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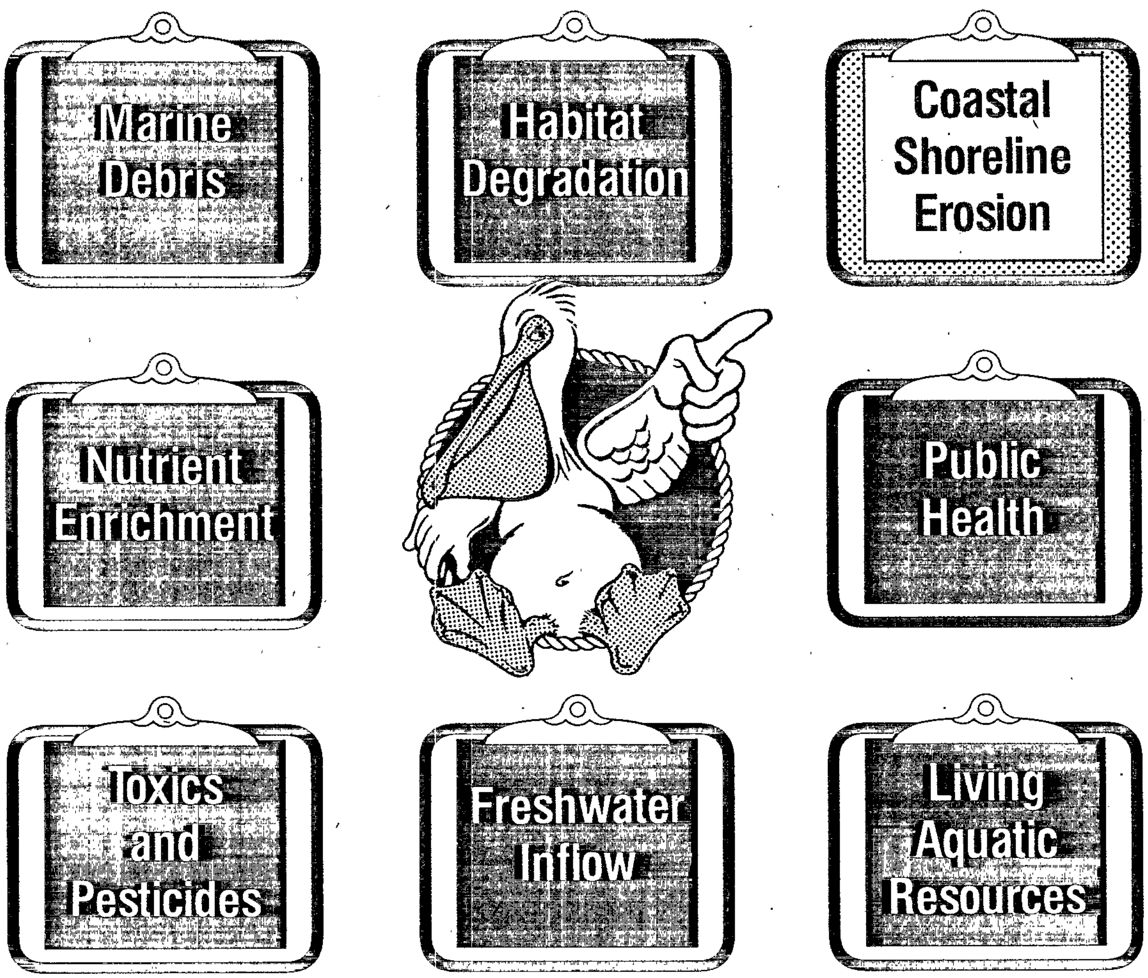
Coastal And Shoreline Erosion Action Agenda For The Gulf Of Mexico

First Generation—Management Committee Report

Framework for Action



Coastal Shoreline Erosion Action Agenda for the Gulf of Mexico

PREFACE

One of the initial goals for the first five years of the Gulf of Mexico Program was to establish a "framework-for-action" for implementing management options for pollution controls, determining research direction and environmental monitoring protocols, and implementing remedial and restoration measures for environmental losses. As a means of developing this framework-for-action, the Gulf Program established eight committees, composed of experts, to deal with the following environmental issue areas:

- Habitat Degradation
- Marine Debris
- Freshwater Inflow
- Nutrient Enrichment
- Toxic Substances & Pesticides
- Public Health
- Coastal & Shoreline Erosion
- Living Aquatic Resources

Each committee was charged with: 1) characterizing the status of the issue, 2) developing goals and objectives for remedial and restoration activities, and 3) developing descriptions of the projects and tasks to be implemented in order to achieve the stated objectives. This information was incorporated into an "Action Agenda" for each environmental issue area.

This document is the first generation of one of these Action Agendas. Representing the consensus of a large number of subject specialists, this document is considered to be a draft working paper for the Gulf of Mexico Program Management Committee. Since this first generation Action Agenda has not been reviewed and approved by all agencies, it is being made available for informational purposes only.

EXECUTIVE SUMMARY

The Gulf of Mexico contains ecological and commercial riches matched by few other bodies of water. Yet its blue-green waters disguise the increasing environmental threats that endanger those resources. In recognition of these threats, Regions 4 and 6 of the U.S. Environmental Protection Agency (USEPA), which share jurisdiction over the five Gulf Coast States (Alabama, Florida, Louisiana, Mississippi, and Texas), initiated the Gulf of Mexico Program in August 1988. The goal of the Gulf of Mexico Program is to protect, restore, and enhance the coastal and marine waters of the Gulf of Mexico and its coastal natural habitats, to sustain living resources, to protect human health and the food supply, and to ensure the recreational use of Gulf shores, beaches, and waters--in ways consistent with the economic well being of the region.

The Gulf of Mexico Program is a cooperative partnership among federal, state, and local government agencies as well as with people and groups who use the Gulf of Mexico. During the early stages of Program development, eight priority environmental problems were identified and the following Issue Committees have been established to address each of these problems: Marine Debris, Public Health, Habitat Degradation, Coastal & Shoreline Erosion, Nutrient Enrichment, Toxic Substances & Pesticides, Freshwater Inflow, and Living Aquatic Resources. There are important linkages among these various Issue Committees and the Gulf of Mexico Program works to coordinate and integrate activities among them.

The Coastal & Shoreline Erosion Committee was charged with characterizing erosion problems and identifying ways to reduce the impacts of erosion. The Issue Committee has been meeting for more than four years--to review information and data collected by citizens and scientists, identify problem areas, discuss actions that can resolve the problems, and evaluate methods for achieving and monitoring results. The culmination of Issue Committee efforts is this Coastal & Shoreline Erosion Action Agenda which specifies an initial set of activities needed to reduce the impacts of erosion in the Gulf of Mexico. This Action Agenda is the first generation of an evolving series of Action Agendas that will be developed to meet the future needs of the Gulf of Mexico.

Chapter 1 of the Coastal & Shoreline Erosion Action Agenda provides an overview of Gulf of Mexico resources and the threats now facing those resources. In addition, Chapter 1 describes the structure of the Gulf of Mexico Program, including the Action Agenda development process.

Chapter 2 is a summary of the scientific characterization information compiled by the Coastal & Shoreline Erosion Committee. To illustrate the impacts of erosion, the Issue Committee has produced a map depicting the historical change of the Gulf of Mexico coastline. This map is available from the Gulf of Mexico Program Office.

Chapter 3 describes the legal and institutional framework currently in place in the Gulf of Mexico to address erosion issues and support coastline protection efforts.

Chapter 4, **The Unfinished Agenda,** contains the goal, objectives, and specific activities established by the Gulf of Mexico Program to address coastal and shoreline erosion. The primary goal is to:

- Reduce the impacts of coastal and shoreline erosion in the Gulf of Mexico.

The scope of this Action Agenda includes the following major areas: mainland shorelines, barrier islands, major bays and estuaries, major waterways, and peninsulas.

Four objectives and 20 action items have been developed to support the goal and these are grouped under three types of activities (see **Index of Coastal & Shoreline Erosion Objectives**). The action items included (in Chapter 4) have been screened by the Gulf of Mexico Program and represent those activities that are currently the most significant and most achievable. This is a fairly comprehensive, but not exhaustive, list. This document begins an evolving process of Action Agendas in which action items are designated, implemented, and then reassessed as progress in the Gulf is made. In the future, new coastal and shoreline erosion action items will be developed to meet the changing needs in the Gulf of Mexico.

No specific implementation projects are proposed in this iteration of the Action Agenda. Rather the Coastal & Shoreline Erosion Committee has focused on the development of a consensus on the most effective responses to critical erosion problems and the monitoring of projects that are already underway at the federal and state levels. It is anticipated that future iterations of the Action Agenda will include specific implementation projects.

Action items contained in Chapter 4 are not listed in priority order. Some of the actions are already underway but not yet completed. Others are included because they will guide federal, state, and local government agencies and private sector organizations in allocating resources where they are most needed and in justifying future management strategies. This Action Agenda should prompt specific agencies and groups to become involved.

The Gulf of Mexico Program recently developed ten short-term environmental challenges to restore and maintain the environmental and economic health of the Gulf. Within the next five years (1993-1997), through an integrated effort that complements existing local, state, and federal programs, the Program has pledged efforts to obtain the knowledge and resources to:

- ❑ Significantly reduce the rate of loss of coastal wetlands.
- ❑ Achieve an increase in Gulf Coast seagrass beds.
- ❑ Enhance the sustainability of Gulf commercial and recreational fisheries.
- ❑ Protect the human health and food supply by reducing input of nutrients, toxic substances, and pathogens to the Gulf.
- ❑ Increase Gulf shellfish beds available for safe harvesting by ten percent.
- ❑ Ensure that all Gulf beaches are safe for swimming and recreational uses.
- ❑ Reduce by at least ten percent the amount of trash on beaches.
- ❑ Improve and expand coastal habitats that support migratory birds, fish, and other living resources.
- ❑ Expand public education/outreach tailored for each Gulf Coast county or parish.
- ❑ Reduce critical coastal and shoreline erosion.

This Coastal & Shoreline Erosion Action Agenda supports these five year environmental challenges.

For the public, this Gulf of Mexico Action Agenda should serve three purposes. First, it should reflect the public will with regard to addressing coastal and shoreline erosion. Second, it should communicate what actions are needed for reducing erosion and provide the momentum for initiating these actions. Third, it should provide baseline information from which success can be measured.

This Action Agenda is a living document; therefore, the Gulf of Mexico Coastal & Shoreline Erosion Committee intends to periodically revise and update the document.

Index of Coastal & Shoreline Erosion Objectives

Erosion Identification, Characterization, & Assessment

Objective: Characterize the Gulf of Mexico shoreline, and identify trends and patterns of shoreline change.

Objective: Assess the severity of coastal erosion Gulfwide, and evaluate causes and impacts.

Erosion Response

Objective: Evaluate existing and potential response alternatives for coastal erosion in the Gulf of Mexico region.

Public Education & Outreach

Objective: Increase individual and public awareness of erosion impacts in the Gulf of Mexico region and the importance of appropriate control measures and options.

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1 OVERVIEW OF THE GULF OF MEXICO

The Gulf of Mexico - A Vast & Valuable Resource

Bounded by a shoreline that reaches northwest from Florida along the shores of Alabama, Mississippi, and Louisiana, and then southwest along Texas and Mexico, the Gulf of Mexico is the ninth largest body of water in the world. The Gulf's U.S. coastline measures approximately 2,609 km (1,631 miles)--longer than the Pacific coastline of California, Oregon, and Washington. The Gulf region covers more than 1.6 million km^2 (617,600 mi^2) and contains one of the nation's most extensive barrier-island systems, outlets from 33 major river systems, and 207 estuaries (Buff and Turner, 1987). In addition, the Gulf receives the drainage of the Mississippi River, the largest river in North America and one of the major rivers of the world. A cornerstone of the nation's economy, the Gulf's diverse and productive ecosystem provides a variety of valuable resources and services, including transportation, recreation, fish and shellfish, and petroleum and minerals.

Encompassing over two million hectares (five million acres) (about half of the national total), Gulf of Mexico coastal wetlands serve as essential habitat for a large percentage of the U.S.'s migrating waterfowl (USEPA, 1991). Mudflats, salt marshes, mangrove swamps, and barrier island beaches of the Gulf also provide year-round nesting and feeding grounds for abundant numbers of gulls, terns, and other shorebirds. Five species of endangered whales, including four baleen whales and one toothed whale, are found in Gulf waters. These waters also harbor the endangered American crocodile and five species of endangered or threatened sea turtles (loggerhead, green, leatherback, hawksbill, and Kemp's Ridley). The endangered West Indian (or Florida) manatee inhabits waterways and bays along the Florida peninsula.

In addition, a complex network of channels and wetlands within the Gulf shoreline provides habitat for estuarine-dependent commercial and recreational fisheries. The rich waters yielded approximately 771 million kg (1.7 billion pounds) of fish and shellfish in 1991. Worth more than $641 million at dockside, this harvest represented 19 percent of the total annual domestic harvest of commercial fish (USDOC, 1992). The Gulf boasts the largest and most valuable shrimp fishery in the U.S. and also contributed 41 percent of the U.S. total oyster production in 1991 (USDOC, 1992). Other Gulf fisheries include diverse shellfisheries for crabs and spiny lobsters and finfisheries for menhaden, herring, mackerel, tuna, grouper, snapper, drum, and flounder. The entire U.S. Gulf of Mexico fishery yields more finfish, shrimp, and shellfish annually than the South and Mid-Atlantic, Chesapeake, and Great Lakes regions combined.

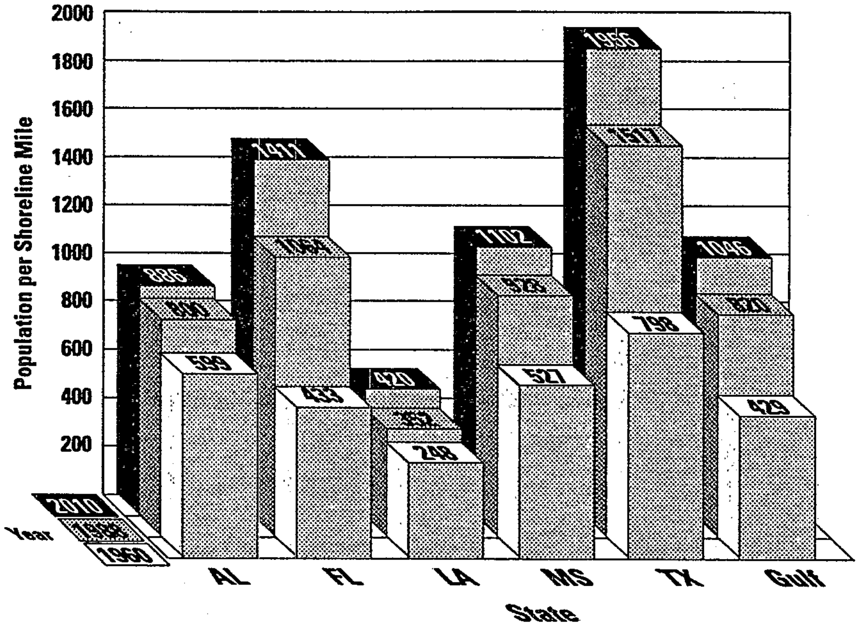
The Gulf's bountiful waters draw millions of sport fishermen and beach users each year. It is estimated that the Gulf supports more than one-third of the nation's marine recreational fishing, hosting four million fishermen in 1985 who caught an estimated 42 million fish (USDOC, 1992). Popular nearshore catches include sea trout (weak fish), cobia, redfish, flounder, grouper, red snapper, mackerel, and tarpon; offshore catches include blue marlin, white marlin, sailfish, swordfish, dolphin, and wahoo. Tourism-related dollars in the Gulf Coast States contribute an estimated $20 billion to the economy each year (USEPA, 1991).

Gulf oil and gas production are equally valuable to the region's economy and are a critical part of the nation's total energy supply. In 1990, more than 1,600 Outer Continental Shelf (OCS) leases were in production, yielding approximately 90 percent of U.S. offshore production. These OCS royalties annually contribute about $3 billion to the Federal Treasury. Thirty-eight percent of all petroleum and 48 percent of all natural gas reserves in the U.S. are estimated to be in the Gulf of Mexico. The industry employs some 30,000 people in the Gulf of Mexico.

Approximately 45 percent of U.S. shipping tonnage passes through Gulf ports, including four of the nation's busiest: Corpus Christi, Houston/Galveston, Tampa, and New Orleans. The second largest marine transport industry in the world is located in the Gulf of Mexico. According to USEPA, vessel trips in and out of American Gulf ports and harbors exceeded an estimated 600,000 trips in 1986. The U.S. Navy is also implementing its Gulf Coast Homeporting Plan, designed to dock at least 25 vessels in Ingelside, TX, Pascagoula, MS, and Mobile, AL.

Millions of people depend on the Gulf of Mexico to earn a living and flock to its shores and waters for entertainment and relaxation. The temperate climate and abundant resources are attracting more and more people. The region currently ranks fourth in total population among the five U.S. coastal regions, accounting for 13 percent of the nation's total coastal population. Although the Gulf region is not as densely settled as others, it is experiencing the second fastest rate of growth; between 1970 and 1980, the population grew by more than 30 percent (USDOC, 1990). According to the U.S. Department of Commerce, the Gulf's total coastal population is projected to increase by 144 percent between 1960 and 2010, to almost 18 million people. **Figure 1.1** shows the Gulf of Mexico coastal population density or population per shoreline mile projected to the year 2010. Florida's population alone is expected to have skyrocketed by more than 300 percent by the year 2010. The increasing coastal population is of concern because as the population increases, so does the potential for environmental degradation.

Figure 1.1 ***Gulf of Mexico Coastal Population per Shoreline Mile***



(Source: USDOC, 1990)

The Gulf of Mexico - A Resource At Risk

Increasing population pressures mean increased use and demands on Gulf of Mexico resources. Until recently, the Gulf was considered too vast to be affected by pollution and overuse. Recent trends indicate, however, serious long-term environmental damage unless action is initiated today. Signs of increasing degradation throughout the Gulf system include the following (USEPA, 1991):

- ❑ Fish kills and toxic "red tides," and "brown tides" were an increasing phenomenon in Gulf waters during the 1980s.

- ❑ Alabama, Mississippi, Louisiana, and Texas are among those states that discharge the greatest amount of toxic chemicals into coastal waters.

- Diversions and consumptive use for human activities have resulted in significant changes in the quantity and timing of freshwater inflows to the Gulf of Mexico.

- More than half of the shellfish-producing areas along the Gulf Coast are permanently or conditionally closed. These closure areas are growing as a result of increasing human and domestic animal populations along the Gulf Coast (USDOC, 1991).

- Louisiana is losing valuable coastal wetlands at the rate of approximately 14-66 km^2/year (5-25 mi^2/year) (Dunbar, *et al.*, 1992).

- Almost 1,800 kg/mi (2 tons/mi) of marine trash covered Texas beaches in 1988.

- Up to 9,500 km^2 (4,000 mi^2) of oxygen deficient (hypoxia) bottom waters, known as the "dead zone," have been documented off the Louisiana and Texas coasts (Rabalais, *et al.*, 1991).

- Gulf shorelines are eroding up to 30 m/year (100 ft/year). Few coastal reaches in the Gulf can be characterized as "stable" or "accreting."

The Gulf of Mexico Program - Goals & Structure

Problems plaguing the Gulf cannot be addressed in a piecemeal fashion. These problems and the resources needed to address them are too great. The Gulf of Mexico Program (GMP) was formed to pioneer a broad, geographic focus in order to address major environmental issues in the Gulf before the damage is irreversible or too costly to correct.

The program is part of a cooperative effort with other agencies and organizations in the five Gulf States, as well as with people and groups who use the Gulf. In addition to the U.S. Environmental Protection Agency (USEPA), other participating federal government agencies include: National Aeronautics and Space Administration (NASA), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), U.S. Department of Commerce (USDOC), U.S. Department of Defense (USDOD), U.S. Department of Energy (USDOE), U.S. Department of the Interior (USDOI), U.S. Department of Transportation (USDOT), U.S. Food & Drug Administration (USFDA), and Agency for Toxic Substances & Disease Registry (ATSDR).

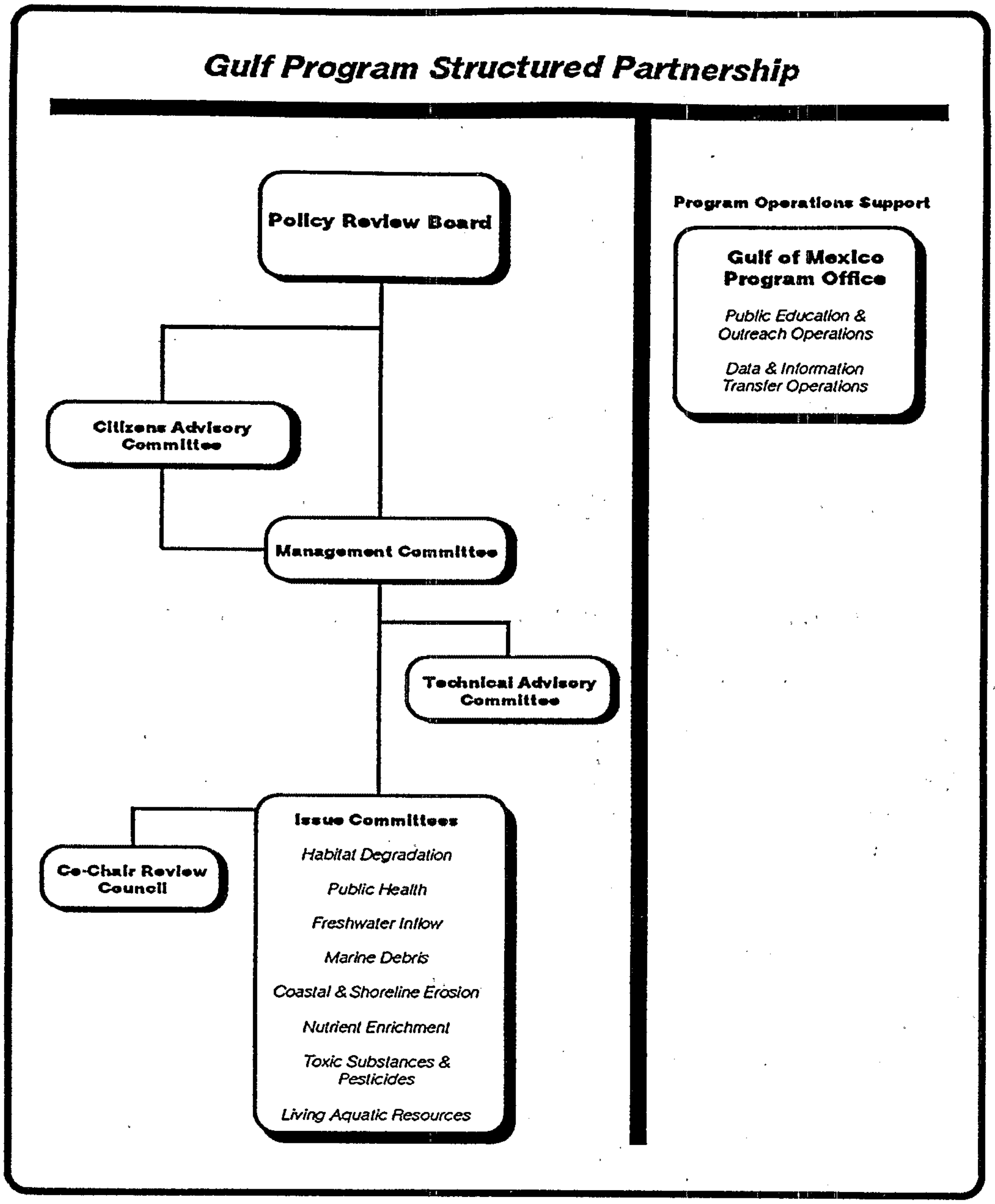
The Gulf of Mexico Program also works in coordination and cooperation with the five National Estuary Programs (NEPs) within the Gulf: Tampa Bay, Sarasota Bay, Galveston Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex. The Gulf of Mexico Program supports and builds on certain activities of these programs, bringing a Gulfwide focus and providing a forum for addressing issues of Gulfwide concern.

By building on and enhancing programs already underway, as well as by coordinating new activities, the Gulf of Mexico Program will serve as a catalyst for change. The program's overall goals are to provide:

- ❑ A mechanism for addressing complex problems that cross federal, state, and international jurisdictional lines;
- ❑ Better coordination among federal, state, and local programs, thus increasing the effectiveness and efficiency of the long-term effort to manage and protect Gulf resources;
- ❑ A regional perspective to address research needs, which will result in improved transfer of information and methods for supporting effective management decisions; and
- ❑ A forum for affected groups using the Gulf, for public and private educational institutions, and for the general public to participate in the solution process.

The Gulf of Mexico Program is supported by four committees: Policy Review Board (PRB), Management Committee (MC), Citizens Advisory Committee (CAC), and Technical Advisory Committee (TAC) (see **Figure 1.2**). Composed of 20 senior level representatives of state and federal agencies and representatives of the technical and citizens committees, the Policy Review Board guides and reviews overall program activities. The Management Committee guides and manages Gulf of Mexico Program operations and directs the Action Agenda activities of the Issue Committees. The Citizens Advisory Committee is composed of five governor-appointed citizens who represent environmental, fisheries, agricultural, business/industrial, and development/tourism interests in each of the five Gulf Coast States. This committee provides public input and assistance in publicizing the Gulf of Mexico Program's goals and results. Representatives of state and federal agencies, the academic community, and the private and public sectors are members of the Technical Advisory Committee and provide technical support to the Management Committee.

Figure 1.2


Gulf Program Structured Partnership
Policy Review Board
Citizens Advisory Committee
Management Committee
Technical Advisory Committee
Issue Committees
Habitat Degradation
Public Health
Freshwater Inflow
Marine Debris
Coastal & Shoreline Erosion
Nutrient Enrichment
Toxic Substances & Pesticides
Living Aquatic Resources
Co-Chair Review Council
Program Operations Support
Gulf of Mexico Program Office
Public Education & Outreach Operations
Data & Information Transfer Operations

The Gulf of Mexico Program has established the following eight Issue Committees, each co-chaired by one federal and one state representative, to address priority environmental problems:

- ❑ **Habitat Degradation** of such areas as coastal wetlands, seagrass beds, and sand dunes;
- ❑ **Freshwater Inflow** changes resulting from reservoir construction, diversions for municipal, industrial, and agricultural purposes, and modifications to watersheds with concomitant alteration of runoff patterns;
- ❑ **Nutrient Enrichment** resulting from such sources as municipal waste water treatment plants, storm water, industries, and agriculture;
- ❑ **Toxic Substances & Pesticides** contamination originating from industrial and agriculturally based sources;
- ❑ **Coastal & Shoreline Erosion** caused by natural and human-related activities;
- ❑ **Public Health** threats from swimming in and eating seafood products coming from contaminated water;
- ❑ **Marine Debris** from land-based and marine recreational and commercial sources; and
- ❑ **Living Aquatic Resources.**

Two cross-cutting technical operating committees support the public education and information and resource management functions of the eight environmental Issue Committees. These are:

- ❑ **Public Education & Outreach Operations**
- ❑ **Data & Information Transfer Operations**

The action planning process used by each Gulf of Mexico Program Issue Committee includes the following key activities:

- ❑ Definition of environmental issues;
- ❑ Characterization of identified problems, including sources, resources, and impacts;
- ❑ Establishment of goals and objectives;
- ❑ Evaluation/assessment of corrective actions and control measures, including cost/benefit analysis;
- ❑ Selection of priority action items;
- ❑ Establishment of measures of success;
- ❑ Implementation of actions; and
- ❑ Evaluation of success and revision of the Action Agenda.

As the Issue Committees progress through each of these activities, ample opportunities are provided for public review and Policy Review Board endorsement is requested at appropriate points. The Gulf of Mexico Program will continuously work to integrate related activities of the eight Issue Committees. Through the consensus of Program participants, a coordinated response will be directed to the successful maintenance and enhancement of resources of the Gulf of Mexico.

The Coastal & Shoreline Erosion Committee

The Co-chairs and membership of the Coastal & Shoreline Erosion Committee are as follows:

Co-Chairs:

Thomas Richardson	U.S. Army Corps of Engineers
Sally Davenport	Texas General Land Office

Members:

Robert Baker	U.S. Geological Survey
Frank Blanchard	Collier Beach Society
Floyd Buch	Port of Corpus Christi
Mary Lou Campbell	Sierra Club
Ralph Clark	Florida Office of Beach Erosion Control
Mel Davis	Texas Soil & Water Conservation Board
John Dingler	U.S. Geological Survey
Peter Doragh	Citizens Advisory Committee
Scott Douglass	University of South Alabama
James Edmondson	South-Central Planning & Development Commission
Edwin Garner	The University of Texas at Austin
Mark Gates	Texas Natural Resource Conservation Commission
Linda Glenboski	U.S. Army Corps of Engineers
Andrew Grayson	Florida Department of Natural Resources
Deborah Heibel	U.S. Army Corps of Engineers
Cathy Hollomon	Mississippi Department of Wildlife, Fisheries & Parks
Richard Hoogland	Gulf of Mexico Fishery Management Council
Charles Hunsicker	Assistant City Manager--Clearwater, Florida
James Johnston	U.S. Fish & Wildlife Service
Robert Jones	Terrebonne Parish Government--Louisiana
Jeff Kellman	Agency for Toxic Substances & Disease Registry
B.D. King III	U.S. Fish & Wildlife Service
Cragin Knox	Mississippi Department of Environmental Quality
Herb Kumpf	National Marine Fisheries Service
Bennett Landreneau	Soil Conservation Service
John Lawrence	Soil Conservation Service
Klaus Meyer-Arendt	Mississippi State University
Robert Morton	University of Texas at Austin
Joann Mossa	University of Florida
Robert Nailon	Texas A&M Marine Advisory
John O'Connor	Florida Association of Conservation Districts
Ervin Otvos	Gulf Coast Research Laboratory
Shea Penland	Louisiana Geological Survey
Ric Ruebsamen	National Marine Fisheries Service

Asbury Sallenger Jr.	U.S. Geological Survey
Samuel Sanders	Soil Conservation Service
Edward Seidensticker	Soil Conservation Service
David W. Smith	Houston Audubon Society
David Smith	U.S. Fish & Wildlife Service
Everett Smith	Geological Survey of Alabama
Thomas Smith	U.S. Army Corps of Engineers
Cliff Truitt	Mote Marine Laboratory
Michael Voisin	Motivatit Seafoods, Inc.
Jeffress Williams	U.S. Geological Survey

Previous Co-Chairs:

Thomas Campbell	U.S. Army Corps of Engineers
Bill Good	Louisiana Department of Natural Resources

The Coastal & Shoreline Erosion Committee developed the following long-term goal for addressing coastal and shoreline erosion in the Gulf of Mexico:

- ❑ Reduce the impacts of coastal and shoreline erosion in the Gulf of Mexico.

In developing this Action Agenda, the Coastal & Shoreline Erosion Committee has sought input and advice from other technical Issue Committees, as well as from organizations, interest groups, and private concerns outside of the Gulf of Mexico Program. An "Action Agenda Workshop" was sponsored by the Coastal & Shoreline Erosion Committee in Galveston, TX, on March 4-5, 1992. Approximately 35 persons, comprising a mix of Program and non-Program participants, gathered there to review an early version of this Action Agenda. In addition to Gulf of Mexico Program participants, representatives from the following agencies, organizations, and industries attended the workshop: Highland Supply Company, Florida Sea Grant College, Center for Marine Conservation, Galveston Beach Preservation Committee, Louisiana Department of Natural Resources, Galveston Bay National Estuary Program, Mississippi-Alabama Sea Grant Consortium, Alabama Department of Economic & Community Affairs, Mississippi Office of Geology, Louisiana State University, Texas A&M University at Galveston, and Brown & Root, Inc.

This meeting generated a significant number of comments that were addressed in the present document. (See **Appendix D: Participants in the Action Agenda Development Process.**)

2 COASTAL & SHORELINE EROSION IN THE GULF OF MEXICO

What is Coastal & Shoreline Erosion?

Erosion is the wearing away of land by the action of natural forces. On a beach, erosion is the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

Erosion is a natural process that has affected the coastal environment for thousands of years. Coastal erosion is a major problem for developed shorelines everywhere in the world. In the U.S., coastal erosion is becoming more critical as it threatens buildings, transportation infrastructure, and environmental habitats, and as it gradually removes natural barriers that buffer the devastating effects of coastal storms.

Causes of Coastal & Shoreline Erosion

Beaches are dynamic systems. Major factors driving coastal change include sea level, sediment supply, and wave and tidal energy. A change in one of these factors can result in visible adjustments to the beach as it seeks a new balance with its physical environment. In a simplified sense, the rate and amount of beach adjustment are functions of the degree of change in its equilibrium factors.

Sea level is rising at a relative rate of about 0.3 m (1 ft) per century along U.S. coastal plains and at varying rates along other coasts. Due to the flat slope of much of the Gulf's coastline, even a relatively low rate of sea level rise can produce substantial shoreline erosion. The highest relative sea level rise rate in the U.S., approximately 1.2 m (3.9 ft) per century, may be found in parts of the Mississippi River delta, where land is also sinking (Titus, 1988).

Sea level rise tends to cause relatively gradual erosion at comparable rates over an entire region. On the other hand, sediment starvation can generate rapid erosion with intense localized effects. Much of this change is due to natural or human-induced gradients in longshore sand transport, which is driven largely by waves. Construction of dams and other river alterations can accelerate erosion by reducing the supply of sediment to the coastal zone. Because individual shoreline reaches often depend on a unique combination of sediment sources, including rivers, eroding bluffs and cliffs, and the continental shelf, any decrease in the supply from these sources may lead to erosion. Seawalls can cut off the sediment supply from eroding bluffs. Poorly designed projects involving groins, breakwaters, or jetties may divert, slow down, or trap moving sediment in their vicinity at the expense of the regional coastal sediment supply. Material dredged from coastal navigation channels and disposed offshore often constitutes a net loss to the coastal sediment supply.

Natural wave action and water level variations cause significant shoreline erosion. Although storms generate the most visible shoreline retreat, such erosion is often substantially "repaired" soon after the storm by the movement of sand back on shore from the same natural forces. Different shorelines are adjusted to different wave and storm climates. For example, whereas New England shorelines are subjected to frequent northeastern storms on an annual basis, Florida's Gulf of Mexico beaches may be most affected by hurricanes spaced decades apart. Changes in the average frequency or intensity of storm events can have a significant effect on shoreline change rates, and some scientists speculate such changes may occur if theories about global warming prove correct.

Responses to Coastal & Shoreline Erosion

The basic problem with responding to coastal erosion is the same one found in dealing with most environmental issues where humans are a significant causative factor; *i.e.*, there are often conflicting priorities that are difficult, if not impossible, to meet fully. For example, one priority may be the protection of coastal buildings, property, and infrastructure. In the U.S., development near the coast is often highly valued. This valuation can serve as a legitimate economic basis for justifying significant expenditures on erosion control measures. However, the most effective erosion control measures for a particular site may conflict with a second priority, which is preservation of recreational beaches and the natural coastal environment. Beaches are utilized and valued by the population at large, and they also serve as important habitats and as nesting areas for species as diverse as least terns and sea turtles. Shoreline erosion that removes beach material seaward of "permanent" human-made structures also removes valuable shoreline habitat that cannot be replaced through natural processes, as it typically would be if the structures were absent. Other erosion control measures may be less effective at dealing with the original problem and, therefore, may violate a third priority, which is the governmental imperative to get the most result for public funds invested in such projects. State or local policies may restrict the range of options available for dealing with an erosion problem, thereby creating constraints that amount to a fourth "priority."

The two principal approaches to reducing the impacts of coastal and shoreline erosion are stabilization and management. The two are not mutually exclusive; in fact, a combination of both often provides the best compromise among competing priorities. Stabilization consists of stopping or slowing the rate of erosion by employing structures, additional sediment, or a combination of structures and sediment. Vegetation can also be used as a stabilization project feature on the open coast or as a principal form of stabilization in sheltered waters. Management involves regulating land use, establishing and enforcing coastal construction standards, and providing for or requiring specific response options such as structure relocation.

Stabilization. Breakwaters, groins, revetments, and seawalls are the structural types most commonly used for shoreline stabilization on the open coast. Breakwaters function by reducing the wave energy impacting the shoreline, therefore lowering the ability of the waves to move sediment. Groins work by blocking the longshore movement of sediment, causing it to accrete or remain in place. Revetments are used to "armor" a shoreface, thereby protecting it from direct wave impact and resulting erosion. Seawalls serve an armoring function as well, although their main purpose is usually to reduce damage caused by storm surge and storm wave impacts on buildings and other property.

Within each structure type, a number of variations are possible. By altering design parameters such as length, spacing, height, porosity, and location, both breakwaters and groins can be configured to have more or less impact on coastal sediment movement. Although the most common form of construction is the engineered pile of rock called "rubble mound," breakwaters, groins, and revetments can be built using a number of material types and design approaches.

Providing additional sediment to an eroding stretch of shoreline is often a preferred way to arrest its recession. The most common method used in this approach is the beach fill project. Large quantities of sand are removed from offshore or inland sources and placed on the eroding beach by dredges or land-based earth-moving equipment. The result, usually in a few months, is a dramatically "restored" beach zone that often includes wide berms and high dunes to protect inland development against storm effects. Stabilization of eroding barrier islands by adding sediment may also be an effective way of preserving their function of sheltering interior shorelines and habitat from open-water wave impact, storm surge, and salt water intrusion. A less common method of providing additional sediment, at least on the Gulf Coast, is sand bypassing at tidal inlets. This technique involves the transfer of sand from one side of an inlet to another by a dredge or special plant in an attempt to emulate the natural transfer that would take place without jetties or artificially deepened channels. Unlike beach fill, this technique does not restore an eroded shoreline, but it may aid in stabilizing it.

Structures and beach fill often are used in combination, since their characteristics are complementary. Used alone, structures such as breakwaters or groins can "trap" moving coastal sediments at the expense of adjacent areas downdrift. Adding additional sediment to the structure field can help reduce or eliminate such effects. Conversely, a major beach fill project that incorporates breakwaters or groins will require less frequent renourishment and may provide a higher level of sustained protection to inland development. Fill in front of a revetment or seawall helps to ensure that such a structure remains intact for protection against more extreme events.

Vegetation should be considered as a critical feature of any Gulf stabilization project that includes dune construction or restoration. In addition to stabilizing recently constructed dunes, appropriate vegetative plantings can help build them by trapping wind-blown sand. Bay and estuary shorelines can be directly stabilized and even accreted through well-managed vegetation programs. Such plantings are often aided at the outset by low-cost structural measures designed to protect the young plants from direct wave attack until they become established. Following establishment, vegetative plantings need a program of regular maintenance.

Poorly conceived attempts at shoreline stabilization can create more problems than they solve. However, even proper design does not guarantee that stabilization will be an acceptable or even feasible alternative for a particular site. Structural stabilization methods tend to have high initial costs and may be viewed as aesthetically or environmentally undesirable. Beach fill requires periodic maintenance to deliver full recreational and protective benefits, and the large sources of beach quality sand needed for construction and renourishment are not always readily available. Beach fill projects can also raise environmental concerns about nearshore water turbidity, sedimentation on coral reefs and other biological resources, and impacts on sea turtle nesting.

Management. Management can reduce the impacts of coastal and shoreline erosion by helping to minimize the degree to which various resources are placed at risk. For example, setback lines are a common feature of many coastal zone management plans. These lines establish seaward limits for permitting various types of buildings and also may specify zones where no construction of any kind is allowed. Periodic review and re-establishment of setback lines help ensure that acceptable levels of erosion risk and resulting impact are maintained.

Construction standards are an important aspect of an overall risk management program, especially for single-family dwellings. Although building such structures to proper specifications will not ensure their habitability or survival once long-term erosion has progressed to a certain point, it can significantly reduce damages due to the short-term erosion and other effects generated by coastal storms.

Setback lines and construction standards work well to limit risk for new coastal development but do little to reduce impacts to existing buildings and infrastructure. Providing financial assistance for relocating or demolishing buildings endangered by coastal erosion can be an effective way to help implement a risk management program by giving existing property owners options other than total loss of their investment. For example, the 1988 Upton-Jones Amendment to the National Flood Insurance Act provided flood insurance payments for structures that are in imminent danger of collapse due to shoreline erosion. Homeowners can receive from the federal government up to 40 percent of the value of a house to relocate it further inland in an erosion-setback zone and up to 110 percent to demolish the house (National Research Council, 1990).

State-by-State Overview

All of the Gulf States have serious erosion problems. Rates of erosion vary greatly depending upon local shoreline characteristics and storm conditions. Parts of Louisiana retreat 19.8 m (65 ft) or more per year, while erosion rates of 4.5 m (15 ft) per year can be found in many other areas of the Gulf (Gulf of Mexico Program, 1991). Several rapidly eroding barrier islands are expected to completely disappear within the next 30 years (USEPA, 1991). Such islands are often the primary defense for wetlands, estuaries, and bays against storms and other open-Gulf effects. Quantifying coastal and shoreline erosion is difficult since long-term averages or trends can mask dramatic short-term reversals and cycles. Although some reaches of shoreline may appear stable or show slow accretion for certain periods of time, these conditions are rare in the long-term.

General historical shoreline trends are depicted by a map "Historical Shoreline Change in the Northern Gulf of Mexico" (available from the Gulf of Mexico Program Office). This map, which is a product of the Coastal & Shoreline Erosion Committee, summarizes average rates of change for Gulf shorelines over the periods for which reliable historical data are available.

The following brief description of erosion in each Gulf State is provided to give a simplified assessment of the magnitude of shoreline erosion throughout the Gulf of Mexico.

Alabama

Overview of the Problem. The Alabama coast stretches from eastern Dauphin Island to the western portion of Perdido Key and includes the shorelines of Mobile Bay and several other bays and sounds. There are about 75 km (47 mi) of shoreline which directly front the Gulf of Mexico. All of these Gulf of Mexico beaches are sandy. One interesting characteristic of the Alabama coast is that the beach sand color varies considerably. East of Mobile Bay Pass, in Baldwin County, the beach sands are a bright white, similar to the adjacent Florida panhandle. West of Mobile Bay Pass, on Dauphin Island, the beach sand is darker, more similar to the neighboring barrier islands of Mississippi. The geologic origin of the coast, particularly east of Dauphin Island, is complex and considered largely unknown. Likewise, the available data documenting historic shoreline change is limited when compared to that for the other Gulf States.

Alabama also has over 725 km (450 mi) of shoreline on bays, sounds, and coastal bayous. Mobile Bay, the eastern end of Mississippi Sound, and the western half of Perdido Bay are the largest estuaries in Alabama. About half of Alabama's total shoreline was eroding between 1917 and 1973, according to one study (Sapp, *et al.* 1975). The Alabama Gulf Coast encompasses three and a half tidal inlets, including one of the world's smallest inlets and one of the world's largest inlets. Human responses to erosion have included a wide variety of attempts at shoreline stabilization within the bays and rivers, but only a few attempts on Gulf beaches.

Gulf of Mexico Beaches. Alabama's Gulf beaches include the two coastal counties, Mobile and Baldwin. Mobile Bay Pass is the dividing line between the two counties. Dauphin Island is a 25 km (15 mi) long barrier island on the Gulf of Mexico west of Mobile Bay Pass. The eastern 6 km (3.7 mi) is several kilometers wide with a sand dune field with elevations of over 14 m (46 ft) above sea level and an extensive maritime forest. The western 19 km (11.8 mi) portion of the island is only several hundred meters wide and has maximum elevations of less than 3 m (10 ft) above sea level and no maritime forest. This low, narrow, western portion frequently overwashes in major hurricanes. Although the island has been continuously inhabited by descendants of Europeans since the 1700s, modern land development only began when the first bridge was built to the island in 1958. The western half of the island is still undeveloped. The western end of Dauphin Island has grown rapidly westward toward Mississippi. Westward accretion has averaged about 50 m/year (164 ft/year) since the turn of the century. Shoreline protection works built around the turn of the century to protect Fort Gaines, a Civil War era coastal fort, have prevented the eastern end of the island from eroding westward.

The easternmost 6 km (3.7 mi) of the island has two reaches of shoreline which are presently receding and a reach of shoreline in between them which is accreting. Recession was measured during 1991-1992 at rates up to 15 m/year (49 ft/year) (Douglass and Haubner, 1992). These changes are consistent with the changes that have occurred during the past decade. Averaged over the past decade, maximum recession rates are 6 m/year (19.7 ft/year). The recession-accretion-recession pattern at the eastern end of the island appears to be a response to changes in the position of the Mobile Bay Pass ebb-tidal shoals and ephemeral islands immediately offshore. Mobile Bay Pass is one of the world's largest tidal inlets. The shoals and islands (commonly called Sand or Pelican Island) provide both sand for the Dauphin Island beaches and wave sheltering to those beaches. The shoreline along the remainder of the beaches to the west appears to have been generally stable during the past decade.

The beaches of Baldwin County, while connected to the mainland geographically, have many characteristics of barrier islands with numerous ponds and tidal lagoons fronted by dune fields. These beaches have patterns of accretion, stability, and recession that vary in location and with time. Most of these beaches show relative stability or accretion from the mid-1800s to the mid-1900s (Stone, 1991), as well as during the past two decades. Exceptions to this are south of Little Point Clear on the Fort Morgan Peninsula and downdrift of Little Lagoon Pass where erosion is occurring. Historic rates of shoreline change are highly variable with time apparently because of repetitious foredune breaching and overwash during hurricanes. In Gulf Shores, Little Lagoon Pass connects the Gulf with Little Lagoon, a 12 km (7.4 mi) long by 1 km (0.6 mi) wide tidal lagoon. Prior to stabilization in 1981, the pass was ephemeral and had opened in several different locations. Since stabilization, at a width of 12 m (40 ft), the pass has remained open for tidal exchange

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Bays and Sounds. Shoreline erosion is apparent along many of the bay and sound shorelines of Alabama. Approximately 2 m/year (6.6 ft/year) of recession has been calculated for the northern shoreline of Mississippi Sound, the western shoreline of Mobile Bay, and the shoreline of Bon Secour Bay (north shore of Fort Morgan Peninsula). Peat outcroppings in the nearshore and tree root exposure are clearly evident along many of these shorelines. Erosion is generally less than 1 m/year (3.3 ft/year) along the eastern shore and the northern end of Mobile Bay (the "Mobile Delta") and the southern shoreline of Mississippi Sound (north side of Dauphin Island). These lesser, but significant, rates of erosion are also common along bayou and estuarine shorelines in the area.

Responses to Erosion. Most of the responses to erosion in Alabama have been along the bay and bayou shorelines. Many private homeowners have built vertical bulkheads. Along the more densely populated areas, including portions of the eastern shore of Mobile Bay, the City of Mobile, the north side of Dauphin Island, and around Perdido Pass, the shoreline is a series of nearly continuous, individual bulkheads. On Gulf of Mexico beaches, most construction is far enough landward of the shoreline to preclude erosion problems. Exceptions include a few private bulkheads at motels and condominiums in Gulf Shores, the jetty-caused erosion west of Little Lagoon Pass in Gulf Shores, and the eastern tip of Dauphin Island. Two successive beachfills have been recently placed in the Lagoon Pass erosion area. A rubble-mound seawall was built on the eastern tip of Dauphin Island around the turn of the century to protect Fort Gaines. An adjacent groin field has failed and is presently flanked. Several minor attempts at shoreline stabilization using other (not rubble-mound) construction materials have structurally failed and were, thus, fairly insignificant in affecting coastal processes.

*Florida**

***NOTE: This account is directly quoted from Balsillie and Clark (1992b) with the authors' permission.**

Overview of the Problem. The State of Florida has over 1,202 km (747 mi) of shoreline fronting directly upon the Gulf of Mexico of which about 671 km (417 mi) are sandy beaches. Of the sandy beaches, 309 km (192 mi) are currently experiencing problematic erosion, of which 163 km (101 mi) are considered critical, and 146 (91 mi) noncritical (Clark, 1991a). In addition, there are at least 5,028 km (3,125 mi) of bay and estuarine shoreline. Not counting river entrances of the Big Bend and tidal channels of the Ten Thousand Islands, Lower Everglades, and the Florida Keys, sandy beaches of the Gulf are affected by 55 barrier tidal inlets resulting, on the average, in an inlet for every 11 km (7 mi) of beach. Presently, except for the Apalachicola River entering the Gulf of Mexico near the east part of the Panhandle Gulf Coast, the rivers of Florida do not contribute appreciable quantities of sand-sized sediment to the state's coasts.

Typically, Florida's Gulf Coast beaches have long-term historical erosion rates of less than 0.5 m/year (1.6 ft/year). Many problem areas have erosion rates on the order of 1.5 m/year (4.8 ft/year), with an extreme erosion rate of 7 m/year (22.4 ft/year) occurring along the southern part of St. Joseph Peninsula. Most of Florida's beach erosion problems, particularly critical erosion, have resulted from stabilization, construction, and development of barrier tidal inlets. Many of the natural undeveloped inlets, being dynamic in their behavior, are also responsible for causing adjacent shoreline shifts viewed to be erosion. Of the 55 barrier beach tidal inlets along the Gulf, 36 have not been altered by humans (*i.e.*, no jetties and no maintenance dredging). Of the remaining, 19 have been dredged to maintain navigation channels, 17 have jetties or terminal groins, and 11 have bridges crossing them. To mitigate adjacent shoreline erosion, sand transfer projects have been conducted at 21 Gulf inlets. Coastal armoring, too, can complicate long-term shoreline behavior. However, except for Panama City Beach along the panhandle and highly developed barrier islands of the lower Gulf Coast, Florida's Gulf coastal regions are generally devoid of such structures.

The geology, physiography and erosional history of Gulf Coast Florida is highly variable. To facilitate more efficient discussion, Florida's Gulf Coast is divided into six general regions: Panhandle, Big Bend, Lower Gulf Coast, Ten Thousand Islands, Lower Everglades, and Florida Keys. These are for the most part further divided into subregions.

Panhandle Gulf Coast. Extending from the Alabama-Florida state line on the west to the mouth of the Ochlockonee River to the east, the panhandle has 351 km (218 mi) of sandy Gulf-fronting beaches and 13 barrier tidal inlets. There are, in addition, 1,358 km (844 mi) of interior bay and estuarine shorelines. On the basis of general shoreline shape, the panhandle can be divided into western and eastern segments, divided roughly in the vicinity of St. Andrews Bay East Entrance. To the west, the shoreline trend is arcuate but smooth; to the east shoreline azimuths change abruptly with peninsulas and barrier islands of varying physiographic form. On the basis on general physiographic factors, each segment can be further divided into two subsegments.

Western Barriers. The western 98 km (61 mi) of the panhandle is characterized by two barrier islands and interspersed beach ridge plateaus. Perdido Key, the westernmost island, is about 24 km (15 mi) in length, of which 20.3 km (12.6 mi) lie in Florida. To the east, Santa Rosa Island, 76.8 km (48 mi) in length, is the longest unbroken barrier island along the Gulf Coast of Florida. These barriers range from 150 to 1000 m (500 to 3,250 ft) in width with dune heights averaging +5 m (17 ft) mean sea level (MSL). Maximum dune crest elevations of up to +12 m (40 ft) MSL can be found. Net sediment transport along these barriers is westward, although a west-east reversal is evident along the eastern tip of Perdido Key (Stone, 1991; Stone, *et al.*, 1992). Erosion occurs along the eastern end of Perdido Key and western end of Santa Rosa Island (Balsillie *et al.*, 1986a, 1986b) ranging from about 1 to 1.5 m/year (3 to 5 ft/year) and has been attributed to historical, repetitious overwashing during hurricanes (Stone and Salmon, 1988) and an increasing wave energy gradient particularly along western Santa Rosa Island (Stone, 1991; Stone *et al.*, 1992).

Middle Mainland. To the east of Santa Rosa Island and East Pass lies a 81.4 km (50.6 mi) reach of mainland coast, an unusual feature in Florida coastal physiography. Back beach primary dunes along this mainland reach attain elevations of from 3.6 to 13.7 m (12 to 45 ft) and beach widths average 60 m (200 ft) (Fischer *et al.*, 1984). Upland coastal terrain is drained by a number of streams flowing to the Gulf from a series of small to medium-sized freshwater lakes. These seasonal outlets are periodically closed due to predominantly westward longshore sediment transport (Stone, 1991). With the exception of relatively short reaches of slight, noncritical erosion near Navarre Beach and just east of East Pass, the reach, extending 57 km (35.5 mi) west of East Pass to 52 km (32.3 mi) east of East Pass, is the longest [109 km or (67.6 mi) total] stable segment of beach long the Gulf Coast of Florida. However, extreme event impacts have resulted in significant dune erosion and associated coastal recession (*e.g.*, Chiu, 1977; Balsillie and Clark, 1979; Balsillie, 1985c; Balsillie *et. al.* 1986a, 1986b).

East from Lake Powell, the shore is characterized by mainland beaches to the vicinity of Panama City Beach where a barrier spit has formed, trending to the southeast across the entrance to St. Andrews Bay. This barrier spit has been bisected by the dredging of an artificial channel (St. Andrews Inlet) for navigation into St. Andrews Bay, creating Shell Island which extends to the east for about 10 km (6.2 mi). New longshore transport of the panhandle west of the inlet is to the west with reversals occurring on a sub-seasonal time framework (Balsillie, 1975, 1977). West of St. Andrews Inlet the barrier spit ranges in width from about 396 to 457 m (1,300 to 1,500 ft), while Shell Island to the east ranges in width from 182 to 1,220 m (600 to 4,000 ft). New westward longshore transport from St. Andrews Inlet and the historic practice of periodically depositing channel maintenance dredging material offshore have resulted in critical erosion for 11 km (7 mi) west of the inlet. Historical erosion reaches a maximum of 2.4 m/year (8 ft/year) about 1.8 km (1.1 mi) west of the inlet (Balsillie *et al.*, 1986a, 1986b). Stapor (1973a) identified a drift divide just east of St. Andrews Inlet with net easterly transport occurring along most of Shell Island. Measured erosion rates (Balsillie *et al.*, 1986a, 1986b) along the island range between 0.5 m/year (1.7 ft/year) to 2 m/year (6.4 ft/year).

San Blas Realignment. Immediately east of Shell Island is an area of confluence of two longshore transport cells. To the southeast, along Crooked Island, net longhore transport is to the northwest. Southeast of Crooked Island is another mainland reach along which net transport is to the southeast (Stapor, 1973a). St. Joseph Peninsula to the south, 27 km (17 mi) in length, is a barrier spit of recent geological age. The spit extends west from the mainland for about 5 km (3 mi) where it forms Cape San Blas, then trends in a north-south direction. St. Joseph Peninsula ranges in width from less than 182 to 1,402 m (600 to 4,600 ft) and is subject to overwash and breaching along several narrow reaches. Primary dunes range in height from 1.5 to 11 m (5 to 37 ft) with beach widths ranging from 21 to 152 m (70 to 500 ft). Except for the northern 3.5 km (2.2 mi) which is accreting, the peninsula is eroding (Stapor, 1971; Tanner, 1975; Balsillie, 1985a; Clark, 1991a), with the most extreme erosion rate fronting the Florida Gulf Coast occurring at Stump Hole, along the southern part of the peninsula just north of Cape San Blas, at 9 m/year (31 ft/year) (Balsillie, 1985a). Cape San Blas lighthouse has been relocated six times to eastern sites since its original construction (Tanner, 1975). Sensitivity of shoreline change to storm tides and wave conditions has been witnessed during two hurricanes in 1985, when 762 m (2,500 ft) of the southward projecting cape disappeared (Clark, 1986). An alongshore drift divide has been identified somewhere along the southern one-third of St. Joseph Peninsula (Stapor, 1971) with St. Joseph Point (north end of the feature) accreting northward due to erosion north of the divide and southerly transport south of the divide contributing sand to the extensive shoals off of Cape San Blas.

Apalachicola-Ochlockonee Barriers. To the east of Cape San Blas, historical rates of accretion are as high as 19 m/year (61 ft/year), suggesting a significant net eastward transport of Cape San Blas sediment. The mainland segment spans 4.7 km (2.9 mi) of coast east to Indian Peninsula, a 4.8 km (3 mi) eastward extending spit. East of Indian Peninsula lies St. Vincent Island, a triangularly shaped barrier comprised of a unique complex of multiple beach ridges trending generally southeast to east-southeast. To the east, St. Vincent Island is the barrier island complex of Little St. George and St. George Islands which is about 47 km (29 mi) long and ranges from 335 to 1,609 m (1,100 ft to 1 mi) in width. Little St. George was once a separate island that is now part of St. George Island. Along an approximate 10.5 km (6.5 mi) reach of western St. George Island, erosion appears to exceed 2 m/year (6.5 ft/year).

Westerly directed net longshore transport occurs along this erosional reach which is bisected by a small human-made jettied inlet (Bob Sikes Cut). East of St. George

Island, and separated by 3.2 km (2 mi) wide East Pass, lies Dog Island, the easternmost coastal barrier island in the northern Gulf of Mexico. Irregularly shaped Dog Island is 11 km (6.9 mi) long with narrow western and broad eastern segments. Two low and narrow areas along the western portion of the island are less than 150 m (500 ft) wide and subject to inundation and breaches from even moderate storm impacts; the eastern segment attains a width of about 1,311 m (4,300 ft). Net longshore transport is bidirectional along the island with the dominant transport occurring westward toward the narrows and eastward near the broadest reach. Long-term trends suggest a maximum erosion rate of over 2 m/year (6.5 ft/year), although more recent data suggest an acceleration in the erosion rate to perhaps 6 m/year (20 ft/year) (Clark, 1986). The easternmost segment of the panhandle region is a mainland peninsula, known as St. James Island, which lies between the Gulf and Ochlockonee Bay. The eastern end of the peninsula extends for a distance of 5.5 km (3.4 mi) from Bald Point southward to Lighthouse Point. From Lighthouse Point, a recent barrier spit extends for about 8 km (5 mi) to the west past Southwest Cape, and terminating in Alligator Point. New longshore transport is to the west along the barrier spit. The reach between Southwest Cape and Lighthouse Point constitutes perhaps the most critical erosion reach along the panhandle. Severe erosion and costly property and structural damages have been incurred by a number of storms during the past 30 years (Clark, 1986).

Big Bend Gulf Coast. The Big Bend is defined as a low to zero wave energy shore (Tanner, 1960) stretching for some 386 km (240 mi) from Ochlockonee Bay to Anclote Key just north of Tampa. It is unique because of its marsh-dominated open-marine character, very wide and shallow fronting shelf, highly crenulated shoreline shape with thousands of creek outlets and embayments, and general lack of beach sands. Concerted geological exploration of the Big Bend is just beginning (*e.g.*, Hine and Belknap, 1986; Hine *et al.*, 1988) with a cooperative effort organized by the University of South Florida, Florida Geological Survey, and the U.S. Geological Survey (USGS). Of the 390 km (241.8 mi) of shoreline (measured "as the crow flies"), only 11.9 km (7.4 mi) have quartz sand beaches. Mashes Sands just north of the Ochlockonee Bay entrance (Clark, 1991b), Shell Point along the northern extremity of the Big Bend, and the Cedar Keys (including Seahorse Key and North Key) and Pine Island along the eastern flank of the Big Bend, represent the major localized deposits of quartz sand beaches along the reach. Of the 11.9 km (7.4 mi) of beach, Clark (1991a) reports that 6.8 km (4.2 mi) are experiencing erosion, of which 4.8 km (3 mi) are critical and 1.9 km (1.2 mi) are noncritical.

Lower Gulf Coast. The barrier islands of the lower Gulf Coast constitute a near continuous chain extending from Anclote Key to Cape Romano, a distance of 295 km (183 mi). Barriers have not formed to the north of Anclote Key due to the lack of sand and low wave energy. There is one sound [7.7 km (4.8 mi)], one mainland reach [5.6 km (3.5 mi)], one relict upland coast [17.9 km (11.1 mi)], and 41 inlets, which are indicative of the number of barrier islands found in this region. The majority of the lower Gulf Coast is characterized as having moderate wave energy shores (Tanner, 1960), although northern and southern areas grade to low wave energy. However, a significant characteristic of the entire reach is that calm seas prevail for up to 30 percent of the average year.

Northern Barriers (Anclote Key to Tampa Bay). Until recently, the lower Gulf Coast of Florida was one of the least studied coasts in the nation. While much of this region as yet requires study, the barrier islands north of the entrance to Tampa Bay have undergone extensive geophysical studies. From Anclote Key to Tampa Bay, there are 14 barrier islands and 11 tidal inlets. With no new sediment being supplied to the beaches, these coastal barriers are comprised of a relatively thin sand lens lying on top of limestone; the sand lens thins and pinches out within 488 m (1,600 ft) of the beach (Davis *et al.*, 1982; Evans *et al.*, 1985). Of the barriers, Three Rooker Bar and North and South Bunces Keys are the youngest, having evolved within the past 20 years. Since 1980, at least five inlets have opened naturally while three others have closed. Most of the islands are erosional with at least 45 km (28 mi) of the 68.7 km (42.7 mi) of beach (about 65 percent) considered to be erosion problems (USACE, 1984a, 1984b; Clark, 1991b). Net longshore transport volumes are slight and generally to the south, although local reversals do occur (Balsillie and Clark, 1992b). Sand Key, the longest barrier island north of Tampa Bay with 22.9 km (14.2 mi) of beach, is the site of several beach restoration projects; also restored are beaches of Treasure Island and Long Key lying to the south of Sand Key.

Middle Islands (Tampa Bay to Charlotte Harbor). From Tampa Bay entrance south to Charlotte Harbor, a distance of about 98 km (61 mi), are low-lying barrier islands which for the most part are long and narrow. Wave energy is moderate (Tanner, 1960), and longshore transport, except for localized influences of some inlets, is to the south. Near the middle of the reach, just to the south of Venice Inlet, lies a 5.6 km (3.5 mi) long mainland beach. Lido Key, near the north central part of the area, is a human-made island which has also received beach renourishment, while Don Pedro Island was within recent times 4 separate keys. Siesta Key, to the south of Lido Key contains Point O'Rocks with a 550 m (1,800 ft) ledge of rock extending into the surf. Seismic profiling north of Tampa Bay Entrance (Davis and Kuhn, 1985) and in the Charlotte Harbor area (Evans and Hine, 1986) indicates that the location of barrier islands and hence tidal inlets is at least partly controlled by irregular bedrock topography (Gibeaut and Davis, 1988) and that the coastal barriers and beaches are comprised of a relatively thin layer of fine quartz sand with only limited seaward extent. However, such extrapolation can be made only in the most generalized sense, since the reach requires more extensive geological investigation. Longshore transport volumes are slight and generally to the south. Clark (1991a) has determined that 52 km (32 mi) of beach (52 percent of the total beach length) along this reach is currently experiencing problematic erosion (USACE, 1980, 1984c, 1984d, 1991a, 1991b). Beach restoration is being conducted along the central part of Anna Maria Island (the northernmost key) and other projects are planned for Longboat Key and Venice.

Charlotte Harbor Complex (Charlotte Harbor to San Carlos Bay Entrance). From the northern extent of Charlotte Harbor at Gasparilla pass south, a distance of 59.5 km (37 mi), lies a sequence of five coastal barrier islands separated from the mainland by the wide bodies of water of Charlotte Harbor, Pine Island Sound, and San Carlos Bay. Within Pine Island Sound lies Pine Island, a large feature about which curves Sanibel Island, the southernmost of this Gulf-fronting coastal barrier island group. These islands range in length from 6.6 to 21 km (4.1 to 12.9 mi), in width from 60 to 4,000 m (200 to 13,000 ft), and have peak coastal elevations of from 1 to 3 m (3 to 10 ft) (Fischer *et al.*, 1984). Wave energy is moderate (Tanner, 1960). Longshore transport processes operate within a series of partially integrated cells (Harvey, 1979).

While the sedimentary environment is currently dominated by sand, the proportion of shell fragments is significant and relatively rare in the southeastern U.S. These sediments have formed the beach ridges by both longshore and onshore sediment transport process (Stapor *et al.*, 1987). High resolution geophysical studies are needed to determine the depth and extent of sand volumes comprising these barriers as well as their offshore extent. Clark (1991a) has determined that 27.4 km (17 mi) of Gulf-fronting beaches of these barriers are experiencing problematic erosion (USACE, 1969; Coastal Planning and Engineering, 1989). The erosion areas are largely confined to the north end of Sanibel Island and islands to the north, with the southern 17.7 km (11 mi) of Sanibel Island being stable to accreting. Note, however, that the entire length of Captiva Island's beach has been restored.

San Carlos-Estero Reentrant (San Carlos Bay Entrance to Gordon Pass). The coast from just south of San Carlos Bay to Wiggins Pass, a distance of 46.7 km (29 mi), is unique by virtue of its change in physiography from north to south. The northern 20 km (12 mi) is characterized by a group of low-lying, narrow islands, of which all but two are small, tightly-packed, and mobile. This reach contrasts with barrier islands farther to the north because: (1) it is sheltered from northwest approaching waves by Sanibel Island, and (2) bays behind the coastal barriers are much smaller and, hence, so are the associated 5 inlets (Hine, 1987). The bay backing the coastal barriers becomes gradually, but distinctly, constricted toward the south where it loses continuity just to the south of Wiggins Pass. Continuing south to Doctor's Pass, some 10 km (6.4 mi), the coast embodies a line of small, discontinuous back-beach water bodies (except where dredged for marinas). Wave energy is moderate to low (Tanner, 1960) with longshore transport small and to the south except for reversals along the northern part of the reach. Beaches along the reach are continuous but narrow, and Clark (1991a) reports that 26 km (16.2 mi) of beach are experiencing problematic erosion due not to a high rate of shoreline change but to the degree of threat to adjacent development (USACE, 1972).

Southern Barriers (Gordon pass to Cape Romano). To the south of Gordon Pass, the coast is again characterized by a chain of six recognized barrier islands with at least eight tidal inlets (inlets frequently open and close along this segment). This southernmost reach of the lower Gulf Coast extends south a distance of about 32 km (20 mi). Wave energy is low (Tanner, 1960), with slight net longshore transport to the south except for local reversals. With the exception of Marco Island's restored beaches, the beaches of this segment are narrow with about 65 percent [20 km (12.5 mi)] of the total beach length currently experiencing problematic erosion (USACE, 1972; Clark, 1991a). These coastal barrier islands constitute the southernmost extent of significant amounts of accumulated sand sediments.

Ten Thousand Islands. Appropriately named, this remote group of essentially uncharted islands is concentrated along 39 km (24 mi "as the crow flies") of Florida Gulf Coast reaching from the lee of Cape Romano south to Pavilion Key and occupying a coastal band about 6.4 km (4 mi) in width. White (1970) notes that the reach differs from sections both north and south and seems to be a gradation between them. Those islands of the group fronting directly on the Gulf, built over the past 3,000 to 5,000 years, are the result of vermetid reefs (Shier, 1969). These colonizing reefs formed the core of the outer islands, which have trapped quartz sand transported across Gullivan Bay from shoals south of Cape Romano (Davis, 1940; Scholl, 1964; Shier, 1969). More interior islands are long, narrow, and twisted oyster bars and indian middens (Parkinson, 1989) which to some extent entrap sediments. Both low-lying island types are vegetated by mangroves and lie atop bedrock limestone (Lane, 1981). Changes in shoreline configuration of the Gulf-fronting islands have never been monitored. However, based on geological evidence, Shier (1969) has noted that storms and hurricanes have caused erosion and that during the past three centuries vermetid reefs have eroded faster than vermetid growth could build new reef. While the outer islands maintain themselves by mangrove and sand migration on their lee sides, they have moved "bodily" toward the mainland. In the absence of any monitoring and quantitative information, geological evidence suggests that erosive forces are slowly at work.

Lower Everglades Gulf Coast. This remote and unique coastal segment extends some 80 km (50 mi) from the vicinity of Pavilion Key at the south end of the Ten Thousand Islands, southeast to East Cape. It is the southwest drainage terminus of the Everglades and Big Cypress Swamp. The entire reach is characterized by low wave energy which increases to the south. Coastal surface sediments are exclusively mud and shell which extend to depths of 3 to 4.5 m (9.6 to 14.4 ft) below MSL and give way to peats and freshwater carbonates in the landward direction (Roberts *et al.*, 1977).

<u>The Sloughs Debouchure.</u> At one time, the entire lower Everglades reach was more homogenous in physiography and mangrove vegetation, similar to that found along Florida Bay. However, over about the past 3,000 years, erosion along the northern portion of the reach and southerly directed longshore transport has resulted in a retreating shoreline (Gleason *et al.*, 1974) along the northern 65 km (40 mi) and deposition along the southern 15 km (9.3 mi). The northern area, which White (1970) termed the "debouchure of the Everglades Sloughs" with its numerous mangrove islands and tidal creeks, is largely characterized by low-lying steep mud banks vegetated by a fringing mangrove forest up to 195 m (640 ft) in width and by a few discontinuous narrow beaches of shell sediments. (Note,

however, that beaches along this reach have not been inventoried). The mangrove forest, attaining heights of 15 m (48 ft), is distinctly zoned with red mangroves along the shoreline and black and white mangroves in the upland forest interior. Although it is known to be subject to erosion, this coast has never been monitored, and no quantitative rate of erosion is available.

Cape Sable. Along the southern 15 km (9.3 mi) of the reach lies Cape Sable, the best developed regressional feature on the south Florida coast. The Cape prograded up to 8 km (5 mi) (Enos and Perkins, 1979), achieving its present status about 1,200 to 1,500 years ago (Roberts *et al.*, 1977). Cape Sable is comprised of three capes (Smith, 1968), which are composed of shell beaches with southeastward longshore transport and which are linked by narrow shell beaches. Older beach ridges lie behind the present beaches, are composed of carbonate-mud material (Gleason *et al.*, 1974), and vegetated with succulents, grasses, and palms with the most landward ridges having a dense hammock vegetation (Roberts *et al.*, 1977). Cape Sable beaches have not been monitored to determine quantitative rates of shoreline behavior and even information to guess at the stability of the reach is not available.

Florida Keys. The Florida Keys, which stretch for over 354 km (220 mi), are an elongated, arc-shaped archipelago separated from the mainland by Florida Bay, a broad but shallow water body compartmentalized by numerous carbonate mud banks. The Keys were formed as the result of the last major drop in sea level which exposed the ancient coral reefs. Those keys considered to front directly on the Gulf of Mexico include the northern shores of the "Lower Keys" and the three distal sandy island groups to the west. The "Upper and Middle Keys" front not on the Gulf, but on Florida Bay and the Straits of Florida, and are comprised of coralline limestone.

Lower Keys. Although the most significant carbonate beaches and dunes of the "Lower Keys" front on the Straits of Florida, several locally significant beaches are found along the "back country" islands of the "Lower Keys" fronting the Gulf. Sedimentation here is due to the entrapping capability of marine grasses and algae. Beach sediments consist primarily of calcareous green algae, limestone fragments, and a variety of mollusks and foraminifera (Jindrich, 1969). Such beaches found along Mud Key, Snipe Point (Snipe Key), Marvin Key (Barracuda Keys), Sawyer Key, and the Content Keys, total about 1.9 km (1.2 mi) in length and average 8 m (25.6 ft) in width. Coastal processes have not been documented for these beaches, but it is thought that the direction of net annual longshore sediment transport is to the southwest.

Distal Keys. Beaches of the three island groups west of Key West have not been studied except in terms of general physiography (Davis, 1942; Stoddart and Fosberg, 1981) and petrography (Ginsburg, 1979). The outer island group (unnamed) nearest Key West and the Marquesas Keys is located 29 km (18 mi) west of Key West and has calcareous sand beaches averaging 7.5 m (25 ft) in width (Clark, 1990a). Beach sediments are comprised of calcareous skeletal fragments of green algae and oolitic sand. Net longshore sediment transport directions vary according to the beach alignment and exposure to wave activity. While shoreline stability is apparent in most areas during the 50 years since Davis conducted his study, significant beach losses have occurred due to the "quiet invasion" of mangroves (Clark, 1990a). Although the length of the outer island beaches nearest Key West is over 4.2 km (2.6 mi), these front on the straits of Florida. The northern shores of these islands appear to be stable mangrove shorelines. The cumulative length of the beaches of the Marquesas Keys is nearly 7.2 km (4.5 mi). Long Beach Key, with over 4 km (2.5 mi) of continuous Gulf beach front is the longest and largest of all the islands west of Key West. Beach sediments are predominantly green algae fragments, a material which is readily produced in the adjacent waters. The dune ridge is stabilized by one of the densest communities of sea oats found along Florida's beaches. The most remote beaches of Florida are those of the Dry Tortugas or Tortugas Keys, which are located about 105 km (65 mi) west of Key West. All six islands of this group have beaches which cumulatively measure 7.2 km (4.5 mi) and are comprised largely of coral fragments as well as green algae. The nearly 3.2 km (2 mi) of beach on Loggerhead Key (the farthest west of all the Tortugas Keys) characterize perhaps the highest wave energy conditions south of Cape Romano. The steeply sloping beaches of Loggerhead Key and Sand Key are fronted by a developing beachrock of calcareous sand which Ginsburg (1979) describes as the only occurrence of marine beachrock in the continental U.S. Beach processes of the Dry Tortugas are generally unresearched and in need of further study to determine erosion/accretion patterns and longshore transport processes.

Historical Shoreline Change Data. Determination of long-term coastal behavior to be pursued and applied in regulating coastal excavation and construction activities in Florida became a mandate of the Florida State Legislature pursuant to the Growth Management Act of 1985. Adopted provisions are set forth in an amendment to the Beach and Shore Preservation Act, Section 161.053, Subsection (6) of the Florida Statutes. Pursuant to requirements of this law, the methodology for procuring and analyzing data, interpreting and accepting results, and application of results are formalized by rule published in Chapter 16 16B-33 of the Florida Administrative Code (Balsillie and Moore 1985; Balsillie, 1985b).

Louisiana

Overview of the Problem. The Mississippi River built the coastal wetlands of Louisiana by taking enormous amounts of sediment eroded from the interior of North America and depositing the material in delta lobes where the river enters the Gulf of Mexico. As the river built its delta in this manner, it lengthened its own route to the Gulf, making it increasingly less efficient hydraulically. Approximately once every thousand years, the river would not return fully to its channel after the annual flood, but instead would establish a new, more efficient route to the Gulf. As the river developed this new route over several flood seasons, it would send less water and sediment down the old route. The old delta, abandoned by the river, would begin to lose land to the Gulf as a result of subsidence (consolidation of underlying soil strata) and Gulf tides, waves, and currents. Meanwhile, the delta at the mouth of the new route would begin to grow. For the last several thousand years, the natural processes were in approximate equilibrium, creating a coast composed of wetlands in all stages of building and loss and an ecosystem of tremendous diversity and productivity.

The natural processes were at odds with humans' desire to inhabit and develop the resources of coastal Louisiana. In the eighteenth century, when Europeans began settling in significant numbers in the Lower Mississippi Valley, they began constructing levees to contain the Mississippi River. In the nineteenth century, when the commercial navigation potential of the river became apparent, Congress initiated actions to clear the Mississippi and maintain it for navigation. In the twentieth century, oil and gas exploration, land reclamation projects, and construction of ports and channels along Louisiana's coast further developed the economic potential of coastal Louisiana. The state and the nation benefited greatly from these developments, but at a very high cost to Louisiana's coastal wetlands.

Today, flood control projects (such as levees) ensure that most sediment now bypasses the areas where it would naturally build and nourish wetlands. As a result, soil deposits no longer compensate for the effects of natural subsidence. These conditions are compounded in many locales where channels dredged for navigation or oil and gas exploration allow salt water to penetrate far inland. In other areas, urbanization, highways, and spoil banks from channel dredging disrupt natural drainage. Stressed by these changes in hydrology or salinity, hundreds of thousands of acres of vegetated wetlands have been lost. In addition, the land--no longer held together by a living root system--has eroded.

Only a small amount of current annual losses results from new human activity in the coastal zone. Through actions taken by the state, private landowners, and industry, the number of coastal wetlands acres destroyed for development under permit has dropped from 1,214 hectares/year (3,000 acres/year) in 1980 to less than 81 hectares/year (200 acres/year) during the 1990s. The vast majority of losses occurring today are the result of continuing, long-term impacts of actions taken by humans decades earlier.

The net impact of human activities on Louisiana's coastal wetlands is that, instead of a natural equilibrium between gain and loss, today the coast has a net loss of some 64.8 km^2/year (25 mi^2/year). Louisiana, which contains about 40 percent of the coastal wetlands in the lower 48 states, is suffering 80 percent of all coastal wetlands losses. While the deteriorating system is highly productive today, the long-term prospect is for catastrophic decline in the economic and other values of the ecosystem and a future shoreline far inland of its present location.

These losses will have impacts well beyond the borders of Louisiana. Populations of migratory birds and other animals, which are directly dependent on the marsh and swamp lands, will decrease dramatically. The impact on commercial fisheries alone will be enormous: projections indicate that by the year 2040, the harvest will have declined by 70 percent. Foreign sources will likely replace this lost production, as is presently the case for some shellfisheries, further aggravating the nation's trade deficit and placing at risk the nearly 50,000 jobs directly related to fishing, processing, and wholesaling activities.

A number of other food staples and basic minerals, such as sugar, rice, salt, sulfur, and lime, are also produced in coastal Louisiana. Lost or reduced production of these basic items will impact national markets.

Flood control works comprising a national investment of nearly $12 billion protect much of the infrastructure in the coastal area. Because the surrounding marshes are integral to the design of these works, continued, substantial loss of wetlands will require that levees and other structures be enlarged or relocated. Outside existing lines of protection, highways, ports, waterways, railroads, pipelines, and other utilities will need to be relocated, or experience major escalations in maintenance and replacement costs. As the coast deteriorates, billions of dollars of infrastructure could be surrendered to the Gulf of Mexico and billions of dollars more spent protecting the remainder.

Responses to Erosion. Several basic approaches using natural processes can be employed to promote optimum benefits from the ecosystem.

- **Creation.** New wetlands can be built on a large scale by making maximum use of the sediment resources of the Mississippi and Atchafalaya Rivers and, on a smaller scale, through use of dredged material and trapping of longshore sediment.

- **Restoration**. Freshwater can be added, salt water blocked, and dredged material banks breached in order to restore the hydrologic conditions which existed before construction of channels and other structures.

- **Protection**. Vulnerable marshes can be protected by repairing and strengthening the landforms which compose the natural skeleton of the region--barrier islands, shorelines, and distributary ridges. Protection also can be accomplished by control and management of particular stresses, such as herbivory.

- **Enhancement**. Overland flow and sinuous channel flow--the natural hydrologic processes of the wetlands--can be promoted where possible, while active management of water levels can be undertaken where necessary.

Different mixes of these approaches are appropriate for different locations, and separate but integrated plans can be prepared for the nine hydrologic basins that make up coastal Louisiana. Individual potential basin strategies are summarized below.

Pontchartrain Basin. In the Pontchartrain Basin, construction of the Mississippi River levees has greatly altered the natural hydrology, depriving the basin of periodic inputs of fresh water, sediments, and nutrients. Further changes arose with the construction of the Mississippi River-Gulf Outlet, a deep-draft navigation channel, which elevated salinities in portions of the basin A strategy for this basin can center around restoration of the hydrologic balance through introduction of Mississippi River water or through reduction of tidal inflow via the Mississippi River-Gulf Outlet and through maintenance of the Lake Borgne/Lake Pontchartrain and Lake Pontchartrain/Lake Maurepas natural land bridges.

Breton Sound Basin. This basin suffers from a lack of freshwater input and extensive saltwater intrusion. A strategy for the Breton Sound Basin can involve construction of new, and outflow management of existing, freshwater diversion projects (such as the USACE project at Caernarvon, completed in 1991). Additionally, the feasibility of developing new barrier islands near the existing shoreline to protect adjacent wetlands can be investigated.

Mississippi River Delta Basin. Wetlands loss in the Mississippi River Delta Basin results primarily from subsidence and compaction. The current sediment inputs from the river are not sufficient to balance this loss. Large-sale, controlled diversion of the river could be employed to most effectively utilize its valuable sediment load. However, implementation would require detailed analysis of its effect on existing economic activity, especially navigation on the river and on federal and state-owned wildlife lands.

Barataria Basin. This basin suffers from being cut off from the river's freshwater and sediment inputs by flood protection levees. Additionally, the increasing tidal prism may be the most significant mechanism by which wetlands are lost in the Barataria Basin. A strategy for the basin could focus on use of existing and proposed freshwater diversion projects to deliver sediments and nutrients, reduction of tidal exchange between the upper and lower basins, maintenance of the existing chain of barrier islands, and maintenance and enhancement of the fringing marshes in the basin.

Terrebonne Basin. Parts of this basin suffer from subsidence and isolation from inputs of freshwater and sediments. Saltwater intrusion is a significant cause of wetland loss in these areas, as are historic oil and gas activity and natural deterioration of the barrier islands. Other areas have experienced substantial freshwater inputs from the Atchafalaya River and are undergoing stress from high water levels. The wide range of problems in the basin requires a strategy of similar scope. Potential features of a plan for this basin include the following: managing high water levels in the upper basin; developing sources of freshwater and sediment for exploring the potential of the Gulf Intracoastal waterway as a freshwater and sediment conduit; and restoring of the barrier islands to provide increased protection from the natural forces of the Gulf of Mexico.

Atchafalaya Basin. The Atchafalaya basin is unique in that it contains a growing delta which has only recently (1973) emerged above the waters of the bay. A basin restoration strategy would probably emphasize delta growth in a manner consonant with the needs of navigation and flood control.

Teche/Vermilion Basin. This is a relatively stable basin which has reached the endpoint of typical deltaic evolution. A strategy here would likely concentrate on protecting against shoreline erosion.

Mermentau Basin. The upper part of the basin suffers from high water levels that stress marshes and contribute to erosion of lake shorelines. Additionally, bank erosion is a problem along waterways in the basin. The lower basin is affected by shoreline erosion, reduced freshwater input, and hydrologic alterations (largely as a result of agricultural and oil and gas activities). A basin strategy could emphasize management of the freshwater resources to reduce stages in the upper basin and increase input to the lower basin. Critical areas of bank erosion would also be addressed.

Calcasieu/Sabine Basin. The hydrology and saltwater regime of this basin were radically altered by construction of the Calcasieu Ship Channel, the Sabine-Neches Waterway, and the Gulf Intracoastal Waterway. A strategy could center around a perimeter defense for the interior marshes, a plan that provides protection against salt water and high water levels through a series of hydrologic restoration projects. The strategy could also include shoreline protection along the Gulf of Mexico and bank protection on the Gulf Intracoastal Waterway.

Mississippi

Overview of the Problem. In Mississippi, the shorelines of all the barrier islands have experienced significant erosion. The beaches of the mainland Gulf shoreline of Mississippi have been lost and rebuilt several times in the last fifty years and significant erosion is occurring along the remaining shorelines (Campbell, 1990).

Comprised of barrier islands, tidal inlets, beaches, and estuaries, the Mississippi Gulf Coast is constantly undergoing environmental and physical changes. Its classification as a micro-tidal, storm-dominated coastline suggests that the occasional short-lived storm events play a significant role in shaping the coastal configuration.

The sea level rise of the past 18,000 years has continually changed the shape and location of the Mississippi coastline. If the present world-wide rise in sea level continues or accelerates, the low-lying delta area of the Pearl and Pascagoula Rivers will be the most severely impacted. The result would be a loss of vast areas of wetlands. Sediment deficiency is another important factor in the Mississippi coastal erosion scenario. Sediment removal from the active nearshore environment by natural processes, such as storm surges and longshore transport, and human activities such as dredging, river damming, and coastal armoring contributes to the general eroding of the shoreline.

Hancock County. Hancock County has two shoreline types along its 32 km (20 mi) coastline. From the Pearl River boundary with Louisiana east to Bayou Caddy the shore consists of natural salt tidal marsh. Portions of this 19.2 km (12 mi) section of coastline have retreated at an average rate as high as 3.9 m/year (13 ft/year) over the last 70 years. From Bayou Caddy east to St. Louis Bay, the shoreline is armored with a seawall constructed from 1915 - 1928. A 9.6 km (6 mi) beach pumped in place to protect the seawall in 1966 has been eroded to only a few remnant pocket beaches despite a renourishment in 1972. Seawall failure and collapse of adjacent Beach Boulevard in several places has prompted a rebuilding of this beach scheduled to begin in the fall of 1992.

Harrison County. The mainland Harrison County shoreline consists of a seawall fronted by 41.6 km (26 mi) of artificially maintained sand beach. The beach was constructed in 1952 to protect the seawall and has been maintained since that time by renourishment from offshore sources. Approximately 650,165 m^3 (85,000 yd^3/year) of sand is lost from this beach due to wave erosion, longshore drift, and aeolian losses. Pilot projects are now underway to stabilize the beach with salt tolerant grasses and dune formation. This beach is a major tourist attraction, and human impacts require continual mechanical maintenance to keep the beach free of trash and debris. The major port of Gulfport is located in the central portion of this shoreline.

Jackson County. Jackson County contains three basic shoreline regimes. The western third is a natural shoreline with single family home sites, where erosion threatens to undermine numerous homes. The central portion contains the Pascagoula River Delta and the major port of Pascagoula, which is modified and maintained by heavy industry. Extensive dredging of channels here may be contributing to the erosion down-drift to the west. The eastern third of the Jackson County coast is a natural salt marsh which is rapidly retreating due to erosion. The Grande Batture Islands offshore have been completely eroded within recent memory.

Barrier Islands. Four barrier islands, located approximately 6-12 miles offshore, are separated from the mainland by a relatively shallow Mississippi Sound and act as a storm buffer for the mainland. These islands are subjected to the highest wind and wave energies of the Mississippi coast and therefore exhibit the greatest relative changes in shape and shoreline movement on the coast. Remnants of a barrier chain, they exhibit erosion and movement from east to west in the direction of longshore drift. Ship Island, Horn Island, and Petit Bois Island are elongated east to west and form part of the Gulf Islands National Seashore. Development on these islands has been limited to park activities. Cat Island is privately owned. A prominent north-south spit attached to the east-west trending main island body reflects sediment redistribution by waves from the eroded eastern island. At one time, the rest of the island was protected by a since-extinct Mississippi delta lobe to the south.

Predominantly westward-oriented current and wave transport of sand along the high-energy Gulf (south) island shores in historical times has steadily extended the barrier islands westward between severe erosional episodes of tropical storm activity.

Responses to Erosion. The mainland coastline is being artificially maintained in its central portion by either hard structures, beach nourishment, or both. The extreme east and west ends of the mainland shoreline consist of natural tidal marshes and currently suffer moderate to heavy erosion. The barrier islands protect the mainland shoreline from the wave energy of the open Gulf. These islands are eroding and migrating to the west as a result of longshore drift (Oivanki, 1992).

A 41.6 km-long (26 mi), wide beach had been established in 1951, in place of a previously destroyed narrow natural beach. The sand was pumped from offshore sediment sources. Despite heavy erosion by Hurricane Camille in 1969, and the regular effects of fair weather longshore drift and wind erosion, a somewhat narrower beach has been artificially maintained ever since. Beach nourishment was repeated on a smaller scale in 1972-73, and again in 1987-88. Pilot projects are now underway to stabilize this beach with natural salt tolerant grasses and dune formation. The major human factor impacting the beach is the tourist population, since this is the main tourist attraction on the Mississippi Coast. Continual mechanical maintenance is needed to keep the beach free of trash and debris (Oivanki, 1992).

Hancock County, west of St. Louis Bay, supports the bare remnants of a 9.6 km (6 mi) beach emplaced in the mid-1960s to protect the seawall there. Erosion has taken all but a few pockets of this beach and undermined the seawall and the adjacent Beach Boulevard in numerous places. A planned renourishment of this beach is scheduled for late 1992. The southwest shoreline of Hancock County, past the seawall, is a salt-tidal marsh and is experiencing moderate erosion due to natural wave and storm energy (Oivanki, 1992).

The complex and diverse nature of the Mississippi Coast requires a multi-faceted approach to the study and solution of problems relating to erosion and land use. In conjunction with USGS, the Mississippi Office of Geology is currently engaged in a multi-year program to document past erosion and monitor current erosion rates.

This should provide accurate data to the public officials charged with managing the impact of coastline changes on the human population and the environment (Oivanki, 1992).

Texas

Regional Framework. Modern beaches and barrier islands of the Texas coast are arranged in an orderly pattern with respect to the principal geomorphic elements of the region. The deltaic systems and a fluvial-deltaic headland referred to as the Trinity delta are depositional features controlling the spatial arrangement of shoreline types and, consequently, barrier island types. During the most recent period of sea level stability, the three headlands formed large promontories in the Gulf of Mexico that focused wave energy and created three cells of littoral drift convergence. These headlands are also the sites of transgressive beaches that have been retreating rapidly for several thousand years.

Field observations and photo interpretations confirm that land losses along the Texas Gulf of Mexico coast are concentrated in three areas of reduced or low sediment supply: (1) between Sabine Pass and Bolivar Peninsula, (2) between the Brazos and Colorado Rivers, and (3) north of the Rio Grande River. Whereas the first two areas are low-lying headlands characterized by muddy substrates and narrow, steep beaches, the third area(near South Padre Island) is a former deltaic headland that was transformed into a transgressive barrier/lagoon complex as the Rio Grande delta foundered.

Coastal Processes. The Texas coast is a storm-dominated region with a small tide range that is constantly changing as a result of active coastal processes linked directly to meteorological vents. Wind and its resulting nearshore processes are clearly the most important geological agents controlling the sediment transport and evolution of the Texas shoreline.

Wind directions and intensities are distributed seasonally, with southeast winds of 16 to 24 km/h (10 to 15 mph) prevailing most of the year. Highest sustained wind velocities accompany major hurricanes, which can drive nearshore currents and large volumes of beach and shoreface sand to the west and southwest along the Texas coast.

Overview of the Problem. Of the 591 km (367 mi) of Texas Gulf shoreline, approximately 60 percent is eroding at rates of between 0.3 and 15 m/year (1 and 50 ft/year), 33 percent is stable, and 7 percent is accreting. Erosion is not confined to the Texas Gulf beaches. Erosion also affects the bay systems, where it causes the loss of agricultural, industrial, and residential lands and threatens the productive wetlands that serve as nursery grounds for sport and commercial fisheries. In total, about two-thirds of Texas bay shores are eroding. Every year along the Gulf shoreline in

Texas, near bay margins, and within alluvial valleys, nearly 607 hectares (1500 acres) are lost to erosion and land submergence. Wetlands constitute about 75 percent of this loss.

Total land losses and rates of loss along the shoreline were estimated by combining historical data of Morton (1977) and Paine and Morton (1989). The results showed that more than 10,927 hectares (27,000 acres) of beachfront land was lost between the mid-1800s and 1982, at an average long-term rate of about 91 hectares/year (225 acres/year). Although some segments of the Gulf shoreline are eroding at an accelerated rate, the rate of total land loss has remained nearly uniform since the 1950s.

The highest rates of historical shoreline movement along the Texas coast are the direct result of human activities. The long-term sustained rates of erosion are greatest at Sargent Beach, which is located between the Brazos and Colorado Rivers. Here, the beach retreats at an average rate of 9.2 m/year (30 ft/year). More important, the rate of erosion has been accelerating since diversion of the Brazos River impounded sediment that would have normally been transported to Sargent Beach by longshore currents.

In the fall of 1989, the Texas Department of Transportation closed Texas State Highway 87 in Chambers and Jefferson counties from High Island to Sabine Pass because of dangerous conditions resulting from severe erosion. In some areas, the highway lies at the water's edge, protected only by a makeshift metal bulkhead. Erosion rates are 1.4 to 2.8 m/year (4.6 to 9.2 ft/year) along this segment of the Texas coast. The elevation of the beach and adjacent coastal lands is less than 1.4 m (4.6 ft) above sea level. Beaches are narrow and dunes are limited. The beaches and surrounding wetlands are frequently inundated by waves of even minor storms.

Gulf of Mexico Shorelines. Accelerated erosion in other areas or recent erosion of formerly stable beaches is attributed to the relative rise in sea level, a lack of near-surface sand in the littoral system, the reduction of sand transported by rivers emptying into the western Gulf, and the impoundment of littoral sand by jetties at harbor entrances.

Rivers are the primary source of sand for building barriers and beaches in the western Gulf of Mexico. Reductions in the sediment supply have occurred due to natural factors such as climatic cycles, but human activities have exacerbated the problem. Flood-control structures have caused many rivers to lose their sediment-transporting capacity.

In addition, structures used to protect navigational inlets and deep-draft channels (jetties) disrupt the longshore current and compartmentalize the coast, preventing sediment exchange from one coastal segment to another. The maintenance of these inlets has generated seven coastal compartments on the open Gulf. Each compartment is bounded by long impermeable jetties and deep navigation channels, and each is isolated from adjacent compartments. As a result of this isolation and recent interference with littoral drift, little sand is shared among any of the seven compartments.

Bay Systems. Of the major Texas bays, land losses are greatest in Copano, Galveston, and Matagorda Bays, the largest bays with the longest open water fetches. Local rates of land loss are largely controlled by composition of shoreline material, orientation of the shoreline with respect to the prevailing wind and wave directions, and the relative rise in sea level. Because the shoreline lengths and processes are similar in these three bay systems, the rates of land loss are also similar.

The Galveston, Matagorda, San Antonio, Copano, and Corpus Christi Bay systems each lost fringing land at gross rates of about 116 hectares/year (287 acres/year) between 1930 and 1982. Surrounded by over 1,600 km (992 mi) of bluffs, marshes, and sand and shell beaches, each bay system has a different proportion of these shoreline types that contributes to differences in land loss rates between the bays.

Responses to Erosion. Only small sections of the Texas Gulf shoreline have been stabilized by hard coastal structures. Long seawalls [>1200 m (>4000 ft)] have been constructed on Galveston, North Padre, and South Padre Islands. At each location, the beaches downdrift of the structures are eroding. Most of the other shoreline developments use bulkheads constructed on the backbeach. These structures currently have little effect on beach stability where sand supply is plentiful, but on other beaches they may reduce beach width and prevent the accumulation of windblown sand.

Local attempts to minimize coastal land loss in Texas have been partly successful. Only large and expensive projects, such as the Galveston seawall, have prevented further upland land loss, often at the expense of downdrift shores. Most of the low-cost shoreline stabilization projects provide temporary protection, but eventually they fail and land loss resumes. Efforts to create new land or to maintain existing land are currently underway along the shores of Galveston Bay, but the long-term durability and effectiveness in mitigating land loss is still uncertain.

Another response to erosion on Texas Gulf beaches is the use of a setback boundary. For post-storm coastal reconstruction activities, this boundary is based on the location of the vegetation line. In addition, 1991 legislation directed the Texas General Land Office to work with The University of Texas, Bureau of Economic Geology, to develop a 50-year erosion-rate setback for new coastal construction.

Erosion is a subject of primary concern on the Texas coast, where it has many serious adverse effects in addition to habitat degradation and loss. Prime tourist beaches are vanishing; the Gulf Intracoastal Waterway is threatened by the possibility of a major breach at Sargent Beach; and agricultural and industrial lands, infrastructure, and private homes are being lost.

Conclusion

Coastal and shoreline erosion is one of the major factors threatening the Gulf coastal environment. Mainland Gulf shorelines and shorelines of major estuarine water bodies and waterways are highly visible and represent the edge of the coastal environment. In spite of the fact that these eroding and disappearing shorelines are obvious, the loss of this valuable resource continues.

One or more of the following factors may be a primary cause of coastal erosion at a given location: sea level rise, land subsidence, coastal storms and wave action, reduced or diverted river sediment loads, navigation channels and canals, and some coastal protection projects. The relative importance of these factors and the nature of their physical effects differ from site to site.

Throughout the Gulf, erosion rates vary, and only a few areas remain stable or actually accrete. The impacts of this erosion include loss of habitat, reduced fishery resources, saltwater intrusion, and loss or degradation of recreational use. The combined causes of erosion accelerate the loss of the natural environment, while the impacts of erosion reduce the area's financial resource base.

All of the federal, state, local, and private interests concerned about the coastal environment are struggling to determine solutions. As these efforts continue, the coastal resources dwindle, as do the natural ingredients needed for restoration. At the same time, competition for these natural ingredients is growing rapidly. The key to limiting further coastal erosion is to develop solutions that are agreeable to all and affordable within limited resources. The more permanent and long-term comprehensive solutions are elusive and will require greater knowledge, assessment of the supporting nearshore and estuarine areas, and continuous maintenance.

Through the Coastal & Shoreline Erosion Committee, the Gulf of Mexico Program presents an opportunity to address the shoreline problems facing the coastal areas of the Gulf in an interagency manner. Expertise and information can be intensified and focused on the many issues in the coastal area by sharing the institutional knowledge and experience accumulated within each agency and the private sector. A team approach by all involved, utilizing all available resources, is the key to developing a successful response to the problem of coastal and shoreline erosion.

3 FEDERAL & STATE FRAMEWORK FOR ADDRESSING COASTAL & SHORELINE EROSION

This section describes the legal and institutional framework currently in place in the Gulf of Mexico to address coastal and shoreline erosion issues. It also outlines some of the positive efforts already underway at the federal, regional, and state levels. (For a description, see **Appendix A**.)

4 THE UNFINISHED AGENDA --
Both Current Commitments & Uncommitted Activities

Goal

- ❑ Reduce the impacts of coastal and shoreline erosion in the Gulf of Mexico.

The scope of this Action Agenda includes the following major areas: mainland shorelines, barrier islands, major bays and estuaries, major waterways, and peninsulas.

Objectives & Action Items

Three types of activity have been designed to meet the goal: 1) Erosion Identification, Characterization, and Assessment; 2) Erosion Response; and 3) Public Education and Outreach. Specific objectives and action items are grouped according to these areas (see **Index of Coastal & Shoreline Erosion Objectives & Action Items**).

Objectives are the specific, short-term targets for attaining the goal. Each objective is followed by action items that describe specific tasks to meet the goals and objectives for the Coastal & Shoreline Erosion Action Agenda. Each action item is presented under an appropriate objective.

No specific implementation projects are proposed in this iteration of the Action Agenda. Rather the Coastal & Shoreline Erosion Committee has focused on development of a consensus on the most effective responses to critical erosion problems and the monitoring of projects that are already underway at the federal and state levels. It is anticipated that future iterations of the Action Agenda will include specific implementation projects.

Lead. The Coastal & Shoreline Erosion Committee has identified a lead agency for each action item. A proposed action item may involve the execution of legislative or regulatory authorities or programmatic initiatives which derive from these authorities. In other cases, a proposed action item may involve the facilitation or coordination of activities among several agencies or organizations. In these cases, and where there is no clear legislative authority involved, the "lead" could be the agency or organization which expresses an interest in taking on the task during Gulf of Mexico Program Issue Committee deliberations, the action planning workshop or public comment period, or, in the Issue Committee's judgment, is best able to guide multiple parties in carrying out the activity. *This does not necessarily mean that the* *agency or organization has agreed to carry out the activity, that it has the necessary funding, or that it should attempt to accomplish the action solely with its own resources. These agencies or organizations should provide the leadership needed to see that action items are executed in an efficient manner. Part of this execution role should include determining the most appropriate products from each action item and information needs that, if fulfilled, would enhance the action item's overall purpose. The Issue Committee understands these action items will require commitments by agencies and organizations that are dependent on budget, and perhaps policy or even authority, decisions.* However, the Issue Committee members hope this document provides the rationale and support for such commitments. It is anticipated that future iterations of this document will incorporate additional specific commitments including actions to address any limitations in authority that may become apparent. This is intended to be a continuous process--as action items are completed they will stimulate the development of new action items.

Initiation Date. The date indicated represents a determination by the Issue Committee of the most realistic *initiation date* for the action item. As lead agencies begin implementation planning for specific action items, these initiation dates may change due to resource availability and prioritization within the individual agencies.

The Gulf of Mexico Program recognizes the need to identify indicators of environmental progress relative to this Action Agenda for coastal and shoreline erosion. Many of the action items specified in Chapter 4 of this document will aid the Program in developing a baseline for measuring success in the future. For the time being, however, acceptance and completion of action items specified in this Action Agenda will be considered a measure of success. As future Action Agendas are written and current action items are completed, new action items will be developed to better measure environmental progress. The Gulf of Mexico Program will coordinate among the eight Gulf of Mexico Program Issue Committees to eliminate overlap and duplication of efforts, as well as to integrate goals and activities across environmental issue areas.

Index of Erosion Objectives & Action Items

Erosion Identification, Characterization, & Assessment

Objective: **Characterize the Gulf of Mexico shoreline, and identify trends and patterns of shoreline change.**

Objective: **Assess the severity of coastal erosion Gulfwide, and evaluate causes and impacts.**

Erosion Response

Objective: **Evaluate existing and potential response alternatives for coastal erosion in the Gulf of Mexico region.**

Public Education & Outreach

Objective: **Increase individual and public awareness of erosion impacts in the Gulf of Mexico region and the importance of appropriate control measures and options.**

Erosion Identification, Characterization, & Assessment

The rates, distribution, and causes of coastal and shoreline erosion in the Gulf of Mexico are currently reported on a limited basis. Current and historical information should be used to develop and refine a statistically valid baseline from which to assess changing erosion conditions throughout the five Gulf States. Future activities and information collection can then be incorporated into the data base and improvements can be measured.

Specific objectives and action items follow:

OBJECTIVE: Characterize the Gulf of Mexico shoreline, and identify trends and patterns of shoreline change.

Action Item 1 - Sources of Gulfwide Erosion Data

Identify and compile, into both bibliographic and spatial data bases, sources of Gulfwide data pertinent to coastal and shoreline erosion including bibliographic sources, data from aerial and sea-borne remote sensing, and field data (*i.e.*, process, morphologic, sediment, and stratigraphic).
Lead: U.S. Army Corps of Engineers.
Initiation Date: 1994

Action Item 2 - Gulf of Mexico shoreline Characteristics

Determine major categories of Gulf shoreline, assemble best estimates of length for each category, determine historical erosion trends for each category (cause and extremes), and prepare report incorporating appropriate graphics to depict distributions, types, and trends.
Lead: U.S. Geological Survey.
Initiation Date: 1994

Action Item 3 - Gulfwide Sand Inventory

Develop a Gulfwide offshore sand inventory which describes sources, volumes, and quality.
Lead: U.S. Geological Survey.
Initiation Date: 1995

Action Item 4 - Local Littoral Sediment Budgets for the Gulf of Mexico

Produce local littoral sediment budgets for the Gulf of Mexico, including contributions to coasts from major sources such as rivers and streams.
Lead: U.S. Geological Survey and U.S. Army Corps of Engineers.
Initiation Date: 1995

Action Item 5 - Erosion Predictive Models

Identify, refine, or develop, as necessary, predictive models on shoreline erosion, sediment transport, and coastal hydrodynamics.
Lead: U.S. Army Corps of Engineers, U.S. Geological Survey, and Environmental Protection Agency.
Initiation Date: 1996

OBJECTIVE: **Assess the severity of coastal erosion Gulfwide, and evaluate causes and impacts.**

Action Item 6 - Causes of Erosion and Shoreline Loss Gulfwide

Identify major causes of erosion and shoreline loss Gulfwide, and determine their relative magnitude for contributing to erosion problems.
Lead: U.S. Geological Survey & U.S. Army Corps of Engineers.
Initiation Date: 1994

Action Item 7 - Impacts of Erosion Gulfwide

Identify the major impacts of erosion and shoreline loss Gulfwide.
Lead: U.S. Geological Survey & U.S. Army Corps of Engineers.
Initiation Date: 1995

Action Item 8 - Erosion Area Prioritization for Gulf of Mexico States

Develop working definitions of critical erosion and model frameworks for prioritizing erosion areas within each Gulf State including major "hot spots."
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee, in cooperation with appropriate agencies and Gulf States.
Initiation Date: 1995

Erosion Response

The most effective way to reduce the impacts of coastal and shoreline erosion is, first, to understand the mechanisms and causes and how they affect the coastline and, second, to incorporate this knowledge into planning. It will cost far more to restore eroded areas later than to plan for erosion now. This should be a shared responsibility among all in the Gulf region--federal, state, and local governments, the private sector, and citizens.

Specific objectives and action items follow:

OBJECTIVE: Evaluate existing and potential response alternatives for coastal erosion in the Gulf of Mexico region.

Action Item 9 - Existing Erosion Control Projects Gulfwide

Publish a summary listing of existing coastal erosion control projects Gulfwide. This summary will include pertinent data such as responsible agencies, type of erosion control, source of information, monitoring programs, and project status.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1993

Action Item 10 - Evaluation of Selected Gulf of Mexico Demonstration Projects

Using the summary from Action Item 9, select a representative group of projects within the Gulf of Mexico region, and task responsible agencies to submit an evaluative report to the Coastal & Shoreline Erosion Committee (see **Appendix E**).
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1994

Action Item 11 - Past Experiences Regarding Erosion Along the Gulf of Mexico Coast

Develop a critical review of past experiences regarding shoreline and coastal erosion along the Gulf of Mexico Coast. The review should focus on the "big picture" (with respect to measures a-g in Action Item 13) including the decision making process, the philosophies that led to the selection of the alternatives, and the costs and benefits that have been realized.
Lead: U.S. Army Corps of Engineers, U.S. Geological Survey, and Soil Conservation Service.
Initiation Date: 1994

Action Item 12 - Selection of Representative Erosion Sites Gulfwide

Identify a set of critically eroding sites that feature causes, physical and socioeconomic situations, and responses that are representative Gulfwide. Also, identify the agencies developing or administering the responses; this information should be summarized graphically or in chart form for distribution.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1995

Action Item 13 - Gulf of Mexico Erosion Response Evaluation

Evaluate the effectiveness of erosion impact responses at representative critically eroding sites. These measures may include but not be limited to: (a) Beach nourishment; (b) Coastal structures for property protection and to extend the life of beach nourishment projects; (c) Vegetative approaches to shoreline protection; (d) Beneficial uses of dredged material on shorelines(including inlets and bypassing); (e) Abandonment/retreat including public acquisition; (f) Release/mobilization of riverine sands from dams and stream beds; and (g) Innovative technologies.
Lead: Responsible agencies identified in Action Item 12.
Initiation Date: 1996

Action Item 14 - Gulfwide Erosion Response Strategies

Develop Gulfwide strategies for responding to coastal and shoreline erosion. Strategies should include recommendations for improved coordination at the state and federal levels and should identify any limitations in authority that could impede execution of strategies.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1996

Public Education & Outreach

Effective responses to the impacts of erosion require an ongoing commitment from an informed citizenry. Public outreach nurtures such a commitment. Public information, education, and involvement are three components of an effective outreach strategy, which can reap significant benefits for the Gulf of Mexico. More and more, public outreach is recognized as an effective resource management tool to address problems resulting from individual actions and to create a sense of stewardship within the community. A committed citizenry presents both a supplement and an alternative to enforcement programs.

Public outreach can foster recognition of the Gulf of Mexico as a regional and national resource, stimulate civic, governmental, and private sector support for changing lifestyles, and develop the financial commitments necessary to preserve the resource. A strong outreach program showing the effects human activities have upon the Gulf will enable all individuals to see themselves as caretakers of a vital, shared resource.

Specific objectives and action items follow:

OBJECTIVE: Increase individual and public awareness of erosion impacts in the Gulf of Mexico region and the importance of appropriate control measures and options.

Action Item 15 - Slide Presentation on Coastal & Shoreline Erosion

Develop a generic slide presentation on coastal and shoreline erosion issues.
Lead: Texas Bureau of Economic Geology.
Initiation Date: 1993

Action Item 16 - Public Information Materials on Coastal & Shoreline Erosion

Develop an inventory of projects, a primer, and other public information materials (*i.e.*, pop-up display for conferences, educational package for elementary and secondary schools) on coastal and shoreline erosion.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1994

Action Item 17 - Public Video on Gulfwide Erosion Issues

Develop a basic, general public video of coastal and shoreline erosion issues throughout the Gulf of Mexico region.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1995

Action Item 18 - Gulf of Mexico Program Electronic Bulletin Board Erosion Data

Identify data on coastal erosion issues that should be included in the Gulf of Mexico Program Office electronic bulletin board.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee.
Initiation Date: 1993

Action Item 19 - Sources of Funding for Coastal & Shoreline Erosion Education

Identify all sources of funding for environmental education on coastal and shoreline erosion issues.
Lead: Gulf of Mexico Program Coastal & Shoreline Erosion Committee, in coordination with U.S. Army Corps of Engineers.
Initiation Date: 1993

Action Item 20 - Network for Disseminating Coastal & Shoreline Erosion Information

Identify, develop, and maintain a network of Gulf of Mexico Program Issue Committees, National Estuary Programs, schools, government agencies, interested groups, and coastal and inland communities to participate in disseminating information on coastal and shoreline erosion issues and solutions.
Lead: Gulf of Mexico Program Coastal and Shoreline Erosion Committee.
Initiation Date: 1994

In Closing...

We intend this document to be a beginning, not an end. Our hope is that this Action Agenda will serve as an inspiration and a call to action for the millions who live and work in the Gulf of Mexico region. Together our coordinated actions can make a difference and reduce the impacts of erosion on the coastal and estuarine shorelines of the Gulf of Mexico.

The Gulf of Mexico Program
Coastal & Shoreline Erosion Committee

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FEDERAL LEVEL

U.S. Department of Defense (USDOD)

U.S. Army Corps of Engineers (USACE)

Federal interest in shore protection began officially in 1930, with the enactment of PL 71-520 which authorized and directed the USACE to engage in shore protection studies in cooperation with state agencies and to establish a special board, the Beach Erosion Board (BEB), to furnish technical assistance. The present day shore protection program under USACE is applicable to the shores of the Atlantic and Pacific Oceans, the Gulf of Mexico, the Great Lakes, the estuaries and bays directly connected with of each of the states; the Commonwealths of Puerto Rico and Northern Marianas Islands; the Territories of the U.S. Virgin Islands, Guam, and American Samoa; and the Federated States of Micronesia and the Marshall Islands. Authority for shore erosion control activities extends only the distance up tributary streams where it can be demonstrated that the dominant causes of erosion and damage are ocean tidal action (or Gulf of Mexico and Great Lakes water motion) and wind-generated waves. Erosion control authority does not address erosion at upstream locations caused by stream flows or vessels. Lake flood protection activities are generally limited to the Great Lakes, or as otherwise specifically authorized under public law.

- **Project Purposes.** Federal shore protection projects have been authorized for a variety of purposes: beach erosion control, shore or shoreline protection, hurricane or hurricane wave protection, and storm protection. For project cost-sharing, the benefits and outputs associated with these purposes conform to the appropriate purposes specified in Section 103 (c) of PL 99-662 (normally, hurricane and storm damage reduction, and/or recreation), and costs are shared in the same percentage as the purpose to which costs are assigned.

- **Preauthorization Studies.** USACE undertakes specific studies relating to shore protection at the request and authorization of Congress, either in response to resolutions adopted by the Committee on Environment & Public Works of the U.S. Senate or the Committee on Public Works & Transportation of the House of Representatives, or by an Act of Congress. Without specific Congressional authorization, USACE may initiate studies for projects, under the authorities of Section 103 of PL 87-874, and Section 14 of PL 79-526, as amended, which comprise part of the USACE Continuing Authorities Program. Reconnaissance studies are 100 percent federally funded; feasibility studies are conducted under a contract (Feasibility Study Cost Sharing Agreement) providing 50/50 federal/non-federal cost sharing.

Projects undertaken by USACE must meet certain requirements or conditions, and be formulated in accordance with specific criteria. Some of the more important requirements, conditions and/or criteria are:

- Beach Creation. Existing shore erosion control authority provides for "restoration" and "protection." It does not provide for federal cost sharing in extending a beach beyond its historic shoreline unless the extension is needed for engineering reasons to provide protection from erosion or as otherwise specifically authorized under public law.

- Coastal Zone Management Plans. Project proposals must be consistent to the maximum practicable extent with approved state coastal zone management plans developed under the authority of the Coastal Zone Management Act.

- Coastal Barrier Resources System. Project proposals must comply with the Coastal Barrier Resources Act of 1982 PL 97-348.

- **Postauthorization Studies.** Planning and engineering studies for shore protection projects authorized under Section 105 (a) and (b) of PL 99-662 are conducted under a contract providing for 50/50 federal/non-federal cost sharing. Evaluation studies for disposal of materials dredged from navigation inlets and channels, during either original federal improvement or maintenance, onto adjacent beaches under Section 145 of PL 94-587, as amended, are initially financed by USACE; the cost of the evaluation report is added to the separable construction costs for placement of dredged material on beaches and cost shared accordingly. Studies for extension of beach nourishment periods under Section 934 of PL 99-662 are initially financed by the federal government. If extension of periodic nourishment is approved, the cost of preparing the reevaluation reports is shared in the same proportion as the allocation of construction costs to the type of benefits accruing from the project.

- **Local Cooperation Agreements.** The commitment of a sponsor of a shore protection project to the non-federal obligations and requirements discussed above is effected through a written Local Cooperation Agreement (LCA), as required by Section 221 of PL 91-611, as amended, to provide local cooperation satisfactory to the Secretary of the Army.

- **Construction.** Construction of authorized projects is a responsibility of USACE. However, local interests may construct portions of projects after they are authorized by Congress and be reimbursed by the federal government within the limitations of Section 215 of PL 90-483, as amended, if prior approval is obtained from the Chief of Engineers.

- **Periodic Nourishment.** Periodic nourishment, by placement of suitable material on a beach at appropriate intervals of time, is considered "construction" for cost sharing purposes when, in the opinion of the Chief of Engineers, such periodic nourishment would be a more economical erosion protection measure than retaining structures such as groins.

- **Clean Water Act (CWA) Section 404.** The U.S. Congress enacted CWA to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." Section 404 regulates the discharge of dredged and fill material into waters of the U.S., and establishes a permit program to ensure that such discharges comply with environmental requirements. The Section 404 program is administered at the federal level by USACE and USEPA. USFWS and the National Marine Fisheries Service (NMFS) have important advisory roles.

  Activities regulated by Section 404 include discharges of dredged and fill material commonly associated with activities such as port development, channel construction and maintenance, fills to create development sites, transportation improvements, and water resource projects (such as dams, jetties, and levees).

- **River & Harbor Act of 1899.** The River & Harbor Act regulates all construction in or modification of traditionally navigable waters. In many respects, its provisions are similar to those of Section 404 of CWA. For example, Section 10 of the River & Harbor Act requires permits issued by USACE for any dredging, filling, or obstruction of navigable waters. Sections 9, 11, and 13 are also relevant to some activities in wetlands and near coastal waters. When a project requires applications for permits under both CWA & River & Harbor Act, USACE often conducts the two permit reviews concurrently.

  Despite its similarity to Section 404, the River & Harbor Act differs from Section 404 in two important ways. First, the activities it covers are much broader than those regulated under Section 404. Second, its jurisdiction extends only to the high water line. As a result, this Act offers the federal government greater regulatory authority within certain areas, but does not apply to all areas regulated under Section 404.

- **Coastal Wetlands Planning, Protection, & Restoration Act (CWPPRA).** CWPPRA establishes a mechanism to plan and fund implementation of wetland protection and restoration projects in coastal Louisiana. Planning and implementation activities are managed by a six-person/federal-state task force. In addition, CWPPRA calls for development of a Conservation Plan for the State of Louisiana, and provides funds for matching grants to assist other coastal states in implementing wetland conservation projects (*i.e.*, projects to acquire, restore, manage, and enhance real property interest in coastal lands and waters).

Federal Emergency Management Agency (FEMA)

FEMA administers the National Flood Insurance Program (NFIP), which provides federally subsidized insurance protection in many coastal and flood-prone areas of the U.S. FEMA maps flood-prone areas, establishes criteria for land management and use, and gives planning recommendations for flood- and erosion-prone areas. FEMA and the designated state agency liaison assist local communities with the development of quality floodplain management programs.

- **National Flood Insurance Act (NFIA) of 1968.** NFIA was enacted by title XIII of the Housing & Urban Development Act of 1968 (PL 90-448) to provide previously unavailable flood insurance protection to property owners in flood-prone areas. It established the NFIP, which is administered by FEMA. NFIP offers flood insurance coverage to participating coastal communities who adopt and enforce floodplain management regulations in flood hazard areas mapped by NFIP. Some of the regulations are designed to protect dunes and mangroves from human alteration.

  In 1988, Congress passed the Upton-Jones Amendment to NFIA to provide an incentive for retreat from the shoreline and to reduce future flood losses. The amendment allows payments of up to 40 percent of the value of the structure for relocation or up to 110 percent to demolish a structure imminently threatened by erosion.

  The National Flood Insurance, Mitigation & Erosion Management Act of 1991 (passed in the House in 1991 and awaiting endorsement by the Senate) adds significant erosion management and mapping authorities to NFIP. The goals of the proposed Act are to: identify the risks associated with flood and erosion hazards; further stabilize NFIP by reducing potential liability after erosion hazards have been fully disclosed; promote relocation of structures prior to damage; and encourage communities to develop long-term coastal erosion management programs.

U.S. Environmental Protection Agency (USEPA)

- **The Clean Water Act (CWA) of 1977, as amended by the Water Quality Act of 1987.** Waters of the U.S. protected by the Clean Water Act include rivers, streams, estuaries, the territorial seas, and most ponds, lakes, and wetlands.

  Section 404. USEPA has primary roles in several aspects of the CWA Section 404 program (see CWA under USACE) including development of the environmental guidelines by which permit applications must be evaluated; review of proposed permits; prohibition of discharges with unacceptable adverse impacts; approval and oversight of state assumption of the program; establishment of the jurisdictional scope of waters of the U.S.; and interpretation of Section 404 exemptions. As a jointly administered program, USACE and USEPA share responsibility for enforcing the Section 404 Program. USEPA can also enforce against non-compliance with permit conditions; however, USEPA generally focuses its resources towards discovering and enforcing against unpermitted (unauthorized) discharges.

National Estuary Program (NEP). In 1987, Congress realized the special need to protect estuaries and established the NEP to protect and improve water quality and enhance living resources. NEP jurisdiction applies not only to the mouth of a river or stream, but to "associated aquatic ecosystems and...tributaries draining into the estuary," up to the historic height of fish migration or tidal influence, whichever is higher.

USEPA, in managing NEP, is directed to identify nationally significant estuaries threatened by pollution, development, or overuse, and to promote the preparation of comprehensive management plans to ensure their ecological integrity. Specifically, NEP: 1) establishes working partnerships among federal, state, and local governments; 2) transfers scientific/management information and expertise to program participants; 3) increases public awareness of pollution problems; 4) promotes area-wide planning to control pollution and manage resources; and 5) oversees development and implementation of pollution reduction and control programs.

The five NEPs within the Gulf of Mexico region are Tampa Bay, Sarasota Bay, Galveston Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex.

- **National Environmental Policy Act (NEPA) of 1969.** NEPA requires consideration of the adverse impacts on environmental resources caused by any federal action, including federally funded or permitted projects. It also requires examination of alternatives to minimize those impacts. Compliance with NEPA is an additional requirement to regulatory programs such as Section 404 of CWA when federal agencies or federal monies are involved in a proposed project. Environmental investigations carried out in accordance with NEPA are documented in an Environmental Assessment or an Environmental Impact Statement (EIS).

- **National Environmental Education Act (NEEA) of 1990.** NEEA is designed to increase public understanding of the natural environment and to advance and develop environmental education and training. The Act builds upon the efforts that USEPA has undertaken and establishes formal communication and advisory links with educational institutions and other federal agencies. NEEA also requires partnership among federal government agencies, local education institutions, state agencies, not-for-profit educational and environmental organizations, and private sector interests.

The Act provides for the following mandates and authorizations: establishes an Office of Environmental Education within USEPA, establishes and operates an Environmental Education and Training Program, authorizes USEPA to enter into grants and contracts, requires USEPA to facilitate internships for college students with agencies of the federal government, requires USEPA to provide national awards recognizing outstanding contributions in environmental education, establishes an Environmental Education Advisory Council & Task Force, establishes a National Environmental Education Foundation, and authorizes funds to carry out the Act.

U.S. Department of Agriculture (USDA)

Soil Conservation Service (SCS)

SCS is USDA's primary technical agency in the areas of soil and water conservation and water quality. SCS focuses its assistance on non-federal land. SCS works primarily with private landowners in planning and applying measures to reduce soil erosion, conserve water, protect and improve water quality, and protect other renewable natural resources, such as plants and wildlife. The guiding principle is the use and conservation treatment of the land and water in harmony with capabilities and needs.

SCS has an office in almost every county in the U.S. where it works closely with local subdivisions of state government called Soil & Water Conservation Districts. The conservation districts are governed by local people and typically have legislative mandates to plan and implement comprehensive soil and water conservation programs within their boundaries. These boundaries usually coincide with county lines.

SCS's basic authorities were created by P.L. (74) - 46, P.L. (83) - 566, and P.L. (78) - 534. Program authorities were added under various Farm Bills including those enacted in 1961 (Resource Conservation & Development), 1988 (Swampbuster, Sodbuster, Conservation Compliance, & Conservation Reserve Program) and 1990 (Wetlands Reserve Program and others). Under the Swampbuster provisions, SCS assists landowners to identify and protect wetlands. Loss of USDA benefits and severe economic consequences can result for agricultural producers who convert wetlands to make possible the production of agricultural commodities.

SCS also conducts soil surveys and operates a system of 27 Plant Materials Centers for selecting, developing, testing, and releasing plants for use in conservation programs.

SCS works with private landowners and others to preserve, protect, and restore wetlands and to develop wildlife and fisheries habitat.

Department of the Interior (USDOI)

Fish & Wildlife Service (USFWS)

USFWS manages extensive coastal lands as wildlife preserves and conducts research on coastal wetlands, fish and wildlife populations, and changes in habitat. In order to reduce impacts on habitats, USFWS coordinates with federal and state action agencies to ensure that fish and wildlife considerations are incorporated into water resources projects.

- **Fish & Wildlife Coordination Act, as amended in 1958.** The Fish & Wildlife Coordination Act requires that wildlife conservation be given consideration equal to the concern for other aspects of the water resource development projects of USACE, Bureau of Reclamation, and other federal agencies. This Act has empowered USFWS and NMFS to evaluate the impact on fish and wildlife of all new federal projects and federally permitted projects, including projects permitted under Section 404.

- **Endangered Species Act of 1972 (as amended).** As habitats for a great variety of plants and animals, some wetlands are offered protection under this Act. The principal purposes of the Act are the conservation of threatened and endangered species and the ecosystems on which they depend. Among its provisions, Section 7 of the Act requires federal agencies to ensure that any actions they authorize, fund, or carry out will not jeopardize the continued existence of any listed species, or result in the destruction or adverse modification of its designated critical habitat.

National Park Service (NPS)

NPS administers an extensive system of public lands, including lakeshores and seashores, set aside for the protection of natural environments, the preservation of historic properties, and the education and enjoyment of citizens.

- **Statewide Comprehensive Outdoor Recreation Plan (SCORP).** SCORP identifies state wildlife protection and recreation area needs and establishes priorities for proposed acquisition and development projects.

U.S. Geological Survey (USGS)

USGS conducts research on the geologic framework of coasts and on sediment-transport processes; collects and analyzes hydrologic data; makes topographic, geologic, and hydrologic maps of coastal areas; and investigates ancient and modern coastal environments.

Scientific studies of sedimentary processes and seismicity traditionally have been part of the USGS mandate, and recently, Congress directed USGS to take the lead in geologic studies of the coastal zone and wetlands by creating a National Coastal Geology Program. Areas of study include erosion, polluted sediments, and wetlands deterioration.

Minerals Management Service (MMS)

MMS studies the potential impact of offshore activities, including the placement and construction of petroleum pipelines, on coastal wetlands and resources. MMS also funds research through state geoscience agencies for identifying mineral resources in the coastal zone.

U.S. Department of Commerce (USDOC)

National Oceanic & Atmospheric Administration (NOAA)

NOAA conducts studies of wetlands and coastal habitats that support marine resources; prepares nautical charts and geodetic surveys of coastal areas; monitors storm activities; operates an environmental satellite system; and administers a grants program for marine research. NOAA administers the federal Coastal Zone Management Program as directed by the Coastal Zone Management Act.

- **Habitat Strategic Plan.** NOAA has recently developed the Habitat Strategic Plan, the agency's long-range strategy for coordinated and concerted action to address the deterioration of the nation's coastal, estuarine, and riverine habitats and populations of living marine resources dependent upon such habitats. NOAA's legislative responsibilities and capabilities in habitat protection, wetlands ecology, resource conservation, toxicology, ocean system dynamics, fishery management, biological processes, and coastal habitat management provide a solid foundation for addressing these issues through an inter-disciplinary approach. NOAA has invested over $100 million per year in programs and activities that focus on habitat-related problems and issues along the nation's coasts and throughout the Exclusive Economic Zone (EEZ), including protectorates and trust territories in the Pacific Ocean and Caribbean Sea.

  The NOAA Habitat Strategic Plan provides detailed, agency-wide guidance for addressing the priority issues affecting habitat important to living marine resources throughout the nation's coastal waters. This document complements "NOAA's Investment in Coastal Environmental Quality," which is being published separately, but focuses specifically on living marine resources' habitats. NOAA's role in this effort is: 1) to develop the scientific understanding of how human activities affect natural ecosystem functioning and 2) to assess and predict the effects of specific land and water development proposals on coastal environments and their living marine resources. NOAA's goal for habitat protection is to "protect, conserve, and restore the quantity and quality of habitats of living marine resources to maintain populations of commercial, recreational, and ecologically important species at optimal sustainable levels."

- **Coastal Barrier Resource Act (CBRA) of 1982.** CBRA prohibits any federal program from supporting construction in areas within the Coastal Barrier Resources System (CBRS). Exceptions to CBRA include development associated with conservation, public recreation, research, and national security. CBRA became effective in 1982, and helps to protect the important wetland resources of coastal barrier islands. One program restricted by CBRA in many high-risk coastal areas is the federal Flood Insurance Program.

  Coastal Barrier Improvement Act of 1990. CBRA was amended by the 101st Congress and titled the "Coastal Barrier Improvement Act of 1990." This Act mandates technical revisions to the CBRS maps, modifies CBRS boundaries, and allows additions to CBRS. The Act names exceptions to the prohibition of federal expenditures such as mineral extraction, navigation improvements, road maintenance, and projects that protect wildlife resources.

- **Coastal Zone Management Act (CZMA) of 1972.** In 1972, CZMA was passed "to preserve, protect, develop, and where possible, to restore or enhance, the resources of the nation's coastal zone for this and succeeding generations." CZMA was designed to help coastal states, on a voluntary basis, develop plans to manage and protect coastal zone resources, including those affected by offshore energy development projects. CZMA provides financial and technical assistance during the planning and administration of programs that meet minimum federal standards. Approval of state plans is the responsibility of the Secretary of Commerce, acting through NOAA.

  The implementation of many of these plans requires active involvement of local communities. In accordance with the federal Act's "consistency" provisions, states with approved plans have the authority to veto federal permits for activities in wetlands or coastal waters that are inconsistent with the state's coastal zone management plan. These states receive various grants for construction and land acquisition projects and permitting efforts. Under the Estuarine Research Reserve System, the Act also provides matching grants to states for the acquisition of estuarine areas for research and education.

- **National Sea Grant College Program.** The National Sea Grant College Program conducts research and supports extension programs in wetlands, coastal habitats, and coastal engineering. The four Gulf of Mexico programs are at Texas A&M, Louisiana State University, Mississippi/Alabama Consortium, and the University of Florida.

- **Coastal Ocean Program (COP).** COP is a cross-cutting NOAA effort to provide the highest quality science delivered in time for important coastal policy decisions. COP activities are organized around four goals. These address the major coastal ocean issues of Environmental Quality, Fisheries Productivity, and Coastal Hazards; and the fourth, Information Delivery, operates at the science-policy interface.

National Aeronautics & Space Administration (NASA)

NASA's Space Shuttle Earth Observations Office (SSEOO) is responsible for photographing and cataloging photos of the earth from Space Shuttle missions. Astronauts are trained in scientific observation of geological, oceanographic, environmental, and meteorological phenomena. During each mission, project personnel monitor the Earth for events of special interest such as hurricanes and floods. Real color, black and white, and color infrared photos are taken by astronauts with a hand-held camera at altitudes ranging from 204 to 555 km (127 to 214 mi) above the Earth.

STATE LEVEL

Alabama

The Alabama Coastal Area Management Program (ACAMP) is currently being revised. ACAMP divides coastal area program responsibilities between two state agencies. The Alabama Department of Economic & Community Affairs (ADECA) is responsible for administration and planning, while permitting and enforcement activities are conducted by the Alabama Department of Environmental Management (ADEM).

The Alabama Coastal Construction Control Line (CCCL) is designed to provide long-term protection of the beach and dune system by prohibiting construction seaward of the established setback line (ADEM, Administrative Code, 8-1-.16).

The Shoreline Erosion Mitigation Program states that, in mitigating a shoreline erosion problem, non-structural erosion control methods shall be used to the maximum extent practicable. Placement of groins, jetties, and breakwaters as erosion control devices shall be permissible only when no other technically feasible alternative is available (ADEM, Administrative Code, 8-1-.08).

Statutes

- Act 73-971 Prohibition of picking of wild sea oats.
- Act 81-563 Prohibition of vehicles on beaches and dunes.

Florida

The State of Florida has instituted several regulatory initiatives in an attempt to slow the rate of coastal erosion along its Gulf of Mexico coastline. The thrust of these initiatives began in 1970, in the Florida State Legislature, with a series of statements recognizing the harmful effects of beach and shore erosion on "the economy and general welfare of the people" of Florida (Balsillie, 1988).

Soon after issuing these statements, the legislature passed the Beach & Shore Preservation Act (Chapter 161, Florida Statutes), charging the Florida Department of Natural Resources (DNR) with the responsibility for its administration. Through the years, however, the program of beach and coast preservation has reached a level of significant specialization with regard to technical issues quantifying natural processes as well as a broadened program format. Presently, major program elements include: the establishment of regulatory jurisdictions; construction regulation, enforcement activities, and associated technical aspects; and a funding mechanism for public civil works projects (Balsillie, 1988).

The Growth Management Amendment, enacted in 1985, subject to Florida Statutes subsection 161.053 (6), requires that long-term shoreline change trends be employed to regulate coastal development activities (Balsillie, 1988). This Act extends construction jurisdiction upland of Coastal Construction Control Lines (CCCL) and defines zones where CCCLs are not established. Specifically, local communities are required to adopt acceptable standards for development activities. This has evolved into the Thirty-Year Erosion Projection Program.

Regulatory Agencies & Programs

- **The Florida Coastal Management Program.** Although coastal planning efforts had been ongoing in Florida prior to 1978, development of the current Florida Coastal Management Program (FCMP) was authorized by legislation in that year. Often referred to as the "No New Nothing Act," the Florida Coastal Management Act of 1978, assigned the Florida Department of Environmental Regulation (DER) as lead agency and authorized DER to "compile a program based on existing statutes and existing rules." The resulting plan received federal approval in September 1981. FCMP networks 26 acts and their implementing rules and involves 16 state agencies, with DER, DNR, and the Department of Community Affairs (DCA) responsible for the majority of the day-to-day program administration.

  While coordination of agency activities affecting the coastal zone is a major function of the coastal management program, the program has also supported and coordinated activities intended to carry out the purposes of CZMA and developed new initiatives to preserve and protect the state's coastal resources.

  Section 161.161, F.S., also dictates that DNR, Division of Beaches & Shores, must develop and maintain a comprehensive, long-term management plan for Florida's beaches on a district-by-district basis. Responsibilities include identification of areas of critical beach erosion, determination of the most viable means to address identified erosion problems, compilation of a list of beach erosion control projects, and development of solutions for enhancing and protecting beach resources for review and action by the Governor and Cabinet and State Legislature (Balsillie, 1988).

- **Bureau of Coastal Engineering & Regulation.** Regulatory responsibilities for the Florida coast are conducted by the Bureau of Coastal Engineering & Regulation.

- **Bureau of Coastal Data Acquisition.** The Bureau of Coastal Data Acquisition of DNR administers the CCCL program according to Section 161.053, F.S., which in part reads:

  The legislature finds and declares that the beaches of the state, by their nature, are subject to frequent and severe fluctuations and represent one of Florida's most valuable natural resources and that it is in the public interest to preserve and protect them from imprudent construction which can jeopardize the stability of the beach-dune system, accelerate erosion, provide inadequate protection to upland structures, and endanger adjacent property and the beach-dune system. In furtherance of these findings, it is the intent of the Legislature to provide that the department, acting through the division, shall establish coastal construction control lines on a county basis along the sand beaches of the state fronting on the Atlantic Ocean and the Gulf of Mexico. Such lines shall be established so as to define that portion of the beach-dune system which is subject to severe fluctuations based on a 100-year storm surge or other predictable weather conditions, and so as to define the area within which special structural design consideration is required to insure protection of the beach-dune system, any proposed structure, and adjacent properties, rather than to define a seaward limit for upland structures (Balsillie, 1988).

Counties not considered "sandy-beach" counties do not have CCCLs. As of February 1988, all counties within program jurisdiction had setback or control lines established, and a second review phase was underway. Establishment of CCCL's on a county-by-county basis requires three significant efforts: (1) field data collection, (2) storm tide and dune erosion modeling, and (3) CCCL restudy and adoption (Balsillie, 1988).

- **Beach Erosion Control Program.** Chapter 16B-36, F.A.C., sets forth policies and procedures for administering the Beach Erosion Control Assistance Program to provide funding assistance to local governments in support of alleviating serious sandy beach erosion problems and for the protection and preservation of sandy beach resources of Florida. Projects may include:

    - Beach restoration/renourishment
    - Sand transfer, bypassing, and stockpiling
    - Jetties, groins, breakwaters, revetments
    - Sand trap construction and maintenance
    - Dune construction and revegetation
    - Beach-dune overwalks
    - Protective walkways or other measures for dune protection/preservation
    - Sand fencing
    - Biological and hydrological monitoring studies,
    - Sand source studies
    - Educational signs
    - Other projects of desirable intent

Two guidelines accompany these projects: 1) Erosion Control Lines (ECL) must be located a sufficient distance landward of the line of mean high water to provide for an equitable distribution of a restored beach between State and upland ownership (subject to provisions of sections 161.141 through 161.211, F.S.), to guarantee public use of beach resources seaward of the ECL; and 2) project applicants must provide permanent public access to project areas at approximately 1/2-mile intervals with adequate vehicle parking areas (Balsillie, 1988).

Louisiana

The State & Local Coastal Resources Management Act (SLCRMA) La. R.S. 49:21, was passed by the Louisiana Legislature in 1978, and received federal approval in October 1980. Presently the program is being administered by the Coastal Management Division (CMD) within the Department of Natural Resources (DNR), Office of Coastal Restoration & Management.

During the Second Special Session of 1989, the Louisiana Legislature passed Act 6, which requires the State of Louisiana to annually develop a Coastal Wetlands Conservation & Restoration Plan from both a short and long range perspective. The initiative for passing Act 6 was provided when it passed a voter referendum by approximately 75 percent.

Regulatory Agencies & Programs

- **Department of Natural Resources (DNR).** CMD of DNR is charged with implementing the Louisiana Coastal Resources Program (LCRP). LCRP attempts to protect, develop, and restore or enhance the resources of the state's coastal zone. Its broad intent is to encourage multiple uses of resources and adequate economic growth while minimizing adverse effects of one resource upon another without imposing undue restrictions on any user.

  CMD's regulatory responsibilities include administering the Coastal Use Permit (CUP) Program, the Consistency Program, & the Enforcement Program.

  CUP is the basic regulatory tool of CMD and is required for certain projects in the coastal zone, including, but not limited to, dredge and fill work, bulkhead construction, shoreline maintenance, and other development projects. CMD has processed about 15,500 CUP applications since the inception of the program.

  The Consistency Program requires activities of all federal and some state governmental agencies to be consistent with LCRP. Particular attention is given to environmental, economic, and cultural concerns. Most federal agencies conduct their own consistency determination, and, if projects are found to be inconsistent with state regulations, they are not pursued. Examples of projects requiring a consistency determination are hurricane protection levees; USACE maintenance, dredging, locks, and drainage structures; navigation projects; freshwater diversions; and beach restoration projects.

The Enforcement & Monitoring Program ensures that any unauthorized projects in the coastal zone are investigated and action is taken. The program also monitors activities permitted by the CUP Program for compliance with permit conditions. The program also gives the secretary of DNR the authority to enforce either legal or administrative procedures including fines, cease and desist orders, and restorative or mitigation work. The field investigative staff regularly monitors the entire coastal area for unauthorized activities and for non-compliance with permit conditions.

The Coastal Restoration Division has the responsibility for implementing the Coastal Wetlands Conservation & Restoration Plan which is designed to restore, preserve, and enhance Louisiana's coastal wetlands. The plan is the result of over 25 years of research and involves many innovative techniques designed to work with nature. The plan is an evolving one and includes a large number of individual projects which are designed to meet specific needs. Current restoration techniques include freshwater diversion, sediment diversion, marsh management, sediment capturing, shallow bay terracing, and structural shoreline erosion abatement devices.

On the local level, parish programs have been approved in Jefferson, Orleans, St. Bernard, Cameron, St. James, Lafourche, and Calcasieu. Elements included in local coastal program include:

- Assessment of an area's environment, natural resources, and socioeconomic and demographic profiles;
- Plan for the proper management of these resources and their interaction with other state and federal programs;
- Zoning plan for the area;
- Description of the proposed permit program; and
- Breakdown of the parish's environmental management units (EMUs), including a description and analysis of each.

Mississippi

The Mississippi Coastal Program was approved by the Commission on Wildlife Conservation on August 22, 1980, and has been updated throughout its implementation. This program is built around ten goals for guiding decisions affecting the development of Mississippi's coastal resources. These goals include, but are not limited to, the following:

- ❑ Providing for reasonable industrial expansion in the coastal area and ensuring the efficient utilization of waterfront industrial sites so that suitable sites are conserved for water dependent industry.

- ❑ Favoring the preservation of the coastal wetlands and ecosystems, except where a specific alteration of a specific coastal wetland would serve a higher public interest in compliance with the public purposes of the public trust in which the coastal wetlands are held.

- ❑ Encouraging the preservation of natural scenic qualities in the coastal area.

- ❑ Considering the national interest involved in planning for and siting facilities in the coastal area.

Regulatory Agencies & Programs

The agencies responsible for the Coastal Program are the Bureau of Marine Resources (BMR), the Bureau of Pollution Control, the Bureau of Land & Water Resources, and the Department of Archives & History. These four agencies are responsible for monitoring state and federal decisions that affect the coastal area and for ensuring that such decisions are made in accordance with program councils.

- **Bureau of Marine Resources.** BMR is the lead agency responsible for the overall administration of the coastal program. This agency regulates projects and activities under the Wetlands Protection Law and saltwater fisheries statutes. There are three types of activities regulated under BMR's jurisdiction. These are activities physically located in coastal wetlands (*i.e.*, piers, bulkheads), those not located in the coastal wetlands but affecting them by indirect means (*i.e.*, construction), and the erection of structures on sites suitable for water dependent industry.

  The Mississippi Coastal Program calls for the accurate, long-range assessment of shore-line erosion based on scientific research. The subjects where research will be concentrated include: wave refraction diagrams; long-term changes in the shoreline, wind transport, littoral transport rates, wave spectra, and source materials for beach nourishment; and erosion by boat wakes.

  The program also makes funds available for the preservation or restoration of wetlands and access areas. These funds will be used to restore and preserve beaches in areas that have been subject to severe wind erosion. Local governments will play a lead role in any such project.

  BMR has also set marine construction standards for shoreline erosion control. This includes discussing which protection methods are recommended for each type of shoreline and defining these methods, explaining the impacts of each type of erosion control option, and asserting specific design recommendations for bulkheads, revetments, and vegetation.

The program calls for support for erosion control projects from USACE and from local governments. These projects include beach replenishment and dredged material disposal techniques.

Development is directly regulated to minimize adverse impacts. This is done by addressing special management areas (SMA). SMAs detail all regulations affecting an area and specifically state what will and will not happen in an area, ensuring that development will occur in a predictable manner.

Texas

The Open Beaches Act (Sections 61.001-61.025 of the Texas Natural Resources Code), passed by the Texas Legislature in 1959, guarantees the public's right of free and unrestricted access to the "public beach," which extends from the line of mean low tide to the line of permanent vegetation of the shoreline bordering the Gulf of Mexico. The Act makes it unlawful to prevent or impede access to or use of the public beach by erecting barriers or by posting signs declaring a beach closed to the public.

The Dune Protection Act (Sections 63.001-63.122 of the Texas Natural Resources Code), prohibits damage to or destruction of dunes or dune vegetation seaward of a dune protection line. Activities in critical dune areas must be permitted by the coastal county or municipality which ensures that damage to dunes and dune vegetation is avoided to the greatest extent practicable.

Regulatory Agencies & Programs

The Texas Legislature has distributed authority for coastal resource management among a number of state agencies. This system has evolved historically with no formal coordination mechanism to ensure a consistent management approach.

- **Texas General Land Office (GLO).** GLO, in conjunction with the School Land Board, manages the state's coastal public lands. GLO has developed a coastal management plan for Texas beaches and the state-owned submerged land underlying the Gulf of Mexico. On June 7, 1991, the Texas State Legislature passed two bills creating a State-Owned Wetlands Conservation Plan and a Coastal Management Plan addressing coastal erosion, beach access, dune protection, and planning and coordination of these activities. The Governor of Texas has given notice to the USDOC that Texas will submit a coastal management plan for approval under the federal Coastal Zone Management Act.

The Commissioner of the GLO may issue permits for geological, geophysical, and other investigations within the tidewater limits of the state. The Commissioner may also grant easements or leases for rights-of-way across state lands for pipelines and other transmission lines. In addition, the Commissioner is responsible for technical assistance and compliance under the Dune Protection Act and implementation of the Texas Coastal Preserve Program with the Texas Parks & Wildlife Department.

- **School Land Board.** The School Land Board, in conjunction with the GLO, manages the state's coastal public lands. The Board may grant leases to certain governmental bodies for public purposes; leases for mineral exploration and development; easements to littoral landowners; channel easements to surface or mineral interest holders; leases to educational, scientific, or conservation interests; and permits for limited use of previously unauthorized structures.

- **Soil & Water Conservation Board.** The Texas State Soil & Water Conservation Board has the responsibility to plan, implement, and manage programs and practices for abating agricultural and silvicultural nonpoint pollution. The State Board also administers a voluntary conservation program with and through 212 local soil and water conservation districts which encompass over 99 percent of the surface acres of Texas. With a voluntary program, conservation practices are being applied by over 215,000 cooperating landowners on more than 120 million acres.

- **Texas Parks & Wildlife Department (TPWD).** TPWD operates the state parks system and wildlife refuges. A permit must be obtained from TPWD for the disturbance or dredging of sand, shell, or marl in public waters not authorized by other state or federal agencies. Public waters are defined as all the salt and fresh waters underlying the beds of navigable streams under the jurisdiction of the Parks & Wildlife Commission. TPWD is responsible for reviewing and commenting on state and federal permits affecting Texas wildlife resources and for protection of endangered or threatened species.

- **Texas Railroad Commission.** The Commission has extensive authority in the oil and gas industry and in pollution prevention and abatement. The Commission also regulates intrastate natural gas pipelines and issues drill permits for oil and gas wells. In addition, the Commission regulates surface mining for lignite, uranium, and iron ore to make sure that the resources are properly developed and the environment protected.

- **Texas Department of Transportation (DOT).** DOT is responsible for road construction and planning. DOT administers federal funds for mass transit and may plan, purchase, construct, lease, and contract for public transportation systems in the state. DOT constructs and maintains bridges and ferries, serves as the state sponsor of the Gulf Intracoastal Waterway, and can acquire easements and rights-of-way from GLO for channel expansion, relocation, or alteration.

- **Texas Natural Resource Conservation Commission (TNRCC).** TNRCC has the responsibility for protecting surface and groundwater quality. In addition to this responsibility, the Commission oversees surface water rights administration, dam safety management, the NFIP and flood control improvement project administration, injection well program administration, waste minimization initiatives, and water district supervision. (Effective September 1, 1993, the Texas Water Commission was combined with the Texas Air Control Board to form the Texas Natural Resource Conservation Commission.)

  TNRCC has the authority to develop/enforce regulations affecting streamflow to the Gulf. These regulations are contained in Chapters 11.147 and 11.152 of the Texas Water Code. The 69th Texas Legislature assigned the responsibility for water rights permitting to TNRCC and gave the TPWD authority to be a party in hearings on applications for permits to store, take, or divert water--actions that can change the pattern or quantity of freshwater inflow. The Legislature directed TNRCC to consider effects on bays and estuaries for all water rights permits, with a specific directive to include protective provisions in certain permits by applying a performance standard when making decisions concerning water rights on rivers and streams leading to bays and estuaries.

- **Texas Antiquities Committee.** The Texas Antiquities Committee, created by the Texas Antiquities Code, is responsible for preserving and protecting the state's historical and archaeological resources. The Committee requires permits for activities involving salvage or study of state archaeological landmarks, including historical sites and artifacts of interest such as sunken ships, buried treasure, and art works. The Committee issues eight types of permits covering virtually every aspect of historical and archaeological investigation, including reconnaissance, testing, excavation, and destruction.

- **Texas Attorney General's Office.** The Texas Attorney General's Office is not a regulatory agency, but it has a role in resource management as the state's enforcement agency for the Open Beaches Act and other coastal legislation. The office protects the public's beach access rights and can bring suit on behalf of other state agencies to enforce state laws.

- **Bureau of Economic Geology.** The Bureau of Economic Geology at The University of Texas is responsible for much of the mapping of coastal resources, energy, minerals, land, geology, and biology. It also monitors erosion along the Texas Gulf Coast.

- **Governor's Office of Budget & Planning.** The Governor's Office of Budget & Planning prepares recommendations for the budget and is responsible for administration of state review and comment procedures for all federal or federally funded projects.

PROJECTS CURRENTLY UNDERWAY TO RESPOND TO COASTAL & SHORELINE EROSION IN THE GULF OF MEXICO

This listing can and will be used to make summary statements concerning the "state of the response" to coastal and shoreline erosion along the Gulf of Mexico.

Alabama

- Isle Dauphine Club bulkhead--Successive structures on Isle Dauphine have failed and been re-built to protect a tee on the golf course from erosion. This shoreline is partially sheltered by ephemeral islands (Sand Island/Pelican Island) several kilometers offshore. The islands are on the outer edge of the ebb-tidal delta of Mobile Bay Pass.

- Dauphin Island Park and Beach Board beachfill--To replicate a recently eroded sand dune, 11,468 m^3 (15,000 yd^3) of material was placed on the beach in June 1991. Most of the material washed away within a year. This beach has been experiencing erosion that threatens the integrity of several structures, including a fishing pier, a bathroom, and some picnic pavilions. The fill material was from the other side of the barrier island and, although it was predominately sand, it had enough silt and oyster shell content to make the fill unpleasant for bathers.

- East end of Dauphin Island seawall and groins--These structures were built in 1909-1910 by USACE to protect Ft. Gains from erosion. The western groin field has been flanked several times and is presently several hundred feet from shore. This shoreline is partially sheltered by ephemeral islands (Sand Island/Pelican Island), several kilometers offshore.

- West Beach, Gulf Shores beach nourishment--In June 1991, 114,679 m^3 (150,000 yd^3) of sand from a nearby lagoon were placed on the beach. More sand from the lagoon was placed on the beach in the spring of 1992. The nourishment project was court-ordered. This erosion was downdrift of jetties to Little Lagoon.

- Orange Beach/Perdido Pass Inlet sand transfer--Sand dredged from Perdido Pass has been occasionally placed on the adjacent beaches and in constructed dunes.

Florida

- Vista Del Mar Condo, Perdido Key, sand-filled bags--These bags were placed after Hurricane Elena. There are three elongated bags stacked on each other, two on the bottom and one on top like a triangle. The bags do not experience wave action daily because they are located above the day to day shoreline. They function as a sill during storm overwash events.

- Perdido Key inlet sand transfer--About 5,351,682 m^3 (seven million yd^3) of sand from the Pensacola Pass entrance channel deepening were placed on the Johnson Beach portion of Gulf Islands National Seashore in 1990. Almost 2,293,578 m^3 (three million yd^3) were placed in the nearshore.

- Dunes Motel, Pensacola Beach seawall--Hurricane Elena destroyed the seawall and undermined a building which was later destroyed by Hurricane Juan. This structure was located over 30m (100 ft) seaward of all nearby structures. Debris has now been removed.

- Pensacola Beach overwashed sand replacement--At the request of Florida DNR, town and homeowners scraped overwashed sand from roads and driveways and placed it on the beach after Hurricane Frederic.

- East Pass inlet sand transfer--Sand dredged from the Pass has previously been placed in a storage pile on Eglin Air Force Base property.

- Panama City beach nourishment--During the spring of 1976, sand was pumped from the nearshore profile onto the beaches to construct a storm berm/dune. This was paid for with FEMA disaster relief monies after Hurricane Eloise.

- Panama City bulkheads--At least 50 percent of the coast is armored with wooden or concrete bulkheads. Many of these were destroyed in 1975 by Hurricane Eloise. Others were destroyed in 1983 storms.

- Treasure Island Motel, Panama City Beach seawall--The seawall was destroyed by Hurricane Juan. The motel was also damaged, but has since been rebuilt. Adjacent property was not permitted for repair. This wall was seaward of all other adjacent property. Its presence probably caused extra erosion/recession on unprotected adjacent property during Hurricane Juan.

- Pinnacle Port Condo, Bay County, dune/geotextile-- The dune, built in 1985, is constructed around a staked down geotextile. Periodically, replantings are placed over geotextile. The dune was designed as a protection from minor high tides and storms. A requested permit for a seawall was denied by Florida DNR. The original developer had been strongly warned not to build so close to the water's edge.

- St. Andrews State park inlet sand transfer--A total of over 764,900 m^3 (one million yd^3) of sand from adjacent St. Andrews Pass placed on beaches during 1985, 1982, and 1973.

- Shell Island land acquisition--The land was purchased with state money under the Save Our Coast Program.

- Mexico Beach inlet sand transfer--A small, stabilized inlet channel was developed from a creek in the 1950s. From 1971-1975, the city removed sand from the canal by dragline and placed this sand on downdrift beaches. This was the site of a USACE jet-pump sand bypassing experiment in 1973-1974. From 1974-1975, the city installed their own fixed jet-pump sand bypassing system that was destroyed by Hurricane Eloise. It has been estimated that 20,652 m^3/year (27,000 yd^3/year) were moved by the jet-pump.

- Mexico Beach bulkheads--Many of the bulkheads were destroyed by Hurricane Kate.

- St. Joseph Peninsula inlet sand transfer--In 1985, 229,470 m^3 (300,000 yd^3) of sand dredged from St. Joseph Point Channel were placed on the updrift beaches.

- Sikes Cut, St. George Island, inlet sand transfer--A pass was cut in 1954 to Apalachicola Bay. Dredged sand was placed on downdrift, western beaches at a rate of about 30,596 m^3/year (40,000 yd^3/year). During the 1960s and 1970s, this disposal site was in the bay waters.

- St. George Island St. Park dune construction and vegetation--Fencing with some sea oat plantings was built to establish a dune field to protect a roadway along the state park. The project was begun after Hurricane Kate, extending from the late 1970s to early 1980s.

- Alligator Point groin field--Rubble groins were built from 1971-1972. Several sand bag groins were built also, but they did not survive Hurricane Agnes in 1972.

- Southwest Cape of Alligator Point retreat and revetment--Several houses were moved to the back of lots, and several revetments were constructed. A state study recommended rebuilding as a cost effective alternative. Other alternatives were also considered (*e.g.*, redesigning the roadway as a pile-supported elevated causeway and buying property).

- Lighthouse Point, Franklin County, roadway not reconstructed--In 1985, hurricanes destroyed a roadway and the recommendation was to not rebuilt a section of the roadway. A 1.4 km (0.9 mi) section of the road has been recommended for landward relocation, but this recommendation has not yet been implemented. Approximately 305 m (1000 ft) of seawall was destroyed by the same storms.

- Mashes Sands land acquisition--An eroding barrier island was purchased through the State of Florida's environmentally endangered lands bill.

- Honeymoon Island State Park beach restoration--Beachfill and some groins were constructed with sand from a nearby land source and transported to site by trucks.

- Clearwater Beach groin field and bulkhead--No additional information available.

- Clearwater Beach fishing piers which function as groins--"Wave deflection" panels were built under the piers. These panels extend down into the waves so the piers function as permeable groins.

- Clearwater beach inlet sand transfer--Sand was transferred from the inlet onto the beaches in front of vertical bulkheads in 1982. A terminal groin is located adjacent to the pass.

- Clearwater/Sand Key inlet sand transfer/beach nourishment--In 1981-1984, 458,940 m^3 (600,000 yd^3) of sand from Clearwater Pass was placed on beaches of the city of Clearwater along the north portion of Sand Key. In 1990-1991, 14,533 m^3 (19,000 yd^3) of sand was truck-hauled to the beaches from an inland site. Previously, sand from Clearwater Pass had been pumped onto these beaches in 1972 [50,483 m^3 (66,000 yd^3)] and 1977 [142,271 m^3 (186,000 yd^3)].

- Belair Beach and Belair Shores bulkheads--There are approximately 3.2 km (2 mi) of different bulkhead types, predominately privately constructed, vertical concrete bulkheads. This stretch of coast is probably 100 percent armored. Much of the bulkheads were destroyed by Hurricane Elena.

- Indian Rocks Beach beach nourishment--In 1990, 994,370 m^3 (1.3 million yd^3) of sand were placed on the beach. Previous smaller, emergency beachfills were placed on this in 1969 [109,381 m^3 (143,000 yd^3)] and 1973 [305,960 m^3 (400,000 yd^3)]. The source of the sand was Egmont shoals.

- Indian Shores beach nourishment--In 1991, 841,390 m^3 (1.1 million yd^3) of sand were placed on the beach. The source of the sand was Egmont shoals.

- Redington Shores and North Redington Beach nourishment--In 1986, an offshore breakwater was constructed with 290,662 m^3 (380,000 yd^3) of beachfill. The elevation of the top of the breakwater was lowered in 1988 from +.5 m (1.5 ft) (mean low water) to +.2 m (0.5 ft). There are many private bulkheads in the area. This is a case where the results of a formal coastal engineering monitoring program were used to improve the engineered solution after several years.

- Madiera Beach groin field--This groin was built in the 1950s.

- Treasure Island Beach Nourishment/inlet sand transfer--In 1986, 415,341 m^3 (543,000 yd^3) of sand from offshore of Pass-a-Grille were placed on the beach. Previously, there were nine other beachfills totaling 1,376,820 m^3 (1.8 million yd^3), from 1964 to 1985, with sand sources including Johns Pass, Blind Pass, and offshore. Coastal structures are common along the beaches. The beachfills bury an old groin field, and there is a terminal groin at Blind Pass at the south end of Treasure Island. There is a dune restoration project on the current beachfill.

- St. Petersburg Beach/Long Key beach nourishment--In 1991, 152,980 m^3 (200,000 yd^3) of sand from Blind Pass were placed on the north end of the beach. In 1986, 84,139 m^3 (110,000 yd^3) were placed on the southern portion of the island. In 1980, 185,871 m^3 (243,000 yd^3) were placed on the north end. About half of the 1980 fill was placed in shallow water, not directly on the beach. Smaller fills, in 1968 and 1975, totaled 80,315 m^3 (105,000 yd^3). There is a terminal groin, detached breakwater, and about 304.8 m (1,000 ft) of presently buried bulkheads at the north end of the island. There are intermittent and buried bulkheads along the remainder of the island. There is a terminal groin at the south end of the island which has been rehabilitated twice since construction in 1941.

- Pass-a-Grille Dune restoration/revegetation--Constructed dunes within a public park have been stabilized with vegetation.

- Mullet Key Beach nourishment/inlet sand transfer--Three channel dredging projects have used Mullet Key beaches for sand disposal. In 1977, 573,675 m^3 (750,000 yd^3) of sand from Tampa Harbor were placed on the Gulf beaches. About half as much sand was also placed on the Mullet Key beaches that face Tampa Bay. In 1973 and 1964, 382,450 m^3 (500,000 yd^3) and 106,321 m^3 (139,000 yd^3) of sand from Egmont Channel were placed on the island beaches.

- Ft. Desoto Park interlocking waffle-block revetment--The history of this revetment is unknown, but probably it was built by federal interests.

- Egmont Key revetment with groin field--This history of this groin field is unknown, but it is possibly 1800s vintage. It has failed and is visible in the water.

- Anna Maria Island coastal structures--All of Bradenton Beach and most of Holmes Beach are armored with seawalls, bulkheads, revetments, rubble groins, pier groins, and a terminal groin at Longboat Pass. Many of these structures were damaged and failed during Hurricanes Elena and Juan. A federal beach nourishment project was scheduled to be constructed in 1992-1993.

- Anna Maria Island beach nourishment--Construction of a large beach nourishment project was scheduled to begin at this beach in the fall of 1992.

- Longboat Key groins and seawalls--This coast has had a serious erosion problem since initial construction in the 1950s. There have been many generations of failed erosion control projects (*e.g.*, seawalls, revetments, groins). A locally-funded beach nourishment project is scheduled for the fall of 1992.

- Lido Key beach nourishment/inlet sand transfer--Lido Key beach was restored in the 1970s, with sand transferred from New Pass.

- Siesta Key bulkheads and revetments--No additional information was available.
- Casey Key revetment--A revetment has replaced an older, failed groin field with bulkheads.
- Venice Beach bulkheads and revetment--Venice Beach has mostly vertical concrete bulkheads with rubble toe protection in front.
- Casperson Beach groin field--Casperson Beach has a series of five rubble mound groins. There is erosion downdrift of the groin field.
- Mansoto Key revetment--No additional information was available.
- Englewood Beach groin field with bulkheads--No additional information was available.
- Mansoto Key inlet sand transfer--Sand from Stump Pass was placed on beaches in 1980.
- Boca Grande bulkheads--There has been some sand from inlets placed on beaches at the tip of Gasparilla Island. There is a terminal groin at the south end of the island.
- North Captiva Island land purchases--Several houses at the north end of North Captiva Island were abandoned when the land was purchased by the state. Several attempts at short segments of revetment have failed.
- Captiva Island beach renourishment--In 1981, 497,185 m^3 (650,000 yd^3) of sand were placed along 3.2 km (2 mi) of beach; this was extended with 1,223,840 m^3 (1.6 million yd^3) in 1989.
- Ft. Myers Beach inlet sand transfer--There was an inlet sand transfer from the north.
- Lover's Key land purchase--An eroding island was purchased by the state.
- Bonita Beach seawall--Beach nourishment is being planned for this area.
- Delnor-Wiggins beach nourishment/inlet sand transfer--To maintain Wiggins Pass, sand has been placed on the adjacent beaches three times: 38,245 m^3 (50,000 yd^3) to the north in 1984; 25,242 m^3 (33,000 yd^3) to the south in 1990; and 26,007 m^3 (34,000 yd^3) to the south in 1991.
- Naples groin field--No additional information was available.

- Keewaydin Island inlet sand transfer--Sand was removed from Gorden's Pass and placed on Keewaydin Island.

- Keewaydin Island artificial seaweed--A seaweed experiment failed.

- Marco Island beach nourishment--Three segments of fill were placed on the beach in 1991. Prior to the fill there was a revetment armoring the coast.

Louisiana

- Holly Beach offshore breakwaters--Rubble-mound breakwater sections were constructed in 1990-1992 with lengths of 91.4 m (300 ft) and gap widths between the breakwater of roughly 76.2 m (250 ft). The breakwaters are roughly 122-183 m (400-600 ft) offshore. There is no beachfill behind the breakwaters.

- Highway 82 seawall--The seawall is gobi block articulated revetment. It was built in the 1950s or 1960s and failed structurally due, apparently, to underlying sediments being pulled out from the units, contributing to unit-by-unit unraveling. The remains of the seawall are still visible and still providing some limited protection. The 1990 Holly Beach breakwater project is built seaward along this same stretch of coastline.

- Isle Deneirs barrier island restoration--This restoration project was constructed in 1985-1986, to raise the profile of the uninhabited barrier island to prevent overwashing and eventual reduction to a submerged shoal. A 3.2 km (2 mi) long section of barrier island restoration, adjacent to the 1986 project, is planned for 1993.

- Wine Island Shoal restoration--In 1990, a rock containment dike/pond was filled with dredged material from the Houma ship channel and overfilled with sand.

- Timbalier Island canal filling--In 1988, Texaco filled in a section of an existing canal which ran parallel to the barrier island. The barrier island had historically breached at this location, and the canal was filled to prevent future breaching.

- West Timbalier Island seawall--This is a rubble revetment seawall that was built in the 1970s as a public works project to protect a barrier island breach to a canal which is perpendicular to the barrier island.

- West Timbalier Island beach nourishment--This sand dune construction/barrier island restoration project was built, in 1986, to seal a threatened breach in the barrier island. The project was damaged, in 1992, by Hurricane Andrew.

- East Timbalier Island seawall--Petroleum interests surrounded a barrier island with rubble to protect the integrity of the island. The island was providing wave sheltering for their production facilities.

- Grand Isle beach nourishment--Portions of a dune cross-section that includes a clay core was built in the 1980s.

- Grand Isle seawall--This rock seawall with groins was built during the last several decades. The structures are seaward of the constructed dune. This shoreline overlaps with USACE beach nourishment projects.

Mississippi

- Hancock County seawall--This stepped seawall is several decades old. Some sand was pumped onto beaches before Hurricane Camille. This coastline is partially protected by a chain of barrier islands about 16 km (10 mi) offshore.

- Fort Massachusetts beach nourishment--Sand from the dredging of the Gulfport ship channel has been placed around the historic fort four times.

- Harrison County (Biloxi) seawall and beach nourishment--This beach has been nourished from borrow areas several hundred meters offshore several times in the past few decades. Much of the seawall protects US Highway 90. This coastline is partially protected by a chain of barrier islands about 16 km (10 mi) offshore.

- Horn Island Pass inlet sand transfer--Sand from the dredging of the Pascagoula ship channel in Horn Island Pass has been placed to the west to form an entirely constructed island.

- Jackson County seawalls and bulkheads--Much of this seawall is a rounded paved retaining wall protecting roadways. Some of the wall is fronted by pocket beaches, and some is fronted by water. This coastline is partially protected by a chain of barrier islands about 16 km (10 mi) offshore.

Texas

- South Padre Island bulkheads--Individual property owners after 1967 built vertical concrete bulkheads within foredunes.

- North Padre Island seawall--The beach has a stepped seawall .

- Brazoria County Christmas trees--This project involves dune construction with Christmas trees followed by planting. A volunteer effort has evolved into a formal "Dune Day" program with 4-H Clubs, Scouts, and private industry support. Up to 300 volunteers and 10,000 trees are employed each year.

- Surfside inlet sand transfer--Sand from the Freeport ship channel was placed on the beach in the summer of 1991.

- Galveston seawall and groin field--A large, curved, gravity seawall was built in segments beginning in 1902 and ending in 1961. An extensive groin field was built to protect the beach sands at the toe of the seawall in 1939. Toe protection rubble has been added to the toe of the seawall as recently as 1989. The wall is one of the largest seawalls in the U.S. It was built after America's deadliest natural disaster, the hurricane of 1900, which killed 6,000 people, to prevent future flooding disasters. A beach nourishment project is planned for the beaches in front of the wall in 1993.

- Highway 87 (Jefferson County) relocation--This project is a highway re-alignment away from the Gulf. The highway is often overwashed during storms and has been occasionally rebuilt farther from the sea to prevent undermining, The highway was closed by the Texas Department of Transportation in 1989, following damage caused by Hurricane Jerry. There is a proposed roadway reconstruction approximately 91.4 m (300 ft) inland of its present position. Excess construction fill material will be used to reconstruct dunes between the existing beach and the new road right-of-way.

ACAMP	Alabama Coastal Area Management Program
ADECA	Alabama Department of Economic and Community Affairs
ADEM	Alabama Department of Environmental Management
AL	Alabama
ATSDR	Agency for Toxic Substances and Disease Registry
BEB	Beach Erosion Board
BMR	Bureau of Marine Resources
CAC	Citizens Advisory Committee, Gulf of Mexico Program
CBRA	Coastal Barriers Resources Act
CBRS	Coastal Barrier Resources System
CCCL	Coastal Construction Control Line
CMD	Coastal Management Division
COP	Coastal Ocean Program
CUP	Coastal Use Permit
CWA	Clean Water Act
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Plan (or Program)
DCA	Department of Community Affairs
DER	Department of Environmental Regulation
DOT	Texas Department of Transportation
DNR	Department of Natural Resources
ECL	Erosion Control Line
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EMU	Environmental Management Unit--Louisiana Parishes
FCMP	Florida Coastal Management Program
FEMA	Federal Emergency Management Agency
FL	Florida
FLDER	Florida Department of Natural Resources
GLO	Texas General Land Office
GMP	Gulf of Mexico Program
GMPO	Gulf of Mexico Program Office
LA	Louisiana
LCA	Local Cooperation Agreement
LCRP	Louisiana Coastal Resources Program
LGS	Louisiana Geological Survey
MC	Management Committee--Gulf of Mexico Program
MMS	U.S. Minerals Management Service
MS	Mississippi
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NEEA	National Environmental Education Act
NEP	National Estuary Program
NEPA	National Environmental Policy Act

NFIA	National Flood Insurance Act
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
OCS	Outer Continental Shelf
PRB	Policy Review Board, Gulf of Mexico Program
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SCS	Soil Conservation Service
SLCRMA	State and Local Coastal Resources Management Act
SMA	Special Management Area
SSEOO	Space Shuttle Earth Observations Office
TAC	Technical Advisory Committee
TSC	Technical Steering Committee, Gulf of Mexico Program
TPWD	Texas Parks & Wildlife Department
TNRCC	Texas Natural Resource Conservation Commission
TX	Texas
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior
USDOT	U.S. Department of Transportation
USEPA	U. S. Environmental Protection Agency
USFDA	U.S. Food & Drug Administration
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
WES	USACE Waterways Experiment Station

accretion	May be either NATURAL or ARTIFICIAL. Natural accretion is the buildup of land, solely by the action of the forces of nature or a BEACH by deposition of water- or airborne material. Artificial accretion is a similar buildup of land by reason of a human act, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means. See AGGRADATION.
advance	(of a beach). (1) A continuing seaward movement of the shoreline. (2) A net seaward movement of the shoreline over a specified time. See PROGRESSION.
aggradation	See ACCRETION.
alluvium	Soil (sand, mud, or similar detrital material) deposited by streams, or the deposits formed.
alongshore	Parallel to and near the shoreline. See LONGSHORE.
amplitude, wave	The magnitude of the displacement of a wave from a mean value. An ocean wave has an amplitude equal to the vertical distance from still water level to wave crest. For a sinusoidal wave, the amplitude is one-half the wave height.
armor unit	A relatively large quarrystone or concrete shape that is selected to fit specified geometric characteristics and density. It is usually of nearly uniform size and usually large enough to require individual placement. In normal cases it is used as primary wave protection and is placed in thicknesses of at least two units.
artificial	The process of replenishing a beach with material (usually **Nourishment sand)** obtained from another location.
awash	Situated so that the top is intermittently washed by waves or tidal action. Condition of being exposed or just bare at any stage of the tide between high water and chart datum.
backbeach	See BACKSHORE.
backrush	The seaward return of the water following the uprush of the waves. For any given tide stage the point of farthest return seaward of the backrush is known as the LIMIT of BACKRUSH or LIMIT BACKWASH.
backshore	That zone of the shore or beach lying between the foreshore and the coastline comprising the BERM and BERMS and acted upon by waves only during severe storms, especially when combined with exceptionally high water. See BACKBEACH.
backwash	(1) See BACKRUSH. (2) Water or waves thrown back by an obstruction such as a ship, breakwater, or cliff.
bar	A submerged or emerged embankment of sand, gravel, or other unconsolidated material built on the sea floor in shallow water by waves and currents. See BAYMOUTH BAR, CUSPATE BAR.
barrier beach	A bar essentially parallel to the shore, the crest of which is above normal high water level; also called OFFSHORE BARRIER and BARRIER ISLAND.

barrier lagoon	A bay roughly parallel to the coast and separated from the open ocean by barrier islands.
basin, boat	A naturally or artificially enclosed or nearly enclosed harbor area for small craft.
bathymetry	The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.
bay	A recess in the shore or an inlet of a sea between two capes or headlands, not so large as a gulf but larger than a cove. See BIGHT and EMBAYMENT.
baymouth bar	A bar extending partly or entirely across the mouth of a bay.
bayou	A minor sluggish waterway or estuarial creek, tributary to, or connecting, other streams or bodies of water, whose course is usually through lowlands or swamps; sometimes called SLOUGH.
beach	The zone of unconsolidated material that extends landward from the low water line to the place where there is marked changed in material or physiographic form or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach--unless otherwise specified--is the mean low water line. A beach includes FORESHORE and BACKSHORE. See SHORE.
beach accretion	See ACCRETION.
beach berm	A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.
beach cusp	See CUSP.
beach erosion	The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.
beach face	The section of the beach normally exposed to the action of the wave uprush; the FORESHORE of a BEACH. (Not synonymous with SHOREFACE.)
beach fill	Material placed on a beach to renourish eroding shores.
beach ridge	See RIDGE, BEACH.
beach scarp	See SCARP, BEACH.
beach width	The horizontal dimension of the beach measured normal to the shoreline.
bench mark	A permanently fixed point of known elevation. A primary bench mark is one close to a tide station to which the tide staff and tidal datum originally are referenced.
berm, beach	See BEACH BERM.

berm crest	The seaward limit of a berm; also called BERM EDGE.
bight	A bend in a coastline forming an open bay; a bay formed by such a bend.
blown sands	See EOLIAN SANDS.
bluff	A high, steep bank or cliff.
bottom	The ground or bed under any body of water; the bottom of the sea.
bottom (nature of)	The composition or character of the bed of an ocean or other body of water (*e.g.*, clay, coral, gravel, mud, ooze, pebbles, rock, shell, shingle, hard, or soft).
boulder	A rounded rock more than 10 inches in diameter; larger than a cobblestone.
breaker	A wave breaking on a shore, over a reef, etc. Breakers may be classified into four types. *Spilling*--bubbles and turbulent water spill down the front face of a wave. The upper 25 percent of the front face may become vertical before breaking; breaking generally occurs over quite a distance. *Plunging*--crest curls over an air pocket; breaking is usually with a crash; smooth splash-up usually follows. *Collapsing*--breaking occurs over the lower half of a wave, with minimal air pocket and usually no splash-up; bubbles and foam are present. *Surging*--wave peaks up, but bottom rushes forward from under a wave, and the wave slides up the beach face with little or no bubble production. Water surface remains almost plane except where ripples may be produced on the beachface during runback.
breaker depth	The still-water depth at the point where a wave breaks; also called BREAKING DEPTH.
breakwater	A structure protecting a shore area, harbor, anchorage, or basin from waves.
bulkhead	A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.
buoy	A float; especially a floating object moored to the bottom to mark a channel, anchor, shoal, rock, etc.
buoyancy	The result of upward forces, exerted by the water on a submerged or floating body, equal to the weight of the water displaced by this body.
bypassing, sand	Hydraulic or mechanical movement of sand from the accreting updrift side to the eroding downdrift side of an inlet or harbor entrance. The hydraulic movement may include natural movement as well as movement caused by humans.
canal	An artificial watercourse cut through a land area for such uses as navigation and irrigation.

cape	A relatively extensive land area jutting seaward from a continent or large island which prominently marks a change in, or interrupts notably, the coastal trend; a prominent feature.
causeway	A raised road across wet or marshy ground or across water.
cay	See KEY.
Central Pressure Index (CPI)	The estimated minimum barometric pressure in the eye (approximate center) of a particular hurricane. The CPI is considered the most stable index to intensity of hurricane wind velocities in the periphery of the storm; the highest wind speeds are associated with storms having the lowest CPI.
channel	(1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connection link between two bodies of water. (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation. (3) A large strait, as the English Channel. (4) The deepest part of a stream, bay, or strait through which the main volume or current of water flows.
chart datum	The plane or level to which soundings (or elevations) or tide heights are referenced (usually LOW WATER DATUM). The surface is called a tidal datum when referred to a certain phase of tide. To provide a safety factor for navigation, some level lower than MEAN SEA LEVEL is generally selected for hydrographic charts, such as MEAN LOW WATER or MEAN LOWER LOW WATER. See DATUM PLANE.
chop	The short-crested waves that may spring up quickly in a moderate breeze and which break easily at the crest.
coast	A strip of land of indefinite width (may be several kilometers) that extends from the shoreline inland to the first major change in terrain features.
coastal area	The land and sea area bordering the shoreline.
coastal plain	The plain composed of horizontal or gently sloping strata of clastic materials fronting the coast and generally representing a strip of sea bottom that has emerged from the sea in recent geologic time.
coastline	(1) Technically, the line that forms the boundary between the COAST and the SHORE. (2) Commonly, the line that forms the boundary between the land and the water.
continental shelf	The zone bordering a continent and extending from the low water line to the depth (usually about 180 meters) where there is a marked or rather steep descent toward a greater depth.
contour	A line on a map or chart representing points of equal elevation with relation to a DATUM. It is called an ISOBATH when connecting points of equal depth below a datum; also called DEPTH CONTOUR.

controlling depth	The least depth in the navigable parts of a waterway, governing the maximum draft of vessels that can enter.
core	A vertical, cylindrical sample of the bottom sediments from which the nature and stratification of the bottom may be determined.
cove	A small, sheltered recess in a coast, often inside a larger embayment.
crest of berm	The seaward limit of a berm; also called BERM EDGE.
crest of wave	(1) The highest part of a wave. (2) That part of the wave above still-water level.
crest width, wave	See CREST LENGTH, WAVE.
current	A flow of water.
current, drift	A broad, shallow, slow-moving ocean or lake current; opposite of CURRENT, STREAM.
current, ebb	The tidal current away from shore or down a tidal stream; usually associated with the decrease in the height of the tide.
current, eddy	See EDDY.
current, feeder	Any of the parts of the NEARSHORE CURRENT SYSTEM that flow parallel to shore before converging and forming the neck of the RIP CURRENT.
current, flood	The tidal current toward shore or up a tidal stream; usually associated with the increase in the height of the tide.
current, inshore	See INSHORE CURRENT.
current, littoral	Any current in the littoral zone caused primarily by wave action; *e.g.*, LONGSHORE CURRENT, RIP CURRENT. See CURRENT, NEARSHORE.
current, longshore	The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.
current, nearshore	A current in the NEARSHORE ZONE.
current, offshore	See OFFSHORE CURRENT.
current, periodic	See CURRENT, TIDAL.
current, permanent	See PERMANENT CURRENT.
current, rip	See RIP CURRENT.
current, stream	A narrow, deep, and swift ocean current, as the Gulf Stream. See CURRENT, DRIFT.
current system, nearshore	See NEARSHORE CURRENT SYSTEM.

current, tidal The alternating horizontal movement of water associated with the rise and fall of the tide caused by the astronomical tide-producing forces; also CURRENT, PERIODIC. See CURRENT, FLOOD and CURRENT, EBB.

cusp One of a series of low mounds of beach material separated by crescent-shaped troughs spaced at more or less regular intervals along the beach face; also BEACH CUSP.

cuspate bar A crescent-shaped bar uniting with the shore at each end. It may be formed by a single spit growing from shore and then turning back to again meet the shore or by two spits growing from the shore and uniting to form a bar of sharply cuspate form.

cuspate spit The spit that forms in the lee of a shoal or offshore feature (breakwater, island, rock outcrop) by waves that are refracted and/or diffracted around the offshore feature. It may be eventually grown into a TOMBOLO linking the feature to the mainland. See TOMBOLO.

datum, chart See CHART DATUM.

datum, plane The horizontal plane to which soundings, ground elevations, or water surface elevations are referred; also REFERENCE PLANE. The plane is called a TIDAL DATUM when defined by a certain phase of the tide. The following datums are ordinarily used on hydrographic charts:

Mean Low Water--Atlantic coast (U.S.)
Mean Lower Low Water--Pacific and Gulf coasts (U.S.)
Low Water Datum--Great Lakes (U.S. and Canada)

A common datum used on topographic maps is based on MEAN SEA LEVEL. See BENCH MARK.

debris line A line near the limit of storm wave uprush marking the landward limit of debris deposits.

decay of waves The change waves undergo after they leave a generating area (FETCH) and pass through a calm or region of lighter winds. In the process of decay, the significant wave height decreases and the significant wavelength increases.

deep water Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water. See SHALLOW WATER.

deflation The removal of loose material from a beach or other land surface by wind action.

delta An alluvial deposit, roughly triangular or digitate in shape, formed at a river mouth.

depth The vertical distance from a specified tidal datum to the sea floor.

depth of breaking The still-water depth at the point where the waves breaks.

depth contour	See CONTOUR.
depth controlling	See CONTROLLING DEPTH.
diffraction	(of water waves) The phenomenon by which energy is transmitted laterally along a wave crest. When a part of a train of waves is interrupted by a barrier, such as a breakwater, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.
dike (dyke)	A wall or mound built around a low-lying area to prevent flooding.
diurnal	Having a period of cycle of approximately one TIDAL DAY.
diurnal tide	A tide with one high water and one low water in a tidal day.
dolphin	A cluster of piles.
downdrift	The direction of predominant movement of littoral materials.
drift	(noun). (1) Sometimes used as a short form for LITTORAL DRIFT. (2) The speed at which a current runs. (3) Floating material deposited on a beach (driftwood).
drift current	A broad, shallow, slow-moving ocean or lake current.
dunes	Ridges or mounds of loose, wind-blown material, usually sand.
ebb current	The tidal current away from shore or down a tidal stream; usually associated with the decrease in height of the tide.
ebb tide	The period of tide between high water and the succeeding low water; a falling tide.
echo sounder	An electronic instrument used to determine the depth of water by measuring the time interval between the emission of a sonic or ultrasonic signal and the return of its echo from the bottom.
eddy	A circular movement of water formed on the side of a main current. Eddies may be created at points where the main stream passes projecting obstructions or where two adjacent currents flow counter to each other; also EDDY CURRENT.
eddy current	See EDDY.
embayed	Formed into a bay or bays, as an embayed shore.
embayment	An indentation in the shoreline forming an open bay.
entrance	The avenue of access or opening to a navigable channel.
eolian sands	Sediments of sand size or smaller which have been transported by winds. They may be recognized in marine deposits off desert coasts by the greater angularity of the grains compared with waterborne particles.

erosion	The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.
escarpment	A more or less continuous line of cliffs or steep slopes facing in one general direction which are caused by erosion of faulting; also SCARP.
estuary	(1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.
eye	In meteorology, usually the "eye of the storm" (hurricane); the roughly circular area of comparatively light winds and fair weather found at the center of a severe tropical cyclone.
fairway	The parts of a waterway that are open and unobstructed for navigation. The main traveled part of waterway; a marine thoroughfare.
fathom	A unit of measurement used for soundings equal to 1.83 meters (6 feet).
fathometer	The copyrighted trademark for a type of echo sounder.
feeder beach	An artificially widened beach serving to nourish downdrift beaches by natural littoral currents or forces.
feeder current	See CURRENT, FEEDER.
feeling bottom	The initial action of a deepwater wave, in response to the bottom, upon running into shoal water.
fetch	The area in which SEAS are generated by a wind having a fairly constant direction and speed.
flood current	The tidal current toward shore or up a tidal stream, usually associated with the increase in the height of the tide.
flood tide	The period of tide between low water and the succeeding high water; a rising tide.
foam line	The front of a wave as it advances shoreward, after it has broken.
following wind	Generally, the same as a tailwing; in wave forecasting, wind blowing in the direction of ocean-wave advance.
foredune	The front dune immediately behind the backshore.
foreshore	The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low-water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall. See BEACH FACE.
forward speed	Rate of movement (propagation) of the hurricane eye in (hurricane) meters per second, knots, or miles per hour.

freeboard	The additional height of a structure above design high water level to prevent overflow. Also, at a given time, the vertical distance between the water level and the top of the structure. On a ship, the distance from the waterline to main deck or gunwale.
full	See RIDGE, BEACH.
generation of waves	The creation and growth of waves caused by a wind blowing over a water surface for a certain period of time. The area involved is called the GENERATING AREA or FETCH.
geomorphology	That branch of both physiography and geology which deals with the form of the Earth, the general configuration of its surface, and the changes that take place in the evolution of landform.
groin	A shore protection structure build (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.
groin system	A series of groins together to protect a section of beach; commonly called a groin field.
ground swell	A long high ocean swell; also, this swell as it rises to prominent height in shallow water.
ground water	Subsurface water occupying the zone of saturation. In a strict sense, the term is applied only to water below the WATER TABLE.
gulf	A large embayment in a coast; the entrance is generally wider than the length.
gut	(1) a narrow passage such as a strait or inlet. (2) a channel in otherwise shallower water, generally formed by water in motion.
half-tide level	See MEAN TIDE LEVEL.
harbor	Any protected water area affording a place of safety for vessels. See PORT.
head of rip	The part of a rip current that has widened out seaward of the breakers. See CURRENT, RIP; CURRENT, FEEDER; and NECK (RIP).
height of wave	See WAVE HEIGHT.
hide tide	(HW) The maximum elevation reached by each rising tide.
high water	See HIGH TIDE.
high water line	The intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the National Ocean Service is an approximation of the high water line. For specific occurrences, the highest elevation on the shore reached during a storm or rising tide, including meteorological effects.
higher high water	(HHW). The higher of the two high waters of any tidal day. The single high water occurring daily during a period when the tide is diurnal is considered to be a higher high water.

higher low water (HLW). The higher of two low waters of any tidal day.

hindcasting, wave The use of historic wind charts to calculate characteristics of waves that probably occurred at some past time.

hook A spit or narrow cape of sand or gravel which turns landward at the outer end.

hurricane An intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 33.5 meters per second (75 mph or 65 knots) for several minutes or longer at some points. TROPICAL STORM is the term applied if maximum winds are less than 33.5 meters per second.

hurricane path or track Line of movement (propagation) of the eye through an area.

hydrography (1) A configuration of an underwater surface including its relief, bottom materials, coastal structures, etc. (2) The description and study of seas, lakes, rivers, and other waters.

impermeable groin A groin through which sand cannot pass.

inlet (1) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (2) An arm of the sea (or other body of water) that is long compared to its width and may extend a considerable distance inland. See TIDAL INLET.

inlet gorge Generally, the deepest region of an inlet channel.

inshore (zone) In beach terminology, the zone of variable width extending from the low water line through the breaker zone; also SHOREFACE.

inshore current Any current in or landward of the breaker zone.

insular shelf The zone surrounding an island extending from the low water line to the depth (usually about 183 meters (100 fathoms)) where there is a marked or rather steep descent toward the great depths.

isobath A contour line connecting points of equal water depths on a chart.

isthmus A narrow strip of land, bordered on both sides by water, that connects two larger bodies of land.

jet To place (a pile, slab, or pipe) in the ground by means of a jet of water acting at the lower end.

jetty On open seacoasts, a structure extending into a body of water, which is designed to prevent shoaling of a channel by littoral materials and to direct and confine the stream or tidal flow. Jetties are built at the mouths of rivers or tidal inlets to help deepen and stabilize a channel. See TRAINING WALL.

key A low, insular bank of sand, coral, etc., as one of the islets off the southern coast of Florida; also CAY.

knot	The unit of speed used in navigation equal to 1 nautical mile (6,076.115 feet or 1,852 meters) per hour.
lagging	See TIDES, DAILY RETARDATION OF.
lagoon	A shallow body of water, like a pond or lake, usually connected to the sea.
land breeze	A light wind blowing from the land to the sea, caused by unequal cooling of land and water masses.
land-sea breeze	The combination of a land breeze and a sea breeze as a diurnal phenomenon.
landlocked	Enclosed, or nearly enclosed, by land--thus protected from the sea, as a bay or a harbor.
landmark	A conspicuous object, natural or artificial, located near or on land, which aids in fixing the position of an observer.
lead line	A line, wire, or cord used in sounding. It is weighted at one end with a plummet (sounding lead); also SOUNDING LINE.
lee	((1)) Shelter, or the part or side sheltered or turned away from the wind waves. (2) (Chiefly nautical) The quarter or region toward which the wind blows.
leeward	The direction toward which the wind is blowing; the direction toward which waves are traveling.
length of wave	The horizontal distance between similar points on two successive waves measured perpendicularly to the crest.
levee	A dike or embankment to protect land from inundation.
limit of backrush (limit of backwash)	See BACKRUSH, BACKWASH.
littoral	Of or pertaining to a shore, especially of the sea.
littoral current	See CURRENT, LITTORAL.
littoral deposits	Deposits of littoral drift.
littoral drift	The sedimentary material moved in the littoral zone under the influence of waves and currents.
littoral transport	The movement of littoral drift in the littoral zone by waves and currents; includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.
littoral transport rate	Rate of transport of sedimentary material parallel or perpendicular to the shore in the littoral zone; usually expressed in cubic meters (cubic yards) per year; commonly synonymous with LONGSHORE TRANSPORT RATE.

littoral zone	In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.
load	The quantity of sediment transported by a current. It includes the suspended load of small particles and the bedload of large particles that move along the bottom.
longshore	Parallel to and near the shoreline. See ALONGSHORE.
longshore bar	A bar running roughly parallel to the shoreline.
longshore current	See CURRENT, LONGSHORE.
longshore transport rate	Rate of transport of sedimentary material parallel to the shore; usually expressed in cubic meters (cubic yards) per year; commonly synonymous with LITTORAL TRANSPORT RATE.
low tide (low water)	(LW) The minimum elevation reached by each falling tide. See TIDE.
low water datum	An approximation to the plane of mean low water that has been adopted as a standard reference plane. See DATUM, PLANE, and CHART
low water line	The intersection of any standard low tide datum plane with the shore.
lower high water	(LHW) The lower of the two high waters of any tidal day.
lower low water	(LLW)The lower of the two low waters of any tidal day. The single low water occurring daily during periods when the tide is diurnal is considered to be a lower low water.
mangrove	A tropical tree with interlacing prop roots, confined to low-lying brackish areas.
marigram	A tropical tree with interlacing prop roots, confined to low-lying brackish areas.
marsh	An area of soft, wet, or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.
marsh, salt	A marsh periodically flooded by salt water.
mean high water	(MHW) The average height of the high waters over a 19-year period. For shorter periods of observations; corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

mean low water (MLW) The average height of the low waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All low water heights are included in the average where the type of tide is either semidiurnal or mixed. Only lower low water heights are included in the average where the type of tide is diurnal. So determined, mean low water in the latter case is the same as mean low water.

mean sea level The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings; not necessarily equal to MEAN TIDE LEVEL.

mean tide level A plane midway between MEAN HIGH WATER and MEAN LOW WATER; not necessarily equal to MEAN SEA LEVEL; also HALF-TIDE LEVEL.

median diameter The diameter which marks the division of a given sand sample into two equal parts by weight, one part containing all grains larger than that diameter and the other part containing all grains smaller.

middle-ground shoal A shoal formed by ebb and flood tides in the middle of the channel of the lagoon or estuary end of an inlet.

mixed tide A type of tide with a large inequality in either the high or low water heights, with two high waters and two low waters usually occurring each tidal day. In strictness, all tides are mixed, but the name is usually applied without definite limits to the tide intermediate to those predominantly semidiurnal and those predominantly diurnal.

monochromatic waves A series of waves generated in a laboratory; each wave has the same length and period.

monolithic Like a single stone or block. In coastal structures, the type of construction in which the structure's component parts are bound together to act as one.

nautical mile The length of a minute of arc, 1/21,600 of an average great circle of the Earth. Generally one minute of latitude is considered equal to one nautical mile. The accepted U.S. value as of 1 July 1959 is 1,852 meters (6,076.115 feet), approximately 1.15 times as long as the U.S. statute mile of 5,280 feet; also geographical mile.

neap tide A tide occurring near the time of quadrature of the moon with the sun. The neap tidal range is usually 10 to 30 percent less than the mean tidal range.

nearshore (zone) In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of NEARSHORE CURRENTS.

nearshore circulation The ocean circulation pattern composed of the CURRENTS, NEARSHORE and CURRENTS, COASTAL. See CURRENT.

nearshore current system	The current system caused primarily by wave action in and near the breaker zone and which consists of four parts: the shoreward mass transport of water; longshore currents; seaward return flow, including rip currents; and the longshore movement of the expanding heads of rip currents. See NEARSHORE CIRCULATION.
neck	(1) The narrow band of water flowing seaward through the surf; also RIP. (2) The narrow strip of land connecting a peninsula with the mainland.
nodal zone	An area in which the predominant direction of the LONGSHORE TRANSPORT changes.
nourishment	The process of replenishing a beach. It may be brought about naturally by longshore transport or artificially by the deposition of dredged materials.
oceanography	The study of the sea, embracing and indicating all knowledge pertaining to the sea's physical boundaries, the chemistry and physics of seawater, and marine biology.
offshore	(1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf. (2) A direction seaward from the shore.
offshore barrier	See BARRIER BEACH.
offshore current	(1) Any current in the offshore zone. (2) Any current flowing away from shore.
offshore wind	A wind blowing seaward from the land in the coastal area.
onshore	A direction landward from the sea.
onshore wind	A wind blowing landward from the sea in the coastal area.
opposing wind	In wave forecasting, a wind blowing in a direction opposite to the ocean-wave advance; generally, a headwind.
outfall	A structure extending into a body of water for the purpose of discharging sewage, storm runoff, or cooling water.
overtopping	Passing of water over the top of a structure as a result of wave runup or surge action.
overwash	That portion of the uprush that carries over the crest of a berm or of a structure.
parapet	A low wall built along the edge of a structure such as a seawall or quay.
pass	In hydrographic usage, a navigable channel through a bar, reef, or shoal, or between closely adjacent islands.
peninsula	An elongated body of land nearly surrounded by water and connected to a larger body of land.
perched beach	A beach or fillet of sand retained above the otherwise normal profile level by a submerged dike.

permanent current	A current that runs continuously, independent of the tides and temporary causes. Permanent currents include the freshwater discharge of a river and the currents that form the general circulatory systems of the oceans..
permeable groin	A groin with openings large enough to permit passage of appreciable quantities of LITTORAL DRIFT.
pier	A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, recreational facility, etc., rather than to afford coastal projection. In the Great Lakes, a term sometimes improperly applied to jetties.
pile	A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.
pile, sheet	A pile with a generally slender flat cross section to be driven into the ground or seabed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.
piling	A group of piles.
Plain, Coastal	See COASTAL PLAIN.
planform	The outline or shape of a body of water as determined by the still-water line.
plateau	A land area (usually extensive) having a relatively level surface raised sharply above adjacent land on at least one side; table land; a similar undersea feature.
plunging breaker	See BREAKER.
point	The extreme end of a cape; the outer end of any land area protruding into the water, usually less prominent than a cape.
port	A place where vessels may discharge or receive cargo; it may be the entire harbor including its approaches and anchorages, or only the commercial part of a harbor where the quays, wharves, facilities for transfer of cargo, docks, and repair shops are situated.
prism	See TIDAL PRISM.
Propagation of waves	The transmission of waves through water.
prototype	In laboratory usage, the full-scale structure, concept, or phenomenon used as a basis for constructing a scale model or copy.
quarrystone	Any stone processed from a quarry.
quay	(Pronounced KEY). A stretch of paved bank, or a solid artificial landing place parallel to the navigable waterway, for use in loading and unloading vessels.

quicksand Loose, yielding, wet sand which offers no support to heavy objects. The upward flow of the water has a velocity that eliminates contact pressures between the sand grains and causes the sand-water mass to behave like a fluid.

radius of maximum winds Distance from the eye of a hurricane, where surface and wind velocities are zero, to the place where surface windspeeds are maximum.

recession (of a beach) (1) A continuing landward movement of the shore-line. (2) A net landward movement of the shoreline over a specified time; also RETROGRESSION.

reef An offshore consolidated rock hazard to navigation, with a least depth of about 20 meters (10 fathoms) or less.

reef, sand See BAR.

reference plane See DATUM PLANE.

reflected wave That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.

refraction (of water waves) (1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed; the part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alinement with the underwater contours. (2) The bending of wave crests by currents.

retardation The amount of time by which corresponding tidal phases grow later day by day (about 50 minutes)

retrogression (of a beach) (1) A continuing landward movement of the shore-line. (2) A net landward movement of the shoreline over a specified time; also RECESSION.

revetment A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

ria A long, narrow inlet, with depth gradually diminishing inward.

ridge, beach A nearly continuous mound of beach material that has been shaped by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits; British usage, FULL.

rip A body of water made rough by waves meeting an opposing current, particularly a tidal current; often found where tidal currents are converging and sinking.

rip current A strong surface current flowing seaward from the shore. It usually appears as a visible band of agitated water and is the return movement of water piled up on the shore by incoming waves and wind. With the seaward movement concentrated in a limited band its velocity is somewhat accentuated. A rip consists of three parts: the FEEDER CURRENTS flowing parallel to the shore inside the breakers; The NECK, where the feeder currents converge and flow through the breakers in a narrow band or "rip"; and the HEAD, where the current widens and slackens outside the breaker line. A rip current is often miscalled a rip tide; also RIP SURF. See NEARSHORE CURRENT SYSTEM.

rip surf	See RIP CURRENT.
riparian	Pertaining to the banks of a body of water.
riparian rights	The rights of a person owning land containing or bordering on a watercourse or other body of water or its banks, bed, or waters.
riprap	A protective layer or facing of quarrystone, usually well graded within wide size limit, randomly placed to prevent erosion, scour, or sloughing of an embankment of bluff; also the stone so used. The quarrystone is placed in a layer at least twice the thickness of the 50 percent size or 1.25 times the thickness of the largest size stone in the gradation.
rubble	(1) Loose angular waterworn stones along a beach. (2) Rough, irregular fragments of broken rock.
rubble-mound structure	A mound of random-shaped and random-placed stones protected with a cover layer of selected stones or specially shaped concrete armor units. (Armor units in a primary cover layer may be placed in an orderly manner or dumped at random.)
runnel	A corrugation or trough formed in the foreshore or in the bottom just offshore by waves or tidal currents.
runup	The rush of water up a structure or beach on the breaking of a wave; also UPRUSH, SWASH. The amount of runup is the vertical height above still-water level to which the rush of water reaches.
salt marsh	A marsh periodically flooded by salt water.
sand	See Soil CLASSIFICATION.
sandbar	(1) See BAR. (2) In a river, a ridge of sand built up to or near the surface by river currents.
sand bypassing	See BYPASSING, SAND.
sand reef	See BAR.
scarp	See ESCARPMENT.
scarp, beach	An almost vertical slope along the beach caused by erosion by wave action. It may vary in height from a few centimeters to a meter or so, depending on wave action and the nature and composition of the beach.
scour	Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.
sea breeze	A light wind blowing from the sea toward the land caused by unequal heating of land and water masses.
sea level	See MEAN SEA LEVEL.
seas	Waves caused by wind at the place and time of observation.

sea state	Description of the sea surface with regard to wave action; also called state of sea.
seawall	A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See BULKHEAD.
semidiurnal tide	A tide with two high and two low waters in a tidal day, each approximately the same.
set of current	The direction toward which a current flows.
setup, wind	See WIND SETUP.
shallow water	Water of such depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water. See TRANSITIONAL ZONE and DEEP WATER.
sheet pile	See PILE, SHEET.
shelf, continental	See CONTINENTAL SHELF.
shelf, insular	See INSULAR SHELF.
shoal (noun)	A detached elevation of the sea bottom, comprised of any material except rock or coral, which may endanger surface navigation.
shoal (verb)	(1) To *become* shallow gradually. (2) To *cause* to become shallow. (3) To *proceed* from a greater to a lesser depth of water.
shore	The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a BEACH.
shoreface	The narrow zone seaward from the low tide SHORELINE, covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions. See INSHORE (ZONE).
shoreline	The intersection of a specified plane of water with the shore or beach (*e.g.*, the high water shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on National Ocean Service nautical charts and surveys approximates the mean high water line.
silt	See SOIL CLASSIFICATION.
slack tide (slack water)	The state of a tidal current when its velocity is near zero, especially the moment when a reversing current changes direction and its velocity is zero. Sometimes considered the intermediate period between ebb and flood currents during which the velocity of the currents is less than 0.05 meter per second (0.1 knot). See STAND OF TIDE.
slip	A berthing space between two piers.

slough See BAYOU.

sound (noun) (1) A wide waterway between the mainland and an island or a wide waterway connecting two sea areas. See STRAIT. (2) A relatively long arm of the sea or ocean forming a channel between an island and a mainland or connecting two larger bodies, as a sea and the ocean, or two parts of the same body; usually wider and more extensive than a strait.

sound (verb) To measure the depth of the water.

sounding A measured depth of water; on hydrographic charts the soundings are adjusted to a specific plane of reference (SOUNDING DATUM).

sounding datum The plane to which soundings are referred. See CHART DATUM.

sounding line A line, wire, or cord used in sounding, which is weighted at one end with a plummet (sounding lead); also LEAD LINE.

spilling breaker See BREAKER.

spit A small point of land or a narrow shoal projecting into a body of water from the shore.

spit, cuspate See CUSPATE SPIT.

spring tide A tide that occurs at or near the time of a new or full moon and which rises highest and falls lowest from the mean sea level.

stand of tide An interval at high or low water when there is no apparent change in the height of the tide. The water level is stationary at high and low water for only an instant, but the change in level near these times is so slow that it is not usually perceptible. See SLACK TIDE.

still-water level The elevation that the surface of the water would assume if all wave action were absent.

stockpile Sand piled on a beach foreshore to nourish downdrift beaches by natural littoral currents or forces. See FEEDER BEACH.

storm surge A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress. See WIND SETUP.

storm tide See STORM SURGE.

strait A relatively narrow waterway between two larger bodies of water. See SOUND.

surf The wave activity in the area between the shoreline and the outermost limit of breakers.

surf zone The area between the outermost breaker and the limit of wave uprush.

surging breaker	See BREAKER.
swale	The depression between two beach ridges.
swash	The rush of water up onto the beach face following the breaking of a wave; also UPRUSH, RUNUP.
swash mark	The thin wavy line of fine sand, mica scales, bits of seaweed, etc., left by the uprush when it recedes from its upward limit of movement on the beach face.
swell	Wind-generated waves that have traveled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch (SEAS).
terrace	A horizontal or nearly horizontal natural or artificial topographic feature interrupting a steeper slope, sometimes occurring in a series.
thalweg	In hydraulics, the line joining the deepest points of an inlet or stream channel.
tidal current	See CURRENT, TIDAL.
tidal datum	See CHART DATUM and DATUM PLANE.
tidal day	The time of the rotation of the Earth with respect to the Moon or the interval between two successive upper transits of the Moon over the meridian of a plane, approximately 24.84 solar hours (24 hours and 50 minutes) or 1.035 times the mean solar day; also called lunar day.
tidal flats	Marshy or muddy land areas which are covered and uncovered by the rise and fall of the tide.
tidal inlet	(1) A natural inlet maintained by tidal flow. (2) Loosely, any inlet in which the tide ebbs and flows; also TIDAL OUTLET.
tidal period	The interval of time between two consecutive, like phases of the tide,.
tidal pool	A pool of water remaining on a beach or reef after recession of the tide.
tidal prism	The total amount of water that flows into a harbor or estuary or out again with movement of the tide, excluding any freshwater flow.
tidal range	The difference is height between consecutive high and low (or higher high and lower low) waters.
tidal wave	(1) The wave motion of the tides. (2) In popular usage, any unusually high and destructive water level along a shore. It usually refers to STORM SURGE or TSUNAMI.

tide	The periodic rising and falling of the water that results from gravitational attraction of the Moon and Sun and other astronomical bodies acting upon the rotating Earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the vertical movement.
tide, daily retardation of	The amount of time by which corresponding tides grow later day by day (about 50 minutes); also LAGGING.
tide diurnal	A tide with one high water and one low water in a day.
tide, ebb	See EBB TIDE.
tide, flood	See FLOOD TIDE.
tide, mixed	See MIXED TIDE.
tide, neap	See NEAP TIDE.
tide, semidiurnal	See SEMIDIURNAL TIDE.
tide, slack	See SLACK TIDE.
tide, spring	See SPRING TIDE.
tide station	A place at which tide observations are being taken. It is called a *primary* tide station when continuous observations are to be taken over a number of years to obtain basic tidal data for the locality. A *secondary* tide station is one operated over a short period of time to obtain data for a specific purpose.
tide, storm	See STORM SURGE.
tombolo	A bar or spit that connects or "ties" an island to the mainland or to another island. See CUSPATE SPIT.
topography	The configuration of a surface, including its relief and the positions of its streams, roads, building, etc.
training wall	A wall or jetty to direct current flow.
tropical cyclone	See HURRICANE.
tropical storm	A tropical cyclone with maximum winds less than 34 meters per second (75 miles per hour). See HURRICANE.
trough of wave	The lowest part of a waveform between successive crests; also, that part of a wave below still-water level.
tsunami	A long-period wave caused by an underwater disturbance such as a volcanic eruption or earthquake; also SEISMIC SEA WAVE; commonly miscalled "tidal wave."
typhoon	See HURRICANE.

undertow — A seaward current near the bottom on a sloping inshore zone. It is caused by the return, under the action of gravity, of the water carried up on the shore by wave; often a misnomer for RIP CURRENT.

updrift — The direction opposite that of the predominant movement of littoral materials.

uplift — The upward water pressure on the base of a structure or pavement.

uprush — The rush of water up onto the beach following the breaking of a wave; also SWASH, RUNUP.

waterline — A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush. (Approximately, the intersection of the land with the still-water level.)

wave crest — See CREST OF WAVE.

wave decay — See DECAY OF WAVES.

wave direction — The direction from which a wave approaches.

wave forecasting — The theoretical determination of future wave characteristics, usually from observed or predicted meteorological phenomena.

wave generation — See GENERATION OF WAVES.

wave height — The vertical distance between a crest and the preceding trough. See SIGNIFICANT WAVE HEIGHT.

wave pindcasting — See HINDCASTING, WAVE.

wave period — The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point. See SIGNIFICANT WAVE PERIOD.

wave propagation — The transmission of waves through water.

wave, reflected — That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.

wave refraction — See REFRACTION (of water waves).

wave spectrum — In ocean wave studies, a graph, table, or mathematical equation showing the distribution of wave energy as a function of wave frequency. The spectrum may be based on observations or theoretical considerations. Several forms of graphical display are widely used.

wave steepness — The ratio of the wave height to the wavelength.

wave train — A series of waves from the same direction.

wave trough	The lowest part of a wave form between successive crests; also that part of a wave below still-water level.
wave, wind	See WIND WAVES.
wavelength	The horizontal distance between similar points on two successive waves measured perpendicular to the crest.
weir jetty	An updrift jetty with a low section or weir over which littoral drift moves into a predredged deposition basin which is dredged periodically.
wharf	A structure built on the shore of a harbor, river, or canal, so that vessels may lie alongside to receive and discharge cargo and passengers.
whitecap	On the crest of a wave, the white froth caused by wind.
wind chop	See CHOP.
wind, following	See FOLLOWING WIND.
wind, offshore	A wind blowing seaward from the land in a coastal area.
wind, onshore	A wind blowing landward from the sea in a coastal area.
wind, opposing	See OPPOSING WIND.
wind setup	On reservoirs and smaller bodies of water (1) the vertical rise in the still-water level on the leeward side of a body of water caused by wind stresses on the surface of the water; (2) the difference in still-water levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. See STORM SURGE (usually reserved for use on the ocean and large bodies of water).
wind tide	See WIND SETUP, STORM SURGE.
wind waves	(1) Waves being formed and built up by the wind. (2) loosely, any wave generated by wind.
windward	The direction from which the wind is blowing.

The Coastal & Shoreline Erosion Committee

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As determined by the members of the Coastal & Shoreline Erosion Committee, the following is the updated list of potential demonstration projects to address shoreline and coastal erosion.

GMPO ID #	State	Explanation
93-013	TX	Plant smooth cordgrass to reduce shoreline erosion.
93-056	TX	Stabilize eroding shoreline along the Gulf Intracoastal waterway with rock riprap.
93-060	FL	Construct a dune with vegetation to protect against a barrier breach.
93-088	LA	Establish a fringe marsh along Bayou Lafourche.
93-212	TX	Stabilize eroding shoreline along the Gulf Intracoastal Waterway using concrete mat, rock groin, and cordgrass.
93-213	TX	Restore an existing levee and protect with vegetation.
93-218	FL	Restore primary dune system on a heavily used island.
93-233	FL	Recreate red mangrove habitat and protect it with a temporary tire breakwater.
93-291	MS	Place sand on a beach to test a coastal dynamics model.
93-305	LA	Install 130 timber pylons to dissipate wave energy.
93-001	LA	Install temporary ring wall enclosures for protecting seed germination sites.
93-017	LA	Construct a stone levee to protect marshes.
93-020	AL	Restore marsh using vegetation and hay bales.
93-032	AL	Use fertilizer to enhance disturbed dune vegetation.
93-041	TX	Restore a Gulf beach using material dredged from the submerged portion of an accreting spit.
93-055	TX	Document physical coastline and map vegetation.
93-061	FL	Construct elevated dune walkovers to enhance protection of the dune system.
93-140	FL	Provide a source of plant materials for restoring dunes.
93-181	LA	Monitor marsh management structures.
93-182	LA	Document effectiveness of X-mas tree sediment fences.
93-194	TX	Use X-mas trees for dune restoration.
93-208	TX	Use space shuttle imagery to monitor shoreline changes.
93-245	AL	Relocate structures and create dunes.
93-268	FL	Develop a shoreline erosion computer model.
93-295	TX	Evaluate impacts of sediment mining on erosion and habitat.