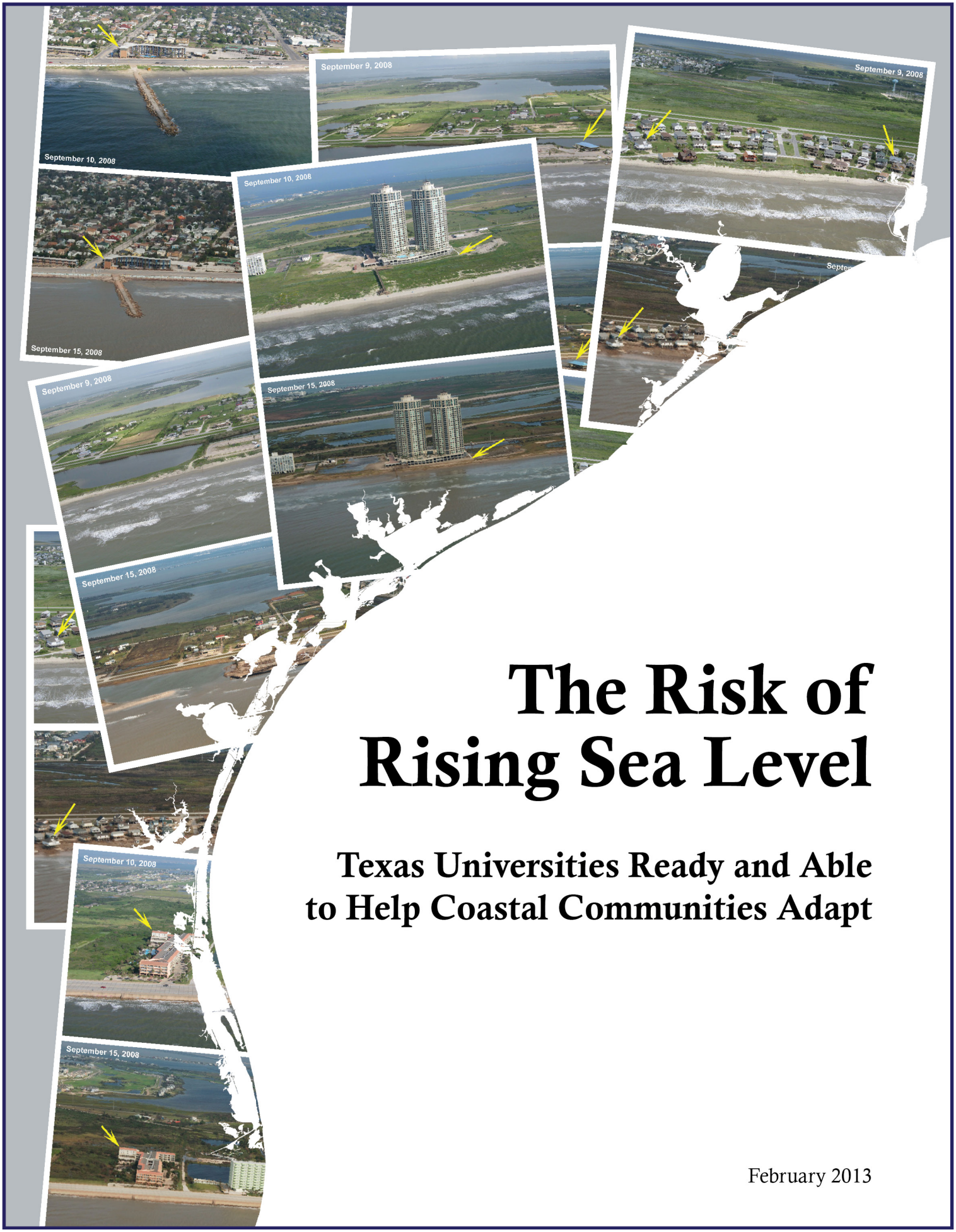

The Risk of Rising Sea Level

Texas Universities Ready and Able to Help Coastal Communities Adapt

February 2013

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Executive Summary: The Risk of Rising Sea Level

Texas Universities Stand Ready and Able to Help Coastal Communities Adapt

Although it may not be noticeable to the naked eye, the sea is rising along the Texas Gulf Coast. In fact, by 2100, much of the Texas coast will likely be under at least a foot of water, which poses a risk not only to the economic vitality of low-lying areas, but also to areas immediately beyond that are within reach of a storm surge. However, one foot of rise is considered the best-case scenario. Some models project a rise of 6 feet. Regardless of how much the Gulf rises relative to the Texas coast in the coming decades, it is clear from experience that even small increases in sea level will exacerbate coastal flooding, contaminate coastal freshwater supplies with salt water, shrink barrier islands, erode beaches, displace marshes, and magnify the impact and cost of extreme weather events such as hurricanes and tropical storms. The recent devastation caused by Hurricane Sandy was, in fact, made worse by a foot of sea-level rise over the last century.

The Texas coast is an engine of the Texas economy. It supports a robust tourism industry built around its natural resources and is an industrial hub of state, national and global significance. Sea-level rise spells trouble not only for sensitive coastal environments but also for residents, communities, and the many vital industries and infrastructure supporting them. Other Gulf Coast states, notably Louisiana and Florida, have taken significant strides forward to study sea-level rise, and they have begun to prepare for the inevitable. Adaptation strategies have been identified and cost-benefit ratios calculated by several different communities to determine what protective measures can be implemented. Texas lags behind other states in these efforts, and remains, for the most part, unprepared.

To provide leadership on this issue, The University of Texas at Austin hosted a workshop in September 2012 to identify the current status of sea-level rise along the Texas Gulf Coast and to assess risks to the ecosystems, communities, and economy of the region. Twenty-eight scientists from six of Texas' leading academic institutions participated in the workshop, representing the depth of expertise and capacity of the state's university community to work collaboratively on this complex societal challenge. Representatives from the nonprofit, governmental, and private sectors also attended the workshop, signifying broad-based support from many stakeholders for participating in the planning process that must occur as coastal communities adapt to rising seas.

The following pages provide an overview of what is currently known about sea-level rise and highlight the opportunity before us. The response to sea-level rise is long-term but requires that we start planning today if we are to get ahead of the issue. Critical to this effort is additional research that must be conducted to grasp the full magnitude of the threat and to serve as the basis for adaptation to changes on the horizon.

To keep this effort moving, the university community is committed to working with entities directly affected by rising sea level including cities, counties, and regional councils of government; industries, including utilities, petrochemical companies, and commercial fisheries; seaports and airports; realtors and builders; neighborhood associations; economic development foundations; consumer groups; environmental interests; and others. The university community is eager to work to increase awareness of the risks of rising sea level and provide the research essential for planning and preparedness.

What is the issue?

Sea level is rising, as it has been for thousands of years since the last ice age. The current 1/5-inch-per-year rate of sea-level rise in the Gulf is about five times the average rate calculated over the previous 4,000 years and is one of the highest rates reported globally. The volume of ocean water has been increasing from ice and glacial melting, and expanding as it warms, and both processes have accelerated recently and are now adding to the oceans' volume at about twice the former rate. The current rate of sea-level rise is expected to accelerate further, doubling or even tripling by the end of the 21st century as a warming atmosphere fuels further expansion of the oceans, and threatens to melt significant portions of the Greenland and Antarctic ice sheets. How high could sea level rise? Prior to the last ice age, during another very warm period approximately 122,000 years ago, sea levels were about 20 feet higher than they are today.

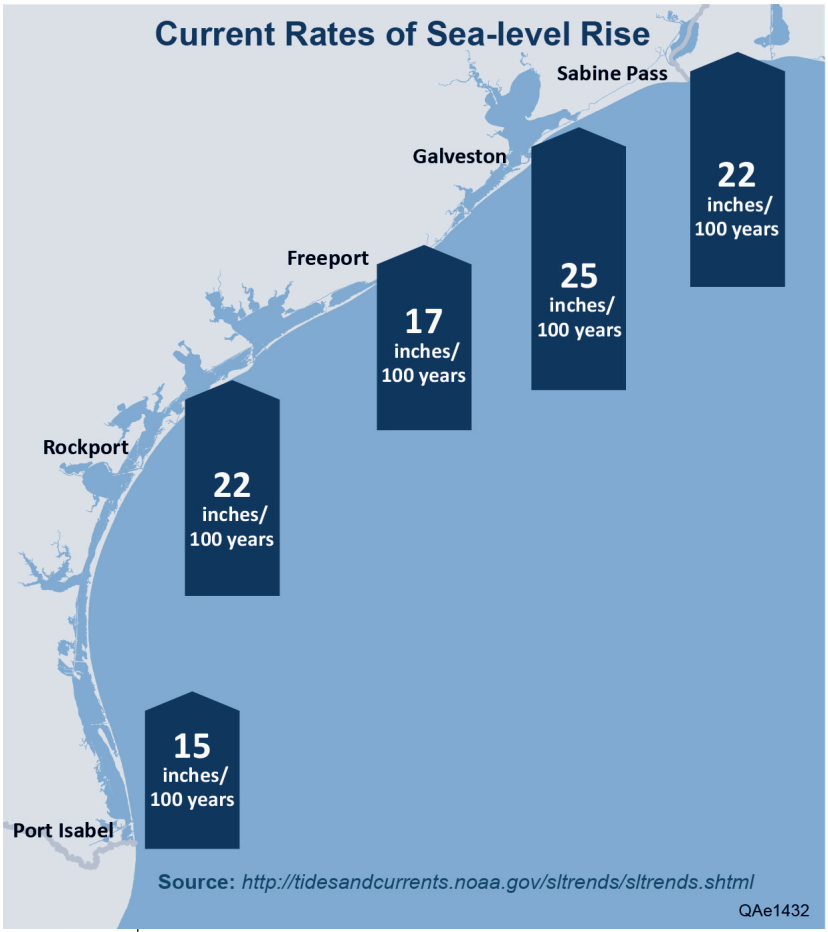
Along the 367 miles of the Texas coast two phenomena are occurring: the Gulf of Mexico is rising, and the land is either stable or subsiding. In combination, they cause *relative* sea-level rise, relative because the measured magnitude of change may be higher or lower than the ocean surface change alone. Texas is fortunate to have tide gauges that have measured sea level during the last 40 to 100 years. These tide gauge records show different rates of relative sea-level rise over time (see map at right). Geographic variation in the rate of rise along the coast is due to land subsidence caused by compaction of sediments, fault activity along the coast, and human activities, in particular groundwater pumping and oil and gas extraction. Land subsidence is especially prevalent in the Houston-Galveston region. Average maximum rates of subsidence at the center of this region were as high as nearly 5 inches per year between 1964 and 1973. Fortunately, rates of subsidence since then have dramatically decreased due to curtailment of groundwater pumping.

Another factor currently impacting our coasts is a paucity of sediment carried to the coast by rivers. Most Texas rivers deposit their sediment in bays, where sediment helps sustain deltas and wetlands; only the Brazos River and Rio Grande flow directly to the coast. Sediment delivered to the coast by these two rivers has greatly decreased because of dams and, in the case of the Rio Grande, increased water withdrawals. In the past, sediment delivered by both rivers resulted in the construction of large deltas in the Gulf, which were major sources of sand for barrier islands. In the absence of sediment delivery, these barriers are now undergoing unprecedented and unsustainable erosion, which makes the coast ever more vulnerable to damage from severe storms.

Deltas within Texas bays represent a critical transition zone and unique ecosystem. Reduction in the amount of sediment delivered by rivers such as the Sabine, Trinity, Lavaca, and Nueces has resulted in extensive erosion and even destruction of these deltas.

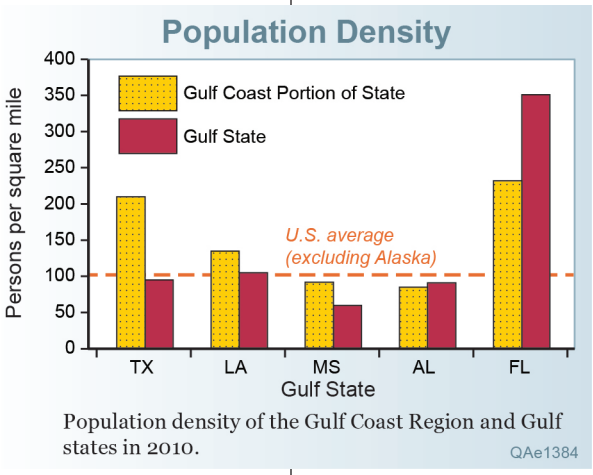
With little new sediment being added to the coast by rivers, the Texas shoreline is retreating. The rate of retreat is variable, reflecting the existing distribution of sediment, barrier island thickness, and amount of sand that lies immediately offshore of the barriers. Tropical storms and hurricanes remove sand from the shoreline, transporting it far offshore, where it is lost from the system. The combination of shoreline retreat, beach erosion, and sea-level rise is particularly threatening to the future of our coastal communities.

A best-case scenario of sea-level rise can be derived by simply extending current rates of rise into the future. Under this scenario, sea level along the Texas coast will be 1-2 feet higher, depending on location, by 2100. This rise will markedly affect Texans, our economy, and the environment because coastal populations and infrastructure will have expanded further in size and proximity to the coast, as has been seen during the last 50 years. A worst-case scenario is an almost unfathomable 6 feet of rise.



Why Should We Care?

The relatively flat and low-lying nature of the Gulf coastal plain makes it especially vulnerable to sea-level rise. Most of the Texas coast is eroding inland, due in part to the effects of both sea-level rise and subsidence. Texas has some of the highest coastal erosion rates in the country. Research shows that 64% of the Texas coast is eroding at an average rate of about 6 feet per year, and some locations lose more than 30 feet per year. As a whole, the Texas coast is eroding at an average rate of 2.3 feet per year, which translates into the loss of 235 acres of land along the Texas Gulf shoreline per year. The shoreline along Texas estuaries and lagoons is more than 15 times the length of the Gulf shoreline, and that shoreline is retreating as well. From 1930 to 1995, more than 50% of the shoreline surrounding West Bay (part of the Galveston Bay System behind Galveston and Follets Islands) retreated; less than 3% of the natural shoreline advanced. Not all of this erosion is caused by sea-level rise, but as the rate of rise increases, it will become an increasingly important process that will accelerate the rate of erosion.



Population density of the Gulf Coast Region and Gulf states in 2010.

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Texas also experiences a small tidal range, that is, the vertical difference between low- and high-tide levels. Coastal wetlands, deltas, barrier islands, and estuarine systems are finely tuned to this small range. Consequently, Texas coastal habitats are especially sensitive to even minor changes in sea level. Data collected along the coast show that on low-lying barrier islands, a relative sea-level rise of just 4 inches can convert fringing low marshes and flats to open water and sea grass beds, and dry high marshes and flats to wet low marshes and flats. Wetlands are lost completely where human or natural barriers exist that prevent landward migration. Ecological shifts of this kind adversely impact habitats and water quality that are essential for sustaining commercially- and recreationally-valuable fish, oysters, and other living organisms.

For example, relative sea-level rise has led to loss of wetland marshes and increases in open water along the upper coast of Texas, including Galveston Bay. This area lost more than 43,000 acres of salt and fresh marshes and more than 4,000 acres of tidal flats between the 1950s and 2004. South of Galveston Bay, the picture is more complicated. Marshes have eroded in many places where sedimentation has been unable to keep pace with rising sea level. However, fresh and salt marshes have increased in other, previously upland areas. While gains of some wetland habitats may occur in localized areas, this net loss of marsh is expected to continue due to flooding, inundation and erosion caused by a combination of subsidence and sea-level rise. The current rate of sea-level rise is approaching the point at which wetland growth rates will be unable to keep up with rising water. When this occurs, these wetland habitats will be replaced by open water.

Historically, the Texas coastline was protected from storms and surges by long barrier islands and wetlands. However, reduced sediment delivery, wetland destruction, and coastal development have been eroding that protective system. In the absence of natural buffers, people, homes and other structures take the brunt of storm surges. Texas scientists estimate that the loss of 1 acre of native coastal wetland boosts flood damage by $1.5 million. As wetlands recede inland, so does the land itself, bringing the Gulf closer to homes and businesses and increasing the risk of storm surges and flooding.

So, what does the risk of rising sea level mean to people and commerce in Texas? In the direct path of rising seas are 18 counties along the Texas coast, which include 6 of the top 20 most-populated counties in the state. Combined, these counties represent less than 6% of the landmass in Texas, but they hold nearly 25% (6.1 million) of the state's 2010 population. Population density along the Texas Gulf Coast is more than twice that of the rest of the state, and growth in this region is outpacing Texas' population growth.

Also in harm's way are four of the United States' 10 busiest ports are in Texas: Houston, Corpus Christi, Beaumont, and Texas City (see list to the left). Fifty-two percent of all foreign crude oil imports were received at Texas ports in 2010.

Leading Ports in Tonnage in 2009

U.S. Rank	Port	Short Tons *(Millions)*
1	South Louisiana, LA	213
2	Houston, TX	211
5	Corpus Christi, TX	68
6	New Orleans, LA	68
7	Beaumont, TX	68
10	Texas City, TX	53
11	Lake Charles, LA	52
12	Mobile, AL	52
13	Baton Rouge, LA	52
14	Plaquemines, LA	51
16	Pascagoula, MS	37
17	Tampa, FL	35
19	Port Arthur, TX	34
27	Freeport, TX	27
47	Galveston, TX	10

In 2009, 15 of top 50 U.S. ports, by tonnage, were located in the Gulf Coast Region.

Source: U.S. Army Corp of Engineers, 2010

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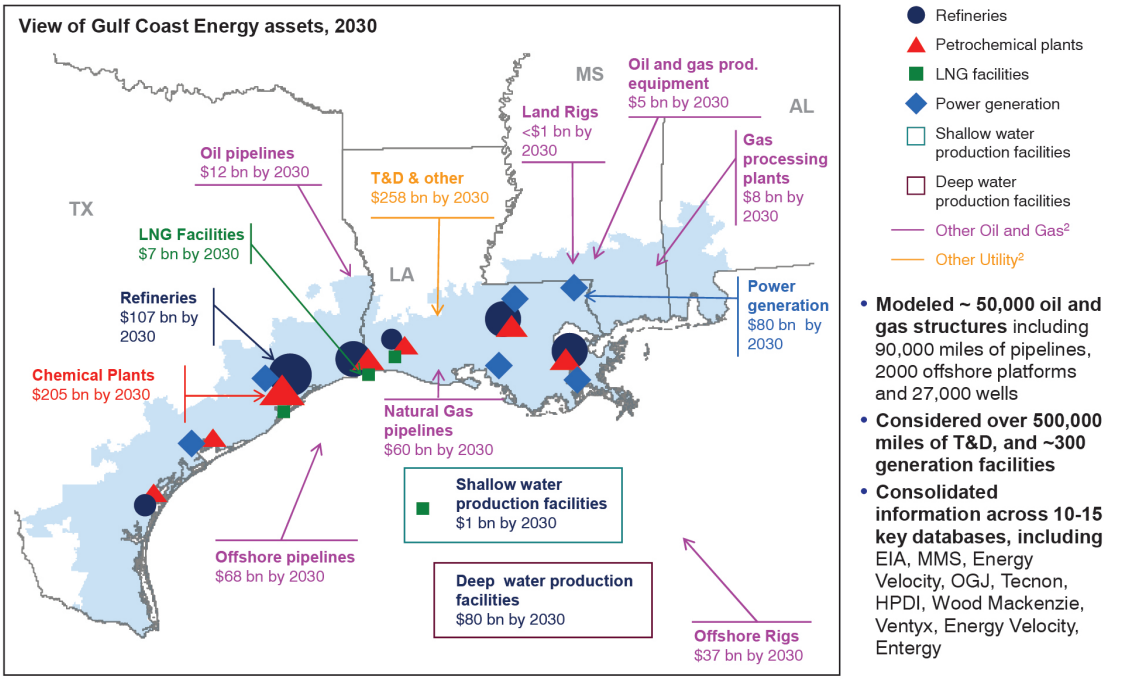
Texas ports generate $5 billion in local and state tax revenue and $48 billion in personal income. They create 1 million direct jobs and 1.3 million indirect jobs annually. Texas ports account for 19% of all U.S. port tonnage, and they accept cargo from trading partners all over the world.

Projected Replacement Value of Gulf Coast Energy Assets in 2030



- **Modeled ~ 50,000 oil and gas structures** including 90,000 miles of pipelines, 2000 offshore platforms and 27,000 wells
- **Considered over 500,000 miles of T&D, and ~300 generation facilities**
- **Consolidated information across 10-15 key databases, including** EIA, MMS, Energy Velocity, OGJ, Tecnon, HPDI, Wood Mackenzie, Ventyx, Energy Velocity, Entergy

Source: Entergy, 2010

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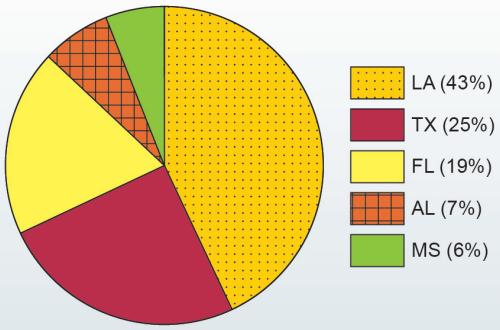
In addition to the state's ports, shipping lanes, and associated assets, Texas hosts refineries, petrochemical facilities, utility assets (e.g., generation, transmission and distribution (T&D) facilities), oil and gas production and transportation infrastructure, and LNG terminals. These assets are also vulnerable to storm surge and sea-level rise. A recent study by Entergy, a power-generating utility based in Louisiana that serves East Texas, estimated the current value of Gulf Coast energy assets at ***$800 billion*** considering 2,000 offshore platforms, 90,000 miles of pipelines, 300 power plants, and 500,000 miles of T&D lines among many other assets (see figure above). Almost all of these assets are in Texas and Louisiana and offshore in the Gulf of Mexico from these states' coastlines.

In addition to energy infrastructure, coastal cities, road infrastructure, fisheries, recreational and tourism infrastructure and facilities, coastal waterways, and ecosystem services are also at risk from adverse impacts of sea-level rise. For example, Texas accounts for 25% by value of all commercial fishing landings in the Gulf Coast region (see figure at right). Ninety-seven percent of Gulf of Mexico commercial seafood landings rely on estuaries and wetlands to survive. Those same estuaries support 75% of North American migratory birds during their migration, including waterfowl important to birdwatchers and recreational hunters.

Landings by Value



Distribution of the $660 million of commercial fishing value by state, an average annual value from 2007 to 2009.
Source: National Marine Fisheries Service, 2010

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What does the future hold?

Ongoing sea-level rise will contaminate coastal freshwater aquifers with salt water, increase the frequency and severity of coastal flooding and push storm surges further inland, shrink barrier islands, erode beaches, displace wetlands, and magnify the impact of extreme weather events such as hurricanes and tropical storms. For example, by 2100, Galveston could experience inundation events associated with small- to mid-size hurricanes 6-7 times more frequently than today and the island could flood every year. In harm's way along the Texas coast are cities and settlements, roads, railways, and airports, industrial complexes, ports, drinking water supplies and systems, sewage disposal systems, agricultural lands, tourist attractions, real estate, and natural coastal ecosystems.

The financial costs to mitigate and adapt to sea-level rise are difficult to determine. However, inaction is likely to be orders of magnitude more costly than adaptation. A recent study of Galveston Bay showed that, given current economic conditions, a 2-foot rise in sea-level would cause an additional property loss of $1.7 billion from a Hurricane Ike-equivalent storm. The odds of a 100-year flood or worse occurring along the Texas coast by 2030 at the present rate of sea-level rise is about 14%. If the rate of rise accelerates, the likelihood of coastal flooding will be even greater, and the resulting damage and insurance claims may become overwhelming.

What is being done to adapt to sea-level rise in Texas and elsewhere?

Texas has fallen behind other Gulf states in adaptation planning for sea-level rise, and remains, for the most part, unprepared. Today, sea-level rise is rarely considered by governments, organizations, and individuals as they make decisions about where to develop, how to build, or what to preserve. However, anticipated increases in sea level will impact the longevity, safety, and return-on-investment of current and future projects.

A recent (2012) extreme weather event, Hurricane Sandy, serves as a fresh reminder of the devastation that can be associated with sea-level rise. Although Sandy was unusually severe, resulting from the confluence of several weather patterns, the water in New York Harbor now stands 11 to 16 inches higher than it did a century ago. That historic amount of rise in water level does not account for a 14-foot storm surge, but it did contribute to a surge that was higher and more destructive than it would have been otherwise. Damage estimates for Hurricane Sandy make it the second-costliest U.S. storm, second only to Hurricane Katrina.

Aftermath of Superstorm Sandy (photo: U.S. Geological Survey)

Accounting for changes in sea level that may be expected to occur over the lifetime of projects is one step toward making informed decisions. Planning for the long-term effects of sea-level rise will also help us better prepare in the short-term for flood damage from coastal storms. For example, as a result of Sandy, governors of the affected states are calling for implementation of adaptation measures such as providing backup generators for hospitals, relocating power systems to higher floors in buildings, and taking action to make public transit systems less flood-prone.

Other states along the Gulf Coast, notably Louisiana and Florida, have taken significant strides forward to study sea-level rise, and they have begun to prepare for the inevitable. Vulnerability assessments have been conducted, adaptation strategies have been identified, and cost-benefit ratios calculated by several different communities to determine what protective measures can be implemented (see figure on next page).

Where do we go from here?

Coordinated research is needed to determine how sea-level rise will affect coastal communities, including natural environments, local businesses and private property, government facilities, and other infrastructure. In the absence of planning and preparation, we can expect rising sea level to inflict serious damage. We have the opportunity to start answering questions such as where, when, and to what extent sea-level rise poses a danger.

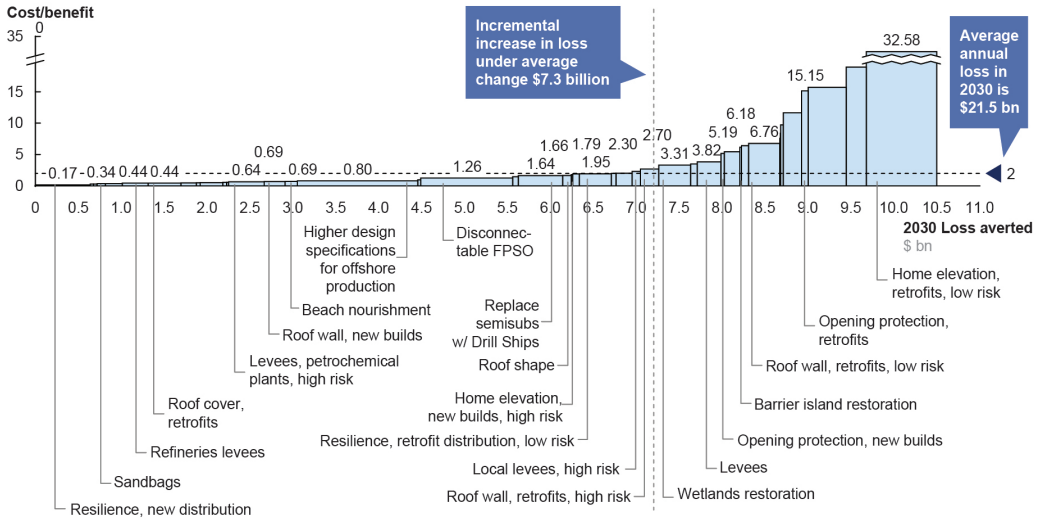
Recognizing the capabilities of Texas' academic institutions to collect and analyze data, transform these data into useful information, communicate the findings to Texans, and assist policy makers and stakeholders in adapting to our changing circumstances, The University of Texas at Austin hosted a workshop in September 2012 to identify the current status of sea-level rise and the potential risks posed to the ecosystems, communities, and economy of the region. The workshop was attended by 28 researchers from 4 different university campuses who represented a wide range of expertise. The willingness of participants to contribute to the workshop, and the consensus represented by this white paper, illustrate the readiness of the Texas university community to help decision makers and stakeholders start assessing the threat and develop an integrated plan to reduce the economic and environmental impacts of sea-level rise in Texas.

The Texas university community is already leading research efforts to understand how large natural events (hurricanes, tropical storms, storm surges) impact coastal environments. Understanding comes from monitoring sea level, the seafloor, sediment, water quality, and other parameters on the Texas Gulf Coast. Even with these efforts, gaps in knowledge remain, and these gaps place the Texas Gulf Coast at increased risk of adverse impacts to property and human lives.

Research gaps to address include:

- What are the coastal impacts of natural and human alterations in sediment supply from rivers to the coast?
- How will the Texas coast respond to different rates of sea-level rise?
- How will sea-level rise and changing storm patterns translate into localized erosion, flooding, damage to infrastructure, and loss of ecosystems?
- Could sea-level rise cross a critical threshold that causes ecosystems and the services they provide (e.g., nursery grounds for commercially-valuable shellfish)

Analysis of Cost Effectiveness of Measures to Mitigate Against Sea-Level Rise



Cost-benefit (C/B) ratios of measures to offset anticipated annual losses that would occur in 2030 across the Gulf Coast. Seven billion dollars in annual expected loss could be averted by measures with a C/B ratio of less than 2.

Source: Entergy, 2010

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to collapse? What would be the socio-economic consequences of such a collapse?

- What is the vulnerability of coastal communities to increased storm surge under various sea-level rise scenarios? How would the risk profile change if barrier islands were no longer in place?
- How can short-term/market-driven development interests be persuaded to heed predictions of sea-level rise?
- What types of land-use patterns are better suited for adapting to sea-level rise?
- What are the "no-regrets" policies that local governments can enact that will mitigate coastal hazards while adapting to sea-level rise?
- What coastal protection measures are physically and economically feasible and socially and environmentally acceptable in different locations, and how much time do we have to start implementing these measures?
- At what point is retreating from the shoreline more cost effective than defending coastal land?
- How uncertain is the information about sea-level rise and other coastal (physical, ecological, and socioeconomic) processes, and what are the implications of these uncertainties for decision making?

Sea-level rise presents an opportunity for Texas to tap the powerful resource that exists within its colleges and universities. The university research community is eager to initiate and lead science-based policy responses to this major societal issue.

Conclusion

The Texas Gulf Coast provides resources that drive the Texas economy, provide food and fuel for a rapidly growing human population, and sustain and nourish life. The quality and abundance of these resources are paramount to sustained growth in Texas. The Texas coastal region also represents a vital hub of industrial activity of national and even global significance.

The time is now to begin assessing the risks posed by sea-level rise in preparation for the long-term planning and implementation of adaptation strategies that will ultimately be necessary to protect the ecosystems, communities, and economy of the Texas Gulf Coast. Critical to this effort is additional research needed to fully understand the magnitude of the issue and to serve as the basis for adaptation to changes on the horizon. The Texas university community is uniquely capable of providing planners, policy makers and other stakeholders with the data, information, and analyses necessary to protect and preserve this vital region.

Contact Us

For more information about the issue, to become a partner in research or to get involved in adaptation planning for the Texas coast, please contact:
Dr. Wendy Gordon, Ecologia Consulting at wendy@ecologiaconsulting.com

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