Appendix G


Moa Lin/USFWS

View of refuge

Some Notes on Sea-level Rise and Projected Impacts on Chincoteague National Wildlife Refuge

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Introduction

Since the origin of the Earth, roughly 4.5 billion years ago, huge changes have occurred including the formation of continents, creation of the various oceans, and major climate shifts initiating numerous continental glaciations and causing fluctuations in sea levels. Given the recent changes in climate (e.g., melting of glaciers and polar ice, observed decreases in ice and snow, and rising air and ocean temperatures) and our interest in how this might affect the future of Chincoteague National Wildlife Refuge, the emphasis of this note is on the fluctuations of sea level in the Mid-Atlantic region and predictions of where sea level is going in the future. Chincoteague NWR has been listed as one of the 10 most endangered refuges threatened by global warming in a Defenders of Wildlife report (Schyler 2006).

For the last million years, the Earth's climate has changed from a cold ice age to a warm interglacial period back to an ice age roughly every 100,000 years. These changes have had enormous impacts on plant and animal life, human societies, and on sea level with lowest levels during cold periods and highest levels during warm periods. So changing sea level is not a recent phenomenon. During the warmest interglacial period about 130,000 years ago, the Earth's temperature was 2-3° F warmer than today's temperatures and ocean levels were 13-20 feet higher than today (Pew Center on Global Climate Change 2007).

The most recent cycle started over 100,000 years ago, when a 39-42°F (4-10° C) drop in global temperatures over thousands of years caused a major change in climate. Winter snows did not melt completely in summer in northern latitudes and as the snowpack accumulated, the weight of the snow caused ice to form below the surface. Ice formed on slopes then began to move downslope forming a glacier. This eventually led to the buildup and advance of continental ice sheets into lower latitudes. About 25,000 years ago, the Laurentide ice sheet moved out of Canada and about 18,000 years ago extended as far south as northern New Jersey and northeastern Pennsylvania on the East Coast. At this time, nearly half of North America was covered by a continental glacier over one mile thick in places (Figure 1). At this time, a significant amount of the Earth's fresh water was locked in glacial ice. Consequently, much fresh water was not returned to the oceans, leading to a significant drop in sea level: it was roughly 400 feet (120m) below its current level (Figure 2). What is now the "continental shelf" was the "coastal plain" 25,000 years ago (yellow areas in Figures 1 and 3). The Mid-Atlantic coast was roughly 40-50 miles offshore of its presentday location (Figure 3). This area was exposed for about 10,000 thousand years and was occupied by tundra and boreal forest much like what is found in Canada today. Elk, moose, and grizzly bears were dominant mammals

(Davis 2006). The waters were cold like Arctic waters and supported species like walrus, sea lions, and bearded seals (Harington 2008).

Figure 1. General extent of glacial ice and exposed continental shelves more than 25,000 years ago. (Source: Short 2008)

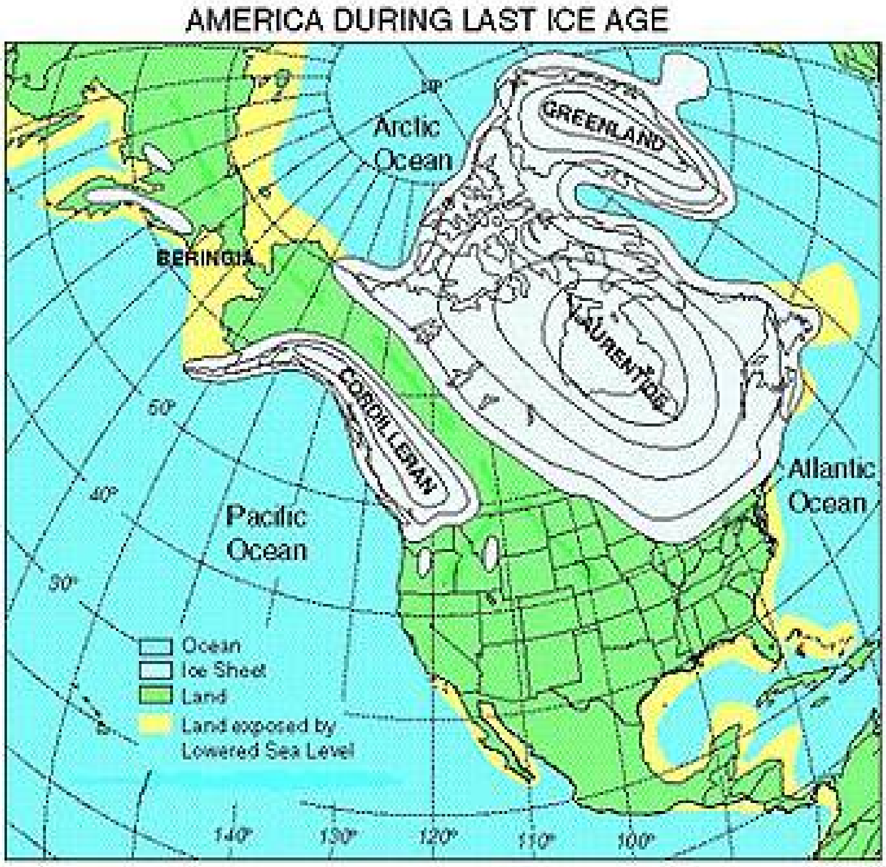


Figure 2. Changes in sea level over the past 18,000 years. (Source: Titus et al. 2009)

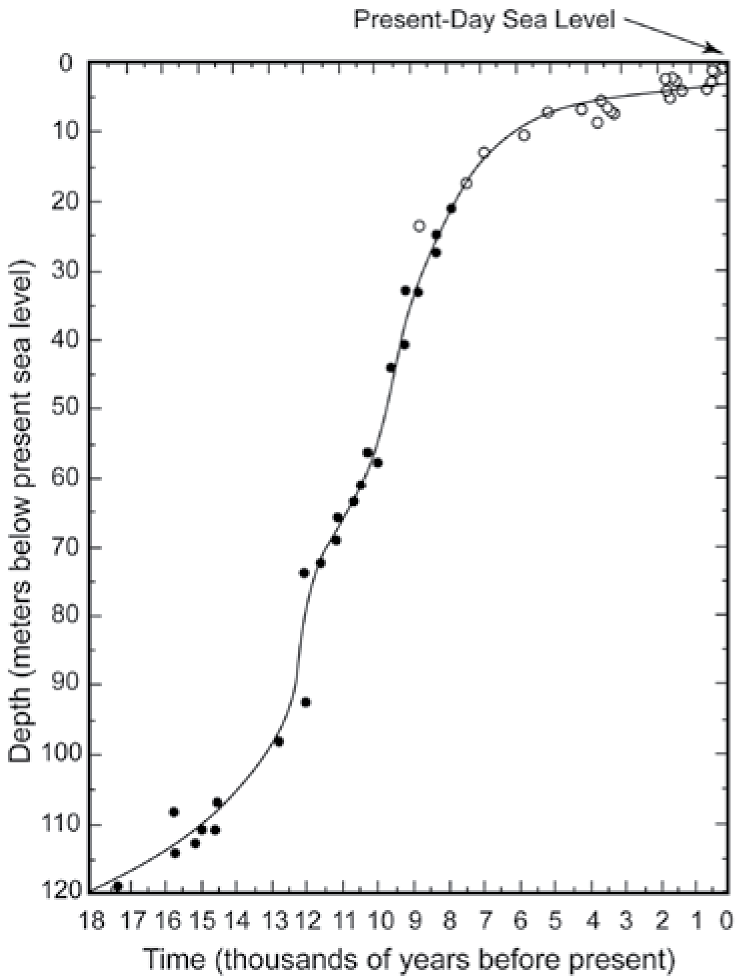
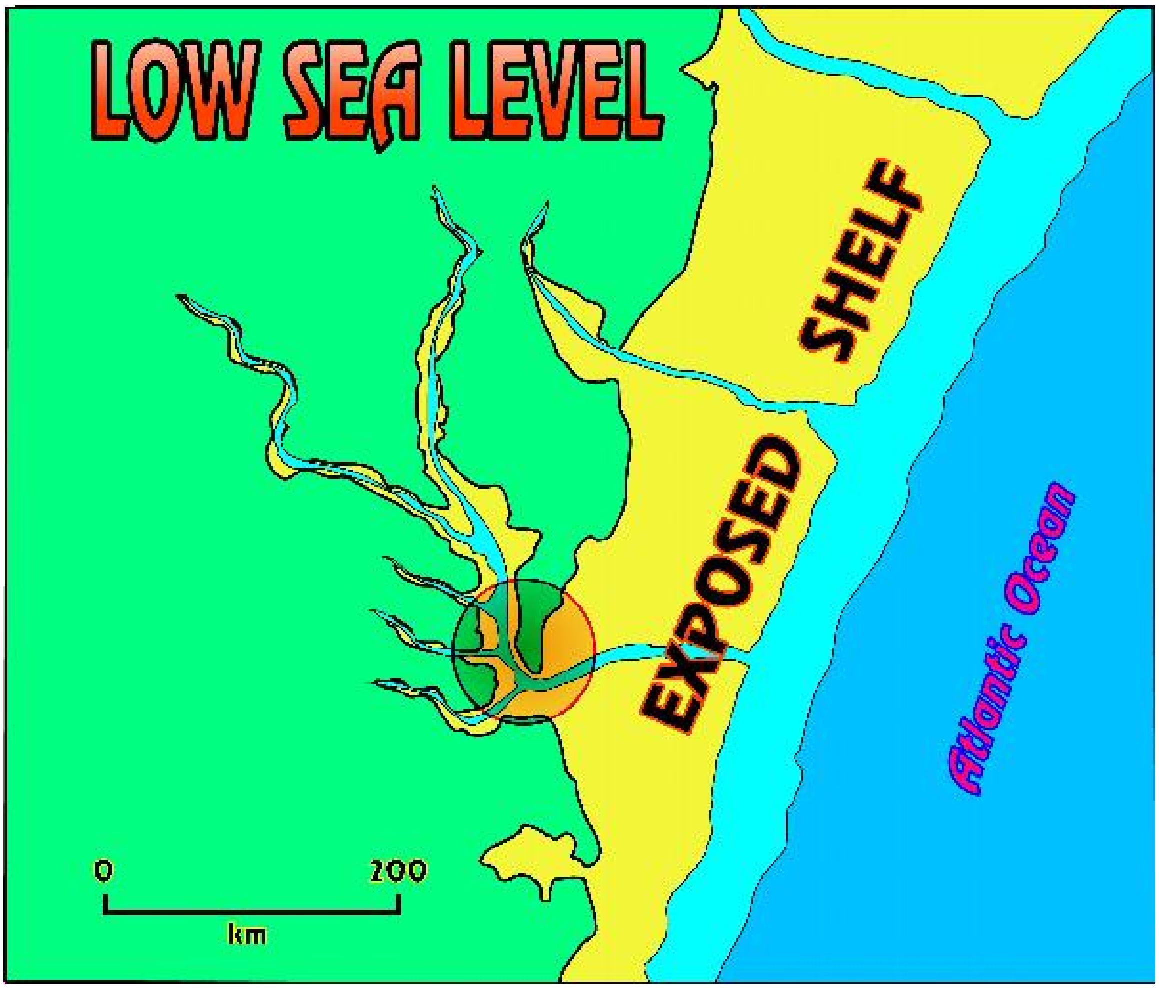


Figure 3. The western Atlantic shoreline showing continental shelf (yellow area), the "shore" more than 15,000 years ago when sea level was at its lowest recent level. (Source: U.S. Geological Survey, Coastal and Marine Geology, Woods Hole Field Center)



Climate began to change again about 15,000 years ago and the warmer temperatures caused the Laurentide glacier to begin melting. The meltwater ran off the land and into the ocean causing sea levels to rise. The rise was not a steady one, but was marked by a rapid increase from 15,000 to 8,000 years ago, at rates as high as 0.5m per decade (Hansen 2007)! Around 6,000 years ago, the rate of sea level slowed to 0.5mm/year due to a reduction in the rate of ice melting. This allowed shorelines to stabilize and the Mid-Atlantic shoreline may have looked much like it does today (minus the human-induced alterations, of course). These more stable conditions promoted the formation of barrier islands and spits that facilitated the establishment of coastal marshes in sheltered lagoons behind the protective barriers and along the low-lying shores of tidally influenced rivers. As sea level continued to rise at modest rates (less than 2mm/year), most tidal marshes were able to keep pace with the higher levels by raising their elevations through accumulation of organic matter and/or increased sedimentation, while others were able to move landward to suitable lowlands that would now be flooded frequently by tidal waters. This process continued for thousands of years and is still taking place where suitable lowlands are available for "marsh migration." Dead trees or stumps in today's marshes provide direct evidence of this migration (Figure 4). Human development of the coastal plain, however, has prevented this natural process in many places by the construction of bulkheads and similar structures that harden shorelines.

Figure 4. Dead trees in the marshes are a familiar site in some coastal wetlands.

Recent Sea-level Rise Rates

As global temperature rise, two main factors cause sea level to rise: 1) warming ocean waters expand (thermal expansion) and 2) melting of polar ice and continental glaciers (adds more water to the oceans). Reduction of snow cover and melting of mountain glaciers also contribute to sea level rise. Land subsidence is an important local factor affecting “relative” sea level rise. In some cases, human activities such as extraction of oil, gas, and groundwater in coastal regions that accelerate subsidence exacerbate the adverse impact of sea-level rise on coastal lands.

From 3000 years ago to the late 1800s (the beginning of the “industrial revolution”), the rate of sea-level rise was very low: 0.1-0.2mm/year (Titus et al. 2009). During the last century, the average global rise in sea level was 1.7mm/year (Church and White 2006). From 1993-2003, the rate of sea-level rise rose an average of 3.1mm/year (IPCC 2007). It is not clear whether this increase is simply a decadal response or an indicator of a longer term trend. It is, however, very likely that the losses of polar ice sheets during this decade significantly contributed to the increase (Titus et al. 2009).

Predicting the Future

At the outset, it is vital that due to the increased attention being given to sea level rise, readers recognize that information on this topic as well as climate change in general is expanding at a great pace. The discussion herein is based on information available in August 2009. We expect that in the future, additional information will be available to modify current predictions and expectations. In the 1990s, the United Nations Environment Programme and the World Meteorological Organization created the Intergovernmental Panel for Climate Change (IPCC), a multi-national scientific committee, to examine and interpret scientific information on climate change and its impacts on the environment and society.

The 2007 IPCC report on global climate change lowered predictions from their 1995 report. Now a 0.6-1.9 foot (7-23 inch or 18-59cm) increase in sea level is predicted over the next 100 years, whereas earlier, they were predicting a 0.3-2.9 foot rise by 2100. The new estimate excludes any increase in meltwater from the Greenland and Antarctica ice sheets. The IPCC admits that this is a very conservative estimate. Moreover, recent observations of accelerated ice flow and melting from Greenland and from western Antarctica glaciers could contribute substantially to increasing current sea levels (Titus et al. 2009). If the Greenland ice sheet disappeared, it would add 23 feet (7m) to sea level (IPCC 2007). (Note: During the last interglacial period, 125,000 years ago, reductions of polar ice led to a 13-20 foot (4-6m) rise in sea level.) It is interesting to note that the projected rise may not be a simple steady increase in sea levels, but instead may be rapid due to a quick collapse of large portions of the polar ice sheets (Pew Center on Global Climate Change 2007). A 2007 study that accounted for continued increases in greenhouse gas emissions predicted that sea level could rise 1.6-4.5 feet (0.5-1.4m) by the end of the 21st century (Rahmstorf 2007). This work and the view of other climatologists suggest that global sea level could rise by 3.3 feet or more (one meter or more) by 2100 and that it may rise meters more over the next several centuries.

Mid-Atlantic Impacts

In the Mid-Atlantic region (New Jersey through Virginia), sea level is rising due to global changes and to land subsidence. During the past century, sea-level rise rates were higher than global rates, ranging from 2.4-4.4 mm/year which translated to about a one-foot rise (0.3m) by 2000. These rates are the highest rates of sea-level rise in the United States, excluding Louisiana and Texas where human-induced coastal subsidence is significant contributing factor (Titus et al. 2009).

Rising seas are already changing the coast, submerging the lowest tidal wetlands, eroding coastal beaches, increasing flooding of lowlands, and altering salinity regimes in coastal waters. Low salt marshes are being converted to tidal flats, while existing tidal flats are becoming permanently inundated shallow water habitats. In places of more pronounced erosion, marshes are changing directly to shallow waters. With increased tidal flooding, high marshes are changing to low marshes, and low-lying uplands or neighboring freshwater wetlands are becoming high marshes. Also, salt water is penetrating further upstream changing the local ecology. While this process has occurred in the past, the pace at which these changes are happening has accelerated and their magnitude has increased in recent times. These changes have important consequences to fish and wildlife dependent on estuaries. The rapidity of the changes will likely overwhelm the ability of many animals to adapt to the new conditions.

Climate change may also increase storm frequency and intensity which will further threaten shorelines and coastal resources. The shoreline of Assateague Island, already threatened by erosion from the current sea-level rise rate, is even more vulnerable with predicted increases of 2mm/year (Figure 5). If the rate increases by a little as 2mm/year, the island may begin migrating landward and may break up into smaller sections (segmentation). This same rate will likely pose increased risk to backbarrier marshes (Figure 6). The impacts of a 7mm/year rise would be devastating.

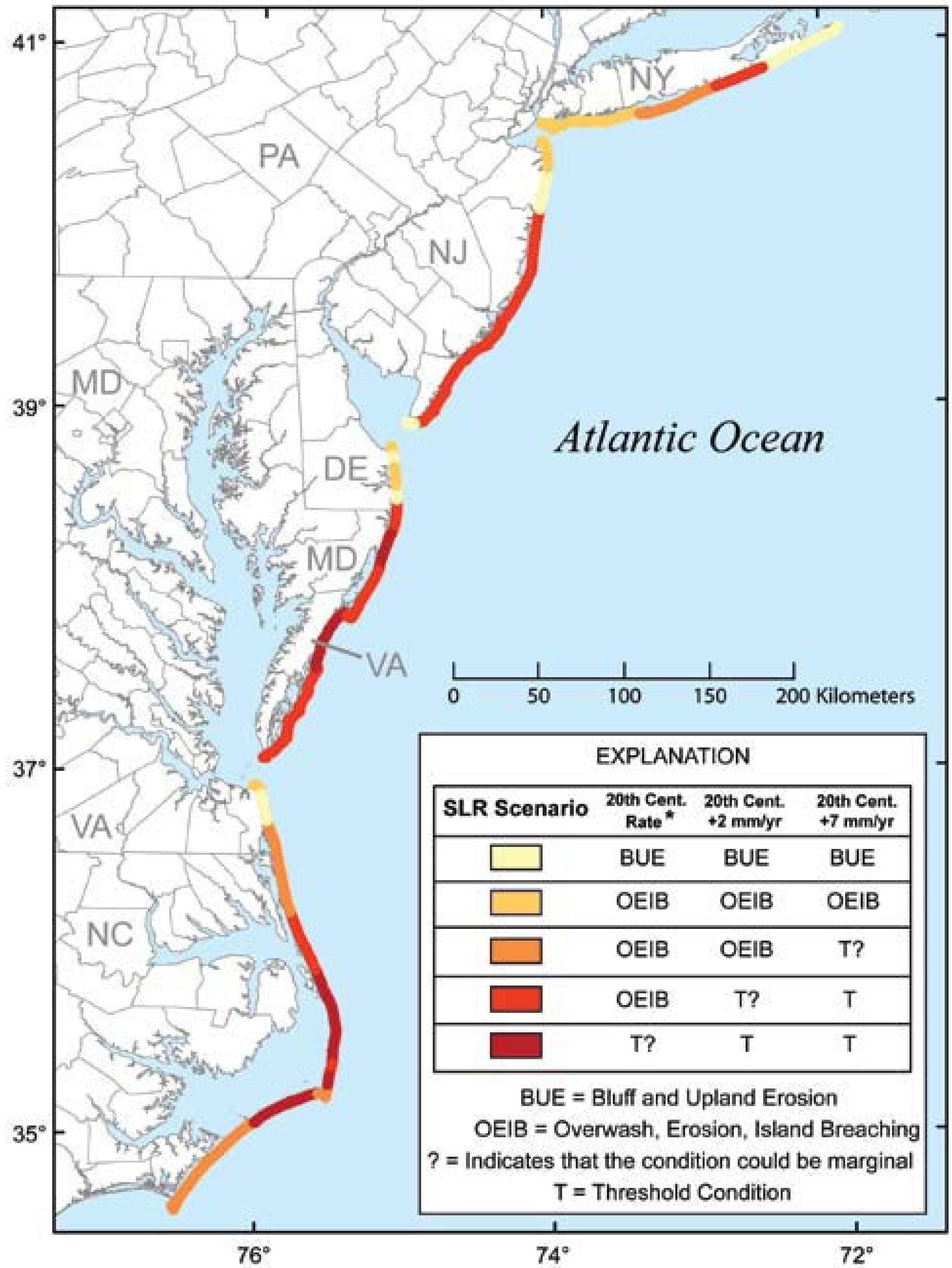


Figure 5. Map showing that Assateague Island may already be near its threshold condition and that just a 2mm/year rise in the rate of sea-level rise will push it over the threshold which may initiate barrier beach migration and segmentation. (Source: Titus et al. 2009)

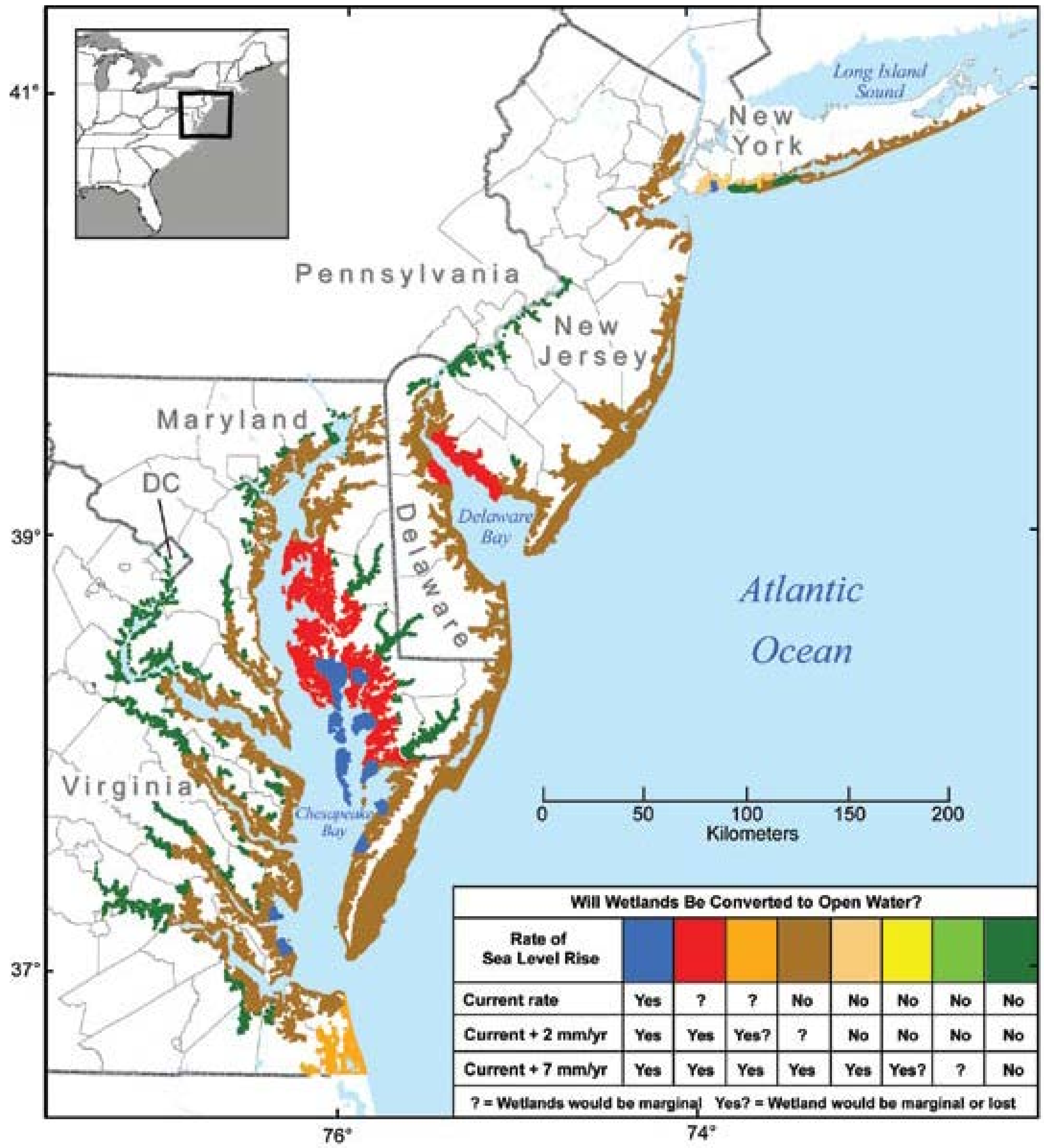


Figure 6. Map showing where tidal wetlands may be converted to open water at three rates of sea-level rise. A 2mm/year rise in the rate should continue the conversion of low marsh to tidal flat and may even transform these marshes to open water. (Source: Titus et al. 2009)

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