

The US Military on the Front Lines of Rising Seas

Exposure to Coastal Flooding at Naval Air Station Key West, Florida

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) Key West 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 Key West, Florida, 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).

Low-lying Florida faces rising sea levels along its 1,200-mile coastline: water is encroaching from both the Atlantic and the Gulf coasts and up through the Everglades (Oskin 2013). The situation is acute in the Florida Keys, where seas are projected to rise between 3.8 and 6.2 feet over the course of this century. Most of the Keys' land area lies at elevations of three feet or less above sea level (Halley, Vacher, and Shinn 1997).

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 NAS Key West. 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



THE INLAND MARCH OF HIGH TIDE

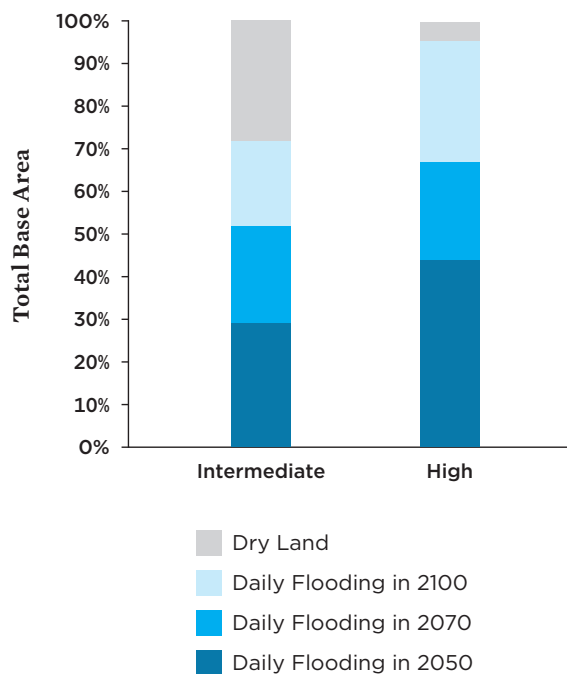
NAS Key West is located in the low-lying Florida Keys. The Keys are uniquely vulnerable to sea level rise because they sit atop porous limestone, which allows salt water to penetrate up through the ground and limits the effectiveness of sea walls and levees. By 2100, between 70% and 95% of the station is projected to be inundated by daily flooding.

some of the military's decisions, a "highest" scenario based on a more rapid rate of increase (Parris et al. 2012).¹ We modeled tidal flooding, permanent inundation, and storm surge from hurricanes.² The results below outline potential future flooding to which NAS Key West could be exposed, assuming no new measures are taken to prevent or reduce flooding.³ This analysis finds the following key results:

TIDAL FLOODING AND LAND LOSS

- **Areas currently unaffected by tidal flooding could flood with each high tide.** Extreme high tides do not typically flood NAS Key West today. But in the intermediate scenario, low-lying areas are inundated 300 times per year by 2050.
- **Flooding during extreme high tides will become more extensive.** In the intermediate scenario, extreme-tide flooding encompasses more than half of NAS Key West's land area by 2050; in the highest scenario, such flooding encroaches on the runways of Boca Chica Field.

FIGURE 1. Major Land Loss Is Projected for NAS Key West



As high tide reaches farther inland, extensive land loss is possible at NAS Key West. Affected land may include developed and undeveloped areas and even wetlands that reside above the current high tide mark. NAS Key West is projected to see substantial loss of currently developed and utilized areas, particularly with the faster rate of sea level rise.

- **Extensive land loss at NAS Key West is possible.** Some parts of NAS Key West are projected to flood with such frequency by 2070 that they would effectively be part of the tidal zone as opposed to dry, usable land. Indeed, given about four feet of sea level rise by the end of the century, as projected in the intermediate scenario, high tides would encompass roughly 70 percent of the station's land area; with just over six feet of rise, as projected in the highest scenario, high tides would encompass 95 percent of the area.

STORM SURGE

- **Sea level rise exposes previously unaffected areas of NAS Key West to storm surge flooding.** Today, about 80 percent of NAS Key West is exposed to flooding by Category 1 storms; in either scenario, 95 percent or more of the base is exposed by 2050.
- **Sea level rise makes storm surge flooding more severe.** The area inundated by five feet or more of seawater during storm surges will increase over the century.

Base Information

NAS Key West is located within the Lower Florida Keys in Monroe County. The low-lying Keys are uniquely vulnerable to sea level rise because they are underlain by porous limestone bedrock, which eliminates the possibility of building sea walls or levees that would hold back the sea.

NAS Key West

Branch:	Navy
Established:	1823
Size (Acres):	5,800
Personnel:	800
Tenant Commands:	30

SOURCE: DOD 2016; MARCOA 2016.

The station's primary facility, Boca Chica Field, lies on Boca Chica Key, four miles northeast of Key West. NAS Key West has several annexes throughout Monroe County, including on Key West itself (DOD 2016).

NAS Key West trains fighter pilots from all branches of the armed forces. The station can house 100 aircraft and more than 800 personnel while also providing port operations for visiting ships (MARCOA 2016). NAS Key West provides key training and support for the nation's military operations and readiness, as it serves all branches of the military. The installation is home to several important commands, including the

It is difficult to defend against gradual sea level rise in the Keys, due to low elevation, and porous limestone that allows salt water to infiltrate up through the ground.

Joint Interagency Task Force South, which combats illicit narcotics trafficking; the US Coast Guard Sector Key West; and the Army Special Forces Underwater Training School (DOD 2016).

Historic Exposure to Storm Surge and Flood Hazards

In any given year, there is an estimated 25 percent chance that Key West will be hit by a tropical cyclone (MCIM 2015). When storms strike, NAS Key West is highly exposed to the surge that can be generated. A Category 1 storm hitting today exposes more than 80 percent of NAS Key West to flooding

from storm surge. Category 2 or stronger storms expose more than 95 percent of the base to flooding.

Since 1851, there have been 76 hurricanes that have come within 150 nautical miles of NAS Key West (NOAA n.d.). In 2005, four hurricanes came within 150 nautical miles, including Dennis, Katrina, Rita, and Wilma; most recently, Hurricane Ike passed within this distance in 2008 (NOAA n.d.). Hurricane Wilma pushed water levels nearly five feet above normal and resulted in an estimated \$33 million in total damages (City of Key West 2016; MCIM 2015; Kasper 2007).

NAS Key West has considered seawall upgrades for protection of its airfield against storm surge (Barham 2011). It is difficult to defend against gradual sea level rise in the Keys, however; in addition to the hazard presented by South Florida's low elevation, its porous limestone geology allows salt water to infiltrate up through the ground (Monroe County 2011; Miller 1990).

Future (Projected) Exposure to Storm Surge and Flood Hazards

SEA LEVEL RISE

The intermediate scenario projects that NAS Key West will experience nearly four feet of sea level rise and the highest



Hurricane Dennis passed just south of Key West in July, 2005. NAS Key West's Truman Annex is shown here, as a Navy security team makes their way through flood waters.

scenario projects over six feet of rise by 2100. This rise will lead to increased exposure to different types of coastal flooding. It also threatens to inundate land and contaminate the region's drinking water (UCS 2015).

TIDAL FLOODING AND LAND LOSS

As sea level rises, tidal flooding associated with extreme tides is expected to become more extensive and frequent. Tidal flooding does not affect critical parts of NAS Key West today. In both the intermediate and highest scenarios, however, such flooding is expected to inundate critical infrastructure, such as the runways at Boca Chica Field, by 2070.

The intermediate scenario projects that, by 2050, tidal flooding could occur roughly 300 times per year in currently flood-prone areas, while in the highest scenario it occurs 560 times per year, with the daily high tide or even more frequently. With such regular flooding, affected areas could become unusable land within the next 35 years. In the highest scenario, NAS Key West's currently flood-prone areas would be underwater 85 percent of the year by 2070.

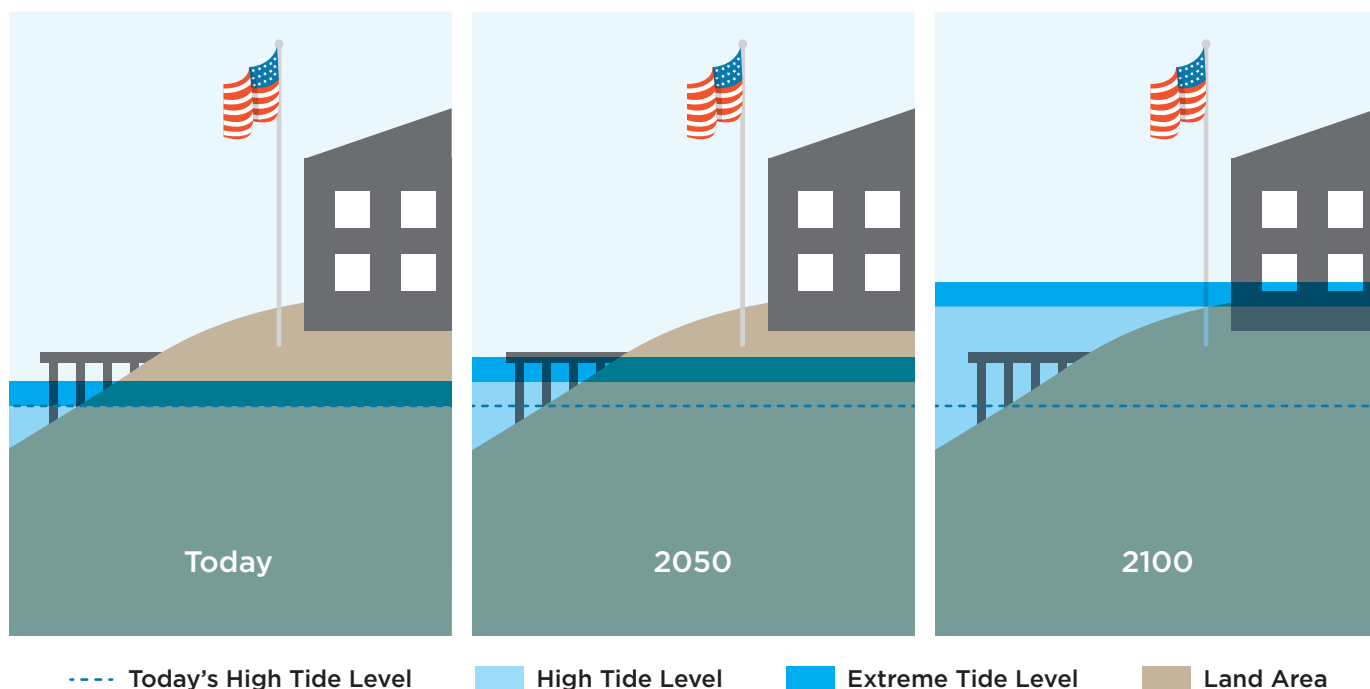
At NAS Key West, the difference between high and low tide is small enough that, with the projected increases in sea

TABLE 1. NAS Key West Could See More than Six Feet of Sea Level Rise by 2100

Year	Intermediate	Highest
2050	1.1	1.7
2070	2.0	3.2
2100	3.8	6.2

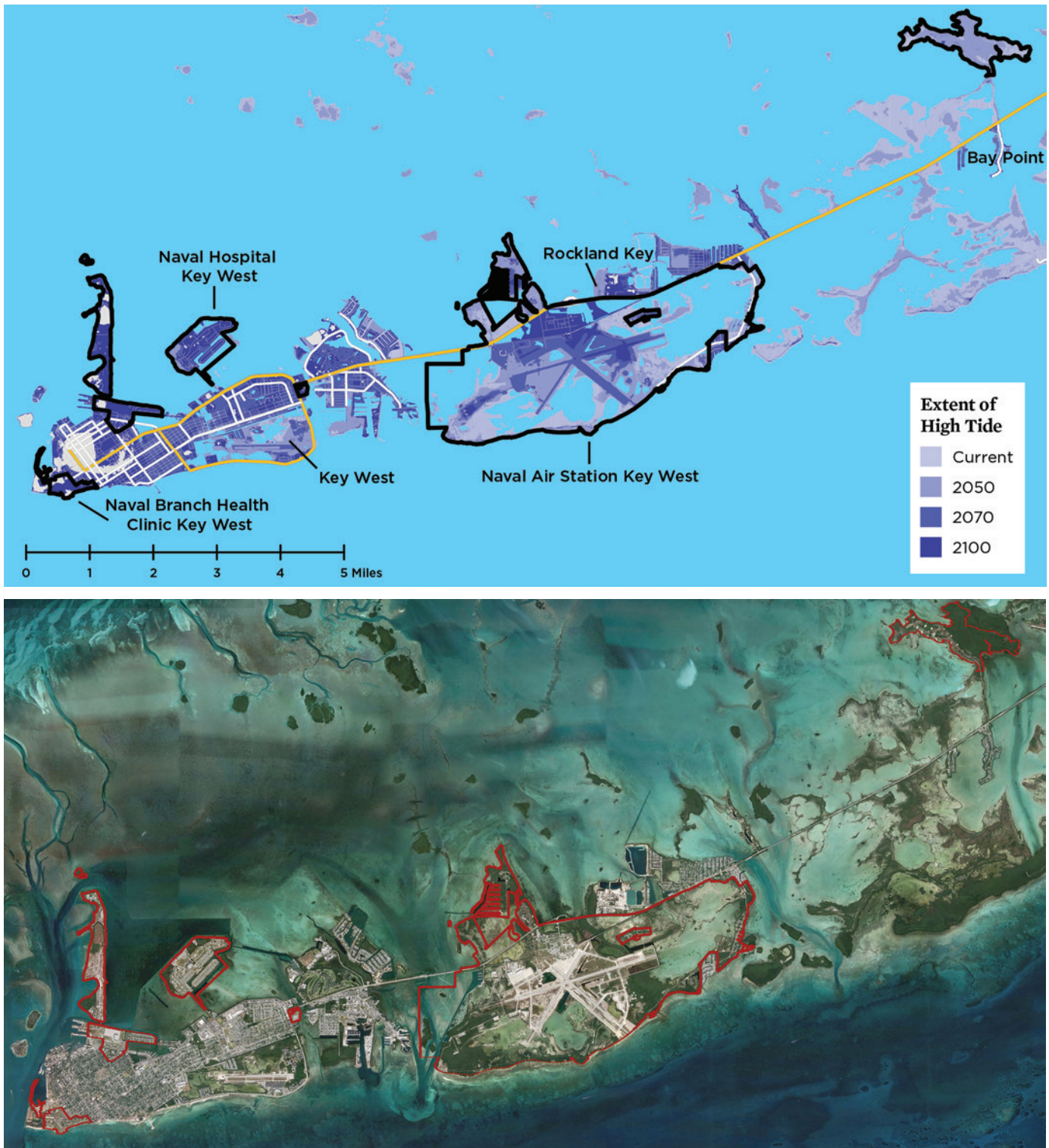
In the intermediate scenario, ice sheet loss increases gradually in the coming decades; in the highest scenario, more rapid loss of ice sheets occurs. The latter scenario is included in this analysis to help inform decisions involving an especially low tolerance for risk. Moreover, recent studies suggest 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).

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.

FIGURE 3. NAS Key West Is Expected to Lose Currently Utilized Land



The projected reach of future daily high tides, shown in the top panel, encompasses currently utilized land at NAS Key West, shown in the bottom panel. The highest scenario is mapped here.

SOURCE: GOOGLE EARTH.

TABLE 2. Low-Lying Areas of NAS Key West Projected to Be Permanently Inundated by 2100

Year	Intermediate		Highest	
	Events per Year	% of Year	Events per Year	% of Year
2012	3 ± 3	0	3 ± 3	4
2050	301 ± 39	13	560 ± 46	41
2070	567 ± 40	60	48 ± 35	85
2100	1 ± 0	100	1 ± 0	100

Projected sea level rise will lead to constant or near-constant flooding around NAS Key West. Shown here are flood events in low-lying, flood-prone areas projected by the intermediate and highest scenarios. 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. As flood conditions begin to span multiple high tide cycles, the number of distinct flood events gradually drops toward one, while the duration of flooding increases until it is constant.

level, flood conditions will eventually exist even at low tide. In the highest scenario, flood events begin to span many high tide cycles during the last half of this century. As a result, the number of individual flood events decreases but the duration of flood conditions increases until flooding is essentially constant and the land that was once above the high tide mark is permanently inundated. Beyond today's flood-prone areas, the 6.2 feet of sea level rise projected for the end of the century would mean that nearly all—95 percent—of NAS Key West's land area will become part of the tidal zone.

THE CHANGING THREAT OF HURRICANES

Over time, sea level rise exposes a greater proportion of NAS Key West's area to inundation by Category 1 storms. In both scenarios, areas of the base that are unaffected by storm surge

today—such as the Trumbo Point facilities on Fleming Key, north of Key West—will be exposed to flooding by 2050. In both the intermediate and highest scenarios, area exposed to flooding from a Category 1 storm increases from 83 percent today to 95 percent or more in 2050.

Sea level rise also increases the depth of flooding NAS Key West can expect with major storms. Whereas nearly all the flooding from a Category 1 storm today is five feet deep or less, nearly 80 percent of the base could be exposed to flooding five to 10 feet deep by 2100 according to the intermediate scenario.

WORST-CASE SCENARIOS

A Category 5 storm today exposes virtually all of NAS Key West to storm surge, with the majority of the base being flooded with water 10 to 15 feet deep. Sea level rise will make this catastrophic flooding even more severe. In the highest scenario, 37 percent of the base is exposed to 15-to-20-foot deep flooding in 2070. By 2100, that proportion rises to 80 percent.

Mobilizing on the Sea Level Rise Front Lines

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). Given the Keys' history of exposure to hurricanes, Navy leadership recognizes many of the flood risks NAS Key West faces. The station has flood risk mitigation efforts under way, including maintenance of its seawall and planning measures (Barham 2011).

Beyond today's flood-prone areas, the 6.2 feet of sea level rise projected for the end of the century would mean 95 percent of NAS Key West's land area will become part of the tidal zone.

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 NAS Key West, face all of these risks.

The gap between the military's current sea level rise preparedness and the threats outlined here is large and growing.

This analysis provides snapshots of potential future exposure to flooding at NAS Key West. For the Navy to take additional 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 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.
- ² 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 was included in this study.
- ³ This analysis involved consultation with contacts at multiple installations. However, in some instances, 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.

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