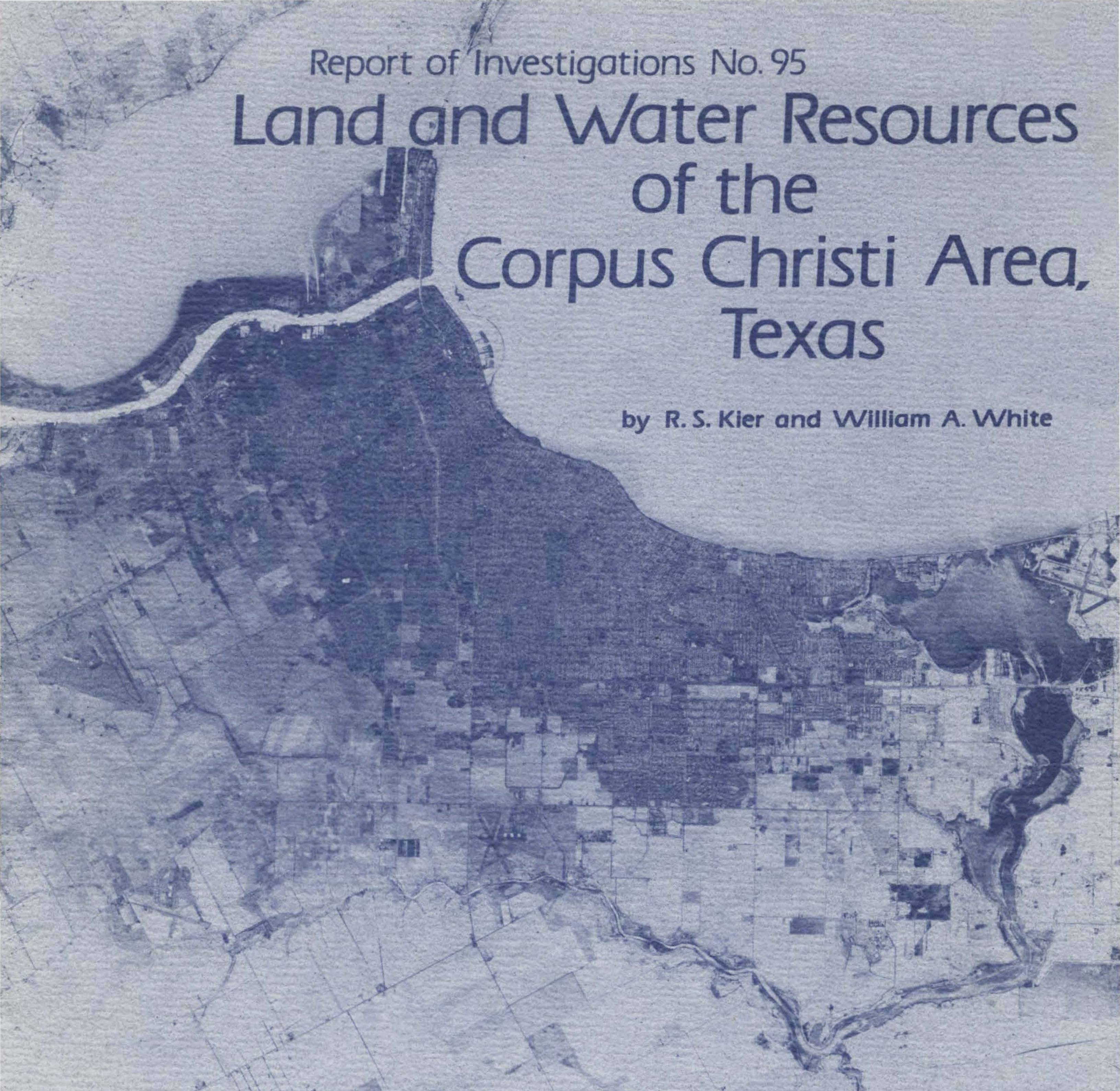
Report of Investigations No. 95

Land and Water Resources of the Corpus Christi Area, Texas

by R. S. Kier and William A. White



Bureau of Economic Geology
W. L. Fisher, Director

The University of Texas at Austin
Austin, Texas 78712

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INTRODUCTION

Effective use of the Texas Coastal Zone and its vast and varied resources depends on adequate knowledge of the characteristics and distribution of natural and man-made land and water environments. If competing demands for these resources are to be balanced, sound scientific data that define properties, inherent carrying capacities, and interrelationships of the environments must be gathered. Development and use of land and water resources consistent with their natural capabilities will minimize or prevent many environmental problems. Understanding the limiting parameters of an environment, and its capability to withstand man's impact while serving as a resource to him, is essential.

Land and water resources have been analyzed in the Corpus Christi area—Aransas, Nueces, Refugio, and San Patricio Counties along the central Texas coast (fig. 1). The city and port of Corpus Christi compose the largest metropolitan center in the area. This report analyzes the types, extent, and distribution of land and water resources in the Corpus Christi area.

GENERAL SETTING

The Corpus Christi area lies within the Coastal Bend region of the Texas coast. The city of Corpus Christi is in the southern part of the area on the shore of Corpus Christi Bay. Other cities, towns, and ports include Robstown and Bishop in Nueces County; Sinton, Mathis, Odem, Taft, Gregory, Portland, Ingleside, and Aransas Pass in San Patricio County; Rockport in Aransas County; and Refugio and Woodsboro in Refugio County. Aransas National Wildlife Refuge and several

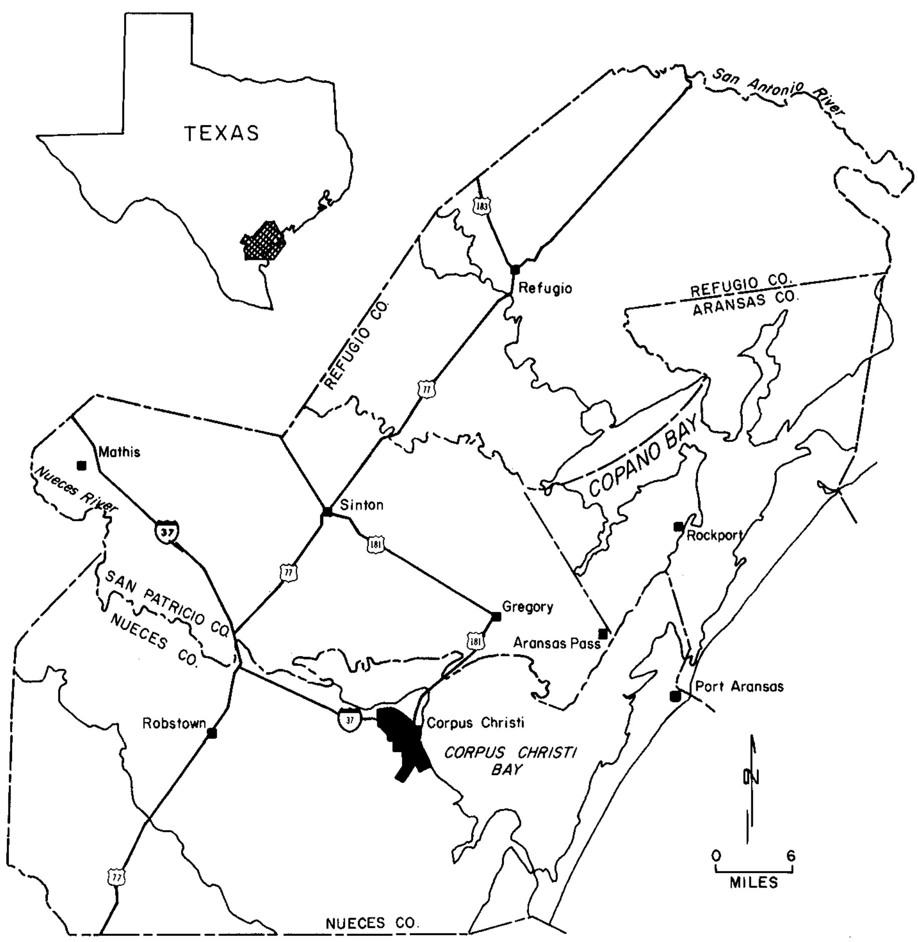

Figure 1. Index map to Corpus Christi area—Aransas, Nueces, Refugio, and San Patricio Counties, Texas.

State parks also lie within the area. Approximately 3,145 square miles of land and water compose the Corpus Christi area.

Climatologically, the four-county Corpus Christi area ranges from dry subhumid in the northeast to semiarid in the southwest (Thornwaite, 1952). Average rainfall varies from 36 inches in northeastern Refugio County to 26 inches in southwestern Nueces County. Precipitation averages and gross lake evaporation in the four-county area are shown in figure 2. Monthly precipitation over a 40-year period is shown in table 1.

The Coastal Plain in the Corpus Christi area is a flat to gently rolling surface inclined slightly seaward at an average gradient of 4 to 5½ feet per mile. Maximum elevation is 200 feet at the western border of San Patricio County.

The Nueces, Aransas, and Mission Rivers transect the Coastal Plain. The San Antonio River, joined by the Guadalupe River about 10 miles upstream from San Antonio Bay, flows along the northern boundary of Refugio County. All rivers are more or less entrenched into the soft Coastal Plain sediments. Average incision is about 15 to 20 feet; maximum incision is up to 80 feet along the Nueces River where it enters the Corpus Christi area.

Numerous creeks also cross the Coastal Plain: Oso, Chiltipin, Blanco, Melon, Copano, and Artesian Creeks, as well as several others. Many of these creeks have also cut into the Coastal Plain, and nearly all are actively extending their courses by headward erosion. Brackish- to salt-water marshes, fresh-water marshes, and swamps occupy low places in coastal areas and river valleys.

Major estuaries in the Corpus Christi area are Nueces, Corpus Christi, Aransas, Copano, and Mission Bays. All the estuaries are shallow with a maximum water depth of 14 to 15 feet, and they lie in the drowned lower portions of ancient river valleys.

Mustang, St. Joseph (San Jose), and Padre Islands lie about 6 miles offshore and parallel to the mainland shore. In the Corpus Christi area, tidal passes—Cedar Bayou, Aransas Pass, Lydia Ann Channel, and Corpus Christi Pass—occur at the ends of the barrier islands. Newport Pass, Packery Channel, and the water-exchange pass (Fish Pass) also cross the islands. Cedar Bayou, Newport Pass, Packery Channel, and Corpus Christi Pass are now closed except during major storms; Aransas Pass has been dredged to depths up to 45 feet.

In recent years, Mustang and north Padre Islands have been receiving a large influx of tourists and permanent residents. The Corpus Christi area is the closest seaside resort to Austin, San Antonio, and much of South Texas. Large tracts of privately owned land were subdivided, and some are being developed into first- and second-home recreational communities.

In addition to tourism and other sorts of recreation, such as hunting and fishing, the economy of the Corpus Christi area is largely based on production of oil and gas, agriculture, and commercial fishing (Haynes and Hazleton, 1974). More than half of the land in the Corpus Christi area is underlain by muddy substrates with clay-rich soils. These are well suited for dryland production of crops, primarily cotton, soybeans, and grain sorghum. Sand substrates with sandy soils support broad expanses of native grasses and are most commonly used for grazing.

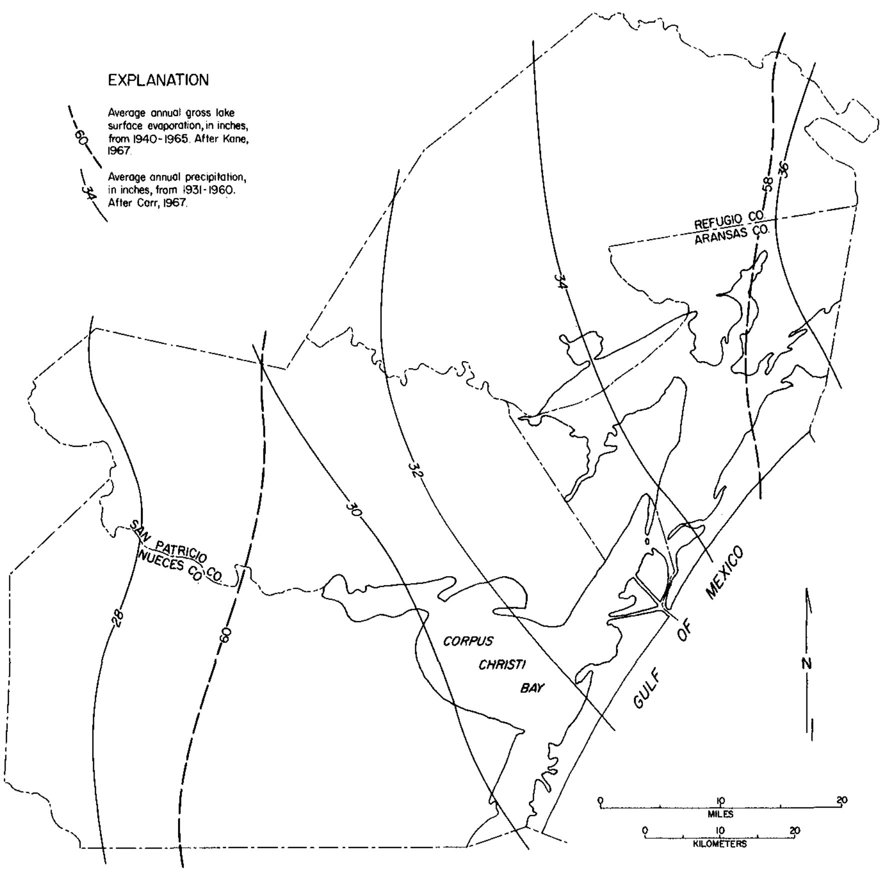

Figure 2. Average annual gross lake surface evaporation and precipitation (in inches), Corpus Christi area (modified from Woodman and others, 1978; data from Kane, 1967, and Carr, 1967).

PROJECT DESCRIPTION AND ACKNOWLEDGMENTS

Mapping of land and water resources in the Corpus Christi area was undertaken in 1970 as part of a multidisciplinary study at The University of Texas at Austin, originally called "Establishment of Operational Guidelines for Coastal Zone Management" and later called "Methodology to Evaluate Alternative Management Policies: Application in the Texas Coastal Zone." Support for this research was provided jointly by the Research Applied to National Needs Program of the National Science Foundation, Grant GI-34870X, and the Division of Planning Coordination, (now the Office of Budget and Planning), Office of the Governor of Texas, through Interagency Cooperative Contracts IAC (72-73)-806 and IAC (74-751-0685.

The base for the land and water resources map was constructed from U.S. Geological Survey 7.5-minute topographic maps. Bathymetry is from U.S. Coast and Geodetic Survey navigational charts. Cultural features including roads and railroads were updated to 1973; urban build-up areas were mapped on 1971 aerial photomosaics from Edgar Tobin of San Antonio.

Principal sources of map data were environmental geologic mapping for the Corpus Christi Sheet (Brown and others, 1976) and the Port Lavaca Sheet (McGowen and others, 1976) of the *Environmental Geologic Atlas of*

Table 1. Monthly precipitation in Corpus Christi, 1932-1973.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	
1932	1.13	1.87	1.50	2.42	1.65	1.78	0.32	1.83	7.53	0.66	0.90	1.08	22.67	
1933	0.70	1.89	0.47	0.44	3.69	2.72	2.54	2.27	4.71	1.99	1.33	0.31	23.06	
1934	4.78	1.38	1.67	3.74	1.24	0.34	5.46	0.15	6.36	1.04	4.11	0.70	30.97	
1935	1.87	0.86	2.06	1.16	4.97	1.56	1.37	0.43	12.45	5.76	0.81	5.69	38.99	
1936	0.61	0.34	3.29	1.92	5.27	3.05	2.17	3.23	3.93	0.95	0.47	1.05	26.28	
1937	0.42	0.58	2.05	0.43	1.19	0.82	2.07	1.66	0.57	2.04	4.09	8.13	24.05	
1938	1.39	1.74	0.48	1.81	1.20	0.66	0.12	4.51	1.44	0.20	1.55	6.44	21.54	
1939*	1.78	0.14	0.86	1.53	2.22	5.19	0.75	1.36	2.65	1.14	0.06	2.06	19.74	
1940	0.76	1.10	1.57	0.05	4.17	2.84	4.02	0.66	3.14	3.49	1.23	2.12	25.15	
1941	1.06	4.80	1.99	7.40	10.44	4.54	2.25	0.51	0.90	4.56	0.79	2.89	42.13	
1942	0.14	4.67	0.97	0.21	1.93	3.30	10.23	5.48	3.97	1.59	1.09	0.09	33.67	
1943	4.07	1.74	1.76	0.36	4.95	0.36	0.48	0.35	4.26	0.81	4.01	3.72	26.87	
1944	2.27	0.15	1.69	0.95	5.90	0.17	T	7.52	3.99	0.23	1.55	2.03	26.45	
1945	0.98	2.37	4.01	3.65	0.61	2.58	2.52	5.96	1.82	3.48	0.43	1.73	30.14	
1946	3.66	1.60	0.67	3.97	4.88	4.84	1.61	3.09	4.53	3.52	0.99	0.73	34.09	
1947	1.77	0.18	1.36	1.48	5.29	1.83	3.50	5.05	1.06	1.04	8.53	2.17	33.26	
1948	0.86	1.71	2.51	1.11	1.77	0.52	1.03	4.14	6.64	1.44	0.64	0.06	22.43	
1949	1.03	2.25	1.62	4.83	0.19	1.11	4.56	1.40	5.16	6.36	T	1.77	30.28	
1950	0.34	2.51	0.59	2.70	1.62	1.58	1.39	0.42	4.22	T	0.10	0.01	15.48	
1951	0.55	1.08	2.36	0.63	0.95	4.02	0.22	0.14	14.54	0.90	1.43	0.09	26.91	
1952	0.22	0.32	0.78	3.17	3.22	0.46	3.88	0.10	5.52	0.00	2.97	0.67	21.31	
1953	0.17	1.33	0.30	0.30	0.88	0.25	0.14	12.64	0.78	5.24	0.69	1.42	24.14	drought
1954	0.35	0.01	0.41	2.98	0.92	2.42	0.14	0.45	3.56	4.44	0.10	0.24	16.02	
1955	0.91	1.32	0.07	0.04	2.11	0.28	0.95	0.83	11.70	1.55	1.69	0.42	21.87	
1956	0.43	0.85	0.09	8.04	3.60	0.62	0.98	1.33	1.00	2.76	1.13	0.90	21.73	
1957	0.14	1.48	2.74	2.53	4.82	5.34	0.00	2.12	2.42	0.40	5.24	0.77	28.00	
1958	10.78	5.24	0.64	0.37	0.81	0.75	1.13	1.33	8.42	8.43	0.84	3.88	42.62	wet
1959	1.74	4.53	0.31	1.39	4.49	5.69	2.29	5.58	2.41	7.73	0.76	1.52	38.44	
1960*	1.56	1.07	1.97	3.26	1.93	3.77	1.42	7.06	1.61	10.66	2.24	7.80	44.35	
1961	2.38	2.08	0.08	3.78	T	5.64	4.37	3.30	3.14	0.05	1.09	0.53	26.44	
1962	0.22	0.06	0.41	1.18	0.24	2.93	T	0.90	5.37	0.39	1.13	2.66	15.49	
1963	0.19	1.36	0.09	0.31	0.85	2.35	0.49	2.99	0.92	2.61	1.64	0.86	14.66	drought
1964	1.61	1.53	1.14	0.08	4.39	0.38	2.25	0.50	6.98	0.19	0.21	2.45	21.71	
1965	0.86	4.41	0.78	0.80	4.01	1.99	1.25	2.64	2.09	1.36	1.96	3.14	25.29	
1966	2.12	1.15	0.69	5.03	7.23	4.35	1.23	4.15	2.84	0.85	0.07	0.18	29.89	
1967	2.63	2.38	0.08	0.23	1.83	0.35	1.05	5.36	20.33	2.86	0.28	0.84	38.22	
1968	2.11	2.42	0.90	0.82	9.38	8.36	5.43	0.62	6.34	3.68	1.34	0.13	41.53	
1969	0.35	2.92	0.49	2.89	2.07	0.13	0.03	2.83	2.05	2.85	5.09	1.87	23.57	wet
1970	1.79	1.01	1.55	0.15	3.92	9.16	1.72	7.32	8.51	3.13	0.81	0.40	39.47	
1971	0.03	0.22	T	2.29	4.55	1.24	0.31	8.32	12.17	3.96	0.44	3.42	36.95	
1972	1.23	3.41	1.44	1.53	5.99	3.65	2.82	3.74	9.49	0.46	2.48	0.17	36.41	
1973	2.18	1.42	0.16	1.73	0.58	13.35	0.52	5.63	7.58	9.95	0.31	0.12	43.53	
Record mean 1932-1973	1.54	2.12	1.15	1.98	3.18	2.83	1.92	3.12	5.16	2.73	1.60	1.86	28.86	

*Indicates a break in the data sequence during the year, or season, due to a station move or relocation of instruments.

Data source: U.S. Department of Commerce, 1973.

the Texas Coastal Zone. Additional environmental geologic information was obtained from Charan Achalabhuti (1973) and J.F. Brewton (personal communication, 1972). The environmental geologic units were interpreted from 7.5-minute Edgar Tobin Aerial Surveys photomosaics and corresponding U.S. Geological Survey topographic maps, both at a scale of 1:24,000, or approximately 2.5 inches per mile. Interpretation and mapping of environmental geologic units were based on genetic grouping of major natural and man-made features of the Coastal Zone. In addition to interpretation of aerial photographs, mapping involved extensive field work, aerial reconnaissance, and utilization of available published data for the region.

Surface lineations shown on the land and water resources map were also mapped for the *Environmental Geologic Atlas of the Texas Coastal Zone.* The lineations were recognized on aerial photomosaics by alignments of streams or other natural features and by textural or tonal anomalies. Only lineations crossing two or more mosaics and seen by three or more geologists were mapped.

Much of the information contained in this study was originally published by Kier and others (1974a and 1974b). Land and water resources were mapped by R.S. Kier, assisted by A.W. Erxleben. W.A. White and R.S. Kier, assisted by M.J. Dildine, compiled the data on energy and mineral resources. Others who assisted at various stages of the study are Ann Bell, D.L. Bell, P.C. Patton, W.E. Powers, A.E. St. Clair, and J.T. Woodman.

This report was critically reviewed by L.F. Brown, Jr., R.J. Finley, L.E. Garner, and A.E. St. Clair. Cartography was by R.L. Dillon. J.W. Macon supervised drafting of the illustrations.

LAND AND WATER RESOURCE UNITS

DEFINITION AND DERIVATION

Land and water resource units were defined by St. Clair and others (1975) as ". . . mappable entities, either natural or man-made, that are defined by the physical, chemical, and biological characteristics or processes which govern the type or degree of use that is consistent with both their natural quality and productive utilization." This definition is a refinement of the concept of resource capability presented earlier by Brown and others (1971).

Land and water resource units are delineated by considering basic facets of the land—geology, pedology, biology, and hydrology. Current land use is also considered as it pertains to the natural capability of land and water areas to sustain present and potential uses without significant degradation. The analysis focuses on characteristics or processes that are of concern to man because they affect or are affected by his use of the land. Characteristics or processes that determine natural capability are many and diverse; factors that limit the use of a land or water area for specific activities are particularly important. Limiting natural characteristics or processes include (1) potential for flooding by hurricane-driven tides or surges and by overbanking rivers; (2) erosional and depositional action by wind and water; (3) physical properties of soils and substrates such as shrink-swell potential, corrosion potential, and permeability; (4) slope and relief; (5) biotic habitation, activities, and tolerances; (6) vegetation stability; (7) natural water currents and quality; and (8) active or potentially active faulting and subsidence.

Areas having similar geologic, biologic, and/or natural process characteristics, and responding similarly to man's use are grouped together as a single land or water resource unit. Elements of primary concern are then singled out in naming and categorizing the units. For example, an area that has poor foundation characteristics but that is also subject to frequent flooding is classified

Table 2. Land and water resource units. Aransas, Nueces, Refugio, and San Patricio Counties.

Coastal Plain	
A1	Highly permeable recharge sand
A2	Moderately to highly permeable recharge sand
A3	Moderately permeable sand and silt
A4	Mud-veneered, moderately to highly permeable sand
A5	Mud-veneered, moderately permeable sand and silt
A6	Low to moderately permeable sandy mud with moderately permeable sand veneer
A7	Sand-veneered, low-permeability mud
A8	Low-permeability mud
A9	Mixed mud and sand with local mud-filled channels
A10	Mud-filled channels, beach swales, and topographic lows
A11	Calichified sand
A12	Lakes, ponds, sloughs, and streams
A13	Ephemeral lakes, ponds, and sloughs
Active floodplains	
B1	Highly permeable sand and gravel
B2	Low to moderate permeability mud and silt
B3	Elevated natural levees
B4	Small active streams or stream alluvium
Barrier islands	
C1	Beach
C2	Fore-island dunes and vegetation-stabilized barrier flats
C3	Active dunes and sand blowouts
C4	Storm washover areas
C5	Tidal flats
Wetlands	
D1	Brackish- to salt-water marsh
D2	Fresh-water marsh
D3	Swamps
Man-made features	
E1	Made land and spoil
E2	Subaqueous spoil
E3	Aransas National Wildlife Refuge
Bays, lagoons, estuaries, and open Gulf	
F1	River-influenced bay
F2	Enclosed and/or restricted bay
F3	Open bay
F4	Tidally influenced open bay
F5	Tidal inlets and subaqueous tidal deltas
F6	Bay-margin sand and muddy sand
F7	Oyster reef, adjacent reef flank, and interreef areas
F8	Grassflats
F9	Upper shoreface
F10	Lower shoreface and open Gulf
F11	Local sand and shell beaches and berms
Aerial-photograph lineations	

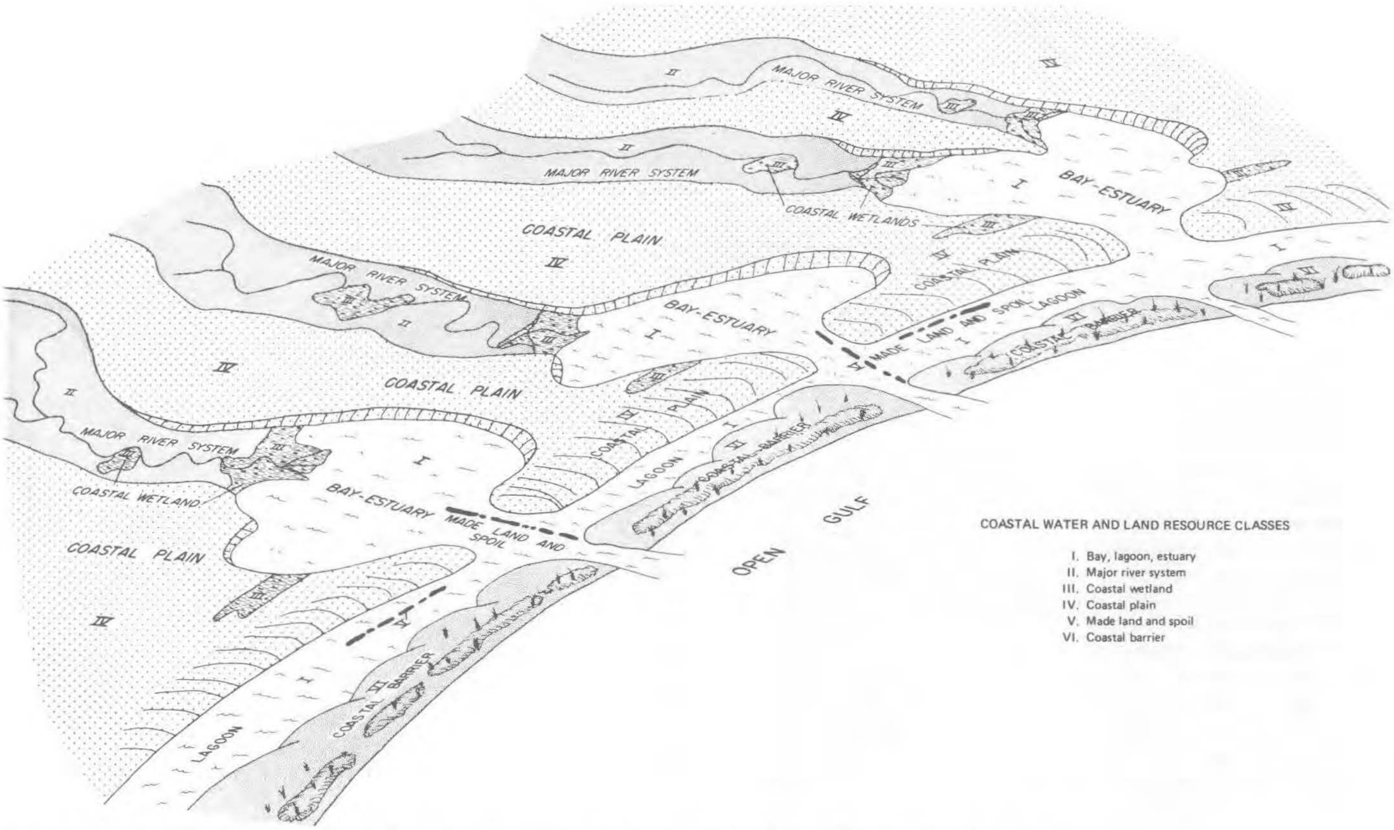

Figure 3. Schematic map of major natural systems, Texas Coastal Zone (modified from Brown and others, 1971).

according to its flood-prone character because this is of first-order significance with respect to man's use of the area. Units are grouped according to the natural systems in which they occur (table 2, fig. 3). Alternatively the units can be grouped according to related first-order environmental properties as shown in table 3. Continued reassessment of each factor related to man's use of the land assures completeness and consistency. A flow diagram illustrating the process of land and water resource analysis is presented in figure 4.

UTILITY

Analysis of land and water resources provides an environmental base line against which to measure the consequences of man's activities. This analysis is based on the natural characteristics of land and water resources without considering potential engineering improvements; of course, man is capable of engineering structures to compensate for adverse conditions. Knowledge of natural capability, however, provides a measure of the extent and scope of modifications needed to make a particular land or water area suitable for a given use. This information is particularly useful in the planning and development stages where there are more alternatives. An inventory of land and water resources is valuable, therefore, in selecting areas that are best suited for a particular activity. Recognizing sensitive environments helps planners to minimize the impact of development on critical resources, such as ground- and surface-water reservoirs, biologically productive areas, and natural storm barriers.

Thus, consideration of land and water resources promotes conservation of valuable resources, maintenance of environmental quality, and balanced use of natural resources for residential and industrial development and recreation. Consideration of the characteristics of land and water also helps to prevent problems by providing an early warning of hazardous or otherwise undesirable conditions that may require expensive solutions. Specific characteristics or processes that are of interest can be isolated through the use of special-purpose maps, as shown in figure 4. Construction of special-purpose maps is explained in a later section.

KINDS OF RESOURCE UNITS

Forty land and water resources were defined in the Corpus Christi area (table 3). These include (1) physical units—geologic substrate and soils units where the characteristics of the materials are most important; (2) process units—tidal inlets, hurricane surge channels, and floodplains where active physical processes such as erosion, deposition, and flooding are dominant; (3) biologic units—reefs, marshes, and grassflats where biologic activity and habitation are of primary significance; (4) man-made units—spoil heaps, made land, and wildlife preserves where man's activity has resulted in important environmental modification; and (5) water units—where the nature and the distribution of sediment substrate, salinity patterns, circulation, turbidity, fresh-water influx, biologic communities, and water chemistry are the important parameters. These units were in turn grouped into natural systems (tables 2 and 3). The natural systems are (A) Coastal Plain; (B) active floodplains; (C) barrier islands; (D) wetlands; (E) man-made features; and (F) bays, lagoons, estuaries, and open Gulf.

A. Coastal Plain

Sediments composing the Coastal Plain accumulated in Pleistocene and Holocene rivers, deltas, and coastal barrier island-shoreline environments. During one or more of the interglacial periods of the Pleistocene,

Table 3. Comparison of land and water resources classified by natural systems with land and water resources classified by first-order environmental properties.

	Hydrologic units	Process units	Physical-property units	Biologic units	Man-made units	Bay, lagoon, and estuary units
Coastal Plain						
A1 Highly permeable recharge sand	X					
A2 Moderately to highly permeable recharge sand	X					
A3 Moderately permeable sand and silt			X			
A4 Mud-veneered, moderately to highly permeable sand			X			
A5 Mud-veneered, moderately permeable sand and silt			X			
A6 Low to moderately permeable sandy mud with moderately permeable sand veneer			X			
A7 Sand-veneered, low-permeability mud			X			
A8 Low-permeability mud			X			
A9 Mixed mud and sand with local mud-filled channels			X			
A10 Mud-filled channels, beach swales, and topographic lows		X				
A11 Calichified sand			X			
A12 Lakes, ponds, sloughs, and streams	X					
A13 Ephemeral lakes, ponds, and sloughs	X					
Active floodplains						
B1 Highly permeable sand and gravel		X				
B2 Low to moderate permeability mud and silt		X				
B3 Elevated natural levees		X				
B4 Small active streams or stream alluvium		X				
Barrier islands						
C1 Beach		X				
C2 Fore-island dunes and vegetation-stabilized barrier flats	X	X				
C3 Active dunes and sand blowouts	X	X				
C4 Storm washover areas		X				
C5 Tidal flats		X				
Wetlands						
D1 Brackish- to salt-water marsh				X		
D2 Fresh-water marsh				X		
D3 Swamps				X		
Man-made features						
E1 Made land and spoil					X	
E2 Subaqueous spoil					X	
E3 Aransas National Wildlife Refuge					X	
Bays, lagoons, estuaries, and open Gulf						
F1 River-influenced bay						X
F2 Enclosed and/or restricted bay						X
F3 Open bay						X
F4 Tidally influenced open bay						X
F5 Tidal inlets and subaqueous tidal deltas		X				
F6 Bay-margin sand and muddy sand		X				
F7 Oyster reef, adjacent reef flank, and interreef areas				X		
F8 Grassflats				X		
F9 Upper shoreface		X				
F10 Lower shoreface and open Gulf		X				
F11 Local sand and shell beaches and berms		X				

rivers transported large quantities of sand, silt, and clay from the interior of Texas to deltas and embayments on the ancient Gulf shoreline. Long, narrow barrier islands or strandplains were also present along the ancient shoreline. The processes that were active during sedimentation resulted in a variety of deposits, each with unique characteristics. Natural carrying capacity is determined primarily by the physical, hydrological, and biological aspects of the different land and water areas.

Dryland farming is the dominant land use in Nueces and San Patricio Counties where muddy soils predominate. In the western half of San Patricio County and, to a lesser extent, in northwestern Nueces County, some of the farmland is irrigated, principally with ground water. In Aransas and Refugio Counties, most of the land is underlain by sand or muddy sand and is used as rangeland-pastureland. Locally, muddy soils are cultivated where they are sufficiently well drained. Thirteen resource units have been recognized in the Coastal Plain.

B. Active Floodplains

Floodplains of the Nueces, Aransas, San Antonio, and Mission Rivers, and of the numerous creeks that cross the Coastal Plain in the Corpus Christi area are active, dynamic environments. The natural capability of the floodplains is determined by their susceptibility to frequent flooding and erosion as well as by their physical and biological characteristics. Floodplains along the major rivers have been built over the last 4,500 to 18,000 years in scallop-shaped valleys deeply incised into Coastal Plain sediments during the last glacial event. The valleys have been only partly filled, and the drowned lower portions are now part of Nueces, Corpus Christi, Copano, Mission, and San Antonio Bays.

Normal stream processes that have built the floodplains are still occurring. Most of the time when stream flow is low, very little sediment is carried or eroded by streams. During and after storms and in times of rising water, however, streams carry considerable amounts of sediment that have been contributed by tributaries and eroded from channel banks. Flood water that overtops stream banks loses velocity as it spreads over the broad floodbasin adjacent to the channel and deposits its sediment load. If channel-bank erosion is severe during floods, the streams may migrate to a new position.

Floodplain sediments are composed of mud, silt, sand, and some gravel. Several kinds of deposits record past flooding and channel migration: sandy point-bar deposits commonly form along the inside banks of stream beds; raised levees composed of sand, silt, and mud line stream margins; and muddy overbank and floodbasin deposits lie in topographic lows and abandoned segments of the channel course between the levees and the valley walls.

Smaller creeks have also cut into the Coastal Plain sediments and are actively extending their channels through headward erosion. Examples are Oso, Melon, Copano, Petronila, and Chiltipin Creeks. Most of the time these streams are dry or barely flowing. During and shortly after storms, however, the creeks can become bankfull torrents. While in flood, the streams remove material that has slumped off the soft steep banks or has been brought in by slopewash. Large volumes of eroded Coastal Plain sediment are moved along these creeks to rivers, bays, estuaries, and marshes during periods of high rainfall. These creeks are a significant source of sediment entering coastal waters each year.

Many small streams in Nueces, San Patricio, and parts of Refugio Counties have had all or portions of their courses straightened or channelized. New channels have been dug to alleviate flooding of flat farmlands, and these also commonly empty into the small creeks. The artificial drainage system does reduce flooding upstream, or at least helps drain valuable farmland, but at the cost of increasing peak discharge downstream, and of greater rates of erosion where channel banks are soft, unlined, or unvegetated. The drainage channels may also lead to lowering of the water table in certain areas by reducing time available for recharge. Four distinct capability units have been recognized in active floodplains.

C. Barrier Islands

Barrier islands lie offshore and parallel to much of the Texas coast. St. Joseph Island is the northernmost island in the Corpus Christi area, lying between Cedar Bayou and Aransas Pass. The island is from 1 to 5 miles wide and is about 23 miles long. Mustang Island lies between Aransas Pass and Corpus Christi Pass (closed). This island is about 18 miles long and averages 2 miles wide. Padre Island is the longest and southernmost of the Texas barrier islands. Only the northern tip, which is approximately 2 miles wide, is included in the Corpus Christi area.

The barrier islands are Holocene and Modern in age and have been built primarily by Gulfward accretion since sea level reached its present position about 4,500 years before present (B.P.). Landward of the islands lie numerous bays, estuaries, and lagoons; seaward of the barrier islands is the open Gulf of Mexico.

Sand and shell are dominant constituents of the islands. Beaches, fore-island dunes, vegetated barrier flats, active dunes and sand blowouts, tidal flats, and hurricane-surge channels are the capability components of the barrier-island system. Salt- and fresh-water marshes also occur on barrier islands; they are discussed under the wetlands category. All environments exist in a delicately balanced state of dynamic equilibrium. Alteration of one environment can strongly influence and lead to changes in other environments.

Barrier islands have three important functions: (1) as a first-line defense against the effects of storm-driven tides and hurricane surge, (2) as a source of fresh to moderately fresh ground water, and (3) as a site of extensive and varied recreation and second-home development. Of these functions, protection of the more populous mainland coast from the full fury of hurricanes is by far the most important. Tropical storms, including hurricanes, strike the Texas coast on an average of once every 1.5 years (Hayes, 1967). Since 1900, at least four hurricanes, including Hurricane Carla in 1961 and Hurricane Celia in 1970 have passed through or near the Corpus Christi area. Barrier islands, beaches, and dunes absorb much of the effect of these severe storms, blocking high waves and slowing spillover into the bays and estuaries. This in turn tends to reduce flooding and damage on the mainland.

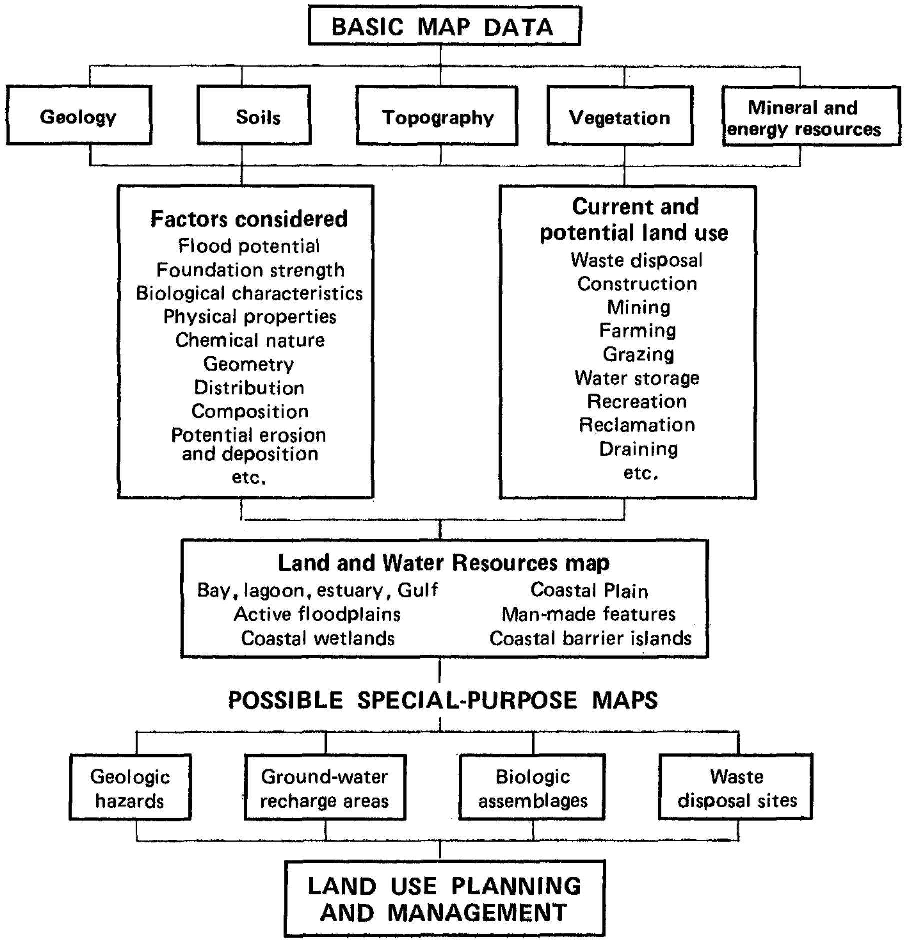

Figure 4. Flow diagram illustrating analysis of land and water resources (modified from Kier, 1974).

Vegetative cover on dunes and barrier flats is critical to the stability of barrier islands. Without stabilization provided by vegetation, loose sand that composes barrier islands would be washed or blown into the bays by storms or even by the daily wind regime, and the islands would quickly be leveled. The vegetation is extremely delicate. Once destroyed, the vegetation is slow to become reestablished, particularly in arid south-central Texas.

Barrier islands are also local sources of fresh to brackish water. At least four wells operating on Mustang and St. Joseph Islands produce water with less than 3,000 mg/l total dissolved solids (TDS). The density difference between sea water and fresh water recharged by precipitation falling on the islands confines fresh water to a lens beneath the barrier islands. Downward and outward movement of the fresh water prevents salt-water intrusion. High permeability of barrier-island sand assures that virtually all precipitation, the only natural source of fresh water on barrier islands, is contributed to the ground-water system.

Brackish-water conditions in the barrier island aquifer develop when rainfall is insufficient to dilute or flush salts that accumulate from storm surge and the ever-present salt spray, and by gradual mixing along the fresh-water/salt-water interface. Ground water under the barrier islands in the Corpus Christi area contains up to 10,000 mg/l TDS, most of which is sodium chloride.

A perched aquifer such as a barrier island aquifer can easily be polluted by contaminants from waste disposal sites, holding ponds, sludge pits, or septic tanks; effluent or leachate will enter the ground-water system. Once the aquifer is polluted, rainfall is the only source of clean water available to flush the aquifer. Along the semiarid south-central Texas coast, rainfall may be inadequate to accomplish this.

Large tracts of the barrier islands are being subdivided and developed into first- and second-home recreational communities. New motels, condominiums, and marinas are being constructed near Port Aransas, along Corpus Christi and Packery Channels, and in the center of Mustang Island. Residential and commercial developments on barrier islands risk damage by floods and high winds. Should the dunes be breached, storm tides will inundate low-lying areas. Raised water levels in the bays from sea water pumped through tidal passes (F-5) and across washover areas (C-4) and from high rainfall runoff from the mainland can add to flooding. Fast-moving flood waters can quickly erode the loose sand, removing foundation support. Only if foundation pilings, which elevate structures above flood levels, are sunk deeply into the sand can damage from sand erosion be limited. Pilings also provide an anchor to counter the forces of high winds.

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. There are five resource units in the barrier-island system.

D. Wetlands

Coastal wetlands form a unique natural system characterized by their dominant vegetation types and overall biologic productivity. These are the environments that serve as habitats and nursery grounds for many game and commercially valuable fish and animals. Resource components recognized in the wetland system are (1) brackish- to salt-water marsh, (2) fresh-water marsh, and (3) swamp. Where brackish- to salt-water marsh is mapped adjacent to fresh-water marsh, the boundary is interpretational and may vary from time to time reflecting long-term climatic fluctuations or subsidence of the substrate.

E. Man-Made Features

Over the past 100 years, man has made many alterations in coastal environments and has created new environments. The characteristics of these altered and new environments are generally variable, but on the whole they are distinctive in that man-made and modified areas have their own special attributes and limitations. Resource units described here are subaerial spoil and other made land, subaqueous spoil, and the Aransas National Wildlife Refuge. Man-made features such as canals and reservoirs were included with small coastal lakes (A-12) under the Coastal Plain system. Culturally defined entities, other than the preserve, are excluded, although generalized areas of urban buildup are shown for reference on the map accompanying this report.

F. Bays, Lagoons, Estuaries, and Open Gulf

Bays, lagoons, and estuaries are shallow water bodies occupying drowned portions of ancient river valleys and elongate lows between the modern barrier islands and the mainland. Seven water resource units were delineated in the bay, estuary, and lagoon environments: river-influenced bay; enclosed and/or restricted bay; open bay; tidally influenced open bay; bay-margin sand and muddy sand; grassflats; and oyster reefs, adjacent reef flank, and interreef areas. One land resource unit, local sand and shell beaches and berms, was also delineated. Two water resource units, the upper shoreface and the lower shoreface and open Gulf shelf, were mapped in the Gulf environments. One water resource unit, tidal inlets and tidal deltas, is transitional between the open Gulf and bay environments.

All of these environments are dynamic, and their boundaries change with variations in ambient conditions. Geologically, bays are evolving and transient, displaying slow but natural changes in shoreline positions and water depths. Biologically, bays, lagoons, and estuaries and fringing marshes are highly productive, delicately balanced subsystems that are essential to the life cycles of many commercially valuable marine organisms. Chemically, the water masses are highly variable and susceptible to the external influence of man's activities in the shallow waters and on nearby land.

The quality of the estuarine environment is largely dependent on inflow from rivers. Nutrients and debris from the rivers provide a considerable amount of food for organisms in the bays, and some biota need fresh- to brackish-water conditions to survive. Flood waters from rivers help to flush the bays periodically and to prevent buildup of contaminants that sluggish tidal flow cannot remove. Significant reductions in fresh-water influx by damming rivers or by withdrawing large quantities of fresh water may impair bay quality and biologic productivity. The importance of fresh-water inflow to estuarine quality must be balanced against (1) potential flood control, (2) water supply, (3) recreational value of artificial lakes, and (4) potential use of reservoir water for maintaining fresh-water inflow to the bays during droughts, when salinities, water temperatures, and pollutants can reach dangerous levels. Communication between the bays and Gulf waters through tidal channels is also essential to maintain productive environments.

Boundaries between bay, lagoon, and estuary units are those interpreted in part from photomosaics constructed from late 1950's photographs, and in part from observed circulation and salinity patterns in the bays and estuaries. As much as possible, more recent photographs and coastal charts were used to update the information. Many boundaries, such as those between the open bay and the tidally influenced open bay, are gradational and are subject to rapid and sudden shifts with short-term weather conditions. This should be considered in evaluating the characteristics, limitations, and possible uses of the bay, estuarine, and lagoonal environments.

The full-color land and water capability map of Nueces, San Patricio, Refugio, and Aransas Counties shows, in addition to the distribution of land and water units, cultural features in the area, urban concentrations, surface lineations (taken from aerial photographs), and topography and bathymetry. The units are described on the map. More extensive information including limiting factors, use considerations, and natural suitability of the units is contained in table 4 (in pocket).

DESCRIPTION OF AREA

GEOLOGY[1]

Sedimentary materials in the Corpus Christi area were deposited by formerly and presently active geologic processes in delta, fan, river, bay-estuarine, and barrier-island-shoreline systems (fig. 5). The oldest substrate in the Corpus Christi area, A-11, was deposited in a fan-like environment at the end of the Pliocene Epoch or near the beginning of the Pleistocene Epoch (approximately 3 million years ago). Younger Pleistocene-age deposits (3 million years to approximately 18,000 years old) compose most of the Coastal Plain. Units A-2 through A-9, and some of unit A-10 accumulated in river, delta, and delta-margin environments during one of the interglacial intervals—probably the Sangamon, according to Wilkinson and others (1975). Figure 6 depicts the time periods, terminology, and relative sea-level changes associated with glacial and interglacial stages.

During early Wisconsin glaciation (fig. 6), the last major period of glaciation, a considerable amount of the world's water was frozen on the continents. Sea level during this time was as much as 450 feet lower than it is today. The ancestral Nueces, Aransas, Mission, and San Antonio Rivers cut deeply into the Coastal Plain and discharged sediment far out on the continental shelf, approximately 50 miles out from the present shoreline.

Between early and late Wisconsin glacial events, sea level apparently returned to today's level. Waves and marine currents reworked the older Sangamon delta deposits, and well-sorted, fine-grained sand (A-1) accumulated in a barrier-island or shoreline environment. Discontinuous lakes and lagoons developed landward of these deposits.

Beginning about 50,000 to 60,000 years ago, the continental glaciers again advanced. By about 30,000 years ago, late Wisconsin glaciation had reached its maximum extent, and sea level was approximately 400 feet lower than it is today. The rivers crossing the Coastal Plain again cut downward; tributaries to these rivers formed the valleys now occupied by Oso, Port, and St. Charles Bays.

About 18,000 years ago, at the beginning of the Holocene, sea level began to rise gradually and haltingly as the last period of glaciation diminished. River valleys began to fill with sediment. On the balance, though, deposition could not keep pace with the rise in sea level, and the lower portions of the entrenched valleys were drowned. Shorelines of the modern bays and estuaries commonly reflect the position of old meander scars.

Modern processes became active about 4,500 years ago. Since then, sea level has

[1]Information mostly from Brown and others (1976) and McGowen and others (1976).

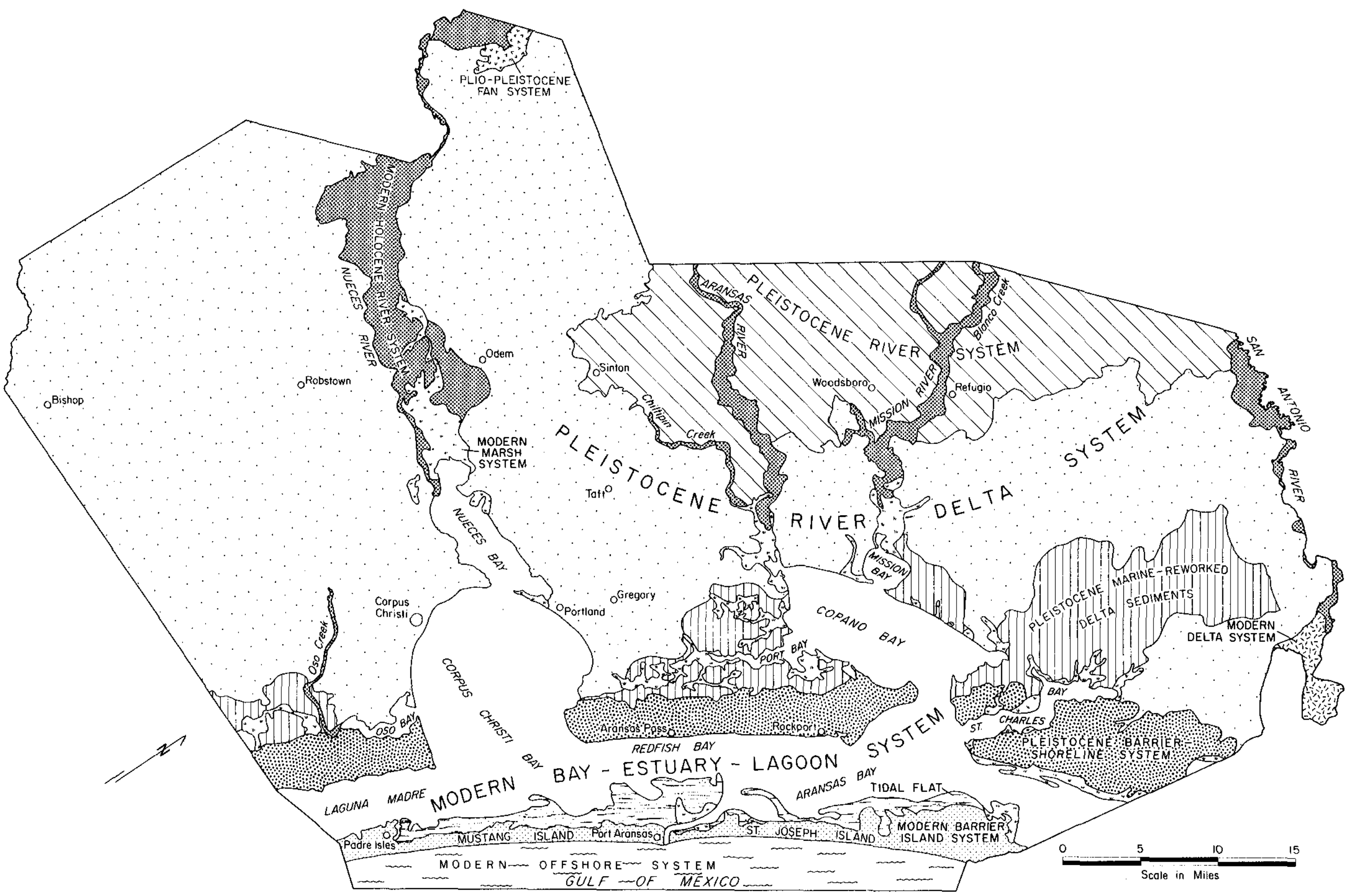

Figure 5 Natural systems of the Corpus Christi area. These systems are composed of genetically related environments, sedimentary substrates, biologic assemblages, and areas where physical processes are dominant.

Table 5. Characteristic range (determined by inspection) of arithmetic means for engineering properties of land resource units (after Kier and others, 1978).

	LAND RESOURCE UNITS								
	A1	A3	A6	A8	B	C	E	F	F11
Unit dry weight (pounds per ft^3)	94.6 -107.2*	99.0 -108.6	107.7 -110.1	96.1 -100.8	91.2 -103.5*	—	94.8 -102.2	96.0*-108.0*	93.0*-117.0*
Natural moisture content (percent dry weight)	17.0*- 28.0*	16.6 - 26.6	15.4 - 30.5	23.9 - 28.1	19.7 - 24.9	—	21.5 - 27.0	37.9 - 53.7*	14.0*- 30.0*
In-place vane shear (tons per ft^2)	0.3*- 1.2*	1.4*	—	0.4 - 1.2*	1.7*	—	0.3*- 0.6*	0.1*- 0.8*	0.1*- 1.0*
Standard penetrometer (blows per ft)	7.3 - 46.3	16.5 - 44.1	17.7 - 35.7	9.9 - 32.9	2.0*- 15.0*	20.4 -55.8	8.3 - 11.3	13.1*- 40.0*	11.4*- 16.3*
THD cone penetrometer (blows per ft)	—	37.3 - 85.8	20.4*- 49.7*	9.8*- 33.3	—	7.3*-76.0*	6.0*- 10.0*	4.0*- 9.0*	—
Unconfined compression Q_u (tons per ft^2)	0.1*- 1.8*	1.7 - 2.4	3.1 - 4.5	1.6 - 2.2	1.6 - 2.0	—	0.8 - 1.2	0.1*- 0.5*	0.1*- 1.0*
Triaxial shear Q_c (tons per ft^2)	0.1*- 0.4*	0.2*- 0.9*	0.3*- 1.5*	0.3*- 1.1*	0.4*- 1.2*	—	—	0.4*- 0.6*	0.6*
Triaxial phi (degrees)	23.0*- 37.0*	11.3*- 34.3*	7.1*- 39.0*	12.0*- 25.7*	7.9*- 13.1*	—	—	22.5*- 35.0*	23.5*
Hand penetrometer (tons per ft^2)	—	0.6*- 3.4*	1.5*- 2.3*	2.1 - 3.6	—	—	2.4*- 2.7*	0.2*- 0.4*	2.8*
Absorption swell (percent volume)	—	1.2*	1.5*- 3.9*	3.5 - 4.0	3.5*	—	—	—	—
Absorption pressure (tons per ft^2)	—	0.3*- 0.5*	0.4*- 2.6*	1.2 - 3.2	1.2*	—	—	—	—
Linear dry shrinkage (percent distance)	4.9*- 5.1*	2.7*- 9.5*	5.3*- 21.0*	15.9 - 24.2*	18.0*- 21.5*	—	7.1*- 10.0*	—	—
Liquid limit (percent dry weight)	22.5*- 31.0*	27.6 - 40.7*	38.3*- 59.4*	52.9 - 67.9	29.0*- 54.0*	—	31.0*- 51.2*	42.7 - 63.1	41.0*- 64.0*
Plastic limit (percent dry weight)	14.0*- 16.7*	15.3*- 20.5	18.3 - 20.3*	21.6 - 26.0	19.8*- 23.0*	—	15.0*- 20.6	22.4 - 28.3	15.0*- 18.0*
Plastic index	8.0*- 14.2*	9.0 - 31.5	19.9 - 22.8	30.8 - 42.6	20.4*- 24.0*	—	23.0 - 31.0*	20.3 - 34.8	26.0*- 46.0*
Percent gravel in sample	0.0*	0*- 6.0	—	0*- 3.0*	—	0.0	1.0*	—	0*
Percent sand in sample	91.3*- 92.0*	75.7*- 90.0*	—	32.0*- 47.7*	—	98.0 - 99.0*	26.0*	—	65.0*
Percent silt in sample	—	12.0*- 13.0*	13.7*- 29.7*	—	—	—	28.0*	—	—
Percent clay in sample	—	4.0*- 9.0*	31.3*- 44.2*	—	—	—	45.0*	—	—
Percent sample passing 200 sieve	7.1 - 12.6	22.6 - 39.3	53.3 - 59.4*	71.1 - 99.0*	36.0 - 40.1	1.0*- 11.5*	36.0*- 52.3	50.0*	8.0*- 40.0*
Vertical or horizontal permeability (cm/sec)	—	—	—	0.0	0.0	—	—	—	—
Void ratio (volume voids/volume solids)	—	0.7*	0.5*- 0.8*	0.6*- 0.9*	0.7*- 0.8*	—	—	—	—

*Indicates means calculated from fewer than 10 test values.

probably risen less than 15 feet, reaching its present position about 2,800 to 2,500 years ago (fig. 6). Several natural changes began to occur when sea level reached its present position: (1) the estuaries began to fill with sediment from rivers and streams, from bay margins and oyster reefs, and from the Gulf of Mexico; (2) small streams extended their courses headward; (3) offshore shoals coalesced into barrier islands, gradually restricting the bays and estuaries behind them—portions of these islands have begun to erode now; (4) marshes became established; and (5) wind action modified several sandy areas that were deposited earlier. The coastline in the Corpus Christi area will continue to change in response to Modern natural and man-induced processes.

PHYSICAL PROPERTIES OF LAND RESOURCE UNITS

Delineation of land and water resources allows qualitative assessment of relative physical properties of the land resource units. Through empirical observation and deductive reasoning, it is possible to infer, in general, such important physical parameters as corrosion potential, grain-size distribution, shrink-swell potential, and bearing strength. These qualitative statements are contained in the descriptions of the land and water resource units.

Land resource units that are physically defined can also be characterized using engineering test data. Engineering and soils testing firms and many public agencies involved in construction have extensive files of test data collected to assess site suitability and foundation requirements for commercial, institutional, and even residential developments. By considering all values for a particular kind of test performed on a given kind of land resource unit, a representative value or range of values can be derived that characterizes a physical property of that unit. Such a characterization can be extended to untested but similar resource areas on a local or perhaps even a regional scale, thus providing a measure of quantification without undertaking an expensive, systematic testing program.

Quantitative characterization of land resource units in the Corpus Christi area was investigated in a pilot study during 1972 and 1973. Results of this study, the approach used, and summaries of the data are reported in Kier and others (1978) and are not duplicated here. As an example, however, table 5 shows characteristic mean values of certain engineering tests for selected land resource units; figure 7 shows how the mean values for four kinds of tests vary with depth in two different land resource units. The complete results confirm the qualitative statements about physical properties in the descriptions of the land resource units.

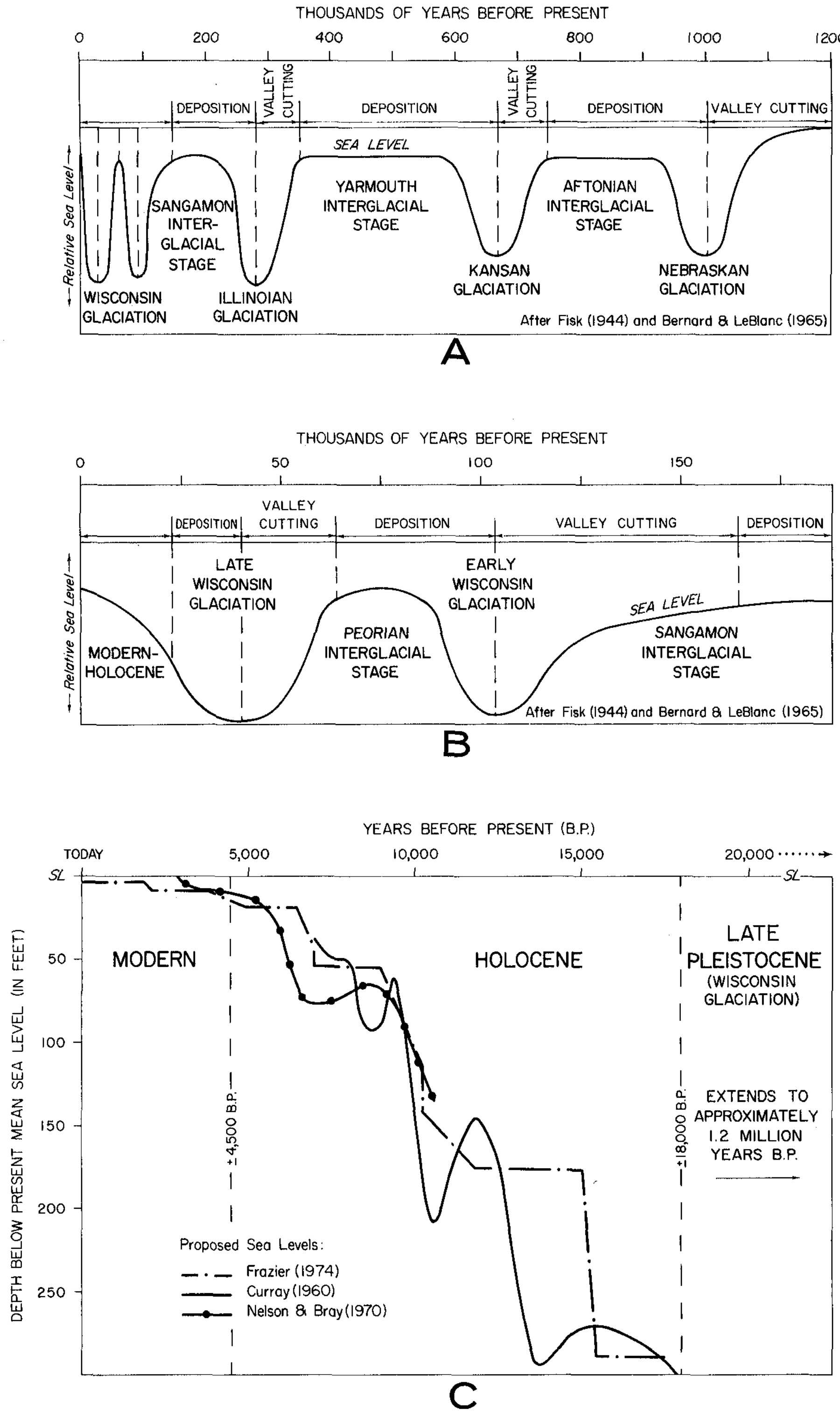

Figure 6. Sea-level changes related to glacial and interglacial stages. (A) Generalized Pleistocene sea-level variations and associated erosional and depositional episodes. (B) Generalized sea-level changes during late Wisconsin glaciation. (C) Proposed sea-level changes during the last 20,000 years (from various authors); sketch defines use of Modern and Holocene in text (after Brown and others, 1976, fig. 5, p. 15).

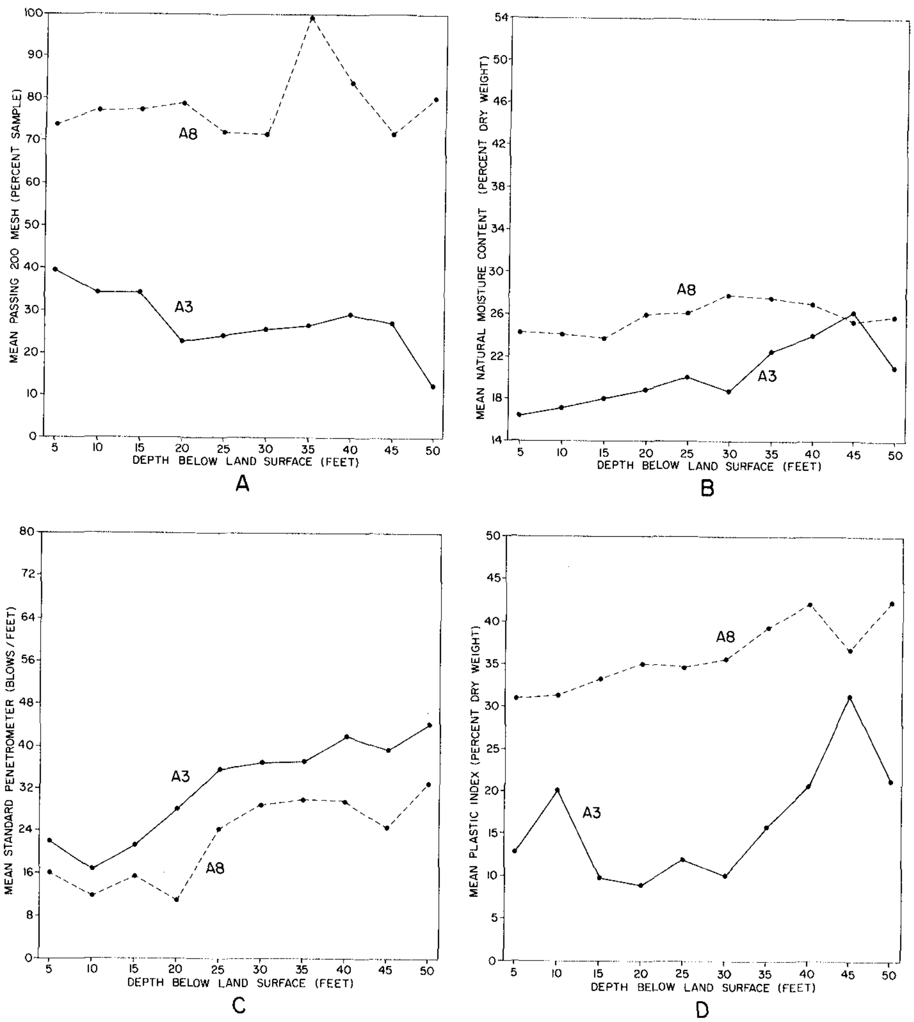

Figure 7. Variations with depth in mean values of selected engineering tests for land resource units A3 and A8 (after White and others, 1976; modified from original data by Kier and others, 1974b). (A) Percentage of sample passing through 300 mesh sieve. (B) Natural moisture content. (C) Standard penetrometer values. (D) Plasticity index values.

GROUND WATER

Approximately one-third of the demand for fresh water in the Corpus Christi area in the early 1970's was met by ground-water supplies (tables 6 and 7). Water used for rural-domestic and livestock purposes accounted for the largest proportion of ground-water pumpage—about 58 percent; water used for irrigation in Nueces and San Patricio Counties was the other large use—about 25 percent. Surface water, primarily from Lake Corpus Christi on the Nueces River near Mathis, is the principal fresh-water supply for the city of Corpus Christi. Numerous other nearby communities on the mainland and on Mustang and north Padre Islands also depend on Lake Corpus Christi for fresh water.

Ground-water resources of the Corpus Christi area were investigated as part of the study of land and water resources in the four counties (Kier and others, 1974b). Complete results of the investigation are reported in Woodman and others (1978) and are not duplicated here. In general, it appears that withdrawal of ground water can be increased by slightly over 50 percent on a sustained basis before pumpage exceeds recharge and ground water is removed from storage in the aquifer. Abundant quantities of good quality water, however, are not evenly distributed throughout the Corpus Christi area. Development of relatively shallow aquifers is most favorable in the northern and eastern parts of the Corpus Christi area (fig. 8) where the permeability of surface materials is higher and recharge of the aquifers is greater. Development of deeper, artesian aquifers is most favorable in the northern and western parts of the Corpus Christi area (fig. 9). Within local areas in southwestern Refugio and Nueces Counties extensive water use has led to significant (50 to 200 feet) declines in artesian pressure.

Table 6. Ground-water use, Corpus Christi area.*

COUNTY	AGRICULTURAL *Inventory year 1969*			INDUSTRIAL *Inventory year 1971*		MUNICIPAL *Inventory year 1971*		DOMESTIC-LIVESTOCK *(Estimated)*		TOTAL	
	Number of irrigated acres	Water use Acre feet/year	MGD	Water use Acre feet/year	MGD	Water use Acre feet/year	MGD	Water use Acre feet/year	MGD	Water use Acre feet/year	MGD
Aransas	0	0	0	2	0.1	198	0.2	600	0.5	800	0.7
Nueces	1,101	802	0.7	883	0.8	633	0.6	2,000	1.8	4,320	3.9
Refugio	0	0	0	485	0.4	860	0.7	900	0.8	3,240	1.9
San Patricio	13,634	6,097	5.4	175	0.2	1,422	1.3	12,400	11.0	20,100	18.0
TOTAL	14,700	6,900	6.1	1,540	1.5	3,110	2.8	15,900	14.1	27,500	24.5

- Totals are approximate because some of the pumpage, particularly for domestic and livestock purposes, is estimated.
- Pumpage figures are shown to the nearest 0.1 million gallon per day and to the nearest acre foot.
- Acre feet per year totals are rounded to *three significant figures.*

*Data from various sources, mostly Texas Water Development Board inventory files as presented in Kier and others (1974b) and Woodman (1975).

MINERAL AND ENERGY RESOURCES

Production of mineral and energy resources in Aransas, Nueces, San Patricio, and Refugio Counties differs significantly from county to county in terms of dollar value (fig. 10). Mineral production value has been substantially greater in Refugio County, where the value in 1974 was over $295.0 million, compared to $155.7 million in Nueces County, $56.6 million in San Patricio County, and $15.1 million in Aransas County. In general, from 1959 to 1973 the dollar value of mineral and energy resources produced has increased in Refugio and Nueces Counties, decreased in San Patricio County, and remained about the same in Aransas County (fig. 10). Rather dramatic increases in the value of resources produced occurred in Refugio and San Patricio Counties in 1974 (fig. 10).

Production of energy resources—natural gas, petroleum, and natural gas liquids—accounts for most of the resource income in all four counties (tables 8 and 9). (For the locations of oil and gas fields, see McGowen and others, 1976, and Brown and others, 1976; for a broader perspective on the distribution of energy resources, see St. Clair and others, 1975.) Production of other mineral resources has been rather limited in the four-county area. Commodities produced (Nueces and San Patricio Counties only; table 8) included cement, lime, stone, and clay. The clay was used in the production of cement, and the stone (carbonate material from calichified deposits) was used as road-base material. Sand and gravel are commonly extracted from local deposits along the Nueces River in Nueces and San Patricio Counties for use in concrete aggregate.

In the past, oystershells have been dredged from Nueces Bay primarily for use in construction materials; at times, oystershell production has exceeded 1 million cubic yards per year (Ryan, 1961). From 1969 to 1974 (fig. 11), 2,547,065 cubic yards of oystershells was dredged from Nueces Bay (Texas Parks and Wildlife shell dredger's reports, 1969 through 1974). Shell production was discontinued in Nueces Bay after 1974, however, because shell reserves were practically exhausted.

Available records show that Copano Bay is the only other bay in the four-county area in which oystershell material was produced. In 1964 and 1965, 125,000 cubic yards of oystershell was dredged from Copano Bay. The presence of live reefs in Copano and Aransas Bays has discouraged extensive shell production because Texas Parks and Wildlife regulations prohibit dredging close to live reefs. Studies of Corpus Christi Bay indicated that shell reserves are insignificant (Kerr, 1968).

County	mgd
Nueces	59.6
San Patricio	1.6
Refugio	0.0
Aransas	0.0
Total	**61.2**

Table 7. Surface-water demand in the Corpus Christi area (modified after Sherman and Malina, 1974, Table III-2, p. III-6).

Nueces	Natural gas, petroleum, natural gas liquids, lime, cement, and stone
San Patricio	Petroleum, natural gas, natural gas liquids, stone, and clays
Refugio	Petroleum, natural gas, natural gas liquids
Aransas	Natural gas, petroleum, natural gas liquids

Table 8. Mineral commodities produced by county in 1974, in order of production value (compiled from Hawkins and Girard, 1977).

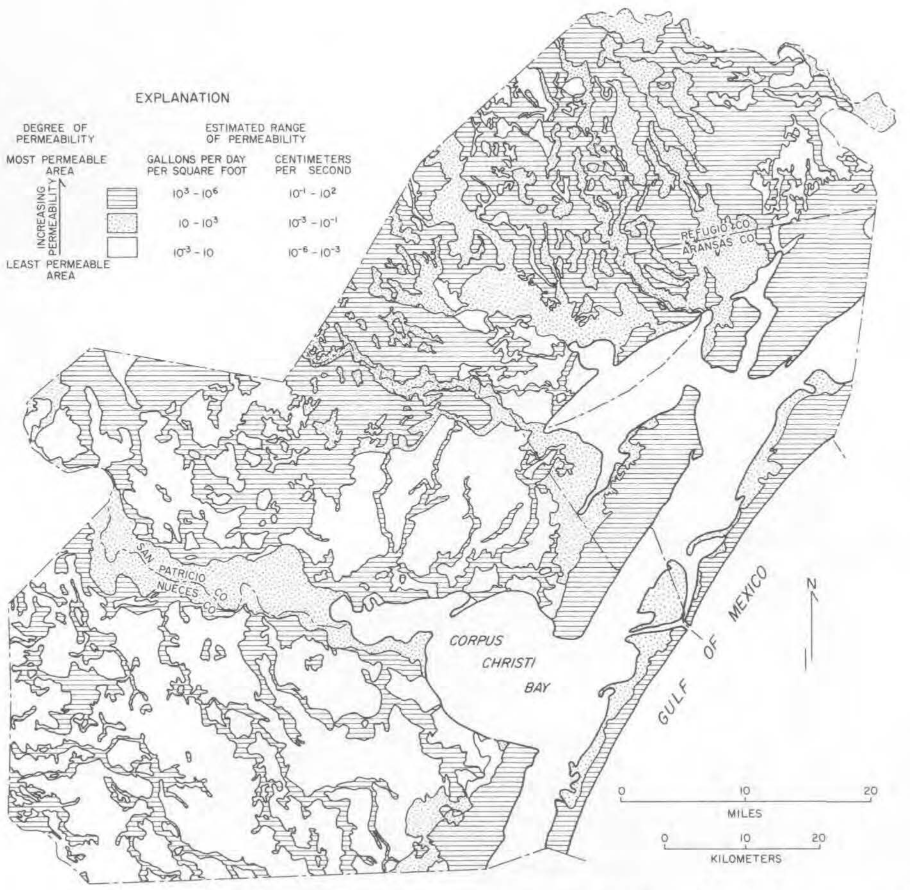

Figure 8. Relative permeabilities of surface materials, Corpus Christi area (after Woodman and others, 1978).

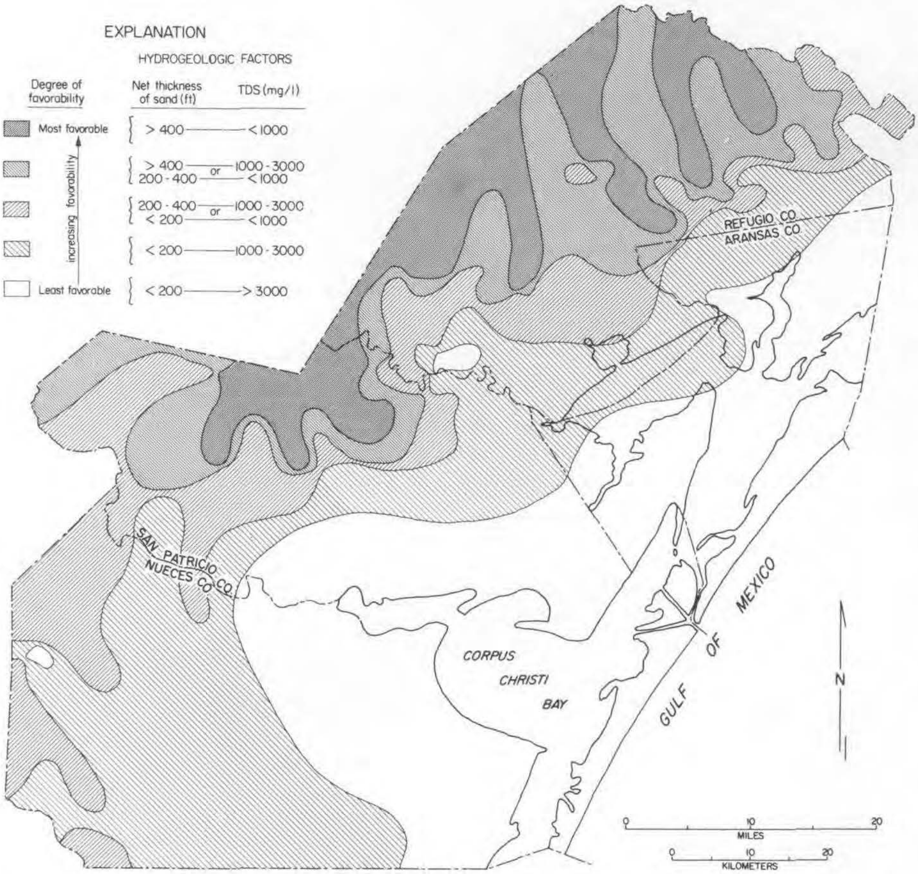

Figure 9. Relative favorability for future development of artesian ground water in the Corpus Christi area (after Woodman and others, 1978).

Table 9. Production statistics by county, 1976 (from the Railroad Commission of Texas, 1976, table 30).

	Gas, well gas (MCF)	Condensate (bbls)	Crude oil (bbls)	Casinghead gas (MCF)
Aransas	17,551,004	250,491	361,097	899,316
Nueces	155,910,079	634,625	4,239,798	10,475,204
Refugio	56,033,997	100,351	36,347,561	51,863,606
San Patricio	34,771,238	1,078,666	3,842,148	8,408,887
TOTAL	264,266,318	2,064,133	44,790,604	71,647,013

NATURAL HAZARDS

A variety of natural phenomena that affect the Corpus Christi area and particularly Mustang and north Padre Islands may be classified as hazards to man and his property. The most serious hazards are hurricane winds, storm-surge flooding, river flooding, and shoreline erosion. For a comprehensive treatment of these hazards, see Brown and others (1974) and White and others (in press).

Hurricanes

Hurricanes are severe tropical cyclones that have wind velocities of at least 74 mph (Dunn and Miller, 1964). Wind gusts may exceed sustained windspeeds by up to 50 percent. In the northern hemisphere, low-level winds on the right side (looking in the direction of storm movement) of the storm tend to have the greatest velocity because of the forward motion of the storm.

The diameter of hurricanes ranges up to 600 miles, and 100 to 200 miles is an average storm size. Carla, one of the largest storms to strike the Texas coast, was 300 miles in diameter; Celia, one of the smallest hurricanes, was only 80 miles in diameter. Forward motion of hurricanes averages 8 to 12 mph. Hurricanes last an average of 9 days, from the time winds reach hurricane strength to the time the storm begins to dissipate and windspeed falls below 74 mph.

As a hurricane approaches land, the barometric pressure falls, and the tide rises 3 to 4 feet above normal. This tidal rise or "forerunner" can occur along several hundred miles of coastline. When the hurricane reaches land, high onshore winds and low barometric pressure produce a storm surge. The highest surge generally occurs 10 to 20 miles to the right of where the eye crosses the coastline. Rarely, a series of "hurricane waves" or seiches forms. Such waves cause water levels to rise very rapidly. Exclusive of seiches, known hurricane surge heights in Texas have ranged as high as 22 feet at Port Lavaca on Lavaca Bay. Significant storm-surge heights measured at Port Aransas and their respective dates are listed in table 10.

Locally, hurricane surge builds high enough to wash over the islands. Areas of Mustang and north Padre Islands that are presently classified as active hurricane-washover channels and fans are Packery Channel, Newport Pass, and Corpus Christi Pass. Surficial features indicate that other washovers were active during the recent geologic past.

Major hurricane damage is the result of (a) salt-water flooding, (b) high waves, (c) fresh-water flooding, and (d) wind. Hurricane surge associated with Hurricane Carla, which had the most extensive storm surge documented in the Corpus Christi area, flooded about 294 square miles (McGowen and others, 1976, table 10, p. 91; Brown and others, 1976, table 10, p. 104). High storm waves superimposed on storm surge can reach unusually great heights. These waves of rapidly moving water, often with entrained debris, pound man-made structures and can quickly erode sediment beneath the structures. Prolonged torrential downpours from hurricanes, which can exceed 10 inches in 24 hours, cause creeks and rivers to flood. Rainfall associated with Hurricane Beulah exceeded 30 inches in some places over a 4- to 5-day period. Beulah aftermath rainfall along the central Texas coast ranged from 11 to 14 inches between September 19 and September 26, 1967 (U.S. Army Corps of Engineers, 1968). Land inundated in the Corpus Christi area by storm-surge and fresh-water flooding associated with Hurricane Beulah was approximately 249 square miles (McGowen and others, 1976, table 10, p. 91; Brown and others, 1976, table 10, p. 104).

Hurricane winds blowing at speeds up to 150 mph and with gusts that may exceed 180 mph do considerable damage to man-made structures. Such high winds, and particularly the gusts, impose extreme lateral loads on walls, upward suction on roofs, and rapidly changing pressure differentials between air inside and outside of the structures. Not uncommonly, tornadoes with estimated wind velocities of up to 500 mph occur during and immediately after hurricane passage. At least 115 tornadoes were associated with Hurricane Beulah (Brown and others, 1974).

Principal sources of damage from hurricanes may be caused by any one or more of the above characteristics of hurricanes. Carla, which passed over the north end of Matagorda Island in 1961, did most of her damage with storm surge and waves. Beulah, which made landfall near the Texas-Mexico border, produced extensive rains and fresh-water flooding in the flat South Texas country. Celia, which crossed directly over Port Aransas, caused most of her damage with sustained winds and gusts of very high velocity.

Two factors necessitate awareness of the hurricane hazard in the Corpus Christi area: (1) the inevitability of repeated hurricane impact and (2) the increase in development and accompanying population growth in low-lying areas, particularly the barrier islands. Hurricanes and other tropical cyclones strike the Texas coast on the average of once every 1.5 years (Hayes, 1967). From hurricane records covering 85 years (1886-1970), Simpson and Lawrence (1971) calculated the probability that a tropical cyclone will occur in any one year for 50-mile segments of the United States coast. Their data indicate that each year the central Texas coast, including the Corpus Christi area, has a 13-percent chance of being affected by some type of tropical cyclone. The chance that any hurricane will strike in any given year is 7 percent, whereas the probability that a great hurricane

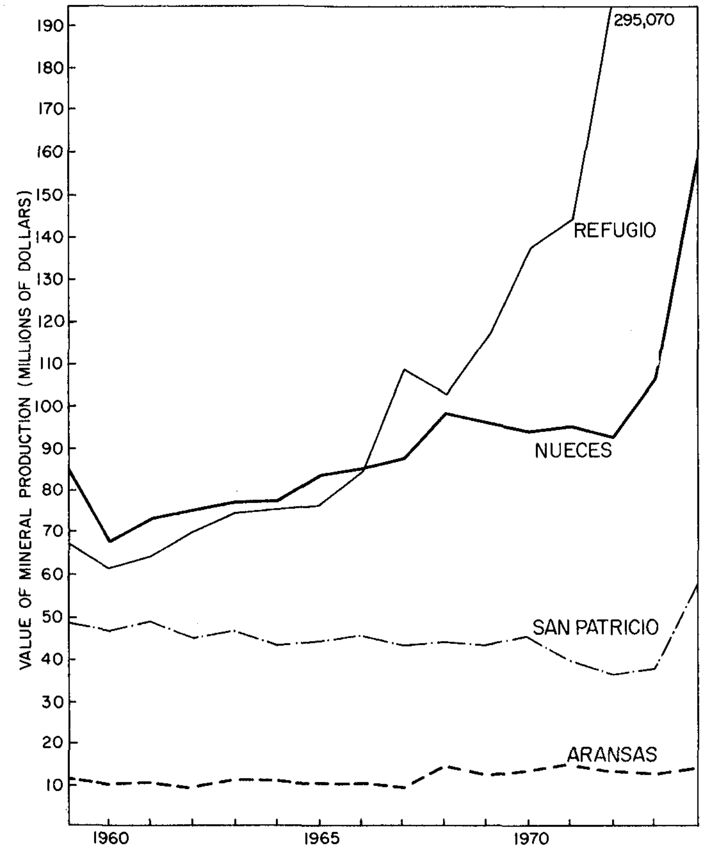

Figure 10. Value of mineral production by county, 1959-1974 (compiled from Netzeband and others, 1960–1969; Jones and others, 1970; Zaffarano and others, 1972; Wood and Girard, 1973; and Hawkins and Girard, 1977).

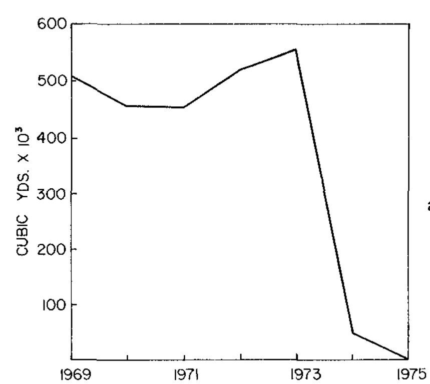

Figure 11. Oystershell production, Nueces Bay, 1969-1975 (compiled from Texas Parks and Wildlife Shell Dredger's Reports).

Table 10. Maximum hurricane surge heights in excess of 5 feet, recorded at Port Aransas, 1919 to 1974 (after White and others, in press, table 2).

Year	Surge height (feet)	Reference
1919	11.5	Price (1956)
1933	5.0	Price (1956)
1945	9.0	Bodine (1969)
1961	9.3	U.S. Army Corps of Engineers (1962)
1967	9.4	U.S. Army Corps of Engineers (1968)
1970	9.2	U.S. Army Corps of Engineers (1971)

will occur in any given year is 4 percent. Hurricane landfalls in the Corpus Christi area occurred in 1912, 1934, 1936, and 1970 (Celia) (Brown and others, 1974; Morton and Pieper, 1977). Other hurricanes with landfall elsewhere along the coast have also had great impact on the Corpus Christi area—notably the hurricanes of 1919, 1961 (Carla), and 1967 (Beulah).

Since 1900, over 6,500 people have lost their lives in hurricanes (6,000 in one storm alone that struck Galveston in 1900). An estimated $1.3 billion in damages has been caused by all the hurricanes that have struck the Texas coast (data from National Hurricane Center *in* Brown and others, 1974). Although deaths attributable to hurricanes have been declining because of increasingly better forecasting techniques and early warning procedures, property damage is increasing. Damage estimated at $1.1 billion or 85 percent of the total damage mentioned above, has resulted since 1960. At the level of investment in 1977, a modest-sized hurricane can be expected to cause hundreds of millions of dollars in damages. With increasing development of the coastline, the dollar value of property damaged or destroyed by a hurricane is bound to increase.

Flooding

In addition to flooding caused by hurricane surge and aftermath rainfalls mentioned previously, flooding by salt water and fresh water can be associated with frontal storms or "northers" and normal instability of tropical air masses during the spring, summer, and early fall. Strong, persistent winds before and after frontal passage can drive considerable amounts of water, called wind tides, onto low-lying areas. Rainfall from northers and other storms can cause flooding as streams overflow their banks and as water accumulates in poorly drained depressions (particularly units A-9 and A-10). Because of the low relief in the area, rainfall at the rate of several inches per hour or total rainfall of several inches or more over a few days is sufficient to cause flooding. Even small thunderstorms can cause small streams to flood (B-4).

Shoreline Erosion

Shorelines along the Gulf and bays respond to the interaction of sediment supply, storms, sea-level changes, and man's activities producing net gain, net loss, or no change in the land area. Historical monitoring of shorelines in the Corpus Christi area (see Kier and others, 1974b; White and others, 1977; and especially Morton and Pieper, 1976 and 1977) indicates that during the last century net Gulf and bay shoreline changes, although erosional overall, have been relatively stable compared with shorelines along other parts of the Texas coast. Only locally do long- and short-term rates of erosion along the Gulf exceed 10 feet per year. Erosional bay shorelines appear to be retreating at lesser rates.

Relative stability of the Gulf shoreline in the Corpus Christi area is apparently due largely to convergence of longshore drift between St. Joseph Island and central Padre Island. Because of the interrelationship between the predominant southeasterly winds in the northwestern Gulf of Mexico and the configuration of the shoreline at the Coastal Bend, longshore currents caused by waves impinging on the coast at an angle meet between latitudes 27° N. and 28° N. (Bullard, 1942; Lohse, 1952; and Curray, 1960). Sediment carried by these currents tends to accumulate within this zone of convergence helping to offset losses of sand offshore and into the bays. Most of the sediment discharged by local rivers and streams in the area is trapped in the bays and estuaries. If sand supplied by longshore transport updrift and downdrift is reduced, Gulfward shoreline erosion may increase.

Land-Surface Subsidence

Land-surface subsidence is a common problem along the upper Texas coast. Subsidence has caused submergence of some land areas, including residential areas, and has increased susceptibility of other land areas to flooding, either from storm tides or from rain runoff. Locally, parts of Houston have subsided as much as 8.5 feet (Brown and others, 1974). The principal cause of the subsidence is withdrawal of artesian ground water, and the corresponding decline of the piezometric surface. As the hydraulic pressure is reduced in sand aquifers, water trapped in interstratified clays drains slowly into the sands, and the clays compact. This in turn allows the ground surface to subside (Turner, Collie, and Braden, Inc., 1966; Gabrysch, 1969; and Brown and others, 1974).

In the Corpus Christi area, only minor subsidence has occurred. Leveling surveys conducted in 1942 and 1950 by the U.S. Coast and Geodetic Survey (now the National Ocean Survey of the National Oceanic and Atmospheric Administration) indicate as much as 3 feet of subsidence centered near Clarkwood, northeast of Corpus Christi, and extending outward as much as 6 miles (Gustavson and Kreitler, 1976; Brown and others, 1974). Interstitial pressure declines associated with production in the Saxet oil field, particularly natural gas production, are the probable cause. The subsidence is definitely not due to withdrawal of fresh artesian ground water because there are no water wells in the vicinity.

In Nueces County near Bishop, where subsidence might be expected because of relatively large declines in the piezometric surface, subsidence indicated by leveling surveys in 1917 and 1951 is insignificant (C.W. Kreitler, 1976, personal communication). Most of the ground-water pumpage at Bishop, however, has occurred since 1951.

Faulting

The only active fault known in the Corpus Christi area occurs in the Saxet oil field and is apparently associated with the subsidence near Clarkwood. A 6-foot scarp has appeared along the trace of a regional subsurface fault extrapolated to the surface (Gustavson and Kreitler, 1976). Movement along the fault has occurred since production in the field began (W.A. Price, personal communication in Gustavson and Kreitler, 1976).

Aerial-photograph lineations interpreted to indicate the surface traces of potentially active faults or fracture zones are shown on the Land and Water Resources map. In the Houston area many known active faults correspond to aerial-photograph lineations (Kreitler, 1976). To date, no lineation mapped in the Corpus Christi area shows evidence of active movement, such as recurring breaks in highway pavement. The active fault in the Saxet oil field does not correspond to a mapped lineation; the fault trace, although visible in the aerial photomosaics, is too short to have been mapped as a lineation. Therefore, movement along faults does not appear to present a significant hazard in the Corpus Christi area at this time. Nevertheless, analogy with the Houston area suggests that it is prudent to identify whether any new construction will occur near a lineation, and possibly to design foundations to withstand some differential movement.

LAND AND WATER RESOURCES MAP

USE OF MAP[2]

The map of the Corpus Christi area has been designed to be self-explanatory, but a brief discussion of how to read and interpret the map may aid the user.

Orientation

The Corpus Christi area has been oriented so that the Gulf shoreline is parallel to the bottom of the paper. An index map in the lower left corner shows the location of the area in Texas; the index map is oriented with north to the top. The precise orientation of the map is given by the latitude and longitude lines plotted on the map. The magnetic declination in 1971 is given in the lower right corner of the map.

Coordinate Systems

Two coordinate systems are shown on the map to permit accurate location of any area or feature. Latitude and longitude in 15-minute increments are shown along the margins of the map; these lines may be projected across the map by connecting similar coordinates. Latitude lines run east to west parallel to the equator and refer to positions north of the equator. Numerical designations of latitude lines slope downward to the right of the map and vary from 27°45′ N. to 28°30′ N. Longitude lines run north to south from the poles and refer to positions west of the Prime Meridian at Greenwich, England. Numerical designations of longitude lines slope downward to the left on the map and vary from 97°00′ W. to 97°45′ W.

The Universal Transverse Mercator (UTM) grid is shown by blue lines crossing the map at intervals of 25,000 meters with blue tic marks at 5,000-meter intervals and coordinates at the map margin. Coordinate values refer to distance in meters from a central meridian and from the equator.

The UTM system is particularly useful for encoding data from the map for computer processing. Unlike the latitude and longitude system, UTM grids are rectilinear across a zone of the earth's surface, facilitating location of data points with a linear scale and computation of areal measurements (U.S. Departments of the Army and the Air Force, 1951). To accommodate rectilinear grids on a spherical surface, separate zones are defined every 6 degrees of longitude and every 8 degrees of latitude. Central meridians are given an arbitrary value of 500000 m E. The grid extends 3 degrees east and 3 degrees west of the central meridian; coordinate values increase to the east and decrease to the west. For example, the value 700000 m E is 200,000 meters east of the central meridian. North to south values increase away from the equator. Thus, the value 3075000 m N is 3,075,000 meters north of the equator.

[2]Modified from St. Clair and others, 1975.

Map Scale

The fractional scale of the Land and Water Resources map of the Corpus Christi area is 1:125,000. This means that 1 unit on the map equals 125,000 similar units on the ground. For example, 1 inch on the map equals 125,000 inches on the ground or approximately 2 statute miles (63,360 inches equals 1 statute mile). Graphic scales in statute miles, nautical miles, and kilometers are also shown on the map.

Topography and Bathymetry

Elevations and topographic configurations of the land surface are shown by solid and dashed contour lines which trace equal elevations above mean sea level. The contour interval, the vertical distance represented by successive contour lines, is 5 feet in most parts of the map and 10 feet where more detailed information was lacking or where the contour lines would be too crowded to be read if the smaller interval had been used.

Depths of the bay bottom and Gulf sea floor are shown by blue lines, called bathymetric lines, which trace equal depths below mean sea level. The vertical interval represented by the bathymetric miles is 6 feet; a 3-foot contour line is shown where depths of 3 feet occur along the bay shoreline.

Map Units

Land and water resource units on the map are characterized by unique colors, patterns, or both, and by a letter and number symbol such as A-3. The map explanation contains a brief description of each unit. Characteristics such as composition, engineering properties, use limitations, biologic characteristics, water-body characteristics, active processes, and current land use are presented where important.

Table 4 provides more detailed information about each land and water resource unit. The last four columns provide interpretations of the data presented in the other columns:

1. Economic potential—uses from which direct economic benefit may be derived, particularly if these uses are not widely known. Examples are extraction of **fill**, development of ground-water resources, and flood protection.
2. Limiting-use factors—characteristics of the land or water resource unit that would tend to limit or make difficult many uses of the area. Examples are susceptibility to soil heaving, susceptibility to flooding, and importance as a wildlife habitat.
3. Natural suitability—uses for which there are few or no limitations. For example, a unit with low permeability and low susceptibility to flooding may be naturally suitable for a solid-waste disposal operation or a holding pond.
4. Recommended-use considerations—measures for avoiding or alleviating potential problems associated with certain uses of the land. The problems generally result from the natural characteristics of the unit. For example, if construction is planned on a unit with high shrink-swell potential, this should be considered in the foundation design.

This information—economic potential, limiting-use factors, natural suitability, and recommended-use considerations—allows recognition and evaluation of potential uses in terms of inherent suitabilities and possible problems accompanying use. It must be clearly understood, however, that descriptions of the units and interpretations of uses and use limitations are based on analysis of general characteristics of land and water resources that are somewhat variable, and that these are natural characteristics and therefore do not reflect potential engineering modifications. Furthermore, the information is largely qualitative and empirical. Thus, the map descriptions and interpretations are a good planning tool and should help to chart best uses of the land and water resources, but site-specific investigations will still be necessary for some decisions, particularly if quantitative data are required.

Table 11 contains the areal extent in square miles and in acres of each resource unit by county, the percentage of the total area in each county occupied by the particular resource unit, and the areal extent of each resource unit in the entire four-county area. Computations were made by automated data processing techniques from data digitized manually using a point-count method. Point spacing was equivalent to 250 meters (approximately 0.15 mile; each point represents about 15.1 acres) along the coast and 500 meters (approximately 0.3 miles; each point represents about 62 acres) inland. Boundaries between the different density grids were arbitrarily located along 10,000-meter lines of the UTM system. For a complete description of the encoding process see Kier and others (1974a).

Table 12 summarizes in a matrix format natural use capabilities of the resource units for selected activities. Units are rated for each activity according to the potential for significant problems that could affect man or the environment. Valuations are based on natural capability of the units without considering special planning or engineering that could significantly improve the use potential of the unit.

Table 11. Areal measurements of land and water resource units in the Corpus Christi area.

Resource unit	Aransas County			Nueces County			Refugio County			San Patricio County			Total—Four-county area	
	Square miles	*Acres*	*% area*	*Square miles*	*Acres*	*% area*	*Square miles*	*Acres*	*% area*	*Square miles*	*Acres*	*% area*	*Square miles*	*Acres*
A1	89.6	57,340	17.2	27.7	17,731	2.46	3.3	2,085	0.40	18.2	11,678	2.64	138.8	88,834
A2	—	—	—	—	—	—	140.8	90,084	17.47	58.4	37,382	8.46	199.2	127,466
A3	40.2	25,739	7.7	204.5	130,887	18.14	202.2	129,396	25.10	177.0	113,299	25.64	623.9	399,321
A4	—	—	—	—	—	—	54.4	34,786	6.75	15.9	10,179	2.30	70.3	44,965
A5	29.8	19,067	5.7	8.4	5,351	0.74	20.3	12,975	2.52	3.3	2.105	0.48	61.8	39,498
A6	8.5	5,459	1.6	<0.1	60	0.01	91.4	58,527	11.35	—	—	—	100.0	64,046
A7	2.6	1,633	0.5	—	—	—	10.4	6,627	1.29	24.6	15,753	3.57	37.6	24,013
A8	0.6	358	0.1	465.4	297,855	41.27	65.4	41,860	8.12	259.5	166,070	37.58	790.9	506,143
A9	<0.1	62	0.0	—	—	—	72.3	46,293	8.98	4.3	2,726	0.62	76.7	49,081
A10	13.2	8,460	2.5	19.2	12,274	1.70	22.8	14,566	2.83	15.0	9,603	2.17	70.2	44,903
A11	—	—	—	—	—	—	—	—	—	5.1	3,272	0.74	5.1	3,272
A12	15.1	9,673	2.9	12.8	8,208	1.14	7.7	4,943	0.96	10.3	6,574	1.49	45.9	29,398
A13	—	—	—	—	—	—	3.3	2,101	0.41	—	—	—	3.3	2,101
B1	—	—	—	20.1	12,894	1.79	38.4	24,575	4.77	48.1	30,778	6.97	106.6	68,247
B2	—	—	—	3.0	1,905	0.26	7.8	5,020	0.97	4.9	3,166	0.72	15.7	10,091
B3	—	—	—	1.2	756	0.10	6.9	4,387	0.85	4.4	2,832	0.64	12.5	7,975
B4	1.1	731	0.2	15.6	9,961	1.38	12.4	7,909	1.53	12.6	8,043	1.82	41.7	26,644
C1	1.4	918	0.3	1.2	756	0.10	—	—	—	—	—	—	2.6	1,674
C2	14.9	9,565	2.9	15.6	9,976	1.38	—	—	—	—	—	—	30.5	19,541
C3	1.0	653	0.2	3.3	2,086	0.29	—	—	—	—	—	—	4.3	2,738
C4	17.5	11,182	3.4	5.4	3,461	0.48	—	—	—	—	—	—	22.9	14,643
C5	18.7	11,944	3.6	14.6	9,372	1.30	2.5	1,606	0.31	4.6	2,923	0.66	40.4	25,845
D1	21.1	13,530	4.1	1.8	1,134	0.16	7.8	5,005	0.97	10.5	6,725	1.52	41.2	26,394
D2	8.2	5,272	1.6	4.5	2,857	0.40	6.7	4,310	0.84	11.3	7,255	1.64	30.7	19,694
D3	—	—	—	—	—	—	0.7	417	0.08	0.4	257	0.06	1.1	674
E1	3.7	2,364	0.7	24.0	15,373	2.13	—	—	—	1.0	651	0.15	28.7	18,388
E2	5.4	3,484	1.0	17.2	11,034	1.53	—	—	—	—	—	—	22.6	14,518
F1	5.2	3,344	1.0	8.1	5,185	0.72	8.1	5,175	1.00	—	—	—	21.4	13,704
F2	60.1	38,491	11.5	19.6	12,561	1.74	14.2	9,098	1.76	<0.1	30	0.01	94.0	60,180
F3	55.0	35,179	10.5	101.7	65,118	9.02	0.1	77	0.01	—	—	—	156.8	100,374
F4	4.3	2,722	0.8	20.9	13,393	1.86	—	—	—	—	—	—	25.2	16,115
F5	4.6	2,924	0.9	6.7	4.308	0.60	—	—	—	<0.1	30	0.01	11.4	7,262
F6	16.5	10,560	3.2	10.1	6,485	0.90	2.3	1,467	0.28	—	—	—	28.9	18,512
F7	12.2	7,838	2.3	3.1	2,010	0.28	2.0	1,282	0.25	—	—	—	17.3	11,130
F8	11.2	7,138	2.1	38.9	24,911	3.45	0.1	93	0.02	<0.1	30	0.01	50.3	32,172
F9	4.0	2,566	0.8	3.8	2,403	0.33	—	—	—	—	—	—	7.8	4,969
F10	51.6	33,033	9.9	46.6	29,793	4.13	—	—	—	—	—	—	98.2	62,826
F11	3.7	2,364	0.7	2.6	1,632	0.23	1.4	911	0.18	0.8	500	0.11	8.5	5,407

Table 12. Use potential of land and water resource units, Corpus Christi area. Evaluations are based on natural capability which can be improved by engineering.

Explanation

- \+ Significant problems unlikely on vegetated barrier flat only—activities on fore-island dunes generally undesirable
- X Significant problems likely (will require special planning and engineering)
- — Use potential varies with resource units and federal restrictions
- O Possible problems
- (blank box) Significant problems unlikely
- ░ Not applicable

Land and water resource units	Liquid-waste disposal: Surface disposal of untreated liquid wastes	Liquid-waste disposal: Shallow subsurface disposal of untreated liquid wastes	Liquid-waste disposal: Maintenance of feed lots	Solid-waste disposal: Disposal of solid-waste materials	Shoreline construction: Construction of jetties, groins, and piers	Shoreline construction: Construction of storm barriers and/or seawalls	Coastal and inland construction: Light construction	Coastal and inland construction: Construction of highways (excluding causeways)	Coastal and inland construction: Heavy construction	Coastal, inland, and offshore construction: Flooding as a result of dam construction	Coastal, inland, and offshore construction: Construction of production platforms and other oil well development activities	Coastal, inland, and offshore construction: Placement of pipelines and/or subsurface cables	Coastal, inland, and offshore construction: 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
Coastal Plain																				
A1 Highly permeable recharge sand	X	X	X	X	░	░				O	O		O	X		░	X			X
A2 Moderately to highly permeable recharge sand	X	X	X	X	░	░				O	O		O	O		░	X			X
A3 Moderately permeable sand and silt	X	X	X	X	░	░					O		O	O		░	X			X
A4 Mud-veneered, moderately to highly permeable sand	X	X	X	X	░	░	O	O	O	O	O	O	O	O		░	O			X
A5 Mud-veneered, moderately permeable sand and silt	X	X	X	X	░	░	O	O	O		O	O	O	O		░	O			X
A6 Low to moderately permeable sandy mud with moderately permeable sand veneer	X	O	O	O	░	░			O		O	O				░	X			O
A7 Sand-veneered, low-permeability mud	X		O		░	░	O	O	O			O				░				O
A8 Low-permeability mud	O				░	░	O	O	O			O				░				O
A9 Mixed mud and sand with local mud-filled channels	X	X	X	X	░	░	O	O	O		O	O				░				X
A10 Mud-filled channels, beach swales, and topographic lows	X	X	X	X	░	░	O	O	O		O	O	O	O	O	O				X
A11 Calichified sand	O	O	O	O	░	░														O
A12 Lakes, ponds, sloughs, and streams	X	X	░	X	░	░	░	░	░		O	O	X	░	X	X	░			X
A13 Ephemeral lakes, ponds, and sloughs	X	X	X	X	░	░	X	X	X		O	O	O	O	O	░	░			X
Active floodplains																				
B1 Highly permeable sand and gravel	X	X	X	X	░	░	X	O	X	O	O	O	X	O	O	░	X			X
B2 Low to moderate permeability mud and silt	X	X	X	X	░	░	X	O	X	O	O	O	O		O	░	X			X
B3 Elevated natural levees	X	X	X	X	░	░	X	O	X	O	O	O	X	X	X	░	X			X
B4 Small active streams or stream alluvium	X	X	X	X	░	░	X	O	X	O	O	O	O	O	X	░	X			X
Barrier islands																				
C1 Beach	X	X	░	X	X	X	X	X	X	░	X	O	X	X	X	░	░	O		O
C2 Fore-island dunes and vegetation-stabilized barrier flats	X	X	X	X	░	X	+	+	+	░	+	O	X	X	X	░	X	X	+	X
C3 Active dunes and sand blowouts	X	X	X	X	X	X	O	O	X	░	O	O	X	O	O	░	░	X	O	X
C4 Storm washover areas	X	X	X	X	X	X	X	X	X	░	X	X	X	O	X	░	░	O		X
C5 Tidal flats	X	X	X	X	O	O	X	X	X	░	O	O	O	O	X	░	░			░
Wetlands																				
D1 Brackish- to salt-water marsh	X	X	░	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X
D2 Fresh-water marsh	X	X	░	X	░	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X
D3 Swamps	X	X	░	X	░	░	X	X	X	X	X	X	X	X	X	X	X	X	O	X
Man-made features																				
E1 Made land and spoil	X	X	X	X	░	░			O			O	O			░	X	O		O
E2 Subaqueous spoil	X	X	░	X	O	O	░	░	░	░	O	O	O	░	O	░	X	░		░
E3 Aransas National Wildlife Refuge	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bays, lagoons, estuaries, and open Gulf																				
F1 River-influenced bay	X	X	░	X	O	X	░	░	░	░	O	O	X		X	░	░	░		░
F2 Enclosed and/or restricted bay	X	X	░	X	O	X	░	░	░	░	O	O	O		O	░	░	░		░
F3 Open bay	X	X	░	X	O	X	░	░	░	░	O	O	X		X	░				░
F4 Tidally influenced open bay	X	X	░	X	O	X	░	░	░	░	O	O	O		X	░				░
F5 Tidal inlets and subaqueous tidal deltas	X	X	░	X	X	X	░	░	░	░	O	O	X		X	░				░
F6 Bay-margin sand and muddy sand	X	X	░	X	X	X	░	░	░	░	O	O	X	X	X	░				░
F7 Oyster reef, adjacent reef flank, and interreef areas	X	X	░	X	X	X	░	░	░	░	X	X	X	X	X	░				░
F8 Grassflats	X	X	░	X	X	X	░	░	░	░	X	X	X	X	X	░	X	X		░
F9 Upper shoreface	X	X	░	X	O	X	░	░	░	░	X	O	X	░	X	░	░	░		░
F10 Lower shoreface and open Gulf	X	X	░	X	O	░	░	░	░	░	O	O	░	░	░	░	░	░		░
F11 Local sand and shell beaches and berms	X	X	X	X	O	O	X	X	X		O	O	X	X	X	░	O			O

Table 13. Land resource units for a derivative map of flood-prone areas.

Flood-prone units	Land resource units
Frequent fresh-water flooding	A9, A10, A13, B1, B2, B4, D2, D3
Infrequent fresh-water flooding	A7, A8, B3, D1
Hurricane (storm-surge) flooding	A1, A5, C1, C2, C3, C4, C5, D1, E1, F11

Table 14. Land resource units for a derivative map of physical properties.

Physical properties	Land resource units
Dominantly sand: highly permeable, low shrink-swell potential, low plasticity and compressibility, high foundation strength (except where surface sand very loose), poor slope stability, excavation easy, high corrosion potential, low moisture-retention capacity.	A1, B1, C1, C2, C3, C4, C5 (barrier islands only), F11
Dominantly clayey sand and silt: moderately to highly permeable, low shrink-swell potential, low plasticity and compressibility, high foundation strength, poor to moderate slope stability, excavation easy, high corrosion potential, low to moderate moisture-retention capacity.	A2, A3, A4, A5, A11*, B2, B3
Dominantly mud: low permeability, high plasticity and compressibility, low to moderate foundation strength, poor slope stability, excavation moderate to difficult, very high corrosion potential, moderate to high moisture-retention capacity.	A6†, A7, A8, A9, A10, A13
Coastal marshes and swamps: commonly to permanently inundated by salt water and/or fresh water, very low permeability, foundation conditions poor, very high corrosion potential, poorly drained.	D1, D2, D3, C5 (excluding barrier islands)
Made land and spoil: mixed composition, properties variable.	E1, E2, E3

*Slope stability, ease of excavation, and corrosion potential differ from general physical properties category.

†Physical properties of this unit are generally somewhat more favorable than other units in this physical properties category.

Table 15. Land resource units for a map of solid-waste disposal suitability.

Waste disposal suitability units	Land resource units
Good: low permeability, low flood potential, flat to gently rolling topography.	A7, A8
Moderate: moderate permeability, low flood potential, rolling topography.	A6, A11
Poor: moderate to high permeability and/or high flood potential, or high biologic productivity.	A1, A2, A3, A4, A5, A9, A10, A12, A13, B1, B2 B3, B4, C1, C2, C3, C4, C5, D1, D2, D3, E1, F11

APPLICATION OF THE MAP

The map of land and water resources in the Corpus Christi area and the accompanying text are intended as a planning and management tool. Although the planning process involves social considerations (for example, legal constraints, economics, cultural heritage, and public participation) in addition to consideration of the natural environments, fair and effective planning and management must be based on sound scientific data that define the properties and inherent carrying capacities of the environments and the interrelationships of those environments. Orderly growth and development are dependent on early recognition of the limiting parameters of the environmental resources and their most productive uses. Use of land and water resources consistent with their natural capabilities will minimize or preclude many environmental problems.

The Land and Water Resources map and text provide the basis for formulating general management policy in the Corpus Christi area through presentation of the characteristics of natural environments in a variety of formats—map, text, tables, and illustrations. In the planning and management processes, the information presented here allows preliminary evaluation of the effects of projected uses of land and water resources in the four-county area. Preliminary site-selection studies can be carried out quickly and comprehensively without resorting to expensive onsite investigations of many possible localities. The number of potential sites can be narrowed and special problems readily identified.

During planning, specific kinds of information are commonly needed for special purposes. By compiling information on overlays, special-purpose maps can be derived from the Land and Water Resources map. Specific information may be extracted from the map and text or generalized from the data. For example, a separate map of all land resources susceptible to flooding can be constructed (table 13 lists all resource units susceptible to flooding). Similarly, a physical properties map can be derived by combining all resource units with like physical properties (table 14). The 23 land resource units can be reduced to a few groups that reflect the general physical parameters of resource units in the Corpus Christi area. Tables 15 and 16 show which units are important in constructing derivative maps of suitability for solid-waste disposal and recharge potential. Additional possibilities for special-purpose maps are listed in table 17; others could be developed according to need.

SUMMARY

Competing demands of industrial, residential, and recreational development, which sometimes result in conflicting interactions with natural environments, emphasize the need to define and delineate existing land and water resources in the Corpus Christi area. Delineation of land and water resources is based on the realization that natural and man-modified areas have distinct, mappable characteristics that may strongly influence the interaction of these areas with various kinds of human activities. Comprehensive inventories that help define resource capabilities and limitations provide a basis for understanding and predicting the effects of (1) man on the environment and (2) the environment on man.

Forty land and water resource units, defined and mapped in the Corpus Christi area—an area including Aransas, Nueces, Refugio, and San Patricio Counties—were classified into the following systems: (A) Coastal Plain; (B)active floodplains; (C) barrier islands; (D) wetlands; (E) man-made features; and (F) bays, lagoons, estuaries, and open Gulf. Fundamental definition and delineation of the units were based on characteristics such as natural processes and hazards and physical, chemical, and biological properties. In addition to being classified by systems, units were classified by elements considered most significant in governing the response of the unit to man's activities. Use of the map, text, and tabular information, and construction of special-purpose derivative maps can contribute to planning for future development of the Corpus Christi area.

Table 16. Land resource units for a map of aquifer recharge potential.

Aquifer recharge units	Land resource units
Good: high permeability	A1, A2, A3, B1, C1, C2, C3, C4
Moderate: moderate permeability	A4, A5, A6, A11, B3, C5
Poor: low permeability	A6, A7, A8, A9, A10, A13, B2

Table 17. Types of derivative maps that can be constructed from the Land and Water Resources map. Other derivative maps can be generated as the need arises (modified from St. Clair and others, 1975).

Types of derivative maps	Method of derivation from Land and Water Resources map
Physical properties	Group units according to similar physical properties (see table 14).
Solid-waste disposal	Rate units according to permeability, flood potential, topography, etc. (see table 15).
Flood-prone areas	Outline areas described as being susceptible to flooding (see table 13).
Construction suitability	Rate units according to bearing strength, shrink-swell potential, flood potential, slope stability, etc.
Natural hazards	Delineate active surface faults and areas subject to inland flooding, hurricane surge, hurricane winds, and rapid erosion.
Ground-water protection areas	Outline areas described as aquifers or areas of aquifer recharge (see table 16).
Greenbelts	Determine areas which should remain undeveloped based on hazards, biologic productivity, etc.
Slope	Use topographic contours to determine ratio of change in elevation to horizontal distance. Delineate areas of several slope ranges (<5%, 5-10%, >10%).
Critical biologic areas	Delineate areas of high biologic productivity which should be undisturbed.

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