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FACT SHEET

The US Military on the Front Lines of Rising Seas

Exposure to Coastal Flooding at Naval Air Station Oceana Dam Neck Annex, Virginia

HIGHLIGHTS

With seas rising at an accelerating rate, coastal military installations are increasingly exposed to storm surge and tidal flooding. The Union of Concerned Scientists (UCS) conducted analyses of this changing exposure for 18 military installations along the East and Gulf coasts. Analysis for Naval Air Station (NAS) Oceana Dam Neck Annex, Virginia, found that in the second half of this century, in the absence of preventive measures, this installation can expect more frequent and extensive tidal flooding, loss of currently utilized land, and substantial increases in the extent and severity of storm-driven flooding to which it is exposed.

The US Armed Forces depend on safe and functional bases, such as NAS Oceana Dam Neck Annex ("Dam Neck"), Virginia, to carry out their stated mission: to provide the military forces needed to deter war and to protect the security of the country. A roughly three-foot increase in sea level would threaten 128 coastal Department of Defense (DOD) installations in the United States and the livelihoods of the people—both military personnel and civilians—who depend on them (NAS 2011). In the area of Dam Neck, seas are projected to rise between 4.5 and 6.9 feet by the end of this century.

To enable decision makers to better understand the sea level rise threat, and where and when it could become acute, UCS has performed a new analysis of 18 East and Gulf coast military installations, including Dam Neck.[1] These sites were selected for their strategic importance to the armed forces, for their potential exposure to the effects of sea level rise, and because they represent coastal installations nationwide in terms of size, geographic distribution, and service branch.

UCS projected exposure to coastal flooding in the years 2050, 2070, and 2100 using the National Climate Assessment's midrange or "intermediate-high" scenario (referred to here as "intermediate") and, in light of the low tolerance for risk in some in the military's decisions, a "highest" scenario with a more rapid rate of

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THE INLAND MARCH OF HIGH TIDE

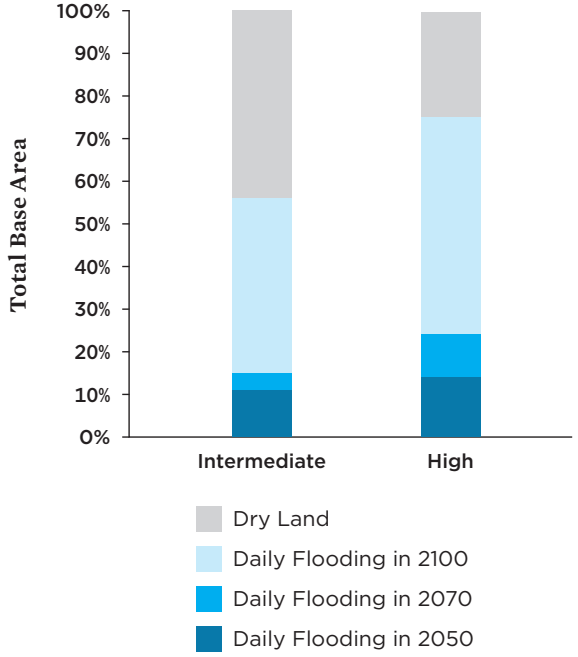
Dam Neck is located on the Atlantic coast in the Hampton Roads area of Virginia, a region where natural subsidence, low-lying topography, and changing ocean circulation patterns contribute to above-average rates of sea level rise. By 2100, between roughly one half and three quarters of the station's land area could be inundated by daily high tides, depending on the pace of sea level rise.

increase (Parris et al. 2012).[2] We modeled tidal flooding, permanent inundation, and storm surge from hurricanes.[3] The results below outline potential future flooding to which Dam Neck could be exposed, assuming no new measures are taken to prevent or reduce flooding.[4] This analysis finds the following key results:

TIDAL FLOODING, PERMANENT INUNDATION, AND LAND LOSS

- **Sea level rise threatens to permanently inundate certain areas**. If the wetland areas of Dam Neck do not naturally adapt to rising seas, they could flood hundreds of times per year by 2050 in either scenario. In the intermediate scenario, these areas are underwater about 95 percent of the year by 2100; in the highest scenario, they are always underwater.
- **Extensive land loss at Dam Neck is possible**. The highest scenario projects 6.9 feet of sea level rise by 2100, which puts 75 percent of Dam Neck underwater during daily high tides—roughly equal to the area exposed to flooding by a Category 1 hurricane today.

FIGURE 1. Dam Neck Will Experience Land Loss



As high tide reaches farther inland at Dam Neck, extensive land loss is possible. Affected land may include developed and undeveloped areas and even wetlands that reside above the current high water mark. In both scenarios, Dam Neck loses currently developed and utilized areas.

STORM SURGE

- **Sea level rise exposes previously unaffected areas of Dam Neck to storm surge flooding**. Dam Neck is highly exposed to storm surge today, with roughly 75 percent of the station exposed to flooding during a Category 1 storm. By 2100, a Category 1 storm under either scenario exposes at least 95 percent of the station to storm surge flooding.
- **Sea level rise exposes Dam Neck to deeper, more severe flooding**. In an end-of-century worst-case scenario involving a Category 4 storm, nearly 60 percent of the installation floods to a depth of 20 or more feet.

Base Information

Dam Neck is located within the Hampton Roads metropolitan area, one of the East Coast's regions most vulnerable to sea level rise because of its low-lying topography and natural subsidence (VIMS 2013). The station, which is part of the larger NAS Oceana, lies along the Atlantic coast and is five miles south of the town of Virginia Beach. Much of Dam Neck's land lies less than six feet above sea level. It is also situated within an East Coast sea level rise hot spot, where these local factors combine with changing ocean circulation patterns to create above-average sea level rise (Sallenger, Doran, and Howd 2012).

Dam Neck

Branch:	Navy
Established:	1941
Size (Acres):	1,100
Personnel:	5,600
Tenant Commands:	12 to 20
Students Annually:	20,000

SOURCE: DOD 2016.

The Navy's pilots receive fleet combat and tactical training at Dam Neck (City of Virginia Beach 2016). The station is also home to the Naval Special Warfare Development Group. Along with NAS Oceana and Naval Auxiliary Land Field Fentress, both located nearby, Dam Neck is responsible for generating more than $1 billion in goods, services, and payroll each year (City of Virginia Beach 2016).

Historic Exposure to Storm Surge and Flood Hazards

The Hampton Roads region has long endured flooding from hurricanes and lesser storms (HRPDC 2011). Because the to-

pography and geology of the region make it naturally vulnerable to sea level rise, coastal flooding problems are worsening (VIMS 2013; HRPDC 2012). Rising seas have already led to problematic high tide flooding in the region (Spanger-Siegfried, Fitzpatrick, and Dahl 2014; Sweet et al. 2014).

Since 1857, 65 hurricanes have passed within 150 nautical miles of the Hampton Roads areas (NOAA n.d.). In 2003, Hurricane Isabel caused a storm surge along the Virginia coast that was four feet or more and caused severe flooding (Beven and Cobb 2014; Murphy 2013).

Dam Neck is particularly vulnerable to sea level rise because of its low-lying topography and natural subsidence.

Dam Neck conducts beach nourishment along its shoreline every eight years and maintains a large dune that was built to protect upland infrastructure from storm surge (Lauterbach 2016). This may protect the station from surge during certain storm configurations and approaches. But because the dune does not extend along the whole shoreline, parts of the station (especially north and south of the dune) are still exposed to flooding from storm surge as well as from seawater entering through Shipps Bay to the south.

TABLE 1. Dam Neck Could See More than Six Feet of Sea Level Rise by 2100

Year	Intermediate	Highest
2050	1.4	2.0
2070	2.5	3.6
2100	4.5	6.9

In the intermediate scenario, ice sheet loss increases gradually in the coming decades; in the highest scenario, more rapid loss of ice sheets occurs. The latter scenario is included in this analysis to help inform decisions involving an especially low tolerance for risk. Moreover, recent studies suggest that ice sheet loss is accelerating and that future dynamics and instability could contribute significantly to sea level rise this century (DeConto and Pollard 2016; Trusel et al. 2015; Chen et al. 2013; Rignot et al. 2011). Values shown are local projections that include unique regional dynamics such as land subsidence (see www.ucsusa.org/MilitarySeasRising).

Future (Projected) Exposure to Storm Surge and Flood Hazards

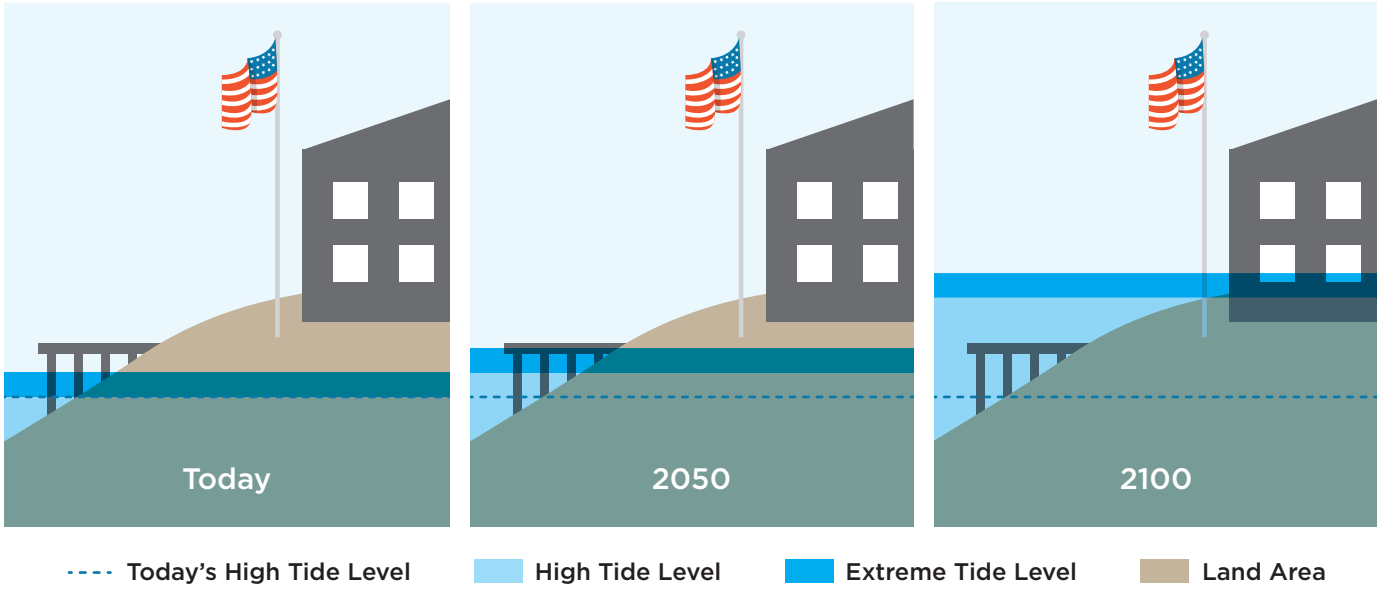
SEA LEVEL RISE

Dam Neck experiences 4.5 feet of local sea level rise by 2100 in the intermediate scenario and nearly seven feet of rise in the highest scenario, which leads to increased exposure to different types of coastal flooding.

US Navy

Marines, sailors, and local elementary school students participate in a beach run at Dam Neck Annex. In the backdrop is the 1 mile-long engineered dune that is maintained to protect the inland infrastructure from storm surge.

FIGURE 2. How Sea Level Rise Causes Tidal Flooding and Land Loss



As sea level rises, extreme tides cause local flood conditions to occur more often, to a greater extent, and for longer time periods. And the daily high tide line can eventually begin to encompass new areas, shifting the tidal zone onto presently utilized land. In this analysis, land inundated by at least one high tide each day is considered a loss. This is a highly conservative metric: far less frequent flooding would likely lead to land being considered unusable.

TIDAL FLOODING AND LAND LOSS

Dam Neck's extremely low elevation and susceptibility to flooding from both its immediate coastline and from the south via Shipps Bay greatly expose it to sea level rise and, eventually, land loss.

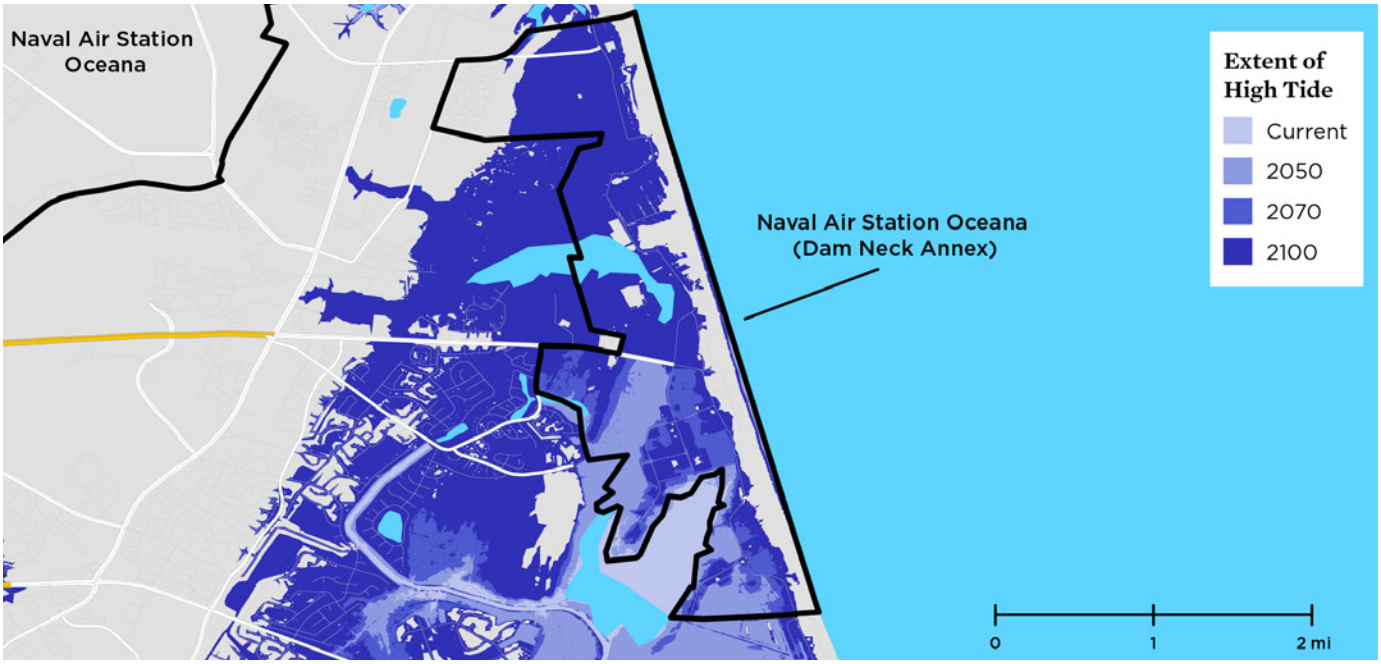
Flood-prone areas in this region experience about nine floods per year today. By 2050, that number rises to roughly 280 in the intermediate scenario and to 540 in the highest scenario. In the highest scenario, about 15 percent of the station's land area is underwater at high tide.

TABLE 2. Flood-Prone Areas Could Be Underwater 100% of the Time by 2100

	Intermediate		Highest	
Year	Events per Year	% of Year	Events per Year	% of Year
2012	9 ± 4	0	9 ± 4	0
2050	276 ± 16	10	538 ± 26	26
2070	641 ±17	40	525 ± 26	77
2100	124 ±27	96	1 ± 0	100

As flood conditions in low-lying areas begin to span multiple high tide cycles, the number of distinct flood events gradually drops toward one, while the duration of floods increases until flooding is constant. Installations such as Dam Neck will be affected by tidal flooding depending on the presence of flood-prone land on-site. Events per year are reported as the average over a five-year period with one standard deviation. Percent of year is reported simply as the average over a five-year period.

FIGURE 3. Dam Neck Is Expected to Lose Currently Utilized Land to the Sea



Future daily high tides, shown on the top, are projected to inundate currently utilized land at Dam Neck, shown on the bottom. The highest scenario is mapped here.

SOURCE: IMAGE © TERRAMETRICS. DATA FROM SIO, NOAA, US NAVY, NGA, AND GEBCO.

During the final decades of the century, flood events in this area will begin to span many high tide cycles. As a result, the number of individual flood events will decrease but the duration of floods will increase. Flooding will be essentially constant and the affected land permanently inundated. In the highest scenario, flood-prone areas throughout the region experience flooding with each of the two daily high tides and are underwater more than 75 percent of the time by 2070. By 2100, high tide engulfs 75 percent of Dam Neck's area—an area equivalent to that flooded by Category 1 hurricanes today.[5]

Extra-high tidal flooding—flooding that reaches beyond the daily tide—is expected to become both more extensive and more frequent. Today, the wetland areas of Dam Neck flood during extra-high tides nine times per year on average. But in both scenarios, those areas are permanently inundated by 2100. Extra-high tides engulf more than 80 percent of the station's land area by that year in the highest scenario.

By 2100, high tide could engulf 75 percent of Dam Neck's area.

THE CHANGING THREAT OF HURRICANES

Category 1 hurricanes are the most likely type to affect this area.[6] Today, a Category 1 storm exposes roughly 75 percent of the installation to flooding resulting from storm surge; sea level rise increases that exposure. In both scenarios, a Category 1 storm hitting in 2100 causes 95 percent of the station to flood—the area that would flood in a Category 3 storm today.

Flood depth also increases as sea level rises. Today, only 5 percent of the station floods to a depth of five or more feet during a Category 1 storm. But in both scenarios, more than half the station floods to this depth in 2100.

All of Dam Neck is exposed to flooding from Category 3 and Category 4 hurricanes today. While sea level rise will not increase the extent of inundation at the installation from Category 3 or 4 storms, it will affect inundation depth. Today, less than 1 percent of the station experiences flooding 20 or more feet deep during Category 4 storms. In the highest scenario, almost 20 percent of the station experiences this extremely deep flooding by 2070. By 2100, almost 60 percent of the installation floods to a depth of 20 or more feet.

Mobilizing on the Front Lines of Sea Level Rise

A vital trait of our nation's military is its ability to adapt in response to external threats. Climate change and sea level rise have emerged as key threats of the 21st century, and our military is beginning to respond (Hall et al. 2016; USACE 2015; DOD 2014). Recognizing the threat, Dam Neck is managing its flood risks using multiple measures, including beach nourishment and the maintenance of a one-mile-long rock-core dune that helps to protect upland infrastructure (Lauterbach 2016).

US Navy

Dune management activities at Dam Neck in spring, 2010, when sailors planted 13,000 dune-stabilizing grass plants as part of broader efforts to maintain the dune as an effective storm surge barrier.

But here and across US coastal installations, there is still far to go: the gap between the military's current sea level rise preparedness and the threats outlined by this analysis is large and growing. Low-lying federal land inundated by rising seas, daily high-tide flooding of more elevated land and infrastructure, and destructive storm surges—most of the installations analyzed, including Dam Neck, face all of these risks.

This analysis provides snapshots of potential future exposure to flooding at Dam Neck. For the Navy to take action on the front line of sea level rise, however, it will need more

detailed analysis and resources to implement solutions. Congress and the DOD should, for example, support the development and distribution of high-resolution hurricane and coastal flooding models; adequately fund data monitoring systems such as our nation's tide gauge network; allocate human, financial, and data resources to planning efforts and to detailed mapping that includes future conditions; support planning partnerships with surrounding communities; and allocate resources for preparedness projects, on- and off-site, many of which will stretch over decades.

Military bases and personnel protect the country from external threats. With rising seas, they find themselves on an unanticipated front line. Our defense leadership has a special responsibility to protect the sites that hundreds of thousands of Americans depend on for their livelihoods and millions depend on for national security.

ENDNOTES

1 *NAS Oceana is a Naval complex that includes several installations. This analysis focuses on Dam Neck Annex only.*

2 *The intermediate sea level rise scenario assumes ice sheet loss that increases over time, while the highest scenario assumes rapid loss of ice sheets. The latter scenario is particularly useful for decisions involving an especially low tolerance for risk. These results are a small subset of the full analysis. For more information, the technical appendix, and downloadable maps, see www.ucsusa.org/MilitarySeasRising.*

3 *UCS analyzed storm surge depth and exposure extent for each base using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, developed by the National Oceanic and Atmospheric Administration (NOAA), for storm events ranging in severity from Category 1 to Category 4 in addition to tidal floods. Both storm surge and flooding during extra-high tides can be significantly exacerbated by rainfall and wave action, neither of which we included in this study.*

4 *This analysis involved consultation with Dam Neck. However, preventive measures may be planned or in place that are not reflected in the analysis; these could affect the degree of current and future flooding.*

5 *This flooding does not come directly from the ocean. Rather, seawater inundates the station at high tide via Shipps Bay and the wetlands to the south of the base.*

6 *Nor'easters are more common in the region and known to generate damaging storm surge. As SLOSH models only hurricanes, we did not include lesser storms such as nor'easters in this analysis. Increases in surge extent and depth should be expected with these storms as well.*

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