APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY:
RESILIENT ADAPTATION TO INCREASING RISK

STATE CHAPTER

D-3: State of Rhode Island

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. Introduction

The purpose of the North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk is to catalyze and spearhead innovation and action by all to implement comprehensive coastal storm risk management 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. The U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration's (NOAA) Infrastructure Systems Rebuilding Principles define 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 Risk Management Framework Appendix discusses state-specific conditions, risk analyses and areas, and comprehensive coastal storm risk management (CSRM) strategies in order to provide a more tailored Framework for the State of Rhode Island (RI). The Rhode Island Coastline Focus Area Analyses (FAA) Report is included as an attachment to the state chapter.

II. Planning Reaches

Planning reaches for Rhode Island 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).

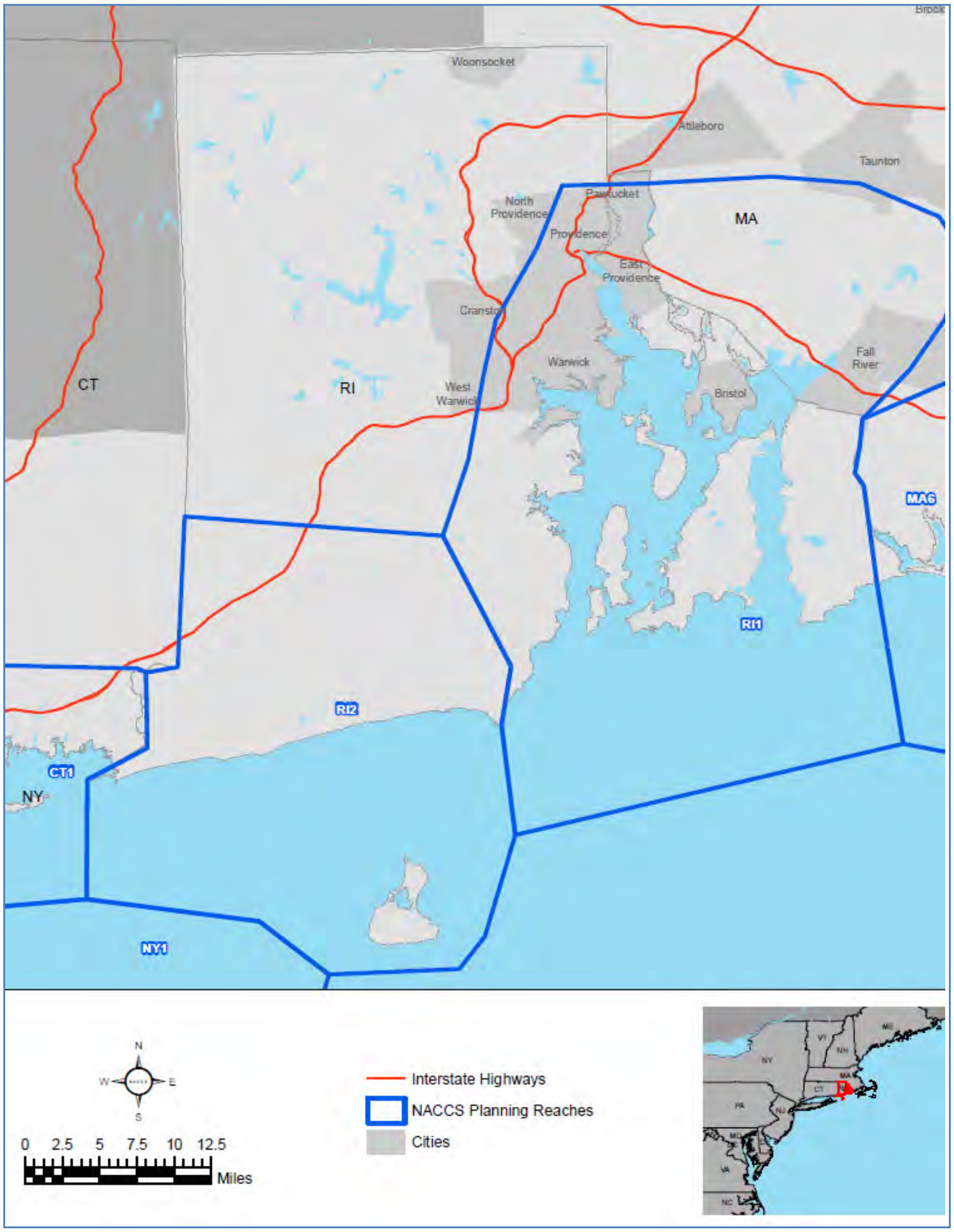


Figure 1. Planning Reaches for the State of Rhode Island

There are two planning reaches in Rhode Island, designated as RI1 and RI2. RI1 covers the Narragansett Bay area in general, starting at the Massachusetts border and ending at Point Judith. This reach includes most of the state's more dense population centers including Newport, Barrington, East Providence, Providence, Cranston and Warwick. The cities in the upper bay are the site of some very significant regional port facilities. RI2 encompasses the south shore of Rhode Island. This reach, though less populated, is known for its recreational beaches and is therefore very important to the state's economy. Towns included in this reach are South Kingstown, Charlestown, and Westerly.

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

The existing conditions for the State of Rhode Island are summarized in that only the Fox Point Hurricane Protection Barrier in Providence, RI provides reliable coastal storm risk management against storm surge. 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 Rhode Island (U.S. 2010 Census data)

Table 1. Affected Population by Hurricane Sandy for the State of Rhode Island

County	Population
Washington	126,979
Kent	166,158
Providence	626,667
Bristol	49,875
Newport	82,888
Total Population Affected	**1,052,567**

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.

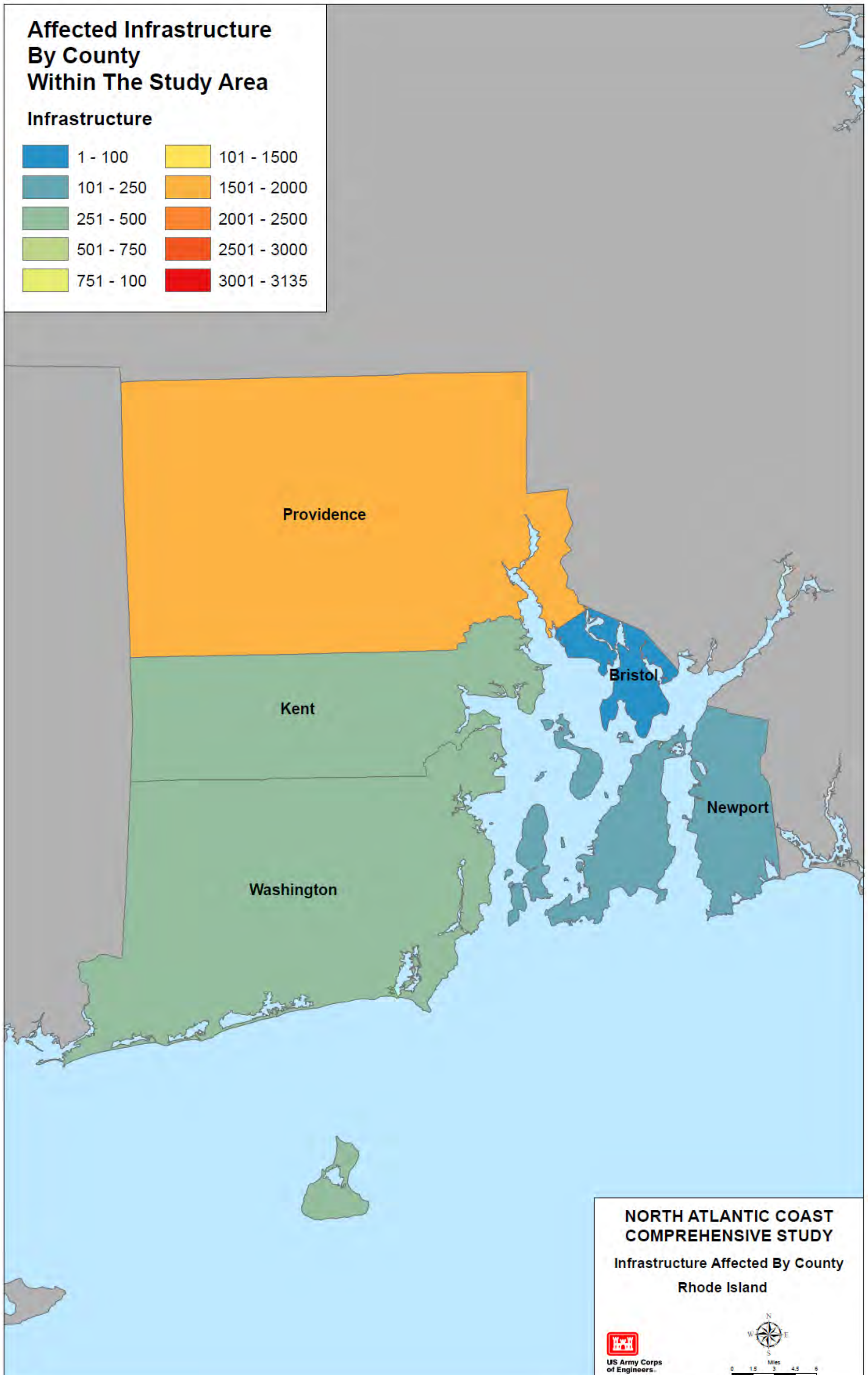


Figure 3. Affected Infrastructure by Hurricane Sandy for the State of Rhode Island

Table 2. Affected Infrastructure elements by Hurricane Sandy for the State of Rhode Island

County	Infrastructure
Bristol	82
Kent	409
Newport	225
Providence	1594
Washington	428
Total Infrastructure Affected	**2,738**

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 resilience. A base year of 2018 has been identified when USACE projects discussed below will be implemented and/or constructed.

USACE, with the help of the Rhode Island state contact (Rhode Island Coastal Resources Management Council [RI CRMC]), inventoried the state, community, and private shore stabilization projects. Some of these projects may have been damaged during Hurricane Sandy. USACE understands that Rhode Island and the local communities have or are currently rebuilding and restoring the shoreline and damaged infrastructure and property to pre-Sandy conditions under emergency authorities and programs. Given this priority, and the apparent lack of resources to commence new coastal storm risk management efforts at this time, USACE has assumed that the state's post-Sandy landscape condition will be the pre-Sandy condition. A complete list of existing USACE projects within the entire study area is presented in Appendix C – Planning Analyses.

USACE New England District asked Rhode Island to consider the above post-Sandy landscape condition description and respond as to the statement's accuracy, or fully describe and explain the state's post-Sandy landscape condition with definable projects, programs, acts, statutes, or plans in order to assist the USACE in continuing the development of the post-Sandy Comprehensive Study.

The Executive Director of the RI CRMC indicated via email correspondence (July 19, 2013) that his agency agrees with the USACE assumption that the state's PSMLFC will be the pre-Sandy condition (Rhode Island Coastal Resources Management Council, 2013).

USACE has identified 20 Federal projects in Rhode Island as part of its post-Sandy landscape condition; 4 of which are storm damage reduction projects and 16 are navigation projects (see Figure 4). RI CRMC provided the USACE information regarding 2,201 coastal storm risk management projects: 1407 were classified as seawalls/bulkheads and 794 were classified as revetments (see

Figure 5). This includes all coastal structures (publicly or privately owned). No information was available regarding the specific level of risk management afforded by these projects.

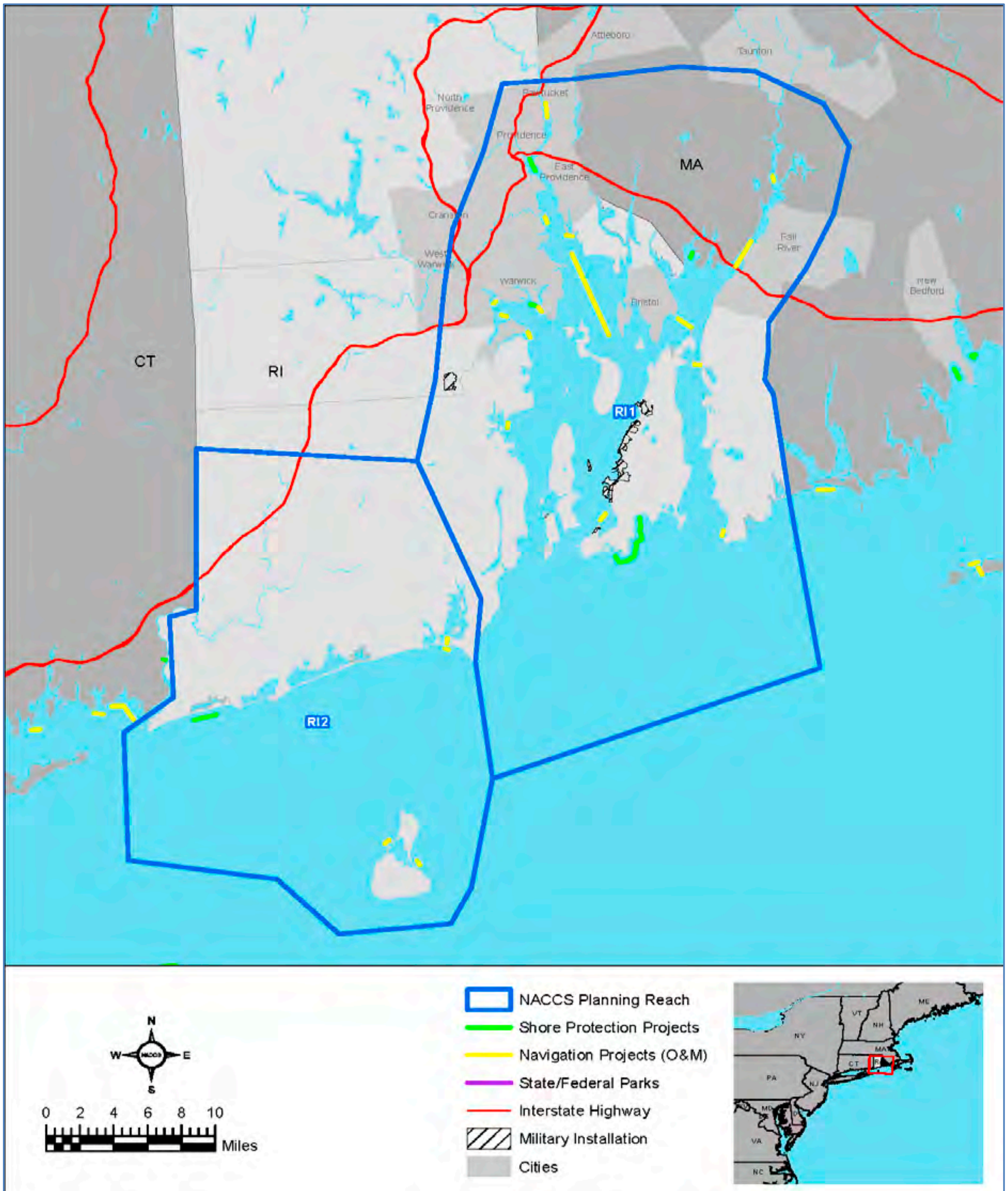


Figure 4. Federal Projects included in the Post-Sandy Landscape Condition

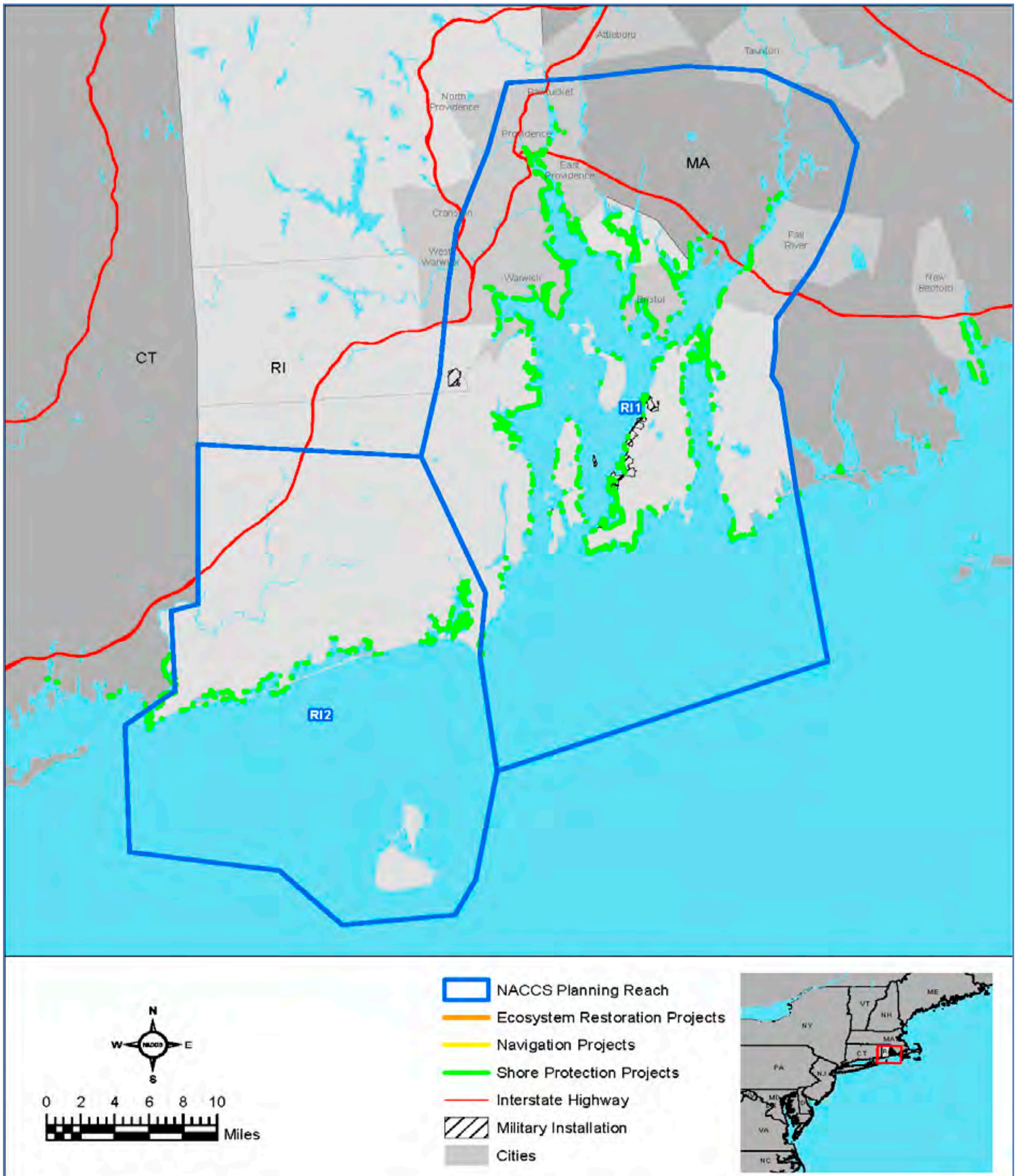


Figure 5. State Projects included in the Post-Sandy Landscape Condition

Sea Level Change

The current USACE guidance on development of sea level change (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 the NACCS Main Report.

These USACE and NOAA future sea level change scenarios have been compared to state- or region-specific sea level change scenarios. The scenario presented by the Rhode Island Coastal Resource Management Program, is frequently referenced, if unofficially, by various bureaus within the State of Rhode Island (Figure 6). Comparison of the USACE Low, Intermediate, and High and NOAA High relative sea level change scenarios (for the Newport, RI NOAA tide gauge) with the Rhode Island Coastal Resource Management Program (2012) scenarios for the State of Rhode Island indicate similar trends, but some uncertainty in future water levels. Thus, importance should be placed on scenario planning rather than on specific, deterministic single values for future sea level change. Such sea level change scenario planning efforts will help to provide additional context for state and local planning and assessment activities.

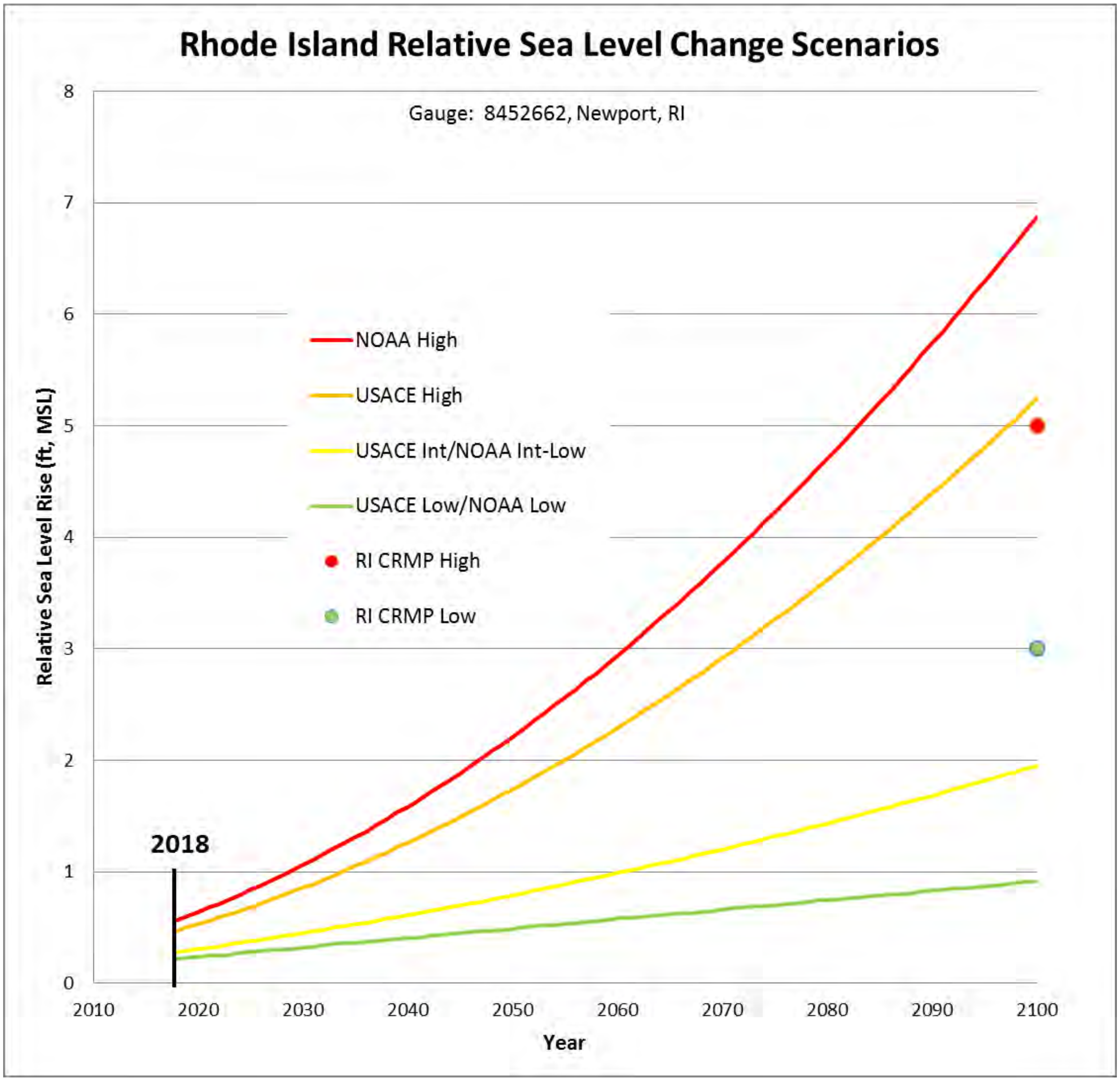


Figure 6. Relative Sea Level Change for Rhode Island (RI Coastal Resource Management Program, 2012) and for Newport, RI for USACE and NOAA Scenarios.

To consider the effects of sea level change on the future landscape change, future sea level change scenarios have been developed by the USACE (ER 1100-2-8162, 2013) and NOAA (2012). Figure 7 shows areas that would be below mean sea level at four 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.

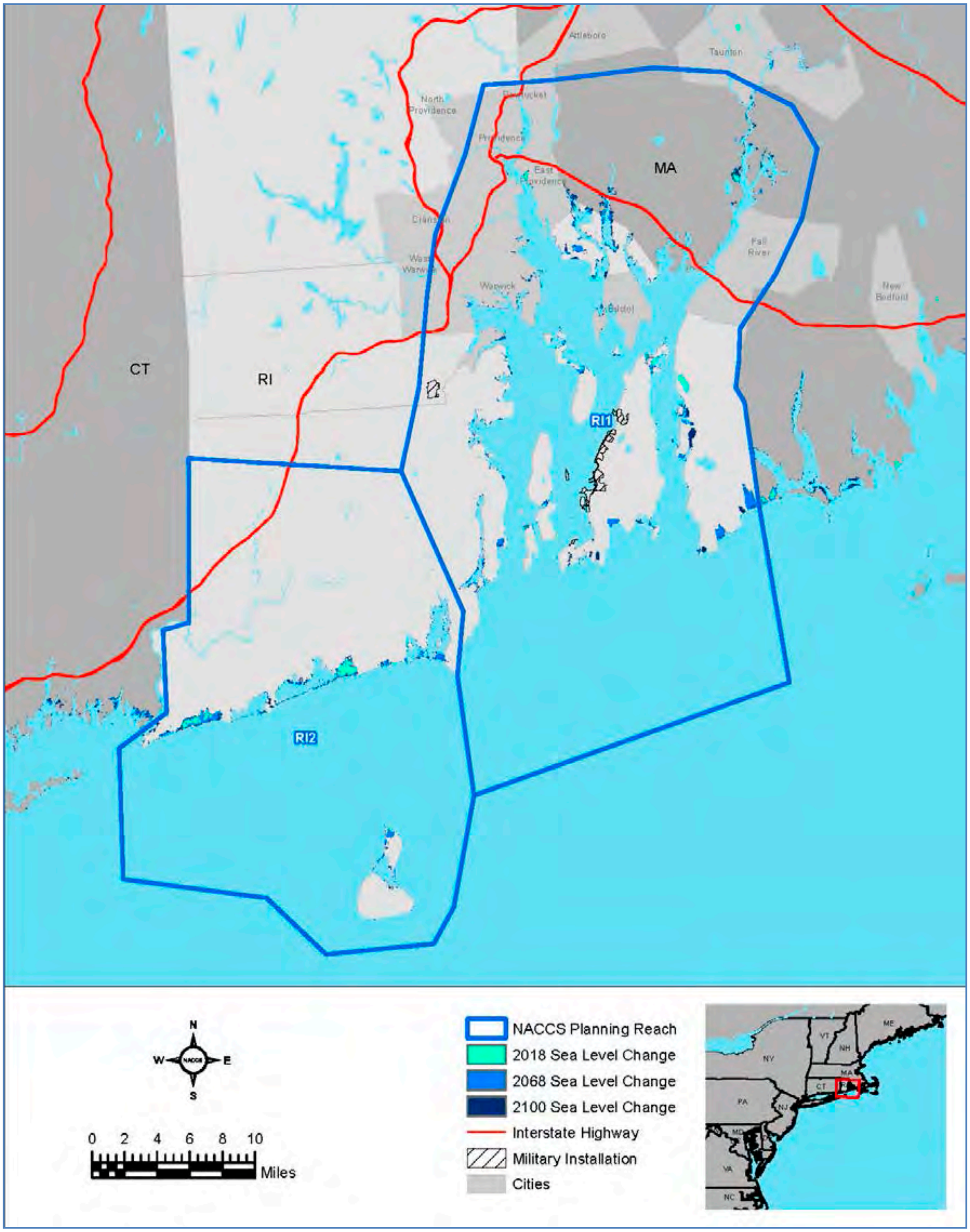


Figure 7. USACE High Scenario Future Mean Sea Level mapping for the State of Rhode Island

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 presents the USACE High scenario inundation and the forecasted increase in residential development density derived from ICLUS data for Rhode Island. 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 sea level change on environmental and cultural resources will be considered in the Environmental and Cultural Resources Conditions Report. Additional information related to the forecasted population and development density is included in Appendix C – Plan Formulation.

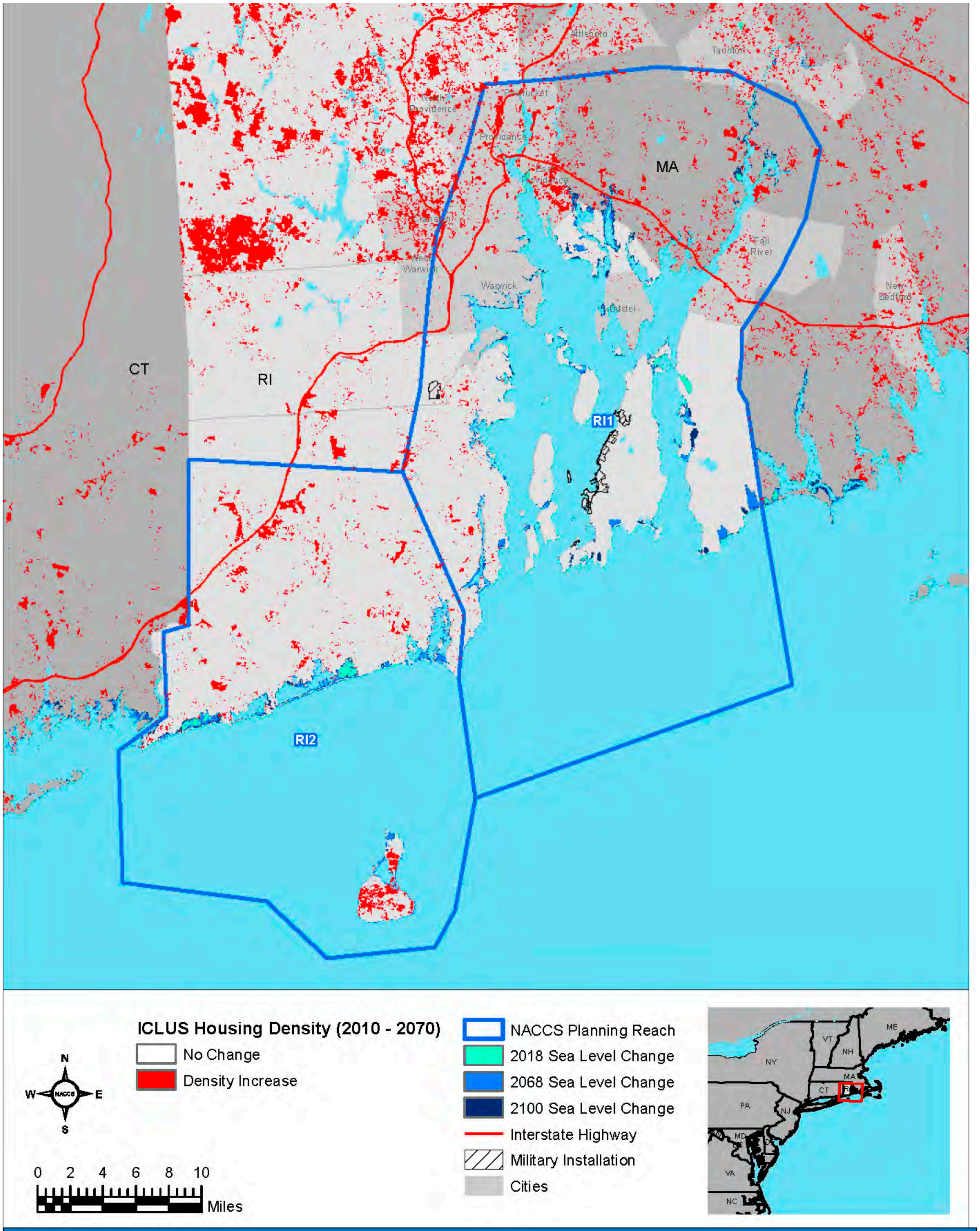


Figure 8. USACE High Scenario Future Mean Sea Level Inundation and Forecasted Residential Development Density Increase for the State of Rhode Island

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

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

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

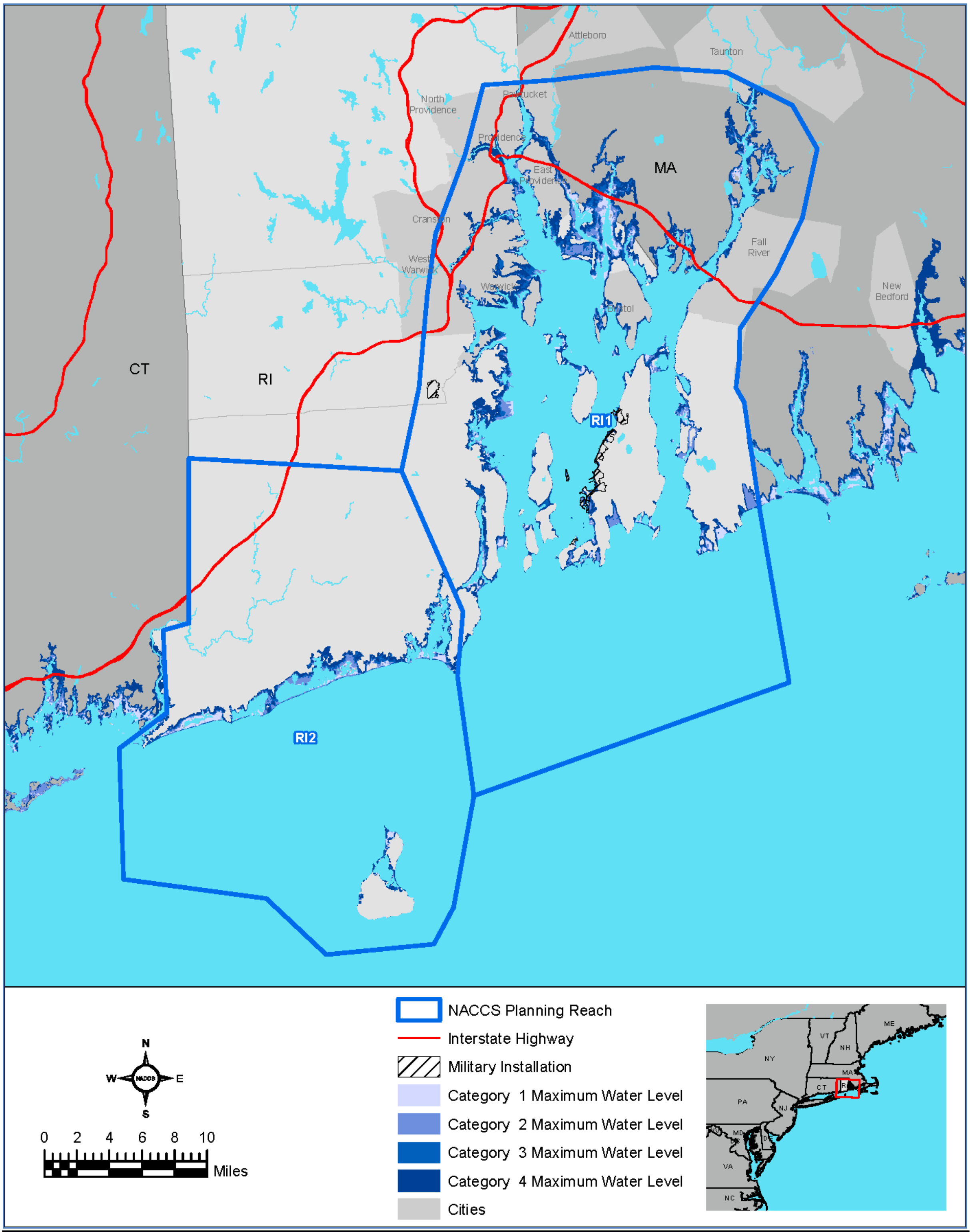


Figure 9. Impacted Area Category 1-4 Water Levels for the State of Rhode Island

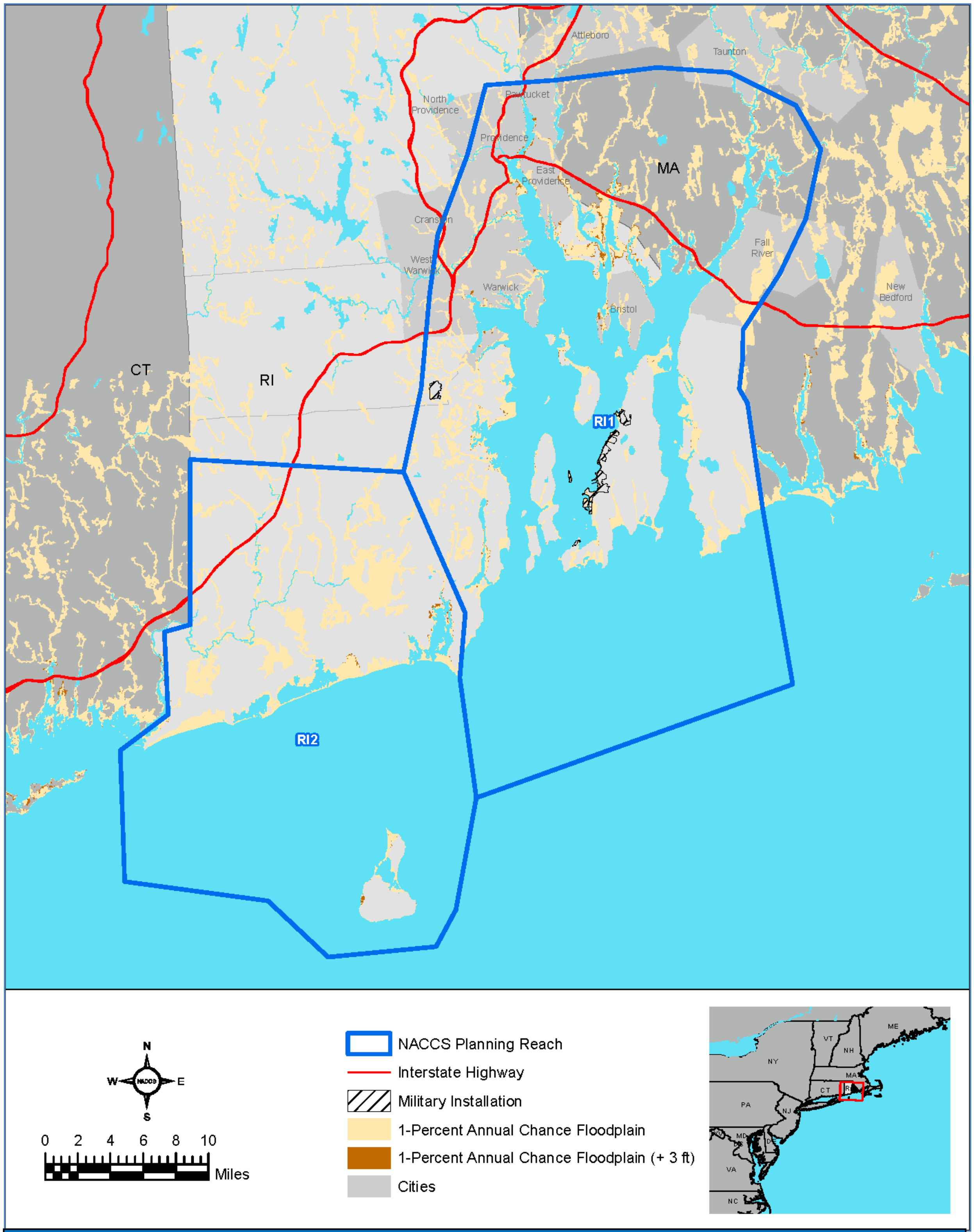


Figure 10. Impacted Area 1 Percent + 3 feet Water Surface for the State of Rhode Island

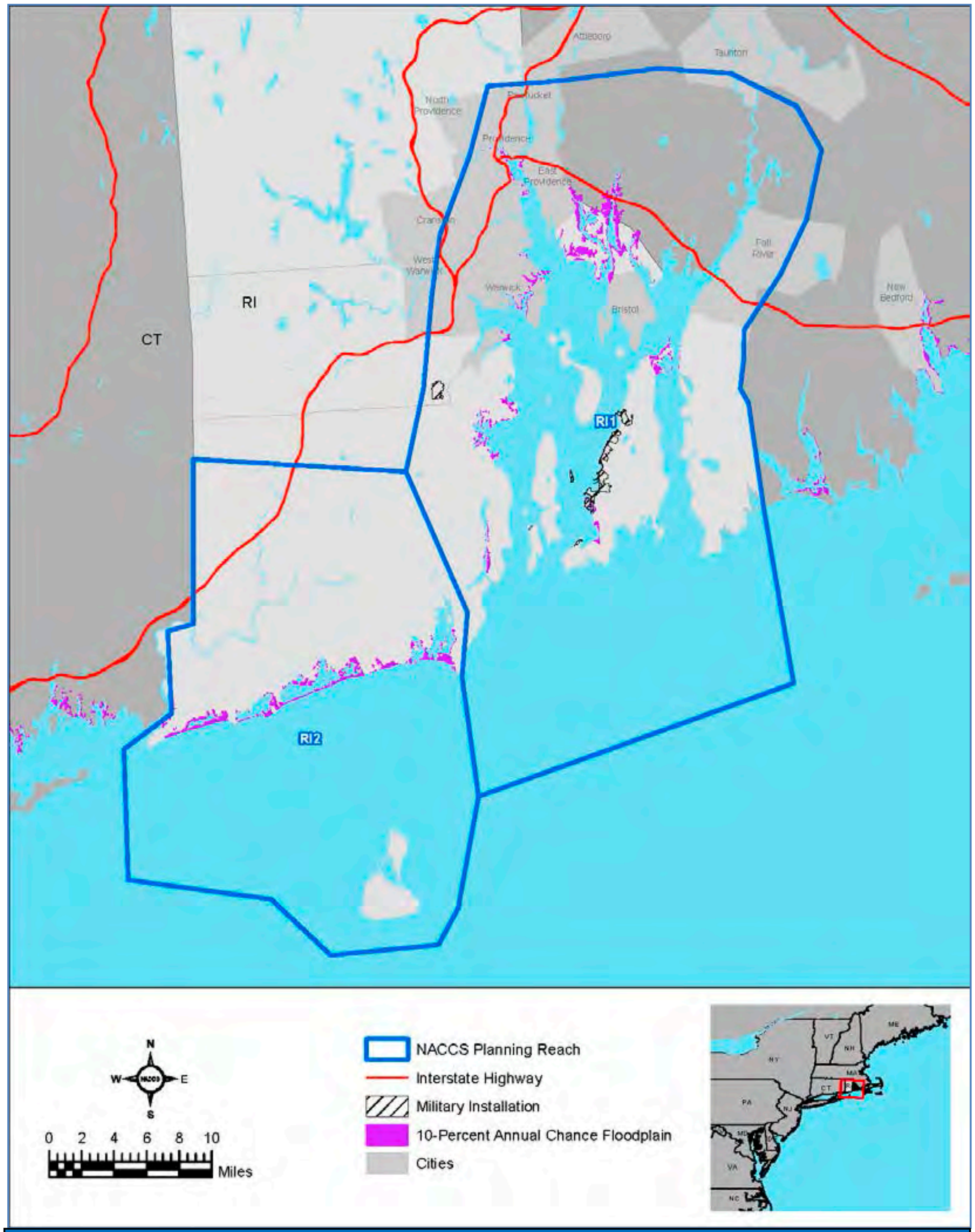


Figure 11. Impacted Area 10 Percent Water Surface for the State of Rhode Island

Environmental Resources

Sand beaches and vegetated dunes provide an important buffer between coastal waters and infrastructure. With increases in sea level and storminess, Rhode Island's shoreline will change significantly. The beaches on Rhode Island's south shore will be especially vulnerable to increased erosion and migration as sea level changes.

It is expected that CSRM projects constructed by USACE would continue to receive renourishment for 50 years after initial construction. The remaining beaches and dunes that are not maintained by the state and local communities are at risk of damage from sea level change. If beaches are armored, adjacent beaches will erode and sediments will not be available for natural replenishment of sand in areas that are not supplemented with beach nourishment projects. The beaches serve as important habitat for shorebirds such as nesting piping plovers and numerous coastal species.

Changes to Rhode Island's coastal barrier beaches from increased storm overwash and breaching have implications for the state's ecologically important salt ponds (coastal lagoons) located behind them. Salt ponds are important shallow water marine ecosystems in Rhode Island that have historically been productive habitat for commercially important fish and shellfish as well as resident and migrating shorebirds and water birds. Increased storminess and sea level change have the potential to negatively impact eelgrass from increasing sand sediment and changing salinity, flushing, and depth in the salt ponds, which has the potential to significantly alter the ecosystem.

Coastal wetlands have the potential to adapt and keep pace with sea level change through vertical accretion and inland migration if there is space available at the same elevation relative to the tidal range and a stable source of sediment. Sea level change forces coastal wetlands to migrate inland causing upslope transitional brackish wetlands to convert to saline marshes and the saline marshes on the coastline to drown or erode. Inland migration of salt marshes could also be disrupted by armored structures, such as seawalls, which would contribute to the loss of marshes. In addition, these wetlands will generally be unable to accrete at a pace greater or equal to relative sea level change, so a rise in sea level will cause a net loss of marsh acreage. The loss of marshes will adversely impact many shorebirds including nesting sharp-tailed sparrows, seaside sparrows, and willets, commercially important species of fish and shellfish, allow more pollutants to reach coastal waters, and leave the coastline more vulnerable to storms and erosion.

Coastal freshwater wetlands in Rhode Island are particularly sensitive to extreme high tides resulting from an increase in storm frequency or magnitude; these high tides can carry salts inland to salt-intolerant vegetation and soils. If these coastal freshwater wetland communities are unable to shift inland, freshwater flora and fauna could be displaced by salt-tolerant species.

Although there is generally more room for wetland to migrate in parks and refuges, these areas will still lose salt and freshwater marshes and dry land to open water because of the effects of sea level change.

Sea level change could result in the permanent inundation of tidal mud flats and low offshore islands. This would result in the loss of critical nesting bird habitat for species such as roseate terns and common terns and as a feeding and resting area. Rhode Island is a valuable stopover for a wide variety of migratory species, particularly in the fall for species that breed throughout the tundra of Canada and Alaska and stop in Rhode Island and coastal New England to refuel before heading further south to the southern United States, Caribbean, and South America.

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

IV. NACCS Coastal Storm Exposure and Risk Assessments

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

IV.1. NACCS Exposure Assessment

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

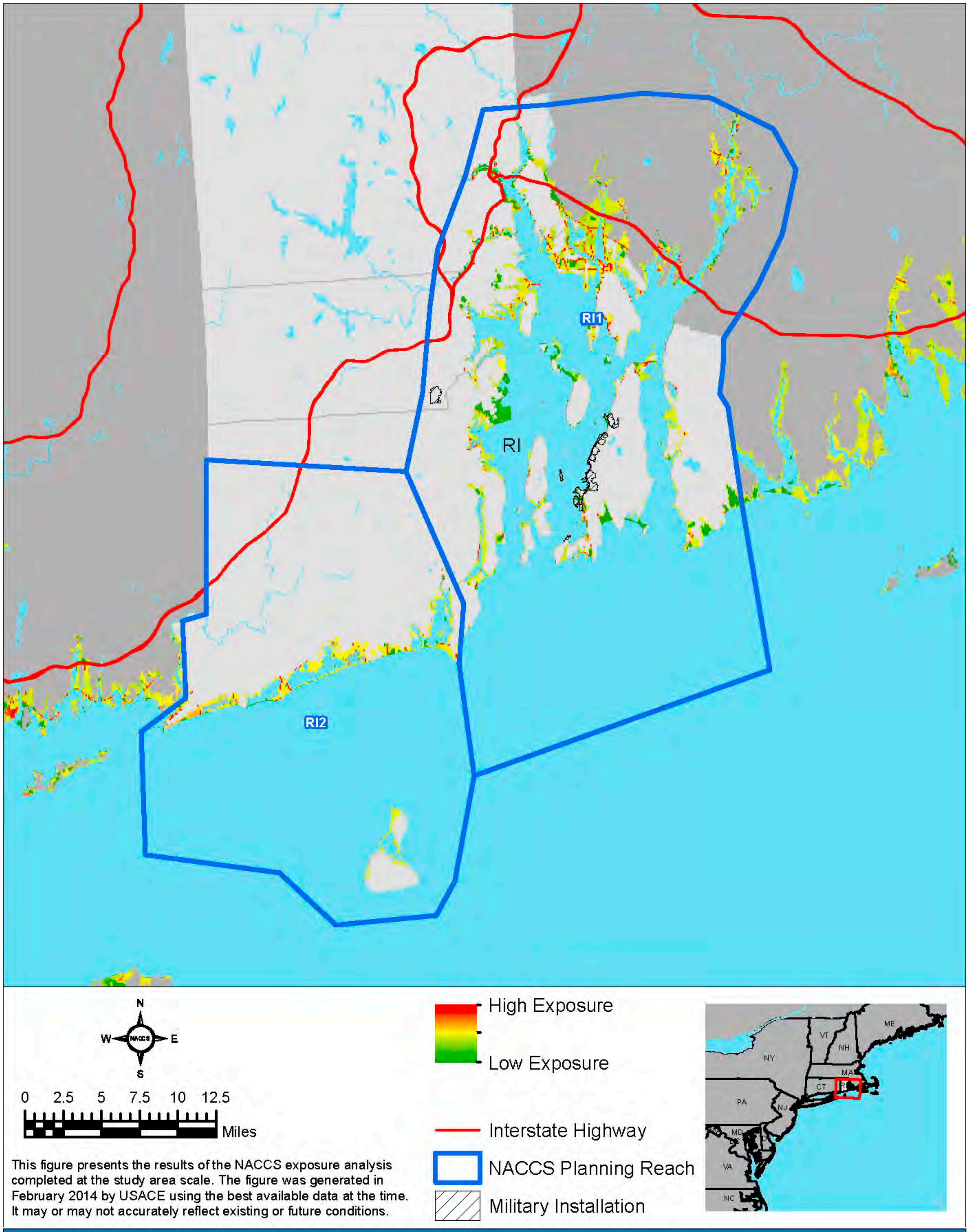


Figure 12. Population and Infrastructure Exposure Index for the State of Rhode Island

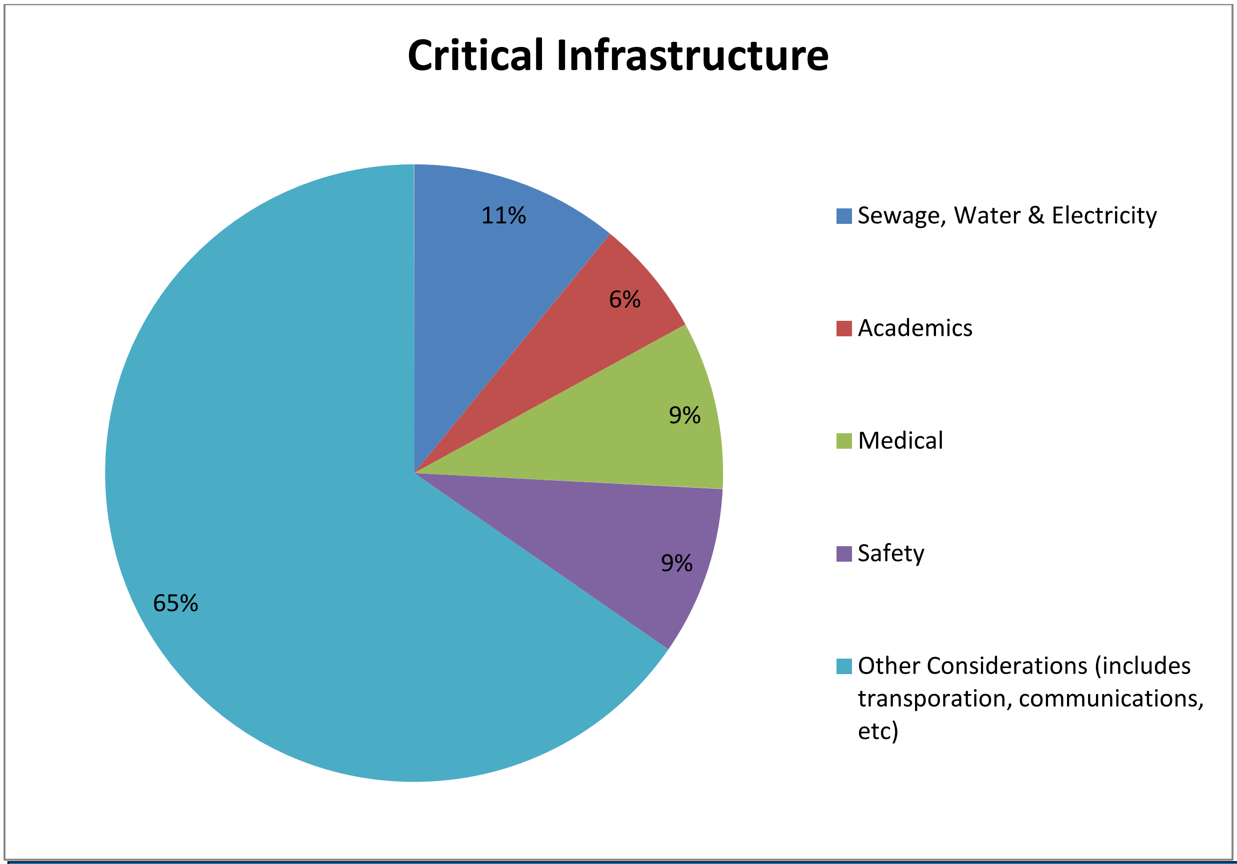


Figure 13. Vulnerable Infrastructure Elements Within the Category 4 MOM Inundation Area in the State of Rhode Island.

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. The social vulnerability characterization 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 Rhode Island. Areas with relatively higher concentrations of vulnerable segments of the population are identified from this analysis.

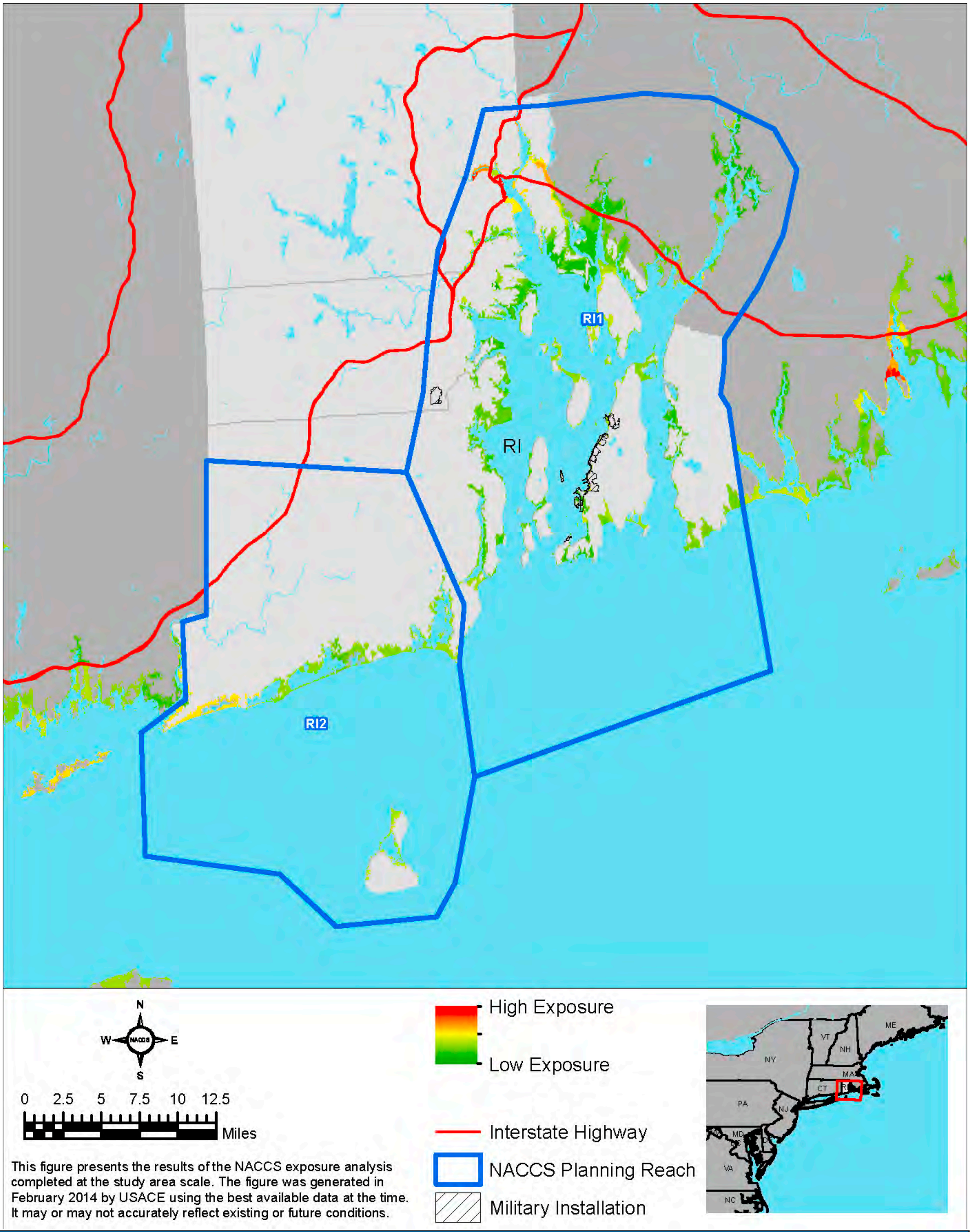


Figure 14. Social Vulnerability Index for the State of Rhode Island

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 Rhode Island.

Reach: RI1

Based on the social vulnerability analysis, eight areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 6412, 6402, 6414, 6409.01, 6411.01, 6413, 6410, and 6403 (Bristol County, MA). The areas in census tracts 6412, 6414, 6410, and 6403 were identified as vulnerable mainly due to a considerable percent of the population being non-English speakers. Census tract 6411.01 was also identified as vulnerable due to a large percent of the population being below the poverty level. Census tracts 6402, 6411.01, and 6403 were also identified as vulnerable due to a large percent of the population being over 65 years old.

Reach: RI2

Based on the social exposure analysis, no areas were identified within this reach as having relatively high social exposure (values above 70.0).

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 Rhode Island. 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.

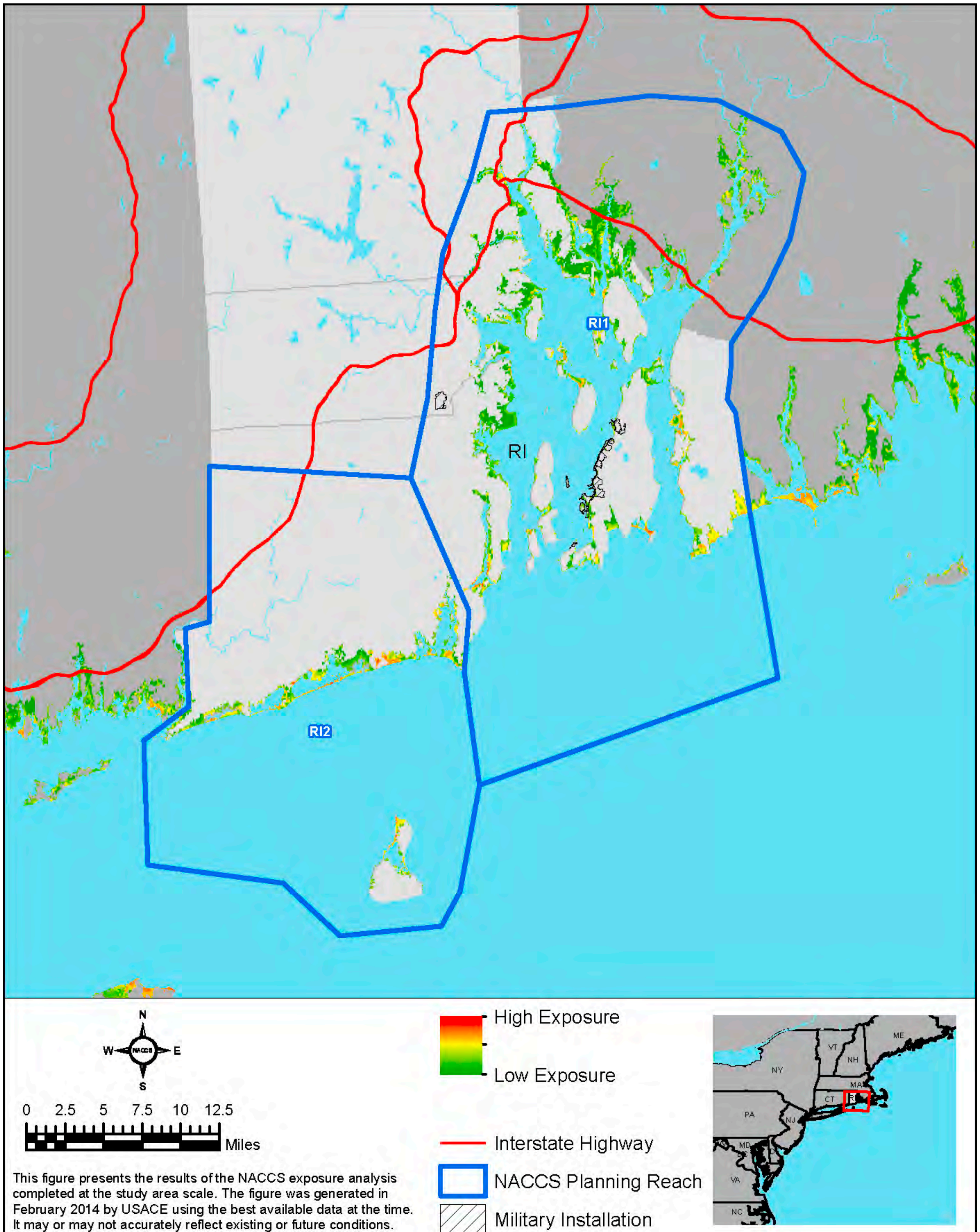


Figure 15. Environmental and Cultural Resources Exposure Index for the State of Rhode Island

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

A description of the high environmental and cultural resource exposure areas for each planning reach is described below.

Reach: RI1

This analysis resulted in approximately 150 acres of high (orange) environmental and cultural resources exposure index area in planning reach RI1.

About 150 acres of Narragansett Beach and Sachuest Point comprise the Coastal Barrier Resources System (CBRS) in these exposure areas. In addition, the John Chafee National Wildlife Refuge and the Sachuest Point National Wildlife Refuge make up nearly 260 acres of U.S. Fish and Wildlife Service (USFWS) protected land. Slightly over an acre of land is available as habitat for piping plovers and red knots.

Nearly all of shoreline in these exposure areas is coarse-grained (~2.5 acres). About 130 acres of tidal emergent marshes provide habitat in this exposure area.

There is a cultural resources buffer area of approximately 154 acres within the high environmental and cultural resources exposure index area in planning reach RI1.

Reach: RI2

This analysis resulted in approximately 80 acres of high (orange) environmental and cultural resources exposure index area in planning reach RI2.

Block Island, Card Ponds, East Beach, Maschaug Ponds, Misquamicut Beach, Napatree, and Quonochontaug Beach comprise about 75 acres of the CBRS in this exposure area, while about 80 acres from the Block Island, Trustom Pond, and Ningret National Wildlife Refuges as U.S. Fish and Wildlife Service (USFWS) protected areas. Almost 30 acres is available as habitat for piping plovers and red knots. About 35 acres of state park are also included in this exposure area.

The vast majority of this shoreline in this high environmental and cultural resources exposure index area is coarse-grained sands; over 20 acres compared to the less than one acre of fine-grained muds and organics shoreline. Over 20 acres of tidal emergent marsh and nearly seven acres of scrub-shrub are also located in this environmental and cultural resources exposure index area.

There is one historic site, the Block Island North Light, and approximately 80 acres of cultural resources buffer in the high environmental and cultural resources exposure index area in planning reach RI2.

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 Rhode Island.

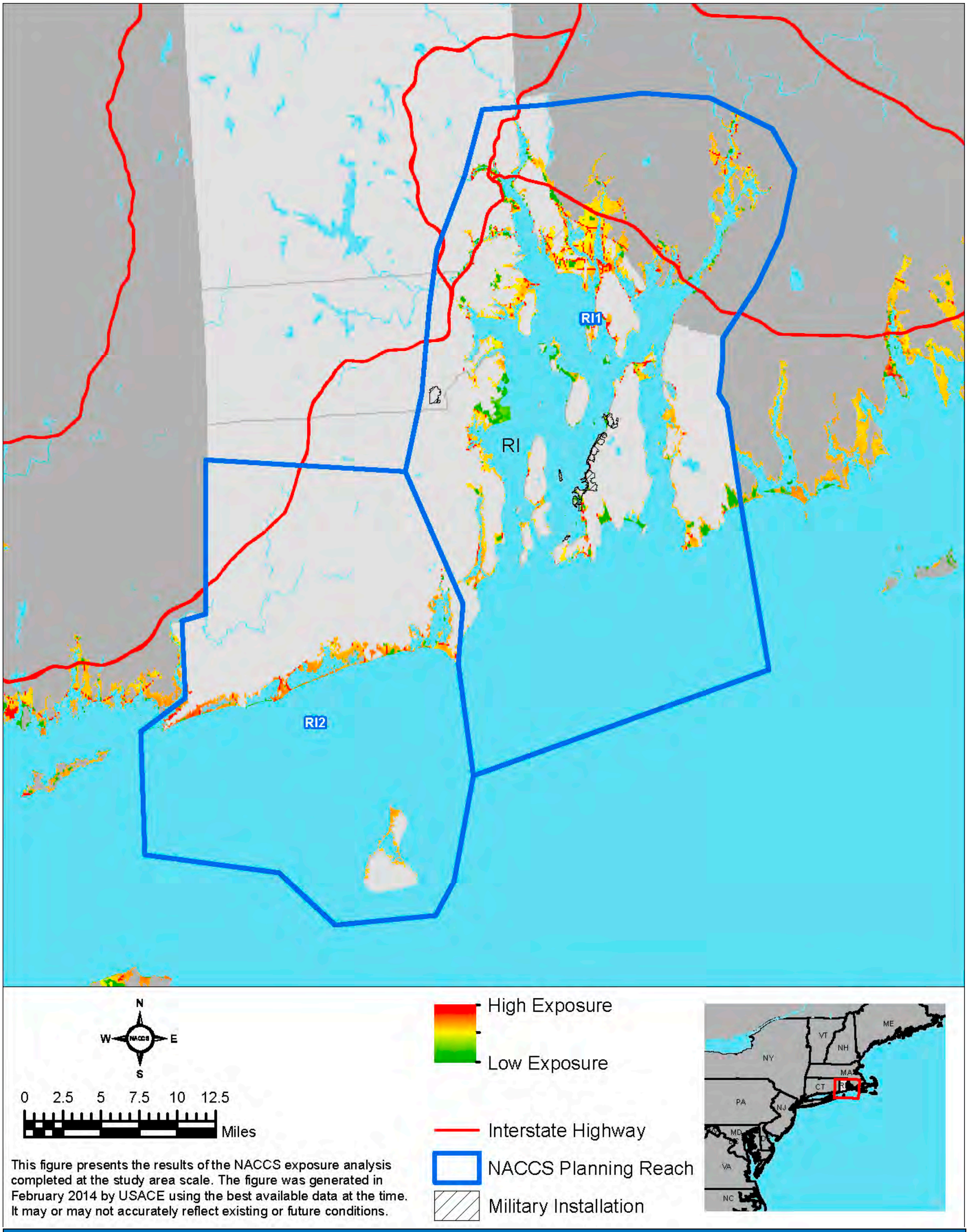
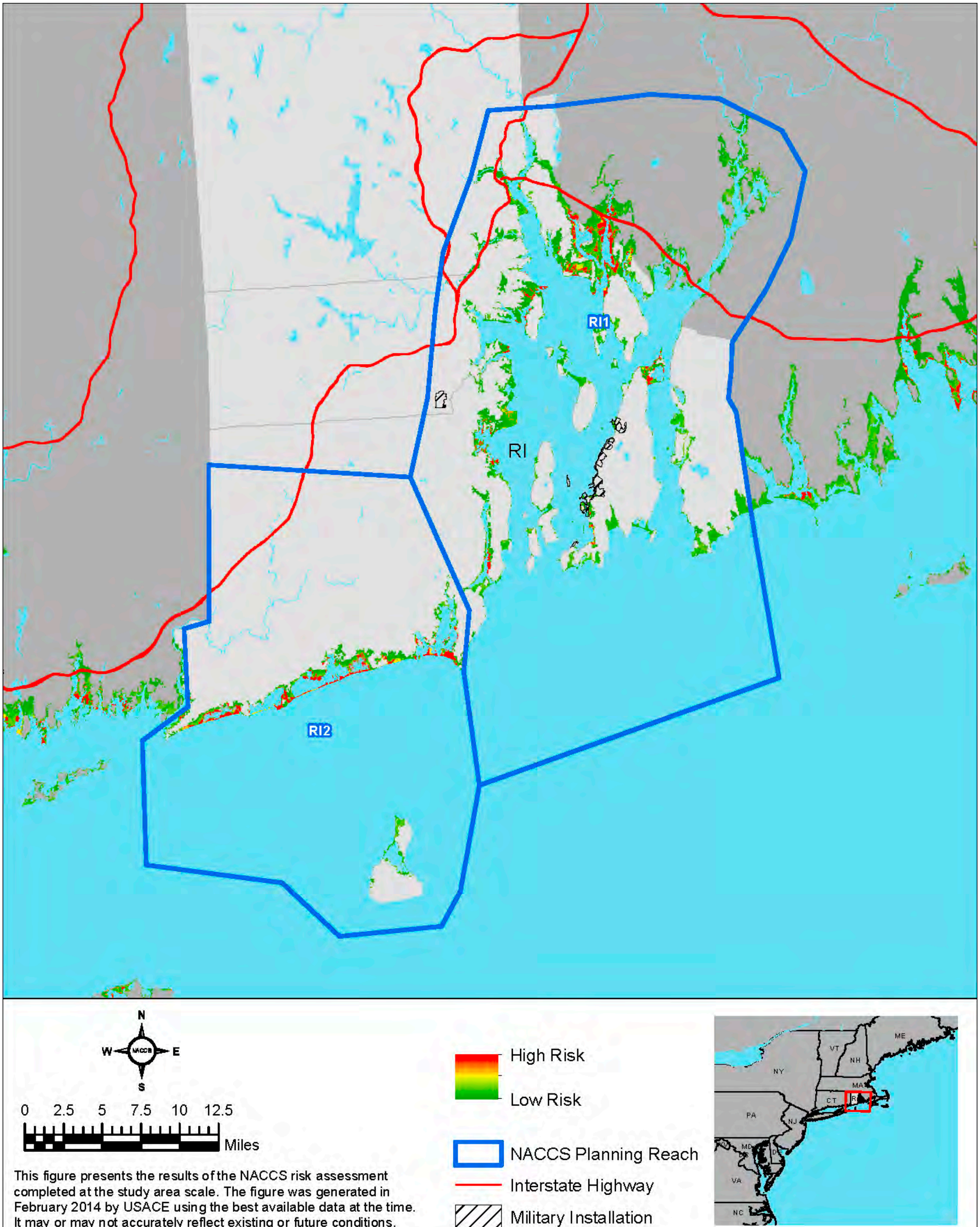


Figure 16. Composite Exposure Index for the State of Rhode Island

IV.2. 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 Rhode Island.



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

Figure 17. Risk Assessment for the State of Rhode Island

IV.3. NACCS Risk Areas Identification

Applying the risk assessment to the State of Rhode Island identified 9 areas for further analysis (Figure 18). These locations are identified by reach on Figures 19 and 20 and are described in more detail below.

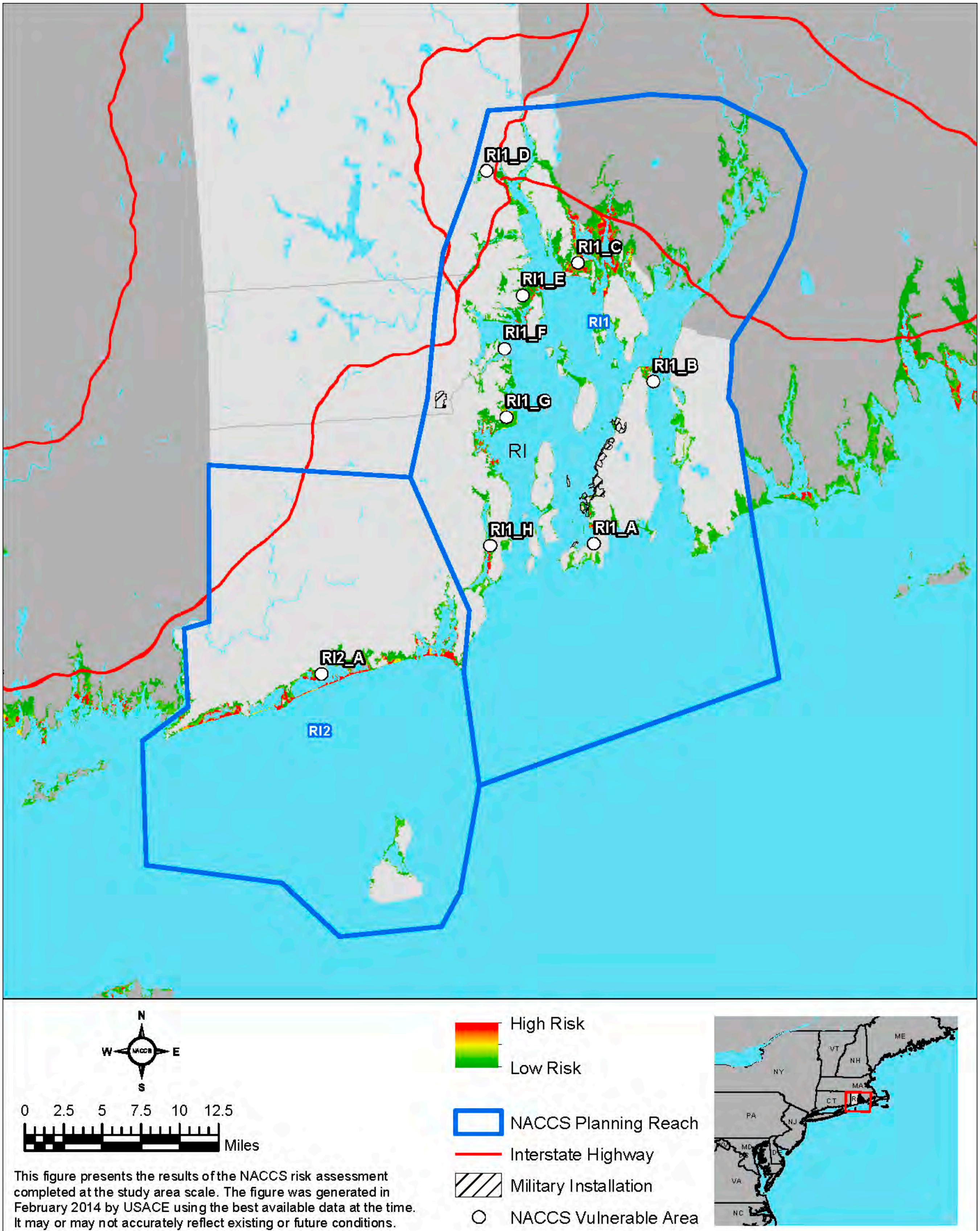


Figure 18. Risk Areas in the State of Rhode Island

Reach: RI1

The shoreline of Rhode Island Reach 1 (Figure 19) is classified as a mixture of urban, wetland and beach shoreline. The upper portions of Narragansett Bay are highly developed while the lower portions less so. The reach contains a few USACE coastal flood risk management projects and an extensive 1 percent floodplain.

Eight areas of high exposure were identified in this reach and are described in this section. Several of the identified exposure areas center on fairly dense urban areas of the cities of Newport, Barrington, East Providence, Providence (site of an existing hurricane barrier), and Warwick. There are also less populated areas of high exposure located in the towns of Portsmouth, East Greenwich, North Kingstown, and Narragansett.

RI1_A: Downtown Newport

This area of high exposure encompasses the waterfront area of Newport and extends from the Wellington Avenue area up to Coddington Cove. It extends about ½ mile inland and includes many residential and commercial properties, a rail line, municipal and state infrastructure and roads, and a recreational and commercial boat harbor. This area also includes the Newport Naval Ship Yard.

RI1_B: Mount Hope Bay Area

This area of high exposure begins at about the Mount Hope Bay Bridge and extends to the Sakonnet River Bridge. It includes the northern portion of the town of Portsmouth and includes a significant number of residential and commercial property, a rail line, municipal and state infrastructure and roads, and a recreational marina.

RI1_C: Warren - Barrington

This area of high exposure was particularly striking as it encompasses a significant portion of the towns of Warren and Barrington and extends up in to the backshore areas of the Warren and Barrington Rivers. Hundreds, if not several thousand, residential and commercial properties are in this area of high exposure including all of the municipal and state infrastructure associated with them.

RI1_D: Providence - East Providence

This area of high exposure covers the Port of Providence in these two cities. It extends from Watchemoket Cove in East Providence, north into the City of Providence, west into the Olneyville area, then south to the area in Providence known as Washington Park. Significant commericial development fills this area of high exposure including bulk cargo facilities (e.g., heating oil, sand and gravel) as well as ship servicing facilities and water treatment facilities. The commercial interests that exist here are very important to both the local and regional economies. The area also includes downtown Providence, which is the capitol of the state. The area is protected by the Fox Point Hurricane Barrier, but only up to a Category 3 hurricane. Anything greater than a Category 3 hurricane will cause catastrophic damage to the city’s commercial and residential development which is significant behind the barrier. The area also includes critical rail service, several important state (e.g., Route 6) and local roads, and major highways such as Interstate 95 and 195.

RI1_E: Warwick

Like Barrington, the eastern protions of Warwick were identified as being very problematic with regard to a catastrophic surge event. The area of high exposure begins near Brush Neck Cove on the west side and extends east to the Providence River and then north of Conimicut Point. Hundreds, if not several thousand, residential and commercial properties are in this area of high exposure including all of the municipal and state infrastructure associated with them. There are also several important recreational marinas located in Warwick Cove.

RI1_F: East Greenwich

This low-lying area of high exposure is just to the east of Greenwich Cove on Sandy Point and includes several hundred residential structures along with the municipal infrastructure associated with them.

RI1_G: North Kingstown

This area of high exposure involves the Wickford Harbor and Quonset Point areas of North Kingstown. The area is marked by pockets of residential development and small boat harbors as well as local and state infrastructure. Quonset Point is the site of regionally significant business development and offloading facilities for automobiles on the old naval air station property.

RI1_H: Pettaquamscutt River

This low-lying area of high exposure is located in the town of Narragansett and South Kingstown and includes several pockets of residential development along with the municipal infrastructure associated with them.

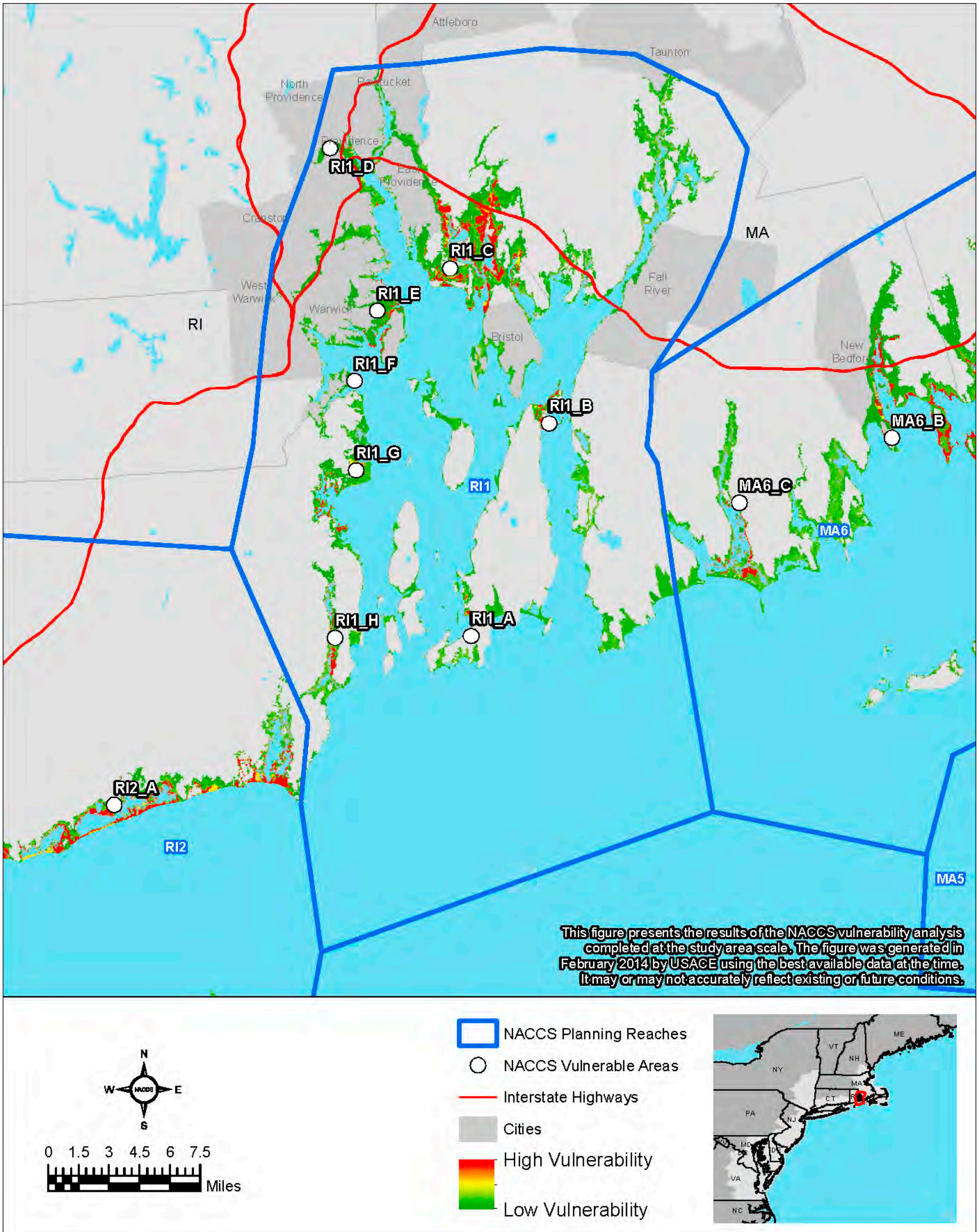


Figure 19. Rhode Island Reach: RI1 Vulnerable Areas

Reach: RI2

The shoreline of Rhode Island Reach 2 (Figure 20) is classified as wetland, urban, beaches, and estuaries. The area of high exposure encompasses the entire coastline in this reach and includes the towns of Narragansett, South Kingstown, Charlestown, and Westerly. There are significant areas of residential development and population in these areas including a significant recreational (seasonal) population. The Galilee State Pier facilities are home to a significant fishing fleet and the closest ferry service line that services Block Island. The reach contains one USACE coastal flood risk management project and an extensive 1 percent floodplain.

The entire reach was identified as an area of high exposure. Given that the area is a south facing shoreline and exposed to the open Atlantic Ocean, the reach, designated RI2_A, is particularly vulnerable to storm surge and wave attack. The area has experienced significant coastal storm damage in the past including that due to Hurricane Sandy.

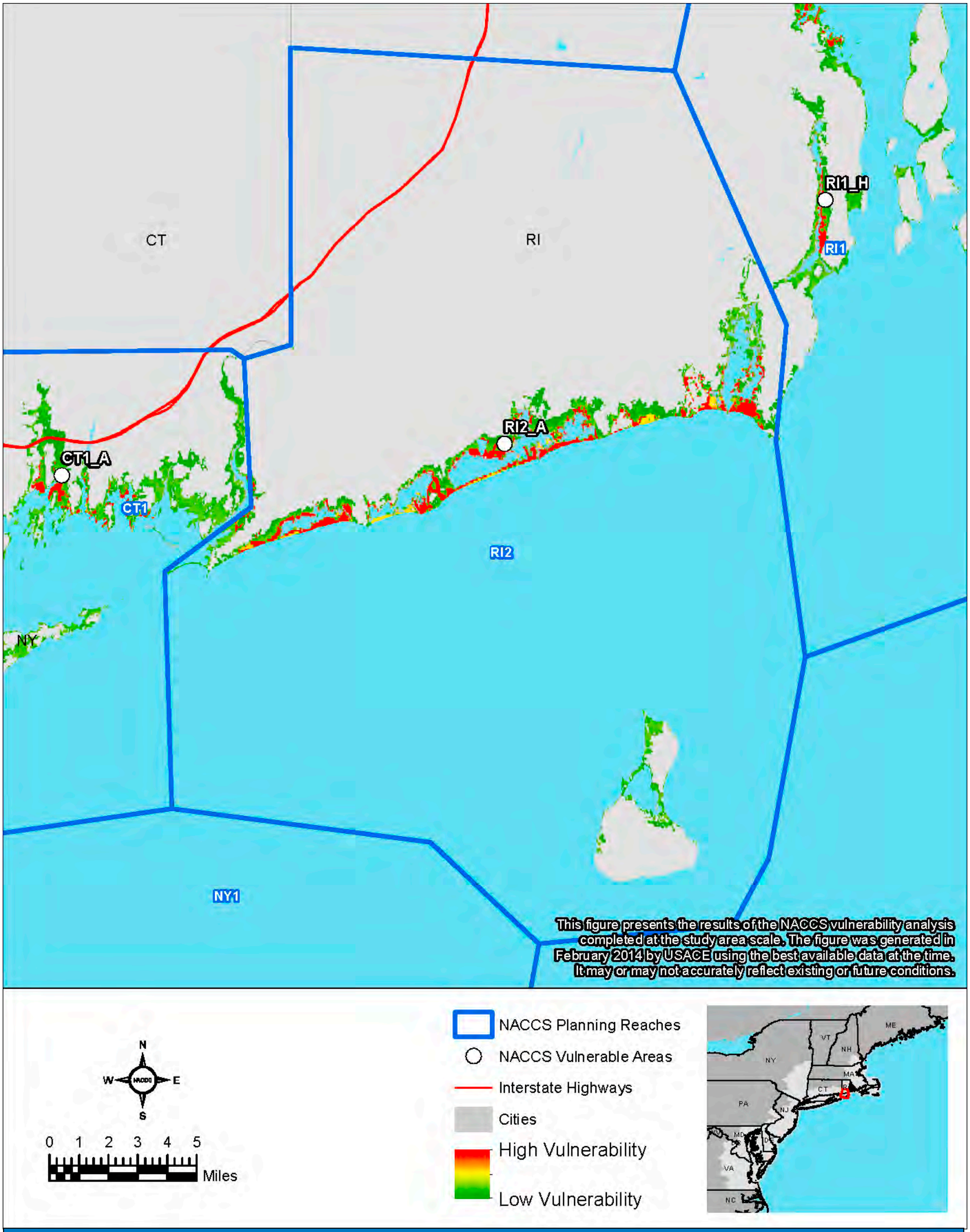


Figure 20. Rhode Island RI2 Vulnerable Areas

V. Coastal Storm Risk Management Strategies and Measures

V.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 21 presents the location and extent of each shoreline type in the State of Rhode Island. Table 4 summarizes the measures applicability based on shoreline type. It is assumed non-structural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale.

Additionally, a conceptual analysis of geographic applicability of NNBF measures presented in Table 3 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 22 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 the Planning Analyses Appendix

The lengths of shoreline type on an individual reach basis are provided on Figures 23 through 24.

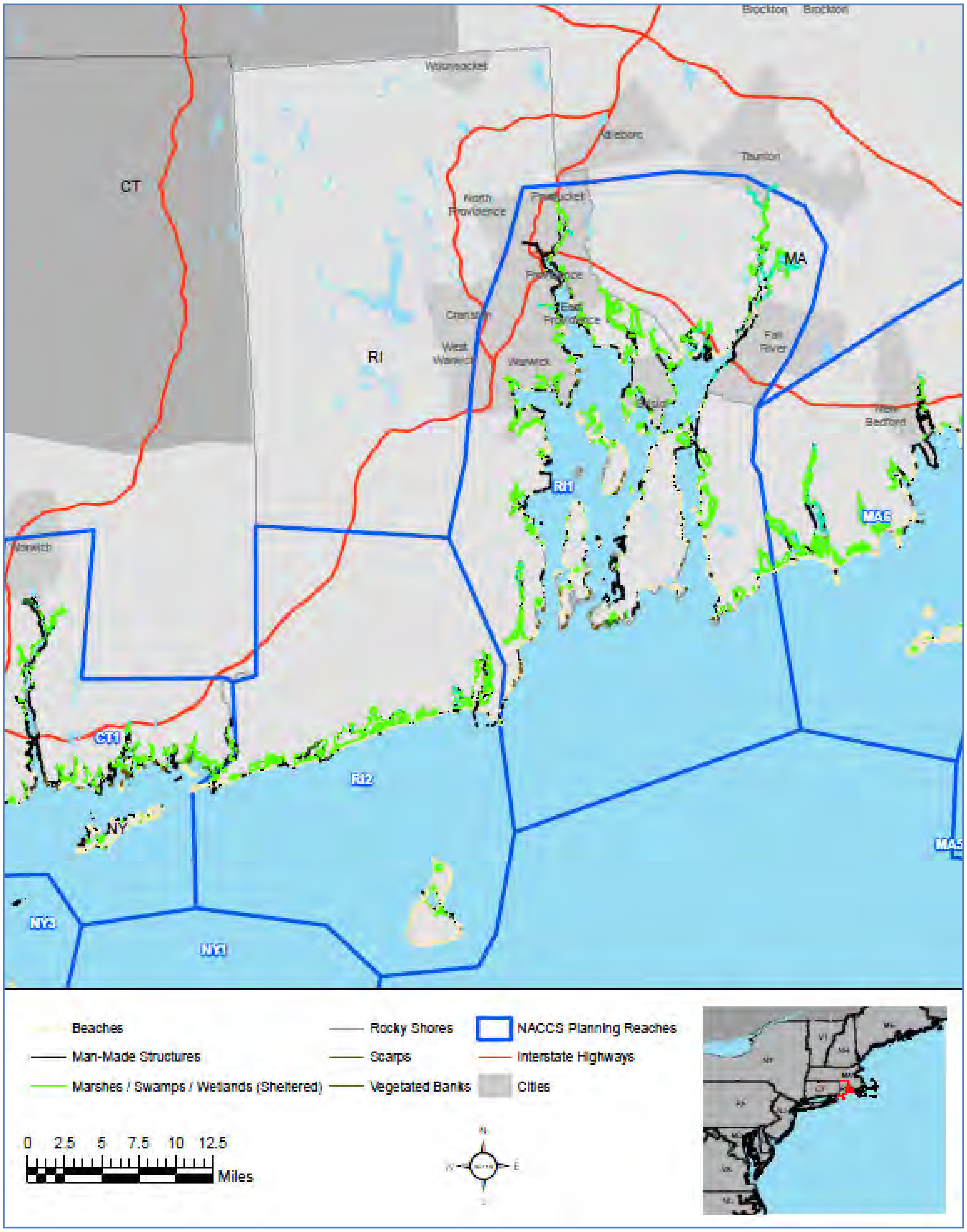


Figure 21. Shoreline Types for the State of Rhode Island

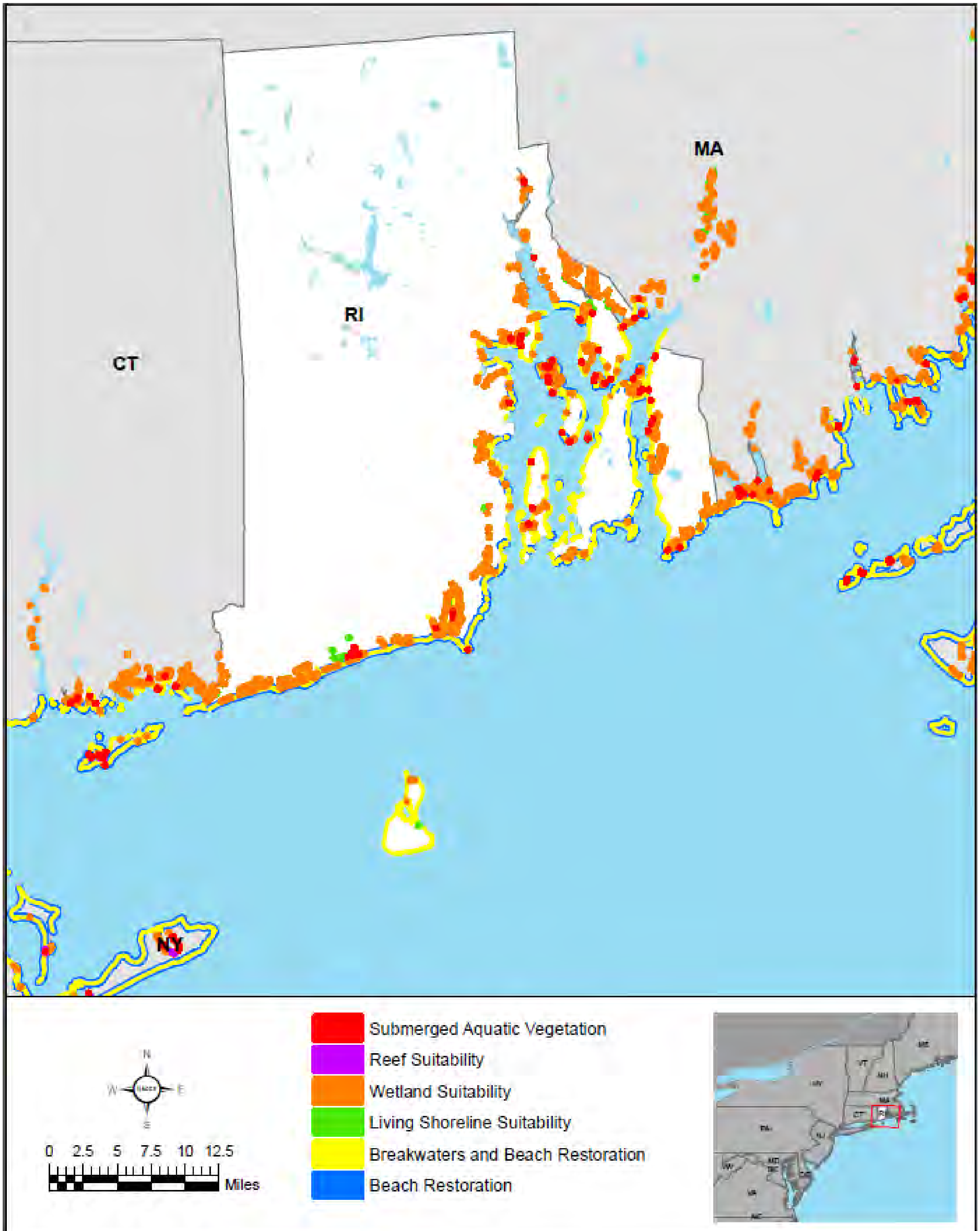


Figure 22. NNBF Measures Screening for the State of Rhode Island.

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, it is 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.*

Table 4. Shoreline Types by Length (feet) by Reach

Sum of Shoreline Length (ft) By Reach	Column Labels								
Row Labels	Beaches	Manmade Structures (Exposed)	Manmade Structures (Sheltered)	Marshes / Swamps / Wetlands (Sheltered)	Rocky Shore (Exposed)	Scarps (Exposed)	Vegetated High Bank (Sheltered)	Vegetated Low Bank (Sheltered)	Grand Total
RI1	**33,518**	**71,407**	**58,763**	**201,617**	**2,611**	**121**		**3,540**	**371,577**
RI1_A	952	8,733	2,602	342	2,611				15,240
RI1_B	9,004	11,108	1,761	20,261					42,134
RI1_C	4,348	2,917	9,346	101,755				1,828	120,194
RI1_D	1,492	14,365	29,418	2,021		121			47,417
RI1_E	8,987	7,584	4,227	29,152					49,950
RI1_F	525	6,377		1,010					7,912
RI1_G	8,210	20,323	7,123	32,290				1,263	69,209
RI1_H			4,286	14,786				449	19,521
RI2	**64,962**	**24,900**	**83,953**	**458,397**			**5,474**	**19,092**	**656,778**
RI2_A	64,962	24,900	83,953	458,397			5,474	19,092	656,778
Grand Total	**98,480**	**96,307**	**142,716**	**660,014**	**2,611**	**121**	**5,474**	**22,632**	**1,028,355**

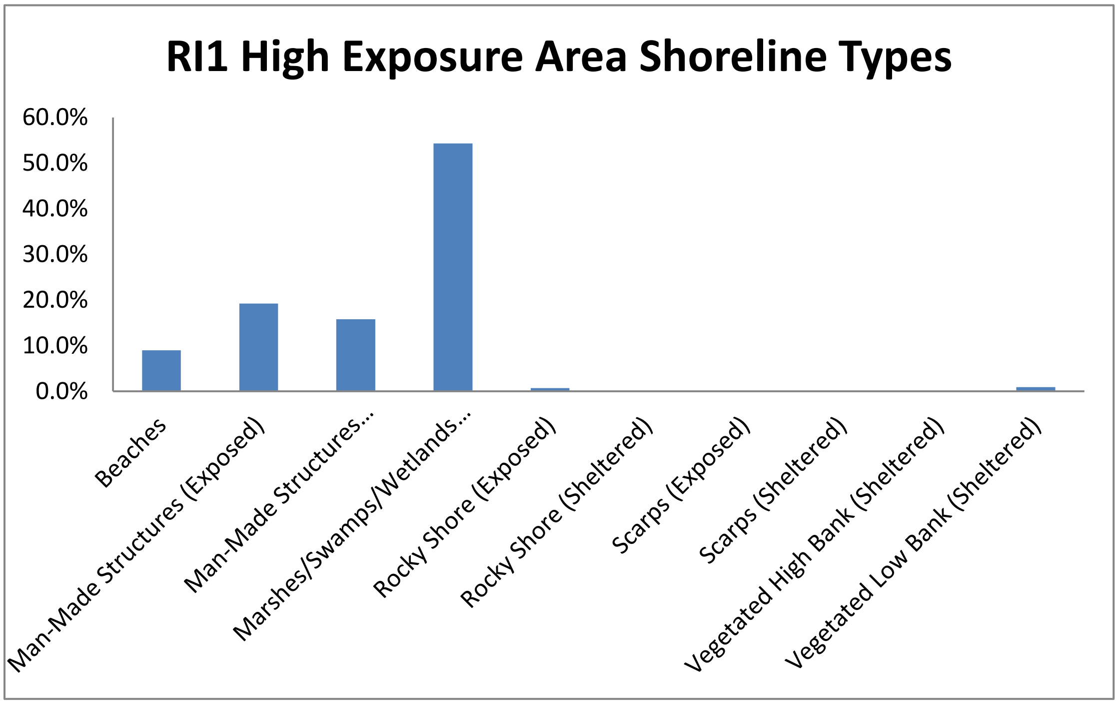


Figure 23. RI1 Shoreline Types

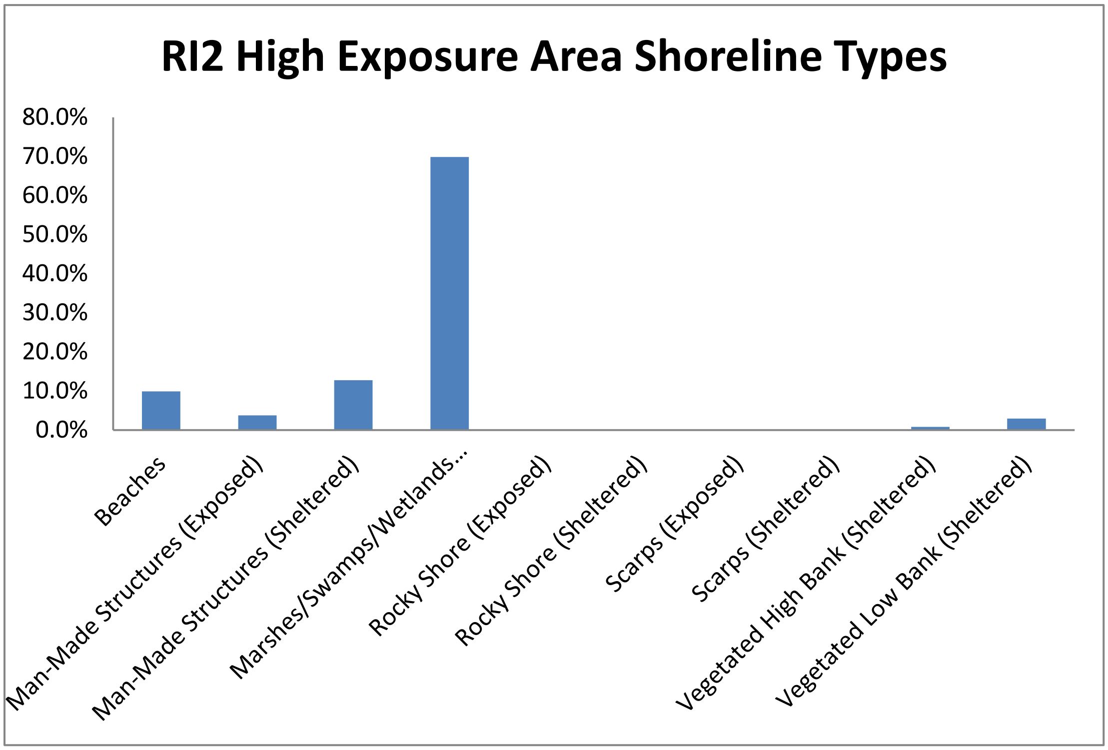


Figure 24. RI2 Shoreline Types

V.2. Cost Considerations

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

VI. Tier 1 Assessment Results

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

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
RI1_A	Beaches	H	3	2	1									
RI1_A	Manmade Structures (Sheltered)	H					3	2	1					
RI1_A	Rocky Shores (Exposed)	L											1	
RI1_A	Wetland (Sheltered)	L									1	3	4	2
RI1_B	Beaches	H	3	2	1									
RI1_B	Manmade Structures (Sheltered)	H					3	2	1					
RI1_B	Wetlands (Sheltered)	L									1	3	4	2
RI1_C	Beaches	H	3	2	1									
RI1_C	Manmade Structures (Sheltered)	H					3	2	1					
RI1_C	Vegetated Low Banks (Sheltered)	H						2	1					
RI1_C	Vegetated Low Banks (Sheltered)	L				2					1			
RI1_C	Wetlands (Sheltered)	L									1	3	4	2
RI1_D	Beaches	H	3	2	1									
RI1_D	Manmade Structures (Sheltered)	H					3	2	1					

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
RI1_D	Scarps (Exposed)	L				3					1		2	
RI1_D	Wetlands (Sheltered)	L									1	3	4	2
RI1_E	Beaches	H	3	2	1									
RI1_E	Manmade Structures (Sheltered)	H					3	2	1					
RI1_E	Wetlands (Sheltered)	L									1	3	4	2
1_F	Beaches	H	3	2	1									
RI1_F	Wetlands (Sheltered)	L									1	3	4	2
RI1_G	Beaches	H	3	2	1									
RI1_G	Manmade Structures (Sheltered)	H					3	2	1					
RI1_G	Vegetated Low Banks (Sheltered)	H						2	1					
RI1_G	Vegetated Low Banks (Sheltered)	L				2					1			
RI1_G	Wetlands (Sheltered)	L									1	3	4	2
RI1_H	Manmade Structures (Sheltered)	H					3	2	1					
RI1_H	Vegetated Low Banks (Sheltered)	H						2	1					

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
RI1_H	Vegetated Low Banks (Sheltered)	L				2					1			
RI1_H	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Manmade Structures	H					3	2	1					

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
	(Sheltered)													
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			
RI2_A	Wetlands (Sheltered)										1	3	4	2
RI2_A	Wetlands (Sheltered)										1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
RI_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures	H					3	2	1					

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
	(Sheltered)													
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Beaches	H	3	2	1									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	**Beaches**	**H**	**3**	**2**	**1**									
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	**Manmade Structures (Sheltered)**	**H**					**3**	**2**	**1**					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	**Beaches**	**H**	**3**	**2**	**1**									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	**Wetlands (Sheltered)**	**L**									**1**	**3**	**4**	**2**
RI2_A	Beaches	H	3	2	1									

Table 5. Comparison of Measures within NACCS Risk Areas in the State of Rhode Island

Risk Areas	NACCS Shoreline Type	Level of Risk Reduction	Beach Restoration with Breakwaters	Beach Restoration with Groins	Beach Restoration with Dunes	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Overwash Fans	Living Shoreline	Wetlands	Reefs	SAV Restoration
RI2_A	**Manmade Structures (Sheltered)**	**H**					**3**	**2**	**1**					
RI2_A	Wetlands (Sheltered)	L									1	3	4	2
RI2_A	**Beaches**	**H**	**3**	**2**	**1**									
RI2_A	Manmade Structures (Sheltered)	H					3	2	1					
RI2_A	**Wetlands (Sheltered)**	**L**									**1**	**3**	**4**	**2**
RI2_A	Beaches	H	3	2	1									
RI2_A	**Manmade Structures (Sheltered)**	**H**					**3**	**2**	**1**					
RI2_A	Vegetated Low Banks (Sheltered)	H						2	1					
RI2_A	Vegetated Low Banks (Sheltered)	L				2					1			
RI2_A	Wetlands (Sheltered)	L									1	3	4	2

VII. Tier 2 Assessment of Conceptual Measures

As part of the NACCS Tier 2 analysis for the State of Rhode Island and in coordination with the RI CRMC, Rhode Island reach 2 was selected as an example area to apply the NACCS Tier 2 assessment. Defined as Area RI2_A, the area includes the Towns of Narragansett, South Kingstown, Charlestown, and Westerly. The example area represents an area within the State of Rhode Island at risk to coastal flooding and includes a wide range of problems and needs. This area was selected for additional analysis due to increased coastal erosion issues and the overall need for enhanced coastal resilience to surrounding communities. The area has a significantly developed waterfront areas in addition to the Galilee State Pier facilities that are home to a significant fishing fleet and the closest ferry service line that services Block Island.

As demonstrated in Table 6, this risk area was subdivided into 22 sub-regions. Each sub-region offers a unique set of CSRM measures which may act as an example for similar geomorphic settings in the State of Rhode Island by state and local agencies, and non-governmental organizations (NGOs).

Table 6. Tier 2 Analysis Example Area Relative Cost/Management Measure Matrix for the RI2_A Risk Area

Sub-Region Strategy RI2_A											
Existing Coastal Flood Risk Management Projects				**Risk Management Strategies (RI)**							
				Preserve			***Accommodate***			***Avoid***	
				Structural Measures (1 percent floodplain plus 3 feet)		Regional/ Gates (0.2 percent)	NNBF (10 percent)	Non-Structural (10 percent floodplain)		Acquisition (10 percent floodplain)	
Revised Polygon	Description	Existing Project - 2018 Post-Sandy	Estimated Design Level	Description	Cost Index	Description	Description	Description	Cost Index	Description	Cost Index
RI2_A_1	N/A	None	N/A	No. Few properties; will not support a large protection project.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_2	N/A	None	N/A	No, shore fronts a golf course	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_3	N/A	None	N/A	No, virtually no property in the floodplain	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_4	N/A	None	N/A	Beach fill/dune project along shore. Flanking protection possibly needed in the village.	1.00	N/A	N/A	Floodproofing	0.44	Acquisition and Relocation	0.72
RI2_A_5	N/A	None	N/A	No. Many properties already have seawalls or revetments. 1 percent flood protection unlikely.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_6	N/A	None	N/A	Beach fill/dune project along shore.	1.00	N/A	N/A	Floodproofing	0.59	Acquisition and Relocatio	0.22

										n	
RI2_A_7	N/A	None	N/A	No. A few properties located high in the floodplain.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_8	N/A	None	N/A	No. Beach fill/dune or revetment project w/ 1 percent flood protection unlikely.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_9	N/A	None	N/A	No. Many properties already have seawalls or revetments. 1 percent flood protection unlikely.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_10	N/A	None	N/A	No. Beach fill/dune or revetment project w/1 percent flood protection unlikely.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_11	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	0.49	Acquisition and Relocation	1.00
RI2_A_12	N/A	None	N/A	No. 100-yr protection unlikely with so many properties already elevated.	N/A	N/A	N/A	Floodproofing	N/A	No	N/A
RI2_A_13	N/A	None	N/A	No. Many properties already have seawalls or revetments. 100-yr protection unlikely.	N/A	N/A	N/A	Floodproofing	0.49	Acquisition and Relocation	1.00
RI2_A_14	N/A	None	N/A	No. A few properties located high in the floodplain.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_15	N/A	None	N/A	Beach fill/dune project along shore.	1.00	N/A	N/A	Floodproofing	0.07	Acquisition and Relocatio	0.15

										n	
RI2_A_16	N/A	None	N/A	No. A few properties located high in the floodplain.	N/A	N/A	N/A	N/A	N/A	No	N/A
RI2_A_17	N/A	None	N/A	No. Jerusalem village surrounded by water on 3 sides. A structure comprehensive enough to provide 1 percent flood LOP will not be permitted.	N/A	N/A	N/A	Floodproofi ng	1.00	Acquisiti on and Relocatio n	0.92
RI2_A_18	N/A	None	N/A	No. Many properties already have seawalls or revetments. 1 percent flood protection unlikely.	N/A	N/A	N/A	Floodproofi ng	0.49	Acquisiti on and Relocatio n	1.00
RI2_A_20	N/A	None	N/A	No. Many properties already have seawalls or revetments. 1 percent flood protection unlikely.	N/A	N/A	N/A	Floodproofi ng	0.49	Acquisiti on and Relocatio n	1.00
RI2_A_21	N/A	None	N/A	No. A structure comprehensive enough to provide 1 percent flood level of protection will not be permitted.	N/A	N/A	N/A	Floodproofi ng	1.00	Yes	0.80
RI2_A_22	N/A	None	N/A	No. Many properties already have seawalls or revetments. 1 percent flood protection unlikely.	N/A	N/A	N/A	N/A	N/A	No	N/A

Table 6 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 avoid, accommodate, and preserve strategies for coastal storm risk management for this particular area. For each of the areas identified, management measures were selected based on knowledge of the area and available data and analyses including shoreline type, topography, extent of development from aerial photography, sea level change inundation, extreme water levels, flood inundation mapping. Other information considered in the identification of measures includes existing CSRM projects, conceptual costs, and the change in vulnerability associated with a combination of measures.

The risk reduction associated with the management measures corresponds to the qualitative evaluation of measures presented in Table 6, such as high for a 1 percent flood plus 3 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 the greater the relative costs. This enables the users to compare the measures associated with the risk management strategy in order to evaluate affordability and ultimately leading to an acceptable level of risk tolerance. The combination of measures leading to a selection of a plan as described in the NACCS Framework would further quantify risk reduction, and evaluate and compare the change in the risk based on the total cost of the plan. This would be completed at a smaller scale, Tier 3, which would be able to incorporate refined exposure and vulnerability, and evaluation of other risk management measures, as well as refined costs.

VIII. Focus Area Analysis

One Focus Area Analyses (FAA) has been developed for the State of Rhode Island, which is the Rhode Island Coast. The purpose of the FAA is to determine if there is an interest in conducting further study to identify structural, non-structural, NNBF, and policy/programmatic CSRM strategies and opportunities. The complete FAA is provided in an attachment to this Rhode Island State Chapter. A summary discussion of the content of this analysis for the FAA is provided below.

Rhode Island Coast

The purpose of this FAA is to:

- Examine the area to identify problems, needs, and opportunities for improvements relating to CSRM, flood risk management, and related purposes.
- Identify a non-Federal sponsor(s) willing to cost share potential future investigations.

The study area is located along the coast of Rhode Island. The southern edge of the state faces the Atlantic Ocean with Narragansett Bay forming an inlet stretching to the north for approximately 28 miles as shown on Figure 25 below. The study area includes the towns of Westerly, Charlestown, South Kingstown, Narragansett, and Newport. Specific analysis was conducted on the Town of Westerly on the southwestern shoreline of Washington County. Additional details can be found in the Focus Area Analysis Report included as an attachment to this appendix.

Figure 25. Rhode Island Focus Area Analysis Boundary

IX. Agency Coordination and Collaboration

IX.1. Coordination

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

Interagency points of contact and subject matter experts were asked in early 2013 to assist in preparing the scope for the NACCS and to be engaged in data gathering and development of analyses as part of the NACCS. This coordination complements the NACCS website located at http://www.nad.usace.army.mil/CompStudy.aspx and webinars for several coastal resilience topics.

From a letter dated September 4, 2013 requesting feedback with respect to the preliminary problem identification and vulnerability mapping, the USACE New England District received no information. However, state contacts did request by email on September 18, 2013 that Mount Hope Bay be included as a specific risk area on the mapping. The area in question is covered by site RI1_B and will be followed up with RI CRMC in the near future.

IX.2. Related Activities, Projects, and Grants

Specific Federal, state, and NGO efforts that have been prepared in response to PL 113-2 are discussed below for the State of Rhode Island. Additional information regarding Federal and NGO projects and plans applicable to the entire NACCS Study Area are discussed in the Appendix D: State and District of Columbia Analyses, while additional information regarding the alignment of interagency plans and strategies is discussed in the Agency Collaboration and Coordination Report.

Federal Efforts

The U.S. Department of the Interior (DOI) 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. The full list of funded projects can be found at: http://www.nfwf.org/hurricanesandy/Documents/doi-projects.pdf.

In August 2013, the Department of the Interior announced that USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grants Program. This program will support projects that reduce communities' vulnerability to the growing risks from coastal storms, sea level change, flooding, erosion and associated threats through strengthening natural ecosystems that also benefit fish and wildlife (NFWF, 2013). The Hurricane Sandy Coastal Resiliency Competitive Grants Program will provide approximately $100 million in grants for over 50 proposals to those states that were affected by Hurricane Sandy. States affected is defined as those states with disaster declarations as a result of the storm event. The grants range from $100,000 to over $5 million and were announced on June 16, 2014. More information on the program can be found at www.nfwf.org/HurricaneSandy, and the full list of projects can be found at: http://www.doi.gov/news/upload/Hurricane-Sandy-2014-Grants-List.pdf.

Table 7 presents the list of specific Federal projects and plans that have been funded for the State of Rhode Island that have been identified to date. Figure 26 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.

Table 7. Post-Sandy Funded Federal Projects and Plans in Rhode Island

Agency	State	Funded Projects	Cost
USFWS/DOI	CT/RI	Aquatic Connectivity and Flood Resilience in CT and RI: Removing the White Rock and Bradford Dams and Assessing the Potter Hill Dam Fishway on the Pawcatuck River & Removing the Shady Lea Mill Dam in North Kingstown.	$2,294,250
USFWS/DOI	RI/MA/NH/ME	Protecting Property and Helping Coastal Wildlife: Enhancing Salt Marsh and Estuarine Function and Resiliency for Key Habitats on Impacted Wildlife Refuges from Rhode Island to Southern Maine	$4,150,000
U.S. Geological Survey (USGS)/DOI	CT/DE/MD NC/NJ/NY RI/VA	GS2-5D Forecasting Biological Vulnerabilities: Building and delivering data visualization, multiscale datasets, and models of reduced biological systems resilience to future storms in support of informed natural-resource decision making.	$1,025,000
USFWS/DOI	CT/DE/MD NJ/NY/RI/VA	Building a predictive model for submerged aquatic vegetation prevalence and salt marsh resilience in the face of Hurricane Sandy and sea level change.	$217,000
USGS/DOI	CT/DE/MA MD/ME/NH NJ/NY/RI/VA	GS2-3B: Storm Surge Science Evaluations to Improve Models, Risk Assessments, and Storm Surge Predictions	$1,500,000
USFWS/DOI	CT/DE/MA MD/ME/NH NJ/NY/RI/VA	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Tidal Wetland Habitats and Species in the Face of Storms and Sea Level Change	$2,200,000
USFWS/DOI	CT/DE/MA ME/NJ/NY/RI VA	A Stronger Coast: Three USFWS Region 5 multi-National Wildlife Refuge projects to increase coastal resilience and preparedness	$2,060,000
USFWS/DOI	CT/DE/MA MD/ME/NH NJ/NY/RI/VA	Resilience of the Tidal Marsh Bird Community to Hurricane Sandy and Assessment of Restoration Efforts	$1,573,950
USFWS/DOI	CT/DE/MA MD/NJ/NY/RI VA	Coastal Barrier Resources System Comprehensive Map Modernization - Supporting Coastal Resiliency and Sustainability Following Hurricane Sandy	$5,000,000
USFWS/DOI	CT/DE/MA MD/ME/NH NJ/NY/RI/VA	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Beach Habitats and Beach-Dependent Species in the Face of Storms and Sea Level Rise	$1,750,000
USGS/DOI	CT/DE/MA MD/ME/NH NJ/NY/RI/VA	GS2-3A: Enhance Storm Tide Monitoring, Data Recovery, and Data Display Capabilities	$2,200,000

Table 7. Post-Sandy Funded Federal Projects and Plans in Rhode Island

Agency	State	Funded Projects	Cost
USGS/DOI	CT/DE/MA MD/NC/NJ NY/PA/RI/VA	Topographic Surveys: Light and Radar (LIDAR) Elevation Data	$4,050,000
USGS/DOI	CT/DE/MA MD/NC/NJ NY/RI/VA	GS2-5A Evaluating Ecosystem Resilience: Assessing wetland ecosystem functions and processes in response to Hurricane Sandy impacts	$1,240,000
NFWF/DOI	RI	Restore 30 acres of salt marsh and create two additional marsh restoration designs in Ninigret National Wildlife Refuge in southern Rhode Island. Project will strengthen the marsh's resilience and serve as a model to similar restoration projects throughout the state.	$3,673,650
NFWF/DOI	RI	Enhance over 124 acres of Sachuest Bay's beaches and wetlands in Middletown, Rhode Island. Project will improve water quality, enhance natural infrastructure, and improve existing grey infrastructure.	$3,386,913
NFWF/DOI	RI	Incorporate green infrastructure into community policies in Newport, Warwick, and North Kingstown, Rhode Island. Project will increase resilience, build local decision maker capacity, and serve as a replicable model for neighboring states.	$400,000
NFWF/DOI	RI	Create a natural resource resilience assessment and action plan for 2,064 acres in Charleston and County of Washington, Rhode Island. Project will identify mitigation options that will strengthen watershed resilience and protect nearby communities.	$240,206
NFWF/DOI	RI	Develop monitoring network, coastal maps, and best engineering practices for southern shore of Rhode Island. Project will generate best practices and policies, test modeling resources, and is the first step to developing a statewide coastal resilience program.	$1,228,622
NFWF/DOI	CT/RI	Develop a flood and storm resilience management plan for Pawcatuck River Watershed and 11 communities in southern Rhode Island and Connecticut. Project will aid in the watershed's resilience enhancement, restore habitat, and protect local communities.	$917,869
NFWF/DOI	OH/RI	Engage Ohio and Rhode Island communities in projects that will improve their coastal resilience. Project will encourage communities to participate more, provide an ecosystem resilience roadmap, and potentially lower flood insurance costs.	$448,753

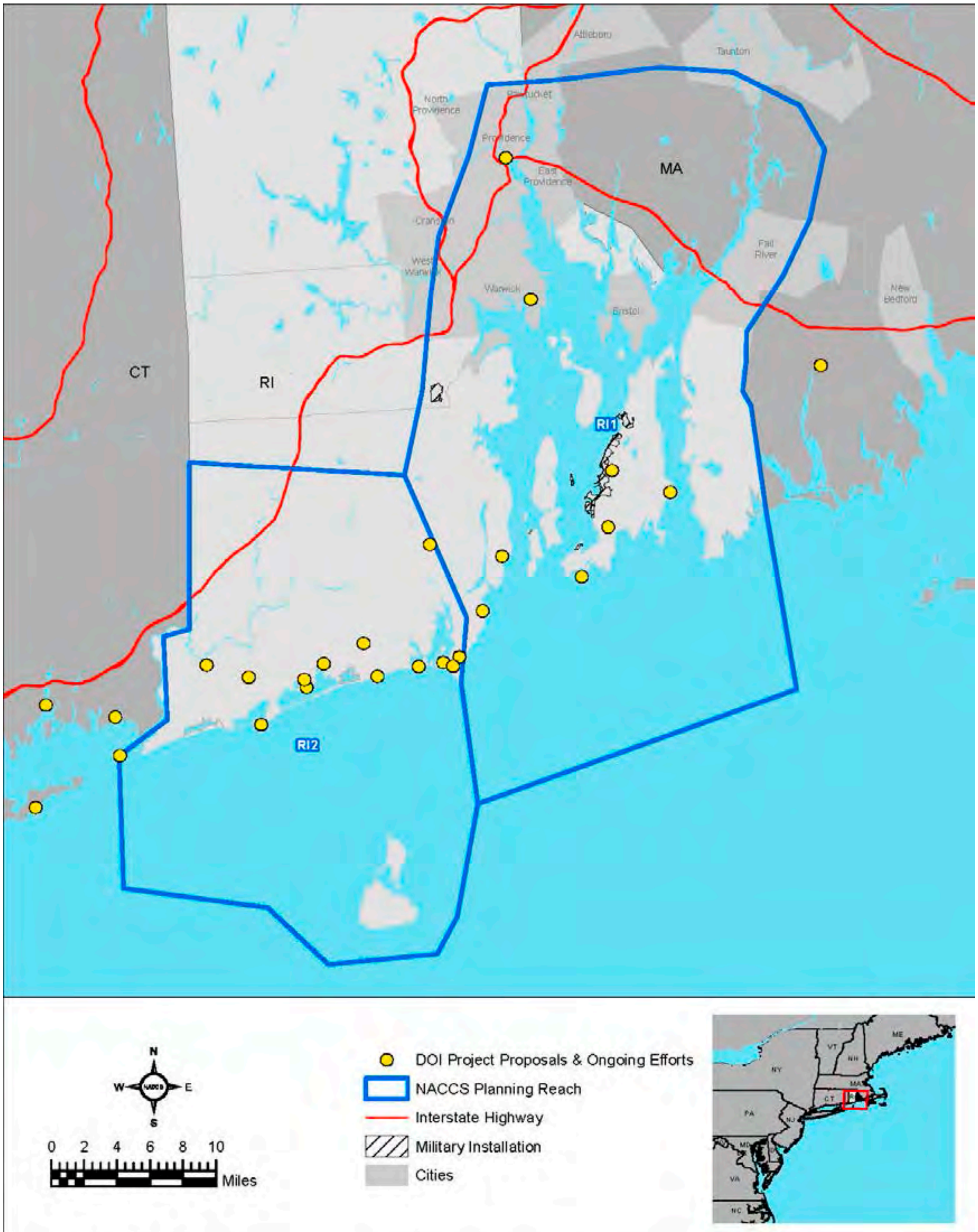


Figure 26. DOI Project Proposals and Ongoing Efforts

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

NOAA is working to complete various data collections activities as part of the PL 113-2 funding allocations within the National Ocean Service, National Marine Fisheries Service, and the National Weather Service, including mapping, modeling resilience, and technical assistance (NOAA, 2012).

Mapping activities include aerial photogrammetric 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/.

As part of the Natural Resources Conservation Service Emergency Watershed Protection Program, the U.S. Department of Agriculture has acquired floodplain easements for approximately 750 acres in Connecticut (Old Field Creek, West Haven), New York (New Creek/West Branch, Staten Island), and New Jersey (Bay Point). The cost was approximately $19.2 million. The easements are intended to assist victims of Hurricane Sandy and prevent future damages in flood-prone areas. Additionally, not only do the easements reduce future exposure, the floodplain easements represent habitat conservation opportunities as part of natural features for floodplain storage and wave attenuation. Additional information on the easements can be found at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1240996.pdf.

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 at: http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx

The U.S. Department of Housing and Urban Development (HUD) has allocated approximately $12 billion for recovery actions to rebuild areas affected by Hurricane Sandy through the Community Development Block Grant (CDBG) Program. 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 Rhode Island, $19.91 million of CDBG funds were made available for areas affected by Hurricane Sandy.

The Harvard University Graduate School of Design team is exploring the wider potential of NNBF, specifically exploring vegetation as the primary component. Working at a regional scale, the study considers both the physical and hydrodynamic conditions of Narragansett Bay to identify locations where forest scale plantings may have beneficial mitigation and attenuation effects.

IX.3. Sources of Information

A review of Federal, state, municipal, and academic literature was conducted and various reports covering topics related to coastal resilience and risk management in Rhode Island were considered in the development of this state narrative and are listed in Table 8.

Table 8. Federal and State of Rhode Island Sources of Information

Resource	Source/Reference	Subject	Key Findings Synopsis
RI Special Area Management Plans	http://www.crmc.ri.gov/samps.html	Coastal Zone Management Policy	The Coastal Resources Management Council (CRMC) is authorized under the Federal Coastal Zone Management Act of 1972 to develop and implement Special Area Management Plans (SAMPs) to address specific regional issues. These plans are ecosystem-based management strategies that are consistent with the council's legislative mandate to preserve and restore ecological systems.
RI Hazard Mitigation Plan	http://www.riema.ri.gov/preparedness/preparenow/prepare_docs/RI_State_HM_Plan%20Final.pdf	Hazard Mitigation	This Plan represents Rhode Island's efforts to approach mitigating the effects of natural disasters on a multi-hazard basis.
CRMC Policy Related to Coastal Hazards	http://www.crmc.ri.gov/coastalstorms.html	Coastal Hazards	These regulations are designed to minimize the impact of coastal hazards. Policies regulating where to build on a vulnerable property, construction of shoreline facilities, and beneficial reuse of dredged materials help to mitigate some of the hazards associated with living along the coast.
Climate Change in RI: What's Happening Now and What You Can Do	http://www.planning.ri.gov/documents/comp/RI_factsheet.pdf	Climate Change	Joint publication between the state and the University of Rhode Island that highlights the problem, its impact, and what people can do.
RI Population Projections 2010-2014	http://www.planning.ri.gov/documents/census/tp162.pdf	Demographics	State population projections report published in 2013.
RI CRMC Maps Website	http://www.crmc.ri.gov/maps.html	Maps and GIS Data	RI CRMC website that provides maps and GIS downloads for public use.
RI DEM Map Viewer	http://www.dem.ri.gov/maps/index.htm	Maps and GIS Data	RI DEM website that provides maps and GIS downloads for public use.

X. References

Bridges, T. S., Wagner, P. W., Burks-Copes, K. A., Bates, M. E., Collier, Z., Fischenich, J. C., Gailani, J. Z., Leuck, L. D., Piercy, C.D., Rosati, J. D., Russo, E. J., Shafer, D. J., Suedel, B. C., Vuxton, E. A., and Wamsley, T. V. 2015. Use of Natural and Nature-based Features for Coastal Resilience. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Dronkers, J., J. T. E. Gilbert, L.W. Butler, J.J. Carey, J. Campbell, E. James , C. McKenzie, R. Misdorp, N. Quin, K.L. Ries, P.C. Schroder, J.R. Spradley, J.G. Titus, L. Vallianos, and J. von Dadelszen. 1990. Strategies for Adaption to Sea Level Rise. Report of the IPCC Coastal Zone Management Subgroup: Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change.

National Fish and Wildlife Foundation (NFWF). 2013. www.nfwf.org/HurricaneSandy,

National Oceanic and Atmospheric Administration (NOAA) (n.d.). Environmental Sensitivity Index (ESI) Maps. Available at http://response.restoration.noaa.gov/esi. Accessed September 14, 2014.

NOAA (2012). Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1; Climate Program Office, Silver Spring, MD.

Rhode Island Coastal Resources Management Council. "Post Sandy Landscape Conditions." Message to USACE NE District. 19 Jul. 2013. Email.

U.S. Army Corps of Engineers (USACE) (2013). Incorporating Sea Level Change in Civil Works Programs. USACE Circular No. 1100-2-8162. Washington, DC.

U.S. Army Corps of Engineers (USACE). (2014). North Atlantic Coast Comprehensive Study. Available at http://www.nad.usace.army.mil/CompStudy.aspx.

U.S. Environmental Protection Agency (EPA). (2009).

Internet URLs

http://www.nad.usace.army.mil/CompStudy.aspx

http://www.nfwf.org/hurricanesandy/Documents/doi-projects.pdf.

www.nfwf.org/HurricaneSandy

http://www.doi.gov/news/upload/Hurricane-Sandy-2014-Grants-List.pdf.

http://oceanservice.noaa.gov/hazards/sandy/.

http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1240996.pdf.

http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx

http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2013/HUDNo.13-153.

http://www.crmc.ri.gov/samps.html

http://www.riema.ri.gov/preparedness/preparenow/prepare_docs/RI_State_HM_Plan%20Final.pdf

http://www.crmc.ri.gov/coastalstorms.html

http://www.planning.ri.gov/documents/comp/RI_factsheet.pdf http://www.planning.ri.gov/documents/census/tp162.pdf

http://www.dem.ri.gov/maps/index.htm

http://www.crmc.ri.gov/maps.html

ATTACHMENT A

Focus Area Analyses Report

ATTACHMENT A

Rhode Island Coastal Flood Risk Management and Storm Damage Assessment

Table of Contents

List of Figures

List of Tables

1. Authority

This investigation is being conducted as a part of the North Atlantic Coast Comprehensive Study (NACCS) under the authority of Public Law 113-2, the Disaster Relief Appropriation Act of 2013, Chapter 4. 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 document identifies activities warranting additional analysis that could possibly be pursued under PL113-2 but also through other Corps authorities including the Planning Assistance to States Program, Floodplain Management Services Program, Section 103/14/204 of the Continuing Authorities Program, or Public Law 84-71.

Funds in the amount of $50,000 were appropriated in Fiscal Year 2013 under PL 113-2 and were specifically designated to conduct a flooding related focus area analysis along the Rhode Island coastline.

2. Purpose

In October 2012, Hurricane/Post-Tropical Cyclone Sandy moved from the Caribbean to the East coast of the U.S. and made landfall along the southern NJ shore on October 29th. The storm resulted in over 200 deaths; making Sandy the deadliest hurricane to hit the U.S. mainland since Hurricane Katrina in 2005, as well as the deadliest hurricane/post-tropical cyclone to hit the U.S. East Coast since Hurricane Agnes in 1972. (NOAA, 2013) Damage estimates from Sandy exceed $50 billion, with 24 states impacted by the storm.

The purpose of this focus area analysis is to capture and present information regarding the possible cost-shared future phases of study to provide structural and/or non-structural coastal storm risk management, flood risk management, ecosystem restoration, and other related purposes for the Rhode Island coastline and identify potential non-Federal sponsor(s) to cost share in future investigations. The report includes a description of the focus area analysis study area, a description of recent storm damages experienced, preliminary plan formulation, and potential issues affecting future phases of study.

3. Location and Congressional District

a. The focus area analysis study area is located along the coast of Rhode Island. The southern edge of the state faces the Atlantic Ocean with Narragansett Bay forming an inlet stretching to the north for approximately 28 miles as shown in Figure 1 below. The study area includes the towns of Westerly, Charlestown, South Kingstown, Narragansett and Newport. Specific analysis was conducted on the Town of Westerly on the southwestern shoreline of Washington County.

b. The assessment area lies within the jurisdiction of the following Congressional Districts:

1st Congressional District – Rep. David N. Cicillene
2nd Congressional District – Rep. James R. Langevin

Figure 1. Rhode Island Reconnaisance Study Area

4. Prior Reports and Existing Projects

The following prior investigations regarding coastal storm damage reduction were reviewed as part of this NACCS focus area analysis:

a. Prior Reports

1) A comprehensive plan to restore and protect Misquamicut Beach was developed by the USACE (New England Division) as an "Interim Hurricane Survey of Westerly, Rhode Island" and transmitted by the Secretary of the Army to Congress in July 1964. The project was subsequently authorized by Congress in December 1965. However, due to a lack of local interest, the project was never constructed and was subsequently de-authorized in January 1986.

2) **Misquamicut Beach, Shore Protection and Flood Damage Reduction Reconnaissance Report, Westerly, Rhode Island (January 1994)**. The report could not determine an economically justified plan for storm damage protection along the Westerly shoreline. The study was terminated and no further action taken.

b. Existing Projects

1) **Sand Hill Cove Beach, Narragansett**. This beach erosion control project, east of the entrance to Point Judith Pond, was completed in 1955 and consists of widening the beach by 65 feet, constructing five stone groins and a steel bulkhead behind the eastern half of the beach.

2) **Misquamicut Beach, Beach Erosion Control Project**. The project was authorized by the River and Harbor Act of 14 July 1960 (PL 86-645), as amended. The authorized beach erosion control project involved the placement of approximately 80,000 cubic yards of a suitable sand fill along 3,250 feet of shoreline. The beach is roughly 150 feet wide shoreward of the mean high water line with a top elevation of +7.5 feet MLW.

3) **Fox Point Hurricane Barrier**. The project was authorized by the Chief of Engineers on July 3, 1958 under the Flood Control Act (PL 85-500). The project was constructed between 1961 and 1966 and consists of a 700-foot long concrete barrier, 25 feet high, that contains three tainter gates; a pumping station and two flanking earth fill/stone dikes (780 and 1400 feet long).

4) **Cliff Walk, Newport**. Construction of the Cliff Walk Beach Erosion Control Project was authorized by the River and Harbor Act of 27 October 1965, as amended. Constructed in 1972 the project extends over a shoreline distance of 9,200 feet from Memorial Boulevard to Sheep Point and consists of intermittent reaches of backfill, dumped rip-rap, stone mounds, stone slope revetment, concrete toe walls, and repairs to existing structures including the walkway itself. Follow-on work in 1994 included another 8,800 feet of shore protection from Sheep Point to Bailey Beach as well as improvements to the original section of the project.

5) **Oakland Beach, Warwick**. Authorized in April 1980 under the Hurricane and Storm Damage Reduction program (Section 103), the project provides for direct placement of suitable sand fill on both sides of the existing seawall that protects the parking area. The project includes construction of five groin structures and the placement of rock revetment in front of the seawall between the groins. Work was completed in August 1981.

5. Plan Formulation

During a USACE study, six planning steps are repeated to focus the planning effort and eventually to select and recommend a plan for future implementation. The process is detailed in the Corps Engineer Regulation, ER 1105-2-100 and supporting Corps guidance and regulations. The six planning steps are: (1) specify problems and opportunities, (2) inventory and forecast conditions, (3) formulate alternative plans, (4) evaluate effects of alternative plans, (5) compare alternative plans, and (6) select recommended plan. As part of the focus area analysis, specific problems and opportunities were identified. The paragraphs that follow present the results of the initial iterations of the planning steps that were conducted during the focus area analysis. This information will be refined during future phases of study.

5.1 Problems and Opportunities

The general water resource problem to be addressed is the vulnerability of coastal Rhode Island to storm damage from wave attack, storm surge and erosion. These forces constitute a threat to human life and increase the risk of flood damages to public and private property and infrastructure.

The south shore of Rhode Island is a headland-barrier beach system that extends for approximately 30 miles from the western point at Watch Hill in Westerly to Point Judith in Narragansett. The headlands were formed by silt, sand, gravel and boulders deposited by glacial melt waters. The primary source of sediment on the south shore of Rhode Island comes from erosion of the headlands, the dunes on the barrier beaches, and sediment on the shore that is at depths of less than 40 feet (RIEMA, 2011). Narragansett Bay is a predominantly rocky coast line with intermittent pocket beaches.

Due to the geography of southern New England in relation to the Atlantic coast, Rhode Island is vulnerable to both extra-tropical storms such as nor'easters, and tropical storms such as hurricanes. Historically, most hurricanes striking the New England region have re-curved northward on tracks which paralleled the eastern seaboard maintaining a slight north northeast track direction (RIEMA, 2011). The State of Rhode Island geographically projects eastward into the Atlantic with a southern exposed shoreline; placing it directly in the path of any storms tracking along the eastern seaboard.

Table 1 below presents a list of Emergency and Disaster declarations made by the Federal Emergency Management Agency (FEMA). Rhode Island has had nineteen (19) storm-related emergency declarations involving coastal flooding and damages since 1954.

Table 1. FEMA Disaster and Emergency Declarations

Disaster Number	Date	Incident Description	Declaration Type
4107	3/22/2013	Severe Winter Storm	Major Disaster
4089	11/3/2012	Hurricane Sandy	Major Disaster
3355	10/29/2012	Hurricane Sandy	Emergency
4027	9/3/2011	Tropical Storm Irene	Major Disaster
3334	8/27/2011	Hurricane Irene	Emergency
3311	3/30/2010	Severe Storms and Flooding	Emergency
1894	3/29/2010	Severe Storms and Flooding	Major Disaster

Disaster Number	Date	Incident Description	Declaration Type
1704	5/25/2007	Severe Storms and Flooding	Major Disaster
3255	9/19/2005	Hurricane Katrina Evacuation	Emergency
3203	2/17/2005	Snow	Emergency
3182	3/27/2003	Snowstorm	Emergency
1091	1/24/1996	Blizzard	Major Disaster
3102	3/16/1993	Blizzard	Emergency
913	8/26/1991	Hurricane Bob	Major Disaster
748	10/15/1985	Hurricane Gloria	Major Disaster
548	2/16/1978	Snow, Ice	Major Disaster
3058	2/7/1978	Blizzards and Snowstorms	Emergency
39	8/20/1955	Hurricane Diane, Flood	Major Disaster
23	9/2/1954	Hurricane Carol	Major Disaster

http://www.fema.gov/disasters/grid/state-tribal-government/34

History of Nor'Easters

A nor'easter (also called northeaster) is a cyclonic storm that moves along the east coast of North America with continuously strong northeasterly winds blowing in from the ocean. These winter weather events are known for producing heavy snow, rain, and oversized waves that often cause beach erosion and structural damage.

This type of storm is a primary concern for Rhode Island residents; not only because of the damage potential, but because there is a frequent rate of recurrence. Nor'easters have an average frequency of one or two per year, with a storm surge equal to or greater than two feet. The comparison of hurricanes to nor'easters reveals that the duration of high surge and winds in a hurricane is six to 12 hours while a nor'easter's duration can be from 12 hours to three days (RIEMA, 2011).

The blizzard of 1978 remains the worst winter storm on record for Rhode Island. It was a slow moving nor'easter accompanied by astronomically high tides that caused serious coastal flooding, beach erosion, broken seawalls and massive property damages. Although not all damages were in the coastal areas, the state suffered 26 fatalities and damages in excess of $15 Million (Strauss, 2003).

The Halloween Storm of 1991 was another strong extended nor'easter that caused flooding in tidal areas and over wash of the dunes along the southern coast during times of high tide. This in turn caused flooding in Westerly that damaged many businesses and flooded approximately one third of the residential area (Westerly, 2010). Additional nor'easters include the 2003 President's Day Storm, the 2005 Blizzard, and the March 2010 Nor'easter that caused significant coastal flooding.

History of Major Hurricanes

Five hurricanes, of category 3 or greater, occurring in 1635, 1638, 1815, 1869, and 1938 have made landfall on the New England coast since European settlement (Jeffrey P. Donnelly, 2001). Based on National Weather Service records, Rhode Island has experienced approximately 30 hurricanes throughout recorded history with 14 occurring in the 20th century (RIEMA, 2011).

The most notable storm to hit Rhode Island was the hurricane of September 21, 1938 which brought major devastation to the State, with 262 deaths and damage estimated at $100 million (RIEMA, 2011). Another major hurricane occurred on September 14, 1944; no lives were lost, but property damage was over $2 million. The coastal area from Westerly to Little Compton experienced the heaviest damage.

Ten years later, Hurricane Carol hit Rhode Island resulting in 19 deaths and $200 million in property damage (RIEMA, 2011). Hurricane Carol arrived on August 31, 1954 shortly after high tide. Even though the storm arrived after high tide, resulting in a lower storm tide, Narragansett Bay received storm surge greater than 14 feet in the upper reaches of the bay. In the capital city of Providence, the surge was recorded at 14.4 feet, surpassing that of the 1938 Hurricane (NOAA). Entire coastal communities were nearly wiped out from Westerly to Narragansett (RIEMA, 2011).

The next major storm to warrant a FEMA Major Disaster Declaration was Hurricane Diane in August 1955 which caused $5 Million in property damages when its 6-foot tidal surge hit Rhode Island (RIEMA, 2011).

Hurricane Gloria, which was downgraded to a tropical storm over New England, caused two fatalities in Rhode Island and damages close to $20 million when it struck on September 27, 1985. Fortunately, the storm arrived at low tide and reported surges were less than five feet in Rhode Island (Grammatico, 2002).

On August 19, 1991, the eye of Hurricane Bob passed over Block Island and made landfall over Newport. Hurricane Bob caused a storm surge of five to eight feet along the Rhode Island shore with approximate property damages of $115 million (NOAA Coastal Services Center, 1999). Extensive beach erosion occurred from Westerly, eastward. Some south facing beach locations on Martha's Vineyard and Nantucket islands lost up to 50 feet of beach to erosion (NOAA).

Hurricane Irene made landfall on the RI coast during morning high tide on August 28, 2011, bringing storm surge values recorded at two to 4.8 feet with storm tides of 4.5 to 8.2 feet (NAVD88) (NOAA-US Dept. Commerce). The storm surge into Narragansett Bay caused some coastal damage, although Providence, at the head of the bay, was spared downtown flooding in part due to its hurricane barrier (Wikipedia).

Hurricane/Post-tropical Cyclone Sandy was a late-season storm that came ashore in the U.S. near Brigantine, New Jersey on October 29 with 80 mph sustained winds and record storm tide heights. Its impact was felt along the entire East Coast of the United States from Florida northward to Maine; causing historic devastation and substantial loss of life.

5.2 Watershed-Specific Problem Identification

This focus area analysis is being conducted as a result of damages that occurred along the Rhode Island coastline due to Hurricane Sandy.

Hurricane Sandy

The arrival of Hurricane Sandy on October 29, 2012 was preceded by Coastal Flood Warnings and mandatory evacuations for coastal towns, low lying areas and mobile homes. Major evacuations from Rhode Island towns along Narragansett Bay and the Southern Atlantic Coast included: Bristol, Charlestown, Middletown, Narragansett, South Kingstown, Tiverton and Westerly. The Fox Point

Hurricane Protection Barrier was closed to reduce potential flooding in Providence, saving an estimated $606,000 in flood damage (USACE, 2012).

The storm surge destroyed houses and businesses, damaged pilings and deck supports, blew out walls on lower levels, and moved significant amounts of sand and debris into homes, businesses, streets, and adjacent coastal ponds. Propane gas tanks were dislodged from houses, septic systems were damaged and underground septic tanks were exposed, creating potential hazardous material exposure. The National Guard was called out to restrict entry to the community of Misquamicut (located in the town of Westerly) due to the devastation.

The Westerly Sun newspaper reported that “houses were ripped from their stilts and deposited in the streets while other structures appeared precariously perched over the ocean.” In some areas, roads were either flooded or covered in three feet of sand.

More than $39.4 million in support from four federal disaster relief programs is helping Rhode Island recover from Hurricane Sandy’s effects. FEMA’s website reports the National Flood Insurance Program (NFIP) has paid more than $31.1 million for more than 1,000 claims. In addition to NFIP claims, Federal aid also included more than $5.3 million in Public Assistance (PA) grants for state and local agencies and private nonprofits, and more than $423,000 in Individual Assistance grants paid directly to eligible individuals and families to meet basic needs for housing and cover other essential disaster-related expenses. The U.S. Small Business Administration has provided approximately $2.6 million in low-interest disaster recovery loans to Rhode Island homeowners, renters and business owners of all sizes (FEMA, 2013).

FEMA’s PA program has approved more than 260 projects to reimburse local and state agencies for 75 percent of eligible Sandy-related costs that include emergency response, debris removal, and repair or replacement of facilities or infrastructure (FEMA, 2013).

The US Department of Housing and Urban Development allocated $3.24 million in Community Development Block Grant Disaster Recovery funding to support projects that address the impacts of Hurricane Sandy (RIHCD, 2013).

A spatial analysis, using GIS and SLOSH data (Sea, Lake and Overland Surges from Hurricanes) was used to determine the number of structures vulnerable to coastal storm damage. Figure 2 below shows the coastal areas at risk of flooding during Category 2 and category 4 Hurricanes.

Table 2 below shows the number of structures located in these southern coastal areas. The Category 2 and Category 4 Hurricanes correspond closely to storms having a 100-year and 500-year return interval.

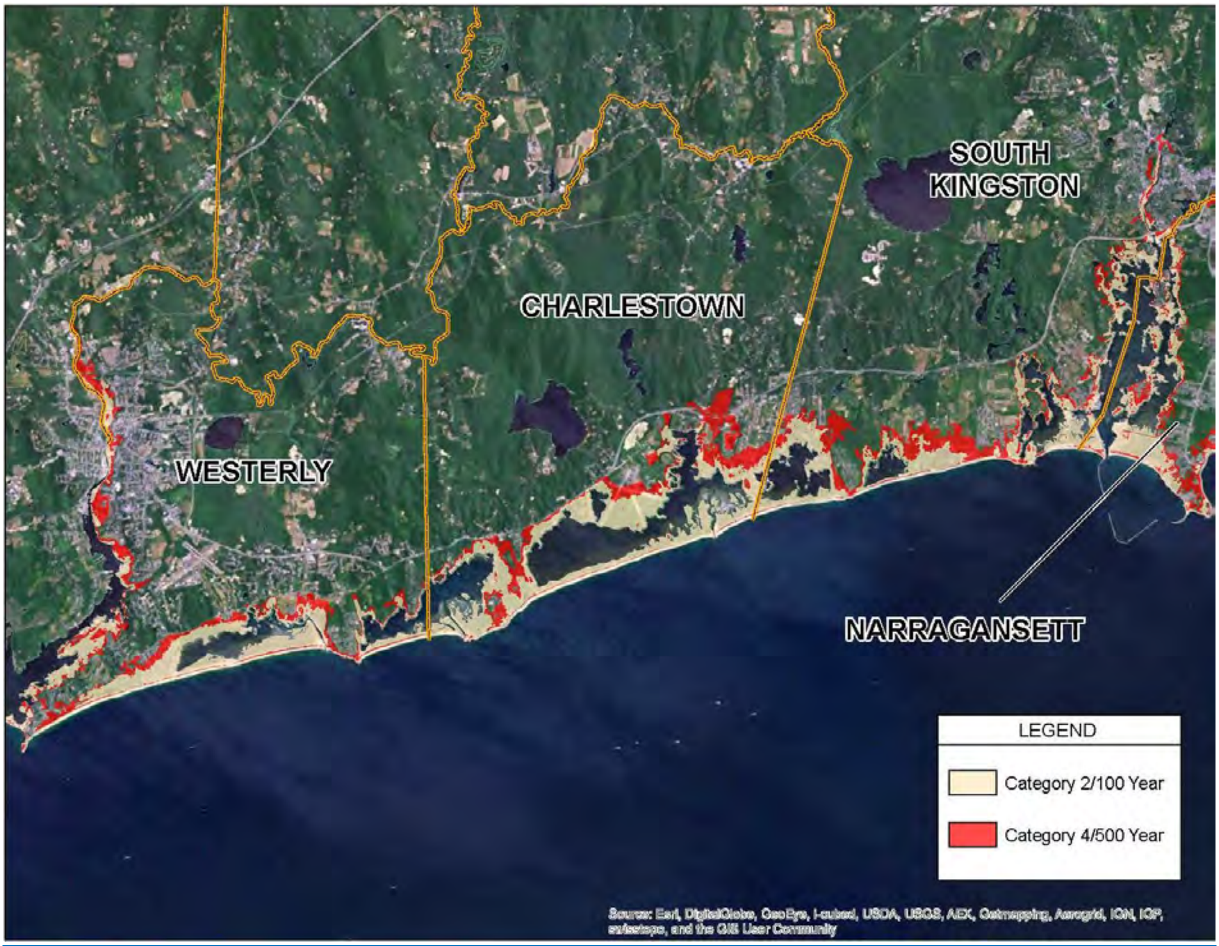


Figure 2. Category 2 and Category 4 Inundation Areas

Table 2. Number of Structures in Floodplain

Town	CAT2/ 100 YR	CAT 4/ 500 YR
Narragansett	1,000	1,800
South Kingstown	1,200	1,500
Charlestown	900	1,300
Westerly	1,700	2,100
TOTAL	4,800	6,700

Areas specifically impacted by significant flooding and coastal storm damage caused by Hurricane Sandy are discussed in the following sections; starting at the eastern town of Narragansett and moving west toward Misquamicut Beach in Westerly.

Narragansett, RI

Storm surge in Narragansett caused shoreline erosion and damage to buildings, roads and a section of the seawall (Figure 3 below). One home was totally destroyed and six other residences had major damage. Several low-income housing authority units and four town-owned single family residences were also damaged. NFIP claims for Sandy damage for the entire town were in excess of $4.1 million (RIHCD, 2013).

The Coast Guard House Restaurant in Narragansett, a historic landmark overlooking the ocean, was severely damaged (see Figure 4 below).

A low-lying segment of Col. John Gardner Road in the Bonnet Shores neighborhood was significantly damaged by the storm surge. A section of approximately 1,000 feet was undermined and washed away (RIHCD, 2013). A section of sidewalk from State Pier No. 5 to the town beach was also damaged and 200 feet of seawall was overturned. The state was awarded $3.0 million by the US Department of Transportation in quick release emergency relief funds to address the damages (RIDOT, 2012).

Figure 3. Portion of the Narragansett Seawall overturned during Sandy

Figure 4. Damage to Historic Coast Guard House Restaurant

South Kingstown and Charlestown, RI

South Kingstown is the largest town in Washington County, based on land and water area combined, in the state of Rhode Island (Wikipedia). Located on the south shore between the towns of Charlestown and Narragansett, it includes the coastal villages of Green Hill, Snug Harbor and Matunuck.

Hurricane Sandy destroyed a recreational facility in the basement of the Green Hill Beach Club, but the elevated portion of the clubhouse remained. The building finally collapsed after consecutive days of large post-storm surf that took out the last remaining support pilings. The club had been built 51 years ago and served 225 families (SRIN, 2013).

Structures damaged or lost include the South Kingstown Town Beach pavilion, a local tavern, and three of the historic Browning Beach Cottages, which were built over 100 years ago. The on-going erosion and storm threat also prompted the South Kingstown Zoning Board to permit the relocation of 28 first and second row cottages at Roy Carpenter's Beach on Cards Pond Road.

In Charlestown, Hurricane Sandy altered the shoreline, damaged and destroyed buildings and infrastructure, spread debris, and caused utility interruptions.

Damage to the Charlestown breach-way (inlet to Ninigret Pond) resulted from the pounding of storm waves against the east side of the inlet channel. A number of rocks lining the channel were pushed into the channel causing parts of the bank to be nearly underwater at high tide. The stone embankment is no longer safe to walk on. Charlestown and the State of Rhode Island are also applying for federal aid to repair the inlet.

Figure 5. Ocean Mist bar and restaurant on Matunuck Beach Road in South Kingstown

Figure 6. Matunuck Homes after Hurricane Sandy

Figure 7. South Kingstown Houses, which had decks and 20-30 feet of grass in their yard prior to Sandy erosion

Figure 8. Three Historic Victorian houses on Browning Beach were so badly damaged that they had to be destroyed (Providence Journal Photo)

Westerly, RI

The Census Tract, encompassing Watch Hill, Misquamicut and Weekapaug, has a density of 326 people per square mile. However, due to large numbers of seasonally-occupied dwellings, population density in these coastal Census Tracts more than doubles during the summer months.

When two or more claims within 10 years are made on a specific property that exceeds $1,000 per claim, such damage is categorized as a repetitive loss. Repetitive losses are one indication of vulnerable areas in the community. According to FEMA, Westerly had 38 repetitive loss properties, primarily residential, that have made 130 claims this year, with 441 since 1978, primarily in the vicinity of Atlantic Avenue (Westerly, 2010).

Figure 9. Westerly, Rhode Island home facing Misquamicut Beach damaged following Hurricane Sandy (FEMA Photo)

Figure 10. Contents of damaged houses line the streets in Westerly, Rhode Island near Misquamicut Beach (FEMA Photo)

5.3 Planning Objectives

National

Federal water resources planning and development should both improve the economic well-being of the Nation for present and future generations and protect and restore the environment. America's water resources – streams, rivers, wetlands, estuaries, lakes, and coasts – are at the heart of our economy, our environment and our history. These water resources support billions of dollars in commerce, provide drinking water for millions of Americans and supply needed habitat for fish and wildlife and other benefits. The National Objective for water resources planning is to develop water resources projects based on sound science that maximize net national economic, environmental, and social benefits. Consistent with this objective, the United States will demonstrate leadership by modernizing the way the Nation plans water resources projects by:

- Protecting and restoring natural ecosystems and the environment while encouraging sustainable economic development;
- Avoiding adverse impacts to natural ecosystems wherever possible and fully mitigating any unavoidable impacts;
- Avoiding the inappropriate use of flood plains, flood-prone areas and other ecologically valuable areas.
- Developing projects that are resilient in light of future climate change and relative sea level change.

Public

No specific concerns were raised during this focus area analysis effort as no significant public outreach was conducted. However, there are a number of concerns that have been voiced during similar efforts that include:

- The perception that the Corps is only interested in building large, expensive storm damage reduction projects without giving adequate consideration to non-structural approaches.
- A general concern with the time and cost involved in the Corps civil works process.

5.4 Planning Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in this focus area analysis are as follows:

- Compliance with state CZM policy and local land use plans and regulations;
- Avoid negative effects on habitat of Federal and State threatened and endangered species within the study area;
- Storm damage reduction measures must not cause additional flooding or erosion in adjacent areas.

5.5 Future Without Project Condition

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

5.6 Measures to Address Identified Planning Objectives

A management measure is a feature or activity at a site, which addresses one or more of the planning objectives. A wide variety of measures will be considered in the future phases of study. A description of the measures considered in this level of study is presented below:

1) No Action. The Corps is required to consider “No Action” as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). “No Action” assumes that no project would be implemented by the Federal government or by local interests. “No Action”, which is synonymous with the Without Project Condition, forms the basis from which all other alternative plans are measured.

2) Non-Structural. Various non-structural alternatives including buy-outs/ relocations, elevating structures, and flood-proofing are all considered viable measures for the damage zones located along the coast of Rhode Island.

3) Structural. Measures such as beach fills, breakwaters, groins, seawalls and dikes may be examined. Construction of a structural feature serves to prevent waters from reaching residential property, businesses and roads. Analysis of a beach fill, wall or dike system will be focused on those areas with a population density or commercial activity level sufficient to allow economic justification.

4) NNBF. Natural and nature-based features refer to the intentioned use of natural and engineered features to produce engineering functions in combination with ecosystem services and social benefits. Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests.

5) Additional Measures to Complete Alternatives. The Feasibility-level analysis may identify measures that might be required to generate a “complete” alternative. These may also include elements of an overall project in which the Corps does not have authority to become a cost-sharing participant. Additionally, ecosystem restoration opportunities will be examined where the dual purposes of storm damage reduction and ecosystem restoration may be served.

5.7 Preliminary Evaluation of Alternatives

For this focus area analysis the study team decided to analyze a structural alternative for the most damaged area along the coast, specifically, Westerly. The team decided to calculate the total damages that could occur across a range of probable storm events for the area along the Misquamicut shoreline and around Winnapaug Pond. This site was chosen as it is the only concentrated area of development in the watershed damaged during Hurricane Sandy and as such is the site most likely to warrant federal participation in a future project. The analysis was done by taking the following steps:

- Determining the number, type, and approximate elevation of structures in the damage area using GIS data available from the state of Rhode Island and 2001 LIDAR from RI Dept. of Transportation (latest available).
- Documenting the extent of the damage area and the depth of floodwaters.
- Collecting damage data from the State for the event.
- Utilizing standardized stage-damage curves for residential and commercial properties to develop an overall stage-damage function. Structure values were obtained from an online assessment database for the town of Westerly.
- Developing a stage-frequency curve for the Misquamicut area using the most recent FEMA Flood Insurance information.
- Developing an overall stage-frequency function for the area and calculating the expected annual damages using the Corps of Engineers HEC-FDA program (Hydrologic Engineering Center Flood Damage Analysis program).

For purposes of focus area analysis the hydrologic data available from the 2012 Flood Insurance Study was utilized to provide a general planning level estimate of flood stage in the area. The resultant damages by storm event are presented in Table 3 below.

Table 3. Without Project Damages by Event – Misquamicut, Westerly, Rhode Island

Probability	Recurrence Interval (Years)	$000
0.5	2	$1,462.5
0.2	5	$4,381.8
0.1	10	$8,739.5
0.04	25	$21,757.8
0.02	50	$33,907.8
0.01	100	$47,416.4
0.004	250	$70,876.6
0.002	500	$94,121.5

The expected annual damages to structures for the Misquamicut area are estimated to be $4,682,510 in the without-project condition. There are approximately 55 residential and 1035 commercial properties in the study area. This total is broken down by damage category in Table 3. When the cost of infrastructure repair, emergency services, debris removal, and beach renourishment is factored in, damages will be substantially higher than those presented in Table 4 below.

Table 4. Expected Annual Damages for Misquamicut Area, Westerly RI

Category	Without Project	With Project	Project Benefits
Residential	$4,378,550	$1,158,560	$3,219,990
Commercial	$303,960	$100,410	$203,550
Total	$4,682,510	$1,258,970	$3,423,540

A combination beach fill and floodwall (reinforced concrete over sheeting) or earthen dike was considered for the damaged areas along Misquamicut. The Westerly project will consist of 10,000 feet of newly created beach/dune sand fill. It is estimated that it will require about 750,000 cubic yards of sand to create a dune with an elevation of 17' and a berm of 6.5' NAVD88. Cost estimates were based on dredging the sand from an off-shore source. Two flanking flood walls will be constructed to protect the backshore neighborhood and businesses. The west wall is 2,100 feet long and the east wall is 3,800 feet long. Both tie into high ground and vary in height: 14' on the west side and 11' on the east side. The flood walls would be constructed of cast in place, reinforced concrete over driven steel sheet pile. A gate or stop-log closure system would be required for the openings of the wall at Atlantic Avenue. A pump system will be needed to handle interior drainage (~55 cfs). Floodwalls were chosen over the engineered dike (70' at its base) as walls take up less space and require less real estate acquisition and wetland impacts. It was assumed that the beach fill and structures provide 50 year level of protection.

The initial estimate for cost of this alternative is $25,913,000. The cost includes initial construction, design, supervision and administration.

Calculating interest during construction for a 24-month period based on the FY 2013 interest rate of 3.75%, for a 50 year project life, and using the capital recovery factor of 0.00457, yields an annual cost of $2,752,300. Annual benefits are $3,423,500, therefore, the benefit to cost ratio for this alternative would be 1.24 with annual net benefits of $671,200.

5.8 Conclusions

In addition to the measure described above, other alternatives that should be analyzed in future phases of study include: beach fill projects, elevating structures or utilities, flood proofing, NNBF, and small protective floodwalls. The magnitude and types of benefits from the proposed actions would include National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ), including prevention or reduction of: flood damages, emergency costs, transportation impacts and delays, loss of income, loss of commerce; quality of life impacts, loss of life, and loss of habitat and open space impacts. Detailed benefits and costs of the alternatives will be developed during future phases of study.

6. Preliminary Financial Analysis

Given the size of the study area there could be more than one study and multiple sponsors. Potential non-federal sponsors 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. 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 an array of solutions that have the potential to be economically justified, environmentally acceptable, addressable through engineering solutions, and consistent with USACE polices and the Infrastructure Systems Rebuilding Principles (NOAA & USACE, 2013).

At this time, the only state agency that has shown interest in acting as a future non-federal sponsor is the Rhode Island Coastal Resources Management Council. However, none of the coastal communities or other pertinent state agencies (e.g. RI Department of Environmental Management) have been approached about potential interest in future phases of study.

Any future investigation will require that a Project Management Plan and cost estimate for the study be developed.

8. Views of Other Resource Agencies

Due to the funding and time constraints of the focus area analysis phase, limited and informal coordination has been 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.

9. Selected References Consulted

CRMC (2012). *The State of Rhode Island Coastal Resource Management Program (as Amended)*. Retrieved July 17, 2013, from http://www.crmc.ri.gov/regulations/RICRMP.pdf

RIDOT (2012, November 2). *RI Dept. of Transportation*. Retrieved August 7, 2013, from RI.gov: http://www.ri.gov/DOT/press/view.php?id=17851

RIEMA (2011). *RI State Hazard Mitigation Plan*. Rhode Island Emergency Management Agency.

RIHCD (2013). *State of Rhode Island Action Plan--Hurricane Sandy Relief*. US Dept. of Housing & Urban Development. Federal Register:Volume 78, Number 43.

Westerly (2010, December*). Town of Westerly Natural Hazard Risk Assessment and Mitigation Strategy*. Retrieved July 21, 2013, from Town of Westerly Government Website: http://www.westerly.govoffice.com/vertical/Sites/%7B3CFB1749-9DE7-4A17-B2EA-594A2B09CB46%7D/uploads/Mitigation_Plan_adopted_final_10-2012_R.pdf