

# BRIEFER

No. 27 | October 14, 2015

---

## Hampton Roads, Virginia and the Military's Battle Against Sea Level Rise

*Matt Connolly*

---

**“The greatest concentration of military might in the world...”**

Throughout U.S. history, Virginia has been known for its legacy of support for the military and its service members. Today, Virginia maintains a bustling military presence, hosting an interconnected network of major bases and training ranges, over 200,000 active duty military and civilian personnel, and approximately 5,000 defense-related companies. The Commonwealth's strategic assets - including its unique land and water geography, advanced transportation infrastructure, specialized workforce, and dynamic private sector -- have proven to be highly compatible with the needs of the Department of Defense (DoD), which has invested billions of dollars in Virginia's military facilities and capabilities.<sup>1</sup> Virginia consistently ranks among the top U.S. states in DoD spending - ranked first at \$54.7 billion in Fiscal Year 2014.<sup>2</sup>

The epicenter of Virginia's defense activities is in the Hampton Roads region, comprised of 10 cities and five counties in southeast Virginia along the mouth of the Chesapeake Bay. In the words of former Defense Secretary Leon Panetta, “Simply put, this region houses perhaps the greatest concentration of military might in the world.”<sup>3</sup>

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 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, and the U.S. Army Training and Doctrine Command.<sup>4</sup>

Of the 29 military sites in Hampton Roads, the largest and most important is Naval Station Norfolk. Located along one of the world's best natural deepwater harbors, the base provides support for the entire U.S. Atlantic Fleet and is homeport to 59 ships -- including aircraft carriers, submarines, cruisers, destroyers, large amphibious ships, and a variety of supply and logistics ships. Approximately 46,000 military and 21,000 civilian personnel and contractors serve at NS Norfolk, which also houses 18 naval air squadrons and serves as one of DoD's busiest supply centers.

Hampton Roads is also home to other nationally significant bases, including Joint Base Langley-Eustis, as well as major defense contractors that support the military, including the only shipyards capable of building and overhauling U.S. aircraft carriers and one of the two providers of U.S. submarines.

Unfortunately, some of the most important national security assets in Hampton Roads are also the most vulnerable. The rapid rate of climate change-fueled sea level rise -- occurring over twice as fast in Hampton Roads than the global average<sup>5</sup> -- is contributing to frequent flooding and significant damage and disruption at NS Norfolk and other low-lying bases in the region. For DoD to ensure the long-term viability of its facilities in Hampton Roads, the impacts of climate change and sea level rise must be addressed.

### Virginia's Accelerated Rate of Sea Level Rise

Global sea level rise is a well-established consequence of higher global temperatures, which melt ice sheets and glaciers and cause thermal expansion of seawater. In any given location, the amount of relative sea level rise can vary with local factors such as rising or sinking land, or shifts in ocean circulation.

Since the late 1880s, tide gauges have shown that global sea level rise averaged approximately 8 inches.<sup>6</sup> But in Norfolk, sea level rise has increased 18 inches since 1900 and 8.79 inches since just 1970.<sup>7</sup> This higher relative sea level rise is primarily due to sinking land surface (subsidence) in the region. Recent studies have also suggested that changes in the flow of the Gulf Stream linked to warming of the polar region may be contributing to higher sea levels along the U.S. Mid-Atlantic coast.<sup>8</sup> Taken together, these factors are causing Hampton Roads to experience the most rapid and highest amounts of relative sea level rise on the Atlantic Coast.

Sea level rise in the region is expected to not only continue but accelerate for the foreseeable future. Under business-as-usual projections, relative sea level rise in Hampton Roads is expected to increase by at least an additional 2.3 feet and possibly as much as 5.2 feet by 2100.<sup>9</sup> Worst-case scenarios project 7.5 feet of sea level rise by the end of the century.<sup>10</sup>

According to the National Oceanic and Atmospheric Administration (NOAA), 82% of the Virginia coastline is considered at high or very high risk to sea level rise, and Hampton Roads is the largest population center at greatest risk from sea level rise outside of New Orleans.<sup>11</sup>

### Key Points:

- The Department of Defense has concluded that rising sea levels and climate disruptions impair military readiness and are a "present security threat, not strictly a long-term risk."
- The Hampton Roads region, home to 1.7 million people and over two dozen military sites, is the second most vulnerable region in the U.S. to hurricanes, storms, and sea level rise.
- Major military facilities in Hampton Roads lie mostly or completely below 10 feet above mean sea level.
- Naval Station Norfolk, the largest naval complex in the world, is directly exposed to storm surge and sea level rise, which is contributing to flooding that is disrupting base operations and damaging critical infrastructure on and around the base.
- Some scenarios project that sea level around Norfolk will rise by seven feet or more in the next 100 years.
- A U.S. Army Corps of Engineers risk assessment found that, by the second half of this century, 60 to 80 percent of Naval Station Norfolk could be flooded during storms the size of Hurricane Isabel in 2003.
- The Navy, National Security Council, and local, state and federal agencies have launched a first-of-its-kind, inter-governmental pilot project to increase Hampton Roads' resilience to the impacts of sea level rise.

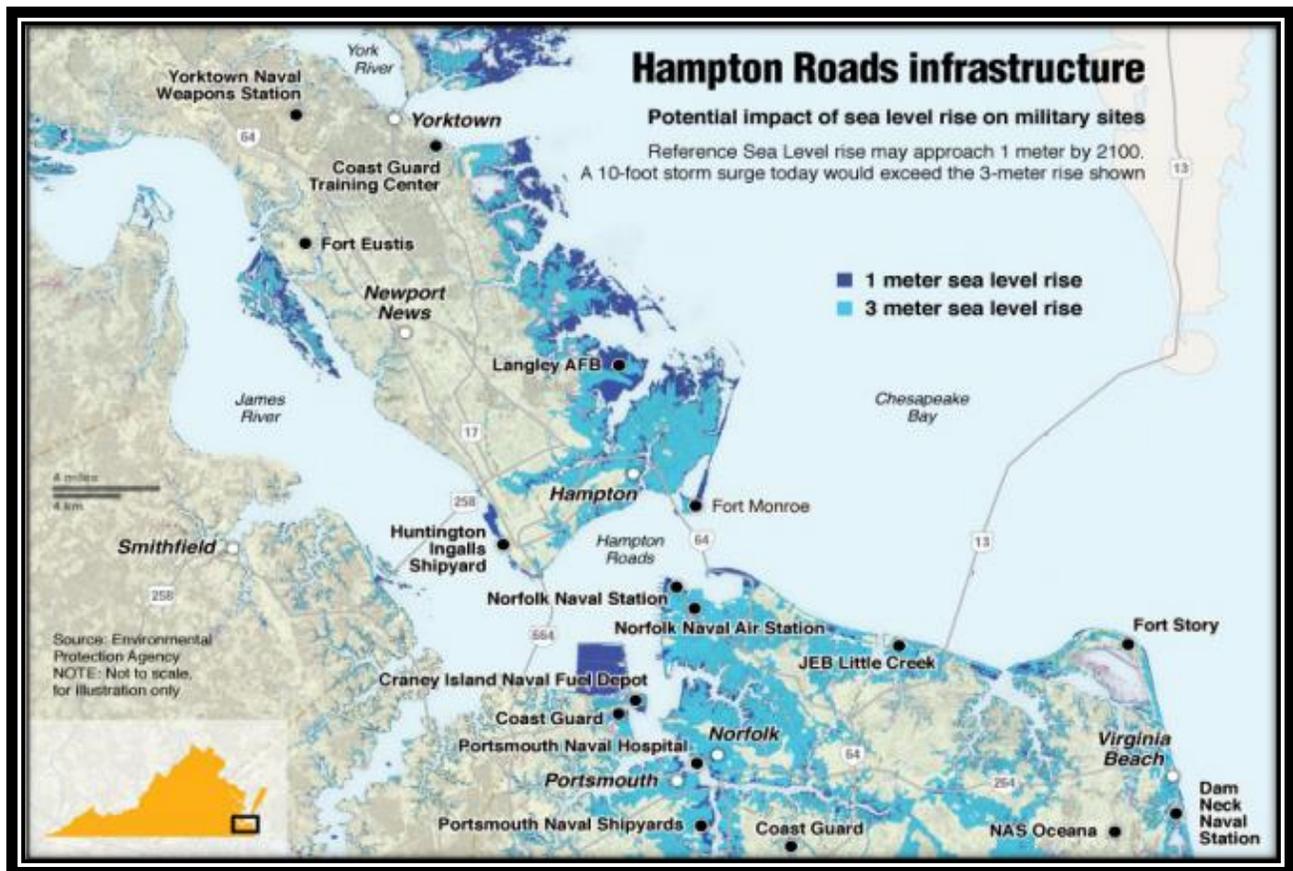
## Flooding and Storm Events in Hampton Roads

Even seemingly small increases in sea level rise can have dramatic effects. By raising the launchpad for tides and storm surge, higher sea levels have increased the frequency, magnitude, and duration of flooding events in Hampton Roads.<sup>12</sup> In some areas of Norfolk, floods that in the past were only caused by unusually strong storms are now often happening during a little above normal high tide.<sup>13</sup>

Major DoD facilities in Hampton Roads are extremely vulnerable to flooding, as NS Norfolk, Norfolk Naval Shipyard, and Joint Base Langley-Eustis lie mostly or completely below 10 feet above mean sea level. Commanding officers at NS Norfolk, which has over 12 miles of waterfront

and an average elevation of 8 to 10 feet above sea level, have reported that flooding creates frequent interruptions to day-to-day base operations -- costing time, attention, and budgetary resources.<sup>14</sup>

Hampton Boulevard -- the main access road to NS Norfolk-- is subject to flooding from normal rainstorms, impeding the flow of traffic on and off the base for the more than 60,000 sailors and civilians who work on site. Studies project that by 2040, Hampton Boulevard will be underwater, and impassable, for 2-3 hours a day simply from normal tide action.<sup>15</sup> On the base's waterfront, many of the 13 World War II-era piers require significant maintenance due to the impact of sea level rise -- and each pier will cost \$35-40 million to replace.<sup>16</sup>



Source: CNA Military Advisory Board

One of the biggest concerns accompanying rising seas is the increased likelihood of historic flooding that can cause catastrophic damage to the military's critical, immovable infrastructure. An analysis by Climate Central illustrates how sea level rise multiplies the probability of historic storms: "An extreme flood reaching 4.9 feet above the present high tide line at the Chesapeake Bay Bridge would today require a 1%-annual-chance combination of storm surge and tide. But after 1.4 feet of sea level rise, a flood reaching the same absolute elevation would only require a 1.4-ft lesser combination of storm and tide, coming with a roughly 10% annual chance. This transition from rarity to fairly common event would take place by mid-century in a "medium" sea level rise scenario."<sup>17</sup>

In recent years, Hampton Roads has emerged as a case study in the military's vulnerability to the combination of sea level rise, storm surge and high tide. When Hurricane Isabel hit Hampton Roads in 2003, tidal levels rose almost 8 feet, putting most of Langley Air Force Base underwater. The storm affected 200 facilities on the base, costing \$166 million in recovery efforts. Isabel caused an additional \$130 million in damage to Navy infrastructure in the region. More recently, NS Norfolk sustained severe damage from an August 2012 Nor'easter, which caused "base and roadway flooding, over-topped piers, disrupted utilities, eroded the shore line, pier and bulkhead scour, destabilized the ground, and increased loads on structures."<sup>18</sup>

As sea level continues to rise, the potential for future losses is enormous. According to the author of a 3-year U.S. Army Corps of Engineers study<sup>19</sup> on the vulnerability of NS Norfolk, the impact of flooding from a storm the size of Hurricane Isabel --plus the projected increases in sea level rise -- could cripple the base's existing infrastructure: "at some point between a 1.5-foot and three-foot rise of the sea, the Navy base, and much of Hampton Roads, would be underwater for hours, or even days, following a large storm. It also underscored the degree to which the naval station's systems rely on civilian infrastructure outside its gates."<sup>20</sup> The study concluded that "based on our analysis of NS Norfolk's site-specific vulnerabilities, we found sea level rise to be a significant and pervasive threat multiplier to mission sustainability, significantly increasing loadings on built infrastruc-

ture, and dramatically increasing risks to system capabilities and service provisioning."

### **DoD's Call to Action: A "Whole of Government" Response**

The vulnerability of Hampton Roads' bases and infrastructure is well-known to DoD leadership. For more than a decade, DoD has recognized climate change as a threat to its facilities, infrastructure, and military readiness and operations. The 2010 Quadrennial Defense Review recognized that climate change will affect DoD "in two broad ways": first, by acting as an "accelerant of instability or conflict, placing a burden to respond on civilian institutions and militaries around the world"; and second, by its physical impact on DoD facilities and capabilities, including the "30 U.S. military installations that were already facing elevated levels of risk from rising sea levels."<sup>21</sup>

DoD's strategy for responding to climate change was outlined and updated in its 2014 Climate Change Adaptation Roadmap, which established three broad goals to increase resilience to climate change: 1) Identify and assess the effects of climate change on DoD, 2) Integrate climate change considerations across DoD and manage associated risks, and 3) Collaborate with internal and external stakeholders on climate change challenges.<sup>22</sup>

In releasing the Roadmap, Secretary Chuck Hagel highlighted the particular vulnerability of DoD's Hampton Roads facilities: "In places like the Hampton Roads region in Virginia, which houses the largest concentration of U.S military sites in the world, we see recurrent flooding today, and we are beginning work to address a projected sea-level rise of 1.5 feet over the next 20 to 50 years."<sup>23</sup>

Because of the inherently global nature of climate change, DoD's Roadmap called for a comprehensive, "whole-of-government" approach to confronting climate change challenges: "Domestically, this means working across our federal and local agencies and institutions to develop a comprehensive, whole-of-government approach to a challenge that reaches across traditional portfolios and jurisdictions."

One example of DoD's "whole-of-government" response to climate change is underway in Hampton Roads. Through a first-of-its-kind, DoD-

sponsored Pilot project, leaders from across the Hampton Roads community are working to establish an intergovernmental planning body to prepare for the impacts of sea level rise on a regional scale.

### **All-hands-on-deck: The Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project<sup>24</sup>**

Following the November, 2013 Executive Order 13653, “Preparing the United States for the Impact of Climate Change,” DoD began working with other federal agencies and local communities to assess and address their common vulnerabilities to climate change. As part of this effort, DoD selected three regions, including Hampton Roads, to create pilot projects involving DoD installations working with local communities to develop regional planning processes to prepare for the effects of climate change.

The Hampton Roads Pilot Project, housed at Old Dominion University (ODU) in Norfolk, was launched in June 2014, bringing together all levels of government and the private sector to develop a coordinated approach to sea level rise adaptation.

One of the early goals of the Pilot has been closing the gap between the various, disjointed efforts in the region to respond to sea level rise. Prior to the Pilot, several scientific reports and planning documents related to sea level rise in Hampton Roads were in progress or completed -- by federal agencies (DoD, the Army Corps of Engineers, NASA, NOAA, FEMA), state bodies (the Governor’s Climate Change and Resiliency Update Commission and the Secure Commonwealth Panel), and municipalities and other local entities (the city of Norfolk, the Hampton Roads Planning District Commission, and Old Dominion University).<sup>25</sup>

Absent from these disparate efforts, however, was intergovernmental coordination or state or federal policies to guide decision-making for sea level rise adaptation. To integrate these efforts, the Pilot set out to establish an intergovernmental Memorandum of Agreement providing for the organizational structures and procedures needed for the region to coordinate key plans and policies on sea level rise adaptation. Upon completion in 2016, the Pilot intends to create a “whole of government” template -- serving as a model for other areas affected by sea level rise -- for regional collaboration on

sea level rise adaptation policies and plans, ranging from land use and infrastructure construction to solutions to legal barriers to regional planning.<sup>26</sup>

With heavy involvement from the National Security Council, Navy, Coast Guard, Air Force and Army Corps of Engineers, the Hampton Roads Pilot project is also designed to help DoD vet and prioritize its infrastructure assets in the region. For DoD installations in Hampton Roads, a “whole of government” approach is a matter of necessity and mutual dependence.<sup>27</sup> Just as the local communities rely on DoD for almost half of its economic activity, the military depends on the surrounding communities for transportation infrastructure, power and water utilities, housing, local workforce, and more. Roads submerged by floodwaters are just one area of mutual concern that requires integrated military and civilian planning. A recent study of the roadways serving military sites in Hampton Roads found that 25 of the region’s 38 “military and supporting sites” are located within areas where critical roadways are most vulnerable to potential submergence as a result of sea level rise and storm surge.<sup>28</sup>

The Center for Naval Analyses (CNA) Military Advisory Board also illustrated the importance of DoD integrating its climate change adaptation strategies with state and local governments: *“Put simply, DOD may modify roads and bridges, seawalls, piers, runways, and other mission critical infrastructure on its installations, but the roads and bridges off base that are used by military commuters will also need to be evaluated for potential sea-level-rise impacts and modified as needed. The same holds true for water systems, local airports, local schools attended by military dependents, and other state and local infrastructure. As a result, mitigation solutions cannot be developed and implemented by DOD alone.”*<sup>29</sup>

### **Moving from Roadmap to Reality**

DoD’s involvement in the Hampton Roads Pilot Project is just one indication of the national security establishment’s growing sense of alarm and urgency regarding the risks of climate change. In recent years, DoD has been working on several fronts to evaluate and respond to the risks of climate change, ranging “from the strategic (DoD’s Arctic Strategy) to the mundane (ensuring backup

power and computer servers are not in basements where facilities are facing increased flood risk).<sup>30</sup>

DoD has also begun work to “mainstream” climate change considerations into its existing processes and operations. In congressional testimony in 2014, Dr. Daniel Chiu, Deputy Assistant Secretary of Defense for Strategy and Force Development stated, “the Department initiated in 2013 a review of existing directives, policies, manuals, and associated guidance document and criteria to identify which ones should incorporate considerations of a changing climate. The initial screen reviewed 58 documents and identified 28 policies, programs and procedures for update; five have already been updated, all dealing with installations.”<sup>31</sup>

But despite these steps, there remains a void in actionable policies for installations to manage the impacts of climate change. DOD has acknowledged that “more comprehensive and region/installation-specific vulnerability assessments are needed to determine which adaptive responses are appropriate.”<sup>32</sup> DoD is currently working to complete a baseline survey of its nearly 7,000 bases, installations, and other facilities that would be used to integrate climate change considerations into planning, operations, and training.<sup>33</sup>

Where climate change adaptation policy is lacking in some areas, it remains incomplete in others. For example, DoD recently updated its Unified Facilities Criteria (UFC) for Installation Master Planning guidance, specifying that the effects of climate change be “considered” in installation planning efforts. However, “which climate scenarios should be used, nor acceptable levels of risks for functions or systems, are not specified. Given the wide range of potential global sea level rise in 2100, as well as the fact that regional sea level rise will vary considerably, such guidance is not sufficient for planning purposes.”<sup>34</sup>

The need for comprehensive climate change adaptation policies is apparent at NS Norfolk, where Navy planners have started to evaluate options to “build and redevelop structures that will be resilient to a two-foot rise in sea level by 2050.”<sup>35</sup> Planners are evaluating options such as “building

new unloading decks with utility lines and shutoff valves safely above potential water levels, adapting existing infrastructure with flood walls around dry docks and installing tide gates, raising pier elevations, and siting facilities out of impacted areas.”<sup>36</sup>

However, making these plans a reality face considerable institutional and policy hurdles. There are currently no funding sources dedicated to climate change adaptation infrastructure projects, and according to a 2014 report by the Government Accountability Office, DoD has failed to prioritize infrastructure projects related to climate change adaptation: “Installation officials rarely propose climate change adaptation projects because the services’ processes for approving and funding military construction projects do not include climate change adaptation in the criteria use to rank potential projects.”<sup>37</sup> Further complicating the issue for planners at installations like NS Norfolk is the lack of coordinated planning with the surrounding community, whose decisions impact the vital transportation infrastructure and utilities that support DoD bases. (Hopefully, the Hampton Roads Project will fill this gap.)

Ultimately, there are limits to what DoD installation planners can do to prepare for climate change without more direction and support from policymakers in Congress and DoD. Given the long lead-time required to make military infrastructure more resilient, and short timeline for action, it is essential that policymakers develop actionable policies that support tactical and strategic planning in the face of climate change. And as the Hampton Roads region shows, DoD’s planning for climate change should not be conducted in a vacuum -- confronting climate change requires all-hands-on-deck.

- 
- <sup>1</sup> Virginia Commission on Military Installations and Defense Activities. "Growing the Military Mission in the Commonwealth of Virginia." May 1, 2015. [https://vada.virginia.gov/media/3955/150420-final-vda-exec-summary\\_public-report.pdf](https://vada.virginia.gov/media/3955/150420-final-vda-exec-summary_public-report.pdf)
- <sup>2</sup> U.S. Department of Defense Office of Economic Adjustment. "Defense Spending by State Fiscal Year 2014." [http://www.defense.gov/Portals/1/Documents/pubs/FY2014\\_Defense\\_Spending\\_by\\_State\\_Report.pdf](http://www.defense.gov/Portals/1/Documents/pubs/FY2014_Defense_Spending_by_State_Report.pdf)
- <sup>3</sup> Secretary of Defense Speech to the Hampton Roads Chamber of Commerce. October 19, 2012. <http://archive.defense.gov/Speeches/Speech.aspx?SpeechID=1729>
- <sup>4</sup> Hampton Roads Chamber of Commerce website: "Our Military". <http://www.hamptonroadschamber.com/page/our-military/#NASO>
- <sup>5</sup> Eggleston, Jack, and Pope, Jason, 2013. "Land subsidence and relative sea-level rise in the southern Chesapeake Bay region." U.S. Geological Survey Circular 1392. <http://pubs.usgs.gov/circ/1392/pdf/circ1392.pdf> At the Sewells Point tidal station in Norfolk, sea levels rose at an average rate of 4.4 mm/yr from 1927 to 2006, compared to a global average of about 1.8 mm/year of sea level rise.
- <sup>6</sup> 2014 National Climate Assessment. U.S. Global Change Research Program. May 2014. <http://nca2014.globalchange.gov/report>
- <sup>7</sup> USA Today. "Scientists warn sea levels could swamp coasts." October 8, 2014 <http://www.usatoday.com/story/weather/2014/10/08/tidal-floods-sea-level-rise/16873241/>
- <sup>8</sup> Old Dominion University. "Connection Between Gulf Stream and Sea Level Rise Confirmed by ODU Study." February 15, 2013. [https://www.odu.edu/news/2013/2/gulf\\_stream\\_sea\\_level#Vhazq-xViko](https://www.odu.edu/news/2013/2/gulf_stream_sea_level#Vhazq-xViko)
- <sup>9</sup> Atkinson, Larry P., Ezer, Tal, and Smith, Elizabeth. "Sea Level Rise and Flooding Risk in Virginia." The Sea Grant Law and Policy Journal. Volume 5 Number 2. <http://nsglc.olemiss.edu/sglpi/vol5no2/2-atkinson.pdf>
- <sup>10</sup> The Daily Press. "Report offers storm-risk framework for Hampton Roads, coastal communities." January 30, 2015. <http://www.dailypress.com/news/science/dp-nws-corps-flood-risk-study-20150130-story.html>
- <sup>11</sup> National Oceanic and Atmospheric Administration website. <http://stateofthecoast.noaa.gov/vulnerability/welcome.html>
- <sup>12</sup> Virginia Institute of Marine Science. "Recurrent Flooding Study for Tidewater Virginia." Submitted to the Virginia General Assembly in January 2013. [http://ccrm.vims.edu/recurrent\\_flooding/Recurrent\\_Flooding\\_Study\\_web.pdf](http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf)
- <sup>13</sup> Atkinson, Larry P., Ezer, Tal, and Smith, Elizabeth. "Sea Level Rise and Flooding Risk in Virginia." The Sea Grant Law and Policy Journal. Volume 5 Number 2. <http://nsglc.olemiss.edu/sglpi/vol5no2/2-atkinson.pdf>
- <sup>14</sup> U.S. Department of Defense Strategic Environmental Research and Development Program (SERDP). "SAB Tours Norfolk." June 29, 2015. <https://www.serdp-estcp.org/News-and-Events/Blog/SAB-Tours-Norfolk>
- <sup>15</sup> Washington Post. "In Norfolk, evidence of climate change is in the streets at high tide." May 31, 2014. [http://www.washingtonpost.com/business/economy/in-norfolk-evidence-of-climate-change-is-in-the-streets-at-high-tide/2014/05/31/fe3ae860-e71f-11e3-8f90-73e071f3d637\\_story.html](http://www.washingtonpost.com/business/economy/in-norfolk-evidence-of-climate-change-is-in-the-streets-at-high-tide/2014/05/31/fe3ae860-e71f-11e3-8f90-73e071f3d637_story.html)
- <sup>16</sup> Stiles, William A. Executive Director, Wetlands Watch. "A "Toolkit" for Sea Level Rise Adaptation in Virginia." 2012. <http://www.wetlandswatch.org/Portals/3/WW%20documents/sea-level-rise/ASCE%20Meeting%20Paper.pdf>
- <sup>17</sup> Climate Central. "Virginia and the Surging Sea: A vulnerability assessment with projections for sea level rise and coastal flood risk." September 2014. <http://sealevel.climatecentral.org/uploads/ssrf/VA-Report.pdf>
- <sup>18</sup> National Oceanic and Atmospheric Administration Climate Program Office. "Case Study Series: Water Resource Strategies and Information Needs in Response to Extreme Weather/Climate Events. Virginia: Tidewater Area. January 2013. [http://cpo.noaa.gov/sites/cpo/Projects/SARP/CaseStudies/2013/Tidewater%20VA%20Case%20Study%20Factsheet%20Extreme%20Weather%20Events\\_2013-1-30v1.pdf](http://cpo.noaa.gov/sites/cpo/Projects/SARP/CaseStudies/2013/Tidewater%20VA%20Case%20Study%20Factsheet%20Extreme%20Weather%20Events_2013-1-30v1.pdf)
- <sup>19</sup> K. A. Burks-Copes and E. J. Russo. "Risk Quantification for Sustaining Coastal Military Installation Assets and Mission Capabilities." Prepared for the Strategic Environmental Research and Development Program (SERDP). Project RC-1701. Submitted June 6, 2014. <https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Climate-Change/Vulnerability-and-Impact-Assessment/RC-1701>
- <sup>20</sup> Association of Defense Communities. "Climate Change Jeopardizes Norfolk Naval Station, Study Concludes." November 6, 2013.

---

<http://www.defensecommunities.org/headlines/climate-change-jeopardizes-norfolk-naval-station-study-concludes/#>

<sup>21</sup> U.S. Department of Defense 2010 Quadrennial Defense Review (QDR). February 2010. [www.defense.gov/qdr](http://www.defense.gov/qdr)

<sup>22</sup> U.S. Department of Defense FY 2014 Climate Change Adaptation Roadmap. October 13, 2014  
[http://www.acq.osd.mil/ie/download/CCARprint\\_wForeword\\_c.pdf](http://www.acq.osd.mil/ie/download/CCARprint_wForeword_c.pdf)

<sup>23</sup> Ibid

<sup>24</sup> Old Dominion University Center for Sea Level Rise, Homebase for The Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project. <http://www.centerforsealevelrise.org/>

<sup>25</sup> Toll, Ray (Old Dominion University, CAPT, USN (Retired)). Presentation to ODU Campus Retreat: "Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project." August 6, 2014.  
<http://www.centerforsealevelrise.org/wp-content/uploads/2014/08/Pilot-Project-Presentation.pdf>

<sup>26</sup> Ibid. Some of the initial deliverables being pursued by the Pilot include creating an information clearinghouse with real-time measurement of sea level rise as well as localized scientific projections, mapping, and simulation information. This Pilot will also aim to provide policy guidance, analyses of regionally relevant legal issues, and a scientific framework to understand critical infrastructure interdependencies in Hampton Roads.

<sup>27</sup> Middleton, Leslie. *Bay Journal*. "Norfolk: The Navy on the Leading Edge." October 2014.  
<http://www.chesapeakequarterly.net/sealevel/main13/>

<sup>28</sup> Hampton Roads Transportation Planning Organization. "Hampton Roads Military Transportation Needs Study: Roadways Serving the Military and Sea Level Rise/Storm Surge." July 2013.  
<http://www.hrtpo.org/uploads/docs/Roadways%20Serving%20the%20Military%20&%20Sea%20Level%20Rise-Storm%20Surge%20Report.pdf>

<sup>29</sup> CNA Military Advisory Board. "National Security and the Accelerating Risks of Climate Change." May 2014.  
[https://www.cna.org/cna\\_files/pdf/MAB\\_5-8-14.pdf](https://www.cna.org/cna_files/pdf/MAB_5-8-14.pdf)

<sup>30</sup> Written testimony of Mr. John Conger, Performing the Duties of Assistant Secretary Of Defense, before the U.S. Senate Armed Services Committee's Subcommittee on Readiness and Management Support. March 11, 2015  
[http://www.armed-services.senate.gov/imo/media/doc/Conger\\_2003-11-15.pdf](http://www.armed-services.senate.gov/imo/media/doc/Conger_2003-11-15.pdf)

<sup>31</sup> Written testimony of Dr. Daniel Y. Chiu, Deputy Assistant Secretary of Defense for Strategy and Force Development, before the U.S. Senate Appropriations Committee's Subcommittee on Defense. May 21, 2014.  
<http://www.appropriations.senate.gov/sites/default/files/hearings/Chiu%20statement.pdf>

<sup>32</sup> U.S. Department of Defense FY 2012 Climate Change Adaptation Roadmap.  
[http://www.acq.osd.mil/ie/download/green\\_energy/dod\\_sustainability/2012/Appendix%20A%20-%20DoD%20Climate%20Change%20Adaption%20Roadmap\\_20120918.pdf](http://www.acq.osd.mil/ie/download/green_energy/dod_sustainability/2012/Appendix%20A%20-%20DoD%20Climate%20Change%20Adaption%20Roadmap_20120918.pdf)

<sup>33</sup> Leggett Jane A. Congressional Research Service Report: "Climate Change Adaptation by Federal Agencies: An Analysis of Plans and Issues for Congress." February 23, 2015. <https://www.fas.org/sgp/crs/misc/R43915.pdf>

<sup>34</sup> Smith, Riley W. "The Good, the Bad, and the Robust: Climate Change Adaptation Choices for the Port of Rotterdam, Port of San Diego, and Naval Base Kitsap – Bremerton." University of Washington, 2015.  
[https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/33252/Smith\\_washington\\_02500\\_1415\\_3.pdf?sequence=1](https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/33252/Smith_washington_02500_1415_3.pdf?sequence=1)

<sup>35</sup> U.S. Department of Defense Strategic Environmental Research and Development Program (SERDP). "SAB Tours Norfolk." June 29, 2015. <https://www.serdp-estcp.org/News-and-Events/Blog/SAB-Tours-Norfolk>

<sup>36</sup> National Oceanic and Atmospheric Administration Climate Program Office. "Case Study Series: Water Resource Strategies and Information Needs in Response to Extreme Weather/Climate Events. Virginia: Tidewater Area. January 2013.  
[http://cpo.noaa.gov/sites/cpo/Projects/SARP/CaseStudies/2013/Tidewater%20VA%20Case%20Study%20Factsheet%20Extreme%20Weather%20Events\\_2013-1-30v1.pdf](http://cpo.noaa.gov/sites/cpo/Projects/SARP/CaseStudies/2013/Tidewater%20VA%20Case%20Study%20Factsheet%20Extreme%20Weather%20Events_2013-1-30v1.pdf)

<sup>37</sup> U.S. Government Accountability Office. "Climate Change Adaptation: DOD Can Improve Infrastructure Planning and Processes to Better Account for Potential Impacts." May 2014. <http://www.gao.gov/assets/670/663734.pdf>