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Vanishing Beaches: Coastal Erosion and its Impact on Coastal Communities
U.S. House of Representatives Subcommittee on Fisheries, Wildlife and Oceans
Oversight Field Hearing
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The Moving Gulf of Mexico Shoreline of South Texas

The natural character of sandy beaches is to change shape constantly and to move landward (retreat) or seaward (advance). The changes are caused by changes in the forces that move the sand, namely wind, waves, and currents, and by the supply of sand. Short- and long-term changes in the level of the ocean also controls shoreline movement. The setting of the shoreline and the supply of sand determine how the shoreline changes at a particular location. Setting refers to whether a beach is sheltered from waves, is adjacent to a tidal or storm channel, or is next to a jetty or seawall, to state a few examples. Much research has been conducted on the various time and spatial scales of shoreline change. These various scales of change have different effects on environmental and coastal development issues. To understand and predict the rate of shoreline change and hence to formulate an effective management strategy, we need to distinguish between long-term, short-term, and episodic changes and to understand their causes. In the following discussion, long-term change refers to changes occurring over a hundred to thousands of years, short-term change refers to movement occurring over several months to 10’s of years, and episodic change is that which occurs in response to a single storm.

Long-Term Change

Geologists have compared several Texas shoreline positions that were mapped over the last 100 years and have found that, overall, the shoreline has continued to shift as it has since about 4,000 years ago when sea level approached its current position following the last ice age. Along the south Padre Island Gulf of Mexico coast, the shoreline retreated more than 1,000 ft since 1880, but 30 miles north of Mansfield Channel in central Kenedy County the shoreline was stable or advanced a couple hundred feet since 1880. Along Brazos Island, the shoreline advanced up to 500 ft from 1854 to the 1930’s after which it began retreating. The jetties at Brazos Santiago Pass and Mansfield Channel, and the human-caused reductions in the flow of the Rio Grande have altered shoreline change patterns since the 1930’s.

We basically understand that it is the changing of sea level relative to the land (relative sea-level change) and the increase and decrease in sand supply to the coast that causes the shoreline to retreat or advance over a period of 100 years or more. The south Texas coast is experiencing long-term sea-level rise, which has moved the shoreline landward through simple inundation and by shifting the action of waves and currents landward. Relative sea-level rise over the last several thousands of years has also limited sand supply to the coast by drowning ancient river valleys and forming the coastal bays, such as Baffin and Corpus Christi Bays. Rivers that used to supply sand to the beaches now dump their sand at the heads of these bays, where it is kept from reaching the open coast.

The Rio Grande is the only river in south Texas that currently reaches the Gulf, but its ability to carry sand to the coast has been greatly diminished from several thousands of years ago. This is because of a decrease in water flow as a result of climate changing to more arid conditions since the end of the last ice age. More recently, the building of the Falcon Dam in 1955 and other dam and water diversion activities since 1955 have greatly diminished the Rio Grande's capacity for carrying sand to the coast. Today, the mouth of the Rio Grande is at times closed by a sand bar because the river flow is not even powerful enough to overcome the force of waves moving sand alongshore.

These conditions mean that sand available for building beaches and dunes along the south Texas shoreline today is mostly derived from sediments originally deposited more than 4,000 years ago in the ancient Rio Grande Delta. The old delta deposits, however, include a lot of muddy sediment that does not form beaches. Furthermore, much of the available sand has already been incorporated into Padre and Brazos Islands since 4,000 years ago when sea level approached its current level and waves and currents started to erode the Rio Grande Delta lobe. Now the major source of sand for any given location on the Gulf of Mexico shoreline is that which is eroded from beaches updrift of the location. Thus the natural geological setting of the lower Texas coast has created a shoreline that is low in sand supply and is undergoing long-term relative sea-level rise. For these reasons, the shoreline will continue to retreat in the foreseeable future unless human intervention prevails.

Sand moves along the beach as well as in an onshore-offshore direction. Currents created by waves that approach the beach at an angle cause the sand to move alongshore. Tidal currents paralleling the shore may also be important especially near inlets such as Brazos Santiago Pass, Mansfield Channel, and temporary storm washover channels. The wind creates the waves and the prevailing winds on the southern lower Texas coast are from the southeast. The orientation of the shoreline along south Padre Island is northwesterly as a result of the remnant promontory created by the ancient Rio Grande Delta. Thus most of the time waves approach the shoreline at an angle open to the north causing the average net direction of sand movement to be toward the north along south Padre Island. Along north Padre Island, however, the winds and waves move sand toward the south creating a zone of convergence of beach sand in the vicinity of Big Shell Beach along central Padre Island. Central Padre Island, therefore, is the recipient of sand eroded from beaches to the north and south, and the shoreline has advanced there since the mid 1800's. The exceptionally high dunes backing Big Shell beach are further evidence for this zone of convergence of sand. Changes in weather patterns, however, can cause temporary reversals in the direction of alongshore sand movement and hence alter shoreline change patterns created by the long-term average conditions.

Short-Term Change

A shoreline that has retreated over the last 100 years may have experienced periods of relative stability or even shoreline advance. Shoreline change that occurs over about 10 years or less and that may be in the opposite direction of the long-term trend is difficult to understand and predict. These short-term shoreline changes can also be quite variable alongshore. One portion of the coast may be experiencing rapid retreat while just a few miles away stable or advancing conditions may prevail. This is often the case along Padre Island where the occasional opening of washover channels causes temporary changes to the alongshore sand budget. It is important, however, for coastal residents and managers to understand that even though a particular beach may have been advancing or stable over the last several years, if it has been retreating for the previous decades, then retreat will eventually resume. An exception to this would be if something fundamental, such as a “permanent” increase in the sand supply, changes in the system.

Short-term shoreline change is caused by changes in the heights and directions of waves arriving at the beach, the frequency of storms, and shifts in the amount of sand immediately offshore of the beach out to 20 to 30 foot water depth. Shifts in offshore sand deposits are caused by waves, currents generated by waves, and tidal currents. Along much of the south Texas coast, this sand is swept up into two or three alongshore bars and in deposits at the mouths of channels such as Brazos Santiago Pass and the entrance of Mansfield Channel (Figure 1). These offshore sand deposits are available to feed the beach and lesson the rate of erosion or reverse it from time to time. The difficulty of tracking this sand is one of the things that make understanding short-term shoreline change so difficult. Furthermore, waves and currents are responsible for moving and depositing the sand, but the presence of the sand in turn affects the actions of the waves and currents. This is known as a feedback loop in natural systems and can make predicting the outcome of seemingly simple processes extremely difficult.

Large storms redistribute significant volumes of sand which can affect shoreline change rates for several years causing them to be quite different from the long term rates. This was documented along the upper Texas coast after Hurricane Alicia struck the south end of Galveston Island in 1983 and transported much sand offshore and alongshore. This storm altered the patterns of shoreline change for at least 5 years as the sand moved back to the beaches from offshore at some locations but was not available at others. After Alicia, portions of the shoreline experienced accelerated retreat, changed from being stable to retreating, experienced accelerated advance, or changed from retreating to advancing. Thus large storms not only cause episodic shoreline retreat, but they can also alter shoreline change patterns for years.

Figure 1. 2002 aerial photograph of South Padre Island about 3.5 miles north of Brazos Santiago Pass. Bars, which store sand, are delineated by breaking waves.

Episodic Shoreline Retreat

From Brazos Santiago Pass to about 25 mi north of Mansfield Channel there is no major natural source of new sand. The sand that makes up the barrier islands and that extends 1 to 2 mi offshore is all that is available to the beaches and dunes. Most of the time, the beaches are struck by waves that are less than 5 ft high. The average difference between low and high tide on the open coast is only 1.6 ft. Dune heights may reach more than 30 ft, but at many locations they are much lower or nonexistent. Beaches are relatively narrow and gently sloping, and the land behind the beaches and dunes is low in elevation and generally slopes toward the bays. These conditions mean that when a large storm does strike the coast, it has profound effects that last for a long time. In northern Kenedy and Kleberg Counties, sand supply is greater than to the south, and dunes are higher and more continuous. These conditions provide a buffer to storm impacts.

Hurricane Carla in 1961 caused significant beach erosion along the entire Texas coast. Even though Carla made landfall 150 miles to the north at Port O'Connor, Gulf beaches adjacent to Mansfield Channel on South Padre Island retreated 100 to 150 ft in just a few days. Undoubtedly, the shoreline advanced for perhaps a year or more following the storm as the beach made an initial recovery, which was the case for Galveston Island beaches following Hurricane Alicia in 1983. By 1975, however, the shoreline was 150 to 400 ft landward of its pre-Carla position, except for a section extending 2 miles south of the Mansfield Channel jetties where sand built up against the jetty and caused the shoreline to advance up to 1,000 ft. Hurricane Bret struck in August of 1999 and caused about 100 ft of shoreline retreat in the central Padre Island area. This area has a stable or advancing long-term trend of shoreline change, and by 2000 the shoreline had advanced back to its 1995 location.

It is important for coastal residents to realize that shoreline retreat is not always a continuous and steady process with a little more of the beach eroded each year. Tropical storms and hurricanes along the lower Texas coast can move the shoreline more than 100 ft landward in a day. There is often dramatic recovery for months and years following a storm, but it is often incomplete in an area undergoing long-term retreat, and the shoreline may remain significantly landward of its pre-storm position. In places where the shoreline is relatively stable or advancing, people should still consider the amount of erosion that may occur during a single storm and not build too closely to the shore. Even though shoreline change rates are given as annual rates, they must be considered "average" annual rates for the period over which the historical shorelines were compared. A particular shoreline with a long-term retreat rate of 5 ft per year would be expected to be 300 ft landward in 60 years. A single storm, however, could cause a large amount of this movement. Furthermore, even though a shoreline may be advancing in the long run, it is still subject to episodic retreat during storms.

Storm Washover Features

The storm surges and waves associated with Hurricane Carla (1961) and more recently Hurricane Bret (1999) created temporary breaches in the beaches and dunes of Padre Island (Figure 2). The flow of seawater was concentrated in these breaches and formed channels. In some areas, discrete breaches and channels did not occur, but broad areas were inundated with landward flowing water. These breaches and areas are called storm washover features (Figure 3). The importance of recognizing these features lies in the fact that the same areas tend to be washed over during subsequent storms, and therefore, should not be developed. If the storm is severe enough and close enough, however, a broad expanse of shoreline may be completely inundated.

Figure 2. Hurricane washover channels on Padre Island, Texas, 2.5 miles north of Port Mansfield Channel. Hurricane Bret formed these channels when it struck on August 22, 1999. More than a dozen other former washover channels were re-activated by Bret. The photographs in this mosaic were taken on August 30, 1999.

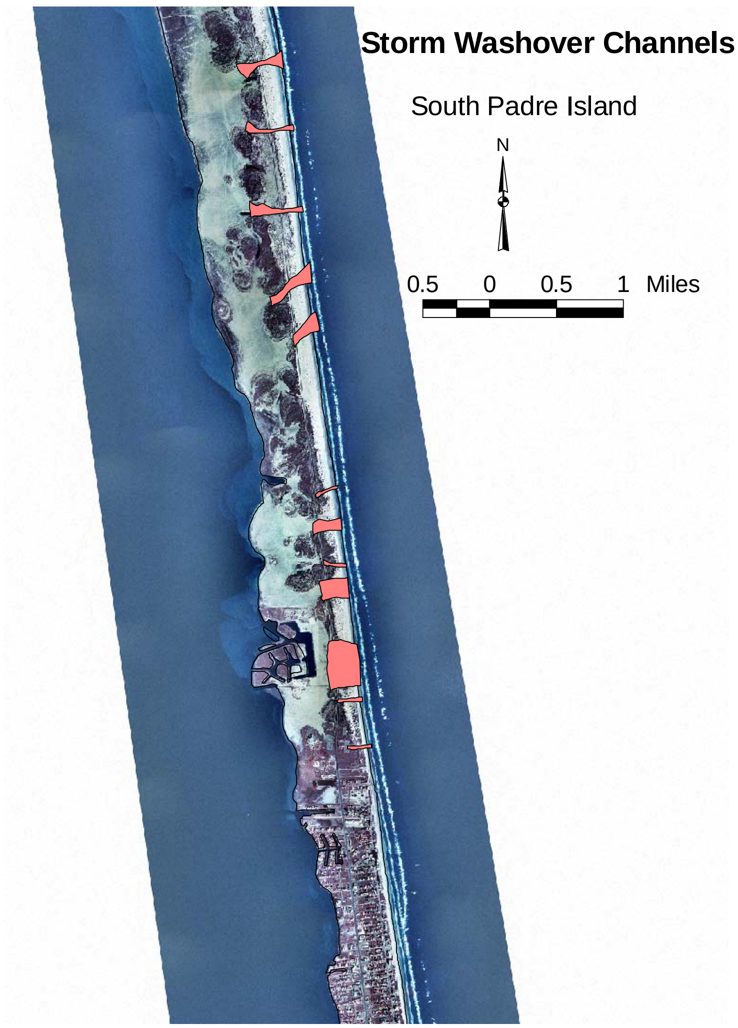

Figure 3. Storm washover channels and areas on South Padre Island just north of the developed area in 2002.

The Pattern of Shoreline Change Today and the Effects of Human-Made Structures: Rio Grande to Mansfield Channel, Texas

The Bureau of Economic Geology in the Jackson School of Geosciences, The University of Texas at Austin has conducted the Texas Shoreline Change Project. This project acquired and compiled historical shorelines into a Geographic Information System (GIS) for comparison. Shorelines were derived from 19th century maps, aerial photography acquired since the 1930's, and most recently from topographic airborne lidar surveys. Shoreline change rates are calculated by comparing select historical shorelines with the aim to predict likely future long-term shoreline change. Rates are calculated every 50 meters along the Gulf shoreline. Following is a discussion of the data for the south Texas Gulf of Mexico shoreline.

The long-term average annual rate of shoreline change for the Gulf shoreline from the Rio Grande to Mansfield channel is calculated by comparing historical shorelines dating back to 1930. Earlier shorelines are not used because of the human-caused changes in the flow of the Rio Grande and the obstruction to alongshore sand movement created by the jetties at Brazos Santiago Pass and Mansfield Channel. These changes have caused a "permanent" change in the sand budget of the beaches and dunes beginning about 1930, and because the intent of calculating the rate of change is to provide an indication of what will likely happen in the future, the pre-1930 shorelines are not used.

Overall, the shoreline from the Rio Grande to Mansfield Channel is retreating at a rate of 2 to 15 ft per year (Figure 4). Adjacent to the Brazos Santiago and Mansfield Channel jetties, however, the shoreline is stable or advancing. The jetties at Brazos Santiago Pass extend ½ mile offshore and shelter the beach on South Padre Island from waves approaching from the southeast. Wave refraction also tends to bend the waves from the southeast to be more from the east in the area north of the jetties. This process reduces alongshore sand transport to the north and may cause movement to the south along the southern 3 miles of South Padre Island. On the south sides of Brazos Santiago Pass and Mansfield Channel, the jetties simply block sand from moving farther to the north. The jetties have caused an impoundment of sand in these locations, but it appears that the shoreline on the north side of Brazos Santiago Pass and on the south side of Mansfield Channel stabilized by the 1970's. Significant further advance is not expected. Sand continues to pile up against the jetty, however, on the south side of Brazos Santiago Pass.

Shoreline retreat is notably higher near the mouth of the Rio Grande and in a 5-mi area just south of the Cameron-Willacy County line (Figure 4). The reduction in flow of the Rio Grande since the 1950's has reduced the supply of sand to the coast, and now the shoreline is retreating. The area south of the Cameron-Willacy County line is a particularly low-lying portion of the barrier island where storm surges often washover the entire island transporting beach sand to the Laguna Madre.

From 1937 to 1995, approximately 474 acres of land eroded from the highly developed South Padre Island Gulf coast from Brazos Santiago Pass to 12 miles north where the road is often covered by sand. This erosion was partly offset by 145 acres of accretion created by sand deposited in an area adjacent to the Brazos Santiago north jetty to a point 2.5 mi north of the jetty where the beach becomes erosional. Comparing the projected 2055 shoreline with the 1995 shoreline reveals that an additional 511 acres of land may be lost.

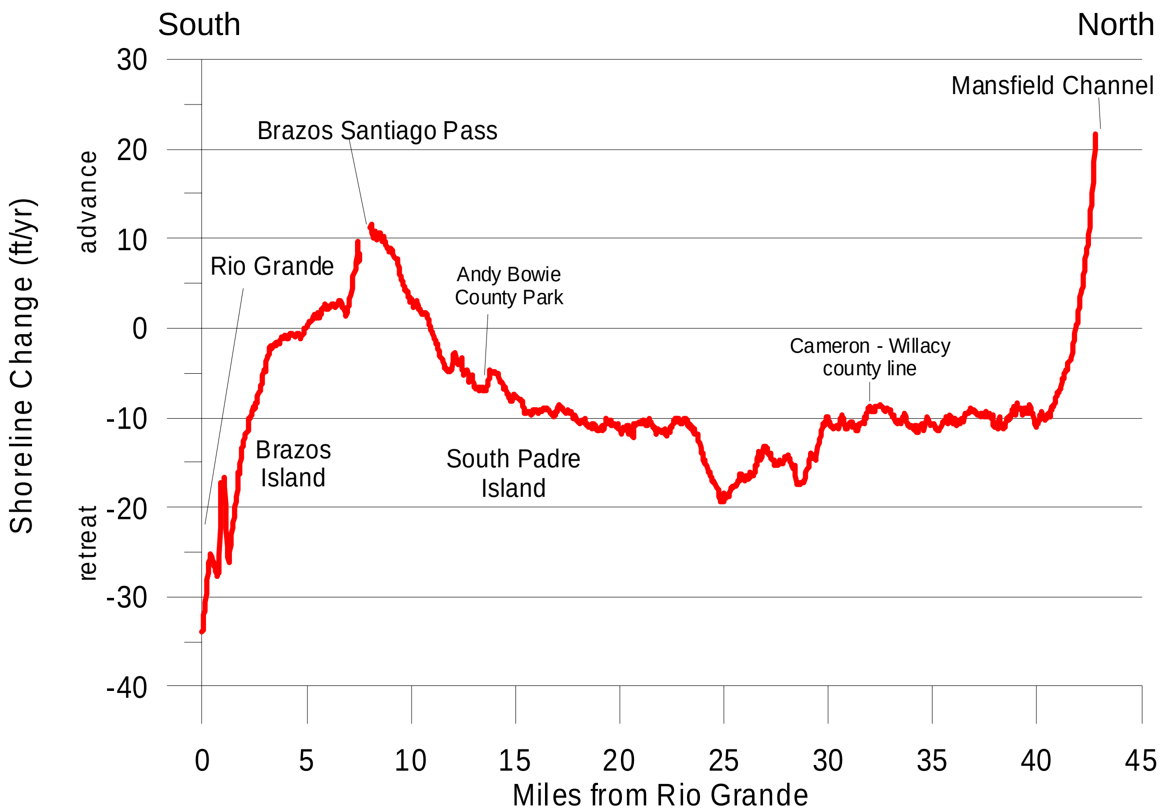

Figure 4. Average annual rate of Gulf of Mexico shoreline change from the Rio Grande to Mansfield Channel.