APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY:
RESILIENT ADAPTATION TO INCREASING RISK

STATE CHAPTER

D-8: State of Maryland

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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 encourage 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). The U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration's (NOAA) Infrastructure Systems Rebuilding Principles defines resilience 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 Storm Risk Framework Appendix discusses state specific conditions, risk analyses and areas, and CSRM strategies in order to provide a more tailored Framework for the State of Maryland. Attachments include the Baltimore Metropolitan Water Resources Focus Area Analyses (FAA) Report, as well as the State of Maryland response to the USACE State Problem, Needs, Opportunities correspondence.

II. Planning Reaches

Planning reaches for Maryland have been developed to offer smaller units than state boundaries from which CSRM and coastal resilient community decisions can be made. These planning reaches are based on natural and manmade coastal features including shoreline type, USACE CSRM projects, and the 1 percent floodplain (Figure 1).

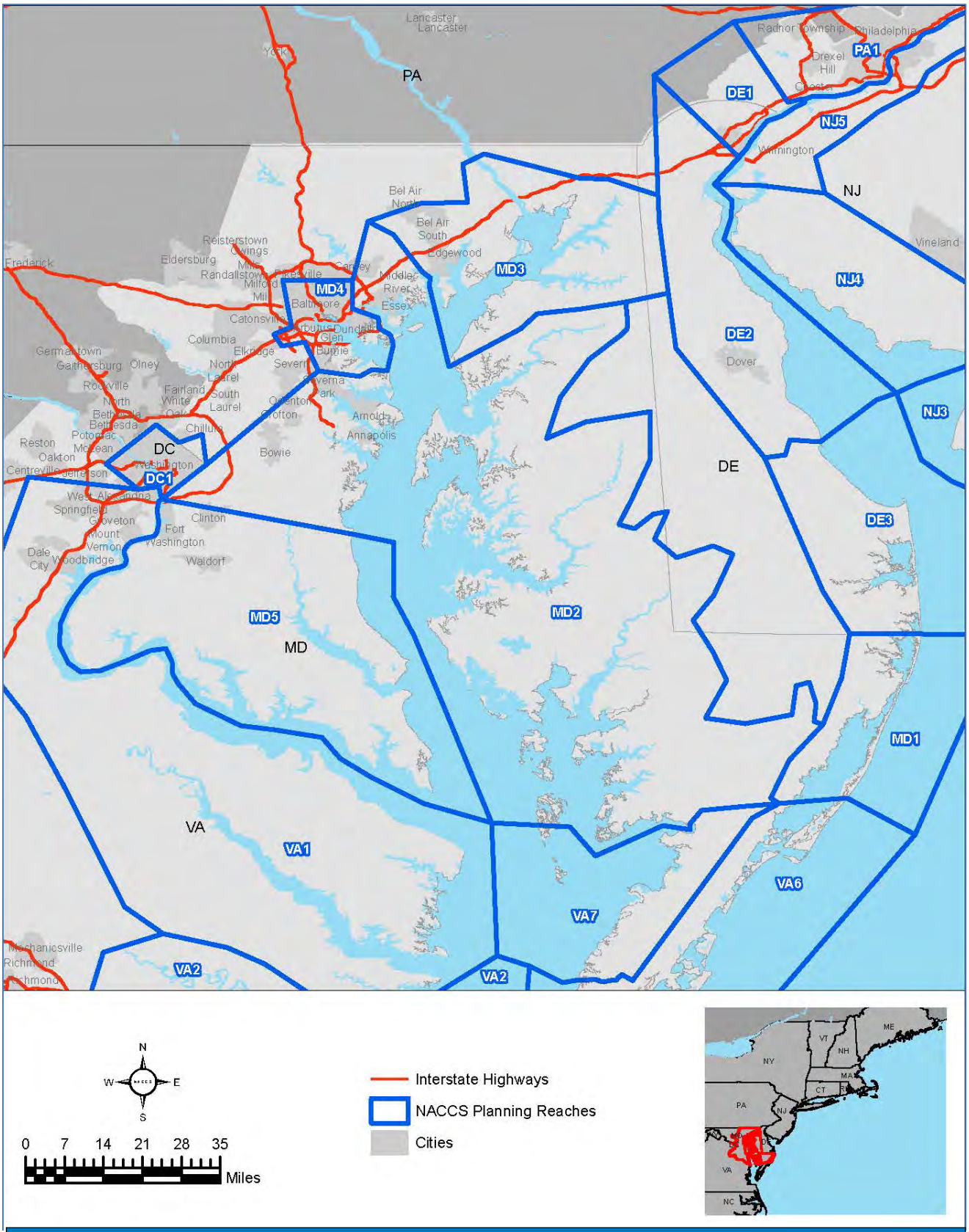

Figure 1. Planning Reaches for the State of Maryland

There are five planning reaches in Maryland, designated as MD1 through MD5. MD1 includes areas of the Maryland coastal bay watersheds from the Delaware to Virginia state border. Major cities/towns include Ocean City, Ocean Pines, and Berlin. MD2 includes the majority of the Chesapeake Bay coast on the lower eastern shore as well as areas of the western shore, including the City of Annapolis. Also included in the MD2 reach is Smith Island, Poplar Island, and the Blackwater National Wildlife Refuge. The MD3 reach includes the northeastern portion of the Chesapeake Bay coastline. The Town of Elkton and City of Havre de Grace along with Aberdeen Proving Grounds is located in this reach. MD4 includes the City of Baltimore metropolitan area, including areas of Baltimore City, Baltimore County, and Anne Arundel County. The Port of Baltimore is located within this reach. MD5 includes the southwestern coastal areas of the Chesapeake Bay, extending up the Potomac River to the District of Columbia.

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 resiliency are compared. Further discussion of the existing conditions is provided in Appendix C – Planning Analyses.

The existing conditions are 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. Affected Population by Hurricane Sandy for the State of Maryland (2010, U.S. Census Data)

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Table 1. Affected Population in the State of Maryland by the Effects of Hurricane Sandy Within the NACCS Study Area

Jurisdiction (County)	Population
Anne Arundel	537,656
Baltimore County	805,029
Baltimore City	620,961
Calvert	88,737
Caroline	33,066
Cecil	10,108
Charles	146,551
Dorchester	32,618
Harford	244,826
Howard	287,085
Kent	20,197
Prince George's	863,420
Queen Anne's	47,798
Somerset	26,470
St. Mary's	105,151
Talbot	37,782
Wicomico	98,733
Worcester	51,454
Total Population	4,148,642

Figure 3 and Table 2 summarize pertinent information regarding infrastructure affected by Hurricane Sandy. Critical infrastructure elements include sewage, water, electricity, academics, trash, medical, and safety.

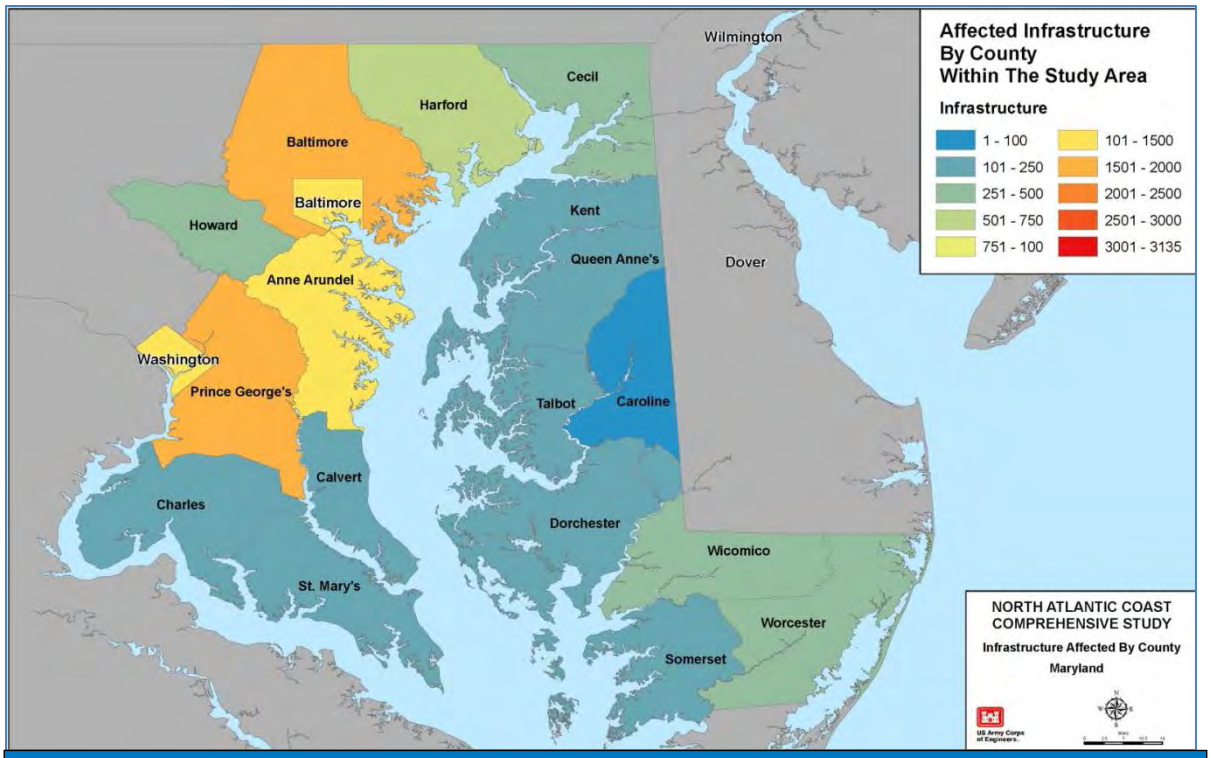

Figure 3. Affected Infrastructure by Hurricane Sandy for the State of Maryland

Table 2. Affected Infrastructure Elements by Hurricane Sandy

Jurisdiction	Infrastructure Count
Anne Arundel	949
Baltimore	2,988
Calvert	141
Caroline	92
Carroll	1
Cecil	355
Charles	235
Dorchester	155
Harford	579
Howard	494
Kent	113
Montgomery	14
Prince George's	1,529
Queen Anne's	153
Somerset	173
St. Mary's	186
Talbot	188
Wicomico	305
Worcester	285
Total Infrastructure Affected	**10,006**

A detailed discussion 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 resiliency. A base year of 2018 has been identified when USACE projects discussed below will be implemented/constructed.

A total of 75 existing USACE projects in Maryland are included in the post-Sandy landscape condition. Eight of these projects are CSRM projects, two are environmental restoration projects, and sixty-five are navigation (NAV) projects (Figure 4). A complete list of existing USACE projects within the entire study area is presented in Appendix C – Planning Analyses.

The post-Sandy landscape condition also includes active (at the time of the landfall of Hurricane Sandy) state and local/communities' CSRM projects in the State of Maryland. Based on coordination with the State of Maryland it is understood that few of these projects suffered any damage due to Hurricane Sandy. Therefore, at this time the USACE has made the assumption that the states' most likely future condition will be the pre-Sandy condition. The State of Maryland was queried with regard to the statement's accuracy in a June 5, 2013 letter, and there was no disagreement as to the statement's accuracy.

Since the Atlantic coastline of Maryland is limited to Ocean City and Assateague Island, both of which have Federal projects on the ocean-side, there are no state or local projects along the coast. Figure 5 presents state projects along the coastal back bays, the Chesapeake Bay, and estuarial tributaries to these water bodies, including the Potomac River.

The Maryland Department of Natural Resources (MDDNR) provided the USACE information regarding coastal storm damage or shore protection projects. The projects that were constructed by the state are shown in Figure 5. As shown, there are thousands of privately constructed CSRM projects around the state, with a portion of them being state funded. The majority are classified as seawalls/bulkheads, but there are also many revetments, and natural shoreline stabilization. Few of these private projects, with the likely exception of community protection projects, are designed to protect from a major event. Many of the projects protect against smaller, more frequent storms and aid the prevention of erosion. There was no other information available regarding the specific level of protection afforded by these projects.

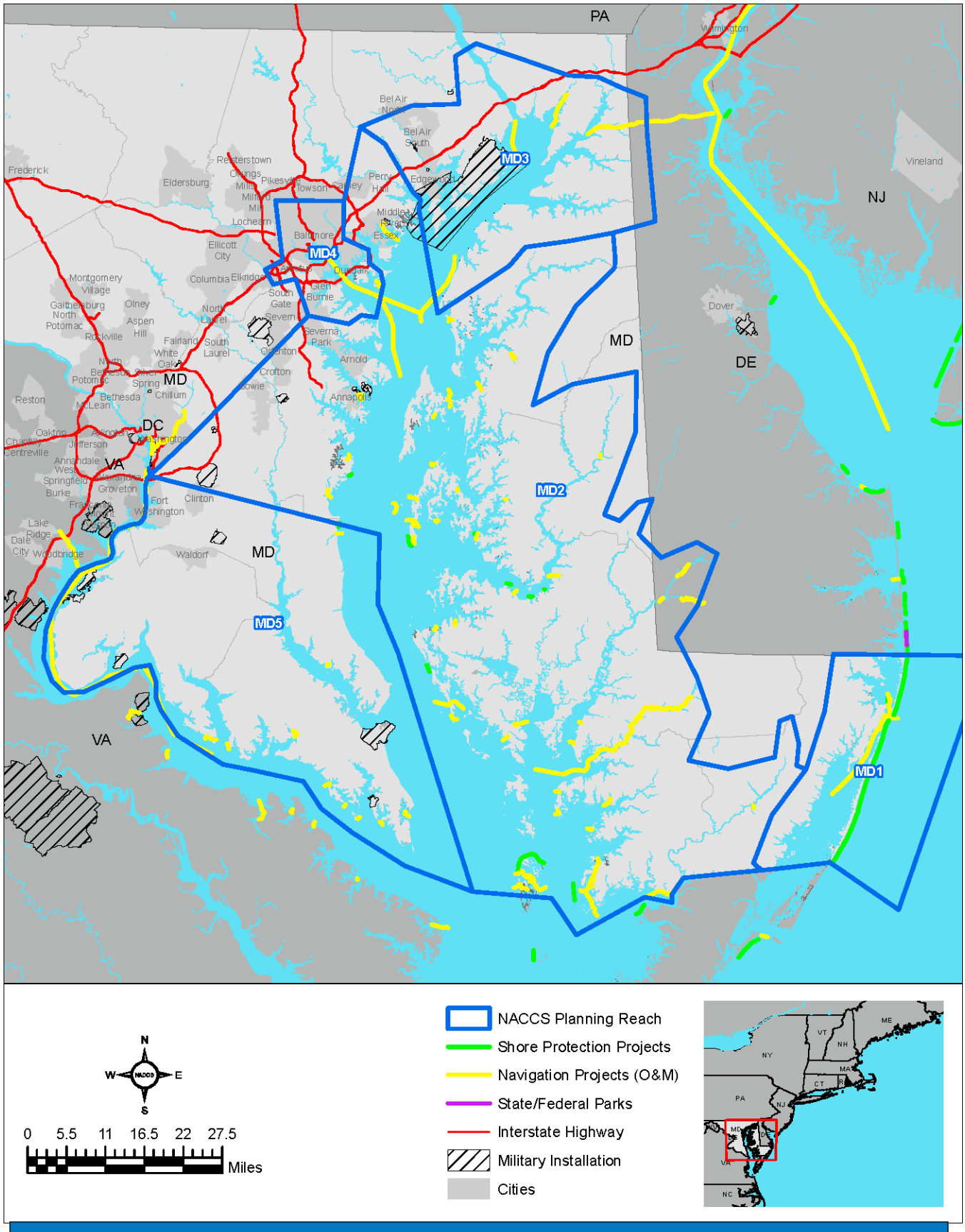

Figure 4. Federal Projects Included in the Post-Sandy Landscape Condition

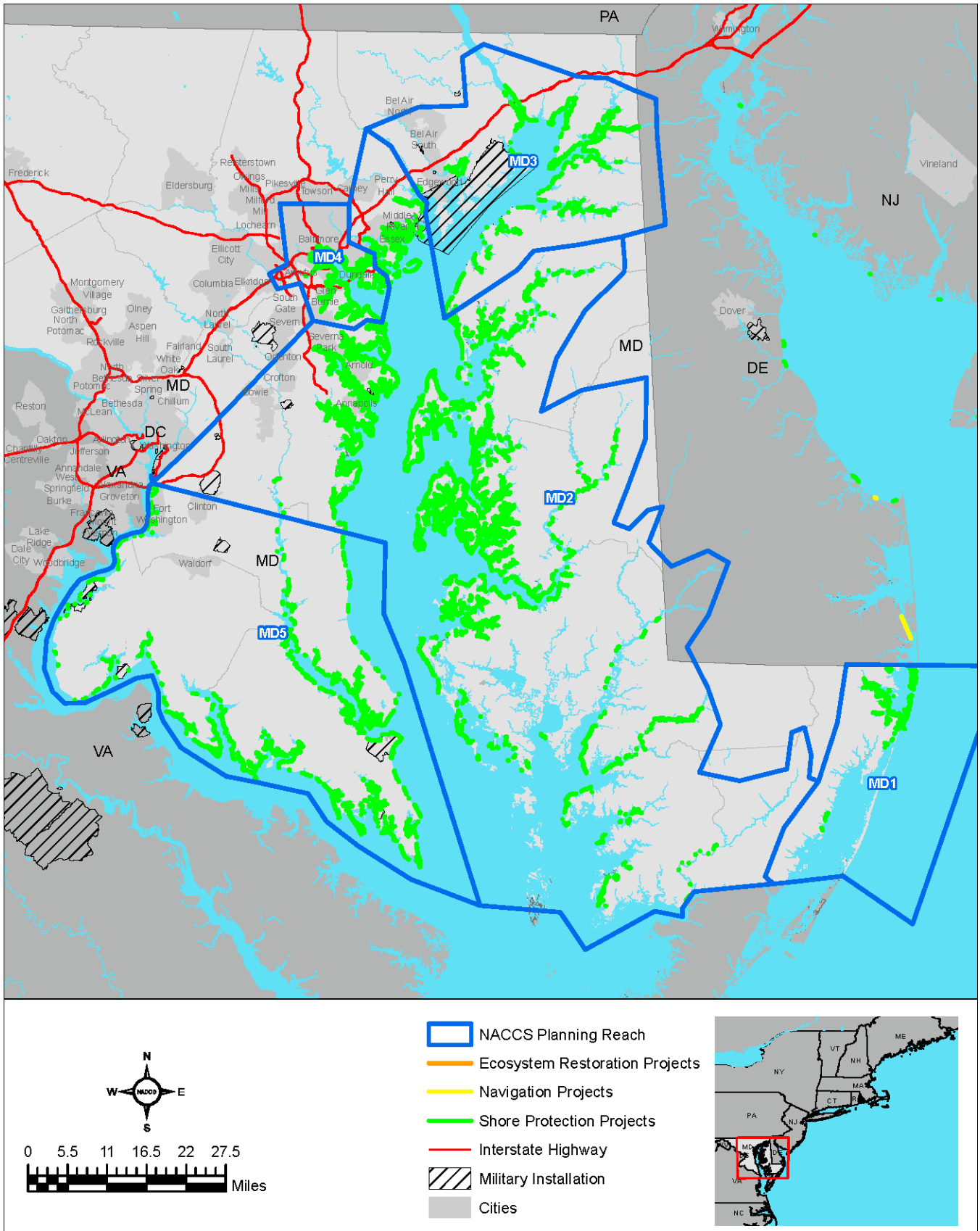

Figure 5. State Projects Included in the Post-Sandy Landscape Condition

Sea Level Change

The current USACE guidance on development of SLC (USACE, 2013) outlines the development of three scenarios: Low, Intermediate, and High (Figure 6). The NOAA High scenario (NOAA, 2012) is also plotted on 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 Chapter IV in a section titled 'Evaluation of Sea Level and Climate Change' of the Main Report.

These USACE and NOAA future SLC scenarios have been compared to state or region specific SLC scenarios. The State of Maryland adopted guidelines to evaluate SLC in Maryland Executive Order 01.01.2012.29: Climate Change and Coast Smart Construction. The executive order references SLC projections completed by the Maryland Climate Change Commission's Scientific and Technical Working Group and presented in Updating Maryland's Sea Level Rise Projections Report, dated June 26, 2013. Figure 6 includes a comparison of the USACE Low, Intermediate, and High and NOAA High relative SLC scenarios (for the Annapolis, MD NOAA tide gauge) with the projections included in the Updating Maryland's Sea Level Rise Projections Report. Thus, importance should be placed on scenario planning rather than on specific, deterministic single values for future SLC. Such SLC scenario planning efforts will help to provide additional context for state and local planning and assessment activities.

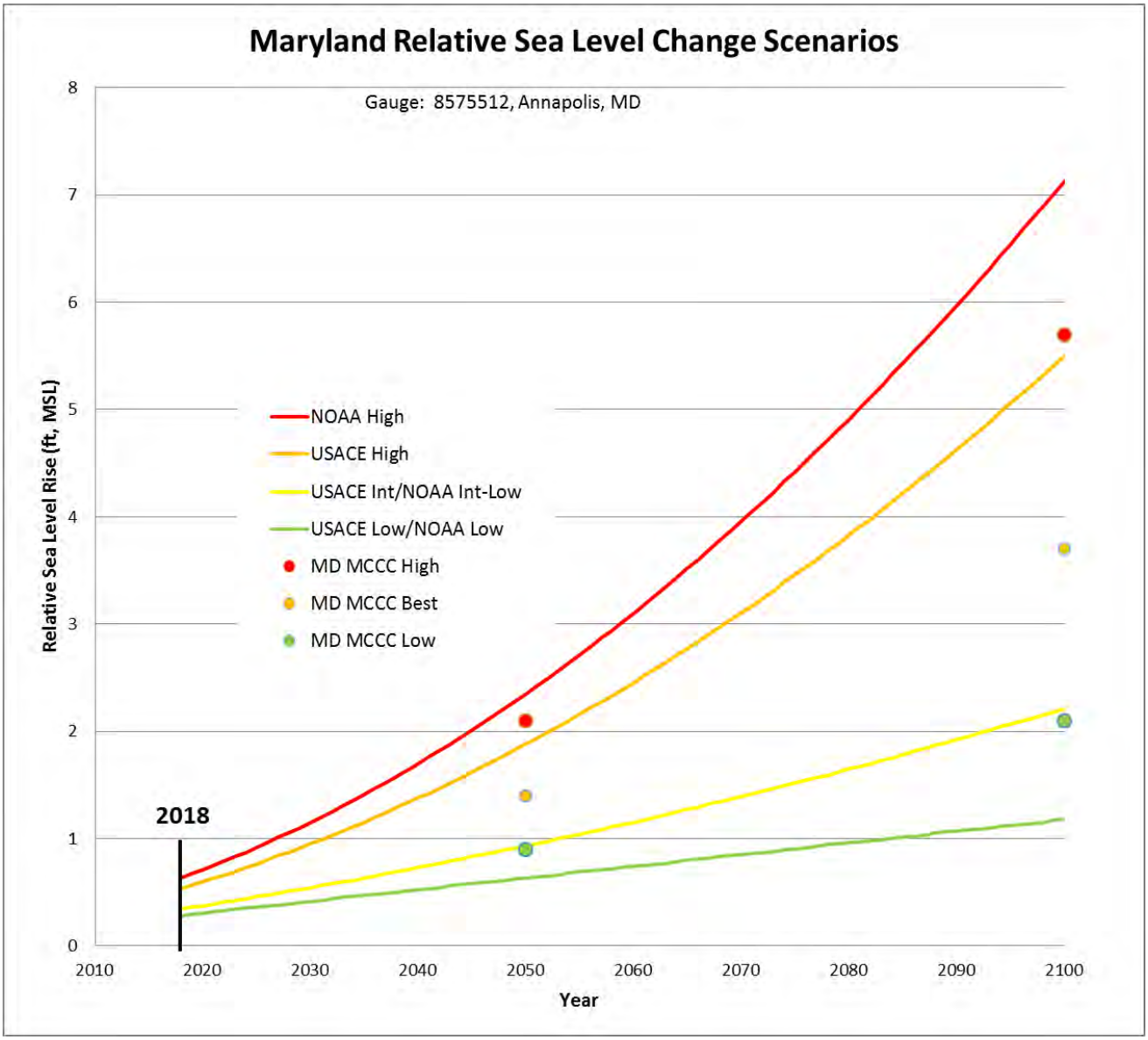

Figure 6. Relative Sea Level Change for Annapolis, MD for USACE and NOAA Scenarios and the State of Maryland.

To consider the effects of SLC on the future landscape change, future SLC scenarios have been developed by USACE (2013d) and NOAA (2012). Figure 7 shows areas that would be below mean sea level (MSL) at three future times (2018, 2068, 2100) 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.

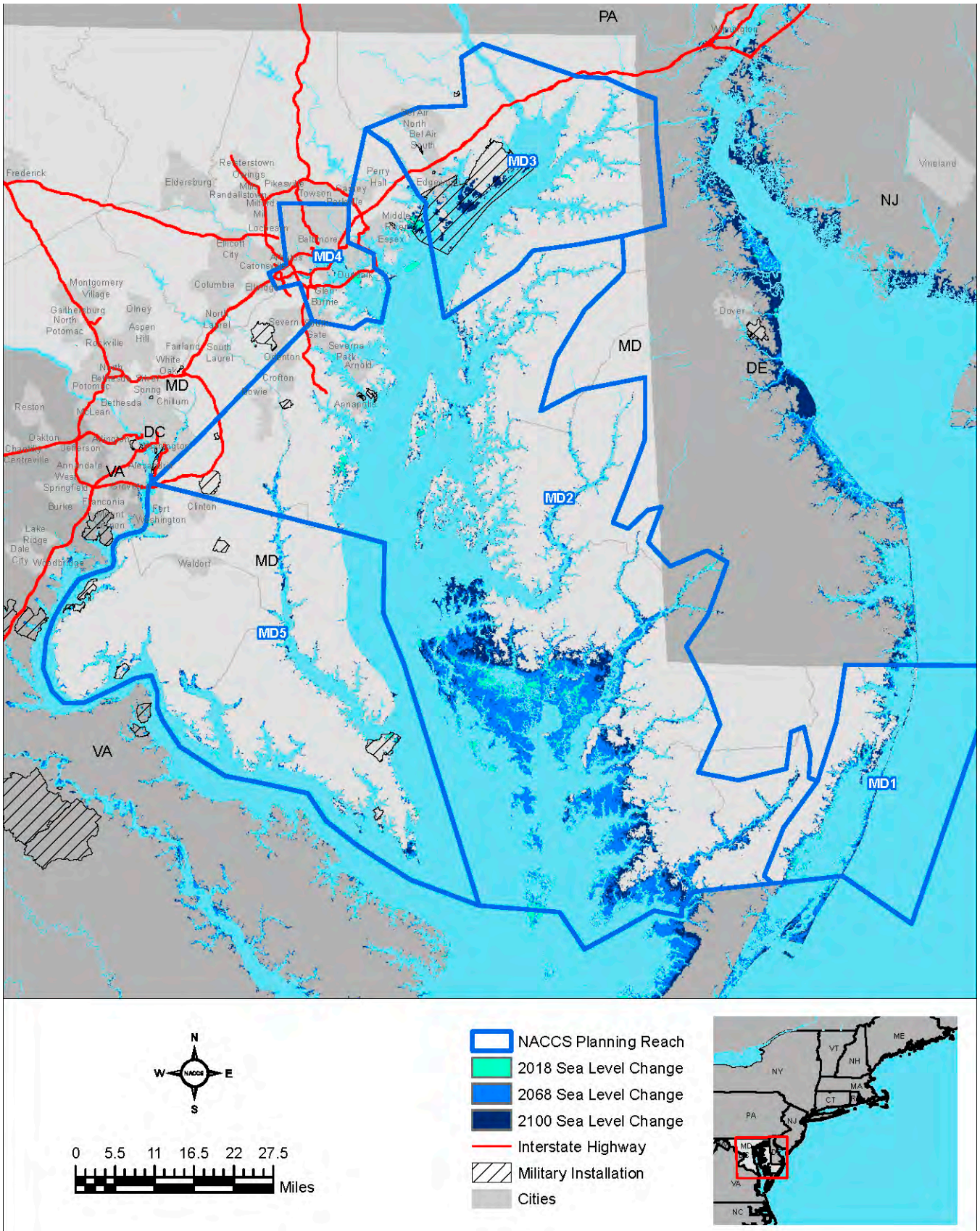

Figure 7. USACE High Scenario Future Mean Sea Level Mapping for the State of Maryland

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 (USEPA, 2009). Figure 8 present the USACE High scenario inundation and the forecasted increase in residential development density derived from ICLUS data for the State of Maryland. 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 are 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.

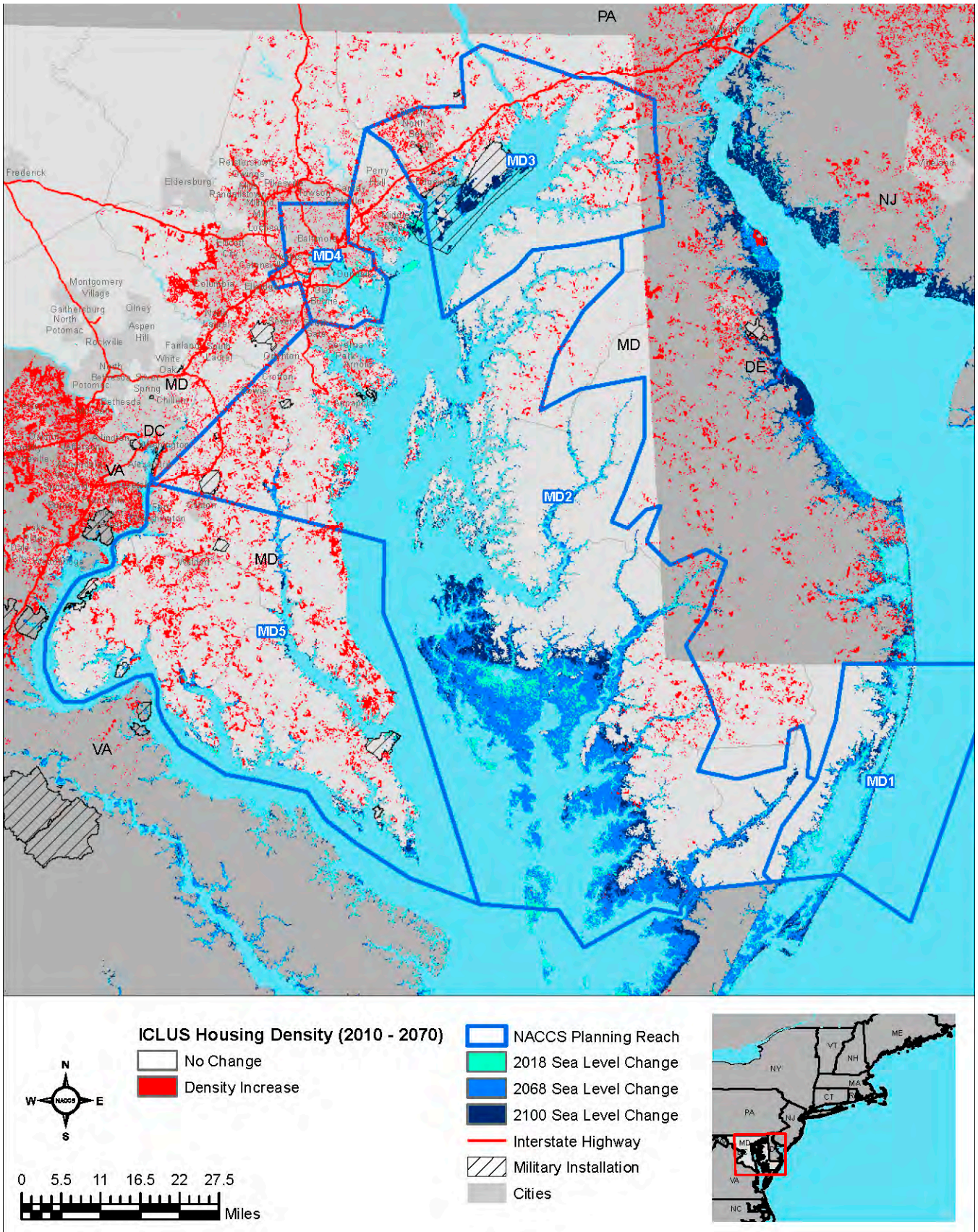

Figure 8. USACE High Scenario Future Housing Density Increase Mapping for the State of Maryland

Extreme Water Levels

As part of the Coastal Storm Risk Management 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 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 1percent 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 Category 4 hurricanes.

Figure 10 presents the approximate 1 percent floodplain plus 3 feet for the same area to illustrate areas exposed to projected inundation levels, which is closely aligned with the USACE high scenario for projected SLC by year 2068 as well as New York City's new building ordinance. 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.

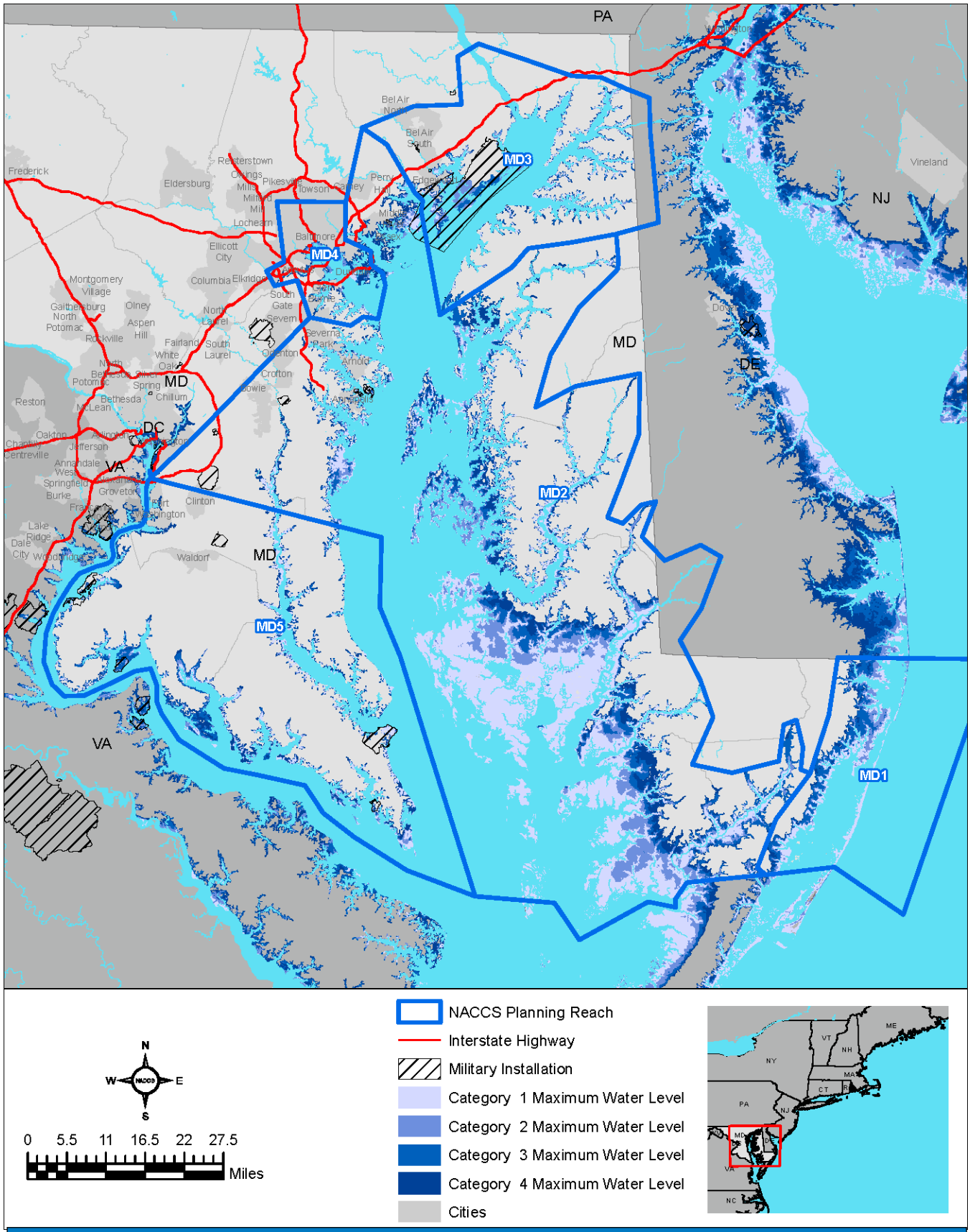

Figure 9. Impacted Area Category 1 Through 4 Water Levels for the State of Maryland

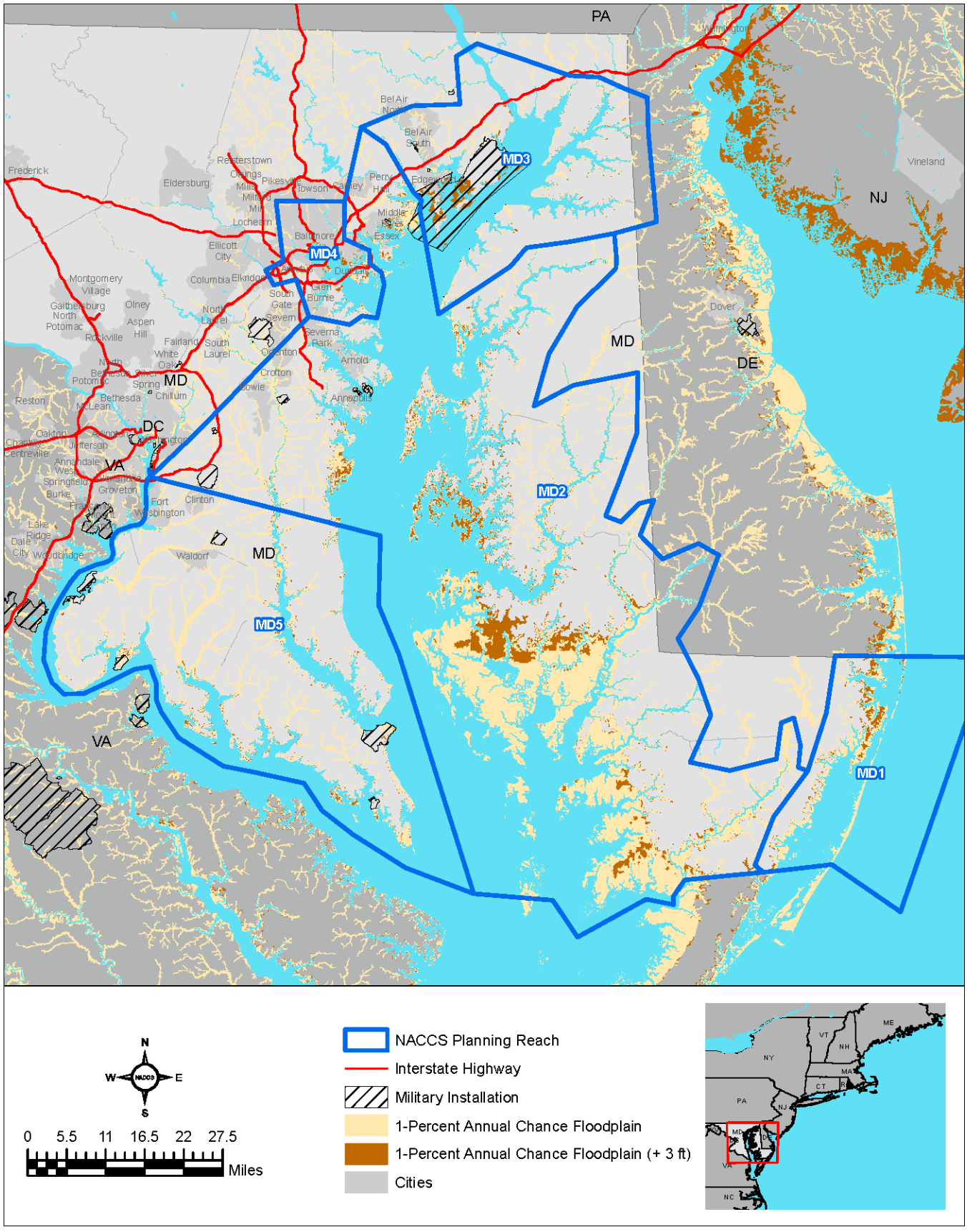

Figure 10. Impacted Area 1 percent + 3 feet Water Surface for the State of Maryland

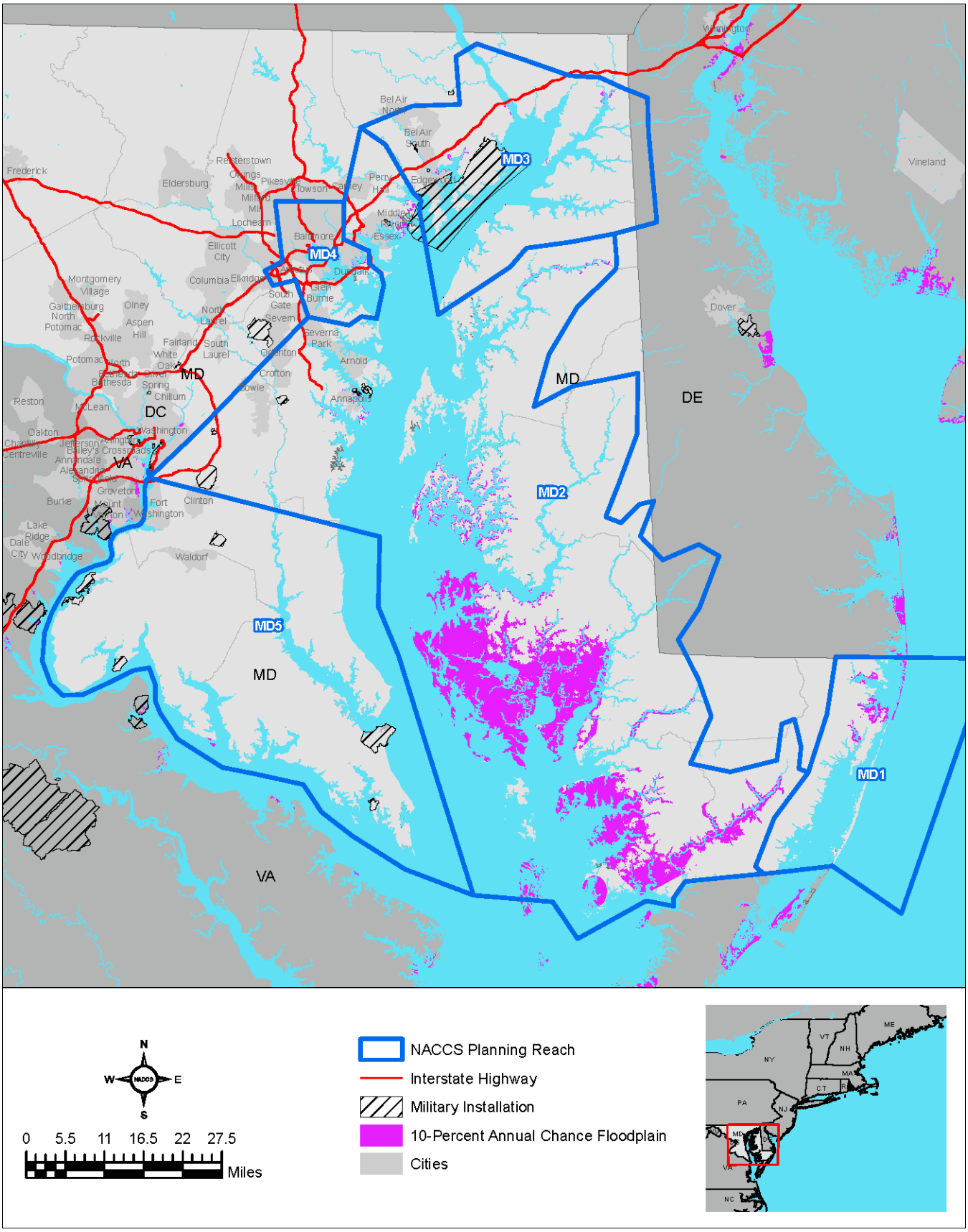

Figure 11. Impacted Area 10 Percent Water Surface for the State of Maryland

Environmental Resources

Atlantic Coast

USACE would continue to dredge sand for nourishment of the Ocean City beaches from offshore sources under the Atlantic Coast of Maryland Shoreline Protection Project for the full authorized project life until 2044 because of the city's regional economic importance. Increased volumes of sand could be added to maintain the project coastal storm risk management functions to compensate for SLC over the next several decades, which would likely be offshore in Federal waters. Offshore resources are located in more relatively stable condition than along the nearshore, so dredging could potentially have greater ecological impacts that may need further evaluation.

It is anticipated that USACE will continue maintain the jetties along the north and south sides of the Ocean City Inlet and continue routine dredging of the Federal navigation channel for decades into the future because of its importance to commercial and recreational navigation.

The Assateague Island Long Term Sand Management project has a project life to 2028, but would be vulnerable to interruption or cancellation in light of uncertain future Federal budgets and lesser economic importance of the project. Failure to continue the project could destabilize the northern end of Assateague Island and cause conversion of barrier island habitat to open water (ocean and bay). Sparsely vegetated overwash habitat of the north end of the island is of great importance for rare species. Destabilization of the northern end of the island via cessation of the Assateague project or via accelerated SLC could potentially create additional overwash habitats further south along the island, or cause a net loss of these habitats. If the rate of SLC accelerates substantially, it is expected that Assateague Island's retreat rate towards the mainland would increase and that island elevations would be lowered. These conditions would likely favor an increased rate of inlet formation and dynamics along the entirety of the island. This could favor increased formation of dynamic bayside flood tidal shoals and islands. With warming temperatures, it is likely that increased nesting on Assateague Island by sea turtles would occur.

Because of naturally steeper topography on the landward side of Maryland's coastal bays, opportunities for coastal wetlands migration (retreat) are naturally limited. Additionally, substantial portions of the northern coastal bays shoreline are hardened with development landward of existing wetlands, which generally limits migration opportunities there. Consequently, it is likely that there would be a loss of coastal wetlands as the sea rises.

Submerged aquatic vegetation (SAV) acreage within Maryland's coastal bays is at risk from worsening eutrophication, but efforts underway to manage nutrient pollution will likely improve conditions eventually. Only two species of SAV occur within Maryland's coastal bays (eel and widgeon grass). Eel grass is at about its southern limit and vulnerable to warming water temperatures. In the event water temperatures warm substantially, eel grass could be eliminated and coastal bays SAV acreage would decrease and what remains show greater interannual variation. However, formation of additional inlets through Assateague Island could increase flushing with ocean water, offsetting climate change impacts.

Shallow waters of the coastal bays would increase in area as the sea rises concomitant with shoreline erosion and drowning of coastal wetlands. Bay island losses to erosion and drowning appear unlikely to be offset by new island formation (latter as depicted in NOAA, 2013). Low-lying developed areas on the mainland would become increasingly vulnerable to coastal flooding during storm surges as the sea rises.

Commercial wind energy production is likely on the Continental Shelf off Maryland. The magnitude of this activity is speculative at this time, but ultimately could involve tens of turbines producing 100s of megawatts of energy.

Chesapeake Bay

Within the Chesapeake Bay, SLC will primarily impact shoreline erosion, degradation of remote island habitat, submergence of eastern shore wetlands, and estuary projects such as Poplar Island. SLC also threatens to exacerbate and prolong the process of erosion along the developed western rim of the Chesapeake Bay. The following resources are available to determine the amount of SLC needed to impact certain developed areas and wetland within the Maryland portion of the Chesapeake Bay: http://www.csc.noaa.gov/slr/viewer/#. Depending on the location within the Chesapeake Bay, flooding could occur easily with just a foot of SLC, while other locations would not get flooded until there is about 6 feet of surge. Low lying areas such as the Tangier Fire Department are projected to experience a great deal of flooding with just 1 foot of SLC while areas in higher elevations such as St. Michaels, Maryland does not show sea level impacts until SLC reached 3 feet or higher. With respect to the marshes within the Chesapeake Bay, the extensive wetland complexes on the southern eastern shore of Maryland's Chesapeake Bay, particularly those of Dorchester, Somerset, and Wicomico Counties, are highly vulnerable to SLC. This area includes the Chesapeake Bay Estuarine Complex that was designated by the Ramsar Convention as Wetlands of International Importance in 1987. (http://www.ramsar.org/cda/en/ramsar-documents-list/main/ramsar/1-31-218_4000_0__) Expansive forested freshwater wetlands would be lost with 1 feet of SLC. Between 1 and 2 feet of SLC, the wetland complex will transition to open water. The Maryland Coastal Atlas (http://dnr.maryland.gov/map_template/coastalmaps/coastal_atlas_shorelines.html) projects that with 5-10 ft of SLC rise, most of the peninsulas and islands that extend into the Bay today will be vulnerable to loss (this is largely concentrated along the Talbot, Dorchester, Somerset, and Wicomico County shorelines). Conversely, with just 1 foot of SLC, areas that were once upland on the eastern shore of Maryland will slowly turn into saltwater/brackish/and freshwater emergent marsh/wetland habitat (NOAA SLR viewer).

Islands, remote and inhabited, within the Chesapeake Bay, such as James, Sharps and Tilghman Island have slowly but progressively succumbed to the forces of erosion and inundation. Today, Sharps Island no longer exists, and as of 1994, James Island was measured to be about 92 acres, while Tilghman Island was measured to be about 1,302 (Johnson, 2000). Over time, these islands would be reduced in areal extent if no actions are taken to protect and restore those valuable habitats. Smith Island is the last permanently inhabited island in the Chesapeake Bay, and is experiencing severe erosion, flooding, inundation, and loss of wetlands. The entire island is less than 3 feet above sea level. The level of commitment and fiscal resources, on the part of Federal, state, and local agencies, to protect Smith Island and other Bay Islands from rising sea levels only foreshadows the degree of involvement the State will be facing to protect the coastal mainland and its natural resources in future years. These wetland complexes are particularly valuable to wildlife resources. For example, these complexes are positioned in the Atlantic Flyway where a large group of avian species rely on this habitat for foraging and nesting.

The eastern shore of Maryland along the Chesapeake Bay is also the area identified by the Maryland Coastal Atlas to be most affected by increased storm surges. For example, in areas where the elevation change may only be as much as 1 foot per mile, gradual submergence of a large geographical area, including large expanses of tidal wetlands is likely overtime (Johnson, 2000). A

significant portion of Maryland's eastern shore is less than 5 feet above sea level. The western shore north of Baltimore including Baltimore and Harford Counties is also vulnerable to increased storm surges, with the most recent extensive surge experience in the region being associated with Hurricane Isabel in 2003.

A more detailed explanation of existing habitat as well as the effects of coastal flooding and SLC 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 – Economics and Social Analyses, and C – Planning Analyses.

V. 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 Public Law (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.

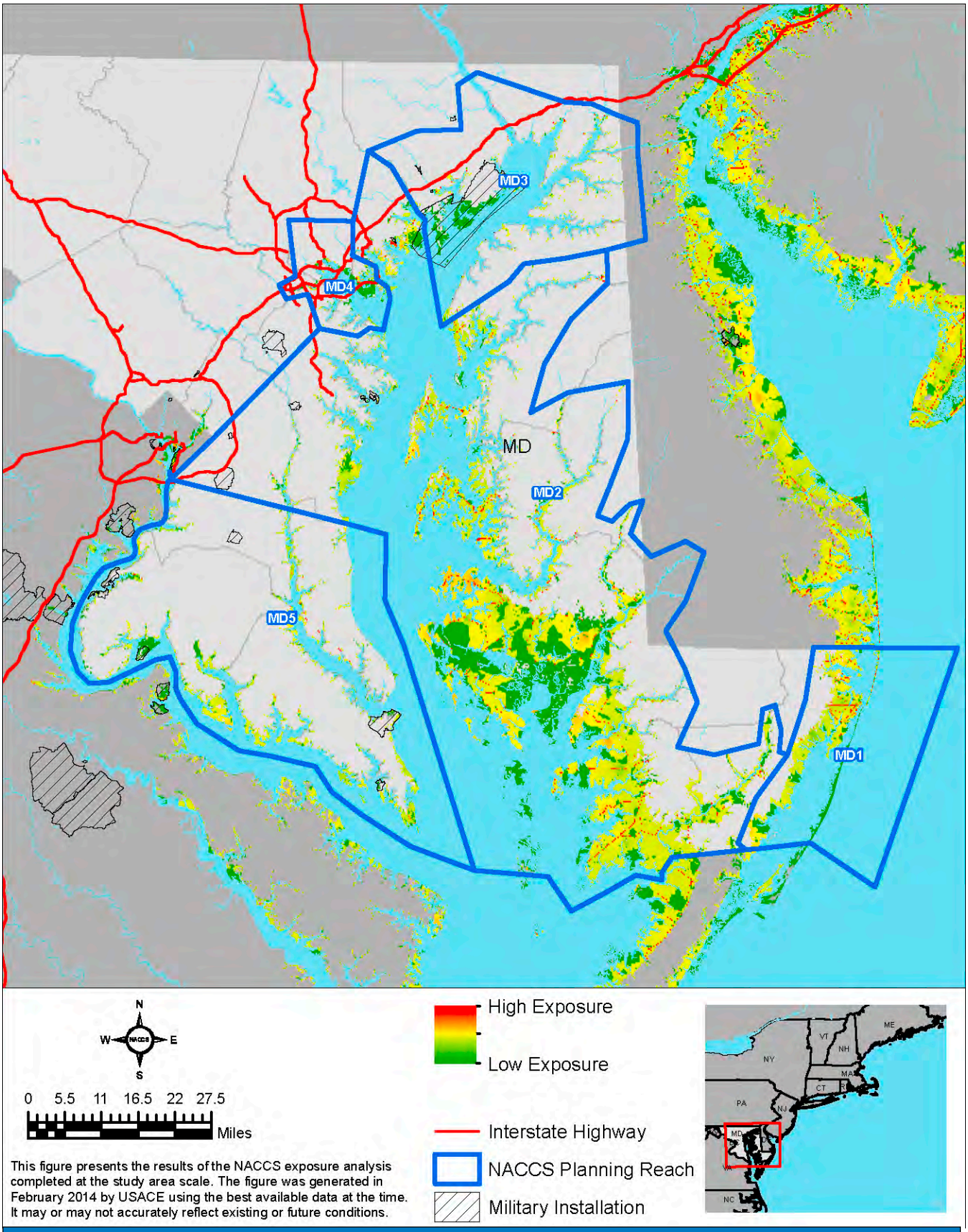

Figure 12. Population and Infrastructure Exposure Index for the State of Maryland

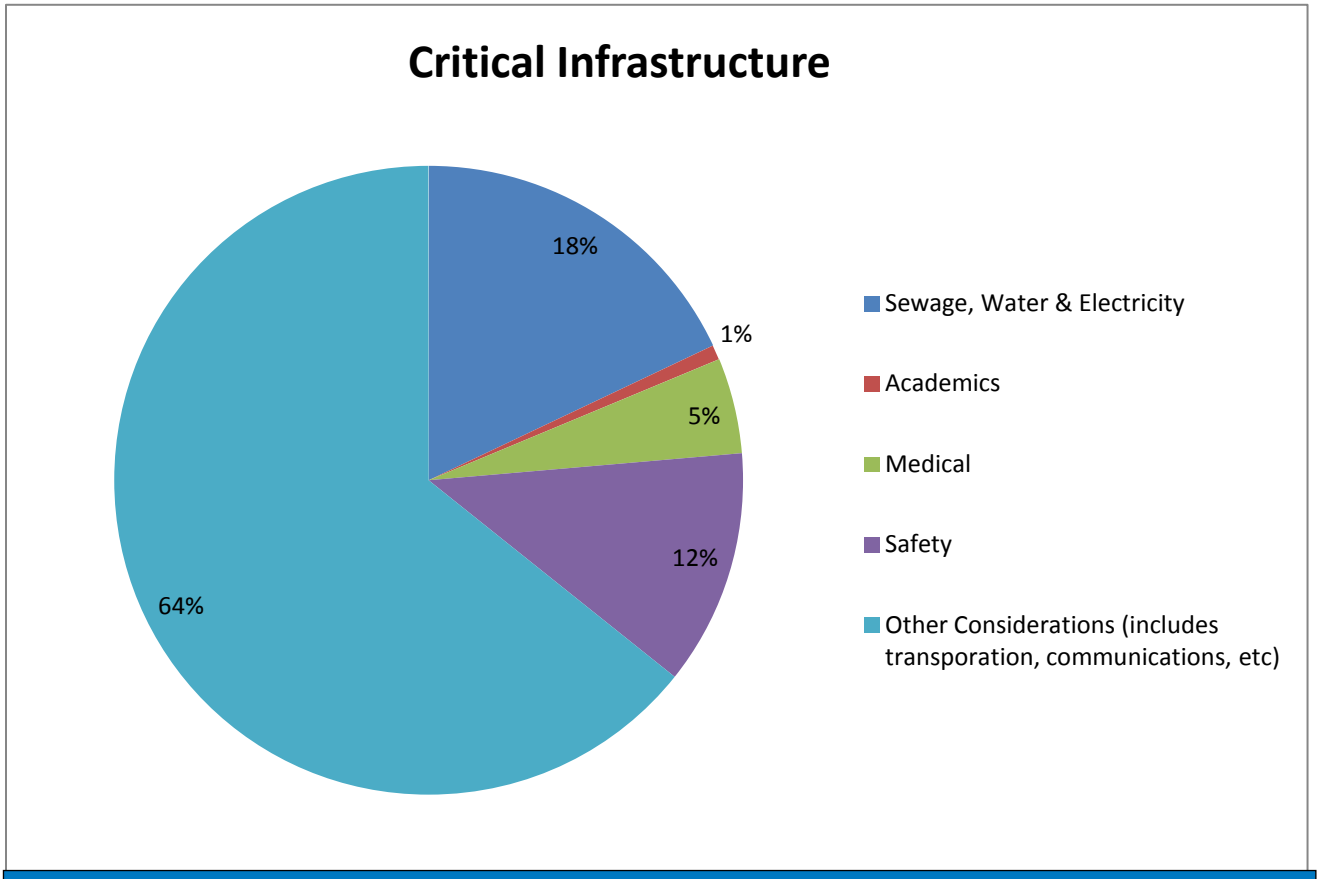

Figure 13. Critical Infrastructure Elements Within the Category 4 MOM Inundation Area in the State of Maryland.

*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.

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 State of Maryland. Areas with relatively higher concentrations of vulnerable segments of the population are identified from this analysis.

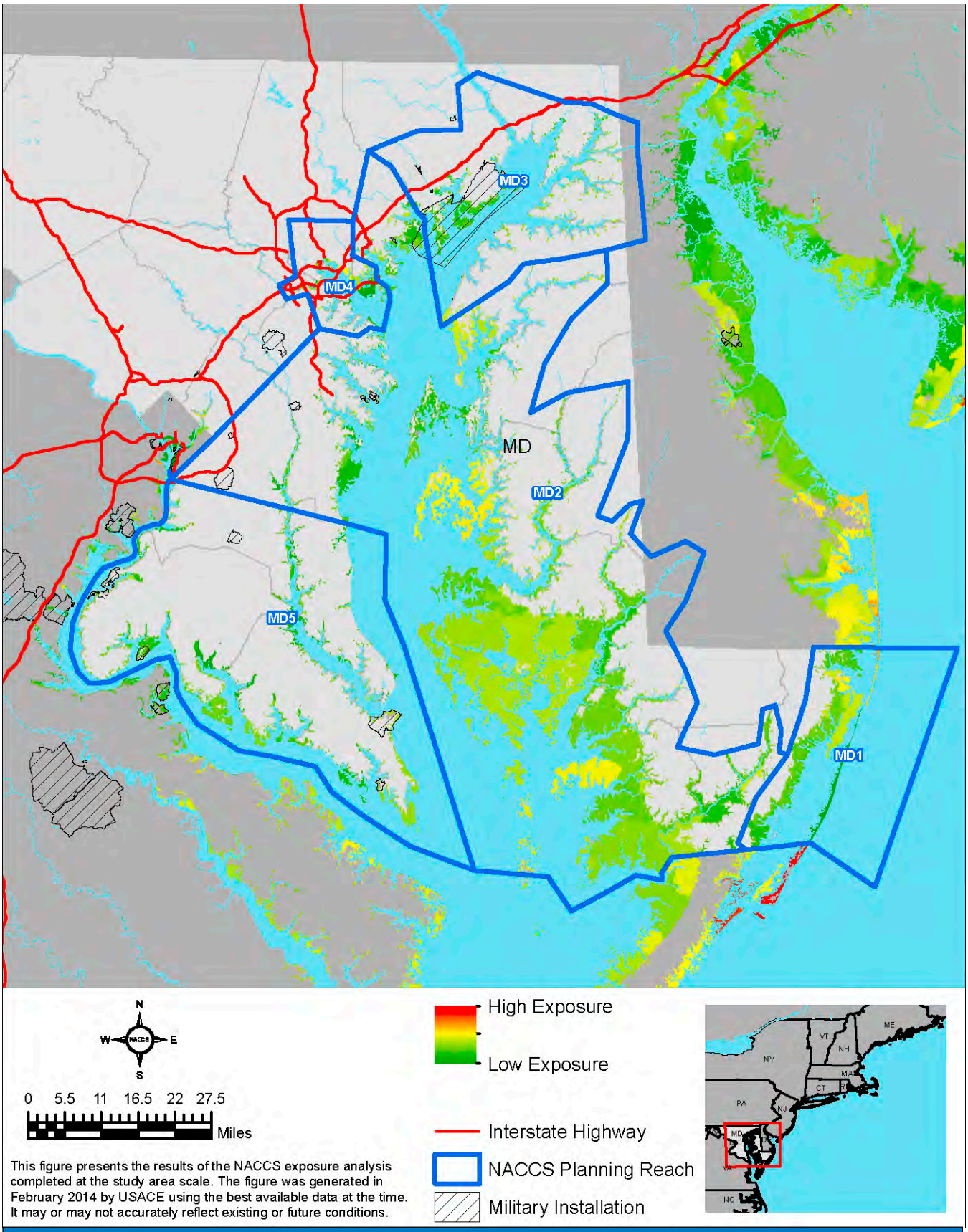

Figure 14. Social Vulnerability Exposure Index for the State of Maryland

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 State of Maryland. MD1, MD2, MD3, and MD5 did not include any Census tracts that would be considered as a relatively high social vulnerability.

Reach: MD4

Based on the social vulnerability analysis, one area was identified within this reach as an area with relatively high social vulnerability. Census tract 2607(Baltimore City, MD) was identified as vulnerable due to a considerable percent of the population being non-English speakers.

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 Maryland. 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.

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

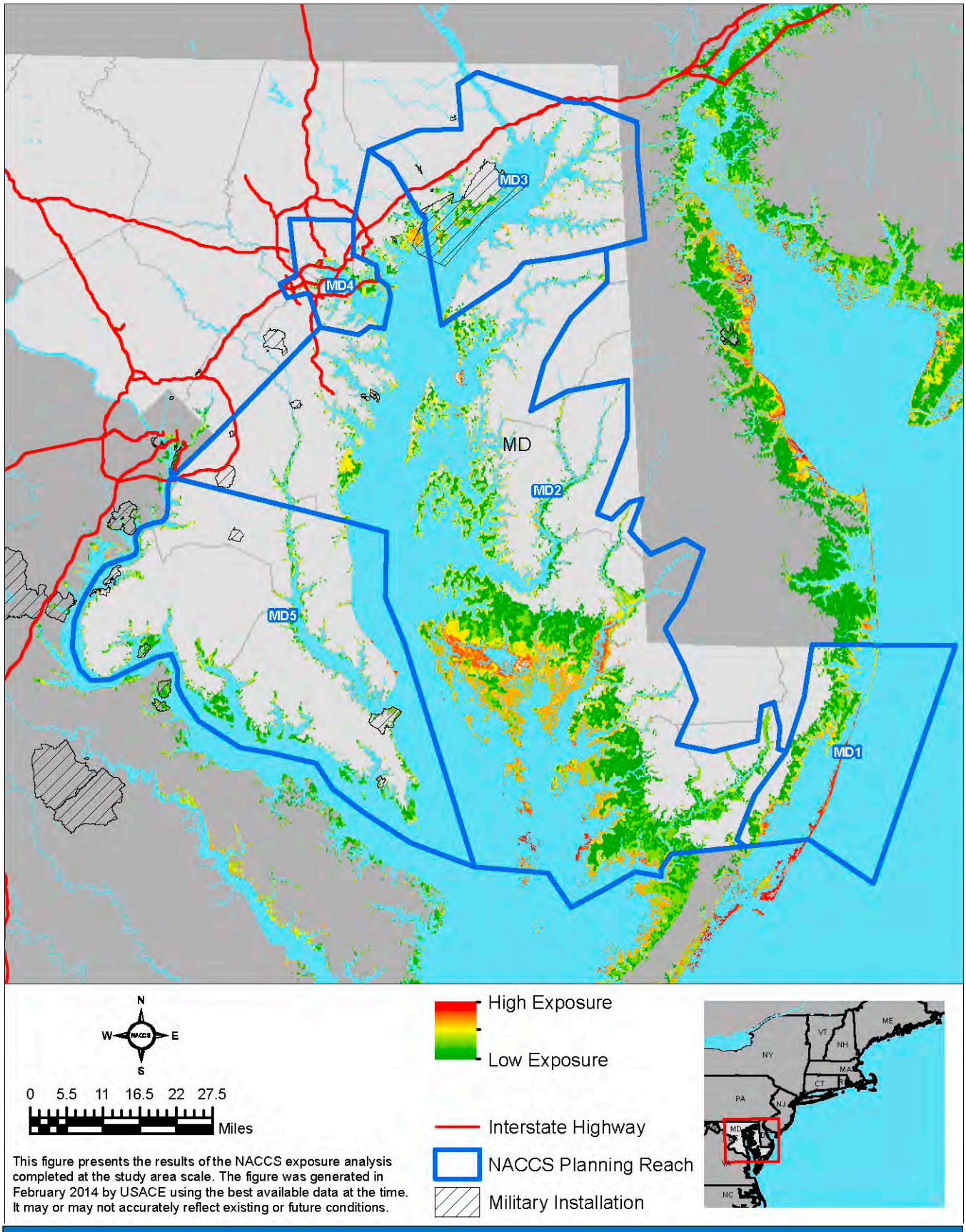

Figure 15. Environmental and Cultural Resources Exposure Index for the State of Maryland

Reach: MD1

This analysis resulted in approximately 45,000 acres of high (red and orange) environmental and cultural resources exposure index area in MD1. The region includes Assateague Island, which is comprised of parkland owned by the National Park Service (Assateague Island National Seashore), Maryland Department of Natural Resources (Assateague State Park), and U.S. Fish and Wildlife Service (Chincoteague Island National Wildlife Refuge), and protected under the Coastal Barrier Resources Act of 1982. Assateague Island, a primary resource in Maryland, encompasses approximately 7,500 acres which provides valuable habitat for a variety of fish and wildlife species, as well as providing recreation value. Islands within the coastal bays in the vicinity of the Ocean City Inlet are contained within Sinepuxent Bay Wildlife Management Area (WMA). On the mainland, Vaughn State WMA fronts Chincoteague Bay, and Isle of Wight WMA fronts Isle of Wight Bay. Additionally, there are a number of smaller parks along the coastal bay shoreline managed by local governments. This region contains more than 1,000 acres of The Nature Conservancy (TNC) Priority Conservation Area.

Two federally listed species occur on Assateague Island: piping plover and seabeach amaranth. Assateague Island is the only important nesting area for piping plover on the Atlantic Coast, supporting an average of 53 breeding pairs from 2003 through 2012 (Environmental and Cultural Resources Report, Attachment 1). SLC impacts to Assateague and actions taken to protect neighboring human development poses a threat to and could degrade plover nesting habitat (Environmental and Cultural Resources Report, Attachment 1). Identification of seabeach amaranth on Assateague Island in 1998 was the first sighting of the species between New York and North Carolina in 26 years (Environmental and Cultural Resources Report, Attachment 1). Efforts have been undertaken since that first sighting that has maintained a natural population between 400 and 900 plants on Assateague Environmental and Cultural Resources Report, Attachment 1). Seabeach amaranth is vulnerable to expected increases in SLC and storm activity. The federally listed Loggerhead sea turtle nests infrequently on southern Assateague. The high exposure area in this region contain more than 10 nesting sites for colonial nesting water birds, but overall in the region there are an even larger number (31) of colonies identified as vulnerable by United States Fish and Wildlife Service (USFWS) (USFWS, 2014). The coastal bays area contains notable seagrass acreage, but coverage varies annually. Since 1986, acreage has ranged from a minimum of about 5,000 acres to a maximum of about 20,000 acres. The coastal bays contain about 18,000 acres of brackish tidal wetlands, the majority of which is salt marsh. The coastal bays contain about 18,500 acres of nontidal wetlands, the majority of which is forested. There is a cultural resources buffer area of just over 1,000 acres. There were no historic properties identified in this reach.

Reach: MD2

This analysis resulted in approximately 38,000 acres of high (red and orange) environmental and cultural resources exposure index area in MD2. There are several coastal barrier islands that are protected under the Coastal Barrier Resources Act of 1982 including: Barren Island, Cedar/Janes Island, Eastern Neck Island, Fox Islands, Hazard Island, Holland Island, Jenny Island, and Joes Cove. All of these coastal barrier islands encompass over 8,000 acres of unique and valuable habitat. Within this region of Maryland, there are approximately 8,700 acres of USFWS protected national wildlife refuges including Blackwater National Wildlife Refuge which has been designated a "Wetlands of International Importance" by the Ramsar Convention as well as more than 8,000 acres of TNC Priority Conservation Area. Blackwater encompasses more than 27,000 acres of primarily tidal wetland habitat.

Blackwater supports a large breeding population of bald eagles and the migration of large numbers (20,000 to 25,000) of ducks and geese (Environmental and Cultural Resources Report, Attachment 1). Blackwater is also valuable habitat for forest interior dwelling birds and the federally endangered Delmarva Peninsula fox squirrel. The tidal marshes at Blackwater are highly vulnerable to SLC which occurs at a about twice the rate in this portion of Maryland's Eastern Shore compared to the rate worldwide (Environmental and Cultural Resources Report, Attachment 1).

There are also more than 2,800 acres of city, county, and state parks which provide not only valuable habitat for various fish and wildlife species, but have recreational value as well. The federally listed Northeastern Beach Tiger Beetle (threatened) is present, with its habitat encompassing around 1,000 acres. This area also includes 19 valuable nesting sites for colonel water birds and several different types of valuable habitat for various fish and wildlife species including more than 700 acres of seagrass habitat. Vulnerable waterbird nesting colonies are concentrated in this region (Environmental and Cultural Resources Conditions Report, Attachment A). Island colony sites are favored and are at particularly high risk. Island habitats are expected to be lost at an increasing rate as the rate of SLC increases. There is a cultural resources buffer area of over 12,000 acres which also includes important lake, river, pond, and stream habitat. This area also includes several historic ship wrecks and a large number of National Register of Historic Places (NRHP) listed properties, although these are objects such as historic vessels moored at various port towns around the bay.

Reach: MD3

This analysis resulted in approximately 160 acres of high (orange) environmental and cultural resources exposure index area in MD3. The reach includes more than 45 acres of TNC Priority Conservation Area, as well as 25 acres of city, county, and state parks which provide not only valuable habitat for various fish and wildlife species, but have recreational value as well. The federally listed Northeastern Beach Tiger Beetle (threatened) is present, with its habitat encompassing approximately 32 acres. There are several different types of valuable habitat within the region for various fish and wildlife species including over 23 acres of seagrass habitat and 20 acres of freshwater forest/shrub wetland habitat. There is a cultural resources buffer area of just over 60 acres which also includes important lake, river, pond, and stream habitat. This region also contains several valuable historic sites, including the Havre de Grace Lighthouse, Rodgers Tavern, and the skipjack Martha Lewis.

Reach: MD4

This analysis resulted in no high environmental and cultural resources exposure index area in Reach MD4 although the reach does have a high concentration of NRHP listed properties, many of them National Historic Landmarks. Fort McHenry, a National Monument is located in this reach.

Reach: MD5

This analysis resulted in approximately 1,100 acres of high (orange) environmental and cultural resources exposure index area in Reach MD5. The reach contain several coastal barrier islands that are protected under the Coastal Barrier Resources Act of 1982 including; Chicken Cock Creek, Cove Point Marsh, Flag Ponds, and McKay Cove; these islands encompass approximately 170 acres of unique and valuable habitat. There are also more than 200 acres of TNC Priority Conservation Area, and roughly 120 acres of city, county, and state parks which provide not only valuable habitat for various fish and wildlife species, but have recreational value as well. The federally listed northeastern beach tiger beetle and the puritan tiger beetles are both present, with their habitat encompassing over

400 acres in the high exposure index area of this reach. There are also several different types of valuable habitat such as of emergent marsh (approximately16 acres), and unconsolidated shore habitat (approximately13 acres) which encompasses of sand, gravel, and cobble. There is a cultural resources buffer area of just over 210 acres which also includes important lake, river, pond, and stream habitat.

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 State of Maryland.

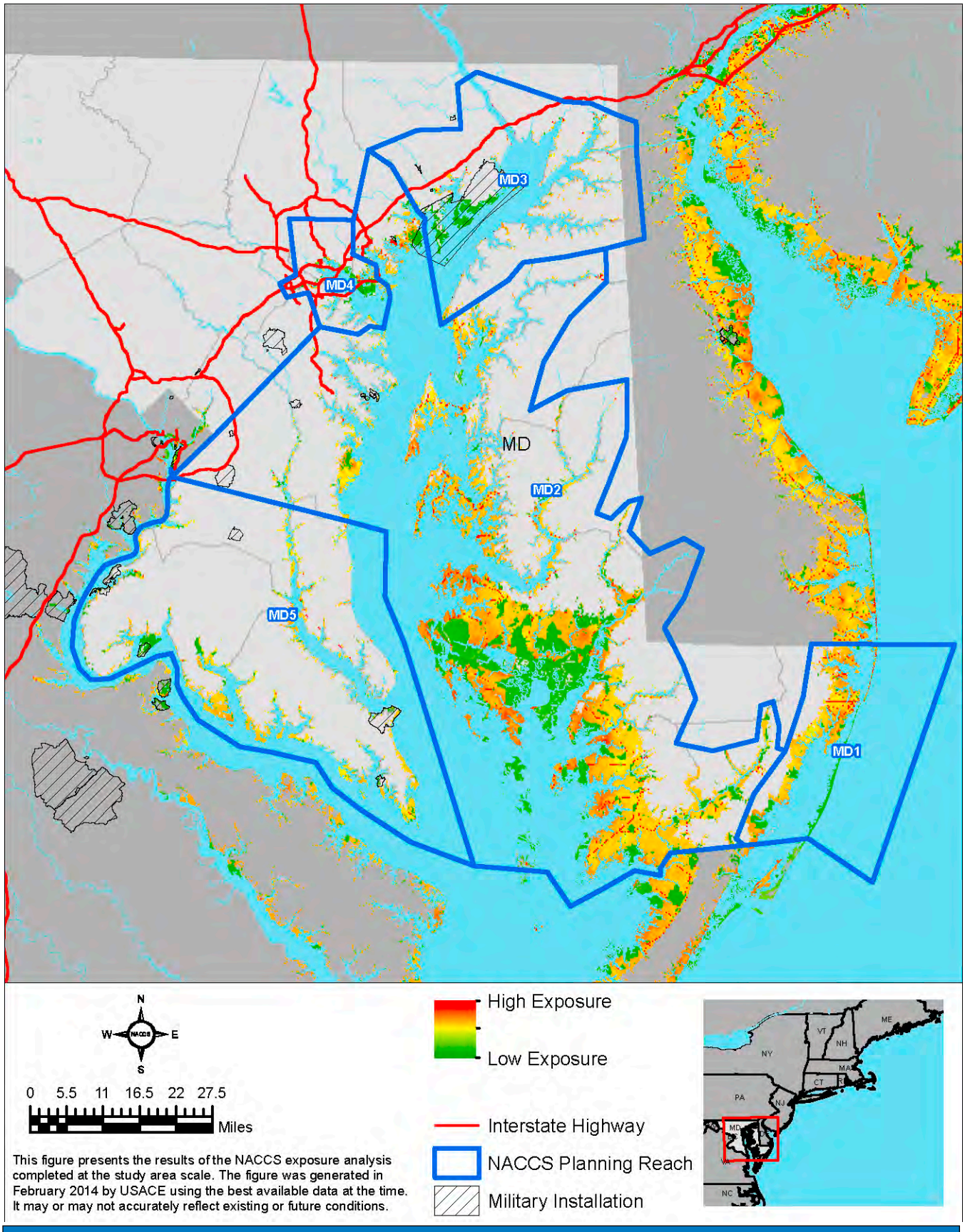

Figure 16. Composite Exposure Index for the State of Maryland

VI. 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 State of Maryland.

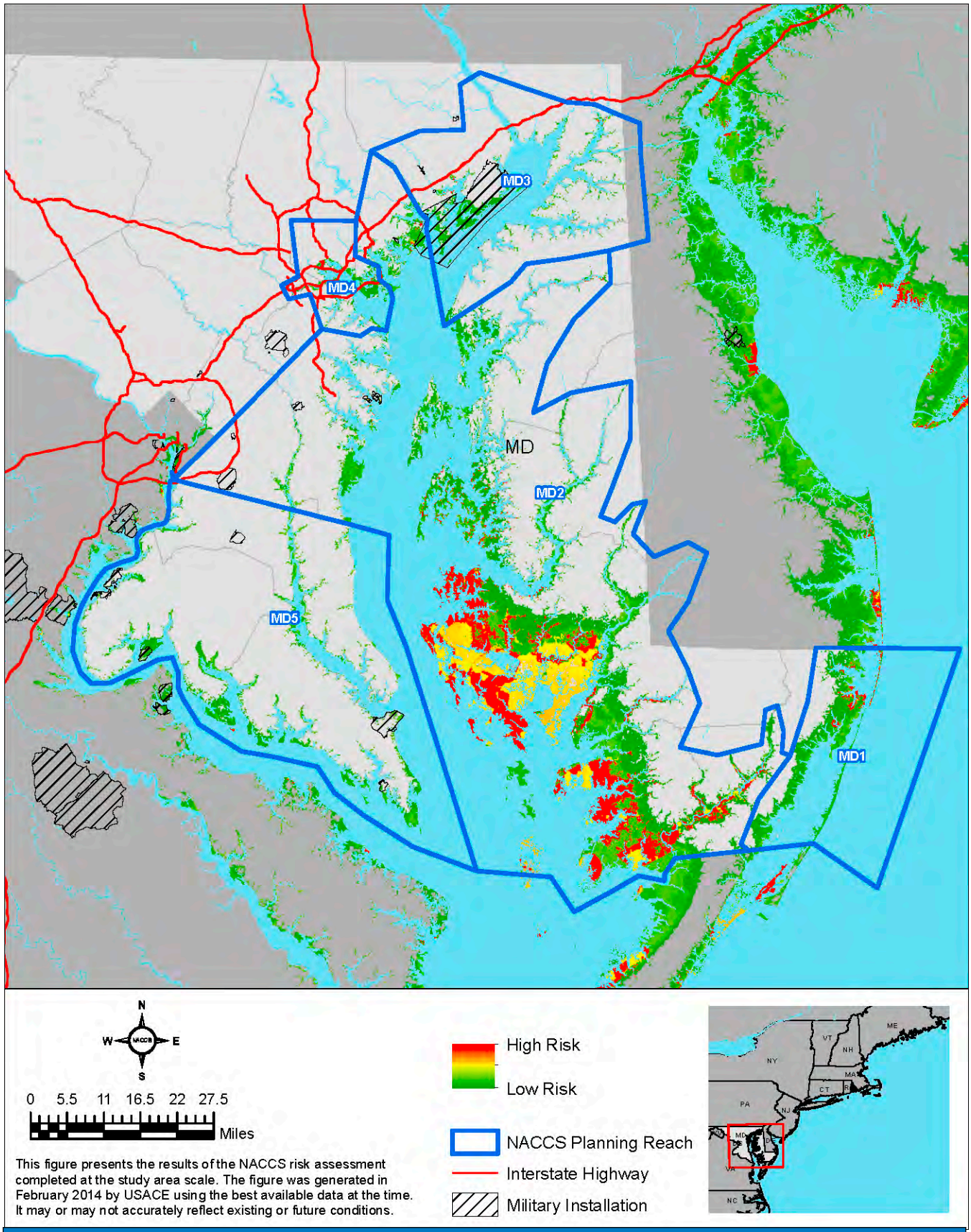

Figure 17.Risk Assessment for the State of Maryland

VII. NACCS Risk Areas Identification

Applying the risk assessment analysis to the State of Maryland identified 37 areas for further analysis (Figure 18). These locations are identified by reach in Figures 19 through 23 and are described in more detail below.

MD1 includes areas of eastern Maryland, from the Delaware to the Virginia border. Major cities/towns and administrative areas include Ocean City, Berlin, Bishopville, and Assateague Island. Figure 19 presents the general locations of the MD1 risk areas.

MD1_A: Ocean Pines Area

MD1_A includes an area in Worcester County to the northwest of Ocean City, north of Route 90 and surrounding the St. Martin River. The closest town is Bishopville, to the north. The area includes mostly residential properties, including portions of the Ocean Pines community. The area was flagged for high risk due to its level of infrastructure, population density, and social vulnerability. Within the hotspot are two fire stations, a cellular tower, and numerous residential properties. At least half of the hotspot lies within the Cat2 MOM. Almost the entire coastline within the hotspot is rated as having high vulnerability per the U.S. Geologic Survey (USGS) Coastal Vulnerability Index (CVI). The coastline is very susceptible to tide and wave action. A moderate level of erosion is also present.

MD1_B: West of Ocean City

MD1_B encompasses an area in Worcester County directly west of Ocean City, along Route 50. Tributaries include Herring Creek, Jenkins Creek, Perch Gut, and Mud Creek. The presence of Route 50 within the areas is significant, as it is designated as a primary hurricane evacuation route. The area is noted as having high risk due to the level of infrastructure, population density, and social vulnerability. Within the hotspot are two cellular towers, two electric substations, a fire department, two rail road bridges, and a school within the national shelter system. The area almost entirely lies within the Cat2 MOM. Coastal vulnerability per the USGS CVI ranges from moderate to very high within the hotspot area. Areas to the western extent are rated very high for tide and wave action, as well as erosion.

MD1_C: Ocean City

MD1_C includes Ocean City in Worcester County, from the inlet to the northernmost extent within the state. The area includes both the ocean side and bay side (Isle of Wright Bay and Assawoman Bay). Ocean City has relatively high risk due to the level of infrastructure, population density and social vulnerability. Within the delineated risk area are two cellular towers, four electric substations, multiple fire departments and law enforcement offices, two urgent care facilities, a local Emergency Operations Center (EOC), and at least five properties within the national shelter system. Both the bayside and ocean side of Ocean City are susceptible to inundation, mostly within the Cat2 MOM. Coastal vulnerability ranges from moderate (bayside) to high (ocean side) within the risk area. Both ocean side and bayside areas are rated high for tide and wave action.

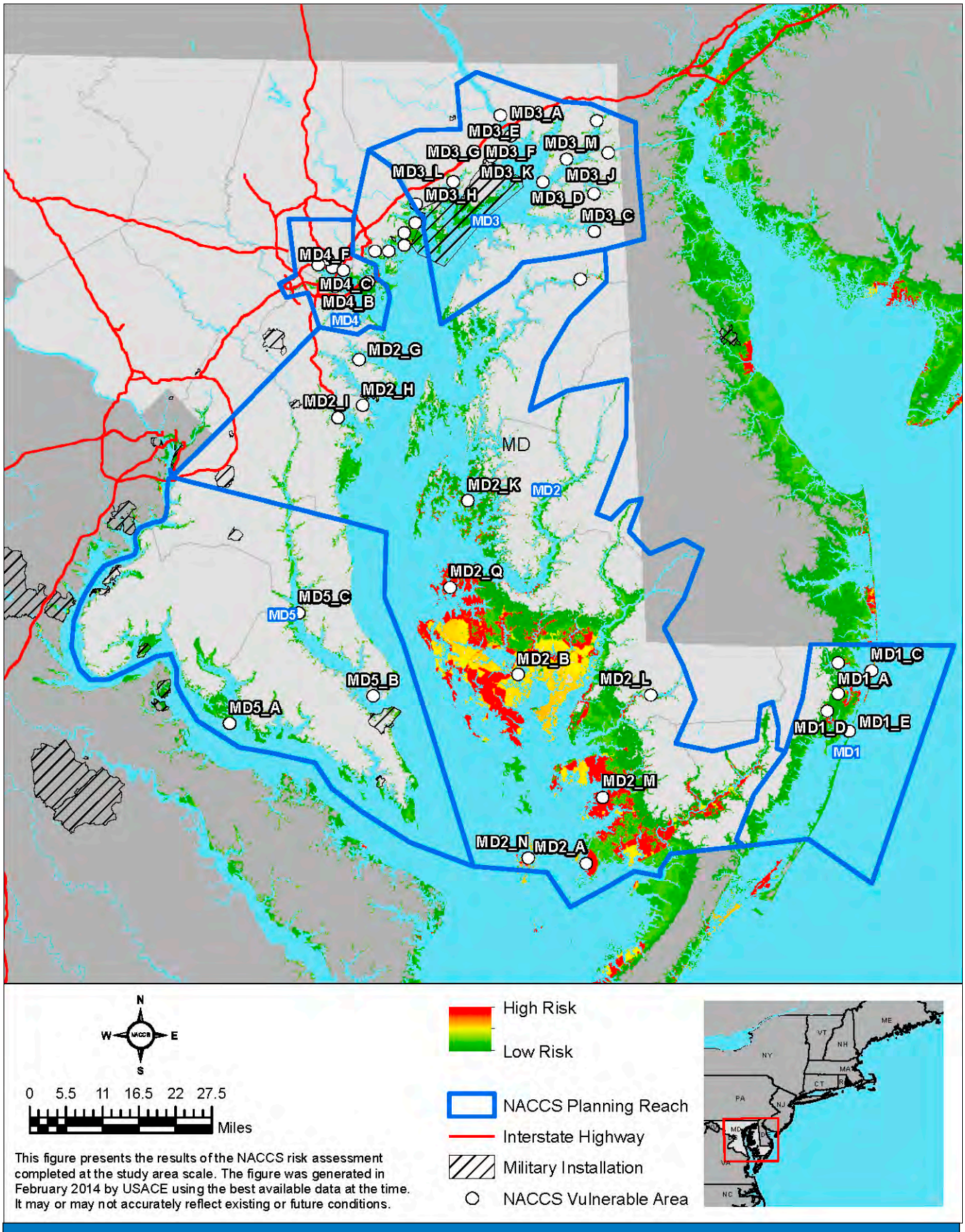

Figure 18. Risk Areas in the State of Maryland

The Atlantic Coast of Maryland Hurricane Shoreline Protection Project is a Federal storm risk reduction project that protects the ocean coast of Ocean City, Maryland. Constructed from 1990-1992, it provides: a sheetpile/concrete bulkhead and seawall along the Ocean City boardwalk for about 1.4 miles from 4th to 27th street; the placement of about 3.6 million cubic yards of sand along the Ocean City coastline to widen and raise the beach profile for 8.3 miles from 3rd Street, north to the Maryland-Delaware state line with an additional 0.3 mile transition into Delaware; and, the construction of a vegetated sand dune for 6.9 miles from 27th Street, north to just beyond the MD-DE state line. It also provides for periodic beach re-nourishment and monitoring over the 50-year project life (1994-2044).

MD1_D: Berlin

MD1_D is the area east of Route 113 and the Town of Berlin, also located in Worcester County. Trappe Creek is the main tributary within the area of note. This particular area rates higher in risk due to infrastructure, population density and social vulnerability in particular. Within the vicinity is a cellular tower.

MD1_E: Northern Assateague Island

MD1_E includes the northern portion of Assateague Island in Worcester County, Maryland. Assateague Island is within the boundary of Assateague Island National Seashore, a unit of the National Park Service (NPS). The risk area includes land owned and operated by the National Park Service and the Maryland Department of Natural Resources, Assateague Island State Park. The southern portion of the island, not included in the risk area, is owned by the NPS. This area, per NPS policy, may be allowed to breach; therefore, identification of measures is not necessary. The risk area includes both the ocean side and bayside (Sinepuxent bay). Assateague Island is identified as a relatively high risk area due to the environmental resources and critical habitat it contains. The island also acts as a barrier to the coastal communities to the west. The coastline along northern Assateague is rated moderate to very high according to the USGS CVI. The ocean side in particular is susceptible to tide and wave action, as well as a very high erosion rate.

Northern Assateague Island is the focus of the Federal Assateague Island Restoration project which is designed to restore longshore sediment transport that was interrupted by the construction of jetties at the Ocean City inlet in 1934. In 2002 restoration of the beach profile was completed on part of the northern portion of the island and a low storm-berm was also constructed. Beginning in 2003 25 years of mobile sand bypassing was begun using a hopper dredge to place sand in the nearshore zone of Assateague Island.

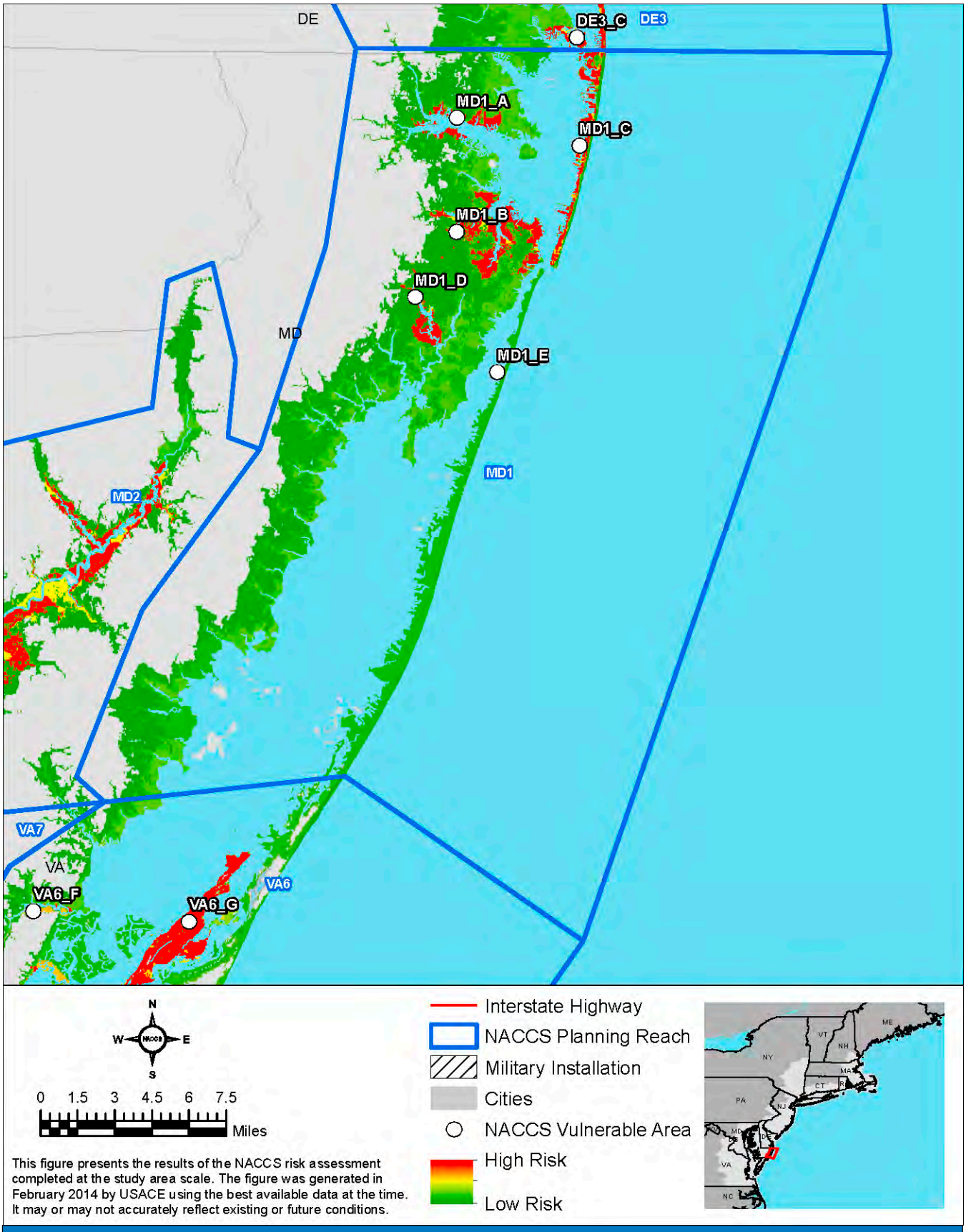

Figure 19. MD1 Risk Areas

Reach: MD-2

MD2 Includes a large portion of the state, extending across portions of Baltimore, Anne Arundel, Dorchester, Worcester, and Somerset counties. This reach includes the existing USACE Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island and the planned Mid-Chesapeake Bay Island ecosystem restoration project. Figures 20 and 21 present the general locations of the MD2 risk areas.

MD2_A: Crisfield

MD2_A encompasses Crisfield, and portions of James Island and Cedar Island, within Somerset County. Major tributaries include the Little Annemessex River, Jenkins Creek and Back Creek. The area is highlighted due to many factors, including environmental risk, social vulnerability, and patches of infrastructure/population density within the town. Within the risk area are a hospital, nursing home, electric generators/substations, cellular towers, fire and law enforcement, a ferry port, and multiple national shelters. The area is almost entirely inundated by the Cat2 MOM. According to the USGS CVI, the area identified is rated very high in regards to coastal vulnerability. The shoreline has very high tide and is extremely susceptible to erosion. The City of Crisfield experienced extensive damages from Hurricane Sandy surge into the harbor. According to FEMA, approximately 10 homes were destroyed, 320 incurred major damages, and 215 incurred minor damages with another 375 affected by Hurricane Sandy (Maryland, 2013). The City of Crisfield expressed interest to USACE to investigate coastal flood risk under the Continuing Authorities Program Section 103 authority.

MD2_B: Blackwater

MD2_B includes the Blackwater area within Dorchester County and just south of Cambridge. The area includes Fishing Creek, Hooper's Island, Fishing Bay, and Nanticoke to the east. Blackwater National Wildlife Refuge is a highly valuable resource within the MD2 reach and North Atlantic region. The area is very susceptible to impacts from SLC. The area is relatively high risk due to environmental resources such as critical habitat for waterfowl, as well as infrastructure to the northeastern portion along Route 50 (Vienna). The salt marsh associated with the Blackwater National Wildlife Refuge is recognized for international importance by the Ramsar Convention. The risk area also includes multiple rail road bridges, four fire stations, three electric substations, two national shelters, two cellular towers, a law enforcement office, and a wastewater treatment plant. According to the USGS CVI, the area identified is rated very high in regards to coastal vulnerability. The shoreline has very high tide and is extremely susceptible to erosion.

MD2_C: Essex

MD2_C includes areas around the Back River in Essex within Baltimore County. Smaller tributaries within the risk area include Deep Creek, Back Creek, and Northeast Creek. The area is highlighted as relatively high risk due to infrastructure and population density, as well as high social vulnerability. The area is mainly residential but also has transportation access points, such as a bus station and rail road bridges. According to USGS CVI the shoreline within the hotspot is susceptible to very high tide and moderate wave action.

MD2_D: Middle River West

MD2_D includes the area of Middle River in Baltimore County. The major tributary is Middle River, with smaller tributaries being Hopkins Creek, Norman Creek and Hogpen Creek. The area is relatively high risk due to high infrastructure and population density, as well as social vulnerability. The area within

potential inundation zones includes residential properties, an airport, and industrial properties. According to USGS CVI the shoreline within the hotspot is susceptible to very high tide and moderate wave action in regards to coastal vulnerability.

MD2_E: Middle River East

MD2_E includes the northern portion of Middle River, particularly the Saltpeter Creek area in Baltimore County. The area is highlighted as relatively high risk due to infrastructure, particularly northeast corridor rail road tracks.

MD2_F: Gunpowder Falls

MD2_F includes an area in Baltimore County surrounding Gunpowder Falls State Park, as well as a portion of the park itself. Major tributaries include Gunpowder River, Bird River and Railroad Creek. The area is highlighted as relatively high risk due to its infrastructure. Critical infrastructure within the risk area includes two nursing homes and a railroad bridge. Many residential areas also located here. Many of these areas are at risk based on the Cat2 MOM. According to the USGS CVI the shoreline experiences very high tides and is susceptible to moderate wave action.

MD2_G: Severna Park

MD2_G is a mainly residential area near Severna Park in Anne Arundel County. The area is just north of Anne Arundel Community College and along the Magothy River. The area is highlighted as relatively high risk due to its high infrastructure and population density. The area is mainly residential. According to the USGS CVI the shoreline experiences very high tides and is susceptible to moderate wave action.

MD2_H: Annapolis

MD2_H includes the Annapolis shorelines in Anne Arundel County. There are several tributaries in the area, including the Severn River and the Chesapeake Bay proper. The area is relatively high risk due to its infrastructure and population density levels, as well as higher social vulnerability. Of note in the area are multiple rail road bridges, a nursing home, urgent care facility, and the U.S. Naval Academy. The City of Annapolis also includes a historic district. There are many residential neighborhoods near or along the shoreline. According to the USGS CVI the shoreline experiences very high tides and is susceptible to moderate wave action.

MD2_I: Edgewater

MD2_I encompasses the areas of Riva and Edgewater in Anne Arundel County. Major tributaries include the South River, Glebe Bay, and Beards Creek. The area is relatively high risk due to its infrastructure and population density levels, as well as higher social vulnerability. The area of inundation includes mostly residential areas. According to the USGS CVI the shoreline experiences very high tides and is susceptible to moderate wave action.

MD2_K: St. Michaels/Easton

MD2_K includes the St. Michaels and Easton areas in Talbot County. Much of the coastline is directly on the Chesapeake Bay, and the Choptank and Miles Rivers. The area is relatively high risk due to high levels of infrastructure and population density, as well as very high social vulnerability, and environmental resources. Within inundation zones are electric substations, national shelters, two fire stations, a police station, cellular tower, and transportation infrastructure including rail road bridges and

ferry ports. According to the USGS CVI much of the southernmost shoreline experiences very high tides and is susceptible to moderate wave action, as well as very high levels of erosion. Shorelines to the north, along the Miles River are susceptible to very high tides and moderate wave action, but are not as susceptible to erosion.

MD2_L: West Salisbury

MD2_L includes areas west of Salisbury, along the Wicomico River in Wicomico County. The area is considered relatively high risk due to high levels of infrastructure and population density, as well as high social vulnerability. Within inundation zones are oil storage facilities, a fire station, and numerous transportation points/infrastructure including rail road bridges, ferry ports, and bus stations.

MD2_M: Princess Anne/Pocomoke/Snow Hill

MD2_M includes the towns of Princess Anne, Pocomoke City, and Snow Hill within Worcester and Somerset counties. The risk area includes areas north and west of Crisfield and much of the shoreline is directly on the Chesapeake Bay. The area is considered relatively high risk due to high levels of infrastructure and population density, as well as high social vulnerability. Within inundation zones are eight law enforcement offices, seven national shelters, five cellular towers, four electric substations, three fire stations, two prisons, an Emergency Operations Center (EOC), a nursing home, and a power generation plant. Additionally, the risk area includes transportation infrastructure, mainly rail road bridges. According to the USGS CVI, the area identified is rated very high in regards to coastal vulnerability. The shoreline has very high tide, moderate wave action and is extremely susceptible to erosion.

MD2_N: Smith Island

MD2_N includes Smith Island in Somerset County. The island is surrounded by the Chesapeake Bay and lies on the Maryland-Virginia border. There is an existing USACE project on Smith Island that is authorized but not yet constructed. The area is deemed relatively high risk based on a few factors. The northern portion of the island has environmental resources and while infrastructure and population density is relatively low, social vulnerability is high. Some critical infrastructure includes three electric generation units, an electric substation and a power generation plant, as well as two fire stations and a few transportation points of importance (a ferry and bridge). According to the USGS CVI, the area identified is rated very high in regards to coastal vulnerability. The shoreline has very high tide, moderate wave action and is extremely susceptible to erosion.

MD2_O: Chester River

MD2_O covers a portion along the Chester River from Chestertown to Millington in Queen Anne's and Kent counties. The area is considered relatively high risk due to its social vulnerability and pockets of infrastructure. The area is primarily residential.

MD2_Q: Cambridge

MD2_Q includes the town of Cambridge and areas along the Choptank River in Dorchester County. The major tributary is the Choptank River. The area is relatively high risk based on a few factors. The area has some environmental resources of importance, pockets of higher infrastructure and population density, as well as higher social vulnerability. Some critical infrastructure in the potential inundation areas includes five fire stations, three national shelters, a hospital, two bus stations, four bridges, and

an electric substation. According to the USGS CVI, the area identified is rated very high in regards to coastal vulnerability. The shoreline has very high tide, moderate wave action and is extremely susceptible to erosion.

MD2_R: Bowleys Quarters

MD2_R includes Bowleys Quarters, adjacent to Martin State Airport in Baltimore County. The major tributary is Seneca Creek. This area is identified as relatively high risk due to pockets of infrastructure and population density, as well as social vulnerability. The area has residential and industrial properties. Critical infrastructure includes a fire department, as well as three electric generation units, an electric substation and a power generation plant. According to the USGS CVI the shoreline experiences very high tides and is susceptible to moderate wave action. Bowleys Quarters has a history of flooding during storm events and was severely impacted during Hurricane Isabel in 2003.

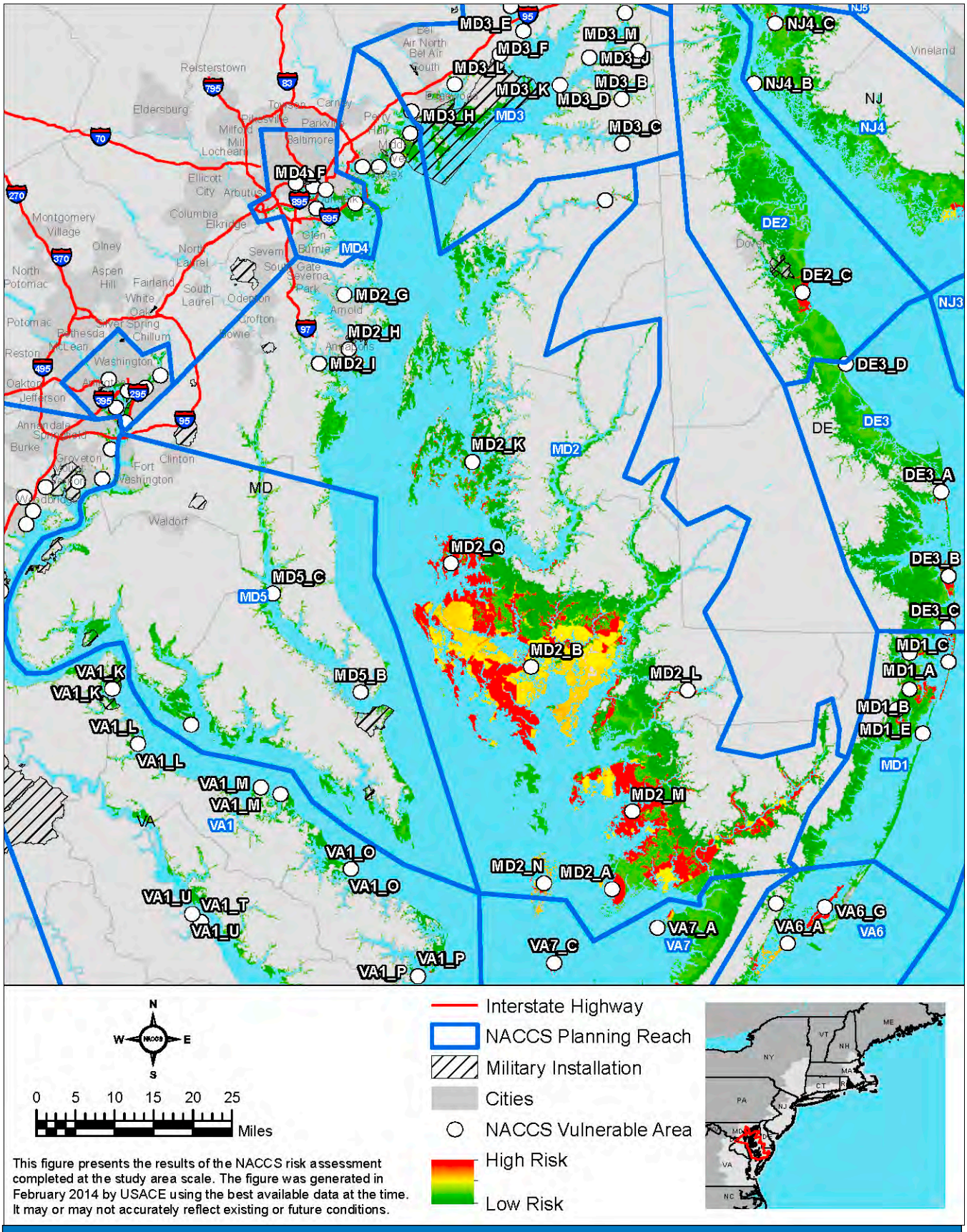

Figure 20. MD2 Risk Areas

Reach: MD-3

MD3 includes areas in the northeastern Maryland, within Harford and Cecil counties. Figure 21 presents the general locations of the MD3 risk areas.

MD3_A: Port Deposit

MD3_A includes the Town of Port Deposit within Cecil County, Maryland. It is located on Route 222, between the granite cliffs of Bainbridge, and the east bank of the Susquehanna River. It is located south of the Conowingo Dam. The area is noted as having relatively high risk due to high levels of infrastructure and social vulnerability. Critical infrastructure in the area includes a fire station and national shelter.

MD3_B: Cecilton

MD3_B and D include areas near Cecilton, Maryland in Cecil County, Maryland. The area includes a coastal community and marina along the Bohemia and Little Bohemia Rivers, and is served by a primary north-south state road, Route 213.

MD3_C: Galena

MD3_C includes the Town of Galena in Kent County, Maryland. DE. The area includes several marinas along the Sassafras River.

MD3_D and E: Removed (duplicates of MD3_D and MD3_E)

MD3_F: Havre De Grace/Perryville

MD3_B includes the Town of Havre De Grace and the Town of Perryville in Harford and Cecil counties, Maryland. The Towns of Havre De Grace and Perryville are located near I-95 between Baltimore, MD and Wilmington, DE. The towns are separated by the Susquehanna River and both have shoreline within the Chesapeake Bay. The area is noted as relatively high risk due to the levels of infrastructure and social vulnerability, in addition to some areas of environmental risk. Critical infrastructure within inundation zones includes a rail road bridge, fire station, and nursing home. According to the USGS CVI shorelines along the bay in the risk area are susceptible to very high tide and moderate wave action.

MD3_G: Aberdeen

MD3_C includes an area within Aberdeen, Maryland. The U.S. Army, Aberdeen Proving Ground (APG) is included in the risk area, and is within close proximity to U.S. Route 40, Interstate 95, Amtrak and CSX rail lines. In addition to APG, there risk area includes residential areas. The area is relatively high risk due to its level of infrastructure/population density and social vulnerability. According to the USGS CVI the shorelines within the hotspot are susceptible to very high tide and moderate wave action.

MD3_H: Joppatowne

MD3_E includes an area in the town of Joppatowne in Southwestern Harford County, Maryland. Joppatowne is a subset of the larger Joppa area, located near Interstate 95 and Route 40. The main tributaries are the Gunpowder River and Little Gunpowder River. The area is relatively high risk due to its levels of infrastructure and population density, as well as social vulnerability. Critical infrastructure within the potential inundation zones includes a rail road bridge and electric substation. According to

the USGS CVI the shorelines within the hotspot are susceptible to very high tide and moderate wave action.

MD3_L: Abingdon/Belcamp

MD3_D is an area between the towns of Abingdon and Belcamp in Harford County, Maryland. Abingdon lies 25 miles northeast of Baltimore on Maryland Route 7, near Bush River, between MD 24 and Interstate 95. The area is relatively high risk due to its level of infrastructure and population density, as well as social vulnerability. Critical transportation infrastructure lies within potential inundation zones, specifically four rail road bridges. According to the USGS CVI the shorelines within the hotspot are susceptible to very high tide and moderate wave action.

MD3_I: Elkton

MD3_F includes areas within the town of Elkton in Cecil County, Maryland. Elkton is located near Route 40 and Interstate 95, located at the northeastern portion of the Chesapeake Bay proper. The main tributaries are the Elk River and Little Elk Creek. The area is relatively high risk due to its higher levels of infrastructure and population density, as well as social vulnerability. Critical infrastructure that lies within the risk area includes multiple rail road bridges and a prison. According to the USGS CVI, the shorelines are susceptible to very high tide and moderate wave action, as well as very high erosion.

MD3_K: Elk Neck

MD3_K includes a coastal community in Cecil County, Maryland near Elk Neck State Park adjacent to the East and Elk Rivers. The area is served by State Route 272, which is the only vehicle access to the community.

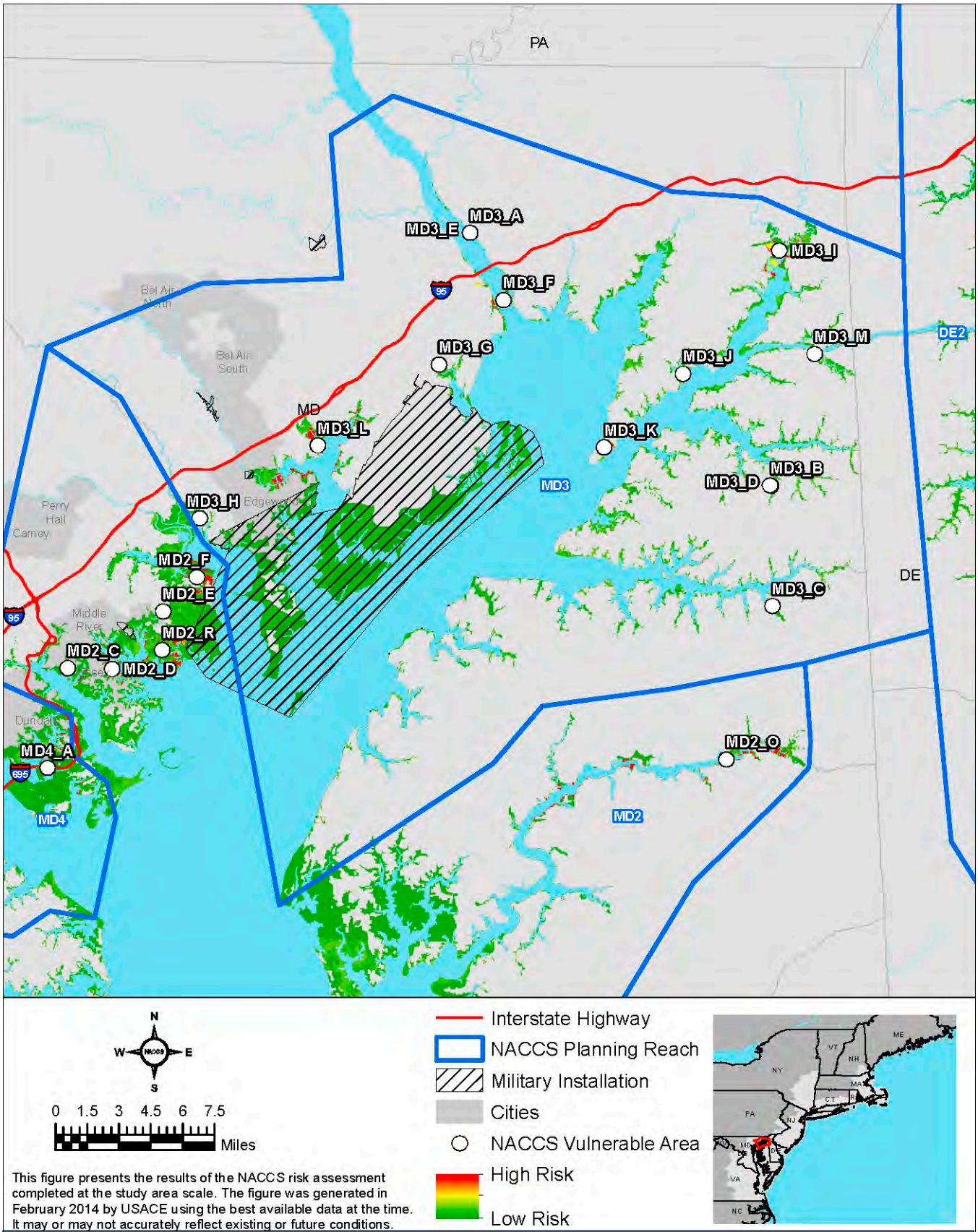

Figure 21. MD3 Risk Areas

Reach: MD-4

Planning Reach MD4 includes areas mainly within the City of Baltimore, but also some areas within Anne Arundel and Baltimore Counties. Figure 22 presents the general locations of the MD4 risk areas.

MD4_A: Fort Howard/Edgemere

MD4_A includes an area just southeast of Dundalk in Baltimore County, Maryland. The area is in the town of Fort Howard and the Edgemere area near Sparrows Point and the shuttered Bethlehem Steel mill, just south of Baltimore. The Sparrows Point shipyard site was also a major center for shipbuilding and ship repair. The area was noted as relatively high risk due to its high levels of infrastructure and population density, as well as social vulnerability. The area includes residential and industrial areas. Critical infrastructure in the potential inundation areas includes many electric generation units (12), power generation plants (2) and electric substations (6), two fire stations and law enforcement offices, a natural gas import terminal, bus stations (2), ports (12) and a rail road bridge. According to the USGS CVI within the risk area are susceptible to very high tide and moderate wave action.

MD4_B: Curtis Bay

MD4_B includes the area of Curtis Bay in south Baltimore. Curtis Bay is one of the southernmost neighborhoods in Baltimore City and is adjacent to Anne Arundel County along Maryland Route 2. The Curtis Bay neighborhood is located in highly industrialized waterfront area. The area was deemed relatively high risk due to its higher levels of infrastructure and population density, as well as social vulnerability. Critical infrastructure that lies within potential inundation zones includes multiple ports, three rail road bridges and a road tunnel. It also includes many electric generation units (4), a power generation plant and an electric substation. According to the USGS CVI the shorelines within the risk area are susceptible to very high tide and moderate wave action.

MD4_C: Fort McHenry

MD4_C includes the Fort McHenry area within the City of Baltimore. Fort McHenry is on the Locust Point peninsula, just southeast of the Baltimore's Inner Harbor area. Fort McHenry sits right along Interstate 95 with the Patapsco River to the south. Fort McHenry National Monument and Shrine is owned by the National Park Service. Adjacent to Fort McHenry and within the risk area are facilities for the Baltimore Fire Department's marine unit, a USACE facility, and a Naval Reserve facility. The area was noted as relatively high risk mainly due to its high levels of infrastructure and population density, but also due to some pockets showing social vulnerability. Critical infrastructure that lies within potential inundation zones includes a fire station and law enforcement office, a road tunnel and two port facilities. According to the USGS CVI within the risk area, the shorelines are susceptible to very high tide and moderate wave action.

MD4_D: Baltimore Inner Harbor

MD4_D includes the neighborhoods of Federal Hill, Fells Point, Canton and Baltimore's Inner Harbor area. Inundation zones extend several blocks north of the Inner Harbor, along Route 83, through central Baltimore. Patapsco River is the major tributary to the south. The area was noted as relatively high risk due to its high levels of infrastructure and population density, as well as social vulnerability. Critical infrastructure that lies within potential inundation zones includes a law enforcement office, wastewater treatment plant, port, a few rail stations and two electric substations. According to the

USGS CVI within the hotspot, the shorelines are susceptible to very high tide and moderate wave action.

MD4_E: Gwynns Falls

MD4_E includes an area in western Baltimore City, called Gwynns Falls. The area is split by Interstate 395 and also includes Interstate 95 to the south. The area includes industrial and residential neighborhoods, as well as M&T Bank Stadium. The area was noted as relatively high risk due to its high levels of infrastructure and population density, as well as social vulnerability. Critical infrastructure that lies within the risk area includes rail road bridges, an electric substation, a law enforcement office and a petroleum terminal storage facility. According to the USGS CVI within the risk area, the shorelines are susceptible to very high tide and moderate wave action.

MD4_F: North Curtis Bay

MD4_F includes an industrial area east of Fort McHenry and north of Curtis Bay. Interstates 895 and 95 run through the area. The risk area is bound by the Inner Harbor to the west, Patapsco River to the south, and Colgate Creek to the east. The area was noted as relatively high risk due to its high levels of infrastructure, as well as social vulnerability. Critical infrastructure that lies within the risk area includes an electric substation, law enforcement office and a petroleum terminal storage facility. According to the USGS CVI within the risk area, the shorelines are susceptible to very high tide and moderate wave action.

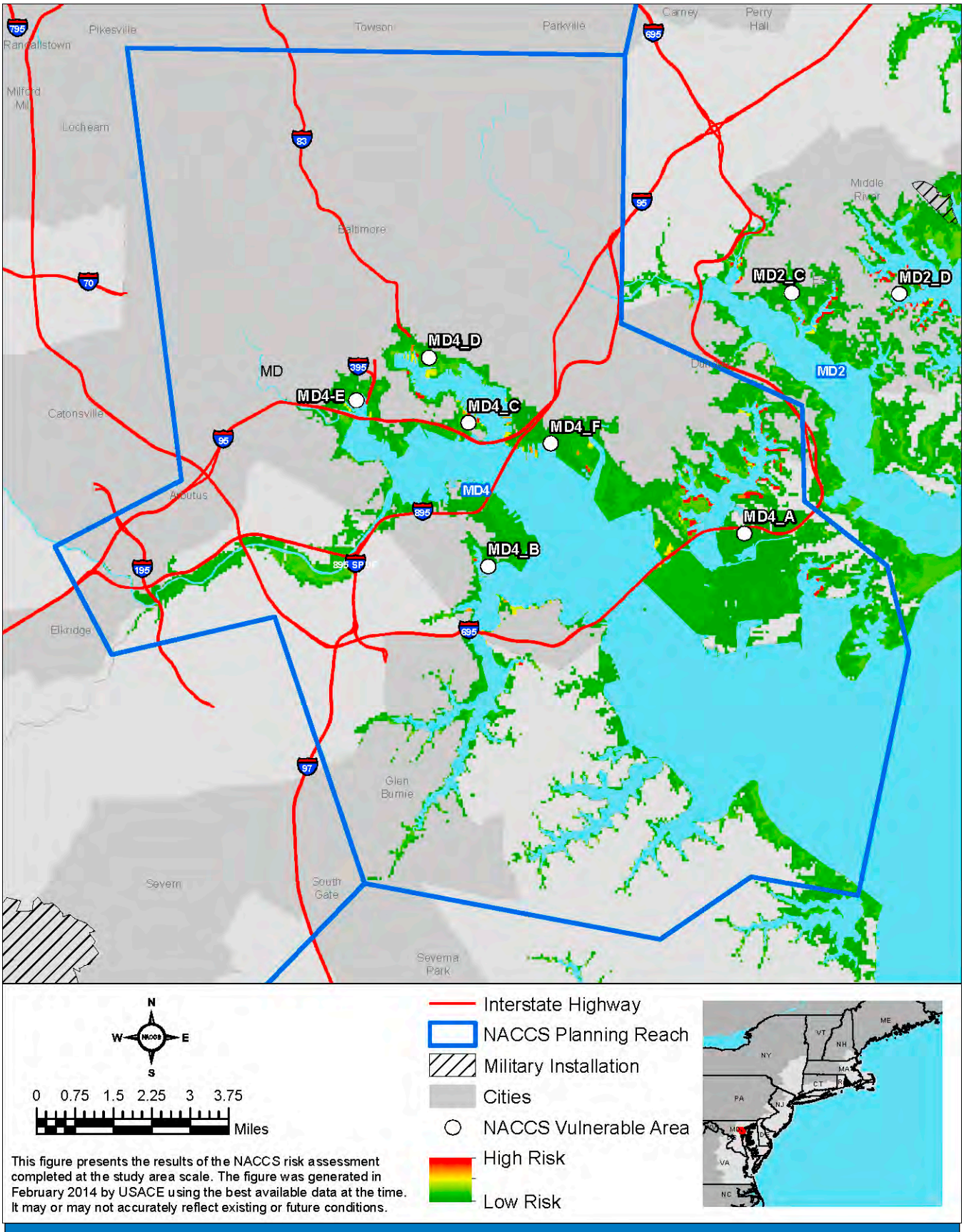

Figure 22. MD4 Risk Areas

Reach: MD-5

MD5 includes areas of Charles and St. Mary's Counties. Figure 23 presents the general locations of the MD5 risk areas.

MD5_A: Rock Point/Cobb Island

MD5_A is located southeast of St. Mary's County and east of Charles County. The risk area lies within Rock Point and Cobb Island which are located between Neale Sound and Wicomico River and surrounded by the Potomac River. The risk area lies entirely within the Cat 2 MOM. The area is primarily residential.

MD5_B: Town Creek/Solomons Island

MD5_B is located north of Town Creek and Solomons Island and lies within Mill Creek tributary of the Chesapeake Bay. The risk area includes the Naval Air Station Patuxent River. Nearly half of the risk area is located within the Cat 2 MOM. The area is relatively high risk due to its level of infrastructure.

MD5_C: Western Calvert County

MD5_C is located north of 231 and west of Calvert County. The area is surrounded by the Patuxent River. Nearly half of the risk area is located within the Cat 2 MOM. The area is primarily residential. The area is relatively high risk due to its level of infrastructure.

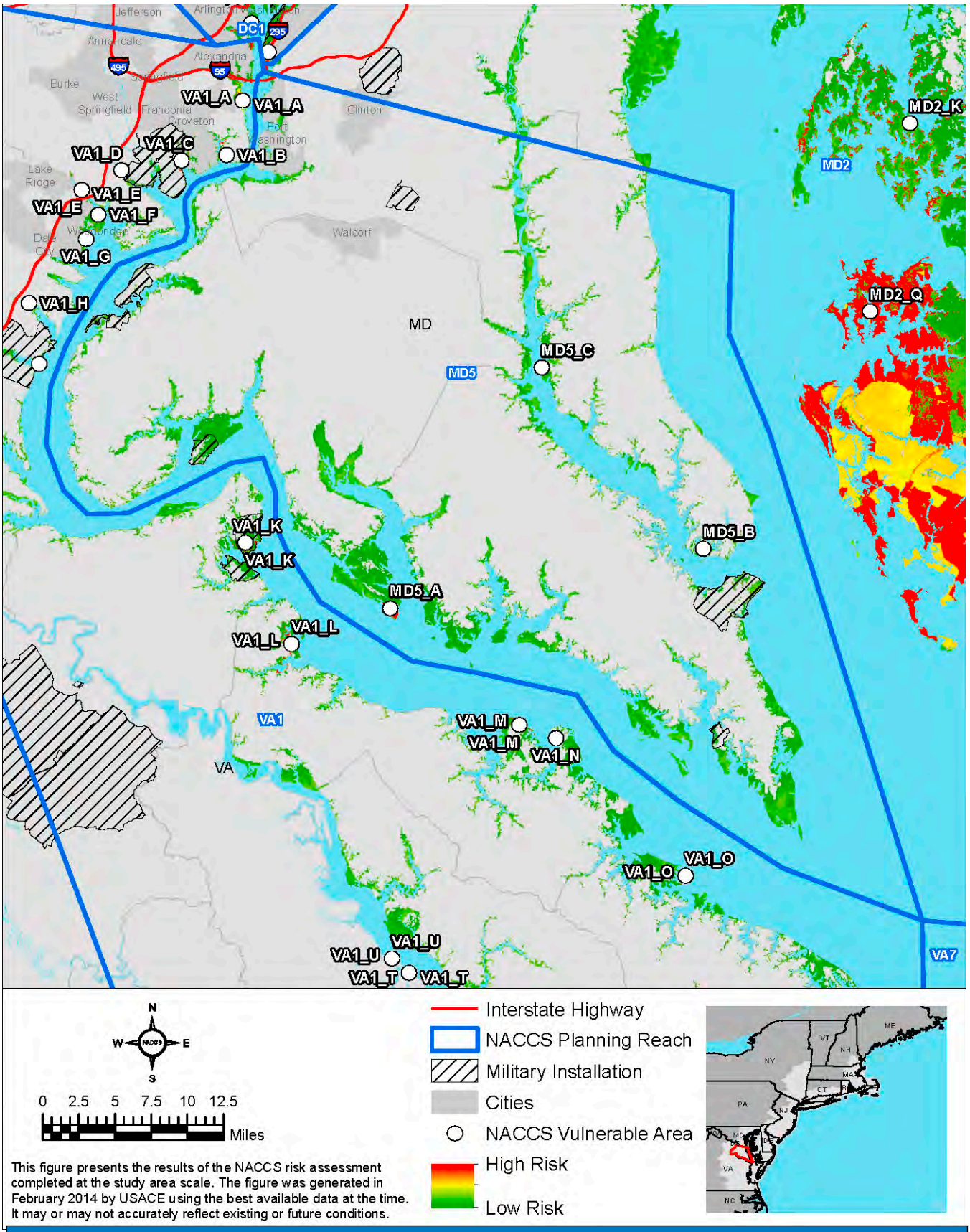

Figure 23. MD5 Risk Areas

VIII. Coastal Storm Risk Management Strategies and Measures

VIII.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 n.d.). Figure 24 presents the location and extent of each shoreline type in the State of Maryland. Table 3 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 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 the Framework, further evaluation of the results would be required at a smaller scale and with finer data sets. Figure 25 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.

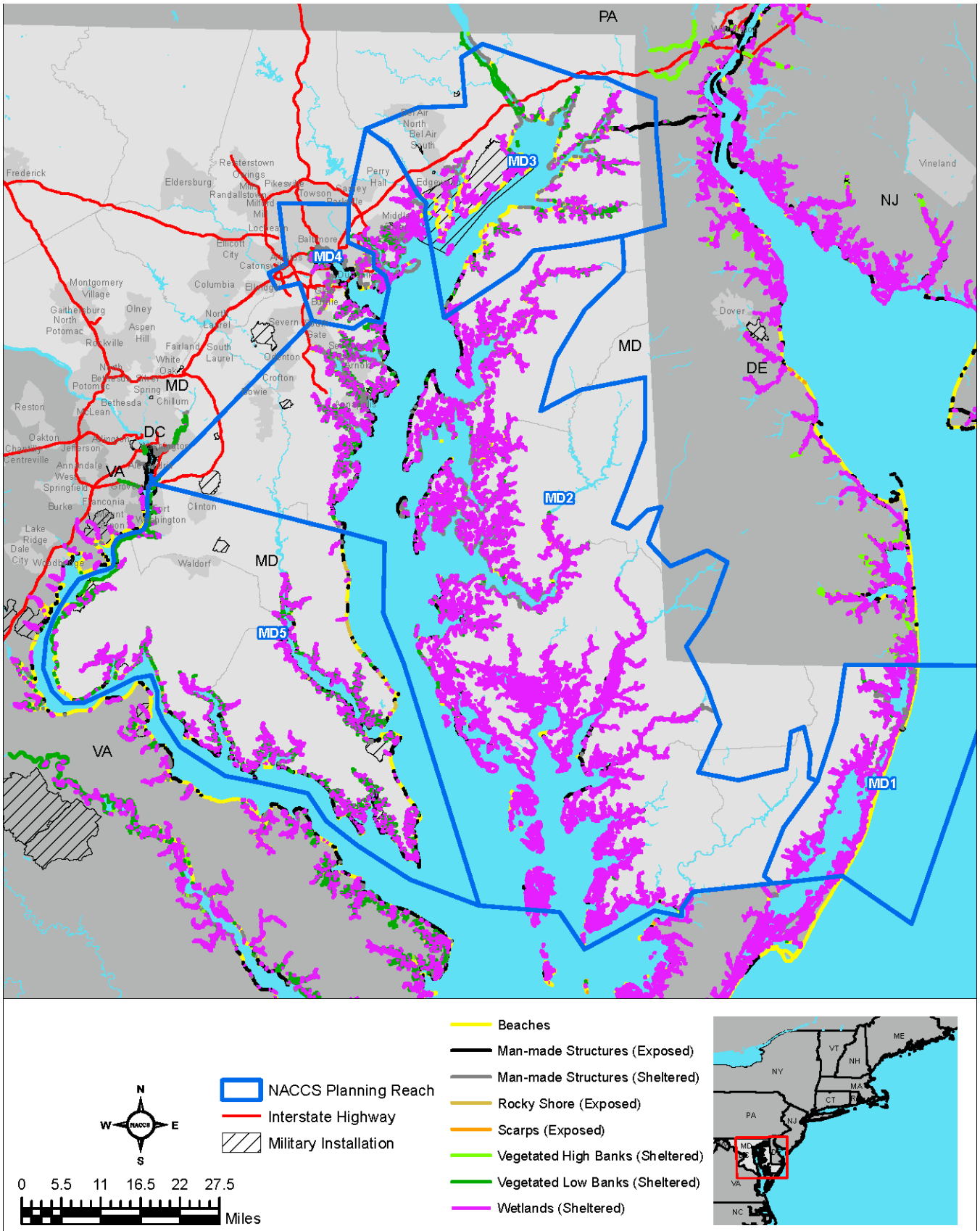

Figure 24. Shoreline Types for the State of Maryland

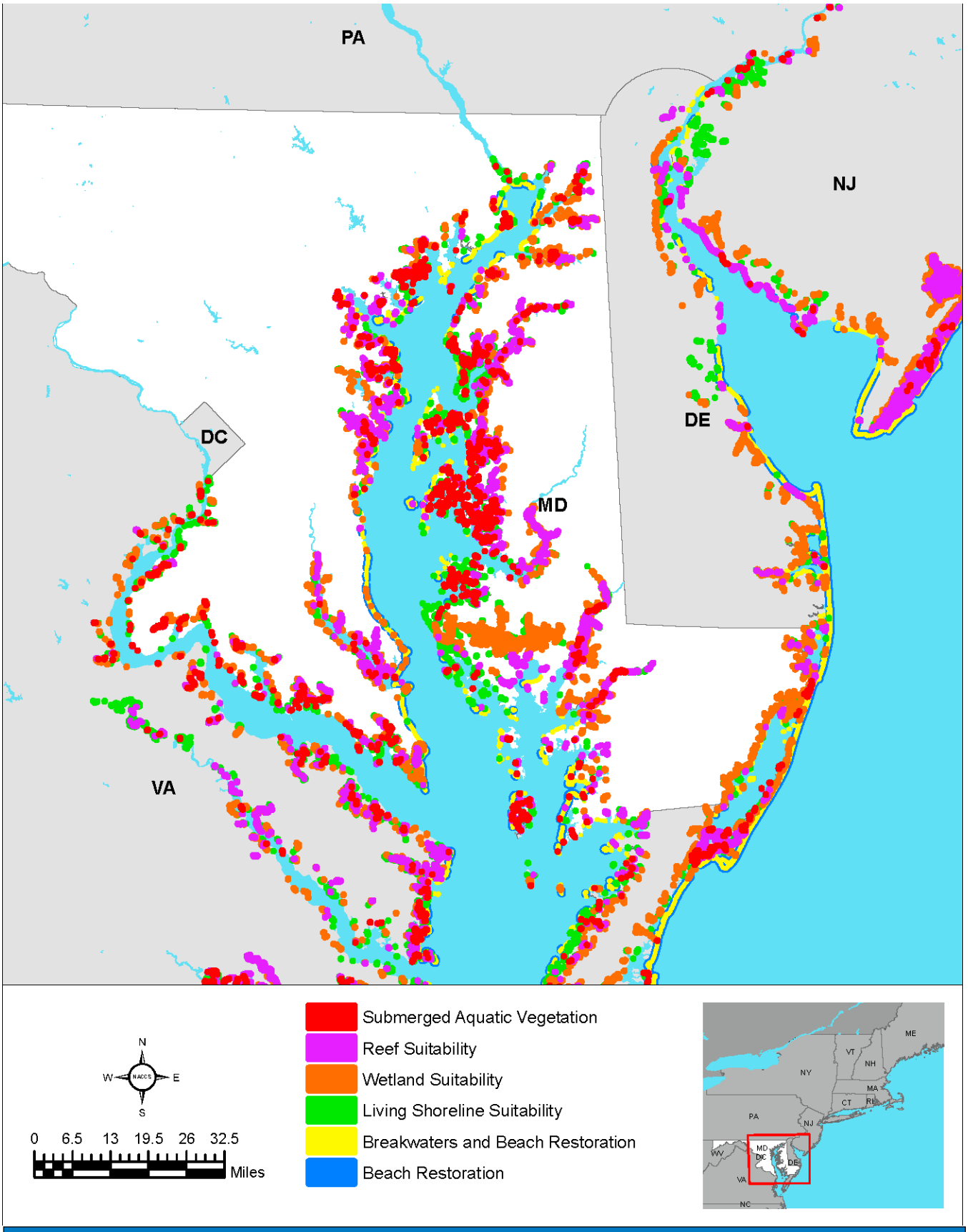

Figure 25. NNBF Measures Screening for the State of Maryland

Table 3. 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.*

Figures 26 through30 present the percentage of shoreline types for each of the five reaches in Maryland. Tables 4 through8 present the length in feet for each shoreline type.

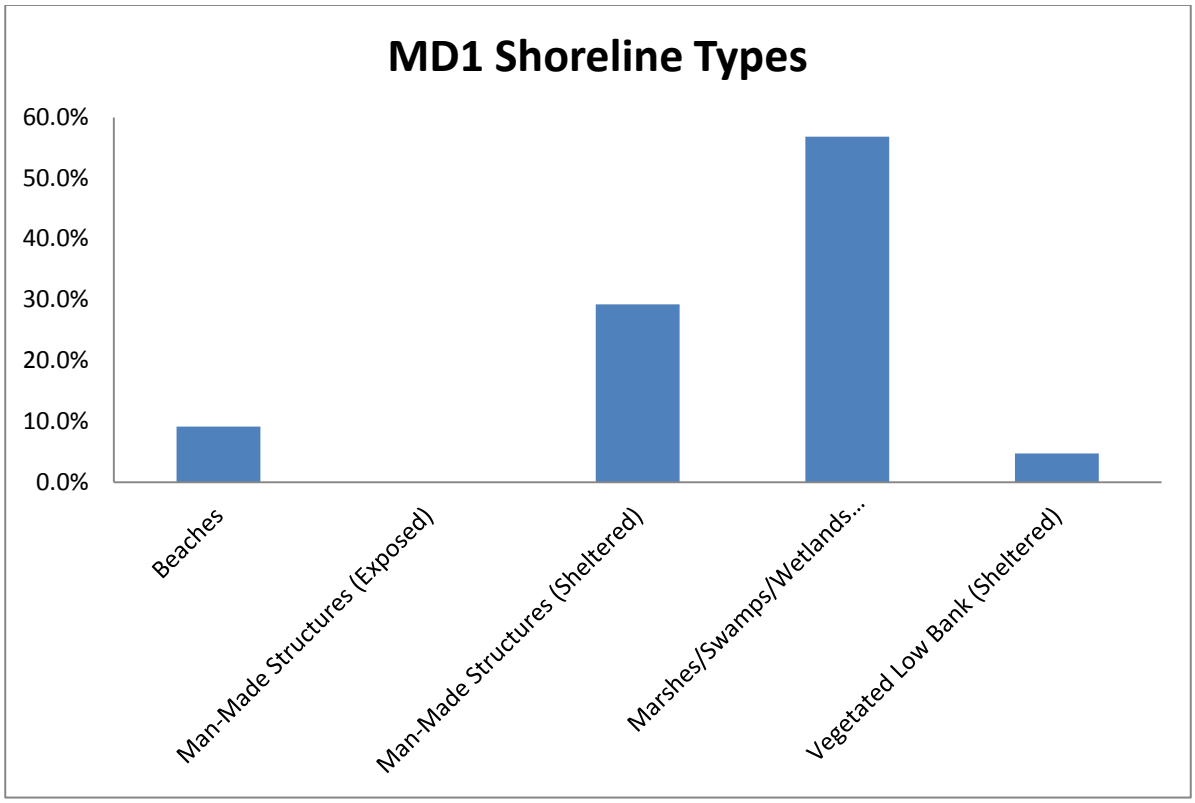

Figure 26. MD1 Shoreline Types

Table 4. MD1 Shoreline Type by Length(feet)

Sum of Shoreline Risk Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
MD1	**90,340**	**172**	**288,647**	**560,259**			**46,701**	**986,119**
MD1_A	171		30,763	75034			21,446	127,414
MD1_B	330		76,189	177075			15,361	268,955
MD1_C	30,537	24	179,646	81,867				292,074
MD1_D			589	40,305			9,432	50,326
MD1_E	59,302	148	1,460	185,978			462	247,350

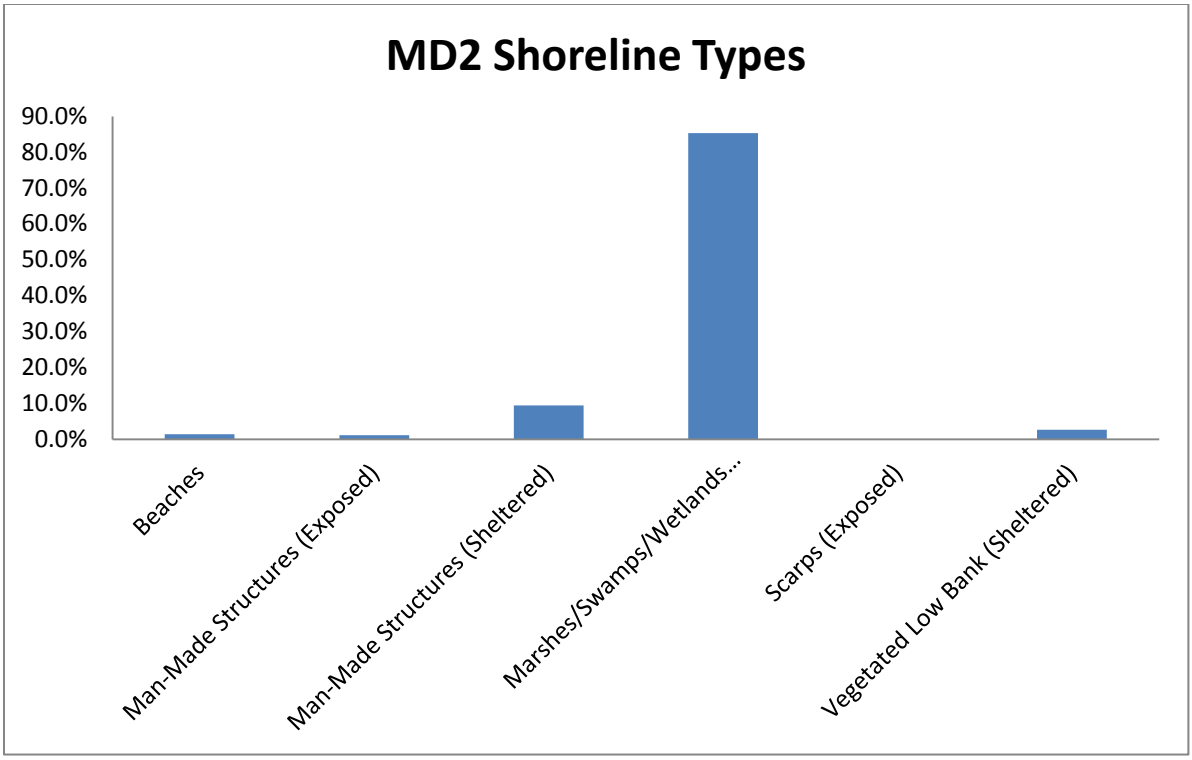

Figure 27. MD2 Shoreline Types

Table 5 MD2 Shoreline Type by Length (feet)

Risk Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
MD2	**210,658**	**171,448**	**1,421,190**	**12,684,228**	**450**		**406,406**	**14,894,380**
MD2_A		7,258	25,980	272,708				305,946
MD2_B	44,443	77,559	51,654	6,442,405			26,970	6,643,031
MD2_C			10,038	24,225			23,683	57,946
MD2_D	220		41,352	8,463			20,377	70,412
MD2_E			79	10,972				11,051
MD2_F	540		10,709	9,586				20,835
MD2_G	436		6,433	1,474			1,396	9,739
MD2_H	7,220	11,625	91,547	43,283			33,416	187,091
MD2_I	2,871		27,918	22,242			6,635	59,666
MD2_K	50,236	12,014	696,603	1,200,892	450		125,592	2,085,787
MD2_L	1,484		53,783	214,255				269,522
MD2_M	13,954	14,773	21,187	2,136,684			14,552	2,201,150
MD2_N	6,825	2,599	6,282	1,133,805				1,149,511
MD2_O	26,025		26,363	170,889			34,235	257,512
MD2_Q	56,404	45,620	282,957	950,730			119,550	1,455,261
MD2_R			68,305	41,615				109,920

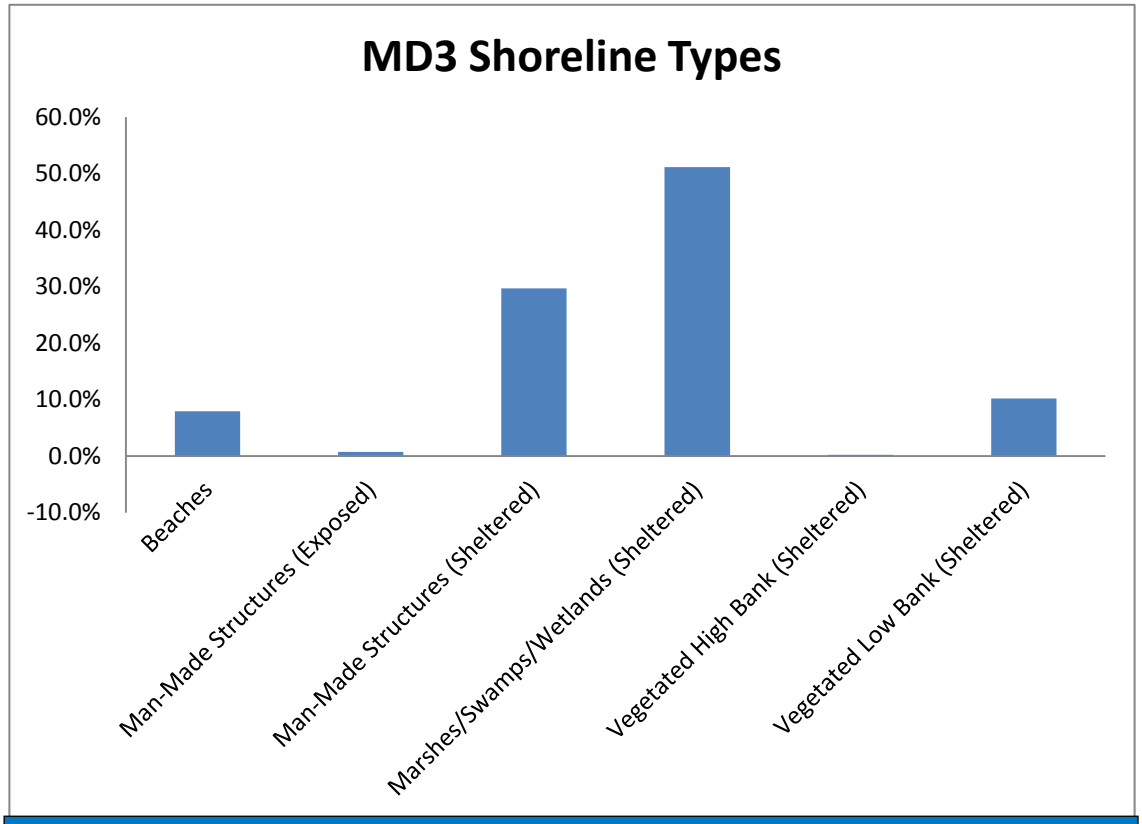

Figure 28. MD3 Shoreline Types

Table 6. MD3 Shoreline Type by Length(feet)

Risk Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
MD3	**27,074**	**2,542**	**101,998**	**173,868**		**788**	**34,783**	**339,866**
MD3_A			1,603					1,603
MD3_C							1,995	1,995
MD3_F	8,171		46,373	4,527		788	19,442	79,301
MD3_H			16,973	13,838				30,811
MD3_I				65,140			11,809	76,949
MD3_J	269			1,112			1,537	2,918
MD3_K	2,794		4,186	2,507				9,487
MD3_L	15,840		29,367	86,154				131,361
MD3_M		2,542	3,496	590				6,628

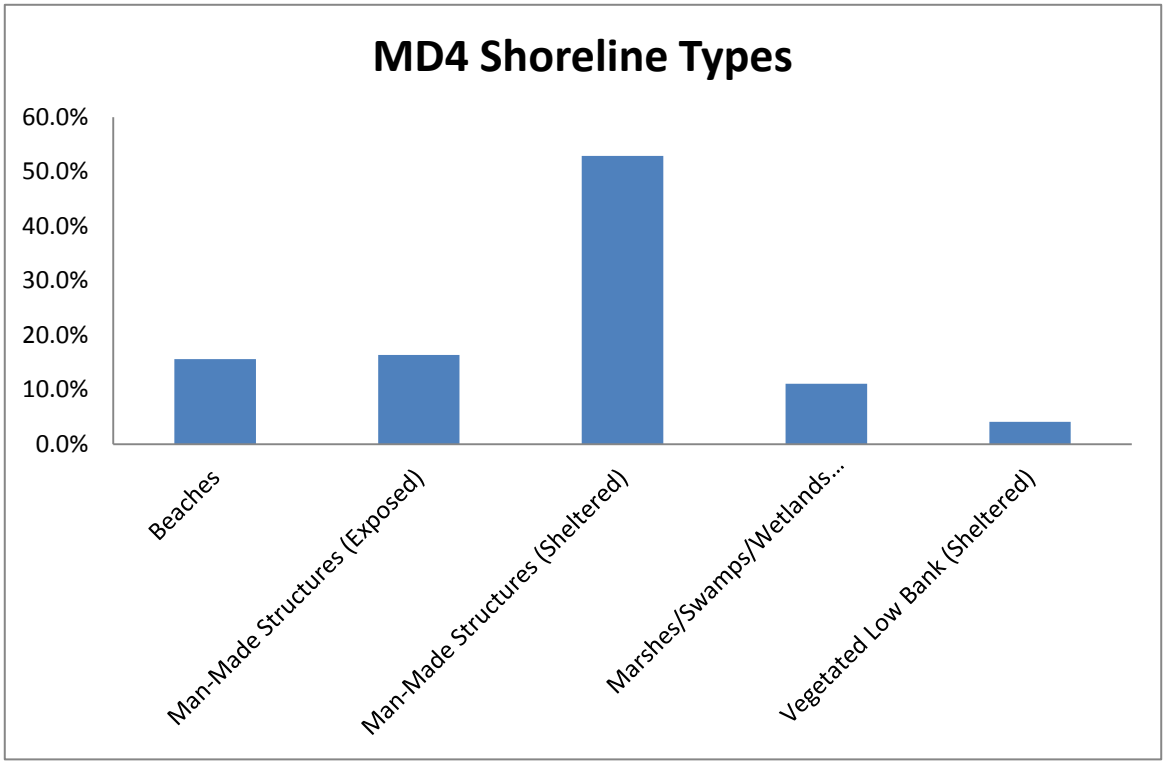

Figure 29. MD4 Shoreline Types

Table 7. MD4 Shoreline Type by Length(feet)

Risk Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
MD4	**73,237**	**76,761**	**248,358**	**52,152**			**19,245**	**469,753**
MD4_A	62,633	21,549	109,065	32,555			5,356	231,158
MD4_B	10,604	38,105	50,091	14,690			4,543	118,033
MD4_C		7,909	14,161	1,104				23,174
MD4_D			31,357					31,357
MD4_E			7,523	3,803			9,346	20,672
MD4_F		9,198	36,161					45,359

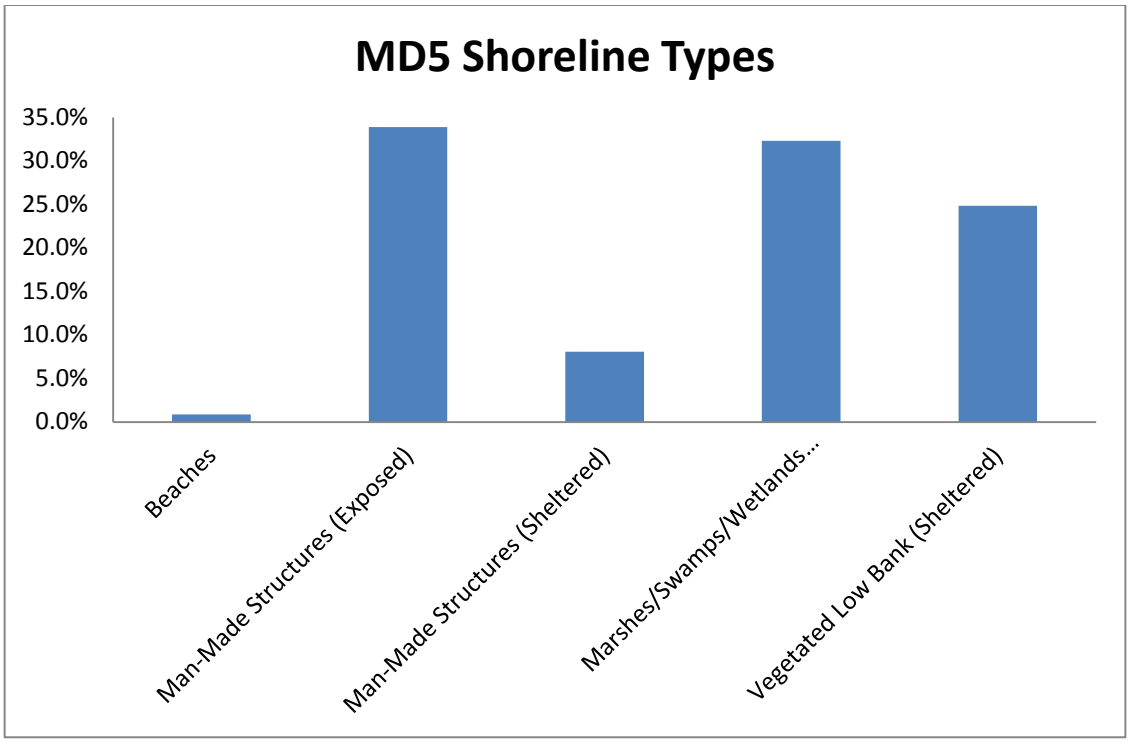

Figure 30. MD5 Shoreline Types

Table 8. MD5 Shoreline Type by Length (feet)

Risk Areas	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
MD5	**271**	**10,334**	**2,463**	**9,852**			**7,584**	**30,504**
MD5_A		10,134	2,199	8,899			4,356	25,588
MD5_B	37		264	880			3,228	4,409
MD5_C	234	200		73				507

VIII.2 Cost Considerations

Conceptual design and parametric cost estimates were developed for the various coastal storm risk management measures together with quantities and parametric costs (typically per linear foot of shoreline) 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. Additional information on the various measures is included in Appendix C – Planning Analyses.

IX. Tier 1 Assessment Results

Table 9 presents the results of the State of Maryland 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 9, 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 9 only presents the change in risk and the parametric unit cost estimates for structural measures, including NNBF.

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD1_A	Beaches	High	1	3	2								
MD1_A	Manmade Structures (Sheltered)	High					3	2	1				
MD1_A	Vegetated Low Banks (Sheltered)	High						2	1				
MD1_A	Vegetated Low Banks (Low)	Low				2				1			
MD1_A	Wetlands (Sheltered)	Low								1	3	4	2
MD1_B	Beaches	High	1	3	2								
MD1_B	Manmade Structures (Sheltered)	High					3	2	1				
MD1_B	Vegetated Low Banks (Sheltered)	High						2	1				
MD1_B	Vegetated Low Banks (Sheltered)	Low				2				1			
MD1_B	Wetlands (Sheltered)									1	3	4	2
MD1_C	Beaches	High	1	3	2								
MD1_C	Manmade Structures (Exposed)	High	1	3	2								
MD1_C	Manmade Structures (Sheltered)	High					3	2	1				
MD1_C	Wetlands (Sheltered)	Low								1	3	4	2
MD1_D	Manmade Structures (Sheltered)	High					3	2	1				
MD1_D	Vegetated Low Banks (Sheltered)	High						2	1				
MD1_D	Vegetated Low Banks (Sheltered)	Low				2				1			
MD1_D	Wetlands									1	3	4	2

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
	(Sheltered)												
MD1_E	Beaches		1	3	2								
MD1_E	Manmade Structures (Exposed)												
MD1_E	Man-made Structures (Sheltered)						3	2	1				
MD1_E	Vegetated Low Banks (Sheltered)	High											
MD1_E	Vegetated Low Banks (Sheltered)	Low											
MD1_E	Wetlands (Sheltered)	Low								1	3	4	2
MD2_A	Manmade Structures (Exposed)												
MD2_A	Manmade Structures (Sheltered)	High					3	2	1				
MD2_A	Wetlands (Sheltered)	Low								1	3	4	2
MD2_B	Beaches	High	1	3	2								
MD2_B	Manmade Structures (Exposed)												
MD2_B	Manmade Structures (Sheltered)	High					3	2	1				
MD2_B	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_B	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_B	Wetlands (Sheltered)	Low								1	3	4	2
MD2_C	Manmade Structures (Sheltered)	High					3	2	1				

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD2_C	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_C	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_C	Wetlands (Sheltered)	Low								1	3	4	2
MD2_D	Beaches	High	1	3	2								
MD2_D	Manmade Structures (Sheltered)	High					3	2	1				
MD2_D	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_D	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_D	Wetlands (Sheltered)	Low								1	3	4	2
MD2_E	Manmade Structures (Sheltered)	High					3	2	1				
MD2_E	Wetlands (Sheltered)	Low								1	3	4	2
MD2_F	Beaches	High	1	3	2								
MD2_F	Manmade Structures (Sheltered)	High					3	2	1				
MD2_F	Wetlands (Sheltered)	Low								1	3	4	2
MD2_G	Beaches	High	1	3	2								
MD2_G	Manmade Structures (Sheltered)	High					3	2	1				
MD2_G	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_G	Vegetated Low Banks (Sheltered)	Low				2				1			

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD2_G	Wetlands (Sheltered)	Low								1	3	4	2
MD2_H	Beaches	High	1	3	2								
MD2_H	Manmade Structures (Exposed)												
MD2_H	Manmade Structures (Sheltered)	High					3	2	1				
MD2_H	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_H	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_H	Wetlands (Sheltered)	Low								1	3	4	2
MD2_I	Beaches	High	1	3	2								
MD2_I	Manmade Structures (Sheltered)	High					3	2	1				
MD2_I	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_I	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_I	Wetlands (Sheltered)	Low								1	3	4	2
MD2_K	Beaches	High	1	3	2								
MD2_K	Manmade Structures (Exposed)												
MD2_K	Manmade Structures (Sheltered)	High					3	2	1				
MD2_K	Scarps (Exposed)	Low				2				1		3	
MD2_K	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_K	Vegetated Low	Low				2				1			

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
	Banks (Sheltered)												
MD2_K	Wetlands (Sheltered)	Low								1	3	4	2
MD2_L	Beaches	High	1	3	2								
MD2_L	Manmade Structures (Sheltered)	High					3	2	1				
MD2_L	Wetlands (Sheltered)	Low								1	3	4	2
MD2_M	Beaches	High	1	3	2								
MD2_M	Manmade Structures (Exposed)												
MD2_M	Manmade Structures (Sheltered)	High					3	2	1				
MD2_M	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_M	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_M	Wetlands (Sheltered)	Low								1	3	4	2
MD2_N	Beaches	High	1	3	2								
MD2_N	Manmade Structures (Exposed)												
MD2_N	Manmade Structures (Sheltered)	High					3	2	1				
MD2_N	Wetlands (Sheltered)	Low								1	3	4	2
MD2_O	Beaches	High	1	3	2								
MD2_O	Manmade Structures (Sheltered)	High					3	2	1				
MD2_O	Vegetated Low Banks (Sheltered)	High						2	1				

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD2_O	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_O	Wetlands (Sheltered)	Low								1	3	4	2
MD2_Q	Beaches	High	1	3	2								
MD2_Q	Manmade Structures (Exposed)												
MD2_Q	Manmade Structures (Sheltered)	High					3	2	1				
MD2_Q	Vegetated Low Banks (Sheltered)	High						2	1				
MD2_Q	Vegetated Low Banks (Sheltered)	Low				2				1			
MD2_Q	Wetlands (Sheltered)	Low								1	3	4	2
MD2_R	Manmade Structures (Sheltered)	High					3	2	1				
MD2_R	Wetlands (Sheltered)	Low								1	3	4	2
MD3_A	Manmade Structures (Sheltered)	High					3	2	1				
MD3_C	Vegetated Low Banks (Sheltered)	High						2	1				
MD3_C	Vegetated Low Banks (Sheltered)	Low				2				1			

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD3_F	Beaches	High	1	3	2								
MD3_F	Manmade Structures (Sheltered)	High					3	2	1				
MD3_F	Vegetated High Banks (Sheltered)	High											
MD3_F	Vegetated Low Banks (Sheltered)	High						2	1				
MD3_F	Vegetated Low Banks (Sheltered)	Low				2				1			
MD3_F	Wetlands (Sheltered)	Low								1	3	4	2
MD3_H	Manmade Structures (Sheltered)	High					3	2	1				
MD3_H	Wetlands (Sheltered)	Low								1	3	4	2
MD3_I	Vegetated Low Banks (Sheltered)	High						2	1				
MD3_I	Vegetated Low Banks (Sheltered)	Low				2				1			
MD3_I	Wetlands (Sheltered)	Low								1	3	4	2
MD3_J	Beaches	High	1	3	2								
MD3_J	Vegetated Low Banks (Sheltered)	High						2	1				
MD3_J	Vegetated Low Banks (Sheltered)	Low				2				1			
MD3_J	Wetlands (Sheltered)	Low								1	3	4	2
MD3_K	Beaches	High	1	3	2								
MD3_K	Manmade Structures (Sheltered)	High					3	2	1				

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD3_K	Wetlands (Sheltered)	Low								1	3	4	2
MD3_L	Beaches	High	1	3	2								
MD3_L	Manmade Structures (Sheltered)	High					3	2	1				
MD3_L	Wetlands (Sheltered)	Low								1	3	4	2
MD3_M	Manmade Structures (Exposed)												
MD3_M	Manmade Structures (Sheltered)	High					3	2	1				
MD3_M	Wetlands (Sheltered)	Low								1	3	4	2
MD4_A	Beaches	High	1	3	2								
MD4_A	Manmade Structures (Exposed)												
MD4_A	Manmade Structures (Sheltered)	High					3	2	1				
MD4_A	Vegetated Low Banks (Sheltered)	High						2	1				
MD4_A	Vegetated Low Banks (Sheltered)	Low				2				1			
MD4_A	Wetlands (Sheltered)	Low								1	3	4	2
MD4_B	Beaches	High	1	3	2								
MD4_B	Man-made Structures (Exposed)												
MD4_B	Manmade Structures (Sheltered)	High					3	2	1				
MD4_B	Vegetated Low Banks (Sheltered)	High						2	1				

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD4_B	Vegetated Low Banks (Sheltered)	Low				2				1			
MD4_B	Wetlands (Sheltered)	Low								1	3	4	2
MD4_C	Man-made Structures (Exposed)												
MD4_C	Manmade Structures (Sheltered)	High					3	2	1				
MD4_C	Wetlands (Sheltered)	Low								1	3	4	2
MD4_D	Manmade Structures (Sheltered)	High					3	2	1				
MD4_E	Manmade Structures (Sheltered)	High					3	2	1				
MD4_E	Vegetated Low Banks (Sheltered)	High						2	1				
MD4_E	Vegetated Low Banks (Sheltered)	Low				2				1			
MD4_E	Wetlands (Sheltered)	Low								1	3	4	2
MD4_F	Manmade Structures (Exposed)												
MD4_F	Manmade Structures (Sheltered)	High					3	2	1				
MD5_A	**Manmade Structures (Exposed)**												
MD5_A	Manmade Structures (Sheltered)	High					3	2	1				

Table 9. Comparison of Measures within NACCS Risk Areas in the State of Maryland

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
MD5_A	**Vegetated Low Banks (Sheltered)**	**High**						**2**	**1**				
MD5_A	Vegetated Low Banks (Sheltered)	Low				2				1			
MD5_A	Wetlands (Sheltered)	Low								1	3	4	2
MD5_B	Beaches	High	1	3	2								
MD5_B	Manmade Structures (Sheltered)	High					3	2	1				
MD5_B	Vegetated Low Banks (Sheltered)	High						2	1				
MD5_B	Vegetated Low Banks (Sheltered)	Low				2				1			
MD5_B	Wetlands (Sheltered)	Low								1	3	4	2
MD5_C	Beaches	High	1	3	2								
MD5_C	Manmade Structures (Exposed)												
MD5_C	Wetlands (Sheltered)	Low								1	3	4	2

X. Tier 2 Assessment of Conceptual Measures

The NACCS Tier 1 assessment for the State of Maryland identified areas of risk to the flood hazard, and various management measures applicable to the shorelines within the risk areas by using the aggregated measure matrices presented in Table 4 of the State Appendix Overview. To apply the principles associated with the Framework, the NACCS Tier 2 analysis considers the three strategies to address coastal flood risk, including: 1) avoid, 2) accommodate, and 3) preserve.

In Maryland, the City of Annapolis, included in Maryland risk area MD2_H, was selected as an example area to apply the NACCS Tier 2 assessment. Annapolis is at risk to coastal flooding from the Chesapeake Bay, which propagates surge into the Severn River, Spa Creek, and College Creek as well as other tributaries. In 2003, the Hurricane Isabel storm surge resulted in a 6.4 feet (NAVD88) water surface elevation measurement at NOAA Station #8575512. Extensive flooding and damages

occurred as a result. At the time of the storm, the water surface elevations associated with Hurricane Isabel were approximately that of the FEMA 1-percent annual chance storm. Revised hydrodynamic modeling for the Chesapeake Bay was recently completed and incorporated into the Preliminary Anne Arundel County Flood Insurance Study, dated May 23, 2013. The revised 1-percent annual chance still water elevations for Spa Creek, College Creek, and Back Creek are 4.5, 4.6, and 4.5 feet (NAVD88), respectively.

To address flood risk to the City of Annapolis, flood risk management measures were evaluated for the Eastport and City Dock areas of the city (Whitney (a), 2011; Whitney (b), 2011). In addition, the Naval Academy and Naval Support Facility Annapolis have evaluated flood risk and potential measures to reduce damages. Initial flood risk management actions to address flooding include installing check valves at storm drain outlets, which during high water events flood street, as well as non-structural measures, such as floodproofing. In addition, the city embarked on an education program for the community and businesses in the area to communicate flood risk and potential mitigation efforts, including the consideration and installation of non-structural measures.

The city is currently working with the MDDNR following FEMA's guidance to develop and implement flood hazard mitigation opportunities, which would address sea level risk impacts. There would be limited opportunity for structural measures, and floodproofing may be the primary management measure available to reduce damages from coastal flood risk. The U.S. Naval Academy has participated as part of the city's planning effort, and has also evaluated opportunities to address flood risk.

For the NACCS Tier 2 analysis, risk area MD2_H was subdivided into eight smaller risk areas using the Category 4 MOM inundation mapping. The majority of the shoreline in the city includes bulkhead to maintain stationarity and limit erosion. As a result, only three of the eight areas included structural management measures. The NACCS Tier 2 analysis included evaluation of the existing bulkheads and potentially raising as a floodwall in the Eastport and City Dock risk areas. The approximate elevations, using the preliminary Digital Flood Insurance Rate Maps (DFIRM) mapping and flood insurance study stillwater elevations, initially considered was 7.5 feet (NAVD88), which would be the 1 percent flood plus three feet of risk and uncertainty associated with SLC. However, further coordination with the City of Annapolis indicated that the City was considering mitigation efforts related to a flood water surface elevation of 10 feet (NAVD88). Correspondingly, the bulkhead/FW raising, which would be aligned with the current shoreline and in both the City Dock and Eastport areas, would achieve the level of risk reduction associated with the 1 percent flood event, plus three feet event.

For the City Dock area, the alignment would extend from intersection of Decatur Street and McNair Road (U.S. Naval Academy) adjacent to College Creek, setback from the current open space areas on the Naval Academy's property adjacent to the Severn River, along the existing bulkhead of Spa Creek, and then ending at higher ground following the Duke of Gloucester Street. The Eastport area alignment would follow the existing bulkhead shoreline from the intersection of 6th Street and Severn Avenue adjacent to Spa Creek and ending at high ground near Chester Avenue adjacent to Back Creek.

The third risk area evaluated for a structural measure is located in Anne Arundel County, just outside of the City of Annapolis jurisdictional boundary. This area located includes high density residential areas near Chesapeake Harbour Drive East and a marina. The shoreline adjacent to the Severn River includes stone revetment with a narrow sandy beach. Beach restoration was proposed as the management measure for this area.

For non-structural measures, the 10 percent annual chance floodplain was used to evaluate non-structural opportunities. No structures on the properties were included in the 10 percent annual chance floodplain as part of this evaluation. Similarly, as part of the NACCS, NNBF measures like wetlands and living shorelines assumes a level of risk reduction for water surface elevations associated with the 10 percent-annual-chance flood. No NNBF measures were considered. Considering extensive areas of bulkhead and revetment currently exist in this area, erosion associated coastal storms could be considered relatively low.

Table 10 presents the results of the Tier 2 analysis. The Tier 2 analysis evaluates the relative costs associated with management measures included in the three primary strategies for coastal storm risk management for this particular area. For each of the areas identified, management measures were selected based on general knowledge and data available, including shoreline type, topography, extent of development from online aerial photography, and flood inundation mapping. The risk reduction associated with the management measures corresponds to the qualitative evaluation of measures presented in Table 4 of the overview section, such as high for a 1 percent flood plus three feet and low for a 10 percent 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 value the greater the relative costs for the respective management measure. The cost index allows comparison of the measures associated with the risk management strategy in order to evaluate affordability and ultimately leading to an acceptable level of risk tolerance. For the Maryland example area, the cost index of 1.0 represents the only measures to compare at this scale of analysis. 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 10. City of Annapolis Tier 2 Results

				Preserve				Accommodate				Avoid	
				Structural Measures (100yr plus 3')		Regional/ Gates (500yr)		NNBF (10yr)		Non-Structural (10yr)		Acquisition (10-year floodplain)	
Sub Risk Area	Description	Existing Project -2018 Post Sandy	Estimated LOP	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index
1	Narrow sandy beach backed by low dune and wetlands, high-density development/condos; private shoreline protection including revetments, segmented breakwaters; marina	None	N/A	Beach Restoration (NNBF)	1.00	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
2	Back Creek Harbor and Southern shore Spa Creek	None	N/A	Bulkhead/FW (10' structure)	1.00	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
3	Severn River and Northern Shore Spa Creek (Naval Academy)	None	N/A	Bulkhead/Levee (10' structure)	1.00	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
4	Severn River and College Creek	None	N/A	No	N/A	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A

5	Severn River and Southern Shore Weems Creek	None	N/A	No	N/A	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
6	Southern Shore Weems Creek upstream of State Route 70/Rowe Blvd	None	N/A	No	N/A	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
7	College Creek upstream of State Route 70/Rowe Blvd	None	N/A	No	N/A	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A
8	College Creek upstream of State Route 70/Rowe Blvd; Spa Creek upstream of 6th Street Bridge; Back Creek upstream of Springdale Avenue	None	N/A	No	N/A	No	N/A	N/A	N/A	No Structures within 10yr floodplain	N/A	No Structures within 10yr floodplain	N/A

Further coordination with the City of Annapolis indicated that, particularly in the City Dock area, a large structural measure limiting access to the shoreline may not be acceptable among the business community and historical district distinction. In addition, the City of Annapolis is currently evaluating non-structural measures, specifically floodproofing opportunities for residences and businesses to accommodate the flooding risk and promote resilience following the next storm event. Although the avoid strategy was not specifically considered for this Tier 2 analysis because no structures were included in the 10 percent-annual-chance floodplain, numerous structures are located in the 1-percent annual-chance floodplain. In addition, long-term SLC scenarios (USACE High) for the year 2100 forecast an increase of approximately 5.5 feet to mean sea level. Accommodating to SLC and flooding associated future storms by non-structural measures would reduce flood risk and increase resilience in the City of Annapolis. Climate change adaptation planning considerations incorporating long-term scenario planning presented in the NACCS may introduce various tipping points at points in time where the city may adjust its coastal flood risk management strategy.

XI. Focus Area Analysis Summary

The purpose of the Baltimore Metropolitan Water Resources Focus Area Analyses was to conduct a finer level of analysis and a smaller scale. As part of the NACCS, nine areas within the study area were identified for further analysis to identify problems, needs, and opportunities within those areas. The nine areas represent areas that preliminarily identified vulnerable coastal populations when preparing the First and Second Interim Reports.

As part of the focus area analysis, coordination with stakeholders and flood risk managers from Federal, state, and local officials occurred to identify areas at risk to coastal flooding or other water resources problems. Previous flooding events that resulted in extensive damages including Hurricane Isabel in 2003 were discussed, as well as ongoing flood risk management projects and initiatives. Following initial coordination as part of meetings and webinars, problems, needs, and opportunities were considered along with corresponding objectives and constraints. The results of the focus area analysis presented those management measures that incorporate existing initiatives and projects along with the needs and opportunities.

XII. Agency Coordination and Collaboration

XII.1 USACE Studies, Projects, and Programs

Comprehensive CSRM and increasing coastal resilience can be achieved by recognizing the benefits of, and implementing, other ongoing and related efforts in the Maryland and DC areas. USACE programs that could be used for cost-shared technical assistance include the Floodplain Management Services Program, Planning Assistance to States, Section 510 (Chesapeake Bay Environmental Restoration and Protection Program which includes design-construction of projects on publicly-owned land for protection of eroding shorelines, protection of essential public works, wastewater treatment plants, and water supply, beneficial uses of dredged material). In addition, ongoing and planned USACE future phases of study that could assist with the continuing effort to reduce risk and increase resilience for areas within the Chesapeake Bay region include the Chesapeake Bay Shoreline Erosion (phase II and III), Lower Susquehanna River Watershed Assessment (for the consideration of the beneficial use of sediment stored behind dams on the lower Susquehanna River mainstem) (watershed assessment not future phases of study), Chesapeake Bay Oyster Restoration Program, Janes Island CAP 103, North Beach Section 510, and Smith Island.

XII.2 Federal Projects and Programs

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. Specific projects and plans that have been prepared in response to the Supplemental bill have been researched to include by reference into the NACCS state appendices. The following table identifies those plans and projects that have been identified to date based on research and coordination efforts with NACCS stakeholders. The NACCS will incorporate new information based on further coordination prior to draft report preparation.

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 Grant Program which will support projects that reduce communities' vulnerability to the growing risks from coastal storms, SLC, flooding, erosion and associated threats through strengthening natural ecosystems that also benefit fish and wildlife (NFWF, 2013). States affected is defined as those states with disaster declarations as a result of the storm event. The grants range from $100,000 to $5 million and requests for proposal were due by January 31, 2014. On June 16, 2014, the Department of Interior announced $102.7 million for 54 projects along the North Atlantic Coast. USACE may participate with other stakeholders to implement the projects that received grant funding. Table 11 presents the list of specific projects proposed for the State of Maryland. The complete list of projects is available here http://www.doi.gov/news/upload/Hurricane-Sandy-2014-Grants-List.pdf.

Table 11. Federal Projects and Plans		
Agency	**Project**	**Cost**
USFWS/DOI	Increasing Salt Marsh and Resiliency for Blackwater National Wildlife Refuge	$4,985,000
USFWS/DOI	Creating a Green Infrastructure Road Map to Protecting the Chesapeake Bay Shoreline	$862,700
USFWS/DOI	Increasing Community and Ecological Resiliency by Removing a Patapsco River Fish Barrier	$7,767,000
USFWS/DOI	Protecting North Beach's Salt Marsh and Emergency Route	$616,000

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. Detailed distribution of funding within each category can be found here http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx.

The U.S. Department of Housing and Urban Development has allocated approximately $12 billion for recovery actions to rebuild areas affected by Hurricane Sandy through the Community Development Block Grant Program (CDBG). To be eligible to receive funds, each grantee must conduct a comprehensive risk assessment to address climate change impacts, changes in development patterns and population, and incorporate resilience performance standards identified in the Hurricane Sandy Rebuilding Strategy. More information can be found at http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2013/HUDNo.13-153. In Maryland, $28.6 million of CDBG funds were made available to Somerset County on the lower Eastern Shore. Table 12 presents information related to coastal flood risk management projects included in the CDBG funding allocated to Somerset County and the City of Crisfield (Maryland, 2014).

Table 12. Somerset County and City of Crisfield CDBG Projects		
Project	Location	Cost
Phase 1 (Design Funding) - Great Point Restoration Breakwater Project	City of Crisfield	$400,000
Great Point Restoration Breakwater Project	City of Crisfield	$2,800,000
Repair and Improvements of Tidal Dike System	City of Crisfield/Somerset County	$1,750,000
Phase 1 (Study Funding) - Jetty at Rhodes Point	Somerset County (Smith Island)	$25,000
Construction of Jetty at Rhodes Point	Somerset County (Smith Island)	$4,747,000

In May 2014, the Bureau of Ocean Energy Management (BOEM) and the State of Maryland signed a cooperative agreement for $200,000 with the purpose of consolidating and evaluated 30 years of data to identify sand resources along the Atlantic outer continental shelf (BOEM, 2014). The information generated from this agreement would identify sand resources for beach nourishment and coastal resilience.

Executive Order 13508, signed in 2009, reestablished the Federal effort to restore and protect the Chesapeake Bay watershed, a national treasure. The goals associated with the strategy include restoring clean water, recovering habitat, sustaining fish and wildlife, and conserving land and increasing public access (EPA, 2010). The response to Executive Order 13508 requires strong leadership and collaboration among Federal, state, and local government agencies, along with NGOs, academia, and the public and private interests. As part of a systems approach, recovering habitat and conserving land include components associated with the NACCS Framework to address coastal flood risk and promote resilience. With forecasted increases in SLC, the Chesapeake Bay region is at risk to further habitat loss, particularly in the lower eastern shore of Maryland. Conserving land, particularly in potential transition areas from forest or agricultural areas to wetlands, could assist in the acclimation and response to the potential impacts from forecasted SLC as inundation occurs over time.

In 2005, the Chesapeake Bay Program's Tidal Sediment Task Force of the Sediment Workgroup published a report contending that Bay shorelines must be treated differently, and that protection and restoration of the shorelines and better management of shoreline development must occur to address tidal and storm erosion (CBP, 2005). Typically, private landowners along the Bay and its tributaries employ bulkheads or revetments to reduce erosion of the fastland. Collaboration among Federal, state, and local agencies along with the private landowners would be required to identify the areas of severe erosion, evaluating the appropriate solution, and permitting and implementing the necessary action.

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.

Figure 31 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.

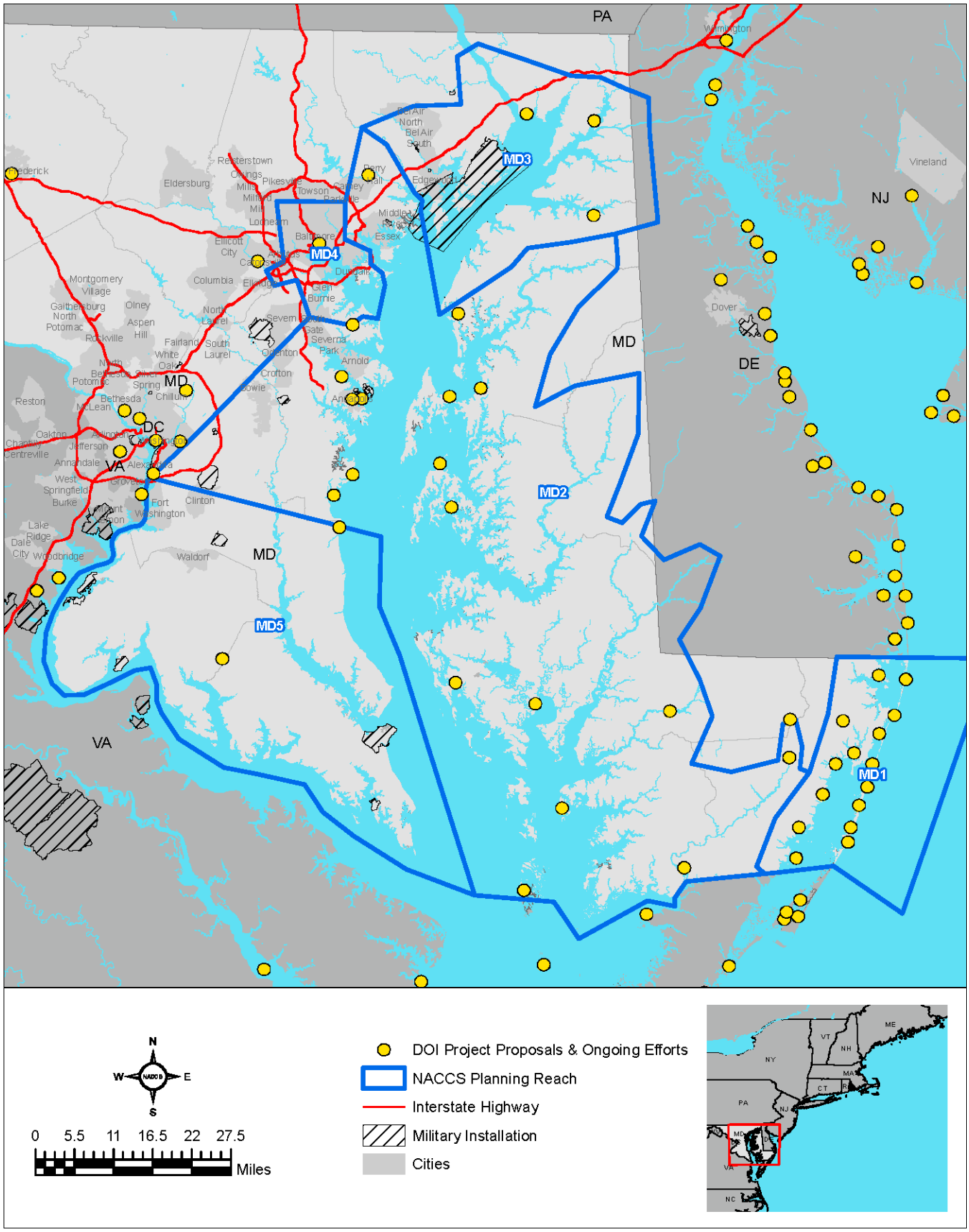

Figure 31. Federal Actions and Proposed DOI Grant Projects

State of Maryland

The State of Maryland and the coastal counties have implemented laws and programs to help protect people, infrastructure and ecosystem resources from flooding and storm damage. The State efforts are summarized in three sources: a "technical guide" for shoreline protection that Baltimore District has developed for Maryland DNR, a State executive order issued in December 2012, and "Maryland's Enforceable Coastal Policies" that was compiled by the State in 2011.

The State of Maryland and its counties are very progressive on the issue of coastal storm damage and flooding. Although the Atlantic Ocean shoreline of the state is not large compared to the other northeastern states, the total length of Chesapeake Bay shoreline within Maryland is substantial at approximately 7,000 miles. Therefore, there are many laws and policies that guide development within critical areas within the state and acceptable forms of shoreline protection. A summary of Maryland enforceable coastal policies can be found at this website: http://www.dnr.state.md.us/ccp/pdfs/mecp.pdf

Many shoreline projects on the Chesapeake Bay and tributaries in Maryland will address storm induced shoreline erosion as a primary project purpose with flood risk reduction as a secondary concern. The Maryland Living Shoreline Protection Act of 2008 requires landowners to consider erosion control measures in a set priority order: (1) No Action and Relocation, (2) Nonstructural/Living Shoreline, (3) Revetment, (4) Offshore Breakwaters, (5) Groins, and (6) Bulkheads. A structural practice cannot be undertaken unless the Maryland Department of the Environment (MDE) determines that erosion is severe enough that an erosion control measure must be installed. Once it is determined that a "no action" or relocation alternative is not sufficient, a nonstructural/living shoreline method must be used unless a waiver is granted by MDE. Waivers may be granted for certain areas that have been pre-designated to be unsuitable or impracticable for living shoreline stabilization.

The State has also produced a Hazard Mitigation Plan that details the risk to population and infrastructure from flooding, coastal storm damage, SLC and other factors. The counties have produced similar reports, which are regularly updated. These reports typically are not focused on structural protection projects. Selected measures detailed in the Maryland Hazard Mitigation Plan are listed in Table 13.

As part of coordination of the problem areas described in Section III, the Maryland DNR submitted comments and noted areas of concern that may be exposed to impacts from SLC within the next 25 years. The areas identified include Assateague State Park, Worcester County; Janes Island State Park, Somerset County; southern portions of Kent Island and Kent Narrows, Queen Anne's County; St. George's Island and Point Look Out State Park, St. Mary's County; and the Shady Side Peninsula of North Beach, Anne Arundel County. DNR also identified areas of Maryland subject to repetitive coastal flooding, including the following: Pasadena, Highland Beach, and Shadyside, Anne Arundel County; Millers Island, Edgemere, and Wilson Point, Baltimore County; North Beach, Chesapeake Beach, and Cove Point, Calvert County; North East, Cecil County; Taylors Island and Wingate, Dorchester County; Havre de Grace, Harford County; Rock Hall, Queen Anne's County; Kent Island, Kent County; Oxford, Talbot County; and Snug Harbor, West Ocean City, and Ocean Pines, Worcester County. Additionally, areas of the Chesapeake Bay shoreline including high banks and bluffs provide habitat for tiger beetles in Calvert, Kent, and Cecil Counties, which are exposed to wave action and erosion.

Additional sources of information are listed in Table 14.

Table 13. Selected measures for Hazard Mitigation in Maryland	
Hazard Mitigation Measure	Status
Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties	Proposed
Apply for mitigation grant funding to acquire and demolish homes	Proposed
Incorporate climate change and coastal hazard consideration into building codes	Proposed
Future phases of study for temporary floodwall or other protective measure for Baltimore Harbor and other urban areas	Proposed
Identify flood prone roads; replace/mitigate undersized/clogged culverts; reconstruct roads	Proposed
Dredge Port of Baltimore shipping channels	Ongoing
Continue the strategic placement of dredged material at containment islands to mitigate the effects of wave action and storm surge along populated shorelines and exposed wetland habitat of the Chesapeake Bay	Ongoing/Proposed

Table 14. Federal and State of Maryland Sources of Information

Resource	Source/Reference	Key Findings Synopsis
Building Resilience to Climate Change	http://www.dnr.state.md.us/dnrnews/pdfs/climate_change.pdf	On October 15, 2010, the Maryland Department of Natural Resources established policy to provide direction and guidance regarding the Department's investments and management of land, resources, and assets in the face of climate change.
Coastal Land Conservation in Maryland: Targeting Tools and Techniques for Sea Level Rise Adaptation and Response	http://www.dnr.state.md.us/ccp/pdfs/sealevel_rise_response.pdf	Presents SLAMM v6 model outputs for Maryland Chesapeake Bay for 2050 and 2100 showing areas of wetland conversion from SLC. Also provides areas targeted for conservation based on wetland migration and migration pathways.
The Likelihood of Shore Protection along the Atlantic Coast of the United States: Volume 1: Mid-Atlantic	http://risingsea.net/ERL/shore-protection-and-retreat-sea-level-rise-Maryland.pdf	This report develops maps that distinguish shores that are likely to be protected from the sea from those areas that are likely to be submerged, assuming current coastal policies, development trends, and shore protection practices. Key findings: 1) The prospects for shore protection appear to be largely established along all of the 31-mile Atlantic Ocean coast; 2) Along the 768 miles of estuarine shoreline, the prospects for shore protection are much less certain than along the ocean. These lands include approximately 173.3 square miles of dry land within about 3 feet above the tides; 3) Despite the momentum toward coastal development, all of our options still appear to be open for more than 72 percent of the low dry land in Maryland; 4) The areas where shore protections unlikely are concentrated along the Eastern Shore of Chesapeake Bay, the southern portion of Worcester County, and Charles County along the Potomac River.
Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase I: Sea Level Rise and Coastal Storms	http://www.mde.state.md.us/assets/document/Air/ClimateChange/Chapter5.pdf	The Phase I Adaptation Strategy, produced by the Maryland Commission on Climate Change's Adaptation and Response Working Group, provided recommendations for reducing risk associated with SLC and coastal storms. To protect Maryland's future economic wellbeing, environmental heritage, and public safety, the Strategy recommends a suite of 18 legislative and policy actions aimed at: Promoting programs and policies aimed at the avoidance or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas; Shifting to sustainable economies and investments; and avoiding assumption of the financial risk of development and redevelopment in highly hazardous coastal area; Enhancing preparedness and planning efforts to protect human health, safety and welfare; and Protecting and restoring Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay Islands, that inherently shield Maryland's shoreline and interior.

Resource	Source/Reference	Key Findings Synopsis
Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change Phase II: Building Societal, Economic, and Ecological Resilience	http://www.green.maryland.gov/pdfs/MDclimate.pdf	The Strategy synthesizes the most recent climate change literature to evaluate adaptation options and recommends adaptation strategies to reduce Maryland's overall vulnerability to climate change. The Strategy outlines adaptation strategies to reduce the impacts of climate change, including SLC, increased temperature and changes in precipitation within the following sectors: Human Health; Agriculture; Forest and Terrestrial Ecosystems; Bay and Aquatic Environments; Water Resources; and Population Growth and Infrastructure. The Phase II Strategy provides the basis for guiding and prioritizing state-level activities with respect to both climate science and adaptation policy within short to medium-term timeframes.
Maryland's Enforceable Coastal Policies	http://www.dnr.state.md.us/ccp/pdfs/mecp.pdf	The document presents Maryland's approved enforceable coastal policies. The policies were approved by NOAA on March 18, 2011. Prior to the creation of the document, Maryland's enforceable coastal policies were not available to Federal agencies and others involved in the Federal consistency process in a consolidated, user-friendly format.
Maryland Coastal Bays: Alternative Futures Project	http://www.dnr.state.md.us/irc/docs/00015759.pdf	Worcester County (especially the Coastal Bays Watershed portion) has a high growth rate and this is projected to continue. To accommodate this growth, it must be directed to areas with infrastructure at appropriate densities. Concentrating growth necessitates increased attention to the design of development. Therefore, in order to accommodate future growth efficiently, development should occur in Priority Funding Areas and be well designed.
Updating Maryland's Sea-level Rise Projections	http://ian.umces.edu/pdfs/ian_report_413.pdf	The report recommends that is it is prudent to plan for sea level to be 2.1 feet higher in 2050 along Maryland's shorelines than it was in 2000 in order to accommodate the high end of the range of the panel's projections. Maryland has 3,100 miles of tidal shoreline and low-lying rural and urban lands that will be impacted. The experts' best estimate for the amount of SLC in 2050 is 1.4 feet. It is unlikely to be less than 0.9 feet or greater than 2.1 feet. Their best estimate for SLC by 2100 is 3.7 feet. They concluded that it is unlikely to be less than 2.1 feet or more than 5.7 feet based on current scientific understanding.
Maryland Department of Natural Resources	http://dnr.maryland.gov/ccs/coastalatlas/shorelines.asp	The Maryland Department of Natural Resources has developed a tool for property owners to assess their risk of flooding, county by county, using this interactive map.
National Geographic	http://www.chesapeakeadaptation.org/	National Geographic, NOAA and Burke Consulting were among the partners that came up with a map to assess the risk of SLC Bayside.

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ATTACHMENT A

Focus Area Analyses Report

ATTACHMENT A

Baltimore Metropolitan Water Resources Focus Area Report

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List of Acronyms

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRS	Community Rating System
DP3	Disaster Preparedness and Planning Project
FEMA	Federal Emergency Management Agency
FWOP	Future Without Project
HTRW	Hazardous, Toxic and Radioactive Wastes
MEMA	Maryland Emergency Management Agency
MPA	Maryland Port Administration
NACCS	North Atlantic Coast Comprehensive Study
NBI	Nature-Based Infrastructure
NCDC	National Climatic Data Center
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
POC	Point of Contact
PURRI	Patapsco Urban River Restoration Initiative
PL	Public Law
RSM	Regional Sediment Management
SAV	Submerged Aquatic Vegetation
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
USACE	U.S. Army Corps of Engineers

1 Study Authority

The focus area analysis presented in this report is being conducted as a part of the North Atlantic Coast Comprehensive Study (NACCS) authorized under the Disaster Relief Appropriations 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 coastal storm risk management activities warranting additional analysis that could be pursued within the Baltimore metropolitan area. Public Law 84-71 is a plausible method for further investigation.

Additionally, the Baltimore metropolitan area has an existing authorization, as follows.

The Committee on Public Works and Transportation of the United States House of Representatives adopted a House resolution on April 30, 1992, which authorized USACE to investigate water resource and coastal flood risk management problems in the Baltimore metropolitan area.

"Resolved by the Committee on Public Works and Transportation of the United States House of Representatives, That the Board of Engineers for Rivers and Harbors, is requested to review the report of the Chief of Engineers on the Baltimore Metropolitan Area, Maryland, published as House Document 589, Eight-seventh Congress, Second Session, and the reports of the Chief of Engineers on Baltimore Harbor and Channels, Maryland, and Virginia, published as House Document 181, Ninety-fourth Congress, First Session, and House Document 86, Eighty-fifth Congress, First Session, and other pertinent reports, to determine whether modifications of the recommendations contained therein are advisable at the present time, in the interest of flood control, hurricane risk reduction, navigation, erosion, sedimentation, fish and wildlife, water quality, environmental restoration, recreation, and other related purposes."

2 Study Purpose

The purpose of this focus area report is to capture and present information regarding possible cost-shared, future phases of study to provide structural and/or non-structural coastal storm risk management, flood risk management, ecosystem restoration, and other related purposes for the Baltimore Metropolitan Water Resources study area.

The focus area report will:

- Examine the Baltimore Metropolitan Water Resources area to identify problems, needs, and opportunities for improvements relating to coastal storm risk management and related purposes.
- Identify a non-Federal sponsor(s) willing to cost-share the potential future investigation.

3 Location of Study / Congressional District

The study area encompasses the portions of the City of Baltimore and surrounding metropolitan areas along the tidally influenced areas that were subject to recent flooding, storm surge, and damages as a result of Hurricane Sandy and other recent storms. The impacts of Hurricane Sandy in the study area were relatively minimal compared to the large-scale destruction experienced from Hurricane Isabel in 2003 and other past storm events of record.

The study area was defined based upon the predicted storm surge extent from the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model along the coastal areas surrounding Baltimore. The study area includes the Gunpowder River (within Baltimore County) at the northeast boundary extending south-southwest along coastal areas and inlets of the Baltimore County coastline, the Middle River, the Back River, the Patapsco River, Baltimore Harbor and the Port, Baltimore City and downtown inner harbor, and southeastward along coastal areas of Anne Arundel County (Curtis Creek and Orchard Beach), and Pinehurst at the southernmost part of the study area. The eastern boundary extends out into Chesapeake Bay to encompass seaward land extensions and small islands.

The study area is characterized by flat and low lying elevations covering more than 215 square miles. Streams and rivers in the study area all drain to the Chesapeake Bay through broad tidal estuaries. A map of the study area is included as **Figure 1**.

The study area contains parts of Maryland's 1st (Representative Andrew Harris), 3rd (Representative John Sarbanes), 4th (Representative Donna Edwards), 6th (Representative Dutch Ruppersberger), and 7th (Representative Elijah Cummings), Congressional Districts. In addition, Congressional interest in the study area lies with Senators Barbara Mikulski and Benjamin Cardin.

4 Prior Studies and Existing Projects

This focus area report will identify problems and opportunities for the Baltimore Metropolitan Water Resources study area as they relate to coastal storm risk management and related purposes. The occurrence of flooding within the study area has been well documented. Various prior studies and existing projects in the study area were reviewed for relevancy to this study. Types of projects and studies include those related to navigation, coastal storm risk management, ecosystem restoration, and water resources management. Community resilience is also an increasingly relevant topic included for consideration in projects and studies. The intent of community resilience is to consider past, present, and future exposure to hazards such as coastal flooding, and to influence and improve the capacity to withstand and recover from adverse storm related situations.

All of these projects and studies illustrate the importance of balancing competing coastal system interests and needs with preservation of the surrounding environment. These projects and studies could provide useful information as coastal storm risk management measures are considered for the Baltimore Metropolitan Water Resources study area.

Table 1 summarizes various studies and projects undertaken by Federal, state, and local agencies. Sections 4.1 through 4.2 provide brief descriptions of studies and projects.

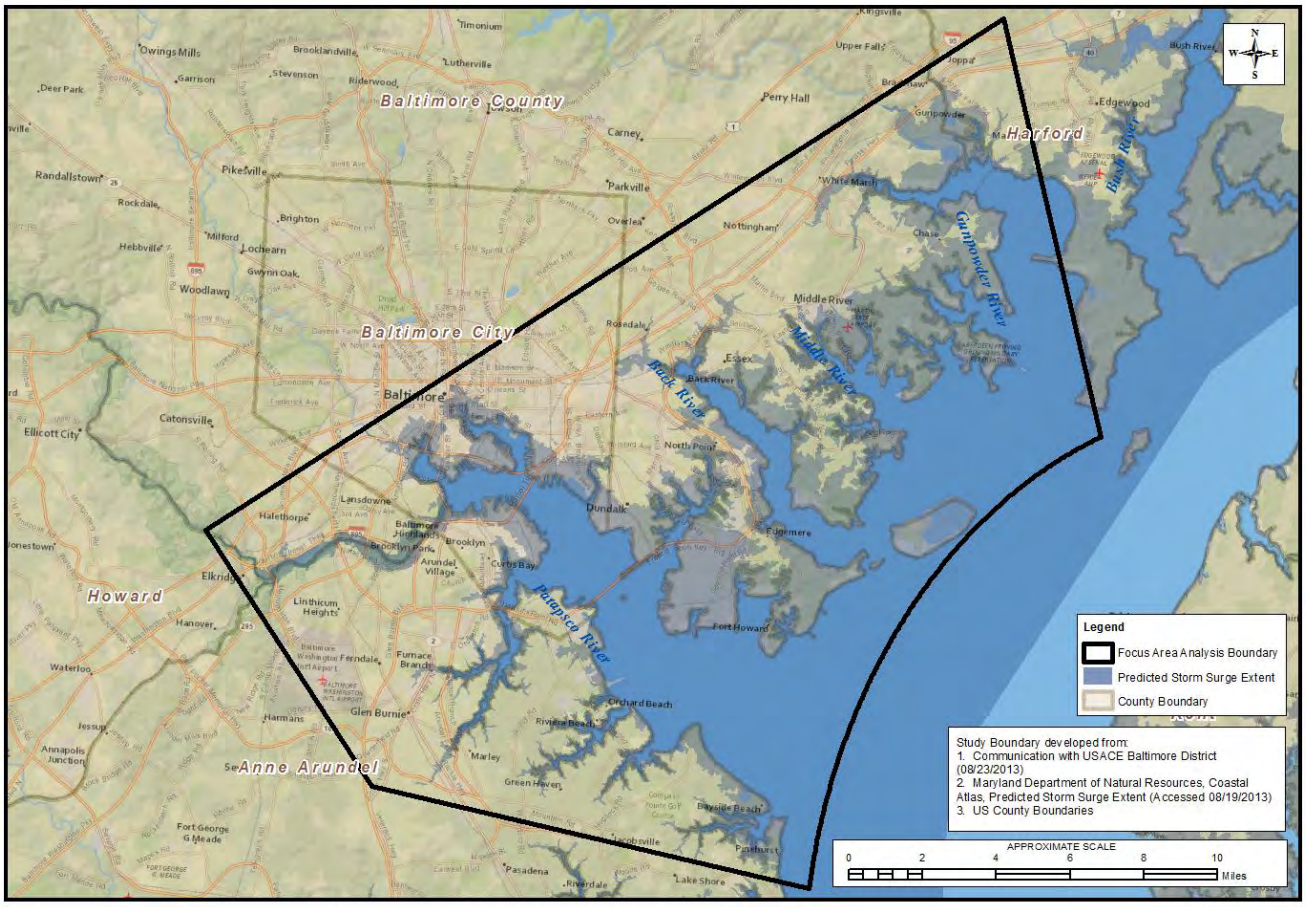

Figure 1. Baltimore Metropolitan Water Resources Focus Area Analysis Boundary

Table 1. Summary of Prior Studies and Projects

Study / Report	Focus Area	Structural / Non-Structural	Time Frame [Ongoing / Proposed Short Term / Proposed Long Term]	Status	Navigation	Coastal Storm Risk Management	Flood Risk Management	Ecosystem Restoration	Water Resource Management	Community Resilience
USACE										
Chesapeake Bay Shoreline Erosion Study, Maryland Coastal Management	Maryland Coast of Chesapeake Bay-water quality	N	Ongoing	PMP for Phase II FS		X		X		
Baltimore Metropolitan Water Resources	Baltimore City, Gwynn Falls Watershed-degraded storm sewers/streams	S	ST	Construction				X	X	
Baltimore Metropolitan Patapsco and Back River Watersheds Reconnaissance Report 905(b) Analysis, June 2008.	Patapsco and Back Rivers watersheds	S/N		Reconnaissance	X		X	X		
Warner Street, Middle Branch of the Patapsco River	Baltimore City - degraded ecosystem, WQ	S	LT	Design/ Construction				X	X	
Paul S. Sarbanes Ecosystem Restoration Project	Poplar Island	S	ST	Construction	X	X		X		
Baltimore Harbor, Chesapeake Bay, Back River, Patapsco River	Navigation channels	S	LT	O&M	X					
Patapsco Urban River Restoration Initiative (PURRI)	Middle Branch estuary and shoreline habitat	S/N	LT	Study				X	X	X

Study / Report	Focus Area	Structural / Non-Structural	Time Frame [Ongoing / Proposed Short Term / Proposed Long Term]	Status	Navigation	Coastal Storm Risk Management	Flood Risk Management	Ecosystem Restoration	Water Resource Management	Community Resilience
State of Maryland										
2011 Maryland State Hazard Mitigation Plan Update	State-wide	S/N	LT	Plan		X	X	X	X	X
Updating Maryland's Sea-level Rise Projections, 2013	State-wide	N	LT	Study						X
Vision 2025	Maryland Port Administration, Port of Baltimore	N	LT	Plan	X			X	X	X
Local										
Anne Arundel: Tropical Cyclone Isabel, Lessons Learned (2008)	Anne Arundel County	N	ST	Study						X
Anne Arundel General Development Plan (2009)	Anne Arundel County	N	ST	Plan						X
Sea Level Rise Strategic Plan, Phase I Report: Vulnerability Assessment (2010)	Anne Arundel County	S/N	LT	Study		X				X
Anne Arundel Seal Level Rise Strategic Plan (2011)	Anne Arundel County	S/N	LT	Plan		X				X
Anne Arundel All Hazard Mitigation Plan (2012)	Anne Arundel County	N	LT	Plan		X	X	X	X	X
Baltimore County Multi-Hazard Mitigation Plan (2012)	Baltimore County	S/N	LT	Plan		X	X		X	X
Baltimore County Master Plan 2020 (2010)	Baltimore County- Storm water Mgmt, WQ, Inner Harbor redevelopment	S/N	LT	Plan	X			X	X	X

Study / Report	Focus Area	Structural / Non-Structural	Time Frame [Ongoing / Proposed Short Term / Proposed Long Term]	Status	Navigation	Coastal Storm Risk Management	Flood Risk Management	Ecosystem Restoration	Water Resource Management	Community Resilience
City of Baltimore Comprehensive Master Plan (2009)	City of Baltimore	S/N	LT	Plan					X	X
All Hazards Plan for Baltimore City (2004)	City of Baltimore	N	LT	Plan					X	X
Baltimore Sustainability Plan (2009)	City of Baltimore	N		Plan						X
Baltimore Climate Action Plan (2013)	City of Baltimore	N	LT	Plan						X
Disaster Preparedness and Planning Project, DP3 (2013)	City of Baltimore	S/ N	LT	Plan						X

4.1 Federal

USACE has several ongoing studies/projects in the study area related to ecosystem restoration and coastal storm risk managment and navigation. The Chesapeake Bay Shoreline Erosion Study, Baltimore Metropolitan Water Resources, Gywnns Falls Watershed, the Patapsco Urban River Restoration Initiative, Warner Street, Middle Branch of the Patapsco River, and Baltimore Metropolitan Patapsco and Back River Watersheds studies/projects all focus on pollutant reduction, protection and restoration of nearshore environments, and contribution to improved water quality and habitat recovery at specific locations and within the Chesapeake Bay.

The Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island, Talbot County, Maryland, an ecosystem restoration project south of the Route 50 Bridge, is designed to accept approximately 68 million cubic yards of clean dredged material from the Baltimore Harbor and Channels navigation project.

USACE operates and maintains by dredging several Federally-authorized navigation channels in the study area, the most extensive of which include the Chesapeake Bay. USACE maintains an extensive system of deep-draft navigation channels serving the Port of Baltimore. These channels are up to 50 feet deep and are located in the bay, the Patapsco River, Middle Branch, Northwest Branch and Curtis Bay. There are also many shallow navigation channels throughout the study area. The Port of Baltimore is a vital commercial gateway with a high value to the nation and currently ranks 11th in foreign commercial tonnage.

4.2 State

The 2011 Maryland State Hazard Mitigation Plan Update serves as guidance for hazard mitigation for the State of Maryland. Its vision is supported by a central goal, objectives and strategies for Maryland state government, local governments and organizations that will reduce or prevent injury to people, property, infrastructure and critical state facilities from natural hazards.

The plan features comprehensive natural hazard identification, risk assessment and vulnerability analysis, which ranks hazard risks across the state's counties. The plan also includes mitigation strategies to address the identified vulnerabilities. (Maryland Emergency Management Agency [MEMA], 2011).

All local government hazard mitigation plans must comply with the goals and objectives set forth in the state plan.

The report titled, "Updating Maryland's Sea-level Rise Projections," developed by the Maryland Commission on Climate Change is based on an executive order issued by the Governor in 2012 that requires state agencies to consider the risk of coastal flooding and sea level rise to capital projects. This report responds to the directive using recent scientific results to produce projections useful for sea level rise adaptation in Maryland. The report clearly states that it is prudent for the state to plan for a relative sea level rise of 2.1 feet by 2050.

The Vision 2025 plan was prepared for the Maryland Port Administration (MPA) and the Port of Baltimore and presents a set of broad strategic visions pursuant to the mission of the MPA as it guides the Port through the next decade, examining economic benefits to the State. One of the Vision's goals is to explore options for the beneficial use of dredged material (MPA, 2007).

4.3 Local

Hazard Mitigation Plans

Baltimore County, Anne Arundel County and the City of Baltimore, developed their own local versions of hazard mitigation plans with features similar to and in compliance with the Maryland State Hazard Mitigation Plan. These plans include mitigation strategies to manage coastal storm risk from flooding and to improve resilience.

The Baltimore County plan included several flood mitigation activities within the study area:

1) National Flood Insurance Program (NFIP) – enforces floodplain management in identified flood hazard zones; prohibits new development in the 100-year riverine floodplain; and allows citizens to purchase flood insurance not normally available through private insurers.
2) Building Codes – requires that anyone rebuilding in the 100-year flood zone must elevate their first floor (including utilities) with an added foot of freeboard; new or rebuilt homes will have no basement, and the ground floor must be used as a garage or for storage (with flood venting).
3) Acquisition – in the recent past Baltimore County acquired 100 homes in several floodplains to preserve as greenways, thereby eliminating future storm damage.

The City of Baltimore All Hazards Plan (2004) developed a priority list of mitigation strategies; those strategies related to flood risk management include:

1) Improving water/waste water infrastructure to prevent flooding from overflows.
2) Updating zoning code to restrict some uses in the floodplain.
3) Assessing opportunities to acquire properties in the floodway.
4) Studying the threat and possible mitigation and policy changes for sea level rise.
5) Raising the freeboard requirement from 1 foot to 2 or 3 feet.

The Anne Arundel County Hazard Mitigation Plan (2012) more generally targeted risk management from multiple hazards, and deferred development of any mitigation strategies related to flooding.

Other Local Plans

Anne Arundel's Lessons Learned from Tropical Cyclone Isabel (2008) provided many insights related future planning for their emergency management operation, functions, and coordination. The report on Strategic Sea Level Rise (2011) identified potential future risk and vulnerabilities due to sea level rise and concluded that the County should take preventative planning measures and actions to minimize any damages or loss of important resources. Specific actions considered are more "planning" in nature and include evaluation of non-structural shoreline stabilization, evaluation of private well and septic systems, protection of archaeological and cultural resources, community engagement with the maritime community to deal with potential impacts to marinas, and shoreline inventories with erosion problems.

Both Baltimore County and the City of Baltimore developed master plans for their respective areas, and Anne Arundel County developed a general development plan. The intent of all of these plans is to provide guidance on managing community growth, and redevelopment, as well as economic, environmental (watershed) and community sustainability. Plan recommendations for flood management can be inferred from watershed management discussions and are conceptual and/or policy driven.

The City of Baltimore developed and adopted their Climate Action Plan (2012) which also accounts for strategies contained in the Sustainability Plan (2009) to reduce greenhouse gas emissions and to mitigate global climate change. The Sustainability Plan promotes 29 priority goals with strategies to realize a clean, healthy, efficient, green, mobile, aware and invested community. The Sustainability Plan also included a section on climate adaptation which acknowledged future increased vulnerability to coastal flooding. Key areas targeted for mitigation strategies from the Climate Action Plan include:

1) Energy Savings and Supply
2) Land Use and Transportation
3) Growing a Green City

Baltimore City, Disaster Preparedness and Planning Project (DP3)

The Disaster Preparedness and Planning Project (DP3) (2013) also prepared by the City of Baltimore is another step toward recognizing the city's vulnerability to impacts from severe hazard events and using a forward-thinking approach to the mitigation planning process. This plan integrates hazard mitigation planning (focused on past events) and climate adaptation (focused on events likely to happen in the future). The DP3 plan identifies six major goals:

1) Protecting the health, safety and welfare of Baltimore City residents and visitors.
2) Preventing damage to structures, infrastructure, and critical facilities.
3) Building resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private).
4) Enhancing the City of Baltimore's adaptive capacity and building institutional structures that can cope with future conditions that are beyond past experience.
5) Promoting hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore.
6) Becoming a Community Rating System (CRS) classified community.

Multiple strategies and actions are included in the DP3 plan that address proposed improvements for infrastructure, buildings, communication systems, transportation, waterfront areas, wastewater management, storm water management, solid waste, natural systems, and public services.

The specific strategies and implementable actions presented in the DP3 report are categorized within four major sectors:

1) Infrastructure, includes strategies/actions for:
    - Energy (electricity system)
    - Liquid fuels
    - Communication systems
    - Transportation
    - Waterfront
    - Wastewater
    - Stormwater

- Solid Waste
- Policy and government decision making

2) Buildings, includes strategies/actions for:
   - City codes and design guidelines
   - Structural
   - Non-structural
3) Natural Systems includes strategies/actions for:
   - Urban Parks and forests
   - Water supply and management
4) Public health and human services, includes strategies/actions for:
   - Emergency preparedness and response
   - Health
   - Education and engagement
   - Food system

5 Plan Formulation

Six planning steps in the Water Resource Council's Principles and Guidelines are followed to focus the planning effort and recommend a plan for potential future investigation. The six steps are:

- Identifing problems and opportunities
- Inventorying and forecasting conditions
- Formulating alternative plans
- Evaluating effects of alternative plans
- Comparing alternative plans
- Selecting a recommended plan

The iterations of the planning steps typically differ in the emphasis that is placed on each of the steps.

This focus area report emphasizes identification of problems and opportunities. The following sections present the results of the initial iterations of the planning steps conducted during this focus area analysis. This information will be refined in future iterations of the planning process that will be accomplished during future study phases.

5.1 Problems and Opportunities

Flooding is a persistent concern in Maryland, a coastal state with more than 12 percent of its surface area in floodplains and nearly 8,000 miles of tidal shoreline associated with the Chesapeake Bay and its tributaries. The study area is highly urbanized, and based on existing geography, topography, and proximity to tidally influenced areas, it is highly vulnerable to flooding and other coastal hazards such as erosion, severe winds, and severe weather events. The study area terrain makes it increasingly susceptible to coastal, riverine and flash flooding. Combined with projections for climate change and

sea level rise, the vulnerability of this area to future flooding events and storm damage is effectively increased. The Port of Baltimore estimates that 298 acres of its facilities will be affected by sea level rise and coastal flooding.

A number of factors indicate the potential for increased damage from coastal storms along the coast of the Baltimore Metropolitan area. Steady population growth and continuing near-shore development is increasing the risk of human injury and property loss. The slowly sinking of land in the Chesapeake region, due to the combined effects of ground water withdrawal, and crater-related ground subsidence (USGS, 2013) also may play a role in the high rate of relative sea level rise documented for the Chesapeake Bay region. These factors effectively double the global rate of sea level rise in Maryland's coastal areas and increase the vulnerability of coastal areas to surge. In addition, inundation of these coastal areas may lead to negative environmental impacts. When wastewater treatment facilities are inundated, partially treated or untreated sewage is often released, which can impact water quality. Similarly, inundation of sites identified through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), otherwise referred to as Superfund sites, or other hazardous waste sites will also severely impact water quality.

Additionally, potential shoaling of navigation channels and turning basins impairs the Port of Baltimore's maritime industry—an economic engine for the area. Port facilities, infrastructure and private terminals have experienced flooding and debris flows from coastal storm events. With the current expansion of the Panama Canal which will double the Canal's capacity, the Port of Baltimore's resulting economy of scale advantage for larger ships will likely change the logistics chains for both U.S. imports and exports. Injection of successive new generations of *post-Panamax* vessels into the world fleet could be a "game-changer" for the U.S., including the Port of Baltimore, over the long term,.

Between 1993 and 2010, 1,179 flooding events were recorded for Maryland in the National Atmospheric and Oceanic Administration (NOAA) National Climate Data Center (NCDC) storm database (MEMA, 2011). Presidential declarations for seven flood-related disasters were made for Baltimore County between 1971 and 2011. In Baltimore City alone, annualized damages due to coastal flooding are estimated at $2.2 million. While the study area experienced minimal damages from Hurricane Sandy, damages from previous storms are well documented. The study area was hit particularly hard with storm surge, during Hurricane Isabel in 2003, that exceeded the record set in 1933, and caused severe coastal erosion and property damage. Hurricane Isabel was a 100-year flood event. Heavy rains that occurred several days after Isabel added to localized and flash flooding in the area. Storm surge was under-predicted, rising 1-3 feet higher than forecasted in portions of the Chesapeake Bay. Baltimore's Inner Harbor and Fells Point Historic District along with other waterfront neighborhoods were flooded with up to 8 feet of water. Anne Arundel County was also hit hard and several communities were completely isolated due to flooding. Anne Arundel County also had one of the highest incident rates of power outages and thirty percent of the water production capacity was out of service. Damages incurred by the State of Maryland reached $400 million for Hurricane Isabel in 2003. As part of this focus area report, plan formulation will include identification of potential measures to help these vulnerable areas become more resilient to coastal storm damage.

In order to collect data on problems and opportunities for the Baltimore Metropolitan Water Resources study area, stakeholder meetings and webinars were conducted with USACE, state and local agencies. **Appendix A** includes a list of points of contact (POCs) invited to participate in meetings and webinars, meeting materials and letters requesting feedback. **Appendix B** includes meeting minutes with a list of participants, and **Appendix C** includes comments received from agencies and stakeholders that were

unable to attend meetings and/or webinars or from attendees that provided additional feedback following meetings and webinars. Stakeholder input was incorporated into the development and analysis of potential measures for this focus area report. A summary of stakeholder input is included in **Table 2.**

Table 2. Summary of Stakeholder Input - Problems

Problem Area	Problems Identified	Reference
Fells Point Historic District, Baltimore City	Vulnerability to coastal flooding	City Staff, 8/16/13 meeting
Middle Branch Patapsco Waterfront, Baltimore City	Vulnerability to coastal flooding	City Staff, 8/16/13 meeting
Curtis Bay, Baltimore City	Vulnerability to coastal flooding	City Staff, 8/16/13 meeting
Various areas, Baltimore City	Multiple: coastal flooding, vulnerability, climate adaptation	City Planning Staff, 9/5/13 meeting
Baltimore County/Baltimore City Various areas • **Sparrows Point** • **Bowleys Quarters Firehouse** • **Wastewater Pump Stations** • **Back River Wastewater Treatment Facility**	Vulnerability to coastal flooding	County Staff, 7/29/13 meeting
Maryland Port Administration (MPA), Baltimore Harbor	Multiple: coastal flooding, vulnerability, inland /landside drainage Vulnerability to coastal flooding	MPA Staff, 9/5/13 meeting
Anne Arundel County, Curtis Creek	Vulnerability to coastal flooding	Email dated 9/16/13. Reports referenced: Tropical Cyclone Isabel, Anne Arundel County – Lessons Learned; Sea-level Rise Strategic Plan for Anne Arundel County
Anne Arundel County, County-wide	Vulnerability to coastal flooding	Email dated 9/16/13. Reports referenced: Tropical Cyclone Isabel, Anne Arundel County – Lessons Learned; Sea-level Rise Strategic Plan for Anne Arundel County

5.2 Objectives

5.2.1 National Objectives

The national or Federal objective of water and related land resources planning is to contribute to National Economic Development (NED) consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.

USACE also has a national objective for National Ecosystem Restoration (NER) in response to legislation and administration policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat.

Projects which produce both NED and NER benefits will result in a "best" recommended plan so that no alternative plan or scale has a higher excess of NED benefits plus NER benefits over total project costs. This plan shall attempt to maximize the sum of net NED and NER benefits, and to offer the best balance between two Federal objectives. Recommendations for multipurpose projects will be based on a combination of NED benefit-cost analysis, and NER benefits analysis, including cost effectiveness and incremental cost analysis.

In addition to Federal water resources planning objectives, the main goals of the NACCS under which this focus area analysis is being conducted, are to:

1) Reduce risk to which vulnerable coastal populations are subject.
2) Ensure a sustainable and robust coastal landscape system, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure.

Specific objectives for this focus area report are to:

1) Manage risk from storm surge.
2) Manage flood risk.
3) Provide adaptive and sustainable solutions for future development that account for future changes such as sea level rise, land subsidence and climate change.
4) Maintain or improve ecosystem goods and services provided (social, economic and ecological balance).
5) Incorporate opportunities for nature-based infrastructure alone and in combination with traditional measures. .
6) Maintain economic viability of the working coastline including navigation channels and ports.
7) Improve emergency response and evacuations by improving the transportation systems before and during flood events.
8) Incorporate problems, needs, and opportunities identified by stakeholders to manage flood risk.
9) Manage erosion occurring along the shorelines.

10) Manage risk to National Register of Historic Places and other cultural resources.

5.3 Planning Constraints

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

5.3.1 Institutional Constraints

1) Comply with all Federal laws and executive orders, such as the National Environmental Policy Act (NEPA), the Clean Water Act, Endangered Species Act and Executive Order 11988.
2) Avoid increasing the flood risk to surrounding communities and facilities.
3) Avoid solutions that cannot be maintained, whether due to expense or complicated technologies, by the non-Federal sponsors.
4) Comply with local land use plans and regulations.
5) Difficulty in funding long-term operation and maintenance.
6) Permitting with Federal, state, and local agencies.
7) Acquisition of real estate and easements.

5.3.2 Physical Constraints

1) Some areas within this study area are highly urbanized, and the density of population may limit the amount of space available for staging and constructing a project.
2) Avoid additional degradation of water quality, which would put additional stress on aquatic ecosystem.
3) Avoid impacting or exacerbating existing hazardous, toxic and radioactive wastes (HTRW) that have been identified within the project area.
4) Minimize the impact to authorized navigation projects.
5) Minimize the impact to other projects and areas where risk has been managed, such as sensitive wetlands, wildlife management areas, etc.
6) Minimize effects on cultural resources and historic sites, structures and features.
7) Loss of streetscape character and potential economic loss by elevation of structures or placement of floodwalls / levees.
8) Some offshore areas may not have the structural integrity to support structures.

5.4 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.

5.5 Measures to Address Identified Planning Objectives

This section identifies a broad range of potential solutions (measures) to address the study area objectives. Many of these measures are outlined in "Coastal Risk Reduction and Resilience: Using the Full Array of Measures" (USACE, September 2013). Any of these potential measures will be weighed against a "No-action Plan" in the future phases of study.

5.5.1 Structural Measures

Structural measures are used to control floodwaters. Broad-based structural measures identified include:

1) Seawall/Revetment: Seawalls are built parallel to the shoreline with the purpose of reducing overtopping and consequent flooding of areas behind the seawall due to storm surge and waves. Revetments are onshore sloping structures which manage shoreline erosion. Areas immediately seaward of seawalls or revetments may be impacted because of isolation from an inland sediment source.

2) Groins: Groins are narrow structures, built perpendicular to the shoreline, that stabilize a beach experiencing longshore erosion. Beach material will accumulate on the updrift side of a groin, but the downdrift side will experience erosion caused by isolation from the longshore sediment transport source. Both the accretional and erosional effects extend some distance alongshore away from the groin.

3) Detached Breakwaters: The primary function of a detached breakwater is to reduce beach erosion by reducing wave heights in the lee of the structure. The reduction in wave heights reduces longshore and cross-shore sediment transport. Detached breakwaters are built nearshore, in shallow water, and generally parallel to the shoreline. They are low-crested structures which decrease wave energy and help promote an even distribution of material along the coastline. Since detached breakwaters can impact the transport of beach material, there can be erosional impacts in downdrift areas. In addition, detached breakwaters, when submerged, can cause a non-visible hazard to boats and swimmers.

4) Berms / Levees: Berms, levees, or dunes can be constructed along the shoreline, tying into high ground or surrounding an area entirely, to reduce risk of storm surge, 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 are often composed of earthen materials. Levees or berms also need to be constructed to prevent or control underseepage of floodwaters through the existing soils. They may need to include pumping stations to remove interior stormwater drainage. Roads sometimes need to be ramped to cross these features.

5) Multipurpose Berms/Levees: Berm and levee features require a large footprint to remain stable. However, it is possible to incorporate features in the design of the levees, such as parking areas/garages, commercial or residential development, recreational greenways, etc., to take advantage of the increased elevation.

6) Floodwalls and Bulkheads: Floodwalls or bulkheads can be constructed along the shoreline, tying into high ground or surrounding an area entirely to reduce risk of 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 floodwaters,

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 to any waterside property.

7) Flood/Tide Gates: A flood or tide gate can be constructed across a waterway to provide risk reduction 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 to 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 gate, as 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 either additional storage will need to be created and/or pumping stations will need to be added to remove interior drainage upstream of a flood or tide gate.

8) Portable Floodwalls: Portable floodwalls are a potentially viable measure when complete portability is necessary and no permanent fixings or structures are desired. Portable floodwalls are typically constructed of lightweight aluminum and rely on the weight of the water to press down and stabilize the wall to create a water tight seal. Temporary floodwalls can vary in height to accommodate the change in existing elevation and optimize cost. However, , installation of a system of portable floodwalls may need to begin several days prior to a pending event depending on available resources. Therefore, portable floodwalls may not be suitable for some events and areas when installation time exceeds event warning time. . Additionally, portable floodwalls are not applicable where subject to storm wave action.

9) Portable Berms/Cofferdams: Portable cofferdams are another rapidly deployable, temporary method that can be used for flood risk management. The cofferdam, made of commercial grade vinyl coated polyester, is a water inflated dam, which consists of a self-contained single tube with an inner restraint baffle/diaphragm system for stability. The dam has the ability to stand alone as a positive water barrier without any additional external stabilization devices. The system can be installed easily in the field when needed and removed when the threat is over. Once laid out, it can be inflated using any available water source. Each unit is up to 100 feet long and 8 feet high. Portable cofferdam units can be joined together by overlapping end to end at any angle to provide risk reduction to large areas.

   Temporary pumps are required to fill the cofferdam units; however, the pumps can be used as temporary pump stations to pump trapped water on the “dry” side of the cofferdam and discharge the water into the “wet” side.

10) Storm Surge Barrier: Storm surge barriers are often coupled with levees to prevent storm surge from propagating up waterways. Storm surge barriers generally consist of a series of movable gates that are normally open to let flow pass, but will close when storm surge exceeds a certain water level.

11) Road, Rail, or Light Rail Raises: Roads can be raised on berms or levees. The advantage of raising a road is two-fold. First, to raise main evacuation routes so they will not be flooded

during a coastal and heavy precipitation event. Secondly, existing easements can provide some of the property needed for the footprint for building a berm or levee. However, main routes in the Baltimore metropolitan area are heavily developed. In order to raise existing main routes, a large amount of property along the roadways likely will 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 on berms or levees. A road, rail, or light rail line raise may create interior drainage problems if stormwater storage is insufficient. Additional storage space and/or pumping stations may be required to remove interior stormwater drainage.

12) Beach and Dune Restoration: Shoreline restoration by sand nourishment or replenishment of beaches subject to erosion. Restoration often includes include dune restoration/enhancement to provide additional risk reduction for flooding and wave action.

13) Stormwater System Improvements: Existing stormwater systems 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.

14) Bridge Trash Racks: Trash racks can be installed upstream of critical bridges to collect debris during a flood event to help preserve the structural integrity of the bridge support structure.

5.5.2 Non-Structural

Broad-based non-structural measures identified include:

1) Acquisition / Buyouts: Homes that are subject to repetitive loss from flooding and are outside of an area for a proposed structural flood risk management project are viable 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. Acquisitions and buyouts restore the natural floodplain in the location of previous development.

2) Early Warning Systems: Flood warning systems are important to notify citizens of a flooding event. Coastal storms typically have a several-day timeframe where the community is aware of the possibility of impact, but last minute changes in speed and direction 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 means to reach out to their citizens before and during a large storm event. Large precipitation events from storms other than coastal storms 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.

3) Elevating Structures: This measure involves elevating the building in place so that the lowest floor is above the flood level for which floodproofing is provided. The building is jacked up and set on a new or extended foundation.

4) Floodproofing: There are two types of floodproofing techniques: dry floodproofing and wet floodproofing. Dry floodproofing keeps the floodwaters from entering the structure while wet floodproofing allows the floodwaters to enter the building but minimizes the damages.

   Dry floodproofing involves sealing the walls of structures such as buildings with waterproofing compounds, impermeable sheeting, or other materials and using closures for covering openings from floodwaters. Dry floodproofing is most applicable in areas of shallow, low-velocity flooding.

   Wet floodproofing allows the structure to flood inside while ensuring minimal damage to the building and any contents. By allowing the force of the water to pass through a building, the interior flooding allows hydrostatic force on the inside of the building walls to equally counteract the hydrostatic force on the outside, thus eliminating the chance of structural failure. Wet flooding practices include installation of flood vents in the ground floor or crawl space to allow floodwater to flow through the building without causing structural damage or conversion of ground floor living space to uninhabitable space such as a carport or open garage.

5) Increase Storage: In order to reduce flooding from precipitation events, natural storage of the watershed can be restored or additional storage can be added. Restoration of natural storage includes restoring wetlands and returning floodplains to undeveloped states in riverine areas. Increasing natural storage 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 green stormwater management.

6) Public Engagement and Education: A community can aid in flood risk management by educating its citizens about the existing flooding hazards and what their citizens can do to reduce risk their property. Additionally, if a flood risk management project is constructed, educating the community on residual project risk must occur.

7) Relocating Utilities and Critical Infrastructure: A community can manage risk to its own public infrastructure by relocating utilities underground and moving critical infrastructure out of floodplain areas. Examples of critical infrastructure include hospitals and shelters.

8) Preservation: Land preservation programs should be developed to place environmentally sensitive land in permanent easements to better manage watersheds and their interrelated systems.

9) Resilience Performance Standards: Develop resilience performance standards for infrastructure to be used when making investment decisions. These standards may include information such as the recurrence interval of a storm that infrastructure should be designed to withstand, how long different end users can be without power, or how and when to include climate change or sea level rise into design standards.

10) Emergency Response Systems: Emergency response systems include preparation for floods in anticipation of the flood event and flood-fighting plans to assist after the fact. The plans should include contingency and emergency floodproofing and must be properly integrated with emergency evacuation plans.

11) Modify / Remove Structures for Better Channel Function: Channel alterations such as modifying or removing features or widening/deepening channels can help reduce flooding by improving channel function.

12) Design or Redesign and Location of Services and Utilities: Services and utilities can be relocated to areas of low risk or to higher areas not subject to flooding. Additionally, existing services/features can be elevated above the flood elevation or can include flood-proofing features in the design.

13) Surface Water/Stormwater Management: Management of surface water and stormwater systems can improve water quality, decrease erosion, and increase storage to minimize flood risks in the event of a storm. The development of a surface water or stormwater management plan can help facilitate best management practices of the systems.

14) Building Codes and Zoning: Climate change and coastal hazard considerations should be incorporated into building and zoning codes. 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 elevated above flood elevations and structures to be built on piling foundations in areas of wave action. Zoning can be used to avoid activities on the floodplain other than those compatible with periodic flooding.

15) Strategic Acquisition: Purchase of undeveloped land for flood risk management.

16) Emergency Plans/Hazard Mitigation Plans: Emergency planning allows a community to be prepared for storm events, such as flood inundation from coastal storms. Hazard mitigation plans are developed to document hazards a community is exposed to and determine mitigation measures a community would like to 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.

17) Retreat: Consider managed retreat, allowing wetlands and beaches to take over land that is currently dry. Include land use and zoning appropriate for coastal storm risk management.

18) Wetland Migration: Adjust zoning laws to allow for wetland migration

19) Regional Sediment Management (RSM): Continuation of RSM practices in place and identifying new opportunities.

20) Coastal Zone Management: Coastal Zone Management regulates activities within the “Coastal Zone” to ensure that development is accomplished with the least amount of damage to the coastline.

5.5.3 Natural and Nature-Based Infrastructure

Nature-Based Infrastructure (NBI) refers to the planned use of natural and engineered features to produce engineering functions in combination with ecosystem services and social benefits. Natural and nature-based features include a spectrum of features, ranging from those that exist due exclusively to the work of natural process to those that are the result of human engineering and construction. The built components of the system include nature-based and engineered structures that support a range of objectives, including coastal storm risk management (e.g., seawalls, levees), as well as infrastructure providing economic and social functions (e.g., navigation channels, ports, harbors, residential housing).

Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests. The relationships and interactions among the natural and built features comprising the coastal system are important variables determining coastal vulnerability, reliability, risk and resilience.

1) Green Stormwater Management: Management practices can be used to reduce impervious areas and increasing storage on a localized basis for stormwater. Some examples include bio-swales, rain gardens, green roofs, rain barrels or cisterns. Green stormwater management practices 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. Green stormwater management can also allow for opportunities to add public recreational features and provide for ecosystem restoration, while providing for wave attenuation and stormwater storage.
2) Constructed or Rehabilitated Reefs: Reefs can act as a natural barrier to dampen storm wave activity.
3) Salt Marshes: Salt marshes can provide sediment stabilization to an area, and can dissipate and/or attenuate oncoming wave action. Depending on the cross-shore width of a salt marsh, it has the potential to reduce storm surge effects. The traditional rule of thumb (USACE, 1963) was that for every 2.7 miles of marsh, storm surge is reduced by one foot; however, the degree of flood risk reduction that wetlands provide from storm surge is extremely complicated.
4) Freshwater Wetlands: Freshwater wetlands can provide flood management by detention and/or storage for floodwaters. Infiltration through a freshwater wetland to an aquifer below can assist in groundwater recharge and provide water quality benefits. Freshwater wetlands also provide sediment stabilization benefits.
5) Vegetated Dunes and Beaches: Vegetation helps to stabilize dunes and beaches from erosion due to wind and wave action.
6) Vegetated Submerged Aquatic Vegetation (SAV), Salt Marshes and Wetlands: Vegetated features help to break waves, attenuate wave energy, slow the inland transfer of storm water and increase infiltration.
7) Oyster and Coral Reefs: Reefs can act as a natural barrier to reduce to dampen wave action, while providing essential habitat to marine organisms.
8) Barrier Island Restoration: Barrier islands act as the first line of defense in reducing risk to the mainland from storm surge and wave action. Restoration includes increasing barrier island elevation or plan form (length/width) and can include vegetation components such as dune/beach grass to stabilize sediments and increase wave dissipation.
9) Maritime Forests / Shrub Communities: The dense vegetation of maritime forests and shrub communities helps to stabilize soils while dissipating wave action and slowing the inland transfer of storm water.

The broad measures identified herein, structural, non-structural, and nature-based, have the potential for further development to target specific areas for coastal storm risk management. The goal of measures development is to achieve the objectives by combining one or more measures while avoiding constraints. Measures identified will be further evaluated, screened and used in combination (as

appropriate) in future phases of study to determine area-specific project viability to meet the planning objectives.

5.5.4 Area Specific Measures

The previously described broad-based measures (structural, non-structural, nature-based are applicable to most areas within the study area. Specific area-focused measures provided through stakeholder input and/or otherwise derived from previous studies, particularly any existing hazard mitigation plans, are listed below. This comprehensive list includes some measures that are beyond the purview of USACE. Potential measures that could be evaluated as part of a future study phases are included herein.

5.5.4.1 Statewide

The Maryland State Hazard Mitigation Plan (2012) identified the following measures as related to coastal storm risk managment and flood risk management; the following are applicable to the study area:

1) Structural:
   - Identify flood risk management measures for flood prone wastewater treatment plants.
   - Conduct a feasibility analysis for a temporary floodwall or other flood risk management measure for Baltimore Harbor and other flood prone urban areas.
   - Develop and implement a plan to improve pump stations susceptible to damage in flood prone areas.
   - Identify flood prone roads and replace/mitigate undersized and clogged culverts.
   - Reprofile and reconstruct roads in low-lying, flood prone areas.
2) Non-structural
   - Improve stormwater management throughout the state.
   - Work with responsible state agencies to identify mitigation strategies for state-owned facilities.
   - Require, through policy, that new state capital improvement projects incorporate hazard mitigation principles (e.g., prohibit new projects in hazard-prone areas such as floodplains or the coastal high hazard area; requiring above code design requirements for critical facilities).
   - Ensure that local flood risk management regulations are up to date and consistently enforced.
   - Incorporate climate change and coastal hazard considerations into building codes for coastal communities.
3) Nature-Based:
   - Incorporate nature-based aspects into structural and non-structural measures as much as possible to reduce storm damage and improve resilience.

5.5.4.2 Baltimore County

The Baltimore County Multi-Hazard Mitigation Plan (2012) identified the following measures as related to coastal storm risk management.

1) Structural

- Use structural mitigation measures and techniques as appropriate to minimize future flood risk.

2) Non-structural:

- Regulate the location, type and intensity of new development in hazard areas including flood-zone regulations and coastal erosion areas.
- Develop a retrofitting plan to reduce vulnerability of structures in coastal areas.
- Identify historic properties and structures within the 100-year floodplain and develop an action plan to provide risk reduction or relocate them.
- Determine the feasibility of acquiring undeveloped lands in hazard prone areas.
- Develop a comprehensive storm water management plan.
- Institute a maintenance program for storm water detention basins, culverts and storm drains to minimize future flooding events.
- Develop a watershed management plan.
- Evaluate the Resource Conservation zones to determine if an overlay zoning district is needed that applies additional development standards for sensitive lands, such as wetlands and coastal areas.
- Develop stricter building codes in hazard areas.
- Analyze the floodplain areas to assess suitability for conservation or recreational use.
- Utilize the most vulnerable parts of the floodplain as a greenway, park or wildlife habitat.

Additional problem areas identified by County staff (during a July 2013 meeting) indicate that structural flood risk management measures should be considered for the following Baltimore County facilities.

- Bowleys Quarters Firehouse
- Wastewater Pump Stations
- Back River Wastewater Treatment Facility

5.5.4.3 Baltimore City

The following measures for Baltimore City were identified in multiple previous reports, including the All Hazards Plan (2004), and the DP3 (2013), as well as identified through stakeholder input. Many of these measures are potential considerations for the Fells Point Historic District, the Inner Harbor Area, Middle Branch, and areas along Curtis Bay.

1) Structural

- Waterfront Infrastructure - Enhance the resilience of the City's waterfront to better adapt to impacts from hazard events and climate change.
  - Raise bulkhead height along shoreline areas most at risk.
  - Stabilize and armor unprotected shorelines with vegetation and/or stone.
  - Develop integrated flood risk management systems using structural (engineering) and non-structural (wetlands) measures.

- Water/Wastewater Infrastructure
  - Improve stormwater and waste water infrastructure to prevent flooding from overflows.
  - Prioritize storm drain upgrades and replacement in areas with reoccurring flooding.
  - Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk.

2) Non-structural

- Retrofit existing buildings in the 100-year floodplain to increase resilience.
- Assess opportunities to acquire properties in the floodplain; update a list of flood prone and repetitive loss buildings to consider for acquisition.
- Energy Infrastructure
  - Provide risk management for and enhance the resilience and redundancy of electricity system.
  - Identify, harden and water seal critical infrastructure relative to electrical, heating, and ventilation hardware within the floodplain.
  - Determine low-lying substation vulnerability and outline options for adaptation and mitigation.
  - Evaluate and provide risk management measures to low lying infrastructure - switching vaults, conduit and transformers.
- Communication Infrastructure
  - Identify best practices for the installation and management of floodproofing of all communications infrastructure at risk of water damage.
- Transportation Infrastructure
  - Integrate climate change into transportation design, building and maintenance.
  - Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets.
  - Improve stormwater management, operations and maintenance for stream flooding that erodes away bridge supports.
  - Prioritize infrastructure upgrades for roads identified at risk of flooding through the use of elevation data and SLOSH model results.
  - Raise streets in identified flood prone areas as they are redeveloped.
  - Conduct an in-depth analysis of the impacts of drain fields that feed the harbor.
  - Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels.
- Waterfront Infrastructure - Enhance the resilience of the City's waterfront to better adapt to impacts from hazard events and climate change.
  - Develop integrated flood risk management systems using structural (engineering) and non-structural (wetlands) measures.
  - Review and enhance coastal area design guidelines to better mitigate the impacts of flooding.
- Water/Wastewater Infrastructure

  - Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities to account for future climate projections
  - Retrofit and harden low-lying pumping stations and treatment plants.
  - Improve stormwater and waste water infrastructure to prevent flooding from overflows.
  - Increase stormwater recharge areas and quantity management.
  - Prioritize storm drain upgrades and replacement in areas with reoccurring flooding.
- Enhance and strengthen waterfront zoning and permitting.
- Strengthen city codes to integrate anticipated changes in climate.
- Enhance building codes that regulate building within a floodplain or near the waterfront.
- Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or re-development.
- Evaluate the impacts of sediment loading on reservoir capacity.
- Encourage information sharing within the Chesapeake Bay community to assist in developing best management practices.
- Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance.
- Develop City policy which requires new city government capital improvement projects incorporate hazard mitigation principles.
- Develop and implement hazard resilience measures for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

3) Nature-Based

- Encourage use of permeable pavement in non-critical areas – low-use roadways, sidewalks, parking lots and alleys.
- Evaluate green corridors and parks for possible improvements for flood risk management
- Incorporate urban landscaping requirements and permeable surfaces into community managed open spaces.
- Manage watershed forests to provide maximum benefits for water quality and to maintain resilience during extreme weather events.
- Preserve and protect natural drainage corridors.
- Increase green building requirements for all new construction.
- Require vegetative roofs for all new commercial, industrial, multifamily, and city-owned development.
- Utilize vegetative roofs, rain gardens and bioswales to capture water.
- Require water conservation requirements such as rain barrels and cisterns on City-owned properties, and residential, commercial and industrial properties.
- Identify opportunities where stream restoration efforts will offset maintenance costs.

5.5.4.4 Anne Arundel County

1) Structural

- Identify those segments or components of the public water and sewer infrastructure systems in vulnerable areas where malfunctions or capacity constraints due to flooding or groundwater infiltration have been a known problem and where future impairment would have the most severe impacts in terms of properties or neighborhoods being served, and determine the range of feasible alternatives that can be implemented in both the short term and longer term to ensure adequate service.
- Identify those road segments in vulnerable areas where flooding has been a known problem and where future impairment would have the most severe impacts, potentially cutting off access to individual properties or entire neighborhoods, and study feasible alternatives that can be put in place in both the short term and longer term to ensure road access.
- Protect historic sites and buildings in place where financially and technically feasible using shoreline stabilization measures.

2) Non-structural

- Incorporate sea level rise planning into all related County functions
- Identify high priority sites in future updates of the County's Land Preservation, Parks and Recreation Plan and General Development Plan.
- Target highest priority sites for acquisition using Program Open Space or other preservation funds where available and consistent with the purpose of those funding programs.
- Develop an inventory of sites that can be targeted for wetland or forest mitigation projects by private developers where development plans propose off-site mitigation.
- Assess whether revisions are needed to current design standards for public infrastructure capital projects to reduce future operation and maintenance problems in areas vulnerable to future sea level rise impact
- Engage the public and promote the establishment of conservation easements on private properties in high priority sites to provide resource protection as well as tax incentives for private property owners.
- Revise the County's development regulations to discourage the granting of variances and modifications that allow stream and wetland impacts in the Critical Area, unless the applicant can demonstrate that there is no alternative site design possible that would not result in an effective taking of private property.
- Revise the County's development regulations to increase wetland and stream buffer setbacks in the Critical Area in accordance with State Critical Area Commission recommendations, at a minimum.
- Assess the feasibility of potential revisions to building code requirements that would minimize sea level rise impacts to existing and future development in the Federal Emergency Management Agency (FEMA) 100-year non-tidal and coastal high hazard flood zones. These might include increasing elevation requirements, revised standards for foundation design, use of flood-resistant building materials, or other building design criteria.
- Assess whether revisions are needed to current State and local construction or design regulations and standards for private wells and/or private on-site septic systems in vulnerable or flood-prone areas

- Develop guidelines and requirements for the potential displacement of vulnerable historic resources when shoreline stabilization is not a feasible strategy for permanent protection.

3) Nature-Based

- Develop an inventory of sites that can be targeted for wetland or forest mitigation projects by private developers where development plans propose off-site mitigation.

6 Preliminary Financial Analysis

Given the size of the study area (215 square miles), there could be more than one study and multiple sponsors.

The potential non-Federal sponsors identified in **Table 3**, would be required to provide 50 percent of the cost of the potential future investigation. Up to 100% of the non-Federal sponsor's share could be work in-kind. The potential non-Federal sponsor is also aware of the cost sharing requirements for potential project implementation. A letter of support from the non-Federal sponsor stating willingness to pursue potential future investigation and to share in its cost and an understanding of the cost sharing that is required for project implementation will be required.

7 Summary of Potential Future Investigation

Based on the identified measures, potential alternative plan development, and future screening of alternatives, there appears to be a large array of solutions that have the potential to be economically justified, environmentally acceptable, addressable through engineering solutions, and consistent with USACE policies and the Infrastructure Systems Rebuilding Principles (NOAA and USACE, 2013).

Table 3 summarizes the potential non-Federal sponsors with potential interest in future phases of study to address coastal storm risk management in the Baltimore Metropolitan Water Resources study area.

Table 3. Potential Future Investigation and Non-Federal Sponsors

Non-Federal Sponsor	Area of Interest	Navigation	Coastal Storm Risk Management	Flood Risk Management	Nature-based	Water Resource Management	Community Resilience
State of Maryland, Maryland Port Administration (MPA)	Temporary floodwall or other flood risk management measure for Baltimore Harbor, Port and various private terminal flood risk management	X	X	X	X	X	X
Baltimore County	Unincorporated area of Baltimore County near Dundalk, MD: Sparrows Point, former industrial area consider for redevelopment		X	X	X	X	X
Baltimore County and Baltimore City	Flood risk management measures for critical infrastructure: Back River wastewater treatment facility and various pump stations		X	X			X
Baltimore City	Downtown Baltimore/Inner Harbor Areas/Curtis Bay		X	X	X	X	X
Baltimore City	Middle Branch Patapsco Waterfront urban renewal and redevelopment areas; habitat creation, recreational areas		X	X	X	X	X
Baltimore City	Fells Point Historic District		X	X	X	X	X

8 Views of Other Resource Agencies

Due to the funding and time constraints of this focus area analysis, very limited coordination was conducted with other agencies. Coordination with other resource agencies is being conducted as part of the overall North Atlantic Coast Comprehensive Study Additional coordination would occur during the future phases of study.

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APPENDIX A

STAKEHOLDER INQUIRY LETTER AND EMAIL TRANSMISSION
LIST OF CONTACTS – BALTIMORE METROPOLITAN AREA

STAKEHOLDER INQUIRY LETTER:

CENAB-PL-P 28 August 2013

Dear Stakeholder,

The United States Army Corps of Engineers (USACE) is conducting the North Atlantic Coast Comprehensive Study (NACCS) under the authority of Public Law 113-2, the Disaster Relief Appropriations Act of 2013, Chapter 4, which authorized USACE investigations as follows:

- "*That using up to $20,000,000 of the funds provided herein, the Secretary shall conduct a **comprehensive study** to address the flood risks of **vulnerable coastal populations** in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps.*
- "*….as a part of the study, the Secretary shall **identify those activities warranting additional analysis by the Corps**".

The goals of the NACCS are to:

- Promote resilient coastal communities with sustainable and robust coastal landscape systems, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure; and
- Provide a risk reduction framework (reducing risk to which vulnerable coastal populations are subject) consistent with USACE-NOAA Rebuilding Principles.

To identify those activities warranting additional analysis, USACE is conducting a Reconnaissance-Level Analysis (RLA) for Baltimore Metropolitan Water Resources. The area that will be studied as part of this RLA is shown in Figure 1 (attached).

The purpose of the RLA is to determine if there is a Federal (USACE), interest in participating in a cost-shared feasibility study to formulate and evaluate specific coastal flood risk management projects in the Baltimore Metropolitan Water Resources study area. Possible coastal flood risk management measures could include: structural, non-structural, natural, nature-based, and policy and programmatic measures or a combination of them, if a feasibility study is initiated.

To conduct the RLA**, USACE requests feedback from your jurisdiction** on related problems and potential opportunities to address these issues such as those experienced during Hurricane Sandy and other storm**s.**

<u>Specific feedback requested is as follows:</u>

1) **Problem identification for your area:**
    a. Did your area experience storm surge?
    b. Be specific on particular areas and water bodies within your jurisdiction that experienced storm surge.
    c. What factors, if any, exacerbated damages from storm surge?

2) **Description of damages for your area:**
   a. Provide a narrative including the types of infrastructure damaged or temporarily out of use, structure (building) damages, personal injuries/fatalities.
   b. Provide a map depicting the spatial extent of damages.

3) **Prior related studies or projects (local, state, federal) in the damaged area.**

4) **List measures that your jurisdiction has considered to address the problem** (for documentation purposes, should there be a follow-on study).

Responses should be emailed to:

Ginger Croom, croomgl@cdmsmith.com (USACE Contractor)

Or faxed to Ginger Croom at 617-452-6594

Due to the aggressive schedule to complete the RLA and to meet the Congressional mandate to complete the NACCS, please provide responses to these questions by **September 10, 2013.**

If you have any questions related to this request, please contact Ginger Croom, CDM Smith (USACE Contractor) at 617-452-6594 or me at 410-962-8156.

For more information on the NACCS, please visit:

http://www.nad.usace.army.mil/Missions/CivilWorks/HurricaneSandyCoastalRecovery/NorthAtanticComprehensiveStudy.aspx

Sincerely,

Andrew Roach

USACE, Baltimore District

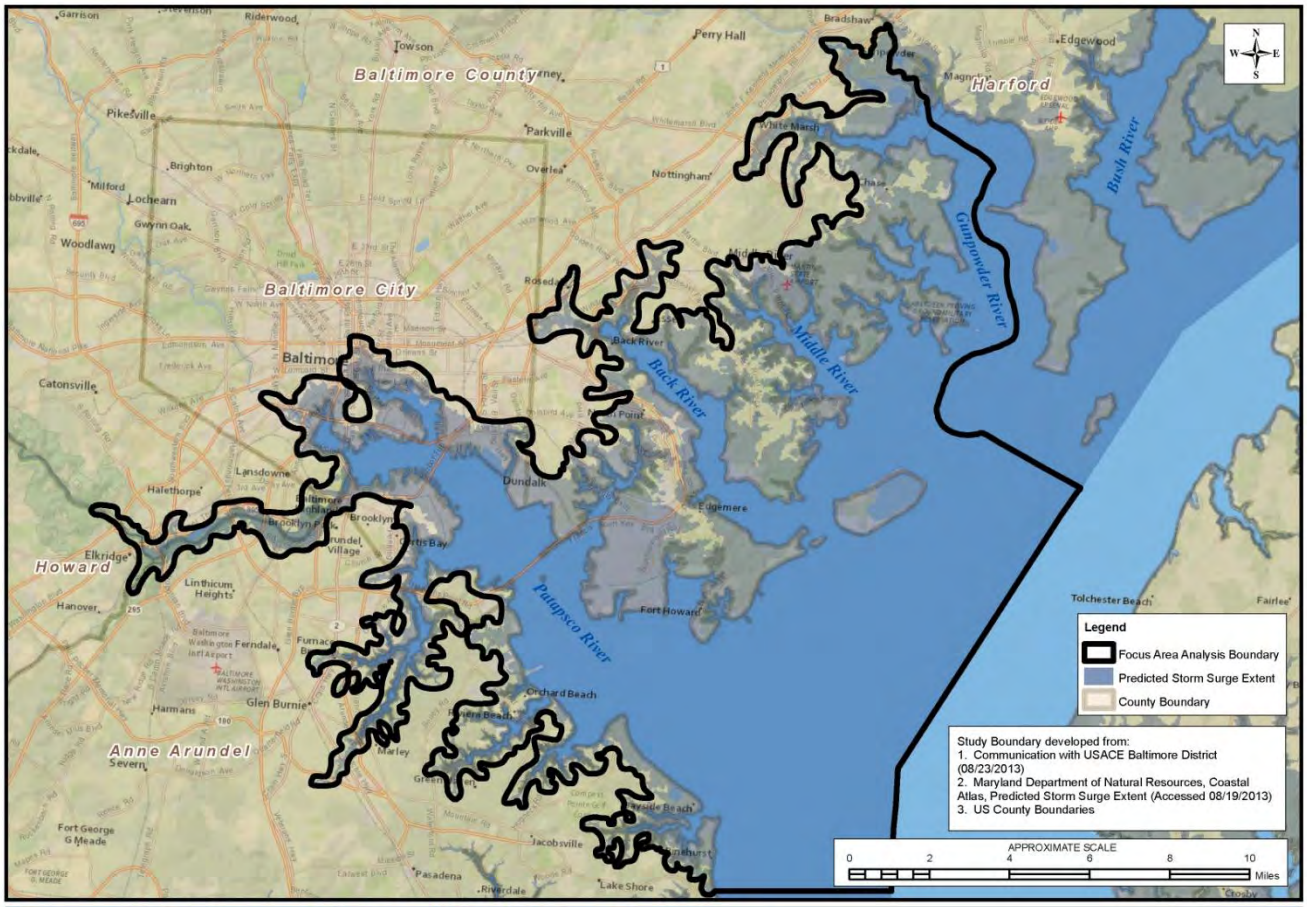

Figure 1. Baltimore Metropolitan Water Resources Focus Area Analysis Boundary

EMAIL TRANSMISSION:

From: Croom, Ginger

Sent: Friday, August 30, 2013 2:27 PM

To: kristin.baja@baltimorecity.gov; beth.stronmen@baltimorecity.gov; dthomas@baltimorecountymd.gov; swelzant@baltimorecountymd.gov; dadams@baltimorecountymd.gov; EmergencyManagement@aacounty.org; pwcust00@aacounty.org; pwelli16@aacounty.org; IPLESH00@aacounty.org; jwhite@marylandports.com; lneuman@aacounty.org

Cc: Roach, Andrew A NAB; Robbins, David W NAB; Bierly, Daniel M NAB; Roberts, Karla NAB; Newman, Martha P NAB; Bartel, Jamie M.; Bui, Frances; Klonsky, Lauren S.

Subject: USACE NACCS - Reconnaissance-Level Analysis for Baltimore Metropolitan Water Resources

Attachments: Baltimore Metropolitan Water Resources RLA.pdf; Figure_1_Baltimore_RLA.pdf

Dear Stakeholder,

Please see attached letter and map sent on behalf of the United States Army Corps of Engineers (USACE).

A meeting will be held on **Thursday, September 5 at 9:30 am at USACE Baltimore District,** City Crescent Building, 10 South Howard Street, Baltimore. The purpose of the meeting is to provide a summary of the North Atlantic Coast Comprehensive Study, and the Reconnaissance-Level Analysis that is being conducted for the Baltimore Metropolitan area.

Please contact Andrew Roach, USACE Baltimore at 410-962-8156, or me with any questions regarding this request.

Please send any information in response this request directly to me (USACE Contractor).

Thank you.

Ginger Croom, PE

Associate

CDM Smith

50 Hampshire Street

Cambridge, MA 02139

617-452-6594 (ph and fax)

617-999-9631 (mobile)

POINTS OF CONTACTS:
Baltimore Metropolitan Area

Jurisdiction	Entity	Name	Role	Phone	e-mail	Address
Baltimore City	Department of Planning, Office of Sustainability	Kristin Baja	Hazard Mitigation Planner	410-396-5917	kristin.baja@baltimorecity.gov	417 East Fayette St., 8th Floor Baltimore, MD 21202-3416
Baltimore City	Department of Planning, Office of Sustainability	Beth Strommen	Director	410-396-8360	beth.stronmen@baltimorecity.gov	417 East Fayette St., 8th Floor Baltimore, MD 21202-3416
Baltimore County	DPW	David Thomas	Assistant to the Director	410-887-3984	dthomas@baltimorecountymd.gov	Room 307, County Office Building 111 West Chesapeake Avenue Towson, MD 21204
Baltimore County		Steve Welzant			swelzant@baltimorecountymd.gov	
Baltimore County		Doug Adams			dadams@baltimorecountymd.gov	
Maryland Port Administration	Maryland Port Administration	James White	Executive Director	800-638-7519	email from NAB (existing contact)	401 East Pratt Street, Baltimore, MD 21202
Anne Arundel County	County Executive Office	Laura Neuman	County Executive	410 222-1821	lneuman@aacounty.org	The Arundel Center, 44 Calvert Street, Annapolis, MD 21404
Anne Arundel County	Office of Emergency Management	Lt. James Fredericks	Director	410 222-0600	EmergencyManagement@aacounty.org	7480 Baltimore Annapolis Blvd., Suite 102 Glen Burnie, MD 21061
Anne Arundel County	DPW			410-222-7500	pwcust00@aacounty.org	2664 Riva Road Annapolis, MD 21401
Anne Arundel County	DPW-Engineering			410-222-7500		2664 Riva Road Annapolis, MD 21401
Anne Arundel County	DPW-Watershed and Ecosystem Restoration Services	Ginger Ellis	Planning Administrator	410-222-7500	pwelli16@aacounty.org	2664 Riva Road Annapolis, MD 21401
Anne Arundel County	Central Services	Bill Schull	Acting Central Services Officer	410-222-7644		2664 Riva Road Annapolis, MD 21401
Anne Arundel County	Permit Application Center, Department of Inspections and Permits	Jay Leshinskie	Commercial Permit Coordinator	410-222-7790	IPLESH00@aacounty.org	2664 Riva Road Annapolis, MD 21401

APPENDIX B

MEETING DOCUMENTATION FROM KICK-OFF/STAKEHOLDER MEETINGS

STAKEHOLDER MEETING:

North Atlantic Coast Comprehensive Study

Baltimore Metropolitan Water Resources
Focus Area Analysis - Memorandum for Record
Subject: Stakeholder Coordination Meeting

On July 29, 2013, the U.S Army Corps of Engineers (USACE) met with a representative from the Baltimore County, Department of Public Works to discuss the North Atlantic Coast Comprehensive Study (NACCS) Baltimore Metropolitan Water Resources Focus Area Analysis. Two people attended the meeting. The meeting introduced the Focus Area Report generation process and discussed unrelated work addressing flooding in the Roland Run watershed.

US Army Corps of Engineers

North Atlantic Coast Comprehensive Study

Baltimore Metropolitan Water Resources

Focus Area Analysis

Stakeholder Meeting

July 29, 2013

Attendees: Andrew Roach – Planner at USACE (Focus Area Study Manager)

David Thomas, PE – Baltimore County, Department of Public Works

Meeting Minutes:

Meeting was organized to introduce the Recon-Like Analysis for the Baltimore Metropolitan Area, as well as discuss unrelated work addressing flooding in the Roland Run watershed.

- Baltimore County Hazard Mitigation Plan has expired. The county is working on a new version, which will be completed in approximately 6 months.
    - Steve Welzant is the point of contact
    - Hazard Mitigation Plan includes County's coastal flooding priorities and mitigation measures
- Infrastructure of concern:
    - Bowleys Quarters firehouse floods: 2-3 feet of water
    - Wastewater pump stations – experience flooding
    - Backriver wastewater treatment facility
- Building codes are being updated – 2 foot freeboard requirement

KICK-OFF MEETING:

NAB RLAs – Baltimore and D.C. Study Areas
16 Aug 2013
11 am
Kickoff Meeting/Telecon

Attendees:
Dave Robbins – NAB PM
Dan Bierly - NAP Planning
Martha Newman – NAB Planning
Andrew Roach will be main POC – in training this week
Jamie Bartel, Frannie Bui, Ginger Croom – CDM Smith

Washington, D.C. Study Area

1. **General**
   Previous meetings D.C. Flood Risk Management Committee, (NAB staff, CDM Smith participated via conference call).

2. **Study Areas**
   Discussed study areas and need to include contiguous areas (portions of several counties) surrounding D.C. This includes portions of planning reaches that are identified as part of the study area effort, **ACTION: CDM Smith will provide updated draft maps (by 8/20).**

3. **Relevant existing projects/studies**
   - Existing levee projects – Potomac Park levee
   - 17th street closure, construction contract to complete a closure – not an issue for recon but ongoing effort to be aware of
     - Levee itself is existing project, but was not constructed to level of protection for which it was originally authorized
     - Have had problems with construction contractor, construction not complete
     - Current design flow is 700,000 cfs (Potomac, which includes tidal influence). 65% design is completed, but not built, currently built to level that does not meet 100-year level of protection. Authorized budget is insufficient to raise the levee, would need higher project cost/budget to be authorized. If 700,000 cfs is not high enough then need to factor that into our analyses
   - Bloomingdale neighborhood – area characterized by stormwater drainage issues. Current CSO long-term control plan (LTCP) is ongoing (DC Water project). This ongoing project may inadvertently address these local drainage issues and alleviate local flooding in this neighborhood.

NOTE: As with Bloomingdale, stormwater management issues will likely be recurring theme in many watersheds or communities (729 watershed assessment)- How do we address these in the RLAs? Decide we will include mention of stormwater management issues in the RLAs.

   - Federal Triangle – stormwater issue behind Potomac Park levee (existing USACE project) study completed that identified recommendations to install cisterns under mall (NPS project) – may be an opportunity to address/reference. There is a potential opportunity to

consider pump station(s) in this area. Pump stations and/or related improvements could be considered as a potential opportunity in the RLA.

- DC Metro – considering raising Metro parapet walls in the Triangle and the Archives (incorporate as potential problem) – reference NY subway flooding problems post-Sandy. Need to protect critical infrastructure components similar to those damaged in Sandy.
- Reference Jonathon Reeves comment that was submitted post meeting—several secondary effects of coastal flooding/inundation in the area that USACE may be able to address for mitigation - want to be pro-active and address secondary effects of coastal flooding, addressing critical infrastructure
- Blue Plains WWTP – ongoing construction of seawall, associated with enhanced nitrogen removal system (part of the Chesapeake Bay restoration efforts). However, the seawall is only confined to that new construction area, leaving other areas exposed. FEMA Maps (2010) – show that a portion of the facility would be inundated. Again, theme is to address problem areas with a need to protect critical infrastructure.
- Existing USACE levee project, City of Alexandria and Arlington Co., susceptible to sea-level rise; levee height likely not adequate
- Cameron Run – another problem area with inundation – various other areas across Potomac, Fairfax County and City Alexandria – USACE has existing general investigation (GI) in the watershed (CDM Smith does much work for FFX County – will
- National Harbor area – look at this also, it is a new development area on the river susceptible to seal level rise

4. **POCs /list of potential sponsors**
   - Pat Mano at the district could assist in contact efforts/reaching out to groups
   - D.C., Prince George (PG) County, Fairfax County, Arlington Co., Alexandria, NGOs? **ACTION: CDM Smith to contact NoVA entities and PG County**
   - Contact Stacy Underwood (relevant to NGO question).
   - Need meeting(s) with Fairfax, Arlington, P.G. Counties, Alexandria and D.C.

5. **Communication**
   - Weekly status calls with NAB – would be primarily with Andrew, but cc: Dan, Dave, Karla, Martha

<u>Baltimore Study Area</u>

1. **General**
   Previous meetings – Baltimore County and City of Baltimore (NAB staff participated, **ACTION: NAB to provide CDM Smith meeting notes for record)**

2. **Study Areas**
   Discussed study areas and need to include contiguous areas (portions of several counties) surrounding Baltimore. This includes portions of planning reaches that are identified as part of the study area effort, **ACTION: CDM Smith will provide updated draft maps (by 8/20).**

3. **Relevant existing projects/studies/problem areas**

Baltimore County

Andrew Roach held a meeting with Baltimore County previously. Baltimore City and County are well aligned with the process of identifying respective hazard mitigation plans (HMPs)/projects; problem areas were identified as they relate to future climate change impacts and considered damages incurred from Hurricane Isabel (2003). CDM Smith will use the draft HMP as a reference source. **ACTION - need POC from NAB to get HMP report.**

Baltimore City

NAB (Dave Robbins, Dan Bierly, others) met today 16 Aug. **ACTION: NAB to provide CDM Smith meeting notes for record.**

- 4 primary areas or "hot spot" areas to address in RLA

1) Port – critical infrastructure, need to evaluate area for problems/opps – include private terminals also due to concern of potential damages

2) Fells Point – historic district susceptible to tidal flooding, City is going to look to a contractor to separately evaluate potential problems in the specific area (low point with dense development close to the water's edge) – storm drainage, storm surge are problems. Flooding problems during Isabel, no interest in a flood wall, but still should mention/consider as a potential opportunity in the RLA.

3) Middle Branch, Patapsco – waterfront areas, prime for re-development, one area in particular is already starting re-development (developer already started but went out of business). Area very susceptible to storm surge. **Opps for green-infrastructure here (however not building into water due to wetlands restoration ongoing).**

4) Downtown/inner harbor – business attractions in area; much info in HMP on this area

5) Existing study authorities – Baltimore Metropolitan Water Resources Authority

Anne Arundel County

1) Sparrows Point (community by the bridge); Curs Creek, Curs Bay—all areas susceptible to wave action/fetch

2) Primarily residential areas as indicated on map

3) Less far along with their work to identify problem areas

4. POCs

- Baltimore City office of sustainability – Planning Division, contact them for information on HMPs (POC – will provide information on this modeling/report) – NAB should have existing contact (met with on 16 Aug)
- Baltimore County – NAB has contact (Andrew met previously)
- Maryland Port Administration (MPA) – **ACTION: CDM Smith to contact on behalf of NAB, coordinate with NAB existing contacts**

- Harford and Anne Arundel Counties – need to contact –ACTION – **CDM Smith to contact on behalf of NAB**
- Discussed meeting with ALL 4-5 Baltimore stakeholders – 1 meeting

5. **Communication**
   - Weekly status calls with NAB – would be primarily with Andrew, but cc: Dan, Dave, Karla, Martha

6. **Miscellaneous**
   - DEP has HAZUS data, DP3

Summary of Action Items

CDM Smith

- Provide updated maps based on today's discussion 20 Aug
- Contact NoVA entities and PG County, week of 19 Aug for overall coordination and meeting set-up
- Contact Fairfax County to get additional information on Cameron Run – both problem and potential solutions County would like to see addressed
- Contact Stacey Underwood (relevant to NGO question)
- Contact MPA (coordinate with NAB on existing contact for dredging projects)
- Contact Harford and Anne Arundel Counties

NAB

- *Provide* CDM Smith meeting notes from Baltimore County and Baltimore County meetings
- Provide CDM Smith both Baltimore City and Baltimore County POCs for overall coordination, and so CDM Smith can request HMP

STAKEHOLDER MEETING:

North Atlantic Coast Comprehensive Study

Baltimore Metropolitan Water Resources
Focus Area Analysis - Memorandum for Record
Subject: Stakeholder Coordination Meeting

On Thursday, September 5, the U.S Army Corps of Engineers (USACE) met with representatives from the City of Baltimore and the Maryland Port Administration and CDM Smith to discuss the North Atlantic Coast Comprehensive Study (NACCS) Baltimore Metropolitan Water Resources Focus Area Analysis. Seven people attended the 1.5 hour meeting (6 in-person and 1 via teleconference).

Dave Robbins and Andrew Roach from USACE provided introductions and the meeting purpose –Baltimore Metropolitan Water Resources Focus Area Analysis.

Dave Robbins from USACE presented handouts of a PowerPoint presentation which provided information on the overall NACCS, and Andrew Roach addressed the focus area analysis as part of the NACCS. Andrew Roach also discussed the information that is being requested from various stakeholders pertinent to complete the focus area analysis.

US Army Corps of Engineers

North Atlantic Coast Comprehensive Study

Baltimore Metropolitan Water Resources

Focus Area Analysis

Stakeholder Meeting

September 5, 2013

9:30 AM – 11:30 AM

Location: USACE Baltimore District, 10 S. Howard Street, Baltimore, MD

Attendees: Andrew Roach – Planner at USACE (Focus Area Study Manager)

Dave Robbins – NACC Project Manager at USACE

Karla Roberts – NACC Study Manager at USACE

Martha Newman – Planner at USACE

Kristin Baja – Hazard Mitigation Planner at Baltimore City Office of Sustainability Bill Richardson – Environmental Manager at Maryland Port Administration

Ginger Croom – Project Manager at CDM Smith

Jamie Bartel – Project Manager at CDM Smith (via phone)

Meeting Minutes:

- Introductions and Overview
  - **Dave Robbins,** USACE, addressed the meeting participants and provided an overview of the study area and purpose of the focus area analysis.

- Presentation
  - **Dave Robbins**, USACE, went through a presentation on the NACCS with the meeting participants.
  - **Andrew Roach,** USACE, went through a presentation on the focus area analysis for Baltimore Metropolitan Water Resources, which is being conducted as part of the NACCS.

Feedback Requested (Letter to Stakeholders 8/30/13)

Problem identification – MPA

- Sandy and Isabel impacts (Isabel impacts much more severe than Sandy– Wind, Precipitation, flooding around terminals. Timing of high tide combined with aging infrastructure (storm drains) was an issue
- Surge from Isabel did come over terminals. Bulkheads around terminals are approx. 9'
- CDM Smith requested whether MPA has GIS mapping to show Isabel effects near MPA terminals
- Masonville DMCF, now as a barrier – otherwise Masonville would be more vulnerable
- Bill Richardson asked whether impacts to shipping channels/lanes are being evaluated in the NACCS or this analysis. Noted sedimentation problems in navigation channels from large storm events. MPA experienced impacts from Sandy due to channel fill more than any other impacts

Problem identification – Baltimore City

- Sandy – biggest impacts were precipitation from actual storm, and impacts to low lying areas such as Jones Falls.
- Isabel – see DP3 report (available 9/11/13)
- Baltimore City has M&N working on a study currently for Fells Point – engineering analysis of deployable

flood wall and other alternatives. Study is currently in process. Next meeting with Baltimore/City and M&N on this study is 9/23/13.

Prior Studies/Reports to consider as part of current study:

- Baltimore City DP3 Plan will include input from agencies, community members and HAZUS data. Information from both Isabel (2003) and Sandy will be included. Report will be organized by sector areas (rather than by hazard type), such as infrastructure, public services, etc. Includes measures such as regulating to existing 100-year and 500-year flood levels, and freeboard of 2' vs. 1' above BFE. As part of DP3, Baltimore City is working with FEMA to evaluate storm scenarios if Sandy would've turned earlier and come closer to Baltimore.

Measures being considered

- Red line, is being required to raise lines, especially along Boston St. corridor
- Requirements for 14' above BFE, near new Harbor East development

Other Discussion and Q&A:

- Maryland Executive Order for SLR, climate change
- Baltimore City is incorporating these elements into DP3
- Baltimore developers are part of Baltimore City's plan/process – major developers are in agreement to regulate to current standards and to raise freeboard.

Q: Kristin Baja – how are varying areas (in MD) being evaluated in NACCS, example? Maryland Eastern Shore vs. Baltimore City
A: Dave Robbins – described NACCS reaches: Baltimore City, Port of Baltimore, Sparrows Point, etc, and that measures are being evaluated by shoreline type, what are most appropriate measures to consider based on risk, vulnerability, etc.

Q: Bill Richardson: How are areas being characterized for risk and vulnerability? Is it just based on Sandy impacts or can Irene impacts be considered also, since that storm had a greater impact on the Baltimore area. MPA facilities experienced much more flooding/surge during Isabel than Sandy.
A: Dave Robbins: The NACCS is looking at vulnerable areas and opportunities to reduce risk.

Meeting adjourned at 11:30 am

---End of Minutes---

APPENDIX C

STAKEHOLDER FEEDBACK

Anne Arundel County Provided the following documents via email:

1) Sea Level Rise Final Plan

2) AA County Sea Level Rise Final Report

3) Tropical Storm Isabel Final Internal

USACE Requested Information – Anne Arundel County Responses

9/13/13

1) Problem identification for your area:
   a. Did your area experience storm surge?

      No, for Hurricane Sandy.

      Yes, for Hurricane Irene (2011)

      Yes, for Hurricane Isabel (2003)
   b. Be specific on particular areas and water bodies within your jurisdiction that experienced storm surge.

      Please see attached. The areas of greatest impact due to storm surge are located primarily in the southern end of the county in the Deale and Shady Side Communities. Additionally, areas of Pasadena along the Bay experience storm surge.
   c. What factors, if any exacerbated damages from storm surge?

      The issue of Sea Level Rise has and will continue to increase damages related to storm surge. For properties directly on the coastal areas of the county, storm related debris in the water has exacerbated damages in large storms.

2) Description of damages for your area:
   a. Provide a narrative including the types of infrastructure damaged for temporarily out of use, structure (building) damages, personal injuries/fatalities.
   b. Provide a map depicting the spatial extent of damages.

      We do not have a map but the attached After Action Report for Hurricane Isabel contains much of the requested information.

3) Prior related studies or projects (local, state, federal) in the damaged area.

   Please see attached Sea Level Rise report.

4) List measures that your jurisdiction has considered to address the problem (for documentation purposes, should there be a follow-on study).

   None.

From: Christine Romans [mailto:PWROMA22@aacounty.org]
Sent: Friday, September 13, 2013 4:15 PM
To: Croom, Ginger
Cc: Chris Phipps; Karen Cook; Teresa Chapman; Jay Leshinski; Jan Russell; Larry Tom
Subject: USACE request - NACCS RLA

Ms. Croom - As requested by letter date August 30, 2013, attached is the information we have available to support the NACCS study efforts. Please contact me if you have additional questions and I can direct the inquiry to the appropriate County personnel.

Thank you.

Christine A. Romans

Acting Director, Inspections and Permits

Anne Arundel County

2664 Riva Road

Annapolis, Maryland 21401

410-222-7790 (office)

christine.romans@aacounty.org

ATTACHMENT B

USACE State Problems, Needs, and Opportunities Correspondence with Individual State Responses

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt. Governor*
Joseph P. Gill, *Secretary*
Frank W. Dawson III, *Deputy Secretary*

May 2, 2014

Amy Guise
Chief, Planning Division
Department of the Army
Baltimore District, Corps of Engineers
P.O. Box 1715
Baltimore, MD 21203-1715

Re: North Atlantic Coast Comprehensive Study: State of Maryland Problems, Needs and Opportunities for Future Planning Initiatives

Dear Ms. Guise:

The State of Maryland continues to express interest and supports various Federal, state, and local agency initiatives to communicate flood and erosion risks from coastal storms to vulnerable coastal populations and communities. This is evident as part of the Maryland's collaboration with the USACE North Atlantic Coast Comprehensive Study to address erosion and flood risk to vulnerable coastal populations. As part of continued collaboration with USACE and for inclusion in the NACCS documentation submitted to Congress, this letter serves to provide additional information related to Maryland's problems, needs, and opportunities with respect to coastal storm risk management and resilience.

The Maryland Department of Natural Resources (MD DNR) concurs with the USACE's determination of relative high vulnerability for the 37 areas within the five planning reaches identified in the NACCS. In addition to the 37 areas identified, we have determined through an internal spatial analysis that additional shoreline areas in Maryland have existing and future shoreline conditions and coastal storm risk management and resilience needs that warrant a determination of high vulnerability in the NACCS documentation. These areas include:

Anne Arundel County: Shadyside Peninsula, Muddy Creek, Franklin Point
Baltimore/Harford County: Gunpowder, Hammerman and Dundy Creeks, North Point State Park and Millers Island
Calvert County: Chesapeake, North and Dares Beach
Cecil County: Charlestown
Charles County: Cobb Island, Colton Island, St. George's Island, New Towne Neck, Poplar Neck and Rodo Beach
Prince George's County: Bladensburg and the Town of Edmonston

Queen Anne's County: Grasonville and Kent Narrows
St. Mary's County: Jefferson Islands Club, St. Catherine Island, Point Lookout State Park
Somerset County: Janes Island (note that there is a planned off-shore breakwater system already under study by USACE in this area; however, more will need to be done in the future to extend the life of the island), Deal Island (particularly the coastal impoundment managed by the Chesapeake Bay National Estuarine Research Reserve), French Town Marsh, and White Haven Ferry Road
Worcester County: Ocean City, Assateague Island State Park, and the Atlantic coastal bay islands, including Skimmer and Reedy Islands

All of these areas are subject to coastal storm surge and erosion risk and may likely require either structural, natural or nature-based solutions within near-to moderate timeframes. Prior to further project selection, design and implementation within any of these areas, we would also like to request that a mechanism be established for identifying the habitat of sensitive species which may be negatively impacted by potential activities. For example, within "planning reaches" MD-3 and MD-5 the presence of State and Federally listed Puritan Tiger Beetle (Cicindella puritana) is not clearly identified.

In addition to the general areas of concern noted above, MD DNR requests that authorization under the Continuing Authorities Program, Section 107, River and Harbor Act of 1960, as amended for the Shallow Draft Navigation and Jetty Project at Rhodes Point, Smith Island be reactivated. Rhodes Point is located along the southwestern shoreline of Smith Island in Somerset County, Maryland. Smith Island is located 12 miles west of Crisfield, Maryland and 95 miles south of Baltimore and straddles the Maryland and Virginia state line. Smith Island is actually a cluster of marsh areas, separated by shallow tidal guts. The small pockets of uplands are used as residential portions of the three towns: Tylerton, Ewell and Rhodes Point. The area of interest was Sheep Pen Gut, which connects Rhodes Point to the Chesapeake Bay. The current Federal navigation channel that serves Rhodes Point goes through Sheep Pen Gut. The primary navigation problem being experienced by the waterman is the rapid shoaling in the existing Federal channel. As detailed on the USACE Project Fact Sheet (March 15, 2010), the recommended plan was a twin jetty with a realigned channel combined with a spur or jetty extension and a sill.

Plans and specifications for this project were 99 percent complete, however USACE Headquarters disapproved the Baltimore District's waiver request to the WRDA Implementation Guidance to increase the Federal project limit to $7 million in accordance with Section 2022 of the WRDA of 2007. Since 2004, when the study was originally planned and designed, the amount of marsh erosion and sediment accumulation within the navigational approaches to Rhodes Point has worsened, placing the community of Rhodes Point at extreme risk. Reconsideration of this project by the USACE and U.S. Congress for funding authorization remains a major state and local priority.

In conclusion, I would like to draw attention to a project proposed by MD DNR (submitted for funding in January 2014 through the DOI/NFWF Hurricane Sandy Coastal Resiliency Competitive Grants Program) for the development of a Coastal Resiliency Master Plan for the State of Maryland. The Master Plan would establish priorities for future natural and nature-based coastal storm risk and erosion solutions to enhance community resiliency. A primary component of the project is the identification of shoreline segments where natural features provide the most potential risk reduction to the greatest number of people or greatest amount of infrastructure (potential protection priority areas) as well as shoreline segments with vulnerable communities that lack natural infrastructure (potential restoration priority areas). It is envisioned that the assessment will be informed by ecological and spatial data available from a wide range of federal, regional and state sources, including the NACCS.

If funding for the Coastal Resiliency Master Plan is secured, MD DNR would welcome further engagement, advice and technical support from the USACE in support of project implementation. However if funding is not realized, we would welcome the exploration of a partnership with USACE to conduct this high priority state project.

Thank you again for the opportunity to participate in the process to develop, review and provide feedback on the NACCS. As always, we look forward to working with you on future collaborations and projects that enhance Maryland's resilience to climate change, sea level rise, coastal storms and other extreme events.

Sincerely,

Joseph P. Gill
Secretary