APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY:
RESILIENT ADAPTATION TO INCREASING RISK

STATE CHAPTER

D-10: Commonwealth of Virginia

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I. Introduction

The purpose of the North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk (NACCS) is to catalyze and spearhead innovation and action by all to implement comprehensive coastal storm risk management (CSRM) strategies. Action is imperative to increase resilience and reduce risk from, and make the North Atlantic region more resilient to, future storms and impacts of sea level change (SLC). Resilience is defined by the U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration's (NOAA) Infrastructure Systems Rebuilding Principles as the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.

The goals of the NACCS are to:

- Provide a risk management framework, consistent with NOAA/USACE Infrastructure Systems Rebuilding Principles; and

- Support resilient coastal communities and robust, sustainable coastal landscape systems, considering future sea level and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure.

The NACCS Main Report addresses the entire study area at a regional scale and explains the development and application of the NACCS Coastal Storm Risk Management Framework from a broad perspective. This State Coastal Risk Management Framework Appendix discusses state specific conditions, risk analyses and areas, and comprehensive coastal storm risk management (CSRM) strategies in order to provide a more tailored Framework for the Commonwealth of Virginia. Attachments include the City of Norfolk Focus Area Analyses (FAA) Report and the Commonwealth of Virginia's response to the USACE State Problems, Needs, and Opportunities correspondence.

II. Planning Reaches

The Commonwealth of Virginia was one of the 26 states affected by Hurricane Sandy. The study area includes the entire coastline of Virginia, both the mainland and Virginia portion of the Delmarva Peninsula, or Eastern Shore. Virginia's Coastline is divided between the Chesapeake Bay Estuary, which includes the Elizabeth, James, York, and Rappahannock Rivers and the Atlantic Ocean. Planning reaches were developed based on natural and manmade coastal features including shoreline type, existing USACE CSRM projects, and the 1 percent floodplain to allow for more detailed analysis. A map of the seven planning reaches in Virginia is shown in Figure 1.

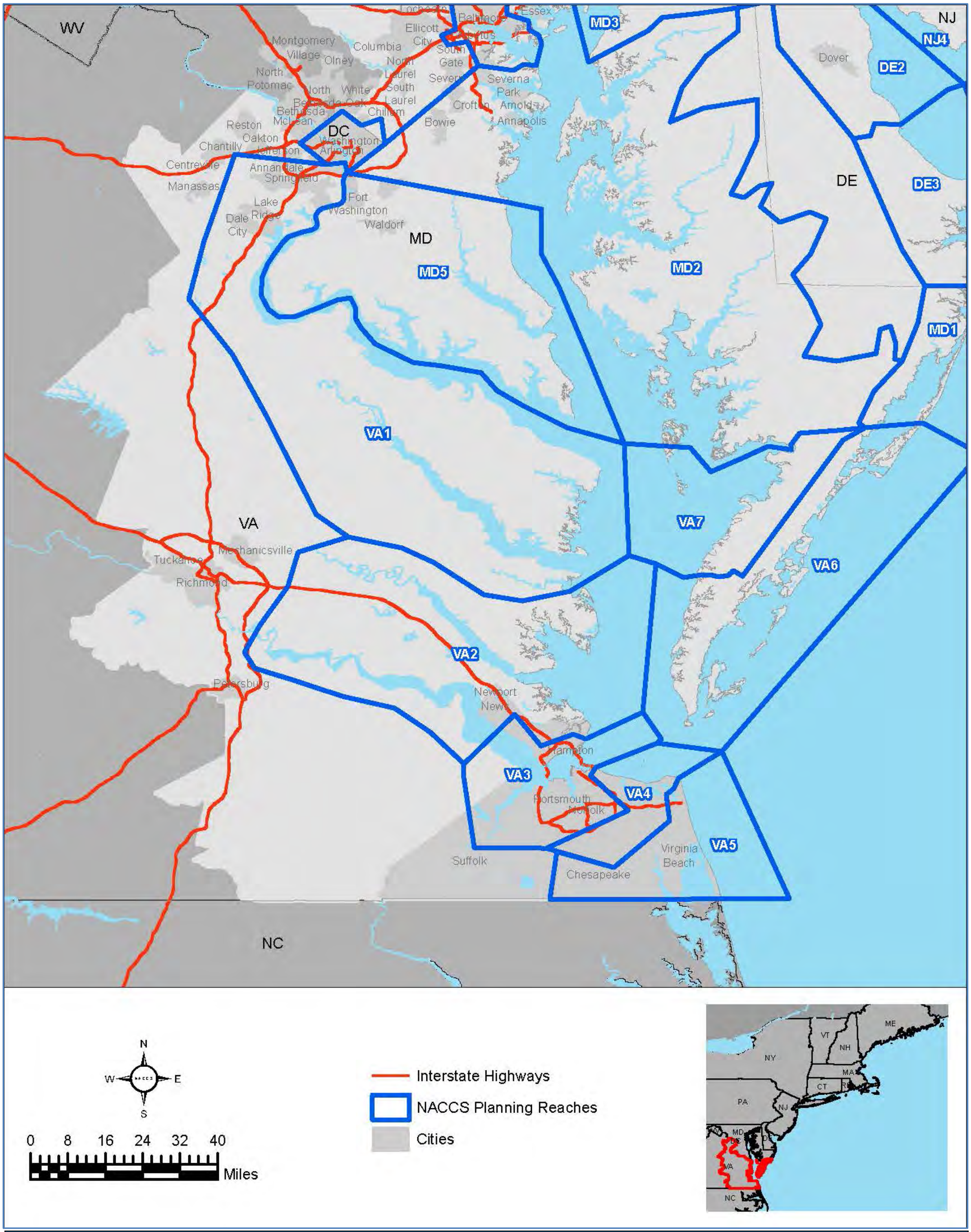


Figure 1. Planning Reaches for the Commonwealth of Virginia

III. Existing and Post-Sandy Landscape Conditions

III.1. Existing Conditions

The existing conditions are the conditions immediately after the landfall of Hurricane Sandy. This existing conditions analysis includes consideration of the population, supporting critical infrastructure, environmental conditions, inventory of existing CSRM projects and associated project performance during Hurricane Sandy, Federal Emergency Management Agency (FEMA) and Small Business Administration response and recovery efforts, FEMA flood insurance claims, and shoreline characteristics that were vulnerable to coastal flood risk associated with Hurricane Sandy. Development of detailed existing conditions across the study area illuminates the vulnerabilities to storm damage that exist. This process helps to identify coastal risk reduction and resilience opportunities. The existing condition serves as the base against which all proposed risk reduction and resilience are compared. Further discussion of the existing conditions is provided in Appendix C – Planning Analyses.

The existing conditions for the Commonwealth of Virginia are summarized in that while coastal storm risk is managed along the Atlantic Ocean coast by a number of Federal coastal storm risk management projects, there are still areas that are not well protected due to the limited number of coastal storm risk management projects. The existing conditions are further discussed herein through an analysis of the population and supporting critical infrastructure affected by Hurricane Sandy within the study area. Figure 2 and Table 1 summarize pertinent information regarding population affected by Hurricane Sandy.

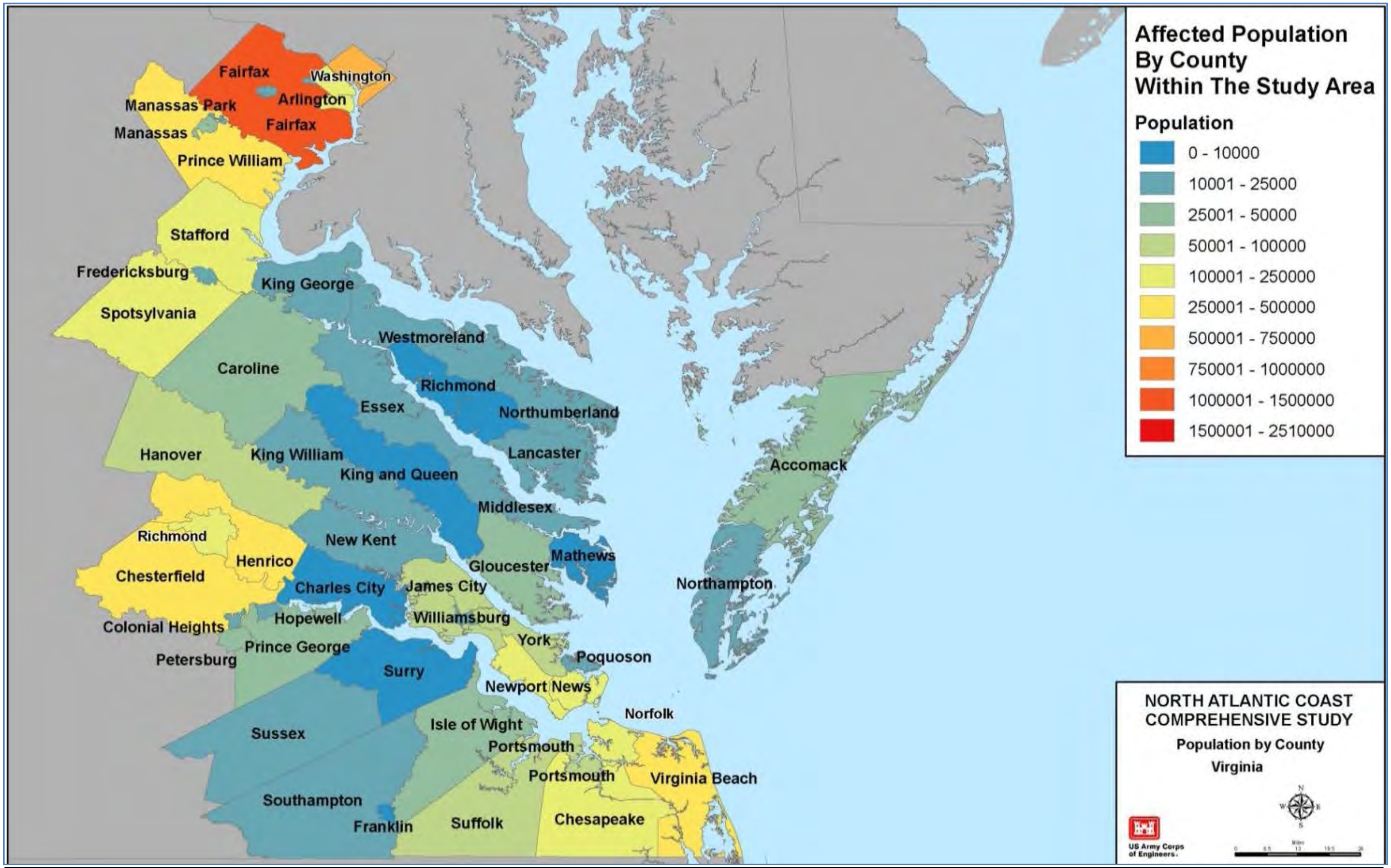


Figure 2. Virginia Population Affected by Hurricane Sandy (2010 U.S. Census data)

Table 1. Affected Population by Hurricane Sandy for the Commonwealth of Virginia

City/County	Population	City/County	Population
Accomack	33,164	Manassas Park	1,4273
Alexandria	139,966	Mathews	8,978
Arlington	20,7627	Middlesex	10,959
Caroline	28,545	New Kent	18,429
Charles City	7,256	Newport News	180,719
Chesapeake	222,209	Norfolk	242,803
Chesterfield	316,236	Northampton	12,389
Colonial Heights	17,411	Northumberland	12,330
Essex	11,151	Petersburg	32,420
Fairfax	22,565	Poquoson	12,150
Fairfax	108,1726	Portsmouth	98,911
Falls Church	12,332	Prince George	35,725
Franklin	8,582	Prince William	402,002
Fredericksburg	24,286	Richmond	9,254
Gloucester	36,858	Richmond	204,214
Hampton	137,436	Southampton	18,570
Hanover	99,863	Spotsylvania	122,397
Henrico	306,935	Stafford	128,961
Hopewell	22,591	Suffolk	84,585
Isle of Wight	35,270	Surry	7,058
James City	67,009	Sussex	1,2087
King and Queen	6,945	Virginia Beach	437,994
King George	23,584	Westmoreland	1,7454
King William	15,935	Williamsburg	1,4068
Lancaster	11,391	York	65,464
Manassas	3,7821	**Total Population Affected**	**2,934,694**

Figure 3 and Table 2 summarize pertinent information regarding critical infrastructure (sewage treatment, water, electricity, schools, waste management, medical, and public safety services) affected by Hurricane Sandy.

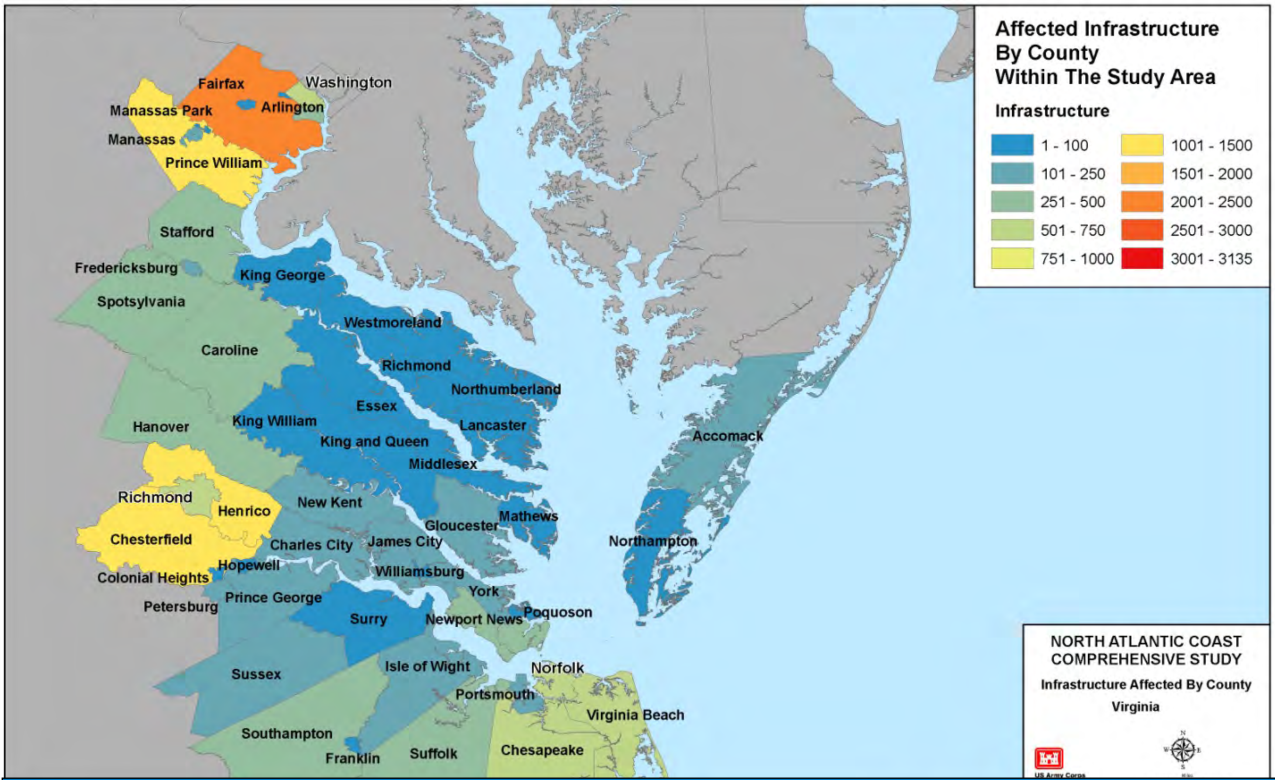


Figure 3. Affected Infrastructure by Hurricane Sandy for the Commonwealth of Virginia.

Table 2. Affected Infrastructure Elements by Hurricane Sandy

City/County	Infrastructure	City/County	Infrastructure
Accomack	215	Manassas Park	15
Alexandria	292	Mathews	27
Arlington	546	Middlesex	45
Caroline	282	New Kent	176
Charles City	188	Newport News	369
Chesapeake	633	Norfolk	718
Chesterfield	966	Northampton	85
Colonial Heights	58	Northumberland	49
Essex	86	Petersburg	239
Fairfax	62	Poquoson	18
Fairfax	2037	Portsmouth	222
Falls Church	28	Prince George	207
Franklin	41	Prince William	770
Fredericksburg	101	Richmond	59
Gloucester	123	Richmond	724
Hampton	334	Southampton	266
Hanover	483	Spotsylvania	306
Henrico	896	Stafford	326
Hopewell	99	Suffolk	364
Isle of Wight	194	Surry	83
James City	199	Sussex	207
King and Queen	90	Virginia Beach	619
King George	82	Westmoreland	64
King William	94	Williamsburg	57
Lancaster	52	York	192
Manassas	158	**Total Infrastructure Affected**	**14,324**

A detailed description of the environmental existing conditions is provided in the Environmental and Cultural Resources Conditions Report.

III.2. Post-Sandy Landscape

The post–Sandy landscape condition is defined as the forecasted scenario or most likely future condition if no NACCS CSRM action is taken, and is characterized by CSRM projects and features, and socio-economic, environmental, and cultural conditions. This condition is considered as the baseline from which future measures will be evaluated with regard to reducing coastal storm risk and promoting resilience. A base year of 2018 has been identified when existing USACE projects discussed below will be implemented or constructed.

Existing USACE Projects

A significant portion of Virginia's border is coastline on the Atlantic Ocean or Chesapeake Bay, and there are numerous USACE projects along that coastline. Navigation is a major component of Virginia's economy and The Port of Hampton Roads is one of the largest deepwater ports on the east coast. There are five Federal navigation channels located in the area where the mouth of the Chesapeake Bay meets the Atlantic Ocean; the Norfolk Harbor-Atlantic, Cape Henry, Thimble Shoal, Willoughby, and Norfolk Harbor-Norfolk Harbor channels allow commercial and Naval vessels to navigate from the Atlantic Ocean into the Chesapeake Bay and to access the Port. Additional smaller Federal navigation channels and inlets are located within the bay and its tributaries. Two more inlets, Rudee and Chincoteague Inlets, are located on the Atlantic coast of Virginia. In addition to these navigation projects, there are USACE constructed shore stabilization and flood risk management projects scattered along portions of Virginia's Atlantic and Chesapeake Bay coasts. The four largest CSDR projects in Virginia are the Wallops Island, Virginia Beach, and Sandbridge Beach projects, which are located on the Atlantic coast, and the Chesapeake Bay Shoreline (Buckroe Beach) project, which is located on the Chesapeake Bay. In addition to these CSDR projects, there are smaller Federal shore stabilization projects such as seawalls, bulkheads, and revetments along Virginia's coast. The Norfolk floodwall project protects a large portion of the City of Norfolk's downtown business district.

There is also one USACE project in Virginia, the Willoughby Spit and Vicinity Coastal Storm Damage Reduction Project, that has been authorized but not constructed. However, this project received funding after Hurricane Sandy for construction. The project will provide a widened beach berm along the Chesapeake Bay coastline in the City of Norfolk and is expected to be completed by 2018. A complete list of existing USACE projects within the entire study area is presented in Appendix C – Planning Analyses. Figure 4 shows the USACE projects considered in the Post-Sandy landscape condition.

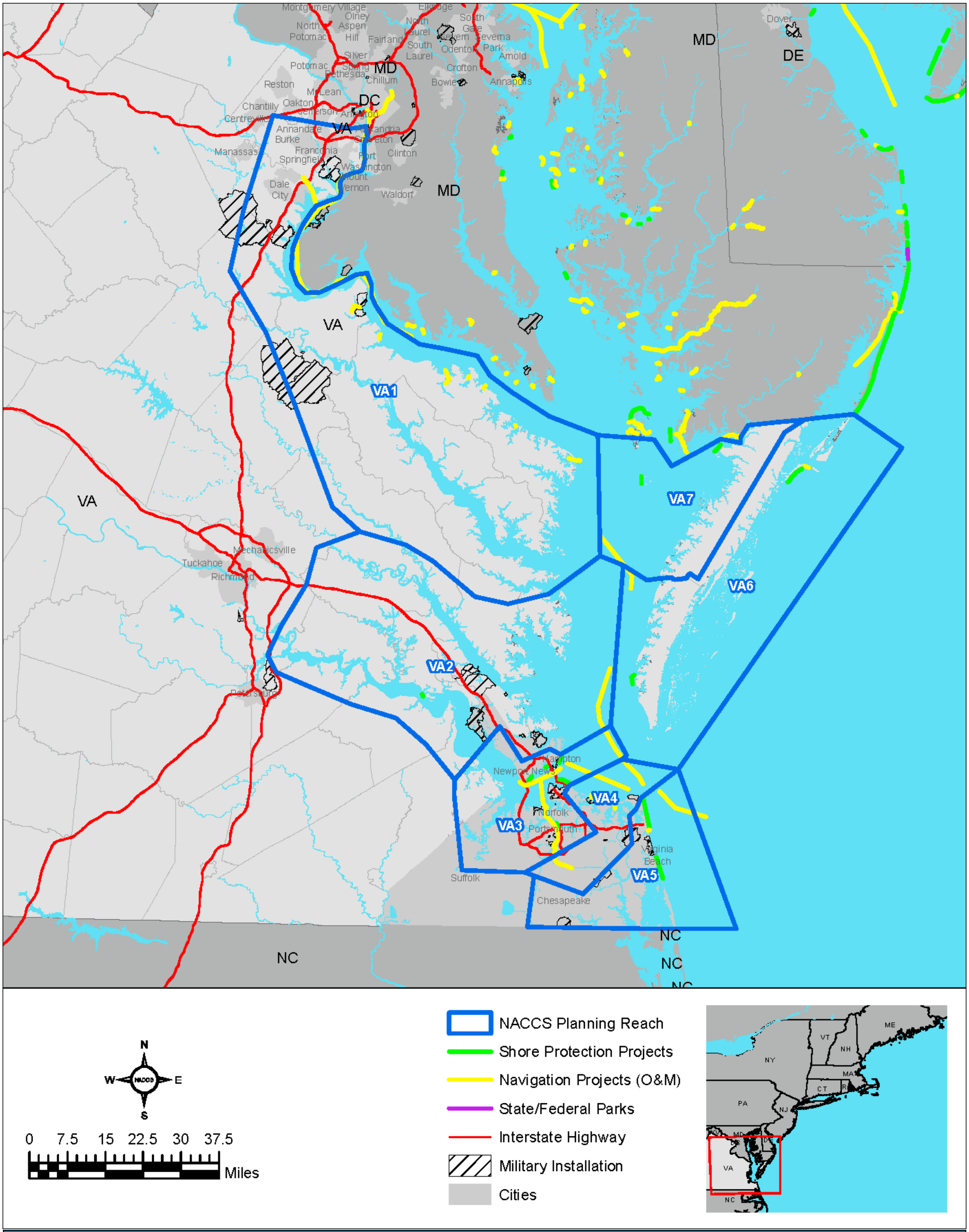


Figure 4. Federal Projects Included in the Post-Sandy Landscape Condition

Existing Non-USACE Projects

In addition to participating in cost shared projects with the USACE, many localities in Virginia implement their own coastal shore stabilization and navigation projects. The City of Virginia Beach regularly renourishes and maintains its Chesapeake, Baylake, Ocean Park, Lynnhaven Shores, and Cape Henry beaches. The City of Norfolk has constructed a series of nearshore breakwaters along the maintained and renourished stretch of beach and dunes at Willoughby, which is located on the Chesapeake Bay. The City of Norfolk has also rehabbed the floodwall originally constructed by the USACE as well as built various living shorelines throughout the city. The City of Hampton also nourishes Salt Ponds and Factory Point beaches and has constructed nearshore breakwaters at Buckroe and Factory Point beaches. Figure 5 shows the non-Federal projects present in the Post-Sandy landscape condition.

The localities in coastal Virginia are expected to continue maintaining their beaches and existing projects, specifically, the cities of Virginia Beach, Norfolk, and Hampton have all expressed that they plan to continue their beach and dune sand renourishment efforts. The City of Norfolk also will be replacing aging stormwater drainage infrastructure and elevate roadways in areas of the city where coastal flooding is an issue. Additional work will focus on environmental restoration activities, including the construction of oyster reefs in the Lafayette River, coastal wetlands, and living shorelines. The City of Hampton also plans to construct living shorelines. Both Norfolk and Hampton plan to also continue and expand their non-structural efforts. The City of Norfolk plans to acquire properties that are chronically flooded, revise zoning requirements city wide, and expand and automate their tidal gage network. Hampton will continue to apply for funding through the Hazard Mitigation Grant Program to elevate residential structures in special flood hazard areas and will complete a Tidal Flooding and Protection Plan for the entire city.

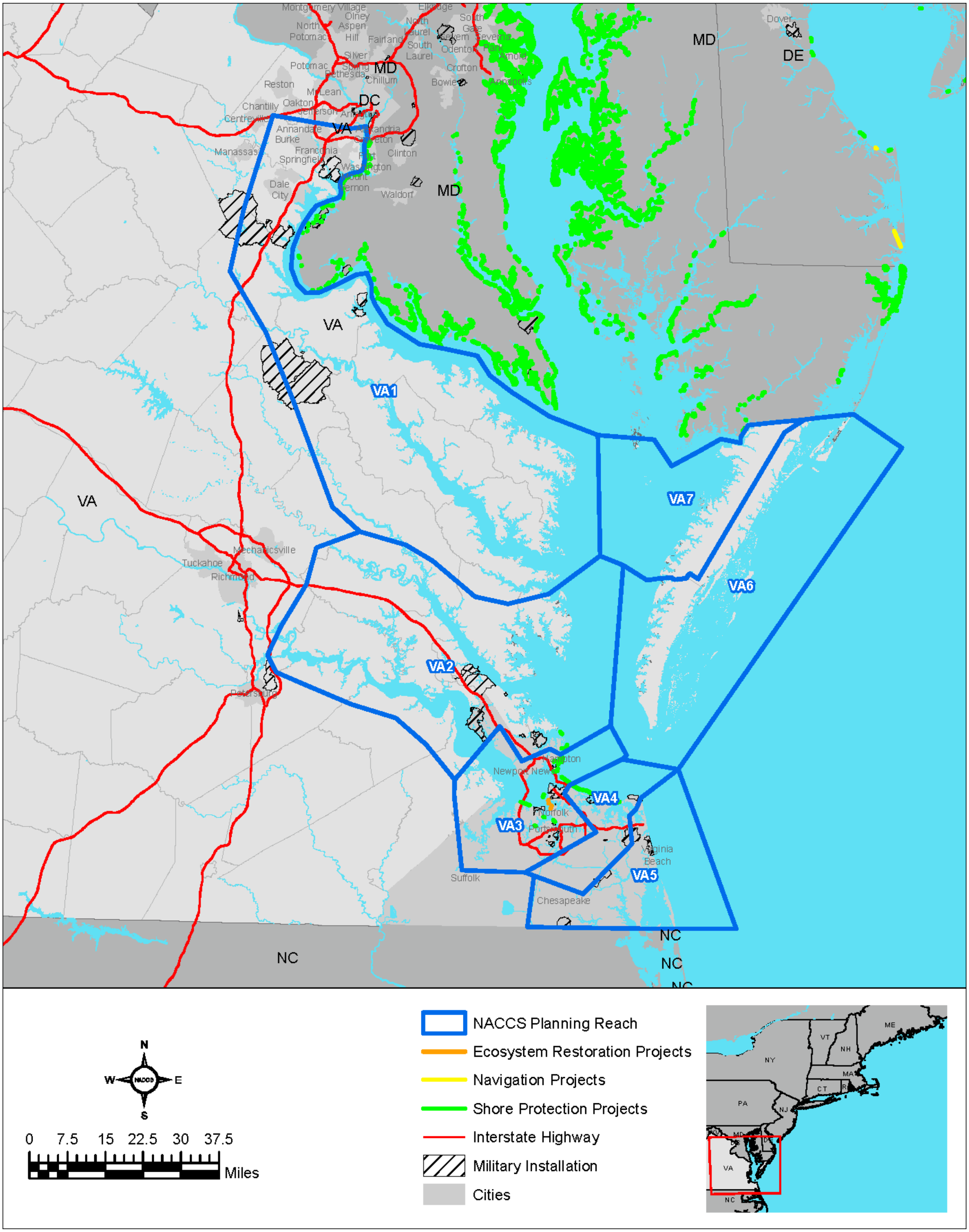


Figure 5. Non-Federal Projects Included in the Post-Sandy Landscape Condition

Sea Level Change

The current USACE guidance on development of sea level change (SLC) (USACE, 2013) outlines the development of three scenarios: Low, Intermediate, and High (Figure 6). The NOAA High scenario (NOAA, 2012) is also plotted in Figure 6. The details of different scenarios and their application to the development of future local, relative sea level elevations for the NACCS study area are discussed in the NACCS Main Report.

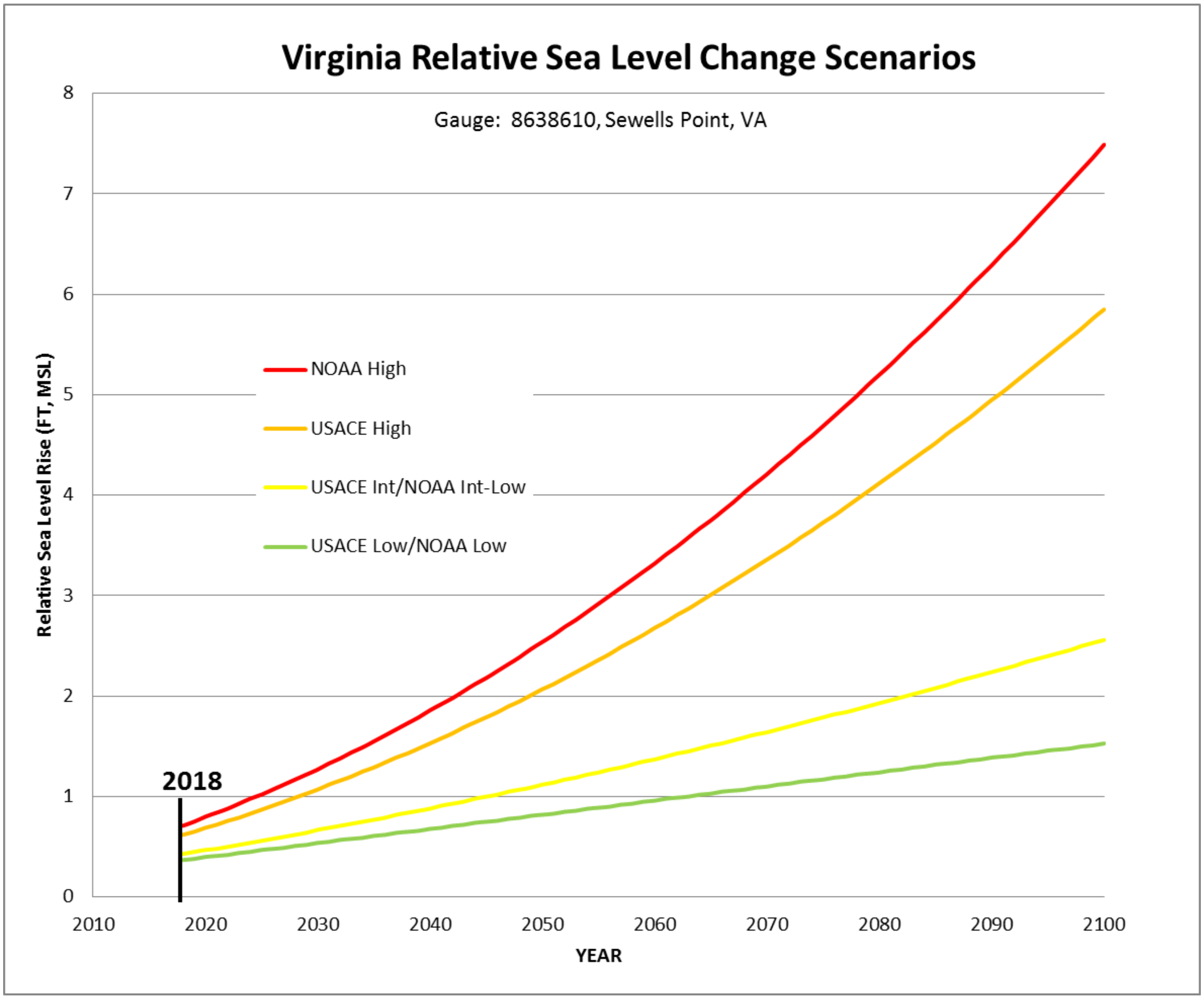


Figure 6. Relative Sea Level Change for Virginia for USACE and NOAA Scenarios.

There is not currently an official SLC scenario that is used exclusively by the Commonwealth of Virginia and/or its municipalities for long-range coastal planning. However, in recognizing the need to consider SLC in planning for the future, in 2012 the General Assembly funded the Virginia Institute of Marine Science (VIMS) to conduct a study on the recurrent flooding problem in Virginia, which includes the effects of SLC. In this report, "Recurrent Flooding Study for Tidewater Virginia, Virginia Senate Document No. 3 (2013)", the end-of-the-century forecasts for regional SLC range from 1.5 to 7.5 feet. It is important to note that these forecasts are for relative sea level change, which includes global sea level change projections and land subsidence in the coastal Virginia region. Based on current research and forecasts for the region, sea level is anticipated to be 1.5 feet higher within 20 to 50 years. Sea level change scenarios should be considered in planning efforts both at the state and local levels if coastal communities are to be resilient and able to adapt to coastal storm risk. The forecasts in the VIMS Recurrent Flooding Study are frequently referenced, if unofficially, by various agencies and localities within the Commonwealth of Virginia as they plan for the future.

To consider the effects of SLC on the future landscape change, future SLC scenarios have been developed by USACE (ER 1100-2-8162, 2013) and NOAA (2012). Figure 7 shows areas that would be below mean sea level (MSL) at four future times (2018, 2068, 2100, 2118) based on the USACE High Scenario. A detailed discussion of mapping basis and technique for this and other mapping is provided in Appendix C – Planning Analyses.

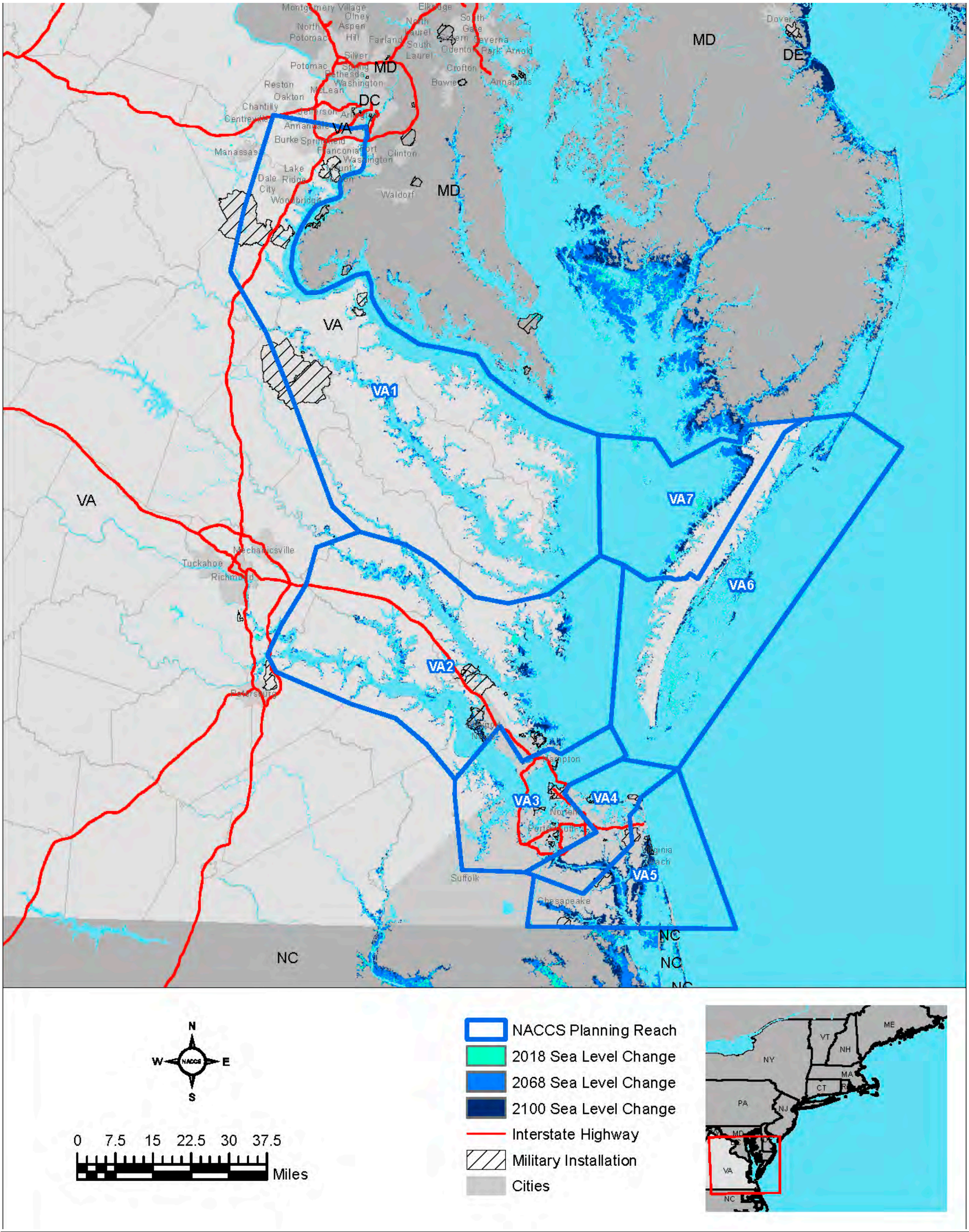


Figure 7. USACE High Scenario Future Mean Sea Level Mapping for the Commonwealth of Virginia

Forecasted Population and Development Density

Using information and datasets generated as part of the U.S. Environmental Protection Agency's (EPA) Integrated Climate and Land Use Scenarios (ICLUS), inferences to future population and residential development increases by 2070 were evaluated (EPA, 2009). Figure 8 presents the USACE High scenario inundation and the forecasted increase in residential development density derived from ICLUS data for Virginia. Changes to environmental and cultural resources, and social vulnerability characteristics will not be considered as part of the overall forecasted exposure index assessment. Discussions of likely future impacts with respect to SLC on environmental and cultural resources will be considered in the Environmental and Cultural Resources Conditions Report. Additional information related to the forecasted population and development density is included in Appendix C – Planning Analyses.

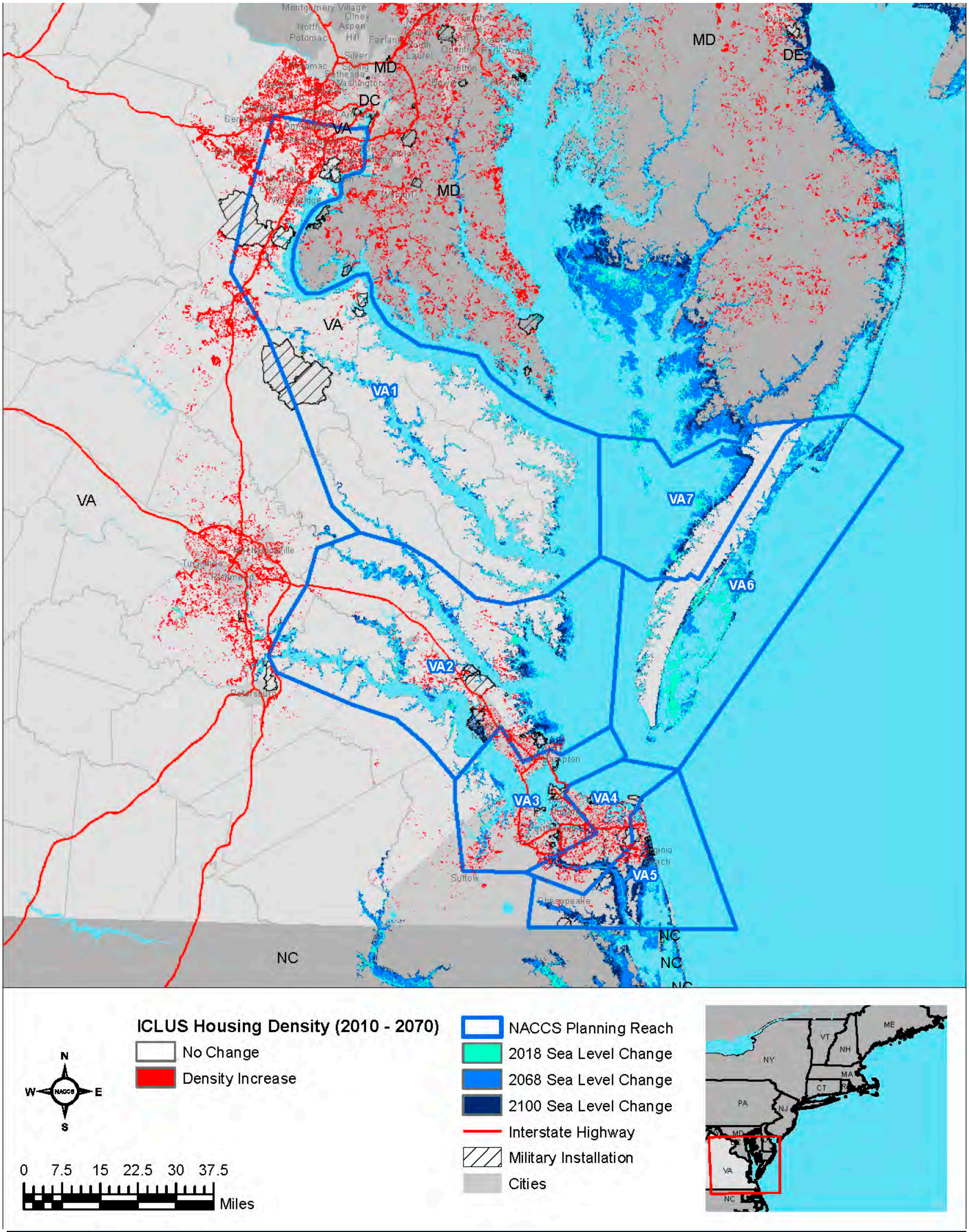


Figure 8. USACE High Scenario Future Mean Sea Level Inundation and Forecasted Residential Development Density Increase for the Commonwealth of Virginia

Extreme Water Levels

As part of the CSRM Framework, the extent of coastal flood hazard was completed by using readily available 1 percent flood mapping from FEMA, preliminary 10 percent flood values from the Engineer Research and Development Center (ERDC) extreme water level analysis, and the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) modeling conducted by NOAA. The inundation zones identified by the SLOSH model depict areas of possible flooding from the maximum of maximum (MOM) event within the five categories of hurricanes by estimating the potential surge inundation during a high tide landfall. Although the SLOSH inundation mapping is not referenced to a specific probability of occurrence (unlike FEMA flood mapping, which presents the 0.2 percent and 1 percent flood elevation zones), a Category 4 hurricane making landfall during high tide represents an extremely low probability of occurrence but high magnitude event. In most cases it is only possible to provide risk reduction to some lower level like the 1 percent flood. Figure 9 presents the SLOSH hydrodynamic modeling inundation mapping associated with Category 1 through 4 hurricanes, which is also used for evacuation modeling in Virginia.

Figure 10 presents the approximate 1 percent floodplain plus 3 feet for the same area to illustrate areas exposed projected inundation levels which are closely aligned with the USACE high scenario for projected SLC by year 2068. Areas between the Category 4 and 1 percent plus 3-foot floodplain represent the residual risk for those areas included in the NACCS study area and Category 4 MOM floodplain.

Figure 11 presents the limit of the current 10 percent floodplain (an area with a 10 percent or greater chance of being flooded in any given year). The purpose of the 10-percent floodplain is to consider the possibility of surge reduction related to some natural and nature-based features (NNBF) management measures such as wetlands, living shorelines, and reefs.

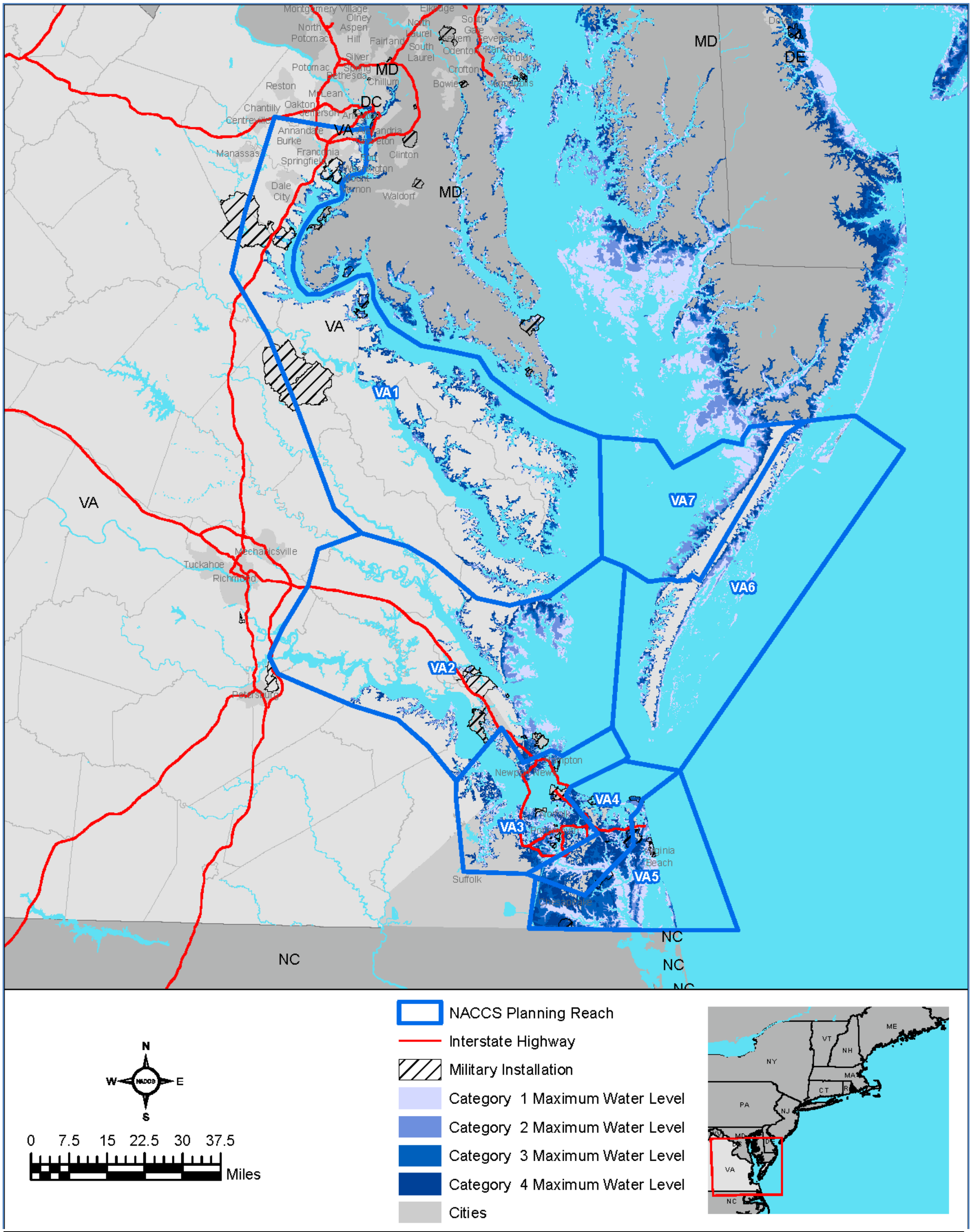


Figure 9. Impacted Area Category 1 – 4 Water Levels for the Commonwealth of Virginia

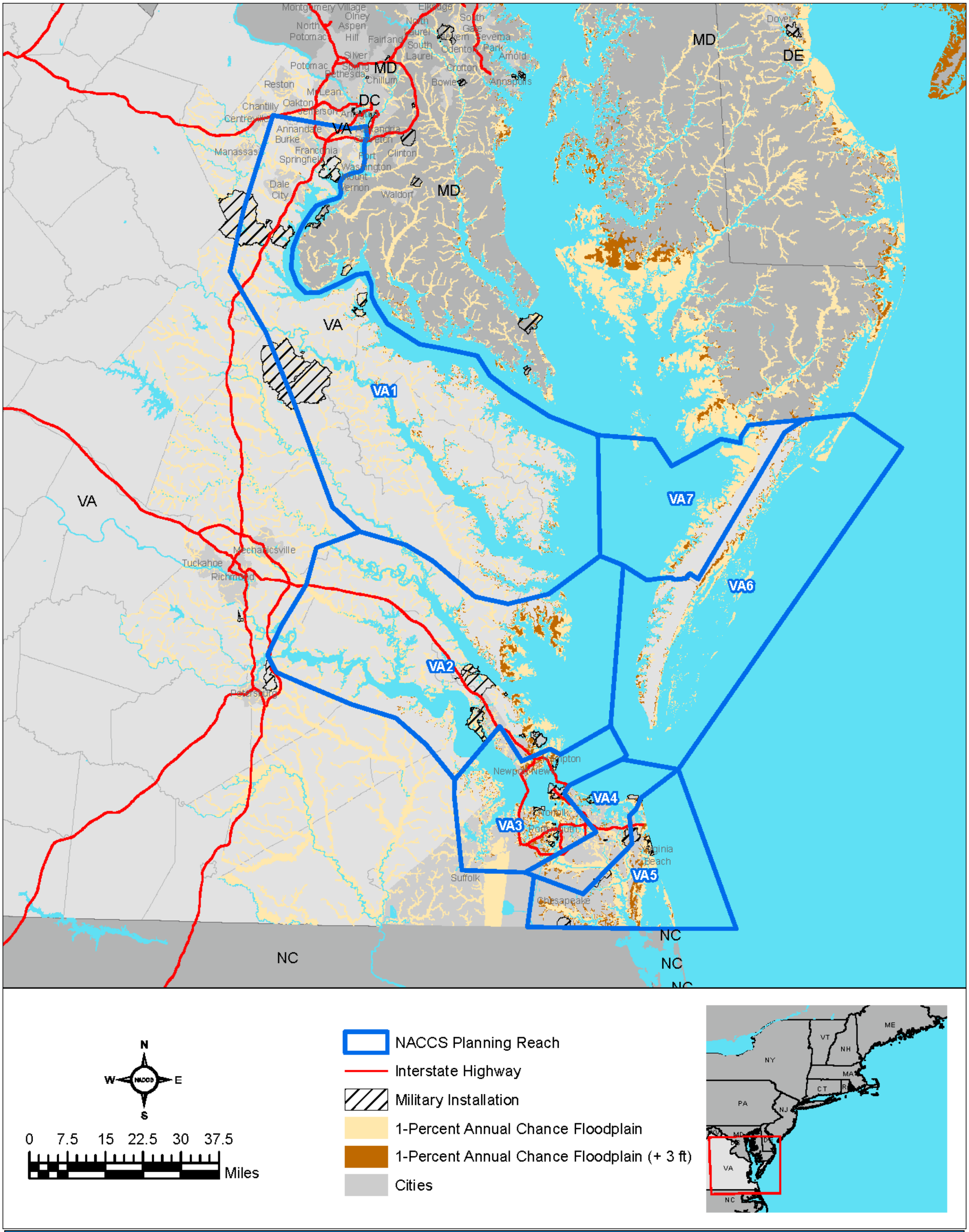


Figure 10. Impacted Area 1 Percent + 3ft Water Surface for the Commonwealth of Virginia

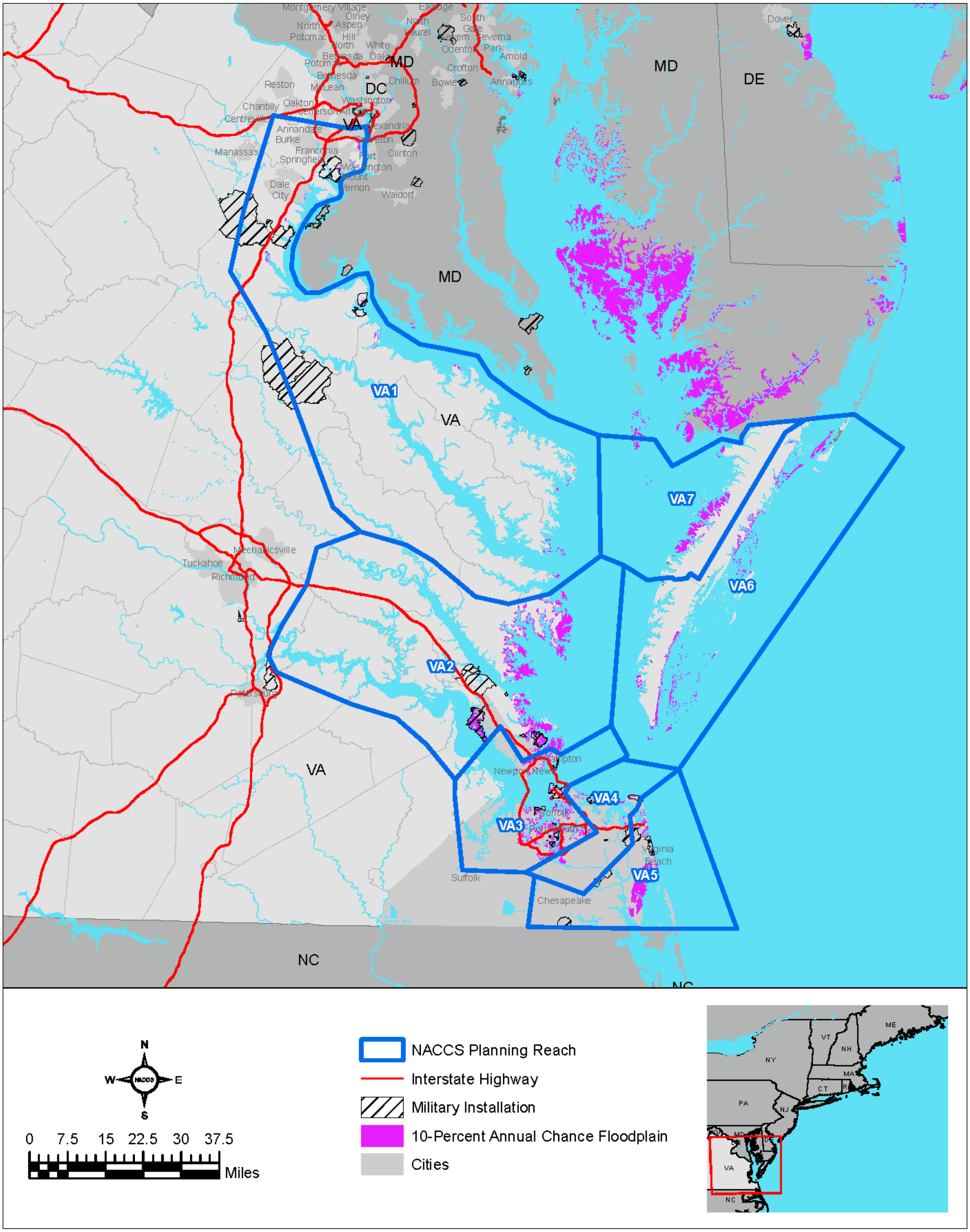


Figure 11. Impacted Area 10 percent Water Surface for the Commonwealth of Virginia

Environmental and Cultural Resources

Virginia, which has roughly half of the Chesapeake Bay within its borders, holds extensive natural resources that are vulnerable to impacts due to climate change, which include increased frequency and power of coastal storms (including Nor'easters as well as Hurricanes and tropical storms), SLC, rising sea temperatures, and ocean acidification (a reduction in oceanic pH due to absorption of carbon dioxide from the atmosphere). It is also a region experiencing subsidence due to glacial rebound, which is expected to exacerbate the impact of SLC. Risks to natural resources in the region range from expected extirpation of some species, extensive losses of certain habitat types such as barrier islands and submerged aquatic vegetation (SAV) beds. Under the two scenarios selected, USACE 2068 and 2118 High SLC, extensive landmass, including wetlands and upland habitat, is predicted to be lost in all of the Virginia planning reaches, which encompass most of the Commonwealth and are within the region most likely to be impacted by coastal storms and SLC. Estimates of land loss due to SLC are shown in Table 3.

Table 3. USACE 2068 and 2118 High SLC Scenarios

REACH	YEAR	Acres Lost	Square Miles Lost
VA1	2068	84,535	132
VA2	2068	174,587	273
VA3	2068	57,367	90
VA4	2068	20,014	31
VA5	2068	4,906	8
VA6	2068	143,237	224
VA7	2068	74,453	116
VA1	2118	196,238	307
VA2	2118	258,447	404
VA3	2118	117,198	183
VA4	2118	43,348	68
VA5	2118	9,292	15
VA6	2118	200,313	313
VA7	2118	102,839	161

Coastal storms and SLC currently and will continue to have widespread effects on historic resources in Virginia. Erosion and inundation of archaeological sites on the islands of the Eastern Shore, Chesapeake Bay, and along the bay's tributaries has been widespread in the past and are expected to accelerate. The lower Virginia Peninsula, including Jamestown Island and Mulberry Island (Fort Eustis), and Wallops Island with concentrations of historical resources are at risk to the impacts of SLC. Historic districts in Norfolk and Portsmouth, already areas that experience frequent flooding, could be partially inundated by the mid-twentieth century. Dozens of National Register of Historic Places listed plantations, Native American sites, and small town historic districts, many of them designated National Historic Landmarks, in Virginia's Tidewater region will be threatened.

A more detailed explanation of these effects can be found in the Environmental and Cultural Resources Conditions Report.

IV. NACCS Coastal Storm Exposure and Risk Assessments

The extent of flooding, as presented in Figures 9 to 11, was used to delineate the areas included in the coastal storm risk and exposure assessments. An exposure index was created for population density and infrastructure, social vulnerability characterization, and environmental and cultural resources. In addition, the three individual indices were combined to create a composite exposure index. The purpose of combining individual exposure indices into a composite index was to provide an illustration of example values for features of the system, with population density and infrastructure weighted at 80 percent of the total index, and social vulnerability characterization and environmental and cultural resources weighted at 10 percent each. For the purpose of the Framework, the overall composite exposure assessment identified areas with the potential for relative higher exposure to flood peril considering collectively the natural, social, and built components of the system. Additional information related to the development of the NACCS risk and exposure assessments is presented in Appendices B –Economic and Social Analyses, and C – Planning Analyses.

IV.1. NACCS Exposure Assessment

The Tier 1 assessment first required identifying the various categories to best characterize exposure. Although a myriad of factors or criteria can be used to identify exposure, the NACCS focused on the following categories and criteria, as emphasized in PL. 113-2.

Population Density and Infrastructure Index

Population density includes identification of the number of persons within an areal extent across the study area; infrastructure includes critical infrastructure that supports the population and communities. These factors were combined to reflect overall exposure of the built environment. Figure 12 presents the population density and infrastructure exposure index. Figure 13 presents the percentages of infrastructure included within the population density and infrastructure exposure index.

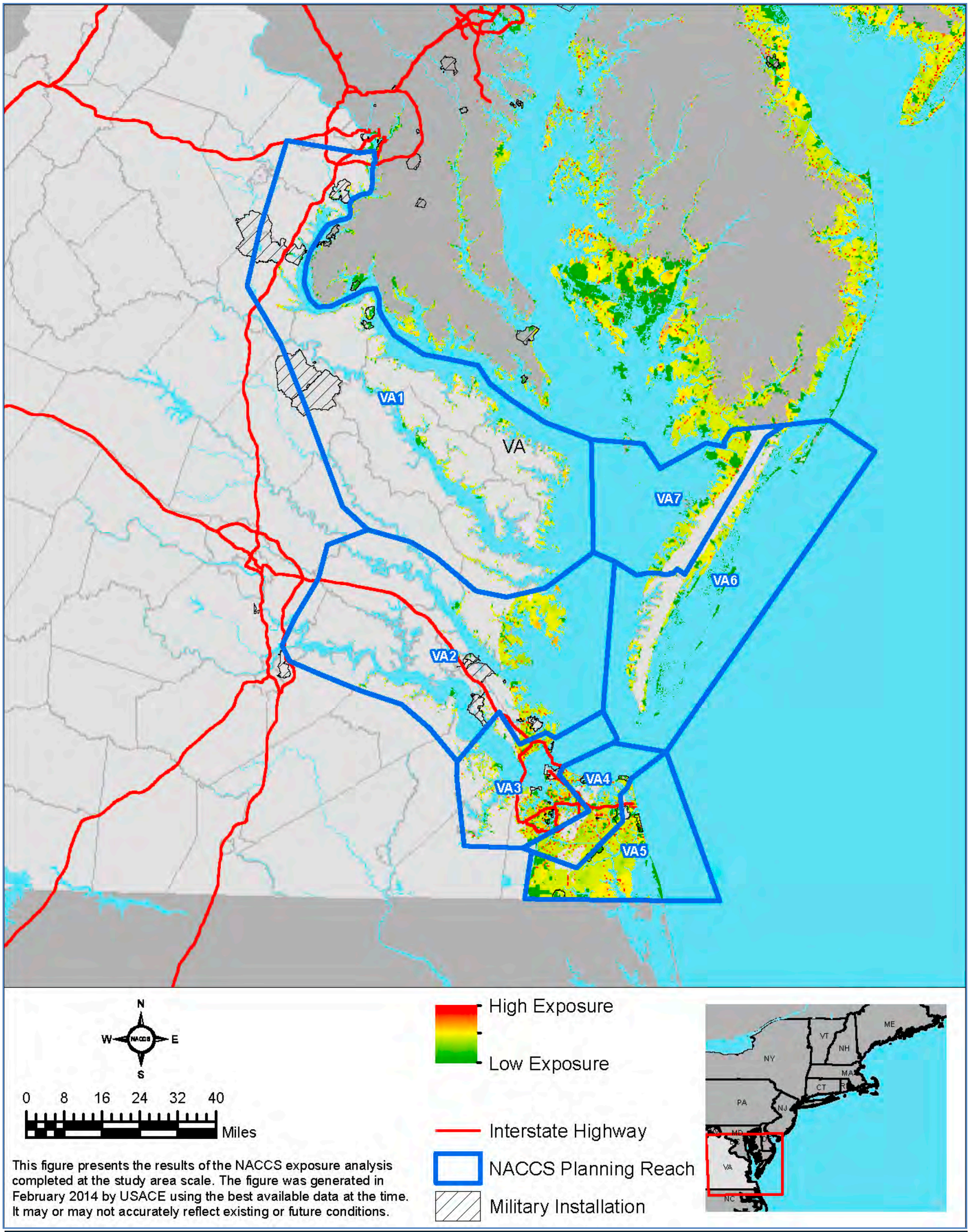


Figure 12. Population and Infrastructure Exposure Index for the Commonwealth of Virginia

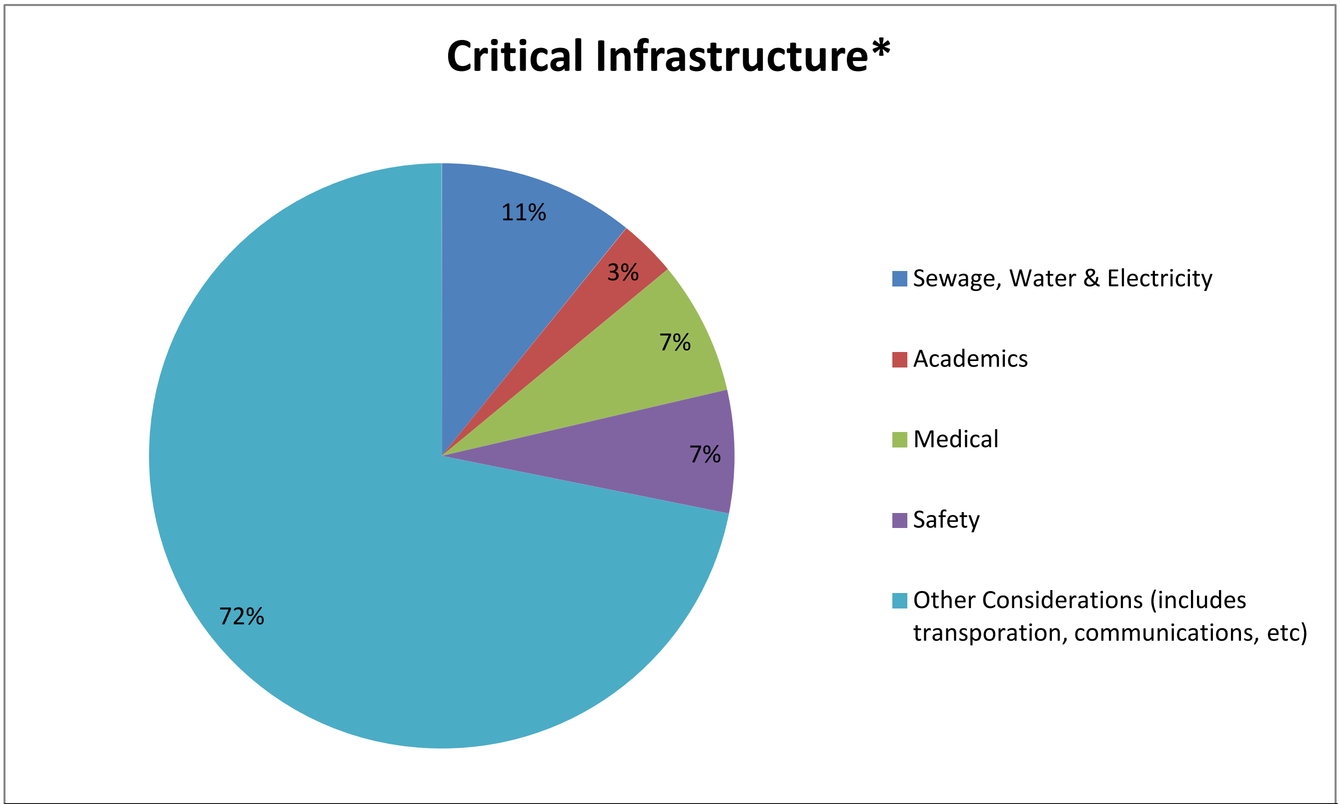


Figure 13. Vulnerable Infrastructure Elements Within the Category 4 MOM Inundation Area in the Commonwealth of Virginia.

*The information presented in this chart represents the critical infrastructure identified in the HSIP Gold data layer within the Category 4 MOM inundation area. At this scale, the information presented is intended to be approximate/illustrative and may not capture all critical infrastructure. Local data should be used in any follow on analyses.

Infrastructure Exposure in VA1

VA1 includes the City of Alexandria, and Fairfax, Prince William, Prince George, Stafford, Westmoreland, Essex, Middlesex Counties. Reach VA1 includes 22 high exposure areas for critical infrastructure. The reach includes portions of the City of Alexandria and adjoining Fairfax County along Cameron Run, including the neighborhood of Huntington and the Alexandria waterfront where there are numerous bridges, major roads including Interstate 495 and Route 1, several prisons, and four sites which are part of the national shelter system. There are also several power generation plants and substations. This area is of national historical significance and at least 16 historic sites are located within the area. Several areas along Cameron Run, particularly in the Huntington neighborhood, have a history of flooding.

VA1 also encompasses a largely residential area in Fairfax County near Route 1 and immediately east of Mount Vernon. Tributaries include North Branch and Little Hunting Creek. Within the area are numerous bridges, two major roads, including Route 1, two properties in the national shelter system, and four nursing homes. Pohick Creek tributary is located in the southern portion of the area where there is a wastewater treatment plant that is located on the boundary of CAT4 MOM inundation.

In Prince William County, along the Occoquan River, directly downstream of the Occoquan Reservoir, including the riverside area of the town of Occoquan, nearly the entire area is within the Category 2

Maximum of Maximums (CAT2 MOM) and thus would also be inundated by the CAT4 MOM. This area contains two law enforcement facilities and several bridges.

Southeast of Woodbridge in Prince William County, near the confluence of the Occoquan River and the Potomac River, there are several bridges and the entire area is within the CAT4 MOM. At the southern boundary of Prince William County along the Potomac River there are several fire stations and bridges and an airport at Marine Base Quantico.

In Stafford County, including Aquia Creek and Aquia Channel, there are two substations and nearly the entire area is within the CAT2 MOM and thus would also be inundated by the CAT4 MOM.

VA1 also includes King George County at Dahlgren along the Potomac River where Naval Support Facility Dahlgren is located. Several bridges are also within the vicinity, as well as an airfield and its supporting infrastructure. There are also two fire stations. Much of the area is within the CAT4 MOM.

VA 1 also includes Westmoreland County along the shore of the Potomac River at Colonial Beach. Colonial Beach has an area of sandy shoreline protected with a series of four segmented breakwaters connected to the shore by tombolos. The vicinity includes shoreline areas on the Potomac River, as well as more sheltered areas in Monroe Bay. There are several fire stations and law enforcement facilities within the area as it is largely residential.

In northern Northumberland County on the Potomac River, the entire town of Lewisetta is nearly entirely within the CAT4 MOM. In eastern Northumberland County on the Chesapeake Bay the towns of Reedville and Sandy Point are located on Ingram Bay and they are almost entirely within the CAT4 MOM. The vicinity also includes several airfields and ferry facilities. There is also high vulnerability to tide and wave action due to its position on the Chesapeake Bay.

At the mouth of the Rappahannock River on the Chesapeake Bay are Lancaster County, Fleets Island, and portions of the mainland. Nearly this entire area lies within the CAT2 MOM and thus would also be inundated by the CAT 4 MOM. The coastline in this area is very susceptible to tide and wave action.

VA1 also includes portions of Essex County on the Rappahannock River downstream of the town of Tappahannock which are within the authorized boundary of the Rappahannock River Valley National Wildlife Refuge, though it does not include National Wildlife Refuge lands.

In eastern Middlesex County at the mouth of the Rappahannock River on the Chesapeake Bay, the coastline is very susceptible to tide and wave action and there is one gas station within the CAT4 MOM.

Infrastructure Exposure in VA2

VA2 includes the counties of Charles City, Chesterfield, Gloucester, Hanover, Henrico, Isle of Wight, James City, King and Queen, King William, Mathews, New Kent, Prince George, Surry, and York and the cities of Hampton, Hopewell, Newport News, Poquoson, and Williamsburg. The major water bodies from north to south include a small portion of the Piankatank River near Mathews County, Mobjack Bay, York River, Back River, and James River. VA2 includes eight areas where critical infrastructure is highly exposed. The topography is characterized by low-lying, flat, marshy coastline with numerous inlets, marshes, and creeks forming many smaller peninsulas near sea level along the Chesapeake Bay. This coastline then gives way to gently rolling topography to an elevation of almost 200 feet as you move northwesterly. The communities that border the Chesapeake Bay, Mathews, Gloucester, and York Counties and the cities of Poquoson and Hampton, are the most exposed to coastal flooding and sea level change.

Mathews County is at the eastern tip of the region known as the Middle Peninsula and is bordered, with the exception of five miles along Gloucester County, almost entirely by water. The terrain is generally flat rising from sea level to about 42 feet with the average elevation less than 10 feet (FEMA, 2007). This leaves the community highly exposed to coastal flooding and soil erosion. The predominately rural community has attracted an increasing number of retirees and vacationers (Middle Peninsula Natural Hazards Mitigation Plan, 2010). In the 2013 update of the Commonwealth of Virginia Hazard Mitigation Plan, Mathews County was identified as an area of dense Repetitive Loss (RL) properties, the tenth highest in Virginia in repetitive loss claims paid accumulating over $7 million dollar in claims and ninth highest in Severe Repetitive Loss (SRL), with over $1 million in claims (Commonwealth of Virginia Hazard Mitigation Plan, 2013). According to FEMA, a SRL property is defined as a residential property that is covered under the National Flood Insurance Program (NFIP) flood insurance Policy and has at least four NFIP claims over $5,000 each, and the cumulative amount of such payments exceeds $20,000 or for which at least two separate claims have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building. Two critical structures vulnerable to flooding include the Mathews Courthouse Wastewater Treatment Plant and the New Point Comfort Lighthouse. As of the 2010 update of the Middle Peninsula Natural Hazards Mitigation Plan, a mitigation plan is in place to take the wastewater treatment plant offline in the event of flooding and transfer sewage to a facility in York County. Additionally, the county has plans to undertake stabilization work around the foundation of the lighthouse. Two schools, Thomas Hunter Middle School and Lee Jackson Elementary School, are vulnerable to flooding in a Category 4 storm. To mitigate future flooding damage, a plan has been developed to retrofit the Mathews County Courthouse on the lower level (Middle Peninsula Natural Hazards Mitigation Plan, 2010). Mathews County is working to reduce risk by applying for hazard mitigation funding to lessen/eliminate flood damage on RL and SRL. Additionally, the county will work with owners to floodproof commercial structures to reduce their vulnerability to flooding. Additional mitigation actions identified in the Middle Peninsula Natural Hazard Plan include retrofit projects at three fire stations.

Gloucester County is located in the southeastern portion of the region known as the Middle Peninsula, west of Mathews County, and is the most populous county in the region. The terrain ranges from flat, marshy areas at the coast to an elevation of approximately 130 feet with gently rolling hills in the western portion of the county (FEMA, 2010). The majority of the area of low-lying area falls along the shores of Mobjack Bay, specifically in the area of Guinea Neck where flooding at high tide is common (VIMS, 2013). Similar to Mathews County, RL is densely developed along the coastline, totaling over $5 million. Critical and public facilities highly exposed to flooding include Achilles Elementary School. To mitigate future flood damage, Gloucester County requires an additional one foot above the Base Flood Elevation (BFE). Gloucester County is striving to reduce risk through mitigation and has applied for and received several grants under the FEMA Hazard Mitigation Grant Program (HMGP). The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration (FEMA). As of 2010, Gloucester has been awarded $6 million for 65 properties, benefiting 110 residents. Additionally, the county has applied for $4 million in grant funding for assistance 41 homes. The community also participates in the Community Rating System (CRS) and has achieved a Class 7 rating since entering the program in 1992. The CRS is a voluntary program for the NFIP that provides incentives in the form of discounts on Flood Insurance for community activities that go beyond the minimal floodplain management standards, reducing the vulnerability to floods (FEMA CRS, 2013).

Northwest of Gloucester County, along the York River, is King and Queen County. Located in the north central portion of the Middle Peninsula which is formed by the Rappahannock and Pamunkey–York Rivers, it is the least populous county within the region. The elevations range from flat, marshy areas along the shoreline to nearly 200 feet further inland. The lower reaches of the York, Poropotank, and Mattaponi Rivers are subject to tidal flooding (FEMA, 2009). Due to the available topography relief, there are no critical or public facilities within the 1percent or 0.2 percent annual chance floodplains (Middle Peninsula Natural Hazards Mitigation Plan, 2010). The Middle Peninsula Regional Airport is located in the southern portion of the county. The terminal and runway are outside of the 0.2 percent annual chance floodplain, based on current, effective FIRM, dated June 2009.

King William County is west of King and Queen County and is bordered by the Pamunkey and Mattaponi Rivers. The elevations range from sea level along the coast to 200 feet further inland (FEMA, 2009). The Town of West Point is located in the southern tip of the county where the Pamunkey and Mattaponi Rivers join to form the York River. The Rock-Tenn Containerboard Mill, located in the Town of West Point, is the largest employer in the region with a workforce of 550 (Info@YesVirginia.org, 2012). As of June 2, 2008, there had been 72 flood insurance policy claims since 1978, with a total of seven RL properties. A sewer pump station located at 2nd Street is vulnerable to flooding (Middle Peninsula Natural Hazards Mitigation Plan, 2010).

New Kent County shares the floodplain of the Pamunkey with King William County. The elevations within the county range from sea level at the coastline to approximately 178 feet further inland (FEMA, 2009). The meandering river provides for wide, flat wetland areas. A subdivision of homes is located in one such area, between Diascund Creek and the Chickahominy River. This and similar areas are identified as areas with exposure to flooding. As of the 2011 update of the Richmond-Crater Multi-Regional Hazard Mitigation Plan, New Kent County had two RL properties and no SRL. The county has no critical or public facilities located within or near the floodplain (Richmond Regional and Crater Planning District Commissions, 2011).

South of New Kent County is Prince George County. Elevations range from sea level to approximately 175 feet. The county experiences tidal flooding along the Appomattox and James Rivers (FEMA, 2012). As of February 2011, the county had 21 Flood Insurance Claims totaling $186,840 and three RL properties.

Moving south along the Chickahominy River is James City County. As of the 2011 update of the Peninsula Hazard Mitigation Plan, the community has 27 RL and two SRL properties. The county has identified high priority mitigation actions focusing on RL and SRL areas such as Chickahominy Haven along the Chickahominy River and Powhatan Shores, just north of Jamestown Island along Powhatan Creek. Chickahominy Haven experienced damaging flooding during Hurricane Isabel and Nor'Ida. Additionally, James City County participates in the CRS program and has maintained a Class 7 rating as of May 2013 (FEMA CRS, 2013).

Southeast of James City County is York County, and the cities of Williamsburg, Newport News, Poquoson, and Hampton. York County is characterized by a series of distinct level flats and rolling plains progressing from the low-lying areas along the Chesapeake Bay progressing to uplands in the northwestern portion of the county to an elevation of approximately 100 feet. The floodplains and residential development are concentrated in the southeastern area along the peninsula landforms created by the tidal waters of the Chesapeake Bay, York River, and their estuaries (FEMA, 2009). A little over 10% of York County's land area is in the 1 percent floodplain (HRPDC, 2011). As of October 2011, the county has 199 RL properties totaling over $11 million in claims and eight SRL properties

(Commonwealth of Virginia Hazard Mitigation Plan, 2013). York County is a StormReady community. York County joined the CRS Program in 2005 and has achieved a Class 8 rating (FEMA CRS, 2013).

To the west of York County is the City of Newport News. Reach VA2 focuses on the northwest areas of Newport News. The topography ranges from sea level to an elevation of approximately 70 feet. Most of the city is flat, with an average elevation of approximately 20 feet. Numerous tributaries of the Warwick River, a tidal estuary of the James River, flow west through portions of the city. Joint Base Langley–Eustis, the U.S. Army Training and Doctrine Command, is located on a peninsula characterized by marsh islands, bays, creeks, and inlets between the James and Warwick Rivers. The majority of the area is below five feet in elevation (FEMA, 1986). Areas adjacent to the base are almost entirely developed with small pockets of wooded areas that increase as you move to the north in the city. The City of Newport News has two pump stations and one water treatment plant located within the 1percent annual chance floodplain.

To the east of the City of Newport News and southeast of York County lies the City of Hampton. The northern portion of the city, including the tidally influenced southwest branch of the Back River and a portion of Newmarket Creek is covered by Reach VA2. The topography is low and flat with elevations generally lower than 13 feet. Large areas of the city are below eight feet leaving some areas vulnerable to flooding from high tides (FEMA, 2008). Twenty-seven percent of the city's land area is in the 1 percent floodplain. With a trend from forested land to urban development, more properties are located within the floodplain. According to the 2011 update of the Peninsula Hazard Mitigation Plan, the City of Hampton has sustained 4,718 claims to the NFIP since 1978 for a total of over $61 million. When compared to adjacent communities, the City of Hampton makes up 66% of the total claims filed (HRPDC, 2011) and is leading the Commonwealth in total amount paid in RL with 796 properties and 27 SRL properties. This number depicts a significant increase in the number of properties from 2008 (Commonwealth of Virginia Hazard Mitigation Plan, 2013). One third of the city's critical facilities, a majority of which are public works, fall within the 1 percent floodplain. Additionally, Hampton is home to Joint Base Langley-Eustis and NASA Langley Research Center. The City of Hampton is working to mitigate risk for its citizens including the development of higher standards than are set by FEMA, requiring one foot above BFE. The city participates in the CRS program, achieving a Class 8 rating. The city applies for and receives mitigation funding for RL and flood prone structures.

North of Hampton is the City of Poquoson**.** Topography is typical of lower Tidewater Virginia that borders the Chesapeake Bay, with generally flat terrain and numerous inlets, marshes, and creeks that form many small peninsulas. The majority of the city is below seven feet elevation. The city encompasses 78.4 square miles, of which 62.9 square miles are water. The eastern portion of the city is dominated by Plum Tree Island National Wildlife Refuge covering 5.5 square miles, or approximately one third of Poquoson's land area. According to the Virginia Institute of Marine Science's Comprehensive Coastal Inventory, the shoreline bank stability is fair, with low beach and marsh erosion. There are areas of high erosion including Plum Tree Island (AMEC, 2009). Due to flat terrain, Poquoson is highly susceptible to flooding from coastal events. Ninety percent of the city lies within the 1 percent floodplain. According to the Virginia Hurricane Evacuation Restudy, the entire city could be inundated by a category 2 hurricane or higher, including the category 4 MOM. According to the 2009 update of Poquoson's Hazard Mitigation Plan, 48 of the city's 59 critical facilities fall within the 1 percent floodplain (AMEC, 2009). The city is second in the Commonwealth for RL claims at over $33 million (Commonwealth of Virginia Hazard Mitigation Plan, 2013). Roadways are also highly exposed to flooding. Of the two routes that lead into and out of the city, only one, Victory Boulevard, is above the 1 percent floodplain. The City has worked diligently to reduce flood loss and its standards are more stringent than the NFIP, including one foot above BFE. The city actively participates in CRS, achieving a Class 9 rating (FEMA CRS, 2013) and chairs a workgroup for the Hampton Roads Chapter. The city has successfully performed mitigation projects, elevating 270 homes through a combination of funding from ICC, CDBG, and HMGP (AMEC, 2009).

Infrastructure Exposure in VA3

VA3 includes cities of Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, Suffolk, and Virginia Beach as well as Isle of Wight County. VA3 begins in the southern end of the City of Newport News, extending from the Mulberry Island to the mouth of the James River and includes three areas where critical infrastructure is highly exposed. The area is characterized as mostly developed with small patches of wooded areas. The southern tip of the city is home to Huntington Ingalls Industries Newport News Shipbuilding, in addition to coal loading piers and facilities, and numerous docks and terminals. Six percent of the city's land area is located in the 1percent floodplain, half of which is identified as residential. According to the 2011 update of the Peninsula Hazard Mitigation Plan, six of the 181 critical facilities and 1,864 buildings fall within the 1 percent flood (HRPDC, 2011). As of November 2010, 33 Virginia communities were identified as "*Storm Ready*" Communities by the National Weather Service including the City of Newport News. Storm Ready is a nationwide community preparedness program to assist communities to develop plans to manage severe weather.[1]

East of the City of Newport News is the southern portion of the City of Hampton. Similar to the rest of the city, the southern portion has many RL properties. Flooding occurs along the Newmarket Creek, Back River, and other tidal tributaries within the area (VIMS, 2013). South of the City of Hampton is the City of Norfolk, a densely populated, urbanized city, 70% of which is classified as residential. The low-lying, flat community has 144 miles of shoreline bordered by the Chesapeake Bay, Elizabeth River, and other tributaries. The city is also home to the world's largest naval base, Naval Station Norfolk, as well as the North American Headquarters for NATO, Norfolk International Terminals, and Norfolk International Airport (Salter's Creek Consulting, 2011). According to a 2013 update of the Commonwealth of Virginia Hazard Mitigation Plan, the city had RL claims totaling over $31 million, the third highest in the state. The City is actively working to mitigate risk and actively conducts engagement with citizens. The city's mitigation actions include maintaining and protecting the city's beaches and shoreline, improving stormwater management infrastructure, mitigating flood prone properties, and improving their CRS class rating. Numerous mitigation projects were completed with HGMP funding following Hurricanes Floyd and Isabel (Salter's Creek Consulting, 2011). The City of Norfolk has participated in the CRS program since 1992, achieving a Class 9 rating.

To the west of the City of Norfolk is the City of Portsmouth. Similar to the City of Norfolk, the City of Portsmouth is heavily developed; with 60% of its land area classified as residential (Salter's Creek Consulting, 2011). The topography is generally flat with elevations seldom exceeding 15 feet. The city is has approximately 76 miles of shoreline bordering the western and southern branches of the Elizabeth River and numerous tributaries reaching inland areas (FEMA, 2009). As of 2011, the City of Portsmouth has sustained RL claims totaling over $6 million. The City of Portsmouth entered the CRS program in 1992 and has obtained and maintained a Class 9 rating. The city has developed and adopted a Flood Management Plan that identifies RL and properties of similar risk. The city has more stringent guidelines than NFIP and requires 1.5 feet above BFE.

[1] Peninsula Hazard Mitigation Plan Update, June 2011, P. 3-10

South of the cities of Portsmouth and Norfolk is the City of Chesapeake. The topography is low-lying and flat, with the highest elevation near 25 feet. The average elevation is approximately 12 feet. Excluding the Dismal Swamp, one third of the city is wetlands. The eastern, western, and southern branches of the Elizabeth River all fall within the city. Flooding is experienced throughout the city. Some areas that experience tidal flooding include the industrial area of Money Point, Crestwood, Crest Harbor, River Walk, Bells Mill Road, and Inland Colony. The city works to mitigate flood prone properties through HMGP funding. The city has more stringent guidelines than the NFIP and requires one foot above BFE. In Chesapeake, RL is responsible for 29% of all flood claims but constitutes only 1.3% of all Flood Insurance Policies (City of Chesapeake, 2008). As of 2011, the city had 303 RL properties for a total of over $12 million in claims.

To the west of the cities of Chesapeake and Portsmouth is the City of Suffolk. The topography is flat and marshy at sea level near the shoreline rising to an elevation of approximately 85 feet. The majority of Suffolk is considered rural and agricultural land. Development in Suffolk is concentrated near the west, north, and central portions of the city (Salter's Creek Consulting, 2011). Flooding occurs through the city, but tidal flooding is particularly a problem in the northern section of the city where it borders the confluence of the James and Nansemond Rivers, and also is a problem along the Nansemond River and its tributaries (FEMA, 2011). There are 13 RL properties in the city for a total of over $1 million in claims (Commonwealth of Virginia Hazard Mitigation Plan, 2013). To mitigate risk, the City of Suffolk developed a floodplain management plan, including mitigation goals to reduce flood risk (Salter's Creek Consulting, 2011).

West of the City of Suffolk is Isle of Wight County. The elevations within the county range from sea level in the flat marsh along the shoreline to approximately 100 feet in the gently rolling hills further inland. The majority of the county is considered rural and agricultural land with developed areas concentrated in the towns of Smithfield and Windsor (Salter's Creek Consulting, 2011). The coastal areas along the James and Pagan Rivers and their tributaries are vulnerable to tidal flooding (FEMA, 2002). The county has 21 RL properties for a claim total of nearly $1.5 million (Commonwealth of Virginia Hazard Mitigation Plan, 2013). Isle of Wight County has targeted flood prone property in coastal high hazard zones for acquisition projects to mitigate future flood risk. Additionally, the county has identified 374 properties for elevation projects due to recurring flooding.

Infrastructure Exposure in VA4

VA4 includes portions of the cities of Chesapeake, Norfolk, and Virginia Beach and has ten areas where critical infrastructure is highly exposed. For Chesapeake, flooding sources include the southern branch of the Elizabeth River, from Deep Creek to where the Intracoastal Waterway meets the VA5 reach; for Norfolk, along the Chesapeake Bay shoreline, from Ocean View to the corporate boundary with Virginia Beach, Little Creek, Mason Creek, and Lake Whitehurst; and for Virginia Beach, along the Chesapeake Bay shoreline, from the corporate boundary with Norfolk to Cape Henry, most of the Lynnhaven River Basin, and the upper portion of West Neck Creek, which flows south into the North Landing River. The terrain is essentially flat, with ground elevations averaging approximately 12 feet. Sand dunes rise to about 15 feet. The floodplains for VA4 abound with commercial, industrial, and residential development and public utilities. Chesapeake has a 2012 estimated population of approximately 229,000, Norfolk at 246,000, and Virginia Beach at 447,000 (U.S. Census Quick Facts). Economic development for all three cities is focused on tourism, military, government, education, housing/commercial development, and farming activities.

With the many miles of shoreline, low topography, and exposure to open water, VA4 is exposed to tidal flooding, wave action, and erosion from hurricanes and nor'easters. Most recently, Virginia has been impacted by Hurricanes Isabel (2003) and Irene (2011), the Nor'Ida nor'easter event (2009), and Hurricane Storm Sandy (2012). Within the reach, low topography makes residential areas in the following areas highly exposed to flooding: along the southern branch of the Elizabeth River (also includes industrial areas) and the Intracoastal Waterway in Chesapeake, Little Creek in Norfolk, and West Neck Creek in Virginia Beach (including the Little Creek Naval Base). For those areas subject Category 4 flooding, special areas of interest would include the municipal center and the Navy Fentress Airfield in Chesapeake, the Norfolk International Airport in Norfolk, and Oceana Naval Base and the Fort Story military installation in Virginia Beach. The Category 4 storm event covers over half of the VA4 reach.

All communities participate in the National Flood Insurance Program (NFIP) and repetitive flood losses have been recorded for structures. For Chesapeake, as of 2007 in their 2008-2013 Hazard Mitigation Plan, 9,109 NFIP policies were in place and 113 RL properties with 336 claims made. Chesapeake has identified the following planning areas as most flood prone: South Norfolk and Indian River, Greenbrier and Rivercrest, Great Bridge and Southern Chesapeake, Deep Creek and Camelot, and Western Branch. As of 2007, most of the city's RL properties were in Rivercrest and Great Bridge. The Great Bridge, South Norfolk, Indian River, and Western Branch areas each have over 1,000 structures identified in the 1 percent floodplain, where Deep Creek and Rivercrest each have over 3,500. According to the City of Norfolk's 2011 Hazard Mitigation Plan, the city had 12,021 NFIP policies in place, 732 RL properties with 1,840 claims made, and 32 SRL properties with 164 claims made. According to the City of Virginia Beach's 2011 Hazard Mitigation Plan, the city had 25,268 NFIP policies in place, 441 RL properties with 1,247 claims made, and 24 SRL properties with 149 claims made.

The cities located within the Hampton Roads area have all actively pursued measures to mitigate flooding and continue to do so. In their Hazard Mitigation Plans, flooding is identified as a top priority. In the past, within VA4, Chesapeake has been active in shoreline stabilization and coastal zone management, Chesapeake Bay Preservation Act, open space management, storm water management, watershed management, engagement and education to the public. The city has also established a one foot requirement above the 1 percent flood, utilized FEMA's Severe and Repetitive Loss Program to elevate homes and acquire homes for open space, completed storm water infrastructure improvements, and enhanced engagement and education. Federal locks are located on the Dismal Swamp Canal and the Southern Branch of the Elizabeth River, both part of the Intracoastal Waterway, at Deep Creek and Great Bridge, respectively, to accommodate differing water levels and storm tides. According to their 2008-2013 Hazard Mitigation Plan, future mitigation actions for Chesapeake include utilizing FEMA's Community Rating System, continue using FEMA's Severe and Repetitive Loss Program, evaluate manufactured homes and trailers for flooding, evaluate critical facilities and roads for flooding, and continue public engagement and education

Norfolk has been active in shoreline stabilization and coastal zone management, Chesapeake Bay Preservation Act, open space management, storm water management, watershed management, engagement and education to the public. The city has also established an 18 inch requirement above the 1 percent flood and participated in FEMA's Severe and Repetitive Loss Program. The City realizes sea level change and subsidence are important issues to consider and plan for. After Hurricanes Floyd and Isabel, the city participated in numerous buyouts and elevation projects using FEMA's Hazard Mitigation Grant Program. They have also implemented an automated flood data collection system, worked with Fugro Atlantic to evaluate a tide gate in the Pretty Lake area near Little Creek, and have maintained a Class 9 rating with FEMA's Community Rating System. According to their 2011 Hazard Mitigation Plan, future mitigation actions for Norfolk include continuing to maintain the beaches and shorelines, continue to focus on education and engagement for flooding, and acquiring, elevating, relocating, or retrofitting RL structures, floodproofing public safety facilities, placing existing utilities underground, and working towards a Class 8 rating in FEMA's Community Rating System.

Virginia Beach has been active in shoreline stabilization and coastal zone management, Chesapeake Bay Preservation Act, open space management, storm water management, watershed management, engagement and education to the public. The City has also established a one foot requirement above the 1 percent flood and participated in FEMA's Severe and Repetitive Loss Program. The city realizes sea level change and subsidence are important issues consider and plan for. According to their 2011 Hazard Mitigation Plan, future mitigation actions for Virginia Beach include acquiring, elevating, relocating, or retrofitting repetitive loss structures, investigating the use of coastal barrier technologies and tidal stream diversion techniques, providing incentives for landscape and dune management, improving/updating alert, warning, and notification capabilities, enhancing public engagement for flood prone structures that do not have flood insurance, retrofitting public safety facilities, placing existing utilities underground, and continued participation in FEMA's Severe and Repetitive Loss Program.

Infrastructure Exposure in VA5

VA5 is the southernmost reach in Virginia, mostly within Virginia Beach and a small portion in lower Chesapeake. VA5 includes four areas where critical infrastructure is highly exposed. Flooding sources include 28 miles of shoreline along the Atlantic Ocean, the upper reaches of Broad Bay and Mill Dam Creek, Rudee Inlet, Back Bay, portions of West Neck Creek, and the North Landing River, which are all located within the City of Virginia Beach; and the Northwest River and the Dismal Swamp Canal, located within the southernmost portion of City of Chesapeake. The terrain is essentially flat, with ground elevations averaging approximately 12 feet. Within the 28 miles of ocean shoreline, there are approximately 20 miles of sand dunes that vary in height from 12 feet to 25 feet. Shallow waters of less than 20 feet fringe the coastal shoreline and depths in the inland bays and connecting waters are generally less than 10 feet (City of Virginia Beach FEMA Flood Insurance Study). The floodplains of Virginia Beach abound with commercial, industrial, and residential developments and public utilities. Most of the development in Virginia Beach has taken place in the northern half of the city and the southern half remains mostly rural. The southern portion of Chesapeake is also mostly rural with farming activities. Virginia Beach has a 2012 estimated population of approximately 447,000 and 229,000 for Chesapeake (U.S. Census Quick Facts). Economic development for both cities is focused on tourism, military, government, education, housing/commercial development, and farming activities.

With the many miles of shoreline, low topography, and exposure to open water, VA5 is exposed to tidal flooding, wave action, and erosion from hurricanes and nor'easters. Within the reach, low topography in the southern portions of Virginia Beach and Chesapeake make many residential areas vulnerable to flooding. For those areas subject Category 4 flooding, special areas of interest in Virginia Beach include the oceanfront resort area, a portion of Fort Story military installation, Dam Neck Naval installation, a Virginia National Guard Post, the beaches at Sandbridge, Back Bay National Wildlife Park, First Landing State Park, the Atlantic Intracoastal Waterway along the North Landing River, and the municipal center. Areas of interest in Chesapeake include the Chesapeake Municipal Airport, Fentress Naval Airfield, Naval Support Activity Northwest Annex, and the Dismal Swamp Canal, which is also part of the Intracoastal Waterway. The Category 4 event covers almost all of the reach.

Both communities participate in the National Flood Insurance Program (NFIP) and the narrative for VA4 contains detailed information and statistics on RL. Within the reach, two Federal coastal storm damage reduction beach projects account for approximately two thirds of the shoreline. The Virginia Beach Hurricane Protection project covers most of the Atlantic Ocean shoreline area between Cape Henry and Rudee Inlet and to the south, the Sandbridge Beach project extends down to the Back Bay National Wildlife Refuge. Dam Neck Military Base is located along the Atlantic Ocean between Rudee Inlet and Sandbridge, which also has an engineered beach and dune system. The Intracoastal Waterway flows through the neighboring City of Chesapeake, connecting it to the North Landing River in Virginia Beach and the Elizabeth River in the City of Norfolk. As mentioned in the narrative for VA4, a Federal lock is located along the Intracoastal Waterway at Great Bridge, in the City of Chesapeake, which was designed to accommodate differing water levels and to keep storm tides from entering the North Landing River/Back Bay area from the Elizabeth River. According to their respective Hazard Mitigation Plans and as described in more detail for VA4, the cities of Virginia Beach and Chesapeake each plan to continue current flood risk management efforts and implement new ones in the future.

Infrastructure Exposure in VA6

VA6 includes six areas where critical infrastructure is highly exposed. VA6-A includes an area in Accomack County to the southwest of the Town of Chincoteague and Assateague Island. The area includes prime coastal habitat, and specifically USFWS protected areas as well as coastal barrier resource system (CBRS) designation. VA6-A includes the Wallops Flight Facility Shoreline Restoration and Infrastructure Protection Program, which is administered by the NASA in cooperation with the U.S. Department of the Interior Bureau of Ocean Energy Management, Regulation, and Enforcement and USACE. The existing project includes rock seawall and beach nourishment. There is a recent proposal to extend the existing seawall approximately 4,600 feet south of its southernmost point, which currently extends approximately 6,800 feet south of the intersection of State Route 803 and North Seawall Road. The beach nourishment included the initial nourishment of approximately 3.2 million cubic yards of sand in 2012, with an additional 0.8 million cubic yards planned for every five years.[2] Additionally, VA6-A includes a portion of the USACE Chincoteague Inlet Ocean Bar Federal Navigation Project.

VA6-B is located in Accomack County, Virginia, southeast of the Town of Accomack. The majority of the population and infrastructure in this general area of VA6 is confined along the U.S. Route 13 corridor, which is located upstream of the CAT4 MOM inundation. However, there are a smaller communities located along the mainland shore of the coastal bays, including the unincorporated areas near Locustville and the Town of Wachapreague. There is a volunteer fire company located in the Town of Wachapreague that is located in the CAT4 MOM inundation area. Although no existing coastal storm risk reduction projects are located in VA6-G, there are eight USACE Federal navigation projects, including the following: Wire Passage, Metompkin Bay, Parker Creek, Cedar Island Bay, Burtons Bay, Wachapreague Channel, Finney Creek, and Bradford Bay. Similar to problem area VA6-A, the area of problem area VA6-B includes areas of prime coastal habitat. There are CBRS and USFWS NWR designated areas within the problem area. The coastline has a high exposure to tide and wave action from the Atlantic Ocean. The area was also identified as very highly exposed to erosion and sea level change.

VA6-C includes the southern portion of the Delmarva Peninsula along the eastern shore in Northampton County, Virginia. The area includes coastal bays, including Outlet, South, and Smith

[2] Final Programmatic Environmental Impact Statement, Wallops Flight Facility Shoreline Restoration and Infrastructure Protection Program, October, 2010: http://sites.wff.nasa.gov/code250/docs/SRIPP_Final_PEIS_Volume_I.pdf

Island Bays. The causeway to the Chesapeake Bay Bridge-Tunnel via U.S. Route 13 extends through the southern portion of the problem area. The area includes prime coastal habitat, and USFWS protected areas as well as CBRS. The coastline has a high exposure to tide and wave action from the Atlantic Ocean. The area was also identified as very exposed to erosion and sea level change.

VA6-D includes the southern portion of the Delmarva Peninsula along the western shore in Northampton County, Virginia. The area includes an existing array of breakwaters and beach nourishment north of the Cape Charles Marina along Bay Avenue part of a USACE coastal storm risk reduction project completed in the late 1980s. In addition, VA6-D includes an existing USACE Federal navigation project in the Town of Cape Charles to maintain the Cape Charles City Harbor. There are areas along the shore south of the town that could be used as placement sites for sandy material. As part of a more developed community, there are areas within the Town of Cape Charles of higher population densities and infrastructure. The problem area includes a volunteer fire company and the Cape Charles Police Department structures within the CAT4 MOM inundation area. The Cape Charles Ferry is also located in the area. There is also an area of industry along the shore of the Chesapeake Bay, south of the Cape Charles City Harbor. The area includes an area CBRS in the southernmost extent, near the Old Plantation Creek confluence with the Chesapeake Bay. The coastline has a very high exposure to tide and sea level change. The area was also identified as moderately exposed to erosion and waves.

VA6-F is located on the Delmarva Peninsula mainland along the southwest portion of the Chincoteague Bay in Accomack County, Virginia. The area is adjacent to Mosquito Creek on the Wallops Flight Facility, which is owned by NASA. This area was added to the areas identified as part of the NACCS analysis because this portion of the facility that would be inundated by storm surge includes areas of the Surface Combat Systems Center airport. The coastline has a very high exposure to tides and erosion. The area was also identified as having a high exposure to sea level change.

VA6-G includes the northern portion of the Delmarva Peninsula in Virginia, including Chincoteague and Morris Islands. The area includes portions of the Town of Chincoteague on Chincoteague Island. Chincoteague Island is served by State Route 175 causeway, which is the only land access to the island. Chincoteague Island is sheltered from direct impacts from coastal storms to the east by Assateague Island, which in Virginia is designated as the USFWS Chincoteague National Wildlife Refuge (NWR). Although an area identified for high environmental risk, the Virginia portion of Assateague Island designated as the Chincoteague NWR was not included as a problem area because of an existing comprehensive conservation plan allows for existing management strategies to maintain the refuge or, where appropriate, restore the ecological integrity. The USFWS is currently reevaluating the Chincoteague NWR as part of its 15-year comprehensive conservation management plan revision process. Although no existing coastal storm risk reduction projects are located in VA6-G, there are three USACE Federal navigation projects, including Lewis Creek, Chincoteague Inlet Inner Harbor, and Chincoteague Harbor of Refuge. The town includes concentrated areas of population and infrastructure, which would be included in the CAT4 MOM and 1 percent plus three feet inundation area. Critical infrastructure that would be inundated by storm surge includes a cell phone tower and an electric substation. Additionally, the Chincoteague police station, emergency operations center, and a volunteer fire station would be affected. The town also includes three gas stations that could have service interrupted in the event of a major coastal storm event. The Town of Chincoteague is noted for its cultural resources, including a history of import seafood industry to harvest oysters, clams, crabs, and fish. The coastline has a very high exposure to tides and erosion, and high exposure to waves and sea level change.

VA6-F is located on the Delmarva Peninsula mainland along the northwest portion of the Upshur Bay in Accomack County, Virginia. This area was added to the areas identified as part of the NACCS analysis because the area includes a concentrated area of residential development. Additionally, VA6-F includes a portion of the USACE Quinby Creek Federal Navigation Project. The coastline has a very high exposure to waves, tides, erosion, and sea level change.

Infrastructure Exposure in VA7

VA7-A includes the northern areas of the Virginia portion of the Delmarva Peninsula along the western shore in Accomack County, Virginia. VA7 includes two areas where critical infrastructure is highly exposed. The area also includes the Town of Saxis. There is an existing USACE coastal storm risk management project located along the shore of the Town of Saxis. In addition, USACE, Norfolk District completed a feasibility study under the Continuing Authorities Program Section 206 to create habitat, including submerged aquatic vegetation, low marsh, and beach on the landward side of segmented breakwaters in the general vicinity of the existing coastal storm risk management project. The Starlings Creek navigation project is also located in the area. As part of a more developed community, there are areas within the Town of Saxis with higher population densities and infrastructure. One volunteer fire company is included within the CAT4 MOM inundation area. The area includes an area CBRS in the southernmost extent, near Starling Creek, Fishing Creek, and Drum Bay. The coastline has a very high exposure to tide erosion, waves, and sea level change.

VA7-B is located in Accomack County, Virginia west of the Town of Onancock, along the shore and tributaries of the Pocomoke and Tangier Sounds in the Chesapeake Bay. The majority of the population and infrastructure in this general area of VA7 is confined along the U.S. Route 13 corridor, which is located above the CAT4 MOM inundation. However, there are smaller communities located along Pocomoke and Tangier Sound coastline, including portions of the Town of Onancock and the unincorporated areas near Chessonessex, East Point, and Harborton. In the Town of Onancock, in addition to the Tangier-Onancock Ferry that operates between May and September, there is a petroleum, oil, and lubricants facility located in the 1 percent plus three feet inundation area. Additionally, the Virginia Institute of Marine Science included numerous structures identified in the area as incurring repetitive losses through the National Flood Insurance Program.[3] The coastline has a very high exposure to sea level change, tide, and erosion, with a moderate exposure to waves.

Social Vulnerability Characterization Index

The social vulnerability characterization captures certain segments of the population that may have more difficulty preparing for and responding to natural disasters and was completed using the U.S. Census Bureau 2010 Census data. Important factors in social vulnerability include age, income, and inability to speak English.

Figure 14 presents the social vulnerability characterization exposure index for the Commonwealth of Virginia. Areas with relatively higher concentrations of vulnerable segments of the population are identified from this analysis.

[3] Repetitive losses are defined as having received two or more claim payments of more than $1,000 from the National Flood Insurance Program within any rolling 10-percent period for a home or business. The data was Included in the Recurrent Flooding Study for the Tidewater Virginia, Virginia Institute of Marine Science, January 2013. http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf

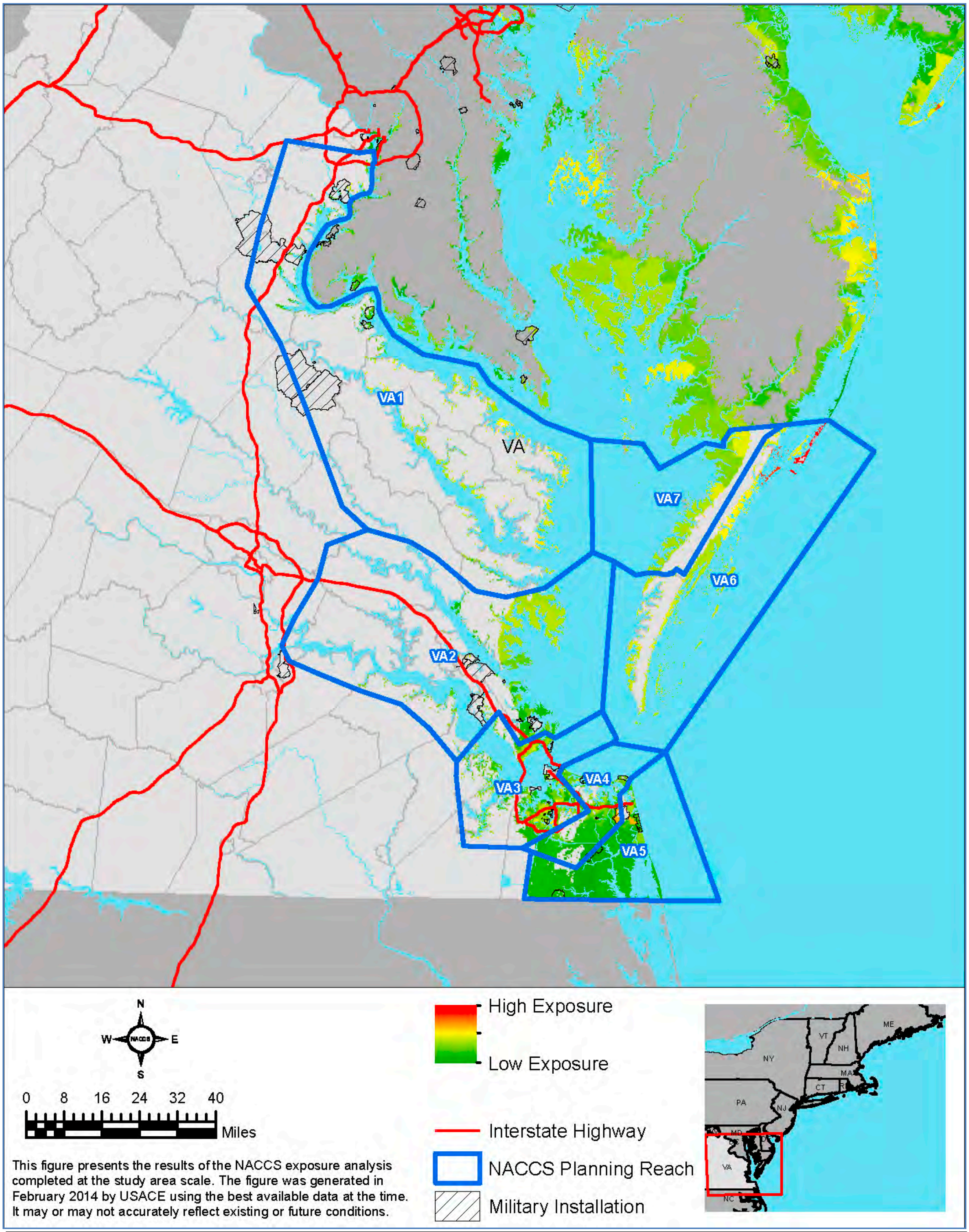


Figure 14. Social Vulnerability Exposure Index for the Commonwealth of Virginia

The identification of risk areas based on the social exposure analysis is provided below on a reach by reach basis for each of the planning reaches in the Commonwealth of Virginia.

Reach: VA1

Based on the social exposure analysis, six areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 4217.01, 4523.01, 4525.02, 4306, and 9006 (Fairfax County, VA), and 109 (District of Columbia). These areas, with the exception of census tract 109, were identified as vulnerable mainly due to a large percent of the population being non-English speakers. Census tract 109 was identified as vulnerable mainly due to a large percent of the population being below the poverty level.

Reach: VA2

Based on the social exposure analysis, no areas were identified within this reach as having relatively high social vulnerability.

Reach: VA3

Based on the social exposure analysis, seven areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 301 (Newport News City, VA), 2118 (Portsmouth City, VA), 114 (Hampton City, VA), and 25, 41, 42, and 48 (Norfolk City, VA). These areas were identified as vulnerable mainly due to a large percent of the population being under the poverty level. The areas identified within census tracts 2118, 41, 42, and 48 also have a considerable percent of the population under 5 years old. And, census tract 42 has a considerable percent of the population over 65 years old.

Reach: VA4

Based on the social exposure analysis, no areas were identified within this reach as having relatively high social vulnerability.

Reach: VA5

Based on the social exposure analysis, no areas were identified within this reach as having relatively high social vulnerability.

Reach: VA6

Based on the social exposure analysis, one area was identified within this reach as an area with relatively high social vulnerability (values above 70.0). This area was located within census tract 9801 (Accomack County, VA). This area was identified as vulnerable mainly due to a large percent of the population being under the poverty level, as well as a considerable percent of non-English speakers.

Reach: VA7

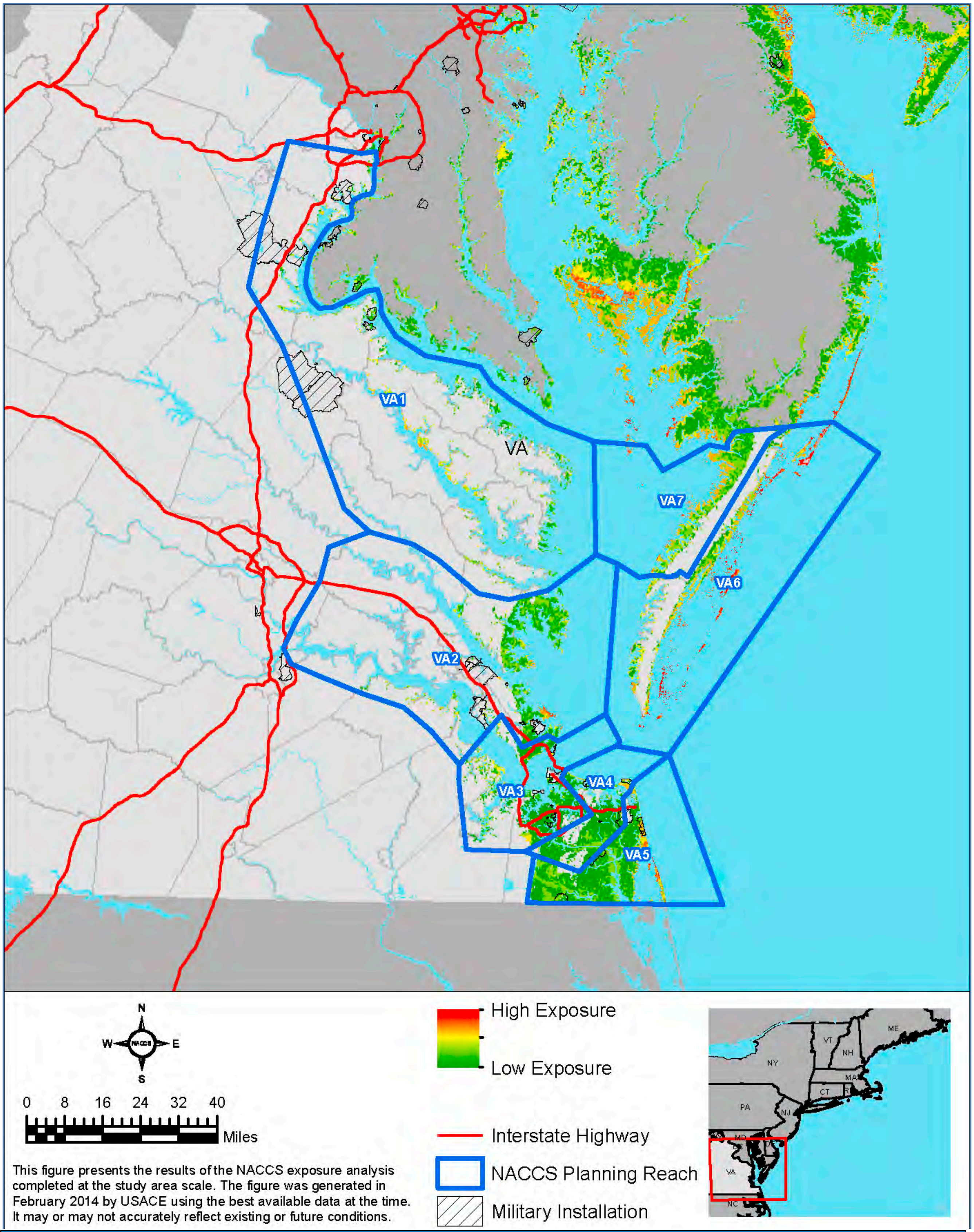
Based on the social exposure analysis, no areas were identified within this reach as having relatively high social vulnerability.

Environmental and Cultural Resources Exposure Index

Environmental and cultural resources were also evaluated as they relate to exposure to the Cat 4 maximum inundation. Data from national databases, such as the National Wetlands Inventory and The

Nature Conservancy Ecoregional Assessments; data provided from USFWS, including threatened and endangered species habitat and important sites for bird nesting and feeding areas; shoreline types; and historic sites and national monuments, among others were used in this analysis to assess environmental and cultural resource exposure. It should be noted that properties with restricted locations, typically archaeological sites, and certain other properties were omitted from the analysis due to site sensitivity issues.

Figure 15 depicts the environmental and cultural resources exposure index for the State of New Jersey. This exposure analysis is intended to capture important habitat, and environmental and cultural resources that would be vulnerable to storm surge, winds, and erosion. It should be noted though, that mapped areas displaying high exposure index scores (shown in red and orange) may not include all critical or significant environmental or cultural resources, as indexed scores are additive; the higher the index score, the greater number of resources present at the site. Impacts and recovery opportunity would vary across areas and depending on the resource affected.



This figure presents the results of the NACCS exposure analysis completed at the study area scale. The figure was generated in February 2014 by USACE using the best available data at the time. It may or may not accurately reflect existing or future conditions.

Figure 15. Environmental and Cultural Resources Exposure Index for the Commonwealth of Virginia

It should be noted that some regions that may be recognized as important in one category or another may not show up on the maps as a location identified as a High (red and orange) Environmental and Cultural Resource Exposure area. These areas may have met only one or just a few of the criteria used in the evaluation. Further, due to the minority contribution of cultural resources in the analysis (40 percent) and their general lack of proximity to key natural resource areas, historic properties may not be strongly represented.

A description of the High Environmental and Cultural Resource Exposure Areas for each planning reach is described below.

Reach: VA1

Results of the this analysis show that this reach holds small areas of high (orange and red) environmental and cultural resources exposure index area in the Northern Neck region of the Commonwealth, as well as the Rappahannock River, mostly on its northern shores. Most of the high exposure index areas lie along the Chesapeake Bay coast of the Northern Neck, a peninsula of land lying between the Potomac and Rappahannock Rivers. This region is known for limited development, agriculture, extensive forested and wetland areas, and significant oyster harvests from the Rappahannock River. VA1 has approximately 181 acres of high environmental and cultural resources exposure index areas. Of these, most are cultural resources buffer area around natural resource sites (approximately 190 acres), Rare, Threatened and Endangered species sites (approximately 150 acres for the Northeastern Beach Tiger Beetle), CBRA (Coastal Barrier Resources Act) areas (approximately 150 acres), or emergent marsh (approximately 130 acres). Small amounts of seagrass (approximately 40 acres), unconsolidated shorelines (approximately 20 acres) and USFWS protected areas (approximately 20 acres) and wetlands (approximately 10 acres) make up most of the remainder. Local parks in the area hold about one acre of high index area as does the Occoquan Bay National Wildlife Refuge (Federal Park). There are three colonial waterbird nesting sites within this reach.

Reach: VA2

The analysis shows reach VA2 holds a large acreage of high environmental and cultural resources exposure index area; approximately of 2,900 acres (red and orange). In this reach, the highest exposure index areas are concentrated along the shores of Mobjack Bay region and Poquoson River region. This area is not heavily urbanized, although a number of smaller towns and cities, including Gloucester, York, and the town of Poquoson are found in this reach. Oyster resources were once extensive, particularly in the Mobjack Bay region, though there is little commercial harvest from public oyster grounds today. These areas, especially the Poquoson River watershed, have extensive wetland fringes and flats associated with them that are particularly vulnerable to loss due to inundation (approximately 2,600 acres, mostly emergent marsh) as well as nearshore CBRA areas (approximately 2,800 acres), including a portion of Gwynn's Island, which is located near the mouth of the Piankatank River on Virginia's Middle Peninsula region, and large natural areas under USFWS protection (approximately 4,600 acres) and USFWS wetlands (approximately 40 acres). Colonial waterbirds utilize a small amount of these various habitats nesting sites, with 23 known nesting sites scattered throughout. Rare, Threatened, and Endangered species habitat is significant (approximately 400 acres) in the region, with the majority of this habitat for the Northeastern Beach Tiger Beetle and a smaller amount for the Piping Plover. Mobjack Bay contains very little seagrass but the Poquoson River is known to have an extensive seagrass bed, nearly 215 acres that are vulnerable to loss. Significant areas of unconsolidated shoreline are vulnerable to loss, most of these are sand or mudflat shores (approximately 150 acres). Non-Federal parkland within the identified high environmental and cultural resources exposure index area measures roughly 110 acres. There is a significant cultural resources buffer area of approximately 2,900 acres. It is likely that there are many Native American and early Colonial sites within the buffer. The Jamestown Island portion of the National Colonial Historic Park is also present in the VA2 high environmental and cultural resource exposure areas. This historic landmark is the site of the first permanent English settlement in North America, and Virginia's colonial capital during most of the 17th century is the loci of a concentration of historic archaeological resources among the most significant in the nation.

Reach: VA3

This analysis resulted in no high environmental and cultural resources exposure index area in VA3.

Reach: VA4

For Reach VA4, his analysis resulted in approximately 11 acres of high environmental and cultural resources exposure index area. This area lies primarily in around the lower James River and its confluence with Chesapeake Bay and extended coastward to the confluence with lower Chesapeake Bay and the Atlantic Ocean. This reach covers most of the cities of Norfolk, Chesapeake, and Virginia Beach as well as a portion of First Landing State Park, which has beach, dune, wetland, and forested wetland habitat on the shores of Lower Chesapeake Bay. It also covers the small Lynnhaven River, the lying near the confluence of the south shore of Chesapeake Bay and Atlantic Ocean. This reach has small acreages of high environmental and cultural resources exposure index area most of which is either CBRA habitat (approximately 11 acres) or non-Federal parkland (approximately 10 acres). Very small areas of emergent marsh (approximately 2 acres), seagrass (approximately 2 acres) and mudflat (approximately 1 acre) were also noted in VA4. One colonial waterbird nesting site has been recorded within this high exposure index area of this reach. There is a small cultural resource buffer area of roughly 11 acres; extensive Woodland Period archaeological sites have also been found on shoreline areas within the high exposure index area of this reach.

Reach: VA5

This analysis resulted in approximately 3000 acres of high (red and orange) environmental and cultural resources exposure index area for VA5. This reach covers the southern oceanic coastline of Virginia, extending from First Landing State Park through the City of Virginia Beach, several military installations and then Back Bay NWR to the North Carolina Border. These low-lying coastal areas are particularly vulnerable to storm and sea-level rise related impacts. TNC identified nearly 3000 acres of priority conservation areas within this reach. USFWS protected wetlands total about 420 acres. Park acreage (approximately 210 acres) is significant, most of these areas lie within the low-lying areas of First Landing State Park. This park holds extensive estuarine marshland, as well as bald cypress swamps, both of which are especially vulnerable to inundation. Environmental and cultural resources exposure index area in this reach also includes emergent marsh (approximately 1,600) acres and unconsolidated sandy shore (approximately 100 acres), which in Virginia is almost entirely sandy beach habitat. Much of this habitat type lies within Back Bay NWR. A small acreage of mud flat habitat is included in this reach (approximately 8 acres). Scrub-shrub acreage (approximately 50 acres) is mostly on Back Bay NWR. The total coastal habitat that is vulnerable in this reach total more than 1,700 acres. Colonial waterbirds use VA5, though such use is limited (4 sites). Rare, Threatened, and Endangered species habitat is significant in this reach at roughly 1,450 acres. The federally listed Loggerhead turtles also nest along the Virginia coastline, including Virginia Beach and Back Bay NWR, lying in between Virginia Beach and the North Carolina Border in VA5 and the Piping plover is also found here. CBRA areas (approximately 3,000 acres) also include beach habitat along the City of Virginia Beach, First Landing State Park, and Back Bay NWR. VA5 has a larger cultural resources buffer areas consisting of approximately 3,000 acres.

Reach: VA6

VA6 covers the seaside Eastern Shore peninsula of Virginia, a thin reach of land which forms the border between much of Chesapeake Bay and the Atlantic Ocean. This analysis resulted in approximately 52,000 acres of high (red and orange) environmental and cultural resources exposure index area, the largest such areas in any reach of Virginia. A series of barrier islands can be found in this reach, just offshore of the mainland and extending the entire reach of the peninsula. VA6 has large acreage of vulnerable mud flats (approximately 460 acres) within the high exposure index area. There is an extensive area of sandy beach shoreline (approximately 4,400 acres) with much of this high exposure index area consisting of sandy shorelines of the barrier islands. The CBRA areas (approximately 45,000 acres) are the largest in the Commonwealth. Other vulnerable habitat types found in the high exposure index areas included estuarine marsh (approximately 37,000 acres), scrub-shrub (approximately 600 acres), and maritime forest, a rare habitat in the Commonwealth (approximately 80 acres). The VA6 reach high environmental and cultural resources exposure index area also holds vulnerable seagrass beds (approximately 140 acres). Much of this is in the sheltered embayments formed in the lee of the barrier islands, though some can be found on the Bayside of the Eastern Shore within Chesapeake Bay as well. The majority of this acreage lies along the barrier island chain of Virginia's Seaside Eastern Shore. The barrier islands and associated habitat they protect along the Eastern Shore, lying in VA6, have the extent largest priority areas in the Commonwealth. These islands are mostly protected from development, either by being part of TNC's Virginia Coastal Reserve or USFWS Chincoteague, Eastern Shore of Virginia and Fisherman's Island NWRs. TNC priority conservation areas includes a large region of vulnerable habitat (approximately 51,500 acres), most of which is within the coastal barrier island system. The total vulnerable habitat protected by USFWS is about 28,000 acres including protected freshwater emergent and freshwater forest/shrub wetlands in the area (approximately 730 acres).

Significant vulnerable non-Federal Park (approximately 200 acres) lie within this reach as well, providing important natural habitats also used for human recreational use. In addition to the habitat they contain, they also serve as important nesting sites for colonial seabirds, with 407 documented nesting sites, the highest of any reach in Virginia. Additionally, threatened and endangered species are found on the islands and in the area they protect, including sea turtles (of which loggerheads nest in the area of VA6), seabeach amaranth (*Amaranthus pumilus*), only found on Chincoteague NWR at present, the red knot (*Caladris canutus rufa*), which uses this region as a staging area during its migrations, and the piping plover (*Charadrius melodus*), which in Virginia nests mostly on the barrier islands, though it also utilizes other islands in Virginia as nesting sites, and the northeastern beach tiger beetle. As a result, there are extensive acreages of vulnerable threatened and endangered species habitat in this reach (approximately 124,000 acres). This reach also contains the largest extent of cultural resource buffer area, at approximately 51,500 acres of this priority area and two cultural sites, the Cape Charles Lighthouse and the Assateague Lighthouse. Archeological sites present include a number of highly significant Native American sites dating to the Early through Late Woodland periods on Mockhorn Island, and other remote shorelines.

Reach: VA7

This region is commonly considered the Bayside Eastern Shore, as well as open waters along the east side of Chesapeake Bay. This analysis resulted in approximately 1,030 acres of high (red and orange) environmental and cultural resources exposure index area for Reach VA7. The reach has extensive CBRA lands covering roughly 946 acres. In offshore Bay waters are located several small islands that are CBRA habitat, including the inhabited Tangier Island, and the uninhabited Smith and Uppards Islands. The high exposure area within the reach has extensive seagrass beds (approximately 400 acres), both in the lee of Uppards and Tangier Island as well as along the shoreline and embayments of the peninsula. TNC has considerable acreage (approximately 1,000 acres) of priority conservation area within the high environmental and cultural resources exposure index area. Emergent marsh (approximately 500 acres) has sizeable acreage within the environmental and cultural resources exposure index areas. Also there are small areas of terrestrial habitats, including maritime forest (approximately 2 acres) and scrub-shrub (approximately 16 acres). Colonial seabirds use these habitat areas at a modest level, with 12 sites currently in use. Rare, Threatened, and Endangered species utilize significant acreage (approximately 600 acres) in this reach. The shorelines within this reach are vulnerable, with mud flats (approximately 380 acres) as well as sandy shorelines (approximately 290 acres) within the environmental and cultural resources exposure index areas. USFWS protected wetlands consist of about 10 acres, and are freshwater emergent and freshwater forested/shrub wetlands in this reach. USFWS protected areas approximate 160 acres for this reach. Most of the endangered shorelines are along Back Bay NWR, which include nesting habitat for loggerhead sea turtles. Threatened and Endangered species vulnerable habitat in this reach is roughly 600 acres, most of which is for the northeastern beach tiger beetle. Colonial waterbirds have 48 vulnerable nesting colonies within the high exposure index areas of this reach. VA7 also has considerable acreage of cultural resources buffer (approximately 1034 acres) and one cultural site, the Pocomoke Farm archaeological site on a creek near Pocomoke Sound.

Composite Exposure Index

All three of the exposure indices were summed together to develop one composite index that displays overall exposure. Figure 16 depicts the composite exposure index for the Commonwealth of Virginia.

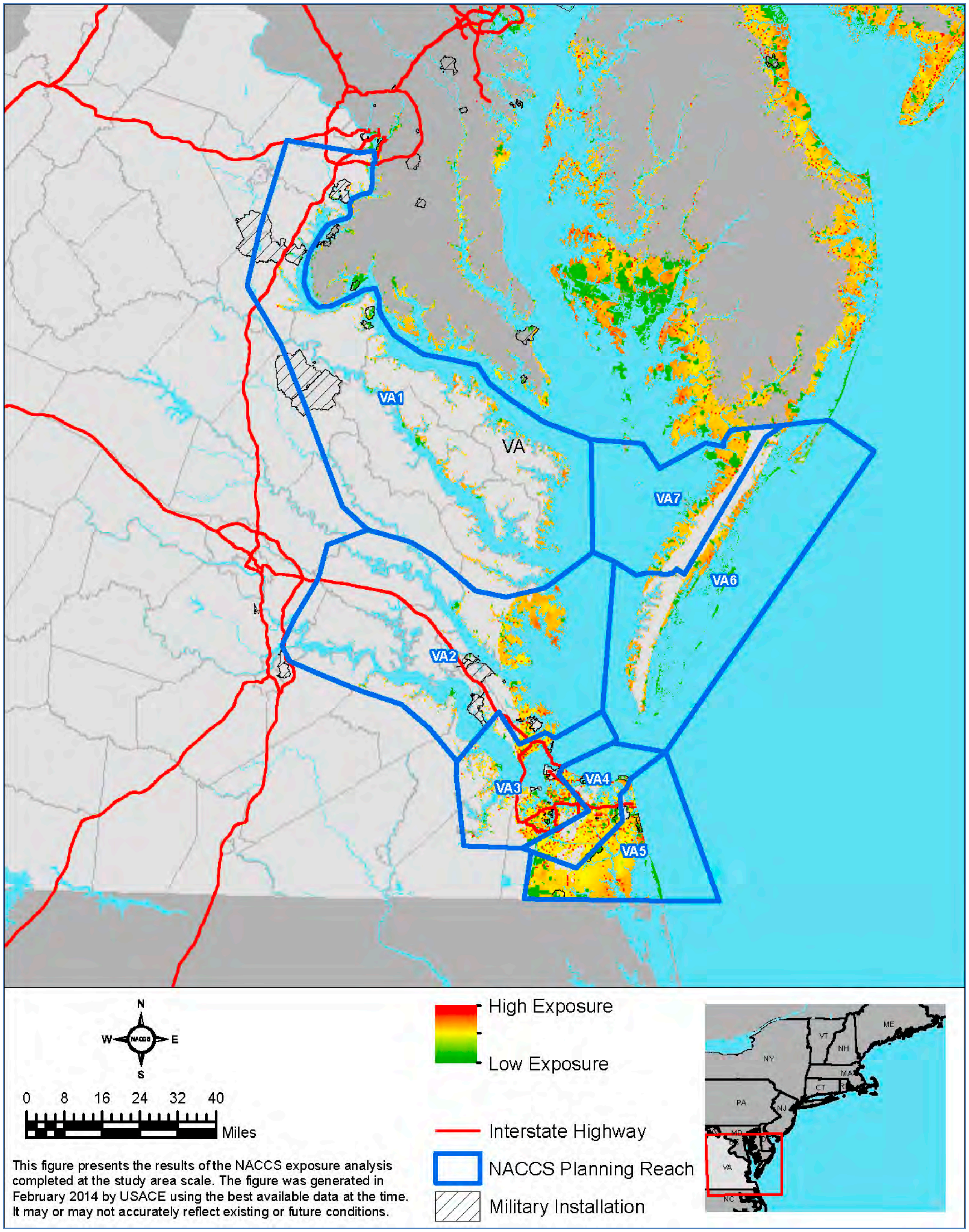


Figure 16. Composite Exposure Index for the Commonwealth of Virginia

V. NACCS Risk Assessment

Exposure and coastal flood inundation mapping is used to identify the specific areas at risk. Once the exposure to flood peril of any area has been identified, the next step is to better define the flood risk. The Framework defines risk as a function of exposure and probability of occurrence. For each of the floodplain inundation scenarios, Category 4 MOM, 1 percent flood plus three feet, and the 10 percent flood, three bands of inundation were created. The bands correspond with the flooding source to the 10-percent inundation extent, the 10-percent to the 1-percent plus three feet extent, and the 1-percent plus three feet to the CAT4 MOM inundation extent. The 1-percent plus three feet extent was defined as the CAT2 MOM because at the study area scale there were areas that did not include FEMA 1-percent flood mapping. This process was completed for the composite exposure assessment in order to generate the NACCS risk assessment. The data was symbolized to present areas of relatively higher risk, which based on the analysis, corresponds with the three bands that were used in the analysis. Subsequent analyses could incorporate additional bands, which would present additional variation in the range of values symbolized in the figure. Figure 17 depicts the results of this risk assessment using the composite exposure data for the Commonwealth of Virginia.

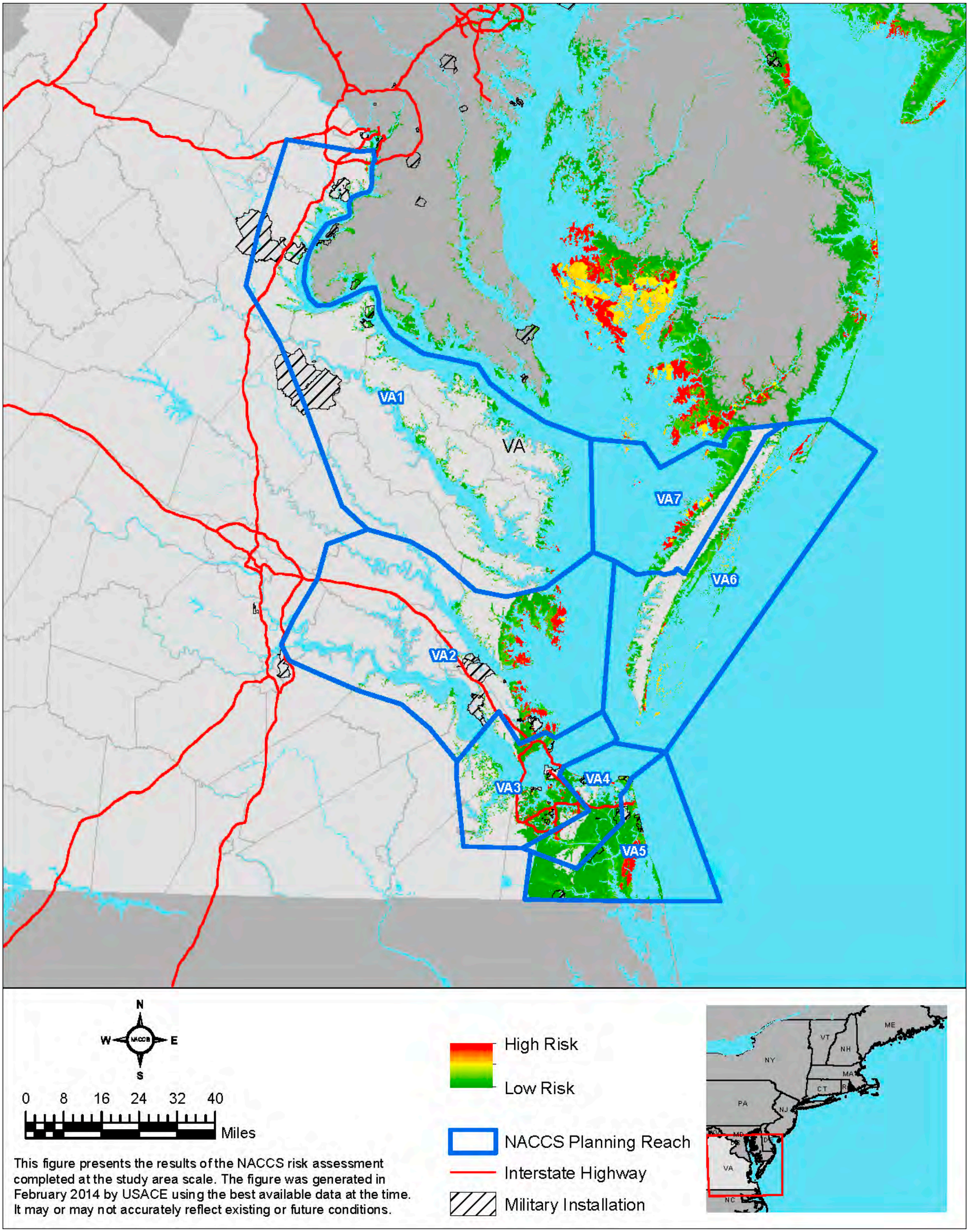


Figure 17. Risk Assessment for the Commonwealth of Virginia

VI. NACCS Risk Areas Identification

Applying the risk assessment to the Commonwealth of Virginia, 55 areas have been identified for further analysis (Figure 18) within the seven planning reaches. These locations are identified by reach in Figures 19 through 25 and are described in more detail below.

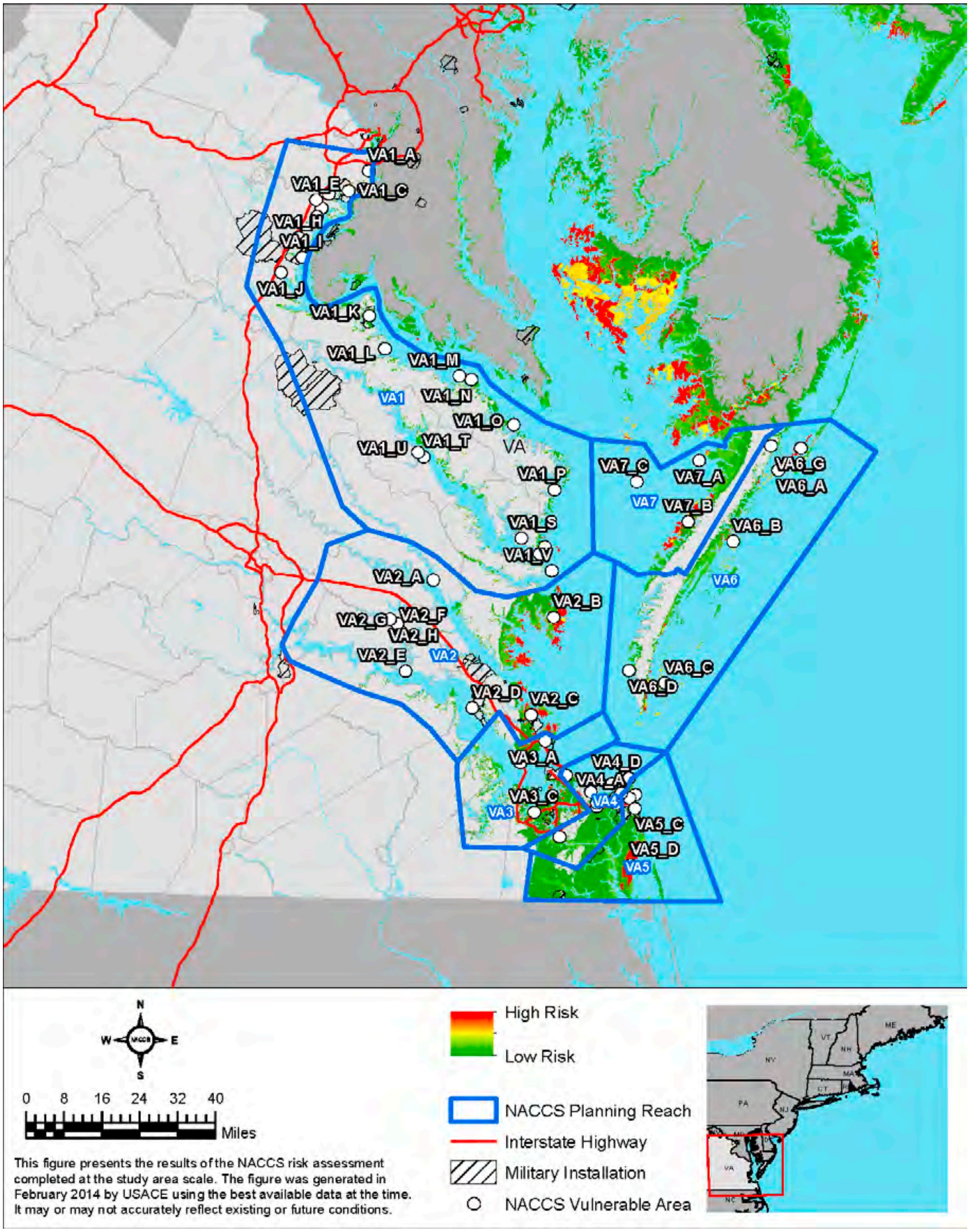


Figure 18. Risk Areas in the Commonwealth of Virginia

VA1

VA1 is the largest reach in Virginia. It includes areas of northern Virginia bordering the Potomac River and extends along the shore of the Chesapeake Bay south to the Rappahannock River, which is also included. Major cities within the reach include Alexandria, Quantico, Woodbridge, and Tappahannock. VA1 also includes portions of the Rappahannock River Valley National Wildlife Refuge and numerous historic sites of national importance, including George Washington's home, Mount Vernon.

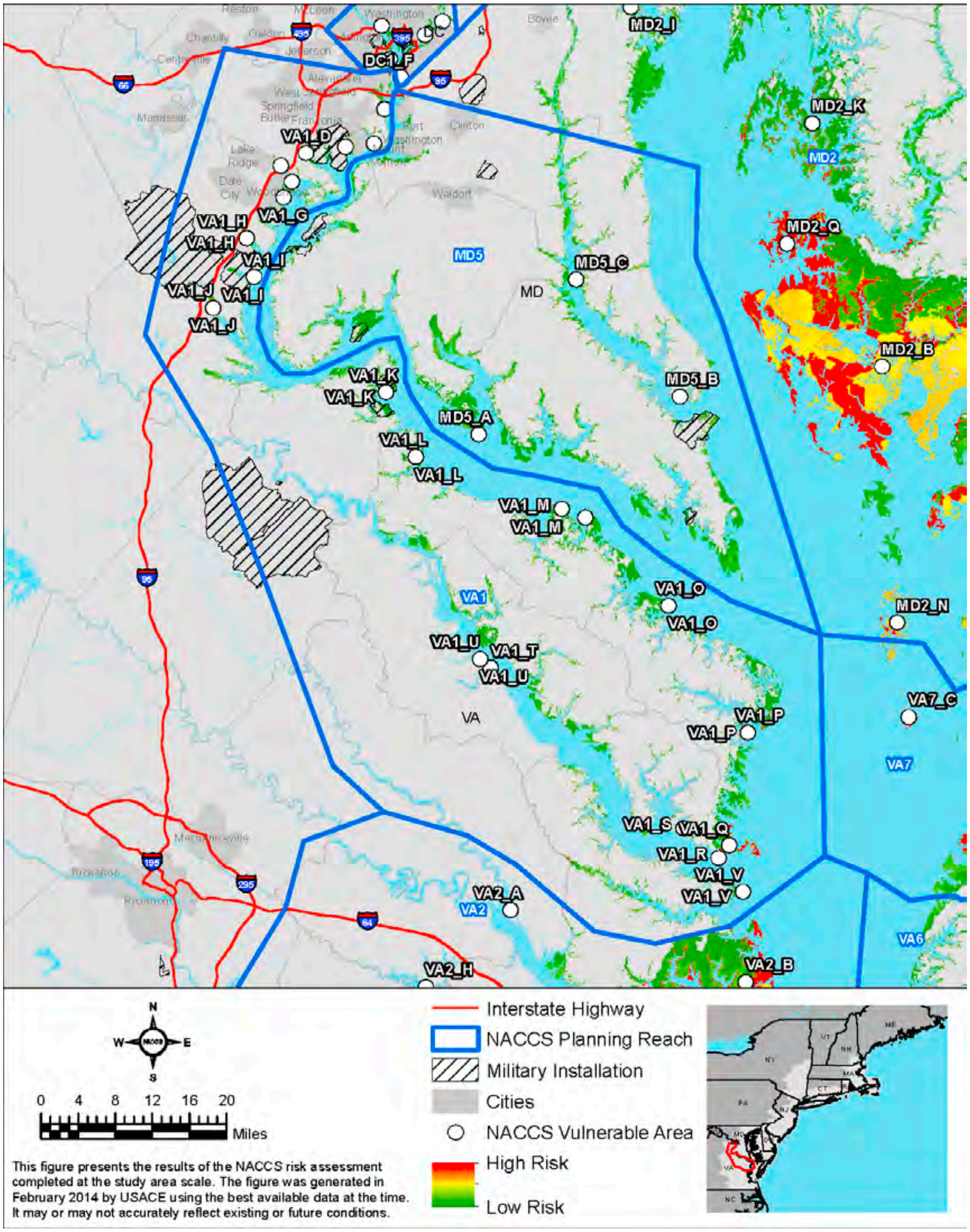


Figure 19. VA1 Risk Areas

VA2

VA2 is the second largest reach in Virginia. It includes the entire York River, the majority of the James River, and the entire land mass between them, which is commonly referred to as the Virginia Peninsula. The northern portion of VA2 also includes part of the Middle Peninsula, which is bordered by the York River to the south and the Rappahannock River to the north. The eastern boundary of the reach is in the Chesapeake Bay between the mouth of the York River and the southern end of Virginia's Eastern Shore which, for this study, is included in VA6. VA2 covers the northern portion of the Hampton Roads region, including Newport News, Poquoson, Williamsburg, Gloucester County, and Mathews County. The only Federal shore stabilization project in the reach is the Jamestown Island Seawall, which is located on the James River in the middle of the Virginia Peninsula. The seawall was not originally constructed to reduce flood risk and was designed to protect the shoreline from erosion where relics are buried within historic Jamestown Settlement site. At the southern edge of the reach, the City of Hampton has constructed breakwaters and maintains the beach at Factory Point. During a coastal storm event, the breakwaters would reduce the effect of increased wave energy and the beach would act as buffer between waves and storm surge, which reduces exposure to the area behind it.

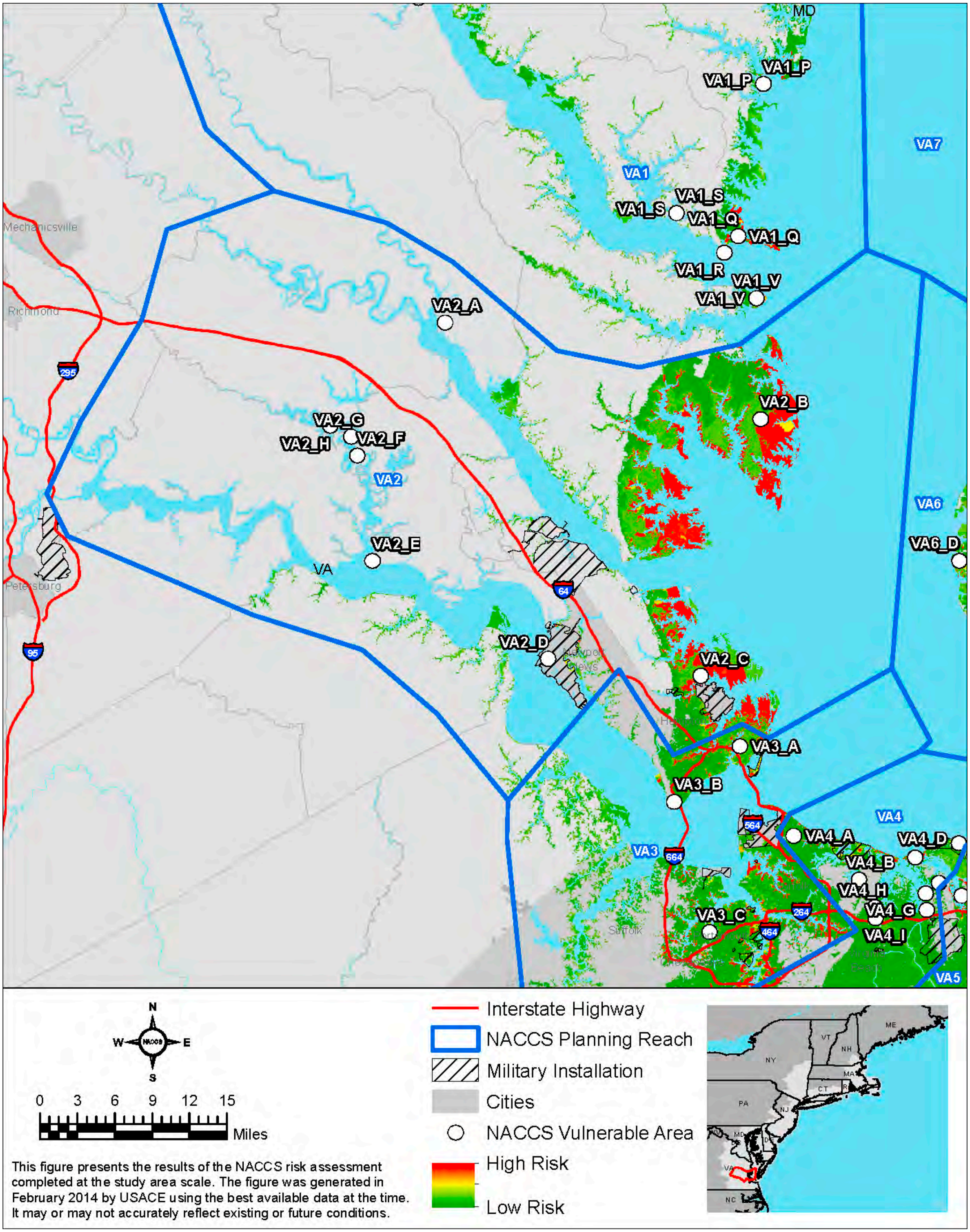


Figure 20. VA2 Risk Areas

VA3

VA3 is located where the southern portion of the James River meets the Chesapeake Bay. It also includes the Willoughby Bay and the Elizabeth, Nansemond, and Lafayette Rivers. The Port of Hampton Roads and Craney Island Dredged Material Management Area are located within the reach on the Elizabeth River. VA3 covers a large segment of the Hampton Roads Region, including Hampton, southern Newport News, Suffolk, Portsmouth, Chesapeake, and Norfolk. The majority of Virginia's Federal deep draft navigation channels are in VA3. The Cape Henry and Thimble Shoal channels are at the mouth of the Chesapeake Bay and the Willoughby and Norfolk Harbor Channels are on the Elizabeth River. There are also some Federal shore stabilization and flood risk management projects located throughout the reach: Hampton Institute, Anderson Park, and the Norfolk floodwall project. Hampton Institute and Anderson Park are both small shoreline stabilization projects that were designed only to prevent land loss under normal conditions and would not provide coastal storm risk management to any structures during a coastal storm event, as tide levels and wave heights would exceed the design of the revetment structures. There are three projects in VA3 that were designed for the purpose of coastal storm damage reduction on the Chesapeake Bay. One of these, the Chesapeake Bay Shoreline project, is a USACE project that was cost shared with the City of Hampton. The project widened the beach in front of the existing seawall that was constructed by the city and has been regularly renourished since initial construction. The city has also constructed nearshore breakwaters at the project. The other two beach projects, Salt Ponds and Willoughby, were implemented by the cities of Hampton and Norfolk, respectively. The City of Hampton regularly uses material dredged from Salt Ponds Inlet as beachfill to maintain the dunes and beach at Salt Ponds. In Norfolk, the city has been maintaining the beach in Willoughby and has also constructed nearshore breakwaters in the area. Because these projects are all well maintained and have been designed to reduce storm damages, the risk of flooding and other storm damage is lower in the areas they protect than in locations without similar flood risk management measures.

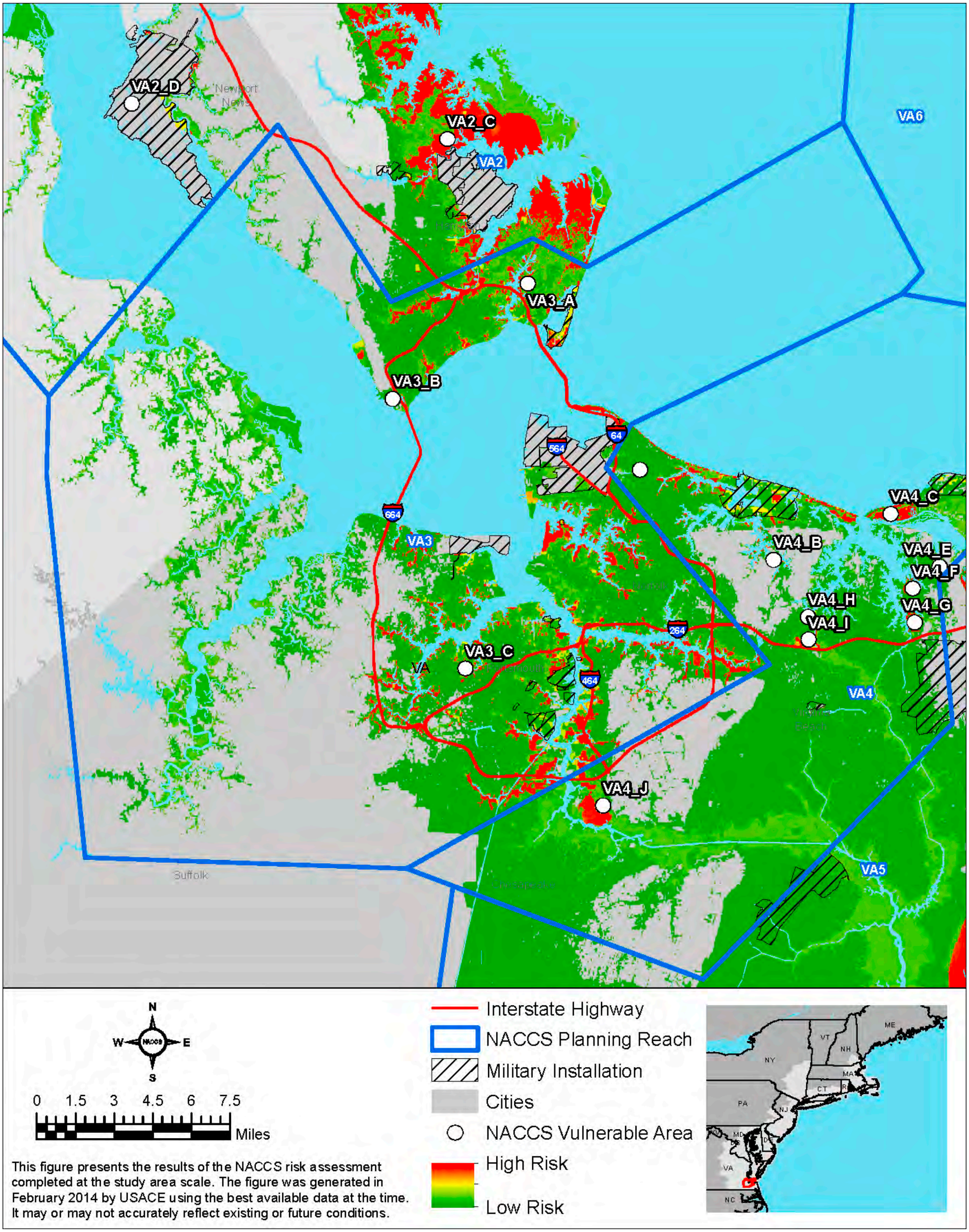


Figure 21. VA3 Risk Areas

VA4

VA4 is the smallest reach in Virginia, but it contains the section of shoreline at the mouth of the Chesapeake Bay up to the point where it meets the Atlantic Ocean. The reach includes the cities of Norfolk, Virginia Beach, and Chesapeake and the reach shoreline is divided almost equally in half between Norfolk and Virginia Beach by the Little Creek Inlet. The City of Norfolk maintains the beach and dunes along the section of shoreline between Willoughby Spit and Little Creek Inlet. They have also constructed breakwaters along the beach for added coastal storm risk management from wave energy and erosion. On the other side of the Little Creek Inlet, the City of Virginia Beach maintains approximately a third of its portion of the total shoreline length in VA4. The city renourishes and maintains the public beaches on either side of the Lynnhaven Inlet, usually with material dredged from the inlet, including the Chesapeake, Baylake, Ocean Park, Lynnhaven Shores, and Cape Henry beaches. Because these projects are all well maintained and have been designed to reduce storm damages, the risk of flooding and other storm damage is lower in the areas they protect than in locations without similar flood risk management measures.

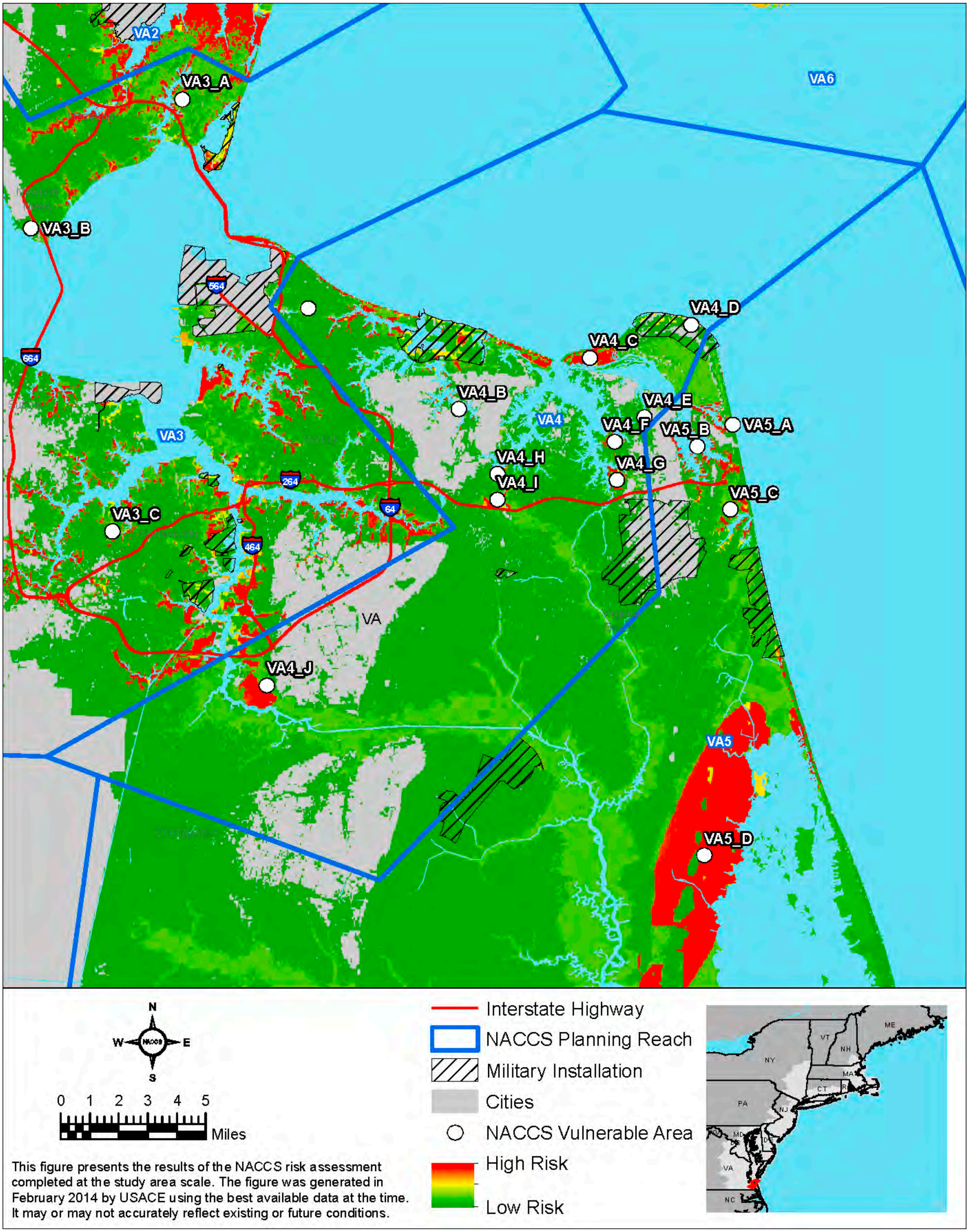


Figure 22. VA4 Risk Areas

VA5

VA5 is the southernmost reach in Virginia. It includes the section of shoreline on the Atlantic Ocean below the Chesapeake Bay, which is mostly within the City of Virginia Beach. The section of shoreline immediately south of the Virginia Beach coastline is part of the Back Bay National Wildlife Refuge. The western inland portion of the reach includes part of the City of Chesapeake. Two Federal coastal storm damage reduction beach projects account for approximately two thirds of the shoreline in VA5. The Virginia Beach Hurricane Protection project covers most of the area between Cape Henry and Rudee Inlet and to the south, the Sandbridge Beach project extends down to the Back Bay National Wildlife Refuge. Both projects were recently renourished as part of a regular maintenance cycle. In addition to the widened berm, the Virginia Beach project includes a concrete seawall and upland stormwater management features. Because these projects are all well maintained and were designed to reduce storm damages, the risk of flooding and other storm damage is lower in the areas protected by these projects than in locations without similar measures. While both projects provide substantial coastal storm risk management against storm damage, the seawall enhances the Virginia Beach project's risk reduction potential.

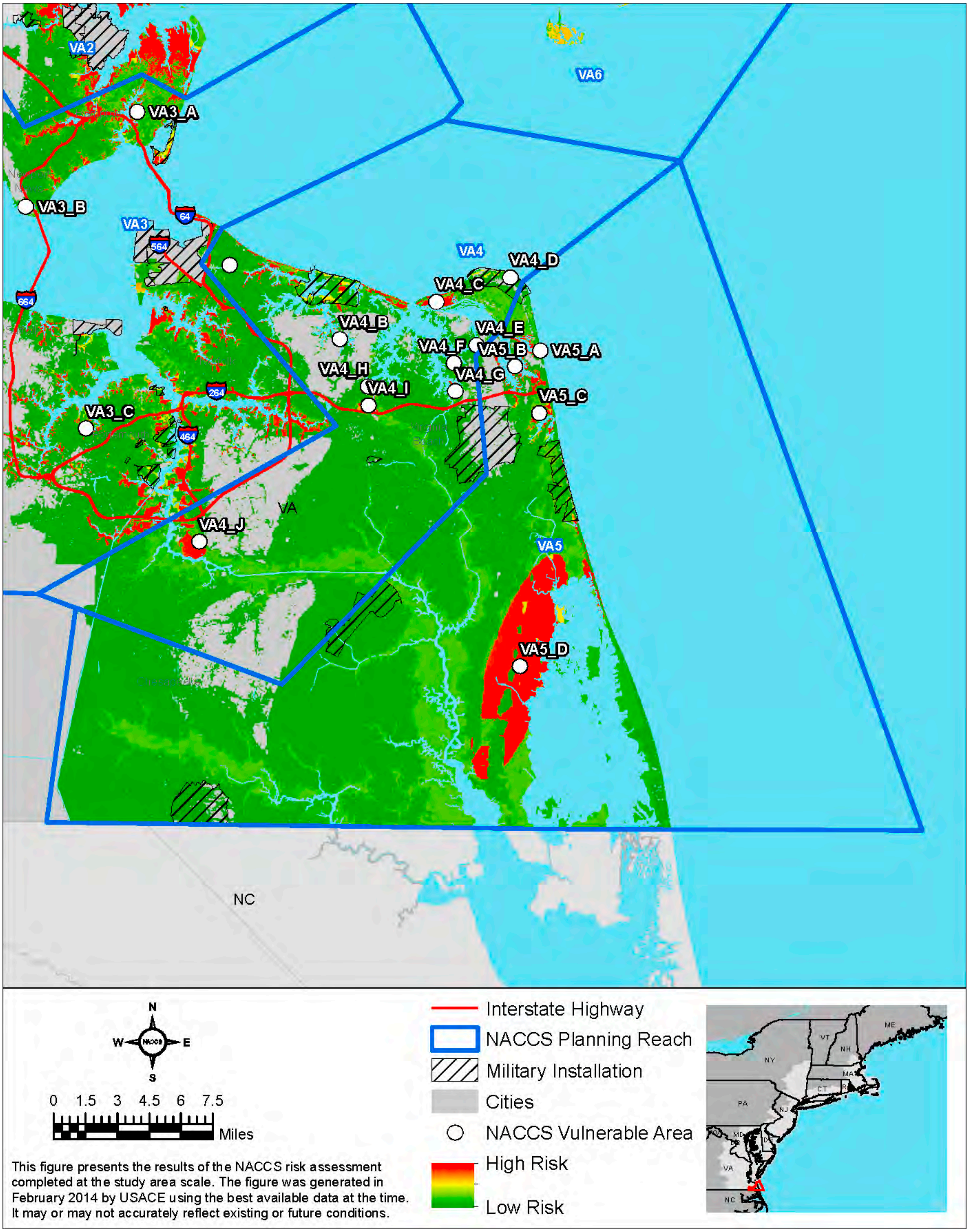


Figure 23. VA5 Risk Areas

VA6

VA6 includes areas of eastern Virginia, from the Maryland border south to include the Virginia portion of the Delmarva Peninsula, including coastal areas of the Chesapeake Bay and Atlantic Ocean. The coastal barrier islands located in the reach include Assateague, Wallops, Cedar, Paramore, and Smith Islands. Within portions of Accomack and Northampton Counties, the major cities/towns include Chincoteague, Atlantic, and Cape Charles. VA6 also includes portions of the U.S. Fish and Wildlife Service's (USFWS) Chincoteague National Wildlife Refuge (NWR) on Assateague Island and the National Aeronautics and Space Administration's (NASA) Wallops Flight Facility on Wallop's Island. Other regionally significant features within VA6 include the Chesapeake Bay Bridge-Tunnel, which connects the Delmarva Peninsula with the City of Norfolk, Virginia, and the Town of Chincoteague. The primary economic industries of the largely rural Delmarva Peninsula are agriculture (poultry), seafood, and tourism. VA6 is served by U.S. Route 13, the primary north-south artery located in the southern Delmarva Peninsula, connecting the City of Norfolk, Virginia with the City of Salisbury, Maryland. Barrier islands and coastal bays, including Chincoteague, Hog Island, Outlet, South, and Smith Island Bays provide shelter to the mainland from the Atlantic Ocean. The western shore of the Delmarva Peninsula is exposed to the open waters of the Chesapeake Bay. Areas of the coastal bays and along the western shore of the peninsula include tidal salt marsh and emergent wetlands in tributaries.

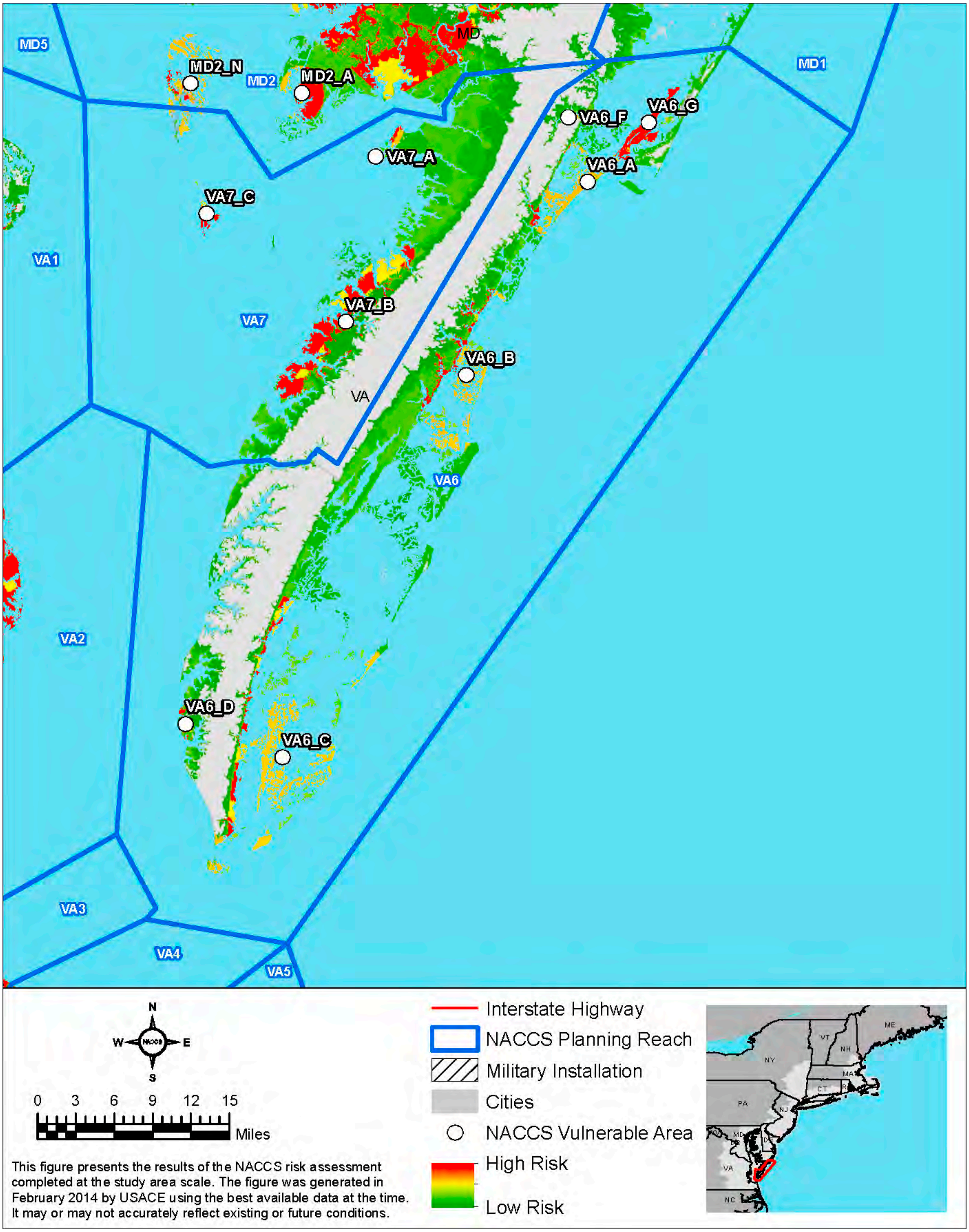


Figure 24. VA6 Risk Areas

VA7

VA7 includes areas of the northern Virginia portion of the Delmarva Peninsula and the coastal areas of the Chesapeake Bay in Accomack County. Developed areas within the reach include the Town of Saxis and areas east of the unincorporated areas near Pungoteague. The Delmarva Peninsula's primary economic industries are agriculture (poultry), seafood, and tourism.

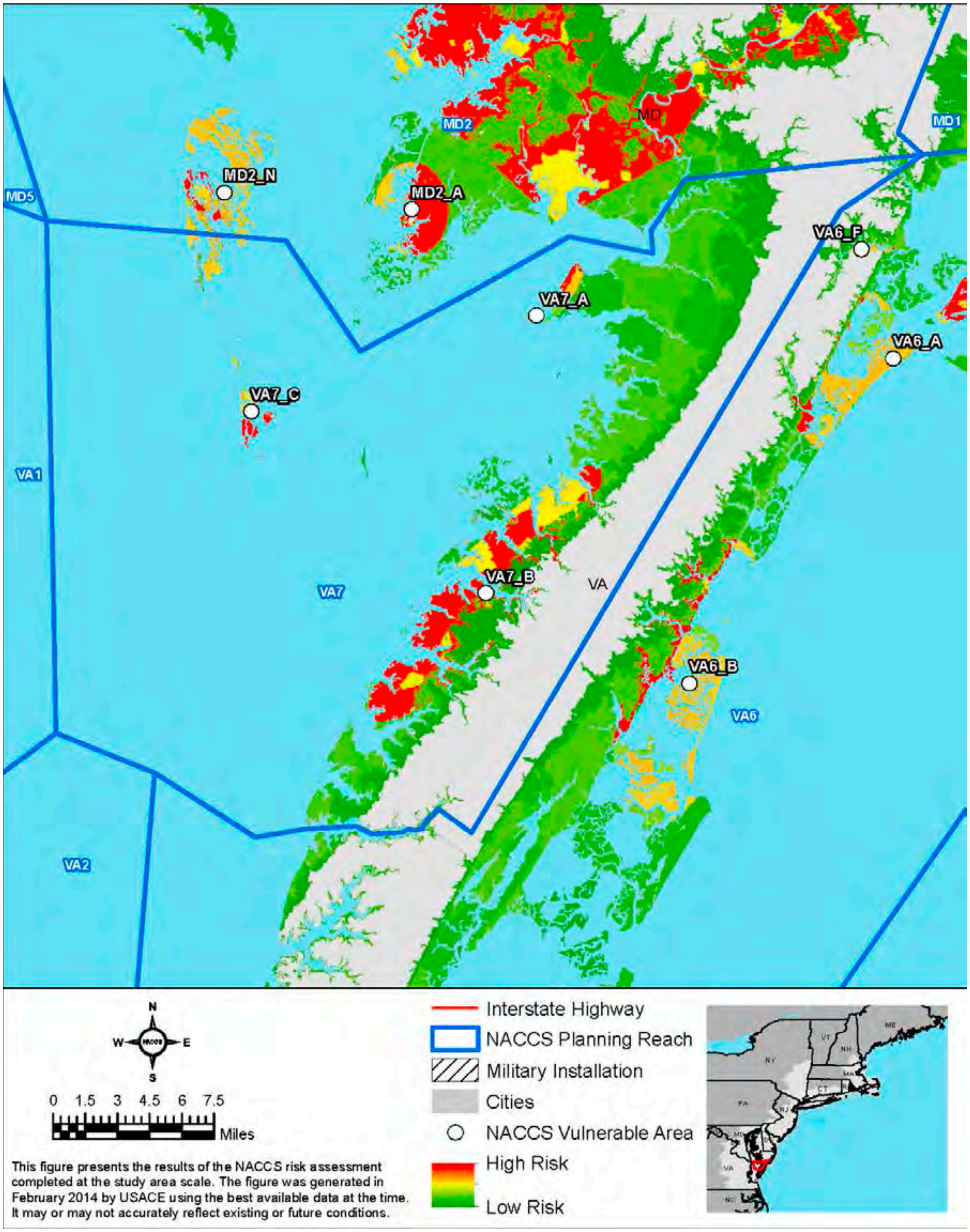


Figure 25. VA7 Vulnerable Areas

VII. Coastal Storm Risk Management Strategies and Measures

VII.1. Measures and Applicability by Shoreline Type

The structural and NNBF measures were further categorized based on shoreline type for where they are best suited according to typical application opportunities and constraints and best professional judgment (Dronkers et. Al. 1990; USACE 2014). Shoreline types were derived from the NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA, varies). Figure 26 presents the location and extent of each shoreline type in the Commonwealth of Virginia. Table 4 summarizes the measures applicability based on shoreline type. It is assumed non-structural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale.

Additionally, a conceptual analysis of geographic applicability of NNBF measures presented in Table 4 was completed, including beach restoration, beach restoration with breakwaters/groins, living shorelines, reefs, submerged aquatic vegetation, and wetlands. The GIS operations that were used for the NNBF screening analysis are described in the Use of Natural and Nature-Based Features for Coastal Resilience Report (Bridges et. al., 2015). In addition to the NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA, n.d.), other criteria that was considered was habitat type, impervious cover, water quality, and topography/bathymetry. Consistent with the theme of this Framework, further evaluation of the results would be required at a smaller scale and with finer data sets. Figure 27 presents the location and extent of NNBF measures based on additional screening criteria. Additional information associated with the methodology and results of the analysis is presented in Appendix C – Planning Analyses.

The lengths of shoreline types in each reach are provided in Figures 28-34.

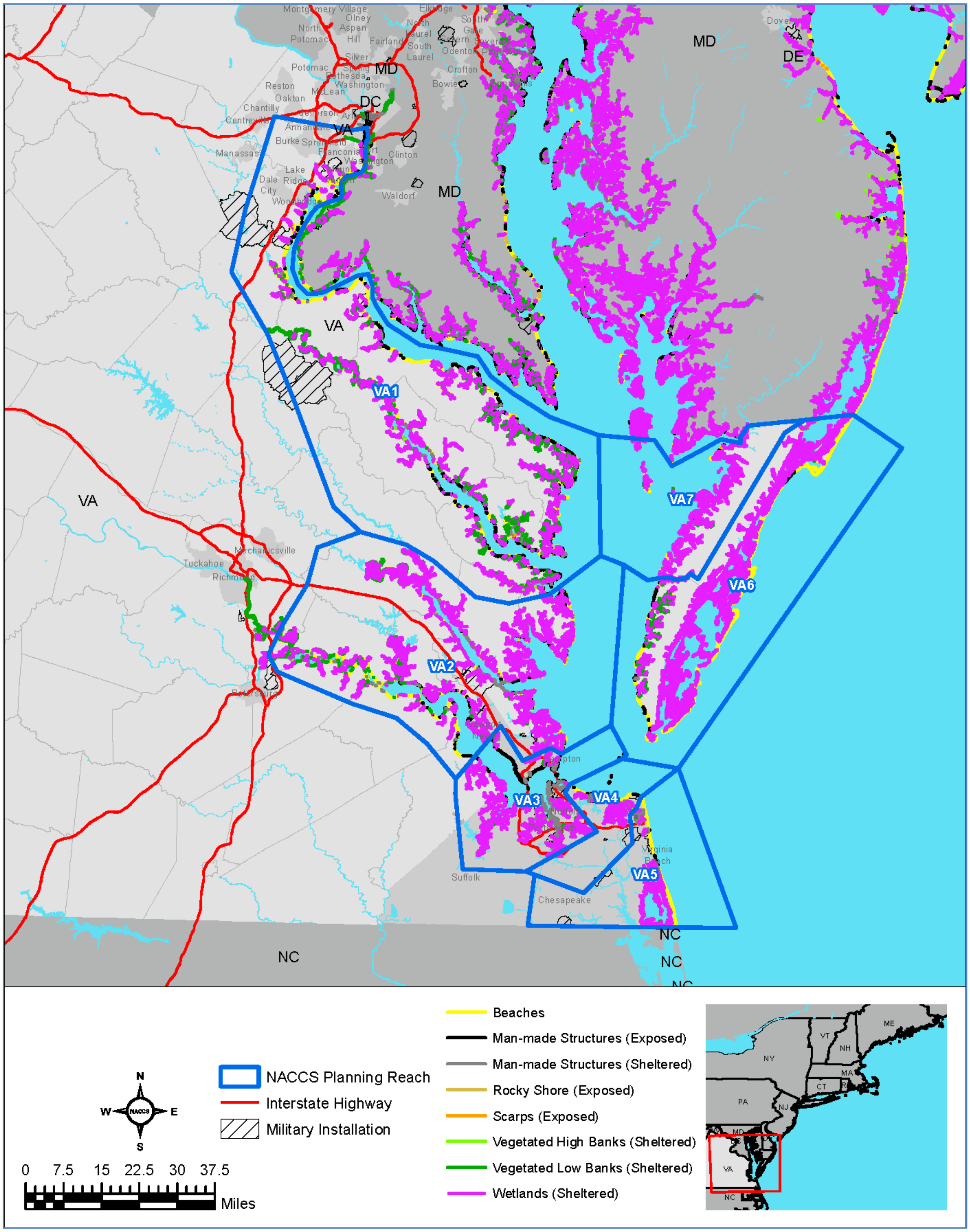


Figure 26. Shoreline Types in the Commonwealth of Virginia

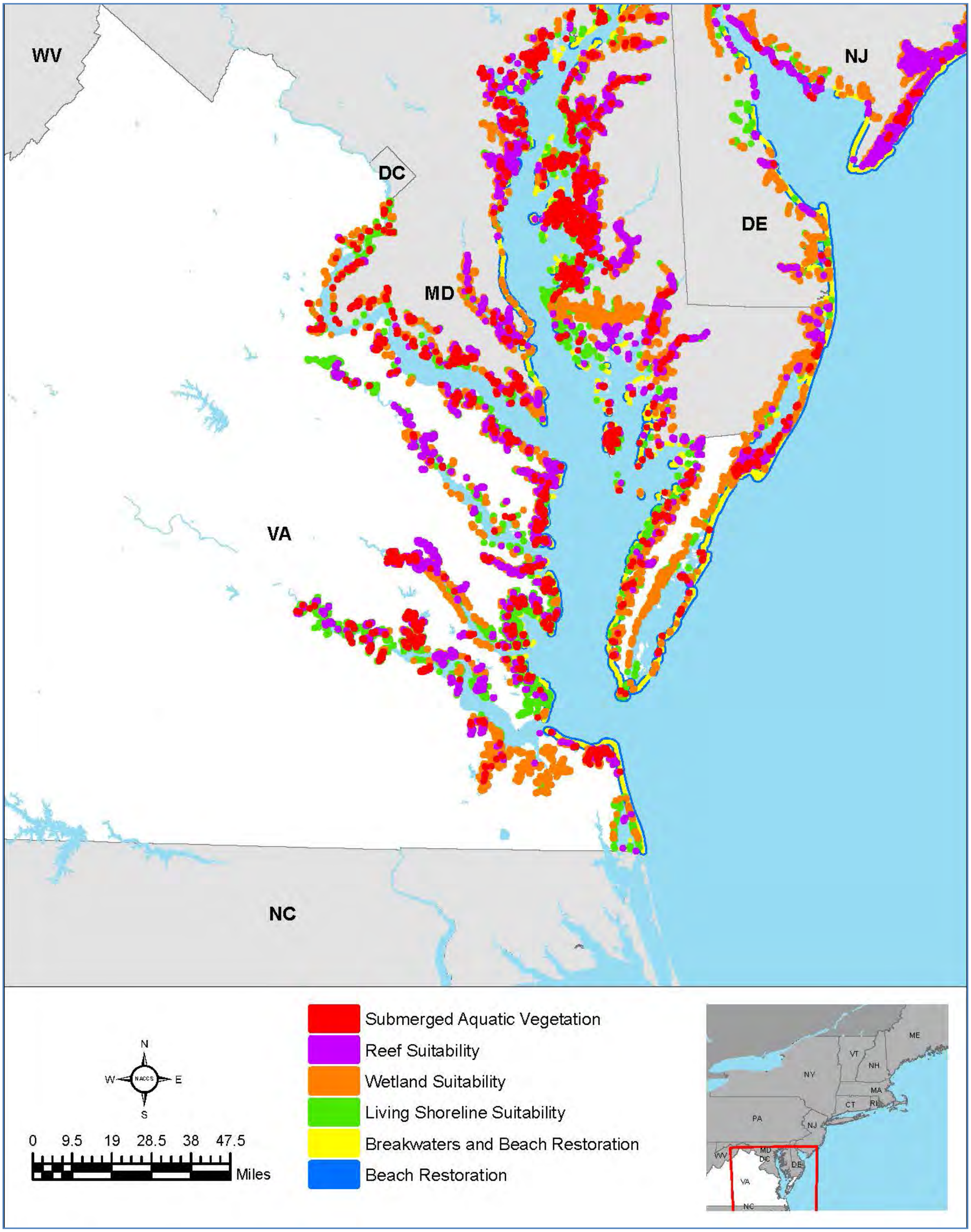


Figure 27. NNBF Measures Screening for the Commonwealth of Virginia.

Table 4. Structural and NNBF Measure Applicability by NOAA-ESI Shoreline Type

Measures	Rocky shores (Exposed)	Rocky shores (Sheltered)	Beaches (Exposed)	Manmade structures (Exposed)	Manmade structures (Sheltered)	Scarps (Exposed)	Scarps (Sheltered)	Vegetated low banks (Sheltered)	Wetlands/Marshes/ Swamps (Sheltered)
Structural									
Storm Surge Barrier[1]									
Barrier Island Preservation and Beach Restoration (beach fill, dune creation)[2]			x						
Beach Restoration and Breakwaters[2]			x						
Beach Restoration and Groins[2]			x						
Shoreline Stabilization						x	x	x	
Deployable Floodwalls					x				
Floodwalls and Levees		x			x			x	
Drainage Improvements	x	x	x	x	x	x	x	x	x
Natural and Nature-Based Features									
Living Shoreline						x	x	x	x
Wetlands							x		x
Reefs	x	x				x			x
Submerged Aquatic Vegetation[3]									x
Overwash Fans[4]									
Drainage Improvements	x	x	x	x	x	x	x	x	x

[1] *The applicability of storm surge barriers cannot be determined based on shoreline type. It depends on other factors such as coastal geography.*

[2] *Beaches and dunes are also considered Natural and Nature-Based Features*

[3] *Submerged aquatic vegetation is not associated with any particular shoreline type. Initially assumed to apply to wetland shorelines.*

[4] *Overwash fans may apply to the back side of barrier islands which are not explicitly identified in the NOAA-ESI shoreline database.*

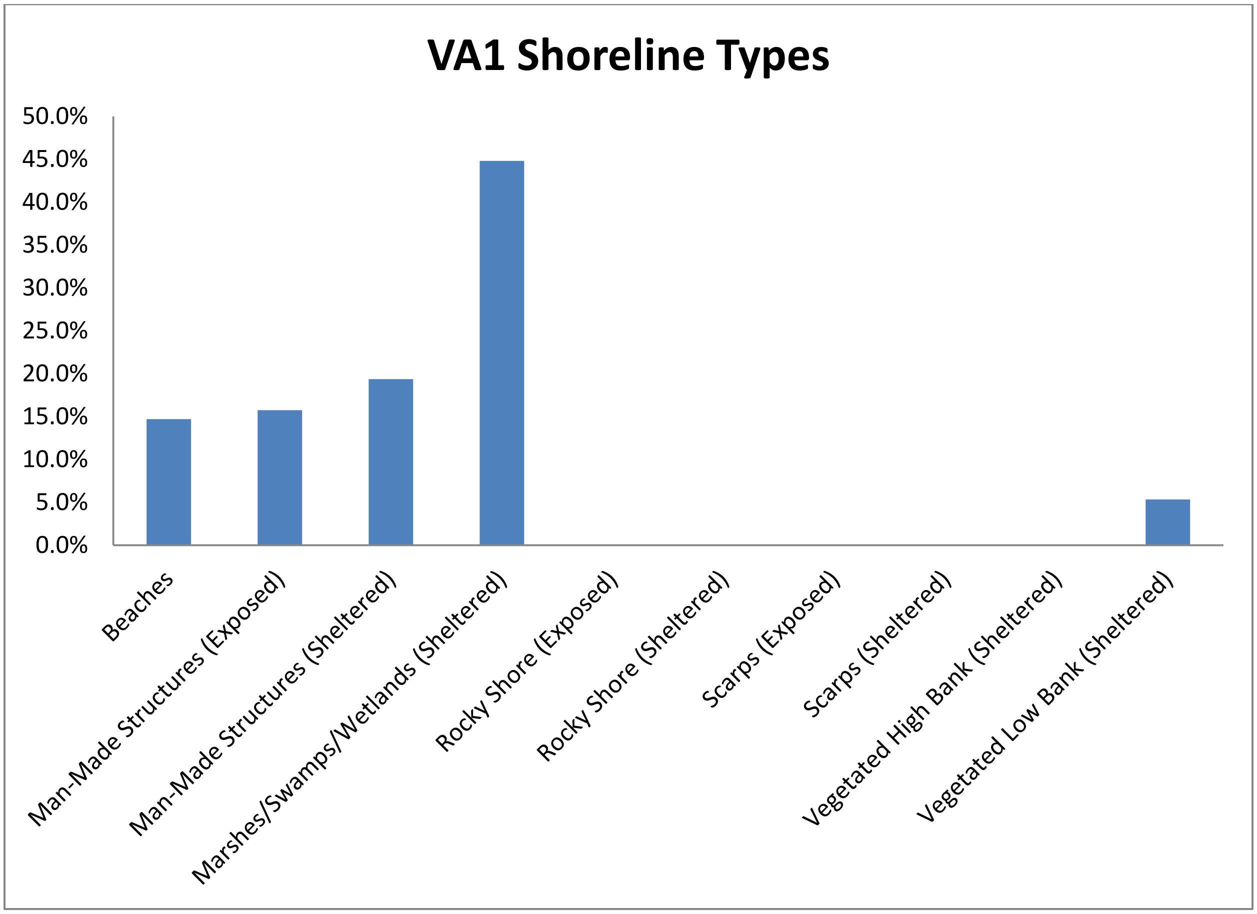


Figure 28. VA1 Shoreline Types

Table 5. Reach VA1 Shoreline Type (feet)

Reach/ Vulnerable Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes/ Swamps/ Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
VA1_A	892	32088	1023			29243	33027	96273
VA1_B	1919	1086	3503				31638	38146
VA1_C	2457	2880	8474	822		449	14500	29582
VA1_D							3529	3529
VA1_F	2753			422				3175
VA1_G	2966	3363	915				3350	10594
VA1_H							8577	8577
VA1_I	3072	3923	2229				1004	10228
VA1_J							1874	1874
VA1_K	6731	2092	5850	1426		2445	16653	35197
VA1_L	21481	9172	37599			1830	57144	127226
VA1_M	4411	11857	387				9614	26269
VA1_N	3049	10	4197				1180	8436
VA1_O	3238	4873	9828				4250	22189
VA1_P	32760	12652	38624			7752	62506	154294
VA1_Q	39673	31323	27482		706	6093	135248	240525
VA1_R	1450	982					634	3066
VA1_S			4922					4922
VA1_T	467		9916				5350	15733
VA1_U	1193		7325			313	5470	14301
VA1_V	7913	30087	17477			1545	20732	77754
Grand Total	**136425**	**146388**	**179751**	**2670**	**706**	**49670**	**416280**	**931890**

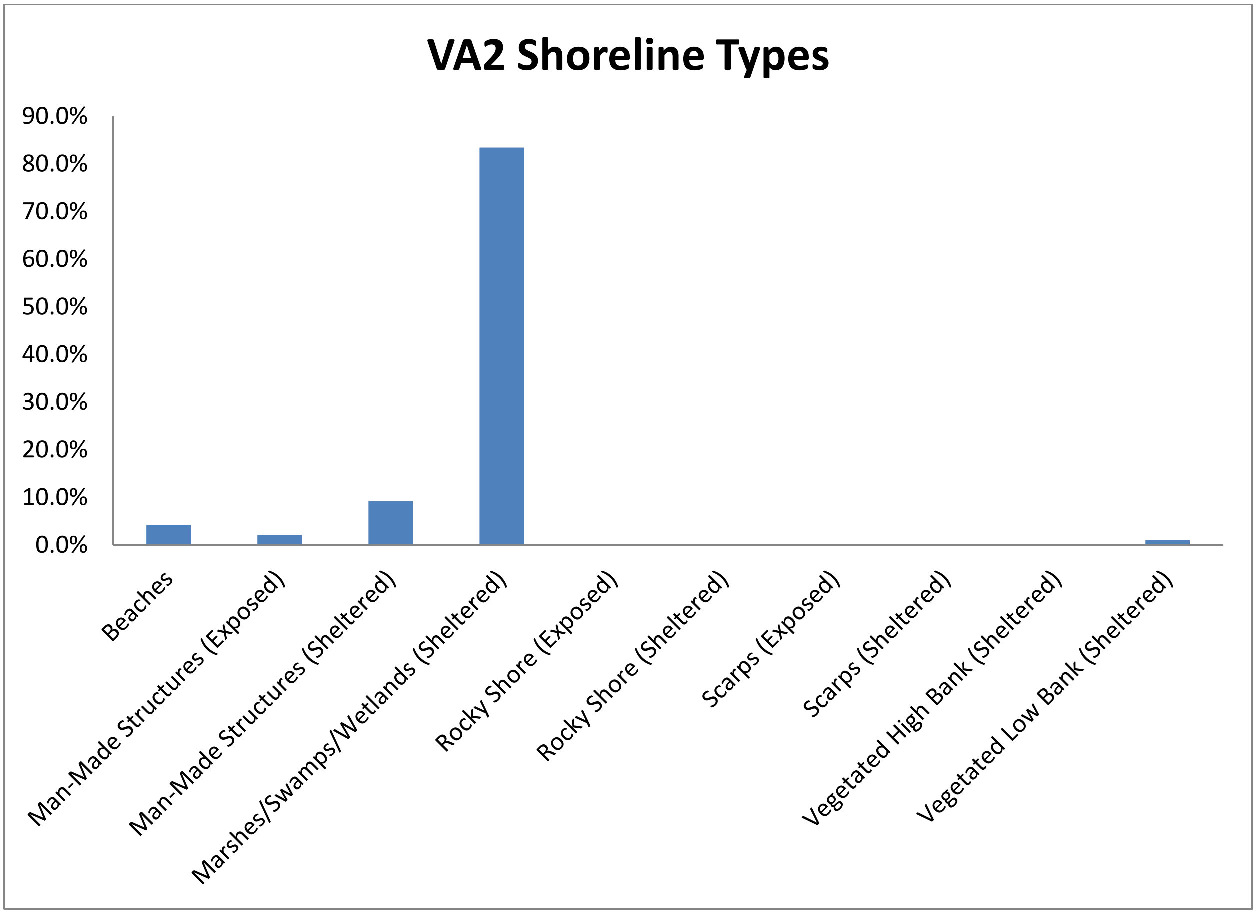


Figure 29. VA2 Shoreline Types

Table 6. Reach VA2 Shoreline Type (feet)

Reach/ Vulnerable Areas	**Beaches**	**Manmade Structures (Exposed)**	**Manmade Structures (Sheltered)**	**Marshes/ Swamps/ Wetlands (Sheltered)**	**Scarps (Exposed)**	**Vegetated High Bank (Sheltered)**	**Vegetated Low Bank (Sheltered)**	**Grand Total**
VA2	**205,786**	**100,622**	**450,030**	**4,078,185**	**1,073**	**7,061**	**48,662**	**4,910,269**
VA2_A	390		10,009	94,421		3,480		108,304
VA2_B	170,811	72,729	187,261	2,558,194	1,073	3,581	9,881	3,014,919
VA2_C	26,372	11,928	223,657	1,009,793			17,241	1,296,410
VA2_D	6,535	9,974	5,980	410,830			18,332	451,690
VA2_E	1,678	5,991	3,469				1,887	13,025
VA2_F			19,654	4,946			1,321	25,921

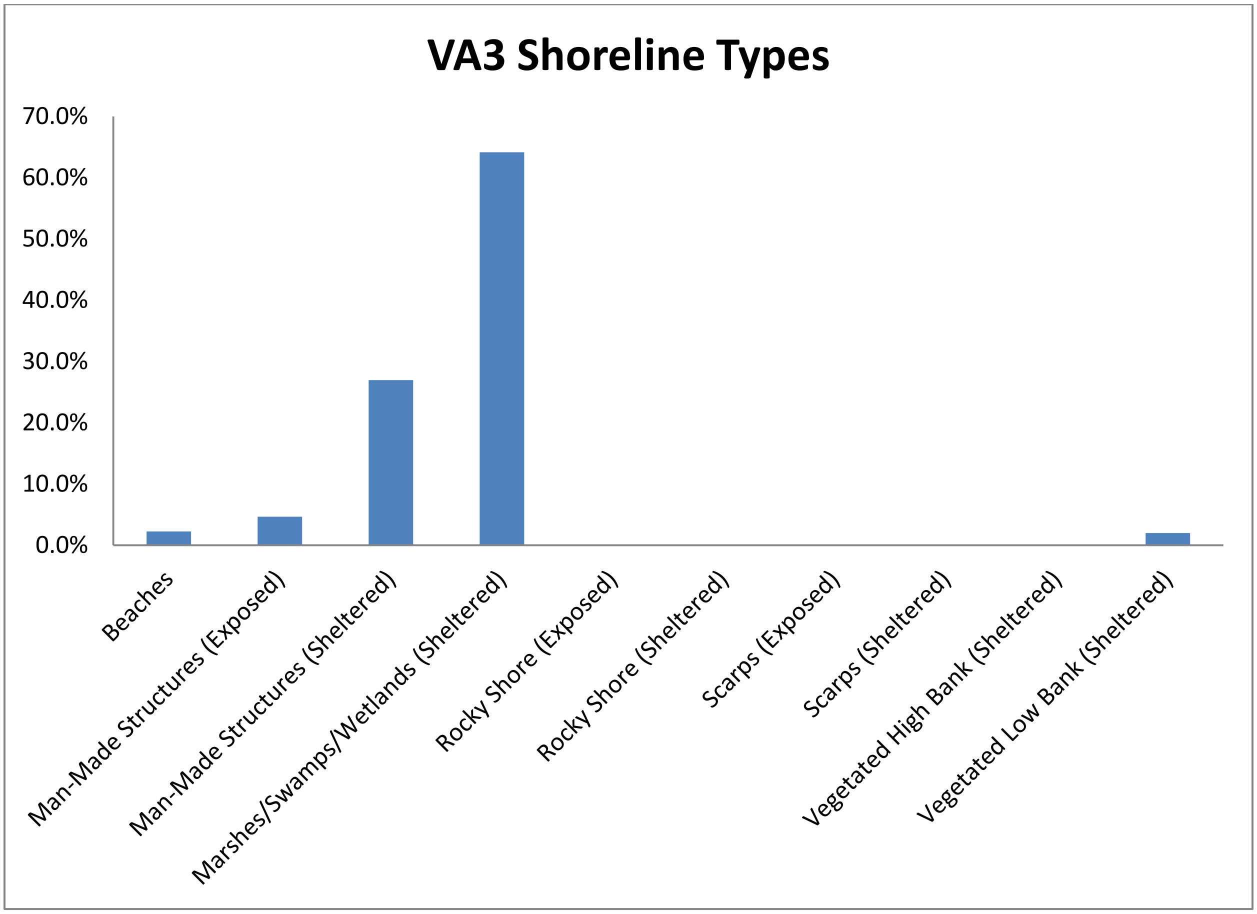


Figure 30. VA3 Shoreline Types

Table 7. Reach VA3 Shoreline Type (feet)

Reach/ Vulnerable Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes/ Swamps/ Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
VA3	**50,499**	**105,210**	**607,162**	**1,445,220**		**288**	**45,295**	**2,253,283**
VA3_A	19,807	40,645	119,380	196,510			4,923	381,203
VA3_B	1,174	47,101						48,268
VA3_C	29,518	17,464	487,782	1,248,710		288	40,372	1,823,812

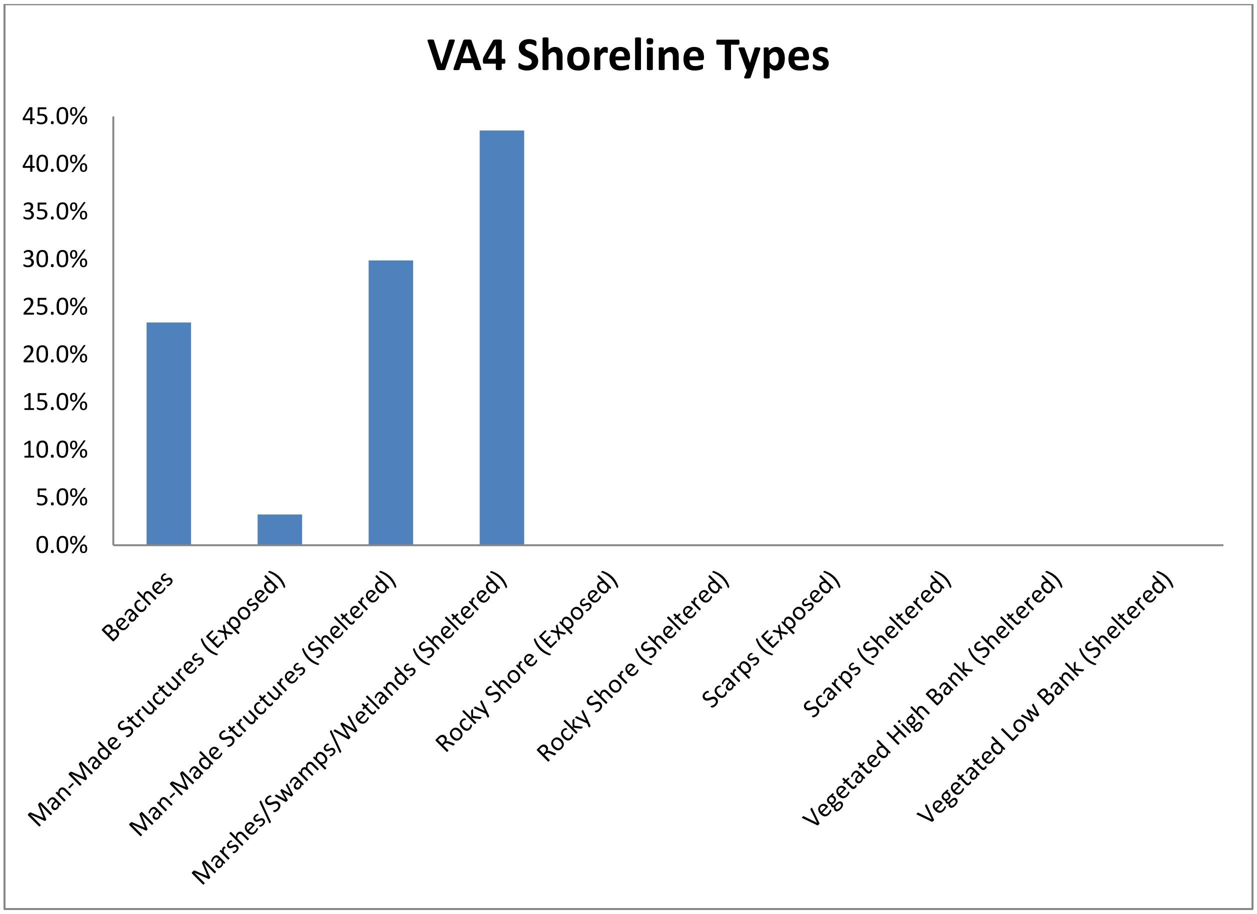


Figure 31. VA4 Shoreline Types

Table 8. Reach VA4 Shoreline Type (feet)

Reach/ Vulnerable Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes/ Swamps/ Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
VA4	**79,566**	**10,959**	**101,695**	**148,061**				**359,511**
VA4_A	25,527	3,380	41,504	107,228				177,639
VA4_B	18,277	1,007	17,328	5,954				42,566
VA4_C	25,018		39,317	920				65,255
VA4_D	10,744	6,572						17,316
VA4_E			1,989	3,797				5,786
VA4_F			1,557	4,781				6,338
VA4_G				14,716				14,716
VA4_H				8,182				8,320
VA4_I								19,092
VA4_J				2,483				2,483

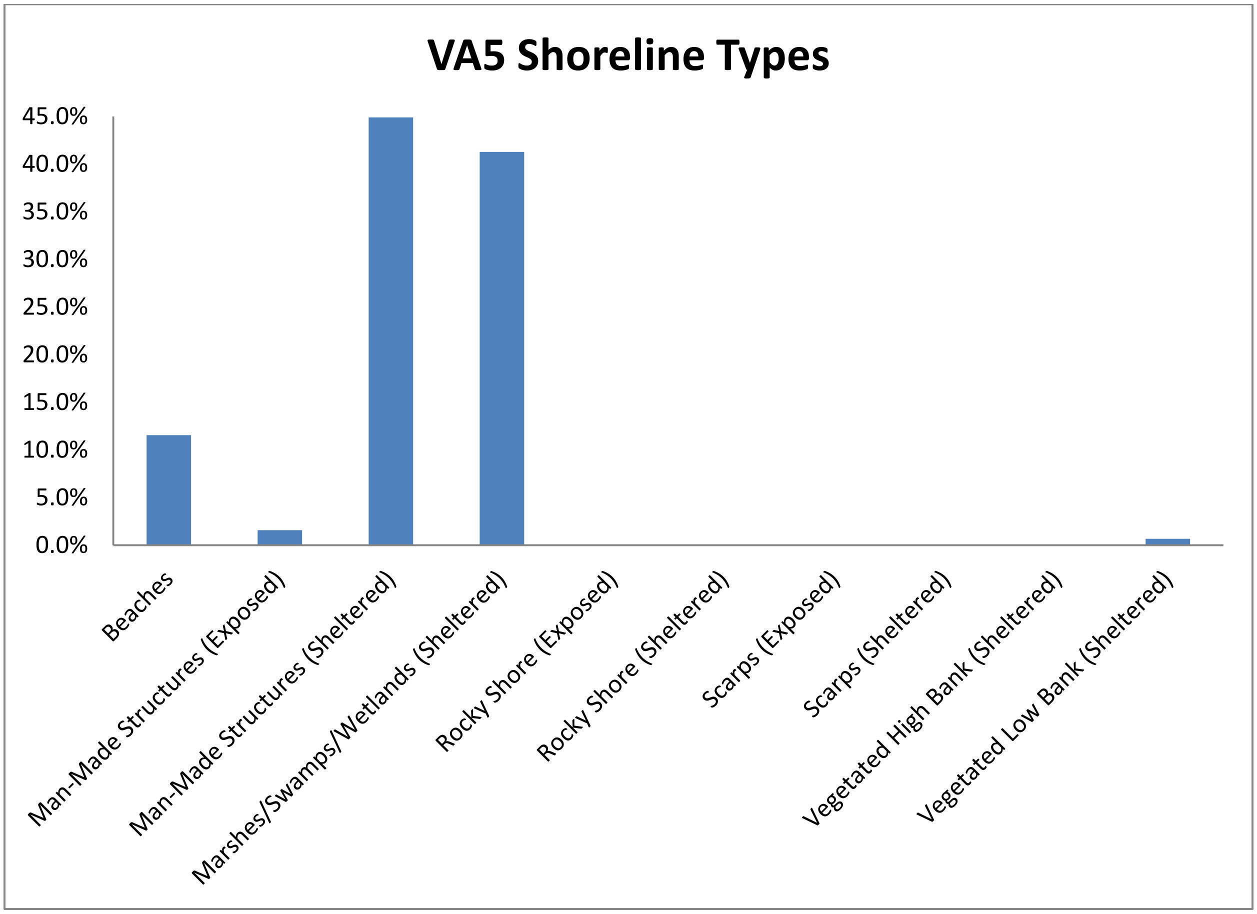


Figure 32. VA5 Shoreline Types

Table 9. Reach VA5 Shoreline Type (feet)

Reach/ Vulnerable Areas	**Beaches**	**Manmade Structures (Exposed)**	**Manmade Structures (Sheltered)**	**Marshes/ Swamps/ Wetlands (Sheltered)**	**Scarps (Exposed)**	**Vegetated High Bank (Sheltered)**	**Vegetated Low Bank (Sheltered)**	**Grand Total**
VA5	**82,855**	**11,350**	**321,719**	**295,819**		**332**	**4,720**	**716,878**
VA5_A	77,799	11,350	65,972	9,439				164,563
VA5_B	5,056		219,018	23,146		332	773	248,331
VA5_C			27,548	22,441			2,469	52,464
VA5_D			9,181	240,793			1,478	251,520

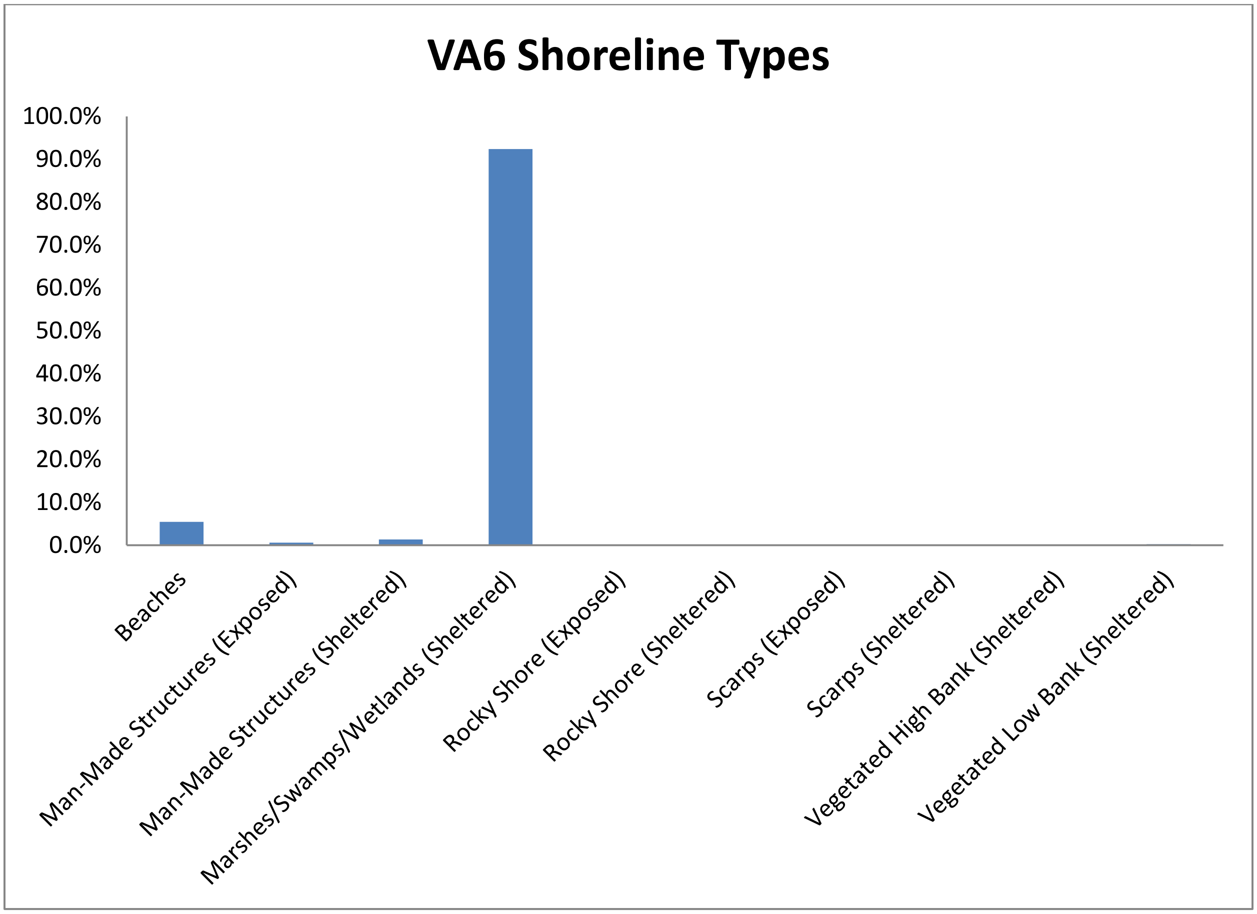


Figure 33. VA6 Shoreline Types

Table 10. Reach VA6 Shoreline Type (feet)

Reach/ Vulnerable Areas	**Beaches**	**Manmade Structures (Exposed)**	**Manmade Structures (Sheltered)**	**Marshes/ Swamps/ Wetlands (Sheltered)**	**Scarps (Exposed)**	**Vegetated High Bank (Sheltered)**	**Vegetated Low Bank (Sheltered)**	**Grand Total**
VA6	**317,463**	**34,629**	**78,281**	**5,354,112**			**13,474**	**5,824,075**
VA6_A	32,059	15,558	3,461	817,447			5,139	873,664
VA6_B	89,223			1,024,659				1,113,882
VA6_C	174,419	10,777	2,041	3,058,953				3,272,306
VA6_D	19,959	6,485	8,942	48,914			8,335	92,635
VA6_F				38,179				38,179
VA6_G	1,803	1,809	63,837	365,960				433,409

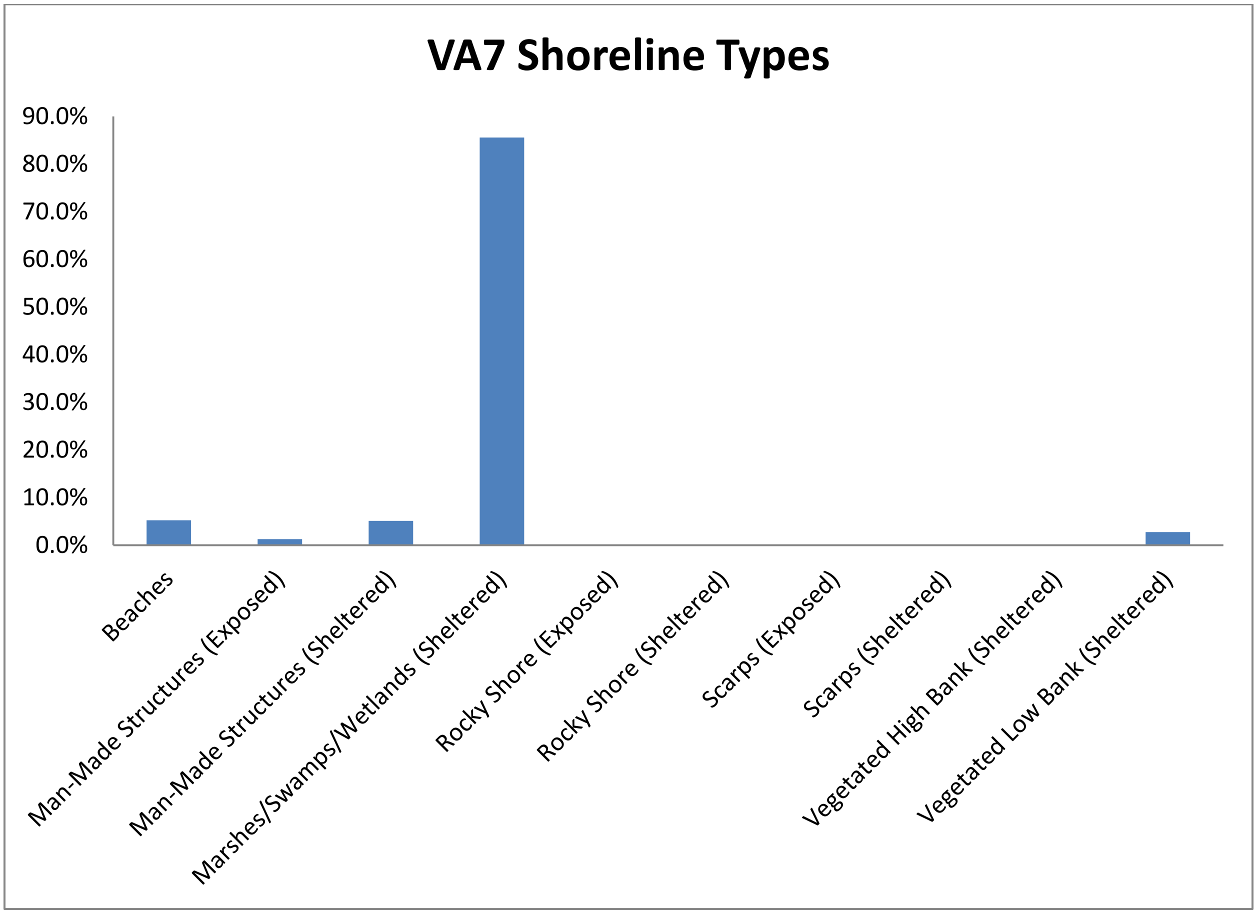


Figure 34. VA7 Shoreline Types

Table 11. Reach VA7 Shoreline Type (feet)

Reach/ Vulnerable Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes/ Swamps/ Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
VA7	**55,087**	**13,306**	**53,746**	**895,169**	**305**		**28,540**	**1,046,153**
VA7_A	14,635	3,138	2,891	84,734	305			105,703
VA7_B	10,877	4,907	42,102	645,887			28,540	732,313
VA7_C	29,575	5,261	8,753	164,548				208,137

VII.2. Cost Considerations

Conceptual design and parametric cost estimates (typically per linear foot of shoreline) were developed for the various coastal storm risk management measures based on a combination of available cost information for existing projects and representative unit costs for all construction items (e.g., excavation, fill, rock, plantings) based on historical observations.

VIII. Tier 1 Assessment Results

Table 12 presents the results of the Commonwealth of Virginia risk areas and the comparison of management measures. The reference to the level of risk reduction in the table relates to the flooding attribute of the storm damage reduction and resilience storm damage reduction function presented in Table 1 of the overview section. The level of risk reduction (High or Low) is based on a 1 percent chance flood plus three feet (High) or 10 percent chance flood (Low) level. For each shoreline type within the risk area presented in Table 5, the numerical sequence of the measures for each shoreline type within the respective risk area relates to the change in risk and the parametric unit cost estimates for the applicable measures. Nonstructural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale. As a result, Table 5 only presents the change in risk and the parametric unit cost estimates for structural measures, including NNBF.

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_A	Beaches	H	3	2	1									
VA1_A	Manmade Structures (Exposed)	H												
VA1_A	Manmade Structures (Sheltered)	H					3	2	1					
VA1_A	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_A	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_A	Wetlands (Sheltered)	L									1	3	4	2
VA1_B	Beaches	H	3	2	1									
VA1_B	Manmade Structures (Exposed)	H												
VA1_B	Manmade Structures (Sheltered)	H					3	2	1					
VA1_B	Wetlands (Sheltered)	L									1	3	4	2

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_C	Beaches	H	3	2	1									
VA1_C	Manmade Structures (Exposed)	H												
VA1_C	Manmade Structures (Sheltered)	H					3	2	1					
VA1_C	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_C	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_C	Wetlands (Sheltered)	L									1	3	4	2
VA1_D	Wetlands (Sheltered)	L									1	3	4	2
VA1_F	Beaches	H	3	2	1									
VA1_G	Beaches	H	3	2	1									
VA1_G	Manmade Structures (Exposed)	H												
VA1_G	Manmade Structures (Sheltered)	H					3	2	1					
VA1_G	Wetlands (Sheltered)	L									1	3	4	2
VA1_H	Wetlands (Sheltered)	L									1	3	4	2
VA1_I	Beaches	H	3	2	1									
VA1_I	Manmade Structures (Exposed)	H												
VA1_I	Manmade Structures (Sheltered)	H					3	2	1					

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_I	Wetlands (Sheltered)	L									1	3	4	2
VA1_J	Wetlands (Sheltered)	L									1	3	4	2
VA1_K	Beaches	H	3	2	1									
VA1_K	Manmade Structures (Exposed)	H												
VA1_K	Manmade Structures (Sheltered)	H					3	2	1					
VA1_K	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_K	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_K	Wetlands (Sheltered)	L									1	3	4	2
VA1_L	Beaches	H	3	2	1									
VA1_L	Manmade Structures (Exposed)	H												
VA1_L	Manmade Structures (Sheltered)	H					3	2	1					
VA1_L	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_L	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_L	Wetlands (Sheltered)	L									1	3	4	2
VA1_M	Beaches	H	3	2	1									

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_M	Manmade Structures (Exposed)	H												
VA1_M	Manmade Structures (Sheltered)	H					3	2	1					
VA1_M	Wetlands (Sheltered)	L									1	3	4	2
VA1_N	Beaches	H	3	2	1									
VA1_N	Manmade Structures (Exposed)	H												
VA1_N	Manmade Structures (Sheltered)	H					3	2	1					
VA1_N	Wetlands (Sheltered)	L									1	3	4	2
VA1_O	Beaches	H	3	2	1									
VA1_O	Manmade Structures (Exposed)	H												
VA1_O	Manmade Structures (Sheltered)	H					3	2	1					
VA1_O	Wetlands (Sheltered)	L									1	3	4	2
VA1_P	Beaches	H	3	2	1									
VA1_P	Manmade Structures (Exposed)	H												
VA1_P	Manmade Structures (Sheltered)	H					3	2	1					
VA1_P	Vegetated Low Banks (Sheltered)	H						2	1					

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_P	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_P	Wetlands (Sheltered)	L									1	3	4	2
VA1_Q	Beaches	H	3	2	1									
VA1_Q	Manmade Structures (Exposed)	H												
VA1_Q	Manmade Structures (Sheltered)	H					3	2	1					
VA1_Q	Scarps (Exposed)	L				3					1		2	
VA1_Q	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_Q	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_Q	Wetlands (Sheltered)	L									1	3	4	2
VA1_R	Beaches	H	3	2	1									
VA1_R	Manmade Structures (Exposed)	H												
VA1_R	Wetlands (Sheltered)	L									1	3	4	2
VA1_S	Manmade Structures (Sheltered)	H					3	2	1					
VA1_T	Beaches	H	3	2	1									
VA1_T	Manmade Structures (Sheltered)	H					3	2	1					
VA1_T	Wetlands (Sheltered)	L									1	3	4	2

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA1_U	Beaches	H	3	2	1									
VA1_U	Manmade Structures (Sheltered)	H					3	2	1					
VA1_U	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_U	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_U	Wetlands (Sheltered)	L									1	3	4	2
VA1_V	Beaches	H	3	2	1									
VA1_V	Manmade Structures (Exposed)	H												
VA1_V	Manmade Structures (Sheltered)	H					3	2	1					
VA1_V	Vegetated Low Banks (Sheltered)	H						2	1					
VA1_V	Vegetated Low Banks (Sheltered)	L				2					1			
VA1_V	Wetlands (Sheltered)	L									1	3	4	2
VA2_A	Beaches	H	3	2	1									
VA2_A	Manmade Structures (Sheltered)	H					3	2	1					
VA2_A	Vegetated High Banks (Sheltered)	L												
VA2_A	Wetlands (Sheltered)	L									1	3	4	2
VA2_B	Beaches	H	3	2	1									

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA2_B	Manmade Structures (Exposed)	H												
VA2_B	Beaches	H	3	2	1									
VA2_B	Manmade Structures (Exposed)	H												
VA2_B	Manmade Structures (Sheltered)	H					3	2	1					
VA2_B	Scarps (Exposed)	L				3					1		2	
VA2_B	Vegetated High Banks (Sheltered)	L												
VA2_B	Vegetated Low Banks (Sheltered)	H						2	1					
VA2_B	Vegetated Low Banks (Sheltered)	L				2					1			
VA2_B	Wetlands (Sheltered)	L									1	3	4	2
VA2_C	Beaches	H	3	2	1									
VA2_C	Manmade Structures (Exposed)	H												
VA2_C	Manmade Structures (Sheltered)	H					3	2	1					
VA2_C	Vegetated Low Banks (Sheltered)	H						2	1					
VA2_C	Vegetated Low Banks (Sheltered)	L				2					1			
VA2_C	Wetlands (Sheltered)	L									1	3	4	2

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA2_C	Beaches	H	3	2	1									
VA2_C	Wetlands (Sheltered)	L									1	3	4	2
VA2_D	Beaches	H	3	2	1									
VA2_D	Manmade Structures (Exposed)	H												
VA2_D	Manmade Structures (Sheltered)	H					3	2	1					
VA2_D	Vegetated Low Banks (Sheltered)	H						2	1					
VA2_D	Vegetated Low Banks (Sheltered)	L				2					1			
VA2_D	Wetlands (Sheltered)	L									1	3	4	2
VA2_E	Beaches	H	3	2	1									
VA2_E	Manmade Structures (Exposed)	H												
VA2_E	Manmade Structures (Sheltered)	H					3	2	1					
VA2_E	Vegetated Low Banks (Sheltered)	H						2	1					
VA2_E	Vegetated Low Banks (Sheltered)	L				2					1			
VA2_F	Manmade Structures (Sheltered)	H					3	2	1					
VA2_F	Vegetated Low Banks (Sheltered)	H						2	1					

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA2_F	Vegetated Low Banks (Sheltered)	L				2					1			
VA2_F	Wetlands (Sheltered)	L									1	3	4	2
VA3_A	Beaches	H	3	2	1									
VA3_A	Wetlands (Sheltered)	L									1	3	4	2
VA3_A	Manmade Structures (Sheltered)	H					3	2	1					
VA3_A	Wetlands (Sheltered)	L									1	3	4	2
VA3_A	Beaches	H	3	2	1									
VA3_A	Manmade Structures (Exposed)	H												
VA3_A	Manmade Structures (Sheltered)	H					3	2	1					
VA3_A	Beaches	H	3	2	1									
VA3_A	Manmade Structures (Exposed)	H												
VA3_A	Manmade Structures (Sheltered)	H					3	2	1					
VA3_A	Vegetated Low Banks (Sheltered)	H						2	1					
VA3_A	Vegetated Low Banks (Sheltered)	L				2					1			
VA3_A	Wetlands (Sheltered)	L									1	3	4	2
VA3_A	Beaches	H	3	2	1									

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA3_A	Manmade Structures (Exposed)	H												
VA3_A	Manmade Structures (Sheltered)	H					3	2	1					
VA3_A	Wetlands (Sheltered)	L									1	3	4	2
VA3_A	Beaches	H	3	2	1									
VA3_A	Manmade Structures (Exposed)	H												
VA3_A	Manmade Structures (Sheltered)	H					3	2	1					
VA3_A	Wetlands (Sheltered)	L									1	3	4	2
VA3_B	Beaches	H	3	2	1									
VA3_B	Manmade Structures (Exposed)	H												
VA3_C	Beaches	H	3	2	1									
VA3_C	Manmade Structures (Exposed)	H												
VA3_C	Manmade Structures (Sheltered)	H					3	2	1					
VA3_C	Vegetated High Banks (Sheltered)	L												
VA3_C	Vegetated Low Banks (Sheltered)	H						2	1					
VA3_C	Vegetated Low Banks (Sheltered)	L				2					1			

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA3_C	Wetlands (Sheltered)	L									1	3	4	2
VA4_A	Beaches	H	3	2	1									
VA4_A	Manmade Structures (Exposed)	H												
VA4_A	Manmade Structures (Sheltered)	H					3	2	1					
VA4_A	Wetlands (Sheltered)	L									1	3	4	2
VA4_B	Beaches	H	3	2	1									
VA4_B	Manmade Structures (Exposed)	H												
VA4_B	Manmade Structures (Sheltered)	H					3	2	1					
VA4_B	Wetlands (Sheltered)	L									1	3	4	2
VA4_C	Beaches	H	3	2	1									
VA4_C	Manmade Structures (Sheltered)	H					3	2	1					
VA4_C	Wetlands (Sheltered)	L									1	3	4	2
VA4_D	Beaches	H	3	2	1									
VA4_D	Manmade Structures (Exposed)	H												
VA4_D	Beaches	H	3	2	1									
VA4_D	Manmade Structures (Exposed)	H												
VA4_E	Manmade Structures (Sheltered)	H					3	2	1					

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA4_E	Wetlands (Sheltered)	L									1	3	4	2
VA4_F	Manmade Structures (Sheltered)	H					3	2	1					
VA4_F	Wetlands (Sheltered)	L									1	3	4	2
VA4_G	Wetlands (Sheltered)	L									1	3	4	2
VA4_H	Wetlands (Sheltered)	L									1	3	4	2
VA4_J	Wetlands (Sheltered)	L									1	3	4	2
VA5_A	Beaches	H	3	2	1									
VA5_A	Manmade Structures (Exposed)	H												
VA5_A	Manmade Structures (Sheltered)	H					3	2	1					
VA5_A	Wetlands (Sheltered)	L									1	3	4	2
VA5_B	Beaches	H	3	2	1									
VA5_B	Manmade Structures (Sheltered)	H					3	2	1					
VA5_B	Vegetated High Banks (Sheltered)	L												
VA5_B	Vegetated Low Banks (Sheltered)	H						2	1					
VA5_B	Vegetated Low Banks (Sheltered)	L				2					1			
VA5_B	Wetlands (Sheltered)	L									1	3	4	2

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA5_C	Manmade Structures (Sheltered)	H					3	2	1					
VA5_C	Vegetated Low Banks (Sheltered)	H						2	1					
VA5_C	Vegetated Low Banks (Sheltered)	L				2					1			
VA5_C	Wetlands (Sheltered)	L									1	3	4	2
VA5_D	Manmade Structures (Sheltered)	H					3	2	1					
VA5_D	Vegetated Low Banks (Sheltered)	H						2	1					
VA5_D	Vegetated Low Banks (Sheltered)	L				2					1			
VA5_D	Wetlands (Sheltered)	L									1	3	4	2
VA6_A	Beaches	H	3	2	1									
VA6_A	Manmade Structures (Exposed)	H												
VA6_A	Manmade Structures (Sheltered)	H					3	2	1					
VA6_A	Vegetated Low Banks (Sheltered)	H						2	1					
VA6_A	Vegetated Low Banks (Sheltered)	L				2					1			
VA6_A	Wetlands (Sheltered)	L									1	3	4	2
VA6_B	Beaches	H	3	2	1									

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA6_B	Wetlands (Sheltered)	L									1	3	4	2
VA6_C	Beaches	H	3	2	1									
VA6_C	Manmade Structures (Exposed)	H												
VA6_C	Manmade Structures (Sheltered)	H					3	2	1					
VA6_C	Wetlands (Sheltered)	L									1	3	4	2
VA6_D	Beaches	H	3	2	1									
VA6_D	Manmade Structures (Exposed)	H												
VA6_D	Manmade Structures (Sheltered)	H					3	2	1					
VA6_D	Vegetated Low Banks (Sheltered)	H						2	1					
VA6_D	Vegetated Low Banks (Sheltered)	L				2					1			
VA6_D	Wetlands (Sheltered)	L									1	3	4	2
VA6_F	Wetlands (Sheltered)	L									1	3	4	2
VA6_G	Beaches	H	3	2	1									
VA6_G	Manmade Structures (Exposed)	H												
VA6_G	Manmade Structures (Sheltered)	H					3	2	1					
VA6_G	Wetlands (Sheltered)	L									1	3	4	2

Table 12. Comparison of Measures within the NACCS Risk Areas in the Commonwealth of Virginia

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
VA7_A	Beaches	H	3	2	1									
VA7_A	Manmade Structures (Exposed)	H												
VA7_A	Manmade Structures (Sheltered)	H					3	2	1					
VA7_A	Scarps (Exposed)	L				3					1		2	
VA7_A	Wetlands (Sheltered)	L									1	3	4	2
VA7_B	Beaches	H	3	2	1									
VA7_B	Manmade Structures (Exposed)	H												
VA7_B	Manmade Structures (Sheltered)	H					3	2	1					
VA7_B	Vegetated Low Banks (Sheltered)	H						2	1					
VA7_B	Vegetated Low Banks (Sheltered)	L				2					1			
VA7_B	Wetlands (Sheltered)	L									1	3	4	2
VA7_C	Beaches	H	3	2	1									
VA7_C	Manmade Structures (Exposed)	H												
VA7_C	Manmade Structures (Sheltered)	H					3	2	1					
VA7_C	Wetlands (Sheltered)	L									1	3	4	2

IX. Tier 2 Assessment of Conceptual Measures

The NACCS Regional Analysis (Tier 1 Assessment) for the Commonwealth of Virginia identified areas of risk based on flood inundation mapping, exposure, and vulnerability to the flood hazard, and various management measures applicable to the shorelines within the vulnerable areas by state using the aggregated measure matrices presented in Table 4 of the State Appendix Overview. To apply the principles associated with the NACCS CSRM Framework, the NACCS Tier 2 analysis considers the three strategies to address coastal flood risk, including: 1) avoid, 2) accommodate, and 3) preserve.

The single risk area for local Scale analysis is the City of Hampton Tier 2 Assessment. This analysis was performed to further evaluate flood risk as part of the CSRM Framework. The example area, defined as VA3-A, represents an area within the commonwealth of Virginia at risk to coastal flooding and includes a wide range of problems, needs and opportunities for CSRM. This area was selected for additional analysis due to the lack of existing Federal projects as well as the overall need for enhanced coastal resilience to surrounding communities due to significantly developed waterfront areas. CSRM measures were considered within the three strategies for this area within the City of Hampton. The identification of measures are based upon several natural and physical characteristics including shoreline type (Table 3) land use/development, topography, sea level change inundation, extreme water levels, existing CSRM projects, and aerial photography, as well as conceptual costs and the change in vulnerability associated with a combination of measures. As demonstrated in Table 14, this area of high risk was subdivided into six sub-regions. Each sub-region offers a unique set of CSRM measures which may act as an example for similar geomorphic settings in the Commonwealth of Virginia by state and local agencies, and non-profit organizations.

Three structural measures were considered appropriate for this area: beach fill and/or breakwaters along the exposed Chesapeake Bay shorelines, shoreline stabilization measures such as revetments, seawalls, and floodwalls along the hardened and/or interior shorelines, and drainage improvements throughout the area. This strategy was developed considering existing constructed projects such as the Anderson Park shore stabilization project. NNBF measures were also considered in areas where there are existing wetlands and non-hardened shorelines, such as in Mill Creek and Long Creek. These NNBF measures, which include living shorelines and wetland restoration/creation, were also considered as part of an adaptation strategy together with non-structural measures such as floodproofing structures. Finally, a managed retreat strategy consisting of the acquisition and relocation of structures in areas subject to very frequent flooding (more a 10 percent annual chance) was also evaluated. Together, the measures evaluated cover the full range of flood risk management strategies and illustrate and integrated approach to risk reduction and increased resilience by combining structural, NNBF, and non-structural measures.

The risk reduction associated with the management measures corresponds to the qualitative evaluation of measures presented in Table 13, such as high for a 1 percent flood plus three feet and low for a 10-percent-annual-chance flood. The cost index was derived from parametric unit cost estimates divided by the highest parametric unit cost of all the management measure in the area. The higher the cost index the greater the relative costs. This enables the users to compare the measures associated with the risk management strategy in order to evaluate affordability and ultimately leading to an acceptable level of risk tolerance. The combination of measures leading to a selection of a plan as described in the NACCS Framework would further quantify risk reduction, and evaluate and compare the change in the risk based on the total cost of the plan. This would be completed at a smaller scale, Tier 3, which would be able to incorporate refined exposure and vulnerability, and evaluation of other risk management measures, as well as refined costs.

Table 13. Risk Management Strategies (Virginia)

				Preserve				***Accommodate***				***Avoid***	
	Existing Coastal Flood Risk Management Projects			Structural Measures (100yr plus 3')		Regional/Gates (500yr)		NNBF (10yr)		Non-Structural (10yr)		Acquisition (10-year floodplain)	
Revised Polygon	Description	Existing Project - 2018 Post-Sandy	Estimated LOP	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index
1		None		Drainage improvements throughout the Southwest Branch Back River/Newmarket Creek area.	0.01	Yes	0.23	None	N/A	Floodproofing	0.92	Acquisition and Relocation	1.00
2		USACE	25 year*	A) Beach restoration and/or breakwaters from King-Lincoln Park to Salter's Creek. B) Drainage Improvements throughout area, especially shoreline north of Salter's Creek.	0.22	No	N/A	None	N/A	Floodproofing	0.92	Acquisition and Relocation	1.00

3		USACE	10 year*	A) Some additional shoreline stabilization/protection measures may be needed along the Hampton River, B) drainage improvements throughout the area.	0.00	Yes	1.00	None	N/A	Floodproofing	0.27	Acquisition and Relocation	0.29
4		None		Drainage improvements throughout the area.	0.00	Yes	1.00	Living shoreline and/or wetlands above Greenhouse Ln. in Mill Creek	0.01	Floodproofing	0.17	Acquisition and Relocation	0.18
5		USACE, local	75 year*	Beach restoration and/or breakwaters on exposed bay shoreline.	1.00	No	N/A	Living shoreline and/or wetlands restoration in Long Creek	0.16	Floodproofing	0.45	Acquisition and Relocation	0.49
6		USACE	50 year*	Beach restoration and/or breakwaters to the north of the existing USACE breakwater project.	0.80	No	N/A	Back bay wetlands creation/restoration in Mill Creek to the north of the protected shoreline	0.12	Floodproofing	0.92	Acquisition and Relocation	1.00

X. Focus Area Analysis Summary

The City of Norfolk Focus Area Analysis is provided as an attachment to this chapter. The purpose of the Focus Area Analyses (FAA) is to determine if there is interest in conducting further study to identify structural, non-structural, NNBF and policy/programmatic CSRM strategies and opportunities. A summary of the content of this analysis is provided below.

An initial day-long charette was held on August 8, 2013 with staff from USACE Norfolk District, the City of Norfolk, and resource agencies to facilitate development of initial problems, opportunities, objectives, constraints, and possible measures for CSRM and resilience in the City of Norfolk. Ideas and information gathered from this charette and from existing literature were incorporated in the FAA, which aimed to:

- Identify the areas of interest in the City of Norfolk for flood risk management analysis.
- Briefly review prior studies, reports, and existing projects.
- Generally identify initial problems, opportunities, objectives, constraints, structural or non-structural FRM measures, and strategies for FRM alternatives for the City of Norfolk.
- Determine if there is interest in pursuing further study for CSRM for the City of Norfolk.

The FAA study area is defined by the City of Norfolk jurisdictional boundaries. The City of Norfolk is located in the Chesapeake Bay watershed aproximately 200 miles southeast of Washington D.C. and approximately 90 miles southeast of Richmond, Virginia. The city is bordered mostly by water with the Chesapeake Bay to the north, Hampton Roads Harbor to the west, and the Elizabeth River to the south. The cities of Chesapeake and Virginia Beach border the city to the south and east, respectively. (Figure 35).

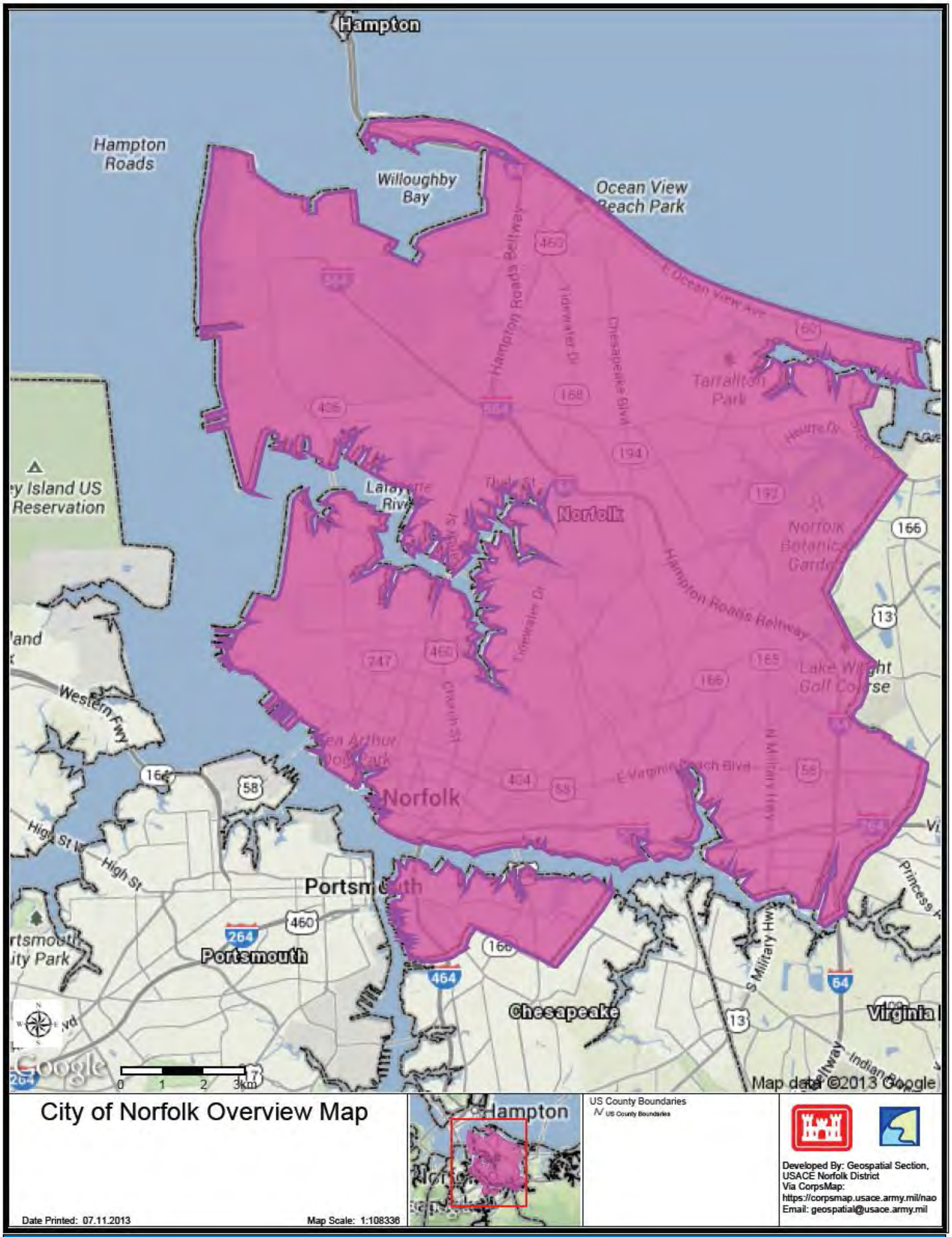


Figure 35. City of Norfolk Focus Area Analysis Boundary

A number of causes contribute to the flooding experienced by the City of Norfolk. The city is surrounded by water on three sides, the Chesapeake Bay to the north, and the Elizabeth River to the West and

South. Additionally, Norfolk is located at a low elevation, which reduces the available drainage gradient. As a result, flooding due to coastal inundation and precipitation is a widespread and frequent occurrence. Structural and non-structural measures were identified to reduce the risk of flooding in the City of Norfolk. The following information explains the basic options that could address the problems and opportunities in the study area. Potential measures that could be evaluated as part of future study phases are listed below.

Structural

1. Berms/Levees
2. Floodwalls and Bulkheads
3. Flood/Tide Gates
4. Road, Rail, or Light Rail Raises
5. Shoreline Stabilization Features
6. Stormwater System Improvements

Non-structural

7. Building Codes and Zoning
8. Buyouts and Relocations of Homes
9. Emergency Plans/Hazard Mitigation Plans
10. Flood Warning Systems
11. House Raising
12. Increase Storage
13. Low Interest Loans to Citizens
14. Public Engagement and Education
15. Relocating Utilities and Critical Infrastructure
16. Tax Incentives for Redevelopment
17. Wet and Dry Floodproofing

X.1. Potential Measures Applicable to Focus Area

Non-structural measures may be applicable to the entire study area and to each alternative to be developed in later phases of study. They may be implemented independently, but more likely will be combined with structural measures. The non-structural measures not listed in Table 14 should be implemented with every alternative plan; examples include building and zone code updates and public engagement and education. A non-structural plan will be identified as part of a future analysis.

The measures identified in Table 14 may be screened from further consideration for each area with additional analysis during later phases of study.

Table 14. Measures for Additional Analysis

Area	Structural Measures							Non-Structural Measures			Comments
	Beach Replenishment	Berm, Levee	Floodwall, Bulkhead	Flood or Tide Gate	Road Raise	Shoreline Protection	Stormwater Improvements	Buyouts/Relocation	House Raising	Restore Natural Storage	
Area 1	X	X	X	X	X		X	X	X		
Bay Shoreline	X										
Pretty Lake			X	X	X		X	X	X		
Mason Creek			X	X			X	X	X		Improve existing tide gate.
Lake Whitehurst		X	X		X						Protect freshwater in lake from outside flooding sources.
Area 2			X	X	X	X	X	X	X	X	
Watershed Protection			X	X	X		X	X	X	X	
Localized Neighborhoods			X			X	X	X	X	X	
Lamberts Point						X					Erosion protection from storm surge events.
Area 3		X	X	X	X		X	X	X		
West Ghent		X	X				X	X	X		
Fort Norfolk			X				X				
The Hague (Ghent)			X	X	X		X				
Freemason			X				X				
Downtown Norfolk			X				X				Increase level of protection existing Floodwall.
Area 4			X	X	X		X	X	X	X	
Tidewater Dr.			X		X		X	X	X	X	
Ohio Creek			X	X	X		X	X	X	X	
Broad Creek			X	X	X		X	X	X	X	
Berkley and Campostella			X		X		X	X	X	X	

The preliminary strategies presented in the previous section will need further development before an array of alternatives is developed an array of those alternatives can be evaluated. Additionally, the structural measures proposed during the later phases of study may have impacts to wetlands and habitat. Coordination with the regulatory agencies and NEPA compliance would be required if further study is pursued in the future.

There are existing reports that have developed FRM alternatives for the City of Norfolk that can serve to demonstrate interest in more than one flood risk management alternative due to economic benefits. The economic analysis for the flood risk management in the areas of The Hague and Pretty Lake identified several scenarios with a benefit-cost ratio above 1.00. Therefore, it is recommended to continue the study further. Through this FAA, several possible alternatives have been identified and evaluated that indicate further study is needed, therefore proceeding into a Comprehensive Flood Risk Management Study for the City of Norfolk is justified and urgently needed if the city is to be resilient to coastal storm risk in the future.

XI. State and Agency Coordination and Collaboration

XI.1. Visioning Meeting

A series of visioning meetings were held throughout the NACCS study area. On Tuesday, March 11, 2014 the USACE Norfolk District conducted an in-person visioning meeting with representatives from the City of Norfolk, other Federal agencies, the Commonwealth of Virginia, non-government organizations (NGOs), and CDM Smith to discuss the North Atlantic Coast Comprehensive Study (NACCS) with specific focus and dialogue concerning the City of Norfolk. Thirty-one people attended the two hour meeting.

In general, a high level of collaboration was evident among city and Federal agency staff as well as state representatives and NGOs attending the meeting. There was significant dialogue regarding how information being developed as part of the NACCS is being coordinated with stakeholders, as well as how information obtained during the visioning session would be incorporated into the NACCS. A main theme of the visioning session was to continue efforts and emphasis on future implementation of flood risk management measures.

Part of the visioning meeting was a facilitated discussion aimed at surfacing participant insights on the vision for coastal storm risk management, including vulnerable areas, potential solutions, and policy and institutional barriers to coastal storm risk management. Major themes that emerged in this discussion were:

- There two main barriers that limit comprehensive coastal planning are the lack of funding and a lack of communication and unified messaging.
- Policy changes and/or legislative solutions that could improve coastal resilience include addressing repetitive losses, engage local stakeholders in the planning process and provide accurate information to the public, amend local land use policies and implement constraints on development, clearly establish which agencies have authority to do comprehensive planning and define roles of each participant (stakeholder, local, and commonwealth level involvement), creative solutions for funding and an incremental sustained effort, and legislative changes on the commonwealth level which could include one common planning goal/level of design for Virginia.
- Management strategies/approaches that are currently working to reduce risk from coastal storms include NNBF, comprehensive flood plain management, elevating structures and changes to zoning, collaboration between agencies for small/short-term projects, flood insurance rates that are associated with level of risk, local FRM/CSRM projects, and communication of coastal risk to the public.
- In order to further reduce risk from coastal storms, a more comprehensive strategy is needed, communication of risk can be better, uniform planning guidance and data sharing among all levels of planners in Virginia and the Federal agencies they coordinate with on a regular basis, and funding for attendance at regional forum discussions.
- It is difficult to determine an “acceptable level of risk” CSRM planning. It is a relative and subjective based on the location and local conditions. No risk is ideal, but for general development, the 100-year event is considered acceptable, while optimally, critical infrastructure areas should consider a 500-1000 year level of flood risk management. The CSRM planning horizon should be at least 50 years and possible impacts and conditions should be considered over the long-term, not just for particular return periods.

XI.2. Coordination

As part of PL 113-2, Federal agencies received appropriations for various purposes within the agencies’ mission areas in response to Hurricane Sandy. As part of the NACCS authorizing language, the NACCS was conducted in coordination with other Federal agencies, and state, local, and tribal officials to ensure consistency with other plans to be developed, as appropriate. Extensive collaboration occurred as part of the NACCS, which is presented in the Agency Coordination and Collaboration Report.

Interagency points of contact and subject matter experts were asked in early 2013 to assist in preparing the scope for the NACCS and to be engaged in data gathering and development of analyses as part of the NACCS. This complemented the ongoing coordination with the public and stakeholders through NACCS website (http://www.nad.usace.army.mil/CompStudy.aspx) and webinars on several coastal resilience topics. Several letters to the relevant agencies in Virginia (Virginia Department of Emergency Management (VDEM) and Department of Environmental Quality [DEQ]) requested feedback with respect to the preliminary problem identification, the post-sandy most likely future conditions, vulnerability mapping, and problems, needs and opportunities for future planning initiatives. Various Virginia agencies, NGO's, and affected localities also conducted a review of a previous draft of this Virginia chapter in April of 2014.

A letter dated September 4, 2013 was sent to various state agencies and mincipalities requesting feedback with respect to the preliminary problem identification and vulnerability mapping. In response to this letter, the Norfolk District received information and comments from the Virginia Department of Emergency Management on October 3, 2013. Comments addressed storm events baseline, vulnerability mapping basis, desgination of critical and other infrastructure, social and environmental modeling/mapping, and green and nature-based infrastructure. Feedback was also received from the Accomack-Northampton Planning District Commission on October 8, 2013 regarding the vulnerability/inundation mapping and the selection of vulnerable areas. The documentation, discussion, and resolution of these comments are contained in the NACCS comment response tracker and will be addressed during future revisions of the report.

In April 2014, each state in the study area was offered the opportunity to include their own identification of problem areas, needs, opportunities and/or desired next steps for coastal resilience by submitting a letter to be included in the NACCS Framework Report. A request for this feedback, including a template letter, was provided to VDEM. Their letter of response, which is included as Attachment B to this Appendix, was received on May 5, 2014. In this letter, VDEM expressed their continued interest in and support for various Federal, state, and local agency initiatives to communicate flood risk from coastal storms. In particular, VDEM noted that there are extensive and vital areas subject to coastal storm surge in Virginia. This is especially critical in the Hampton Roads region, a highly developed region with critical development and a large population vulnerable to SLC and increasingly frequent and intense coastal storms.

XI.3. Related Activities, Projects and Grants

Specific Federal, state, and non-profit organization efforts that have been prepared in response to PL 113-2 are discussed below specifically for the Commonwealth of Virginia. Additional information regarding Federal, state, and non-profit organization projects and plans applicable to all of the states in the NACCS Study Area are discussed in Appendix D: State and District of Columbia Analysis, while additional information regarding the alignment of interagency plans and strategies is discussed in the Agency Collaboration and Coordination Report.

Federal Efforts

The Norfolk and Baltimore Districts are authorized to conduct a Chesapeake Bay Comprehensive Study, and received appropriations from Congress in fiscal year 2014. The investigation is being conducted under the authority provided by the United States Senate Committee on Environment and Public Works, Committee Resolution adopted 26 September 2002. A 905(b) (reconnaissance report) was prepared in direct response to specific language contained in the Committee Resolution that directed Corps of Engineers (USACE) to develop a coordinated, comprehensive master plan within USACE mission areas for restoring, preserving and protecting the Chesapeake Bay ecosystem.

The purpose of the reconnaissance phase was to: (a) to determine whether there was a Federal interest in implementing a project or projects within USACE mission areas for restoring, preserving and protecting the Chesapeake Bay ecosystem; (b) scope one or more project management plans (PMP) focused on restoring, preserving and protecting the Chesapeake Bay ecosystem; and (c) negotiate a feasibility cost-sharing agreement(s) (FCSA) between USACE and non-Federal sponsor(s) (NFS) to cost-share the feasibility phase. The draft 905(b) report ultimately recommended that the Chesapeake Bay Comprehensive Plan precede into multiple feasibility studies with multiple partners throughout the entire study area.

The U.S. Army Corps of Engineers, National Planning Center of Expertise for Coastal Storm Risk Management has prepared a technical memorandum on Impacts to Hurricane Storm Surge Inundation Resulting from Sea Level Change in the Norfolk SLOSH Basin, Responses to Climate Change Pilot Study in June 2014. The investigation will provide planners and decision makers with an initial assessment of two methods to consider when analyzing the possible impact of SLC on storm surge inundation risk. The first approach is referred to as the “bathtub” method, which is the process of adding SLC amounts to known current conditions hurricane storm surge heights to arrive at future conditions surge heights. The second approach is referred to as the “model” method: the process of modeling surge from hurricane events based on increased starting water levels resulting from predicted SLC. The bathtub method is a much simpler, quicker, and less expensive method. This investigation provides the initial data that will be needed to support future investigations to determine in what conditions/scenarios the bathtub method may be acceptable, and what conditions/scenarios the model method would be required.

The Mid-Atlantic Coastal Resilience Institute, which is a partnership between the University of Delaware, NASA, U.S. Fish and Wildlife Service, U.S. Geologic Survey, Chincoteague Bay Field Station of the Marine Science Consortium (which includes 13 Pennsylvania Colleges, College of William and Mary, Virginia Institute of Marine Science, University of Virginia, Virginia Coast Reserve Long-Term Ecological Research Program, University of Maryland (College Park), The Nature Conservancy, will use a regional approach to prepare for sea level rise and its impacts.

The Department of the Interior received $360 million in appropriations for mitigation actions to restore and rebuild national parks, national wildlife refuges, and other Federal public assets through resilient coastal habitat and infrastructure. In August 2013, the Department of the Interior (DOI) announced that USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grants Program which will support projects that reduce communities’ vulnerability to the growing risks from coastal storms, sea level change, flooding, erosion and associated threats through strengthening natural ecosystems that also benefit fish and wildlife. The Hurricane Sandy Coastal Resiliency Competitive Grants Program will provide approximately $100 million in grants for 46 proposals to those states that were affected by Hurricane Sandy. States affected is defined as those states with disaster declarations as a result of the storm event. The grants range from $100,000 to over $5 million and requests for proposal were due by January 31, 2014. More information on the program can be found at www.nfwf.org/HurricaneSandy, and the full list of projects can be found at http://www.nfwf.org/hurricanesandy/Documents/doi-projects.pdf.

Table 15 presents the list of specific Federal projects and plans proposed for the Commonwealth of Virginia that have been identified to date.

Table 15. Post-Sandy Funded Federal Projects and Plans in Virginia

Agency	State	Proposal	Cost
USFWS/DOI	VA	Aquatic Connectivity and Flood Resilience in VA: Replacing the Quantico Creek Culvert in Dumfries	$330,750
USFWS/DOI	VA	Increasing Water Management Capability at Great Dismal Swam NWR to Enhance its Resiliency for Wildlife and People	$3,130,000
USFWS/DOI	VA	Living Shoreline-Oyster Reef Restoration and Construction at Chincoteague NWR, Virginia	$553,425
Rockefeller Foundation	VA	The Rockefeller Foundation launched the 100 Resilient Cities Centennial Challenge to enable 100 cities to better address the increasing shocks and stresses of the 21st century. A grant has been provided to the City of Norfolk, VA, to ensure it remains resilient as a result of rising sea levels.	
NFWF (with TNC)	VA	Green Infrastructure in Accomack and Northampton Counties—Implement green infrastructure projects and enhance decision makers' coastal resilience knowledge in Accomack and Northampton Counties, Virginia. Project will provide resources, knowledge, and a stakeholder process that can aid decision makers' policies and actions.	$1,755,131
NFWF (with City of Norfolk)	VA	Developing a Green Infrastructure Plan and Network for the Lafayette River Watershed—Implement eight shoreline restoration projects and develop a green infrastructure plan and framework for the Lafayette River watershed in Norfolk, Virginia. Project will strengthen the watershed's resilience, engage 40 veterans in a green infrastructure training course, and involve 160 high school students in hands-on projects.	$4,897,343

Table 15. Post-Sandy Funded Federal Projects and Plans in Virginia

Agency	State	Proposal	Cost
NFWF (with Back Bay Restoration Foundation	VA	Developing Coastal Resiliency Regional Models—Develop coastal resilience regional models that enhance over 5,700 acres of wetlands and forests in the Southern Watersheds Area of Virginia. Project will strengthen coastal resilience and serve as an adaptation resource for community leaders and decision makers.	$8,465,843
NFWF (with George Mason University)	VA	Improving and Quantifying Wetlands' Potential to Reduce Storm Surge Impacts—Improve and quantify wetlands' potential to reduce storm surge impacts along the Chesapeake Bay shoreline within four Virginia nature preserves. Project will provide decision makers with information that can influence future management policies.	$551,969
NFWF (with Northeastern Regional Association of Coastal and Ocean Observing Systems—NERACOOS)	VA	Improving Northeast Coast Storm-Related Data Interpretation and Accessibility—Develop a data integration platform for existing storm-related resources that will especially benefit states affected by Hurricane Sandy. Project will improve access and intuitive data interpretation for all users including decision makers.	$653,303
NFWF (with Audubon Society)	VA	Assessing Northeast's Coastal Impoundment Vulnerability and Resilience—Evaluate the Northeast's coastal impoundment vulnerability and resilience with national parks, refuges, and state lands of Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Rhode Island, and Virginia. Project will reduce risk to nearby communities and identify restoration efforts that will strengthen impoundment resilience.	$640,000

Figure 36 presents proposed projects (including DOI grant projects that were not selected to receive grant funding because those that were not selected to receive grant funding represent an opportunity to potentially receive funding in the future) and other ongoing Federal actions using PL 113-2 funding.

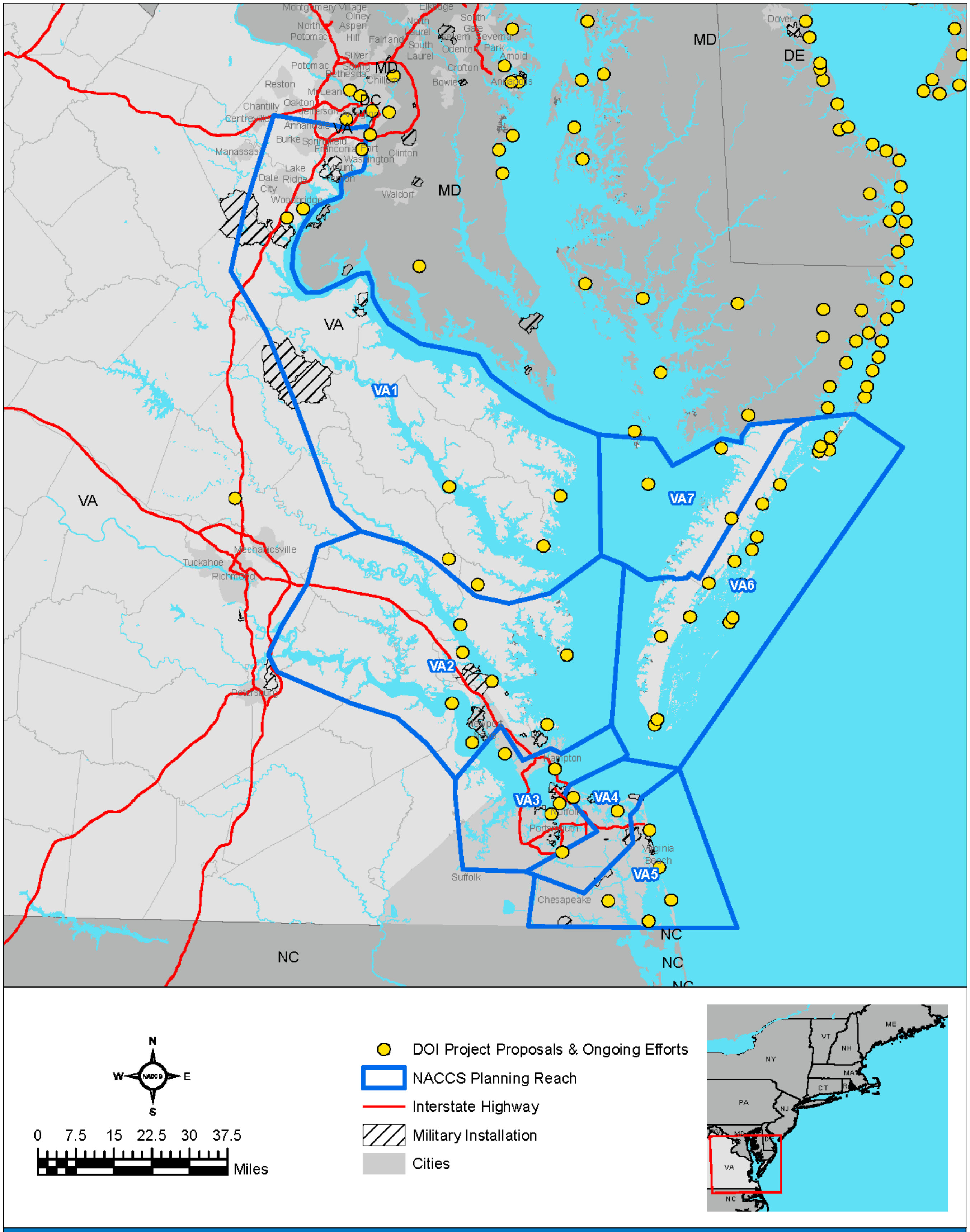


Figure 36. Locations of Proposed Funded Federal Projects in the Commonwealth of Virginia

Other grant opportunities included in the Hurricane Sandy Coastal Resiliency Competitive Grants Program include other topographic surveys, storm tide monitoring, and other resources to assess habitat and opportunities to increase resilience along the North Atlantic Coast.

NOAA is working to complete various data collections activities as part of the PL 113-2 funding allocations within the National Ocean Service, National Marine Fisheries Service, and the National Weather Service, including mapping, modeling resilience, and technical assistance (NOAA, 2013). Mapping activities include aerial photogrammetry surveys, hydrographic surveys, integrated ocean and coastal mapping LIDAR (in coordination with USGS and USACE), and fisheries survey. The National Weather Service also received funds to improve numerical hurricane forecast systems. Additionally, NOAA's Coastal Impact Assistance Program can provide resources and information to support recovery and planning efforts at regional, state, and community levels. More information on the ongoing work can be found at http://oceanservice.noaa.gov/hazards/sandy/

FEMA distributes public assistance funding to states and counties within various categories, including debris removal, protective measures, public buildings, public utilities, recreational, roads and bridges, state management, and water control facilities. A detailed distribution of funding within each category can be found at: http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx.

State, Local, and NGO Efforts

The Commonwealth of Virginia and its coastal localities have implemented laws and programs to help protect people, infrastructure, and ecosystem resources from flooding and storm damage. The Commonwealth also has also produced a Hazard Mitigation Plan that details the risk to population and infrastructure from flooding, coastal storm damage, sea-level rise and other factors. The localities have also produced similar plans, which are regularly updated. More specific measures taken by the localities are included in the infrastructure vulnerability discussion of this chapter.

The Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project established a Draft Charter on July 10, 2014 with the mission "to develop a regional 'whole of government' and 'whole of community' approach to sea level rise preparedness and resilience planning in Hampton Roads that also can be used as a template for other regions." Once the Pilot Project has been completed, Hampton Roads will have an intergovernmental planning organization in place that can effectively coordinate the sea level rise preparedness and resilience planning of Federal, state, and local government agencies and the private sector.

The Rockefeller Foundation launched the 100 Resilient Cities Centennial Challenge to enable 100 cities to better address the increasing shocks and stresses of the 21st century. Out of nearly 400 cities across six continents that have applied, 100 of the world's cities will be selected to receive technical support and resources for developing and implementing plans for urban resilience over the next three years. The City of Norfolk, which is the NACCS Focus Area for the Commonwealth of Virginia, applied for consideration to address their challenges of recurrent coastal flooding and sea level change. The first class of cities was announced on December 3, 2013, selected by seven judges who offer unique expertise on methods and strategies that make a city better prepared to face natural and manmade disaster and Norfolk was one of them. Each of the winning 100 cities will work with The Rockefeller Foundation's partners to develop and implement a resilience plan and become an integrated member of the 100 Resilient Cities Network.

Structures of Coastal Resilience (SCR) is a Rockefeller Foundation-supported project dedicated to studying and proposing resilient designs for urban coastal environments in the North Atlantic region. The University of Pennsylvania (PennDesign) received a grant to study strategies and modes of visualizing the coast in the low-lying Tidewater region where the coast is comprised of a multiplicity of creeks, making conventional barriers and flood risk management systems challenging to build and maintain in the long-term, especially in the face of sea rise. PennDesign Team's resilience strategy is based on the design potential of a unique feature of the coast of Tidewater Virginia that they characterize as 'Fingers of High Ground' (FHG). FHG represent a new design feature that would fit within the USACE category of 'nature-based features' in that they "mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction" (US Army Corps of Engineers, Coastal Risk Reduction and Resilience: Using the Full Array of Measures, Sept. 2013).

XI.4. Sources of Information

A review of Federal, state, municipal, and academic literature was conducted and various reports covering topics related to coastal resilience and risk reduction in Virginia were considered in the development of this state narrative and are listed in Table 16.

Table 16. Federal and Commonwealth of Virginia Sources of Information

Resource	Source/Reference	Subject	Key Findings Synopsis
Hampton Roads Data Book	Hampton Roads Planning District Commission (http://www.hrpdcva.gov/Documents/Economics/Databooks/2012/2012%20Databook.pdf)	Socioeconomics	Presents information about population, economy and commerce, recreation and tourism, real estate, ports and transportation, and quality of life for the cities in the Hampton Roads area of Virginia.
Green Infrastructure Plan for Hampton Roads Region	Hampton Roads Planning District Commission (http://www.hrpdcva.gov/departments/planning/green-infrastructure-plan-for-hampton-roads-region/)	Land Use Planning	The goal is to identify and prioritize a network of valuable conservation lands in order to achieve multiple benefits, such as habitat protection, drinking water supply protection, storm water management, and recreational opportunities. A new component to the plan is the Vulnerability to Development model. This model looks at potential future growth data for the Hampton Roads region to try and identify where this growth will occur. The next step was to identify which areas of the green infrastructure network are most at risk for development. The goal of this analysis is the ability to include development pressure as an element in prioritizing lands for protection through conservation easements or purchase when funding is available through grant programs or other sources.
Virginia Coastal Zone Management Assessment and Strategies	http://coastalmanagement.noaa.gov/mystate/docs/va3092011.pdf	Coastal Planning	This report outlines the high priority resource and issue areas on which the Virginia CZM Program will focus its attention, efforts and match-free funding provided under Section 309 of the CZMA.
FEMA Region III Coastal Analysis and Mapping Study	http://www.r3coastal.com/	Coastal Floodplain Mapping	The FEMA Region III office has initiated a coastal analysis and mapping study to update the coastal storm surge elevations within the Commonwealth of Virginia, Maryland, Delaware, and Pennsylvania including the Atlantic Ocean, Chesapeake Bay and its tributaries, and the Delaware Bay.
Virginia Coastal Geospatial and Educational Mapping System (GEMS)	http://www.coastalgems.org/	Map Data	Coastal GEMS provides extensive information on coastal resources in Virginia in the form of detailed descriptions and interactive spatial (mappable) data including water, land, shoreline, wildlife, and recreational features, as well as conservation planning methods and examples.
Middle Peninsula Climate Change Adaptation	http://www.mppdc.com/articles/reports/MP_Climate_Change_Adaptation_I.pdf	Climate Change/SLC	An assessment of potential anthropogenic and ecological impacts of climate change on the Middle Peninsula.

Resource	Source/Reference	Subject	Key Findings Synopsis
Assessing the Economic and Ecological Impacts of Sea Level Rise for Select Vulnerable Locations Within the Middle Peninsula	http://www.mppdc.com/articles/reports/FINAL_MPPDC_Sea%20Level%20Rise%20Assessment.pdf	SLC	With well over 1,000 linear miles of shoreline, the middle peninsula is under direct threat from accelerated climate change. Specifically, sea level change will impact coastal communities and infrastructure, as well as the region's natural resources.
Climate Change In Hampton Roads--Phase III: Sea Level Rise In Hampton Roads, Virginia	http://wetlandswatch.org/Portals/3/WW%20documents/sea-level-rise/report%20without%20appendices.pdf	SLC	The first section discusses historic and projected sea level change in Hampton Roads. The second section describes the various datasets used in this analysis. The third section describes the methodology used for the analysis. The fourth section provides a brief summary of the results. The fifth section summarizes the project, provides some recommendations, and offers some next steps. The report also includes documentation of the project's public engagement and coordination efforts and a map book as appendices.
Recurrent Flooding Study for Tidewater Virginia	http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf	SLC, FRM	This Recurrent Flooding Study addresses all localities in Virginia's coastal zone. It documents flooding risks based on available records of past road and infrastructure inundation as well as potential flooding risks based on the best available topographic information. It assesses future risk based on projections for sea level change from the National Climate Assessment program modified to incorporate factors specific to Virginia's coastal zone. The study also inventories adaptation options from regional, national, and international sources. Options include planning, management, and engineering strategies that merit particular consideration for application in Virginia.
City of Poquoson, VA Multi-Hazard Mitigation Plan	http://www.ci.poquoson.va.us/sites/default/files/City%20of%20Poquoson%20FINAL%20to%20FEMA%20RIII%20091409.pdf	SLC, FRM, CSDR	Detailed risk assessment and plan to mitigate hazards in terms of prevention, property protection, structural projects, natural resource protection, emergency services, and public information
Chesapeake Bay Shoreline Inventory	VIMS Center for Coastal Resources Management (http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/index.html)	Coastal Planning	Shoreline inventories divide the shore zone into three regions: 1) the immediate **riparian zone**, evaluated for land use; 2) the **bank**, evaluated for height, stability, cover and natural protection; and 3) the **shoreline**, describing the presence of shoreline structures for shore protection and recreational purposes. Available by city/county in VA and MD.

Resource	Source/Reference	Subject	Key Findings Synopsis
Sea Level Rise Planning Maps	VIMS Center for Coastal Resources Management (http://ccrm.vims.edu/climate_change/slr_maps/index.html)	Coastal Planning, SLC	This project created maps depicting the likelihood of shore protection along the Virginia coast as part of a nationwide study reported in "State and local governments plan for development of most land vulnerable to rising sea level along the U.S. Atlantic Coast.", which appeared in *Environmental Research Letters (2009)*. Also includes maps from the companion studies of Maryland and North Carolina.
Interagency Shoreline Management Consensus Document	http://ccrm.vims.edu/publications/pubs/shoreline_project_elements_3.pdf	Coastal Resources Management	This project to develop a consensus position from a VIMS perspective, with funding from the Virginia Coastal Program, may serve as the initiation of an effort to develop consensus guidance on shoreline management that integrates the issues and concerns extant in the various independent management programs in Virginia.
Blue Infrastructure Online Mapping Tool	http://ccrm.vims.edu/gis_data_maps/data/blueinfrastructure/bi_intro.html	Coastal Resources Management	The Blue Infrastructure online mapping tool integrates important aquatic resources that have been compiled for the coastal zone of Virginia using GIS technology.
Virginia's Coastal Program: Strategic Mapping of Management Goals	http://ccrm.vims.edu/publications/pubs/MappingGoals.pdf	Coastal Resources Management	Virginia's Coastal Resources Management Program is a networked program bringing together the activities of many state agencies and institutions to achieve the overarching mission of coastal zone management. The Program's objectives were originally set out in a series of 25 goals in the 1986 Executive Order (Appendix B) that established the Program for theCommonwealth under the federal Coastal Zone Management Act. Beginning in May of 1999, representatives of the Virginia state agencies involved with the networked Coastal Program attended a series of meetings to develop logic maps of these twenty-five goals. This document represents the final results of these efforts. The goals which were mapped are the results of early efforts to reformulate the goals to better fit today's social, economic and environmental objectives, resulting in a total of 24 mapped Program Goals.
Virginia Coastal Resources Management Program Assessment	http://ccrm.vims.edu/vcrmp/Start25.html	Coastal Resources Management	This project involved development of the Virginia State of the Coast Report and an evaluation of the Virginia CRM program performance. As part of the project, the Virginia Coastal Policy Team was led through a logic mapping exercise to develop performance measures and resource need assessments for the program. Logic maps for Virginia Coastal Program Goals
Shoreline Erosion in Tidewater Virginia	http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/virginia/scan_reports/Tidewater%20Shoreline%20Erosion.pdf	Coastal Resources Management	Shoreline erosion study for the Tidewater area of Virginia

Resource	Source/Reference	Subject	Key Findings Synopsis
Comprehensive Coastal Resource Management Plans for Tidewater Localities	http://ccrm.vims.edu/ccrmp/	Coastal Resources Management	This atlas is a portal to guidance, data, and resources for local governments to assist with implementation of new policy mandated by the General Assembly of Virginia for management of tidal shorelines in Virginia.
Changing Tides: A Sea Level Rise Planning Analysis for Virginia Beach, VA	http://www.virginia.edu/ien/docs/BEATLEY_CLASSFINALREPORT.pdf	Coastal Planning, SLC	The City of Virginia Beach begin to conceptualize and respond to the challenges it will need to face over the course of the next 90 years through a combination of mitigation, adaptation, and accommodation strategies, carefully executed through an iterative, comprehensive planning process, the City of Virginia Beach will be able to deftly confront the impacts that climate change will have on its citizens. Moreover, by tackling these issues now, before the impacts are imminent, the City can take a leadership role in climate change planning.

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ATTACHMENT A

Focus Area Analyses Report

ATTACHMENT A

City of Norfolk Focus Area Analysis

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1. Study Authority

This focus area analysis is being conducted as a part of the North Atlantic Coastal Comprehensive Study (NACCS) under the authority of Public Law 113-2, the Disaster Relief Appropriation Act of 2013 (Public Law [PL] 113-2), Title X, Chapter 4 approved 29 January 2013. Specific language within PL 113-2 states, "…*as a part of the study, the Secretary shall identify those activities warranting additional analysis by the Corps.*" This report identifies activities warranting additional analysis that could be pursued for the city of Norfolk. Public Law 84-71 is a plausible method for further investigation.

In addition, there is an existing study authority for a comprehensive Flood Risk Management (FRM) study for the city of Norfolk that was passed by the United States Senate Committee on Environment and Public Works. The authority states:

> "*Resolved by the Committee on Environment and Public Works of the United States Senate, That the Secretary of the Army is requested to review the report of the Chief of Engineers on beach erosion and hurricane protection for Norfolk, VA, dated April 17, 1984, and other pertinent reports, to include existing flood risk management studies and engineering reports to determine whether any modifications of the recommendations contained therein are advisable in the interest of flood damage reduction in the vicinity of Norfolk, Virginia.*"

2. Study Purpose

The purpose of this focus area analysis is to capture and present information regarding the possible cost shared, future phases of study to provide structural and/or non-structural FRM for the city of Norfolk.

This focus area report will:

- Identify areas of interest in the city of Norfolk for further flood risk management analysis.
- Briefly review prior studies, reports, and existing projects.
- Generally identify initial problems, needs, and opportunities for structural or non-structural FRM improvements and strategies for the city of Norfolk.

3. Location of Study/Congressional District

The study area is defined as the city of Norfolk jurisdictional boundaries. The city of Norfolk is located in the Chesapeake Bay watershed approximately 200 miles southeast of Washington DC and approximately 90 miles southeast of Richmond, Virginia. The City is bordered mostly by water with the Chesapeake Bay to the north, Hampton Roads Harbor to the west and the Elizabeth River to the south. The cities of Chesapeake and Virginia Beach bound the City to the south and east, respectively. Refer to Appendix A for a location map of the city of Norfolk.

The assessment area lies within the jurisdiction of the following Congressional Delegations: U.S. Senators Mark Warner and Timothy Kaine (VA), U.S. Representative Scott Rigell (VA-2), and U.S. Representative Robert Scott (VA-3).

4. Prior Studies, Reports, and Existing Projects

There are various studies and reports available for the study area, as well as existing projects. These studies, reports, and projects are discussed in detail in the following sections.

4.1 Prior Studies

1) Virginia Institute of Marine Science (VIMS). *Recurrent Flooding Study for Tidewater Virginia*. January 2013.

   The Recurrent Flooding Study reviews and develops a comprehensive list of ideas and example strategies used in similar settings, to the Tidewater Virginia area, around the United States and the world. The study effort convened a stakeholder advisory panel to discuss and assess the feasibility of applying these strategies and to recommend which options should be investigated further to adapt to relative sea level change.

2) Timmons Group. *City-Wide Drainage Master Plan Final Submittal*. November 2012.

   This effort identified areas throughout the city of Norfolk which require stormwater infrastructure improvements based on readily available compliance information and the capacity and condition of existing infrastructure. The report develops project areas to improve the stormwater system and to reduce precipitation flooding in the City.

3) Moffatt and Nichol. *Lafayette River Coastal Flooding Evaluation – Draft Report*. June 2012.

   This report reviews existing conditions in relation to FRM for the Lafayette River Watershed. It contains descriptions of an available hydrologic and hydraulic model that has been developed for the watershed.

4) Fugro Atlantic. *Preliminary City-Wide Coastal Flooding Mitigation Concept Evaluation and Master Plan Development*. May 2012.

   This report provides an overview of flooding issues in the city of Norfolk. It inventories and predicts damages for parcels and buildings impacted by the current 1% annual chance exceedance (ACE) floodplain from the effective Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) for the city of Norfolk and for the 1% ACE floodplain base flood elevation (BFE) plus one foot in height. (A 1% ACE event, or sometimes referred to as the 100-yr event, is a flood which has a 1% chance of occurring in any given year.) This document reports data recorded from the main tide gauge for the city of Norfolk, the Sewells Point Tide Gauge; and tide gauge stations that were launched temporarily to record data. The report includes an analysis of flooded roadways from the 1% ACE event and the 1% ACE event plus one foot of flooding, and discusses the impact on traffic for these elevations. The report breaks down the City into 11 areas and provides proposed alternatives for each area that would reduce flood risk. The report summary includes a basic analysis of the future considerations of each recommended alternative based on damage estimates and construction cost estimates.

5) Hampton Roads Planning District Commission (HRPDC). *Southside Hampton Roads Regional Hazard Mitigation Plan*. 2011.

This regional hazard mitigation plan covers the city of Norfolk. It provides for an evaluation of all hazards, including flooding from precipitation and coastal events. The plan provides suggestions of mitigation measures that each community would like to implement.

6) Fugro Atlantic. *Flood Mitigation Alternatives Evaluation, Pretty Lake Watershed*. April 2011.

This report provides background information on flooding in the Pretty Lake watershed, modeling of the floodplain and an analysis which predicts expected property damages from flooding. The report also reviews a number of alternatives to reduce flood risk for the Pretty Lake watershed and preliminary cost and benefit information for these alternatives.

7) Fugro Atlantic. *Flood Mitigation Alternatives Evaluation, The Hague Watershed*. April 2011.

This report provides background information on flooding in The Hague watershed, modeling of the floodplain and an analysis which predicts expected property damages from flooding. The report also reviews a number of alternatives to reduce flood risk for The Hague watershed and preliminary cost and benefit information for these alternatives.

8) URS Corporation. *Lafayette River Watershed Master Plan*. November 2010.

The focus of this report is on best management practices to improve environmental quality in the Lafayette River Watershed. The report reviews existing conditions that contribute to water quality issues in the watershed and proposes best management practices, which range from stormwater retrofits to riparian buffers.

9) Moffatt and Nichol. *Flood Mitigation Alternatives Evaluation, Mason Creek Watershed*. April 2010.

This report provides background information on flooding in the Mason Creek watershed, modeling of the floodplain and an analysis which predicts expected property damages from flooding. The report also reviews a number of alternatives to reduce flood risk in the Mason Creek watershed and preliminary cost and benefit information for these alternatives.

10) Federal Emergency Management Agency. *Flood Insurance Study, City of Norfolk*. 2009.

The latest effective flood insurance study available for the city of Norfolk became effective in 2009. The study inventories existing conditions related to flooding in the city of Norfolk and reviews the hydrologic and hydraulic models that developed the BFE used to map the 1% ACE floodplain.

11) Virginia Institute of Marine Science. *Shoreline Evolution Chesapeake Bay Shoreline, City of Norfolk, Virginia*. 2005.

VIMS researchers have mapped and evaluated the existing shoreline and historic shoreline positions through aerial imagery for the bay side of the city of Norfolk.

12) Virginia Institute of Marine Science. *City of Norfolk Shoreline Situation Report, Special Report in Applied Marine Science and Ocean Engineering No. 378, Comprehensive Coastal Inventory Program*. 2002.

This report provides a shoreline evaluation for the entire city of Norfolk, both for the coastline along the Chesapeake Bay and Elizabeth River, and for tributaries of Pretty Lake, Mason Creek, Lafayette River, The Hague, Ohio Creek, and Broad Creek. Maps with aerial imagery delineate existing land use, erosion rates, and shoreline features or structures.

13) Virginia Institute of Marine Science. *Chesapeake Bay Dune Systems: Evolution and Status*. November 2001.

    VIMS researchers have mapped and evaluated the existing dune system on the bay shoreline of the city of Norfolk, from Willoughby Spit to Little Creek Inlet.

4.2 Prior Reports

1) US Army Corps of Engineers, Norfolk District. *Limited Reevaluation Report, Willoughby Spit and Vicinity.* 2013.

   This Limited Reevaluation Report presents a proposed project, which involves the nourishment of a total of 7.3 miles of beach along the Chesapeake Bay shoreline in Norfolk for the purpose of storm damage reduction. The project will result in approximately 1,280,000 cubic yards of beach quality sand to be placed initially in a 3.5-foot (North American Vertical Datum 1988[NAVD88]) high, 60-foot-wide berm, which provides a 250-foot-wide beach at the public beach from the Willoughby Spit to the Little Creek Inlet. The project is designed for nourishment at 9-year intervals on average, with each nourishment cycle requiring approximately 445,100 cubic yards of sand. The sand will be obtained from an offshore borrow site located in the Thimble Shoal Auxiliary Channel.

4.3 Existing Projects

1) Norfolk Flood Protection System, Central Business District (Norfolk Flood Wall)

   According to the effective FEMA Flood Insurance Study (FIS) for the city of Norfolk: “The central business district, located in the southwest corner of the city, is protected by a 2,140 foot floodwall. The wall protects the area from tidal flooding up to an approximate stillwater elevation of 9 feet, NAVD 88 or about 1.5 feet above the 100-Year flood elevation for the area.” The floodwall was authorized as a hurricane-flood protection plan for the city of Norfolk, by the Flood Control Act of 1962 (PL 87-874). Construction of the flood wall by USACE was completed in three phases, with the final phase being completed on the 30th of January 1970. The floodwall system includes a stormwater pumping station and flood wall with street closure gates to allow for access to the river side.

5. Plan Formulation

Six planning steps in the Water Resource Council’s *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) are followed in an iterative process to focus the planning effort and eventually to select and recommend a plan for potential authorization. The six planning steps are: (1) specify problems and opportunities, (2) inventory and forecast conditions, (3) formulate alternative plans, (4) evaluate effects of alternative plans, (5) compare alternative plans, and (6) select recommended plan. The iterations of the planning steps typically differ in the emphasis that is placed on each of the steps.

This focus area analysis emphasizes the identification of problems and opportunities. That is not to say, however, that the other steps should be ignored, since the initial screening of preliminary plans that results from the other steps is very important to the scoping of follow-on studies. This plan formulation section presents the results of the initial iterations of the planning steps that were conducted during this analysis.

A day-long charrette was held on August 8, 2013 with staff from USACE Norfolk District, the city of Norfolk, and resource agencies to facilitate development of initial problems, opportunities, objectives, constraints, and potential measures. The agenda for the charrette and a list of agencies that participated in the meeting are in Appendix B. Ideas and information gathered from this meeting and from existing literature are incorporated into this report. This information will be refined in future iterations of the planning steps during future investigations.

5.1 The Recurrent Coastal Flooding Problem in Norfolk

A number of causes contribute to the flooding experienced by the city of Norfolk. The City is surrounded by water on three sides, the Chesapeake Bay to the north, and the Elizabeth River to the West and South. Additionally, Norfolk is located at a low elevation, which reduces the available drainage gradient. As a result, flooding due to coastal inundation and precipitation is a widespread and frequent occurrence. In order to adequately address localized conditions, the city of Norfolk is broken into four areas for this study. In addition to addressing flooding within the City as a whole, area specific planning problems and opportunities were identified and used to develop potential measures and alternative plans for these local areas. A map delineating these areas is included with the project maps in Appendix A. The following paragraphs review and characterize the current conditions of the entire project area (the city of Norfolk jurisdictional boundaries) and for each of the four areas.

5.1.1 Entire Project Area

The city of Norfolk is low-lying with nearly all portions of the City below elevation 15 feet NAVD88, therefore, drainage gradients are limited. Consequently, a significant percentage of the City is susceptible to flooding from high tides, nor'easters, hurricanes, and other storm events. These flooding events are caused by a combination of heavy precipitation and tidal events; these events range from nuisance flooding to severe. The frequency, extent, and duration of flooding have been documented to be increasing.

In 2010, VIMS and USACE Norfolk District completed an article, *Chesapeake Bay Land Subsidence and Sea Level Change, an Evaluation of Past and Present Trends and Future Outlook*. The report classified the Norfolk area as increasingly prone to severe flooding due to local land subsidence and relative sea level change. Additionally, a report entitled “*Rising Tides, Sinking Coast*” explains how areas of coastal Virginia are sinking about as fast as ocean levels are rising due to glacial rebound of the earth’s crust (Hershner 2012). During the last glacial period, the region was not glaciated while land to the north was. This acted to compress the earth’s crust to the north and raise it in the local study area region. Since these glaciers have melted, the earth’s crust is rebounding, with land once under ice rising and the land to the immediate south sinking. As a result, the local area is experiencing a much higher than normal relative rate of sea level rise, essentially twice the average rate for the United States coasts, and is one of the most vulnerable (along with regions of the Gulf Coast) to impacts due to relative sea level change. Therefore, land subsidence, as well as relative sea level change, will have a major impact on coastal Virginia communities, including the city of Norfolk.

In the last ten years, strong rain events and major storms such as Hurricane Isabel (2003), the 2009 November Nor’easter (Ida), Hurricane Irene (2011), and Hurricane Sandy (2012) have caused flooding in the study area. The closest tide gauge to the city of Norfolk is at Sewells Point in Norfolk, Virginia. The Sewells Point Tide Gauge records water level for the northeastern corner of the city of Norfolk and is used to determine general water levels for other areas in the City. Therefore, actual values could be higher or lower depending on specific layout, bathymetry of the area, and the storm track through the City. Table 5-1 lists the ten highest storm surge values recorded by the National Oceanic and Atmospheric Administration (NOAA) Sewells Point Tide Gauge.

Table 5-1. Storm Surge

Rank	Height (NAVD 88)*	Storm Name	Date	Time
1	6.37	1933 Hurricane	08/23/1933	05:00
2	6.24	Hurricane Isabel	09/18/2003	21:00
3	6.08	Nor'easter Ida	11/12/2009	23:18
4	5.91	Hurricane Irene	08/28/2011	00:18
5	5.67	Nor'easter Ida	11/13/2009	11:12
6	5.14	Hurricane Sandy	10/29/2012	13:12
7	5.08	Nor'easter Ida	11/12/2009	11:00
8	5.07	1936 Hurricane	09/18/1936	05:00
9	4.98	Nor'easter (Unnamed)	11/22/2006	15:06
10	4.93	1998 Nor'easter	02/05/1998	15:06

*Adjusted from Station Elevation 0 ft = 6.03 ft NAVD 88

Seven of the top ten highest storm surge values at the Sewells Point Tide Gauge have all been from storms in the last ten years, and the gauge has been in operation since 1927. This suggests that the frequencies of major storms that affect the City of Norfolk are increasing.

5.1.2 Area 1 - Mason Creek, Pretty Lake, and Willoughby Spit

Area 1 is located on the northern boundary of the City on the Chesapeake Bay. It covers the Willoughby Bay and Little Creek watersheds, as defined by the 12-digit hydrologic-unit codes (HUC). This area includes four sub-areas of interest: the bayside shoreline (including Willoughby Spit), Pretty Lake, Mason Creek, and Lake Whitehurst.

The bayside shoreline includes the areas from the city of Norfolk jurisdictional boundaries to the east, which is marked by the jetties at Little Creek Inlet, to the western tip of Willoughby Spit. It includes the areas known as Willoughby Spit, West Ocean View, Central Ocean View, and East Ocean View. The location and orientation of the study area at the southern boundary of the Chesapeake Bay and immediately within the mouth of the bay have made this area readily susceptible to damage associated with storm activity. Extreme high tides combined with wave attack, resulting primarily from hurricanes and nor'easters, cause severe losses of sand and structural damage to buildings and infrastructure located landward of the beach (USACE, Limited Reevaluation Report – Willoughby Spit and Vicinity). These areas are mixed urban and suburban residential, with commercial development along Ocean View Avenue and Shore Drive.

The Pretty Lake watershed is located in the northeastern corner of the city of Norfolk. Pretty Lake is a tributary of the Little Creek Inlet from the Chesapeake Bay. This area is subject to tidal and storm surge flooding from Pretty Lake, but could also receive flooding from the Chesapeake Bay during a large storm surge event. The Pretty Lake watershed contains mainly residential development with some commercial development along Shore Drive. Much of the development is older, and therefore built before the standards of the National Flood Insurance Program (NFIP) required elevating first floors above the 1% ACE BFE.

The Mason Creek watershed is located adjacent to Naval Station Norfolk, and consists of suburban development. Mason Creek is connected to the Chesapeake Bay through a narrow tidal canal, which is controlled by a manual tide gate on the Navy's property.

Lake Whitehurst is a reservoir located on the eastern side of the city of Norfolk. Although the reservoir does not flood, it serves as a drinking water source and needs protection to prevent significant amounts of stormwater or storm surge entering the freshwater lake. Due to its low elevation, a large storm event could contaminate this lake.

5.1.3 Area 2 - Lafayette Watershed

Area 2 is composed of the entire Lafayette Watershed. This watershed makes up the northern portion of the Elizabeth River HUC, which covers the southwestern parts of the city of Norfolk. The Lafayette River flows into the Elizabeth River, nears its mouth to the Chesapeake Bay. This area is characterized by residential and commercial development, a university (Old Dominion University), and industry.

The main roadways in Area 2 flow north-to-south and provide a large amount of transportation service between downtown Norfolk, where several major interstates converge, and the Norfolk Naval Station. Commercial development exists along these main corridors and urban residential development surrounds much of the university, while more suburban development covers much of the remaining areas in the Lafayette Watershed. The major industry in this area is Norfolk International Terminal, which requires a coastal location, but also utilizes the major transportation corridors in the area for truck shipments, along with the railroad.

The Lafayette Watershed is subject to storm surge flooding during hurricanes or nor'easters, but several neighborhoods in this watershed also experience nuisance flooding from high tides and large rainfall events. The Larchmont Neighborhood on the southern coast near the mouth of the Lafayette River is particularly susceptible to these events.

An additional site that needs special consideration in this study area is the Lamberts Point Landfill. The landfill is located on the western side of Norfolk along the main stem of the Elizabeth River, south of the Lafayette River's confluence with the Elizabeth River. The landfill was closed in the 1980s and is now home to the Lamberts Point Golf Club. It has been noted that the river side of the landfill erodes during storm surge events, spilling landfill contents into the Elizabeth River. Grass plantings and rocks have been placed along the shoreline in the early 1990s; however the area has continued to experience erosion and exposed landfill contents.

5.1.4 Area 3 - The Elizabeth River Mainstem

Area 3 covers the areas on the southern coast of the City of Norfolk, along the main stem of the Elizabeth River. This is the southern portion of the Elizabeth River HUC. This area includes the neighborhoods of West Ghent, Fort Norfolk, The Hague (Ghent), Freemason, and Downtown Norfolk. The residential development in these areas often dates back to the 1800s, but there are several neighborhoods that have been redeveloped since the early 1980s. During most storm events, flooding in this area is separated from Area 2 by a higher ridge line along 23rd street, but severe events and future expectations of sea level change and land subsidence could connect storm surge flooding in this area to the Lafayette watershed.

The West Ghent area is located to the west of Hampton Boulevard and consists of dense suburban development, a few commercial businesses, and an industrial shipyard (MHI Shipyard). The area is subject to flooding from heavy rainfall events and storm surge events.

The Fort Norfolk area is located to the South of Brambleton Avenue, along the Elizabeth River. The area consists of condominiums and office buildings, and is particularly subject to storm surge flooding due to low land elevations and water from the Elizabeth River to its south and The Hague to its north and east. The Fort Norfolk area is also where the Norfolk District Headquarters is located.

The Hague or Ghent area is bounded by Hampton Boulevard to the west, Brambleton Avenue and The Hague water body to the south, 23rd Street to the north, and Monticello Avenue to the east. The area consists of urban and dense suburban residential development, including the Ghent Historic District; commercial businesses along Colley Avenue, 21st Street, and Monticello Avenue; and Sentara Norfolk General Hospital Complex (which includes Eastern Virginia Medical School, EVMS). The area is susceptible to flooding from The Hague water body, a u-shape inlet from the Elizabeth River, during high tides and storm surge events. Due to limited drainage gradients, precipitation events also cause flooding of roadways. The design of the storm sewer system in this area is responsible for tidal flooding and high tide events often will cause the storm sewer inlets to overflow, allowing storm water to flood roadways. Much of the area is built on fill, including The Hague, which was once a tidal creek known as Smith Creek.

The Freemason area is located to the east of Brambleton Avenue and the South of Boush Street, along the Elizabeth River. The area consists primarily of dense residential development, but some commercial businesses are also located in this area. The development in this area and some parts of Downtown Norfolk includes structures located on the water-side of the Downtown Floodwall and several condominiums are built on fill into the Elizabeth River.

Downtown Norfolk is the area located to the east of The Hague/Ghent neighborhood and Freemason, and to the west of Interstate 264 and St. Paul's Boulevard. The area consists of urban development and commercial businesses. There is an existing floodwall and pump station along the Elizabeth River to protect the downtown area from storm surge.

5.1.5 Area 4 - Elizabeth River Eastern Branch

Area 4 covers the areas of the city of Norfolk east of Interstate 264 and St. Paul's Boulevard, and is bounded by the Norfolk jurisdictional boundaries. This area covers the only land area within the Norfolk jurisdictional boundaries situated to the south of the Elizabeth River, the Berkley and Campostella neighborhoods. The Berkley and Campostella area includes residential neighborhoods and industry, mainly several shipyards. Area 4 includes the Military Highway major corridor, which consists of a large amount of large commercial and industrial businesses. Area 4 also includes low-lying areas along Tidewater Drive, Ohio Creek and Broad Creek, tributaries of the Elizabeth River, which are subject to tidal and storm surge flooding.

The Tidewater Drive area includes residential and non-residential buildings and Harbor Park Baseball stadium along the Elizabeth River. The Broad Creek watershed, which also includes several smaller tributaries, is mainly residential with some commercial and industrial use along the main corridors.

Ohio Creek watershed is mainly residential, but includes Norfolk State University and a large city high school.

5.2 Problems and Opportunities

The problems and opportunities presented in this section are divided into area-specific categories. Problems and opportunities that are overarching and pertain to the entire project area are separated from those that are limited in scope to one of the four areas described in the introduction.

5.2.1 Entire Project Area

Problems:

- Storm surge from hurricanes and nor'easters causes a high amount of property damage in the city of Norfolk due to low-lying development.
- Precipitation flooding is compounded by storm surge, since storm sewers have low gradients. In many cases, tidal waters enter the storm sewer system and flood roadways during high tide or storm surge events.
- There is a high cost associated with emergency response during storm events.
- While large flooding events cause damage to property and infrastructure, smaller events that occur on a more frequent basis cause roadways to flood, causing a negative economic impact and limiting emergency response services.
- Evacuation of the coast during large storm events is often hindered due to limited available evacuation routes. Evacuation to shelters is also problematic as roadways leading to shelters may be flooded.
- Industries that must be located on the major waterways, such as ports and shipyards, are in the areas most susceptible to damage from tidal flooding or storm surge. If these businesses do not prepare for future storm events, their viability and the economy of Norfolk and the Nation may be jeopardized.
- Many areas of the city of Norfolk were developed in the late 1800s and early 1900s, when standard practices included filling natural streams and development in the floodplains along major waterways. Additionally, the older development is under designed with respect to structure elevation and the capacity of storm sewer systems.
- The natural floodplain areas within the city of Norfolk have been almost completely developed and very little undeveloped floodplain remains.
- The frequency and magnitude of large coastal storm events is predicted to increase due to climate change, which is expected to increase damages due to flooding in the city of Norfolk.
- The city of Norfolk is highly susceptible to changes in sea level and land subsidence, which is predicted to exacerbate the flooding experienced by the city of Norfolk.

Opportunities:

- Reduce flood risk in the city of Norfolk due to large precipitation or storm surge events.
- Restore natural floodplain functions.

- Increase public understanding of flood risk in the city of Norfolk and provide strategies for mitigating that risk.
- Improve stormwater system conveyance and capacity.
- Develop tools that will allow residents, including “at risk” communities, to mitigate the risk of flooding to their property.
- Restore aquatic ecosystem quality.
- Improve the major transportation routes to withstand inundation due to smaller, more frequent flooding events and during major storm surge events.
- Leverage existing public/private partnerships between the city of Norfolk and private entities to address flood risk in the study area.
- Recognize the needs and provide for the safety of the economically challenged and “at-risk” population living in the project area

5.2.2 Area 1 - Mason Creek, Pretty Lake, and Willoughby Spit

Problems:

- Limited storage capacity and an undersized outlet results in precipitation induced flooding of Mason Creek.
- The outlet gate at Mason Creek is not automated and is located on property owned and managed by the US Navy. As a result, the City does not have control over the operation of the gate.
- Although not included in the project area, flooding of the Naval Station will have significant implications for the city of Norfolk. As naval personnel evacuate the base, they will increase the number of people utilizing the roadways and evacuation routes. Additionally, the Mason Creek Gate is left unmanned when the base is evacuated.
- Longshore transport of sand along Willoughby Spit results in blocked outfalls on the Chesapeake Bay side of the spit and other sedimentation issues on the Willoughby Bay side.
- Flooding of Pretty Lake results in damage to structures and infrastructure.

Opportunities:

- Develop relationships and improve coordination between the city of Norfolk and other agencies interested and affected by flooding in the City, including the Navy (particularly at Pretty Creek and Mason Creek), Department of Defense, the Norfolk International Airport, and others.

5.2.3 Area 2 - Lafayette Watershed

Problems:

- The three primary thoroughfares located in Area 2 (Hampton Boulevard, Granby Street, and Tidewater Drive) are prone to flooding during small events, such as large high tides. It is predicted that the frequency of these events will increase due to sea level change and land subsidence, ultimately escalating the damage and losses due to flooding in this area. These roads are Federal highways and provide access to Naval Station Norfolk, which can affect mission readiness. Flooding impacts access to Old Dominion University (ODU), Sentara General Hospital, and Norfolk International Terminal (NIT). ODU cancels classes several times a year due to roadway flooding and storm surge events. Additionally, flooding blocks access to downtown Norfolk and the hospital via Hampton Boulevard.

- The Larchmont neighborhood floods on a regular basis during significant high tide events in concert with precipitation events, resulting in property damage and economic losses.
- The Lamberts Point Landfill experiences coastal erosion from storm surge events, which removes the landfill covering and allows landfill contents to spill into the Elizabeth River.
- The shoreline along certain residential properties of the Lafayette Watershed is eroding, causing impacts to the ecosystem and damaging private property.
- Transient populations that move to Norfolk for military service on bases in the area lack the knowledge of flood risk to their personal property and the actions they can take to insure or protect their property from flood events. This can result in higher economic losses from a flood event.
- Little park space and almost no waterfront with public access are present in the Lafayette Watershed, limits recreational opportunities for the public.
- The foreign students attending ODU have limited evacuation options and need additional time; approximately two days, to evacuate campus.

Opportunities:

- Reduce flood risk to localized neighborhoods, such as Larchmont, that are particularly susceptible to flooding during smaller and larger events.
- Create public waterfront access and increase recreational opportunities.
- Increase storage capacity for stormwater to mitigate smaller tidal and precipitation events thus reducing flooding to specific neighborhood areas.
- Reduce the potential for flooding damages to the rail line from NIT and economic losses that would result. Currently, the rail line is located at a higher grade than most of the surrounding area; however predicted relative sea level change and land subsidence may cause future flooding.
- Reduce the possibility of breaching the high ridge that separates rainfall and tidal flooding in the Lafayette Watershed (Area 2) from the West Ghent and The Hague areas (part of Area 3).

5.2.4 Area 3 - The Elizabeth River Mainstem

Problems:

- Flooding impacts the transportation corridor to Sentara General Hospital, Light Rail, and cultural resources (such as Chrysler Museum).
- It is unknown if the existing downtown floodwall provides adequate protection to the area if predicted sea level change and land subsidence occur.
- Very little, if any, natural floodplain remains within this area.

Opportunities:

- Protecting the nationally registered historic district, Ghent neighborhood, and cultural resources.

5.2.5 Area 4 - Elizabeth River Eastern Branch

Problems:

- The stormwater infrastructure in Area 4 can only effectively manage flood waters produced by a 2-year precipitation event (which has a 50% chance of occurring in any one year). As a result, tidal and precipitation flooding regularly impacts intensely developed residential, commercial, and industrial areas. Impacts resulting from flooding include damages to personal property, commercial losses, increased emergency response costs and loss of access to multiple commercial shopping areas.
- Transportation on Military Highway, a large commercial access, is limited due to flooding.
- The majority of Area 4 has been developed, so there are limited recreational opportunities.
- High levels of alum are present in sediments of Broad Creek in vicinity of the water treatment plant.
- Many sites within Area 4, including Broad Creek and Ohio Creek, have experienced repetitive losses due to flooding.

Opportunities:

- Create redevelopment opportunities and strategies in Area 4, which has been almost complete been developed, that would address flood risk.
- Provide opportunities for "at risk" populations who live in repetitive or high risk areas to reduce flood risk.

5.3 Objectives

- Reduce flood risk due to storm surge and large precipitation events, both short and long term, in the city of Norfolk.
- Educate the public about flood risk to the city of Norfolk and create strategies that the public can institute to protect their own property.
- Maintain or improve ecosystem goods and services provided (social, economic and ecological balance) in the study area.
- Maintain economic viability of the working coastline, including the ports, fishing, and industry, of the Norfolk waterfront.
- Provide additional recreational opportunities in the city of Norfolk.
- Improve emergency response and evacuations by improving transportation systems during small and large flood events that impact the city of Norfolk.
- Improve coordination between all stakeholders interested in reducing flood risk in the city of Norfolk and the surrounding communities.

- Reduce erosion occurring within the city of Norfolk, particularly Lamberts Point Landfill.
- Maintain or improve ecosystem conditions in the study area.
- Protect nationally registered historic and cultural resources located in Norfolk.
- Provide adaptive and sustainable solutions for future development of the city of Norfolk that account for future changes, such as relative sea level change and land subsidence.
- Create a flood recovery plan for the city of Norfolk that incorporates resiliency.

5.4 Planning Constraints

Planning constraints can be institutional (policy/programmatic, legislative, and funding-related) and physical (such as sensitive ecosystem areas, land use, etc.).

5.4.1 Universal

- Comply with all Federal laws and executive orders, such as the National Environmental Policy Act (NEPA), the Water Act, Threatened and Endangered Species Act and Executive Order 11988.
- Minimize and mitigate effects on cultural resources.
- Avoid additional degradation of water quality, which would put additional stress on the aquatic ecosystem and increase the amount of water quality improvements required to meet the pollutant loading limits set forth by the Chesapeake Bay Total Maximum Daily Load (TMDL)
- Avoid increasing the flooding risk to surrounding communities and facilities.

5.4.2 Project Specific

- Avoid solutions that cannot be maintained by the non-Federal sponsors, whether due to expense or complicated technologies.
- Minimize the relocation of industries that require waterfront property, such as Port Norfolk, and other inflexible resources, including cultural resources and the Norfolk International Airport.
- Avoid impacting or exacerbating existing hazardous, toxic and radioactive wastes (HTRW) that have been identified within the project area.

5.5 Future Without Project Condition

The future without project (FWOP) condition is the most likely condition expected to exist in the future in the absence of proposed projects. The FWOP condition is the baseline against which all project plans are evaluated. FWOP conditions, including sea-level change considerations, will be developed along with the no-action alternative during the future phases of study.

5.6 Measures to Address Identified Planning Objectives

This section identifies a broad range of potential solutions (measures) to address the study area objectives. Any of these potential measures will be weighed against a “No-action Plan” in future phases of study. There are structural and non-structural measures identified to reduce the risk of flooding in the city of Norfolk. The following information explains the options that could potentially address the problems and opportunities identified in this focus area analysis. Although extensive, this list is not comprehensive and does not include the only FRM measures that could be considered during future studies.

5.6.1 Structural Measures

1. Berms/Levees: Berms, levees, or dunes can be constructed along the shoreline, tying into high ground or surround an area entirely, to protect against storm surge and wave run-up, and erosion to the landward shoreline. These measures have a large footprint, since their stability is partially dependent on a maximum side slope from the top to the toe, and the levees are often composed of earthen materials. Levees or berms also need to be constructed to prevent or control underseepage of flood waters through the existing soils. They may need to include pumping stations to remove interior stormwater drainage. Also, roads sometimes need to be ramped to cross these features and reach the shore side.

2. Floodwalls and Bulkheads: Floodwalls or bulkheads can be constructed along the shoreline, tying into high ground or surround an area entirely, to protect against storm surge, wave run-up, and erosion to the landward shoreline. These measures have smaller footprints than berms and levees; but require concrete or steel pilings for stability to withstand force from flood waters, including waves. Floodwalls must also be designed to prevent or control underseepage in the existing soils. Floodwalls may need to include pumping stations to remove interior stormwater drainage, and often include floodgates to allow for access roads. Flood gates can also be added to flood wall system to allow for access roads to any waterside property.

3. Flood/Tide Gates: A flood or tide gate can be constructed across a tributary to provide for protection from coastal inundation upstream of the gate. Flood and tide gates are constructed with openings to allow for recreational or industrial uses of a tributary to continue, and also allow for some connectivity of the ecosystem. There are several types of flood gates; two types include an Obermeyer Gate and a Steel Gate. The Obermeyer gate lifts a steel gate flap to close the gate, whereas a Steel gate slides horizontally into closing position. Inflatable dams can also be used as a temporary gate, since they can be filled with air or water to inflate and act as a closed gate.

   If the watershed upstream of the flood or tide gate does not have enough natural floodplain storage to hold increases in water level due to precipitation runoff, then pumping stations will need to be added to remove interior drainage upstream of a flood or tide gate.

4. Road, Rail, or Light Rail Raises: Roads can be raised on berms or levees. The advantage of raising a road is two-fold. First, raising main evacuation routes so they will not be flooded during a coastal storm and/or heavy precipitation event enhances emergency preparedness in the study area. Secondly, existing easements can provide some of the property needed for the footprint for building a berm or levee. However, main routes in the city of Norfolk are heavily developed. In order to raise existing main routes, a large amount of property along the roadways will likely need to be acquired and this could have a major impact for the main business corridors. Additionally, the side roads leading to these main roads would need to be ramped for access.

   Another option is raising existing rail or light rail lines. The existing rail lines mainly run from east-west across the center of the City, and therefore would not provide protection if raised. Existing light rail from Colley and Brambleton Avenues to the Freemason area follows Brambleton Avenue, which could be considered for road raise. New routes proposed for the light rail system in the city of Norfolk could be built on berms or levees. In particular, there is a need for light rail to extend from the southwestern downtown area to the northwestern portion of Naval Station Norfolk. This alignment could protect the western shoreline of the City and would cross the Lafayette River.

Raising a road, rail, or light rail line may also require pumping stations to remove interior stormwater.

5. Shoreline Protection Features: Shoreline protection features can include hardening structures or living shorelines to reduce erosion. Hardening structures include revetments or sea walls. Living shorelines restore natural habitat and stabilize the shoreline with plantings and natural features. Living shorelines can be constructed in front of shoreline hardening structures for a dual approach towards reducing erosion.
6. Stormwater System Improvements: The existing stormwater system can be improved by increasing capacity, through additional piping and stream channelization, increasing pipe sizes and inlets and adding more storage areas, adding gates to outfall pipes to prevent storm surge from entering the storm sewer system, and pumping water from the storm system.

5.6.2 Non-structural Measures

1. Building Codes and Zoning: Building codes can promote construction techniques that reduce damages to future construction or to areas of redevelopment. Some examples include requiring new structures to be raised above flooding elevations and structures to be built on pier foundations in areas of wave action. Zoning can be used to prohibit using the floodplain for activities other than those compatible with periodic flooding.
2. Buyouts and Relocations of Homes: Homes that are subject to repetitive loss from flooding and are outside of an area proposed for protection by a structural flood risk management project are ideal candidates for buyouts or relocations. A buyout occurs when the homeowner is paid fair market value for the property, and moves to a new location. Relocations can occur when the homeowner has a parcel large enough that a home can be moved to higher ground on the existing parcel or a home can be relocated to a different parcel entirely. Relocations of homes are not probable in any parts of the city of Norfolk since the majority of land is low-lying and developed.
3. Emergency Plans/Hazard Mitigation Plans: Emergency planning allows a community to be prepared for storm events, such as flood inundation from hurricanes or nor'easters. Hazard mitigation plans are developed to document hazards to which a community is exposed and to determine mitigation measures a community would implement to reduce risk from these hazards. It is important for both of these plans to be kept up to date with local issues in order to prepare and recover after a flooding event.
4. Flood Warning Systems: Flood warning systems are important to notify citizens of a flooding event. Hurricanes and nor'easters typically have a timeframe of several days during which the community is aware of the possibility of impact. However, last minute changes in speed and direction of the storm can alter the level of impact dramatically, and evacuations need to be planned well in advance for these types of storms in flat coastal areas. It is important for the community to have the tools to reach out to their citizens before and during a large storm event.

   Large precipitation events from storms other than hurricanes or nor'easters may develop with little notice. Road signs that indicate flooded areas using real-time communications from citizens are one way to alert the community of these issues.

5. House Raising: The first floor living elevation of a home can be raised above flooding elevations to reduce damages. House raising is only appropriate for certain types of structures. Additionally, utilities and major appliances, such as water heaters and air compressors, should also be elevated above the flooding elevation.

6. Increase Watershed Storage Capacity: In order to reduce flooding from precipitation events, the natural storage capacity of the watershed can be restored or additional storage can be added. Restoration of natural storage includes restoring wetlands and returning floodplains to an undeveloped state in riverine areas. Increasing natural storage capacity in stormwater systems includes reducing impervious areas to allow infiltration of runoff from precipitation events. Additional storage can be added through detention ponds and on a more localized basis through rain barrels or cisterns.

   A major component of increasing natural infiltration in stormwater management includes the use of natural and nature-based features or green infrastructure. More specific green infrastructure practices, such as low impact development, can be used to reduce impervious areas and increasing storage of stormwater on a localized basis. Some examples of low impact development include bio-swales, rain gardens, green roofs, rain barrels or cisterns. Natural and nature-based features that involve plantings also allow for evapotranspiration of stormwater, and provide for a pleasing aesthetic component. Reducing impervious areas allows for infiltration of stormwater which reduces runoff quantity and improves runoff quality. Natural and natural-based measures can also allow for opportunities to add public recreational features and provide for ecosystem restoration, while providing for wave attenuation and stormwater storage.

7. Low Interest Loans to Citizens: A community can empower their citizens by offering low interest loans for citizens to implement measures to protect their own property from flooding, such as house raising or wet and dry floodproofing, and for measures that will impact overall stormwater runoff volumes in their neighborhood, such as natural and nature-based features. This option may be particularly valuable to low income citizens who cannot afford to undertake these projects.

8. Public Outreach and Education: A community can reduce flood risk by educating its citizens about the existing flooding hazards and what can be done to protect their property. Additionally, if a flood risk project is constructed, educating the community about residual project risk must occur.

9. Relocating Utilities and Critical Infrastructure: A community can protect its public infrastructure by relocating utilities underground and moving critical infrastructure out of floodplain areas. Examples of critical infrastructure include hospitals and emergency shelters.

10. Tax Incentives for Redevelopment: A community can promote redevelopment of impermeable urban parcels through tax incentives. Due to increasing regulations, redevelopment of areas currently requires stricter standards for runoff quantity and water quality than is required for the current use. Reducing runoff from previously developed sites could reduce flooding during precipitation events. Additionally, building codes can be updated for even stricter standards for areas prone to precipitation or coastal flooding. Redeveloped properties can be designed to accommodate flooding. For example, the use of first floors can be limited to parking areas.

    Additionally, for existing properties, the city of Norfolk can offer reductions in stormwater fees for residential and commercial properties that implement techniques to reduce runoff and improve water quality.

11. Wet and Dry Flood Proofing: Wet floodproofing involves using waterproof materials on a building up to the flooding elevation and locating all electrical and mechanical equipment associated with the building above the flooding elevation, to allow the building to be inundated during a flood event and then dried and reverted back to its intended use. Dry floodproofing involves sealing a building from the outside up to the flooding elevation to prevent floodwaters from entering the building.

    It is important to note that FEMA only allows the first floor of significantly improved or new buildings to be constructed below the base flood elevation of the 1% ACE storm for non-residential structures in non-coastal floodplain zones if the building is dry proofed. Private citizens can implement wet or dry floodproofing if they wish to protect their existing property, but newly developed and redeveloped properties are limited to FEMA building requirements for flood proofing.

5.6.3 Measures Applicable to Each Area

Non-structural measures may be applicable to the entire study area and to each alternative to be developed in subsequent phases of study. They may be implemented independently, but more likely will be combined with structural measures. The non-structural measures not listed in Table 5-2 should be implemented with every alternative for coastal storm risk management; examples include building and zone code updates and public outreach and education. A non-structural plan will be identified during further study. Some of the measures identified in Table 5-2 may be screened from further consideration for each area during subsequent phases of study.

Table 5-2. Measures for Each Area

Area	Structural Measures							Non-Structural Measures			Comments
	Beach Replenishment	Berm, Levee	Floodwall, Bulkhead	Flood or Tide Gate	Road Raise	Shoreline Protection Features	Stormwater Improvements	Buyouts/Relocation	House Raising	Restore Natural Storage	
Area 1	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**		
Bay Shoreline	X										
Pretty Lake			X	X	X		X	X	X		
Mason Creek			X	X			X	X	X		Improve existing tide gate.
Lake Whitehurst		X	X		X						Protect freshwater in lake from outside flooding sources.
Area 2			**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
Watershed Protection			X	X	X		X	X	X	X	
Localized Neighborhoods			X			X	X	X	X	X	
Lamberts Point						X					Erosion protection from storm surge events.
Area 3		**X**	**X**	**X**	**X**		**X**	**X**	**X**		
West Ghent		X	X				X	X	X		
Fort Norfolk			X				X				
The Hague (Ghent)			X	X	X		X				
Freemason			X				X				
Downtown Norfolk			X				X				Increase level of protection existing Floodwall.
Area 4			**X**	**X**	**X**		**X**	**X**	**X**	**X**	
Tidewater Dr.			X		X		X	X	X	X	
Ohio Creek			X	X	X		X	X	X	X	
Broad Creek			X	X	X		X	X	X	X	
Berkley and Campostella			X		X		X	X	X	X	

5.7 Preliminary Alternatives and Strategies

An alternative is a combination of management measures that address one or more planning objectives while not violating the constraints. This focus area analysis does not develop a comprehensive array of alternatives; however, this section does provide a description and discussion of the likely strategies that could be used to develop a full array of alternatives in subsequent phases of study.

Strategy 1 – No action plan.	
Main Component:	Do not implement a flood risk reduction project
Must Be Combined with:	N/A
Can Be Combined with:	N/A
Most Applicable to:	All areas

Strategy 1 is the no action plan. This plan assumes that no additional features would be implemented by the Federal government or local interests to achieve the planning objectives.

Strategy 2 – Provide for beach buffer.	
Main Component:	Beach Replenishment
Must Be Combined with:	N/A
Can Be Combined with:	Berm/Levee, Floodwall/Bulkhead, Shoreline Protection Features, Buyouts/Relocation, or House Raising
Most Applicable to:	Area 1, Bay Shoreline (Willoughby Spit)

Strategy 2 focuses on replenishing the bayside beach on the north shore of the city of Norfolk to provide for a wave buffer during coastal storm events, such as hurricanes or nor'easters. This strategy can be implemented as an alternative independently or be combined with one or more of the measures identified in the table above.

Strategy 3 – Barriers to prevent coastal inundation.	
Main Component:	Berm/Levee, Floodwall/Bulkhead, Road Raise
Must Be Combined with:	Buyouts/Relocation to acquire property for construction
Can Be Combined with:	Shoreline Protection Features, Buyouts/Relocation, or House Raising
Most Applicable to:	All Areas

Strategy 3 focuses on constructing structures to increase the shoreline elevations to prevent coastal inundation. This strategy will require acquisition of property, particularly for berm or levee construction which have larger footprints than floodwalls/bulkheads and road raises. These structural measures can be combined with one or more non-structural measures identified in the table above for different alternative variations. It should also be noted that construction of each of these structural measures will likely need to include a stormwater pump station for interior drainage.

The berm/levee measure will likely drop out of further consideration with more detailed cost estimates, due to property costs needed for construction, since the majority of the city of Norfolk is developed.

The height or level of protection of these structural features along the shoreline is limited to high grade areas that the structure can tie into, unless a structure with higher elevation is built along the entire shoreline encompassing the City. Due to this constraint, it is unlikely that this strategy will provide a solution for large areas, but may be able to protect individual neighborhoods near the shoreline.

Strategy 4 – Flood/Tide gate to limit storm surge rising in tributaries.	
Main Component:	Flood/Tide Gate
Must Be Combined with:	Berm/Levee, Floodwall/Bulkhead, or Road Raise to tie into higher ground
Can Be Combined with:	Buyouts/Relocation or House Raising
Most Applicable to:	Pretty Lake, Mason Creek, Lafayette River, Ohio Creek, Broad Creek

Strategy 4 consists of building a flood/tide gate across the mouth of the tributaries that flow into the city of Norfolk. A flood/tide gate can be constructed under an existing roadway alignment or in a new location. The closer to the mouth of the tributary, the greater area that will be protected by this strategy, however both the cost and environmental impacts will increase.

This strategy requires the flood/tide gate to be accompanied by a structural measure to increase the elevations of the shoreline of the river from which each tributary enters. This will provide protection from storm surge flowing over land and around the flood/tide gate structure during large storm events. For example, the Lafayette River, Ohio Creek, and Broad Creek are all tributaries of the Elizabeth River, therefore constructing a flood/tide gate across each of these tributaries will also require shoreline elevation increases along the Elizabeth River to prevent storm surge from flooding around the flood/tide gate structure.

This strategy can also be implemented with home buyouts/relocation and house raising to protect particularly low-lying areas, or areas closer to the mouth of the tributary then where the flood/tide gate is constructed.

The flood/tide gate structure may or may not require the construction of stormwater pumps, depending on the storage capacity of each tributary to absorb the stormwater volume during large precipitation and tidal events.

This strategy is expected to have significant environmental impacts, but upon preliminary economic analysis this strategy is also expected to have a high benefit-to-cost ratio since it can provide protection to large areas. Flood/tide gates are usually designed to remain open unless there is an approaching storm event. Even when open a flood/tide gate structure will still have a significant footprint within the channel and will impede the natural hydraulic cycle. There is particular concern over reduction in the natural tidal flushing of these tributaries which helps dilute pollutants that are deposited from the urban stormwater system. The rivers within the city of Norfolk are subject to specific TMDL requirements as a part of the Chesapeake Bay TMDL. The concentrations of total phosphorus (TP), total nitrogen (TN), and total suspended sediment (TSS) are limited and provide a constraint to water quality impacts in the City.