COASTAL EROSION

CONVENTIONAL WISDOM & COMMON MISCONCEPTIONS

(excerpted from *Coastal Erosion & Solutions—A Primer* ©CSE 2011)

There is great variability in the shape of the coast and the processes that transform it. Yet at mesoscales, a surprising amount of shoreline is changing at manageable rates. This is not to say all shorelines should be developed, but rather the vulnerabilities of many areas are not so much due to shoreline retreat.

In the case of America's West Coast beaches, many of which are anchored between headlands, high backshore elevations limit the runup of surges and waves over the land. Some pocket beaches lose sand to submarine canyons, but many are in equilibrium, changing at slow rates. Common sense suggests that as long as development is situated well above the highest surge and wave level, and set back some distance from this active zone (and the projected future active zone), the processes of shoreline change will not impact. Other hazards, such as earthquakes and fire, may be of more immediate concern.

Similarly, along some portions of the U.S. East Coast, the backshore is elevated well above the expected 100-year flood elevation [eg – Cape Cod (MA) and Myrtle Beach (SC)], making these areas no more vulnerable to flooding and erosion than inland parcels situated along protected waterways.

Hurricane Damages Also by Wind and Rain

Coastal damages during hurricanes are not always the result of waves and surge. Hurricane *Andrew*, the fifth most costly on record (Pielke et al 2008), in 1992 destroyed 25,000 homes and businesses in Dade County (FL). Few of these properties were situated on the open coast close to the beach. Instead, most were inland, succumbing to the Category 5 winds (speed >155 miles per hour) associated with the storm.

Much of the property damage in North Carolina after Hurricane *Floyd* (1999) was due to intense rainfall which dumped over 20 inches on the low-lying mainland dozens of miles from Pamlico Sound, flooding huge areas. The tidal surges originating from the ocean filled estuaries and sounds, thereby impeding the runoff of torrential rains, particularly where "high ground" was only 3 feet (ft) or so above the normal tide limit. One of the ironies of that storm was to meet people who abandoned their flooded mainland homes and sought refuge on Bogue Banks (a barrier island) in second homes perched on land 30 ft above the sea.

Bogue Banks NC USA—Thirty-five steps to the dry sand beach

*Yes, living **on** the open coast is risky, but so is living **near** the coast.*

Not All Barrier Islands "Roll Over" at Mesoscales

Considering that much of the U.S. East and Gulf Coasts are chains of barrier islands, coastal erosion is often associated with that landform. The conventional wisdom suggests these "ephemeral islands" are doomed to overtopping in storms and destruction under rising seas. The image conveyed is that of a bulldozer tread where storms overtop the barrier, drive sand inland, and roll the island into the lagoon. Back-barrier marshes are temporarily buried by overwash only to emerge as outcrops on the ocean-side beach some time later. This image is compelling because it can be seen happening today in places like Louisiana, Bolivar Island (TX), or Edingsville Beach (SC) where there was a group of "planters cottages" in the 1880s until a hurricane destroyed (or moved) every

Edingsville Beach SC USA—Washover barrier beach, marsh-filled lagoon, tidal tributaries, and forested beach ridges—common features of the coastal zone building. Sallenger (2009) brings to life what happens when catastrophic storms impact low barrier islands.

Some of the highest coastal erosion rates (>10 ft/yr) occur on "washover" barrier islands like Core Banks (NC) or Assateague Island (MD) (on which much of the conventional wisdom regarding "barrier island rollover" is based). Yet, the majority of developed barrier islands do not fit this simple model when considered at century time scales. Bogue Banks (NC), where some people sought refuge after Hurricane *Floyd*, is over a half-mile wide with dunes reaching 45-ft heights. There have

Indian Beach NC USA—After Hurricane Floyd (1999)—top of escarpment is >20 ft above MSL

been no breaches of the 25-mile-long island in the last hundred years, and erosion rates average well under 3 ft/yr (CSE 2007). Likewise, Long Beach Island (NY), Atlantic City (NJ), and Miami Beach (FL) are urban barrier islands with no known history of cross-barrier overwash or breaching during the 20th century.

Galveston (TX) was overwashed and its community largely destroyed in the great hurricane of 1900 (Larson 1999). After the storm, the land was pumped up via dredge spoil, raising the core of the island well above most (but not all) hurricane surge levels. Buildings were raised and a seawall was constructed to further inhibit washovers. [Note: The same cannot be said for the east end beaches (such as Jamaica Beach) on Galveston Island, which were not built up after the storm, or for neighboring Bolivar Island (a low barrier with little relief) which was devastated by Hurricane *Ike* in 2008.]

Another barrier island that has not washed over since the 1920s is Jones Beach (NY). One of the great recreational beaches in the world, Jones Beach owes its persistence to Robert Moses, New York's builder of parks and parkways, who arranged to pump 40 million cubic yards from Great South Bay along the central spine of a chain of washover barriers. The parkway on top of this spine sits above flood levels and provides access for millions of beachgoers every summer.

Kiawah Island SC USA—The eastern end of the island (2008) where shoal-bypassing events between 1990 and 2005 added 5 million cubic yards to the island and created a 3-mile-long barrier beach and lagoon system. Episodic events such as this illustrate how rapidly barrier islands ca form in the presence of an ample sediment supply. [Source: CSE 2009]

Barrier Islands Higher than Mainland Shores

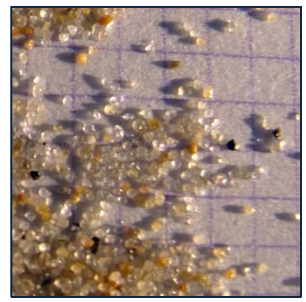
This is not to say that most barrier islands will never wash over. Certainly, if sea levels rise faster than the models predict, this will become commonplace. Yet, barrier islands are, by their very nature, landforms which build vertically under the action of waves and winds. If sea level rises and there is sufficient sandy sediment in the littoral zone and back barrier area, the island will reconstitute itself. Given sufficient sediment supply, barrier islands can form rapidly, even in the face of rising seas (see the photo of Kiawah Island).

Of, perhaps, more immediate concern for coastal zone management are those low-lying interior lands that are not exposed to the building processes of ocean waves. Potentially much more development will be at risk sooner along sheltered estuaries where the land is only about 3 ft above present high tide. Mastic Beach (NY) is just such a community vulnerable to sea-level rise before its protective barrier, Fire Island, is likely to be washed over in many places.

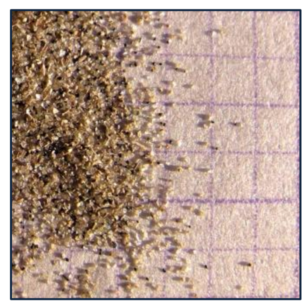
A misconception regarding barrier-island retreat is that the average slope of the inner continental shelf will control the retreat distance. Some scientists have posited that if the average slope of the shelf is 0.001 (1 ft rise over 1,000-ft distance, which is a characteristic value), a 1-ft rise in sea level will translate to a 1,000-ft shoreline recession. While this may be the case over long geologic time scales, empirical evidence shows it is not the case at century time scales in most areas. As Bruun (1962) demonstrated, sea-level rise causes the beach and barrier island to be displaced landward and upward in proportion to the slopes in the active surf zone (which are much steeper than the inner shelf). Therefore, if the slope of the beach is ~1 on 30 (a typical value), a 1-ft sea-level rise would produce ~30-ft shoreline retreat. Beaches tend to equilibrate when their profiles achieve the "normal" healthy volume for the setting. Yes, many other factors modify this result, but not to the degree that the shoreline soon migrates 1,000 ft inland. This becomes important in the debate about solutions.

Muddy vs Sandy Barrier island Coasts

One final misconception about the response of the coast to erosion and rising seas is related to sediment quality. Here again, Louisiana provides an object lesson. Relative sea-level rise near the mouth of the Mississippi River was ten-fold greater than the global average rise during the 20th century. Barrier islands are disintegrating, marshes are drowning, and the land is retreating as fast as anywhere in the world. "As Louisiana goes, so will the US East Coast barriers if sea-level rise accelerates" as some worst-case scenarios predict. But this ignores a key difference between Louisiana barrier islands and most East Coast barriers. Mud and very fine-grained sand are the dominant sediments along the Louisiana coast, whereas fine- to coarse-grained sand dominates along the East Coast.

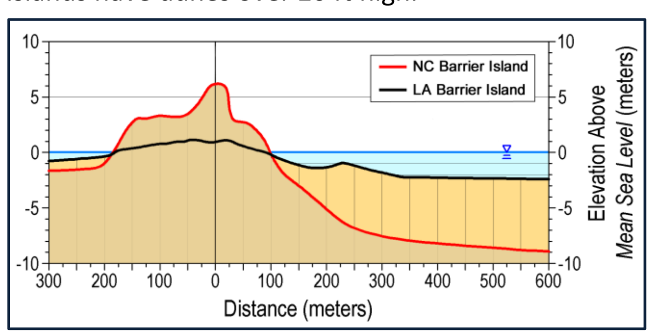


Large grain sand (0.4 mm)



Fine grain sand (0.1 mm)

A typical mean grain size of a Louisiana beach is 0.1 mm, whereas a North Carolina beach is 0.3 mm. This may not seem like a big difference, but it translates to much gentler slopes in Louisiana compared with North Carolina. If one considers the cross-section of a barrier island to be similar to a prism, the Louisiana barrier will be very broad and flat, whereas the North Carolina barrier will be much narrower at the base and steeper along the sides. Louisiana's outer beaches may equilibrate at slopes of 1 on 100, whereas North Carolina's are closer to 1 on 20. Few barrier islands in Louisiana grow more than 6 ft above high water, while many North Carolina barrier islands have dunes over 20 ft high.



Characteristic cross-sections of barrier islands in North Carolina and Louisiana. Coarser sandy sediments lead to a steeper profile and less volume in the base of North Carolina barrier islands compared with the muddy barrier islands of Louisiana which are founded on fine-grained sediments of the delta. Note low relief of the Louisiana cross-section. Ocean is to the right.

Simple geometry of each cross-section shows that Louisiana needs much more muddy sediment to build a broad base before a barrier of 0.1 mm sand can accumulate on top of the mass above the high-tide level. Louisiana's critical need is for more coarse sediment at the coast, which it does not have. North Carolina beaches tend to be founded on coarser sands (0.2 mm in the underwater zone) and composed of 0.3–0.5 mm grain sizes in the dry-beach zone. Not surprisingly, then, Louisiana's barriers are not keeping pace with local sea-level rise, despite valiant attempts to maintain them (Finkl and Khalil 2005). South Carolina, where littoral sediments average 0.2 mm, contains examples of barrier beaches that have emerged from the ocean and have established themselves in a decade (Kana 2002, CSE 2009).

The point of this is to say that the Louisiana response to rapid sea-level rise is not necessarily the best model for many developed barrier islands where sediments are coarser. Just as road builders prefer a base of coarse sand which drains well, barrier islands will form readily in the presence of sandy sediments with higher porosity. They will persist longer under the action of waves, winds, and tides if dunes grow above the storm-surge levels. Washover frequency will lessen along with recession rates because the littoral budget will be conserved seaward of the foredune. Storms may erode the dune, leaving escarpments, but the beach cycle will rebuild the profile using eroded sediment. As long as a healthy profile volume and sufficient wave energy exist in the littoral zone, a barrier beach will be maintained. In contrast, low barrier islands of Louisiana will continue to lose a portion of their littoral volume to the lagoon whenever the islands wash over or breach. This extra loss will yield higher recession rates. How one manages shoreline erosion and development along a more frequently overtopped barrier island, like Bolivar Island (TX), should probably differ from efforts along slowly eroding, high islands, such as Bogue Banks (NC).

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