QE571 .T49 1996

Texas General Land Office

Texas Coastwide Erosion Response Plan

A Report to the
75th Texas Legislature

Prepared by the Texas General Land Office
Garry Mauro, Commissioner

QE
571
.T49
1996

NOAA
Cooperative
Agreement
No. NA570Z0268

August 1996

Texas
General
Land
Office

Texas Coastwide Erosion Response Plan

A Report to the
75th Texas Legislature

NOAA
Cooperative
Agreement
No. NA57OZ0268

August 1996

Printed on recycled paper.

The Texas General Land Office does not discriminate on the basis of race, color, national origin, sex, sexual orientation, religion, age, or disability in employment or the provision of services. To request an accessible format, call 512/463-2613 or contact us through RELAY Texas at 1-800-735-2989 or mail your request to 1700 N. Congress Avenue, Austin, Texas 78701-1495.

Acknowledgments iii
Summary of Policy Recommendations iv

Foreword by Garry Mauro 1

Part 1
Coastal and Shoreline Erosion
Causes of Erosion 3
Measuring Shoreline Changes 4
The Economic Value of Texas Shores 5
Current Erosion Response Policies 9
Current Erosion Practices 13
Selecting a Method of Shore Protection 16
Post-Storm Emergency Response 20
Funding for Erosion Response 23

Part 2
Proposals for Improved Erosion Response
Policy Recommendations 31

Part 3
Critical Erosion Areas
Ranking Critical Erosion 38
Alamo/Magnolia Beach/Indianola Historical Site 40
Aransas National Wildlife Refuge/
Welder Flat State Coastal Preserve 42
Caplen Beach, Bolivar Peninsula, Galveston County 44
Corpus Christi Ship Channel at Port Aransas 46
Galveston Island State Park Bay Shoreline 48
Highway 87 in Jefferson and Chambers Counties 49
Lower Neches River Marsh 51
South Padre Island, Cameron County 52
Treasure Island, Brazoria County 53

Literature Cited 56

Contents

Appendix A
Laws and Rules Addressing Coastal Erosion and Chronology of Changes 60

Appendix B
General Land Office Application Procedures for Bay Erosion Response Projects 66

Appendix C
Glossary 68

Appendix D
Local Authorities Responsible for Permitting Post-Storm Emergency Response Projects 78

Appendix E
Agency Contacts for Bay and Gulf Erosion Response Projects 81

Appendix F
Notes from the Erosion Response Plan Advisory Committee Meeting of July 12, 1995 88

Acknowledgments

The Coastal Division of the Texas General Land Office is pleased to acknowledge the support of this project by the Department of Commerce, National Oceanic and Atmospheric Administration, through Cooperative Agreement No. NA570Z0268. The following Advisory Committee members attended public hearings and meetings and reviewed portions of this plan:

- Dave Behm, citizen, Friendswood
- Mary Lou Campbell, citizen, South Padre Island
- Ed Garner, University of Texas at Austin
  Bureau of Economic Geology
- Brandol Harvey, planner, City of Corpus Christi
- Nicholas C. Kraus, Ph.D, Texas A&M-Corpus Christi,
  Conrad Blucher Institute
- Fred LeBlanc, Mitchell Energy Corporation
- Brandy Littlejohn, citizen, Galveston
- George Nassar, citizen, South Padre Island
- B. J. Page, planner, Town of South Padre Island
- Jennifer Prouty, Ph.D., Texas A&M-Corpus Christi
- Larry Robinson, Matagorda Bay Pilots Association
- Laura Ryman, citizen, Matagorda County
- Jay Smith, citizen, Galveston
- Hon. Robert Stroder, Jefferson County Judge
- Richard Tillman, Calhoun County
  Marine Extension Agent
- Barbara Tipton, citizen, Magnolia Beach
- Dan Yanta, District Conservationist, Natural Resource
  Conservation Service Calhoun County

Summary of Policy Recommendations

An explanation of the following list of policy recommendations is located in Part 2 on page 31.

1. Establish a state funding source for erosion response.

2. Improve coordination among the U.S. Army Corps of Engineers and state and local governments regarding current projects and identify potential erosion response projects.

3. Pursue Texas' fair share of federal funding for erosion response projects.

4. Provide technical assistance to local governments and others to obtain erosion response funding from the Federal Emergency Management Agency.

5. Improve sediment management practices, and consider their effects on the coastal sediment budget.

6. Establish research priorities in support of erosion response planning and project assessment.

7. Promote public education about the impacts of coastal erosion and about appropriate erosion response methods.

Foreword by Garry Mauro

In Texas today, there is a growing awareness of the urgency of the coastal erosion problem. Homes, public highways, recreational beaches, wetland habitat, oil and gas facilities, and commercial establishments along much of the coast are threatened by persistent shoreline retreat.

In 1991, recognizing that coastal erosion was a significant problem, the 72nd Texas Legislature passed Senate Bill 1053, designating the Texas General Land Office (GLO) as the lead state agency to draft a plan providing rules and guidelines for erosion avoidance and remediation, and for ranking critical erosion areas. The GLO has hosted numerous public meetings along the coast to obtain the local perspective on coastal erosion and to learn the erosion-response priorities of coastal residents.

The *Texas Coastwide Erosion Response Plan* describes the state's existing policies for managing coastal erosion and proposes new ones. It describes methods of erosion response for bay and Gulf shorelines and provides specific guidance concerning projects that can be undertaken to protect uplands, marsh, and shallow-water habitat in several identified "critical erosion areas." The plan is designed to help local communities identify critical erosion areas within their jurisdictions and plan for future erosion response.

But most important, this plan proposes new state policies which I believe deserve strong consideration and support in our fight to protect the Texas shoreline. Among the proposed policies is a recommendation to establish a state funding source for erosion response projects. This proposed state funding would allow Texas to attract federal money that is crucial for successful coastal erosion projects. For too long, Texas has allowed available federal dollars to be spent by other coastal states.

Shoreline erosion can have devastating effects. An erosion rate of more than five feet per year has resulted in the closure of nearly 14 miles of State Highway 87, an important hurricane evacuation route in Jefferson County. One Gulf shore oil and gas operator estimated that shoreline erosion may result in an annual loss of more than $2.6 million in state royalty, severance tax, and county tax funds.

Coastal erosion is not confined to the Texas Gulf shoreline; it also affects the bay systems, where it causes the loss of agricultural, industrial, and residential land and destroys productive wetlands. About two-thirds of Texas bay shores are eroding at rates of two to nine feet per year. Erosion along the Gulf Intracoastal Waterway has caused wetland loss at Welder Flats State Coastal Preserve, converting valuable shallow-water habitat to open water.

In some areas along the Gulf shoreline, erosion has overtaken structures erected to protect the shorefront, leaving them on the beach as obstacles that inhibit access to beaches open to public use. Landowners, local governments, and other concerned citizens along the coast have grown increasingly frustrated. Those eager to protect their property against erosion or to mitigate its effects have found little guidance or assistance. Texas has had no central source of information or comprehensive state plan for erosion response.

I am committed to educating the Texas public about coastal erosion and the serious problems that will result if we fail to act now, and to working with local communities as they grapple with complex erosion issues. I call on all coastal citizens to review this plan and support our goal of protecting the state's shoreline. Working together on this issue, I know we will succeed in doing what is best to protect the economic and environmental health of the Texas coast.

GARRY MAURO
TEXAS LAND COMMISSIONER

PART 1
Coastal and Shoreline Erosion

Causes of Erosion

The natural coastal environment of Texas is the product of climate, tides, relative sea-level change, tropical storm frequency, the amount of sediment delivered to the Gulf of Mexico by rivers, and the rate of dispersal of that sediment by waves and currents. Several of these processes contribute to long-term (chronic) shoreline erosion or recession, while others cause short-term (storm-induced) erosion. Chronic erosion or recession is generally more difficult to address than storm-induced erosion. Daily wind and tidal patterns alter shoreline position only moderately. Hurricanes and tropical storms, however, have a significant impact on the shoreline where winds drive nearshore currents and large volumes of beach and shoreface sand to the west and southwest along the Texas coast (McGowen et al., 1977).

Coastal shoreline recession and erosion is attributed to relative rise in sea level (the combined effects of worldwide sea level rise and local subsidence) and to the fact that the amount of sediment removed by wave energy exceeds that supplied to the beach by longshore currents. At Galveston, the relative rise in sea level was measured at 0.63 cm/year (Ramsey, 1991). Because the slope of Texas beaches is relatively flat, any rise in sea level can result in substantial shoreline recession.

Climatic change (from wetter to drier) during the past 18,000 years has decreased the volume of sediments carried to the Texas coast by rivers. Today, droughts can cause stabilizing vegetation to die and increase erosion of bay shorelines and coastal sand dunes.

Storm frequency and intensity are factors contributing to quick and significant erosion. Concentrated storm energy was responsible for the loss of a 150-foot-wide strip of coastal sand dunes on Mustang Island during Hurricane Carla in 1961 (Hayes, 1967).

The main channels of unstabilized (or natural) inlets can migrate over time and cause localized erosion of adjacent shorelines. Stabilized inlets also create areas of accretion and erosion, but at predictable locations.

Human modifications or actions can contribute to or accelerate localized coastal erosion. Jetties, groins, and breakwaters,

for example, are designed to trap littoral sediments. By withholding sand that would normally be carried to downdrift shorelines, they create a deficit in the sand supply. Seawalls, revetments, and bulkheads keep sediment from entering the local littoral current. Wave reflection from any of these structures can cause localized scour at the base of the structure and at its endpoints.

Removal of sediment from the coastal sediment budget by human actions is also a concern. These include commercial extraction of sediments from coastal rivers, dredging and disposal of sediment in confined or upland areas, and employment of improper beach cleaning and management techniques.

Waves generated by boats and ships can erode unprotected shorelines or accelerate erosion in areas already affected by natural erosional processes. An increase in the number of ships with large wakes could prove detrimental to coastal properties unless a means of addressing the problem is implemented.

Measuring Shoreline Changes

Researchers can determine shoreline locations with information gathered from topographic maps, aerial photos, and beach profile and Global Positioning System (GPS) surveys. Shoreline change analyses involve plotting the shoreline at several sites and comparing those positions over time. The more shoreline positions recorded, the better for measuring beach fluctuations and for distinguishing trends in shoreline movement. Statistical, numerical, or geometric models or a combination of them is used to predict the extent of future land losses. Planners and developers can use the predictions for planning future use of the shoreline.

Local governments can assist property owners in addressing risks associated with construction on eroding barrier islands by establishing uniform setback requirements for new construction. The setback provisions are based on the shoreline change rates published by the Bureau of Economic Geology (BEG).

For a detailed discussion of how shoreline changes are quantified, see *Shoreline Movement Along Developed Beaches of the Texas Gulf Coast: A Users' Guide to Analyzing and Predicting Shoreline Changes*, by Robert A. Morton (BEG Open-File Report 93-1, 1993).

The Economic Value of Texas Shores

> The legislature. . . recognizes that storms and erosion of beach and bay shorelines can harm the environment, recreation and tourism, agriculture, industry, recreational and commercial fisheries, waterborne transportation, and property interests.
>
> — *Senate Bill 1053, 72nd Texas Legislature — Regular Session, 1991, Coastal Management Plan for Beach Access, Preservation and Enhancement, Dune Protection, and Coastal Erosion*

The beaches, dunes, and shorelines of the Texas Gulf Coast provide the state and its citizens with many direct and indirect benefits of great value. However, disputes arise when an effort is made to assign a monetary value to the benefits from these coastal natural resources. With the advent of cost/benefit analysis, the importance of determining the monetary value of natural resources has increased significantly. In most cases, especially with federally funded projects, the benefits of a project must outweigh the project costs for construction to be authorized.

The significant benefits of protecting, restoring, or enhancing beaches, dunes, and shorelines are often not recognized, much less valued monetarily. Undervaluing or not valuing all these benefits can keep important erosion response projects from receiving public funding.

Undervaluing or failing to value the benefits of protecting, restoring, or enhancing beaches, dunes, and shorelines often results from limitations in current economic valuation models or from lack of information. While some benefits, such as the recreational benefits of beaches, are widely understood, it is not an easy task to establish a dollar value for those benefits. The monetary value of the recreational benefits of beaches, dunes, and shorelines must be derived from other indicators, such as tourism revenue.

In other instances, benefits are not easy to determine because they are realized at a distance from the resource or accrue to another party. For example, sand loss almost always occurs after a beach has been replenished. While this is considered a loss for the nourished beach, the sand is a benefit to the sedi-

Comparative Annual Spending

(Source: Houston, 1996)

- $1,500,000,000 Japan shore protection/restoration (highest year)
- $199,000,000 U.S. rice subsidies (single state)
- $134,000,000 U.S. wool subsidies (wool value $53 million)
- $61,000,000 U.S. mohair subsidies (mohair value $13 million)
- $34,000,000 U.S. shore protection and restoration

The Sediment Budget

A sediment budget is an accounting method for sediment or sand, just as a household budget is an accounting of monetary income and expenditures. When all of the components of the sediment budget (both inflow and outflow) are added up, the result is an indicator of how the shoreline is likely to behave.

Components of the sediment budget for a stretch of Gulf beach might include:

Inflow

- Sand inflow from a stream or river.
- Offshore sand pushed ashore by long, gentle waves.
- Sand transported into the area by longshore currents.
- Materials eroded from bluffs or dunes.
- Sand blown into the area by wind.
- Sand imported during a beach nourishment project.

Outflow

- Sand drawn into a tidal inlet (flood tidal delta).
- Sand swept offshore at a tidal inlet (ebb tidal delta).
- Sand pulled offshore by steep waves.
- Sand transported out of the area by longshore currents.
- Sand blown out of the area by wind.
- Sand carried landward at washovers.

ment budget when it is carried downdrift and deposited on another beach or deposited in nearshore bars that later feed the beach.

Sometimes a benefit, by its subjective nature, is almost impossible to value monetarily. How can a dollar value be assigned to the relaxation a person may enjoy sitting on the beach? Some economic valuation models try to assess the dollar value of such benefits through the use of questionnaires.

Regardless of the difficulty of assessing the monetary value of beaches, dunes, and shores, it is important to recognize the benefits that these coastal natural resources provide. Projects designed to protect, restore, or enhance these resources should include consideration of these benefits, even if the benefits cannot be assigned a dollar value.

Storm Protection Value

Beaches and dunes benefit upland property owners by protecting upland properties from storm damage. Dunes protect property behind them from storm-surge flooding and can help dissipate the energy of high waves. In addition, dunes serve as sand stores that replenish beaches eroded by storms. Beaches and dunes on barrier islands also protect the fragile estuarine system between the barrier islands and the mainland.

The majority of federal beach nourishment projects focus on reducing coastal storm damage (National Research Council, 1995). If the storm protection benefits of a beach nourishment project can be quantified through economic analysis, the U.S. Army Corps of Engineers (COE) is more likely to participate in the project.

Recreational Value

Beaches and shorelines provide obvious recreational benefits to visitors. From people-watching to bird-watching, sunbathing to kite flying, and volleyball to horseback riding, beaches and shorelines offer many attractions in addition to swimming, surfing, fishing, and boating. According to Houston (1996), beaches are the number-one destination of vacationers in the United States.

Beach visitors make a tremendous contribution to the coastal economy, spending money at coastal community restaurants, grocery and convenience stores, bait shops, gas stations, souvenir and curio shops, recreational facilities (e.g., shorefront miniature golf courses and water slides), and boat and equipment rentals. The national economy benefits by approximately $170 billion annually from beach tourism (Houston, 1996).

Scenic/Aesthetic Value

The primary reason the shoreline is experiencing high development pressures is that people want to enjoy the aesthetic rewards of living and vacationing by the shore. The shore's beauty is the reason people pay a premium to live in beachfront or bayfront homes. Even after suffering property damage from a storm, many people rebuild on the shoreline rather than lose their view. Private homeowners are not the only group to take advantage of the aesthetic value of the coast. The tourism and real estate industries seek prime coastal lands for hotels and resorts.

Public Access Value

The shoreline is also valuable because it provides public access to the bays and Gulf. Under the Texas Open Beaches Act, the Gulf beach is state-owned seaward of the line of mean high tide or mean higher high water. This publicly owned area, along with all of the beach seaward of the vegetation line, may be accessed, used, and enjoyed by the public. In many other states, the beaches are privately owned, and public access to the shore is severely restricted.

Wildlife Habitat Value

Texas beaches, dunes, and bayshores provide valuable habitat and food for hundreds of species of coastal birds, fish, shellfish, reptiles, mammals, and plants. Many threatened and endangered plant and animal species inhabit this ecosystem. They include the American alligator, Kemp's ridley sea turtle, the hawksbill sea turtle, the leatherback sea turtle, the loggerhead sea turtle, the brown pelican, the interior least tern, the piping plover, and the whooping crane.

Global Competition for Foreign Tourism

(Source: Houston, 1996)

- Spain will spend more in its current five-year shoreline restoration program than the United States spent in the last 40 years.
- In the last 40 years, Germany spent about five times as much as the United States on shoreline protection and restoration, amounting to a 25 to 50 times greater share of its gross domestic product. Germany has less than 5% of the length of coastline as the U.S.
- In Miami Beach, the capitalized project cost of the beach nourishment project (initiated in the late 1970s) is about $3 million per year; spending by foreign visitors to Miami Beach is now over $2 billion per year.
- The United States has lost 16% of its market share of international tourists in the past two years, representing 170,000 jobs. Eighty-five percent of spending by foreign tourists in the United States is spent in coastal states.

Waterborne Transportation Value

Beaches and dunes on barrier islands enclose and protect the estuarine resources of the state. A major value of Texas estuaries is their use as a major waterborne transportation route. The Texas section of the Gulf Intracoastal Waterway (GIWW) transported over 82 million short tons of goods valued at $23.9 billion in 1990 (Texas Department of Transportation). Roop and Burke (1991) estimated that the closure of the GIWW due to a breach in Sargent Beach (currently experiencing the worst erosion on the Texas coast) would result in $270 million in economic losses during the first three weeks of closure and $20 million per day thereafter.

Local Economic Value

Beaches, dunes, and shorelines are valuable to the economies of local communities. The local tax base benefits from the high value placed on shorefront property. When this highly valued property erodes away, both the property owner and the local community suffer. In general, taxing entities do not recognize erosion of shoreline property; the property owner often must continue to pay property tax on the eroded land. If the property owner succeeds in having the taxing entity remove the eroded land from the tax rolls, tax revenue decreases. The taxing entity may be compelled to either reduce services or raise the property tax rate.

Option Value

Option value is the value a person places on having a certain option available. For example, a person may be unable to visit the beach often but may be willing to pay to keep the beach available for possible future visits. This person has placed an option value on the beach. Option value is difficult to measure because it is not a market value; a person cannot go to the corner convenience store and buy an option on the beach. In attempting to measure option value, economists must rely on surveys and interviews with individuals.

Existence Value

Existence value, like option value, is difficult to measure be-

cause it is not a market value. Existence value is the value a person places on a resource like a beach, even if that person expects never to make use of the resource.

State Policies

State policies pertaining to coastal erosion are found in a number of statutes and rules, including the Texas Open Beaches Act, the Dune Protection Act, rules of the School Land Board (SLB) pertaining to the issuance of permits, leases, and easements on coastal public lands, the General Land Office rules for management of the beach/dune system, and the Coastal Coordination Council rules for the Texas Coastal Management Program. The specific citations and a complete list of the state laws and rules that address coastal erosion, along with a chronology of their amendments, are found in Appendix A.

The principal state policies may be summarized as follows:

1. Erosion avoidance, remediation, and planning shall preserve and enhance the public's property right to access, use, and enjoy the public beach.

2. "Soft" methods of avoiding, slowing, or remedying erosion (such as shoreline vegetation, beach nourishment, and dune reconstruction) are preferred to the construction of hard or rigid shoreline protection structures.

3. Dunes are to be protected because stabilized, vegetated dunes offer the best natural defense against storms, protect upland properties and state-owned beaches and shores against erosion, and are areas of significant biological diversity.

4. Structures on bay shorelines must be constructed in a manner that does not significantly interfere with the natural coastal processes which supply sediments to shore areas or otherwise exacerbate erosion.

5. Suitable dredged material from commercially navigable waterways should be used beneficially to reduce and minimize erosion, provide shore protection, or ben-

efit the sediment budget or littoral system. The state and local governments may enter into cost-sharing agreements with the federal government to offset any additional costs from the beneficial use of dredged material.

6. Construction along eroding areas of the Gulf shoreline must meet stricter building standards designed to reduce the potential for interference with public beach use should the structure be undermined by erosion.

The purpose of the *Texas Open Beaches Act,* passed in 1959 (TEX. NAT. RES. CODE ANN. §61.011 *et seq.*) is to protect the public's right to "free and unrestricted" access to and from "the state-owned beaches bordering on the seaward shore of the Gulf of Mexico." Under the Open Beaches Act, the burden of proof rests with the private landowner rather than with the beach user in the event of a conflict regarding public traversal or use of private land. The act prohibits the erection of any physical barrier that would impede public access to the beach and any written or oral claim that the public beach is private property or that the public does not have the right of access to it. Government agencies are exempt from the physical barrier prohibition. The Open Beaches Act applies only to Gulf beaches that are accessible by public road or public ferry.

The 1991 amendments to Chapter 33 of the *Texas Natural Resources Code* direct the GLO to work with local governments, other state agencies, and federal agencies such as the COE in erosion response projects that encourage the use of nonrigid structures for shoreline protection. The 1995 amendments to article 5415e-2 of the Texas Natural Resources Code allow the Texas Transportation Commission to cost-share with the federal government in projects that use dredged material for shore protection projects.

The Dune Protection Act (TEX. NAT. RES. CODE ANN. §63.001 *et seq.*) recognizes the importance of coastal sand dunes and the role they play in protecting landward structures from storms as well as supplying sediment to the beaches during storms. In the 1991 amendments, local governments bordering the Gulf of Mexico were required to establish a dune protection line that protects coastal sand dunes and dune vegetation up to

1,000 feet landward of mean high tide.

Chapter 155 of the *Texas Administrative Code* sets out the rules of the GLO and SLB for leasing and management of the state's surface and mineral interests in an estimated four million acres of state-owned submerged lands. Authorization from the commissioner of the GLO or the SLB is required for any project on state-owned land, including private, public, and commercial projects. *The Coastal Public Lands Management Act of 1973,* the chief state law governing the use of state-owned submerged lands, mandates the protection of natural resources.

Promulgated under the *Open Beaches Act and Dune Protection Act,* the General Land Office rules for management of the beach/dune system (31 TAC §§15.1-15.10) cover elements common to all coastal communities. Each coastal county or municipality is responsible for adopting a plan that meets the rules' minimum requirements for dune protection, beach access, coastal erosion, and flood protection. A permit or certificate from the county commissioners' court or municipal government is required for construction activity seaward of the local dune protection line that may affect dunes or dune vegetation or public beach access. Local governments are required to forward copies of applications submitted for proposed projects requiring a dune permit and/or a beachfront construction certificate to the GLO and the Office of the Attorney General (OAG) for review at least 10 days before acting on the application. The GLO and the attorney general may comment on the project's consistency with the approved local plan, but may not hold up or veto a permit or certificate.

The *Texas Coastal Management Program (CMP),* adopted by the state's Coastal Coordination Council, is composed of state statutes, rules, and guidelines for activities that affect coastal natural resource areas such as critical dune areas, critical eroding areas, Gulf beaches, coastal shore areas, coastal barriers, and special hazard areas.

Federal Policies

Under *Public Law 71-570,* the COE was established as the federal agency responsible for studying, planning, and implementing shore protection projects and projects for improving navi-

gation in cooperation with state agencies and local governments. The COE enters into cost-sharing agreements with a local sponsor for beach nourishment if the project is the most suitable and economical method of dredged material disposal. In determining the economic value of a project, the COE does not consider the recreational benefits that the project may provide.

The COE is also responsible for regulating all construction in or modification of navigable waters *(River & Harbor Act of 1899)* and for regulating the discharge of dredged and fill material into waters of the U.S (§404 of the federal *Clean Water Act*). The COE ensures that all permits comply with the environmental requirements. The U.S. Fish and Wildlife Service (USFWS), the Environmental Protection Agency (EPA), and the National Marine Fisheries Service (NMFS) provide important advisory roles to the COE in the permitting process.

The purpose of the *National Flood Insurance Act of 1968* was to provide federally subsidized insurance protection to those who live in coastal and flood-prone areas. The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program by adopting and enforcing floodplain management regulations. In coastal high-hazard areas, structures must be elevated above the base flood elevation (determined by FEMA) and must be constructed according to strict standards to withstand flood and windstorm damage.

The Natural Resources Conservation Service (NRCS) was originally called the Soil Conservation Service when it was established in the U.S. Department of Agriculture. The NRCS works with private landowners and other entities to reduce soil erosion, conserve water, protect and improve water quality, and protect renewable natural resources. In Texas, the NRCS has been very successful in using vegetation to stabilize eroding bay shorelines and in promoting wetland restoration.

Two federal acts that indirectly affect coastal erosion policy are the *Coastal Barrier Resources Act (CBRA) of 1982* and the *Coastal Zone Management Act (CZMA) of 1972*. Both acts are administered under programs in the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. The CBRA limits the amount of federal spending in areas desig-

nated as coastal barrier resource units in order to protect barrier island resources. One program restricted by the CBRA in many high-risk coastal areas is the National Flood Insurance Program.

The 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." Coastal states may develop coastal management programs that follow the federal guidelines. States whose plans receive federal approval are eligible for grants for program implementation, coastal erosion planning, and research. These states have the authority to veto federal permits for activities in wetlands or coastal waters that are inconsistent with the state's plan.

Local Ordinances and Orders

To be consistent with the GLO's beach/dune rules, local governments adopt plans as ordinances or orders that are enforced under the local code for conducting general business.

Current Erosion Response Practices

There are three general ways to address shoreline erosion: (1) stabilize the shoreline by structural or nonstructural methods; (2) relocate or set development back from the shoreline; and (3) take no action.

In stabilizing the shoreline, the landowner's goal is often to draw a line in the sand that says "the sea stops here." Depending on local coastal conditions, achieving a stabilized shoreline can be difficult and expensive. Texans have used many different (and sometimes unsound) methods to protect their shoreline properties from erosion. These include bulkheads, riprap, autos, erratically dumped tires, bags filled with concrete, articulated concrete ramps, and vegetation. (Erosion response terminology is defined in Appendix C.)

Shoreline Stabilization

Structural Stabilization. Structural erosion response methods include seawalls, bulkheads, revetments (which are usually constructed of riprap but can include concrete mats or slabs, bags filled with concrete mix, gabions, and interlocking

brick), groins, jetties, and detached breakwaters. Seawalls, bulkheads, and revetments are designed to maintain the shoreline at a specific location. Such structures limit the availability of sediment for transport. Erosion of unarmored property at the ends of the structure (called flank erosion) is common, and erosion at the toe, common in steep revetments, further decreases the stability of the structure. Seawalls, bulkheads, and revetments may fail if waves overtop them.

Groins, jetties, and detached breakwaters are designed to quickly trap and retain littoral sediment and therefore decrease the volume of sediment delivered to downdrift shores. If the sediment budget remains unbalanced, erosion intensifies. These types of structures are typically used to decrease the need for maintenance of navigable waterways.

Nonstructural Stabilization. Nonstructural, or "soft," stabilization methods include vegetation, beach nourishment, sediment berms, and sediment bypassing. These methods are designed to augment the local sediment budget either through direct placement of sand on the eroding shore or, in the case of vegetation, by slowly trapping littoral sediment. The GLO's Surface Damage Fund has enabled coastal Soil and Water Conservation Districts to demonstrate to the public that eroded bay shorelines in certain wave environments can be successfully protected with temporary wave barriers and marsh grass plantings.

The COE has augmented the sediment budget by placing dredged sediment in water depths affected by wave action to form nearshore sediment berms. The purpose of the nearshore berms is to supply sediment to the shoreline via wave transport. Two nearshore berms have been constructed along the Texas Gulf coast, at South Padre Island and at Galveston Island. The berms are not monitored, so their effectiveness is unknown.

Sometimes, a combination of structural and nonstructural methods is used to protect bay shorelines that are subject to high wave energy. An example of this is found at Grassy Point in Matagorda County. The Palacios Seawall Commission has constructed a detached rock breakwater to decrease wave energy so that sediments will be deposited landward of the struc-

ture. Smooth cordgrass (*Spartina alterniflora*) has been planted in the lee of the breakwater. The project is being monitored for planting success and effects on adjacent shores.

Setback/Relocation

Many coastal states require that new structures and buildings be set back a certain distance from the shoreline. Some states have adopted a minimum distance from a reference feature, while others use the "average annual erosion rate" to help establish minimum setbacks (National Research Council, 1990).

Texas law prohibits construction on the public beach. Landward of the vegetation line, however, new structures may be constructed in accordance with the local community's dune protection and beach access plan. Each community may assist property owners in addressing risks associated with beachfront construction by establishing uniform setback requirements based on the average erosion rate. State law does not impose a mandatory horizontal setback on all coastal construction.

Relocating structures from erosion hazard areas has been sporadic along the Texas coast. From 1987 to 1995, funding was available through the FEMA National Flood Insurance Program for relocation of structures in imminent danger of collapse due to coastal erosion. However, as of July 1994, only 16 Texas landowners had taken part in the program (FEMA, personal communication). FEMA is now developing the Mitigation Assistance Program, which provides cost-sharing grants to states and communities for relocation of structures, acquisition of property, and some shore protection projects. The program should be available to the public in 1996.

No Action

On Gulf shorelines, the typical erosion response method has been one of no action, mainly because shoreline protection projects are very expensive and local governments simply cannot afford them. Many landowners abandon their storm-damaged homes, leaving them on the public beach.

The Line of Vegetation

Under the Open Beaches Act and by historical practice, the line of vegetation determines the landward extent of the public beach along the Gulf Coast. The line is defined as "the extreme seaward boundary of natural vegetation which spreads continuously inland.

In legal terms, the public has an easement to use the beach from the mean low tide line up to the line of vegetation. The easement does not mean the public owns the land; it is a right to use and enjoy the beach.

Sometimes, the area is owned by a private citizen or business. If so, the public has the right to use the landowner's property seaward of the vegetation line. The landowner may not build any structure on the public beach or interfere with or restrict the public's right to use the beach.

Because the line of vegetation naturally migrates, the public's easement is often called a "rolling easement." As the line of vegetation moves, so does the area subject to the easement.

Selecting A Method Of Shore Protection

To plan an effective erosion response strategy for a particular location, the landowner must determine the cause of the problem, take into account applicable local, state, and federal laws, and decide what outcome is desired. This information will ensure the selection of techniques appropriate to the location and to the type of erosion problem encountered.

Gulf Shorelines

The most commonly described erosion problems along the Texas coast are steady shoreline retreat which jeopardizes something of value and the perceived threat of hurricane damage.

Structural Stabilization. Self-help construction of shoreline protection measures such as seawalls, bulkheads, or revetments by individual property owners can accelerate erosion and damage to adjoining properties and natural resources. Provisions of the Open Beaches Act and the GLO beach/dune rules limit or prohibit individuals from building structures on Texas beaches.

Beach Nourishment. Beach nourishment is a method of shore protection that is encouraged by the state legislature. However, finding an economical sand source may be difficult in some Gulf shoreline locations. For the most part, it may be cheaper for local communities to tie into existing COE dredging projects for a sediment source.

Dune Construction and Restoration. Because a healthy dune system is the best defense against beach erosion and coastal storm damage, property owners should concentrate on maintaining this natural defense. In places where the dune system has been damaged or destroyed, restoration should be the focus. The *Dune Protection and Improvement Manual for the Texas Gulf Coast* (GLO, 1991), available from the GLO, provides a comprehensive discussion of dune preservation and restoration techniques. These include the planting of native dune vegetation, use of sand-trapping fences where appropriate, and proper construction and use of dune walkovers. In sand-starved areas of the coast where sand-trapping efforts are unsuccessful, the importation of sand for dune construction or restoration may be necessary.

Bay/Channel Shorelines

The number and complexity of shoreline types and erosion problems are much greater in the bays, estuaries, and channels along the Texas coast than on the open Gulf shoreline. Accordingly, there are more options for controlling erosion and protecting property along bay shorelines.

Often, low-lying bayfront property becomes submerged due to the combined effects of gradual land subsidence and sea level rise. Stabilizing the shoreline location without the use of armor requires an inflow of sediment balanced with the retention of existing sediment.

Before using either the revetment or bulkhead shore protection methods along state-owned lands, an applicant must obtain a boundary survey by a licensed state land surveyor. If all or part of the structure is to be placed on state-owned land, an easement from the GLO is also required.

The use of groins perpendicular to the shore to modify sediment transport is generally not authorized in Texas because of the adverse effects such structures have on adjoining shorelines. Recent revisions to the SLB rules (31 TAC §155.3) only allow the construction of jetties, groins, and breakwaters by public entities for public purposes, and proposed projects must be analyzed to ensure that structures will not induce erosion.

Planting of Vegetation. When a natural shoreline is the desired result and some variation in the shoreline location can be tolerated, a vegetation protection or planting program can be the first step in stabilizing the shoreline and promoting the entrapment of sediment. The ability of vegetation to withstand wave forces can be enhanced by the use of temporary parachute fences or sand fencing, or by geotextiles (engineered woven materials) that help to dissipate energy and protect root systems while allowing the plants to grow through. If the long-term sediment deficit cannot be improved, then other structural measures such as sediment-filled bags or tubes, or shore-parallel rock breakwaters may be warranted in addition to vegetation to help stabilize the shoreline.

Revetment. Where access along the shoreline is not the pri-

mary goal, and dissipation of wave energy is desired, a revetment may be the preferred shoreline protection option. A revetment can be viewed as a shield or facing for the existing shoreline, in contrast to a bulkhead or seawall, which supports the earth behind it. The most common revetment along the Texas bay shorelines is rock riprap. Revetment materials can include rock or rubble, bags filled with sand or lean concrete mix, rock-filled wire mesh gabions, articulated concrete cells or slabs, or combinations of the above. Revetment generally does not allow a fringe marsh to be established.

Bulkhead. Along a higher bluff or on a developed shoreline, the desired result may be a defined, well-protected division between land and water. In this instance, a bulkhead can be built from any of a variety of materials to suit the specific use. Examples include pile-and-plank; steel H-piles with railroad ties; sheet piles of concrete, wood, steel, or synthetics; and cast-in-place concrete gravity structures. Bulkheads do not dissipate wave energy as effectively as a natural shoreline, nor do they protect the shore in front (seaward) of them. In fact, the reflected wave energy can intensify erosive forces immediately seaward of the structure. For this reason, scour protection such as riprap at the bulkhead base is normally integrated into the design. Bulkheads are well suited to shoreline uses such as boating or commercial transportation.

Cost Considerations

Although the ultimate cost of a project depends on many factors, it is possible to provide approximate costs of the various methods for comparison. Maintenance requirements and monitoring costs should be considered along with initial construction costs in choosing an erosion response method or combination of methods.

Beach Nourishment. Beach nourishment is generally a regional approach and not within an individual property owner's means. However, the cost is worth considering in comparison with other methods. In areas of the Texas coast where a nearby (within several miles) supply of imported sand has been identified, nourishment costs, including the necessary pre-construction costs and post-construction monitoring, have been projected at $150 to $200 per foot of nourished beach. The benefi-

cial effect of nourishment at the project location can be expected to diminish over a five- to 10-year period, although downdrift areas will benefit as the sand is transported along the coast. Maintenance of the project through renourishment will be required if longer-term results are desired.

Dune Construction and Restoration. The basic building material for dunes is beach-quality sand. In general, this material must come from an upland (non-beach) source. Commercially available sand can be obtained for $5 to $10 per cubic yard. Depending on the desired width and height of reconstructed dunes, the total cost is on the order of $20 to $40 per foot of beach. Vegetation establishment, as described below, is a critical component of any dune restoration or dune construction project.

Planting of Dune Vegetation. The first step in a vegetation planting program is to ensure that existing and new vegetation is protected. After that, native dune species can typically be acquired commercially at $0.25 to $1.00 per plant, or plants or sprigs can be taken from dense, healthy stands of vegetation near the project site—with the permission of the property owner. Depending on the labor source and the width of the area planted, the total cost could range from $2 to $10 per foot of shoreline, or $15 to $18 per foot in combination with sand fencing to protect the vegetation.

Planting of Wetland (Bay Shoreline) Vegetation. The GLO allows permittees planting vegetation adjacent to state-owned lands to use vegetation from existing stands on state lands as source material, provided that no more than one 6-inch-diameter plug per square yard is taken. Any damage to borrow areas and/or existing adjacent seagrass beds is to be strictly avoided. If the GLO determines that excessive impacts have occurred to any of these areas, the permittee may be required to mitigate the impact.

Revetment. Protection of bay or channel shorelines by revetment can cost $100 to $200 per foot of protected shoreline. Maintenance costs will generally not be incurred for a number of years, or until the structure is damaged by a major storm event. Because of their flexible nature, revetment systems can generally sustain limited damage without catastrophic dam-

age to the protected property.

Bulkhead. The cost of bulkhead construction along bay shorelines can range from $75 to $175 per foot, depending on the height of the structure and the materials used. The cost of bulkheads for commercial use can reach $2 million per mile ($350 to $400 per foot). Maintenance costs are minimal, but damage to a bulkhead can result in significant damage to the upland property.

Post-Storm Emergency Response

Gulf beaches recover from storms when sufficient sediment is transported to the beach from offshore. The factors affecting the rate of recovery are time, the amount of beach erosion caused by the storm, occurrence of subsequent storms, shoreline stability (whether it is a historically eroding beach), climatic variations, and human alteration of natural processes. Human modifications of the beach following a storm can have profound effects on the shoreline. Following Hurricane Opal in the fall of 1995, the state of Florida allowed the beach to be scraped and the sand to be placed in a shore-parallel berm along portions of the Florida Panhandle coast. The state found that the scraped beaches did not recover as quickly as beaches that were not scraped (Leadon, 1996).

In a study of the effects of long-term recovery, Morton and Paine (1985) found that two years after Hurricane Alicia, recovery of the vegetation line along the beaches of West Galveston Island was insignificant because the depth of beach scour was greater than the root depth and no vegetation could take hold. They concluded that natural recovery of the vegetation line to its pre-storm position would be unlikely along the eroding segments of the Galveston Island shoreline. To maximize recovery of the beaches and vegetation line, the natural processes of sedimentation should not be disturbed. It is for this reason that different "emergency" measures must be taken to protect the beaches after storms.

Post-storm response is governed by the local dune protection and beach access plans and the GLO rules for management of the beach/dune system (TAC §§15.1-15.10). The term "emergency erosion response" becomes effective when the governor declares a state of emergency and requests federal assis-

tance following a storm incident. At that time, federal funding may be made available to those with flood insurance for acquiring, relocating, or elevating damaged structures.

If storm erosion moves the natural line of vegetation to a position landward of existing beachfront structures, the attorney general, district attorney or county attorney may enforce the Open Beaches Act by seeking a court order for the removal of such structures from the public beach. This act prohibits the construction of any new structure seaward of the post-storm location of the natural line of vegetation.

Structures Seaward of the Post-Storm Vegetation Line

For structures that were situated landward of the vegetation line prior to a storm but are located seaward of the vegetation line after the storm, the following policies have been used by the OAG.

More than 50% Damaged

PROHIBITED: The repair or reconstruction of any structure that is more than 50% damaged by the storm or any other casualty. If, by visual observation, it is not obvious that more than half of the structure is damaged or destroyed, monetary values will be evaluated to determine whether damage exceeds 50% of the value of the structure. No reconstruction will be allowed unless and until the natural line of vegetation has migrated by natural processes to a position seaward of the structure.

Less than 50% Damaged

PERMITTED: The repair or reconstruction of any structure that is less than 50% damaged.

PROHIBITED: (1) The construction or repair of bulkheads, riprap, or other "hard" beachfront structures, (2) construction activities that interfere with the natural formation of sand dunes on the property, and (3) construction activities that interfere with public use of the beach area immediately adjacent to the structure. If at any time thereafter the structure is more than 50% damaged and is still situated seaward of the natural line of vegetation, the structure may not be repaired or rebuilt unless

and until the natural line of vegetation has migrated by natural processes to a position seaward of the structure.

After Hurricane Alicia, the OAG recommended that coastal landowners check with that office before rebuilding properties adjacent to the public beach. The City of Galveston at that time imposed a 30-day moratorium on the repair of beachfront structures to prevent haphazard construction that might be detrimental to the natural beach recovery process or to public access and use of the public beach.

Structures or Erosion Response Projects within 200 Feet Landward of the Post-Storm Vegetation Line

The OAG has used the following guidelines for structures located within 200 feet landward of the post-storm vegetation line, or for erosion response activities.

PERMITTED: (1) The repair or reconstruction of any habitable structure following the requirements for construction in flood hazard areas (31 TAC §15.6(e)); (2) beach nourishment projects that follow the requirements of 31 TAC §15.7(d); and (3) dune reconstruction projects that follow the requirements of 31 TAC §15.7(e).

PROHIBITED: (1) the construction of any new or repair of any existing bulkhead or "hard" structure as set forth in 31 TAC §15.6(c), regarding construction of new erosion response structures, and §15.6(d) regarding repair of existing erosion response structures; (2) beach maintenance activities that alter the beach profile (such as scraping and creating windrows); and (3) fill projects other than approved dune reconstruction or beach nourishment projects.

Landowners should contact their local city planning department, county engineer's office, or city/county floodplain administrator (listed in Appendix D) for information about obtaining emergency dune protection permits and beachfront construction certificates.

The Open Beaches Act restrictions outlined above do not apply to property along bay shorelines. Property owners should

contact their local building permit authority for information and, if the property is adjacent to state-owned submerged lands, the GLO.

Funding for Erosion Response

Many coastal states, counties, and municipalities are contending with the issue of funding erosion response projects. State legislatures, governor's task forces, county commissioners' courts, city councils, and citizen groups have developed recommendations, passed laws, and implemented programs addressing coastal erosion. Almost all attempt to balance the costs of erosion response projects with the benefits that accrue to shorefront landowners; to local, state, and national government; and to the general population. In many cases, the three levels of government work together to apportion the costs of erosion response projects among those responsible for causing the erosion (when caused by non-natural forces) and those who benefit from the project.

Most erosion response projects are funded through cost sharing; federal, state, and local monies are used to fund the project. The governments' funds are raised through various taxing mechanisms that target different segments of the population—from the federal income tax every wage earner pays to a capital gains tax on the sale of beachfront property.

While our shorelines provide the county, state, and coastal communities with numerous benefits, the U.S. has spent only $34 million annually (1993 dollars) on shoreline protection and restoration in the past 40 years (Houston, 1996). According to Houston (1996), spending on beach restoration has been less than 0.1% of U.S. spending for crop subsidies or foreign aid.

A limited number of funding mechanisms (e.g., taxes, fees, and fines) can be used to finance an erosion response project in Texas. The state has no funding mechanism dedicated to erosion response. Erosion response projects must compete for existing monies with other projects important to local and state government.

Local Funding Options

Beach User Fees. The GLO rules for the management of the

beach/dune system allow local governments with state-approved dune protection and beach access plans to impose beach user fees. The fees collected may be used solely for the provision of beach-related services, which include beach nourishment projects and beach/dune protection and restoration projects.

Hotel/Motel Occupancy Tax and State Hotel Occupancy Tax Refund. Home rule cities have the authority to assess a hotel/motel occupancy tax in addition to that assessed by the state. This tax assessment may be used to fund erosion response projects such as beach nourishment. Cities often use revenue from taxes paid mostly by visitors to improve services or resources the visitors use. In addition, eligible coastal municipalities, as defined by Section 156.2511 of the tax code, are entitled to collect a refund from the hotel occupancy tax collected by the state from hotels within their jurisdiction. This fund must be used for cleaning and maintaining the beach.

Impact Fees. Communities around the country often use "impact fees" to fund resource protection projects. These are fees tied to projects that require local permits or authorizations and that cause some quantifiable "residual" impact to a natural resource even after steps to mitigate the impact have been taken.

For example, the County of Santa Barbara, California, has implemented a mitigation fund to help reduce the level of impacts to coastal resources that cannot be avoided or mitigated through permit conditions. In 1988, the environmental impact statements of four offshore oil and gas projects with onshore components in the county identified potential cumulative impacts to coastal resources and activities (e.g., recreation and tourism) that would occur throughout the life of the project.

To mitigate residual impacts on the county's coastal resources and activities, the county established the Coastal Resource Enhancement Fund (CREF), which funds coastal resource enhancement projects. Project approvals are conditioned on contribution to the CREF. Annual contributions to the CREF are required for the life of the project. A company may make annual payments or a discounted five-year payment. The county adjusts the fee formula value every five years based on the

consumer price index for the preceding five years.

Seawall Tax/Breakwater Authority. Each coastal county and municipality is authorized to build, maintain, protect, and improve seawalls. By statute, counties and municipalities are authorized to levy a special ad valorem property tax of up to $0.50 per $100 valuation to pay for a seawall project. In addition, coastal counties—except Nueces, Kleberg, Kenedy, and Willacy—are authorized to construct breakwaters using existing tax mechanisms (e.g., ad valorem property tax).

The Office of the Attorney General was asked in 1989 whether beach nourishment could be funded with seawall tax money or under the breakwater authority. The attorney general's opinion stated that whether "on the facts of a particular case" a constructed beach could be "accurately characterized" as a seawall, breakwater, or some necessary appurtenance was a fact question. That is, each project is evaluated on the particular facts.

State Funding Mechanisms

Beach Maintenance Fund. The GLO administers the Beach Maintenance Program, a state program that reimburses eligible cities and counties for local expenditures to clean and maintain Gulf beaches. Activities eligible for reimbursement under this program include beach nourishment. State hotel occupancy tax monies spent on beach maintenance cannot be reimbursed by the Beach Maintenance Fund.

Coastal Management Program. Erosion response grant funding through the Texas CMP is administered through the Coastal Coordination Council (CCC). Upon federal approval of the CMP, Texas will receive an estimated $2.4 million per year in federal matching funds to implement the program and advance the program's goals and policies.

One of the ten goals of the CMP is "to minimize loss of human life and property due to the impairment and loss of protective features of CNRAs (Coastal Natural Resource Areas)." In addition, the CMP contains six policies addressing erosion response, five policies addressing construction in the beach/dune system, and several policies addressing shoreline access struc-

tures and facilities.

Because of the focus on shoreline issues in the policies, it is expected that the CMP grants program, once it is developed and implemented, will help fund erosion response planning, design, and construction projects.

General Land Office. The GLO administers the state Surface Damage Account, which is funded by fines and penalties charged for violations and fees for GLO permits and authorizations. The Surface Damage Account may be used to fund conservation or reclamation projects making permanent improvements on Permanent School Fund (PSF) land and to make grants to lessees of PSF land for these purposes. In the past, funds from the Surface Damage Account have been used to purchase wetland vegetation for planting on PSF lands to stabilize the shoreline and protect it from erosion caused by wave action.

Texas Natural Resource Conservation Commission (TNRCC). The Litigation Services Division of TNRCC administers the Supplemental Environmental Project (SEP) program, a discretionary program used in agency-agreed enforcement orders. In settling enforcement actions, TNRCC staff are allowed to work with respondents to present to the Commission a reduced administrative penalty if voluntary contributions are made to fund a SEP.

In general, funding a SEP may not reduce an administrative penalty by more than 50 percent. In addition, expenditures for a SEP must be on at least a one-to-one ratio with the reduction in penalties. Some projects may require a higher expenditure-to-reduction ratio.

Projects that may be accepted for SEP funding are those that will directly benefit the environment in the community where the alleged violation occurred. Projects that may be appropriate for the SEP program and that may provide erosion response are: (1) environmental restoration projects that enhance the environment in the vicinity of the violating facility; (2) projects that provide significant and meaningful environmental education and/or engineering assistance to members of the regulated community or the public; and (3) projects to fund public

works for a neighboring municipality or county that will benefit the environment in a way that is beyond ordinary compliance with the law.

Texas Transportation Commission (TxDOT). In 1995, the 74th Texas Legislature amended the Texas Coastal Waterway Act of 1975 to allow the Texas Transportation Commission to enter into agreements with the COE to share the costs of projects making beneficial use of material dredged from the GIWW.

The commission is required to develop rules that establish eligibility criteria for beneficial-use projects. The legislature defined a beneficial use as "any productive and positive use of dredged material [that] covers broad use categories ranging from fish and wildlife habitat development to human recreation."

Input into the Texas Transportation Commission's rulemaking from coastal landowners whose property is endangered by erosion will help ensure that erosion response projects such as beach nourishment receive high priority.

Texas Water Development Board (TWDB). The TWDB's Flood Control Fund can issue loans to local communities for flood protection projects. The TWDB was instrumental in providing loans to the City of Galveston for the construction of its beach nourishment project in 1995.

Texas Legislature. State funding for erosion response projects can be obtained through direct legislative appropriation.

Federal Funding Mechanisms

Federal Emergency Management Agency. Currently, FEMA provides disaster assistance to coastal communities only after an area has been declared a disaster area by the president of the United States. The disaster assistance includes individual assistance and public assistance. Individual assistance is provided to individuals, families, and small businesses in the form of grants, loans, and temporary housing. Public assistance is provided for the repair of public property such as courthouses, city halls, and public parks.

Coastal property owners having federally funded flood insurance may be able to participate in a newly developed FEMA program that will provide grants to states and communities for the acquisition, relocation, elevation, floodproofing, or demolition of structures, as well as for beach nourishment and technical assistance. Further information may become available on this program in the fall of 1996.

U.S. Army Corps of Engineers. Under its Continuing Authorities Program (CAP), the COE is authorized to construct certain water resource projects without specific congressional approval. Projects constructed under the CAP must include local cooperation and sponsorship. The local sponsor may be a state, county, city, or other fully empowered group. Each project must be economically justified on a benefit-to-cost basis. All CAP projects are subject to the availability of federal funds.

CAP Emergency Bank Protection — Emergency streambank and shoreline protection is available for public and nonprofit property through Section 14 of the 1946 Flood Control Act (as amended). Each project must be a complete solution to the problem involved, and the local sponsor must cover at least 25 percent of project cost, including all costs above $500,000.

CAP Small Beach Protection Projects — Section 103 of the 1962 River and Harbor Act (as amended) allows the COE to design and construct small projects to restore or protect coastal shores from erosion caused by natural wave and current action. The local sponsor's share is at least 35 percent of the total project cost for publicly-owned (non-federal) shores. Federal assistance is limited to $2 million per project.

CAP Mitigation of Shore Damages — The COE can investigate and construct projects to mitigate shore damage resulting from federal navigation works under the authority of Section 111 of the 1968 River and Harbor Act (as amended). The cost-share percentage for mitigation is the same as that of the original project which caused the shore damage. Local interests must operate and maintain the project. The federal participation limit is $2 million per project without congressional approval.

CAP Section 1135 Projects — Section 1135 of the Water Resources Development Act of 1992 authorizes modifications to existing

federal water resource projects to improve environmental quality where it is in the public interest. Project modifications must be feasible and consistent with the intended purposes of the existing project. Local sponsors must provide at least 25 percent of project costs and must operate and maintain the project. Federal participation is limited to $5 million without congressional approval.

Section 933 Projects — Section 933 of the Water Resource Development Act of 1986 authorizes the COE to place suitable dredged material on public beaches. The dredged material must come from construction or maintenance dredging of navigation inlets and channels. The federal share of project costs is 50 percent only if the economic benefits (primarily flood protection and recreation benefits) exceed the added project cost. Otherwise, the COE can still construct the project with the local sponsor contributing all of the added cost.

Section 216 Projects — Section 216 of the Flood Control Act of 1970 authorizes the COE to review the operation of completed projects and to report to Congress with recommendations on the advisability of modifying existing structures or their operation, and for improving the quality of the environment in the overall public interest.

Planning Assistance to States — Section 22 of the Water Resources Development Act of 1974 authorizes the COE to cooperate with any state or state subsidiary in preparing comprehensive plans for the development, utilization, and conservation of water and related resources. The state must provide 50 percent of the cost, and annual federal participation is limited to $300,000 per state.

U.S. Fish and Wildlife Service. The National Coastal Wetlands Conservation Grant Program is authorized by Section 305 of the Coastal Wetlands Planning, Protection and Restoration Act of 1991. Funds are intended for coastal states to acquire, restore, enhance, or manage coastal lands or waters, including wetlands.

Under the Endangered Species Act, the USFWS must protect and preserve endangered species and their habitats. Some eroding areas in Texas are known to be used by endangered species and are therefore entitled to protection and preservation.

Congressional Authorization/Appropriation. Federal funding of erosion response projects can be obtained through direct congressional action. The local sponsor must convince Congress of the need for the project. The congressional committees with jurisdiction over the Water Resources Development Act of 1996 are the Senate Environment and Public Works Committee and the House Transportation and Infrastructure Committee.

Appropriations would come from the Energy and Water Subcommittee of the House Appropriations Committee, along with the Senate Appropriations Committee.

PART 2
Proposals for Improved Erosion Response

Recommended Policy

The following policy recommendations are proposed to better address coastal erosion problems in Texas. The proposed policies are based on the lessons we have learned from implementing ineffective or inadequate policies, and on comments and suggestions from coastal residents.

1. Establish a state funding source for erosion response.

Many critical erosion areas along the Texas Gulf coast require expensive remedies to protect private property and the common law rights of the public on public beaches. Current state policies and programs are not effective in providing landowners with assistance or protection. The main problems impeding coastal erosion response are lack of funding, lack of economical sand sources, and poor coordination among federal, state, and local agencies and coastal citizens.

The greatest obstacle that citizens and local and state governments face in responding to erosion is obtaining adequate financial resources for the planning and construction of erosion response projects. A state source of funding could provide local governments financial assistance in cost-sharing projects with the federal government. For instance, the COE will dredge sediments from Rollover Pass in Galveston County in the winter of 1997. The sediments from the dredging project could be placed on the eroding beaches nearby to provide storm protection to the homes that are now located on the line of vegetation. However, the state, property owners, and Galveston County do not have the funding to share the beach fill costs with the COE.

To solve these problems, the legislature should consider enacting legislation to establish a fund that could be used in conjunction with local funding for approved projects. The act would follow existing state policies by promoting the use of "soft" methods of avoiding, slowing, or remedying erosion and would list the types of projects that could be used in critical erosion areas. The types of projects eligible for funding could include beach nourishment, vegetation planting, sediment bypassing, construction of nearshore sediment berms, dune stabilization and creation, post-storm emergency response, monitoring of project effectiveness, relocation of structures, and acquisition of property. Planning, design, and construction of

the projects listed above would be eligible, as well as the propagation or collection of vegetation suitable for shoreline or dune stabilization.

Additionally, the act could promote broad-based partnerships with local governments, state agencies and river authorities, soil and water conservation districts, marine advisory committees, and coastal industries for planning and implementing projects and for identifying local funding sources.

The major beneficiaries of the legislation would be local governments, property owners, coastal businesses, and beach and bay users. Local governments include cities, counties, and any special districts dedicated to erosion response (e.g., conservation and reclamation districts, and seawall commissions). Many of the proposed erosion response projects would add sediment to the shoreline, resulting in wider beaches for the general public to enjoy. Some projects could remove structures from future erosion threats, which would cost taxpayers less in the long run.

2. Improve coordination among the U.S. Army Corps of Engineers and state and local governments regarding current projects and identify potential erosion response projects.

Although some federal dredging projects directly impact local communities, many local governments and communities are not adequately engaged in the COE's planning processes. As a result, opportunities to address local needs have been missed.

The COE does not provide sufficient forewarning of long-term dredging plans in a manner which facilitates full participation at the local level. While the COE does provide some notice and opportunity to comment on all its projects, this notice is generally published too late to allow local governments and communities to influence the design and budget for the project.

The COE, Galveston District, hosts an annual dredging conference. This conference, principally geared toward dredging contractors, provides some information about proposed dredging activities for the next two years. In effect, the conference report outlines the established dredging practices for specific areas. Little opportunity exists to explore alternatives which

may address the concerns of local communities or change the project design or schedule. As a result, few, if any, local governments take part in the conference.

The COE should reform its long-term planning process to increase the opportunity for local involvement and participation in decision-making. In particular, the COE should promote exploration of alternative dredging options designed to meet the needs of local communities, while still satisfying its duty to maintain navigable channels. The planning process should provide local governments with adequate time to plan for, and acquire funds necessary to serve as local sponsors for, beneficial use projects. Local government representatives should be included in the COE's beneficial uses group.

GLO should continue in its role as the lead state agency for coordinating efforts among federal, state, and local agencies.

3. Pursue Texas' fair share of federal funding for erosion response projects.

A number of underutilized federal funding mechanisms should be tapped. In cooperation with the COE and local governments, the state should identify projects that may qualify for federal funds under COE Continuing Authority Programs and other federal authorities (described in Part I—Funding for Erosion Response). Texas needs the COE to take an active role in enabling these projects to be cost-justified within the funding guidelines. To date, the COE, Galveston District, has not been able to justify federal involvement and funding for any "Section 933" projects in Texas, leaving local governments to pay the bill on their own. The federal government may be responsible for some shoreline erosion problems such as areas of erosion downdrift of jetties and navigation projects.

Texas needs the COE to be proactive in its involvement in shoreline protection because the state and local governments need the federal funding assistance and because some COE navigation or dredging projects yield sediment that could be used for erosion response projects.

4. Provide technical assistance to local governments and others to obtain erosion response funding from the Federal Emergency Management Agency.

As part of its existing statutory responsibilities, the GLO will help local governments and citizens who have federally-funded flood insurance to participate in a new program being developed by FEMA under the National Flood Insurance Reform Act. The new program will provide grants to states and communities at a 75/25 percent (federal/state) cost share for acquisition, relocation, elevation, floodproofing, and demolition of structures, as well as for beach nourishment and technical assistance.

The new FEMA program takes the place of funding under the Upton-Jones Act, which was discontinued in 1995.

5. Improve sediment management practices and consider their effects on the coastal sediment budget.

Sediment management within Texas river systems has long been proposed by coastal citizens as a key element in any plan to alleviate coastal erosion. Although dams stop sediment from reaching the coast, many are so far from the coast that it is difficult to justify the cost of importing the sediment from them to the Gulf beaches. In 1991, for example, the COE, Fort Worth District, published a report that calculated the costs of dredging sediment from Whitney Lake on the Brazos River and depositing it on the beaches of Matagorda County. Whitney Lake was chosen for the study because it is the most downstream reservoir on the Brazos River. (The dam is located approximately 442 river miles from the Gulf of Mexico.) The study found that the sediments within the lake were too fine (silt size or smaller) for beach restoration, and the cost of dredging and transporting, via slurry pipeline, about 76.4 million cubic yards of sediment to the Gulf would be about $787.3 million (COE, 1991). Another study estimated that the cost of dredging sediments from Lake Buchanan on the Colorado River and stockpiling them nearby would range from $4.25 to $5.50 per cubic yard (Engitech, Inc., 1991).

The question of the effect that the mining of sand, marl, and gravel from coastal rivers may have on coastal erosion has also

been raised. Despite these concerns, sediment mining in rivers that empty into the Gulf of Mexico continues to be permitted. New permittees are required to help fund a study of the effect of sand mining on coastal erosion. The study is being conducted by the BEG and the U.S. Geological Survey (USGS), Austin office, and the results are expected in 1997.

Potential alternative sediment sources, such as dredged material disposal sites, are often ignored mainly because the sediment size and the amount of sediment available are unknown. Typically, disposal sites are filled with a mix of beach-quality sand and sediment too fine for use.

The state should take appropriate action in three specific areas of concern relating to sediment management.

First, steps should be taken to reduce the impact of structures on sediment supply. For example, the state should ensure that sediment bypassing is an integral part of future flood control or water supply projects. Plans for new coastal improvements such as jetties, groins, and inlets should incorporate sediment management features (such as bypass systems) or provide for mitigation of the shoreline damage attributable to the structure. Where feasible, existing riverine and coastal structures should be retrofitted to allow sediment bypassing or otherwise reduce the impact of these projects on coastal sediment supply.

Second, dredged material disposal practices should be modified to facilitate the beneficial use of dredged material. The COE should plan for and create disposal areas to stockpile beach-quality sediment. These disposal areas should be located near areas where the material can be used beneficially. In addition, the COE should identify opportunities to reclaim beach-quality sediment from existing dredged material disposal areas.

Third, to the extent warranted by the forthcoming BEG/USGS study, the state should modify its existing policies governing sand, marl, and gravel mining in coastal rivers.

6. Establish research priorities in support of erosion response planning and project assessment.

In the past, coastal erosion investigations and impact assessments have been conducted in support of specific coastal construction projects. Usually, sand source studies and monitoring of erosion response projects have been funded solely by local sponsors. These studies are necessary to evaluate the success of a project or to plan subsequent projects; however, the studies are costly and of limited application in other areas. In many cases, broader, more comprehensive studies and assessments are needed as a foundation for development and implemention of a more comprehensive coastal erosion response program.

The state should establish partnerships with universities to complete the following investigations and impact assessments:

a. identify economically feasible sand sources for beach restoration projects;

b. investigate the use of COE dredged material disposal sites as potential sources of sediment for shoreline restoration projects;

c. conduct annual beach profile survey studies along developed Gulf beaches to measure shoreline changes;

d. establish nursery projects that develop and cultivate disease-resistant vegetation adapted to local conditions;

e. determine the effects of vessel wakes on shorelines;

f. determine the impact of local beach-cleaning and scraping practices on the beach/dune system and, where warranted, develop alternative and less damaging beach-cleaning methods;

g. develop regional and local sand management plans (sediment budgets);

h. implement a wave gauging program (long-term climatology and storm documentation); and

i. develop inlet management plans.

7. Promote public education about the impacts of coastal erosion and about appropriate erosion response methods.

To achieve effective erosion response, the public must be continually informed about the impacts of coastal erosion and the importance of using appropriate erosion response methods. This can only be achieved through a concerted public outreach program. An informed public will produce better stewardship within communities and can assist in the enforcement of state and local programs. Shoreline erosion was one of the chief concerns of coastal residents who testified at public hearings on the proposed CMP. Certainly, the public has an interest in learning more about coastal erosion and what citizens can do to help address it. Existing state policies do not do enough to promote public outreach.

The Texas Sea Grant College Program or another outreach entity should assist agencies in educating the public about the causes of erosion, the latest studies on coastal erosion, and appropriate erosion response methods. This can be achieved through newsletters and state agency guidance documents, public speaking engagements, education of teachers and schoolchildren, and public service announcements.

As part of its existing statutory mandate, the GLO should coordinate and expand efforts to educate the public about coastal erosion problems and possible solutions.

PART 3 *Critical Erosion Areas*

Ranking Critical Erosion

The GLO rules for management of the beach/dune system (31 TAC §§15.1-15.10) define "eroding areas" as "a portion of the shoreline which is experiencing a historical erosion rate of greater than two feet per year based on published data of the University of Texas at Austin, Bureau of Economic Geology." An eroding area is considered critical when the rate of erosion exceeds two feet per year and poses a threat to:

- public infrastructure or areas of national importance,
- public beach access and recreation,
- traffic safety,
- private property, or
- fish or wildlife habitat.

To rank critical erosion areas in a reasonably quantifiable manner, the following factors and ratings are considered (HIGH = 3 pts., MED = 2 pts., LOW = 1 pt.). Areas with higher point totals should receive higher priority for funding.

1. Evacuation routes and public safety

HIGH ..... Evacuation routes are closed due to shoreline erosion, and beach travel is closed.
MED ..... Evacuation routes are open, but reasonably safe beach travel is threatened.
LOW ..... Evacuation routes are open, and beach travel is open.

2. Public access and recreation

HIGH ..... Public access and use are halted due to erosion.
MED ..... Public access and use are threatened.
LOW ..... Public access and use is not affected.

3. Federal/state/local economic impact

HIGH ..... Erosion is the main cause for a decrease in annual tourist dollars and in the tax base.
MED ..... Erosion is partly the reason for decreased revenues.
LOW ..... Erosion is not a reason for decreased revenues.

4. Public/private property value

HIGH..... The total value of threatened property exceeds $100,000, or habitable structures are in imminent danger of collapse due to erosion.

MED ..... The total value of threatened property is equal to or less than $100,000, and/or structures are located within the eroding area boundary.

LOW ..... Property values have not decreased, and/or the structures are located landward of the eroding area boundary.

5. Existing shoreline protection

HIGH..... The shoreline is in its natural state, and no shore protection program has been implemented.

MED ..... The shoreline has been restored by beach nourishment.

LOW ..... The shoreline is armored.

6. Historical erosion rate

HIGH..... Greater than five feet per year.

MED ..... Greater than two feet and less than five feet per year.

LOW ..... Stable or accreting.

7. Loss of wildlife areas/endangered species

HIGH..... Wildlife and endangered species habitat is being lost due to erosion.

MED ..... Wildlife and endangered species habitat is imminently threatened by erosion.

LOW ..... No habitat is threatened by erosion.

8. Human impacts

HIGH..... Erosion is mainly attributed to human impacts (for example, coastal structures or vessel wakes).

MED ..... Erosion is attributed to a mixture of human impacts and natural processes.

LOW ..... Erosion is mainly attributed to natural processes.

Examples of High Ranking Factors

1. Evacuation routes and public safety: Highway 87 in Jefferson County; Magnolia Beach/ Indianola.

2. Public access and recreation: Highway 87 in Jefferson County; Magnolia Beach.

3. Federal/state/local economic impact: Magnolia Beach; Caplen Beach; Corpus Christi Ship Channel at Port Aransas; Highway 87; South Padre Island; Treasure Island.

4. Public/private property value: Caplen Beach; Corpus Christi Ship Channel at Port Aransas; Treasure Island; South Padre Island.

5. Existing shoreline protection (natural): Welder Flats State Coastal Preserve; Lower Neches River Valley.

6. Historical erosion rate greater than 5 ft/yr: Caplen Beach; Highway 87; Treasure Island; South Padre Island.

7. Loss of wildlife areas/ endangered species: Welder Flats; Lower Neches River Valley; Galveston Island State Park bay shoreline.

8. Human impacts: Corpus Christi Ship Channel at Port Aransas; Caplen Beach; Welder Flats State Coastal Preserve; Lower Neches River Valley.

Once the critical erosion areas have been prioritized, the next step is to consider the type of erosion response project that may be planned. Proposed erosion response projects should be ranked on a benefit-to-cost ratio on the basis of the following benefits:

- Preserves coastal sand dunes
- Provides storm protection
- Protects commercial or recreational navigation
- Provides recreational opportunities
- Provides potential tourism income
- Protects the tax base
- Benefits downdrift shorelines
- Protects or provides habitat

On shorelines that are historically stable or accreting yet experience significant erosion due to storm activity, the emergency measures recommended in Part II — Post-Storm Emergency Response — should be followed.

Based on public input, nine critical erosion areas are featured below, including potential solutions and funding sources. Because ranking criteria may depend on the funding source, the nine areas have not been ranked relative to one another. Details about the potential sources and types of funding can be found in Part I — Funding for Erosion Response.

Alamo, Magnolia, Indianola Beach, Calhoun County

Critical Erosion Area: Alamo Beach/Magnolia Beach/ Indianola Historical Site

Problem Description: Alamo, Magnolia, and Indianola beaches are located along the western shore of Matagorda Bay. The shoreline is characterized by salt marshes and shell beaches. The Matagorda Ship Channel is located within one mile of the shoreline, with cargo ships traveling to the Formosa Plastics and ALCOA facilities. Approximately eight miles of shoreline are affected by severe erosion.

Coastal landowners are spending thousands of dollars for shoreline stabilization only to see their efforts fail and their homes threatened. The width of the public beach park at Magnolia Beach is decreasing, and the public road (a hurricane

evacuation route) that extends to Indianola is periodically flooded and needs repair.

Presumed Causes: Historically, wave energy derived from the prevailing winds was the cause of the predominantly erosional state of the shoreline, where approximately 162 acres was lost between 1856 and 1934 (McGowen and Brewton, 1975). Today, these natural coastal processes are combined with waves and surges generated by ship traffic.

Desired Outcome: The goal of the erosion response project is to protect private property, public park beaches, and the public roadway.

Recommendation for Erosion Response: Except for areas to be reestablished as public beach, vegetation in combination with wave-breaking structures should be used to stabilize the shoreline. Beach-quality sand should be used to nourish the public beach. Marsh vegetation should be planted in areas of low wave energy. Along eroding shorelines where the impact of vessel wakes is greatest, riprap or a combination of vegetation with shore-parallel breakwaters could be used.

Because the recommended response is multi-faceted, an erosion response working group consisting of local citizens, local government officials, the Calhoun County Navigation District, the local soil and water conservation district, the COE, and the GLO should be established.

The working group should review the previous recommendations made by the Natural Resources Conservation Service (NRCS), in conjunction with the local soil and water conservation district. These organizations have mapped the eroding areas along the shorelines of Galveston, Matagorda, San Antonio, Copano, and Corpus Christi bays, and have evaluated stabilization methods.

In addition, the working group should consider taking the following actions:

1. determine the availability of beach-quality dredged material for placement at the bayshore beach park;

2. evaluate the feasibility of extracting beach-quality material from existing disposal areas for beach nourishment; and

3. monitor vessel speeds in the navigation channel and evaluate the impact of vessel wakes on the shoreline erosion problem.

Funding Alternatives

Local — User fees; impact fees; seawall tax/breakwater authority; county property taxes; technical assistance through the Soil and Water Conservation District.

State — CMP grant program; GLO surface damage account; TNRCC SEP program; TxDOT cost sharing with COE; TWDB flood control fund; legislative appropriation.

Federal — FEMA grant program; COE Section 933 authority for use of dredged sand; COE Continuing Authorities Program; technical assistance through NRCS; congressional appropriation.

Welder Flats State Coastal Preserve, Calhoun County

Critical Erosion Area: Welder Flats State Coastal Preserve

Problem Description: Welder Flats State Coastal Preserve is located on San Antonio Bay, protected from the Gulf of Mexico by Matagorda Island. Productive marsh area is being converted to open water adjacent to the GIWW. A similar problem exists at the nearby Aransas National Wildlife Refuge. Both the preserve and refuge are known to be used by the endangered whooping crane (COE, 1995).

Presumed Causes: Shoreline recession and deepening of shallow-water habitat areas in the preserve are believed to be caused primarily by wakes from GIWW traffic in channel reaches confined by dredged material disposal areas opposite the preserve shoreline.

Desired Outcome: Shoreline retreat and the deepening of shallow water areas should be halted and reversed to reclaim pro-

ductive marsh and seagrass habitat.

Recommendation for Erosion Response: Wave-dissipating systems such as geotextile tubes or discontinuous breakwaters should be located near the GIWW channel to shield the shallow, open water portions of the coastal preserve from barge tow wakes and surges.

If it is determined that a nonstructural method can accomplish the desired outcome, this will be preferred over any structural solution. The high-energy wave environment created by GIWW traffic may preclude a totally "soft" response. However, if much of the wake energy can be absorbed or deflected before reaching the preserve shoreline, the area between the GIWW and the present shoreline can be restored. The use of limited amounts of dredged material should be considered to restore bottom elevations to depths appropriate for marsh and seagrass reestablishment. Partially segregating the habitat areas from the GIWW can also improve water clarity, which improves conditions for seagrasses.

Additional habitat could be created by properly grading and stabilizing the banks of the dredged material disposal areas opposite the preserve, which presently consist of erosional escarpments or bluffs.

Funding Alternatives

Local — N/A

State — CMP grant program; GLO/TPWD/TNRCC operating funds for the designated coastal preserve; GLO surface damage account; GLO spill response funds for onsite staging area; TNRCC SEP program; TxDOT beneficial use participation; legislative appropriation or assessment of GIWW users.

Federal — USFWS protection of whooping crane habitat under the Endangered Species Act; USFWS National Coastal Wetlands Conservation Grant program; COE Section 216 modification funding; congressional appropriation.

Manmade Waves

Along the coast, most manmade waves come from boats, barges and ships.

Smaller, lighter vessels produce wakes similar to natural, wind-driven waves. The effect of these boat wakes on local erosion can be important if the wakes are a large percentage of the total number of waves in the area.

Other vessels cause wakes and surges that are very different from natural waves or tides, especially in locations where the volume (displacement) of the vessel is large compared to the size of the channel or body of water. When this is the case, the water is forced to move out of the way of the vessel, resulting in swift currents or surges that can move sediment and erode shorelines.

Imagine the motion of the water in a swimming pool when a person wades through, compared to what happens in a bathtub filled with water when a child moves forward and backward. A channel with narrow banks or that is surrounded by shallow water reacts to a large, passing vessel much like the water in the bathtub reacts to the movement of the child.

Caplen Beach, Bolivar Peninsula, Galveston County

Critical Erosion Area: Caplen Beach, Galveston County, Texas

Problem Description: The Gulf-facing beach is receding over time. A nearly vertical cut bluff has developed along several miles of the coast at Caplen Beach, west of Rollover Pass. The beachfront bluff at Caplen is the highest point on Bolivar Peninsula west of High Island. The bluff suffers further cut-back with each episode of wave attack (a combination of large waves and high tides). During these episodes, the bluff is undermined at its toe, resulting in slope failures and collapse onto the beach. The bluff face is unstable and unvegetated, and no dune system remains.

The destruction of several dozens of homes is imminent. Most of these homes were located well back from the shoreline following the devastation of the area by Hurricane Carla in 1961.

Presumed Causes: Several causes of shoreline and bluff retreat in this area can be identified. Regionally, Bolivar Peninsula suffers from a general deficit of sediment, due in part to the presence of the Sabine jetties (a longshore sediment transport barrier) as well as to reduced sediment supply from the Neches and Sabine rivers (due to urbanization and water supply/flood control dams). The GIWW also intercepts sediment formerly carried to the coast along drainage paths from interior marshes along the peninsula.

Low vertical relief and the flatness of stable beach slopes due to the very fine-grained sediment make Bolivar Peninsula especially susceptible to the effects of relative sea level rise. Relative sea level rise includes the effects of any absolute rise in sea level; however, land subsidence is a more significant contributor to relative sea level rise at Bolivar. The land surface has been lowered by a combination of natural compaction of coastal sediments and the reduction of soil pore pressures as a result of fluid (water, oil, and natural gas) pumping (Germiat, 1988). A consequence of gradual relative sea level rise is the landward migration of the shoreline, even if no sand or sediment is eroded from the area.

Although relative sea level rise and background sediment deficit are known to exist on the peninsula, the locally accelerated erosion rate is a direct consequence of the presence of Rollover

Pass and other sediment-trapping structures (Morton, 1975).

The presence of Rollover Pass on the updrift side of Caplen results in a more acute sediment deficit there than along neighboring beaches. In addition, derelict concrete structures and unauthorized self-help seawalls on the public beach to the east are functioning as groins, further reducing the supply of sand available for southwestward longshore transport to the beach at Caplen.

Desired Outcome: The goal of an erosion response plan for the Rollover Pass vicinity is to stop or slow the landward advance of the Gulf shoreline. A near-term goal is to stabilize the eroding bluff at Caplen Beach before any further loss of beachfront homes occurs. Reestablishment of a dune complex is also desired.

Recommendation for Erosion Response: Initiate temporary bluff stabilization measures where homes are threatened, and implement a long-term beach nourishment program. An erosion response plan for the Gulf beaches adjacent to Rollover Pass must include three important components—bluff stabilization, reduction of the sediment deficit, and action to address relative sea level rise.

1. *Bluff stabilization* — The bluff toe can be protected by protective measures such as the installation of large sandbags or similar temporary measures. Such protection should only be considered as temporary, low-level protection. Long-term use of sandbags without beach nourishment may result in the loss of usable beach area and could exacerbate downdrift erosion.

2. *Sediment deficit reduction* — A long-term beach nourishment program can stabilize the shoreline by providing sufficient sediment to balance the local coastal sediment budget. Beach nourishment can also end the need for temporary protection measures. Rollover Bay and the Gulf Intracoastal Waterway offer potential sand sources for beach placement.

Offshore sand sources also exist in the area (Bales and Holley, 1985). A sand bypassing system to transport material across Rollover Pass from east to west should be considered. This would reduce the loss of beach sand into Rollover Bay or into

deeper offshore waters (Wang, 1989). Closure of Rollover Pass to normal tidal flow would achieve the same result. Sediment quantities impounded upstream in Neches and Sabine River projects should be released to the coast where possible, to bring the regional sediment deficit more into balance.

3. *Response to relative sea level rise* — Sand used for beach nourishment should be of sufficient quantity to negate the effects of relative sea level rise on the shoreline position. An alternative to additional beach nourishment is planned retreat of development from the present shoreline.

Funding Alternatives

Local — Beach user fees; impact fees (including user fees for fishing at Rollover Pass and the assessment of fees on other beneficiaries of the pass); seawall tax/breakwater authority; county property taxes.

State — Beach maintenance fund; CMP grant program; GLO surface damage account; TNRCC SEP program; TxDOT beneficial use participation; TPWD Rollover Pass maintenance funds; TWDB flood control fund; legislative appropriation.

Federal — FEMA grant program; COE Continuing Authorities Program; COE Section 933 program; congressional appropriation.

Corpus Christi Ship Channel at Port Aransas, Nueces County

Critical Erosion Area: Port Aransas shoreline adjacent to the south side of the Corpus Christi Ship Channel.

Problem Description: The City of Port Aransas extends from the Corpus Christi Ship Channel to the Gulf of Mexico on the northern tip of Mustang Island. Several federal projects are located within the vicinity of Port Aransas. They consist of a deep-draft channel, a turning basin, rubblestone jetties, and a stone dike. The Corpus Christi Ship Channel bordering the city's northwest jurisdiction has a depth of 45 feet and a bottom width of 500 feet (COE, 1994). Deep-draft vessels and commercial and recreational boaters navigate the channel daily.

The shoreline adjacent to the south bank of the Corpus Christi

Ship Channel is composed of unconsolidated sediments (mostly fill from dredged materials) and is unstabilized. The eroding shoreline stretches from the end of the stabilized area near the Nueces County Fishing Pier westward to Piper Channel. Erosion of the 5,844 linear feet of unstabilized shoreline is of great concern to the City of Port Aransas because the city owns a large portion of the eroding property. Several private landowners and the GLO own the remainder of the shoreline properties. Public access for fishing is threatened and wildlife habitats are impacted by the loss of land.

In addition to the impacts to city, state, and private property, the erosion is wearing away an unstabilized dredged material disposal site located at the western end of the eroding area. The disposal site sediments are the cause of shoaling at the entrance to Piper Channel. City staff report that the landowners' association pays up to $15,000 per month to keep the channel open for the marina subdivision.

Presumed Causes: In its 1994 Section 111 Report, the COE, Galveston District, determined that waves generated by passing ships were the likely cause of the erosion and found that erosion caused by currents was negligible (COE, 1994). With this finding, the COE determined that future federal participation would be withheld.

Desired Outcome: The goal of an erosion response project along the southern shoreline of the Corpus Christi Ship Channel is to protect the city's property from further erosion without accelerating erosion to the downdrift shoreline and properties, as well as stabilizing the Piper Channel inlet.

Recommendation for Erosion Response: The City has requested that the entire 5,844 feet of shoreline be bulkheaded to stop the erosion. The cost of the bulkhead project is estimated at $978,236.00. Kraus and Brown (1995) studied the effects of erosion and subsequent sedimentation of Piper Channel. Their recommendations included establishing a "no wake" zone at the entrance to Piper Channel; planting vegetation on the dunes and cliffs to reduce wind-blown erosion and slumping in combination with light bulkheading for containing the cliff sediment; and placement of an L-shaped tire-encased piling adjacent to the channel.

A plan for an appropriate erosion response project should be developed in partnership by the City of Port Aransas, the Port of Corpus Christi, adjacent landowners, and GLO staff.

The partnership should consider taking the following actions:

1. obtain and evaluate all available data on vessel speed and associated wake and surge impacts on shoreline erosion;

2. monitor vessel speeds and take appropriate action to address their impacts; and

3. ask the COE to revisit the federal cost-share opportunities if it can be shown that dredging costs will be reduced through local action.

Funding Alternatives

Local — Impact fees for channel users/beneficiaries; cooperative arrangement with Port of Corpus Christi; property taxes.

State — CMP grant program; GLO surface damage account; TNRCC SEP program; TxDOT beneficial use participation; legislative appropriation.

Federal — COE Section 1135; congressional appropriation.

Galveston Island State Park Bay Shoreline, Galveston County

Critical Erosion Area: Galveston Island State Park Bay Shoreline, Galveston County

Problem Description: The marshes comprising the Galveston Bay shoreline in Galveston Island State Park are being converted to open water. The rate of loss appears to be increasing following the loss of protective emergent shoals.

Presumed Causes: Wave erosion, exacerbated by recreational vessel wakes, has lowered the elevation of protective shoals bayward of the shoreline. The previously sheltered marshes and shallow open-water areas are now subject to greater wave energy.

Desired Outcome: Shoreline retreat should be halted, and where possible, reversed to reclaim productive marsh habitat. Deepening of shallow areas should be halted and reversed.

Recommendation for Erosion Response: A site-specific assessment of local conditions should be conducted to determine appropriate response measures. Among the possible response alternatives are importing fill material to rebuild the protective shoals, or, if wave energy is excessive, providing a flexible energy-dissipating system to reduce the wave energy to a level the marsh can tolerate.

Funding Alternatives

Local — N/A

State — TPWD state park funds; CMP grant program; TxDOT beneficial use participation; GLO surface damage account; TNRCC SEP program; legislative appropriation.

Federal — USFWS National Coastal Wetlands Conservation Grant Program; COE Section 22 planning assistance; congressional appropriation.

Highway 87 in Jefferson and Chambers Counties

Critical Erosion Area: Highway 87 in Jefferson and Chambers Counties (including a segment along the Sabine-Neches Channel)

Problem Description: Highway 87 in Jefferson County is the coastal route between Port Arthur and High Island. It is also the only access route to Sabine Pass and Sea Rim State Park from either direction. Retreat of the Gulf shoreline over the previous decades has resulted in periodic landward relocation of the highway. At present, about 16 miles of Highway 87 is impassable due to tide and wave damage to the road surface. The closed portion of the highway begins just west of the entrance to Sea Rim State Park and continues west to the intersection with Highway 124 near High Island. Thus, there is no coastal route to High Island or the Bolivar Peninsula from the east. There is presently no vehicular access to the public beaches along the closed route other than by driving on the sand at low tide. Access to oil and gas facilities is also impeded. The

"Improvement" is a relative term.

When a river or stream is "improved" for flood control purposes or channel banks are armored to protect adjacent development, an important source of sediment for downstream reaches may be reduced. Not only is this a factor in the landward retreat of Gulf beaches, but it is possibly more significant to the ongoing submergence of formerly productive coastal wetlands.

Examples of improvements that reduce sediment supply include:
- levees that reduce overbank flooding (and consequent sediment deposition),
- lining of channels with concrete or other armor,
- detention basins that reduce peak flood flows and trap sediment,
- reservoir development for water supply and other purposes,
- impervious surfaces within the floodplain.

marshes of Sea Rim State Park and McFaddin National Wildlife Refuge are also impacted by the retreating shoreline. Loss of marsh area and the heightened threat of saltwater intrusion are major concerns. An additional portion of Highway 87 between Sabine Pass and Port Arthur, the only emergency escape route from Sabine Pass and Sea Rim State Park, is susceptible to flooding and damage because of erosion of the bank of the Sabine-Neches Ship Channel.

Presumed Causes: A deficit of sediment is the primary cause of shoreline retreat along the Jefferson County coastline. A secondary cause is relative sea level rise resulting from land subsidence and compaction. The sediment deficit is a consequence of littoral barriers (especially the Sabine Jetties) and the reduction of fluvial sediment supply from the Neches River and Sabine River watersheds. Sediment supply to the marshes landward of Highway 87 is also impacted by the Gulf Intracoastal Waterway (GIWW), which cuts off a number of natural drainages, is a source of erosive wakes and waves, and acts as a sediment sink in the region. Erosion along the Sabine-Neches Ship Channel is primarily caused by ship wakes.

Desired Outcome: Shoreline retreat should be stopped or slowed to a manageable rate to minimize damage and subsequent loss of extremely productive marsh and wetland habitat. Access to 16 miles of public beaches and marsh areas should be restored. Emergency ingress/egress and economic and recreational benefits should also be restored.

Recommendation for Erosion Response: The state highway should be reconstructed along an alignment that is sufficiently landward of the present shoreline to allow for continued shoreline retreat. A dune restoration plan for the area seaward of the new highway alignment should be implemented along with mitigation of wetland loss. Long-term sediment management of the Sabine and Neches watersheds and ship channels along with the effects of navigation jetties should be explored as part of the response strategy for this area.

Much of the required documentation has already been prepared for a highway relocation project (Horizon, 1992). Opportunities exist for enhancement of degraded wetland areas and creation of habitat for migratory birds and other wildlife

in association with highway reconstruction and protection.

Funding Alternatives

Local — Beach user fees; impact fees; funds from counties that would benefit from a reopened highway, including Jefferson, Chambers, and Galveston counties; county transportation funds; City of Port Arthur economic development funds.

State — TxDOT state highway construction and maintenance funds; TxDOT beneficial use participation; CMP grant program; TPWD Sea Rim State Park revenue; GLO surface damage account; TNRCC SEP program; legislative appropriation.

> *Note:* TxDOT road construction funding can possibly include funds for a protective dune buffer seaward of the highway just as road construction funds are used to protect state highways from various other threats, such as flooding and channel scour. Reconstruction of Highway 87 will improve public safety (emergency routes), public health, access to oil production facilities and spills, hunting and fishing access, and public beach access. Each of these interests contains potential funding sources and involves virtually every state agency.

Federal — USFWS funds through the Endangered Species Act or for the protective value of the project improvements to McFaddin National Wildlife Refuge; COE funding if additional project benefits can be quantified that were not included in previous COE benefit/cost analyses or if less expensive solutions can be developed; congressional appropriation.

Lower Neches River Marsh, Orange County

Critical Erosion Area: Lower Neches River Marsh

Problem Description: Between the mid-1950s and 1978, about 9,400 acres of marshes were displaced primarily by open water along an approximately 10-mile stretch of the lower Neches River Valley north of Sabine Lake (White and Calnan, 1990). The annual rate of loss of vegetated wetlands was over 100 acres per year between 1956 and 1987 for the portion of the lower Neches valley studied (White and Calnan, 1990).

Presumed Causes: Marsh loss in the Neches River valley results from a combination of factors including subsidence, direct and indirect effects of dredged canals and navigation channels, reduction of fluvial sediment due to upstream reservoirs, and artificial levees which inhibit overbank flooding (White and Tremblay, 1995).

Desired Outcome: Appropriate soil elevations within the marsh should be restored and maintained to allow reestablishment of marsh vegetation.

Recommendation for Erosion Response: Dredged material from the Neches River channel, GIWW, and elsewhere should be used to raise soil elevations. Long-term management of Neches River watershed sediment should be implemented.

Funding Alternatives

Local — Impact fees from municipalities, channel users, oil/gas producers.

State — CMP grant program; TxDOT beneficial use participation; TNRCC SEP program; GLO surface damage account; pending natural resource damage assessment funds.

Federal — USFWS National Coastal Wetlands Conservation Grant program; COE Continuing Authorities Program (Section 1135); COE Planning Assistance to States (Section 22); congressional appropriation.

South Padre Island, Cameron County

Critical Erosion Area: Northern 1.6 miles of Gulf beach within the Town of South Padre Island.

Problem Description: The Town of South Padre Island is located on the southern portion of South Padre Island, a low-lying depositional sandy barrier island with many washover channels and relatively high historical erosion rates (greater than five feet per year). There is a large financial investment along the shoreline in the high-density development immediately adjacent to the public beach. These structures are at a high risk for damage from storm surge during hurricanes because most

of the natural dunes on the beachfront properties have been altered.

Presumed Causes: In general, the beaches of South Padre Island have been eroding continuously since the late 1800s (Morton, 1993). The jetties at the Brazos Santiago Pass have influenced the littoral processes by trapping sand, resulting in accretion along approximately two miles of the shoreline north of them. Further northward, though, the amount of sand in the littoral drift is decreased, and the result is erosion of the Gulf shoreline.

Desired Outcome: The goal of the erosion response project is to provide a wider public beach and dune field that will protect private property as well as comply with the requirements of the Town's master plan.

Recommendation for Erosion Response: The master plan adopted by the Town of South Padre Island proposes a beach nourishment and dune restoration project along the Gulf shoreline within the Town's northern limits. The project will create a stable dune area approximately 75 to 100 feet wide and, seaward of the dune field, a 200-foot-wide beach.

Funding Alternatives

Local — Beach user fees; impact fees on new development; hotel occupancy taxes; seawall tax/breakwater authority.

State — Beach Maintenance Fund; CMP grant program; GLO surface damage account; TNRCC SEP program; TDOT beneficial use participation; TWDB flood control fund; legislative appropriation.

Federal — COE Section 933 if additional benefits or reduced costs can be identified; FEMA grant program; congressional authorization.

Treasure Island, Brazoria County

Critical Erosion Area: Gulf and San Luis Pass shoreline in the Treasure Island Subdivision

Problem Description: The Treasure Island Subdivision is lo-

cated along the west shoreline of San Luis Pass (an unmaintained natural pass) on Follets Island. Historical shoreline changes here have varied from erosion between the mid-1800s and 1950s to accretion during the 1960s. Erosion rates were greatest (60 feet per year) between 1974 and 1982 (Paine and Morton, 1989). The present shoreline trend is erosion at greater than ten feet per year (Morton, 1993). The Gulf section of the subdivision was platted in 1962 during more stable shoreline conditions. Today, waves are threatening a private roadway and shorefront homes.

Presumed Causes: The causes of the erosion are mostly natural coastal processes such as wave activity, littoral currents, sea level rise, and possibly the shifting of the natural pass following Hurricane Alicia in 1983. No studies have been conducted to determine the historical movement of the main channel within the pass and the changes in the ebb tidal delta. This information would be helpful in identifying the inlet hazard area adjacent to the pass and could assist in the planning of new coastal developments and erosion response.

Desired Outcome: The erosion response should reduce the threat of damage to the private road and structures.

Recommendation for Erosion Response: Homeowners in the subdivision should work with the local municipal utility district, the county, and state authorities to develop a plan for protecting the roadway and homes.

The following are actions for consideration:

1. Temporarily place riprap at the edge of the private roadway until a beach nourishment project is completed.

2. Deposit sand obtained from the San Luis Pass ebb tidal delta on the eroding beaches.

3. Determine the feasibility of relocating the private roadway and the threatened homes.

Funding Alternatives

Local — Beach user fees; seawall tax/breakwater authority.

State — GLO beach maintenance fund; CMP grant program; TWDB flood control fund; legislative appropriation.

Federal — FEMA grant program; COE Continuing Authority Program (Section 103); congressional appropriation.

Literature Cited and References

Bales, J., and E.R. Holley, 1985. Evaluation of Existing Conditions and Possible Design Alternatives at Rollover Fish Pass, Texas. Center for Research in Water Resources Report No. 210, Department of Civil Engineering, The University of Texas at Austin, 198 pp.

Clark, J. R., 1996. Coastal Zone Management Handbook. CRC Press, Inc., 694 pp.

Division of Emergency Management, September 30, 1987. Disaster Recovery Texas, 101 pp.

Engitech, Inc., 1991. Lake Buchanan Dredging Feasibility Analysis. Report to the Lower Colorado River Authority, 4 pp.

Genega, Stanley G., Major General, U.S. Army, Director of Civil Works. Letter to Texas Land Commissioner Garry Mauro, June 19, 1995.

Germiat, S. J., 1988. An Assessment of Future Coastal Land Loss in Galveston, Chambers, and Jefferson Counties, Texas. Masters thesis, The University of Texas at Austin, 128 pp.

Gulf Intracoastal Canal Association, February 1995. The GICA Link.

Hayes, M. O., 1967. Hurricanes as Geological Agents: Case Studies of Hurricanes Carla, 1961, and Cindy, 1963. University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 61, 54 pp.

Horizon Environmental Services, Inc., 1992. Draft Environmental Assessment—Proposed State Highway 87 Relocation Project, Jefferson County, Texas. Prepared for Jefferson County Commissioners Court and Texas Department of Transportation, Beaumont, Texas, 57 pp. plus appendices.

Houston, J. R., 1995. Beach Nourishment. Shore and Beach, vol. 63, No 1, American Shore and Beach Preservation Association, pp. 21-24.

Houston, J. R., 1996. The Economic Value of Beaches. Proceedings of the 9th National Conference on Beach Preservation Technology, St. Petersburg, Florida, pp.271-280.

Kraus, N.C. and C. A. Brown, 1995. Coastal Processes Assessment for Dredging Requirements Reduction at the Piper Channel En-

trance, Port Aransas, Texas. Kraus and Associates Technical Report 95-1, 35 pp.

Leadon, M., 1996. Hurricane Opal: Damage to Florida's Beaches, Dunes and Coastal Structures. Proceedings of the 9th National Conference on Beach Preservation Technology, St. Petersburg, Florida, pp. 313-328.

Marlowe and Company, November 15, 1995. Energy & Water Appropriations Bill Approved by Congress. Washington Coastal Watch Newsletter, vol. 1995, No. 11.

McGowen, J. H. and J. L. Brewton, 1975. Historical Changes and Related Coastal Processes, Gulf and Mainland Shorelines, Matagorda Bay Area, Texas. University of Texas at Austin, Bureau of Economic Geology, 72 pp.

Militello, A. and N. C. Kraus, 1995. Field Data Collection for Circulation and Vessel-Induced Flow Studies, Aransas National Wildlife Refuge, Sundown Bay, Texas. Conrad Blucher Institute for Surveying and Science, Corpus Christi, Texas, 50 pp. plus appendix.

Morton, R. A., 1975. Shoreline Changes Between Sabine Pass and Bolivar Roads—An Analysis of Historical Changes of the Texas Gulf Shoreline. University of Texas at Austin, Bureau of Economic Geology Geological Circular 75-6, 43 pp.

Morton, R. A., 1993. Shoreline Movement Along Developed Beaches of the Texas Gulf Coast: A Users' Guide to Analyzing and Predicting Shoreline Changes. University of Texas at Austin, Bureau of Economic Geology Open-File Report 93-1, 79 pp.

Morton, R. A. and J. G. Paine, 1985. Beach and Vegetation-Line Changes at Galveston Island, Texas: Erosion, Deposition, and Recovery from Hurricane Alicia. University of Texas at Austin, Bureau of Economic Geology Geological Circular 85-5, 39 pp.

Morton, R. A. and J. G. Paine, 1990. Coastal Land Loss in Texas: An Overview. Transactions, Gulf Coast Association of Geological Societies. vol. 40, pp. 625-634.

National Research Council, 1990. Managing Coastal Erosion. National Academy Press, Washington, D.C., 182 pp.

National Research Council, 1995. Beach Nourishment and Protection. National Academy Press, Washington, D.C., 334 pp.

Paine, J. G. and R. A. Morton, 1989. Shoreline and Vegetation-Line Movement, Texas Gulf Coast, 1974 to 1982, University of Texas at Austin, Bureau of Economic Geology Geological Circular 89-1, 50 pp.

Ramsey, K. E., 1991. Rates of Relative Sea Level Change in the Northern Gulf of Mexico, in Coastal Depositional Systems in the Gulf of Mexico, Twelfth Annual Research Conference Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists Foundation Program with Extended and Illustrated Abstracts, December 5, 1991, pp. 204-210.

Recreation Executive Report, June/July 1995. License Plates Raise Money for Environment.

Reichel, M. M., 1991. The Role of Mitigation Funds in Mitigating Residual Impacts in Coastal Zone '91.

Roop, S. and D. Burke, August 28, 1991. Economic Impacts of an Interruption in Service on the Gulf Intracoastal Waterway at Sargent Beach. Report prepared by the Texas Transportation Institute for the Coalition to Save the Gulf Intracoastal Waterway.

Sharp, Jr., J.M. and D.W. Hill, 1995. Land Subsidence along the Northeastern Texas Gulf Coast: Effects of Deep Hydrocarbon Production. Environmental Geology, vol. 25, pp. 181-191.

Skaggs, L.L. and F.L. McDonald (eds.), 1991. National Economic Development Procedures Manual, Coastal Storm Damage & Erosion, IWR Report 91-R-6. U.S. Army Corps Of Engineers, Institute for Water Resources, Fort Belvoir, Virginia.

Special Committee on Texas Coastline Rehabilitation, 1989. 1987 Report and Recommendations and 1989 Update, 41 pp. plus appendices.

Stronge, W. B., 1993. The Economic Analysis of Beach Restorations: The State of the Art. Proceedings of the 1993 National Conference on Beach Preservation Technology, May 1993. pp. 9-23.

Texas General Land Office, 1991. Dune Protection and Improvement Manual for the Texas Gulf Coast. Austin, Texas, 24 pp.

The Office for Strategic Studies in Resource Policy, 1990. The Future of the Texas Gulf Coast: Strategies for Managing Shoreline Erosion and Dune Protection, Texas A&M University. Report prepared for the Texas General Land Office, 69 pp.

U.S. Army Corps of Engineers, 1973. National Shoreline Study: Texas Coast Shores Regional Inventory Report, Galveston District, 27 pp. plus appendices.

U.S. Army Corps of Engineers, 1991. Sediment Transport Study, Brazos River Basin, Fort Worth District Special Report, 25 pp.

U.S. Army Corps of Engineers, 1994. Port Aransas, Texas, Section 111 Initial Appraisal, Galveston District, 9 pp.

Wang, Y. H., 1989. A Technical Report on Preliminary Designs of Improvements at Rollover Pass and Vicinity, Bolivar Peninsula, Texas, 148 pp.

White, W. A., and T. R. Calnan, 1990. Sedimentation and Historical Changes in the Fluvial-Deltaic Wetlands along the Texas Gulf Coast with Emphasis on the Colorado and Trinity River Deltas. Bureau of Economic Geology, The University of Texas at Austin, 124 pp.

White, W. A. and T. A. Tremblay, 1995. Submergence of Wetlands as a Result of Human-Induced Subsidence and Faulting Along the Upper Texas Gulf Coast. Journal of Coastal Research, Vol. 11 No. 3, Fort Lauderdale, Florida, pp. 788-807.

Zhang, J. et al., 1993. Bank Erosion on the Gulf Intracoastal Waterway at the Aransas National Wildlife Refuge. Dept. Civil Engineering, Texas A&M University, College Station, Texas, 138 pp.

APPENDIX A
Laws and Rules Addressing Coastal Erosion and Chronology of Changes

Coastal Erosion

TEX. WATER CODE ANN. §16.320 — This provision, added by the 72nd Legislature in 1991, authorizes the Commissioner of the General Land Office to "perform all acts necessary to develop and implement a program for certification of structures subject to imminent collapse due to erosion."

TEX. NAT. RES. CODE ANN. §§33.601-33.604 — These sections establish the General Land Office as the lead agency for the coordination of coastal erosion avoidance, remediation and planning, and direct the General Land Office to engage in erosion demonstration projects and studies in conjunction with other state agencies, local governments, and federal agencies. These provisions were added by the 72nd Legislature in 1991 and became effective June 7, 1991.

TEX. NAT. RES. CODE ANN. §33.059 — Authorizes the School Land Board to study various coastal engineering problems, including the protection of the shoreline against erosion. This provision was added by the 63rd Legislature in 1973.

Open Beaches Act

TEX. NAT. RES. CODE ANN. §61.011 — This statutory provision declares that it is the public policy of the state to ensure the public's right of access to and use of public beaches and directs the commissioner to promulgate rules for the "protection of the public easement from erosion caused by development or other activities on adjacent land and beach cleanup and maintenance" (TEX. NAT. RES. CODE ANN. §61.011(d)(2)). The provision declaring the public policy was first enacted by the second called session of the 56th Legislature in 1959. This provision directing the commissioner to promulgate rules was added in 1991 by the 72nd Legislature.

TEX. NAT. RES. CODE ANN. §61.022 — This exemption for certain structures was enacted by the 56th Legislature in 1959. This section was amended in 1991, by changing the heading and adding additional subsections. The provision regarding the exemption for certain structures by the state or U.S. was not altered.

Dune Protection Act

TEX. NAT. RES. CODE ANN. §63.001 — The Dune Protection Act (§63.001 through §63.181) requires the commissioners' court of any county bordering on the Gulf of Mexico to establish a dune protection line on the gulf shoreline. In §63.001(7), the legislature declared that "vegetated stabilized dunes help preserve state-owned beaches and

shores by protecting against erosion of the shore." The Dune Protection Act was enacted by the 63rd Legislature in 1973. Many provisions were amended in 1985 by the 69th Legislature and in 1991 by the 72nd Legislature. Section 63.001(7) was added in 1985.

House Bill 1536

Section 3 of House Bill 1536, passed by the 74th Legislature in 1995, amends TEX. NAT. RES. CODE ANN. art. 5415e-2 by adding Section 6A which allows for the Texas Transportation Commission to cost-share with the federal government for the beneficial use of dredged material.

Beach/Dune Rules

In 1993, the Texas General Land Office adopted the rules for the management of the beach/dune system (31 TAC §§15.1-15.10). These rules became effective February 17, 1993. The provisions sections below address erosion:

§15.1(5) — The General Land Office identified as a goal the prevention of the destruction and erosion of public beaches and encouragement of sound erosion response methods.

§15.1(10) — The General Land Office identified as a goal the education of the public about coastal issues, including erosion.

§15.3(e) — The General Land Office identified all dunes and dune complexes located within 1,000 feet of mean high tide of the Gulf of Mexico as critical dune areas. This identification is based on the determination that the protective functions served by these dunes is essential to the protection of public beaches, submerged lands, and state-owned lands from erosion.

§15.3(m) — Local government plans must demonstrate local coordination on erosion response.

§15.4(d) — A local government may approve a dune protection permit application if it has determined that the proposed conduct will not reduce the effectiveness of any dune as a means of protection against erosion. Among other things, the local government must find that the activity will not result in runoff or drainage patterns that aggravate erosion on or off the site. §15.4(d)(2).

§15.4(f)(2)(B) — This subsection requires that local governments require permittees to minimize construction and pedestrian traf-

fic on or across dune areas, accounting for trends of dune movement and beach erosion.

§15.4(f)(2)(D) — This subsection directs local governments to only authorize construction of artificial runoff channels if the channels are located in a manner which avoids erosion.

§15.4(f)(3) — If the local government determines that adverse effects to dunes will occur, the permittee is required to repair, rehabilitate, or restore the affected dunes and dune vegetation to be superior or equal to the pre-existing dunes and dune vegetation in providing protection against erosion.

§15.6(b) — Local governments shall not allow any construction which may aggravate erosion.

§15.6(c) — Local governments shall not issue a permit or certificate allowing construction of an erosion-response structure.

§15.6(d) — Local governments shall not issue permits or certificates authorizing maintenance or repair of existing erosion-response structures on the public beach or the enlargement or improvement of such construction within 200 feet landward of the natural vegetation line. There is an exception should it be shown that failure to repair the structure will cause unreasonable hazard. §15.4(d)(1) and §15.4(d)(2).

§15.6(f) — Addresses requirements for construction in eroding areas.

§15.6(g) — Construction affecting natural drainage patterns shall not cause erosion.

§15.7(b) — This provision directs local governments to encourage beach nourishment and sediment bypassing for erosion response management and to prohibit erosion-response structures within the public beach and 200 feet landward of the natural vegetation line.

§15.7(e) — Because sand dunes—natural, created, or restored—may aid in slowing beach erosion, this subsection allows local governments to allow restoration of dunes on the public beach under certain listed conditions.

Land Resources

Chapter 155 of Title 31 of the Texas Administrative Code, relating to the management of the surface state in coastal public lands, became effective January 1, 1976. These rules set forth the practice and procedure for administration by the School Land Board in granting a lease, easement, permit, or registration of a structure on coastal public lands. The following provisions address erosion:

§155.3(g)(4)(A) — This provision instructs the School Land Board to analyze a plan for construction of a jetty, groin, or breakwater to ensure that the structure does not create adverse sediment transportation patterns that induce erosion.

§155.3(g)(7)(c) — This provision instructs the School Land Board to consider an application for an easement for a landfill on coastal public lands so that the perimeter of the fill is provided with vegetation, retaining walls, riprap, or other mechanisms for erosion prevention.

§155.24(c)(15)(A)(iii) — The School Land Board may require that a draft environmental impact statement be prepared for a project considered by the board to have a significant impact on the environment. If the proposed activity involves dredging, excavating, filling, or dredged material disposition, the statement must describe the measures which will be taken to reduce adverse environmental impacts, such as keeping erosion at the lowest possible level.

Texas Coastal Management Program

The Coastal Management Program (CMP) was developed to make more effective and efficient use of public funds and to more effectively manage coastal natural resource areas. The directive for development of the CMP was the Coastal Coordination Act, passed by the Texas Legislature in 1991 and amended in 1995. This Act established the General Land Office as the lead agency for the development of the CMP. The CMP was submitted to NOAA for approval on October 19, 1995. Listed below are several of the CMP provisions addressing erosion. The cites are to Title 31 of the Texas Administrative Code:

> §501.2(7) — The Coastal Coordination Council finds that the coast is subject to waterfront construction, including erosion response projects (31 TAC §501.2(a)(7)). Because of possible adverse affects from these projects, the council finds that special management of these uses of the coast is necessary for continued balanced development of the coast (31 TAC §501.2(b)).

§501.14(d)(1)(D) — Hazardous waste land treatment facilities, waste piles, storage surface impoundments and landfills shall not be located within 1,000 feet of an area subject to active coastal shoreline erosion.

§501.14(d)(1)(F) — Piers, docks, wharves, bulkheads, jetties, groins, fishing cabins, and artificial reefs shall be limited to the minimum necessary and shall be constructed in a manner that does not interfere with the natural coastal processes which supply sediments to shore areas or otherwise exacerbate erosion of shore areas.

§501.14(d)(1)(N) — Nonstructural erosion response methods such as beach nourishment, sediment bypassing, nearshore sediment berms, and planting of vegetation shall be preferred instead of structural erosion response methods.

§501.14(d)(1)(Q) — Erosion of beaches and coastal shore areas caused by construction or modification of jetties, breakwaters, groins, or shore stabilization projects shall be mitigated to the extent that the costs of mitigation are reasonably proportionate to the benefits of mitigation.

§501.14(j)(2)(A)(ii) — Adverse effects from dredging and dredged material disposal and placement can be minimized by controlling the location and dimensions of the activity and by locating and designing projects to avoid adverse disruption of erosion and accretion processes.

§501.14(j)(2)(C)(i) — Adverse effects from dredging and dredged material disposal or placement can be minimized through the use of containment levees and sediment basins designed, constructed, and maintained to resist breaches, erosion, slumping, or leaching.

§501.14(j)(4)(B)(i) — Dredged material is a potentially reusable resource and must be used beneficially. Factors to be considered in determining whether the costs of the beneficial use are reasonably proportionate to the benefits include erosion prevention benefits.

§501.14(j)(4)(C)(i) — Beneficial use of dredged material includes projects designed to reduce or minimize erosion or to provide shoreline protection.

§501.14(j)(8) — Mining of sand, shell, marl, gravel, and mudshell on submerged lands shall be prohibited unless there is an affirmative showing of no significant impact on erosion within the coastal zone and no significant adverse effect on coastal water quality or terrestrial and aquatic wildlife habitat within any coastal natural resource area.

§501.14(k)(1)(E) — Nonstructural erosion response methods such as beach nourishment, sediment bypassing, nearshore sediment berms, and planting of vegetation shall be preferred instead of structural erosion response methods. Subdivisions shall not authorize the construction of a new erosion response structure within the beach/dune system, except for a retaining wall located more than 200 feet landward of the line of vegetation. Subdivisions shall not authorize the enlargement, improvement, repair or maintenance of existing erosion response structures on the public beach. Subdivisions shall not authorize the repair or maintenance of existing erosion response structures within 200 feet landward of the line of vegetation except as provided in §15.6(d) of this title (relating to Concurrent Dune Protection and Beachfront Construction Standards).

§501.14(l)(2) — Development in Coastal Hazard Areas. Pursuant to the standards and procedures under Texas Natural Resources Code, Chapter 33, Subchapter H, the GLO shall adopt or issue rules, recommendations, standards, and guidelines for erosion avoidance and remediation and for prioritizing critical erosion areas.

§501.14(p)(1)(A) — Transportation Projects. Pollution prevention procedures shall be incorporated into the construction and maintenance of transportation projects to minimize pollutant loading to coastal waters from erosion and sedimentation, use of pesticides and herbicides for maintenance of rights-of-way, and other pollutants from stormwater runoff.

APPENDIX B
General Land Office Application Procedures for Bay Erosion Response Projects

Modified from "Texas State-Owned Coastal Lands, Permitting Requirements, 1991"

The GLO issues coastal easements, coastal leases, and surface leases for erosion response structures.

1. To determine if a proposed project will require authorization from the state, contact the Texas General Land Office field representative in your area for a preliminary decision.

2. If the project will be located on state-owned land, an application packet will be mailed. To minimize delays in processing the application, applicants must follow the instructions carefully and supply all requested information. For most projects, applications must be accompanied by:

- labeled plat or diagram of the project indicating all associated structures and dimensions;
- deed or tax statement as proof of ownership of littoral property; and
- vicinity map showing the project location;
- application fee.

3. When the completed application form with required attachments is received by the appropriate field office:

- the application will be reviewed to confirm that state-owned submerged land is involved in the project;
- an on-site inspection and environmental assessment of the project site will be made; and
- a fee for the project will be assessed based on the current rate schedule.

4. If the project is approved:

- two original contracts will be mailed to the applicant for review and signature;
- the signed contracts should be returned with the required fees to the GLO for execution by the commissioner; and
- one executed contract will be returned to the applicant, and the other will be kept on file in the GLO.

GLO Field Offices

For the area from the Colorado River to the Sabine River:

Texas General Land Office/Upper Coast Field Office
1181 North D Street
La Porte, Texas 77571-9135
Phone (713) 470-1191

For the area from the Colorado River to the Rio Grande:

Texas General Land Office/Lower Coast Field Office
Natural Resources Center, Suite 2400
6300 Ocean Drive
Corpus Christi, Texas 78412-5599
Phone (512) 980-3030

GLO World Wide Web page:
http://www.glo.state.tx.us

APPENDIX C
Glossary

Accretion — May be either natural or artificial. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a beach by deposition of water or airborne material. Artificial accretion is a similar buildup of land by human actions, such as accretion formed by a groin, a breakwater, or beach fill deposited by mechanical means.

Applicant — Any person applying to a local government for a permit and/or certificate for any construction or development plan.

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.

Bay — A recess in the shore or an inlet of a sea between two capes or headlands, not as large as a gulf but larger than a cove.

Beach — The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of the beach—unless otherwise specified—is the mean low water line. A beach includes a foreshore and backshore.

Beach Access — The right to use and enjoy the public beach, including the right of free and unrestricted ingress and egress to and from the public beach.

Beach/Dune System — The land from the line of mean low tide of the Gulf of Mexico to the landward limit of dune formation.

Beachfront Construction Certificate — The document issued by a local government that certifies that the proposed construction is consistent with the local government's dune protection and beach access plan.

Beach Maintenance — The cleaning or removal of debris from the beach by handpicking, raking, or mechanical means.

Beach Nourishment — The process of replenishing a beach. It may be brought about naturally by longshore sediment transport or artificially by deposition of dredged materials.

Beach Profile - The shape and elevation of the beach as determined by surveying a cross section of the beach.

Beach-related Services — Reasonable and necessary services and

facilities directly related to the public beach which are provided to the public to ensure safe use of and access to and from the public beach, such as vehicular controls, management, and parking (including acquisition and maintenance of off-beach parking and access ways); sanitation and litter control; lifeguarding and lifesaving; beach maintenance; law enforcement; beach nourishment projects; beach/dune system education; beach/dune protection and restoration projects; providing public facilities such as restrooms, showers, lockers, equipment rentals, and picnic areas; recreational and refreshment facilities; liability insurance; and staff and personnel necessary to provide beach-related services. Beach-related services and facilities shall serve only those areas on or immediately adjacent to the public beach.

Beach User Fee — A fee collected by a local government in order to establish and maintain beach-related services and facilities for the preservation and enhancement of access to and from and safe and healthy use of public beaches by the public.

Bottom — The ground or bed under any body of water.

Breakwater — A structure protecting a shore area, harbor, anchorage, or basin from waves.

Bulkhead — A structure or partition to retain or prevent the sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

Channel — (1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water or which links two bodies of water; (2) the part of a body of water deep enough to be used for navigational purposes; (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.

Coastal Easement — A GLO easement on coastal public land issued to an owner of adjacent littoral property for purposes associated with the ownership of that property or to the owner of mineral or surface interests in coastal public lands.

Coastal Lease — A GLO nontransferable lease of coastal public land issued to the Texas Parks and Wildlife Department or to an eligible city or county for public recreation.

Coastal and Shore Protection Project — A project designed to slow shoreline erosion or enhance shoreline stabilization, including, but not limited to, erosion response structures, beach nourishment, sedi-

ment bypassing, construction of man-made vegetated mounds, and dune revegetation.

Construction — The causing or carrying out of any building, bulkheading, filling, clearing, excavation, or substantial improvement to land or the size of any structure. "Building" includes, but is not limited to, all related site work and placement of construction materials on the site. "Filling" includes, but is not limited to, disposal of dredged materials. "Excavation" includes, but is not limited to, removal or alteration of dunes and dune vegetation and scraping, grading, or dredging a site. "Substantial improvements to land or the size of any structure" include, but are not limited to, creation of vehicular or pedestrian trails, landscape work (that adversely affects dunes or dune vegetation), and increasing the size of any structure.

Coppice Mounds — The initial stages of dune growth formed as sand accumulates on the downwind side of plants and other obstructions on or immediately adjacent to the beach seaward of the foredunes. Coppice mounds may be unvegetated.

Critical Dune Areas — Those portions of the beach/dune system as designated by the General Land Office that are located within 1,000 feet of mean high tide of the Gulf of Mexico that contain dunes and dune complexes that are essential to the protection of public beaches, submerged land, and state-owned land, such as public roads and coastal public lands, from nuisance, erosion, storm surge, and high winds and waves. Critical dune areas include, but are not limited to, the dunes that store sand in the beach/dune system to replenish eroding public beaches.

Cumulative Impact — The effect on beach use and access, on a critical dune area, or an area seaward of the dune protection line which results from the incremental effect of an action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time.

Dedication — Includes, but is not limited to, a restrictive covenant, permanent easement, and fee simple donation.

Downdrift — The direction of predominant movement of littoral materials.

Dune — An emergent mound, hill, or ridge of sand, either bare or vegetated, located on land bordering the waters of the Gulf of Mexico.

Dunes are naturally formed by the windward transport of sediment, but can also be created via man-made vegetated mounds. Natural dunes are usually found adjacent to the uppermost limit of wave action and are marked by an abrupt change in slope landward of the dry beach. The term includes coppice mounds, foredunes, dunes comprising the foredune ridge, backdunes, and man-made vegetated mounds.

Dune Complex or Dune Area — Any emergent area adjacent to the waters of the Gulf of Mexico in which several types of dunes are found or in which dunes have been established by proper management of the area. In some portions of the Texas coast, dune complexes contain depressions known as swales.

Dune Protection and Beach Access Plan — A local government's legally enforceable program, policies, and procedures for protecting dunes and dune vegetation and for preserving and enhancing use of and access to and from public beaches, as required by the Dune Protection Act and the Open Beaches Act.

Dune Protection Line — A line established by a county commissioners court or the governing body of a municipality for the purpose of preserving, at a minimum, all critical dune areas identified by the General Land Office pursuant to the Dune Protection Act, §63.011, and §15.3 (f) of this title (relating to Administration). A municipality is not authorized to establish a dune protection line unless the authority to do so has been delegated to the municipality by the county in which the municipality is located. Such lines will be located no farther than 1,000 feet landward of the mean high tide of the Gulf of Mexico.

Dune Vegetation — Flora indigenous to natural dune complexes and growing on naturally-formed dunes or man-made vegetated mounds on the Texas coast and can include coastal grasses and herbaceous and woody plants.

Easement — A legal or contractual right to use property owned by another person.

Eroding Area — a portion of the shoreline which is experiencing a historical erosion rate of greater than two feet per year based on published data of the University of Texas at Austin, Bureau of Economic Geology. Local governments may establish an "eroding area boundary" in beach/dune plans; this boundary shall be whichever is greater; 200 feet, or the distance determined by multiplying 60 years by the yearly erosion rate (based on the most recent data published by the University of Texas at Austin, Bureau of Economic Geology.)

Erosion — The wearing away of land or the removal of beach and/or dune sediments by wave action, tidal currents, wave currents, drainage, or wind. Erosion includes, but is not limited to, horizontal recession and scour and can be induced or aggravated by human activities.

Erosion Response Structure — A hard or rigid structure built for shoreline stabilization which includes, but is not limited to, a jetty, retaining wall, groin, breakwater, bulkhead, seawall, riprap, rubble mound, revetment, or the foundation of a structure which is the functional equivalent of these specified structures.

Estuary — (1) The part of a river that is affected by the tides; (2) the region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.

FEMA — The U.S. Federal Emergency Management Agency. This agency administers the National Flood Insurance Program and publishes the official flood insurance rate maps.

Foredunes — The first clearly distinguishable, usually vegetated, stabilized large dunes encountered landward of the Gulf of Mexico. On some portions of the Texas Gulf Coast, foredunes may also be rare, unvegetated, and unstabilized. Although they may be large and continuous, foredunes are typically hummocky and discontinuous and may be interrupted by breaches and washover areas. Foredunes offer the first significant means of dissipating storm-generated wave and current energy issuing from the Gulf of Mexico. Because various heights and configurations of dunes may perform this function, no standardized physical description applies. Foredunes are distinguishable from surrounding dune types by their relative location and physical appearance.

Foredune Ridge — The high continuous line of dunes which are usually well vegetated and rise sharply landward of the foredune area but may also rise directly from a flat, wave-cut beach immediately after a storm.

Groin — A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

Habitat — The environment occupied by individuals of a particular species, population, or community.

Habitable Structures — Structures suitable for human habitation including, but not limited to, single or multi-family residences, hotels, condominium buildings, and buildings for commercial pur-

poses. Each building of a condominium regime is considered a separate habitable structure, but if a building is divided into apartments, then the entire building, not the individual apartments, is considered a single habitable structure. Additionally, a habitable structure includes porches, gazebos, and other attached improvements.

Hurricane — An intense tropical cyclone in which wind tends to spiral inward toward a core of low pressure, with maximum surface velocities that equal or exceed 33.5 meters per second (75 miles per hour) for several minutes or longer.

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.

Jetty — A structure extending into a body of water, 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.

Levee — A dike or embankment to protect land from inundation.

Line of Vegetation — The extreme seaward boundary of natural vegetation which spreads continuously inland. The line of vegetation is typically used to determine the landward extent of the public beach.

Littoral — Of or pertaining to a shore, especially of the sea.

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 Zone — In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

Local Government — A municipality, county, any special purpose district, any unit of government, or any other political subdivision of the state.

Man-Made Vegetated Mound — A mound, hill, or ridge of sand created by the deliberate placement of sand or sand trapping devices including sand fences, trees, or brush and planted with dune vegetation.

Mean High Water — The average height of the high waters over a recent 19-year period.

Mean Higher High Water — The average height of the higher high waters over a recent 19-year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19-year value.

Miscellaneous Easement — A GLO grant of right-of-way across public lands for an oil, gas, sulfur, or water pipeline, telephone line, electric transmission line, power line, irrigation canal or lateral, road or any other purpose the commissioner (of the General Land Office) considers to be in the best interest of the state.

Mitigation Sequence — The series of steps which must be taken if dunes and dune vegetation will be adversely affected. First, such adverse effects shall be avoided. Second, adverse effects shall be minimized. Third, the dunes and dune vegetation adversely affected shall be repaired, restored, or replaced. Fourth, the dunes and dune vegetation adversely affected shall be replaced or substituted to compensate for the adverse effects.

National Flood Insurance Act — 42 United States Code §4001 *et seq.*

Natural Resources — Land, fish, wildlife, insects, biota, air, surface water, groundwater, plants, trees, habitat of flora and fauna, and other such resources.

Nearshore (Zone) — The area from mean low tide extending seaward across the bar and trough topography with a seaward limit at wave base.

Nearshore Sediment Berm — A bar located in the nearshore zone formed by the deposit of dredged material.

Pass — (see Inlet)

Permit or Certificate Condition — A requirement or restriction in a permit or certificate necessary to assure protection of life, natural resources, property, and adequate beach use and access rights (consistent with the Dune Protection Act) which a permittee must satisfy in order to be in compliance with the permit or certificate.

Permittee — Any person authorized to act under a permit or a certificate issued by a local government.

Person — An individual, firm, corporation, association, partnership,

consortium, joint venture, commercial entity, United States Government, state, municipality, commission, political subdivision, or any international or interstate body or any other governmental entity.

Pile — A long, heavy timber or section of concrete or metal driven into the earth or seabed to serve as a support or protection.

Practicable — In determining what is practicable, local governments shall consider the effectiveness, scientific feasibility, and commercial availability of the technology or technique. Local governments shall also consider the cost of the technology or technique.

Public Beach — "Public beach" as defined in the Texas Natural Resources Code §61.013 (c).

Recession/Transgression — (1) A continuing landward movement of the shoreline; (2) A net landward movement of the shoreline over a specified time.

Retaining Wall — A structure designed to contain or which primarily contains material or prevents the sliding of land. Retaining walls may collapse under the forces of normal wave activity.

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

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.

Sand Budget — The amount of all sources of sediment, sediment traps, and transport of sediment within a defined area. From the sand budget, it is possible to determine whether sediment gains and losses are in balance.

Sand Bypassing — 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 man.

Seawall — An erosion response structure specifically designed to prevent erosion and other damage due to wave action.

Seaward of a Dune Protection Line — The area between a dune protection line and the line of mean high tide.

Shoal (noun) — A detached elevation of the sea bottom, composed of any material except rock or coral, which may endanger 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.

Structure — Includes, without limitation, any building or combination of related components constructed in an ordered scheme that constitutes a work or improvement constructed on or affixed to land.

Subsidence — The sinking of the land surface.

Surface Lease — A GLO lease of upland property for agriculture, recreation, hunting, grazing, or a combination of these uses; in the coastal area, surface leases are used to authorize projects on submerged lands not associated with littoral property, including oil and gas platforms.

Surf Zone — The area of wave activity between the outermost breaker and the limit of wave uprush.

Swales — Low areas within a dune complex located in some portions of the Texas coast which function as natural rainwater collection areas and are an integral part of the dune complex.

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

Washover Areas — Low areas that are adjacent to beaches and are inundated by waves and storm tides from the Gulf of Mexico. Washovers may be found in abandoned tidal channels or where foredunes are poorly developed or breached by storm tides and wind erosion.

Wetlands — Areas inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil, generally including swamps, marshes, bogs, bottomlands, and similar areas.

Most definitions taken or adapted from:

General Land Office Rules for Management of the Beach/Dune System (TAC §§15.1-15.10).

Lewis, R. R. 1989. Wetland Restoration/Creation/Enhancement Terminology: Suggestions for Standardization, *in* J.A. Kusler and M.E. Kentula, eds. Wetlands Creation and Restoration: The Status of the Science. Island Press. Washington, D.C.

U.S. Army Corps of Engineers. 1984. Shore Protection Manual. Vol. II. Coastal Engineering Research Center, Vicksburg, Mississippi. U.S. Government Printing Office, Washington, D.C.

APPENDIX D
Local Authorities Responsible for Permitting Post-Storm Emergency Response Projects

1. **JEFFERSON COUNTY**
   Hon. Robert Stroder
   Jefferson County Judge
   Jefferson County Courthouse
   1149 Pearl Street
   Beaumont, Texas 77701-3619

2. **PORT ARTHUR**
   Mr. Dale Watson
   Director of Planning
   City of Port Arthur
   P.O. Box 1089
   Port Arthur, Texas 77641-1089
   (409) 983-8138

3. **CHAMBERS COUNTY**
   Mr. Don Brandon
   County Engineer
   P.O. Drawer H
   Anahuac, Texas 77514-1708
   (409) 267-3571

4. **GALVESTON COUNTY**
   Mr. G. Mike Fitzgerald
   Galveston County Engineer
   123 Rosenberg, Suite 4157
   Galveston, Texas 77550-1403
   (409) 766-2257

5. **CITY OF GALVESTON**
   Mr. Harold Holmes
   Director of Urban Planning
   City of Galveston
   823 Rosenberg, Suite 401
   Galveston, Texas 77553-2198
   (409) 766-2106

6. **VILLAGE OF JAMAICA BEACH**
   Ms. Sharon Turnley
   City Administrator
   Village of Jamaica Beach
   P.O. Box 5264
   Jamaica Beach, Texas 77554-5264
   (409) 737-1142

7. **BRAZORIA COUNTY**
   Ms. Penny Sturdivant
   County Floodplain Administrator
   131 W. Live Oak, Room 105
   Angleton, Texas 77515-4684
   (409) 849-5711, extension 1295

8. **VILLAGE OF SURFSIDE BEACH**

Mayor Lary Davison
Village of Surfside Beach
1304 Monument Drive
Surfside Beach, Texas 77541-9999
(409) 233-1531

9. **VILLAGE OF QUINTANA**

Mayor Debbie Alongis
Village of Quintana
814 N. Lamar
Quintana, Texas 77541
(409) 233-0848

10. **MATAGORDA COUNTY**

Hon. George Deshotels
County Commissioner, Precinct 2
P.O. Box 571
Matagorda, Texas 77457-0571
(409) 863-7861

11. **NUECES COUNTY**

Hon. Richard M. Borchard
Nueces County Judge
901 Leopard Street, Room 301
Corpus Christi, Texas 78401-3697
(512) 888-0329

12. **PORT ARANSAS**

Mr. Tom Brooks
Port Aransas City Manager
P. O. Drawer I
Port Aransas, Texas 78373
(512) 749-4011

13. **CORPUS CHRISTI**

Mr. Brandol Harvey
City of Corpus Christi
Planning Department
P.O. Box 9277
Corpus Christi, Texas 78469-9277
(512) 880-3232

14. **WILLACY COUNTY**

Hon. Eustolio Gonzales
Willacy County Judge
190 N. 3rd Street
Raymondville, Texas 78580-1940
(210) 689-2710

15. CAMERON COUNTY

Mr. Michael Martin

Cameron County Engineer
1150 East Madison
Brownsville, Texas 78520-5854
(210) 548-9555

16. SOUTH PADRE ISLAND

Mr. B.J. Page

Director of Planning
Town of South Padre Island
P.O. Box 3410
South Padre Island, Texas
78597-3410
(210) 761-1025

APPENDIX E
Agency Contacts for Bay and Gulf Erosion Response Projects

STATE AGENCIES

Texas General Land Office (GLO)

The Texas General Land Office, in conjunction with the School Land Board, manages the state's coastal public lands. 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 for implementation of the Texas Coastal Preserve Program with the Texas Parks and Wildlife Department. The GLO was designated by the legislature and the governor as the lead agency for development of a coastal management program for the state and as the agency to administer the program after entry into the federal Coastal Zone Management Program. In October 1995 Governor Bush submitted the Texas Coastal Management Program to the Department of Commerce for approval under the federal Coastal Zone Management Act.

Address: Coastal Division
Texas General Land Office
1700 N. Congress Avenue, Room 617
Austin, TX 78701-1495
Telephone: (512) 463-5001 or (800) 85-BEACH
Fax: (512) 475-0680
Website: http://www.glo.state.tx.us

School Land Board (SLB)

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 (fishing cabins).

Address: 1700 North Congress Avenue
Austin, TX 78701-1495
Telephone: (512) 463-5016

Soil and Water Conservation Board

The Texas State Soil and Water Conservation Board has the responsibility to plan, implement, and manage programs and practices for abating agricultural and silvicultural nonpoint pollution. The 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.

Address: 311 N. 5th St.
P.O.Box 658
Temple, TX 76503
Telephone: (817) 773-2250

Texas Parks and Wildlife Department (TPWD)

The Texas Parks and Wildlife Department 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 and Wildlife Commission. The TPWD is responsible for reviewing and commenting on state and federal permits affecting Texas wildlife resources and for protection of endangered or threatened species.

Address: 4200 Smith School Road
Austin, TX 78744
Telephone: (512) 389-4800

Texas Department of Transportation (TxDOT)

TxDOT is responsible for road construction and planning. The agency administers federal funds for mass transit and may plan, purchase, construct, lease, and contract for public transportation systems in the state. TxDOT contracts 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.

Address: Dewitt C. Greer State Highway Building
125 E. 11th Street
Austin, TX 78701-2483
Telephone: (512) 305-9509

Texas Natural Resource Conservation Commission (TNRCC)

The Texas Natural Resource Conservation Commission is responsible for the protection of surface and groundwater quality. In addition to this responsibility, the Commission oversees surface water rights administration, dam safety management, the National Flood Insurance Program (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 and enforce regulations affecting streamflow to the Gulf. These regulations are contained in sections 11.147 and 11.152 of the Texas Water Code. The 69th Texas Legislature assigned the responsibility for water rights permitting to TNRCC and authorized the TPWD 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 the TNRCC to consider effects on bays and estuaries of 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.

Address: 12100 Park 35 Circle, Bldg. A
P.O. Box 13087
Austin, TX 78711-3087
Telephone: (512) 239-1000

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. It 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 Antiquities Committee issues eight types of permits covering virtually every aspect of historical and archaeological investigation, including reconnaissance, testing, excavation, and destruction.

Address: 108 W. 16th Street
P.O. Box 12276
Austin, TX 78711-2276
Telephone: (512) 463-6096

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 law. The office protects the public's beach access rights and can bring suit on behalf of other state agencies to enforce state laws.

Address: 209 West 14th Street
P.O. Box 12548
Austin, TX 78711-2548
Telephone: (512) 463-2100

Bureau of Economic Geology (BEG)

The Bureau of Economic Geology at the University of Texas at Austin 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.

Address: University Station, Box X
Austin, TX 78713-7508
Telephone: (512) 471-1534

Governor's Office of Budget and Planning

The Governor's Office of Budget and Planning prepares recommendations for the state budget and administers state review and comment procedures for all federal or federally funded projects.

Address: State Capitol, Room 2S.1
Austin, TX 78701
Telephone: (512) 462-2000

FEDERAL AGENCIES

U.S. Army Corps of Engineers (COE)

Federal interest in shore protection began officially in 1930 with the enactment of PL 71-520, which authorized and directed the U.S. Army Corps of Engineers 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 the COE is applicable to the shores of the Atlantic and Pacific oceans, the Gulf of Mexico, the Great Lakes, and the estuaries and bays directly connected with 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. The COE's authority for shore erosion control activities extends up tributary streams only as far as it can be demonstrated that the dominant causes of erosion and damage are ocean tidal action (or Gulf of Mexico or Great Lakes water motion) and wind-generated waves. Its 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.

Address: U.S. Army Engineer District, Galveston
Attn: CESWG-PL-R
P. O. Box 1229
Galveston, TX 77553-1229
Telephone: (409) 766-3899

Federal Emergency Management Agency (FEMA)

FEMA administers the National Flood Insurance Program, 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.

Address: FEMA-Region VI
Federal Center
800 N. Loop 288
Denton, TX 76201-3698

Telephone: (817) 898-9162

U.S. Environmental Protection Agency (EPA)

The U.S. Environmental Protection Agency has primary roles in several aspects of the Section 404 (Clean Water Act) program, 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. The COE and EPA share responsibility for enforcing the Section 404 Program. The EPA can also enforce against noncompliance with permit conditions.

Address: EPA - Region VI
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

Telephone: (214) 655-6444

U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS)

The Natural Resource Conservation Service is the U.S. Department of Agriculture's primary technical agency in the areas of soil and water conservation and water quality. The NRCS focuses its assistance on nonfederal land. It 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.

The NRCS has an office in almost every county in the U.S., where it works closely with local subdivisions of state government called soil and 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.

The NRCS'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 and Development), 1988 (Swampbuster, Sodbuster, Conservation Compliance, and Conservation Reserve Program) and 1990 (Wetlands Reserve Program and others). Under the Swampbuster provisions, NRCS helps landowners identify and protect wetlands. Loss of USDA benefits and severe economic consequences can result for agriculture producers who convert wetlands to make possible the production of agricultural commodities.

The NRCS conducts soil surveys and operates a system of 27 plant material centers for selecting, developing, testing, and releasing plants for use in conservation programs. It also works with private landowners and others to preserve, protect, and restore wetlands and to develop wildlife and fisheries habitat.

Address: 101 S. Main Street
Temple, TX 76501-7682
Telephone: (817) 774-1261

APPENDIX F
Notes from the Erosion Response Plan Advisory Committee Meeting July 12, 1995

On July 12, 1995, the GLO hosted a meeting of the volunteer advisory committee and staff from state, federal, and local governments to discuss coastal erosion problems with local experts. Presentation topics included how to define critical erosion, mapping shoreline changes, results of a national study on beach nourishment, and management objectives. Advisory members and guests shared their knowledge and personal experience with the coastal experts on erosion response in "brainstorming" sessions. The following is a list of conclusions and recommendations of the advisory committee members.

For an eroding area to be defined as critical, there must be a high rate of erosion that poses a threat to:

- public infrastructure or areas of national importance
- public and traffic safety
- individual property and property value
- beach access and recreation
- habitat
- level of human activity

Criteria for ranking critical erosion areas should include:

- private/personal losses
- public losses/investments
- public access
- commerce/economical impact
- urban areas
- rural areas
- erosion rate
- threatened wildlife areas/endangered species
- threatened storm evacuation routes
- threatened historical sites, archaeological sites, cultural resources
- public safety
- human activity

Critical gulf shore and bayshore erosion areas (not ranked):

- Sargent Beach, Matagorda County
- Corpus Christi Ship channel at Port Aransas, Nueces County

- North Padre Island Seawall, Nueces County
- Bolivar Peninsula (Caplen Beach), Galveston County
- Northern section of the Town of South Padre Island and Andy Bowie Park, Cameron County
- Indianola Historical Site, Calhoun County
- McFaddin Beach, Jefferson County
- West Galveston Island, Galveston County
- Aransas Wildlife Refuge, Aransas County
- Sabine Neches Channel, Jefferson County

Information needed to determine the appropriate erosion response method:

- historical wave climate, ecology, building types data base, engineering history - dredging
- surf zone dynamics
- beach profile shape
- sediment texture, sediment budget, sediment transport-modelling
- depth and width of channels, how they affect the wake of ships
- causes of erosion in that area (document or quantify the causes)
- land use strategies
- cost/benefit analysis
- shoreline movement (quantify)
- value of upland that is threatened
- value of the beach as recreation
- purpose of protection—based on cultural and economic factors
- location of borrow source

Identified data gaps:

- beach/nearshore profile
- wave climate
- bay and estuarine coastal processes
- wave measurements, layers of types of sediments, vegetation types, measure of waves/wave-induced currents by winds
- types of shoreline configuration for upper bays and bayous
- composition, morphology, shoreline type

- sediment forcing (hydrodynamic) waves, wind, current, water level
- location of and quality of sand resources

Regional data gaps:

- West End Galveston beach surveys
- bay shorelines in the critical erosion areas
- human impacts on reestablishing the dune line

Estimated costs of projects:

- seawalls and bulkheads - $50 to $500/ft ($2 mil/mile for Port Aransas bulkheads)
- Christmas trees - low initial cost, higher for upkeep
- armoring - $500-$5000/ft, can buy the land for $1000
- beach nourishment - $300-$500/ft
- public education - minimal materials available $10,000 to produce video
- planting vegetation - $15-$18 per running foot
- groin and detached breakwaters - $500-1000/ft groin
- geotextile bags - $300-500/ft
- hybrid (mix of structural and nonstructural measures) - $1000/ft

Funding sources:

- sales tax to pay for bonds
- percentage from hotel/motel tax
- ad valorem tax increase
- issue bonds
- statewide obligation bonds
- grants from agencies
- private enterprise
- establish erosion districts
- environmental fines
- tourist development tax
- general revenue as a state funding source
- cigarette tax
- lottery proceeds
- assistance from the Corps of Engineers - Sec. 933, to dispose material in least cost method and environmentally acceptable manner (local sponsor can share the additional

cost with the COE)
- ISTEA
- user fees for beach use
- charge entities if they are found to cause shoreline erosion
- establish groups to get congressional appropriations for COE projects, erosion prevention districts can have their own lobbyists
- establish conservation reclamation districts to act as a funding entity

Other beach management recommendations:

- Streamline the process for acquiring easements for vegetation planting projects.
- Use a programmatic approach to address more than individual (or named) sites, but address cumulative sites; e.g., an entire bay area (many areas are too small to be addressed individually).

NOTES

NOAA COASTAL SERVICES CENTER LIBRARY
3 6668 14100 8765