In this future, the management of our impacts on the oceans, coasts, and Great Lakes has also changed. Management boundaries correspond with ecosystem regions, and policies consider interactions among all ecosystem components. In the face of scientific uncertainty, managers balance competing considerations and proceed with caution. Ocean governance is effective, participatory, and well coordinated among government agencies, the private sector, and the public.


Introduction

Of one thing we can be certain, Galveston Bay will change; the bay and watershed are dynamic. Trying to keep any part of these systems static will not work. We know from the geological record that past sea level change, floods and sediment deposition have played major roles in the evolution of the estuarine system we observe today. Less than 200 years ago, large-scale human modification was added to the natural forces that shape the estuary, its watershed, and the physical and biological processes that occur there. As we look to the future and try to define the best management for the Lower Galveston Bay watershed, we must consider the consequences of continued human impact and the inevitability of change. Our challenge is to balance the contrasting uses of the bay and needs of user groups, the needs of nature including humans and other organisms, and the needs of current and future generations of humans and other creatures.

Figure 10.1. Of one thing we can be certain, Galveston Bay will change; the bay and watershed are dynamic.
This chapter envisages the future of Galveston Bay by evaluating historical drivers of change and their impacts on the estuarine system. We use our knowledge of the trends and scale of these forces to extrapolate potential future impacts. Our focus is primarily on those drivers that are associated with people and might be managed by people, including demographic change, trends in economic activity, discernible cultural trends, scientific and technological change, policy changes, and probable interactions among them. Of course, the vision of the future laid out below is not written in stone; many of the conclusions drawn here are debatable and have a degree of uncertainty.

This work was commissioned by the Galveston Bay Estuary Program; its mission is to “preserve Galveston Bay for generations to come.” As noted above, no one can hope to preserve the bay unchanged, as it is today or as it was 200 years ago, before European settlement. The Estuary Program and its partner organizations hope to preserve the ecological functions, processes, and characteristic habitats of the bay that ensure valuable services from its natural ecosystems, the survival of fish and wildlife that depend on the bay and its watershed, and the characteristics of the bay and its watershed that offer aesthetic and spiritual rewards. Based on the historical record examined in this document, management of Galveston Bay has improved over time, and achieving the goals of the Galveston Bay Plan has become more probable.

**Status of the Bay**

Before discussing the possible future of Galveston Bay, it is appropriate to review the material covered in the previous chapters. The Galveston Bay Estuary Program was established to protect the natural resources and ecological services represented by the Galveston Bay watershed. The program was launched only 20 years ago after more than a century of intensive use and modification by humans. Conversion of land for human settlement, agriculture, and industry has significantly changed the landscape of the watershed. While industrial expansion appears to have slowed, commercial and residential development continues. Modifications of the bay’s geomorphology for navigation have resulted in alterations of salinity and water circulation. Extraction of bivalve shell and petroleum resources has changed the nature of bottom sediments and water circulation. Galveston Bay is a system that has been affected by human activity, and is managed to maintain its economic services.

In order to manage the Galveston Bay system for perpetuation of ecosystem services and function, it is necessary to understand which of the processes that characterize the bay can be managed and which cannot be managed. Some processes, such as sea level change and sedimentation, have direct relevance for management decisions (e.g., building structures which protect coastal communities from inundation by sea water or augmenting sediments for the preservation of beaches). Others such as the tidal movement of water in the bay appear less relevant. Humans have modified the flow and circulation of the water in the bay, the shape of the bay, the depth and composition of the bottom, and the landscape of the bay watershed, but humans have little influence over fundamental processes resulting from waves, tides and currents.

Water pollution of the bay and its tributaries has been a consequence of human activity since permanent settlements were constructed on the bay. While measurements of some parameters exceed water quality standards and require management solutions, the levels of most pollutants have declined since the initiation
of intensive water quality management following passage of the federal Clean Water Act in 1972. Despite desirable trends in the concentrations of most pollutants, some continue to represent real risks to human health. Some seafood contamination problems have been recognized only recently, either because the compound or concentration was previously undetectable or testing was not being conducted. For compounds such as dioxin, progress has been made towards identifying sources of the contaminant and addressing release into the environment. Other pollutants such as polychlorinated biphenyls (PCBs) continue to bioaccumulate in the food web despite the longstanding ban on their commercial use and uncertainty about suspected sources remains. Still other risks to human health include the naturally occurring bacterium \textit{Vibrio vulnificus}. The potentially lethal pathogen is common around oyster reefs and on fish, especially in summer months.

Based on anecdotal reports in historical sources, we know that the biological communities in and around Galveston Bay have changed since settlement. Loss of habitat resulting from increased density of human land uses has led to extirpation of populations of some animals. However, since the establishment of baseline monitoring and management for biological resources was established in the 1970s, there appears to have been little change in aquatic animal populations and limited declines in some bird populations. The habitats described in early reports are still present. The fish and invertebrate populations monitored by the Texas Parks and Wildlife Department (TPWD) appear relatively stable over the period of record. There is evidence of the recuperative capacity of the system, exemplified by the resurgence of the brown pelican population and the return of seagrasses to West Bay.

Although Galveston Bay and its lower watershed around Houston are among the best monitored areas in the country for environmental data, there are still information gaps that leave important questions unanswered. We have noted many of these gaps in the previous chapters. Our lack of comprehensive knowledge about the inputs and outputs of nutrients, pollutants, and organisms to the system makes it difficult to forecast specific changes. We are also just beginning to fill in information about the smaller components of the biological communities including bacteria, phytoplankton and tiny benthic organisms, which represent the largest amount of biomass in the bay. Because these gaps in knowledge make detailed forecasting of the future of the system difficult, we will approach the problem from a high level and describe projected changes in general terms.

**Physical Changes**

**Sea Level Change**

Sea level has been rising since the last glacial maximum (18,000 years ago) and continues to do so. Land subsidence has also been occurring over at least a century due to withdrawal of ground water. Subsidence claimed one Galveston Bay subdivision, Brownwood (the subdivision is now mostly underwater and has been turned into a nature center by the City of Baytown), but has slowed as a result of regulation of the withdrawal of groundwater. Rising sea levels have inundated portions of the Gulf beach and fringing marshes. These processes will continue for many years, but it is difficult to predict at what rate. Recent reports from Louisiana conclude that subsidence on the Gulf Coast has been underestimated (Dokka 2006). Over the period from 1908 to 1999 relative sea level at Bolivar Roads increased around 6.5 millimeters
4.4 mm of that increase was estimated to be from local subsidence, according to Gibeaut (2006). The shoreline of Galveston Bay will tend to move north where possible due to relative sea level rise. Unless the height of Follets Island, Galveston Island, and the Bolivar Peninsula are increased, their exposed area will decrease and the amount of low marsh will decline (Gibeaut 2006).

The combination of sea level rise and subsidence will likely increase the extent of land inundation during high tides, storms, and floods. Coastal communities around the bay are trying to deal with this issue in a number of ways. A geohazard map of Galveston Island was created to provide planning information for development and infrastructure on the island (Gibeaut 2007). Permitting requirements in coastal communities around Galveston Bay are being revised to ensure that new structures will be elevated well above sea level; these requirements will help to minimize the problem of inundation, except possibly during extreme storm events similar to Hurricane Ike.

Sea-level rise would be of much less concern if the coastal zone were less populated and less developed. Coastal areas are magnets for human migration and land development, both for economic benefits and recreational amenities. Coastal vulnerability related to sea level rise would not be as acute if population density and the level of investment were less.

The inevitability of future storms as severe as, or more severe than, Hurricane Ike has prompted discussions and studies concerning the desire to protect the facilities and people at risk. The proposed solutions include physical structures such as a longer seawall and expanded levees, along with nonstructural components, such as limits on structures in areas directly exposed to extreme storms. More community discussion is needed if we are to determine the best approach that takes into account all of the economic, social, and ecological concerns.

**Temperature Increases**

The TPWD has documented a rising trend in winter water temperatures in all of the Texas bays south of Galveston Bay (Tolan et al. 2009). Similar trends in Galveston Bay have not yet been observed. As temperatures rise, the geographic ranges of marine and estuarine species change. Historically, during warm periods, mangrove trees sprouted along the bay shoreline, but died due to winter cold. Black mangrove
(Avicennia germinans) is currently growing in various locations in Galveston Bay, which may become part of the permanent range of this species. Establishment of mangrove forest would likely occur at the expense of Spartina marsh and support a similar, but distinct, biological community. Black mangrove is likely one of many species that would move into Galveston Bay in response to warming water. About 40 percent of the species studied for long periods of time have shown significant range extensions over the last 30 years (Parmesan et al. 2003).

**Demographic Change**

**Population Growth**

The activities of the human population living and working in the Galveston Bay watershed are prime determinants of the conditions in the Galveston Bay estuary. The human population of Galveston Bay’s surrounding 5-county region in 2005 was estimated to be 4,328,161 (TSDC 2011). The Texas State Data Center projects the population of the region to be 7,841,227 in 2040 (an increase of 81 percent). In the upper watershed, the population of the Dallas–Fort Worth–Arlington metropolitan area is projected to grow from 5.7 million people in 2005 to 10.1 million people in 2040 (TSDC 2011). These projections amount to more than 18 million people living in the Galveston Bay watershed by 2040, or over half of the population of the state. To put that number into perspective, consider that nearly 25 million people lived in the entire state of Texas in 2009 (USCB 2010).

In terms of the Lower Galveston Bay watershed, an increase of 3.5 million people in the coming decades will likely lead to the conversion of remaining habitat into residential and commercial properties to fulfill human needs for shelter and goods. We estimate from remote sensing analysis (NOAA 2006) that in 2005 18 percent of the land in the 5 counties was covered by human development (e.g., buildings, roads and other construction). This translates to 0.14 acres of developed land per capita. Building to accommodate an additional 3.5 million people at 0.14 acre per person would convert an additional 500,000 acres of undeveloped land and habitat to developed land. In other words, one-third of the 5 counties would be covered by a built environment of pavement, lawns, and buildings. Currently, most developed land is covered by surfaces such as pavement that are largely impermeable to water and directly related to degradation of water quality in area bayous, streams and lakes (see Figure 6.27).
Population Growth and Land Conversion

In the process of converting natural and agricultural land to residential and commercial development, habitat (including wetland habitats) will be lost. Since 2001, regulations allow development to occur on coastal prairie freshwater wetlands without a permit, and thus without mitigation, because those types of wetlands are not under the jurisdiction of Section 404 of the Clean Water Act. Development on other types of wetlands (e.g., fringing marshes on the edge of the bay) can be permitted as long as mitigation efforts include creation or restoration of a larger area of wetlands than the wetland area that was destroyed. Given the population density of portions of Harris and Galveston counties, any mitigation will necessarily be some distance from the lost habitat. Studies estimating the rate of loss of wetlands in the Lower Galveston Bay watershed show that the current loss rate is around 0.3 percent of freshwater wetlands every year. Thirty-five years of continued development, according to historical rates, will result in the loss of an additional 10 percent of our freshwater wetlands, a decline from 162,528 acres to 146,275 acres. In addition to wetlands, the watershed will likely lose coastal prairies, one of the most endangered habitats in the United States. Some of the development will also occur in the eastern part of the watershed where bottomland hardwood floodplain forest is already being converted at a substantial rate. The major reservoirs (Lakes Houston, Conroe, and Livingston) that supply drinking water for the Houston-Galveston metropolitan area are located in these forested landscapes.

Experience tells us that conversion of forests to developed land results in deterioration of overall water quality (Basnyat et al. 1999) and drinking water quality (MSU 1997). Land conversion for development not only removes habitat used by other organisms, but it results in an environment that is problematic for human water supply. Vegetated land has an important function in treatment and storage of storm water. Rainfall may contain atmospheric pollutants and may pick up pollutants as it runs over the ground or other surfaces. When the land is covered by an impermeable surface such as concrete, there is no opportunity for the land and vegetation to absorb the polluted water or to process the pollutants by chemical or biological action. Figure 10.4 illustrates the relationship between water quality in a stream and the percentage of...
developed land or impervious cover in the watershed. The expansion of development in forested habitats around Lake Houston (HGAC 2009), Lake Conroe, and Lake Livingston will have major impacts on natural systems that protect the quality of water supply for people of the region. In other parts of the U.S., metropolitan areas (such as Seattle) have chosen to protect the land situated directly around water supply sources from development to avoid future costs of treatment (COS 2009).

When dense urban development is compared to vegetated land of all types, the average air temperature over the developed area increases; this is known as an *urban heat island* (Oke 1982). The phenomenon has negative effects on human health and energy use. Thus, the increase in developed land in the watershed is likely to result in increased urban heat island effects, especially in the 2 large metropolitan areas of the Galveston Bay watershed.

![Figure 10.4. Stream water quality as it is affected by the percentage of developed land or impervious cover in a watershed. Modified from (CWP 2003).](image)
Change of Commercial Activities
The Trinity River watershed connects the 2 largest metropolitan regions in Texas: Houston and Dallas–Fort Worth, which together drive the state’s economy. The future commercial growth of these urban centers will have direct effects on the land use in the watershed. While the service sector of the urban centers is growing, the agricultural activity of the rural areas will be declining (Combs 2009).

The ports in Galveston Bay will experience changes driven by growth of international trade. In the near future the Panama Canal will be enlarged, permitting the transit of large container vessels from Asia to ports in the Gulf of Mexico. More and larger vessels will transit the bay in the future.

Growth and Impacts of Consumption and Trade
Some of what the bay supplies us is renewable. For example, it is possible to harvest and consume seafood without damaging the productive resource. As long as we continue to do a good job of managing the fishery resources, the bay should provide that service indefinitely. However, some of what we use from the bay and its watershed is nonrenewable.

There is a fixed supply of waterfront land and, when it is converted for housing or commercial use, the supply goes down. There is a variable but finite supply of water entering the bay. As long as people return the water to the system after using it, the bay will be protected. But not all water removed can be returned, and, as human needs cause more water to be consumed, the impact on the natural system will increase.

One way to conceptualize the potential impacts of consumption and trade is to consider the interaction of population growth, consumption of real goods, and the technology used to produce and supply those goods. Most forms of consumption result in some type of pollution. Although the amount of pollution per gallon of gasoline burned or per hamburger consumed declines, the number of consumers in the watershed is increasing. The impacts of consumption of fossil fuels on Galveston Bay could decline in the future given the growing shift from fossil fuel to other forms of energy. However, this change could very well take more than the 35 years we are using as our future horizon for bay management.

As consumption increases, trade will increase, because the population in the watershed already exceeds the productive capacity. Growth of trade translates into more ship traffic to the ports in the bay, with attendant impacts and risks. Trade in foreign seafood directly affects the commercial fishing industry. In addition, trade in exotic animals and plants may decrease the biodiversity of the bay if the exotics are introduced and become invasive.
Opportunities to Preserve Ecosystem Services for Future Generations

It is widely recognized by the agencies managing Galveston Bay that the ecosystem services provided by the natural areas in and around it have significant value and often provide more valuable benefits in the natural state than after conversion to developed land. The devastating impacts of Hurricane Katrina in New Orleans demonstrated the greater value of undisturbed coastal marsh than the navigational channels that had damaged this ecosystem function in southern Louisiana.

In the lower Galveston Bay watershed, a similar comparison can be made for the greater value of undisturbed prairie wetlands. Once these are developed, their ecosystem service of storm water detention and treatment is disrupted. In conventional development, we replace a naturally derived service with constructed systems for storm water removal or detention ponds that are expensive to build and maintain. Methods that work with, instead of against, the natural system are gaining acceptance. These methods, developed under the Smart Growth and Low Impact Development initiatives, demonstrate that it is possible to build structures that humans need without destroying the ecosystem and its services. The costs are often comparable to those of conventional development. When the full, long-term costs are factored in, protection of wetland areas can be cheaper than building engineered storm water systems.

The public has been generally favorable to the concept of protecting nature and ecosystem services in the context of land development. The commitment of the public is expressed in the popularity of properties in high-density, mixed use developments and with the participation of volunteers in water quality monitoring, restoration of habitats, and development of watershed protection plans, etc. The participatory approach to water quality and water supply planning has resulted in a very beneficial dialog among agencies, businesses, environmental organizations, and individuals about the priorities and processes embodied in these issues.

Considerable effort has been expended to correct the problems caused by past development patterns along the bayous of Houston. Many successful projects with significant environmental and aesthetic benefits have been implemented through local organizations, including the Harris County Flood Control District, the Buffalo Bayou Partnership, and the Bayou Preservation Association, to name a few.

Figure 10.5. Earth Day occurs on April 22. Image courtesy Earth Day Network.
Cultural Change

Growth of Environmental Values

In 2010, Earth Day was celebrated for the 40th time. Since the first Earth Day, awareness of environmental issues and of the impact of everyday activities on the environment has grown considerably. Converting awareness to action in our daily lives leads to better environmental stewardship. There are multiple indicators of cultural changes resulting from enhanced environmental values held by Texas residents. Highway litter, which was once very prevalent, has been curtailed and recycling rates have risen primarily as a result of educational campaigns.

This cultural change toward placing a high value on environmental quality can be viewed from a generational perspective. The modern environmental movement started in the 1960s after the publication of *Silent Spring* by Rachel Carson (1962). Earth Day, first celebrated in 1970, was a product of the baby boomer generation. Growth of recycling and concern about environmental impacts on health grew with the “Generation X” of the 1980s. “Generation Y” is inundated with information on environmental issues and appears to be more likely to move beyond environmental awareness to action. There are many indicators of modification of lifestyles to reduce environmental impacts. For example, the number of people choosing to access the bay in motorless water craft (such as kayaks) has increased. Bird watching as a recreational pastime has grown and will encourage protection of the bay and conservation of bird habitat. Environmental organizations taking action to conserve and restore the bay have successful programs supported by volunteers. Volunteer efforts and conservationism should grow with use of social networks based on Internet connectivity, which allows people with similar attitudes to collaborate more easily and become important forces for change.

To the extent that relevant knowledge changes behavior, future stewardship of Galveston Bay should improve. More of the science courses taught in elementary and secondary schools and universities focus on environmental science. Enrollment in environmental degree programs should grow because employment in environmental science positions is expected to increase by 28 percent between 2008 and 2018, much faster than the average for all occupations (USBL 2009). Due to this educational environment, young adults are more likely to understand the impacts of their behavior on water quality and biological communities.
The Successes and Challenges of Protecting Wetlands in Galveston Bay

By Lisa A. Gonzalez

Wetlands continue to be lost in the Lower Galveston Bay watershed. The fringing marshes that line the bay, providing important nursery habitat to estuarine species of finfish and shellfish, appear to be stable in terms of their acreage. This success is largely due to the regulatory protection of this habitat under the Clean Water Act and the ongoing efforts of regional partners committed to wetland restoration under the guidance of The Galveston Bay Plan.

Freshwater wetlands are diverse in nature; they include prairie potholes in remaining coastal prairie as well as riparian habitats and bottomland forests that lie adjacent to rivers and bayous. Freshwater wetlands provide numerous ecosystem services: they provide habitat to many species of birds and wildlife and alleviate flooding as they capture rainfall and slowly release it to waterways. Additionally, wetland plants capture and store nutrients and pollutants, preventing their release to bayous and streams.

Unfortunately, the importance of freshwater wetlands and the ecosystem services that they provide are not always as well recognized or protected as those provided by fringing marshes along the bay shore.

The Lower Galveston Bay watershed’s remaining freshwater wetlands occur outside urban centers, often in the same location where suburban development occurs. People developing land containing freshwater wetlands often see the wetlands’ ability to capture water as a detriment. Many of these wetlands are drained, cleared, and then covered by impervious pavement or buildings. Fortunately, public opinion increasingly views freshwater wetlands as worthy of protection as “natural capital” that provides ecosystem services.
Regulatory protection and quantification of remaining freshwater wetlands presents a great challenge to managers and scientists. Because of Supreme Court rulings in 2001 and 2006, the regulatory protection of these wetlands has been ambiguous. Consistent, quality data on wetland permits and mitigation efforts is needed by scientists and managers to determine the success of “no net loss” of freshwater wetlands (a federal policy mandating gains in wetland acreage equal to or greater than losses). Additionally, studies analyzing the area of wetlands often use different methodologies, yielding results that are often not comparable.

Fortunately, there is an increasing awareness of the importance of freshwater wetlands and the pressures that they face in the Lower Galveston Bay watershed. A freshwater wetland created at Mason Park on Brays Bayou provides stormwater treatment, wildlife habitat, and outdoor recreation and education. Similar projects are planned and will likely be completed with greater frequency in the future. Another important, but less frequently used, tool to protect freshwater wetlands is preservation. Wetland preservation efforts deliberately work to protect natural wetlands that still exist in the Lower Galveston Bay watershed. Wetland preservation is a difficult and complex process. Issues relating to location, land ownership and sale, and future management of the protected wetland must be addressed. Additional resources will likely be brought to bear to advance this important work in the Lower Galveston Bay watershed.

What does the future hold for the wetlands of the Lower Galveston Bay watershed? Great progress has been made toward objectives outlined in The Plan with regard to the protection and restoration of the bay’s fringing marshes. That trend will likely continue as regional partners carry on restoration efforts motivated by challenges such as sea level change. In contrast, the protection of freshwater wetlands is less assured, as traditional development in the watershed continues. In order to attain a meaningful level of protection, a cultural and legal shift in the value placed on freshwater wetlands must occur. The valuation of the ecosystem services that these wetlands provide is the key to their ultimate protection. This environmental approach to valuing land is becoming more accepted and will likely strengthen in years to come.
Effects of Scientific and Technological Change

Pollution from Industry and Agriculture
Science and technology have given us products that can dramatically reduce our environmental footprint. Industrial research and development continues to increase the efficiency with which goods are produced. This means smaller amounts of raw materials processed with less energy input, resulting in less pollution. As research reveals the damage caused by some synthetic chemicals, they may be removed from the market and decline, or at least not increase, in the environment. In the Galveston Bay watershed, there may be lower pollutant loadings despite continued increase in the population. If the public begins to practice more environmentally friendly land management, then runoff from residential land will contain fewer and lower quantities of pollutants. As old industrial equipment and processes are replaced by newer technology and methods, pollution discharges per unit of production will decline.

Complex Pharmaceuticals as Water Pollutants
One area in which technical advances appear to be creating new challenges for improvement of water quality is pharmaceuticals. The pharmaceutical industry has succeeded in producing chemical treatments for a wide variety of health disorders. Many of these compounds are quite stable in the body and the environment. Numerous drugs remain active after passing through wastewater treatment systems, and are released to natural water bodies, including tributaries of Galveston Bay, in active forms. There are already documented cases of fish populations with skewed sex ratios attributed to the high concentration of synthetic hormone-like substances in the water (Barber et al. 2007). As the population in this watershed increases and ages, more pharmaceutical compounds will likely make their way into the waters of Galveston Bay and its tributaries. This problem falls under the heading of \textit{emerging contaminants} and will become a more important issue unless wastewater treatment is improved to remove these compounds.

Policy Change
The federal Clean Water Act, Clean Air Act, and other pieces of legislation have had dramatic effects in reversing some environmental deterioration. Current initiatives hold promise that public policy aimed at reducing impacts on our environment will be maintained and possibly expanded. Near-term economic conditions both in the private and public sector will challenge implementation of revised or new policies. Over the last decade there have been multiple attempts to focus government on problems specific to oceans and coasts. In June 2010, President Obama issued an executive order establishing a National Ocean Council. This council was charged with implementing Interagency Ocean Policy Task Force recommendations that encompass ecosystem-based management, coastal and marine spatial planning, improved resiliency to climate change, regional ecosystem protection, and improved monitoring of coastal and ocean environments (WHCEQ 2009). The executive order makes it the policy of the United States to (1) “protect… and restore the health” of coastal ecosystems; (2) “improve the resiliency” of coastal ecosystems and communities; (3) “bolster the conservation and sustainable uses of land” impacting the health of coastal ecosystems; and (4) “use the best available science and knowledge to inform decisions affecting … our coasts” (WHCEQ 2010).
It appears that protection of threatened and endangered species will be maintained at the federal and state levels. Restrictions on trade in exotic animals and plants aimed at reducing the introduction of exotic species into United States habitats will likely continue. While these political trends for the protection of the environment continue, resource management agencies will be mandated to expand their responsibilities and operate in a more comprehensive manner, e.g., ecosystem-based management. This new policy approach should try to balance the suite of services that natural systems provide to people and develop management approaches for large, interconnected systems. At a minimum, it will necessitate a change from managing single pollutants, single species, or small subunits of a watershed. Resources will be needed to support these changes.

TCEQ’s effort to develop and implement numeric water quality standards for coastal water bodies is of great significance to the Galveston Bay watershed, which faces many challenges. The Clean Water Act mandates protection of water bodies for historical uses. Although some water bodies may be reclassified to clarify the loss of one or more historical uses (e.g. contact recreation use in urban bayous), there will continue to be efforts to reverse the pollution of water bodies in the Galveston Bay watershed. This will be critical to maintaining high-quality drinking water supplies, which will likely be under increasing demand as the population in the watershed grows.

A policy shift has been under way for some time, evidenced by a move from dependence on a reactive regulatory approach for water pollution—addressed through National Pollutant Discharge Elimination System permits and Total Maximum Daily Load (TMDL) programs—to a proactive, incentive-based approach using stakeholder participation and public investment in programs such as Clean Marinas and watershed protection plans (WPP). While we will no doubt continue to wrestle with pollution of urban water bodies, this shift to proactive planning may benefit the urban and suburban tributaries around Galveston Bay. Watershed protection planning may benefit the rural tributaries that have not yet been surrounded by residential development. Public involvement in TMDL and WPP efforts is having a significant side benefit by increasing public knowledge and commitment to the protection of local water bodies.

In conjunction with the need to protect water bodies for human use, there is now a legislated policy requirement that authorities in Texas manage water in tributaries (instream flows) to preserve biological communities by establishing environmental flow regimes. In 2011, the TCEQ approved a rule governing flow regimes for the Trinity and San Jacinto Rivers and seasonal flow levels for the discharge of these rivers to Galveston Bay. The law calls for adaptive management of the freshwater flows to ensure maintenance of sound ecological environments in the estuary and its tributaries. New environmental flow policies are part of the evolution of environmental policy toward regulatory management of an entire system, such as a watershed.
Since hurricanes Rita and Ike hit the Texas coast in 2005 and 2008, there have been policy discussions about regulations and practices that will decrease social and economic vulnerability to severe storms. The Federal Emergency Management Agency and local governments are implementing or considering rules about higher elevation of residences and storm resistant construction methods. The debate about government involvement in flood insurance for properties in coastal floodplains is continuing. Over the next 30 years, we should expect changes in government policy that will decrease the probability of loss of life and property damage from a severe storm. These policy changes will affect owners of property in the Lower Galveston Bay watershed. Current objectives include enhancing shelters, hardening the electricity distribution system and ensuring more distributed generation of power. Better building codes can enhance resilience. Buildings built to the most recent construction codes experienced less damage from Hurricane Ike (Figure 10.9) than those built to earlier codes. Those structures situated on property near the water’s edge share a problem that cannot be solved by building codes. As the water level rises and beaches erode, these homes and businesses will continue to have a high probability of conflict with the policy regulating public beaches and submerged state lands.

Combined with the policies regulating the construction and protection of buildings, local policies related to land use could improve resilience of communities. For example, low impact development practices in the design of new communities would enhance protection of natural habitats, especially wetlands, and reduce the cost of flood protection. One of the challenges of using such ordinances for the protection of natural systems is the amount of development that occurs in counties outside municipal boundaries, where the ability to regulate development is limited because counties do not have ordinance making power.

In addition to the minimization of discharge of dredged sediment, the regulation of discharge of other types of waste and pollutants will likely continue to become more restrictive. TCEQ is in the process of setting standards for nutrient concentrations in freshwater and will apply a similar process to setting standards for estuaries. This may increase the need for watershed protection programs that apply to nonpoint source nutrient pollution (e.g., fertilizer applied to residential yards).

One thing an observer might conclude from the environmental history of the Galveston Bay watershed is that past decision makers believed that they could improve on nature. This is most obvious in the large projects, such as closing Turtle Bay and creating Lake Anahuac or dredging canals in marshes to obtain sediment to create subdivision sites. National environmental policy has already created significant regulatory constraints on such projects. It appears that future policy will favor reduced restructuring of the geomorphology of the bay. Overall, environmental policy at all levels of government appears to be
considering sustainability as a major objective. This suggests that Galveston Bay will be managed with the objective of sustaining the system in as natural a state as possible while accommodating significant human population growth.

**Seeking a Sustainable Future for the Bay**

The above discussion of the drivers of change and their potential impacts on the Lower Galveston Bay watershed is based on past and current behaviors and policies. Thus the predicted outcomes represent a business as usual analysis of trends in the drivers of change and their effects on the bay and its management. Population growth and associated development activities are the most significant drivers. It is possible that policies and human behavior will change more rapidly than we expect and result in significantly different outcomes by 2040. Changes in policies or behaviors that could mitigate population growth and its effects are briefly described in the following paragraphs. In general, these changes amount to adoption of sustainability as a primary goal.

Poorly designed products, ineffective infrastructure, and wasteful behavior are major contributors to pollution. Both pollution and depletion of natural resources can be addressed by adopting the principles of sustainable development. There have been multiple strategies proposed in the last 20 years for achieving sustainable development (NCE 1993; Sitarz 1998; Hawken et al. 1999; NRC 1999). All of these strategies would drastically reduce use and discharge of polluting compounds and would largely eliminate the accumulation of wastes in the environment. Under sustainable development, nonrenewable resources would be recycled and their use reduced, while renewable resources would be used and managed with sustainable yield as a goal. Plans for sustainable development prescribe management of natural resources—e.g., fisheries—in a manner that limits harvest to levels which can be sustained indefinitely.

Low impact development and better land use planning could improve the environmental outlook for the Lower Galveston Bay watershed as promoted by Houston Tomorrow (Crossley 2010) and other regional organizations. To transition from current practices, new consumer preferences would need to be expressed and the legal and regulatory framework modernized so that it does not impede the transition. Many development strategies today have more sustainable results than the traditional suburban sprawl that created the current development patterns prevalent in the Houston and Dallas metropolitan regions.
In a sustainable scenario, populations of fish and shellfish would be managed as components of a healthy ecosystem and would be harvested for optimal sustainable yield. The TPWD has already taken steps to make fisheries harvests along the Texas coast more sustainable by implementing programs like limited entry for shrimp and blue crabs.

Natural habitats, in general, suffer from being evaluated in terms of cash equivalents in a real estate market. The value of species and habitats is not adequately expressed by a simple market value. Sustainability is more likely when people assess natural resources in a holistic manner by recognizing the value of ecosystem services in both market and non-market terms (Costanza et al. 1997; Bolund et al. 1999; Loomis et al. 2000; Farber et al. 2002).

To put it simply, the barriers to a more sustainable balance between people and the Lower Galveston Bay watershed are not about complex technological or scientific innovations. The future is determined more by our priorities. If the people in our region want a sustainable scenario implemented, they can do so through their economic and political decisions.

**Summary**

The predictions of this chapter are those of the authors, unless a citation is provided. We used an approach for our assessment based on that employed for the Millennium Assessment by the United Nations for the world environment. Specifically, concepts were taken from Nelson et al. (2006). We are conservative in our opinion that change will occur slowly and the trends described elsewhere in this document can be extrapolated to predict the near future. However, as noted above, we have a vision of what the relationship between people and nature could be if we place a priority on sustainable development. In all likelihood, the health of Galveston Bay in 2040 will not be radically worse or better than it is today. We expect the health of the bay to change gradually in small increments as it has over the last 20 years. Some parameters will improve as a result of better management and some will deteriorate as a result of increased pressure from development or use. However, catastrophic change has occurred, as the geologic record shows, and can occur again. Catastrophic change due to human influence has typically been rare in the United States, although not unprecedented. Therefore, caution is in order. Significant improvements have resulted from regulatory programs ushered in by modern environmental legislation. However, the pressure of millions of people residing in close proximity to the bay leads to multitudinous small impacts that may outweigh the improvements. That may not prove to be the case under some scenarios of sustainable development or ecosystem-based management. Our opinions are based on years of studying the bay and its interaction with society. We are optimistic that, despite the challenges that await us, ecosystem based management approach combined with an ethic of environmental stewardship will lead to more sustainable use of Galveston Bay.
Literature Cited


