The long-term processes of climate and sea-level change produce the disequilibrium that results in the reshaping of the North Carolina coastal system by individual hurricanes and northeast storms. Rising sea level slowly and systematically floods up the stream valleys and adjacent land slopes. However, it is wave energy during storms that physically erodes the shoreline and moves it further landward in response to rising sea level. A falling sea level results in the abandonment of an old shoreline, as the contact between water and land slowly migrates seaward.

The Quaternary period of geologic time, the last 1.8 million years of earth history, was characterized by multiple episodes of glaciation and deglaciation resulting from extreme fluctuations in the global climate. The Quaternary is further subdivided into the Pleistocene epoch, better known as the ice ages, and the Holocene epoch, the last 10,000 years of earth history. The Holocene is the time of warm global climates associated with the ongoing interglacial time period (between major glacial episodes) and has been witness to the development of modern civilization.

From about 10,000 to 20,000 years ago, the Earth was locked in the last of a long series of glacial episodes that occurred during the Quaternary period. During the last ice age, massive glacial ice sheets, often up to two miles thick, covered the northern half of North America, Greenland, northern Europe, northwestern Asia, mountainous portions of South America, and Antarctica. In North America, the ice sheets extended southward to Cape Cod, Long Island, and the Ohio and Missouri Rivers, forcing the climate zones to systematically shift southward.

During this time, North Carolina's vegetation included boreal (northern) forest species such as spruce, fir, and jack pine. The climate was cold, semi-arid, and dominated by severe storm activity. The river systems consisted of broad and shallow, sediment-choked drainage systems much like you would see in the western United States today. Aeolian (wind-blown) dune fields were common in the river valleys. Because the water that produced these land-based ice sheets was derived from the world's oceans, global sea level was lowered by more than 400 feet worldwide. This drop in sea level placed the North Carolina ocean shoreline on the continental slope between fifteen and sixty miles seaward of the present barrier islands, extending the Coastal Plain completely across the present continental shelf (see the continental shelf-continental slope break in figure 1-17).

Periods of global warming, such as the one that began at the end of the Pleistocene, resulted in deglaciation. Ice sheets began to retreat and discharge the resulting melt-waters back into the world's oceans. The warm climate period that followed is called the Holocene epoch and represents the last 10,000 years of earth history. During the Holocene interglacial, worldwide sea levels slowly rose to their current level (see the last few decades of sea-level rise in figures 1-6 and 1-7).

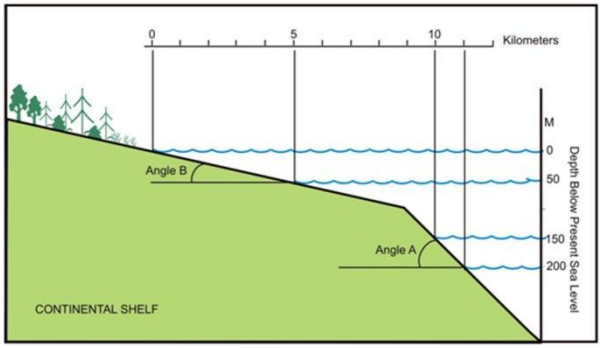

Figure 1-17

A classic sea-level change curve for the late Pleistocene glacial episode and the subsequent Holocene interglacial is presented in figure 1-6. The curve for the Holocene post-glacial period suggests a rise in sea level that started at extremely high rates (about 6.6 feet/100 years) for a millennium, then slowed to moderate rates (about 3.3 feet/100 years) until about 8,000 years ago. At this time the rate of sea-level rise slowed dramatically to the present rates to range from 0.5 to 1.6 feet/100 years. However, it has been demonstrated by many researchers, including the authors, that there were numerous brief periods during this history when sea level actually stopped rising and even temporally dropped.

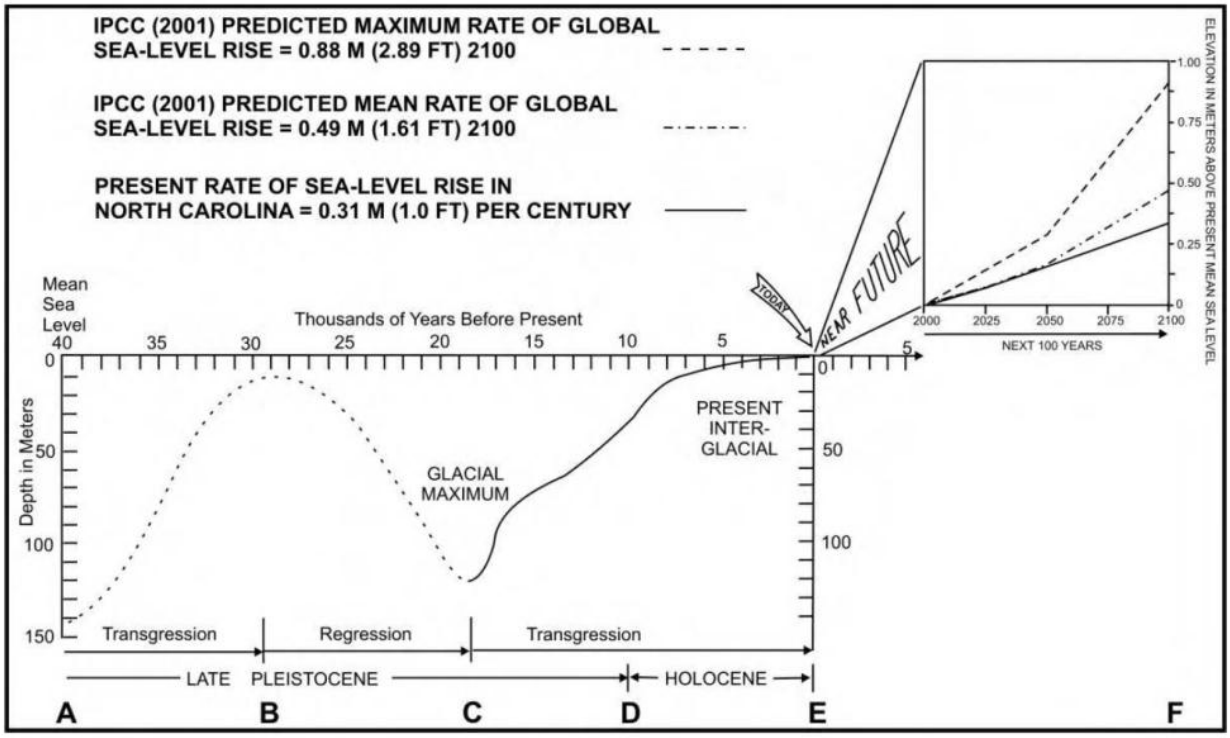

Figure 1-6. Generalized sea-level curve for the past 40,000 years and predictions to year 2100 AD. Predictions are based upon IPCC (2001). Figure 6-2-1, p. 62 in Riggs and Ames (2003).

Rising sea level caused the shoreline and coastal system to migrate upward and westward across the continental shelf to its present location during the Holocene. Thus, the North Carolina coast retreated landward between fifteen to sixty miles with shoreline recession rates that ranged from an average of five feet per year at Cape Hatteras to an average of nineteen feet per year at Topsail Island. Shoreline recession rates for North Carolina through most of the post-glacial history are generally greater than current average global rates of coastal retreat, which range between three to ten feet per year.

But there is still a tremendous volume of ice that occurs in the Greenland and Antarctic glacial ice caps. If all of the glacial ice in these two ice caps were to melt, sea level would be approximately 200 feet higher than at present and much of the modern North Carolina Coastal Plain would be flooded by the ocean. The ocean shoreline would occur approximately along Interstate 95 between Roanoke Rapids and Fayetteville, with the drowned-river estuaries extending up to the river valleys to Raleigh and adjacent Piedmont regions. Such advances and retreats of the glacial ice and the global oceans have occurred numerous times during the Pleistocene epoch. Old beach shorelines, such as the Suffolk Scarp and Currituck Peninsula beach ridges (see figure 1-2, found in the background information for chapter one), clearly demonstrate the location of these ancient shorelines. In fact, the surface sediments, soils, and topography of the Coastal Plain are direct products of these major fluctuations in the Quaternary coastal system.

Data from long-term tide gauge records demonstrate similar rates of sea-level rise for both Charleston, SC and Norfolk, VA (figure 1-7). Because North Carolina's coastline lies between South Carolina and Virginia, we can infer similar changes, resulting in the ongoing flooding of the low coastal land as well as recession of North Carolina's coastal shorelines.

The Intergovernmental Panel on Climate Change Report in 2001 (figure 1-6) predicts increased rates of global sea-level rise over the next century in direct response to known rates of global climate warming. Increased rates of sea-level rise will adversely impact coastlines of North Carolina in the following ways:

1. Accelerated rates of coastal erosion and land loss
2. Increased economic losses due to flooding and storm damage
3. Increased loss of urban infrastructure
4. Collapse of some barrier island segments
5. Increased loss of estuarine wetlands and other coastal habitats

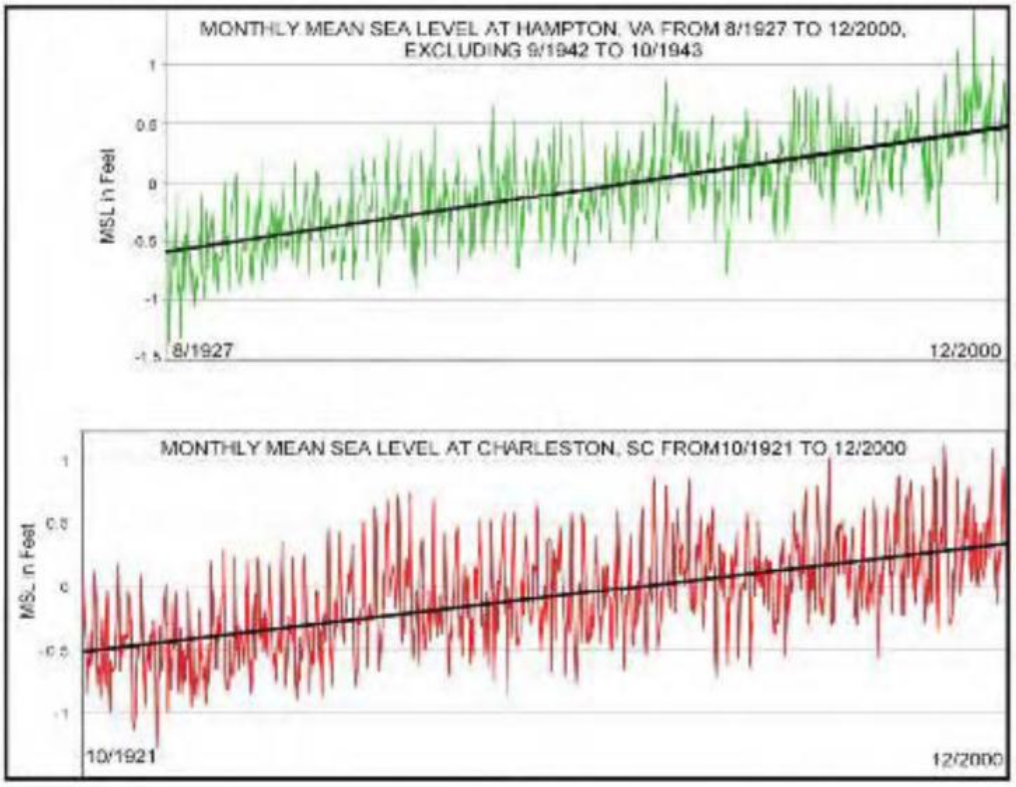

Figure 1-7. Tide gauge data from Hampton, Va. and Charleston, S.C. demonstrate the rate of ongoing sea-level rise. The plotted data are monthly averages of mean sea level that extend from August 1927 and October 1921, respectively, to December 2000. The heavy line through each plot is the graphical representation 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).

The scientific community has only a moderate understanding of the linkages and controls between global warming and changing magnitude and rate of sea-level response, resulting in limited levels of predictability from a societal point of view. Sea level is rising in North Carolina today at a rate of between 1.0 to 1.61 feet/ 100 years. Is this rate of flooding significant for the North Carolina coastal system? On your next trip through the coastal system of the North Carolina Coastal Province, notice how low and flat the land is – with extensive, water-filled drainage ditches occurring adjacent to the highways. The water in these ditches is generally at or close to sea level, and the roads are built on fill dirt dug from these ditches.

The ongoing rise in sea level results in the continuing upward and landward migration of the shoreline. The specific process of shoreline migration is better known as *shoreline erosion*. Rising sea level across the world means that erosion is common to all of North Carolina's thousands of miles of estuarine and ocean shoreline. The only differences are the rates of erosion that are dependent on local tectonic changes in the land, the underlying geologic framework, specific shoreline variables, and varying storm conditions. Locally, a segment of the shoreline may appear stable or actually accrete (add on) sediments. Such a situation represents either an anomalous set of local conditions or is ephemeral in nature.