

# The Human Role, Past and Present

*Galveston will be the seaport sir, for this province. Water plenty, good Harbour, also the anchorage are excellent by non . . .*

—Edward Lovelace to S. F. Austin, June 26, 1882 in McComb, 1986

*Houston, Texas, is Boom Town, U.S.A.*

—James Noel Smith, *The Decline of Galveston Bay*, 1972

**T**he Galveston Bay estuarine system is adjacent to one of the most populated areas in Texas. With a population over 3.3 million in 1990, the Houston metropolitan area ranks second in population only to the Dallas-Fort Worth area among metropolitan areas in Texas (Houston-Galveston Area Council, 1993a). Population growth in the region is expected to continue, with more than four million persons projected to live in the five counties surrounding Galveston Bay by the year 2000 (Houston-Galveston Area Council, 1993a).

The purpose of this chapter is to provide information on the ways people use the resources of Galveston Bay and its adjacent land area. The chapter begins with a look back to the role the bay system played in the lives of native Americans and European explorers and settlers. The chapter then focuses on the changes in the area's economy prompted by the construction of the Houston Ship Channel and the discovery of oil in the area in the early 1900s. Information is then presented on the major current uses of the Galveston Bay system, including agriculture, commercial fishing and oystering, recreation, shipping, and industrial and municipal uses.

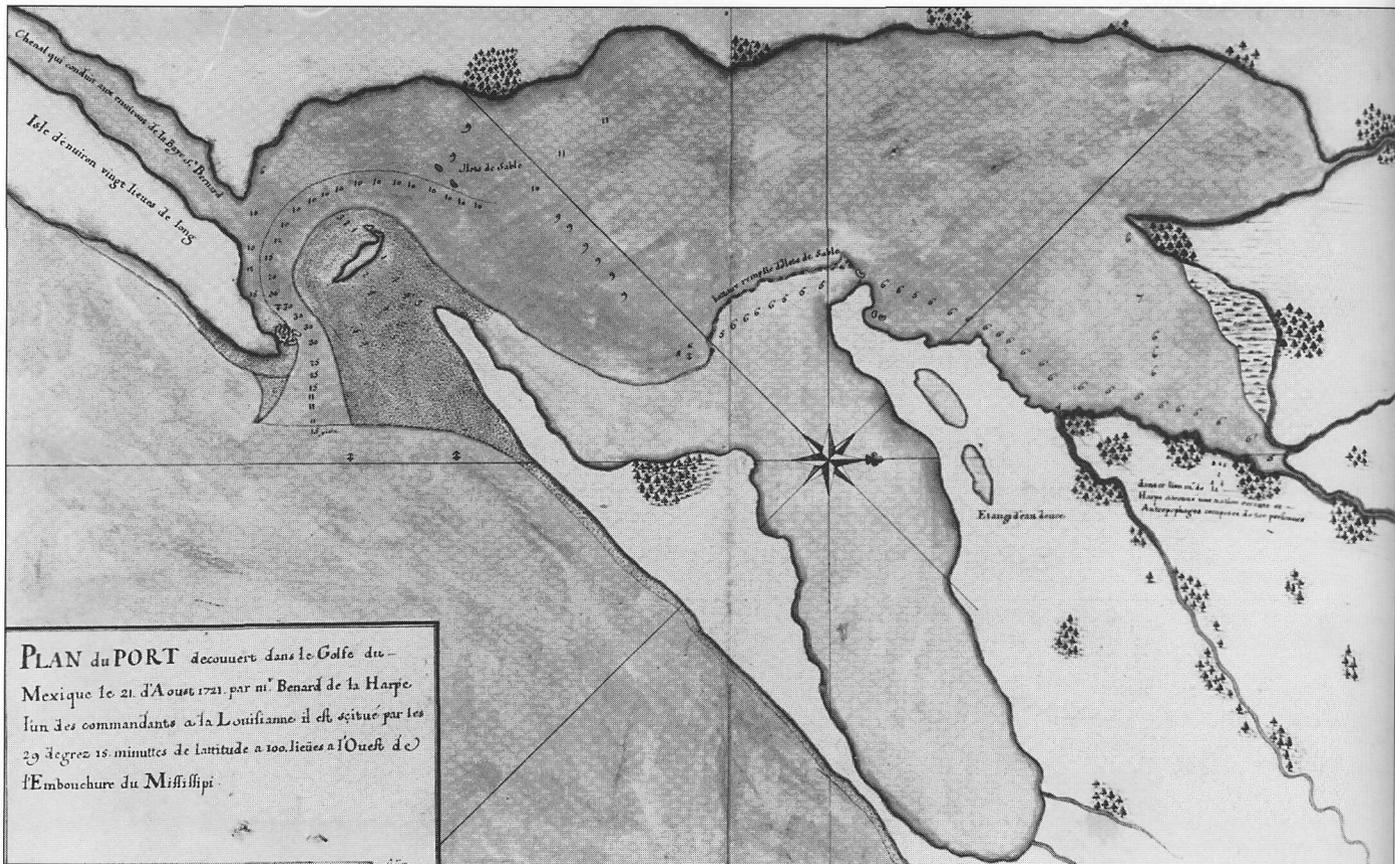
## CHANGES IN BAY USE: AN HISTORICAL PERSPECTIVE

Henson (1993) described the first known human use of Galveston Bay as having occurred about 14,000 years ago when Paleo-Indians hunted woolly mammoths, mastodon, and large

bison in the area. At that time, Galveston Bay had not yet taken its present shape, and the shoreline extended about fifty to one hundred miles farther out in the Gulf from where it is today. For over 13,000 years humans continued to use the bay and its surroundings as a source of food. The only changes these early residents made to their host environment, according to Henson (1993), "were the gradual accumulation of piles of discarded shells" from oysters and clams and "pottery shards scattered around the waterways."

Spanish and French explorers visited the bay area between 1528 and 1722. Upon finding no mineral riches, these explorers turned to trade with the local natives. The bay, in the meantime, was changing from being a food source for the native Indians to a conduit for colonization and settlement. By 1815, the harbor at Galveston Island attracted mercenaries, called filibusters, and privateersmen who claimed to be helping the Mexican republicans in gaining their independence from Spain. By 1822, Anglo Americans began arriving and settling in the area.

The settlers around the bay in the 1820s were primarily agrarians (Henson, 1993). Most were farmers, others were planters of cotton, and a few owned boats and became merchants taking wood and agricultural products to New Orleans or the Mexican ports. The newcomers, both American and European, cleared stands of trees, planted fields and built homes. These changes encouraged erosion and silting of the waterways because of, as stated by Henson (1993), "denuded forest and prairie lands that turned



Source: Rosenberg Library, Galveston Texas

A small party of French explorers surveyed Galveston Bay by canoe in 1721 in hopes of establishing a trading post with local Indians. Although the undertaking failed as a commercial venture, it produced the earliest known map of Galveston Bay.

to dust and mud before blowing or washing into streams and the bay.” In further attempts to make their new homes resemble where they had come from, the immigrants imported trees, crops, and animals that were not previously found in the Galveston Bay system.

Henson (1993, based on Barker, 1924) recounts the following description of the first shipwreck on Redfish Bar:

*The first of many vessels wrecked on Redfish Bar was the schooner Mary from New Orleans in March 1835 with 36 passengers and their goods. The ship drew seven feet and even though the captain sent a boat out to sound for a channel, the signal was too late and he went hard aground. The vessel beat on the bottom and the captain ordered barrels of flour and tobacco jettisoned. Nevertheless, the ship was a total loss and the passengers demanded that the captain pay for their property. This disaster inspired [Stephen F.] Austin to sound and map the bay and he spent over two weeks in 1826 with a crew of nine in three boats marking safe channels.*

The population of Texas and Galveston Bay increased during the 1830s and the bay became a major artery for goods and passengers going to the San Jacinto and Trinity Rivers. Communities around the bay underwent some change after the Battle of San

Jacinto in April 1836 and declaration of the Republic of Texas. Anahuac and Lynchburg remained small transfer depots for goods and passengers heading inland. Two new towns, Houston and Galveston, were both private ventures founded in 1836 and 1837. Houston was established by A. C. and John K. Allen, New York natives who resided in Nacogdoches; Galveston was founded by Michael B. Menard, Thomas F. McKinney, and Samuel M. Williams.

Texas was finally annexed to the United States in December 1845. This, however, initiated a two-year war with Mexico. The war according to Henson (1993) “stimulated business and commerce and brought new people to the bay area, some of whom stayed because of the economic promise.” Galveston in 1850 was the largest town in Texas with 4,177 people (Henson et al., 1993, after Kingston, 1964). The data from the 1850 United States Census show that the bay functioned primarily as a transportation system with limited commercial fishing. However, given the rural nature of the bay shore at the time, Henson (1993) concluded that “one can assume that fishing, like hunting, was also a normal activity of many individuals living in the vicinity...,” and that “the maritime activity, in turn, provided many area residents with the means of their livelihood beyond seamen and boat builders; supplying the vessels with wood, water, and food at the various stops was a way farmers could earn money.”

In 1850, the U. S. Army Corps of Engineers began surveying

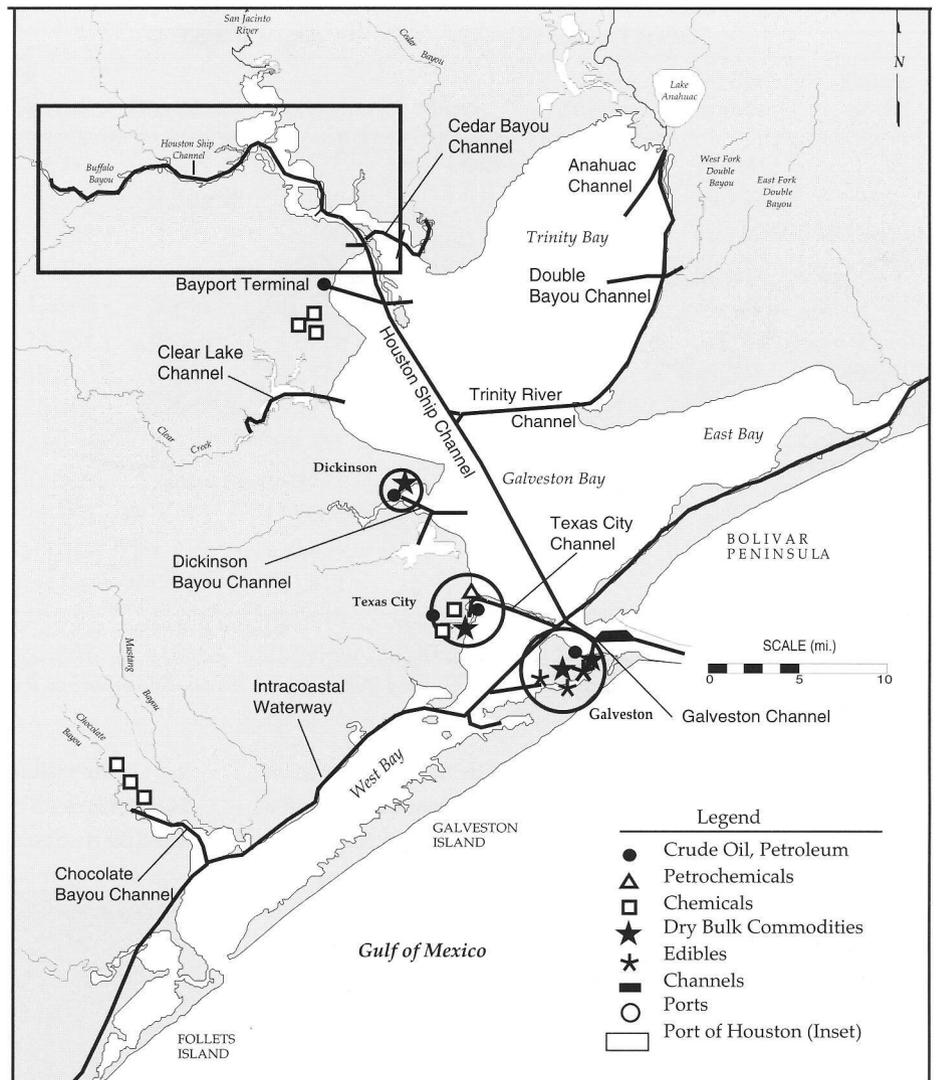
the bay and publishing updated charts detailing the depth of the bay and its channels, buoys and lights. The Corps also marked hazards such as shipwrecks and shoals and marked wharves and piers, towns and roads along the shore. Between the years 1850 and 1914, transport related to deep-water shipping was the principal use of the bay. A bitter rivalry developed between Houston and Galveston as each tried to dominate commerce. While most ships could enter Galveston's harbor through the natural channel, only the shallow-draft river steamers could go up the bay to Houston. This rivalry eventually led to the dredging of the Houston Ship Channel, one of the major events discussed in this chapter as shaping the history of the Galveston Bay system.

Toward the end of that period, about 1903, an inquisitive oil scout brought petroleum production to Galveston Bay. The first producing well was on the shore of Tabbs Bay in 1907. By 1915 there were at least 25 wooden rigs around Tabbs Bay producing about 130,000 barrels of oil per year (Henson, 1993). The discovery of oil in the region in the 1920s ushered in the petroleum/petrochemical and industrial era of use for Galveston Bay.

In summary, to the native Americans, Galveston Bay was a major source of food and raw materials for tools and utensils. During the subsequent years of settlement, Galveston Bay was used for exploration, transportation, and shipping purposes. During the late 1800s and the turn of the century, dredging and **channelization** projects gave rise to prosperous shipping and commerce activities, first in Galveston and subsequently in Houston. Prior to the discovery of oil, agriculture and fishing were the main activities of the region with cotton being the major export commodity (Texas Water Quality Board, 1975). The discovery of oil in the region, however, gave rise to one of the largest petroleum/petrochemical complexes in the world. The economic vitality of the region, in turn, led to the growth of one of the largest metropolitan areas in the nation.

### The Houston Ship Channel and Other Navigation Channels

Much of the growth and development of the Houston area is attributable to the completion of the Houston Ship Channel in 1914 (FIGURE 4.1). The channel permitted ocean-going vessels to traverse the shallow Galveston Bay all the way to Houston, resulting in a tremendous upsurge in new industrial growth in Houston.

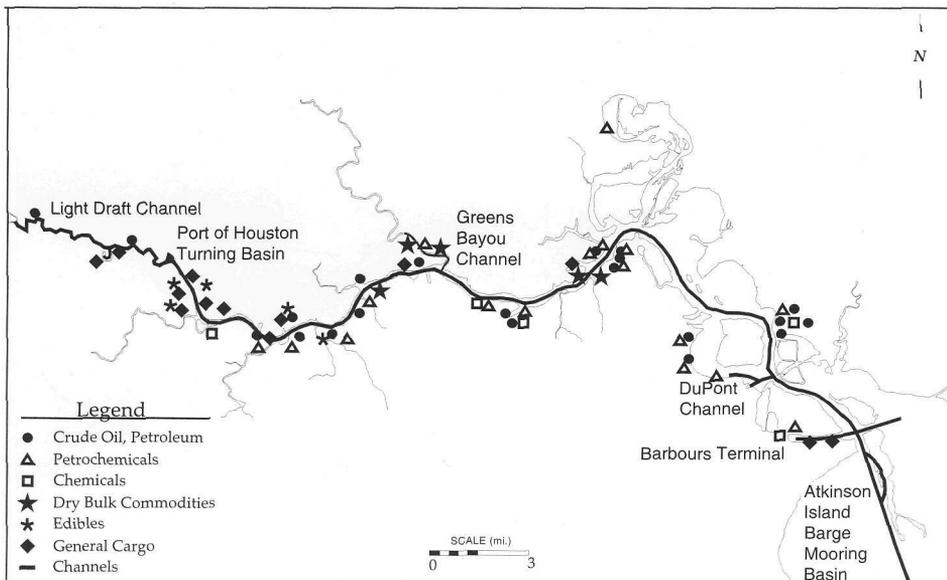


Source: Wermund et al., 1989; United States Army Corps of Engineers, 1985; 1989

**FIGURE 4.1.** Channels, ports, and industries in the Galveston Bay system. Completion of the Houston Ship Channel in 1914 allowed large vessels from the Gulf of Mexico to reach the lower reaches of Buffalo Bayou, stimulating industrial development. The inset area (the highly industrialized upper Houston Ship Channel) is shown in FIGURE 4.2.

Buffalo Bayou and the Houston Ship Channel boast an interesting history (see Sibley, 1968 and Alperin, 1977). As early as 1837 John James Audubon, on a visit to the Galveston Bay area, had described Buffalo Bayou, now the upper Houston Ship Channel, as being "usually sluggish, deep and bordered on both sides with a strip of woods not exceeding a mile in depth" (Farrar, 1926). Also in that same year, the steamboat *Laura* became the first to visit Houston in an attempt to prove that Buffalo Bayou was navigable (McComb, 1981). Steamboat service to Harrisburg began shortly after the Texas revolution. In 1839, city officials passed an ordinance establishing the Port of Houston.

The latter half of the nineteenth century saw the first attempts to significantly widen and deepen Buffalo Bayou to accommodate larger vessels. In 1856 the City of Houston began operating a 70-ft dredge to deepen a passage at Cloppers Bar (near Morgans Point) and to improve Buffalo Bayou. It was not until after the Civil War (1861-1865), however, that Houstonians obtained permission from



Source: Port of Houston Authority, 1992

**FIGURE 4.2.** Channels, ports, and industries in the upper Houston Ship Channel. Development of this region as a major industrial complex was made possible by dredging Buffalo Bayou, the Lower San Jacinto River, and by cutting through Morgans Point.

the State of Texas to dredge a 12-ft deep channel from the main entrance channel at the Gulf of Mexico to their town. Politics and a lack of money delayed the project until the 1870s, when local interests cut a five-mile 14-ft deep canal in upper Galveston Bay through Morgans Point to bypass Cloppers Bar at the tip of Morgans Point (the remnant of the tip of the Morgans Point peninsula is now known as Atkinson Island, see FIGURE 4.2). At that time, luxury steamboats began offering service between Galveston and Houston, and numerous barges, tugs, fishing vessels, and other boats plied the bay.

Meanwhile, federal participation in building the Houston Ship Channel had originated with the Rivers and Harbors Act of 1872. In 1877 Congress authorized the U. S. Army Corps of



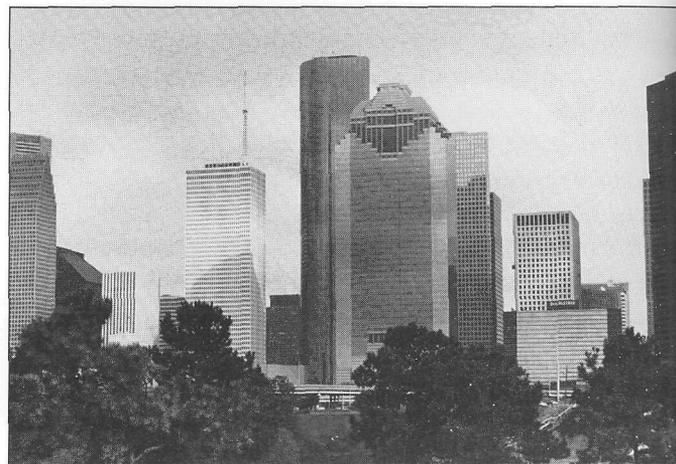
Source: Galveston Bay National Estuary Program

Nearly half of the nation's petrochemical production occurs along Galveston Bay's shores, constituting the largest petrochemical complex in the world.

Engineers to dredge a 12-ft deep and 100-ft wide channel from Bolivar Peninsula to Redfish Bar. The project was accomplished in stages and was eventually extended northward.

The Corps of Engineers in 1880 began designing jetties into the Gulf to attain the long-range plan of a 25-ft deep channel through the inner and outer bars. After almost 20 years of planning and failed experiments with gabions (rock-filled wire baskets), the Corps completed the South jetty to a length of 6.5 miles and the North jetty to almost five miles. The water over the outer and inner bars reached just over 25 ft and 26 ft, respectively. The Corps' dredging project allowed Galveston to emerge as a major port. By 1907, Galveston ranked second among all U. S. ports in the value of foreign exports, with cotton being the predominant article of export (Alperin, 1977).

The rise and success of the port of Galveston prompted Houstonians to begin a deep-water movement of their own in the late 1890s. Their arguments in favor of a more protected port were



Source: Galveston Bay National Estuary Program

Explosive population growth in the early 1980s was fueled by the petroleum and petrochemical industries. Boomtown Houston required expanded sewage treatment capabilities, more highways, and greater areas of impervious cover—all of which placed greater stress on the natural assimilative capacities of Galveston Bay.

strengthened when the 1900 hurricane destroyed much of Galveston and killed thousands of people in the worst natural disaster in United States history. In 1900, the Corps began dredging an 80-ft wide channel, 17.5 ft deep with a dike from Morgans Point to Redfish Bar. It was not until 1910, however, and as a result of a new federal Rivers and Harbors Act, that the dredge project was named the Houston Ship Channel. By 1912, financing was assured and work on the channel was underway. The Houston Ship Channel was officially opened on November ten, 1914. It was 51

mi in length, with a maximum depth of 26 ft and a maximum width of 150 ft.

The Houston Ship Channel was enlarged to a depth of 32 ft and a width of 400 ft after the 1935 Rivers and Harbors Act authorization. The final expansion of the channel started in 1963 and had a project depth of 40 ft. A congressionally authorized study is in progress to consider a proposal to deepen and/or widen the Houston and Galveston channels.

Today, the Houston Ship Channel (FIGURES 4.1 and 4.2) extends approximately 50 mi from the Port of Houston to the Gulf of Mexico. It follows the course of what were formerly the lower portions of Buffalo Bayou and the San Jacinto River in Harris County. It then joins Galveston Bay at Morgans Point, and crosses the bay to the Gulf of Mexico. The narrow, confined, 25-mi long portion of the channel between Morgans Point and the Port of Houston's upper turning basin near downtown Houston is one of the most heavily industrialized water bodies in the world (FIGURE 4.2).

Aside from the Houston Ship Channel, there currently are over 150 mi of other channels in Galveston Bay (FIGURE 4.1). One of the earliest channels completed was a 16-ft deep channel from the deep water near Galveston to a new port in Texas City. Because this channel was laid out perpendicular across a natural scour area called Half Moon Channel, it required extensive dredg-

TABLE 4.1. Population 1850 - 1990 (Number of Persons).

Year	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties	Entire State
1850	4,481	N/A	4,529	4,668	2,522	16,200	212,592
1860	7,143	1,508	8,229	9,070	3,189	29,139	604,215
1870	7,527	1,503	15,290	17,375	4,414	46,109	818,579
1880	9,774	2,187	24,121	27,985	4,999	69,066	1,591,749
1890	11,506	2,241	31,476	37,249	4,230	86,702	2,235,527
1900	14,861	3,046	44,116	63,786	8,102	133,911	3,048,710
1910	13,299	4,234	44,479	115,693	10,686	188,391	3,896,542
1920	20,614	4,162	53,150	186,667	14,637	279,230	4,663,228
1930	23,054	5,710	64,401	359,328	19,868	472,361	5,824,715
1940	27,069	7,511	81,173	528,961	24,541	669,255	6,414,824
1950	46,549	7,871	113,066	806,701	26,729	1,000,916	7,711,194
1960	76,204	10,379	140,364	1,243,158	31,595	1,501,700	9,579,677
1970	108,169	12,187	169,812	1,737,235	33,015	2,060,418	11,196,730
1980	169,587	18,538	195,940	2,409,547	47,088	2,793,612	14,229,191
1990	191,707	20,088	217,399	2,818,199	52,726	3,300,119	16,986,510

Source: Houston-Galveston Area Council, 1993a

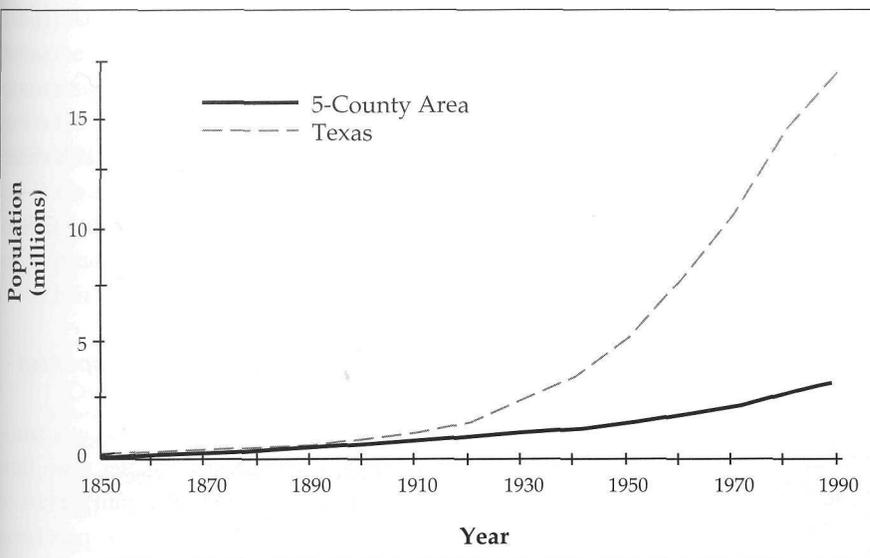
ing to keep it open. Because of this maintenance problem, the channel was protected from currents by building a 5.3-mi timber pile dike along the north side of the channel that was later replaced by a rubble dike in 1934. Today, the Texas City Channel is 40 ft deep and 400 ft wide.

Segments of the Gulf Intracoastal Waterway (sometimes called the "intracoastal canal") that traverses the coastline of the Gulf of Mexico were constructed as early as 1909 by the federal government. The modern channel with a nine-ft depth by 100-ft width configuration was completed in 1942. The Gulf Intracoastal Waterway reach across the Galveston Bay estuary has been deepened and widened to 12 ft by 125 ft (FIGURE 4.1).

Other channels in the bay system (FIGURE 4.1) include the Trinity River Channel along the east side of Trinity Bay, as well as shorter channels dredged from the Trinity River Channel and leading to Anahuac and Double Bayou (in Chambers County). A short channel to the east of the Ship Channel leads to industrial facilities along Cedar Bayou. Channels also were dredged to the west of the Ship Channel into Bayport, Clear Lake, Dickinson Bayou, and Offatts Bayou (located in the mid-part of Galveston Island on the bay side).

### Petroleum and Petrochemical Industries

Oil was first produced in the Galveston Bay area in 1907 on the shore of Tabbs Bay near modern day Baytown. The oil field camp on Goose Creek became a boomtown between 1917-1919 with production of seven to nine million barrels per year. Prior to 1919, the closest



Source: Houston-Galveston Area Council, 1982; U.S. Bureau of the Census, 1983; 1991

FIGURE 4.3. Population growth in the five-county region surrounding Galveston Bay, and in Texas as a whole. Between 1980 and 1982, Houston grew by 12 percent, followed by much slower growth to the present resulting from a recession.

**TABLE 4.2. Population Growth: 1970 - 1990.**

County	Number of Persons			% Growth	% Growth
	1970	1980	1990	1970 - 1980	1980 - 1990
Brazoria	108,169	169,587	191,707	57	13
Chambers	12,187	18,538	20,088	52	8
Galveston	169,812	195,940	217,399	15	11
Harris	1,737,235	2,409,547	2,818,199	39	17
Liberty	33,015	47,088	52,726	43	12
<b>Total</b>	<b>2,060,418</b>	<b>2,840,700</b>	<b>3,300,119</b>	<b>38</b>	<b>16</b>

Source: Houston-Galveston Area Council, 1993a

refineries were in Beaumont and Port Arthur, about 90 mi to the east. The Humble Oil Company (now Exxon) built a refinery in 1919 west of Goose Creek and named their landing Baytown. At that time, there were about 22 industries along the bayou below the turning basin and 16 above it. By the end of the 1920s, however, there were more than 50 businesses along the channel and eight

Water Quality Board, 1975).

Ditton et al. (1989) pointed out that petroleum is frequently thought to be Houston's largest and most valuable industry, however, the chemical and allied products industry ranks first in the Houston area in terms of value added by manufacturing, making up about a third of the total value added by manufacturing for the

**TABLE 4.3. Population Changes for Cities and Places Over 10,000 Population: 1980 - 1990.**

City or CDP <sup>1</sup>	County	Number of Persons		% Growth
		1980	1990	
Houston	Harris	1,611,382	1,630,553	1
Pasadena	Harris	112,560	119,363	6
Baytown	Harris/Chambers	57,339	63,850	11
Galveston	Galveston	61,902	59,070	-5
Texas City	Galveston	41,201	40,822	-1
Kingwood (CDP)	Harris	16,094	37,397	132
Spring (CDP)	Harris	14,692	33,111	125
League City	Galveston/Harris	16,578	30,159	82
La Porte	Harris	19,226	27,910	45
Deer Park	Harris	22,648	27,652	22
Channelview	Harris	17,471	25,564	46
Friendswood	Galveston	10,719	22,814	113
Lake Jackson	Brazoria	19,102	22,776	19
Alvin	Brazoria	17,877	19,220	8
Pearland	Harris/Brazoria	13,958	18,697	34
Cloverleaf (CDP)	Harris	1,533	18,230	1089
Angleton	Brazoria	13,929	17,140	23
South Houston	Harris	13,293	14,207	7
La Marque	Galveston	15,372	14,120	-8
Bellaire	Harris	14,950	13,842	-7
West University Place	Harris	12,010	12,920	8
Humble	Harris	6,729	12,060	79
Freeport	Brazoria	13,444	11,389	-15
Aldine (CDP)	Harris	12,623	11,133	-12
Mission Bend (CDP)	Harris	N/A	10,750	N/A
Galena Park	Harris	9,879	10,033	2

Source: United States Bureau of the Census, 1983; 1991

<sup>1</sup>CDP = Census Designated Place

refineries along the upper Ship Channel with a capacity of about 125,000 barrels of crude per day (Henson, 1993, after McComb, 1969).

By 1930, over 80 percent of the ocean-going tonnage from the Port of Houston was in the form of oil and related chemicals. Also by this time, many large oil companies had established their offices in the area, and refineries were well developed along the upper Houston Ship Channel (FIGURE 4.2). Other chemical and steel industries developed in the region during World War II, so that by 1948 Texas was sixth in the nation in chemical production (Stanley, 1992). It has since risen to first place (Texas

Nearly one-half of the total chemical production in the United States takes place in the Galveston Bay area. Ditton et al. (1989) found that more than 500 chemicals are produced in 300 chemical plants in the area, providing a total of 36,100 jobs and a payroll of \$1.1 billion. The vast majority of the plants are located in Harris County.

Thirty percent of the total U. S. petroleum industry is located adjacent to the bay (Ditton et al., 1989). Most of this industrial development is concentrated in two areas, one along the upper Houston Ship Channel and the other in the Texas City vicinity along the southwestern shore of the bay. Ditton et al. pointed out that the level of infrastructure in the region is an indicator of the extent to which the petroleum industry along the Texas coast is focused on Galveston Bay. Of 31 oil refineries along the Texas coast, 12 are located around Galveston Bay. Of the 74 gas processing plants on the Texas coast, 22 are located in the bay region. Of the 38 pipelines originating from either state or outer continental shelf waters along the Texas coast, 16 make landfall in counties around the bay. Obviously, the petroleum industry is an important presence in the Galveston Bay region.

**The Growth of the Houston Metropolitan Region**

Even though the City of Houston was established in 1836, it remained a smaller town than Galveston, San Antonio and Dallas until the turn of the century. In 1880, for example, the population was just 16,513, trailing Galveston and San Antonio. Population increased to 27,557 in 1890, but Houston still trailed Dallas, San Antonio and

**TABLE 4.4. Population Density:  
1980 and 1990 (Persons per sq mi).**

County	1980	1990
Brazoria	120	136
Chambers	29	31
Galveston	492	546
Harris	1,407	1,645
Liberty	41	46
<b>All Five Counties</b>	<b>533</b>	<b>619</b>

Source: United States Bureau of the Census, 1983; 1991

Galveston. It was not until after the 1900 hurricane devastated Galveston that Houston was ranked second in the state with a population of 44,633. Finally, during the decade after the construction of the Houston Ship Channel, Houston led the state in population.

Much of the area's growth has been attributed to the completion of the Houston Ship Channel in 1914 in combination with the discovery of oil in the region in the 1920s. The ascent of the Houston metropolitan area to the major population and industrial center it is today, however, has taken place largely since World War II. TABLE 4.1 and FIGURE 4.3 provide data from 1850 through 1990 for the five counties around Galveston Bay and for Texas, compiled by the Houston-Galveston Area Council (the regional council of governments) from the U.S. Census of Population. The region has exhibited boomtown characteristics over most of the past 50 years.

Houston's population gains during the 1970s and early 1980s were remarkable. Growth between 1970 and 1980 averaged 3.7 percent annually, and between 1980 and 1982 Houston's population grew an incredible 12 percent. Since 1982, however, population growth has slowed considerably as the region's economy suffered a prolonged recession. Migration traditionally has accounted for a large part of the population growth in the Houston area (Kingston, 1988). The strength of the region's economy and its ability to provide jobs attracted new residents in great numbers. Since the early 1980s, however, growth has been much slower.

#### CURRENT USES OF THE BAY

Based on a telephone survey of households in a four-county area (Chambers, Harris, Galveston and Brazoria), Allison et al.

**TABLE 4.5. Population in a Two-Mile Buffer  
Area Surrounding Galveston Bay.**

County	1990 Population in 2-mi Buffer	% of County Total
Brazoria	8,925	4.66
Chambers	8,979	44.70
Galveston	153,690	70.69
Harris	467,595	16.59
Liberty	9,570	18.15
<b>All Five Counties</b>	<b>648,759</b>	<b>19.66</b>

Source: United States Bureau of the Census, 1991

(1991) estimated that nine percent of the households in the area derived their income from activities directly associated with the bay. Oil production, transportation, and construction were most often cited as bay-related economic activities. The most common recreational uses mentioned by survey respondents included swimming, picnicking, shoreline walks, bird or wildlife watching, and fishing. Whittington et al. (1993) found that 34 percent of area households use the bay for recreational activities. The following sections discuss the major commercial and recreational activities in and around the bay.

#### Current Population

Demographic characteristics for the bay area have been analyzed in detail by the Houston-Galveston Area Council (Houston-Galveston Area Council, 1993a; 1993b). The Galveston Bay system study area defined by the Houston-Galveston Area Council contains Brazoria, Chambers, Galveston, Harris, and Liberty counties.

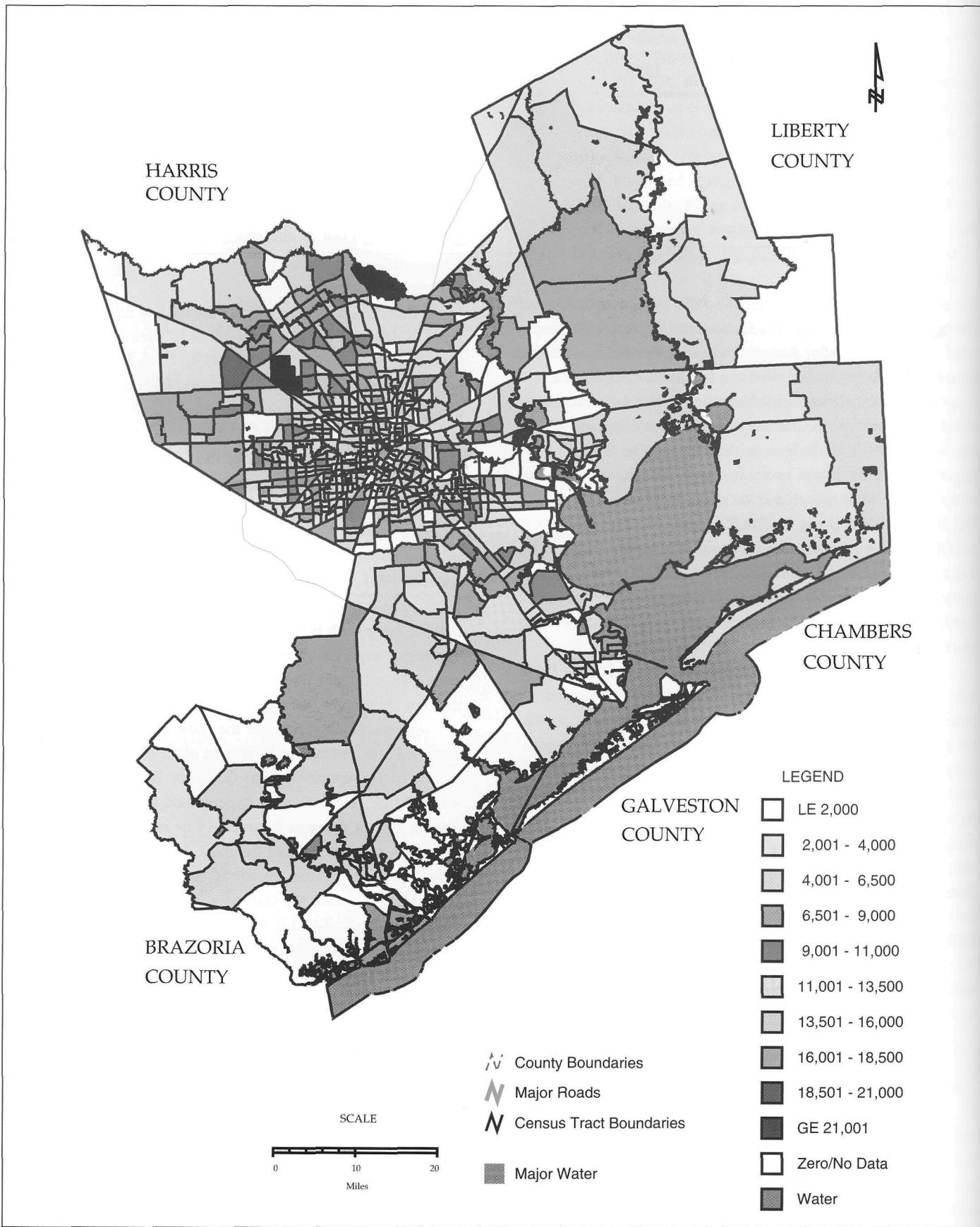
In 1990 the population of the five-county Galveston Bay study area was 3.3 million persons, or 19 percent of the population in the State of Texas. Population data for the years 1970 through 1990 are shown in TABLE 4.2. The data in TABLE 4.2 indicate that the population in the study area increased by 38 percent between 1970 and 1980, but by only 16 percent between 1980 and 1990. These ten-year snapshots of population cannot show that most of the growth between 1980 and 1990 occurred before 1983. The region experienced a high rate of growth in the 1970s and the early 1980s largely due to the expansion of the petrochemical industry. Since then, the population growth rate has declined.

Harris County remains the most populated county in the State of Texas, containing 17 percent of the state population and 85 percent of the population in the Galveston Bay region (see TABLE 4.1). While Harris County experienced the highest population growth rate in the area between 1980 and 1990; Brazoria and Chambers counties marked the most dramatic decrease in rate of growth from the previous decade (TABLE 4.2).

Over the years, the Galveston Bay area has become increasingly urbanized. TABLE 4.3 provides information on 1980 and 1990 populations of cities and places with over 10,000 people. The larger central cities, such as Galveston and Houston, experienced relatively low growth rates. Suburban communities (e.g., Friendswood, Humble, and League City), on the other hand, experienced the largest growth in population. FIGURE 4.4 illustrates the distribution of population by census tract for 1990 (census tracts are sub-county districts used for counting and reporting population for the decennial census).

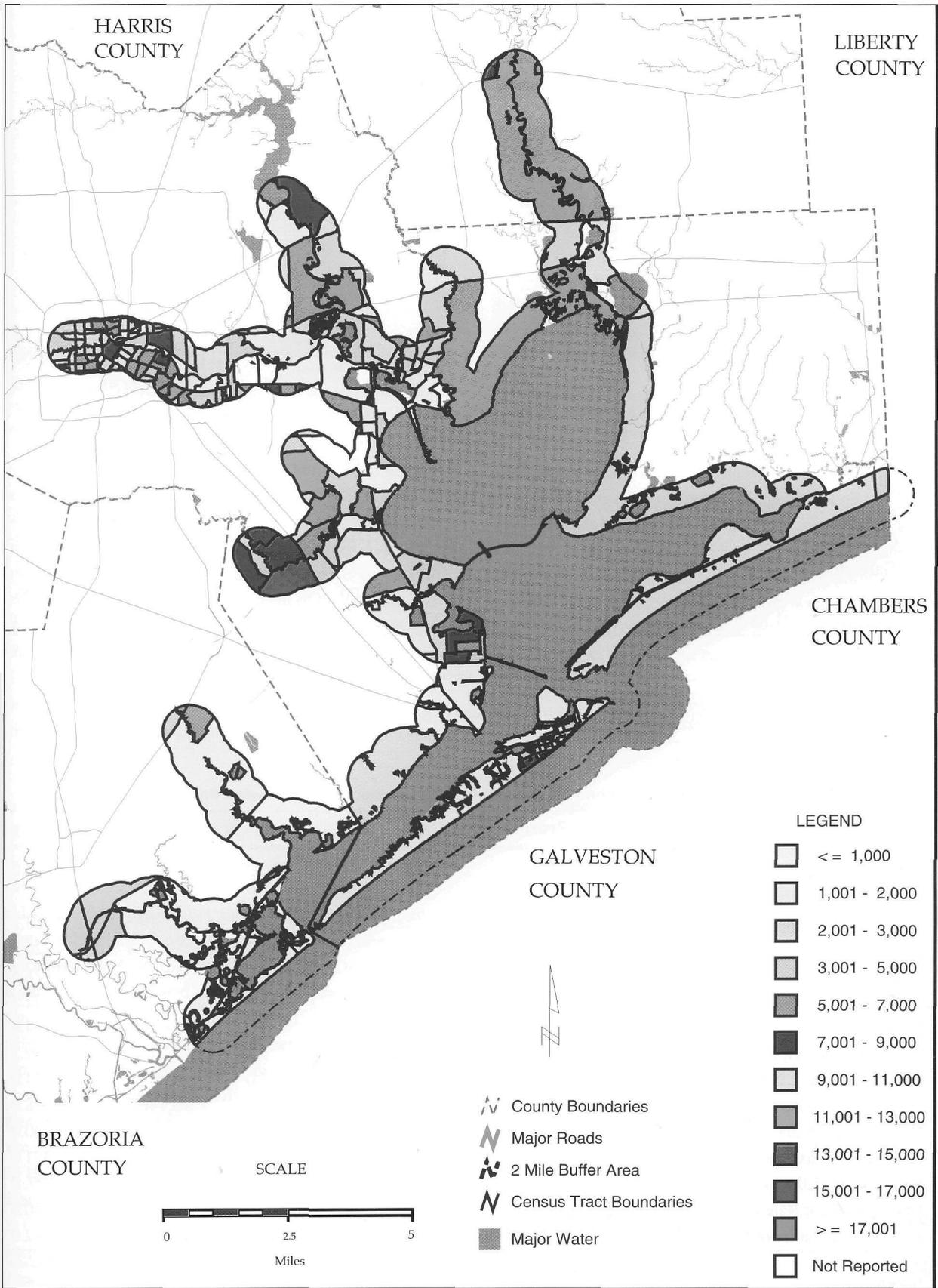
Population density in the five-county area has increased over the last decade from an average of 533 persons per sq mi to 619 persons per sq mi, a 17 percent increase in density (TABLE 4.4). Harris County is the most densely populated county with 1,645 persons per sq mi and Chambers County remains the most sparsely populated county in the study area with 31 persons per sq mi.

The Houston-Galveston Area Council additionally calculated



Source: Houston-Galveston Area Council, 1993a; 1993b

**FIGURE 4.4.** Population of the Galveston Bay region by census tract. Note that the census tracts are in general much smaller in more highly populated areas.



Source: Houston-Galveston Area Council, 1993a; 1993b

**FIGURE 4.5.** Population residing within two miles of the Galveston Bay shoreline, including its tidally-influenced tributaries.

**TABLE 4.6. Land Use by Percentage of Total Acreage.**

Year/ County <sup>1</sup>	Single Family	Multi- Family	Com- mercial	Indus- trial	Public Instit.	Open Space	Protec- ted <sup>2</sup>	Right of Way	Not Devel- oped <sup>3</sup>	Water <sup>3</sup>
<b>1970</b>										
Brazoria	1.28	.05	.24	.53	.11	2.69	.10	.05	86.71	.826
Chambers	.38	.00	.07	.19	.02	1.78	.11	.22	67.33	29.89
Galveston	3.58	.17	1.13	1.94	.26	.31	.21	.27	77.05	15.08
Harris	11.96	.70	2.67	3.49	.64	1.42	.50	1.30	73.83	3.49
Liberty	.76	.01	.15	.16	.03	.02	.24	.07	98.16	.41
<b>1980</b>										
Brazoria	2.28	.07	.29	.96	.16	2.55	.11	.12	86.42	7.04
Chambers	.75	.01	.08	.35	.07	2.43	.16	.32	92.46	3.36
Galveston	3.33	.22	.96	1.42	.27	.33	.07	.22	81.13	12.05
Harris	15.15	1.69	2.99	5.05	.85	3.71	.22	1.29	65.49	3.55
Liberty	1.47	.00	.17	.18	.06	.00	.16	.08	97.86	.00
<b>1990</b>										
Brazoria	2.80	.10	.37	.99	.13	2.53	.11	.25	86.15	6.57
Chambers	.64	.01	.08	.33	.05	1.78	.12	.23	67.20	29.57
Galveston	7.34	.67	4.73	2.59	.55	.38	.15	.43	82.54	.63
Harris	13.29	2.08	3.22	14.59	1.82	7.00	.20	13.73	41.61	2.45
Liberty	1.88	.01	.30	.18	.07	.00	.17	.08	97.63	.00

Source: Houston-Galveston Area Council

<sup>1</sup>Total acreage by County for 1990: Brazoria 1,022,425.6; Harris 1,137,849.6; Liberty 752,851.2; Chambers 555,897.6; Galveston 560,934.4

<sup>2</sup>Protected = Areas considered undevelopable due to resource constraints

<sup>3</sup>The assignment of acreage to undeveloped area or water used inconsistent methodology for 1970 and 1990

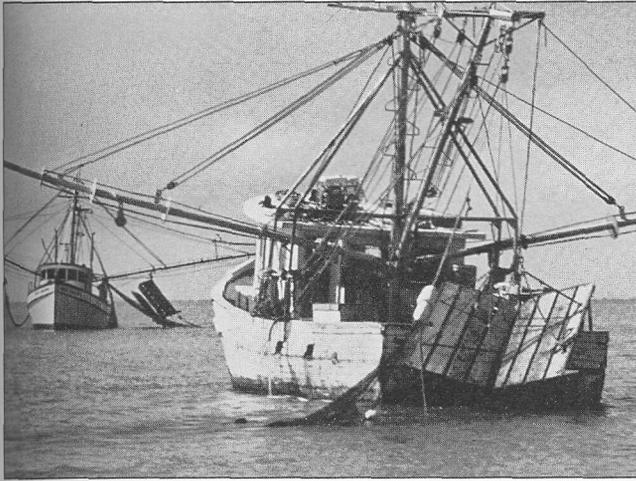
**TABLE 4.7. Selected Economic Data for Counties Surrounding Galveston Bay, 1992.**

Attribute	Brazoria	Chambers	Galveston	Harris	Liberty
Total Employment	67,100.0	5,400.0	80,400.0	1,467,600.0	13,900.0
Percent of Total Employment in:					
Manufacturing	26.3	22.9	10.9	10.8	13.7
Services	14.6	11.5	16.5	27.1	26.6
Government	18.2	22.6	31.3	13.0	21.8
Trade	19.1	19.8	21.1	24.2	22.3
Construction	13.1	5.6	6.5	6.9	4.0
Agriculture Receipts (1,000,000s)	82.0	43.3	7.7	11.2	39.2
Oil Production (1,000s BBL <sup>1</sup> )	3,119.0	2,466.0	1,377.0	4,851.0	2,414.0
Oil Taxable Value (1,000s)	60,827.0	47,544.0	26,776.0	96,146.0	47,008.0
Natural Gas Production (1,000s MCF <sup>2</sup> )	60,241.0	23,967.0	14,239.0	29,106.0	11,180.0
Natural Gas Taxable Value (1000s)	89,610.0	33,942.0	22,884.0	47,098.0	18,371.0
Retail Sales (1,000s)	1,288,775.0	141,396.0	1,436,684.0	28,596,036.0	364,379.0
Unemployment Rate (percent)	7.6	6.6	8.7	7.3	10.6
1990 Per Capita Income (dollars/yr)	13,468.0	12,218.0	13,993.0	15,202.0	9,982.0

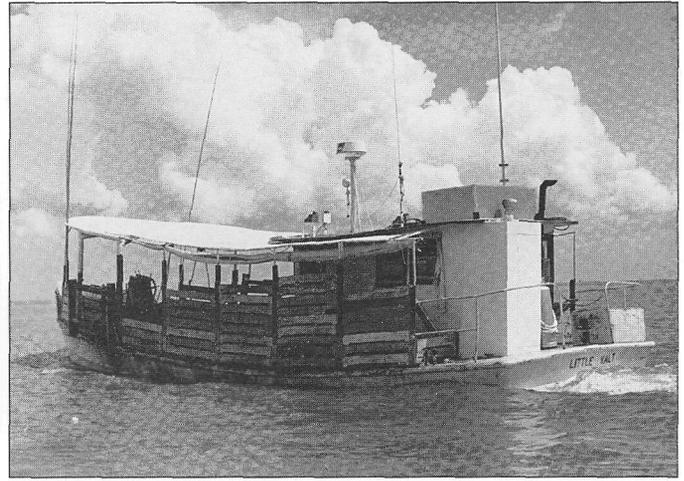
Source: State Comptroller of Public Accounts

<sup>1</sup>Barrels

<sup>2</sup>Million Cubic Feet



Source: Russell W. Kiesling



Source: Texas Sea Grant Grant College Program

This shrimp trawler (left) and oyster lugger (right) typify bay commercial fisheries. Galveston Bay provides the most valuable estuarine fishery on the Texas coast. While over 50 percent of the bay is closed to oyster harvest due to bacterial contamination, oysters can be transferred from closed waters to private leases in approved areas for later harvest.

the number of people living within a two-mile buffer zone around the bay and its tidally influenced stream segments (TABLE 4.5 and FIGURE 4.5). This analysis was completed in order to examine the potential pressures of population and urban land uses immediately surrounding the bay. The buffer area contains 25 percent of the total area of the five counties and 21 percent of the land surface area (major water bodies excluded). As can be seen in TABLE 4.5, over 70 percent of the Galveston County population and almost 45 percent of Chambers County population reside in this two-mile zone. About 20 percent of the 3.3 million people in the five county area live within two miles of the bay and its tidally influenced tributaries.

#### Land Use

Historical land use information for the Galveston Bay area was analyzed by the Houston-Galveston Area Council in a recent socioeconomic report (Houston-Galveston Area Council, 1993a). Most of the land use data presented by the Houston-Galveston Area Council were obtained from the Texas Department of Transportation and the City of Houston Planning Department. These land use data are presented at a highly aggregated level of categorization (TABLE 4.6).

The Houston metropolitan area boasts heavy industry, high-rise office and residential buildings, single-family subdivisions and apartment complexes. Industrial activities, especially petroleum and petrochemical industries, are most prominent in the vast industrial concentrations around the Houston Ship Channel in the eastern portions of Houston and Harris County, including Pasadena, Baytown, Deer Park and La Porte. Other heavy industry is located in the Texas City and Brazosport areas.

Galveston County includes the highly urbanized eastern portion of Galveston Island; the Texas City-La Marque area which is highly industrialized; and League City-Friendswood, a suburban area. Land available for development in Galveston County is limited due to existing development and natural barriers, and much of its

open land does not have good transportation access.

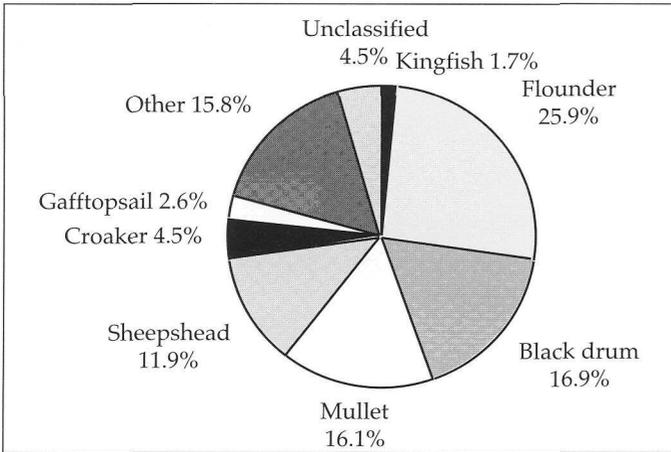
Chambers County remains largely agricultural—primarily rice and soybeans. There are ten county parks as well as the Candy Abshire Wildlife Management Area and the Anahuac National Wildlife Refuge. Additionally, the eastern portion of the county contains several large national priority wetlands designated by the U. S. Fish and Wildlife Service under the Emergency Wetlands Resources Act of 1986, for example: Middleton Marsh, Horseshoe

**TABLE 4.8. Commercial Fish Landings<sup>1</sup> from Galveston Bay Comparing 1890 to 1989.**

Species	Total Landings (1,000s of Pounds)	
	1890	1989
<b>Fish:</b>		
Red Drum	404.2	0.0
Black Drum	4.0	21.8
Flounder	46.0	14.6
Mullet	39.3	108.0
Sheepshead	17.0	16.2
Striped bass	5.0	0.0
Trout	427.4	0.0
Other fish	542.9	60.5
Total Fish	1485.8	221.1
<b>Shellfish</b>		
Oyster	1647.1	705.5
Crabs	162.5	2149.5
Shrimp	138.0	4056.1
Terrapins (Turtles)	2.4	0.0
Other shellfish	0.0	13.4
Total Shellfish	1950.0	6924.5
<b>Total Fish and Shellfish</b>	<b>3435.8</b>	<b>7145.6</b>

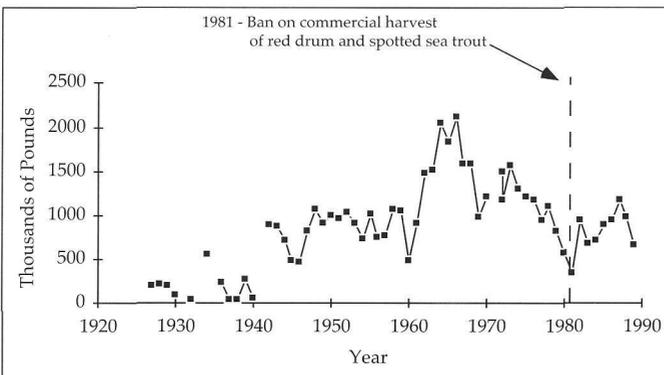
Source Green et al., 1992.

<sup>1</sup>Landings reflect changes in both biological and regulatory factors, and do not indicate more or fewer fish or shellfish present in the bay



Source: Green et al., 1992

**FIGURE 4.6.** Finfish make up only about five percent of the commercial catch from Galveston Bay, which is dominated by oysters, crabs, and shrimp. Commercial harvest of spotted sea trout and red drum was prohibited in Texas bays beginning in 1981, followed by a prohibition on the netting of any sort of finfish.



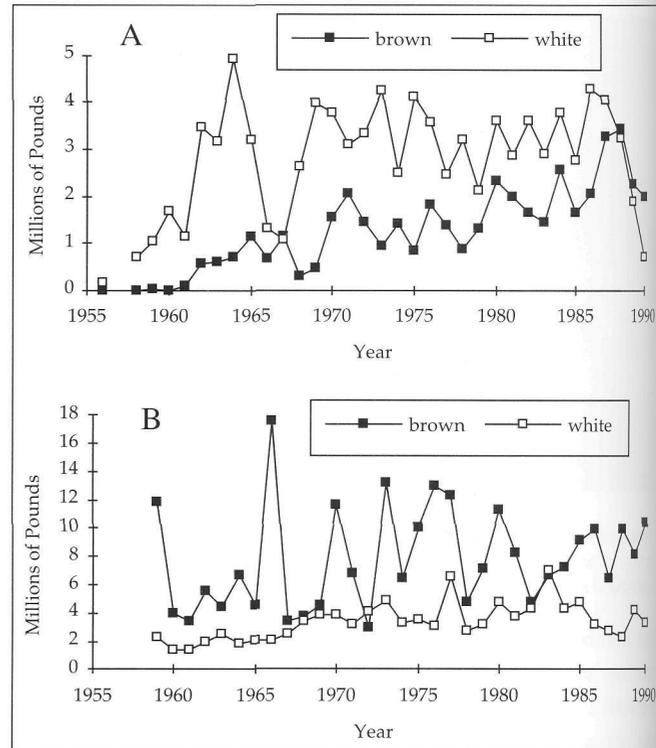
Source: Green et al., 1992

**FIGURE 4.7.** Commercial harvest of finfish from the Galveston Bay system, 1920–1990. The commercial catch is only about 14 percent of the total finfish catch from the bay, the remainder being accounted for by recreational fishing.

Marsh, Lower Marsh, Robinson Bay Marsh, and Delhomme Marsh.

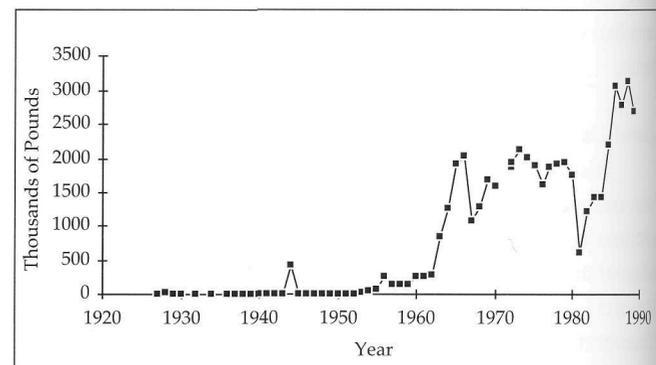
The majority of Brazoria county is rural with a few medium sized communities. Two suburban areas provide residences for commuters to Houston and for employees of the major petrochemical complexes in the county: the Pearland-Manvel-Alvin area in the northern part of the county and the Brazosport area in the southern portion (not in the Galveston Bay watershed). Two national priority wetlands are located in Brazoria County: Freshwater Lake and Hoskins Mound. Hoskins Mound has been incorporated into the Brazoria National Wildlife Refuge, which borders Bastrop, Christmas, and Drum Bays.

TABLE 4.6 presents percentage of land use by major development category by county for 1970, 1980 and 1990. In spite of the region's urban character, the majority of the five county area is undeveloped. Most of the counties have experienced an increase in single family residential area, typical of historical development patterns in this region. Harris County, however, showed a decline in acreage given to single family dwelling units between 1980 and



Source: Green et al., 1992

**FIGURE 4.8.** Commercial shrimp landings 1955–1990 in Galveston Bay (a) and the Gulf of Mexico off Galveston (b). The shrimp fishery is characterized by wide natural variability among years, but is essentially at its maximum sustained yield. Shrimp grow up in estuaries like Galveston Bay, migrating to the Gulf of Mexico as they mature to adults.



Source: Green et al., 1992

**FIGURE 4.9.** Commercial blue crab catch in Galveston Bay 1920–1990. Recent declines in adult size classes have indicated possible over-harvest, a concern being addressed by the Texas Parks and Wildlife Department in new regulatory actions.

1990, with an increase in multi-family dwellings, reflecting an increase in population density.

A current land use map (see FIGURE 5.2) was developed by Newell et al. (1992) using satellite imagery data from November 1991 (note that the land use map developed in their study considers only the contributing drainage areas of the lower watershed which are adjacent to the bay). The land use data presented by Newell et al. (1992) indicated that the majority of the watershed remains agricultural and open/pasture in nature. Urban areas occupied about 19 percent of the watershed (total area = 4,238 sq mi). The percentage

of watershed area for the major land use categories used in the study were:

High-Density Urban	10%
Residential	9%
Open/Pasture	23%
Agriculture	22%
Barren	1%
Wetlands	15%
Water	1%
Forest	18%

A strong relationship exists between land uses and pollution from rainfall runoff. Nonpoint source (NPS) loadings resulting from runoff due to rainfall have only recently received a great deal of attention, but their presence and effect on the bay has been noted for many years. As early as the 1820s, Henson (1993) documented the silting of the waterways due to urbanization: "as early as 1839 a visitor to Houston noted the amount of soil washing down Main Street into the bayou after every rain threatened to fill the steamboat landing."

More recently, NPS loads for a total of eight different water quality constituents in runoff were estimated for the bay area by Newell et al. (1992). A detailed discussion of nonpoint source pollution is found in Chapter Six.

### Economic Activity

The Texas Comptroller of Public Accounts (Sharp, 1993) has compiled recent economic data for counties in the Galveston Bay area and discussed the region's economy (TABLE 4.7). For the five counties around Galveston Bay, almost 90 percent of the employment in 1992 is located in Harris County. Retail sales is similarly concentrated in Harris County. Although oil and gas production is important in all five counties, Brazoria has a large share (about 43 percent) of the area's natural gas production. Not surprisingly, agricultural receipts are greatest in Brazoria, Chambers, and Liberty counties. Even in Harris and Galveston counties, however, agriculture accounted for 11.2 and 7.7 million dollars in receipts respectively in 1992.

Sharp (1993) found that unemployment in 1992 ranged from 6.6 percent in Chambers County to 10.6 percent in Liberty County. Liberty County had the lowest per capita income (\$9,928) and

TABLE 4.9. Licensed Fishermen by Fiscal Year.

License Type	Fiscal Year <sup>1</sup>	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties
<b>Commercial<sup>2</sup></b>	1992	754	261	1,287	1,193	123	3,618
	1991	898	326	1,336	1,631	155	4,346
	1990	954	394	1,498	1,461	197	4,504
	1989	1,050	589	1,910	1,635	282	5,466
	1988	1,220	622	2,327	1,917	276	6,362
	1987	1,284	711	2,258	2,100	309	6,662
	1986	1,457	638	2,261	2,283	280	6,919
	1985	1,271	619	2,353	2,522	292	7,057
	1984	1,657	576	2,518	2,787	268	7,806
	1983	1,905	616	2,960	3,275	312	9,008
<b>Sport<sup>3</sup></b>	1992	32,256	2,755	51,600	199,882	9,073	295,566
	1991	32,537	2,957	51,468	210,420	10,822	308,204
	1990	35,624	3,043	53,398	206,448	11,396	309,909
	1989	33,964	3,229	53,767	231,502	10,076	332,608
	1988	35,369	3,732	52,184	209,997	10,507	311,789
	1987	37,184	3,678	52,529	204,445	10,997	308,833
	1986	40,684	4,105	60,834	206,508	10,424	332,555
	1985	35,228	3,445	46,709	187,381	8,832	272,593
	1984	31,986	3,669	53,190	193,458	10,390	292,691
	1983	37,538	4,355	71,098	215,596	10,761	339,348
1982	35,921	4,386	63,792	218,270	13,909	336,278	

Source: Texas Parks and Wildlife Department, 1993

N/A = Data Not Available

<sup>1</sup>Fiscal Year from 9/1 through 8/31

<sup>2</sup>Commercial fishing licenses held by residents residing within county

<sup>3</sup>Sport fishing licenses sold within county

TABLE 4.10. Direct and Total Economic Impact of Commercial Fishing in Galveston Bay in 1986 (in Millions of 1986 Dollars).

	Ex-Vessel Value of Landings		Total Impact <sup>1</sup>			
			Inshore		Inshore/Offshore	
	Inshore	Inshore/Offshore	Region	State	Region	State
Output	12.50	63.60	32.90	41.10	167.60	209.30
Employment	683.00	3,476.00	799.00	896.00	4,063.00	4,558.00
Income	3.50	18.00	7.30	10.40	37.20	52.70
State Tax Rev.	0.06	0.31	N/A	0.50	N/A	2.80
Local Tax Rev.	0.08	0.43	N/A	0.86	N/A	4.40

Source: Fesenmaier et al., 1987

<sup>1</sup>Total Impact includes direct, indirect, and induced

Harris County the highest (\$15,202) for that year. The State Comptroller has forecast average annual growth rates for employment, retail sales, and personal income for the 13-county state planning region (which includes the five-county Galveston Bay area) that are slightly lower than similar rates for the State of Texas for

**TABLE 4.11. Direct and Total Economic Impact of Commercial Fishing in Galveston Bay in 1976 (in Millions of 1986 Dollars).**

	Fishing Sector	Total Impact <sup>1</sup>	
		Regional	State
Output	115.0	244.2	358.0
Income	38.3	81.3	98.4
State Tax Rev.	0.4	2.3	3.2
Local Tax Rev.	0.5	4.0	4.5

Source: Texas Department of Water Resources, 1981a

<sup>1</sup>Total Impact includes direct, indirect, and induced

the period from 1990-2000 (Sharp, 1993).

Economic activities that are important within the five counties surrounding the bay can be characterized by looking to historical data compiled by various government agencies. The following sections describe these activities.

### Commercial Fishing and Oystering

Galveston Bay historically has been the overall leading fisheries resource base in Texas. Between 1982 and 1986, the annual commercial bay harvest of finfish and shellfish has averaged 11.5 million pounds, approximately one-third of the state total (Osburn et al., 1987).

In 1890, the catch was evenly distributed between finfish and oysters with much less shrimping compared to present-day landings (TABLE 4.8). During this time the bay also supported small fisheries focusing on striped bass and sea turtles. Almost 100 years later, the total landings have more than doubled but are now dominated by oysters, crabs, and shrimp. The annual finfish catch is a relatively small part (4.9 percent) of the total harvest, averaging about one-half million pounds per year (FIGURE 4.6; TABLE 4.8). Part of the reason for this decline is the ban on commercial harvesting of spotted seatrout and red drum imposed in September 1981 due to concerns about over-harvesting (FIGURE 4.7). Currently four species account for nearly 75 percent of the total finfish harvest: southern flounder, black drum, mullet, and sheepshead.

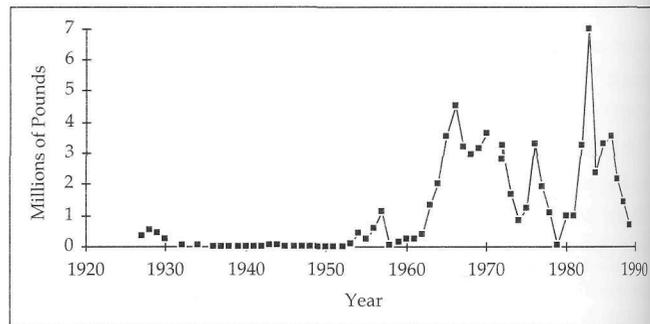
Shrimp, blue crabs, and oysters have been the dominant shellfish species in the commercial catch, making up nearly 95 percent of the total annual bay catch (FIGURES 4.8 through 4.10). Shrimp (white and brown) accounted for nearly half the total seafood harvest between 1982 and 1986. Over three million pounds of white shrimp along with 1.9 million of brown shrimp were caught in the bay in an average year (FIGURE 4.8). There were about 1.8 million pounds of blue crabs (FIGURE 4.9) in an average year's harvest (Osburn et al., 1987). Finally, by weight, the eastern oyster was the single most important species harvested in the bay during the period (3.9 million pounds per year, FIGURE 4.10).

The number of commercial fishing licenses issued between 1982 and 1992 are listed in TABLE 4.9. The data for 1992 indicate a total of 3,618 licenses for the five-county region. Overall, there has been a general ten-year decline of nearly 60 percent in the num-

ber of commercial fishing licenses issued in these counties.

Fesenmaier et al. (1987), in a report to the Texas Water Development Board, estimated the economic impact of commercial fishing. The authors used commercial finfish and shellfish volumes from both inshore (bay system) and offshore landings to estimate the direct and total economic impact of commercial fishing in the Galveston Bay estuary (called the Trinity-San Jacinto estuary in their report). These impacts, including personal income and employment are presented in TABLE 4.10 and TABLE 4.11.

These data suggest the importance of offshore landings supported by the estuary. Offshore seafood landings represent an indirect use of Galveston Bay because much of the seafood, particularly shrimp, spends at least part of its life cycle in the bay. The average annual inshore commercial fish landings (finfish and shellfish) for the estuary were reported to be 11.3 million pounds with an ex-



Source: Green et al., 1992

**FIGURE 4.10.** Commercial oyster catch in Galveston Bay, 1920-1990. In recent decades, as the oyster production in some east coast estuaries like Chesapeake Bay has plummeted, Galveston Bay oysters have supplied many cities throughout the nation.

vessel value of \$12.5 million for 1984 through 1986. Of this, eastern oyster, shrimp and flounder made up almost 91 percent of the total value of landings. Adding the offshore ex-vessel value for this same time period results in more than \$63 million generated, as can be seen in TABLES 4.10 and 4.11. Additionally, these data indicate that the inshore catch provided for 683 full-time jobs (direct employment) with personal income of about \$3.5 million. Adding offshore landings supported by the estuary accounted for 3,476 jobs, and generated personal income of \$18 million. Local and state taxes amounted to \$81,000 and \$61,000, respectively, attributable to inshore landings (Fesenmaier et al., 1987).

Other data published by the Texas Department of Water Resources (1981a) estimated the economic impact to the state from commercial fishing in Galveston Bay to be about \$358 million (TABLE 4.10 and 4.11) in 1976. This dollar amount is higher than the \$209.3 million estimated by Fesenmaier et al. (1987) for 1986.

Galveston Bay oysters are an important commercial species. Prior to 1870, oysters were not harvested commercially because there were no efficient methods for transporting the oysters inland (Stanley, 1992). The development of shipping and processing industries along the coast allowed the growth of the commercial oyster industry.

Most of the oyster reefs in the estuary are located in the cen-



Source: Galveston Bay National Estuary Program



Source: Galveston Bay National Estuary Program

Products ranging from automobiles to bulk products such as grain are handled at the Port of Houston, which now ranks sixth in the world in tonnage.

tral portion of East Bay and in mid-Galveston Bay where fresher waters of the major tributaries mix with saline waters of the gulf. The largest reef complex is around Redfish Bar, between Eagle Point and Smith Point, in central Galveston Bay. Oysters are harvested from both public reefs and private oyster leases in the bay. (Oysters and their reefs have a role in many aspects of the bay; additional information is found in Chapters Three, Five, Seven, Eight, and Nine).

Historical trends in the Galveston Bay oyster harvest are shown in FIGURE 4.10. Stanley (1992) estimated annual production rates ranging from 244,000 to 336,000 pounds of shucked oyster meats for the period between 1900 and 1910. After 1911, Stanley (1992) indicates that harvests dropped substantially from almost 100,000 pounds in 1914 down to slightly below 15,000 in 1920. Within two years, however, production jumped by about ten times to almost 150,000 pounds and varied between 100,000 to over 300,000 until 1930. Between 1930 and 1950, the oyster harvest plummeted to less than 1,000 pounds in some years and no harvest was reported in 1948. Oyster harvesting did not recover substantially until the 1960s when production skyrocketed to four million pounds. Another cycle of rising harvests was capped off in 1983 with a seven million pound harvest. The catch has been declining throughout the late 1980s and has dropped down to about one million pounds per year in the early 1990s.

It should be noted that there are health concerns associated with the commercial harvesting of oysters. The Texas Department of Health has a program to restrict the harvesting of oysters to protect the public from health risks due to pathogens in the bay resulting primarily from human wastes. These public health issues are discussed in more detail in Chapter Nine. Suffice it to say, however, that about 21 percent of the oyster reefs in Galveston Bay (about half the bay's total area) are classified as prohibited or polluted and the Texas Department of Health has declared them off-limits for harvesting. Periodically, additional areas are temporarily closed to harvesting for short durations following heavy rainfall or river floods (Benefield and Hofstetter, 1976; Texas Parks and Wildlife Department, 1988).

### Shipping

While the region has other forms of transportation, shipping is still a major attraction to commercial and industrial interests

**TABLE 4.12. Total Shipping Tonnage in the Galveston Bay System.**

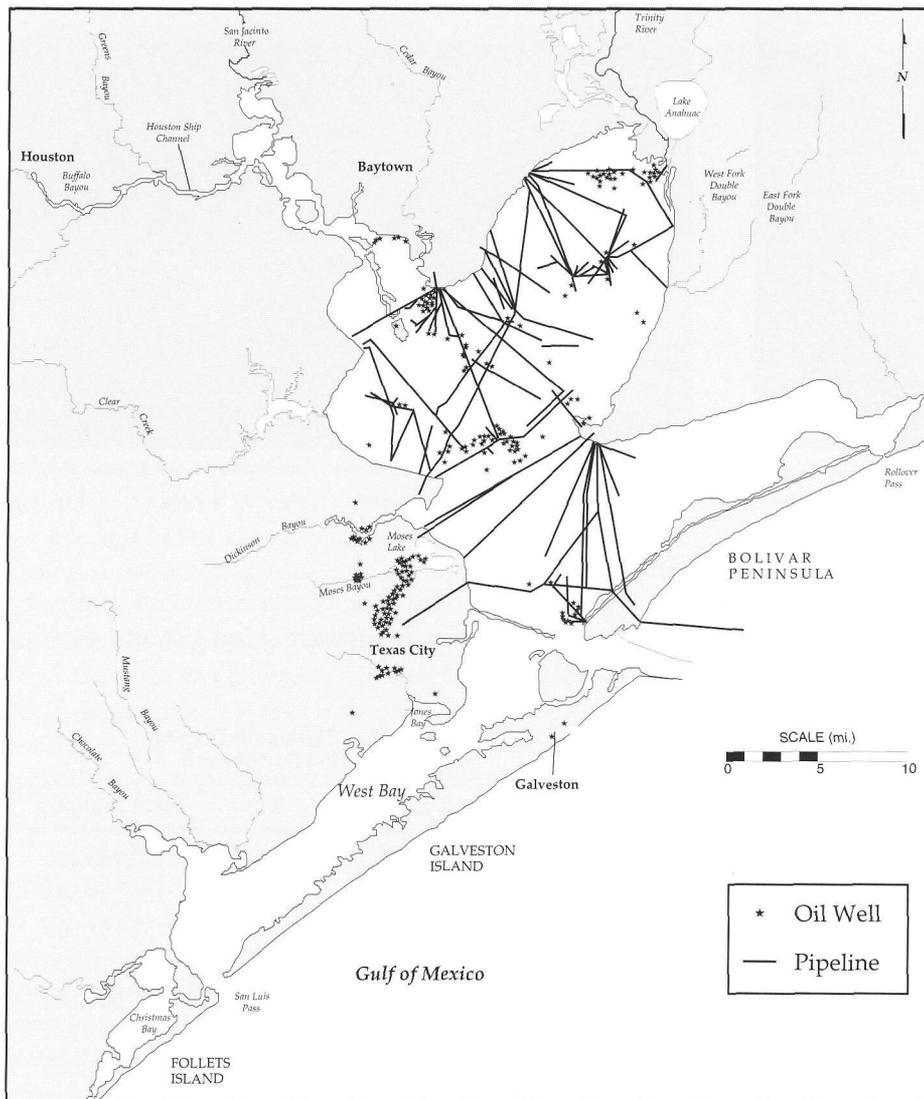
Year	Total Tonnage	Year	Total Tonnage
1970	84,417,200	1980	142,760,400
1971	89,125,700	1981	139,329,500
1972	94,670,900	1982	136,181,300
1973	114,244,100	1983	132,070,000
1974	115,511,700	1984	137,504,100
1975	112,731,500	1985	130,617,700
1976	124,794,700	1986	142,551,900
1977	145,452,300	1987	155,355,900
1978	153,009,400	1988	177,036,700
1979	172,324,600	1989	175,608,200

Source: U.S. Army Corps of Engineers, 1993

**TABLE 4.13. Historical Shipping in Galveston Bay.**

Ports	1955 (1000s Tons)	1970 (1000s Tons)	1988 (1000s Tons)
<b>Major</b>			
Houston Ship Channel	47,000	65,000	125,000
Texas City Channel	14,000	17,000	43,000
Galveston Channel	6,000	3,000	13,000
Chocolate Bayou	100	2,500	3,500
<b>Minor</b>			
Double Bayou	67	6	3
Anahuac Channel	512	480	3
Cedar Bayou	532	487	275
Clear Creek	44	397	N/A
Dickinson Bayou	425	457	722
Trinity River Channel	497	355	4

Source: U.S. Army Corps of Engineers



Source: Texas General Land Office

**FIGURE 4.11.** Petroleum wells and pipelines in Galveston Bay. This infrastructure helps sustain the oil and gas production industry, which directly employs about 11,000 persons in the region.

(Sharp, 1993). Shipping by the major ports (Houston, Galveston, and Texas City) in the region grew dramatically from 1955 to 1988, while the tonnage associated with several smaller ports (Double Bayou, Anahuac Channel, Cedar Bayou, Trinity River Channel) declined to almost nothing (Allison et al., 1991). TABLES 4.12 and 4.13 present data for waterborne commerce in the Galveston Bay system. Total tonnage transported in 1989 has grown to more than double the tonnage shipped in 1970 (U. S. Army Corps of Engineers, 1993).

The dominance of petroleum and related industries around the bay is reflected in the types of commerce on the Ship Channel. The major cargo types are refined petroleum products (37 percent), chemicals and plastics (21 percent), crude petroleum (13 percent) and wheat (13 percent). Wheat, petroleum products and chemicals are the primary exports, while crude petroleum, various mineral ores, steel products and motor vehicles are the main imports (Liebow et al., 1980).

## Oil and Gas Production

Petroleum extraction, while still an important industry, has declined considerably since the 1970s. Platforms for producing oil, condensate, and natural gas and pipelines for its transport (FIGURE 4.11) are present in Galveston Bay in Chambers County (Trinity Bay and Upper Galveston Bay) and Galveston County (Lower Galveston Bay, East Bay, and West Bay). Oil and gas wells on land also are found in Harris, Brazoria, Chambers and Galveston counties.

TABLES 4.14 (oil), 4.15 (gas), and 4.16 (total petroleum) list the petroleum production in four counties around the bay for the years 1979 through 1992. As of April 1993, there were a total of 1,096 producing oil wells and 550 gas wells in the four counties (Texas Railroad Commission, 1993). Total oil production exceeds 11 million barrels per year with a direct value of \$231 million. The Texas Railroad Commission estimated that employment directly and indirectly attributable to the oil industry in the region was about 6,000 persons in 1992. Total gas production was approximately 128 million MCF (million cubic feet) in 1992 with a direct economic value of \$193 million and an associated employment of nearly 5,000 persons.

The discharge of **produced water** into Galveston Bay waters during the extraction of oil and gas has raised environmental concerns regarding the impact of these brines on water quality in the estuary. In 1990 over 353,000 barrels per day of brines were produced in Harris County. In early 1993, the discharge of brine into the Galveston Bay system was estimated to be 137,000 barrels per day (Texas Railroad Commission, 1993). These brine production volumes have declined from their peak values in the early 1980s. Chapters Six and Nine address the resulting water quality problems, biological impacts, and public health issues associated with the discharge of brines into the estuary.

## Shell Dredging

Beginning in 1905, large quantities of shell were removed from the Galveston Bay system for industrial and construction purposes. New industrial processes after World War II greatly increased the value of the shell as a raw material, and the volume of shell removed increased from about four million cubic yards per year in 1945 to over eight million cubic yards per year in the mid-1960s. Increasing environmental concerns resulted in more stringent regulation of the industry, and since 1969 shell dredging has

**TABLE 4.14. Oil Production in the Four County Galveston Bay Region: Brazoria, Chambers, Harris and Galveston Counties.**

Year	Producing Wells	Production (MillionBbl)	Direct Value <sup>1</sup> (Million \$)	Total Value <sup>2</sup> (Million \$)	Jobs Supported <sup>3</sup>
1979	2,848	52	655.7	1,914.6	16,655
1980	2,946	37	802.5	2,343.3	20,384
1981	2,953	32	1,106.2	3,230.1	28,097
1982	2,915	29	916.9	2,677.3	23,289
1983	2,851	26	789.8	2,306.1	20,060
1984	2,777	25	759.3	2,217.2	19,286
1985	2,760	25	691.7	2,019.9	17,570
1986	2,694	24	367.5	1,073.0	9,333
1987	2,460	21	388.2	1,133.5	9,860
1988	2,396	18	283.5	827.8	7,201
1989	2,170	16	289.6	845.5	7,355
1990	2,002	14	315.0	919.8	8,001
1991	1,995	12	246.9	720.9	6,271
1992	1,947	12	231.3	675.4	5,875

Source: Texas Railroad Commission, 1993

<sup>1</sup>The direct value of production reflects the total taxable value

<sup>2</sup>The total value of production includes the direct value plus the indirect value computed as \$1.92 per \$1.00 of production value

<sup>3</sup>The number of jobs is computed as 25.4 jobs per \$1 million in production output. Includes 7.7 jobs in the production industry plus 17.7 jobs in supporting industries

The economic multipliers used are as quoted by the office of the Texas Comptroller of Public Accounts, Austin

**TABLE 4.15. Gas Production in the Four County Galveston Bay Region: Brazoria, Chambers, Harris and Galveston Counties.**

Year	Producing Wells	Production (Million MCF)	Direct Value <sup>1</sup> (Million \$)	Total Value <sup>2</sup> (Million \$)	Jobs Supported <sup>3</sup>
1979	1,120	592	704.5	2,057.1	17,894
1980	1,012	515	772.5	2,255.7	19,622
1981	1,007	408	730.3	2,132.5	18,550
1982	1,003	317	659.3	1,925.1	16,746
1983	898	330	559.0	1,632.4	14,199
1984	918	361	560.0	1,635.2	14,224
1985	898	279	523.9	1,529.8	13,307
1986	791	264	314.4	918.1	7,986
1987	746	253	265.7	775.8	6,748
1988	728	222	274.2	800.7	6,965
1989	697	190	235.1	686.4	5,971
1990	654	179	224.2	654.7	5,695
1991	635	155	184.9	540.0	4,697
1992	596	128	193.6	565.2	4,916

Source: Texas Railroad Commission, 1993

<sup>1</sup>The direct value of production reflects the total taxable value

<sup>2</sup>The total value of production includes the direct value plus the indirect value computed as \$1.92 per \$1.00 of production value

<sup>3</sup>The number of jobs is computed as 25.4 jobs per \$1 Million in production output. Includes 7.7 jobs in the production industry plus 17.7 jobs in supporting industries

The economic multipliers used are as quoted by the office of the Texas Comptroller of Public Accounts, Austin

been banned from the bay. Ward (1993) estimates that approximately 220 million cubic yards of shell was removed between 1910 and 1969, a volume on the same order of magnitude as the cumulative new work excavation from navigation channel work.

### Recreational Uses

The bay is used for numerous recreational activities including duck hunting, saltwater fishing, swimming, nature viewing, pleasure boating, camping, picnicking and sight-seeing (FIGURE 4.12). Not many direct quantitative measures of these activities are available, however, estimates of the amount of money generated from them is an indication of their importance. In 1986, for example, \$122 million was spent in the Galveston Bay area on recreation and tourism; this amount was about one-third of the amount spent on the Texas coast for sport fishing and was 55 percent of the total expenditures for recreation and tourism on the Texas coast (Texas Water Commission, 1988). Gross Texas business resulting from tourism and recreational uses of the Galveston Bay complex amounted to \$425.2 million in 1986 (Texas Water Commission, 1988).

Many of the more popular activities participated in by residents of the Gulf Coast Region as identified in the Texas Outdoor Recreation Plan (TORP), can be associated with the use of Galveston Bay. The percentage of residents expected to at least annually participate in walking, saltwater swimming, and/or picnicking is well over 40 percent (Houston-Galveston Area Council, 1993a; 1993b). More than 20 percent of the region's population is expected to participate in saltwater fishing and the use of open space and about 15 percent will enjoy saltwater boating.

**TABLE 4.16. Total Direct and Indirect Economic Impact from Oil and Gas in the Four County Galveston Bay Region: Brazoria, Chambers, Harris and Galveston Counties.**

Year	Value (Million \$)	Total Jobs
1979	3,971.7	34,549
1980	4,599.0	40,006
1981	5,362.6	46,647
1982	4,602.4	40,035
1983	3,938.5	34,259
1984	3,852.4	33,511
1985	3,549.7	30,878
1986	1,991.1	17,320
1987	1,909.3	16,608
1988	1,628.5	14,166
1989	1,531.9	13,326
1990	1,574.6	13,696
1991	1,260.9	10,968
1992	1,240.6	10,791

Source: Texas Railroad Commission, 1993

In 1986, the Texas Parks and Wildlife Department completed a survey of recreation participation (Texas Parks and Wildlife Department, 1986). TABLE 4.17 presents the total amount of recreation user occasions occurring in one year in the 13-county Gulf Coast Region in 1985 (the population in 1985 of the Gulf

**TABLE 4.17. Total Recreational User Occasions for 1985, For the 13-County Gulf Coast Region of Texas.**

Activity	Number of Occasions <sup>1</sup>
Walking for Pleasure	57,951,297
Bicycling	46,296,097
Jogging	23,727,075
Playground Use	23,283,212
Open Space Activities <sup>2</sup>	14,142,232

Source: Texas Parks and Wildlife Department, 1986

<sup>1</sup>Based on a total population of 3.7 million

<sup>2</sup>Activities such as kite flying, sunbathing, frisbee throwing, exploring, etc., at an undeveloped place open to the public

**TABLE 4.18. Total Recreational User Occasions with a Specific Destination (1985) For the 13-County Gulf Coast Region of Texas.**

Activity	Destination	Number of User Occasions <sup>1</sup>
<b>Hiking</b>	Bolivar Peninsula	15,781 <sup>2</sup>
	Houston Area	226,741
	Galveston Island	190,861
	All Destinations	417,602
<b>Picnicking</b>	Bolivar Peninsula	254,403
	Houston Area	2,387,686
	Galveston Bay Area	259,350
	Galveston Island	1,177,133
	All Destinations	4,078,572
<b>Nature Viewing</b>	Chambers County	17,947
	Houston Area	343,757
	Galveston Bay Area	499,349
	Galveston Island	448,548
	All Destinations	1,309,601
<b>Saltwater Swimming</b>	Bolivar Peninsula	597,462
	Galveston Bay Area	470,510
	Galveston Island	7,505,894
	All Destinations	8,573,866
	<b>Saltwater Fishing</b>	Bolivar Peninsula
Galveston Bay Area		2,393,338
Galveston Island		2,021,712
All Destinations		4,721,206
<b>Saltwater Boating</b>		Bolivar Peninsula
	Galveston Bay Area	2,116,647
	Galveston Island	844,210
	All Destinations	2,960,857

Source: Texas Parks and Wildlife Department, 1986

<sup>1</sup>One user occasion results if any part of a day is devoted to a recreational activity by a single recreationist at a single site

<sup>2</sup>Only partial data available for use

Coast Region was estimated at 3.7 million residents). The data in TABLE 4.17 indicate that recreational activities such as walking, bicycling, jogging, open space and playground use are extremely popular pastimes.

TABLE 4.18 presents the total number of recreation user occasions occurring in one year, with the destination of the user identified. Picnicking, fishing and swimming top the list in terms of participation (most of the saltwater swimming shown for Galveston Island relates to the gulf beaches rather than the bay). Note that the data presented in this table are for Texas residents only; it is unknown how many out-of-state visitors are using the same resources every year.

In May 1993, Whittington et al. (1993) surveyed bay area households about their use of the bay for recreational and other purposes. Results of the survey indicated that approximately 20 percent of the population of the five-county area use the bay for recreational boating and fishing at least once a year (TABLE 4.19). In addition to those households that fish or boat on the bay, 13 percent reported that they used the bay for other recreational activities (hiking, picnicking, camping, hunting, swimming, bird-watching, etc.). Thus, about 34 percent of bay area households, or 400,000 households, use the bay at least once a year for recreational purposes (Whittington et al., 1993). Whittington et al. (1993) noted that many people from outside the five-county area also use the bay for recreational purposes.

### Sport Fishing

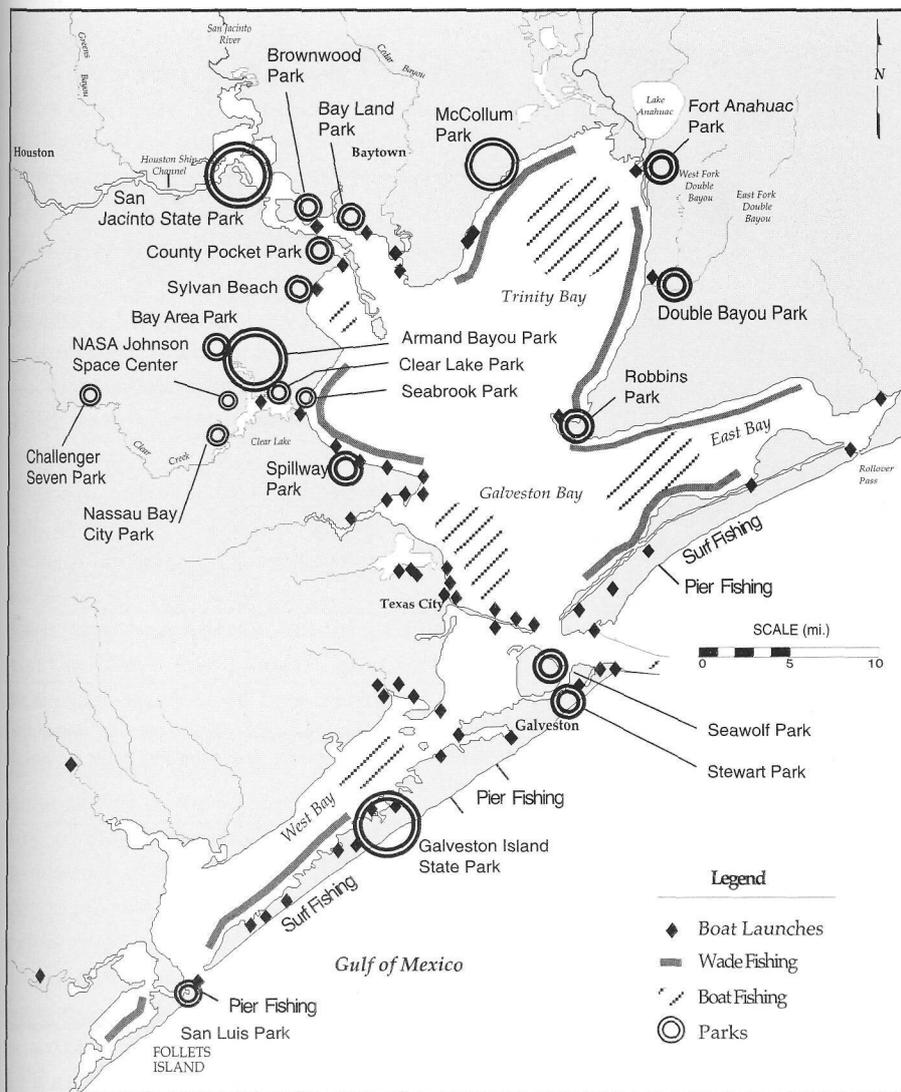
In addition to the important commercial finfish fishery in the bay, there is also a significant sport fishery (see FIGURE 4.12 for locations). In fact, commercial fishing on the average accounts for only about 14 percent of the total catch within the bay, with the remainder (86 percent or 498,960 kg in 1986) going to the sport catch (Texas Department of Water Resources, 1981b; Texas Water Commission, 1988). The bay supports approximately two million hours of sport fishing annually, (FIGURE 4.13) creating economic benefits estimated at \$364 million in 1986 (Texas Water Commission, 1988).

**TABLE 4.19. Estimated Number of Greater Houston/Galveston Area Households that Use Galveston Bay for Recreational Purposes at Least Once a Year.**

Recreational Use	Households Using the Bay	
	Number	%
Fishing/Boating		
Boat/Shore Fishing	125,000	11
Boating (Without Fishing)	50,000	4
Households That Fish and Boat	75,000	6
Total (Fishing and Boating)	250,000	21
Other Recreational Activities <sup>1</sup>	150,000	13
Any Type of Recreation	400,000	34

Source: Whittington et al., 1993

<sup>1</sup>Includes hiking, bird watching, picnicking, camping, hunting, swimming, etc.



Source: Galveston Bay National Estuary Program, 1992

**FIGURE 4.12.** Recreation is a key human use of the bay system. Some features related to boating, fishing, and parks are indicated. Currently, public access to the Galveston Bay shoreline is limited in comparison to beaches on the Gulf of Mexico.

(by numbers) between 1974 and 1985 (Osburn and Ferguson, 1986; FIGURE 4.15).

Sport fishing expenditures associated with the estuary account for approximately 50 percent of all sport fishing expenditures in Texas. Gross direct contribution to the local economy amounted to \$171.5 million in 1986 (TABLE 4.20). These figures are much higher than those reported by the Texas Department of Water Resources for 1976. In 1976, sport fishing expenditures in the estuary were reported by Texas Department of Water Resources to be slightly less than \$8 million (TABLE 4.20).

### Boating

Boating, along with shipping, has been an integral use of the bay throughout history. TABLE 4.21 lists boating registration data for recreational and commercial boats from 1980 through 1992. Overall, there has been a slight decline in the number of annual commercial boating registrations in all the counties since 1980. Still, over a thousand commercial boating registrations were issued in the bay area in 1992.

Recreational boating is popular on the Texas coast in general and around Galveston Bay in particular. The Clear Lake-Galveston Bay area has been referred to as the "yacht capital of Texas." Residents in a four-county area around the bay in 1986 held approximately 102,000 pleasure boat licenses and were served by 38 marinas and 8,000 boat slips (Texas Water Commission, 1988). In

1992, the number of recreational boat registrations was about 98,000 (TABLE 4.21). The bay system accounts for 30 percent of the total number of marinas on the Texas coast and 63 percent of the total wet slips in commercial marinas (Texas Water Commission, 1988). This has grown from a 1976 figure of 27 percent of total marinas and 56 percent of coastal wet slips.

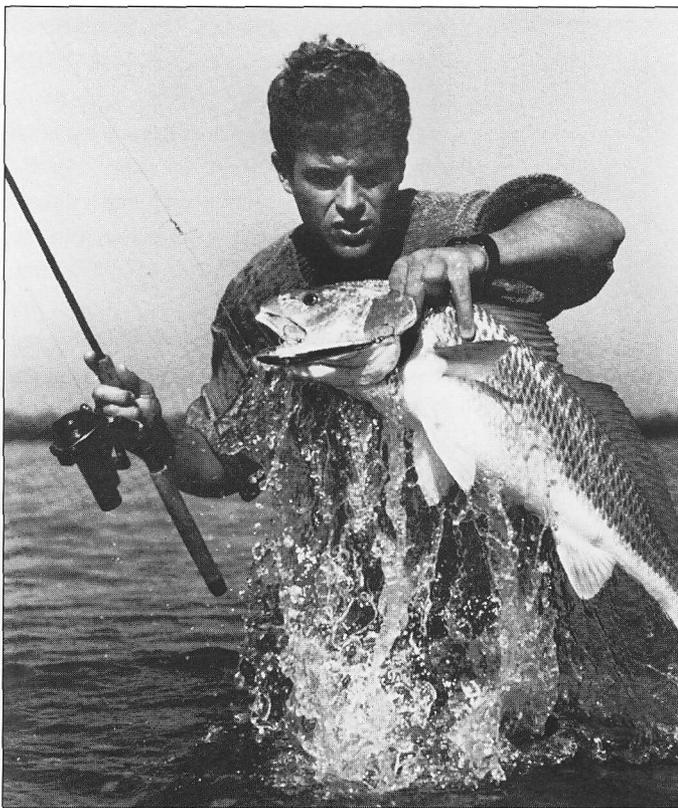
### Tourism

**Ecotourism**, or tourism that is based on nature rather than man-made attractions is the tourist industry's most rapidly expanding sector (Eubanks, 1993). The City of Rockport on the Texas coast, for example, now enjoys over \$4.5 million in economic benefits annually from ecotourists who come to enjoy the whooping cranes at Aransas National Wildlife Refuge. Chambers County, visited by tourists primarily for natural attractions such as bird-watching at High Island or wildlife viewing at the Anahuac National Wildlife Refuge, has experienced significant growth in the tourist

TABLE 4.9 lists the number of recreational fishing licenses issued in the five counties around the bay between 1982 and 1992. The number of recreational fishing licenses issued has declined during this period from 336,278 in 1982 to 295,566 in 1992.

Fishing pressure on the bay due to commercial and recreational catches has increased in recent years while the estimated success of the fishing by sports fishers has been decreasing (FIGURE 4.14). For example, Allison et al. (1991) reported that in the 1974-1976 period over 2.8 million hours of private fishing effort resulted in a total catch of 5.5 million fish, or about two fish caught per hour. In the 1986-1987 period, however, only 2.4 million fish were caught from 2.2 million hours of fishing, an average of about one fish caught per hour.

About three-quarters of the annual sport fishing effort, and catch, occurs between May 15 and November 20. Atlantic croaker, sand sea trout, and spotted seatrout are the sport fishes taken most frequently. Together they comprised 76 percent of the total catch



Source: Craig Biddle

Recreational fishing supports a multi-million dollar economy. Anglers pursue fish such as spotted seatrout, red drum, flounder, and croaker. Here, a wade-fisherman lands a red drum on light tackle.

**TABLE 4.20. Direct and Total Economic Impact (Millions of 1986 dollars) from Sport Fishing Expenditures Related to Galveston Bay.**

	Direct <sup>1</sup>		Total	
	Regional	State <sup>2</sup>	Regional	State <sup>2</sup>
<b>1986</b>				
Output	171.5	181.2	433.2	276.7
Income	53.6	66.1	104.0	154.5
State Tax Revenues	N/A	0.8	7.4	7.8
Local Tax Revenues	N/A	2.3	13.1	13.9
<b>1976-1977</b>				
Output	7.7	7.9	17.7	25.8
Income	2.8	3.0	5.2	7.3
State Tax Revenues	N/A	0.1	0.2	0.3
Local Tax Revenues	N/A	1.0	0.3	0.4

Source: For 1986: Fesenmaier et al., 1987; for 1976-1977: Texas Department of Water Resources, 1981a

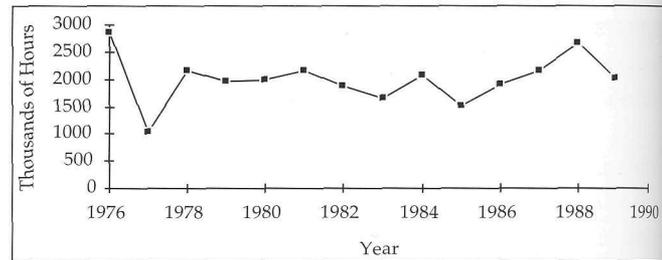
N/A = data not available

<sup>1</sup>Direct impacts for the region and the state differ due to the travel expenditure adjustment

<sup>2</sup>Total statewide expenditures include the regional impacts

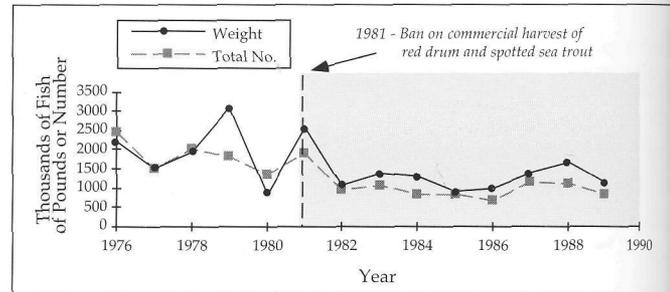
industry between 1975 and 1988, with total expenditures increasing from \$600,000 to over \$9 million (Allison et al., 1991).

Galveston Bay has several ecologically valuable sites that serve as ecotourist attractions. For example, bird-watching at High Island and other locations around the bay attracts visitors from all



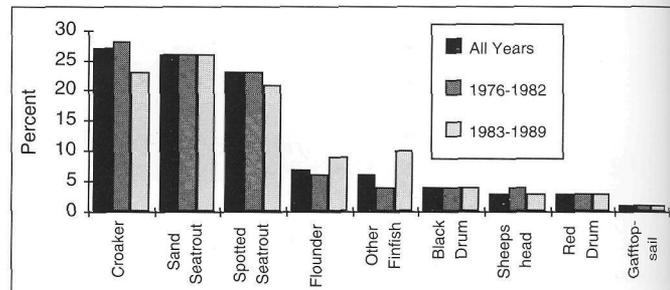
Source: Green et al., 1992

**FIGURE 4.13.** Trends in total hours spent sportfishing in Galveston Bay, 1976-1990. Economic benefits from this activity are estimated to exceed \$364 million annually.



Source: Green et al., 1992

**FIGURE 4.14.** The total recreational and commercial catch of finfish from Galveston Bay, 1976-1990. Fishing pressure has increased, while success per hour per individual has declined.



Source: Green et al., 1992

**FIGURE 4.15.** Composition of the sportfishing catch by species, comparing 1976-1982, 1983-1989, and all years.

over the United States and many foreign countries. Eubanks (1993) listed over 21 potential ecotourist attractions around Galveston Bay: Bolivar Flats, Rollover Pass, High Island, Anahuac National Wild Refuge, Chambers County Ricefields, White Memorial Park, Candy Abshier Wildlife Management Area, Trinity River Delta, Atkinson Island Wildlife Management Area, San Jacinto Battleground, Armand Bayou Nature Center, Challenger Park, Texas City Dike/Moses Lake, Brazoria National Wildlife Refuge, Follets Island, San Luis Pass, West Galveston Island, Galveston Island State Park, North Deer Island, Kempner Park, and Big Reef.

Allison et al. (1991) examined the contribution of tourism to the economic infrastructure of four counties around the bay (Harris, Chambers, Brazoria and Galveston). They found substantial growth between 1975 and 1988, with much smaller increases after 1988 (Allison et al., 1991). Economic data (travel expenditures, payroll, and number of jobs) compiled from the Texas Department of Commerce (Tourism Division) are presented in TABLE 4.22.

Expenditures for tourism in 1992 in Harris, Galveston, Brazoria, and Chambers counties totaled \$3.5 billion; \$307 million, \$91 million, and \$10 million, respectively. The number of jobs for 1992 in Harris, Galveston, Brazoria, and Chambers counties totaled 73,000; 5,600; 1,500; and 130; respectively. Allison et al. (1991) pointed out that the proportion of the expenditures shown in TABLE 4.22 that is directly or indirectly related to the bay is not known. Allison et al. (1991) also noted that growth in travel expenditures for the bay area tended to mirror the growth in tourism expenditures for the state as a whole.

There are other important recreational activities in the Galveston Bay area which have not been discussed in detail because little or no information is available for them. These include swimming and other forms of "contact recreation" such as water skiing, as well as nature study, and hunting. Although there are no data on swimming in Galveston Bay, major areas known to attract contact recreation in bay waters include Mud Lake, Offatts Bayou, the Texas City Dike, Clear Lake and Clear Creek. In terms of nature study, the Armand Bayou Nature Center has the only fully developed interpretive program in the bay area. New programs centering on the bay's resources are being developed by the Galveston Bay Foundation at its Rich Sanctuary in Chambers County and by the City of Seabrook at its Nature Center.

One of the concerns generated by recreational use of the bay is that of shoreline access. Public shoreline access to the bay is generally limited to the parks and boat ramps shown on FIGURE 4.12. As population in the area around the bay grows, there is likely to be demand for additional public facilities in these areas.

In summary, the economic impact from recreational activities in Galveston Bay is quite substantial. Visitors participating in fishing, hunting, picnicking, camping, pleasure boating and sightseeing spent approximately \$122.4 million in 1986 (TABLE 4.23). Gross personal income derived directly from this activity was on the order of \$38.2 million for that year. There were no other data on economic benefits from these activities prior to 1986.

**Agriculture**

Agricultural use of the land surrounding the bay has been declining for many years. Nevertheless, agriculture, and



Source: Galveston Bay National Estuary Program

More than 5000 boat slips are available in the Galveston Bay system. Sixty-three percent of boat slips on the Texas coast can be found around Galveston Bay. Clear Lake (shown here) hosts many of these boats and has been dubbed the "Yacht Capitol" of Texas.

**TABLE 4.21. Number of Boat Registrations for Counties Surrounding Galveston Bay, 1980 - 1992.**

	Year/ Type of Boat	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties
<b>Commercial</b>	1992	114	76	345	505	33	1073
	1991	112	83	364	506	44	1109
	1990	122	107	417	522	53	1221
	1989	131	132	433	514	63	1273
	1988	128	136	499	533	62	1358
	1987	126	135	514	554	52	1381
	1986	121	140	492	546	49	1348
	1985	130	107	523	585	44	1389
	1984	140	118	581	638	43	1520
	1983	147	114	576	613	51	1501
	1982	142	93	509	560	47	1351
	1981	135	86	495	562	51	1329
1980	144	88	527	585	60	1404	
<b>Recreational</b>	1992	9,967	1,334	10,308	76,307	2,740	100,656
	1991	10,069	1,384	10,124	77,335	2,890	101,802
	1990	10,206	1,444	10,160	78,603	2,873	103,286
	1989	10,097	1,493	9,956	78,591	2,822	102,959
	1988	9,909	1,484	9,718	78,592	2,815	102,518
	1987	9,822	1,472	9,608	79,714	2,886	103,502
	1986	9,736	1,479	9,539	81,098	2,938	104,790
	1985	9,668	1,442	9,447	82,519	2,940	106,016
	1984	9,664	1,385	9,503	84,190	2,987	107,729
	1983	9,633	1,385	9,547	85,604	3,103	109,272
	1982	9,605	1,329	9,348	86,127	3,105	109,514
	1981	9,267	1,282	8,982	84,947	3,034	107,512
1980	9,156	1,222	8,838	84,261	2,858	106,335	

Source: Texas Parks and Wildlife Department, 1993

**TABLE 4.22. Jobs and Dollars Derived from Tourism in the Counties Surrounding Galveston Bay (Millions of Dollars Not Adjusted for Inflation).**

Year	Category	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties
1992	Travel	91.20	10.39	306.75	3,511.45	35.21	5947.00
	Payroll	18.60	1.78	6617	1,400.14	8.44	1493.13
	Jobs	1470	130	5580	72550	510	80240
1991	Travel	89.88	10.04	301.03	3,380.73	33.81	5806.49
	Payroll	18.71	1.74	65.91	1,380.45	8.20	1483.01
	Jobs	1520	140	5660	72250	510	80080
1990	Travel	81.57	10.55	284.25	3,136.90	35.10	5538.37
	Payroll	16.67	1.79	61.16	1,242.72	6.50	1328.84
	Jobs	1400	150	5540	69470	570	77130
1989	Travel	73.19	9.80	249.23	2,797.96	33.25	5152.43
	Payroll	15.01	1.64	53.04	1,037.74	6.07	1113.50
	Jobs	1310	140	4970	61670	540	68630
1988	Travel	70.46	81.50	260.10	3,218.79	13.72	5540.57
	Payroll	13.21	1.60	51.73	711.70	2.19	780.43
	Jobs	1264	148	4693	51470	189	577
1985	Travel	29.54	4.78	242.28	3924.56	12.79	8196.97
	Payroll	5.50	0.94	48.80	814.08	2.02	869.34
	Jobs	529	70	4698	69232	197	74726
1980	Travel	49.06	11.13	179.47	2,585.18	8.00	4812.84
	Payroll	9.73	1.70	35.89	548.97	1.46	595.75
	Jobs	1188	193	4623	58811	200	65015
1975	Travel	28.71	0.58	108.17	1,037.15	10.18	3159.80
	Payroll	4.97	0.18	22.41	221.85	1.27	250.88
	Jobs	894	30	4651	41802	141	47518

Source: Texas Department of Commerce (1985; 1990; 1992)

**TABLE 4.23. 1986 Direct and Total Economic Impact from Other Recreation Expenditures Related to Galveston Bay (Millions of 1986 dollars).**

	Direct <sup>1</sup>		Total	
	Regional	State <sup>2</sup>	Regional	State <sup>2</sup>
Output	122.4	131.8	311.0	425.2
Income	38.2	48.5	74.5	113.3
State Tax Revenues	N/A	0.6	5.3	5.7
Local Tax Revenues	N/A	1.6	9.5	10.1

Source: Fesenmaier et al., 1987

N/A = data not available

<sup>1</sup>Direct impacts for the region and the state differ due to the travel expenditure adjustment

<sup>2</sup>Total statewide expenditures include the regional impacts

particularly irrigated agriculture such as rice farming, can be an important factor affecting the bay system. Irrigation, erosion control and pest control practices can affect the amount, timing, and quality of fresh water inflows. Frequently, conversion of agricultural land to more urban uses results in even greater impact on water use and runoff to the bay system.

Between 1967 and 1982, there was a decrease of 21 percent or 297,374 ac in the acreage used for agriculture (Ditton et al., 1989). In 1982, there were over 1.4 million acres of farm land in the four counties surrounding the bay (Harris, Brazoria, Chambers,

and Galveston). The market value of agricultural products sold from the four counties in 1982 was estimated by Ditton et al. (1989) at \$113 million.

The number of farms in Brazoria county increased by 17 percent from 1959 to 1987 with a total of about 1,500 farms in the county in 1987. However, during the same period the size of the average farm decreased by about 28 percent; and the total farmed land in Brazoria county decreased by 15 percent over the period. The unadjusted value of all crops sold tripled during that 28-year period, while the value of livestock sold increased by about 185 percent (Allison et al., 1991).

In Chambers county, the number of farms in 1987 came to 337; a 30 percent decrease from 1959. The unadjusted value of crops sold increased by about 100 percent while the value of livestock sold increased by about 85 percent. The number of large farms (with more than 1000 ac) increased over the period (Allison et al., 1991).

Similar trends in the number and size of farms were experienced in Galveston County. The number of farms decreased by about ten percent

between 1959 and 1978, however, a slight rebound occurred between 1978 and 1987. The unadjusted market value of crops increased by 124 percent from 1959 to 1987, but livestock declined in market value over the period. Most of the farms in Galveston County are in the ten to 500-ac size range (Allison et al., 1991).

The number and size of farms in Harris county also declined over the period between 1959 to 1987, by about 20 percent and 30 percent respectively. The result was a 44 percent reduction in agricultural land from 1959 to 1987. The unadjusted market value of products sold increased by 152 percent with the value of livestock increasing by 38 percent. As with Galveston County, the majority of the farms are in the ten to 500-ac range (Allison et al., 1991).

### Water Use

The location and timing of fresh water inflows affect salinity, circulation and the supply of sediments and nutrients to the bay (see Chapter Five—Physical Form and Processes of the Bay). At the same time, the growth of population and industry in an area is controlled to a large extent by the availability of suitable fresh water supplies. Allison et al. (1991) point out that fresh water is particularly important to economic growth in a four-county region surrounding the bay, since much of the economic activity in the Galveston Bay region is associated with the petroleum and petro-

chemical industries. These industries traditionally have used a large amount of water in their processes. For example, 1,851 gallons of water are required to refine one barrel of petroleum and 55 gallons of water are required to produce one pound of synthetic rubber.

To secure water for population and industry of the metropoli-

ordinary course does not drain into the Galveston Bay system.

TABLE 4.25 provides information on historical water use in the Galveston Bay area compared to the entire State of Texas (Texas Water Development Board, 1991). Although the Galveston Bay area is highly urbanized, the continued importance of agriculture in the region is emphasized by the increase in fresh water used during 1988. Most of that increase was attributable to water used for irrigation (Texas Water Development Board, 1991).

There have been major shifts in recent years in the source of the water used in some parts of the study area. For example, in the City of Houston household use has shifted more toward surface water in an effort to control subsidence in the region. However, there are still some problems with integrating surface water supplies into the current distribution system. Adequate capacity to transport surface water to some locations in the watershed does not exist and will require investment in infrastructure improvements.

Industrial and agricultural uses of groundwater in Harris and Galveston counties have declined by 81 percent and 50 percent since 1976, respectively. To accomplish that reduction in groundwater use, the Trinity River has grown as a major water supply from 3.7 MGD in 1976 to 177 MGD in 1990 (Allison et al., 1991).

Much of the surface water appropriated for human use is returned to the bay system. A statewide water use inventory for 1980 by the Texas Water Development Board found a range of return flows between 27 and 68 percent, with an average of 45 percent, for basins around Galveston Bay. Return flows from



Source: Galveston Bay National Estuary Program

Tourism is a major industry in the bay area. In particular, ecotourism is a growing segment of the industry which utilizes the environment as an attraction. Here, tourists feed laughing gulls from the ferry crossing Bolivar Roads between Galveston Island and the Bolivar Peninsula.

tan area, several reservoirs have been created on major tributaries of the Galveston Bay system. On the San Jacinto River, Lake Conroe and Lake Houston were built for the San Jacinto River Authority and the City of Houston. On the lower Trinity River, Lake Livingston was built principally for the Trinity River Authority and the City of Houston. A dam and associated shallow reservoir now under construction at Wallisville at the mouth of the Trinity is designed to serve as a saltwater barrier to protect fresh water supplies. Turtle Bay, a small brackish side bay off Trinity Bay in the upper bay system which is fed by Turtle Bayou, was converted into Lake Anahuac to provide fresh water supply for the city of Anahuac and for agriculture in Chambers County. (For a discussion of the effects of these impoundments and alterations, see Chapter Five—Physical Form and Processes of the Bay.)

TABLE 4.24 summarizes water use by purpose and source (groundwater or surface water) in 1990 for the five counties surrounding the bay (Texas Water Development Board, 1991). In the five-county area in 1990, over 1,400 million gallons per day (MGD) of fresh water were used. More than two-thirds of that amount was from surface water sources, principally the Trinity and the San Jacinto Rivers. Parts of Galveston County and Brazoria County receive surface water from the Brazos River, which in its



Source: Texas Sea Grant College Program

Agriculture remains an important economic and environmental influence in the Galveston Bay system. Rice farming predominates in the immediate watershed, while row crops such as sorghum, soybeans and cotton are more common in the upper watershed. These activities, including livestock production, can be nonpoint sources of pesticides, fertilizers, and other pollutants, but are overshadowed by even higher pollutant loadings from urban sources.

**TABLE 4.24. 1990 Water Use (Millions of Gallons per Day) by Purpose and Source for Counties Surrounding Galveston Bay.**

Water Purpose	Water Source	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties
<b>Public</b>	Ground	17.0	1.7	6.2	313.1	6.7	344.7
	Surface	7.5	0.9	23.9	126.0	0.0	158.2
	Total	24.5	2.5	30.1	439.1	6.7	503.0
<b>Industrial</b>	Ground	3.3	2.7	0.4	38.4	0.2	45.0
	Surface	175.4	10.9	52.6	287.5	0.0	526.4
	Total	178.7	13.6	53.0	326.0	0.2	571.4
<b>Agriculture</b>	Ground	5.1	0.2	0.8	24.7	10.9	41.8
	Surface	121.7	104.1	17.9	4.0	79.9	327.5
	Total	126.8	104.3	18.7	28.7	90.8	369.2
<b>Total</b>	Ground	25.5	4.6	7.3	376.3	793.7	431.5
	Surface	304.5	115.8	94.4	417.5	17.9	1,012.1
	Total	330.0	120.4	101.7	793.7	97.7	1,443.6

Source: Texas Water Development Board, 1991

**TABLE 4.25. Historical Water Use (Millions of Gallons per Day) for Counties Surrounding Galveston Bay, Compared to Water Use in the Entire State of Texas.**

Year	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties	Entire State
1974	353.2	116.3	102.5	695.1	100.9	1368.0	15,479.5
1977	333.8	111.2	106.4	798.5	102.7	1452.6	14,503.0
1980	477.9	194.7	123.0	781.5	134.7	1711.8	15,914.7
1984	336.4	156.0	97.4	752.8	102.5	1445.1	13,618.6
1985	364.4	109.8	95.0	763.8	95.3	1428.3	12,587.4
1986	325.9	100.6	95.3	769.2	83.6	1374.6	11,682.2
1987	297.1	95.3	98.6	749.2	78.9	1319.1	11,114.2
1988	368.2	145.7	99.9	835.6	165.9	1615.3	12,500.8
1989	323.4	104.7	97.5	753.3	90.3	1369.2	13,434.0
1990	330.0	120.4	101.7	793.7	97.7	1443.5	14,089.6

Source: Texas Water Development Board, 1991

groundwater usage, and diversions from other basins such as the Brazos, are also discharged to the bay's waters. Increases in water usage have obvious implications for fresh water inflow to the bay as well as wastewater collection and treatment systems in the bay region.

### Discharge of Treated Wastewater

Galveston Bay has historically suffered from the discharge of wastewater into its receiving waters. In the late 1800s street drains and sewers in Houston emptied separately but directly into Buffalo Bayou (Henson, 1993). Because of numerous accounts of resulting pollution, the city built the first sewer system in 1899 with a central pumping station on the northeast side where siphon pumps brought the sewage across the bayous (Henson, 1993). Within six years of that time, however, the capacity of the system was exceeded and the quality of its performance was suspect.

More disposal plants were built but in 1916 between 70

and 80 percent of the raw sewage still went directly to the bayou. Untreated disposal continued until the late 1960s when Dr. Joseph Melnick, an expert on virology and epidemiology, found a wide range of bacteria and viruses in the bayou water (Henson, 1993). By the early 1970s, the city began treating its raw sewage with chlorine. Today, much of the wastewater effluent is treated, however many communities around the bay still discharge raw sewage because of breakdowns in the systems and bypasses during flooding events.

In addition to the city of Houston, Galveston and the other smaller communities around the bay improved their wastewater disposal systems by changing from cesspools and outhouses (or septic tanks) to city sewers. In a 1950 study conducted by Galveston County, however, officials found that most of the municipalities were still dumping raw sewage into the bay. Much later, a federal study dealing with water pollution determined that of seven million gallons of sewage in 1970 from the city of Galveston, only 40 percent was adequately treated (Henson, 1993). Galveston eventually began treating its waste-



Source: Galveston Bay National Estuary Program

Galveston Bay receives municipal and industrial wastewater from more than half of all permitted discharges in the state. Shown is a regional industrial treatment facility which receives wastes from many of the ship channel industries.

**TABLE 4.26. Number of Discharge Facilities in Estuarine Drainage Areas (1987).**

Code <sup>1</sup>	SIC <sup>2</sup> Major Group Activity	Major <sup>3</sup>		Minor <sup>3</sup>	
		NCPDI <sup>4</sup>	Total <sup>5</sup>	NCPDI <sup>4</sup>	Total <sup>5</sup>
13	Oil and Gas Extraction	-	-	41	224
15	General Building Contractors	-	-	0	25
20	Food and Kindred Products	-	-	5	6
26	Paper and Allied Products	2	2	1	1
28	Chemicals and Allied Products	50	50	35	61
29	Petroleum and Coal Products	10	10	6	8
30	Rubber and Misc. Plastics Products	-	-	4	5
32	Stone, Clay, and Glass Products	-	-	5	12
33	Primary Metals Industries	4	4	2	7
34	Fabricated Metals Products	1	1	11	21
35	Industrial Machinery and Equipment	-	-	10	21
37	Transportation Equipment	-	-	2	4
42	Trucking and Warehousing	1	1	10	27
44	Water Transportation	-	-	2	4
47	Transportation Services	-	-	2	7
49	Electrical, Gas, and Sanitary Services	102	102	478	511
50	Wholesale Trade - Durable Goods	-	-	5	13
51	Wholesale Trade - Nondurable Goods	1	1	6	16
58	Eating and Drinking Places	-	-	0	8
65	Real Estate	-	-	4	75
70	Hotels and Other Lodging Places	-	-	0	10
72	Personal Services	-	-	4	5
73	Business Services	1	1	0	6
79	Amusement and Recreation Services	-	-	2	6
82	Educational Services	-	-	0	7
86	Membership Organizations	-	-	0	3
99	Nonclassifiable Establishments	-	-	2	2
	Other <sup>6</sup>	-	-	6	26
	<b>Total</b>	<b>173</b>	<b>173</b>	<b>643</b>	<b>1122</b>

Source: Pacheco et al., 1990

<sup>1</sup>Code = Standard Industrial Classification major group code number

<sup>2</sup>SIC = Standard Industrial Classification

<sup>3</sup>Major and Minor are used to classify discharges according to their relative importance as pollutant sources

<sup>4</sup>NCPDI = National Coastal Pollution Discharge Inventory

<sup>5</sup>Facility counts under "Total" include all facilities with NPDES permits listed in the Permit Compliance System

<sup>6</sup>Other includes activities with codes 14,16,17,24,36,40,46,48,54,55,75,76,78,80,83,95,96,97

**TABLE 4.27. Population Projections to the year 2010 for the Galveston Bay Region.**

Year	Brazoria	Chambers	Galveston	Harris	Liberty	All Five Counties
1990	191,707	20,088	217,399	2,818,199	52,726	3,300,119
1995	205,398	22,531	232,443	3,008,008	55,915	3,524,295
2000	220,069	25,271	287,678	3,217,690	58,738	3,809,446
2010	252,627	31,793	310,129	3,707,869	66,053	4,368,471

Source: Houston-Galveston Area Council, 1993b

water effluent prior to discharging it into the bay.

Today, many improvements have been accomplished in terms of municipal wastewater treatment and discharges into the bay. However, a large volume of effluent from industrial and municipal sources is still received by the bay. In 1987, Ditton et al. (1989) estimated that about 3,756 wastewater permittees in the State of Texas were located in the Galveston Bay watershed. About 31 percent were in the immediate vicinity of the bay, with 484 active domestic permittees and 235 active industrial permittees. Pacheco et al. (1990) estimated a total of 224 billion gallons of process water (non-cooling water industrial discharges) were discharged into the bay in 1990. The majority of that flow was from municipal sources (174 billion gallons per year), and the remaining 49 billion gallons were discharged from non-municipal sources. Different types of permit holders are shown in TABLE 4.26.

Armstrong and Ward (1994) estimate an annual **biochemical oxygen demand (BOD)** loading of 4.7 million kg per year in 1990 resulting from waste discharges and 22.4 million kg per year (1969 - 1988 average) from the tributaries. A remarkable 95 percent reduction has been achieved since 1968 in BOD discharged to the upper Houston Ship Channel. This has resulted in water quality improvements and the return of some fish species to the area. More detailed information on the location and trends in wastewater discharge is provided in Chapter Six.

#### **Other Uses: Real Estate Development**

There is extensive residential/commercial real estate use of coastal land. For example, the four counties surrounding Galveston Bay contained 1.1 million or 77 percent of the housing units in the 16 Texas coastal counties in 1980 (Ditton et al., 1989). This pattern was much the same in 1960 and according to recent data from the U.S. Bureau of the Census the four counties accounted for 66 percent of the building permits issued for single and multi-unit housing on the Texas coast in 1987.

While data are not available to distinguish the value of real estate for recreational, aesthetic or commercial purposes, it is obvious that vacation residences built on the bay shore and fishing cabins in and around the smaller bays represent recreational and aesthetic values over and above the value of the structures. Similarly, the many industries and shipping concerns located on the Houston Ship Channel are concentrated there because of the commercial location values represented by water transportation and waste discharge sites.



Source: R. Will Roach

*Cabins in Christmas Bay, viewed from the air (above) and the water (below), are built on oyster reefs. These cabins were built on public lands by private citizens and are leased from the Texas General Land Office. Recent controversial issues related to raw sewage discharges and proximity to publicly-held resources have prompted policy changes.*

## SUMMARY

Galveston Bay has been the focus of numerous uses by humans throughout history, including food supply, transportation, oil and gas production, and recreation. The surrounding watershed has been used for urban development, petroleum and petrochemical production, and agricultural uses. Currently, the estuary accounts for 20 to 70 percent, depending on the species, of the total fisheries production in Texas and one-half of the state's recreational fishing expenditures. Sixty to 70 percent of the Texas' oyster fishery is also concentrated in the estuary. About one-third of the households in the counties surrounding the bay use the bay at least once a year for recreational purposes. Galveston Bay is surrounded by the eighth largest metropolitan area in the United States. Its chief port, the Port of Houston, ranks third among United States ports in total tonnage. More than one-half of the state's wastewater discharge permittees are sited within the estuary's watershed.

Galveston Bay shares many problems with other estuaries of a similar stature chiefly in the rapidly escalating demands placed upon its resources because of an expanding population and associated development. It is estimated that by 1996, the Houston-Galveston area will have a population exceeding 3.6 million, an 11 percent increase from 1990. The year 2010 population is expected to reach nearly 4.4 million residents (TABLE 4.27; Houston-Galveston Area Council, 1993b). This projected growth in population and the associated increasing use of the bay resources pose a resource management challenge that must be addressed to avoid larger resource management problems in the future.



Source: Texas Sea Grant College Program

## FOR MORE INFORMATION

**Ditton, R. B., D. K. Loomis, D. R. Fesenmaier, M. O. Osborn, D. Hollin, and J. W. Kolb. 1989.** Galveston Bay and the Surrounding Area: Human Uses, Production and Economic Values. Pp. 53-66, in Galveston Bay: Issues, Resources, Status and Management. NOAA Estuary-of-the-Month Seminar Series No. 13, (National Oceanic and Atmospheric Administration). Washington, D. C.

**Farrar, R. M. 1926.** The Story of Buffalo Bayou and the Houston Ship Channel. Houston Chamber of Commerce. Houston, Texas.

**Green, A., M. Osborn, P. Chai, J. Lin, C. Loeffler, A. Morgan, P. Rubec, S. Spanyers, A. Walton, R. D. Slack, D. Gawlik, D. Harpole, J. Thomas, E. Buskey, K. Schmidt, R. Zimmerman, D. Harper, D. Hinkley, T. Sager, and A. Walton. 1992.** Status and Trends of Selected Living Resources in the Galveston Bay System. Galveston Bay National Estuary Program Publication GBNEP-19. Webster, Texas.

**Houston-Galveston Area Council. 1993a.** Galveston Bay Area Socioeconomic Planning Data. Houston-Galveston Area Council. Houston, Texas.

**McComb, D. G. 1981.** Houston: A History. University of Texas Press. Austin, Texas.

**McComb, D. G. 1986.** Galveston: A History. University of Texas Press. Austin, Texas

**National Oceanic and Atmospheric Administration. 1989.** Galveston Bay: Issues, Resources, Status and Management. NOAA Estuary-of-the-Month Seminar Series No. 13. Washington, D. C.

**Smith, J. N. 1972.** The Decline of Galveston Bay. A Profile of Government's Failure to Control Pollution in an Endangered American Estuary. The Conservation Foundation. Washington, D. C.

**Stanley, D. W. 1992.** Historical Trends: Water Quality and Fisheries: Galveston Bay. University of North Carolina Sea Grant College Program Publication UNC-SG-92-03. Institute for Coastal and Marine Resources, East Carolina University. Greenville, North Carolina.

## REFERENCES

**Allison, R. C., R. Durand, R. Hill, K. Coppenbarger, N. Hameed, and B. Willey. 1991.** A Socioeconomic Characterization of the Galveston Bay System. Galveston Bay National Estuary Program unpublished report. Webster, Texas.

**Alperin, L. M. 1977.** Custodians of the Coast. United States Army Corps of Engineers, Galveston District. Galveston, Texas.

**Armstrong, N. E., and Ward, G. H. 1994.** Point Source Loading Characterization of Galveston Bay. Galveston Bay National Estuary Program Publication GBNEP-36. Webster, Texas.

**Barker, E. C. 1924.** The Austin Papers. Vol I. Annual Report of the American Historical Association for the Year 1919. U. S. Government Printing Office. Washington, D. C.

**Benefield, R. L., and R. B. Hofstetter. 1976.** Mapping of Productive Oyster Reefs, Galveston Bay, Texas. Texas Parks and Wildlife Department, Project Report 2-218-R, Segment 2. Austin, Texas.

**Ditton, R. B., D. K. Loomis, D. R. Fesenmaier, M. O. Osborn, D. Hollin, and J. W. Kolb. 1989.** Galveston Bay and the Surrounding Area: Human Uses, Production and Economic Values. Pp. 53-66, in Galveston Bay: Issues, Resources, Status and Management. NOAA Estuary-of-the-Month Seminar Series No. 13, (National Oceanic and Atmospheric Administration). Washington, D. C.

**Eubanks, T. L. 1993.** Ecotourism in Galveston Bay: An Economic Opportunity. Pp. 367-369, in Proceedings. The Second State of the Bay Symposium. Feb. 4-6, 1993, (Jensen, R., R. W. Kiesling, and F. S. Shipley, eds.), Galveston Bay National Estuary Program Publication GBNEP-23. Webster, Texas.

**Farrar, R. M. 1926.** The Story of Buffalo Bayou and the Houston Ship Channel. Houston Chamber of Commerce. Houston, Texas.

**Fesenmaier, D. R., T. Ozuna, S. Um, L. L. Jones, W. Roehl, R. G. Q, and A. S. Mills. 1987.** Trinity-San Jacinto Estuary: Economic Impact of Recreational Activity and Commercial Fishing. Texas Water Development Board. Austin, Texas.

**Galveston Bay National Estuary Program. 1992.** Galveston Bay Recreational User's Handbook. Galveston Bay National Estuary Program Publication GBNEP-C1 (revised). Webster, Texas.

**Green, A., M. Osborn, P. Chai, J. Lin, C. Loeffler, A. Morgan, P. Rubec, S. Spanyers, A. Walton, R. D. Slack, D. Gawlik, D. Harpole, J. Thomas, E. Buskey, K. Schmidt, R. Zimmerman, D. Harper, D. Hinkley, T. Sager, and A. Walton. 1992.** Status and Trends of Selected Living Resources in the Galveston Bay System. Galveston Bay National Estuary Program Publication GBNEP-19. Webster, Texas.

**Henson, M. S. 1993.** Historical Report on Galveston Bay. Submitted to Galveston Bay National Estuary Program. Webster, Texas.

**Houston-Galveston Area Council. 1982.** Regional Data Book 1982. Houston-Galveston Area Council. Houston, Texas.

**Houston-Galveston Area Council. 1993a.** Galveston Bay Area Socioeconomic Planning Data. Houston-Galveston Area Council. Houston, Texas.

**Houston-Galveston Area Council. 1993b.** Interim Long Range Plan Forecasts, Access 2010: Revised. Transportation Department, Houston-Galveston Area Council. Houston, Texas.

**Kingston, M., ed. 1964.** The Texas Almanac, 1964-1965. The Dallas Morning News. Dallas, Texas.

**Kingston, M., ed. 1988.** The Texas Almanac, 1988. The Dallas Morning News. Dallas, Texas.

**Liebow, E. B., K. S. Butler, and T. R. Plaut. 1980.** Texas Barrier Islands Region Ecological Characterization: A Socioeconomic Study. Volume 1: Synthesis Papers. FWS/OBS-80/19. U.S. Fish and Wildlife Service, Office of Biological Services. Washington, D. C.

**McComb, D. G. 1969.** Houston: The Bayou City. University of Texas Press. Austin, Texas.

**McComb, D. G. 1981.** Houston: A History. University of Texas Press. Austin, Texas.

**Newell, C. J., H. S. Rifai, and P. B. Bedient. 1992.** Characterization of Nonpoint Sources and Loadings to Galveston Bay. Volume I, Technical Report. Galveston Bay National Estuary Program Publication GBNEP-15. Webster, Texas.

**Osborn, H. R., and M. O. Ferguson. 1986.** Trends in Finfish Landings by Sport-Boat Fishermen in Texas Marine Waters, May 1974-May 1985. Management Data Series No. 90. Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, Texas.

**Osborn, H. R., W. D. Quast, and C. L. Hamilton, 1987.** Trends in Texas Commercial Fishery Landings, 1977-1986. Management Data Series No. 131, Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, Texas.

- Pacheco, P., D. Farrow, T. Manuelides, S. Rohmann, M. Katz, and J. McLeod. 1990.** Point Source Discharges in Coastal Areas of Texas. Draft report. National Oceanic and Atmospheric Administration, National Ocean Survey. Washington, D. C.
- Port of Houston Authority. 1992.** Port of Houston Handbook and Industrial Guide 1992-1993. Houston, Texas.
- Sharp, J. 1993.** Texas Regional Outlook. Texas Comptroller of Public Accounts. Austin, Texas.
- Sibley, M. M. 1968.** The Port of Houston: A History. University of Texas Press. Austin, Texas.
- Stanley, D. W. 1992.** Historical Trends: Water Quality and Fisheries: Galveston Bay. University of North Carolina Sea Grant College Program Publication UNC-SG-92-03. Institute for Coastal and Marine Resources, East Carolina University. Greenville, North Carolina.
- Texas Department of Commerce, Tourism Division. 1985.** County Travel Economic Impact Model. U. S. Travel Data Center. Austin, Texas.
- Texas Department of Commerce, Tourism Division. 1990.** 1988 Travel Spending in Texas. U. S. Travel Data Center. Austin, Texas.
- Texas Department of Commerce, Tourism Division. 1992.** The Economic Impact of Travel on Texas Counties 1990-1991. U. S. Travel Data Center. Austin, Texas.
- Texas Department of Water Resources. 1981a.** Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows. Texas Department of Water Resources Report LP-113. Austin, Texas.
- Texas Department of Water Resources. 1981b.** Plan Summary for the Trinity Basin Water Quality Management Plan. Texas Department of Water Resources Report LP-149. Austin, Texas.
- Texas Parks and Wildlife Department. 1986.** Texans Outdoors: An Analysis of the 1985 Participation in Outdoor Recreation Activities. Texas Parks and Wildlife Department. Austin, Texas.
- Texas Parks and Wildlife Department. 1988.** Texas Oyster Fishery Management Plan. Texas Parks and Wildlife Department Fishery Management Plan Series, Number 1 Source Document. Austin, Texas.
- Texas Parks and Wildlife Department. 1993.** Pers. Comm. with Information Resources Department.
- Texas Railroad Commission. 1993.** Pers. Comm. with Research Section.
- Texas Water Commission. 1988.** Governor's Supplemental Nomination of Galveston Bay as an Estuary of National Significance. Texas Water Commission unpublished report. Austin, Texas.
- Texas Water Development Board. 1991.** Water Use Figures. Texas Water Development Board Planning Division unpublished report. Austin, Texas.
- Texas Water Quality Board. 1975.** Galveston Bay Project Summary Report. Texas Water Quality Board unpublished report. Austin, Texas.
- United States Army Corps of Engineers. 1985.** The Ports of Galveston and Texas City, Texas. United States Army Corps of Engineers Water Resources Support Center. Washington, D. C.
- United States Army Corps of Engineers. 1989.** The Ports of Galveston and Texas City, Texas. United States Army Corps of Engineers Water Resources Support Center. Washington, D. C.
- United States Army Corps of Engineers. 1993.** Pers. Comm. with Galveston District.
- United States Bureau of the Census. 1983.** Census of Population: 1980. United States Department of Commerce. United States Government Printing Office. Washington, D.C.
- United States Bureau of the Census. 1991.** Census of Population: 1990. United States Department of Commerce. United States Government Printing Office. Washington, D.C.
- Ward, G. H. 1993.** Dredge and Fill Activities in Galveston Bay. Galveston Bay National Estuary Program Publication GBNEP-28. Webster, Texas.
- Wermund, E. G., R. A. Morton, and G. Powell. 1989.** Geology, Climate, and Water Circulation of the Galveston Bay System. Pp. 3-22, in Galveston Bay: Issues, Resources, Status and Management. NOAA Estuary-of-the-Month Seminar Series No. 13, (National Oceanic and Atmospheric Administration). Washington, D. C.
- Whittington, D., D. Amaral, and G. Cassidy. 1993.** Research on Economic Resource Valuation Studies in Galveston Bay. Pp. 361-362, in Proceedings. The Second State of the Bay Symposium. Feb. 4-6, 1993, (Jensen, R., R. W. Kiesling, and F. S. Shipley, eds.), Galveston Bay National Estuary Program Publication GBNEP-23. Webster, Texas.