The effect of a storm in a shore zone depends on the interaction of two major factors:

1. The type of shoreline (sand vs. rock, low-sloped ramp vs. vertical bluff, ocean vs. estuarine, etc.)
2. The source, amount, and duration of energy expended.

Storms represent the major new input of energy to a coastal system. Storm energy causes shore zones or beaches to change and evolve through time. Beaches absorb the physical energy occurring at the contact between sea and land.

Little happens to a beach on calm summer days. However, storms that transfer major amounts of energy can result in significant shoreline modification (figure 1-28). The photos in figure 1-28 show the result of tremendous energy exerted on everything in the path of Hurricane Isabel. Barrier-dune ridges, referred to in the photo captions, are not naturally occurring dunes but rather sand ridges that represent major human modification efforts to protect structures (houses and roads) from storm damage.

On a sandy beach, a storm tide will erode, transport, and redeposit not only sand but also structures built upon the sand – including houses and roads (figure 1-28). As energy is expended by the storms, the character of the shore zone responds with dramatic changes, causing a dilemma for humans who wish to build homes and other structures on the barrier islands. Rates of change along the North Carolina shorelines are measured in time frames of days and years, in severe contrast to the expectations of permanence and economic values placed upon waterfront properties.

Figure 1-28. Post-Hurricane Isabel (2003) photographs show the damage in Hatteras Village and the newly opened and quickly closed Isabel Inlet.
Panel A: Storm surge and overwash destroyed large segments of the barrier-dune ridge.
Panel B: This oceanfront motel was destroyed when the barrier-dune ridge was breached by the storm surge.

Panel C: This expensive process cleans the debris from overwash sand for use in building the new barrier dune-ridge.
Panel D: A new barrier-dune ridge is being constructed in front of the destroyed motels.

Panel E: Remnants of N.C. Highway 12 pavement within Isabel Inlet.
Panel F: This photograph depicts the infilled Isabel Inlet, reconstructed N.C. Highway 12, and rebuilt barrier-dune ridge. Photographs are by S. Riggs.

Increasing numbers of storms greatly impact the barrier islands, sea level continues to rise (figure 1-6 and 1-7, see p. 4), and the population living and building permanent structures on this dynamic coast increases sharply (figure 1-4, see p.4). All three processes are predicted to continue into the near future. According to a report by the Bureau of Census, U.S. Department of Commerce, Dare County experienced extremely high growth rates. Todd Miller, Executive Director of the N.C. Coastal Federation, stated in October 2001 (http://www.nccoast.org/Newsroom/pressNortheast.html).

> For the most part, the northeastern part of the coast has grown very slowly over the last ten years. A pair of inland counties (Washington and Bertie) actually lost population during the last decade, while Dare and Currituck were two of the top dozen fastest growing in the state. On top of the permanent population increase, seasonal housing in Dare County more than doubled, increasing by almost 7,000 buildings. Seasonal housing in Currituck County tripled, bringing even more seasonal visitors to a small strip of land.

Human development cannot be approached on a high-energy coastal shoreline the same way that development in Raleigh or Charlotte would take place. For long-term success for both society and the coastal ecosystem, decision makers must face the inevitability of change and utilize the valuable coastal resources in ways that are in harmony with the energy and processes of the natural system. Figure 1-29 shows the long-term coverage (over 132 years) in the ocean shoreline of Ocracoke Island.

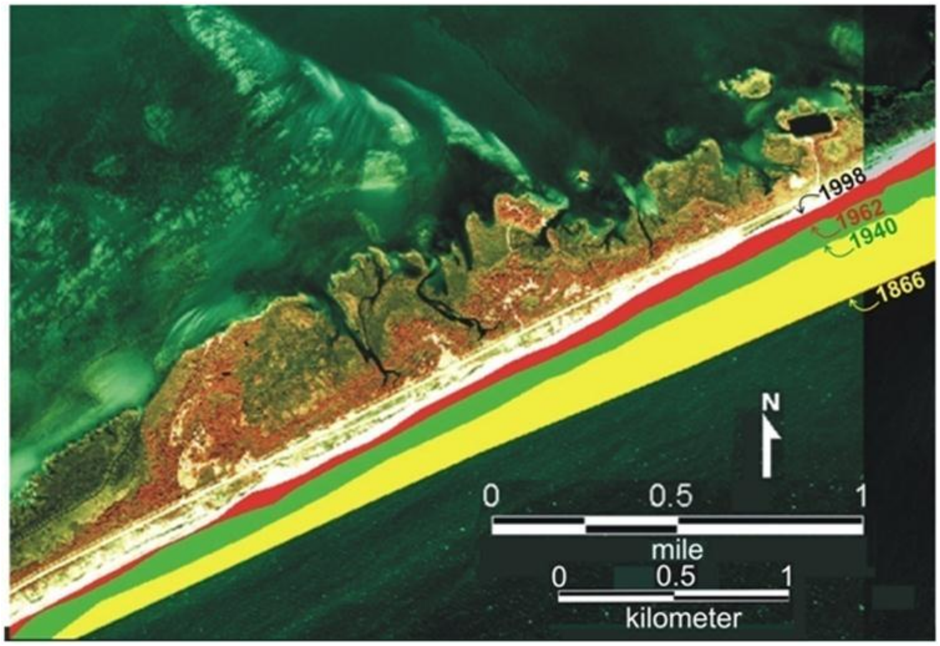

Figure 1-29. Shoreline changes on Ocracoke Island are shown for a time period spanning 132 years (1866-1998). Yellow represents the amount of shoreline recession that occurred between 1866 and 1940; green represents the erosion between 1940 and 1962; red represents the land lost between 1962 and 1998.

In contrast to the longer-term changes of the Ocracoke Island shoreline (figure 1-29), figure 1-30 shows a dramatic change in the shoreline along the Chowan River that occurred in less than an hour during Hurricane Isabel on September 18, 2003. At this locality, a 75-foot high bluff was severely eroded as a six- to eight-foot storm surge rose against the bluff with waves produced by hurricane force winds as the eye of the hurricane passed slightly to the west of the Chowan River. The storm surge dropped and waves subsided as the eye of the storm moved north of the area. However, the bluff had receded up to eighty feet in less than an hour's time period (figure 1-30B).

Shoreline changes are inevitable. While various methods are available to combat erosion and land loss, none are permanent solutions and all have significant environmental tradeoffs. Recognizing and understanding the complex causes and dynamic processes involved in shoreline erosion is the first step towards minimizing the impact of erosion and managing our shoreline resources and economic investments. Ultimately, to both preserve our coastal resources and maximize human utilization, officials must consider the dynamics of the total coastal system when developing long-term management solutions to shoreline erosion.

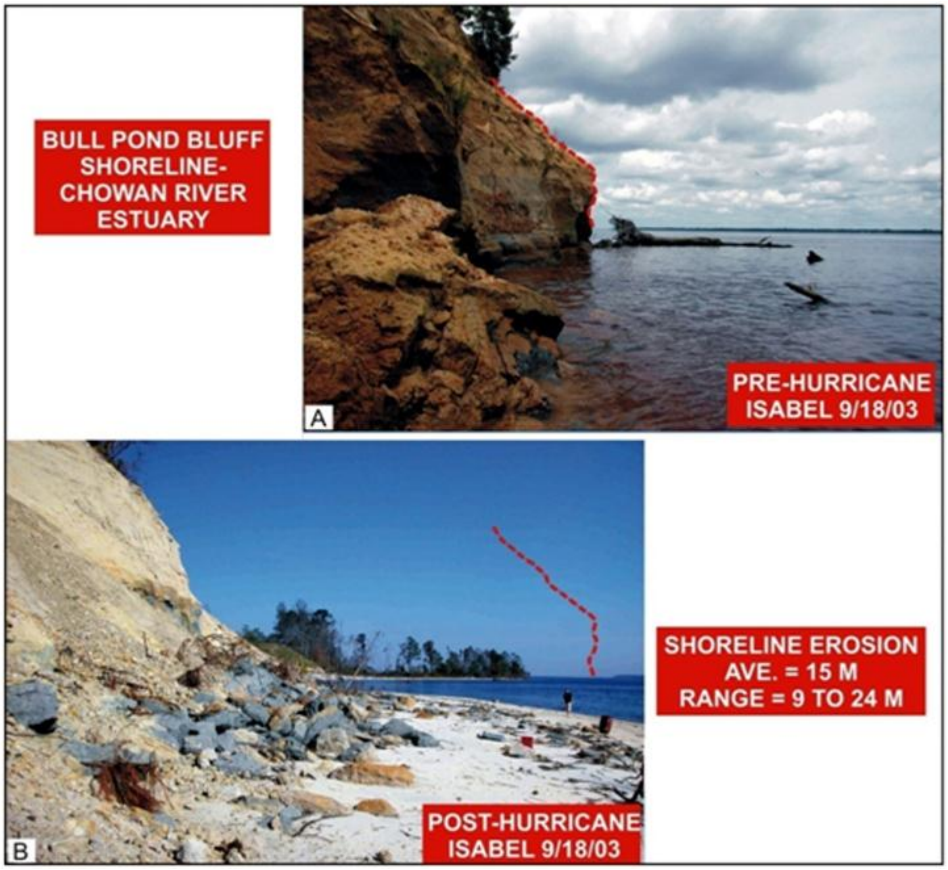

Figure 1-30. Two photographs of an eroding estuarine sediment-bank shoreline along the western side of the Chowan River. Panel A: Pre-Hurricane Isabel photograph was taken prior to the storm on September 18, 2003. This ~75-foot high bluff consists of a lower clay bed (~30 feet thick) with an overlying sand bed (~45-50 feet thick). Panel B: The post-Hurricane Isabel photograph was taken on October 6, 2003 from about the same location along the bluff shoreline as Panel A. The red dashed line in Panel A is in the same relative location as in Panel B. The average bluff shoreline recession was about 50 feet (range from about -30 to -80 feet) for the several segments of accessible bluff shoreline. Figures are the front and back cover of Riggs and Ames (2003).

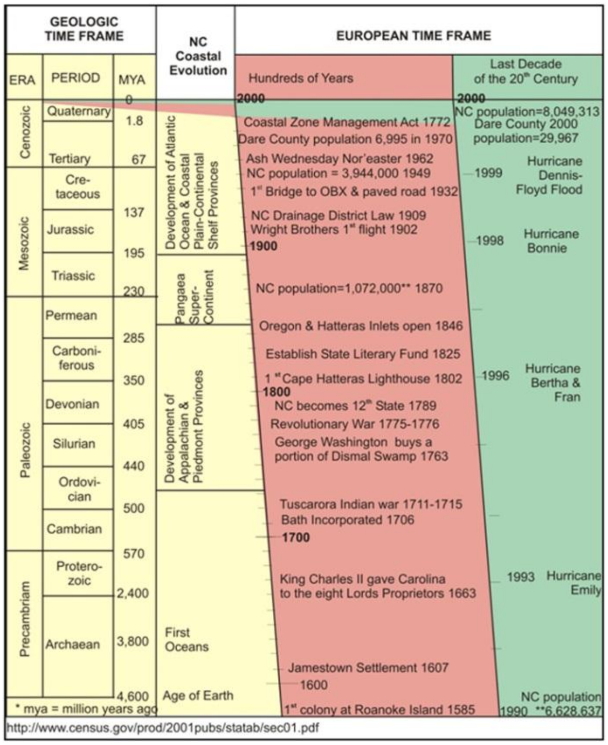

Figure 1-4. This geologic time chart contrasts long-range geologic time that reaches 4.6 billion years back to the earth's formation with the more recent human time frame since European colonization of North Carolina (the last 400 years) and the last decade of the 20th century.

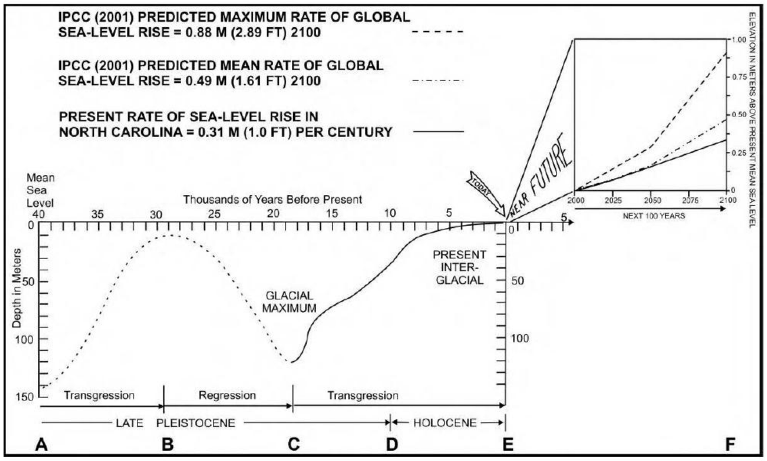

Figure 1-6. Generalized sea-level curve for the past 40,000 years and predictions to year 2100 AD. Predictions are based upon IPCC (2001). Figure 6-2-1, p. 62 in Riggs and Ames (2003).

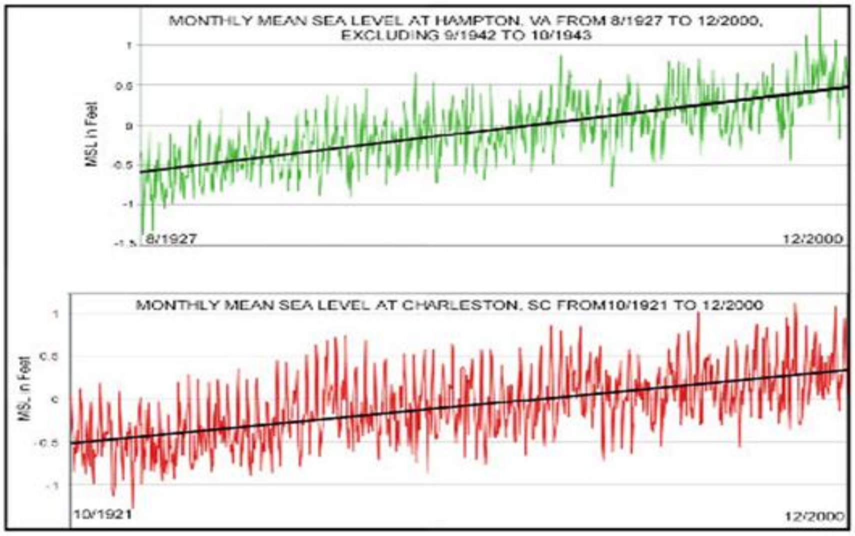

Figure 1-7. Tide gauge data from Hampton, Va. and Charleston, S.C. demonstrate the rate of ongoing sea-level rise. The plotted data are monthly averages of mean sea level that extend from August 1927 and October 1921, respectively, to December 2000. The heavy line through each plot is the graphical representation of the data trend in a series. It is obtained by regression analysis and shows the net rise in sea level during this time period. Similar tide-gauge data developed at Duck, N.C. by the U.S. Army Corps of Engineers only goes back to 1980, but in a 20-year time period, the data suggest a slightly higher rate of sea-level rise of about 1.5 ft/100 yrs for the Albemarle Sound coastal region. The two sets of tide-gauge data in Figure 1-7 are from the National Oceanographic and Atmospheric Administration (NOAA) National Water Level Observation Network (*www.co-ops.nos.noaa.gov/*). Figure 6-3-2, p. 65 in Riggs and Ames (2003).