulf Coast is an important component of the regional economy representing at least several hundred million dollars per year in product value. An accurate assessment of the value along each section of the coastline would require an extensive survey beyond the scope of the present work. Available information was insufficient to reliably estimate such baseline figures as visitation to national and state parks, numbers of vacation homes, tourist hotels, and other accommodation inventories, as well as other data that would provide quantitative measures of the value of coast-related tourism. While each state hosts a significant coast-related tourist industry, it would appear that the most significant concentration of tourism is associated with the Florida coastline, which draws from a nation-wide market.

Conservation and public park areas have been established at locations all along the coastline. With the exception of Alabama, the coastline of each state enjoys at least one important National Park. Florida and Texas would appear to have the most coastline dedicated to national and state conservation purposes. There are also many smaller local park and conservation areas owned by counties and municipalities. In addition, there are private lands along the coast which may be considered as potential future conservation areas. These regions are considered important refuges for many species of flora and fauna, some of which are endangered.

A comprehensive inventory of all park and conservation resources within each zone, including key biotic populations, intensity of human use by hunting, fishing, camping, etc., and other data was not readily available within the scope of the present study. Such data could be obtained by an extensive survey for that purpose. Where such information was conveniently obtained, however, it is included in the appendices. A more comprehensive inventory of man's use of the coastal environment in its various dimensions is desirable, but sufficient information has been obtained to permit at least a subjective comparison, or ranking of the coastal zones as to their probable sensitivity to potential adverse effects of deep-water port development in the vicinity. Considering man's present use of the environment within dissimilar hydrobiological Zones I through V (zones in Figure 1 most likely to be affected by the nine port configurations considered) the sensitivity ranking is as follows:

Sabine Lake to Calcasieu Lake (Zone III) – least sensitive
Atchafalaya Bay to Mobile Bay (Zone IV)
Port Isabel to Baffin Bay (Zone I)
Corpus Christi Bay to Galveston Bay (Zone II)
Pensacola to Cape San Blas (Zone V) – most sensitive

We stress that the designation "least sensitive" does not in any way imply a low valuation upon man's uses of the environment in that zone. It merely expresses our judgment as to relative intensity of man's uses, and the sensitivity of such use to the environmental effects of a deep-water port.

B. ZONAL IMPACT ANALYSIS

In this section, we present the results of our impact analysis of nine prospective deep-water port locations: four inshore (given West to East), and five offshore (given West to East). The inshore locations are: Corpus Christi, Galveston, New Orleans, and Mobile. The offshore locations are: Freeport, Bayou Lafourche, Southwest Pass, Mobile-Pascagoula, and Panama City. The following short narrative summaries describe the elements of environmental impact at each location. Tables 8 through 16 are the impact scoring matrices for each region, and each appears with its associated summary.

1. Inshore Sites

a. Corpus Christi (Lat. 27° 51'N, Long. 97° 05' W – 2.7 miles inside Aransas Pass).

(1) Summary Evaluation (Table 8). The terminal under consideration would be located at a newly deepened entrance to a shallow estuarine body (average depth about 13 feet at MLW) 96,000 acres in extent. The Nueces Bay is the major source of fresh water through Nueces Bay (19,000 acres) and provides the domestic and industrial water supply to the entire region. If the water conservation project (of which Lake Corpus Christi is a part) is completed as planned, there may be no fresh water to the Bay from this source in 13 out of 16 years, rendering Corpus Christi Bay the most metahaline bay of Texas. Corpus Christi Bay flushes very slowly (1,200 days to replace its volume with Gulf Water), rendering the estuarine complex including Corpus Christi and Nueces Bays extremely vulnerable to either a large-scale accidental pollution event (such as an oil spill) or to gradual but progressive increases in waste discharge from all development in the zone.

Salinities and pollution levels have been steadily rising under the combined pressures of industrial growth, population growth, and fresh water diversion. The port development would accelerate these trends. While the bio-productivity of this zone is not considered very high in comparison to other estuarine zones in Texas, it does presently support active commercial and sport fisheries and represents a significant active recreational region whose utility could be diminished by a deep port development in the Bay. In addition, the Aransas Bird Sanctuary could be threatened by any oil spill that propagates up through Aransas Bay.

(2) Coastal and Bottom Features. Because of the location of the port, the required dredging would not appear to have a major impact upon Corpus Christi Bay. A major oil spill, however, is likely to alter the composition of sediments along a significant segment of shoreline, both within and outside the Bay, and would similarly alter the composition of bottom sediments in a large but undetermined area.

(3) Land Features. Alterations of land features would be largely associated with secondary developments which can occur in a variety of locations and will have a set of localized but progressive impacts upon natural land characteristics. The significance of such changes will have to be evaluated with reference to specific sites.

(4) Groundwater. The groundwater table in this region is several hundred feet below mean sea level. It appears thus that the development would have no impact upon groundwaters.

(5) Surface Water. In general, the region has an inadequate surface water supply to support continued development. The Nueces River Basin is the major source and it is presently being developed. However, the existence of a 75 foot channel extending to a marginal pier in protected waters can be expected to

TABLE 8

CORPUS CHRISTI IMPACT SCORES

	NATURAL CHARACTERISTICS	PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
		Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON-BIOLOGICAL	Coastal and Bottom Features	2	0	2	2	–	–	2	3	3	1	2	2	0	1	2	0	0
	Land Features	0	2	0	0	–	–	2	0	0	0	0	0	2	0	0	0	0
	Ground Waters	0	0	0	0	–	–	0	0	0	0	0	0	0	0	0	0	0
	Surface Waters	0	0	0	0	–	–	0	0	0	0	0	0	0	0	0	4	2
	Marine and Estuarine Waters	2	0	2	2	–	–	1	3	3	2	2	1	2	1	2	4	4
BIOTIC	Birds	2	0	0	0	–	–	1	3	3	1	0	0	1	0	0	4	4
	Fish	2	0	2	1	–	–	0	3	3	2	1	1	0	1	2	4	4
	Shellfish	2	0	2	2	–	–	0	3	3	2	1	1	0	1	2	4	4
	Plankton	2	0	1	1	–	–	0	3	3	2	0	0	0	0	2	4	4
	Marshes	2	2	0	0	–	–	2	3	3	2	0	0	2	0	0	4	4
	Column Total	14	4	9	8	–	–	8	21	21	12	6	5	7	4	10	28	26
	Activity Total	43							86								54	

Non-biological Total 65

Biotic Total 118

Total Impact Score 183

Source: Arthur D. Little, Inc.

stimulate regional development associated with the shipment of bulk commodities other than oil. Such development can only increase the need for guaranteed adequate water supplies. To meet future freshwater demands associated with port development may require transfer of water from other basins or desalination plants.

(6) Marine and Estuarine Waters. The impacts of dredging upon water circulation and water quality would be minor and possibly beneficial, as a channel could increase flushing capacity. Construction and maintenance dredging could permanently alter present local circulation patterns and induce changes in both vertical and lateral salinity distribution in the dredged area. A major oil spill in the Bay could impair water quality for years, because natural flushing action within the Bay is unlikely to provide an important aid to man's efforts to clean up. The possibility of a spill occurring within the Bay – where it could be confined, and thus could be considered as an local impact factor – does not preclude a spill in the approach channel.

The discharge of wastewaters from project-related and secondary development activities, even if treated, will accelerate the trend toward declining water quality. The demand for fresh water associated with these developments will only reinforce present developments that presently divert the major sources of fresh water inflow from the Bay.

(7) Birds. Some danger is associated with the proximity of the Aransas National Wildlife Refuge, which could be adversely affected by a major spill in Corpus Christi Bay or just offshore. The exact possible impact is unknown.

(8) Fishes. Due to the fragility of Corpus Christi Bay's ecosystem and the magnitude of impact of oil spills, construction, and secondary development upon its water quality, it appears that fish in the Corpus Christi and Nueces Bay areas would be adversely affected.

(9) Shellfishes. Crabs and shrimp would probably be adversely affected by any permanent water quality changes.

(10) Plankton. Plankton would probably not be permanently harmed by oil spills or the turbidity changes caused by dredging, but could be harmed by changes in water quality due to increased waste discharge in the Bay.

(11) Marshes. Salt marshes in the Bay would be damaged by a large spill, and recovery would probably be slow. Land vegetation may be affected locally by terminal construction and land spoil disposal.

b. Galveston Bay (Lat 29° 28′N, Long 94° 53′W)

(1) Summary (Table 9). Galveston Bay is the third largest port in terms of tonnage in the United States, and encompasses over 800,000 acres with over 350,000 of that being water area. Located between the subhumid and humid

TABLE 9

GALVESTON IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
NATURAL CHARACTERISTICS		Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON-BIOLOGICAL	Coastal and Bottom Features	4	0	4	2	–	–	2	3	3	1	2	4	0	1	2	0	0
	Land Features	0	2	0	0	–	–	2	0	0	0	0	0	2	0	0	0	0
	Ground Waters	4	0	0	0	–	–	0	0	0	0	0	0	0	0	0	4	0
	Surface Waters	0	1	0	0	–	–	0	0	0	0	0	0	0	0	0	4	4
	Marine and Estuarine Waters	4	0	3	1	–	–	1	3	3	2	2	1	2	1	2	4	4
BIOTIC	Birds	0	0	0	0	–	–	1	3	3	1	0	0	0	0	0	4	4
	Fish	2	0	1	1	–	–	0	3	3	2	2	1	3	1	2	4	4
	Shellfish	2	0	2	2	–	–	0	3	3	2	2	1	1	4	2	4	4
	Plankton	2	0	1	1	–	–	0	3	3	2	0	0	0	3	2	4	4
	Marshes	2	2	0	0	–	–	2	3	3	2	0	0	1	0	0	4	4
	Column Total	20	5	11	7	–	–	8	21	21	12	8	7	9	10	10	32	28
	Activity Total	51							98								60	

Non-biological Total: 84

Biotic Total: 125

Total Impact Score: 209

Source: Arthur D. Little, Inc.

climatic zones along the coast of Texas, Galveston has a rainfall average of 46 inches per year and is semi-tropical in temperature. The Bay and the City are separated from the Gulf of Mexico by a series of barrier beaches, inside of which are many productive salt marshes. The beaches forming this barrier complex are very attractive recreational and tourist resources. Galveston is connected to the interior coastal area (and Houston in particular) by the Houston ship channel, which services most of the major shipping in the area. The salinity and flushing of the bay waters depend to a large extent on the river flow from the Trinity and San Jacinto Rivers. In 1970, Galveston and Trinity Bays led the state of Texas in shrimp, oyster, and crab production (its shellfish production exceeding all other Texas bays combined). It was also fifth among the Texas bays in finfisheries.

The assumed location of the terminal is inside the bay off the Houston ship channel. A major amount of dredging would be required to obtain a 75-foot-deep channel to accommodate the supertankers. The accompanying effects on the marsh, water, and marine life could significantly alter Galveston Bay. A major oil misshap in this area within the harbor would cause major damage to the ecosystem. Intensive shoreside development brought about by the development of the port would cause far-reaching detrimental effects to the resources of the area around Galveston.

(2) Coastal and Bottom Features. The Galveston Bay area would be greatly affected by the dredging and dockside facilities required for a ship channel. Moreover, a major oil spill would likely contaminate the bottom sediments throughout the bay, adding many acres to those already polluted.

(3) Land Features. Landside effects would be associated largely with regional development of the area.

(4) Groundwater. There is a possibility that dredging in this bay would adversely affect the already stressed groundwater supplies of the area. Secondary development could potentially threaten the safe water yields of the area.

(5) Surface Water. Any impact upon surface waters would be associated with secondary development, and could be extensive. However, the existence of a 75 foot channel extending to a marginal pier in protected waters can be expected to stimulate regional development associated with the shipment of bulk commodities other than oil. Such development can only increase the need for guaranteed adequate water supplies.

(6) Marine and Estuarine Waters. The estuarine waters would be affected by the dredging and subsequent spoil disposal into the waters, causing sedimentation and general degradation because of the already polluted conditions of the spoils. Any oil spill within these waters would have widespread effects within the bay, because of local containment and interior circulation. The secondary effects for regional development would be widespread and tend to degrade the area's water quality.

(7) Birds. Since the Galveston area is a major feeding and breeding area for many shore and water birds along the Texas coast, an oil spill would have widespread effects on the populations. There could also be secondary effects on the birds due to the widespread and persistent effects of regional development on the bay and coastal area.

(8) Fishes. Though construction effects on the fish of the bay and the area influenced by the bay's development would be short-term and localized, we believe that a large oil spill could have long-lasting effects on the fish, because of spill containment within the bay area and the concentration of effects on both the waters and the associated marshland areas.

(9) Shellfishes. Because the Galveston area exceeds all other Texas bays combined for shellfish production, a major oil spill is likely to destroy or permanently affect, by tainting or large-scale mortalities, the oysters and other shellfish of the bay. Secondary development and the associated increase in BOD, pollutant, and erosion rates would likewise have far-reaching effects on the shellfish of the bay. An oil spill (and possibly supertanker operations as well) could affect the major shrimp habitat off the coast of Galveston.

(10) Plankton. If a spill is contained within the bay area, the concentration of effects on the marine waters within the bay would cause plankton to be affected in a widespread area until the oil was cleaned from the waters or dispersed.

(11) Marshes. Because of the predominance of the marshes within the bay and channel complex (despite the presence of already generally degraded conditions), a possible oil spill and certain effects from regional development would produce long-term effects on the water plants and marshes. Since the marshes are at the base of the food chain, effects would be widespread, amplified within the food chain, and likely to persist.

c. New Orleans (Lat 29° 56′ N, Long 90° 20′ W)

(1) Summary (Table 10). The Port of New Orleans is a major port, but at present suffers from lack of available space within the parish for future expansion of facilities. Along the river between New Orleans and Baton Rouge, however, there is sufficient land suitable for industrial development. New Orleans is located in the humid zone and has over 60 inches of precipitation per year. Precipitation considerably exceeds evaporation, and there is a very high surface runoff.

In Louisiana, the Mississippi River (which serves the Port of New Orleans) is levied almost to the mouth of the river, therefore little of the local drainage reaches the river itself. Commercial fishermen use the river less and less, because of ecological changes resulting, in part, from flood control and navigation projects.

TABLE 10

NEW ORLEANS IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
	NATURAL CHARACTERISTICS	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON BIOLOGICAL	Coastal and Bottom Features	4	0	–	–	–	–	2	3	3	0	0	2	0	–	–	0	0
	Land Features	0	4	–	–	–	–	2	0	0	0	0	0	4	–	–	0	0
	Ground Waters	4	4	–	–	–	–	1	0	0	0	0	0	0	–	–	4	0
	Surface Waters	2	4	–	–	–	–	0	3	3	2	0	2	1	–	–	2	2
	Marine and Estuarine Waters	4	2	–	–	–	–	0	3	1	0	0	0	1	–	–	0	2
BIOTIC	Birds	0	2	–	–	–	–	1	3	1	0	0	0	2	–	–	2	2
	Fish	2	2	–	–	–	–	0	3	3	1	0	0	2	–	–	2	2
	Shellfish	0	0	–	–	–	–	0	0	0	0	0	0	0	–	–	2	2
	Plankton	0	0	–	–	–	–	0	3	0	0	0	0	0	–	–	2	2
	Marshes	0	2	–	–	–	–	2	3	0	0	0	0	2	–	–	2	2
	Column Total	16	20	–	–	–	–	8	21	11	3	0	4	12	–	–	16	14
	Activity Total	44							51								30	

Non-biological Total: 71

Biotic Total: 48

Total Impact Score: 125

Source: Arthur D. Little, Inc.

The Mississippi River is the source of drinking water for approximately 1,500,000 people in the area south of Baton Rouge and is also the water source for more than 60% of the wet industry in Louisiana – a use of approximately two billion galls a day. However, domestic sewage and industrial effluent outfalls are emptied directly into the river, contributing to the heavy pollution load which may have reduced the river's capacity to support a diverse biota. Insecticides and heavy metals in the river have caused many fish kills. Outflowing river waters are predominantly fresh in character, so there are generally no crustaceans or mollusks in the fresh or polluted waters near the mouth of the river.

To the northeast and southwest, surrounding the delta area itself, Louisiana has over 3 million acres of salt marsh area and 7 million acres of estuarine acreage – some of the most productive marshes in the Gulf in terms of fish and mollusks. About 97.5° of Gulf fish are estuarine dependent, and the marshes play an important role in supporting the food chain. In 1970, Louisiana alone landed over $72 million in fish, $40 million in shrimp (from Barataria Bay), and over 9.9 million pounds of oysters.

To construct a deep-water port in the New Orleans area would require an enormous amount of dredging, from the mouth of the river up to New Orleans – some 120 miles. The increased turbidity caused by this activity probably would be insignificant for the already silt-laden Mississippi River. The effect on the biota of the surrounding area may also be minor, because of the levees which essentially keep any degrading effects within the river channel itself.

Because of the degraded level of life in the river at present, there would be little additional damage. This same argument generally holds true for oil spills within the river – except for the broad-reaching effects a large spill would have if it were uncontained, and spread to the contiguous marshes outside the delta area. Dredge spoil disposal will be a problem along the river, because of the large amount of land needed and because of the exceptionally high groundwater table and amount of surface water in the New Orleans area. Water usage, and the general effects of secondary development in an already developed area may also prove to be detrimental.

(2) Coastal and Bottom Features. Dredging would have the most significant effects on this area, because of the large disposal volumes. An oil spill would have widespread effects on the exposed river shoreline, but the dilution should make the effects rather transient. Coastal areas per se would feel minimal effects because of the infeasibility of developing the coastal wetlands areas.

(3) Land Features. The amount of spoils to be disposed of, unless taken elsewhere (which would be highly impractical), would cause large scale effects on the land surfaces in the New Orleans area, because of the amount of material involved. Regional development of the area would cause some changes in land features.

(4) Groundwater. Secondary development may endanger the groundwater supply, and since the groundwaters are close to the surface, the chances of polluting the sources are significant.

(5) Surface Water. The Mississippi River supplies this region with an abundance of water. The surface waters of the New Orleans area are already degraded, and a deep-port would probably further degrade the already poor quality. However, this effect may be relatively insignificant, compared to the impacts on a more pristine area where the waters have been relatively unaffected by development and use.

(6) Marine and Estuarine Waters. The levees enclosing the Mississippi waters would localize the effects of either an oil spill or dredging of the channel to the already turbid and degraded waters of the river. If the effects of an oil spill were to spread uncontained to the surrounding marshes on either side of the delta, then damage could be widespread and persistent. In view of the quality of the waters at present, the effects would be mostly small-scale and localized.

(7) Birds. The effects of a major oil spill on birds of the delta could be very severe under certain conditions.

(8) Fishes. Though definitive studies are not available. we suspect that the Mississippi River is not presently enjoying the diversity of aquatic life once extant. Any effect from a deep port development would thus be generally localized and small-scale.

(9) Shellfishes. Since the levees generally protect the surrounding marshy waters from localized river degradation, effects on the mollusks of the area would probably be minimal and localized.

(10) Plankton, etc. Any effect on the plankton would probably be insignificant compared to existing conditions.

(11) Marshes. The surrounding marshes would experience minimal, local effects from construction and small oil spills, because of the levees and dispersion effects of the river mouth. However, a major spill in the river could adversely affect the marsh lands at the river mouth.

d. Mobile Bay (Lat 30° 22'N, Long 88° 08'W)

(1) Summary (Table 11). The port under consideration would be located less than ten miles inside Mobile Bay, along the axis of the existing ship channel that is already dredged to a depth of approximately 40 feet. This assumption was made to minimize the dredging requirements for a near-shore location. As a result, the impacts of dredging and spoils disposal were considered to be transient and localized.

The dominant impact would be a major oil spill, which could pollute a significant but unknown portion of Mobile Bay and some portion of the waters in

TABLE 11

MOBILE BAY IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																	
		CONSTRUCTION							OPERATION								SECONDARY		
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL					
NATURAL CHARACTERISTICS		Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge	
NON-BIOLOGICAL	Coastal and Bottom Features	2	0	2	2	–	–	2	3	3	0	2	2	0	1	2	0	0	
	Land Features	0	2	0	0	–	–	2	0	0	0	0	0	2	0	0	0	0	Non-biological Total
	Ground Waters	4	0	0	0	–	–	0	0	0	0	0	0	0	0	0	2	0	66
	Surface Waters	0	2	0	0	–	–	0	0	0	0	0	0	0	0	0	2	2	
	Marine and Estuarine Waters	2	0	2	2	–	–	1	3	3	2	2	1	2	1	2	2	2	
BIOTIC	Birds	0	0	0	0	–	–	1	3	3	1	0	0	1	0	0	2	2	
	Fish	2	0	2	1	–	–	0	3	3	2	2	1	0	1	2	2	2	Biotic Total
	Shellfish	2	0	2	2	–	–	0	3	3	2	2	1	0	1	2	2	2	92
	Plankton	2	0	0	0	–	–	0	3	3	2	0	0	0	0	2	2	2	
	Marshes	2	0	0	0	–	–	2	3	3	2	0	0	0	0	0	2	2	
	Column Total	16	4	8	7	–	–	8	21	21	11	8	5	5	4	10	16	14	Total Impact Score
	Activity Total	43							85								30		158

Source: Arthur D. Little, Inc.

the Gulf outside of the Bay, depending on the pattern of tidal currents at the time of the spill. Oil could also damage the extensive marsh areas at the eastern end of the Bay, although this does not appear too likely in view of the dominant water-movement patterns. Nevertheless, it is possible that in excess of ten miles of marshland could be affected, with attendant effects upon the birdlife and other biotic forms. We expect that any such oil-damaged waters and coastal marshland could recover their natural state within a few years, given adequate cleanup procedures.

Though not as intensively developed as the beaches along the panhandle of Florida, Dauphin Island and the adjacent islands off Mississippi form a tourism and recreation resource at the lower end of Mobile Bay. The offshore islands adjacent to Mississippi and Florida make up the Gulf Islands National Seashore.

(2) Coastline and Bottom Features. These would not be severely affected by dredging, assuming a port location at the southeren end of Mobile Bay.

(3) Land Features. With the possible exception of spoils disposal on land, there would appear to be no major landside impact associated with a port. However, regional development would be stimulated along the entire western shore of Mobile Bay towards the City of Mobile. Such development could significantly change the character of the landscape, much of which is low-lying swamp and marsh areas.

(4) Groundwater. Reports of existing problems of saline intrusion into freshwater aquifers in the vicinity suggest that extensive dredging could exacerbate the problem on a large scale. Such changes, if they occur, would be essentially irreversible.

(5) Surface Water. The region is rich in rainfall and abundant surface water. Thus, a demand for water can probably be met without stressing water resources. However, the existence of a 75 foot channel extending to a marginal pier in protected waters can be expected to stimulate regional development associated with the shipment of bulk commodities other than oil. Such development can only increase the need for guaranteed adequate water supplies. In the event of spoils disposal on land, it would be difficult to avoid negative impacts on both surface and ground waters.

(6) Marine and Estuarine Waters. The impact upon Mobile Bay through dredging would be limited to the southern-most vicinity. It does not appear that a port would significantly affect the water quality in the major portion of the Bay, because the dredged channel and the terminal would be located near the entrance. An oil spill would cause widespread pollution, but the effects upon water quality would be transient due to the relatively rapid flushing rate.

(7) Birds. Birds feeding and nesting in the marshy areas would be damaged by an oil spill. An oil spill originating in the Bay could be transported west through Mississippi Sound causing significant adverse impacts over large distances.

(8) Fishes. The effects of terminal construction on fish would be localized, but a major oil spill could adversely affect fish throughout the Bay under certain conditions. Under high river runoff conditions adverse effects would be minimized; however, the damage caused by port development (particularly through accidental oil spills) could be extensive.

(9) Shellfishes. The situation is similar to that for fish.

(10) Plankton. The same situation as for fish.

(11) Marshes. In the event of an oil spill, extensive areas of marsh could be damaged. Most areas would recover, but there might be some localized permanently damaged zones.

2. Offshore Sites

a. Freeport (Lat 28° 30'N, Long 95° 01' W)

(1) Summary (Table 12). Freeport is located approximately 35 miles southwest of Galveston, along the Texas coast, and north of the Lavaca-Tres Palacios estuary, or Matagorda area of Texas. (The Galveston area characteristics have already been mentioned.) The Matagorda area encompasses approximately 224,000 acres of bay and is separated from the Gulf by the Matagorda Peninsula, which is breeched at its mid-point by the Colorado River. The Matagorda area includes the Matagorda Bay, Tres-Palacios Bay, and Lavaca Bay.

This area is the second most important seafood producer in Texas; second on oyster and shrimp production; and third in crab and finfish production. It is important (though not as important as the Aransas area to the south) as a wintering and feeding ground for shore and water birds of the Atlantic and Gulf coasts.

At this site, because of its offshore location, there will be essentially no dredging, except that necessary to accommodate a pipeline to bring oil ashore, and thus there will be minimal transient impact from dredging activities. However, the oil spill effect could be very detrimental, because the area is close to the Galveston Bay area and the Matagorda Complex. Effects upon surface and groundwaters will be largely related to development of the shoreline. The Freeport area is not heavily built up or developed and is in a wet, subhumid, semi-tropical area of the coast. There is little local runoff so there is a possibility of overstressing the surface waters of the area to meet the needs of secondary industrial development.

(2) Coastal and Bottom Features. There would be no major interruption of these features if there isn't any dredging. However, coastal features are bound to be affected by the development of commerce, industry and residential areas, and are particularly vulnerable to the effects of oil spills during the spring change in offshore current regime, when the surface current is directly toward the shore.

TABLE 12

OFFSHORE FREEPORT IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
	NATURAL CHARACTERISTICS	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON BIOLOGICAL	Coastal and Bottom Features	1	–	1	–	(2)	0	1	3	3	0	0	–	–	–	–	0	0
	Land Features	0	–	0	–	0	0	2	0	0	0	0	–	–	–	–	0	0
	Ground Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	4	0
	Surface Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	4	4
	Marine and Estuarine Waters	1	–	1	–	(2)	1	1	3	1	2	0	–	–	–	–	4	4
BIOTIC	Birds	0	–	0	–	(2)	0	1	3	3	1	0	–	–	–	–	4	4
	Fish	0	–	0	–	(2)	1	0	3	1	0	0	–	–	–	–	4	4
	Shellfish	1	–	1	–	(2)	1	0	3	3	1	0	–	–	–	–	4	4
	Plankton	0	–	0	–	0	0	0	3	1	2	0	–	–	–	–	4	4
	Marshes	0	–	0	–	0	0	2	1	1	0	0	–	–	–	–	4	4
	Column Total	3	–	3	–	(10)	3	7	19	13	6	0	–	–	–	–	32	28
	Activity Total	16							38								60	

Non-biological Total 41

Biotic Total 73

Total Impact Score 114

Source: Arthur D. Little, Inc.

(3) Land Features. Land would be mainly affected by the regional development brought about by a deep port.

(4) Groundwater. The groundwater supply in the area is overstressed at this time and secondary development could potentially threaten the safe water yields of the area.

(5) Surface Water. Because of the low runoff in the area, the surface waters are an important factor to consider, as the limited resources may be overstressed by a future demand for water supply.

(6) Marine and Estuarine Waters. The marine and estuarine waters of the Galveston Bay and Matagorda areas could be affected by an oil spill originating at an offshore terminal at the proposed site. However, because of the offshore site, oil spill effects would be less significant than at an inshore location – i.e., widespread effects of less persistence. Effects from the regional development in the Freeport area, however, would have more of a serious effect on the marsh and general natural resource areas of the region. These effects would be relatively widespread, and persistent.

(7) Birds. If an oil spill reaches the waters of Galveston or Matagorda Bay, the flora and fauna in the marshes, and the birds wintering and feeding there would be adversely affected.

(8) Fishes. The effects from port development in the area would be short-term and localized, because the fish and pelagic organisms tend to avoid oil present in the waters. Secondary effects in the area would cause pronounced long-term damage.

(9) Shellfishes. These organisms could be temporarily affected by a large oil spill. However, even temporary effects could be of great significance, because the most productive locations for shrimp in the offshore Texas area are near the terminal site. Regional development, and accompanying secondary effects, could affect the breeding and feeding habitats of shellfish and might cause long-lasting degradation of quality.

(10) Plankton. Same situation as for fish.

(11) Marshes. The marshes of the Galveston Bay and Matagorda Complex would be affected by port development perturbations and possible oil spills. The most long-lasting and far-reaching effects will come from secondary development in the area.

b. Offshore Lafourche (Lat 28° 49'N, Long 90° 04'W)

(1) Summary (Table 13). The waters are turbid, due to the proximity of the mouth of the Mississippi River. The shoreline adjacent to the site is characterized by barrier islands and large, exposed shallow bays with extensive flat marshlands. The

TABLE 13

LA FOURCHE IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
	NATURAL CHARACTERISTICS	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON-BIOLOGICAL	Coastal and Bottom Features	1	–	1	–	(2)	0	1	3	1	0	0	–	–	–	–	0	0
	Land Features	0	–	0	–	0	0	2	0	0	0	0	–	–	–	–	0	0
	Ground Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	4	0
	Surface Waters	0	–	0	–	0	0	1	0	0	0	0	–	–	–	–	2	2
	Marine and Estuarine Waters	1	–	1	–	(2)	0	1	3	1	2	0	–	–	–	–	0	2
BIOTIC	Birds	0	–	0	–	(2)	0	1	3	1	0	0	–	–	–	–	2	2
	Fish	0	–	0	–	(2)	0	0	3	1	0	0	–	–	–	–	2	2
	Shellfish	1	–	1	–	(2)	0	0	3	3	0	0	–	–	–	–	2	2
	Plankton	0	–	0	–	0	0	0	3	1	0	0	–	–	–	–	2	2
	Marshes	0	–	0	–	0	0	2	3	1	0	0	–	–	–	–	2	2
	Column Total	3	–	3	–	(10)	0	8	21	9	2	0	–	–	–	–	16	14
	Activity Total	14							32								30	

Non-biological Total: 29

Biotic Total: 47

Total Impact Score: 76

Source: Arthur D. Little, Inc.

marshes are acknowledged to be among the most productive in the Gulf, and are vitally important to maintaining the Gulf fishing industry. The area is mostly undeveloped, but Grande Isle, the only major salt-water beach of recreational importance in Louisiana, is within 30 miles of the proposed terminal location.

The natural levees of Bayou Lafourche represent essentially the only area of high ground suitable for industrial development for several tens of miles inland. We anticipate that because of the low land profile, and the occurrence of hurricanes and high storm tides, most of the port-related industrial development will occur far inland, along the Mississippi River between New Orleans and Baton Rouge.

The biota of Barataria and Timbalier Bays and the related marshes would appear to be extremely vulnerable to oil spills, but this area has already experienced a broadly publicized oil spill. The proposed terminal site is approximately 16 miles south-southwest of where the Shell Oil Company platform accident occurred in 1970-71. It has been estimated that between 3,500 and 16,660 tons of oil were spilled during the 136 days that the wells were out of control (Stone, 1972). This amounts to from 26 to 123 tons per day; larger than the assumed daily port spill amount, but well within the limits of our "minor" (500-ton single release) spill. An assessment of studies concerned with this spill has indicated relatively little damage to the biota except in the immediate platform area (ibid).

(2) Coastal and Bottom Features. The oil spill mentioned above apparently had no significant effect on the coastal and bottom features. The entire area is characterized by the Louisiana portion of the *National Shoreline Inventory* (1971) as one of non-critical erosion. This is probably due to a general trend of rising sea level in the Gulf at a rate of nearly one centimeter per year since 1940. The only dredging at this site would be in relation to pipeline installation, an insignificant effect in a naturally turbid area.

(3) Land Features. Initially, alteration of land features would be small-scale and associated with the installation of storage facilities and pipelines to existing refinery capacity. However, secondary development inland along the Bayou Lafourche and Mississippi River levees would cause large-scale changes in the present environment.

(4) Groundwater. There has been some saline intrusion into the groundwater noted as far inland as New Orleans. High rates of groundwater withdrawal due to secondary development can be expected to have severe effects in the area. In the Lafourche area, the groundwater table is nearly synonymous with the surface water, and alterations may occur due to the drainage of swamps and marshes.

(5) Surface Water. The surface water already contains high nutrient levels due to natural causes and man's activity. Locally, the surface-water quality will be further impaired by increased development.

(6) Marine and Estuarine Waters. The marine-water quality can be expected to go down in the vicinity of an offshore development because of periodic oil spills. To the extent that spilled oil reaches the bays and marshes, the estuarine waters will be temporarily degraded as well. The currents in this region have not been adequately defined as yet, but available information indicates that the offshore currents flow toward shore.

(7) Birds. Local disturbances to the bird habitat can be expected because of secondary development. Effects of previous oil spills on birds have apparently been minimal and an offshore terminal location would tend to diminish the effects of future spills.

(8) Fishes and Shellfishes. The above comments related to birds apply to fish and shellfish as well. Locally, around a terminal, we expect that the fish habitat would be changed, but it is not possible to tell if the overall change will be detrimental or beneficial.

(9) Plankton. Changes in the water quality brought about by secondary development will alter plankton species composition. Plankton immediately beneath a major oil spill at sea would probably suffer adverse effects, but water currents flush the area and would cause effects to be transient.

(10) Marshes. If an oil spill is transported into the marshes by wind and currents, then wide-spread damage would occur. The probability is small that the same area would be coated with damaging quantities of oil at a frequency to cause the effects to be persistent.

c. Southwest Pass (Lat 28° 56′N, Long 89° 29′W)

(1) Summary (Table 14). The impact of a port off the Southwest Pass would be similar in nature and magnitude to that discussed for Offshore Lafourche. The major differences would be locational, as the port would be sufficiently remote from Grande Isle to preclude the possibility of serious impact upon the coastline in that region. However, a Southwest Pass port would be in South Bay, and close to an extensive zone considered to be an important wildlife refuge area in Louisiana. A major portion of the southwest peninsula is so designated on an official State Parks and Conservation Areas map as the Pass a Loutre Area.

Because of the absence of dredging, effects associated with dredging are not expected. For a terminal at this location secondary development would take place along a northwest axis parallel to the Mississippi River towards New Orleans.

(2) Coastal and Bottom Features. There would appear to be no widespread or very significant potential impact upon coastline and bottom features.

(3) Land Features. Secondary development would take place in a narrow corridor between the Mississippi River levee and the coast on an axis with New

TABLE 14

SOUTHWEST PASS IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																	
		CONSTRUCTION							OPERATION								SECONDARY		
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL					
NATURAL CHARACTERISTICS		Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	900 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge	
NON-BIOLOGICAL	Coastal and Bottom Features	0	–	0	–	(2)	0	0	3	1	0	0	–	–	–	–	0	0	
	Land Features	0	–	0	–	0	0	2	0	0	0	0	–	–	–	–	0	0	Non-biological Total
	Ground Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	4	0	22
	Surface Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	2	2	
	Marine and Estuarine Waters	0	–	0	–	(2)	0	0	3	1	2	0	–	–	–	–	0	2	
BIOTIC	Birds	0	–	0	–	(2)	0	1	3	1	0	0	–	–	–	–	2	2	
	Fish	0	–	0	–	(2)	0	0	3	1	0	0	–	–	–	–	2	2	Biotic Total
	Shellfish	0	–	0	–	(2)	0	0	3	3	0	0	–	–	–	–	2	2	45
	Plankton	0	–	0	–	0	0	0	3	1	0	0	–	–	–	–	2	2	
	Marshes	0	–	0	–	0	0	2	3	1	0	0	–	–	–	–	2	2	
	Column Total	0	–	0	–	(10)	0	5	21	9	2	0	–	–	–	–	16	14	Total Impact Score
	Activity Total	5							32								30		67

Source: Arthur D. Little, Inc.

Orleans. Unless properly controlled, such additional development could seriously add to the environmental stress of prior industrial development in that corridor, which includes a significant stretch of coastal lands.

(4) Groundwater. Due to high groundwater table, excessive pumping from aquifers could contribute to a salt-water-intrusion problem. Since there would be no dredging, salt-water intrusion would be largely associated with how the water requirements of secondary development are met.

(5) Surface Water. The major surface water in the vicinity is the Mississippi River. It does not appear that the river will be affected by the development.

(6) Marine and Estuarine Waters. The important impact would be associated with a major oil spill which would cause widespread, transient pollution.

(7) Birds. Birds present along the coastal marshes could be adversely affected on a large scale by a potential oil spill, and possibly by the secondary development that would occur.

(8) Fishes and Shellfishes. The comment on birds applies to fish in the contiguous waters.

(9) Plankton. The comment on birds applies to plankton in the marshes and in the contiguous waters.

(10) Marshes. Much of the coastline in the vicinity is characterized by marshes. These would be impacted by the possibility of oil spill and by future secondary development.

d. Mobile-Pascagoula (Lat 29° 40'N, Long 88° 30'W)

(1) Summary (Table 15). This offshore site is in an area that would not require major dredging, but some minor dredging would be required for pipeline connection between the terminal and coastal points. Onshore development would probably be distributed between Mobile and Pascagoula. With the exception of major oil spill accidents in deep water, the environmental impacts would be largely associated with shoreside facilities and with secondary development. In the event of an offshore spill, the barrier islands and a high rate of fresh water runoff (which would tend to keep the oil offshore) would provide some degree of protection to the coastal zone.

(2) Coastal and Bottom Features. There would be no major interruption of these features if there isn't any dredging. However, secondary development, together with shoreside facility development, can have a progressive and cumulative impact upon coastline features, depending on the land-use controls and development criteria to be exercised.

TABLE 15

OFFSHORE MOBILE–PASCAGOULA IMPACT STORES

		PORT DEVELOPMENT ACTIVITIES																
		CONSTRUCTION							OPERATION								SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
	NATURAL CHARACTERISTICS	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON-BIOLOGICAL	Coastal and Bottom Features	1	–	1	–	(2)	0	1	3	3	0	0	–	–	–	–	0	0
	Land Features	0	–	0	–	0	0	2	0	0	0	0	–	–	–	–	0	0
	Ground Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	0	0
	Surface Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	2	2
	Marine and Estuarine Waters	1	–	1	–	(2)	1	0	3	1	2	0	–	–	–	–	0	2
BIOTIC	Birds	0	–	0	–	(2)	0	1	3	1	0	0	–	–	–	–	0	2
	Fish	0	–	0	–	(2)	1	0	3	1	0	0	–	–	–	–	0	2
	Shellfish	1	–	1	–	(2)	1	0	1	1	0	0	–	–	–	–	0	2
	Plankton	0	–	0	–	(0)	0	0	3	1	2	0	–	–	–	–	0	2
	Marshes	0	–	0	–	(0)	0	2	1	1	0	0	–	–	–	–	0	2
	Column Total	3	–	3	–	(10)	3	6	17	9	4	0	–	–	–	–	2	14
	Activity Total	15							30								16	

Non-biological Total	Biotic Total	Total Impact Score
26	35	61

Source: Arthur D. Little, Inc.

(3) Land Features. Alterations of land features would be largely associated with secondary developments, which can occur in a variety of locations centering about Mobile and Pascagoula. These will have a set of localized but progressive impacts upon natural land characteristics. The significance of such changes will have to be evaluated for specific sites.

(4) Groundwater. Groundwater resources may be impacted to the extent that the demand for fresh water associated with secondary development would draw upon groundwaters. However, it would appear that the region is abundant in available surface waters and that groundwaters are not likely to be severely impacted.

(5) Surface Water. The development of a port and the secondary developments would create a significant demand for water. It appears that this demand can be met without stressing the water supply.

(6) Marine and Estuarine Waters. A deep-water port would appear to have no major impacts upon water circulation. The two important classes of impact would relate to a major oil spill and to the cumulative effects of secondary development. A major oil spill in deep water would impact water quality over a wide region, but the impact magnitude would be less than if the spill were confined to an estuarine bay. The combination of cleanup operations and natural forces in the deep water would result in rapid recovery of water quality in the impacted zone. Other than oil spills, regional development will result in major increases of waste discharge, which can have serious effects upon water quality adjacent to the mainland, even if treated.

(7) Birds. It would appear that the major concentrations of marsh species would be sufficiently remote from the probable impact zone of an oil spill to be relatively safe from large-scale destruction. However, the Chandler Island Refuge could be severely impacted.

(8) Fishes. An oil spill could adversely affect fish life over a fairly wide region. However, experience has shown that fish life can be restored following cleanup operations. Pelagic fish tend to naturally avoid the contaminated zone. More serious, however, would be the cumulative effects of shoreside pollution associated with secondary development upon all forms of estuarine and other coastal life forms. The extent to which such effects could be minimized by conservation and other environmental control policies in the face of major development is uncertain.

(9) Shellfishes. The major impacts upon these organisms would be associated with waste discharge associated with secondary development. An oil spill accident would not appear to pose a major threat to these species.

(10) Plankton. An oil spill would effectively destroy these organisms over the zone of oil spread. However, they would be restored relatively rapidly under natural conditions. A more serious impact would be the large-scale introduction of pollutants associated with secondary development.

(11) Marshes. There would appear to be no large-scale or long-term adverse effects upon the marshes if the oil from a spill stays offshore.

c. Panama City (Lat 30° 00'N, Long 86° 00'W)

(1) Summary (Table 16). The zone is considered a most significant national resource for tourism, recreation, conservation, and shellfish industry. Port development, even offshore with no dredging requirements, will have very visible effects upon highly valued prior uses of the zone. The dominant impact would be associated with a major oil spill, which would cause considerable large-scale commercial losses in fishing and shellfishing, and cause losses in the tourist industry, possibly for years, by impairing the use of beaches and degrading the aesthetic quality of the shoreside environment.

(2) Coastal and Bottom Features. Since there would be no dredging, there would appear to be only minor local impacts associated with facility construction.

(3) Land Features. The direct impact of the development upon land features would appear minor. However, the impact of secondary development would be felt in a zone having considerable value for conservation and recreation.

(4) Groundwater. There would appear to be no important threat to groundwater resources, even if regional development were to partially exploit groundwaters.

(5) Surface Water. The zone has adequate water resources. and it would not appear that the demand for water is likely to overstress the region's supply.

(6) Marine and Estuarine Waters. The major impact would be associated with a deep water oil spill which would affect a wide area and could affect enclosed bays as well. These effects are likely to be transient.

(7) Birds. If an oil spill reaches the waters of St. Andrew's Bay the flora and fauna in the marshes and the birds residing these would be adversely affected.

(8) Fishes. While the loss in fish life could be considerable in the event of an oil spill (with major commercial and tourism consequences) the effects are not likely to be permanent.

(9) Shellfishes. Important mariculture, including the 500,000-pound annual shrimp harvest in St. Andrews Bay could be impacted. Franklin County leads the Florida Gulf Coast in oyster products, and there are scallop fisheries in Apalachee Bay.

(10) Plankton. Plankton would be temporarily affected in a widespread area in the event of a major or minor oil spill.

TABLE 16

OFFSHORE PANAMA CITY IMPACT SCORES

		PORT DEVELOPMENT ACTIVITIES																	
		CONSTRUCTION							OPERATION									SECONDARY	
			SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL				
	NATURAL CHARACTERISTICS	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge
NON-BIOLOGICAL	Coastal and Bottom Features	1	–	1	–	(2)	0	1	3	3	1	0	–	–	–	–	0	0
	Land Features	0	–	0	–	0	0	2	0	0	0	0	–	–	–	–	0	0
	Ground Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	0	0
	Surface Waters	0	–	0	–	0	0	0	0	0	0	0	–	–	–	–	2	2
	Marine and Estuarine Waters	1	–	1	–	(2)	1	0	3	1	2	0	–	–	–	–	0	2
BIOTIC	Birds	0	–	0	–	(2)	0	1	3	3	1	0	–	–	–	–	0	2
	Fish	0	–	0	–	(2)	1	0	3	1	0	0	–	–	–	–	0	2
	Shellfish	1	–	1	–	(2)	1	0	3	1	0	0	–	–	–	–	0	2
	Plankton	0	–	0	–	0	0	0	3	1	2	0	–	–	–	–	0	2
	Marshes	0	–	0	–	0	0	2	3	1	0	0	–	–	–	–	0	2
	Column Total	3	–	3	–	(10)	3	6	21	11	6	0	–	–	–	–	2	14
	Activity Total	15							38									16	

Non-biological Total: 27

Biotic Total: 42

Total Impact Score: 69

Source: Arthur D. Little, Inc.

(11) Marshes. The salt marshes and estuaries in this zone produce much vegetation. The sea grasses common to the area are considered more vulnerable to oil pollution effects than other types of vegetation. Even so, this vegetation could be restored following an oil spill within a few years.

Whosez

3. Impact Summary

Table 17 summarizes the scores from Tables 8 through 16 that show which activities cause the major impacts on each region. Since an offshore site may be either an artificial island or a single-point-mooring complex, but not both, we have only added the scores for the least impacting option – the single-point mooring – into the totals. Figure 16 shows the relative impact scores of each region studied.

TABLE 17

ENVIRONMENTAL IMPACT SCORE SUMMARY

SITE	PORT DEVELOPMENT ACTIVITIES																					
	CONSTRUCTION							OPERATION								SECON-DARY						
		SPOIL DISPOSAL			FACILITY CONSTRUCT.			PETROLEUM SPILLS					SPOIL DISPOSAL									
	Dredging	On Land	Adjacent to Channel	At Sea	Artificial Island	Single Point Mooring	On Land	14,000 Ton	500 Ton	Minor Daily	Supertankers	Maint. Dredging	On Land	Adjacent to Channel	At Sea	Water Use	Waste Discharge	Construction Subtotal	Operation Subtotal	Secondary Subtotal	Total	Ranking
Offshore Mobile—Pascagoula	3	–	3	–	(10)	3	6	17	9	4	0	–	–	–	–	2	14	15	30	16	61	1
Offshore Panama City	3	–	3	–	(10)	3	6	17	11	6	0	–	–	–	–	2	14	15	34	16	65	2
Southwest Pass	0	–	0	–	(10)	0	5	21	9	2	0	–	–	–	–	16	14	5	32	30	67	3
Lafourche	3	–	3	–	(10)	0	8	21	9	2	0	–	–	–	–	16	14	14	32	30	76	4
Offshore Freeport	3	–	3	–	(10)	3	7	19	13	6	0	–	–	–	–	32	28	16	38	60	114	5
New Orleans	16	18	–	–	–	–	8	21	11	3	0	4	12	–	–	14	14	42	51	28	121	6
Mobile Bay	16	4	8	7	–	–	8	21	21	11	8	5	5	4	10	16	14	43	85	30	158	7
Corpus Christi	14	4	9	8	–	–	8	21	21	12	6	5	7	4	10	28	26	43	86	54	183	8
Galveston	20	5	11	7	–		8	21	21	12	8	7	9	10	10	32	28	51	98	60	209	9

Source: Arthur D. Little, Inc.

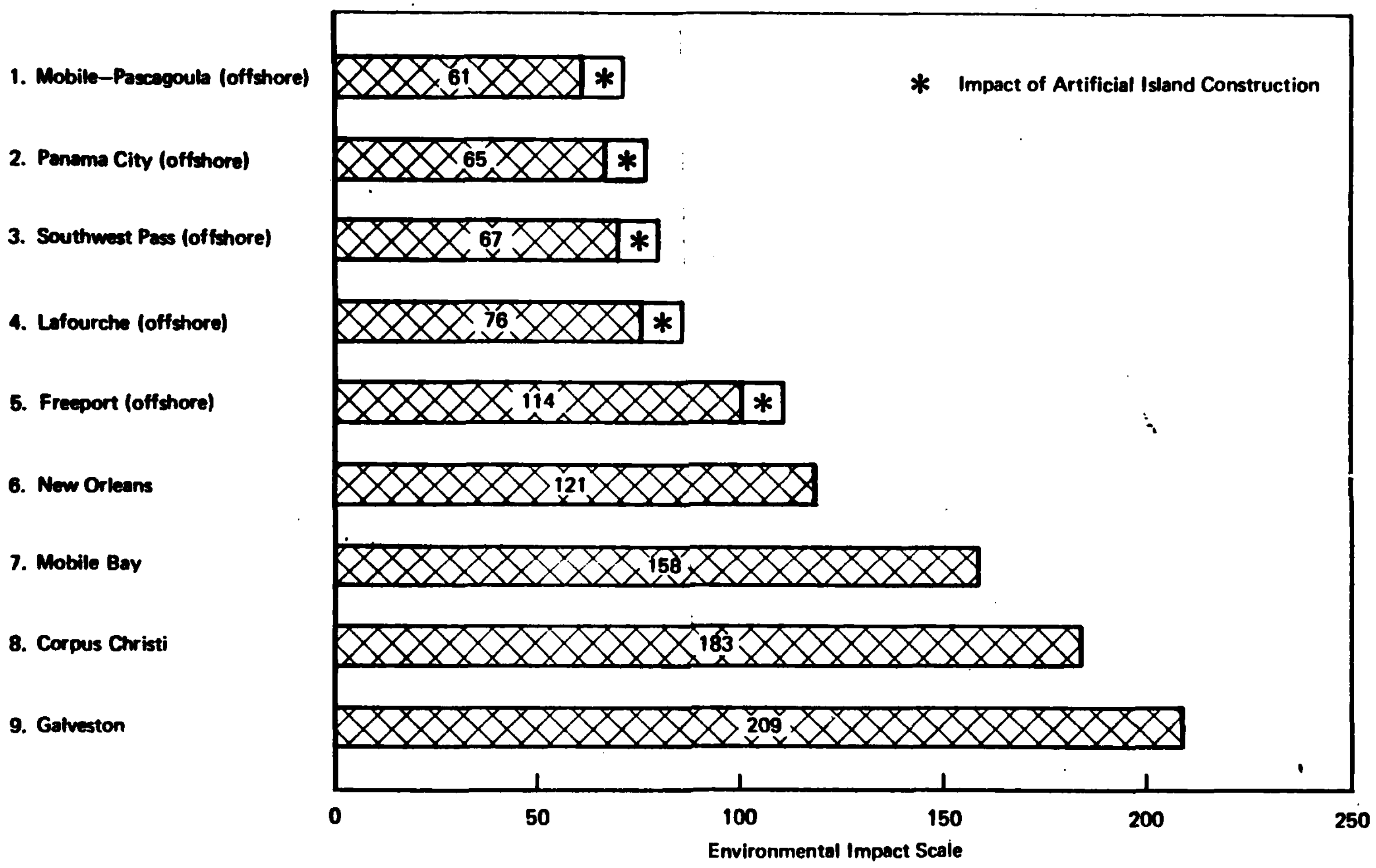


FIGURE 16 RELATIVE REGIONAL IMPACT SCORES

VI. REFERENCES

——, *Crude Oil and Natural Gas Production and Other Mining Operations in Navigable Water Along the Louisiana Coast,* Draft Environmental Impact Statement (EIS), U.S. Army, New Orleans District, Corps of Engineers. February 1972.

——, *Fisheries of the United States, 1970,* Current Fishery Statistics No. 5600, U.S. Department of Commerce, March 1971.

——, *Foreign Deep-Water Port Developments,* Arthur D. Little, Inc., September 1971 (report to U.S. Army Corps of Engineers, IWR).

——, "Louisiana Inventory Report – Lower Mississippi Region," *National Shoreline Study,* U.S. Army, New Orleans District, Corps of Engineers, July 1971.

——, U.S. Deep-Water Port Study, Robert Nathan Associates, May 1972 (report to U.S. Army Corps of Engineers, IWR).

——, *Environmental Guide for the U.S. Gulf Coast,* National Oceanic and Atmospheric Administration (NOAA) Asheville, N.C., 1972.

Hicks, Steacy D., "On the Classification and Trends of Long Period Sea Level Series," *Shore and Beach,* April 1972.

Hicks, Steacy D., "Vertical Coastal Movements from Sea Level Measurements Along the East Coast of the United States," *Journal of Geophysical Research,* 77 (30), October 1972.

Leopold, L.B., F.E. Clarke, B.B. Hanshaw, and J.R. Balsley, *A Procedure for Evaluating Environmental Impact,* Circular 645, U.S. Geological Survey, 1971.

McNulty, J.K., W.N. Lindall, Jr., and J.E. Sykes, *Cooperative Gulf of Mexico Estuarine Inventory and Study, Florida: Phase I, Area Description,* NOAA Technical Report NMFS CIRC-368, Seattle, Washington, U.S. Dept. of Commerce, November 1972.

Stone, J.H., *Preliminary Assessment of the Environmental Impact of a Superport on the Southeastern Coastal Area of Louisiana,* Final Report LSU-SG-72-05, Baton Rouge, Center for Wetland Resources, Louisiana State University, November 1972.

Stover, L.V., *Environmental Impact Assessment: A Procedure,* Miami, Florida, Sanders & Thomas, May 1972.

627.2