

The US Military on the Front Lines of Rising Seas

Exposure to Coastal Flooding at Eglin Air Force Base, 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 of Eglin Air Force Base (AFB) found that in the second half of this century, in the absence of preventive measures, the installation can expect the following: 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 Eglin AFB, 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. Unlike the Miami area, Eglin AFB, located directly on the Gulf Coast of the Florida Panhandle, sees very little tidal flooding today. However, by late this century, as seas are projected to rise between 3.7 and 6.1 feet, the base's Santa Rosa and Okaloosa Island facilities could face significant ocean inundation.

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 Eglin AFB. 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



EGLIN AFB'S BARRIER ISLANDS FACE DAILY INUNDATION

While the mainland section of Eglin AFB has limited exposure to sea level rise this century, its barrier islands, Santa Rosa (shown here) and Okaloosa, could face daily tidal flooding late in the century. These islands provide storm surge protection for the mainland. Though not modeled here, their inundation could affect storm surge exposure of the base's mainland.

risk in 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 Eglin AFB could be exposed, assuming no new measures are taken to prevent or reduce flooding.³ This analysis finds the following key results.

TIDAL FLOODING, PERMANENT INUNDATION, AND LAND LOSS

- **Areas currently unaffected by tidal flooding could flood with each high tide.** Today, extreme high tides do not typically affect Eglin AFB, but low-lying areas of the base are inundated during daily high tides by the end of this century in both sea level rise scenarios.
- **Flooding during extreme high tides will become more extensive.** By 2070, this flooding could affect nearly all of the barrier island facilities within the base.

Some of Eglin AFB's barrier island areas are projected to flood with such frequency by 2070 that they would effectively be part of the tidal zone.

- **Sea level rise threatens to inundate certain areas permanently.** Some of Eglin AFB's barrier island areas are projected to flood with such frequency by 2070 that they would effectively be part of the tidal zone, as opposed to developed, usable land. Indeed, with 6.1 feet of sea level rise projected by the end of the century, most of the barrier island areas of the base would be effectively lost: they would be underwater during daily high tides.

STORM SURGE

- **Sea level rise exposes previously unaffected areas to storm surge flooding.** Most of Eglin AFB's vast mainland areas remain unaffected by storm surge even with a Category 5 storm in 2100. Nevertheless, in the highest scenario, the barrier island area exposed to storm surge inundation roughly quadruples for Category 1 storms between now and 2100.

- **Sea level rise increases the exposure of Eglin AFB to deeper, more severe flooding.** As sea level rises, the depth of inundation related to storm surge increases, particularly on the base's barrier islands. Over time, the area inundated by five or more feet of seawater during storm surges increases.

Base Information

Eglin AFB is located along the Florida Panhandle between Pensacola and Panama City, on the Choctawhatchee Bay. The base is situated primarily on the mainland but includes portions of Santa Rosa Island and Okaloosa Island, which make up one continuous barrier island located south of the mainland.

Eglin AFB

Branch:	Air Force
Established:	1935
Size (Acres):	463,360
Population:	17,000
Units	50
Annual Budget:	\$18.8B
Jobs:	192,000
Replacement Value:	\$4.7B

SOURCE: DOD 2016; NFMSP 2016; TEKE 2015.

Eglin AFB primarily supports and conducts research on weapons systems. The more than 50 units at the base, representing every branch of the military, develop and test new weapons and train members of the Armed Forces in their use (USAF 2016). The installation is also home to a Special Forces Group assigned to protect more than 30 countries in Central and South America and the Caribbean (USAF 2016). The base has a population of about 17,000, including active military, civilians, and contractors (DOD 2016).

Providing more than 190,000 jobs and direct defense spending of more than \$6.9 billion annually, the military presence in the region is an important part of the local economy (NFMSP 2016). The three counties in which Eglin AFB is located are home to an estimated 11,000 members of the Armed Forces and nearly 60,000 veterans (US Census Bureau 2014).

Historic Exposure to Storm Surge and Flood Hazards

Santa Rosa Island serves as a natural barrier that helps protect the base's mainland facilities from storm surge (Evans et al. 2014). The extensive wetlands surrounding the Yellow



US Army

TRAINING ACTIVITIES ON EGLIN'S BARRIER ISLANDS:

On Okaloosa Island, April 2015, a Green Beret (7th Special Forces Group, Airborne) emerges from the Gulf of Mexico as part of a mock rescue effort. Okaloosa Island, along with nearby Santa Rosa Island, can see significant storm surge from hurricanes and is highly exposed to future flooding.

River in the base's northwest corner also likely provide protection, along with wetlands along the Choctawhatchee River. Very little of Eglin AFB, including the Santa Rosa and Okaloosa Island facilities, experiences routine tidal flooding today.

Overall exposure of the mainland portions of the base to storm surge is fairly low, even given the base's location along the hurricane-prone Gulf Coast (Evans et al. 2014). Storm surge inundation, even for the strongest storms (i.e., Category 5), is limited to areas immediately along the coast or adjacent to river channels. The portions of the base that lie along the Santa Rosa and Okaloosa barrier islands, however, bear the brunt of storm surge from hurricanes, and they are extremely vulnerable to flooding. Today, these areas experience widespread inundation from Category 2 storms and are almost completely inundated by Category 3 and stronger storms. Loss of the barrier islands would expose Choctawhatchee Bay to storm surge, which in turn could expose upland areas and infrastructure to flooding and land loss (Evans et al. 2014).

There have been 58 hurricanes that have come within 150 nautical miles of the base since 1851 (NOAA n.d.; NHC

2010). Hurricanes Ivan and Dennis, both Category 3 storms, affected Santa Rosa Island in 2004 and 2005, respectively (Evans et al. 2014). Ivan had a substantial impact on Santa Rosa Island, damaging over 100 structures with a storm tide (storm surge plus tide) between 8.5 and 13.8 feet (Clark and LaGrone n.d.). Dennis caused a storm surge of six to nine feet (Clark and LaGrone n.d.).

The Air Force estimated that two hurricanes combined caused more than \$100 million in damages at Patrick, Eglin, Hurlburt, and Tyndall AFBs in 1995, with some areas submerged in up to 18 feet of water (USAF 2008). During Hurricane Isaac in 2012, the Air Force moved Eglin's F-15 and F-16 fighter jets to Air Force bases in North and South Carolina to protect them from the storm (Clark and LaGrone n.d.).

Future (Projected) Exposure to Storm Surge and Flood Hazards

The intermediate scenario projects that Eglin AFB will experience 3.7 feet of sea level rise locally, and the highest scenario projects 6.1 feet of rise by 2100. In both scenarios, mainland

TABLE 1. Eglin AFB Could See Six Feet of Sea Level Rise by 2100

Year	Intermediate	Highest
2050	1.0	1.7
2070	1.9	3.1
2100	3.7	6.1

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 (DeConato 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).

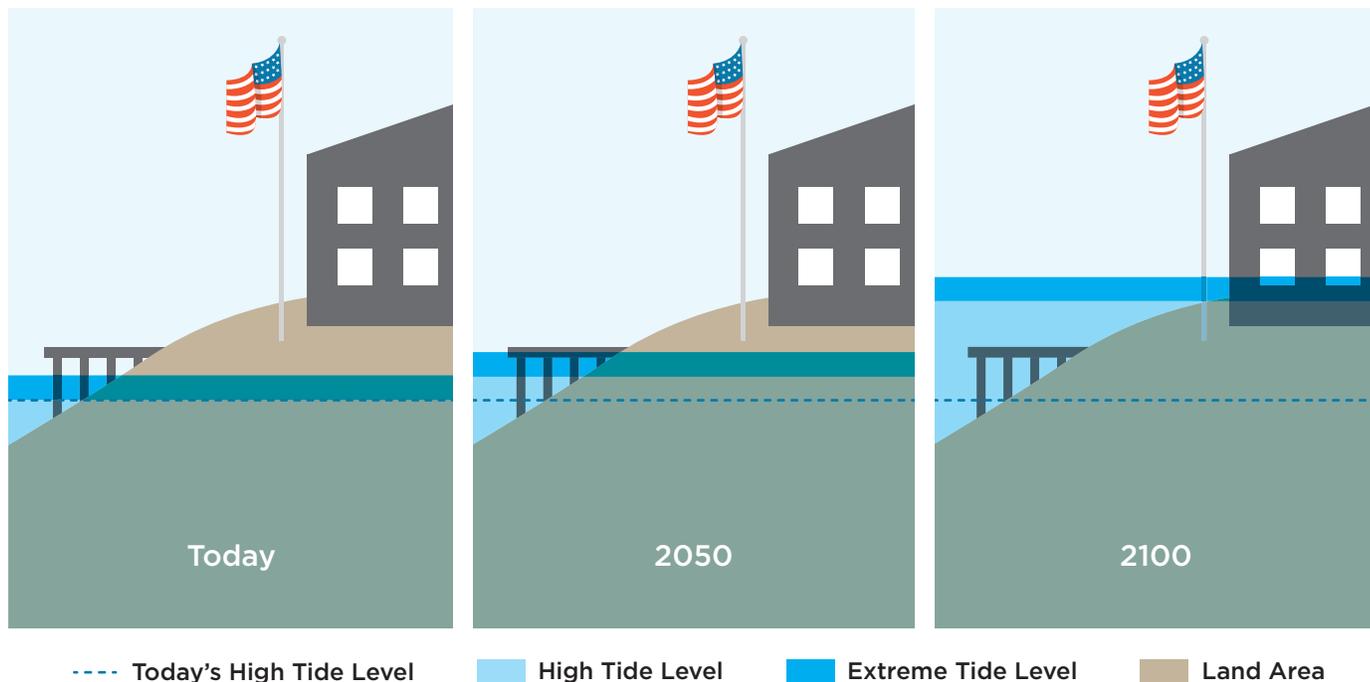
exposure to sea level rise is minimal, with the exception of the low-lying marsh areas along the northwestern border of the base. But Santa Rosa and Okaloosa Islands begin to show inundation at about three feet of sea level rise, and they are nearly completely inundated at six feet. The pace of sea level rise through the end of the century will determine the future viability of the islands: as the rate of sea level rise increases, erosion will exert a greater effect on the islands (Donoghue et al. 2013).

TIDAL FLOODING AND LAND LOSS

As sea level rises, flooding during high tide—uncommon today—is expected to become routine and extensive, particularly on Eglin’s low-lying barrier islands. Tidal flooding occurs roughly 160 times per year in the intermediate scenario and roughly 230 times per year in the highest scenario by 2070. By 2100, low-lying areas are inundated not just at high tide, but also for more than 80 percent of the year in the intermediate scenario, and they are constantly inundated in the highest scenario, as outlined in Table 2.

The flooding that occurs during high tide lasts longer as sea level rises. In locations such as Eglin AFB, the difference

FIGURE 1. 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.

TABLE 2. Rising Flood Frequency in Eglin’s Low-Lying Areas

Year	Intermediate		Highest	
	Events per Year	% of Year	Events per Year	% of Year
2012	0 ± 0	0	0 ± 0	0
2050	8 ± 7	0	84 ± 24	5
2070	158 ± 26	12	228 ± 32	71
2100	103 ± 24	83	1 ± 0	100

Sea level rise will lead to constant or near-constant flooding in parts of Eglin AFB. 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 span multiple high tide cycles, the number of distinct flood events gradually drops, but the duration of flooding increases until it is constant. Installations will be affected by this flooding depending on the presence of low-lying land on-site.

between high and low tide is small enough that, with the projected increases in sea level, flood conditions will eventually exist even at low tide. During the last quarter of this century, flood events in this area will begin to span many high tide cycles. As a result, the number of individual flood events decreases, but the duration of flood conditions increases until flooding is essentially constant and land that was once above the high tide line is permanently inundated (see Table 2). Indeed, in the highest scenario, nearly all of Santa Rosa Island is underwater at high tide by the end of the century (see Figure 2, p. 6). Because barrier islands provide a storm surge buffer for the mainland, this trend toward inundation could have implications for the future exposure of mainland Eglin AFB to storm surge.

In a worst-case scenario for the area, roughly 10 percent of Eglin AFB, or more than 43,000 acres, is exposed to storm surge.

THE CHANGING THREAT OF HURRICANES

Because Eglin AFB is large and its mainland area is protected from storm surge by the barrier islands, there is only a small increase in the percentage of the base’s area exposed to flooding as sea level rises. In absolute numbers, however, the in-

crease in exposed area is large. Today, a Category 2 storm exposes about 11,400 acres of the base to storm surge flooding. That area increases by more than 50 percent—to about 17,700 acres—in 2100 in the intermediate scenario. In the highest scenario, the area exposed to storm surge from a Category 2 storm nearly doubles, to about 22,000 acres.

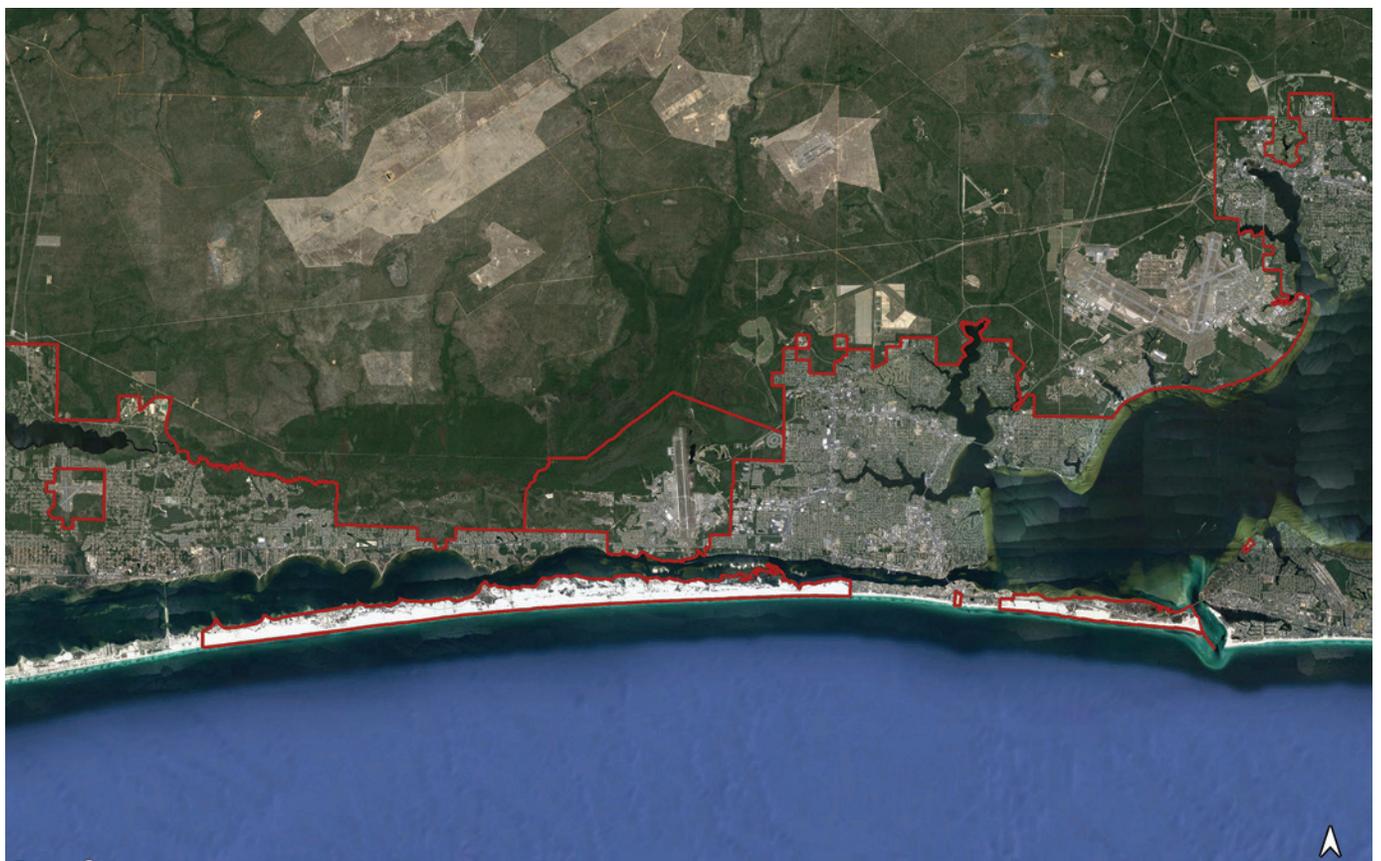
Sea level rise also changes the depth of flooding that the base can expect with major storms. This is particularly evident on Santa Rosa and Okaloosa Islands. Whereas most of the inundation on these islands during a Category 2 storm today is five feet deep or less, in the highest scenario in 2100, most of the inundation on the islands is five to 10 feet deep.

In a worst-case scenario for the area—a Category 5 storm hitting in 2100 in the highest scenario—roughly 10 percent of Eglin AFB, or more than 43,000 acres, is exposed to storm surge. About 5 percent of the base—nearly 30,000 acres—could experience flooding more than five feet deep. The barrier islands would be exposed to 15-to-20-foot-deep flooding. Even in this worst-case scenario, however, the vast majority of Eglin AFB’s mainland facilities are unaffected by flooding.

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). Recent studies by the DOD, for example, inform Eglin AFB’s climate preparedness activities and can help guide the base toward cost-effective investments (Evans et al. 2014; Donoghue et al. 2013).

FIGURE 2. Eglin AFB Is Expected to Face Barrier Island Loss



The reach of future daily high tides, shown on the top panel, encompasses currently utilized land on Eglin AFB's Santa Rosa and Okaloosa Islands, shown on the bottom panel. The highest scenario is mapped here. In this scenario, much of the area shown in purple is permanently inundated.

SOURCE: GOOGLE EARTH.

But here and across 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 Eglin AFB, face all of these risks.

This analysis provides snapshots of potential future exposure to flooding at Eglin AFB. For the base 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.

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- 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 5, 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 Eglin AFB. 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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FIND THE FULL ANALYSIS AND METHODOLOGY ONLINE: www.ucsusa.org/MilitarySeasRising

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