LAND AND WATER RESOURCES, LOWER RIO GRANDE VALLEY, TEXAS

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INTRODUCTION

This report and the accompanying hand-colored maps (Land and Water Resources, Cameron and Willacy Counties, Texas; Land and Water Resources, Hidalgo County, Texas; and Land Use, Lower Rio Grande Valley, Texas), were prepared initially by the Bureau of Economic Geology, The University of Texas at Austin, as part of a multidisciplinary study* of the Lower Rio Grande Valley. The following text is only a portion of the initial report on this study and has been extracted to describe units on the accompanying maps.

LAND AND WATER RESOURCES

Land and water resources of Cameron, Hidalgo, and Willacy Counties were mapped on the basis of first-order environmental characteristics (Brown and others, 1971). First-order characteristics are those considered most important in governing the natural capabilities and limitations of a particular resource for selected uses or activities (table 1). Understanding the natural capabilities and limitations of a resource is vital to anticipate the environmental effects of projected growth and development.

Information used in delineating, mapping, and evaluating land and water resources in the Lower Rio Grande Valley came from a variety of sources including published and unpublished reports, maps, and observations.

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* The section of the initial report from which this information was extracted was prepared by William A. White, Melody R. Holm, Ralph S. Kerr, and Sandra L. Waisley; Edmund G. Wermund, co-principal investigator; Robert S. Kier, Project Coordinator; E. Gus Fruh, Project Director; project studies funded by Resources Applied to National Needs Program, National Science Foundation and the Budget and Planning Office (formerly Division of Planning Coordination), Office of the Governor of Texas.

TABLE 1

COASTAL ZONE LAND AND WATER RESOURCE UNITS -- USE AND CAPABILITIES

(McGowen and others, 1976, modified from Brown and others, 1971)

LAND AND WATER RESOURCE UNITS		ACTIVITIES	LIQUID-WASTE DISPOSAL			SOLID-WASTE DISPOSAL	SHORELINE CONSTRUCTION		COASTAL AND INLAND CONSTRUCTION				COASTAL, INLAND, AND OFFSHORE CONSTRUCTION									
			Surface disposal of untreated liquid wastes	Shallow subsurface disposal of untreated liquid wastes	Maintenance of feed lots	Disposal of solid-waste materials	Construction of jetties, groins, and piers	Construction of storm barriers and/or seawalls	Light construction	Construction of highways (excluding causeways)	Heavy construction	Flooding as a result of dam construction	Construction of production platforms and other oil well development activities	Placement of pipelines and/or subsurface cables	Dredging of canals and channels, and spoil disposal	Excavation, including extraction of natural materials	Filling for development	Draining of wetlands	Devegetation	Traversing with vehicles, including marsh buggies, air boats, dune buggies, and motorcycles	Light recreational activities including hiking, nature trails, and pleasure boating	Use of herbicides, pesticides, insecticides
WATER RESOURCE UNITS	BAYS, ESTUARIES, AND LAGOONS	River-influenced bay, including prodelta and delta front	X	X		X	0	X					0	0	X		X				■	
		Enclosed bay	X	X		X	0	X					0	0	0		0				■	
		Living oyster reefs and related areas	X	X		X	X	X					X	X	X	X	X				■	
		Dead oyster and serpulid reefs and related areas	X	X		X	0	X					0	0	X	0	X				■	
		Grassflats	X	X		X	X	X					X	X	X		X		X	X	■	
		Mobil bay-margin sand	X	X		X	X	X					X	X	X	X	X				■	
		Open bay, lower end with tidal influence	X	X		X	0	X					0	0	X		X				■	
		Subaqueous spoil	X	X		X	0	0					0	0	0		0				■	
		Inlets and subaqueous tidal deltas	X	X		X	X	X					X	X	X		X				■	
		Tidal flats	X	X		X	0	0	X	X	X		0	0	0	X	X			■	■	
LAND RESOURCE UNITS	COASTAL WETLANDS	Salt-water marsh	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Fresh water marsh	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
		Swamps	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	0	X
	COASTAL BARRIERS	Beach and shoreface	X	X		X	X	X	X	X	X		X	0	X	X	X			0	■	0
		Fore-island dunes and vegetated barrier flat	X	X	X	X		X	†	†	†		†	0	X	X	†		X	X	†	X
		Washover areas	X	X	X	X	X	X	X	X	X		X	X	X	0	X			■	■	0
		Blowouts and back-island dune fields	X	X	X	X			X	X	X		X	0	X	0	■		X	0	■	X
		Wind-tidal flats	X	X	X	X		0	X	X	X		0	0	0	0	X			■	■	0
		Swales	X	X	X	X			X	X	X		0	■	X	X	X	X	X	X	■	X
	MAN MADE	Made land and spoil	X	X	X	X			■	■	0	■	■	■	0	■	■		X	0	■	0
	COASTAL PLAINS	Highly permeable sand	X	X	X	X			■	■	■	0	0	■	0	X	■		X	■	■	X
		Moderately permeable sand	X	X	X	X			■	■	■	■	0	■	0	X	■		X	■	■	X
		Impermeable mud	0	■	■	■			0	0	0	■	■	0	■	■	■		■	■	■	0
		Broad, shallow depressions with variable substrate	0	0	0	0			X	0	X	■	0	■	■	■	■		■	■	■	0
		Highly forested upland areas	0	0	0	0			■	■	0	X	0	■	■	■	■		X	■	■	X
		Steep lands, locally high relief	X	0	0	X			0	0	0	■	0	0	■	X	■		X		■	0
		Stabilized dunes	X	X	X	X			0	0	0	■	0		X	X	■		X	X	■	X
		Unstabilized, unvegetated dunes	X	X	X	X			X	X	X	■	X	0	X	■	■			■	■	0
		Fresh-water lakes, ponds, and sloughs, and playas containing fresh water	X	X		X						■	0	0	X		X	X		■	■	X
		Mainland beaches	X	X	X	X	X	0	X	X	X	■	X	0	X	X	X		0	■	■	0
		Areas of active faulting and subsidence	0	0	0	0		0	0	0	X	0	0	X	■	■	0	0	■	■	■	
	MAJOR FLOOD-PLAIN SYSTEMS	Point-bar sand	X	X	X	X			X	0	X	0	0	0	X	0	0		X	■	■	X
		Overbank mud and silt	X	X	X	X			X	0	X	0	0	0	0	■	0		X	■	■	X
		Water	X			X						■	X	0	X		X			■	■	X

[ ] Not applicable

■ Significant problems unlikely

[X] Undesirable—significant problems likely

[0] Possible problems

[†] Significant problems unlikely on vegetated barrier flat. Construction and recreation activities on fore-island dunes are undesirable.

Principal sources of map data are: (1) environmental geologic mapping, Brownsville-Harlingen sheet of the Bureau of Economic Geology's Environmental Geologic Atlas series of the Texas Coastal Zone (Brown and others, in progress) and (2) environmental geologic mapping (unpublished) inland of the Coastal Atlas by Joe L. Brewton. In the two referenced mapping projects, environmental geologic units were interpreted on 7.5-minute Edgar Tobin Aerial Survey photomosaics and corresponding U.S. Geological Survey topographic maps, both at a scale of 1:24,000, or approximately 2.5 inches per mile. Final compilation was at a scale of 1:125,000. The map base for the land and water resources maps was prepared by enlarging A.M.S. (Army Map Service) maps from their original scale of 1:250,000 (1 inch=4 miles) to 1:125,000 (1 inch=2 miles). The process of enlargement caused the width of some cultural features, such as highways, to be greatly exaggerated.

The hand-colored land and water resource maps depict thirty seven different land and water resource units. The kinds and percentages of each land and water resource unit mapped in Cameron, Hidalgo, and Willacy Counties are listed in table 2. Percentages of the various resource units were determined using a grid system of points spaced at 0.5-mile intervals at the map scale of 1:125,000. (In some areas on the hand-colored maps, black contact lines, normally used to separate two different units represented by two different colors, have been colored over. Where this does occur, it is the correct interpretation; the lines colored over should have been removed when the black-line print was prepared for coloring.)

Basic units have been classified within six natural systems (table 2): (A) coastal plain, (B) active floodplains, (C) barrier islands,

Table 2: Kinds and percentages of land and water resources mapped in Cameron, Hidalgo and Willacy Counties.

	Land and Water Resources of the Lower Rio Grande Valley	Percentage of Cameron County Covered By Map Unit	Percentage of Hidalgo County Covered By Map Unit	Percentage of Willacy County Covered By Map Unit	Percentage of Total Area (3 Counties) Covered By Map Unit
A.	COASTAL PLAIN				
	1. Moderately to highly permeable recharge sand	.6	7.1	~~15.0~~ 2.0	3.6
	2. Moderately permeable recharge sand and silt	35.1	10.9	28.7	22.9
	3. Mud veneered, moderately to highly permeable sand	0.0	1.3	0.0	0.6
	4. Mud veneered, moderately permeable sand and silt	4.6	1.2	6.8	3.5
	5. Sand veneered, low permeability mud	0.1	0.0	0.4	0.1
	6. Low permeability mud	12.5	11.2	4.2	10.1
	7. Low permeability mud, saline soils	9.3	0.0	0.0	3.1
	8. Mud-filled channels and topographic lows	5.6	2.3	9.9	5.0
	9. Surficial eolian silt and sand	0.0	16.3	12.9	10.1
	10. Deflation areas, sand and silt	0.0	1.9	3.3	1.6
	11. Windblown sand and silt	3.3	14.5	1.2	7.8
	12. Active sand dunes--mainland	0.0	0.0	.7	0.2
	13. Active clay-sand dunes	2.2	0.3	1.2	1.1
	14. Stabilized sand dunes	0.0	0.0	0.5	0.1
	15. Stabilized clay-sand dunes	0.0	0.0	0.4	0.1
	16. Calichified sand and silt, karst topography	0.0	25.0	5.0	12.3
	17. Calichified sand and gravel	0.0	7.5	0.0	3.4
	18. Lakes, ponds, streams, canals	2.9	0.5	1.6	1.5
B.	ACTIVE FLOODPLAIN				
	1. Small active streams	0.5	0.0	0.1	0.2
	**2. Recharge sand, silt, and mud, floodplain	--	--	--	--
C.	BARRIER ISLAND				
	1. Beach	0.2	0.0	0.1	0.1
	2. Fore-island dunes and vegetation-stabilized barrier flats	0.5	0.0	0.0	0.2
	3. Active dunes and blowouts	0.4	0.0	0.9	0.3
	4. Storm washover areas	0.8	0.0	0.6	0.4
D.	WETLANDS				
	1. Brackish to salt-water marsh	0.04	0.0	0.2	0.1
	2. Permanent and ephemeral fresh-water marsh	0.04	0.0	0.0	0.01
E.	MAN-MADE FEATURES				
	1. Subaerial spoil and made land	1.2	0.0	0.4	0.5
	2. Subaqueous spoil	0.8	0.0	0.7	0.4
F.	BAYS, LAGOONS, AND OPEN GULF				
	1. Enclosed and/or restricted bay	0.02	0.0	0.5	0.1
	2. Open bay	2.3	0.0	1.0	1.0
	3. Tidal inlet and subaqueous tidal deltas	0.9	0.0	0.04	0.3
	4. Bay- or lagoon-margin sand or muddy sand	0.6	0.0	1.7	0.6
	5. Tidal flats	7.5	0.0	8.4	4.4
	6. Grassflats	8.8	0.0	6.4	4.3
	*7. Upper shoreface	0.0	0.0	0.0	0.0
	*8. Lower shoreface	0.0	0.0	0.0	0.0
	9. Sand and shell beaches and berms--mainland	0.1	0.0	0.1	0.1

*F_7 F_8--areas not determined.

**Unit B_2 percentages are included with units A_2, A_6 and A_8 which were mapped within these floodplain areas (north and south boundaries of this floodplain area are defined by levee-dike system and Rio Grande River, respectively.)

(D) wetlands, (E) man-made features, and (F) bays, lagoons and open Gulf. Following is a general discussion of each of the systems and the land and water resource units they contain. The unit symbol and a brief explanation of the capabilities and limitations of each unit is presented in the Appendix.

Coastal Plain

The coastal plain in the Lower Rio Grande Valley is a flat to slightly undulating surface which inclines gradually southeastward toward the Gulf of Mexico. Within the mapped area it rises to a maximum elevation of 380 feet in western Hidalgo County.

Most sediments that comprise the Coastal Plain in the Lower Rio Grande Valley accumulated in ancient (Pleistocene) and recent (Modern-Holocene) rivers, deltas, and coastal barriers (or shoreline environments.) Some of these sediments have been reworked by erosional processes. Eighteen land and water resource units have been delineated and mapped in the coastal plain system.

Sands deposited by river, delta and marine processes (units A1, A2, A3, and A4) are extensive throughout the area. The Pleistocene-age sands cover large, somewhat sinuous areas of Willacy County, northern Cameron County, and a smaller portion of southern Hidalgo County. These sands generally are moderately permeable. However, they are subject to flooding and ponding of water locally due to poor surface drainage, locally high mud content, and high water table. In addition to predominantly sandy units, extensively calichified Pleistocene river deposits (A17) containing significant amounts of gravel occur in extreme western Hidalgo County.

Modern-Holocene sands and silts cover narrow sinuous areas in southern Hidalgo County and the southeastern two-thirds of Cameron County--an area that extends gulfward adjacent to the Rio Grande. These deposits also contain significant amounts of mud, locally, and are subject to some flooding.

Many of the sands, both Modern-Holocene and Pleistocene, serve as recharge units for shallow aquifers in the region. They make poor waste disposal sites. Low shrink-swell potential and high foundation strength make these sands more desirable as construction sites than muds or clays. However, care should be taken with regard to high corrosion potential and susceptibility to flooding and erosion in choosing construction sites.

Mud* deposited in river-floodplains, marshes, flats between delta distributaries, bays, and abandoned river channels (A5, A6, A7, and A9) also covers a significant portion of the three-county area. Some of the mud facies occur as a thin veneer over river and delta sand deposits (A3 and A4).

Pleistocene muds occur as river floodplain overbank and channel fill deposits throughout Willacy County and northwestern Cameron County. Overbank and abandoned river channel muds of Modern-Holocene age occur in the southeastern two-thirds of Cameron County and southern

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* The term "mud" as used in this report refers to both wet and dry sediments with grain size smaller than silt and composed predominantly of clay.

Hidalgo County, near and adjacent to the Rio Grande. These areas are locally susceptible to flooding due to the impermeability of the muds and poor surface drainage.

Coastal plain muds generally have a high shrink-swell potential, low foundation strength, and high corrosion potential, rendering them undesirable or unsuitable for construction without taking appropriate engineering precautions and care in development.

A significant amount of sediments of the coastal plain has been reworked by wind action. Extensive sand sheets (A9, A10, A11) cover portions of Cameron and Willacy Counties and a large part of Hidalgo County. Many of the wind deposits have been stabilized by vegetation (A14, A15), but isolated areas in northern Willacy, northern Cameron, and northern and central Hidalgo Counties contain actively migrating sand dunes and clay dunes (A12, A13).

Natural carrying capacity of coastal plain sediments is largely determined by physical properties, such as sediment size, and hydrological and biological characteristics of the various land and water areas. Instability of some wind blown deposits also is a significant factor in considering land capability. Irrigated farming is the dominant use of land in the Lower Rio Grande Valley. Part of southeastern Cameron County and much of the area covered by windblown sand in northern Willacy and Hidalgo Counties is utilized as range and pasture land.

Active Floodplain

The flat to gently undulating surface of the Lower Rio Grande Valley is laced with abandoned river channels flanked by their natural levees. Extensive modification of the land through the development of drainage ditches, irrigation canals, and floodways have made the task of interpreting active floodplains very difficult. Because of this difficulty, only the obvious flood-prone areas that lie along the Rio Grande, the Arroyo Colorado and and La Joya Creek have been classified in the Active Floodplain System.

Along the Rio Grande a levee and dike system that runs approximately parallel to the northern bank was used to mark the limit of the floodplain unit B2. This area is depicted on the land and water resources map (work map) by a line pattern superimposed over other mapped units. Units that are present within this flood-prone area include: A2 (moderately permeable recharge sand and silt); A6 (low permeability mud,), and A8 (mud filled channels).

Land resource unit B1 occurs in areas along the Arroyo Colorado, La Joya Creek and a small area in northeast Willacy County.

Additional information on flood-prone areas was obtained from U.S. Geological Survey topographic maps on which flood-prone areas had been delineated by the Geological Survey in cooperation with the U.S. Department of Housing and Urban Development, Federal Insurance Administration. These maps were particularly useful in determining probable flood problems associated with projected growth and development in the Lower Rio Grande Valley.

Barrier Islands

Padre and Brazos Islands are barrier islands that lie offshore and approximately parallel to the shoreline of the coastal plain. Padre Island, which is from one to two miles in width, is about six miles (width of Laguna Madre) from the mainland, and extends from Brazos Santiago Pass northward, beyond (approximately 75 miles beyond) the Willacy County line (the limits of the mapped area). Brazos Island lies between Brazos Santiago Pass and the Rio Grande, a distance of about 8 miles. Sand and shell are the dominant constituents of the islands. Four land resource units were mapped on the islands. Island environments exist in a state of delicate balance; alteration of one environment can influence or lead to changes in another.

As a barrier island, Padre Island serves two important functions: (1) it is a line of defense against the effects of storm-driven tides and hurricane surge, and (2) it is a site of extensive and varied recreation and second home development. The islands' role in protecting the mainland coast from the full fury of hurricanes is an extremely important one. Hurricanes and other major tropical cyclones strike the Texas coast on the average of once in every 1.5 years (Hayes, 1967). Since 1900 at least two major hurricanes, the hurricane of September, 1933, and Hurricane Beulah in 1967, have passed through the Lower Rio Grande Valley area. Numerous other passing storms have directly or indirectly affected the area. Barrier islands, beaches, and dunes absorb much of the terrific punishment from these severe storms, blocking high waves and slowing spillover into bays and lagoons. This in turn tends to reduce salt water flooding and damage on the mainland.

Vegetative cover on dunes and barrier flats is critical to the storm protection role of the island. Without stabilization provided by vegetation, loose sand composing the barrier island would be washed into the bay and the island would be levelled. The vegetation is extremely delicate and once destroyed, particularly in the arid south Texas area, has great difficulty becoming reestablished.

Barrier island environments are capable of supporting considerable activity if use is tempered with understanding of the natural system and natural carrying capacity. This understanding is critical because of the far-reaching consequences of misuse of the island resources. In recent years, new motels, condominiums, and marinas have been constructed along south Padre Island northward from Brazos Santiago Pass. Examination of aerial photographs indicates that some structures have been located in ignorance of the natural regime of barrier islands.

Overall foundation strength of barrier island sand is relatively high, shrink-swell potential is negligible, and excavation is easy. High corrosion potential, low slope stability, and wind blown sand are often a hinderance to construction. However, the greatest threat to construction is the risk of damage by floods and winds associated with storms. Flooding by hurricane surge and pounding by large waves can damage structures by direct assault or indirectly by eroding loose sand, thereby removing foundation support. Only if foundation pilings are sunk deeply can damage from sand erosion be limited. The risk of damage by floods is increased when structures are placed in storm washover areas; these areas are natural pathways for hurricane surge waters.

Barrier islands can also be a source of fresh to brackish water. However, in 1960 only one well on south Padre Island in the vicinity of Brazos-Santiago Pass was producing water with less than 1300 parts per million total dissolved solids. Development of a fresh water lens on south Padre Island is hindered by thin reservoir sands, inadequate amounts of rainfall, presence of numerous active washovers, and frequency of inundation by storm and wind driven tides.

Wetlands

Brackish- to salt-water marshes and permanent and ephemeral freshwater marshes occupy some of the coastal area of the Lower Rio Grande Valley (See table 2). However, the marshes are much less extensive than along the coastal zone near and north of Corpus Christi. Most are narrow discontinuous bands fringing the margin of Laguna Madre and flanking tidal channels that extend inland from the lagoon. Salt marsh plant assemblages include glasswort (Salicornia sp.) and salt wort (Batis sp.); smooth cord grass (Spartina alterniflora) is present in only a few locations and only in rather small stands. Fresh marshes may become temporarily established in inland areas following a "wet" season that leaves water ponded in topographic lows. During dryer months the fresh water marsh assemblage may be replaced by an assemblage more characteristic of brackish or saline conditions.

Beyond the evident need to preserve marshes and swamps to protect young crustaceans and fish and wildlife dependent on these resources, use of them is severely limited by frequent or even constant inundation. Foundation strength of the saturated bottom material is low, particularly where mud predominates. Corrosion potential is high.

Man-Made Features

Man has made many alterations in coastal environments and has produced some new environments. The characteristics of these new environments generally are variable, but on the whole, they are distinctive in that man-made and modified areas have their own special attributes and limitations. Two man-made units were mapped--(1) subaerial spoil and made land and (2) subaqueous spoil.

Made land and spoil deposits generally composed of dredged sand, shell and mud are present in Cameron and Willacy Counties in areas adjacent and parallel to dredged channels such as the Brownsville Ship Channel, the mouth of the Arroyo Colorado, Mansfield Channel, and the Intracoastal Waterway.

Bays, Lagoons, and Open Gulf

Bay and lagoon environments were delineated and mapped in the area occupied by shallow Laguna Madre between south Padre Island and the coastal plain. Four subaqueous resource units were delineated in the bay and lagoon system: (1) enclosed and/or restricted bay--this water resource unit occupies a relatively small area in Willacy County near Port Mansfield and southward; (2) open bay--this unit occurs in Cameron County and Willacy County in areas extending lagoonward from Brazos Santiago Pass and Mansfield Channel, respectively; (3) bay or lagoon-margin sand and muddy sand--this unit generally occurs in narrow zones that fringe the mainland margin of Laguna Madre and along the lagoonward side of Padre Island near Brazos Santiago Pass; and (4) grassflats--this unit is the most extensive of the bay and lagoon resource units, occupying a large portion of Laguna Madre from Brazos Santiago Pass to the north boundary of Willacy County. Marine grasses include manatee grass (Cymodocea sp.), shoal grass (Holodule wrightii), and ~~possibly~~ clovergrass (Halophila engelmanii). Also Thallasia

One subaerial unit, sand and shell beaches and berms, is classified with the bay and lagoon system, and is present locally along the mainland side of Laguna Madre in the form of narrow elongate subaerial sand and/or shoal deposits. Tidal flats also are included in the bay and lagoon system. These alternately subaqueous and subaerial units occupy rather broad and extensive areas along the mainland and island shorelines of Laguna Madre. The areas are affected by both astronomical and wind tides.

Two subaqueous resource units lie gulfward of the barrier island--upper shoreface and lower shoreface. The resource unit--tidal inlet and subaqueous tidal deltas--is transitional between the open Gulf and bay environments. This unit is located at the gulfward extension of Brazos

Santiago Pass and Mansfield Channel.

All of these environments are dynamic, and their boundaries shift with changes in ambient conditions. The bay and lagoon system is a complex of numerous interdependent, shifting, and subtle subsystems, all of which are sensitive to induced changes. Many natural or man-made boundaries, such as between the tidal inlets and open bay, are somewhat gradational and are subject to rapid and sudden shifts with short-term cyclic conditions. This should be borne in mind when considering the characteristics, limitations, and possible uses of the bay and lagoon environments. Bay and lagoon waters are intimately linked to the open Gulf, in part through tidal channels; communication between the bays and Gulf waters is essential to maintain productive environments as salinity levels and variability are critical parameters to much of the marine biota.

CURRENT LAND USE

Delineating and mapping land use is a necessary and important part of inventorying existing conditions. This is particularly true in the coastal zone, where the limited land and water resources are much in demand for a myriad of recreational, residential, agricultural and industrial uses.

The current land use map provides: (1) a base map against which future changes in land use can be compared, (2) information on the location of undeveloped land that is available for projected residential, urban, park, and industrial growth, (3) site-specific data for determining the amount of range and farm land which may be irrevocably removed from production by projected growth, and (4) data for evaluating the impact of projected development on the limited resources of the coastal zone.

Current land use in the Lower Rio Grande Valley (Cameron, Hidalgo, and Willacy Counties) was mapped directly on 1971 aerial photomosaics, scale 1:90,000, available from the U.S. Agricultural Stabilization and Conservation Service through the U.S. Department of Agriculture--Soil and Water Division. Additional information was obtained from the latest U.S. Geological Survey 7-1/2-minute topographic maps, and Texas Highway Department maps. Urban development was updated using 1974 aerial photographs (scale 1:30,000) obtained through the U.S. Department of Agriculture. The map base was adapted from the Army Map Service topographic map series, scale of 1:250,000. The finished land use map is at a scale of 1:250,000 and is in the form of a hand-colored work map.

Seven different categories of land use were delineated and mapped. In order of decreasing acreage, these units are: (1) cropland, (2) range-pasture land, (3) natural and man-made water bodies, (4) barren sand and muddy sand, (5) urban and industrial land, (6) subaerial spoil and made land, and (7) marshes. Barren sand, water units, marshes, and spoil were mapped with reference to existing land use mapping by Brown and others (in progress). Irrigated land is also indicated on the map, and with different colored lines is subdivided into acreage irrigated by surface water, ground-water and a combination of the two sources (source of this data was the Texas Water Development Board). A tabulation of the total acreage of range-pasture land, cropland, and urban areas by county is given in table 3.

Cropland

Cropland comprises 54 percent of the land area in the Lower Rio Grande Valley, 1,286,060 acres, with over half of the total acreage occurring in Hidalgo County, the largest of the three counties. Principal crops are grain sorghum, upland cotton, assorted vegetables (including carrots, cabbage, onions, tomatoes, and potatoes), citrus fruits, and sugar cane. It has become a widespread practice to "double crop", i.e., follow cotton or grain with vegetables for harvest in winter and early spring and then to replant grain or cotton for summer harvest.

The most productive areas of the Valley in Cameron and Hidalgo counties have a large percentage of land under irrigation (table 4). Acreages of irrigated land in each county and the sources of the irrigation water are listed in table 5.

Soil salinity is a problem in some cropland areas. Soil scientists have estimated that 25% of cultivated, non-irrigated land in the Lower Rio Grande Valley is highly saline and nonproductive in terms of cultivated crops (Carter and Wiegan, 1964). Among the factors that contribute to localized high soil salinities is rapid increase in clay content with depth. The clay apparently retards infiltration of rain water and prevents leaching of the salt.

TABLE 3

AREAL EXTENT OF RANGE-PASTURE LAND, CROPLAND AND URBAN AREAS MAPPED IN CAMERON, HIDALGO, AND WILLACY COUNTIES (IN ACRES)

	Range-Pasture Land	Cropland	Urban
CAMERON COUNTY	140,148	417,143	32,839
HIDALGO COUNTY	373,318	652,755	36,904
WILLACY COUNTY	168,183	216,162	3,607.0

TOTAL THREE COUNTY AREA

	Range-Pasture Land	Cropland	Urban
Acres	678,650	1,286,060	73,349.0

TABLE 4

PERCENT OF SELECTED CROPS UNDER IRRIGATION AND YIELD PER ACRE (1974)
(FROM TEXAS CROP AND LIVESTOCK REPORTING SERVICE, 1974)

COUNTY	CROP	% IRRIGATED	YIELD (PER ACRE) IRR.	YIELD (PER ACRE) NON-IRR.
Cameron	Upland Cotton	81	502#	176#
	Grain Sorghum	70	66.2 bu.	52.0 bu.
Hidalgo	Upland Cotton	92	428#	218#
	Grain Sorghum	40	62.2 bu.	46.0 bu.
Willacy	Upland Cotton	32	649#	371#
	Grain Sorghum	10	55.3 bu.	49.0 bu.

TABLE 5

ACREAGE OF IRRIGATED LAND, LOWER RIO GRANDE VALLEY
SOURCE: TEXAS WATER DEVELOPMENT BOARD, 1974

COUNTY	SURFACE WATER	GROUND WATER	MIXED SUPPLY
Cameron	287,445	0	0
Hidalgo	378,650	5000 (sprinkler system)	60000 (85% surface water)
Willacy	37,723	0	0

Range-Pasture Land

Range-pasture land comprises approximately 29 percent (678, 650 acres) of the 3-county area, with over half of the total range-pasture land occurring in Hidalgo County. In the northern portion of the mapped area, this land is commonly associated with live-oak mottes that have become established on stabilized aeolian sand dunes. A variety of grasses, vines, and other small plants occur with the thick oak mottes. Cattle graze on the motte-associated vegetation; in addition, the mottes are habitats for abundant wildlife.

In the eastern part of Cameron and Willacy Counties, range-pasture land extends along the coast as a narrow band of grasses and low scrub brush growing on salty soils. The range-pasture land is adjacent to coastal wind-tidal flats and the soil salt content makes farming difficult.

Much of the land, both improved and unimproved, is used for raising cattle, sheep, and dairy animals. In 1974, Hidalgo County was the leading producer of cattle (in the three-county area), while Cameron County led in poultry production (Texas Crop and Livestock Reporting Service, 1974).

Approximately 26, 815 acres of range-pasture land are a part of Federal and/or State-owned lands; Laguna Atascosa and Santa Anna National Wildlife Refuges in Cameron and Hidalgo Counties, respectively, are examples.

Natural and Man-Made Water Bodies

Approximately 8 percent of the 3-county area is covered by water bodies, the largest of which is Laguna Madre. Other large natural water bodies include La Sal Vieja in Willacy County; Laguna Atascosa, Laguna Larga and Loma Alta Lake in Cameron County; and La Sal Del Ray in Hidalgo County. Several large artificial reservoirs also are present, such as Monte Alto Reservoir in Hidalgo County.

These natural and artificial water bodies are used for flood control, municipal water supplies, industrial (including commercial fisheries) and agricultural needs, and recreation.

Barren Sand and Muddy Sand

Approximately 5 percent (of which about 1.3 percent is beach) of the total area is composed of unvegetated to very sparsely vegetated sand and muddy sand. These barren areas include in addition to beaches active dune fields, low-lying tidal flats, and washover channels.

Tidal flats generally are devoid of vegetation, except for algal mats which form following periods of inundation; mats of blue-green and occasionally red algae form a leathery surface that cracks upon desication and drying.

Lands transitional between the wind-tidal flats and eolian sands generally are sites of poorly developed grass vegetation; in these areas wind deflation is an important process and clay dunes are common. Principal use of the barren lands is as wildlife habitats. Transitional lands may support limited grazing on remnant erosional islands (Brown and others, in progress).

Urban and Industrial Land

This land use category includes residential-urban and recreational development, small rural villages, and industrial areas including municipal works, industrial plants and port facilities.

Although the mapped region encompasses the largest concentrations of urban and industrial areas in all of South Texas, these areas comprise only about 3 percent of the three-county area. The largest metropolitan centers are in the Edinburg-McAllen-Pharr area (17,135 acres) in Hidalgo County, and the San Benito-Harlingen area (10,238 acres) and the Brownsville area (10,167 acres) in Cameron County.

Comparison of 1971 and 1974 aerial photographs indicates that during this period the greatest urban and industrial growth occurred in McAllen and Brownsville.

Subaerial Spoil and Made Land

Subaerial spoil is composed of "waste" material--sand, shell and mud--that has been dumped or piled along dredged canals and channels. Made land includes areas that have been filled with dredged materials for development and construction purposes.

Approximately 0.4 percent of the mapped area is subaerial spoil or made land. It occurs primarily along the Brownsville Ship Channel, Intracoastal Waterway, mouth of the Arroyo Colorado and Mansfield Ship Channel.

Older deposits of subaerial spoil and made land have become vegetated with a variety of grasses and plants. Along the Intracoastal Waterway many small cabins used for recreational purposes have been placed on spoil islands. Some islands serve as habitats for waterfowl.

Marshes

Fresh-water and brackish to saline marshes present within the mapped area have been classified together on the land use map. Fresh-water marshes often are ephemeral, occupying low-lying flood prone areas that become vegetated with cattails and slough grass following rains. Saline to brackish-water marshes, locally inundated by tide, form narrow fringes along the mainland shoreline of Laguna Madre and along tidal channels that reach inland from the lagoon. Salt wort, glass wort, and salt grass are common. The marshes are important to wildlife.

HISTORICAL MONITORING--GULF SHORELINE CHANGES ALONG SOUTH PADRE AND BRAZOS ISLANDS

Barrier islands are comprised of dynamic environments in which natural changes often take place in relatively short periods of time. Location of permanent, high-cost structures and recreational complexes on the island, in many areas less than 200 feet from the Gulf shoreline at high tide, makes it essential to be aware of both short- and long-term trends in the position of the Gulf shoreline. Such trends can be determined through historical monitoring.

Historical monitoring involves the use of chronologic photographs, topographic maps and coastal surveys on which the positions of shorelines are documented. Lines representing the shorelines are transferred to a base map using precise cartographic techniques; differences in shoreline positions at various times can then be accurately measured and compared.

The following discussion on historical Gulf shoreline changes and on analysis of those changes along south Padre Island (Mansfield Channel to Brazos-Santiago Pass) and Brazos Island is from Morton and Pieper (1975). General methods and procedures used by the Bureau of Economic Geology in monitoring historical shoreline changes are presented by Morton and Pieper (1975) and also by Fruh, and others, (1976). Included in the methods and procedures is information on sources of data, factors affecting accuracy of data, use and interpretation of topographic surveys and aerial photographs, cartographic procedures, measurements and calculated rates, and justification and limitations of the method.

> "Because of limitations imposed by the technique used, rates of change are subordinate to trends or directions of change. Furthermore, values determined for long-term net changes should be used in context. Values for rates of net change are adequate for describing long-term trends; however, rates of short-term changes may be of greater magnitude than rates of long-term changes, particularly in areas where both accretion and erosion have occurred." (Morton and Pieper, 1975).

Maps and photographs used to determine Gulf shoreline changes on south Padre and Brazos Islands range in dates from November, 1854, to June, 1974; the different vintages of maps and photographs, however, do not necessarily cover the entire length of shoreline in the study area. Sources and dates of the photographs are identified in table 6.

Gulf shoreline positions recorded on the different vintages of maps and photos were measured and compared at 25 points spaced at intervals of 10,000 feet from the Kenedy-Willacy County boundary to the mouth of the Rio Grande (figure 1). Northward of point 13 (figure 1), cultural features are lacking and ground control for plotting shoreline positions on the base map was based on natural features such as stable dunes and the shape of back-island areas. Therefore, the chance for error may increase slightly in some areas north of point 13.

Directions and rates of change were determined and analyzed by Morton and Pieper (1975) for various time intervals at each of the 25 points (figure 1). Net historic changes that have occurred during the last 80 to 120 years along the Gulf shorelines of Brazos and south Padre Islands are shown in figure 2.

Although data on Brazos Island indicate net accretion during the past 120 years, erosion has been the trend at points 23, 24, and 25 since 1937. Accretion has continued at point 22 which is influenced by the south jetty at Brazos Santiago Pass; the jetty interrupts the northward flowing longshore currents and entraps the transported sediments.

TABLE 6

LIST OF AERIAL PHOTOGRAPHS AND MAPS USED IN DETERMINATION OF CHANGES IN VEGETATION LINE AND SHORELINE*
(FROM MORTON AND PIEPER, 1975)

DATE			SOURCE OF PHOTOGRAPHS
April 1937		*	Robin Research Inc.
Nov., Dec. 1954			U. S. Dept. Agriculture
Nov. 1955			U. S. Dept. Agriculture
Jan., Feb. 1960		*	Tobin Research Inc.
Oct. 1961			U. S. Army Corps Engineers
June 1967			U. S. Army Corps Engineers
Sept. 25, 1967			Texas Highway Dept.
Sept. 28, 1967	(mouth of Rio Grande)		Intl. Boundary and Water Commission
July 1968			Texas Highway Dept.
Nov. 1969		*	Natl. Oceanic and Atmospheric Admin.
Oct. 1970		*	Natl. Oceanic and Atmospheric Admin.
June 1974		*	Texas Highway Dept.

List of Maps Used in Determination of Shoreline Changes

DATE	DESCRIPTION	SOURCE OF MAPS
Nov. 1854	Topographic map-453	Natl. Oceanic and Atmospheric Admin.
1867	Topographic map-1045	Natl. Oceanic and Atmospheric Admin.
July 1879-80	Topographic map-1476a, 1476b	Natl. Oceanic and Atmospheric Admin.
1917	Topographic map-3673	Natl. Oceanic and Atmospheric Admin.
1934	15-minute quadrangle	U. S. Geological Survey
Oct. 1958	Changes in location of mouth of Rio Grande 1853-1966	Intl. Boundary and Water Commission

*Indicates vegetation line and/or shoreline was used in map preparation.

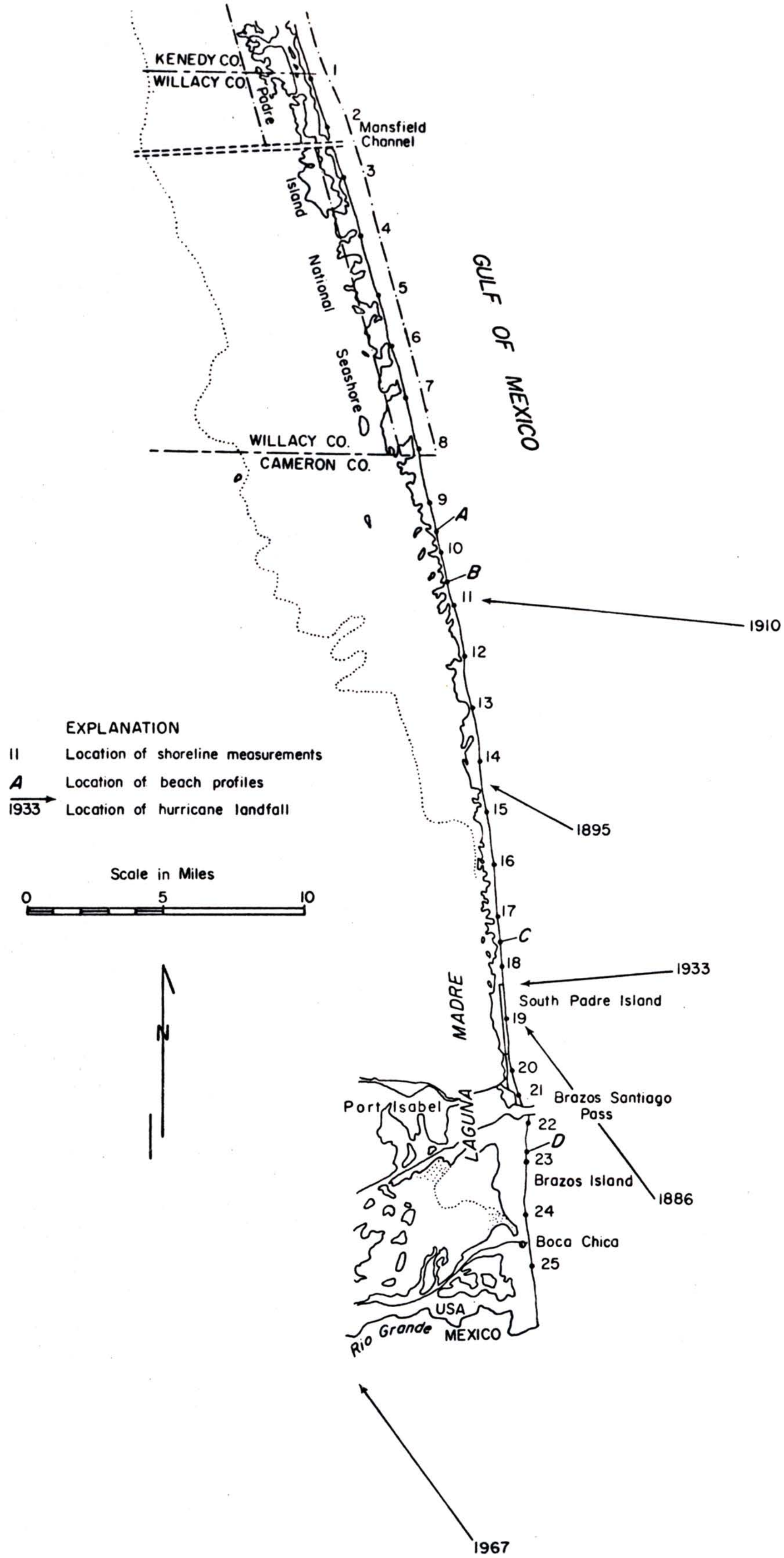


Figure 1: Generalized diagram showing location of shoreline measurements, beach profiles, and hurricane landfall. From Morton and Pieper, 1975.

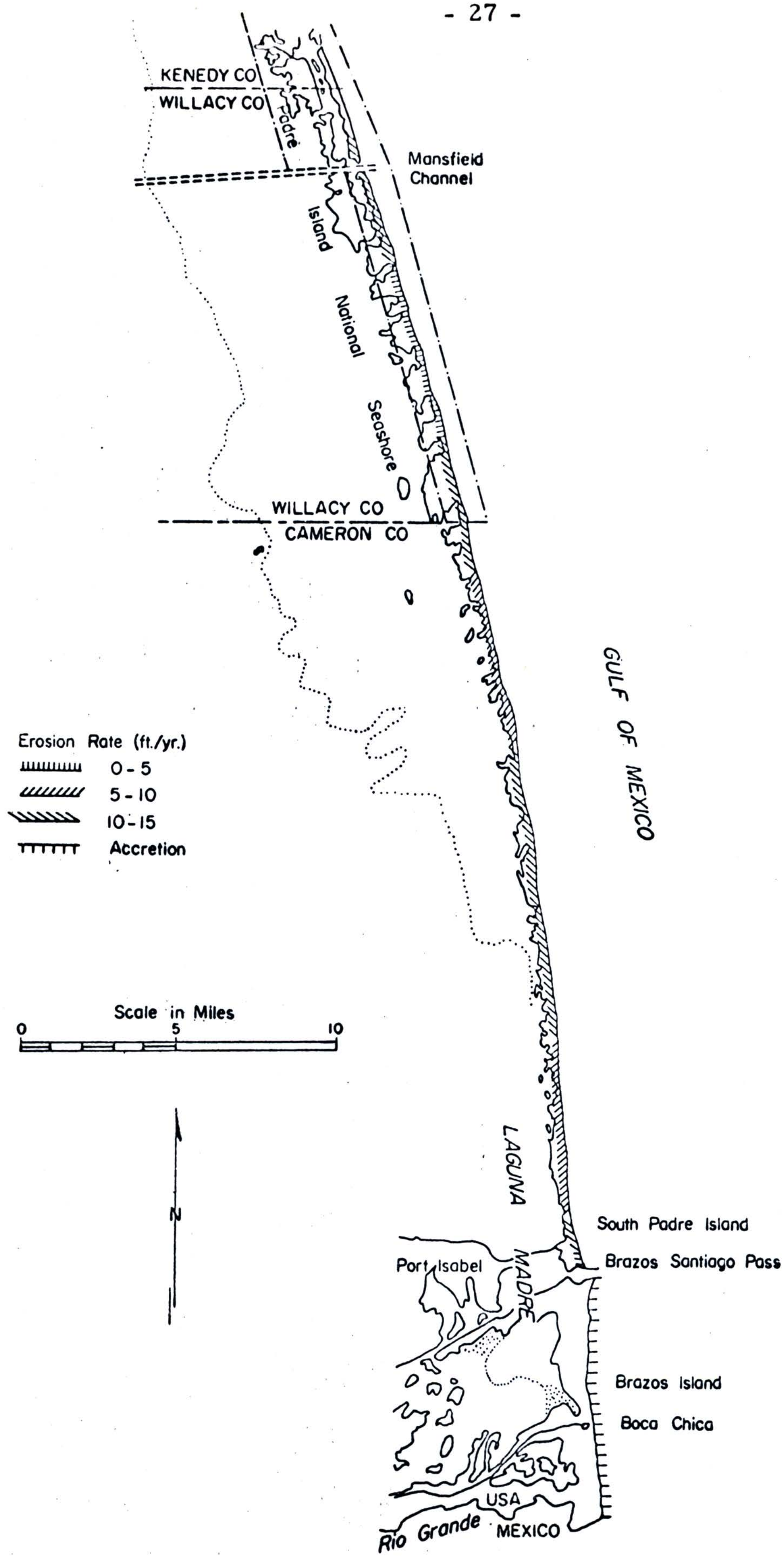


Figure 2: Net shoreline changes along Brazos Island and south Padre Island, based on variable time periods from 1854-1880 to 1974. Maximum extent of time on which these changes are based is 120 years; minimum extent is 94 years. From Morton and Pieper, 1975.

Historical monitoring data on south Padre Island indicate a history of erosion along the Gulf shoreline except for an area adjacent to the north jetty at Brazos Santiago Pass (point 21, figure 1) which has undergone accretion since the jetties were constructed in 1935. Net rates of erosion for points 8 through 20 have ranged from 725 to 1400 feet during an approximate 100-year period. Net annual erosion has ranged from 8 to 13 feet which is considered a moderate rate by Morton and Pieper. Although these figures indicate long-term net change, the values can have misleading implications and do not indicate short-term changes. For example, net rates of erosion from points 8 to 19 during a 14-year period (1960-74) ranged from 3.5 feet to 28.6 feet per year. The average rate for all 12 points for this 14-year period was 14.6 feet/yr.

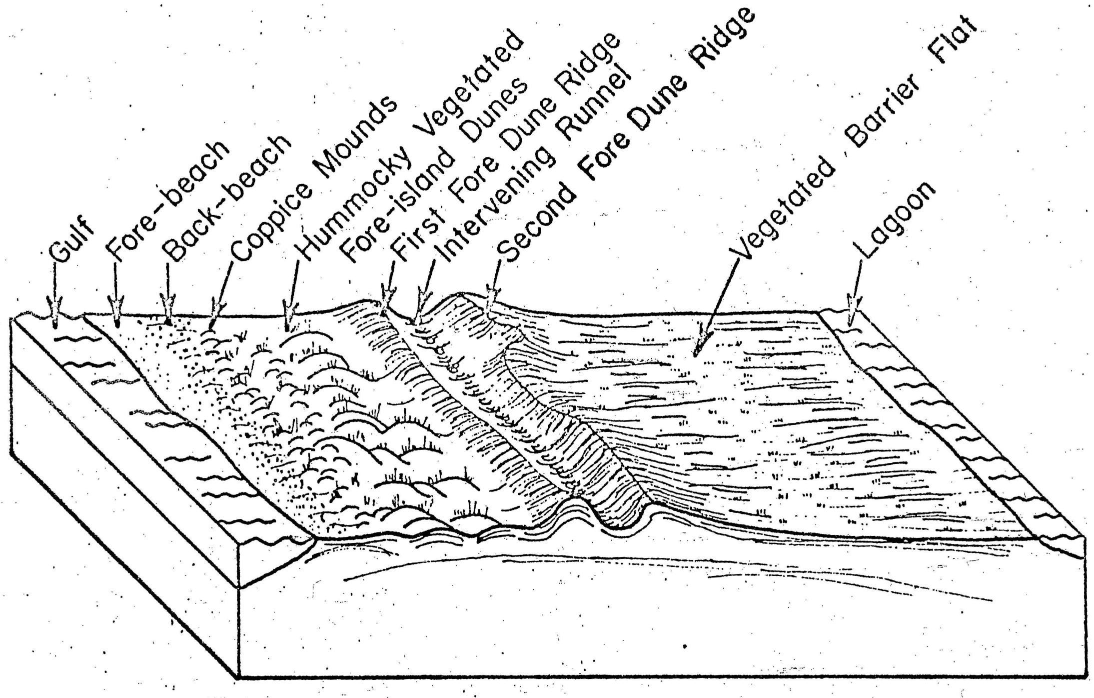
Long-term trends indicated by the historical monitoring data may not be indicative of future long-term trends if the equilibrium between sediment supply and littoral processes is upset. However, there is no evidence to indicate a reversal in the erosional trend and, therefore, Morton and Pieper conclude that the position of the shoreline in this region will continue to retreat landward.

CHARACTERIZATION OF FORE-ISLAND DUNES ON SOUTH PADRE AND BRAZOS ISLANDS

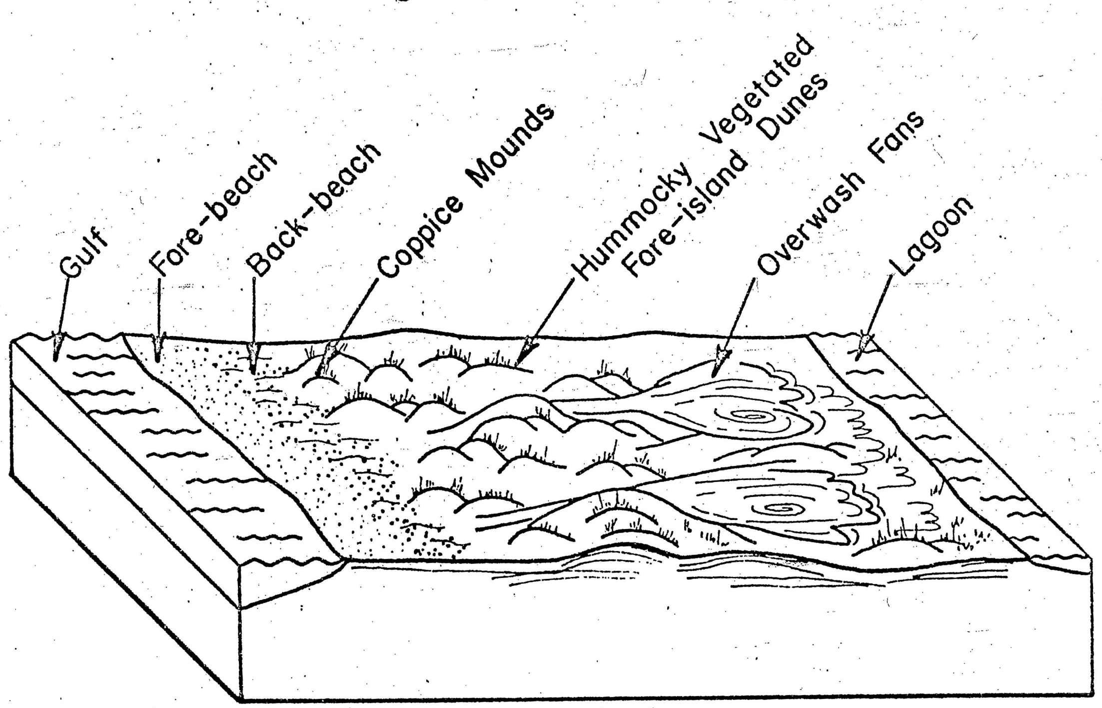
To classify and compare south Padre and Brazos Islands to other barriers, it is useful to consider two end members in the spectrum of modern barrier types based on their response to storms. Because these barrier types respond differently to storms, they should not be managed or developed in the same manner.

The first end member is the high profile island (figure 3) characterized by elevations of greater than 10 feet and one or more well developed continuous fore-island dune ridges. Often, there are smaller discontinuous hummocky foredunes seaward of the first dune ridge and smaller wind shadow or coppice dunes on the back beach seaward of the hummocky foredunes. Height and continuity of these dunes prohibit storm waters from flowing randomly across the island, but restrict it to relatively narrow and permanent washover sites that are commonly reopened by each storm. Where there is sufficient rainfall, the protected back-island area behind the dunes becomes densely vegetated, and is maybe flooded from the bay side of the island during the ebb surge following hurricanes.

The low profile island (figure 3) is characterized by elevations of less than 10 feet and usually consists of low coppice mounds and discontinuous fore-island dunes. These discontinuous dunes allow storm surge to pass across the island by flowing in and around the scattered dunes like water rushing through a maze. The storm washovers may form coalescing fan systems along the back side of the islands, and each new storm adds more sediment to the older fans. Overwash is not necessarily restricted to the same pathway during each storm and often inundates large areas of the island. Godfrey and Godfrey (1973) discussed the difficulties encountered in North Carolina when the limitations in developing a low profile island were not recognized.



High Profile Barrier Island



Low Profile Barrier Island

Figure 3: Generalized diagram of high and low profile barrier islands. From Kier and others, 1976.

As a whole, Brazos and South Padre Islands are low profile islands, generally characterized by elevations of less than 10 feet, sparse vegetation and discontinuous fore-island dunes. Although there is a dune complex with an elevation of 30 feet on Brazos Island, and there are scattered dune complexes of up to 20 feet on South Padre, hurricane flooding is relatively unobstructed. McGowen and Scott (1975) reported that surge flow across south Padre is virtually unconfined during hurricanes. Scour channels are rare, and surge waters spread out among the dunes coalescing into washover fans on the tidal flats along Laguna Madre. McGowen (1975, personal communication) has also reported that borings on south Padre Island indicate the island sand is only 10-15 feet thick and underlain by mud. As mentioned in a previous section, Morton and Pieper (1975) have determined the net long-term erosion rates on south Padre to be on the order of 8-13 feet/year. With these factors in mind, the importance of maintaining and protecting sand that is stored in the dunes is apparent.

Aerial photographs taken five days after Hurricane Beulah reveal that although the gulfward edge of the fore-island dune line retreated landward under the attack of storm waters, several dune complexes were effective in blocking or diverting storm surge thereby protecting local areas behind the dunes. In addition to offering some storm protection, dunes on south Padre Island also serve as massive natural sand "reservoirs" that help the island and its resources adjust and recover from the attack of hurricanes and tropical storms, and erosion. Yet, dunes on south

Padre Island (between Mansfield Channel and the Rio Grande River) were excluded in the 1973 Sand Dune Protection Bill (Senate Bill 268, 63rd Legislature) which stated that these dunes "do not afford significant protection to persons or property inland from this area". (Texas General Land Office and Texas Coastal and Marine Council, 1974).

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APPENDIX

LAND AND WATER RESOURCES OF THE LOWER RIO GRANDE VALLEY--
GENERAL CHARACTERISTICS INCLUDING CAPABILITIES AND LIMITATIONS

COASTAL PLAIN

A1 Moderately to Highly Permeable Recharge Sand:

Low moisture retention capacity, poor waste disposal capability, excavation easy, negligible shrink-swell potential, high foundation strength, high corrosion potential, moderately susceptible to erosion, irrigated cropland.

A2 Moderately Permeable Recharge Sand and Silt:

High mud content locally, shallow aquifer, saline in eastern Cameron and Willacy Counties, locally subject to flooding in Willacy County; low to moderate water retention capacity, excavation easy, low shrink-swell potential, high foundation strength, high corrosion potential, mostly cropland, rangeland in eastern Cameron County and Willacy County.

A3 Mud Veneered, Moderately to Highly Permeable Sand:

Mud cover partially retards recharge of ground water; low to moderate water retention capacity, poor waste-disposal capability, excavation moderate to easy, low to moderate shrink-swell potential, moderate to high foundation strength, high corrosion potential, commonly cropland, locally range-pasture land.

A4 Mud veneered, moderately permeable sand and silt:

Thin mud veneer, partially retards recharge of groundwater, locally subject to flooding in Willacy County; low to moderate water retention capacity, poor to moderate waste-disposal capability, excavation moderate to easy, low to moderate shrink-swell potential, moderate to high foundation strength, very high corrosion potential, mostly cropland.

A5 Sand veneered, low permeability mud:

Thin sand veneer, locally subject to flooding, moderate to high water retention capacity, moderate to good waste-disposal capability, excavation moderate to easy, low to high shrink-swell potential, low to moderate foundation strength, very high corrosion potential, mostly cropland.

A6 Low Permeability Mud:

Locally subject to flooding, moderate to high water retention capacity, cracks extensively when dry, good waste-disposal capability, high shrink-swell potential, low foundation strength, very high corrosion potential, commonly cropland.

A7 Low Permeability Mud, Saline Soils:

Higher salt content in soils than in unit A6, susceptible to hurricane surge flooding in lagoonward areas, saline water table, moderate moisture retention capacity, poor to good waste disposal capability, high shrink-swell potential, low foundation strength, very high corrosion potential, rangeland.

A8 Mud-Filled Channels and Topographic Lows:

Low permeability, high water retention capacity, susceptible to early flooding and ponding of water, poor waste disposal capability, high shrink-swell potential, low foundation strength, very high corrosion potential, high organic content, mostly cropland, rangeland in eastern Cameron and Willacy Counties.

A9 Surficial Eolian Silt and Sand:

Eolian sand and loess (silt) sheet, includes moderately stabilized dunes, moderate to very high permeability, local shallow water table, low to moderate moisture retention capacity, poor waste-disposal capability, low shrink-swell potential; engineering plans should consider thickness of deposits and nature of substrate; grass and brush cover, rangeland.

A10 Deflationary Areas Sand and Silt:

Blowouts area of active deflation, locally transitional between wind-tidal flat and eolian sand, subject to intense wind-tidal activity and flooding near the coast; high water table, inland areas contain numerous small playa lakes, subject to flooding by rainfall runoff and rise of shallow water table; thin eolian sand cover over caliche in Hidalgo County; moderate to very high permeability, low to moderate moisture-retention capacity, poor waste-disposal capability, poor construction site; locally grass covered, thick chaparral in Hidalgo County, some rangeland.

A11 Windblown Sand and Silt:

Sand and silt sheet, incohesive, strong relict grain of levelled dunes, local recharge sand; includes active dune blowout areas, low relief, local hummocky topography, shallow water table supports freshwater marsh in some places during wet periods, moderate to very high permeability, low to moderate moisture retention capacity, poor waste-disposal capability, low to moderate shrink-swell potential, grass-covered, mostly cropland.

A12 Active Sand Dunes:

Sand, incohesive, barren, banner dunes common, local barchan dunes, local relief up to 30 feet; very high permeability, low moisture retention capacity, active erosion and transportation of sand by wind, aerial extent varies with climatic conditions and man's activities, poor waste-disposal capability, poor construction site.

A13 Active Clay-Sand Dunes:

Mixed clay, sand, and silt, higher clay content than stabilized clay-sand dunes (A15), includes eolian accretionary bars and ridges (rincons, potreros), moderate permeability, moderate moisture retention capacity, poor waste-disposal capability, variable shrink-swell potential, poor construction site, sparsely vegetated with grass and brush.

A14 Stabilized Sand Dunes:

Eolian sand, stabilized with extensive complexes of live oak mottes, hummocky topography, devegetating activities encourage active dune formation, moderate to very high permeability, low to moderate moisture retention capacity, poor waste-disposal capability, low shrink-swell potential.

A15 Stabilized Clay-Sand Dunes:

Mixed clay, sand, and silt, higher sand and caliche cotent than active clay-sand dunes, moderate permeability, moderate moisture retention capacity, poor waste-disposal capability, moderate shrink-swell potential, grass and brush cover.

A16 Calichified Sand and Silt, Karst Topography:

Moderate to hard caliche and calichified sand, commonly resistant caprock with numerous solution pits, thin veneer of eolian sand, locally strong relict eolian grain; low to moderate permeability, low moisture retention capacity, poor waste-disposal capability, excavation moderate to difficult, low shrink-swell potential, high foundation strength, low to moderate corrosion potential, grass covered, commonly range-pasture land, some cropland.

A17 Calichified Sand and Gravel:

Gravel concentration highly variable, internal drainage, local solution pits (karst), local veneer of windblown sand or silt, little soil cover in some places, low to moderate permeability, low to moderate moisture retention capacity, poor to moderate waste-disposal capability, excavation difficult to moderate, low shrink-swell potential, high foundation strength, cropland and range-pasture land.

A18 Lakes, Ponds, Sloughs, Streams, and Canals:

Permanent inland fresh water bodies, important for surface water supply, ground-water recharge, and waterfowl habitat; coastal water bodies brackish to saline; all have poor waste-disposal capability, high to very high corrosion potential, and high susceptibility to damage from biocides and other pollutants.

ACTIVE FLOODPLAINS

B1 Small Active Streams:

Small, active headward-eroding streams, sand, silt, mud, and local gravel, alluvium absent locally, recharge, highly susceptible to flooding and bank erosion, poor waste-disposal capability, low foundation strength and bank stability, locally tree covered.

B2 Recharge Sand, Silt, and Mud, Floodplain:

Highly susceptible to flooding, meanderbelt sands and silts with levee and local crevasse splay deposits, located adjacent to and along the north side of the Rio Grande River, high water table, poor waste disposal capability, low shrink-swell potential, generally high foundation strength, high to very high corrosion potential, locally tree-covered, cropland.

BARRIER ISLANDS

C1 Beach:

Loose sand and shell along Gulf shoreline, mean low tide to vegetation line, high permeability, highly susceptible to erosion during storms and flooding by storm tides, subject to modification by wind and water, low moisture retention capacity, poor waste-disposal capability, poor construction site, sand supply for dunes, sand excavation detrimental.

C2 Fore-Island Dunes and Vegetation-Stabilized Barrier Flats:

Sand and shell, modified by eolian activity, highly permeable, perched brackish- to fresh-water aquifer, highly susceptible to flooding and erosion by storm tides, salt-tolerant plants dominant vegetation; maintenance of vegetation is critical in preventing wind and water erosion and providing natural barrier to storm surge, low moisture retention capacity, very poor waste-disposal capability, low shrink-swell potential, very high corrosion potential, poor to fair construction site, sand excavation detrimental.

C3 Active Dunes and Sand Blowouts:

Loose barren sand, highly permeable, active erosion and transportation of sediment by wind, aerial extent varies with climatic conditions and man's activities, low moisture retention capacity, very poor waste-disposal capability, low shrink-swell potential, very high corrosion potential, very poor construction site.

C4 Storm Washover Areas:

Washover channels and fans: loose sand and shell, subject to intensive flooding by storm tides with scour and fill and significant transport of sediment during hurricanes and other storms, subject to extensive modification by wind between major floods, local seasonal fresh-water marsh and grass, algal flats, high permeability, very poor waste-disposal capability, very high corrosion potential, extremely poor construction site.

WETLANDS

D1 Brackish to Salt-Water Marsh:

Mud and local sand substrate, frequently flooded by saline water, grasses and succulent plants dominant, preservation important to marine and estuarine ecology, very poor waste disposal capability, very high corrosion potential, very poor construction site.

D2 Permanent and Ephemeral Fresh-Water Marsh:

Rushes, cattails, and grasses dominant, valuable wildlife habitate especially for waterfowl, permanently to commonly high water table, very poor waste disposal capability, very high corrosion potential, very poor construction site.

MAN-MADE FEATURES

E1 Subaerial Spoil and Made Land:

Mixed mud, silt, sand, and shell, composition and physical properties highly variable, locally steep relief, local subject to extensive erosion, poor solid-waste disposal capability, very high corrosion potential, construction should be undertaken with caution.

E2 Subaqueous Spoil:

Mixed mud, silt, sand, and shell, composition and physical properties highly variable, forms shoal areas next to and separate from subaerial spoil and made land in bays, estuaries, and open Gulf, highly susceptible to erosion by storm waves and currents with consequent redistribution of sediment over bay and estuarine bottoms.

BAYS, LAGOONS, AND OPEN GULF

F1 Enclosed and/or Restricted Bay:

Away from normal tide or riverine influence, poor circulation and exchange with other parts of bay, depths, generally less than 6 feet, high and low extremes of salinity common, frequent deficiency in dissolved oxygen content, low species diversity, poor waste disposal capability, mottled organic-rich mud with local concentrations of shell.

F2 Open Bay:

Moderate tidal and/or riverine influence, moderate to good circulation and exchange with other parts of bay, depths 6 to 15 feet, moderate salinity fluctuations and turbidity, moderate to high dissolved oxygen content, high species diversity, poor waste-disposal capability, mottled mud with local concentrations of shell, scattered clumps of oysters.

F3 Tidal Inlet and Subaqueous Tidal Deltas:

Inlet connects open Gulf and bays, strong tidal currents and rapid sediment transport, sediment deposition in tidal deltas, depths to 40 feet, maintained by dredging, generally normal salinity (35°/oo), high species diversity, free interchange of water necessary to maintain salinity, aid in flushing bays and allow access of fish and shrimp to nursery and feeding ground in bays, poor waste-disposal capability, dominantly sand and shell.

F4 Bay or Lagoon-Margin Sand or Muddy Sand:

Locally high current activity with rapid erosion, transportation, and redeposition of sand, strong wave activity during storms, salinity and water temperature variable, depths less than 3 feet, local sparse grass cover, algae, low species diversity, presence of sand tends to reduce erosion and undercutting of subaerial bay margins, poor waste-disposal capability, poor construction site.

F5 Tidal Flats:

Mixed mud, sand, and shell, subject to sudden and rapid inundation by astronomical, storm, and wind-driven tides, moderate wind erosion between floods, poor waste-disposal capability, very high corrosion potential, poor construction site.

F6 Grassflats:

Muddy sand with shell, generally hypersaline, shallow (< 5 feet), sparse to dense growth of Halodule (Diplanthera), Cymodocea, Halophila, and marine grasses of variable concentration, very important to marine ecology, poor waste-disposal capability, poor construction site, dredging or dumping spoil can permanently destroy this environment.

F7 Upper Shoreface:

Sand and shell offshore to mean low tide to depths of 15 feet, includes surf zone, gradient approximately 30 feet/mile, strong waves and current activity, considerable erosion, transportation, and redeposition of sand, especially during storms, sand supply for beach, normal salinity, poor waste disposal capability, excavation of sand and placement of piers, jetties, and groins may inhibit or accelerate sand movement, altering beach and shoreface equilibrium.

F8 Lower Shoreface and Open Gulf

Muddy fine sand grading seaward into mud, depths 8 feet to 30 feet to 600 feet respectively, affected only by storm waves and currents, normal salinity, high species diversity, poor waste disposal capability, poor construction site.

F9 Sand and Shell Beaches and Berms--Mainland:

Thin subaerial deposits of sand and shell that locally fringe lagoon shoreline, mean low tide to +5 feet, commonly flooded and modified by storms, local salt-tolerant grasses, highly susceptible to erosion, poor waste-disposal capability, poor construction site.