

Lecture #7

BARRIER ISLANDS

What's a barrier island? A *barrier island* is a long, narrow island parallel to the coast that is built up by the deposition of sand. There is commonly a bay or lagoon between the barrier island and the mainland. Mustang Island and Galveston Island (fig. 79), where we'll visit over the next few days, are barrier islands.

Barrier islands may form as *offshore bars* or as *spits*. When waves approach a shore, the shallow water causes the waves to slow down. As the waves slow down they no longer have enough energy to carry the coarser sediment, and sediment is deposited. This deposit is called an "offshore bar." An *offshore bar* is a shallow-water area off the coast formed by deposition of sediment. If enough sediment is deposited, the bar may become a small island that eventually grows into a bigger island with plants and dunes, forming a barrier island.

Some barrier "islands" are not really islands, as they are not completely surrounded by water and have a direct connection to the mainland. These are more properly called "spits," or barrier spits (fig. 80). A *spit* or *barrier spit* is a long narrow deposit of sandy sediment that is attached to a larger area of land. A spit is formed by longshore currents that transport and deposit sand along the shore. Where there is an entrance to a bay or estuary, the longshore current spreads out, loses energy, and is no longer able to transport the sediment. A barrier spit may eventually be cut by a channel that erodes across the spit during a storm, creating a barrier island.

Parts of a barrier island: As you walk across an undeveloped barrier island from the ocean to the lagoon, you cross four major environments: *beach*, *dune*, *barrier flat*, and *lagoon*. Each of these environments (fig. 81) is a reflection of the geologic processes that form them.

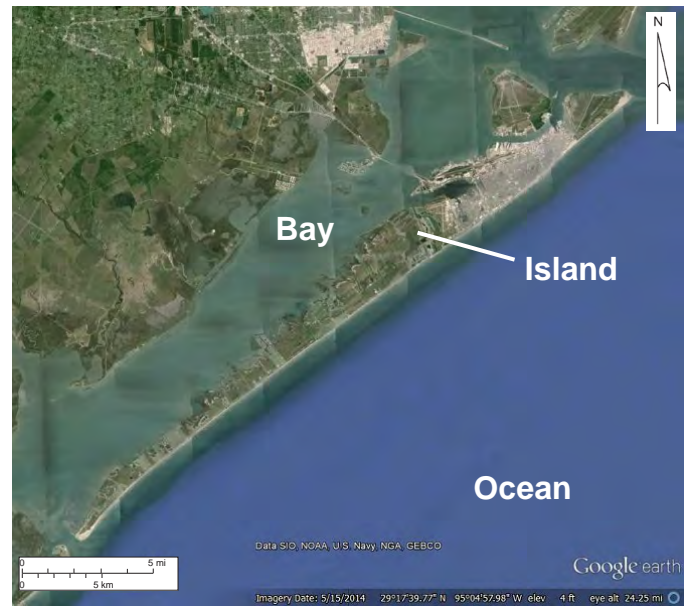


Figure 79. Galveston Island, Texas



Figure 80. Spit on coast southwest of Tampa, Florida.

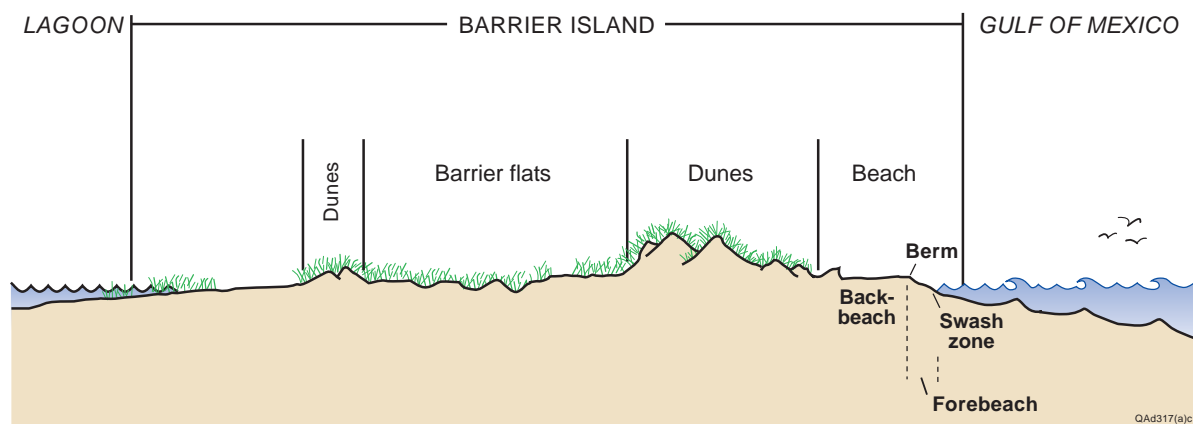


Figure 81. Parts of a barrier island.

Beach: The *beach* is a deposit of sediment where the ocean meets the land; it has no vegetation. If you look closely at a beach (fig. 82), you'll see that the front part of the beach slopes toward the ocean. Behind this area is a flatter part of the beach where we usually toss down our beach towels and spread out our picnic lunch. The beaches we'll see on this trip are all sandy beaches, but there are beaches in other places around the world where the sediment is not sand but coarse gravel or even boulders.

The lowest part of the beach is the *forebeach*. The forebeach slopes toward the ocean. The *backbeach* is the nearly flat upper part of the beach, and the *berm* is where the forebeach meets the backbeach. The part of the forebeach that is washed by the waves is called the *swash zone*. The swash zone moves up and down the forebeach as tides rise and fall.

Dune: *Dunes* are piles of sand deposited by the wind. Barrier islands commonly have sand dunes (fig. 83) right behind the beach. The dunes may or may not have plants growing on them. An area with plants is "vegetated." The sand is blown into the dunes by winds that sweep across the beach. If the winds are strong, some sand may be blown onto the barrier flat or into the lagoon. Some barrier islands have no sand dunes because the dunes have been destroyed by storms or by thoughtless development by people.

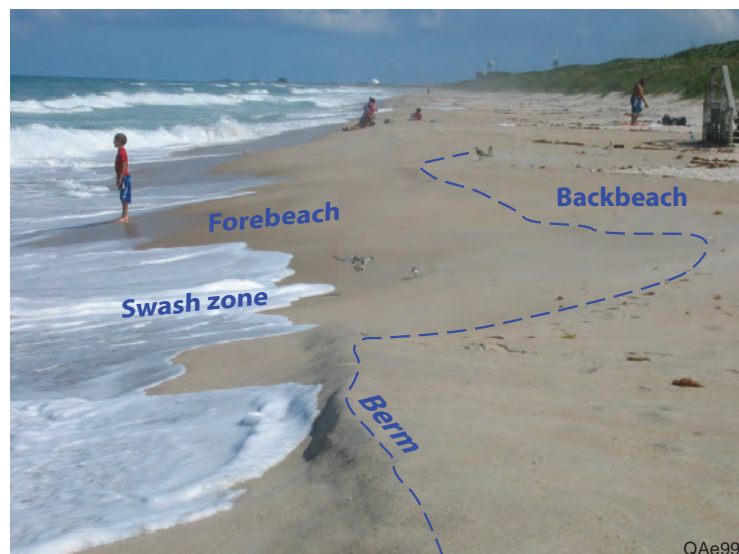


Figure 82. Parts of a beach.



Figure 83. Sand dunes behind beach, Mustang Island, Texas.

The sandy hills behind the beach are sand dunes. The sand dunes with little vegetation are *active sand dunes*; sand dunes that are vegetated with a dense cover of plants are *stabilized sand dunes*. The absence of vegetation on active dunes allows the winds to redistribute the sand. Sand dunes with abundant plants are stabilized by the roots of the plants and resist erosion during storms.

Barrier flat: Behind the dunes is the *barrier flat*, a gently sloping area lower in elevation than the dunes that extends back toward the bay or lagoon. The barrier flat may or may not be vegetated (**fig. 84**). The barrier flat is built mostly by sediment washed across the island in major storms. Some sand is blown here from the dunes, and there may be dunes on the barrier flats (this is quite common on many of the Texas barrier islands).

Lagoon: A *lagoon* is a shallow body of water such as a shallow bay that is separated from the open ocean by a barrier such as an island or a reef; it has no perennial source of freshwater, such as a stream or river. Freshwater enters a lagoon only from rain or temporary runoff from adjacent land areas, and the salinity of the water in a lagoon is commonly higher than that in an estuary. Because it is protected from the large waves of the ocean it is a lower energy environment, and the sediments deposited in lagoons tend to be finer grained than those found on the beach. Because lagoons have shallow water, sea grasses commonly grow on the seafloor of the lagoons. Lagoons in semitropical environments, such as Florida, South Texas, or Central America, commonly have mangroves growing along the shore or as small clumps of trees in the lagoon.

Physics of sand dunes: Physics is the branch of science that deals with matter and energy. When we try to understand the physical laws that control erosion, transportation, and deposition of sediments, we are studying physics. If we consider the physics of wind-deposited dunes, we can easily understand why most dunes are of sand or silt.



Figure 84. Barrier flat, Cape Canaveral, Florida.

Early in GeoFORCE we talked about how moving water erodes, transports, and deposits sediments. A fluid in motion, such as water, has kinetic energy. Remember kinetic energy? The energy of things in motion, $E_k = \frac{1}{2}mv^2$, where m is the mass of the moving water and v is the velocity? The mass of the water, which does not change, and the velocity of the water, which does change, determine the ability of the moving water to erode, transport, and deposit sediment. Air, like water and maple syrup and milk, is a fluid. Moving air has kinetic energy and (like moving water) erodes, transports, and deposits sediment.

A key difference between air and water is that air weighs a lot less than water. A cubic foot of air weighs approximately 0.08 pound; a cubic foot of fresh water weighs approximately 62.4 pounds (a cubic foot of seawater weighs about 64.1 pounds). A cubic foot of water weighs about 800 times more than a cubic foot of air. In physics, we say that the mass of water is about 800 times more than that of air.

So what does this have to do with erosion, transportation, and deposition of sediments? Because water has so much greater mass than air, it is roughly 800 times more efficient at eroding and transporting sediment than air moving at the same velocity. Windblown dunes are made mostly of sand or finer sediments because winds are rarely of sufficient velocity to move larger particles such as gravel.

Importance of barrier islands: There are two main reasons we will spend so much time looking at barrier islands:

- *Barrier islands are a good place to learn about the sedimentary processes of erosion, transportation, and deposition of sediments.*
- *Many coastlines in the world have barrier islands.*

Barrier islands occur along the east coast of the United States from New England to Florida (fig. 85) and around the Gulf of Mexico to the Yucatan Peninsula in Mexico, as well as in many other places around the world. Wherever they occur, barrier islands:

- *Protect the mainland from the waves and storm surge of major storms.*
- *Shelter bays and lagoons that are of critical importance for many species of wildlife, including most species of fish and shellfish that are essential to the commercial fishing industry.*

Barrier islands are also popular places for people to live or spend their vacations. Billions of dollars have been spent developing homes, resorts, and businesses on barrier islands. Protecting barrier islands is important. Any proposed development on a barrier island should be carefully evaluated to be sure that the development does not harm the integrity of the barrier island or harm critical habitats.

Lecture #8

COASTAL PROCESSES

Barrier island processes: Barrier islands are very active environments. Waves are constantly rearranging the sand along the beach and in the shallow offshore areas. Longshore currents can carry sand along the coast. Winds pluck dry sand grains from the surface and pile them into dunes. If a major storm, such as a hurricane, strikes a barrier island, the rain, winds, waves, and currents can cause major



Figure 85. Assateague Island, Maryland, Atlantic coast of the United States.

damage. Beaches can be strongly eroded and the sand moved far offshore. Barrier islands are shaped by moving water and moving air.

Along most of the Gulf coast of Texas, where the land meets the sea, there are barrier islands. Many of the processes we see in action on barrier islands are active on beaches everywhere.

The main agent in moving sand and other sediments on a coast is water in motion—waves and currents.

Waves: Most waves in the ocean are caused by the friction of wind blowing across the surface of the water. Waves come in all sizes, from tiny ripples to giant tsunamis, which are not caused by wind but by some mass movement on the seafloor. The size of a wind-generated wave is determined by several things:

- *the strength of the wind*
- *the duration of the wind*
- *the length of the water surface exposed to the wind*

Word alert: *Duration* means how long something goes on, the time it takes for something to occur. “Johnny sat in his seat for the entire *duration* of the movie, a romantic comedy with no action, because his girlfriend really liked it.”

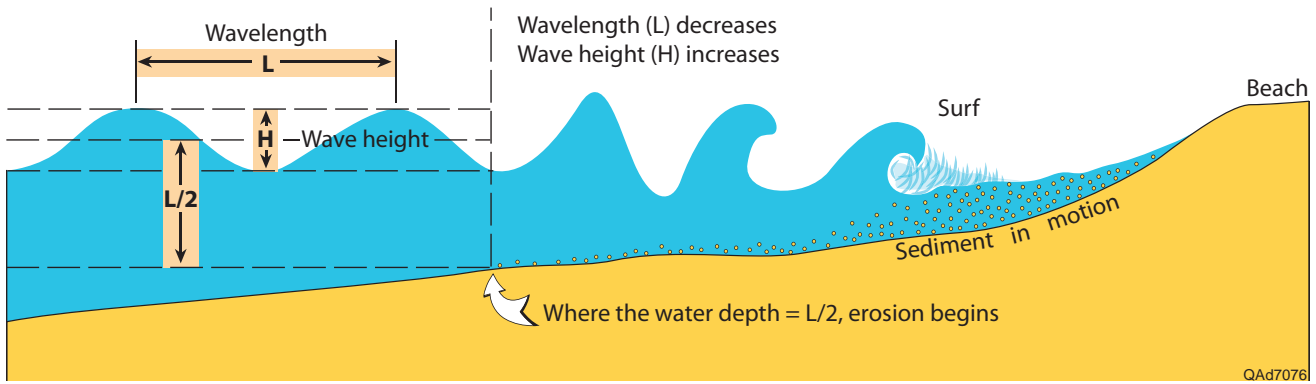


Figure 86. Wave diagram.

The distance from the crest of one wave to the crest of the next wave (fig. 86) is called the **wavelength**. The **wave height** is the tallness of a wave. Waves cause water to move below the surface, but this motion decreases with increasing depth. At a depth below the surface of greater than one-half the wavelength there is no motion in the water due to the waves on the surface.

For example: If wave crests are 80 feet apart (wavelength of 80 feet) and water depths are greater than 40 feet (one-half the wavelength), sediments on the seafloor are not disturbed by the waves. As these same waves approach the shore and water depths become shallower, less than 40 feet, the surface waves cause motion of the water on the seafloor and may erode, transport, and redeposit sediments.

As a wave approaches the shore and the water depth becomes shallower

- *the wave slows down*
- *the waves grow closer together (wavelength decreases)*
- *the wave gets taller (wave height increases)*
- *eventually the wave breaks*

Longshore currents: When waves strike the coast at an angle (fig. 87), a current is formed that transports sediment along the coast parallel to the shore. A current that moves along the shore is referred to as a **longshore current**. Sediment that is transported by

waves and currents along a shore is called **longshore drift**.

Tides: *Tides* are the daily rise and fall of the water in the ocean caused by the gravitational forces of the Moon and Sun (fig. 88). Tides are caused by a relationship between the mass of the sun and the moon as well as their distance from Earth. Even though the moon is much smaller than the sun, it has a larger influence on the tides because it is much closer to Earth.



Figure 87. Waves strike the shore of Boca Grande, Florida, at an angle, producing a longshore current and longshore drift of sediment to the south (downward).

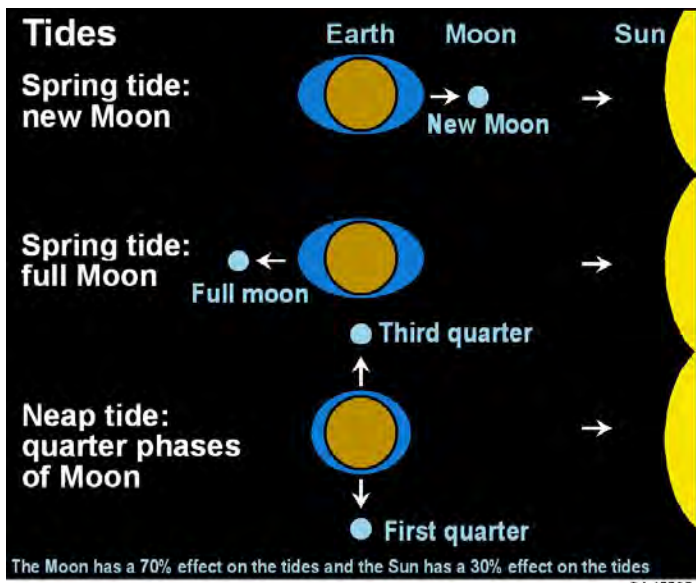


Figure 88. Earth, moon, and sun alignment during spring and neap tides.

As the Earth rotates, the gravitational attraction of the moon and sun “pull” up a bulge of ocean waters when the ocean is facing the moon to create a high tide. There is a paired, high-tide bulge on the “backside” of the Earth.

Tidal range is the vertical distance between water levels at high and low tide. Texas’ tides are usually a few feet or less (about 2 feet on Gulf coast and 1 foot in the bays), but some places outside of Texas have enormous tides. The Bay of Fundy in eastern Canada, for example, has a tidal range of almost 53 feet!

The tidal range and the timing of the tides will change every due to the moon’s orbit around the Earth. The moon orbits the Earth once every 27 days and 8 hours creating the lunar month.

- **Spring tides**, tides occurring twice a month (new and full month) when the gravitational force of the sun combines with the moon creating a larger than normal tidal range.
- **Neap tides**, tides occurring at first and third quarters of the moon when the gravitational force of the sun opposes the moon creating a reduced tidal range.

The factors controlling tidal range are very complex including winds, barometric pressure, rotation of the Earth, and the shape of the ocean basin. But forecasting tidal heights and the timing of high and low tides in a certain area is very predictable because it is based upon the lunar calendar.

You have learned the basic concepts of coastal processes and seen examples of them in the field at Padre Island. We’ll see other examples on the beaches of Mustang Island and Galveston Island. Both of these places are somewhat similar to what you’ve already seen, but each also has some important differences.

Washover fans, washover channels, and barrier flats: Barrier flats are one of the four main subdivisions of a typical barrier island. We saw that the barrier flat—where our hotel is located on Mustang Island—is, well, flat. Development, roads, parking lots, and other infrastructure built on barrier islands are commonly on the barrier flat. We need to discuss the processes that build barrier flats.

When a major hurricane blows into the Gulf of Mexico, the winds push a bulge of water toward the shore so that sea level is temporarily raised. A storm surge of a few feet on a low-lying barrier island allows the waves to erode high on the beach or even into or across the dunes.

During a major storm the large waves may erode a path across the beach, dunes, and barrier flat all the way to the lagoon. Such a channel cut across the barrier island by a storm is called a **washover channel**. As the waters pour into the lagoon, they slow down (lower energy), depositing a blanket of sand and shells (fig. 89). This fan-shaped layer of sediment is called a **washover fan**. After the storm passes, the storm surge recedes, and the channel is usually quickly filled. The barrier island develops a new beach, and over time new sand dunes form behind the beach.

Washover fans are important in building the barrier island. If you look at an aerial

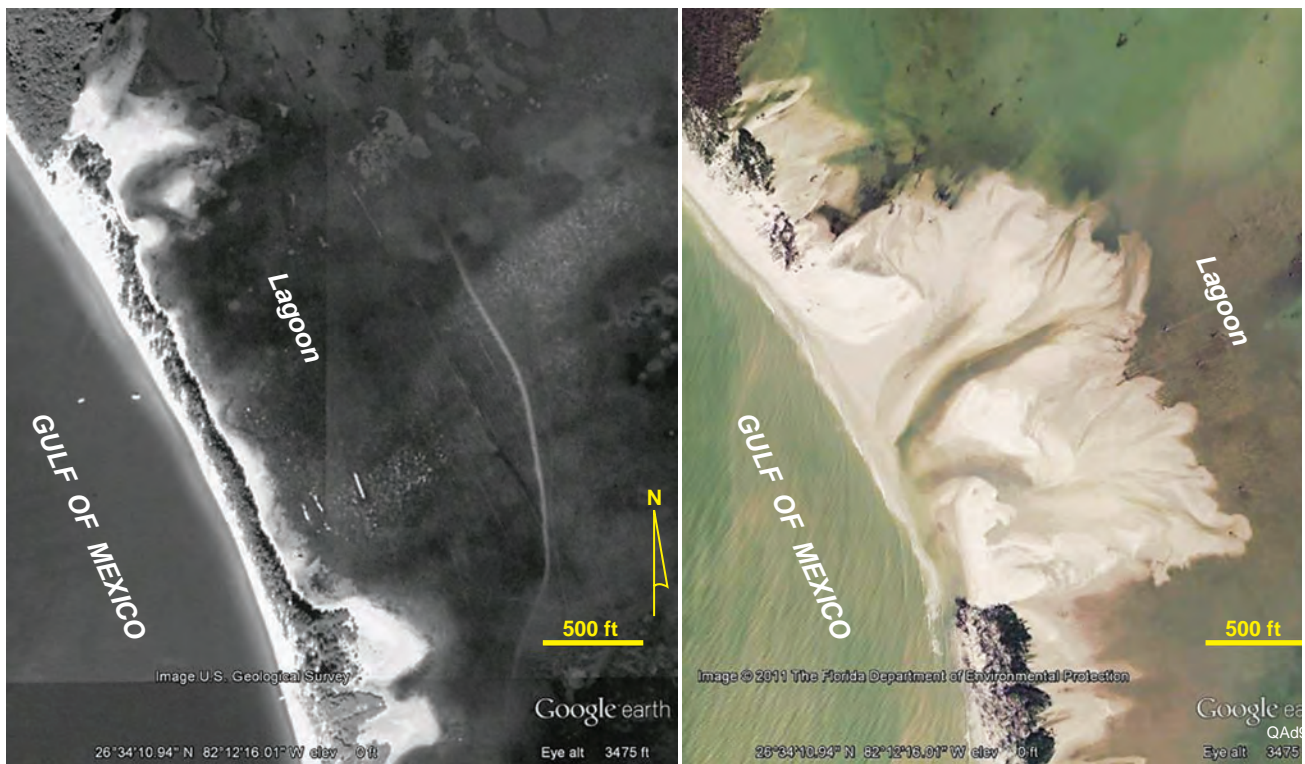


Figure 89. North Captiva Island, Florida before (left) and after (right) washover.

photograph of a barrier island (fig. 90) you may see fan-shaped areas of the barrier flat that extend into the bay or lagoon. Most of these areas are washover fans from past storms. These washovers are soon covered by vegetation.



Figure 90. The wide part of Little Gasparilla Island, Florida, now covered by vegetation, homes, and resorts, may be an old washover fan.

Why do washovers occur at one place in a barrier island but not at another?

During a storm, wave action, rainfall, winds, and storm surge are about the same along any several-mile-long piece of the shore of a barrier island. So why does a washover occur at one place and not at another? Why do long sections of barrier islands appear to have no recent washovers and yet other places on the same island have evidence of several recent washovers?

The answer lies in the dunes. Some sand dunes are tens of feet tall and hundreds of feet wide; other dunes on the same barrier island are much smaller. There may be places where there are no dunes at all. Some sand dunes have a dense cover of vegetation; other sand dunes have almost no vegetation. Large well-developed dunes having abundant plants resist erosion much better than do low dunes or dunes having little vegetation.

Washovers occur most commonly where the sand dunes are the least resistant to erosion—where the dunes are the smallest

and the least well vegetated. Once the dunes have been destroyed, it may take many years for them to become reestablished. If other major storms strike the same coast before the dunes are reestablished, washovers are likely to occur in the same place. Protecting the dunes is critical to maintaining the barrier islands.

Washover channels and tidal inlets:

Behind each barrier island is a body of water, a bay or lagoon. As the tide rises each day, ocean water enters the bay or lagoon; as the tide falls some of the water in the bay or lagoon flows back to the ocean. The water flows into and out of the bay or lagoon through a channel, a *tidal inlet*. Tidal inlets facilitate the exchange of water between the ocean and a bay or lagoon. Tidal inlets allow fish and shrimp and other marine organisms to enter and leave the bay or lagoon, and they are the used by ships and smaller boats.

A *tidal inlet* is a channel through which water flows as a result of rising (flood) or falling (ebb) tides. “Tidal pass” is a less scientific name for a tidal inlet. The tidal inlet “lets in” the tide to the bay or lagoon. Tidal inlets (fig. 91) occur wherever there is a channel leading from the ocean to a restricted body of water, such as the lagoon behind a coral reef or barrier island.

Word alert: *Ebb* means to recede, or flow away. “After the football team lost their first four games, many fans lost their enthusiasm, and attendance began to *ebb*.”

Many tidal inlets through barrier islands were formed as washover channels. Most newly formed washover channels are filled by deposits of sediment over a few weeks or months. Over many years new dunes may be developed. However, if the tidal currents are sufficient to keep the channel open, a new tidal inlet is formed. The amount of water passing through a tidal inlet depends on

- *the height of the tides (tidal range),*
- *the volume of water in the bay or lagoon,*
- *the size and number of tidal passes that drain a given bay or lagoon.*

During a high tide the water level is higher in the ocean than in the bay, and water pours into the bay. When the tide is low, the water in the bay is higher than in the ocean, and water rushes through the tidal inlet to the ocean. Tens of thousands of gallons per second or much more may flow through a tidal inlet. All that water escaping from or racing into a bay may create quite a current, and moving water means erosion and transportation of sediments.

The current velocities are highest where the channel is narrow and slow down as the waters spread out in a bay (during a high tide, or flood tide) or in the ocean (during a low tide, or ebb tide). In an active tidal inlet, sediments



Figure 91. Tidal inlet between Captiva Island (south) and Little Captiva Island, Florida. Note the ebb-tidal delta (low tide) and flood-tidal delta (high tide). Arrows indicate tidal channels. Scale bar is 0.5 mile.

are eroded and transported through the pass and then deposited at either end of the pass (fig. 92). The sediment deposited near the mouth of a tidal inlet in a bay or lagoon by a flood tide is called a *flood-tidal delta*. The sediment deposited near the mouth of a tidal inlet in the ocean by an ebb tide is called an *ebb-tidal delta*.

Day #4

PORT ARANSAS, TEXAS

Orientation

Where are we, what will we see? Mustang Island is a 40-km- (~25-mile-) long barrier island located between Corpus Christi and the Gulf of Mexico, south of San Jose Island and north of Padre Island (fig. 93). It has a unique and complicated ecosystem.

This morning we will visit southern end of Mustang Island and traverse the island from the Gulf of Mexico to the edge of Corpus Christi Bay. As a group we will visit the beach at Packery

Channel, the seawall on North Padre Island, wetlands on the edge of Corpus Christi Bay, and remnant washover channels at Newport Pass and Corpus Christi Pass. In the afternoon, you will split into two groups. The first will learn about the ecosystem in Corpus Christi Bay aboard the R/V Katy. The second group will visit the Texas State Aquarium in Corpus Christi. Tomorrow afternoon the groups will switch.

What will we learn about today? By the end of today's field trip, you will have seen the dynamic environments of a typical Texas barrier island. You will examine the island from the waters of the Gulf of Mexico, up the beach to the top of the foredunes, across the back-barrier environment, to the edge of Corpus Christi Bay.

Today's geo-words: At the end of the day, you should be able to explain:

- *Erosion*
- *Accretion*
- *Tidal inlet*

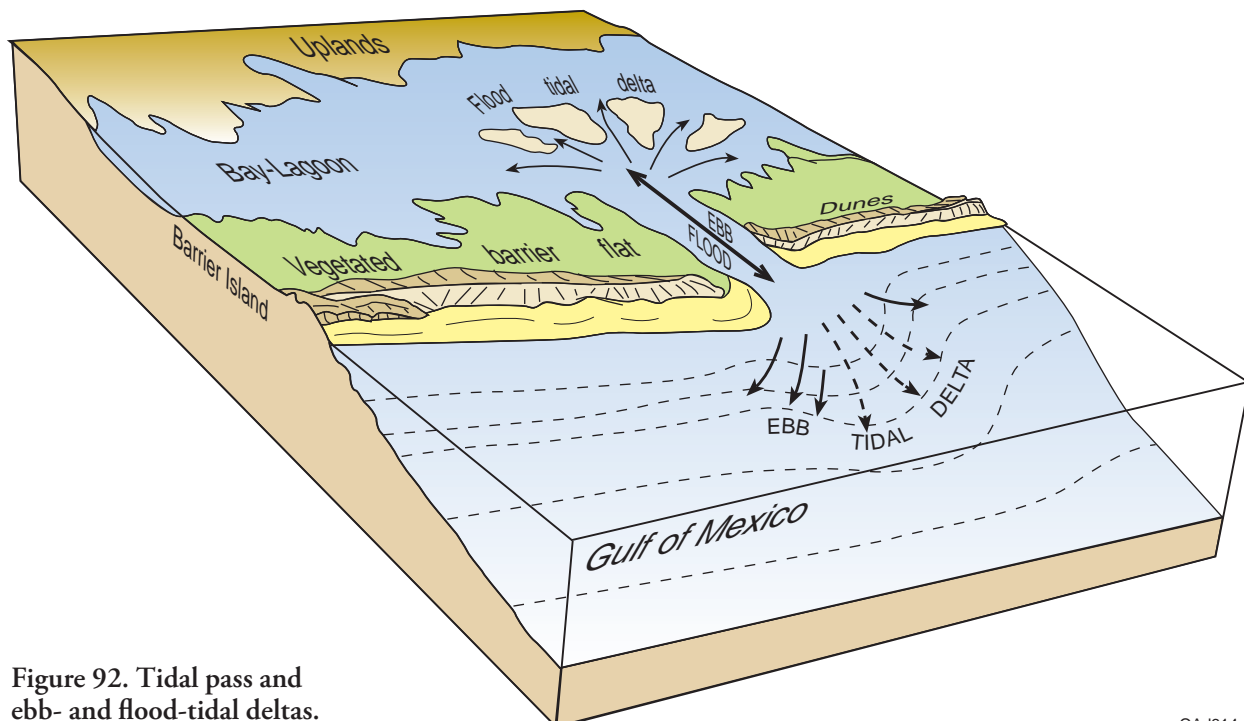


Figure 92. Tidal pass and ebb- and flood-tidal deltas.

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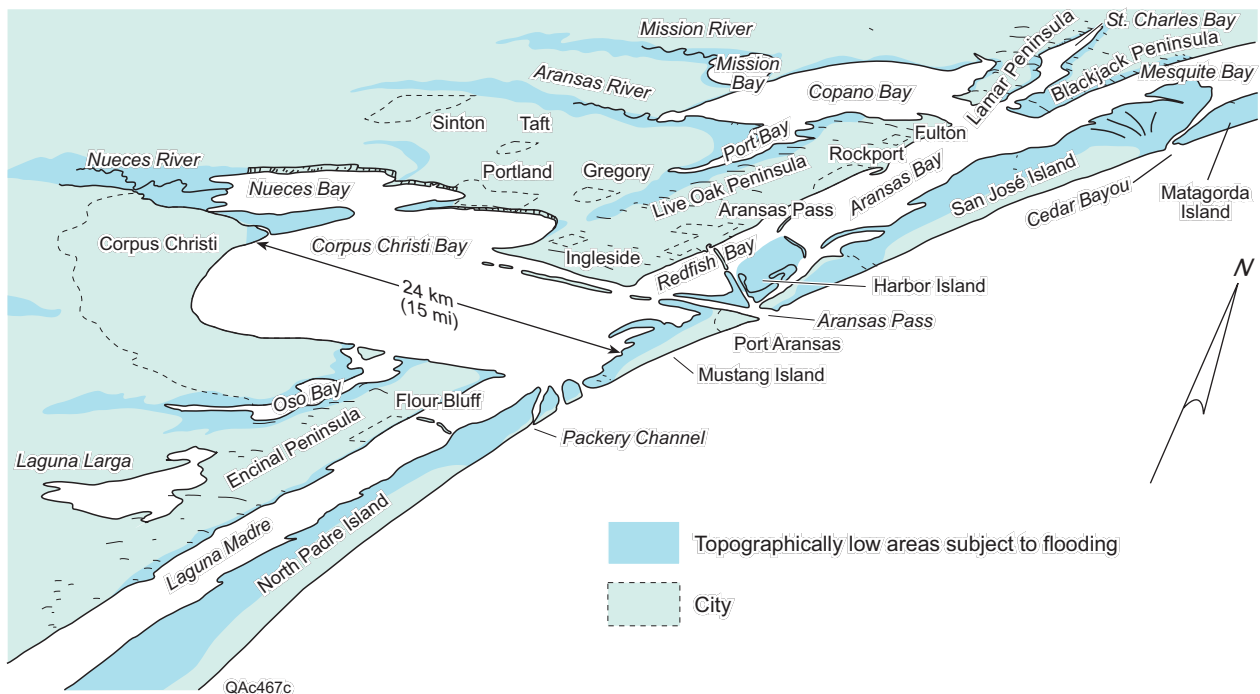


Figure 93. Map showing Texas Coastal Bend barrier islands.

- *Washover channel and washover fan*
- *Dunes, foredune, and coppice dune*
- *Salt marsh*
- *Vegetated barrier flat*
- *Bay margin*
- *Jetty*
- *Beach nourishment*

Stop #6

MUSTANG ISLAND BEACH

On Mustang Island we will see coastal processes (waves, wind, and longshore currents) and barrier island features (beach, dunes, washovers, barrier flats). Learning about these processes and features in a stimulating GeoFORCE classroom lecture is fine, but the place to really learn about natural systems is in the field. At this stop you will:

- *Learn to recognize the parts of a barrier island and beach.*
- *Understand the processes that form the beach and dune and cause longshore drift.*

We will begin our field day at the Gulf of Mexico shore by Packery Channel, the southern end of Mustang Island. Our walking traverse across Mustang Island will take the majority of our time this morning. We will start on the beach near the north jetty of Packery Channel and hike across the island to Corpus Christi Bay (**fig. 94**).

Did you know? History of People on Mustang Island People have lived in the Texas coastal zone for at least 8,000 to 10,000 years, even before there was a Mustang Island and at times when sea level was much lower than it is today. The early inhabitants of Mustang Island were the Karankawa Indians. They ate mostly fish and shellfish, small game and local plants.

The island was first mapped by the Spaniard Alonso Alvarez de Pineda in 1519. The bay behind the island was named Corpus Christi by another Spaniard, Diego Ortiz Parrilla, in 1756. The name “Mustang Island” is derived from wild horses, the “Mesteños,” that roamed the island for hundreds of years until the late 1800’s. In