



## Sea Level Rise Risk Assessment for DoD Coastal Installations

Project # 08-410

### Background:

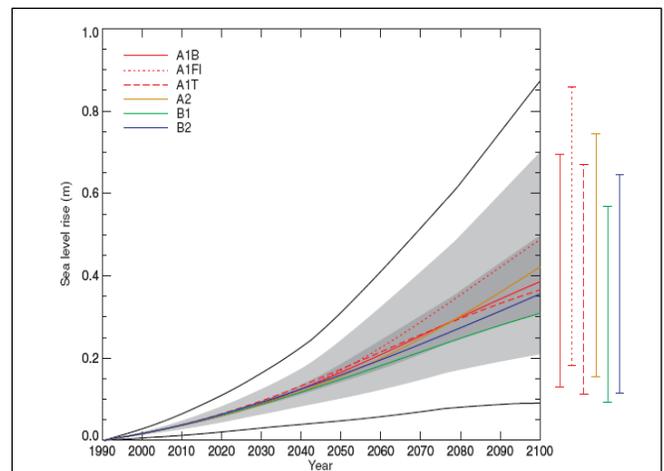
The consensus of the international scientific community is that future sea-level rise based on climate model output will result in an increase in global eustatic sea-level of between 0.5-3.1 feet by 2100, with a "best estimate" of 1.6 feet. This is more than double the rate of eustatic (global sea level) rise for the past century. These sea level rise projections were recently updated in the 2007 Intergovernmental Panel on Climate Change (IPCC) which reported a 0.9 to 1.4 feet rise in sea level by 2100. Uncertainty in ice-sheet decay models has some scientists calling the estimate "conservative". A report in the January 2007 issue of *Science* calls for a 1.6 to 4.6 foot increase in sea level rise by 2100. Coastal North Carolina has been identified as one of the United States most vulnerable regions to climate change. More than 2,000 square miles of North Carolina's coastal ecosystems and urban areas are below one-meter elevation and within the range of projected sea level rise from climate change for the year 2100. Recent studies have demonstrated that, as climate change contributes to inundation, increased shoreline erosion and higher hurricane intensity, coastal DoD installations may experience significant losses in the absence of mitigation and local adaptation.



The shore line of Dare County, NC illustrates the conversion of coastal forests to open water. As the sea level rises forests are first replaced with shrub and marsh vegetation and then gradually transition to open water. Tree boles from what was formerly forestland can be seen rising from the sound.

### Objective:

Given current controversy regarding observed sea level rise in the 20th century, it is not surprising that there is a wide range of predictions of sea level rise for the 21st century. Future sea level rise consists of contributions from continued warming of the ocean as well as melting of glaciers, small ice sheets and Greenland. Installation natural and cultural resources and operations managers would like a particular value of sea level rise to be associated with a specific



Intergovernmental Panel on Climate Change sea level rise scenarios illustrating the range and rate of sea level rise projections. Additional fixed rates of sea level rise were added to SLAMM modeling for inclusion of additional glacial and polar ice cap melting projections.

probability of occurrence. It is important to note that the main cause of uncertainty prior to about 2050 is caused by the lack of agreement on the processes that cause ice sheet melt and associated dramatic increases in sea level rise. Because of the thermal inertia of the oceans, there is little difference in the various sea level rise projections before about 2050, after which different rates of warming due to different projections of future greenhouse concentrations result in large differences in sea level rise. We conducted risk assessments of natural, cultural, and operational resources at risk in five coastal DoD installations in North Carolina (Air Force Dare County Bombing Range, Marine Corps Air Station and Naval Aviation Depot Cherry Point, Marine Corps Base Camp Lejeune, Military Ocean Terminal Sunny Point, and Navy Harvey Point).

**Summary of Approach:**

We used available LiDAR digital elevation data for installations and geospatially referenced inventories of natural, cultural, and operations resources. Internationally recognized sea level rise model scenarios from the most recent 2007 IPCC assessment were used to project best and worse case sea-level rise scenarios to 2100. Changes in vegetation land cover and open water in response to sea-level rise were modeled using the SLAMM model that simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. Successive versions of the model have been successfully demonstrated to estimate impacts sea-level rise on the coasts of the U.S. by the US EPA, US Fish and Wildlife Service, and the National Wildlife Federation. Risk assessments of natural, cultural, and operations resources on installations were projected at ten year intervals to 2100. GIS map products and inventories of resources at risk were produced for each installation during the project. Potential mitigation strategies are discussed for each installation.

**Benefit:**

Climate change will stress the U.S. military by affecting weapons systems and platforms, bases, and military operations. The nature and rate of climate change being observed today and the future consequences being publicly debated by the international scientific community are grave and pose challenges to our national security and the natural and cultural resource of DoD installations. The project’s sea level rise risk assessment moves beyond the arguments of cause and effect and begin planning to address its potentially devastating effects. The consequences of climate change and sea level rise are clear, the disruption of the organization, training, equipping, and planning of the military services. The goal of this project is to quantify the risk of sea level rise on the ability of the services to execute its mission in support of national security and the stewardship of the nation's natural and cultural resources. The project also contributes to state and regional climate change initiatives.

**Accomplishments:**

A summary of sea level rise projections for North Carolina coastal installations indicates that DoD installations will have varying degrees of risk based on actual sea level rise from present to 2100. The two installations facing the greatest risks from sea level

rise are DCBR and Cherry Point Piney Island (BT11). SLAMM simulations indicate that a moderate sea level rise of approximately 0.7 m will flood large portions of these installations. Installations facing moderate risk include Harvey Point, Cherry Point OLF Atlantic, and MCB Camp Lejeune. Impacts from simulations of sea level rise indicate that some base operations could be hindered due to flooding or saturation of infrastructure. Generally these impacts are limited in their spatial extent on the facility. Facilities with minor impacts from sea level rise include the main installation at Cherry Point and Sunny Point.

*Summary of sea level rise risk for NC coastal installations.*

Installation	Sea Level Rise Scenarios			
	1.0 m	A1B Max	A1B Mean	A1B Min
Harvey Point	Moderate	Moderate	Minor	Minor
DCBR	Severe	Severe	Severe	Moderate
Cherry Point	Minor	Negligible	Negligible	Negligible
Piney Island	Severe	Severe	Severe-moderate	Moderate
OLF Atlantic	Moderate	Minor	Minor	Minor
Camp Lejeune	Moderate	Moderate	Minor	Minor
Sunny Point	Minor	Minor	Negligible	Negligible

Determining the risks involved with sea level rise requires an understanding of the systems involved as well as uncertainty associated with the characterization of those systems. The two major sources of uncertainty for this analysis are the future changes in sea level and the response of wetland ecosystems to higher ocean levels. There is a scientific consensus building that eustatic sea level rise will be approximately a meter by 2100. This level will have considerable impacts on the coastal installations in low-lying areas. This study presents results from simulations of various levels of sea level rise in order to address scientific uncertainty surrounding this phenomenon.

Another source of uncertainty involves the response of the marshes and swamps to sea level rise. Accretion is highly variable in space and time. The highest measured values of accretion may be able to keep pace with rising seas. Dynamics and processes at spatial extents too small for the SLAMM model to

consider may slow relative sea level rise rates. Further research is needed to determine under what conditions marshes and swamps will be able to sustain themselves in the face of rising ocean levels.

A close look at the impacts of sea level rise on one installation in coastal North Carolina, the Air Force Dare County Bombing Range, illustrates that SLAMM simulation runs project that sea level rise will radically alter the land cover on the Dare County Peninsula and on the bombing range. Upland losses range from nearly 100% for the 1.5 m rise to 58% for the A1B Minimum scenario during the 2010 to 2100 time period. Forested wetland losses range from 90% to 4% for 2010 to 2100. Inland freshwater marsh losses range from 55% to 0.4% for the same time period. Only simulations using the A1B minimum scenario (eustatic sea level rise by 2100 = 0.15 m) indicate that most of the bombing range will stay intact by 2100. Other scenarios indicate that estuarine open water will replace more than a third of the wetlands on the bombing range by 2100.

Simulation results underscore the vulnerability of the DCBR and the surrounding area due to low elevation throughout the Dare County peninsula. Forested wetlands readily convert to wetter wetland types such as salt marsh, marsh transition, and brackish marsh. These marshes, in turn, transition to tidal flats and then open water 50 to 90 years into the model simulations. Even a moderate acceleration in the rates of sea level rise floods large parts of the peninsula by mid century.

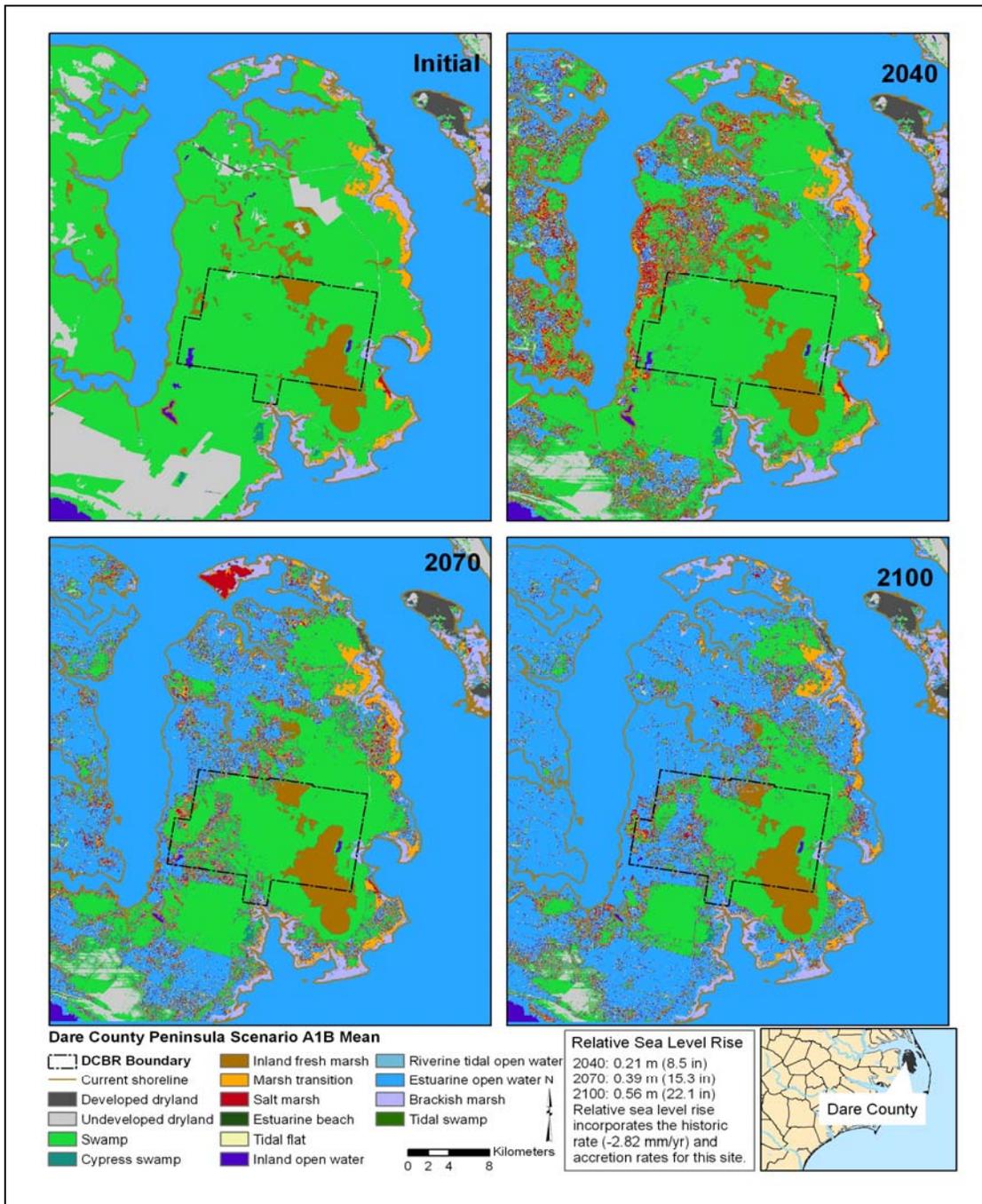
Impacts from sea level rise will eliminate installation functionality due to poor access and the flooding of base infrastructure. Other impacts will include degradation of habitat for rare species such as the American alligator and the red-cockaded woodpecker. Migratory birds and water fowl use this area as a corridor and wintering grounds, the flooding of the forested wetland and marshes will limit the habitat they can use in this area of North Carolina.

Changing environmental conditions may have an impact on accretion values, the rate at which new soil is formed from sediment capture and vegetation litter. The level of salinity is an environmental condition affecting accretion rates in the Dare County peninsula. In general, as salinity levels increase, accretion rates decrease. Inundation of salt marshes may increase accretion rates due to increased nutrient

supplies. Alternatively, saltwater intrusion may accelerate decomposition thus decreasing vertical accretion. More information is needed to determine the impact of salinity on accretion within the Dare County Peninsula. The presence of an extensive ditch and canal system has altered the hydrology of the Dare County peninsula, allowing saline water from the Pamlico estuary to intrude into the interior. Botanists working in this area have noticed more salt tolerant species closer these canals, suggesting that saline water from the canals has entered into the water table, affecting plant composition. A sea level rise mitigation strategy to remedy to impacts from saline water could include the re-establish of oyster reefs and coastal marshes, and the installation of tide gates. Oyster reefs would reduce shoreline erosion and increase the rate of re-establishment of marshes. Tide gates act as one-way valves: allowing fresh water from the peninsula to flow into the estuary, but prevents saline estuary water from entering the canals. The Nature Conservancy and other partners have supported the installation of these structures in order to sustain the productivity and composition of the plant communities living on the Dare County peninsula.

	<b>Dare County Bombing Range</b>		
<b>Land Cover Class (ha)</b>	<b>2010</b>	<b>2050</b>	<b>2100</b>
<b>Undeveloped Upland</b>	69	31	14
<b>Forested Wetland</b>	15,176	14,672	9,797
<b>Inland Fresh Marsh</b>	3,334	3,321	3,128
<b>Marsh Transition</b>	35	362	1,147
<b>Salt Marsh</b>	1	169	1,547
<b>Tidal Flat</b>	0	1	142
<b>Inland Open Water</b>	142	116	72
<b>Estuarine Open Water</b>	2	85	2,916
<b>Brackish Marsh</b>	109	108	104

*Example of vegetation change for a moderate sea level rise scenario. Forested wetlands are reduced by 36% by 2100 and converted to marsh and open water. Estuarine open water covers 15% of the installation by 2100.*



*Land cover change for a moderate sea level rise projection at one NC coastal installation illustrates the dramatic conversion of land to open water for the Dare County, NC peninsula. Under the moderate IPCC sea level rise scenario all Air Force and Navy testing and training operations will be halted by 2100 and major interruptions will begin by 2050 as forest land converts to wetter marsh transition vegetation.*

**Contact Information:**

Robert Mickler  
 Project Manager  
 Alion Science and Technology  
 1000 Park Forty Plaza, Suite 200  
 Durham, NC 27713  
 919.406.2104  
 919.549.4665  
 rmickler@alionscience.com