The Human Role, Present

Written & Revised by Lisa A. Gonzalez

The segment of the planet Earth called the coastal zone is especially important in the context of diversity and human interactions. This is by far the most populated and urbanized portion of our planet, as well as the richest and among the most perturbed. It is a bit surprising that it is also not the most familiar in concept and dimension, in view of the fact that so many people live within it or near it.


Introduction

Human activities in and around Galveston Bay have shaped the watershed for thousands of years. The categories of resource use are wide ranging. From humans’ creation of the first shell middens to the present dredging of numerous navigation channels, human inhabitants have an impact on the bay and its surrounding landscape.

As the human population grows, society’s influence on the physical and ecological components of the estuarine system becomes more pronounced. Anthropogenic stresses are placed upon the bay’s natural resources and the ecosystem services that they provide (such as clean air and water, flood attenuation, and wildlife habitat). The stressors diminish the health of the estuary and its watershed, as well as the quality of life of residents. The physical and ecological condition of Galveston Bay is a general indicator of the well-being of the regional environment. Most people realize that the bay is an important regional ecosystem, and they have a keen interest in protecting and maintaining its productivity for future generations.

Figure 4.1. Salt marsh at the John M. O’Quinn IH 45 Estuarial Corridor. The community of Bayou Vista is seen in the background. Image © 2007 iStockphoto.com.
This chapter will focus on the region’s economic activity and resource use. Information is presented regarding the major uses of the Galveston Bay system, including surface water use, extraction of groundwater and minerals, urban and agricultural land use, commercial fishing, shipping and water-related recreation.

Agencies often group the region’s counties and communities to better analyze certain factors for statistical purposes (economic, social, environmental, etc.). The economic data in this chapter comes from various sources and, depending on the source of the information, may describe slightly different geographic areas of the Lower Galveston Bay watershed. For example, the economic data describing the federal Houston–Sugar Land–Baytown Metropolitan Statistical Area (Houston MSA) consists of 10 counties (Figure 4.2, top). Data gathered by the Houston-Galveston Area Council (H-GAC) describes a 13-county region (Figure 4.2, center). This book deals primarily with the concerns of the Galveston Bay Estuary Program (the Estuary Program), which has a 5-county management area (Brazoria, Chambers, Galveston, Harris and Liberty counties; Figure 4.2, bottom). Data will be presented for the 5 counties of the Estuary Program unless otherwise aggregated according to the geographic area of one of the agencies mentioned above.

**Attributes of the Regional Economy**

**Economic Activity**

The Houston metropolitan region has a large population and is composed of numerous counties and communities. Each county differs in population size as well as in economic activity (e.g., industrial versus agricultural development). However, the social and economic fabric of each is highly integrated; the consequences of an event in one (such as the dissolution of a large business) can often be felt in adjacent communities.

The Houston MSA’s location—in the south central U.S., near the Gulf Coast, and proximate to Latin America—make it a suitable location for industry and trade. The region also possesses an established transportation infrastructure, a relatively low cost of living, and reasonable property costs. The economy of the Houston MSA has diversified greatly since the
crash of the oil industry in the 1980s. While the petroleum industry still plays a large role in maintaining the region’s economic strength, many governmental organizations, business services, and educational and health-service industries now play major roles in the region. Employment in the service sector is driven to some extent by export-oriented sectors—chemicals, energy, and manufacturing in this area. The wealth derived from exports increases consumer spending, which results in employment growth in service-sector businesses (Sambidi 2008).

According to the U.S. Bureau of Labor Statistics (2009), the main employment sectors of the Houston MSA’s economy include trade, transportation, and utilities; government (e.g., the Johnson Space Center); professional and business services; educational and health services; manufacturing; leisure and hospitality; and construction (Table 4.1). As of March 2009, the industries listed below employed nearly 2.6 million people in the Houston MSA (Figure 4.2, top). That employment figure does not include agricultural employment, self-employment, domestic workers, or military.

### Table 4.1. Main employment sectors of the Houston metropolitan economy in March 2009.

<table>
<thead>
<tr>
<th>Employment Industry</th>
<th>Number of People Employed</th>
<th>Percentage of Total Employment</th>
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<tbody>
<tr>
<td>Trade, transportation, and utilities</td>
<td>521,800</td>
<td>20%</td>
</tr>
<tr>
<td>Government</td>
<td>371,100</td>
<td>14%</td>
</tr>
<tr>
<td>Professional and business services</td>
<td>367,900</td>
<td>14%</td>
</tr>
<tr>
<td>Educational and health services</td>
<td>290,500</td>
<td>11%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>237,300</td>
<td>9%</td>
</tr>
<tr>
<td>Leisure and hospitality</td>
<td>231,500</td>
<td>9%</td>
</tr>
<tr>
<td>Construction</td>
<td>198,000</td>
<td>8%</td>
</tr>
<tr>
<td>Financial activities</td>
<td>142,200</td>
<td>6%</td>
</tr>
<tr>
<td>Mining and logging</td>
<td>91,300</td>
<td>4%</td>
</tr>
<tr>
<td>Other services</td>
<td>90,500</td>
<td>4%</td>
</tr>
<tr>
<td>Information</td>
<td>35,500</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total Non-Farm Employment</strong></td>
<td><strong>2,577,600</strong></td>
<td></td>
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Most urban and industrial development is located in Harris and Galveston counties, while Brazoria, Chambers, and Liberty counties have a higher percentage of their land classified as cultivated and grassland. The eastern side of the bay relies on the promotion of its natural resources, which include salt domes, industrial sand, pine and hardwood timber, oil, gas, sulfur, lignite, iron ore, brick clay, salt, and lime (TSHA 2008a, 2008b). Lowland areas and clay soils support the production of rice, the major agricultural crop. The economy is also supported, in part, by a growing tourism industry. As seen in Figure 4.3, Liberty County experiences the highest unemployment rates in the Galveston Bay area. The Chambers County unemployment rate was lowest in the first half of the last decade, but moved higher in the second half to become very similar to that of Harris, Galveston, and Brazoria counties.
As seen in Figure 4.3, of the 5 counties surrounding Galveston Bay, Harris County has experienced the lowest unemployment rates in the region in recent years. Despite the lower percentage, the number of unemployed in Harris County is much greater than in any other county because it has a much larger population.

![Figure 4.3. Average unemployment rates for the 5 counties surrounding Galveston Bay, 2000–2009. Data source: Texas Workforce Commission (TWC 2009).](image)

**The Human Population**

The Galveston Bay system is adjacent to one of the most urbanized and industrialized areas in Texas and the nation. According to the Texas State Data Center’s (TSDC) population estimates for January 2008, more than 4.6 million people reside in the 5 counties surrounding Galveston Bay (TSDC 2011). The Houston metropolitan area ranks sixth largest nationally behind New York, Los Angeles, Chicago, Dallas–Fort Worth, and Philadelphia (USCB 2008a) and Houston is the fourth largest city in the country. As seen in Table 4.2, Harris County remains the most populous in the region, with 3.9 million people. Population growth in the region is expected to continue and is proportionally greatest in suburban Chambers and Brazoria counties. The greatest number of people, however, will be added in Harris County.

Over the years, the bay area has become increasingly urbanized and developed. The larger central cities, such as Galveston and Houston, experienced relatively low growth rates compared to suburban communities (e.g., Pearland at 80 percent and League City at 55 percent) (HGAC 2009). The population density in 2008 in the 5-county area is 876 persons per square mile. Harris County is the most densely
populated county, with 2,269 persons per square mile, and Chambers County remains the most sparsely populated county in the bay area, with 55 persons per square mile.


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<tbody>
<tr>
<td>Brazoria</td>
<td>241,767</td>
<td>296,691</td>
<td>23%</td>
<td>1,386</td>
<td>214</td>
</tr>
<tr>
<td>Chambers</td>
<td>26,031</td>
<td>33,225</td>
<td>28%</td>
<td>599</td>
<td>55</td>
</tr>
<tr>
<td>Galveston</td>
<td>250,158</td>
<td>286,987</td>
<td>15%</td>
<td>398</td>
<td>720</td>
</tr>
<tr>
<td>Harris</td>
<td>3,400,578</td>
<td>3,922,115</td>
<td>15%</td>
<td>1,729</td>
<td>2,269</td>
</tr>
<tr>
<td>Liberty</td>
<td>70,154</td>
<td>77,451</td>
<td>10%</td>
<td>1,160</td>
<td>67</td>
</tr>
<tr>
<td>Total Population</td>
<td>3,988,688</td>
<td>4,616,469</td>
<td></td>
<td>5,273</td>
<td>876</td>
</tr>
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</table>

We calculated the number of people living in census tracts that intersect a 2-mile buffer zone around the bay and its tidally influenced tributaries in order to examine the potential pressures of population and urban land uses immediately surrounding the bay. In the year 2000, there were 390,298 people living in census tracts immediately bordering Galveston Bay. Using U.S. Census Bureau population estimates for the year 2008, we estimate that 460,742 people live in census tracts adjacent to the bay. Comparing these numbers to the information presented in Table 4.2 reveals that approximately 10 percent of the people in the Lower Galveston Bay watershed live near the bay and its tidally influenced tributaries.

The region has exhibited continuous immigration and economic expansion over most of the past 50 years. Much of the region’s growth has been attributed to the construction of the Houston Ship Channel and the discovery of oil in the early part of the 20th century (Melosi et al. 2007). 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. Houston’s population gains during the 1970s and early 1980s were remarkable. The strength of the region’s economy and its ability to provide jobs has continually attracted new residents. According to a recent public attitude survey by Stephen Klineberg (2007), the majority of the respondents (with the exception of those from Galveston County) have a favorable outlook for the region’s economy. Klineberg also found that many new residents to the region prefer to live in outlying suburban counties rather than in Houston or the suburbs of Harris County.
**Housing**

Population is typically the indicator of choice when discussing impacts of human development on biodiversity. However, the use of population statistics alone excludes important information regarding changes in the number and size of households and their effect on regional habitats (Liu et al. 2003). Household dynamics may in fact represent a more accurate means by which to analyze the effects of human development on habitats and biodiversity. An increase in household numbers may denote urban sprawl, shrinking household size (in number of persons), and higher per capita consumption of resources (Liu et al. 2003). When one considers management options, it is nearly impossible to regulate population growth. However, the number and locations of households and housing developments can be managed through state and local policies as is the case in other parts of the country.

![Bar chart showing household growth in the Lower Galveston Bay watershed from 1950 to 2000.](chart)

**Figure 4.4. The number of households in the Lower Galveston Bay watershed has greatly increased since the 1950s.** Data source: National Historical Geographic Information System (MPC 2004).

In addition to an increasing human population in the Lower Galveston Bay watershed, the number of households has increased dramatically over the last 50 years (Figure 4.4). In 1950, the 5-county Galveston Bay region contained 295,535 households. By 2000, the number of households in the region increased more than fourfold to 1,414,633 (MPC 2004). During that same period, more than 35,000 acres of emergent wetlands were lost in the region (White et al. 1993). The number of households is estimated to have surpassed 1,582,000 in 2008 (HGAC 2009). The impact of continued construction of residences and other buildings on habitat is discussed further in Chapter 7.
Shipping and Ports

The bay is an important transportation artery. Many of the area’s petrochemical and other industries rely on the Houston Ship Channel, the Gulf Intracoastal Waterway, and other navigation channels for transportation. While the region has other forms of transportation, shipping is still a major attraction to commercial and industrial interests. Shipping by the major ports (Houston, Galveston, and Texas City) in the region has grown dramatically since 1955, while the tonnage associated with several smaller ports (Double Bayou, Anahuac Channel, Cedar Bayou, Trinity River Channel) has declined to almost nothing (Allison et al. 1991).

Concerns regarding the potential impacts of shipping on the ecosystems of Galveston Bay are often expressed and policy discussions about how to minimize those impacts continue. Related issues include channel dredging, the introduction of exotic organisms, erosion of shorelines from the wakes of large vessels, oil spills, water quality near port facilities, and the effects of lights, noise, and increased train and truck traffic on nearby communities.

The Houston-Galveston Navigation Channels

The construction and maintenance of the Houston Ship Channel has caused widespread changes to bay circulation and salinity. Changes in the size and number of ships visiting the ports of Houston and Galveston have justified periodic expansions of the navigation channel since it was first completed (see Chapter 3). The most recently completed expansion was initially contentious because of concerns about whether the benefits from the proposed 600-foot-wide by 50-foot-deep project justified the impacts on the bay.

For many years debate centered on environmental concerns connected to the Houston-Galveston Navigation Channel project. Of particular concern was open-bay disposal of dredge material (the sediment removed from the ship channel as it is deepened and widened). Open-bay disposal resulted in the deposition of dredge material in unconfined disposal areas in the middle of the bay, covering hundreds of acres of bay bottom. In 1989, the Interagency Coordination Team (ICT) was created to bring about consensus regarding these issues. In 1990, the ICT created a subcommittee known as the Beneficial Uses Group (BUG) to evaluate the possible beneficial uses of dredged material and to incorporate those uses into a dredged material placement plan. The ICT and BUG worked with the Port of Houston Authority and the USACE to create an acceptable solution to a contentious issue.

Dredged material excavated from the Houston Ship Channel (although not from other maintenance dredging activities) is no longer disposed of on open bay bottom, but instead is beneficially used for the
restoration and creation of intertidal marshes, bird nesting habitat, and recreational islands. Habitat restoration sites using dredged material include Atkinson Island, Redfish Island, and locations on the bay side of the Bolivar Peninsula. The outcome of the ICT and the BLIG received broad regional support. Nationally, the resulting plan developed for the Houston Ship Channel serves as a model for other ports planning channel expansion projects. In 2007, the BUG partnership tied for third place in the EPA Gulf of Mexico Program's Gulf Guardian awards.

After nearly 30 years of planning and debate, and modification of the project to address community concerns, the Houston-Galveston Navigation Channel Project was completed in 2005. This expansion enlarged the Houston Ship Channel from its previous dimensions of 400 feet wide by 40 feet deep to a width of 530 feet and a depth of 45 feet. The Galveston Channel is in the process of being deepened from 40 to 45 feet.

The Texas City Channel & Dike

Aside from the Houston Ship Channel, there are many more miles of shipping and boat channels in Galveston Bay. One of the earliest channels completed was a 16-foot deep channel from the Houston Ship Channel to the port of Texas City. This channel required extensive maintenance dredging because it was laid out perpendicular to a natural scour area called Half Moon Channel. A 5-mile-long dike was constructed between 1913 and 1934 (see Chapter 3). Since its annexation by Texas City in 1961, the Texas City Dike has been used as a recreational area popular for picnicking and fishing. It is also a primary docking location for the Texas City shrimp-boat fleet. The Texas City Dike, along with its businesses and docks, was heavily damaged by the storm surge associated with Hurricane Ike in September 2008 (Figure 4.6).

Upon its construction in the early 20th century, the Texas City Dike altered the currents in Lower Galveston Bay and reduced flows to West Bay (Paine et al. 1986; Ward 1991). Before the Texas City Dike was constructed, a larger part of the ebb (outgoing) tide would have been directed into West Bay; now little of the outflow from Galveston Bay enters West Bay. Of the 5 subbays of Galveston Bay, West Bay is one of the 2 most saline (second only to Christmas Bay). The average salinity of West Bay is 22 practical salinity units (psu) compared to an average salinity of 14 psu in Upper and Lower Galveston Bay and 9 psu in Trinity Bay, where the influence of Trinity River inflow is strongest.

A study by the Texas Water Development Board (Matsumoto et al. 2005) modeled changes in bay circulation based on a hypothetical removal of the Texas City Dike (there are no current plans to remove the Texas City Dike). The study found that if the dike was removed from the bay, flow through the Galveston
Channel would decrease by 1 percent, while flow through the area where the dike is situated would increase by 2 percent. The modeled removal had an effect on salinity in both wet and dry periods in and near the Texas City Ship Channel and in West Bay. In the dike removal simulation, salinity decreased by 4 psu in the Texas City turning basin and by 2 psu in mid-West Bay. Additionally, salinity in Galveston Bay and Trinity Bay would hypothetically decrease by 0.6 psu.

**Gulf Intracoastal Waterway**

The Galveston Bay portion of the Gulf Intracoastal Waterway (GIWW) was conceptualized by Stephen F. Austin in 1822 as a canal connecting the Brazos River to Galveston Bay (see Figure 3.11). Completed in 1934 between Galveston Bay and the Sabine River, the GIWW provided a protected inland route for the waterborne shipping and transportation of goods and troops during World War II.

The GIWW now serves as a major shipping and boating conduit on the upper Texas coast. It is used by businesses for the movement of domestic and international cargo, harvesting of fish and shellfish, and servicing of the Gulf oil and gas industry. Recreational interests use the GIWW for fishing, skiing, sightseeing, and protected boating routes. In 2006, more than 74 million short tons of goods worth $25 billion were transported along the Texas Gulf Intracoastal Waterway (TXDOT 2008).

The GIWW extends across the lower portion of Galveston Bay, crossing under the Galveston Causeway and the Galveston Island Railroad Bridge. The narrow channel under the Galveston Island Railroad Bridge was identified by TXDOT (2008) as the greatest risk to navigation along the entire 1,300-mile GIWW. Efforts are underway to raise the estimated $79 million needed to replace the railroad bridge.

The waterway must be annually dredged by the USACE to maintain the depth and width necessary for navigation activities. During fiscal years 2007 and 2008, a total of 1,993,790 cubic yards (cu yd) of sediment was dredged from the Galveston Bay portion of the GIWW (TXDOT 2008), including: 976,670 cu yd from the Brazos River to Bolivar Roads, 500,000 cu yd from Bolivar Roads to Rollover Pass, and 517,120 cu yd from Rollover Pass to High Island.

Over the years objections have been raised regarding the locations for GIWW dredge material disposal. While the statistics for Galveston Bay are not known, TXDOT (2008) reports that of the 9,848,000 cu yd of sediment dredged from the Texas GIWW during 2007–08: 4.6 million cu yd (47%) was deposited in open-bay sites, 3.9 million cu yd (40%) was placed in confinement placement sites, and 1.3 million cu yd (13%) was beneficially used for habitat restoration activities.

**Port of Houston**

The Port of Houston is the largest port in the Galveston Bay area and the eighth largest in the world. As of 2007, the Port of Houston ranked second in the nation in total tonnage and first in foreign tonnage (USACE 2009). It is estimated that in the year 2007 the Port of Houston handled more than 222 million tons of cargo (compared to 175 million tons of cargo in the year 2000). In the year 2007 more than 1.6 million containers were handled and 7,703 vessels entered and exited the port (POHA 2009). This shipping volume is distributed among berths along the Houston Ship Channel, Barbour’s Cut and the Bayport Channel.
Since the last edition of this volume, a major expansion of Port of Houston facilities on the Bayport Channel has begun. This expansion will consist of 7 berths for container vessels and 3 for cruise ships. The entry channel has been dredged to a depth of 40 feet. The expansion will cover 1,100 acres of land between the towns of Shoreacres and Seabrook, which will be developed with container storage, a rail yard, and other facilities. Upon completion, the terminal will have the capacity to handle over 2 million container units per year. The permitting process for this port expansion was controversial due to perceived impacts on local communities, the bay, and associated habitats. Opposition to the port expansion cited increases in air pollution, water pollution, noise, vibration, traffic, and light pollution plus underestimation of wetland loss. Public hearings were held to permit expression of opposition and support to be voiced to the responsible regulatory agency, the USACE. An amended environmental impact statement was required and submitted by the Port of Houston. Additional changes in the facility design were made to reduce the potential impacts. Wetland mitigation acreage was increased. The Corps of Engineers approved the permit for the facility in 2003.

**Port of Texas City**

Compared to the Port of Houston, the Port of Texas City operates on a smaller scale. It is privately owned by the industries and companies that it serves. The Port of Texas City ranks eighth nationally in foreign tonnage and 14th in total tonnage (USACE 2009). In 2007, total tonnage equaled more than 48 million tons. This number is lower than the year 2000 tonnage of 58 million tons (USACE 2009).

During the debate over construction of the Bayport Container Terminal by the Port of Houston, a similar project was initiated at the Port of Texas City. The Texas City International Terminal at Shoal Point will cover 400 acres and provide 6 berths for container ships when fully constructed. The project is also designed to include a 45-acre constructed marsh in Swan Lake to mitigate for the loss of wetland from construction. Permits were approved in 2003 and construction began in 2004.

**Port of Galveston**

The Port of Galveston, operated by the Board of Trustees of the Galveston Wharves, is the smallest of the 3 main ports in Galveston Bay, ranking 55th among the nation’s ports in total tonnage (USACE 2009). In 2007, the Port of Galveston handled approximately 9.4 million tons of cargo (compared to 10.4 million tons in the year 2000).

While the Port of Galveston has a prime location, its proximity to the large Port of Houston has posed major challenges. In 2007, the Ports of Houston and Galveston signed a memorandum of understanding to develop a shipping terminal on Pelican Island, located across the Galveston Channel from the Port of Galveston. In addition to handling vessels with dry and liquid cargoes, the Port of Galveston serves as a cruise ship terminal. Visitors travel to Caribbean ports aboard cruise ships owned by Carnival Cruise Lines and Royal Caribbean.
Decline of the Fishing Village
By Priscilla Weeks

Commercial fisheries, and the communities dependent upon them, are a vital part of our Galveston Bay heritage. Over the past 30 years, the cumulative stresses that commercial fishermen have faced are not only changing the nature of the fisheries, but also the social fabric of fishing communities. These stresses include competition from imports, high fuel costs, increased regulations, an aging workforce that is not being replaced, and coastal gentrification (the displacement of older or poorer communities by newer, wealthier development). Some stresses, such as imports, have been steadily eroding fishermen’s ability to make a living from fishing. Other stresses, like fuel prices, while rising steadily over the years, have acute phases that fishermen must respond to within the span of a season.

Imports
Imports, especially for shrimp but increasingly for oysters, compete with locally caught seafood. Shrimp imports have exceeded domestic production since at least the late 1960s. As the volume of imported shrimp has increased, its price has fallen and prices for domestic shrimp have declined as well. According to a recent study by the Food and Agriculture Organization of the United Nations (FAO), prices for wild caught shrimp have declined 27 percent in the Gulf of Mexico since 1997 and imports have increased 300 percent. Galveston Bay is one of Texas’ most productive bay shrimp fisheries and prior to Hurricane Ike was the state’s most productive oyster fishery, making Galveston Bay fishermen especially vulnerable to increased imports. Fishermen have responded in several ways: by marketing directly to consumers through roadside stands or customer lists and by working with the Texas Sea Grant Extension Program to promote wild-caught product. Research on consumer attitudes indicates that there is a heritage value in eating local seafood and that when tourists eat at a coastal restaurant, they assume the catch is local. This adds to their tourism experience. A marketing campaign, therefore, has potential if enough resources are allocated for a concerted and long-term effort that results in consumers’ preferences for wild-caught product despite price differences.

Scientific evaluation indicates that distinctive, robust flavors exist in wild harvested shrimp as compared to the majority of imported shrimp which are cultured. This may well result in future niche marketing potentials.

—Gary Graham, Marine Fisheries Specialist, Texas Sea Grant

Regulations
The traditional economic strategy fishermen in the harvest sector employ is to hold several licenses and switch between fisheries—shrimp and oysters, for example—depending on the season and strength of the harvest or prices. As more fisheries adopt limited-entry programs or institute moratoriums that are based on history in the fishery and landings, this becomes more difficult. Although fishermen have traditionally employed an economic strategy that mixes fishing and non-fishing activities, fishing is the primary occupation and identity for older fishermen. While the Galveston Bay region has many non-fishery employment opportunities, the average age of fishermen is around 50 and many are unprepared to change occupations.
Fuel

The impact of imported seafood on the price of local seafood is exacerbated by rising fuel prices (Figure 4.7). If fuel is too high in proportion to ex-vessel value of the catch, not only do fishermen make no profit from a trip, it can actually cost them money to fish. While rising fuel prices are a chronic problem, having risen steadily over the years, they are felt as acute crises that must be responded to immediately. In 2007, for example, the price for diesel began at $2.21 a gallon and ended at $3.03. In 2008 it was $4.13, finally ending at $1.71. The drop in price in 2008, however, was too late to help the gulf and bay shrimpers whose summer seasons had closed by then. During the season, while prices were high, some fishermen rigged boats to carry fuel and made purchasing trips to Mexico. Obviously this was not a solution in which everyone could participate and many fishermen were forced to stay on shore, missing a season’s income. Similar price fluctuations occurred in 1980, resulting in some fishermen defaulting on loans.

Workforce

One overall trend facing capture fisheries is an aging population of fishermen and a younger generation that is leaving the fishery. Fishing traditionally has been a family occupation in which the older generation trained the younger. Because few fishermen still encourage their children to enter the profession, the fishing industry is not reproducing the next generation of harvesters. The huge Gulf offshore petroleum industry has also created needs for experienced captains and crewmembers, which have further lured fishermen away from their traditional vocations (Graham 2009). Without fishermen, fishing communities will no longer be fishing communities. An additional stress to fishermen in the harvest sector is the lack of retirement income. Most of their assets are tied up in their boats. The lack of new entrants to the fishery, due to limited entry and a generational shift in occupational preference, means that only a few manage to sell their boats.
Gentrification

Because fishing communities are coastal towns, they are rich with natural amenities, thus attracting both tourists and new, permanent residents. Often, fishing heritage is part of the allure of these communities but ironically, as migration and tourism increase, fewer towns retain the sociocultural and economic structures characteristic of fishing communities even if they retain the symbols of a fishing heritage. Generally, this is the result of several processes. Fishermen are physically displaced as hotels, shops, and expensive homes replace the working waterfront that consists of docks, processing facilities, fish houses and net shops (Figure 4.8). The result is stress not only on production activities, but also on social networks, as the places fishermen regularly meet decline and are replaced by places designed to satisfy the needs of newcomers. As infrastructure is lost in one community, more strain is placed on fishing infrastructure in nearby fishing communities. Displacement happens without suitable relocation of facilities—forcing fishermen to go farther to dock, unload fish, and buy supplies. When fishermen and infrastructure are forced to relocate, social networks are dispersed.

Despite the potential negative impacts of gentrification on commercial fishing, the extent to which it results in the decline of a particular fishing community varies. Generally, towns with industrial-looking docks and infrastructure are seen as unaesthetic. In these cases, fishing is not integrated into the design for the changing community, is not supported, and is pushed farther away from the site of tourism or new development. Conversely, working waterfronts that preserve commercial fishing infrastructure can be integrated into other types of facilities, thus preserving not only jobs but the fishing village character that tourists seek. For example, situated near the Strand and seafood restaurants, the Mosquito Fleet in downtown Galveston adds to the tourist experience.

Use of working waterfronts as a planning feature is gaining more popularity and may be one way to aid fishing communities. Florida, for example, has recently passed working waterfront legislation. On Galveston Bay, Seabrook has incorporated a working waterfront into its master plan.
Dredging Projects

Dredge-and-Fill Operations

In addition to the large federal navigation projects described above, numerous dredge-and-fill operations are conducted annually by private interests and public agencies. Anyone seeking to dredge a navigation channel, fill any portion of a navigable waterway or adjacent wetland, or change the bottom elevation of a navigable waterway is required by Section 404 of the federal Clean Water Act to obtain a permit or letter of permission from the USACE. Similarly, anyone seeking to undertake any construction activity in a navigable waterway must obtain a permit or letter of permission from the USACE as required by Section 10 of the Rivers and Harbors Appropriation Act of 1899. The permits are known collectively as Section 10/404 permits. The difference between these 2 sections of law in their effect on wetland protection is explained further in Chapter 7.

Section 10/404 permits are the primary regulatory tool used to protect wetland habitats in the United States. National wetland policy requires “no net loss” of these habitats, meaning that the acreage of wetlands protected and restored must be greater than the acreage of wetlands lost through permitted dredge-and-fill activities. Mitigation is the term used to describe the restoration, enhancement or construction of wetland habitat affected by permitted land disturbances. Data describing wetland permits and mitigation requirements are maintained by the USACE’s Galveston District. Wetland protection recognizes the value of ecosystem services provided by these natural systems. They are valuable for their contribution to flood protection, water quality, wildlife and fisheries habitat and other beneficial functions. In order for development to occur in wetlands protected by Section 404 of the Clean Water Act, a permit must be obtained and mitigation of the loss must be planned and implemented.

According to Ward (1993), “the single most obvious manifestation of human impacts on Galveston Bay is the physical modifications associated with excavation and disposal of sediments.” Ward estimated that 4,245 Section 10/404 permits were issued in the Galveston Bay region between 1940 and 1991. Since that time, development activities in the watershed have increased, meaning that the number of permits issued for dredge-and-fill activities has increased as well. A recent survey of permit data acquired from the USACE (Lester et al. 2006), estimated that during 1992–2003 the number of permits approved by the USACE (3,067) was almost 75 percent of the number of permits that had been approved in the 50 years prior.
While the data presented in Figure 4.10 are informative, they are incomplete. Data describing the acreage of tidal and nontidal wetlands impacted by these permits are not readily available. Also unavailable are data describing the acreage of mitigated wetlands in the Houston-Galveston region. Wetland losses and gains can be estimated using other data sources such as the NOAA Coastal Change and Analysis Program dataset and the National Wetlands Inventory (see Chapter 7). However, as long as we do not know the extent of permit and mitigation activities in the Lower Galveston Bay watershed, a large piece of the resource management puzzle is missing.

The available data also do not tell us the degree to which recent legal rulings have impacted wetlands of the Galveston Bay system. The 2001 United States Supreme Court ruling known as the SWANCC ruling (Solid Waste Agency of Northern Cook County v. the U. S. Army Corps of Engineers) held that the use of isolated waters or wetlands (i.e., those not adjacent to navigable waters) by migratory birds could not serve as the sole basis for permit jurisdiction under the Clean Water Act. Only jurisdictional wetlands are protected by the permitting process operated under the authority of Sections 10 and 404. If the freshwater wetlands known as “prairie potholes” are no longer jurisdictional, then no government agency has authority to control their use regardless of their wetland status.

In 2006, the U.S. Supreme Court Rapanos-Carabell decision (Rapanos v. United States and Carabell v. U.S. Army Corps of Engineers) sought to clarify the geographic extent of wetlands that could be regulated under the federal Clean Water Act. The decision was split and sent back to the lower courts. In absence of a clear
decision, the USACE issued a guidance document in December 2008 that contains 3 criteria for agencies to use in determining whether a wetland is adjacent to navigable waters and under the jurisdiction of the Clean Water Act: (1) the presence of an unbroken hydrologic connection to jurisdictional waters, (2) the presence of physical barriers between wetlands and jurisdictional waters, and (3) a close physical proximity of wetlands to jurisdictional waters that provides an ecological interconnection.

**Shoreline Modification**

**Public Access to Natural Resources**

Access to Galveston Bay and its natural resources is a concern of many area residents that like to fish, kayak, boat, swim, view nature, or otherwise enjoy Galveston Bay. In order to participate in these types of activities, the general public must be able to access the bay via the shoreline, public boat launches, or parks. Accessing the bay is not always easy, as much of the surrounding land is held in private ownership. Additionally, some public access sites may no longer be usable due to Hurricane Ike. Sixty boat ramps in Galveston Bay were closed due to storm-related damage (FEMA 2008). To facilitate access to coastal natural resources, a number of state agencies and local organizations have created informational guides to assist the public in locating access points.

The *Texas Beach and Bay Access Guide* (GLO 2005) identifies public access points along the Texas Coast. The guide identifies 171 public access points in 4 counties around Galveston Bay (46 sites in Brazoria County, 15 sites in Chambers County, 83 sites in Galveston County, and 27 sites in Harris County; Liberty County is not included in the report). The Texas Parks and Wildlife Department (TPWD 2007) documented, and supplied signage for, the Great Texas Coastal Birding Trail. The Trail identifies access and observation sites to birders along the Texas Coast. The Galveston Bay Foundation (2004) created the *Galveston Bay Drive & Discover Guide* with financial support from the Estuary Program. The Guide describes more than 70 sites of cultural, historical, or ecological interest around Galveston Bay. Additionally, the Cities of Webster, League City, La Porte, Baytown, and Seabrook have also developed trails and shoreline access for low-impact recreation along the bayous in their jurisdictions. Local growth of outdoor recreation opportunities is part of a national trend to support this type of activity. Not only does outdoor recreation increase our quality of life and health, it contributes to the economic health of our region. Southwick and Associates (2006) estimate that active outdoor recreation in Texas and surrounding states was responsible for $27,594,300,000 in annual economic activity and 265,738 jobs.
As population in the area around the bay grows, there will likely be a demand for additional public facilities in those areas. *The Galveston Bay Plan* (GBNEP 1994) proposes improving public access to the shoreline in a manner that is consistent with the protection of the bay’s resources. Recently, the Estuary Program developed a Shoreline Management Action Plan, which seeks to improve public access to Galveston Bay’s natural resources by managing human use of the shoreline and adjacent lands. Management will be guided by the preparation of local shoreline development plans and will include consideration of environmental impacts of shoreline development (i.e., loss of estuarine habitat).

**Shoreline Development and Bulkheads**

While bulkheads, docks, and revetments usually generate lower volumes of dredge-and-fill material compared to channel construction, their environmental impact may be disproportionately greater than the actual physical modifications would suggest (Ward 1993). Most shoreline modifications involve a direct conversion of shoreline and near-shore habitat from a sloping, vegetated, natural state to an abrupt vertical land-water barrier.

Using USACE permit data and assumptions about standard bulkhead configurations, Ward (1993) developed estimates for the amount of shoreline converted from natural habitats to man-made shoreline since World War II. He concluded that 42 miles of the bay shoreline had been bulkheaded, and 28 miles had been converted to docks or revetments. By using an estimate prepared by Orlando et al. (1988) of a 743-mile shoreline around Galveston Bay, about 10 percent (74 miles) of the bay shoreline has been modified: 6 percent (45 miles) by bulkheading and 4 percent (30 miles) by dock and revetment construction. All of these forms of shoreline development replace natural shorelines with fixed artificial materials, which reflect rather than absorb wave energy. Water depth next to the shore increases because the shoreline cannot move with sea-level change and the energy of the water resuspends and moves.

Figure 4.11. As of 1995, nearly 28 percent of the Galveston Bay shoreline was developed. Data source BEG (1995).
sediment from the shore. In Chapter 7 the value of fringing marshes and their edge habitat is discussed. It has greater ecological value than the deepwater habitat created by shoreline development.

Using more recent data, the Galveston Bay Status and Trends Project analyzed shoreline data compiled by the University of Texas Bureau Of Economic Geology (BEG 1995). The shoreline data set, also known as the Environmental Sensitivity Index (ESI), classifies shoreline habitat into a set of 17 shoreline classes to aid with oil spill response. The ESI classes were grouped into 2 major classes (developed and undeveloped shoreline) and analyzed. Of the 782 miles of Galveston Bay shoreline classified by the BEG, nearly 28 percent (215 miles) were classified as being developed and 73 percent (568 miles) were classified as undeveloped shoreline in 1995 (Figure 4.11). It must be noted that while this data set represents the most recent version of the ESI available for Galveston Bay, the data are now more than 10 years old. An updated data set is needed if change in shoreline development is to be calculated in the future.

Other Shoreline Modifications

One of the greatest engineering achievements in the early 20th century is attributed to Galveston’s response to the devastating great storm of 1900. Vast quantities of sand were mined and transported by pipeline to raise the grade of the entire City of Galveston by up to 11 feet above the previous land surface. Fill material was taken from several borrow areas, including Offatts Bayou. By the time the project was completed in 1911, over 9,900 acre-feet of material had been moved to help protect the city from future hurricanes.

In 1931, despite the protests of oil, towing, and timber interests, the Trinity River Irrigation District No. 1 closed the entrance to Lake Anahuac (then called Turtle Bay) to protect rice irrigation systems. The district had authority because of a 1902 provision by Congress that declared Lake Anahuac non-navigable. This 6,000-acre area was isolated from the bay system and converted to a shallow freshwater lake. Other isolations include the privately owned Delhomme hunting area and the impoundment utilized as part of the Reliant Energy Cedar Bayou Generating Station’s cooling system.

The Texas City levee and Moses Lake floodgate are 2 major shoreline modifications built for the purpose of storm and flood protection. The Texas City levee system was built after the storm surge from Hurricane Carla flooded the area in 1961. Completed in 1987, the Texas City levee was meant to protect the city from a 15-foot storm surge caused by a Category 3 or 4 storm (Feldstein 2006). Moses Lake, located directly north of Texas City at Dollar Point, was an open embayment of Galveston Bay prior to the landfall of Hurricane Carla in 1961. At the time of construction of the Texas City levee system, a floodgate was built on Moses Lake (Figure 4.12). The floodgate is lowered during storm conditions and an Archimedes screw pump is used when needed to lower water levels in the lake.

Figure 4.12. Moses Lake floodgate. Image courtesy John Matthews.
While the height of the Texas City levee system has been reduced in some areas due to subsidence (Figure 4.16), the levee and floodgate system performed its intended function during the landfall of Hurricane Ike in 2008. Ike brought a storm surge of more than 12 feet to that part of the bay (East et al. 2008). Coastal communities directly to the north and south of Texas City such as San Leon and Bayou Vista were inundated, while Texas City neighborhoods and the industrial complex were spared. Commercial fishing boats and other vessels able to move into Moses Lake before the storm benefited from the floodgate’s protection.

**Petroleum Discovery and Petrochemical Industries**

Platforms for producing oil, condensate, and natural gas and the pipelines for their transport are present in all parts of Galveston Bay. Additionally, oil and gas wells are found on land in Brazoria, Chambers, Galveston, Harris and Liberty counties. There are a total of 3,021 oil and gas wells in the 5 counties around Galveston Bay (Figure 4.13).

This activity has the potential to affect Galveston Bay through subsidence resulting from removal of subsurface fluids (see Chapter 5) and the unintentional discharge of petroleum or other fluids, which can be toxic to estuarine organisms. In the past, discharge of produced water (i.e., the water pumped out of an oil well along with the oil or natural gas) had the potential to impact water quality in the bay. However, in 1998 the EPA passed regulations prohibiting this practice. Produced water is now dealt with in a number of ways. It can be blocked from reaching the surface, re-injected into the ground, treated and discharged into surface waters, treated and reused (e.g., for agriculture or livestock), or re-used in oil and gas operations.

Ditton et al. (1989) pointed out that petroleum exploration and refining 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 value added by manufacturing. Nearly half the chemical production in the United States takes place in the Galveston Bay area. The vast majority of the plants are located in Galveston and Harris counties.

Most of the industrial development around Galveston Bay is concentrated in 2 areas, one along the upper Houston Ship Channel and the other in Texas City along the southwestern shore of the bay. Ditton et al. (1989) pointed out that the amount 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. Obviously, the petroleum industry is an important presence in the Galveston Bay region. Much of the water and sediment quality monitoring reported in Chapter 6 focuses on the potential impacts of past and present industrial wastewater discharges.

**Water Resources**

**Surface Water**

The location, quantity and timing of freshwater inflows flowing into Galveston Bay from rivers and bayous affect salinity regimes, circulation, and the supply of sediments and nutrients to the bay. Changes in the characteristics of freshwater inflows could impact the species composition of biological communities in the bay. In the past, the environmental needs of the bay were not always taken into account when suitable freshwater supplies were developed for use by the growing human population and industry. Fortunately, that is no longer the case.

Surface water in Texas is owned by the state, which issues permits for diversion and use of the water in its streams. In 1997, Texas passed legislation creating 16 water-planning regions throughout the state. Region H encompasses 15 counties in Southeast Texas and includes the San Jacinto and lower Trinity River basins, which feed into Galveston Bay (Taylor et al. 2000). The Trinity and San Jacinto River basins supply 82 percent of Galveston Bay’s freshwater inflows (Figure 4.14).
The Region H Water Planning Group (RHWPG 2006) estimates current water supplies to Region H to be approximately 3,572,500 acre-feet per year. This amount is expected to decline over the next 2 decades due to the decreasing availability of groundwater. Approximately three-fourths (or 2.7 million acre-feet per year) of the Region H water supply is surface water.

Surface water uses are divided into several categories: municipal water uses, manufacturing uses, irrigation, electric power production, mining, and livestock uses. Much of the surface water appropriated for human use is returned to the bay system. Return flows from groundwater usage and diversions from other watersheds, such as the Brazos River, are also discharged to the bay's waters. Increases in water usage have obvious implications for wastewater collection and treatment systems as well as freshwater inflow to the bay.

As the demand for water has increased in Southeast Texas, humans have begun altering surface water flow in an effort to increase the amount of water available for municipalities, agriculture and industry. The most visible form of human modification is the construction of dams in the major watersheds emptying into Galveston Bay. Four 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. Turtle Bay, a small brackish side bay off Trinity Bay which is fed by Turtle Bayou, was converted into Lake Anahuac to supply freshwater for the city of Anahuac and for agriculture in Chambers County (Figure 4.15).
There have been major shifts in the last decade regarding the source of the water used in some parts of the bay area. For example, in the City of Houston household water use has shifted from groundwater to surface water in an effort to control subsidence in the region (Figure 4.16). 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.

In a continuing effort to develop adequate surface water supplies, Senate Bill 1, passed in 1997, created regional watershed planning groups. Senate Bill 3, passed in 2007, tasks state agencies with the analysis of data, development of models, and the formulation of management solutions using a stakeholder approach. Region H, which encompasses the lower Galveston Bay watershed, submitted its first regional plan to the Texas Water Development Board in 2001. The Region H Water Plan was revised in 2006; the updated plan proposes a number of water management strategies to ensure future freshwater supplies. Proposed strategies include: municipal, industrial, and agricultural water conservation; expanded use of groundwater; interbasin transfers from the Trinity and Brazos river basins; and the construction of 2 additional reservoirs in the Brazos and Trinity river basins.

Expansion of inter-basin transfers is also recommended in the upper Trinity River watershed (Region C) regional plan. As the Dallas-Fort Worth metroplex acquires more water from sources outside the watershed and returns it by municipal and industrial treatment, upper Trinity River flow may increase. Whether inter-basin transfers will result in more water entering the bay will depend on management decisions of water users.

**Groundwater and Subsidence**

Approximately one-fourth of the 3,572,500 acre-feet per year of current water supply for Region H is comprised of groundwater (RHWPG 2006). The majority of the groundwater available to Region H is supplied by the Gulf Coast Aquifer system. This system comprises of 4 aquifers: the Catahoula, Jasper, Evangeline, and Chicot. The available

Figure 4.16. There are more than 3,000 groundwater wells in the Lower Galveston Bay watershed. Subsidence due to subsurface fluid withdrawal was historically a problem in the region. Data sources: (HGSD 2008b; TWDB 2008).
groundwater supply is expected to decrease in coming decades as regulations limiting groundwater withdrawal take effect. In general, groundwater in Texas is subject only to the “rule of capture” and is not regulated. Groundwater Conservation Districts are an exception to this general rule. These districts were created under the Texas Constitution (Article III, Section 52; Article XVI, Section 59) and have the authority to regulate the spacing of water wells, the production from water wells, or both. All Groundwater Conservation Districts are required to develop a groundwater management plan.

Some areas of the Lower Galveston Bay watershed have experienced up to 10 feet of subsidence since 1906 (Figure 4.16). Since the creation of the Harris-Galveston Subsidence District (HGSD) by the Texas Legislature in 1975, the HGSD has been working to reduce groundwater withdrawal and subsidence in Harris and Galveston counties. Because of the groundwater withdrawal management practices formulated by the HGSD, the rate of subsidence has slowed in and around Galveston Bay over the past 20 years. However, groundwater withdrawal and associated subsidence is still occurring in northern and western Harris County (HGSD 2008a).

Reservoir Controversy: Trinity River
The Trinity River flows south from the Dallas–Fort Worth metroplex to its endpoint at Trinity Bay, the northeastern arm of Galveston Bay. The Trinity River is the major source of freshwater inflow for the Galveston Bay system (Figure 4.14). Along the river’s path exist several reservoirs utilized for municipal and industrial water supply, flood control, and crop irrigation.

After World War II, many water management projects were implemented across Texas. Four dams and reservoirs on the Trinity River were authorized in 1950. In 1950 the USACE established a second civil works district in Texas at Fort Worth, in addition to the first, located in Galveston. The projects on the upstream Trinity River were controlled by the Fort Worth District; responsibility for navigation and drainage projects in coastal water bodies was retained by the Galveston District (Gallaway 2001).

The Wallisville Reservoir Project began in 1962. It grew out of an almost century-old navigation project to create a channel from Trinity Bay up to Liberty, Texas, originally proposed to extend to the Dallas area. During the 1950s, saltwater intrusion had damaged the rice crops irrigated by water from the Trinity River. One purpose of the new 19,000-acre, multipurpose project was to prevent saltwater intrusion. Another was to secure more freshwater for the Houston region.

The project was halted in 1973 by a federal district court injunction due to deficiencies in its environmental impact statement. Plans for a 5,000-acre lake were developed between 1973 and 1990, but rejected. In the early 1990s, a revised plan for a pool-less saltwater barrier was finally accepted. The USACE began operation of the Wallisville Saltwater Barrier in 1999. The barrier now functions to prevent the intrusion of saltwater into the Trinity River.

Municipal and Industrial Discharges
Water quality in Galveston Bay has historically been impaired by the discharge of wastewater (see Chapter 6). In the late 1800s, street drains and sewers in Houston emptied separately but directly into Buffalo Bayou (Henson 1993). The city built the first sewer system in 1899 with a central pumping station on the
northeast side of Buffalo Bayou and siphon pumps to bring the sewage across the bayou (Henson 1993). Within 6 years, the capacity of the system was exceeded and the quality of its performance was suspect.

The State Water Pollution Control Act of 1961 authorized Texas to issue permits to municipal and industrial wastewater sources. In 1967, the Texas Water Quality Board was established. It became part of what is today the Texas Commission on Environmental Quality (TCEQ).

Galveston and the other smaller communities around the bay improved their wastewater disposal systems by changing from outhouses and cesspools, or septic tanks to city sewers. In a 1950 study conducted by Galveston County, officials found that most of the municipalities were still dumping raw sewage into the bay. Two decades later, a federal study dealing with water pollution determined that, of 7 million gallons of sewage discharged by the city of Galveston in 1970, only 40 percent was adequately treated (Henson 1993). Today, Galveston treats its wastewater effluent prior to discharging it into the bay. There are still small communities around the bay dependent on septic tanks for sewage treatment. Aging or improperly maintained septic systems contribute to loadings of fecal coliform bacteria and nutrients in local bayous. The progression to centralized sewage treatment service is under way, but it is costly and thus progressing slowly. In a study of communities around Galveston Bay dependent on on-site septic systems, the costs to correct the problem were estimated. For example, Beaumont Place consists of 750 homes with a population of 2,500. Resident annual income is 33 percent below that for the surrounding county. The capital cost estimate to correct its on-site sewer facilities problems ranged from $5.4 million to $7.3 million (HGAC 2005).

A large volume of effluent from industrial and municipal sources is still received by the bay. Pacheco et al. (1990) estimated that 224 billion gallons of process water was discharged into the bay in 1990. The majority of that flow was from municipal sources (174 billion gallons per year). Based on TCEQ data related to wastewater outfall permits data (2009), we estimate that 979 wastewater permits are located in the 5 counties of the Lower Galveston Bay watershed (Table 4.3). Of those, nearly half produce less than 1 million gallons per day (MGD) of domestic sewage, while half produce greater than 1 MGD of domestic sewage and process water (non–cooling water industrial discharges). Nearly three-fourths of all the wastewater permits are located in Harris County.

Two large power generating stations are currently drawing water directly from Galveston Bay for cooling, with important effects on the bay’s internal circulation. The intake for the P.H. Robinson station is located south of Eagle Point and discharges north of Eagle Point near Bacliff. The Cedar Bayou Generating Station has a longer diversion, with the intake in Cedar Bayou and the outlet in the Trinity River Delta in the northwestern part of Trinity Bay. The general flow pattern caused by the P.H. Robinson plant is clockwise around Eagle Point. The most notable effect of the Cedar Bayou plant is occasional flow reversal upstream to the intake.
Table 4.3. Number of permitted wastewater outfalls in the 5 counties surrounding Galveston Bay, categorized by volume (million gallons per day; MGD). Data source: (TCEQ 2009).

<table>
<thead>
<tr>
<th>County</th>
<th>Permitted outfalls with &lt; 1 MGD domestic sewage</th>
<th>Permitted outfalls with ≥ 1 MGD domestic sewage or process water*</th>
<th>Total Number of Permitted Outfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazoria</td>
<td>50</td>
<td>51</td>
<td>101</td>
</tr>
<tr>
<td>Chambers</td>
<td>20</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>Galveston</td>
<td>29</td>
<td>44</td>
<td>73</td>
</tr>
<tr>
<td>Harris</td>
<td>388</td>
<td>365</td>
<td>753</td>
</tr>
<tr>
<td>Liberty</td>
<td>12</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>499</strong></td>
<td><strong>480</strong></td>
<td><strong>979</strong></td>
</tr>
</tbody>
</table>

* including water treatment plant discharge

Land Use

The use of land in Galveston Bay’s surrounding watershed has a profound effect on the resources of the estuary. The amount of developed land (commercial, residential, and agricultural) in a watershed directly affects the amount of available wildlife habitat, the volume of surface runoff, and the types and amounts of nonpoint source contaminants flowing into Galveston Bay and its tributaries. Land use–land cover data classified by the National Oceanic and Atmospheric Administration (NOAA 2006) was used to calculate the amount of developed land in the 5 counties of the Lower Galveston Bay watershed. Categories of undeveloped-land use are discussed in Chapter 7. Table 4.4 includes acreage totals for 4 land-use classes, as defined by NOAA:

- **High-Intensity Developed:** Urban lands with greater than 75 percent impervious surface (surfaces that do not allow other substances like water to pass through them; e.g., streets and sidewalks).
- **Medium-Intensity Developed:** Areas with a mixture of construction and vegetation where impervious surfaces account for 50 to 75 percent of the total cover.
- **Low-Intensity Developed:** Areas with a mixture of construction and vegetation where impervious surfaces account for 21 to 49 percent of total cover.
- **Cultivated:** Areas used for the production of annual crops. Crop vegetation accounts for more than 20 percent of total vegetation. This class also includes all land being actively tilled.

As of 2005, the NOAA classification estimates that 876,810 acres (1,370 square miles) of land are developed in the Lower Galveston Bay watershed (Table 4.4)—more than twice the 600 square mile area of the bay.
### Table 4.4. Acres of developed land in the 5 counties surrounding Galveston Bay, 2005.

Data sources: ¹(NOAA 2006); ²(USCB 2008b).

<table>
<thead>
<tr>
<th>Acres of Land</th>
<th>Brazoria</th>
<th>Chambers</th>
<th>Galveston</th>
<th>Harris</th>
<th>Liberty</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-Intensity Developed¹</strong></td>
<td>6,637</td>
<td>1,544</td>
<td>7,347</td>
<td>104,202</td>
<td>1,241</td>
<td>120,972</td>
</tr>
<tr>
<td><strong>Medium-Intensity Developed¹</strong></td>
<td>16,849</td>
<td>3,916</td>
<td>20,303</td>
<td>227,857</td>
<td>3,702</td>
<td>272,627</td>
</tr>
<tr>
<td><strong>Low-Intensity Developed¹</strong></td>
<td>26,682</td>
<td>14,435</td>
<td>24,876</td>
<td>147,412</td>
<td>15,350</td>
<td>228,754</td>
</tr>
<tr>
<td><strong>Total Developed Land</strong></td>
<td>50,168</td>
<td>19,895</td>
<td>52,526</td>
<td>479,471</td>
<td>20,293</td>
<td>622,352</td>
</tr>
<tr>
<td><strong>Total County Land Area²</strong></td>
<td>887,040</td>
<td>383,360</td>
<td>254,720</td>
<td>1,106,560</td>
<td>742,400</td>
<td>3,374,080</td>
</tr>
<tr>
<td><strong>Percentage of Land Area Developed</strong></td>
<td>6%</td>
<td>5%</td>
<td>21%</td>
<td>43%</td>
<td>3%</td>
<td>18%</td>
</tr>
</tbody>
</table>

### Urban and Industrial Development

Urban development is most pronounced along the western edge of the bay. Land use categories include developed upland (industrial and municipal), cultivated upland (agricultural lands) and undeveloped land (uplands, wetlands and transitional lands) (Pulich et al. 1996).

A strong relationship exists between land uses and pollution from rainfall runoff. Conversion of undeveloped land to impervious surfaces such as roads and parking lots increases the amount of surface runoff flowing into the bayous and bay. This increased amount of surface runoff carries with it pollutants such as oil and grease, herbicides, and fertilizers. Because there is no single, identifiable point source, these types of loadings are called nonpoint sources; they are very diffuse and difficult to manage. The existence and effects of non-point source loadings resulting from runoff have been noted for some time, but the problem has generated more concern over the last decade.

Land use also affects the quantity and quality of habitat (see Chapter 7). Filling wetlands and converting bottomland forests and coastal prairies with their prairie-pothole complexes to residential, commercial, and industrial development reduces the quantity and quality of wildlife habitat. Continuous stretches of native vegetation become divided into separate, isolated fragments leaving the wildlife that inhabits them more vulnerable to human activity.

Harris County is the most developed of the 5 counties around the bay in terms of urban, suburban, and industrial development (Table 4.4). More than 40 percent of the county’s land area has been developed for urban, suburban, and industrial uses. Industrial activities, especially refining and petrochemical industries, are most prominent in the eastern portion of Harris County around the Houston Ship Channel. Highly
industrialized areas are contained in the boundaries of several municipalities, including Houston, Pasadena, Baytown, Deer Park and La Porte.

Galveston County is the second most developed in the Lower Galveston Bay watershed (Table 4.4). It includes the urbanized eastern portion of Galveston Island, the industrialized Texas City–La Marque area and suburban Dickinson, League City, and Friendswood.

Chambers County remains largely agricultural, producing primarily rice and soybeans, but has some petrochemical plants near the border with Harris County. Large areas of land in this county are set aside for conservation and recreation, including the state Candy Abshire Wildlife Management Area and the Anahuac National Wildlife Refuge. It should be noted, that as seen in Table 4.2, Chambers County is growing in terms of population and increases in development could soon follow.

The majority of Brazoria County is rural with a few medium-sized communities. Two suburban areas provide residences for commuters to Houston and employees of the major petrochemical complexes in the county: the Pearland-Manvel-Alvin area in the northern portion of the county, and the Brazosport area in the southern portion (not in the Galveston Bay watershed). Brazoria also has large areas set aside for conservation and recreation, including 2 high priority wetlands, Freshwater Lake and Hoskins Mound, Brazoria and San Bernard National Wildlife Refuges, and Justin Hearst Wildlife Management Area. Brazoria is one of the fastest growing counties in the Lower Galveston Bay watershed in terms of population growth (Table 4.2).

The second edition of this publication (Lester et al. 2002) reported that Liberty County was the fastest growing county in the Galveston Bay Estuary Program 5-county area. However, population growth has slowed and is now outpaced by increases in Chambers and Brazoria counties. Land use in Liberty County is primarily devoted to ranching and agricultural uses. While still rural in nature, the forested lands in this county have decreased in acreage. Between 1996 and 2005, more than 18,000 acres of forested wetlands were lost in the Lower Galveston Bay watershed. Most of that loss occurred in Liberty County and was likely due to land clearing (see Chapter 7).

Figure 4.17. A strong relationship exists between land use and pollution from rainfall runoff. Impervious surfaces such as roads and parking lots increase the surface runoff flowing into the bayous and bay. Image © 2006 iStockphoto.com/Kenny Haner.
Agriculture

Agricultural activities take place in each of the counties surrounding the bay. While the western side of Galveston Bay is heavily urbanized, the lands east of Trinity Bay and north of West Bay have more rural uses. Even along the western shore of the bay, suburban and industrial development is interspersed with grazing and agricultural operations. Agricultural land use is most pronounced in Brazoria and Liberty counties.

According to a recent agricultural census, 7,721 farms were located within the 5 counties surrounding Galveston Bay (Brazoria, Chambers, Galveston, Harris and Liberty) in the year 2007. These farms constituted more than 540,000 acres of crop lands (Table 4.5) (USDA 2007).

Crops harvested in the counties surrounding the bay include rice, sorghum, soybeans, corn, and cotton. Of these, rice represents the largest crop, although overall rice acreage has been declining statewide, including the Galveston Bay watershed, in the past several years due to poor prices. More than 24,000 acres of rice were planted in 2007 with nearly 80 percent of the region’s rice planted in Brazoria and Chambers counties (USDA 2009).

Grazing of livestock (primarily cattle) is evident in every county surrounding the bay. The USDA estimates that, in 2007, 237,000 head of cattle were present in the Lower Galveston Bay watershed. Brazoria County led all others, with nearly 91,000 head of cattle. Harris County reported approximately 49,000 head of cattle (USDA 2009).

<table>
<thead>
<tr>
<th>Number of Farms</th>
<th>Brazoria</th>
<th>Chambers</th>
<th>Galveston</th>
<th>Harris</th>
<th>Liberty</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cropland (Acres)</td>
<td>186,201</td>
<td>115,588</td>
<td>21,819</td>
<td>91,438</td>
<td>127,704</td>
<td>542,750</td>
</tr>
</tbody>
</table>

Agricultural use of the land surrounding the bay has been declining for many years. Nevertheless, agriculture, and particularly irrigated agriculture such as rice farming, can be an important factor affecting the bay system. Irrigation, erosion control, and pest control practices affect the amount, timing, and quality of freshwater inflows. Impacts on the bay include water quality degradation through the introduction of fecal coliform bacteria from livestock waste and the introduction of nutrients, herbicides, and pesticides from crop management. On the other hand, conversion of agricultural land to more urban uses can result in even greater impact on water supply and quality of runoff to the bay system.
Roads and Highways

There are more than 3.7 million vehicles registered in the 5 counties surrounding Galveston Bay (TXDOT 2009a, 2009b). These and vehicles from outside the area travel on roads and highways that cover the land with impervious surfaces preventing water penetration and plant growth. Some of these roads cross portions of Galveston Bay or its tributaries with bridges that impede water flow and create turbulence.

Accommodating growth in number of vehicles has meant continued growth in the land area covered by roads and highways. As the metropolitan area has grown, the number of roads and the number of lanes on the highways have increased. As of 2007, there were 8,797 lane miles in the 5 counties around the bay (TXDOT 2009a, 2009b). Another result of increased growth of the metropolitan area and the number of lane miles is an increase in vehicle miles traveled. In 2007, nearly 74 million daily vehicle miles were traveled on the roads in this region. This is 10 million more daily vehicle miles traveled than were reported in 2000.

Shipping by Rail

Chapter 3 describes the role of railroads in the settlement and development of the area around Galveston Bay. This mode of transportation no longer moves many people (but that may change if additional commuter rail lines are built in the region); however, it is a very important means for moving materials and products for the region’s industry. In 2006, 44 freight railroads operated 10,608 miles of track in Texas (AAR 2006). Of the more than 115 million tons of rail freight originating in Texas in 2006, more than 76 million tons (65 percent) consisted of chemical, nonmetallic mineral and petroleum products. The industrial facilities around Galveston Bay likely served as the origin or destination of the majority of these products.

Fisheries

Commercial Fishing Industry

Finfish

The annual finfish catch is a relatively small part of the total Galveston Bay harvest. Between 1997 and 2001, the annual commercial bay harvest of finfish averaged approximately 209,065 pounds. For the same period, the annual, ex-vessel value of finfish caught in Galveston Bay averaged $211,770 (Culbertson et al. 2004). Four species account for the majority of the total finfish harvest: southern flounder, black drum, mullet, and sheepshead.

Shrimp

White and brown shrimp are the dominant shellfish species in the Galveston Bay commercial catch. Shrimp account for nearly half the total Galveston Bay seafood harvest. Between 1997 and 2001, the annual commercial bay harvest of shrimp averaged nearly 4 million pounds. The annual average ex-vessel value of shrimp caught in Galveston Bay between 1997 and 2001 approached $10 million (Culbertson et al. 2004).
Blue Crab

Blue crab is a popular seafood species found along the Gulf and Atlantic coasts. The Texas Parks and Wildlife Department (TPWD) calculated that 28 percent of the Texas commercial blue crab harvest came from Galveston Bay during 1997–2001 (Culbertson et al. 2004). More than 1.2 million pounds of blue crab was commercially harvested in Galveston Bay in 2001, with an ex-vessel value of $913,341 (Culbertson et al. 2004).

There is no linear trend in the commercial blue crab harvest since 1981. The amount of blue crab harvested in Galveston Bay peaked between 1986 and 1988 and again between 1996 and 1998. Blue crab populations exhibit a declining trend in some areas of Galveston Bay (see Chapter 8).

As blue crab taken from Galveston Bay is a popular commercial species eaten by many people, evaluating the safety of its consumption is critical. According to the Texas Department of State Health Services (TDSHS), blue crab from the Houston Ship Channel and Upper Galveston Bay should be eaten only in limited quantities because of elevated concentrations of dioxin found in crab and fish tissue (See Chapter 9).

Oysters

The Galveston Bay oyster fishery has been an important commercial species for over 100 years. Oysters are harvested from both public reefs and private oyster leases in the bay. Between 1997 and 2001, the annual commercial harvest of oysters from Galveston Bay averaged 4.6 million pounds. For the same period, the annual, ex-vessel value of oysters caught in Galveston Bay averaged more than $10 million (Culbertson et al. 2004). After the storm surge of Hurricane Ike buried more than half of the oyster reefs in the bay, we can expect lower harvests and a long recovery period for this fishery.

It should be noted that there are health concerns associated with the commercial harvesting of oysters. The DSHS has a program to restrict the harvesting of oysters to protect the public from health risks associated with bacterial pathogens in the bay. These public health issues are discussed in more detail in Chapter 9.

Sport Fishing

In addition to the small commercial finfish fishery in the bay, there is a significant sport fishery. Atlantic croaker, sand sea trout, southern flounder, red drum, and spotted seatrout are the sport fishes taken most frequently. Between 1993 and 2003, Galveston Bay yielded the greatest number of recreational marine fish landed (40 percent of the state total) when compared to other Texas bays (Green et al. 2005). One reason for this is the level of fishing effort in and around Galveston Bay. According to TPWD (2008b), more than 269,000 recreational fishing licenses (freshwater and saltwater) were sold in the 5 counties around Galveston Bay in 2007. These totals include resident, non-resident and combination fishing/hunting licenses. Recreational fishing has been estimated to generate over $2.8 billion in economic activity annually.
Other Recreational Uses

Residents of the Texas Gulf Coast use the Lower Galveston Bay watershed for many popular outdoor activities including waterfowl hunting, fishing, swimming, nature viewing, pleasure boating, camping, picnicking, and sightseeing.

The proportion of area residents expected to annually participate in walking, saltwater swimming, and picnicking is well over 40 percent (HGAC 1993). More than 20 percent of the region's population participates in saltwater fishing and the use of open space and about 15 percent enjoys saltwater boating.

Boating

Recreational boating is popular along the Texas Gulf Coast in general and around Galveston Bay in particular. Practically every type of watercraft, from kayaks to million-dollar pleasure cruisers, can be found along the bay and its tributaries. The Clear Lake–Galveston Bay area has often been called the “boating capital of Texas,” with more than 88,000 pleasure boats registered in the 5 counties surrounding the bay (TPWD 2008a). Boater impacts on the bay include disposal of raw or poorly treated sewage, scarring and resuspension of sediment, increased shoreline erosion due to wakes, and damage to seagrass beds.

For many years, the disposal of untreated sewage was one of the main pressures placed on bay resources by boaters. In 1993, the first marina pump-out station was placed on the bay. As of October 2008 there are numerous pump-out stations located around Galveston Bay (Figure 4.18), which, along with boater-education from the Texas Sea Grant Program—have dramatically decreased the raw or poorly treated sewage discharged into bay waters by boaters.

Boating accidents are also a risk for some users of the bay. Various organizations, including the Texas Parks and Wildlife Department and the Coast Guard Auxiliary, offer courses on boating safety. Both organizations also conduct inspections of pleasure boats on Galveston Bay to ensure compliance with safety regulations.
Nature Viewing and Ecotourism

Tourism that is based on nature rather than human-built attractions is the tourism industry's most rapidly expanding sector (Eubanks 1993). Bird-watching has become very popular along the Texas coast, with over 600 species drawing visitors to the area. Rockport, 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 is visited by tourists primarily for natural attractions such as bird watching at High Island or wildlife viewing at the Anahuac National Wildlife Refuge. This county experienced significant growth in tourism between 1975 and 1988, with total expenditures increasing from $600,000 to over $9 million (Allison et al., 1991). There are many stops around Galveston Bay on the Great Texas Coastal Birding Trail which links 500 miles of coastal bird viewing sites from Brownsville to Beaumont.

Galveston Bay has several ecologically and economically valuable sites that serve as ecotourist attractions. For example, bird watching at locations around the bay attracts visitors from all over the United States and many foreign countries. Eubanks (1993) listed over 20 potential birder attractions around Galveston Bay, including Bolivar Flats, High Island, the Anahuac National Wild Refuge, the Candy Abshire Wildlife Management Area, the Trinity River Delta, the Atkinson Island Wildlife Management Area, the San Jacinto Battleground, the Armand Bayou Nature Center, Challenger Park, the Texas City Dike—Moses Lake, the Brazoria National Wildlife Refuge, San Luis Pass, Galveston Island State Park, North Deer Island, and Kempner Park. The Armand Bayou Nature Center has the largest interpretive program for the study of nature in the bay area.

For other important recreational activities in the Galveston Bay area, little or no information is available. These include swimming and other forms of “contact recreation” such as waterskiing and nature viewing. Although there are no data collected on contact recreation in Galveston Bay, there are major areas known to attract contact recreation in bay waters. These areas include Mud Lake, Offatts Bayou, San Luis Pass, the Texas City Dike, Clear Lake and Clear Creek.

Other programs focused on the bay’s resources are offered by the Galveston Bay Foundation, the City of Baytown, Sea Camp at Texas A&M University at Galveston, and some smaller outdoor programs. An assortment of Galveston Bay wildlife and habitats can be viewed at locations around the bay. Major public park facilities include San Jacinto State Park, Sylvan Beach Park, the Texas City Dike, Seawolf Park, and Galveston Island State Park.

A few facilities also provide interpretive services to educate visitors about the organisms and processes associated with the bay. The public is educated about fish and fishing at the Texas Parks and Wildlife Department’s Environmental Learning Center at Sheldon Lake State Park in northeast Harris County and at the Sea Center Texas marine hatchery and visitor center in Lake Jackson. Remnants of coastal prairies and wetlands can be viewed and explained at the Armand Bayou Nature Center in Houston and the Eddie V. Gray Education and Recreation Center in Baytown. These facilities serve a valuable role in educating children and adults on the importance of preservation, restoration, and stewardship.
Hunting
Waterfowl hunting has a rich tradition in Texas and along the Gulf Coast. TPWD (2008b) estimates that more than 64,000 recreational hunting licenses were sold in the 5 county area in 2007. Hunters utilize private wetland areas through lease arrangements and public lands through access programs of the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service. The Anahuac National Wildlife Refuge and Justin Hearst Wildlife Management Area support large concentrations of migratory waterfowl, as do nearby private leases. While not everyone appreciates the role that hunters play in managing wildlife populations, it is hard to ignore their economic impact in Texas and their contributions to wildlife conservation.

Summary
Galveston Bay has supported economic growth in the region and is surrounded by intensive urban and industrial development. Resources in the Galveston Bay watershed have been utilized for construction, transportation, oil, gas and petrochemical production, water supply, fisheries, agriculture and recreational uses.

Projected growth in population and economic activity will result in increasing use of the bay resources. Major expansions and management changes are in progress or proposed for the ports and navigation channels in the Galveston Bay system. More people will place more demands on water supply, roads and highways, and land for development. Controversies have arisen over changes to bay tributaries through channelization and impoundments. Residents want more access to the bay and its associated recreational resources. In cases absent of controversy, governments are responding with programs to meet those demands. Increases in future resource demand must be addressed via planning, funding, monitoring and research to avoid user conflicts and resource degradation in the future.

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