MILITARY EXPERT PANEL REPORT

SEA LEVEL RISE AND THE U.S. MILITARY'S MISSION

September 2016

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Cover Photo:
The lone ship at the pier at the Naval Station, Norfolk, Va., USS Kearsarge (LHD 3) endures the rain and heavy winds from Hurricane Isabel as the storm moved across the Tidewater area. The storm flooded portions of Fleet Parking at the Naval Station, trapping some vehicles in water up to their windows. Hurricane Isabel cost the Navy nearly $130 million in damage in the Mid-Atlantic region of the U.S.. September 2003.
US Navy / Photographer's Mate 1st Class Michael Pendergrass.

Contents

The Center for Climate and Security thanks its many colleagues that informed this study. We would especially like to thank Joan VanDervort and Brenda Ekwurzel for their expert review.

Note from the Military Expert Panel

As military professionals who have spent our adult lives serving the United States, we are concerned about the impact sea level rise is having, and will have, on the ability of our military infrastructure to sustain our nation's operating forces and fulfill strategic objectives. It is clear we must do more to address these risks, and do it soon.

There are a growing number of studies exploring the actual and potential physical impacts of sea level rise on U.S. military installations, and these studies show that the risks are increasing at a faster rate than expected.[1] However, important questions remain only partially answered: How will a changing climate impact our military basing, training, readiness and ability to control and conduct military operations? What are the broader implications for the military's ability to fulfill its mission due to anticipated increases in operations tempo? This report begins to answer those questions and offers a path forward to policy-makers for addressing those risks.

One thing is clear. We cannot wait for perfect information before assessing the risks and impacts, and responding in a way that is commensurate to those risks. The military has long had a tradition of parsing threats through a "Survive to Operate" lens, meaning we cannot assume the best case scenario, but must prepare to be able to effectively operate even under attack. Dealing with climate risks to operational effectiveness must therefore be a core priority.

To get ahead of the risks, this report looks out in time to assess the effects of sea level rise happening simultaneously across a broad range of military infrastructure domestically and globally, and the resulting cascading effects on the ability to train, mobilize, operate and fulfill strategic objectives. The continued strength of the U.S. depends, in large part, on having a clear-eyed assessment of risks and threats to the nation, and addressing them well before they manifest themselves. This report is an attempt to present a clearer picture of sea level rise risks, what that means for our nation's armed forces, what that means for national security, and what we can do about it. In doing so, we hope to modestly contribute to the effectiveness of our nation's military and to help ensure a strong and resilient United States.

Signed,

General Ronald Keys, United States Air Force (ret)
Lieutenant General John Castellaw, United States Marine Corps (ret)
Vice Admiral Robert Parker, United States Coast Guard (ret)
Rear Admiral Jonathan White, United States Navy (ret)
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II Executive Summary

The United States military is the greatest globally-deployed military force in human history. That military force is present in 156 nations, and ready to advance U.S. interests, whether that be on a war-fighting or humanitarian mission. To do so, the U.S. military depends on essential services and infrastructure, both built and natural, to support a trained and ready force.

This capability, however, rests on an assumption of climate stability - including the stability of the 95,471 miles of coastline along which 1,774 U.S. military sites reside across the globe.[2] In the 21st century, the stability of that climate, and the stability of those coastlines from which the military launches its operations, is set to change dramatically due to sea level rise and storm surge. For example, major transportation, command and control, intelligence, and deployment hubs may face unrelenting erratic outages, or curtailment of operations in the future, due to sea level rise and storm surge. In that context, the ability of the Department of Defense (DoD) to fulfill mission requirements will be more costly, take more time, and be hindered by a lack of planned-for assets at critical junctures. As these threats to coastal military infrastructure play out over this century, they may become strategic vulnerabilities that could affect our ability to deter our enemies, defend our interests, and support our friends. In other words, "at a time and a place of our choosing" may not be our choice in the future.

Essentially, the very geostrategic landscape in which the U.S. military operates is going to be different from what it is today. Since the U.S. military's numerous military installations live in that changing landscape, it will have to adapt, and adapt quickly. To use military parlance, the theater is, in essence, flooding. Adjusting to that rapidly changing theater will be absolutely critical for the U.S. military to maintain its ability to fulfill its mission, and for the United States to adequately pursue its national security interests. At the center of this adjustment are coastal military installations - their infrastructure and the adjacent supporting communities - that form the backbone of this global military force.

This report is not an exhaustive look at all of the climate risks and vulnerabilities coastal military installations are facing. However, it synthesizes studies by the Department of Defense (DoD), Congress and independent researchers, explores a range of case studies, analyzes what those findings mean for military readiness, operations and strategy, and lays out areas that deserve more attention.

III Findings and List of Recommendations

This report finds that over the course of the remainder of the 21st century, the U.S. military's coastal military installations, domestically and internationally, face significant risks from climate-driven trends, namely sea level rise and the interaction of sea level rise with an increased frequency and intensity of extreme weather events. This report also finds that these risks, if not sufficiently mitigated, may eventually have wide-ranging effects on the military's ability to effectively fulfill its mission. This includes effects on military readiness, military operations and military and national security strategy. This report also concludes that policies and plans for addressing these risks will have to be commensurate to a scale of risk that goes beyond infrastructure resilience. Indeed, climate change effects such as sea level rise are not just an installation and facility issue for U.S. military forces. They also present operational and strategic risks, and these broader implications must be both better understood, planned for and prevented. The complex relationship between sea level rise, storm surge and global readiness and responsiveness must be explored down to the operational level, across the Services and Joint forces, and up to a strategic level as well. Given that these conclusions are widely shared by the DoD, the report authors recommend that policy-makers support comprehensive and preventive measures, in the near term, to address these risks.

In this context, we offer eight specific recommendations for the near-term aimed at addressing sea level rise risks to the U.S. military's mission.

1. **Continuously identify and build capacity to address infrastructural, operational and strategic risks.**
2. **Integrate climate impact scenarios and projections into regular planning cycles.**
3. **Make climate-related decisions only after considering the highest risk level projections.**
4. **Game out catastrophic scenarios in planning.**
5. **Work with international counterparts at key coastal bases abroad.**
6. **Track trends in climate impacts as uncertainty levels are reduced.**
7. **Maintain close collaboration with adjacent civilian communities.**
8. **Continue to invest in improvements in climate data.**

See page **39-41** for the full recommendations.

IV Introduction: Military Infrastructure in a Changing Security Landscape

The U.S. military force is present in 156 countries across the globe, and includes "nearly 562,000 facilities on 4,800 sites worldwide and covering 24.9 million acres."[3] The Department's ability to deploy quickly and effectively depends on a well-functioning infrastructure of military installations, testing, and training grounds that are secure from threats. Climate change introduces an added risk factor, particularly for those installations and sites along the coast worldwide.[4] In 2008 the National Intelligence Council found that over 30 military sites in the continental United States are already facing elevated risks because of sea level rise.[5] That number has grown in the years since, and the U.S. military has taken notice.[6]

By the end of the 21st century, the climate, sea levels, and the shape of many of the coastlines from which the military builds, trains and launches its operations, will likely be significantly different. Already, on the global scale, "sea level has risen by about 8 inches since the late 1880s".[7] By 2100, projections show an average global mean sea level rise of up to 1 meter (3.3 feet), with upper projections toward 6.6 feet (2 meters)[8] should marine-based sectors of the Antarctic ice sheet collapse.[9] Given that around 10 percent of U.S. military installations and training grounds are located along low-lying and exposed coastlines,[10] the long-term effects in terms of flooding will be significant. However, the effects of sea level rise go well beyond slow-onset effects. As noted by The Strategic Environmental Research and Development Program (SERDP), the DoD's environmental research program, potential risks to installations include:

- Loss or damage to mission essential infrastructure including coastal development; energy and water infrastructure;
- Loss or degradation of mission capabilities;
- Loss of training and testing lands, including beaches and barrier islands;
- Loss of transportation means, facilities, and/or corridors;
- Loss of habitat and associated natural resources;
- Increased risk of storm damage and coastal erosion; and,
- Increased potential for loss of life.

Beyond the significant financial damage that can result from such flooding (including the costs of closures), an increase in the frequency and intensity of flooding, and increased erosion, can render portions of installations generally inoperable for significant periods of time. In key Areas of Responsibility (AORs) for the U.S. military, such as the Asia-Pacific region, a combination of sea level rise and an increase in the severity and intensity of tropical storms could pose enormous problems. For example, U.S. military installations in the region face two major problems. First, they are especially exposed to severe weather events such as cyclones. Second, in the wake of these storms, they not only have to quickly recover their

own capabilities, but they also have to function as a main hub for the humanitarian and disaster relief efforts that follow.[11] As the U.S. implements its Asia-Pacific Rebalance strategy, it will need to strongly consider how climate change will complicate that strategic objective – including its growing humanitarian assistance/ disaster relief (HA/DR) role.

Evidence suggests that climate change may make cyclones and other tropical storms more intense.[12] As these storms interact with a rising sea level, the risks rise of multiple weather related disasters impacting U.S. military installations simultaneously, at home and/or abroad. Couple that with the need to defend U.S. interests in key, contested geostrategic environments, such as the South China Sea (a strategic priority for the military),[13] and that mission may be complicated even further.

In short, the physical landscape in which the U.S. military operates is no longer a fixed "given." Since the U.S. military's numerous coastal military installations lie in a rapidly changing landscape, it will have to adapt, and adapt quickly. Adjusting to that unstable environment will be essential for the U.S. military to be able to maintain its ability to fulfill its core mission. At the center of this adjustment lies a fundamental need to build a resilient military infrastructure that supports the global military force. Time is an important factor. As noted in the 2016 SERDP report on managing uncertainty for coastal risk management, "Uncertainty is not a reason for inaction, because taking no action is a decision in itself."[14] SERDP's 2013 report on climate impacts and coastal military installations also noted that the decisions, or lack of decisions, that are being made today will drive how vulnerable the military's "assets and capabilities" will be, in the face of climatic risks, for "many decades to come."[15]

Floodwaters from storm surge caused by hurricane Isabel fills a corridor at the U.S. Naval Academy. September 2003.
US Navy

Aerial photo of Naval Air Station Key West's Trumbo Point Annex, Florida. April 2016.
US Navy / Mass Communication Specialist 3rd Class Cody R. Babin

This report looks beyond the direct physical impacts of sea level rise on military infrastructure to provide insight into how those physical effects may affect military readiness, operations and strategy. We asked the questions: What might these changes mean for U.S. national security writ large? If it is to meet the goals of protecting the American people, U.S. allies, and national interests, the defense community does not have the luxury of waiting until events transpire to prepare for, respond to, and mitigate these risks. With a number of new efforts complete or underway, the security community now has sufficient understanding of the risks of climate change and sea level rise to justify comprehensive action – especially for coastal bases and their surrounding communities that are already feeling the effects (and incurring the damage). This report provides details from recent analyses,[16] observations on the lessons they convey, and recommendations for U.S. policy makers on how to interpret and act in line with the new findings they present.

FIGURE 1: Coastal Installation Assets

From Strategic Environmental Research and Development Program, 'Assessing Impacts of Climate Change on Coastal Military Installations: Policy Implications', U.S. Department of Defense, 2013:

Coastal military installations include many different assets that are vulnerable to climate changes. These assets include:

- Training/testing lands
- Protective shoreline buffers, barrier islands, and coastal wetlands
- Navigation channels
- Piers and docks
- Roads
- Bridges
- Parking areas
- Office and residential buildings
- Warehouses
- Communication data centers
- Sewage and oily waste treatment facilities
- Fuel tanks and distribution lines
- Water treatment and supply systems (plants, pumps, pipelines, wells)
- HVAC systems (buildings, equipment, distribution pipelines)
- Electriciy system (substations, generators, distribution)

V Review of the Risk Landscape

Scientists have long projected that climate change will contribute to sea level rise, storm surges, flooding, and other challenges for coastal areas, and indeed is already doing so. As these projections have expanded in volume and sharpened in detail, they have indicated increasing challenges for defense installations - particularly along the coast. This had led to an increase in the DoD's attention to sea level rise risks, a number of global and site-specific studies by both the U.S. government and independent researchers, and a generally elevated appreciation for both the scale of risk in the 21st century, and the urgency of action, given the necessity of long planning horizons for complex coastal infrastructure.

History of DoD attention to climate change risks

The U.S. Department of Defense (DoD) has recognized the security implications of a changing climate as far back as 2003.[17] Recognition of the risk, and action to address it, has grown with each passing year[18] – culminating in a "DoD Directive on Climate Change Adaptation and Resilience" in 2016,[19] that provides policy guidance and assigns responsibilities on managing the risks associated with climate change. It directs DoD components to assess the effects of climate change on the department's mission and to take into account those effects when developing plans and implementing them. It also concludes that climate change will be a constant consideration in how the DoD goes about its war mission, acquisition programs, readiness plans, construction projects and security. As noted in the 2010 Quadrennial Defense Review:

> "Climate change will affect DoD in two broad ways: First, climate change will shape the operating environment, roles and missions that we undertake. Second, DoD will need to adjust to the impacts of climate change on our facilities and military capabilities."[20]

The first category includes consideration of climate change as a strategic risk, given the possibility that it will as an "accelerant of instability or conflict, placing a burden to respond on civilian institutions and militaries around the world." The second category includes consideration of the "30 U.S. military installations that were already facing elevated levels of risk from rising sea levels," along with a much larger group of military sites that will face elevated risks throughout the 21st century.[21] As with its treatment of other security risks, the DoD has based its assessment of climate change risks on the best available science.

Previous assessments of climate change risks to coastal military infrastructure

The DoD has seen significant climate change effects on its bases and training areas.[22] From sea level rise, to melting permafrost, to increases in severe storm events, some coastal installations are currently experiencing

impacts to their infrastructure which have implications on the Department's budget and could potentially impair the readiness of defense forces. As a result, DoD is expanding its capacity to analyze and address these challenges. Much of this capacity has been formed in the DoD Strategic Environmental Research and Development Program (SERDP), though other offices within the military Services and the Office of the Secretary of Defense play important roles as well. The U.S. Army Corps of Engineers, for example, has been monitoring sea level rise for decades and continues to play an active role in DoD's analysis of the effects of climate change.

Noting that the intelligence community assessed that at least 30 U.S. defense installations were already seeing increasing risks due to sea level rise, the 2010 QDR tasked the SERDP to lead new assessments of DoD installations to determine how they may be affected by climate change. Its analysts have paid particular attention to coastal infrastructure, given that "[a]bout 10 percent of DoD coastal installations and facilities are located at or near sea level and are already vulnerable to flooding and inundation. Rising sea levels and more intense heavy downpours will make these conditions worse."[23] Early work to answer the QDR's task involved developing tools and methods that would enable the department to do consistent analysis. As this work has continued, defense experts have worked to advance its models and reduce uncertainties in its coastal assessments.[24]

Much of the work to meet this task has been done in coordination with the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and other agencies, some of which have facilities co-located or nearby many defense sites. NASA, for example, has installations co-located with defense installations in Florida, Mississippi, Virginia, and elsewhere.

In addition to the DoD's own work, a number of other efforts have expanded the body of information available to congressional and executive branch decision makers and planners in the past few years. This work is shining new light on the likely scale of damage, level of risk, and likelihood of specific types of challenges that DoD should expect. Though many specific issues are already manifesting at U.S. defense installations today, new reports show even greater risks in the decades ahead – including many that can be expected by 2050, well within the expected lifetime of current investments in facilities and infrastructure.

A 2014 Government Accountability Office (GAO) report provided new clarity on the types of effects climatic and environmental changes are already having on training, readiness, and operations at several U.S. defense installations, including many in coastal areas. Among the examples, the authors reported "the combination of thawing permafrost, decreasing sea ice, and rising sea level on the Alaskan coast have led to an increase in coastal erosion at several Air Force radar early warning and communication installations. According to installation officials, this erosion has damaged roads, utility infrastructure, seawalls, and runways."[25]

More than 70 aircraft fill U.S. Naval Air Station Key West Boca Chica Field's ramp; a facility for air-to-air combat fighter aircraft of all military services and provides world-class pierside support to U.S. and foreign naval vessels. January 2014.
US Navy / Mass Communication Specialist 2nd Class Brian Morales

In April 2016, the Department of Defense released a report titled "Regional Sea Level Scenarios for Coastal Risk Management: Managing the Uncertainty of Future Sea Level Change and Extreme Water Levels for Department of Defense Coastal Sites Worldwide."[26] Led by SERDP, the report was developed by experts from the U.S. Navy, U.S. Army Corps of Engineers (USACE), NOAA, United States Geological Survey (USGS), several universities and companies, and other public institutions.

The 2016 SERDP report, one of the most expansive publicly-released efforts to date, details the methodology used to develop a range of scenarios that could serve as a starting point for vulnerability assessment as well as planning and decision-making for coastal risk management. Researchers used five different sea-level rise projections to develop sea-level and extreme water level scenarios for 2035, 2065 and 2100, which were further adjusted for site-specific considerations. The report accompanies a database of scenarios covering 1,774 DoD sites around the world. It unlocked the complex interplay among subsidence, sea level rise, ice melt, and other factors that are affecting coastal installations. These factors indicate that defense sites will not be uniformly affected, underscoring the importance of acknowledging the range of possible futures for individual installations. The report used a multi-scenario approach to illustrate a range of plausible futures for coastal installation vulnerability. Though this leaves decisions related to uncertainties for policy-makers open, the report notes that a risk management framework leaves no room open for inaction in the faces of these changes. The study also found that even in its lower-end scenarios such as 3.3 feet (1 meter) by 2100, projections for certain would increase by 0.7 to 1.5 feet (0.2 to 0.5 meters) in 2065 and 2100, respectively.[27]

Another team of experts from the Union of Concerned Scientists (UCS) conducted a robust analysis of 18 DoD installations and surrounding civilian infrastructure deemed important for the continuity of defense operations, and analyzed how sea level rise is likely to affect storm surge inundation, tidal flooding, and permanent inundation of each site. It indicates that within the next three decades, these installations will be forced to manage "more than 10 times the number of floods they experience today." The same analysis found that by the end of the century, eight bases may lose a quarter to half of their land, and "Four installations—Naval Air Station Key West, Joint Base Langley-Eustis, Dam Neck Annex, and Parris Island—are at risk of losing between 75 and 95 percent of their land."[28] This report provides a new angle on how decision makers need to consider coastal impacts. To date, much attention has focused on how sea level rise will exacerbate the damage caused by storm surges and affect infrastructure such as piers and dry docks that sit directly against the oceans. New analyses show that a number of bases may see even more daunting challenges from changes to what are today often considered ordinary "nuisances," such as flooding during extra-high tides.

HIGHLIGHT: Nuisance Flooding: Far More Than Just a "Nuisance"

The National Oceanic and Atmospheric Administration (NOAA) describes nuisance flooding as flooding that "causes such public inconveniences as frequent road closures, overwhelmed storm drains and compromised infrastructure." According to that same report, so-called nuisance flooding "has increased on all three U.S. coasts, between 300 and 925 percent since the 1960s.has increased on all three U.S. coasts, between 300 and 925 percent since the 1960s."[29]

The term "nuisance," defined as "a person, thing, or circumstance causing inconvenience or annoyance"[30] does not accurately capture the increasing extent of this type of flooding, and the damages it causes. Given the frequency and extent of the damage to military infrastructure and surrounding support communities from these regular flooding events, the term "nuisance" implies a significant underestimation of the risks associated with it.

All of these reports vary in methods used, the backgrounds of the researchers, and specific geographic or installation focus. Yet there are several trends that are emerging in recommendations for how research and policy responses should continue. This includes the need for:

- Assessing sea level rise interactions with other coastal events
- Addressing the near-term risks of sea level rise; and
- Embracing a range of projections

Assessing sea level rise interactions with other coastal events

To fully understand the potential impact of sea level rise, the scientific community, the DoD and other independent researchers are now looking at other factors such as storm events and surge, tides, and subsidence. The 2016 DoD scenario work includes vertical land change, extreme water level events such as storm surges, and extreme high tides. The UCS findings were based on an analysis of how sea level rise would influence the range of impacts caused by storm surges, permanent inundation, and tidal flooding. Likewise, the 2016 SERDP report (citing a 2014 study) noted:

> "…often when sea-level change scenarios are merged with extreme water level conditions, the focus has been on rare events, such as hurricanes. But evidence is growing that the less severe but more frequent events (that will become even more frequent in the future) are of consequence and need to be factored into decisions."[31]

Referring specifically to Pacific atolls, new modeling conducted by the US Geological Survey as part of a study on DoD installations uses techniques that consider the interaction of higher sea levels with storm-induced "wave-driven" flooding. The results indicate that low-lying atolls may experience more severe inundation sooner than previously estimated, with "wave-driven water levels" causing twice as much land area to be flooded than currently predicted.[32] The multitude of dynamics captured in these and other recent analyses are providing a more complete – and hopefully more realistic – vision of the challenges that lie ahead for coastal defense installations.

Addressing the near-term risks of sea level rise

The timeframes for identifying and projecting impacts are moving closer to the present. Projections of past decades tended to focus on climate change effects likely to take hold in the latter half of this century, and often in the 2075-2100 timeframe. While long-term projections are important, the effects of climate change are already impacting coastal defense installations. Planners for those sites need to know what they may face in the coming decades. The 2016 SERDP report examines scenarios for 2035, 2065, and 2100, which were chosen to align with various infrastructure investment time horizons. The UCS study authors used 2050, 2070, and 2100 for their analysis. For the nearest term, the aforementioned GAO report authors interviewed officials at U.S. installations to identify the types of effects already occurring. Furthermore, much infrastructure at coastal installations is in need of upgrade or replacement. Integrating already planned or forecast construction planning and execution with efforts that will be required to deal with sea level rise will eliminate project duplication or conflicts in project execution and will permit development of realistic long-term infrastructure programming. It will be imperative to execute programs at the right time for the right purposes.

Embracing a range of projections

Finally, there is a growing consensus that planners and policy makers must consider a range of projections of coastal impacts to inform their decisions. This is a concerted shift that has taken root in the past few years, and shows a new mindset regarding how to plan for the coastal impacts the country can expect for defense installations. In the past, a common tendency was to plan for median or most-likely scenarios as a singular "answer" to the question of what future impacts to expect. Analytical efforts conducted since 2015 show a distinct move toward including worst-case, best-case, and extreme-event projections in advice provided to decision makers, who can then act on projections that will account for a broader range of possibilities. In terms of planning and investing in ways that leave the DoD more prepared for the full range of possibilities, accounting for a range of possible outcomes is optimal. Additionally, different scenarios can serve as planning tools for different functions. For example, those planning for engineering, construction, and critical infrastructure such as cyber architecture investments may need to account for the more extreme plausible scenarios, whereas officials more focused on movable activities may be more likely to plan against most-likely changes to their respective bases.

Rain and heavy winds from Hurricane Isabel flood portions of Fleet Parking at Naval Station Norfolk, Va. September 2003.
US Navy / Photographer's Mate 1st Class Michael Pendergrass.

VI Combined Risk Outlook Based on Recent Studies

The research to date paints a picture of increasing military installation exposure to sea level rise along the coastlines of the United States and around the world. Low-lying and exposed areas of coastal bases around the world will be very significantly – if differentially – affected throughout the course of this century. As early as 2050, the low-lying parts of some bases along the East and Gulf coasts of the United States could be underwater for "10 to 25 percent of the year"[33] which would have an enormous impact on the ability to support military operations.[34] According to the SERDP 2016 report, under scenarios projecting a global average sea level rise of 3.3 feet (1 meter) or higher in 2065 and 2100, some DoD sites, including many in the northeastern U.S., will experience an additional 0.7 to 1.6 feet (0.2 to 0.5 meters) over the global average. In 2011 and 2014, the U.S. Army Corps of Engineers produced a report also using a "multiple-scenario approach," and suggested that a global mean sea level rise scenario of "1.5 meters by 2100" be used for planners (4.9 feet), but that "2.0 meters," or 6.6 feet, "is a credible upper bound".[35] These multiple-scenario exercises do not give us perfect information about risks to specific installations, but coupled with the recent SERDP study (2016), they tell us enough to drive planning against both the worst and best cases. Another common thread is the importance of not overlooking the less severe but more frequent "slow-onset" events, such as so-called "nuisance flooding" – which presents consistent and sustained risks for military installations domestically and around the world. In reality, such flooding events, particularly when they become persistent, frequent events, are far from "nuisances," as the cost of such flooding, in terms of infrastructure damage and military readiness, is significant and far more omnipresent than other extreme and short-duration flooding events.

Based on this overview of existing research, this report concludes that sea level rise and the attendant flooding that follows in its wake, coupled with projections of increasingly frequent and intense storms, present significant risks to critical coastal military installations at home and abroad. Further, this report concludes that these climate risks are already being experienced, and are likely to increase significantly for all the timescales explored in the recent literature – from 2035 to 2100. With these conclusions as our foundation, we have below assessed current and future sea level-rise related risks to high-value coastal U.S. military infrastructure, and what that means for overall military readiness, operations and strategy.

VII Discussion: Sea Level Rise and Military Readiness, Operations, and Strategy

The installations examined closely in this report (see page 26-36 for a list of case studies) represent only a portion of the high-value coastal military installations the United States possesses. Additional research, building from the 2016 SERDP report, is needed for a more comprehensive and detailed global survey of sea level rise implications for readiness, operations and strategy. Nonetheless, the collective risks to these sites alone pose enormous challenges to the U.S. military. As is made clear by the reports cited above, and the case studies below, sea level rise and storm surge is already affecting a number of installations that support critical operations. Furthermore, throughout the course of the 21st century, even the best-case sea level rise scenarios pose significant challenges to a broad range of sites that provide critical operational capabilities to the U.S. military, while the medium and worst-case scenarios present risks that could significantly impair the military's overall mission.[36] That mission rests on three critical capabilities and measures of effectiveness for the U.S. military:

- Readiness
- Operations
- Strategy.

These three pillars of the U.S. military are further defined in the following chart. The chart also describes how sea level rise, in a broad sense, affects each of these capabilities and measures of effectiveness.

An aerial view of the Naval Station Mayport, Florida (USA). May 1993.
US Defense / Photographer's Mate 1st Class Slaugenhaupt.

TABLE 1: Climate Change, Readiness, Operations and Strategy

	Definition - from DoD Dictionary of Military and Associated Terms[37]	Example of how sea level rise could affect coastal installation
Readiness	Readiness — The ability of military forces to fight and meet the demands of assigned missions. See also national military strategy."[38]	Sea level rise may compromise coastal military installations that are critical for supporting, materially and logistically, timely operations.
Operations	"Operational readiness — The capability of a unit/formation, ship, weapon system, or equipment to perform the missions or functions for which it is organized or designed. Also called OR. See also combat readiness."[39] Operational Effectiveness - Measure of the overall ability of a system to accomplish a mission when used by representative personnel in the environment planned or expected for operational employment of the system considering organization, doctrine, tactics, supportability, survivability, vulnerability, and threat."[40]	"Installation operations are likely to be affected by climate change. Lands required for training and testing operations may be reduced due to more frequent flooding, long term inundation, and coastline erosion."[41]
Strategy	"Strategy — A prudent idea or set of ideas for employing the instruments of national power in a synchronized and integrated fashion to achieve theater, national, and/or multinational objectives. (JP 3-0)" "National military strategy — A document approved by the Chairman of the Joint Chiefs of Staff for distributing and applying military power to attain national security strategy and national defense strategy objectives. Also called NMS. See also national security strategy; strategy; theater strategy. (JP 1)" "Theater strategy — An overarching construct outlining a combatant commander's vision for integrating and synchronizing military activities and operations with the other instruments of national power in order to achieve national strategic objectives. See also national military strategy; national security strategy; strategy. (JP 3-0)"	Climate change will impact military and national security strategy as it changes the current geographies of instability, affects geopolitical relationships, and influences the operations necessary to fulfill that strategy. Climate risks can increase the likelihood of militaries being called on to respond to conflicts, or provide post-conflict assistance. These evolving dynamics will necessitate adjustments to military strategies. Climate change will present additional challenges to areas of the world that are of strategic significance to the United States, for example the Middle East and North Africa,[42] and the South China Sea.[43]
Climate change	"Climate change — Variations in average weather conditions that persist over multiple decades or longer that encompass increases and decreases in temperature, shifts in precipitation, and changing risk of certain types of severe weather events."[44]	

Based on this typology of military effectiveness, we have conducted a review of sea level rise risks to coastal installations as defined by their current and projected effects on military readiness and operations, as well as strategy. This review is limited by available data on both the exposure of military infrastructure worldwide to sea level rise, and projections for how that exposure will affect the military's current and future missions.

Readiness and Operations

A number of recent studies demonstrate that critical coastal U.S. military installations, both at home and abroad, will be affected by sea level rise, and that this may have a significant impact the military's overall readiness. From the 2013 SERDP report:

> "The effects of climate change will adversely impact military readiness and DoD natural and built infrastructure unless these risks are considered in DoD decisions. Environmental factors are already affecting DoD installations; as the climate continues to change, the nature and severity of these stressors will change as well. Many of the problems caused by changing climate stressors are expected to affect facilities located on and near the coasts; other impacts may affect inland installations as well. Considerations of future climate conditions need to be incorporated into the planning, design, and operations of military facilities, as well as in the strategic infrastructure decisions facing the military Services and DoD as a whole"[45]

U.S. installations house, or are a launching point for, an array of defense operations that are likely to be affected. For example, damage caused by singular disasters or the long-term effects of sea level rise may create serious lags in repair, maintenance, and scheduled operations for naval and coast guard vessels. In some cases, personnel may not be able to access their work sites for weeks or months. This lack of access to

Crewman Qualification Training students hit the surf at the Silver Strand beach in Coronado, California. September 2008.
DVIDsHub / Petty Officer 2nd Class Christopher Menzie

and from coastal installations could affect force deployments and disrupt operations.[46] Electricity supplies, cyber infrastructure, utility corridors, water supplies, stormwater conveyance systems and other civil infrastructure critical to military installations may see reduced reliability, both from storm surge and longer-term processes exacerbated by sea level rise such as saline intrusion into freshwater supplies. This could especially be the case under some of the highest-case sea level rise scenarios identified in recent studies.[47] Other physical impacts may have implications for the functionality of communications or surveillance equipment that are critical for military readiness. Some installations are already experiencing issues related to sea level rise impacts on civil infrastructure they rely on; as climate impacts intensify, these challenges are expected to increase.[48] In the longer-term, civilian planning for climate adaptation in surrounding areas or communities may affect the options available to military installations, but could also improve resilience in ways that benefit military infrastructure and readiness.[49]

Sea level rise can also affect military readiness by causing the loss of outdoor training days or training and testing areas that are difficult or costly to replicate, such as those used for amphibious assault training, coastal components of maneuver corridors, amphibious landing beaches, airfields, and beach/bay training areas.[50] Flooding impacts on transportation networks can impede operations that require cargo and personnel to be moved quickly and safely.[51]

Marine Corps Base Camp Lejeune, North Carolina, and Marine Corps Recruit Depot Parris Island, South Carolina, are illustrative cases. Both serve as key training facilities for the Marines as well as other members of the Armed Forces. Under plausible high risk scenarios, in 35-55 years, low-lying areas of these facilities could be underwater around one third of the year, which could have implications for amphibious assault training and other essential training functions at these installations.[52] Short-term alteration or cancellation of training activities due to flooding or erosion can have broader repercussions for monthly or yearly training schedules, as these changes may necessitate costly modifications to training facilities or changes in support personnel scheduling.[53]

The risks that sea level rise pose to military installations can also impact the ability to effectively carry out operations, such as meeting the demand for search and rescue and humanitarian assistance and disaster response (HA/DR), or countering narcotics trafficking. For example, under plausible highest-case sea level rise scenarios, half of the land area of U.S. Coast Guard Station Sandy Hook in New Jersey could be flooded by extreme tides in 2070,[54] which could significantly impede law enforcement and search and rescue operations in the area, which are launched from the base.[55] Naval Air Station Key West in Florida houses a Joint Interagency Task Force that plays a major role in coordinating counter-narcotics operations in Latin America and the Caribbean. The air station may face regular extreme flooding during high tides by 2070, thus complicating the readiness and operational effectiveness of the Task Force. The loss of functionality due to more extensive and persistent flooding poses challenges to maintaining operational capacity at these important coastal installations, and may drive difficult choices in the future.

The aforementioned GAO report shows another compelling example of impacts on coastal installations that could directly affect operational capabilities – in this case, the deployment of Navy submarines. As officials at Navy installations conveyed to the authors:

> "...sea level rise and resulting storm surge are the two largest threats to their waterfront infrastructure. For example, they explained that they were planning to lengthen a Los Angeles–class submarine to convert it to a training platform and that this will entail cutting the submarine in half. During this process, the submarine will sit in a dry dock with its interior open. Officials explained that they were concerned about possible storms and associated storm surge, noting that if salt water was allowed to flood the submarine's systems, it could result in severe damage. Such damage would delay completion of the submarine's lengthening by 3 to 4 months. Officials from another Navy shipyard we visited stated that flooding of a submarine in dry dock could result in catastrophic damage inside the submarine and additional, severe damage to equipment on the floor of the dry dock."[56]

In the 2035-2100 timeframe, sea level rise will likely affect a very broad range of coastal military installations both domestically and internationally. Unless the U.S. military is able to reconstruct and relocate these installations elsewhere at a pace that matches sea level rise impacts, this could result in a significant challenge to military readiness and operations on a global scale. Langley Air Force Base, which faces significant exposure to sea level rise and storm surge risks, is home to the majority of the U.S. military's F-22 force, as well at the 480th Intelligence, Surveillance, Reconnaissance Wing. This is the heart of the Air Force's Distributed Common Ground Station that drives primary intelligence, surveillance and reconnaissance planning and execution for global operations. Disruptions to this base could have significant consequences for military operations across the globe.

Key operational hubs outside the United States also face significant exposure to sea level rise. Diego Garcia in the Indian Ocean, for example, is home to a joint U.K.-U.S. military facility that provides support for a range of critical war-fighting operations in the region, including as a staging area for special operations forces[57], submarine support for those special operations, and long-range bomber flights into Afghanistan.[58] Diego Garcia is, however, a low-lying atoll whose natural barriers to accelerating sea level rise and storm surge (coral reefs) are being significantly degraded by climate trends.[59] Projections for increasing hurricane intensity in the near-term increase its exposure even further, thus presenting a critical risk to US operations in a politically volatile region.[60]

As the risk of more frequent or even cascading flooding at multiple bases grows with sea level rise, so does the risk of significant delays in depot level maintenance of ships, submarines and squadrons leading to deployment delays that impact readiness and responsiveness worldwide. This also increases the risk that U.S. forces will not be able to adequately respond to threats and crises within their desired timeframes. Even a few days' delay in responding to threats such as sea mines in maritime choke points could have significant implications for operational effectiveness and global security.

FIGURE 2: Contrasting Installation Sea Level Rise Vulnerability - The Importance of Place

	Naval Station Norfolk	Marine Corps Base Camp Pendleton
Mission	Provides fleet support and facilities to ensure readiness for the US Atlantic Fleet	Amphibious assault training center supporting combined air, sea, and ground combat training
Setting	Located in a major metropolitan area of 4300 acres in Hampton Roads area of Virginia at the confluence of the Elizabeth and James Rivers	Primarily natural, undeveloped areas of 125,000 acres along the exposed Southern California coast between Orange County and San Diego
Stressors	Co-occurence of storm surge, high tides and increasing sea level with heavy precipitation	Co-occurence of large waves, high tides and increasing sea level
Pathways	Inundation and flooding from elevated sea level, but limited morphologic change	Beach and bluff erosion driven by the combined effect of waves and increasing sea level
Impact	Critical aboveground "built" infrastructure assets such as piers, pylons, distribution lines, and generators	Amphibious training areas, groundwater supply systems, and coastal natural resources

Source: This is a reproduction of a figure from 'Assessing Impacts of Climate Change on Coastal Military Installations: Policy Implications', Strategic Environmental Research and Development Program, 2013, pg 17.

STRATEGY

Current understandings about the physical impacts of sea level rise on coastal installations raise questions around broader strategic impacts as climate change accelerates. How might military engagement and security cooperation in the Asia-Pacific region be affected if U.S. and partner-country installations are altered dramatically by sea level rise in the coming decades? How will sea level rise impacts on key nuclear installations affect the U.S. ability to maintain a secure and effective nuclear deterrent? If extreme weather events flood coastal military installations, how will that impact the military's ability to respond to disasters caused by this extreme weather?

There is an inherent element of uncertainty in assessing these risks and formulating robust responses. However, making decisions in an environment of uncertainty around future sea level rise, its impact on coastal military installations and cascading consequences for readiness, operations and strategy, requires a set of skills the national security community has developed for other circumstances, and is beginning to apply to decisions around climate risks. Specifically, this includes decision-making frameworks that use a range of possible scenarios, rather than determining a 'most likely' future condition.[61]

The Military Sealift Command fleet ocean tug USNS Apache, and the Safeguard-class rescue and salvage ship USS Grapple endure a rare snow storm on board Naval Amphibious Base Little Creek, Va. February 2015.
US Navy / Photographer's Mate 2nd Class Daniel J. McLain

For example, the key objectives of DoD's Asia-Pacific Maritime Security Strategy are to ensure continued freedom of the seas, deter conflict and coercion, and promote adherence to international law and standards.[62] The resilience and location of key operational capabilities in the Asia-Pacific region are also important for the fulfillment of broader strategic goals of the military, such as the U.S. Asia-Pacific Rebalance. As noted by Constantine Samaras in "The U.S. Asia-Pacific Rebalance, National Security and Climate Change":

> "The DoD estimates the replacement value of the structures they use in the Pacific to be nearly $180 billion, which is greater than the combined 2014 annual budgets of the Departments of Commerce, Energy, Homeland Security, State, and Transportation. Given that level of government investment, DoD has recognized that climate resiliency at existing facilities should be integrated at the installation, Service and Departmental levels. Yet it is important that climate change impacts not be treated as just an environmental challenge, but be recognized as an issue that will define the landscape in which the future unfolds. In the rebalance to Asia, the choice of installation locations and the types of investments at each location enable a set of military capabilities in both the near- and long-term. The implementation of the rebalance provides an opportunity to assess the impacts of climate change on Pacific installations, estimate the corresponding effects on capabilities, and most importantly, take action to keep these capabilities going forward."[63]

Sea level rise at just one site can have a significant impact on strategy. Hampton Roads, Virginia, dubbed "the greatest concentration of military might in the world" by former Secretary of Defense Leon Panetta,[64] is by itself an invaluable operational and strategic hub for both the United States and its allies. It is home to NATO's Allied Command Transformation, U.S. Joint Forces Command, U.S. Fleet Forces Command, the U.S. Air Force's Air Combat Command, U.S. Marine Corps Forces Command, the U.S. Army Training and Doctrine Command, and is the backbone of the U.S. Atlantic Fleet. It is also a low-lying site and very exposed to sea level rise and storm surge. If significant portions of the Hampton Roads infrastructure, including Naval

Station Norfolk, were regularly inundated, as is projected under a number of scenarios for the years 2035-2100[65], the impediment to force deployments[66] for critical Atlantic, Mediterranean and Pacific war-fighting and humanitarian operations – many of which are tied to core strategic goals of the United States – would be significant. Due to these risks to high-value operational and strategic capabilities, military planners have begun to make plans for adapting facilities to cope with a two-foot rise in sea level over the next 35 years.[67]

A number of strategically-significant installations outside the United States also face exposure to seal level rise. The Marshall Islands in the Pacific, for example, hosts the Ronald Reagan Ballistic Missile Defense Test Site, which is a pillar of U.S. Strategic Command, and a main missile testing asset for the DoD. From this site, the United States prepares against the possibility of nuclear attacks, as it allows the immediate detection of any missile launch emanating from Asia (the primary concern being North Korea).[68] Given its location, it also acts as a strategic territorial bulwark in a time when the Chinese military is growing in strength and force projection. This strategic asset is under considerable risk. The Marshall Islands are seeing increasingly intense impacts of storms and sea level rise, both exacerbated by the warming of the planet, and recent studies suggest that they may become uninhabitable in mere decades.[69]

The Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll, Republic of the Marshall Islands. August 2015. US Army

Additional examples of the plausible strategic impacts of sea level rise can be found at U.S. installations along the East and West coasts, for U.S. Pacific islands and territories, and for international sites that host critical operational and strategic defense functions (see examples listed in the following study sections). Despite these strategic concerns, a comprehensive assessment of sea level rise and broader climatic impacts on U.S. military and national security strategy has not yet been conducted. As noted in a 2013 SERDP report:

> "...operations affecting mission readiness for a majority of installation personnel are likely to be deemed critical. Failure pathways should be evaluated critically. Climate change may reveal new vulnerabilities not previously considered. **At a strategic level, a similar analysis of the criticality of assets to mission accomplishment can be conducted [emphasis added].** This will help the military Services and DoD to focus vulnerability and impact assessments on the highest priority assets."[70]

Conducting assessments of strategic impacts will, however, not be sufficient. As noted in some of DoD's most recent work on this topic, "Outside of decisions explicitly associated with climate change mitigation and adaptation, many climate-sensitive decisions are not currently recognized by decision-makers as such."[71] Therefore, information on the implications of sea level rise risks to military installations, and how that affects military and national security strategy, will need to find its way to senior leadership in order to drive high-level adjustments in strategic thinking about climate impacts. This includes ensuring that senior leadership accounts for increased demand for DoD capabilities as a result of climatic shifts, such as HA/DR missions, which in turn will drive prioritization of investments in the climate resilience of key, strategic defense installations.[72]

HIGHLIGHT: Strategic Implications - The U.S. Asia-Pacific Rebalance

Sea level rise can present challenges for the U.S. military's existing strategic priorities, including the U.S. "rebalance" to the Asia-Pacific region. As noted by Costas Samaras in a recent publication by the Center for Climate and Security[73]:

Source: Constantine Samaras, 'U.S. Military Basing Considerations during a Rebalance to Asia: Maintaining Capabilities under Climate Change Impact,' in 'The US Asia-Pacific Rebalance, National Security and Climate Change', The Center for Climate and Security, 2015.

"*More than 40,000 DoD buildings sit on Pacific installations and sites comprising more than 1,400 square miles, or 21 times the size of Washington, D.C. The DoD's rebalance to Asia sets up a range of long-term choices about how the Department plans for the future, yet it is infrastructure that provides the footing for the objectives of the rebalance. U.S. bases in the Pacific serve many different roles as they enable major systems, including force projection, training, equipping, Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR), supply, humanitarian, and other critical missions. These bases are a visible component of the U.S. security commitments to its allies, and are critical for deterrence, reassurance, and ensuring regional stability. Climate change impacts such as increased heat, changes in precipitation, and sea level rise will affect the performance and life cycle costs of DoD's existing and planned infrastructure, which will affect the military capabilities of the Pacific installations. Hence as part of the rebalance, DoD needs to ensure the military capabilities enabled by installations in the Pacific are maintained under a changing climate.*"

VIII Case Studies

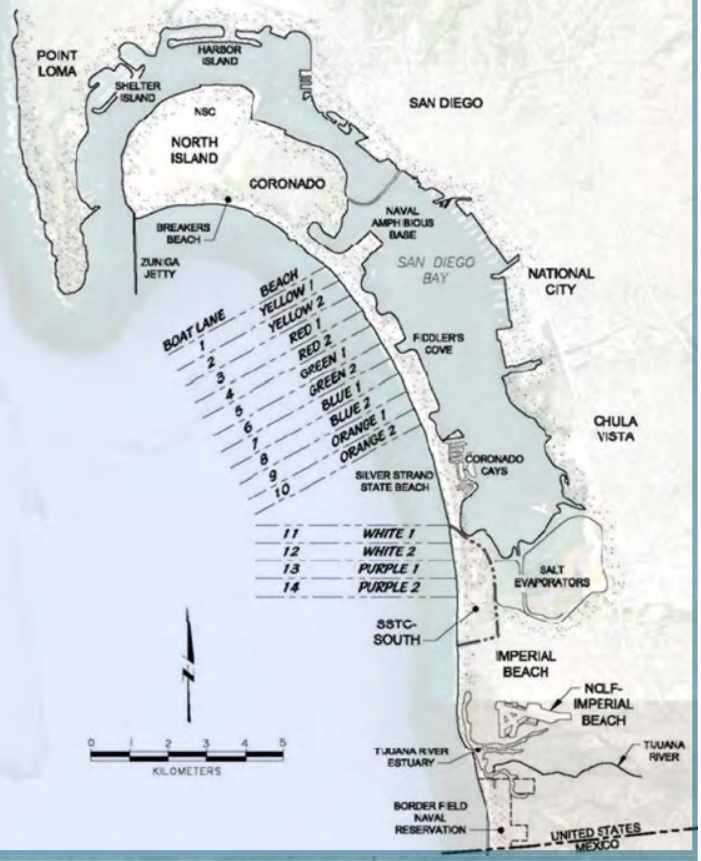
States and territories in the continental Unites States (CONUS), outside the continental United States (OCONUS), in other nations that house defense installations critical to military readiness, operations and strategy, and which face significant challenges due to sea level rise and storm surge, are numerous. Below is a brief survey of sea level rise and storm surge risks to key, high-value coastal military installations that provided the foundation for the discussion above. These cases are organized alphabetically by state, territory, country or military-administered island, as well as site-specific implications in terms of readiness, operations and strategy.

California

Naval Base Coronado and Marine Corps Base Camp Pendleton. Naval Base Coronado is home to a number of installations including Naval Amphibious Base Coronado, one of the country's two amphibious training bases, and Naval Air Station North Island, part of the Navy's largest aerospace-industrial complex, many of whose runways, weapons and munitions storage facilities, aircraft and ship maintenance facilities and berthing are located in low-lying areas. Marine Corps Base Camp Pendleton is a busy installation with a broad array of training facilities used for a variety of agencies and purposes, including maintaining combat readiness for Fleet Marine Force units. In an analysis from 2014, SERDP found that Naval Base Coronado has a:

> "…high sensitivity…to inundation and flooding as a function of the generally low-lying nature of the installation, and the significant exposure along the open shoreline of the Pacific. For training areas, this translates into inundation impacts with average beach widths reduced to about 29 for 1.0 m SLR, and further reductions to a remaining area of 5% for 2.0 m SLR."[74]

U.S. Navy Gunner's Mate 3rd Class Dakota Griffin waits for personnel to debark a landing craft, air cushion onto a beach landing site aboard Camp Pendleton Calif., during Composite Training Unit Exercise. March 2015.
DVIDsHub / Cpl. Elize McKelvey



Top: Schematic map shows North Island, Coronado, Silver Strand, Imperial Beach, and Border Field facilities with amphibious boat lane (number) and beach (color) designations.
(Overlay adapted from US Navy 2010; Image data: Google, SIO, NOAA, US Navy, NGA, GEBCO, LDEO-Columbia, NSF)

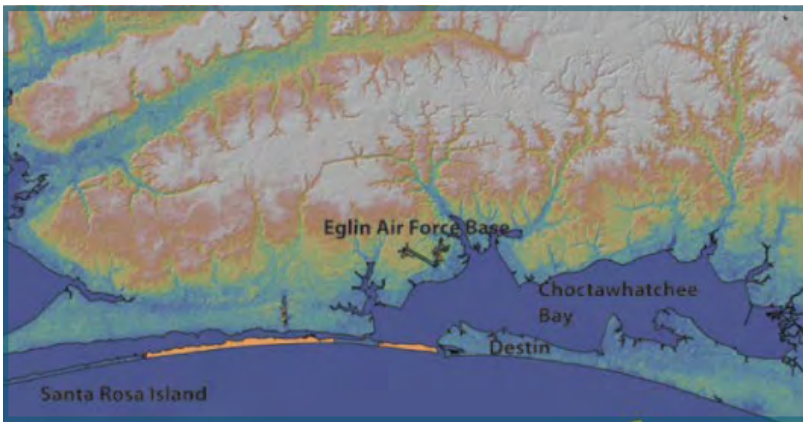
Bottom: Schematic map of MCBCP showing the major divisions of the coastline, Sections A-F and potentially vulnerable coastal facilities.
(Overlay adapted from US Government 2002; Image data: Google, SIO, NOAA, US Navy, NGA, GEBCO, DigitalGlobe, CSUMB, SFML, CA-OPC)

The same analysis found overall financial vulnerability estimates for Camp Pendleton ranging from $1 million to $1600 million under a 6.6 feet (2 meter) sea level rise scenario.[75]

Diego Garcia

Diego Garcia, a low-lying atoll in the Indian Ocean, is home to a joint U.K.-U.S. military facility that provides logistics and operations support for U.S., U.K. and Allied forces in the region. Navy Support Facility Diego Garcia replenishes naval surface combatants and guided-missile nuclear-powered submarines (SSGN) capable of carrying out strike and special operations.[76] An Air Expeditionary Wing supports long range bomber operations, including in Afghanistan, as well as tactical aircraft. Diego Garcia is also used for special forces staging and the prepositioning of Army and Marine Corps brigade sets.[77] Most of Diego Garcia does not exceed 6.5 feet (2 meters) in elevation. While mean sea level has actually been falling at this installation, it is still vulnerable to increasing hurricane intensity in the near-term,[78] and will be increasingly vulnerable to extreme water level events as sea level rise accelerates. As the corals surrounding the atoll are degraded by climate impacts, the islet will become more vulnerable to wave attack, erosion and salinization of freshwater supplies.[79]

Florida



Source: US Department of Defense, Strategic Environmental Research and Development Program, 'Effects of Near-Term Sea-Level Rise on Coastal Infrastructure'

Eglin Air Force Base, Naval Air Station Key West and Naval Station Mayport. These three installations based in Florida are critical testing, training and operational hubs, supporting important military operations in Latin America and the Caribbean. Eglin is a weapons training site and operational launch pad for the 7th Special Forces Group, whose area of responsibility includes 32 countries in Latin America and the Caribbean, and which has also been active in supporting the missions in Iraq and Afghanistan.[80] Many of the base's test facilities, as well as its radar and communications systems, sit at low-elevation along the Gulf Coast, and are vulnerable to hurricane winds and storm surge - particularly the parts of the base on the Santa Rosa Barrier Island.[81] Naval Air Station Key West is a training facility for tactical aviation squadrons from all branches of the Armed Forces, and houses important commands including Joint Interagency Task Force South (JIATFS), which plays a significant operational role in countering narcotics trafficking[82] - a core element of the U.S. counter-narcotics strategy in the region. The JIATFS mission may change throughout the remainder of the 21st century, but it will likely continue to do interagency intelligence fusion, and moving the task force would carry a significant cost. As Naval Air Station Key West is located entirely on low-lying keys that cannot be protected by seawalls or levees, training and operations could be significantly affected by sea level rise, increased storm surge and attendant flooding, if alternative solutions are not implemented. Recent studies suggest that in 35 years, "extreme tide flooding could affect half of the station's land area," and by 2070 "daily high tides could flood 70-95 percent of Naval Air Key West.[83] "Naval Station Mayport is third-largest fleet concentration area in the US, whose ability to deploy could be complicated by daily flooding of its low-lying areas by 2070.[84]

Members of the Army National Guard's 20th Special Forces Group at Naval Station Mayport, Florida. April 2015.
DVIDsHub / Staff Sgt. Adam Fischman

Georgia

Aerial Photo of King's Bay Naval Base. April 2001. EDIBOBB

Hunter Army Airfield and Naval Submarine Base Kings Bay. Hunter Army Airfield supports nearby Fort Stewart with command, control, training, administration, logistical and civilian-military support; the Stewart/Hunter Military Complex is the Army's largest East Coast installation.[85] The airfield features the longest runway on the East Coast (11,375 feet/3467 meters), a 350+ acre aircraft parking area, as well as a sizeable Arrival/Departure facility and nearby railhead, which facilitate deployment of the 3rd Infantry Division from Fort Stewart.[86] Hunter Army Airfield is also home to Coast Guard Air Station Savannah, which is the largest helicopter unit in the Coast Guard and performs search and rescue functions in the area.[87] Although current flooding at the airfield primarily affects wetlands, the installation is dependent on materials and equipment arriving at the port in nearby Savannah, and so is indirectly affected by more disruptive flooding incidents there, which are projected to occur on average 10 times a year in the latter half of the century. This tidal flooding can also affect low-lying roadways and neighborhoods in the area, impacting housing and transport for base workers and personnel. A quarter of the base is currently exposed to flooding from a Category 1 hurricane; this is projected to increase to 30-45 percent by the end of the century. A Category 4 storm in 2100 under the highest scenario would expose three quarters of the base to flooding, with more than half of that 10 feet (3 meters) or more deep."[88]

Naval Submarine Base Kings Bay hosts the Navy's Atlantic fleet of nuclear-powered submarines carrying ballistic or guided missiles, including Trident ballistic and guided missile submarines, Trident II D-5 and Tomahawk Land Attack Missiles; as such, it is an important part of the U.S. strategic nuclear deterrent.[89] The base currently experiences occasional tidal flooding in low-lying wetland areas. According to a recent scenario analysis, the base would flood with every tide by 2070 under the highest scenario, reducing the protection these areas provide to inland parts of the base. Other low-lying areas of the base could become unusable land in the next 35 years, and by the end of the century tidal flooding is highly likely to inundate the roadways in the southern part of the base. A Category 1 hurricane currently exposes half of the base to storm surges, and about a fifth of it to 5 feet (1.5 meters) or more of flooding. By the end of the century, this type of storm would expose half of the base to this depth of flooding. Under the highest scenario, a Category 4 storm at the end of the century would expose 95 percent of the base to more than 20 feet (6.1 meters) of flooding.[90] Flooding of the surrounding community may also significantly hinder the movement of personnel and logistical support to and from the base. This portends potential catastrophic impacts to the readiness and responsiveness of our strategic nuclear submarine force.

U.S. Marine Corps helicopter flies over a simulated amphibious beach assault at Marine Corps Base Hawaii. July 2014.
DoD / Mass Communication Specialist 1st Class Charles E. White

Hawaii

Though historical problems with storms and tsunamis have resulted in many U.S. military sites in Hawaii being placed on higher ground (e.g. Schofield Barracks, Wheeler AAF), a number of Hawaii's critical defense installations are at or close to sea level. The islands house more than 100,000 active duty, National Guard, and Reserve forces and their dependents.[91] The functions of these personnel and the sites at which they work range from serving as the headquarters of U.S. Pacific Command (USPACOM) and Pacific Fleet (the largest fleet command in the world), to contributing to the world's largest maritime defense force exercises, to civil defense and homeland security support, to hosting specialized chemical, biological, radiological, and nuclear response forces. The scale of operations launched from military bases in Hawaii, ranging from humanitarian assistance and disaster relief operations, to important mil-mil exercises with partner nations in the broader Asia-Pacific region, is significant.

These operations, launched from Hawaiian defense sites, form the backbone of the U.S. Asia-Pacific Rebalance strategy, which is designed to bolster support for U.S. allies and partners in the region, expand partnerships with emerging economies, defend freedom of movement in critical geostrategic waterways, such as the South China Sea, and foster both competition and cooperation with China. Sea level rise and storm surge are projected to affect installations at sea level in Hawaii, such as Pearl Harbor, Hickam and Kaneohe Bay, which could place strains on USPACOM's and the Pacific Fleet's capacity to mobilize quickly in support of both humanitarian and strategic missions. As a 2010 statewide assessment concluded, "The emerging consensus in Hawaii and the Pacific islands is that we will face a suite of challenges due to climate change; but the most immediate threat, and the one that we can most directly address is sea level rise."[92]

Maine

Portsmouth Naval Shipyard. Portsmouth Naval Shipyard is one of only four shipyards in the country. It repairs, overhauls and modernizes the U.S. Navy's nuclear powered submarines.[93] According to a recent analysis: "By 2050, low-lying areas in this region could experience between 80 and 190 floods per year—compared to fewer than a dozen currently—depending on the scenario."[94] By the end of the century, areas currently key to operations could become part of the tidal zone, and extreme tides could bisect the shipyard around a dozen times per year. Within this same timeframe, around a quarter of the base would be exposed to storm surges more than 5 feet (1.5 meters) deep from a Category 1 hurricane."[95] Local communities that support the shipyard, especially workers, already face challenges due to flooding of public road infrastructure, which is projected to increase with modest levels of sea level rise.[96] These events would dramatically impede the ability to conduct and complete critical maintenance on the U.S. nuclear submarine fleet.

Marshall Islands

The Marshall Islands, once the site of U.S. nuclear weapons testing, now host various important defense functions. Based in the Kwajalein Atoll and extending into nearly 700,000 square miles of surrounding ocean, the Ronald Reagan Ballistic Missile Defense Test Site is a key DoD asset for testing missiles and missile interceptors and conducting work for U.S. Strategic Command, NASA, and others. Kwajalein is also housing the new "Space Fence" radar system and operations center to contribute to space situational awareness for U.S. forces.[97] There, as described by *The Washington Post*, "the United States can practice launching or deflecting nuclear attacks, provide a territorial bulwark against China,

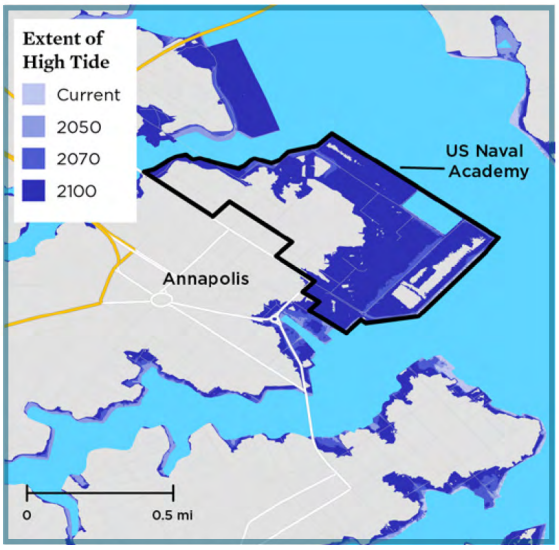
Top: Kwajalein Atoll Satellite Image. April 2005. NASA

Bottom: MV Delta Mariner docks at Meck Island with support equipment for use in the Missile Defense Agency's program. January 2009. U.S. Missile Defense Agency

immediately detect any launch out of Asia (read: North Korea) and provide a rocket-launch apparatus to civilian companies such as SpaceX."[98] The Marshall Islands are seeing increasingly intense impacts of storms and sea level rise, both exacerbated by the warming of the planet. Regular headlines, and, as of recent years, peer-reviewed studies, speak to the growing realization that the Marshall Islands may become uninhabitable in the decades ahead.[99] One 2015 USGS-led study showed that for this and other low-lying areas of the Pacific Islands, "the combined effect of storm-induced wave-driven flooding and sea level rise on island atolls may be more severe and happen sooner than previous estimates of inundation predicted."[100] As a result, the country's leaders are now playing a more prominent role in international diplomatic and legal mechanisms to reduce risks from both nuclear weapons and climate change, which many of its citizens link as comparable existential threats.

Maryland

U.S. Naval Academy. The U.S. Naval Academy educates and trains future professional officers in the Navy and Marine Corps.[101] "It is currently exposed to periodic tidal flooding, and by 2070 these flood-prone areas could be underwater 85 percent of the time, affecting up to 10 percent of the academy's land area. By the end of the century, Category 2 hurricanes could expose a third of the academy to a 5-10 feet (1.5-3 meters) deep storm surge."[102] These effects would render the current site of the U.S. Naval Academy unusable. Indeed, current tidal flooding is already a problem for workers residing in the surrounding community.[103] Therefore dramatic adaptation projects, including time-phased plans to protect and improve protection over time, must be considered in strategic infrastructure planning.



The USNA projected reach of daily high tides.
Source: "The US Military on the Front Lines of Rising Seas", UCS fact sheet, p5.

New Jersey

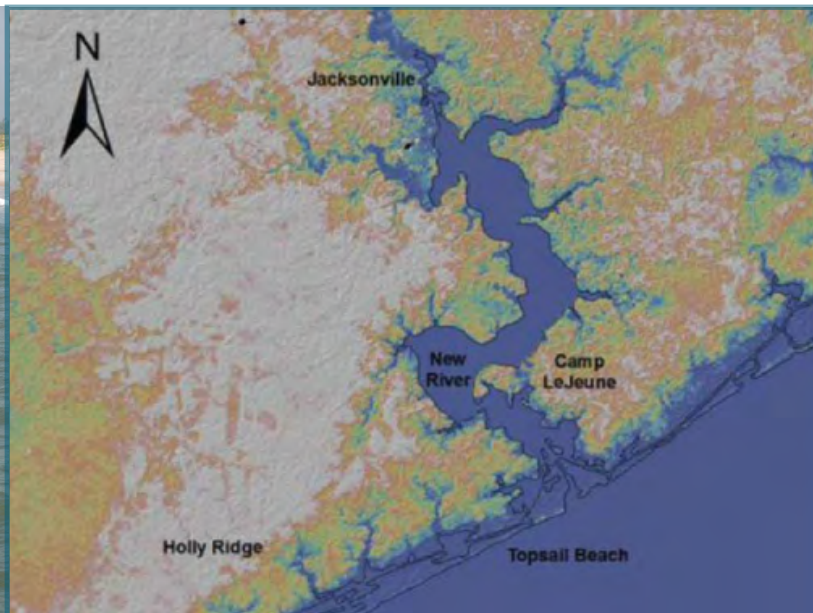
U.S. Coast Guard Station Sandy Hook. U.S. Coast Guard Station Sandy Hook houses response boats and Coast Guard cutters. It performs search and rescue operations and is responsible for law enforcement, environmental protection, and coastal security for waterways in the region.[104] This includes aforementioned key radar and VHF-FM communications equipment for the vessel traffic service in New York City, and a boat maintenance facility.[105] By 2070, extreme tides could expose over half of the base to flooding, and by the end of the century up to three quarters of the station's current land could flood daily with high tides. By 2100 a Category 1 hurricane could, under one high-impact set of scenarios, flood up to 80 percent of the base with a 5-10 feet (1.5-3 meter) deep storm surge.[106] Given that the base was severely crippled by Superstorm Sandy, and is not yet fully reconstituted today, this is not by any means an abstract projection.[107]

Sailors load a patrol boat onto a trailer at U.S. Coast Guard Station Sandy Hook during hurricane relief efforts in Highlands, N.J. US Navy / Mass Communication Specialist 1st Class Martin Cuaron

North Carolina

Marine Corps Base Camp Lejeune. Marine Corps Base Camp Lejeune is a training base with amphibious assault training facilities and live fire ranges that primarily serves Marines, but active-duty forces from the Navy, Army, Air Force and Coast Guard also train here. Six additional nearby facilities, including Marine Corps Air Station New River, support the Base Camp. Tidal flooding does not affect a high percentage of the camp's area at present, but by 2070 extreme high tides are projected to flood roadways and further low-lying areas, including barrier islands, ocean-facing coast and river shorelines, some of which will be underwater 10-35 percent of the time. By 2100, flood events could span multiple high tide cycles, permanently inundating the camp's barrier island 45-90 percent of the year. In this timeframe 25 percent of the camp is exposed to flooding from a Category 1 hurricane, and a Category 4 storm exposes 40 percent of the base to flooding, 20 percent of it more than 20 feet (6.1 meters) deep.[108] Further, many of the housing, logistics, training, administrative, ammunition storage, and impact ranges at Camp Lejeune are clustered along the New River Estuary and along the ocean facing beaches.[109] Among the impact ranges affected would the MCB Rifle Range and the K-2 Impact Range. The Courthouse Bay area near the New River Inlet would be especially vulnerable as would the built up area between the InterCoastal Waterway and Onslow Beach. The movement of personnel and logistics to and from Camp Lejeune will also likely be impeded.

Amphibious Assault Vehicles storm the beaches of Camp Lejeune, N.C., during a capabilities exercise. May 2005.
US Navy / Photographer's Mate 3rd Class Julianne F. Metzger



Source: US Department of Defense, Strategic Environmental Research and Development Program, 'Shoreline Evolution and Coastal Resiliency at Two Military Installations: Investigating the Potential for the Loss of Protecting Barriers'

South Carolina

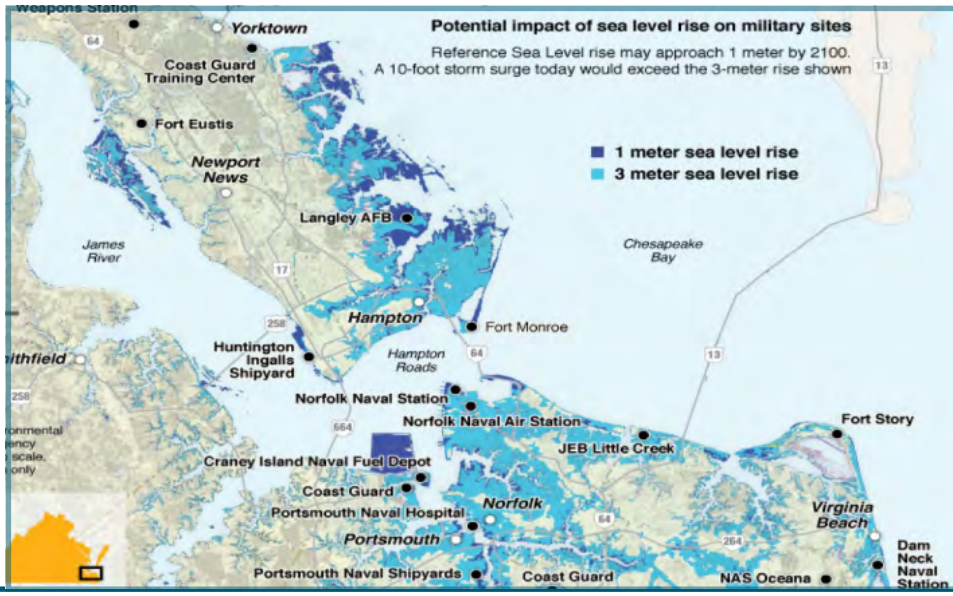
Marine Corps Air Station Beaufort and Marine Corps Recruit Depot Parris Island. Marine Corps Air Station Beaufort hosts Marine Corps and Navy fighter and attack squadrons, and has one of the world's largest airstrips. It is currently home to six Marine Corps F/A- 18 squadrons and one F-35B Fleet Replacement Squadron[110] constituting all of the Marine strike fighters on the East Coast. When the transition to the F-35B is complete, all Marine and British pilots and maintenance personnel will be trained at Beaufort.[111] Seventy aircraft, or 23 percent of the Marine Corps' entire inventory of tactical fighters, will be homebased there. The investment in Beaufort to support the F-35B runs into hundreds of millions of dollars.[112] Curtailing of operations in Beaufort will have far-reaching consequences for both the U.S. and the United Kingdom.

Marine Corps Recruit Depot Parris Island is one of two places where Marine recruits are trained. A naval hospital and housing complex are adjacent to these sites. At present, tidal flooding affects low-lying areas on Parris Island around 10 times annually; in 35 years, under the highest scenario these will be underwater around one third of the year. Later in the century, extreme tides could flood 85 percent of Parris Island around 10 times a year, and by 2100, three quarters of the island would be inundated daily by high tides. Both areas are also exposed to storm surges, with 90 percent of Parris Island currently exposed to 5-10 feet (1.5-3 meters) of flooding from a Category 1 hurricane; by 2100, this increases to 70 percent of the installation exposed to 10-15 feet (3-4.6 meters) deep flooding. A Category 4 storm in 2100 would flood 90 percent of Parris Island and the third of MCAS Beaufort with more than 20 feet (6.1 meters) of water.[113] All these scenarios have the potential to significantly reduce Marine recruit training days. While such training could theoretically be relocated, Parris Island offers unique and ideal conditions for the kind of training Marines require. Further, the best candidates for Marine training sites are along coastlines – with low-lying coastlines being particularly optimal. Such a relocation would be undesirable, potentially costly and politically difficult, with implications for military readiness and operations.

Virginia

Hampton Roads. In the Hampton Roads area of Virginia, natural subsidence, low-lying topography and changing ocean circulation patterns are contributing to a higher rate of sea level rise than the global average. Each military branch has facilities in Hampton Roads, with over 100,000 military and 40,000 civilian personnel serving in the area. Major military units and headquarters in

Source: CNA Military Advisory Board Report, "National Security and the Accelerating Risks of Climate Change"



The lone ship at the pier at the Naval Station, Norfolk, Va., USS Kearsarge endures the rain and heavy winds from Hurricane Isabel. September 2003. US Navy / Photographer's Mate 1st Class Michael Pendergrass.

Hampton Roads include NATO's Allied Command Transformation, U.S. Joint Forces Command, U.S. Fleet Forces Command, the U.S. Air Force's Air Combat Command, U.S. Marine Corps Forces Command, the U.S. Army Training and Doctrine Command, and the largest regional concentration of U.S. Coast Guard capabilities and personnel. The collective operational and strategic value of these commands cannot be overestimated, as they serve as centers for fulfilling U.S. strategic objectives in the Pacific, the Middle East and North Africa, and Europe.

Worryingly, many of these critical, strategic defense assets in Hampton Roads, which are essential for overall military readiness and a range of critical operations, are quite vulnerable to climate change. According to one assessment, the rapid rate of climate change-fueled sea level rise is occurring over twice as fast in Hampton Roads than the global average.[114] The site is already experiencing an increase in periodic flooding of its low-lying areas. Commanding officers at Naval Station Norfolk, a key installation in the Hampton Roads region, have reported that increased flooding creates frequent interruptions to day-to-day base operations, which costs time, attention, and budgetary resources.[115] The future looks worse. Naval Station Norfolk is already a maximum of 10 feet (3 meters) above sea level.[116] Low-lying areas of the base flood periodically and in 35 years may be underwater 10 percent of the year. By the end of the century, 10-60 percent of the station may be exposed to extra-high tides, with up to 20 percent of its land becoming permanently inundated. All of NS Norfolk is exposed to flooding from a Category 3 or 4 hurricane today. With sea level rise continuing at current rates, 55-95 percent of the station would be exposed to flooding more than 10 feet (3 meters) deep from a Category 4 storm in 2070-2100. Category 1 storms over the same time periods expose 35-75 percent of the station to flooding, with about 15 percent of the station below 5 or more feet (1.5 meters) of water by the end of the century.[117] Nearby Langley Air Force Base faces even more significant risks, with the highest plausible scenario in a recent study suggesting significant daily flooding by 2050.[118] As mentioned previously, it houses most of the F-22 force as well at the 480th Intelligence, Surveillance, Reconnaissance Wing. This is the heart of the Air Force's Distributed Common Ground Station, which supports a broad array of global operations through primary intelligence, surveillance and reconnaissance planning.

Washington, DC

Joint Base Anacostia-Bolling and Washington Navy Yard. Joint Base Anacostia-Bolling (JBAB) is situated between the Potomac and Anacostia rivers in Southeast DC, and is comprised of the former Naval Support Facility Anacostia and the former Bolling Air Force Base.[119] JBAB hosts the Defense Intelligence Agency Headquarters, which provides military intelligence to policymakers and force planners in the DoD and intelligence community,[120] By 2050, the tidal flooding which periodically affects low-lying areas of JBAB could happen twice a day, and by 2070 roughly half of JBAB could flood daily, becoming part of the tidal zone. By the end of the century, a Category 1 hurricane could expose 65-75 percent of the base to flooding, and under the highest scenario a Category 4 storm could flood 75 percent of Bolling AFB and over 95 percent of NSF Anacostia, over half of which would be more than 5 feet (1.5 meters) deep."[121] Severe infrastructure damage or outages could affect secure communications capabilities for a significant number of senior Air Force leaders, if these effects come to pass and the site's missions remain as they are today. "Washington Navy Yard is home to the Commander of Navy Installations Command which manages shore installations (ports, airfields, housing) for the U.S. Navy, as well as several other commands including the Naval Facilities Engineering Command and Naval Inspector General.[122] According to a recent study, "In the highest scenario, 30 percent of the base's land area becomes part of the tidal zone by the end of the century, and a Category 4 hurricane could expose 75 percent of the base to a storm surge, although a portion of its land area has enough elevation to not be flooded."[123] Critical equipment and communications infrastructure, including classified intelligence systems, and military housing would all be at risk. The Blue Plains waste treatment plant is already at risk, and is building a sea wall designed to withstand a 500-year interval storm surge.[124]

Aerial view of Navy Yard in the S.W. quadrant, Washington, D.C.
Library of Congress / Carol M. Highsmith

HIGHLIGHT: Arctic Infrastructure

While risks to infrastructure in and near the Arctic were not a focus of this study, they should not be ignored or underestimated. As highlighted in a 2014 GAO study of climate risks to military infrastructure:[125]

"At 8 out of 15 locations we visited or contacted, officials stated that they had observed rising temperatures and associated potential impacts or mission vulnerabilities, as described by DOD in the [Arctic] Roadmap. For example, the combination of thawing permafrost, decreasing sea ice, and rising sea level on the Alaskan coast have led to an increase in coastal erosion at several Air Force radar early warning and communication installations. According to installation officials, this erosion has damaged roads, utility infrastructure, seawalls, and runways. For example, at one radar early warning installation, 40 feet of shoreline has been lost as a result of erosion and the erosion has damaged half of the runway. As a result, only small planes or helicopters are able to land in this location, as opposed to larger planes that could land on the runway when it is fully functional. This means that access to the radar installation is limited. At another radar early warning installation, increased erosion has dam aged a seawall, allowing increasingly large waves to damage the overrun area of a runway. According to installation officials, daily operations at these types of remote radar installations are at risk due to potential loss of runways, and such installations located close to the coastline could be at risk of radar failure if erosion of the coastline continues."

Further research into implications for readiness, operations and strategy needed

Despite existing information about the projected extent of sea level rise and storm surge for coastal military installations in the 21st century, a more granular understanding of impacts is needed. Developing more specific, and accurate assessments of how sea level rise can impact readiness and operations requires detailed, site-specific examinations of installations' and the surrounding supporting community's geographical features, such as topography and land type, and their exposure to extreme water levels, e.g. the potential height of storm surges in the area. Systematically combining this analysis with assessments of installations' missions and activities, and how they relate to the coast, can help create vulnerability assessments specific to individual installations; these in turn can inform planning for how to maintain military readiness and infrastructure, part of which may involve prioritizing critical installation functions.[126]

Work to develop these tools and frameworks is underway, alongside other efforts to integrate climate information into DoD mission requirements. These tools will form an important basis for more in-depth analysis of the implications of these challenges for military readiness and operations. For the most part, however, analysis of these third-order impacts remains to be undertaken.

HIGHLIGHT: Protecting the "Jewels in Our Crown of Capability"

In a July 2016 speech, General Ron Keys, United States Air Force (ret), described his concerns regarding sea level rise risks to some of Virginia's key defense sites:

"[W]e have 19 bases that we consider jewels in our crown of capability that are going to be affected by sea level rise. And it doesn't have to rise eight feet. It only has to rise a couple of inches, and a good nor'easter pulls in, and all of a sudden we're under water. If you look at Langley Air Force Base where our Raptors reside, it's only seven feet above mean sea level right now. The problem is the land is subsiding, sea level is rising, the currents are changing. We could, in about fifteen years, have 100 days of tidal flooding. Which means with just the normal high tide, we lose access to certain parts of our base...

We need to start considering, what can we do? Now I can build a moat, or a barrier around Langley Air Force Base, but the problem is a lot of my people live in Newport News, live in Hampton. A lot of my electricity comes in from outside. My fuel comes in from outside. So at some point we get to the point: 'I've got to move to higher ground.' And we have started talking about that because that's going to be a bloodletting when we tell the Congressman from Virginia that we're picking up Langley Air Force Base and we're going to Oklahoma. That's not going to play well. So we need to start talking about that."[127]

U.S. Marines with Combat Assault Company, 3rd Marine Regiment drive an assault amphibious vehicle through the salvage yard wetland at Marine Corps Base Hawaii. February 2014. DoD / Lance Cpl. Matthew Bragg

IX Conclusion and Recommendations

This report finds that over the course of the 21st century, the U.S. military's coastal military installations, domestically and internationally, face significant risks from climate-related effects, namely sea level rise and the interaction of sea level rise with an increased frequency and intensity of extreme weather events. This report also finds that these risks, if not sufficiently mitigated, may eventually have wide-ranging effects on the military's ability to effectively fulfill its mission. This includes effects on military readiness, military operations and military and national security strategy. This report also concludes that policies and plans for addressing these risks will have to be commensurate to a scale of risk that goes beyond infrastructure resilience. Indeed, climate change effects such as sea level rise are not just an installation and facility issue for U.S. military forces, and these broader implications must be both better understood, planned for and prevented. The complex relationships to global readiness and responsiveness must be explored down to the operational level, across the Services and Joint forces, and to a strategic level as well. Given that these conclusions are widely shared by the DoD, the report authors recommend that policy-makers support comprehensive and preventive measures, in the near term, to address these risks. In this context, the Military Expert Panel offers the following specific recommendations.

1. Continuously identify and build capacity to address infrastructural, operational and strategic risks. All of the country's defense installations, and the sites from which U.S. defense forces operate globally, support DoD's ability to perform its steady-state work, conduct whatever missions arise, and meet the goals established by the national security strategy. The types of impacts highlighted in this report, and past reports by the DoD and others, may indeed already be driving new operational and strategic risks, and will likely drive more in the future. In this context, policy-makers need to help bolster the DoD's capacity for comprehensively addressing the operational and strategic risks associated with a changing climate;

2. Integrate climate impact scenarios and projections into regular planning cycles.
Military installations undergo regular maintenance and upgrades, often according to predictable cycles. Where it is not doing so already, the DoD and Department of Homeland Security (DHS) – for Coast Guard installations – should fold current and projected climate impact analyses into the plans used to make decisions as routine assessments and investments are made, and policy-makers should robustly support the recommended infrastructure modifications that flow from those analyses. Infrastructure modifications are long term (decades) in their execution, and the necessity for preparatory work must be understood. Policy-makers should therefore support long range planning and infrastructure upgrades and modifications that reduce and mitigate flood risks, as well as more short-notice funding as unforeseen risks become apparent. Additionally, the DoD and DHS should integrate climate change metrics and catastrophic weather event scenarios into their assessment planning and vulnerability ratings in their Critical Infrastructure Protection Plans;

3. Make climate-related decisions only after considering the highest risk level projections.

If, continuing the trend of recent years, scenarios and projections of coastal impacts continue to grow more worrisome as they are refined, the defense community should assume that some of what we now believe are worst-case scenarios will actually be the median or even best-case scenarios. Put simply, the world is already seeing effects that are worse than projections of past decades indicated they would be – and they are occurring much earlier than the timescales predicted in the past. While trends may change, in terms of risks to defense readiness and budgets, it is possible that what we now see as worst-case effects may not actually be the worst we will see in the future. To ensure that the DoD is adequately prepared, policy-makers should support decisions by the DoD that take the highest climate risk level projections into account;

4. Game out catastrophic scenarios in planning.

To fully understand the range of risks that could be triggered by the types of effects highlighted in this report and others, the U.S. government should begin to model impacts at a few critical bases, and their surrounding support communities, that are likely to see the most severe effects. This analysis should begin with installations that host unique functions not conducted at many other installations – for example, those that repair and refuel nuclear-powered naval assets – and should use the most severe credible scenarios developed to date for those sites. Things to consider would be warning times, dispersal options, local impact, recovery requirements, and impacts on supported forces;

5. Work with international counterparts at key coastal bases abroad.

The examples cited in this report for coastal risks globally show the importance of proactively working with allies and partners on risks to key defense sites. This international cooperation should take several forms, depending on the risks most relevant to the defense equities of each country involved. U.S. defense forces already conduct humanitarian assistance /disaster relief (HA/DR) exercises that take climate trends into account. Other productive cooperative activities could include sharing sea level rise projections relevant to military and coast guard facilities, and sharing lessons regarding U.S. bases already being impacted by sea level rise, such as the critical defense sites in the Virginia Beach-Hampton Roads area. Where data or projections of relevant areas outside of U.S. territory need updating, DoD and other government agencies should seek to develop them in cooperation with other countries. This should include cooperation in reviewing whether data can be leveraged from existing terrestrial monitors and remote sensing assets.

Whether conducted bilaterally or multilaterally, this work can help fulfill U.S. strategic goals by increasing awareness of global operating environments, building the capacity of allied and partner nations, strengthening relationships in key regions such as the Asia-Pacific, and competing for influence with other global powers;

6. Track trends in climate impacts as uncertainty levels are reduced.

The scientific community will continue to reduce uncertainties related to projections of the coastal impacts of sea level rise and storm surge. As uncertainties are reduced, government and non-governmental experts should track whether the overall picture of possible impacts becomes worse or better. Decision makers will need confidence in the degree to which environmental trends are following model projections, and that they have time to change course if past projections are wrong (e.g., if sea level rise effects, flooding, and disasters are more extreme or otherwise different from what previous projections indicated). A 2016 DoD report indicated that this must extend to identifying the conditions under which weather and climatic impacts are most likely to prevent the conduct of specific missions. These variables "should be tracked and documented over time to ensure mission sustainability."[128] Tracking these trends, and identifying climate conditions that prevent specific missions, can be incorporated into existing processes, such as the planning work already conducted for the use of testing and training ranges;

7. Maintain close collaboration with adjacent civilian communities.

Many coastal installations are inextricably linked to neighboring "support communities" that provide housing for military personnel at the installation, the homes for critical personnel who work at the installation, and in some cases lifeline utility support for the installation. As the military continues to develop its plans for dealing with sea level rise and other climate-related effects at the installation, it becomes critical to not only include the support communities in the planning efforts, but also determine how the two communities can best work together to optimize the results. The efforts underway in the Hampton Roads area are indicative of the level of cooperation that can be established among multiple military services and the communities with which they work on a daily basis.

8. Continue to invest in improvements in climate data.

Throughout the process of producing this study, it became increasingly clear that the lack of trend data on sea level rise and storm surge implications regarding loss of training days, damage to equipment and infrastructure, repair and maintenance costs, and risks to support communities that are critical to base operations, is hindering proactive decision-making. This is the case for defense sites at home and abroad. While U.S. leaders will have to act in the face of uncertainty to prevent climate change from impairing operations, readiness, budgeting, and installation management, better data will help facilitate effective planning. Luckily, DoD recognizes the challenge. Even in its 2016 report, one of the most extensive bodies of work to date on climate impacts to coastal defense sites, the authors note, "The limitations of currently available data sources and the manner in which the global models are used to provide information affected the manner in which scenario information could be provided spatially and temporally." As the authors explain, in many cases a lack of even basic information, such as tide gauge data, created difficulties in projecting future sea level rise and other issues. The difficulties were compounded for areas for which topographic or bathymetric data were relatively poor. In summary, the DoD report concludes that the "importance cannot be overstated" of improving data quality and consistency.[129] Many of the department's ongoing studies of climate change effects in coastal areas are designed to help fill data gaps. Support for these projects and their expansion will be critical.

Notes

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THE CENTER FOR CLIMATE AND SECURITY

Military Expert Panel Report

Sea Level Rise: Implications for the U.S. Military's Mission

September, 2016

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