APPENDIX D: STATE AND DISTRICT OF COLUMBIA ANALYSES

NORTH ATLANTIC COAST COMPREHENSIVE STUDY:
RESILIENT ADAPTATION TO INCREASING RISK

STATE CHAPTER

D-4: State of Connecticut

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I. Introduction

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

The goals of the NACCS are to:

- Provide a risk management framework, consistent with NOAA/USACE Infrastructure Systems Rebuilding Principles; and
- Support resilient coastal communities and robust, sustainable coastal landscape systems, considering future sea level and climate change scenarios, to reduce risk to vulnerable populations, property, ecosystems, and infrastructure.

The NACCS Main Report addresses the entire study area at a regional scale and explains the development and application of the NACCS Coastal Storm Risk Management Framework from a broad perspective. This State Coastal Risk Framework Appendix discusses state-specific conditions, risk analyses and areas, and comprehensive CSRM strategies in order to provide a more tailored Framework for the State of Connecticut (CT). The Coastal Connecticut Focus Area Analyses (FAA) Report is included as an attachment to the state chapter.

II. Planning Reaches

The planning reach for Connecticut has been developed to be the entire coast of the state for which CSRM and coastal resilient community decisions can be made. This planning reach is based on natural and manmade coastal features including shoreline type, USACE CSRM projects, and the 1 percent floodplain (Figure 1).

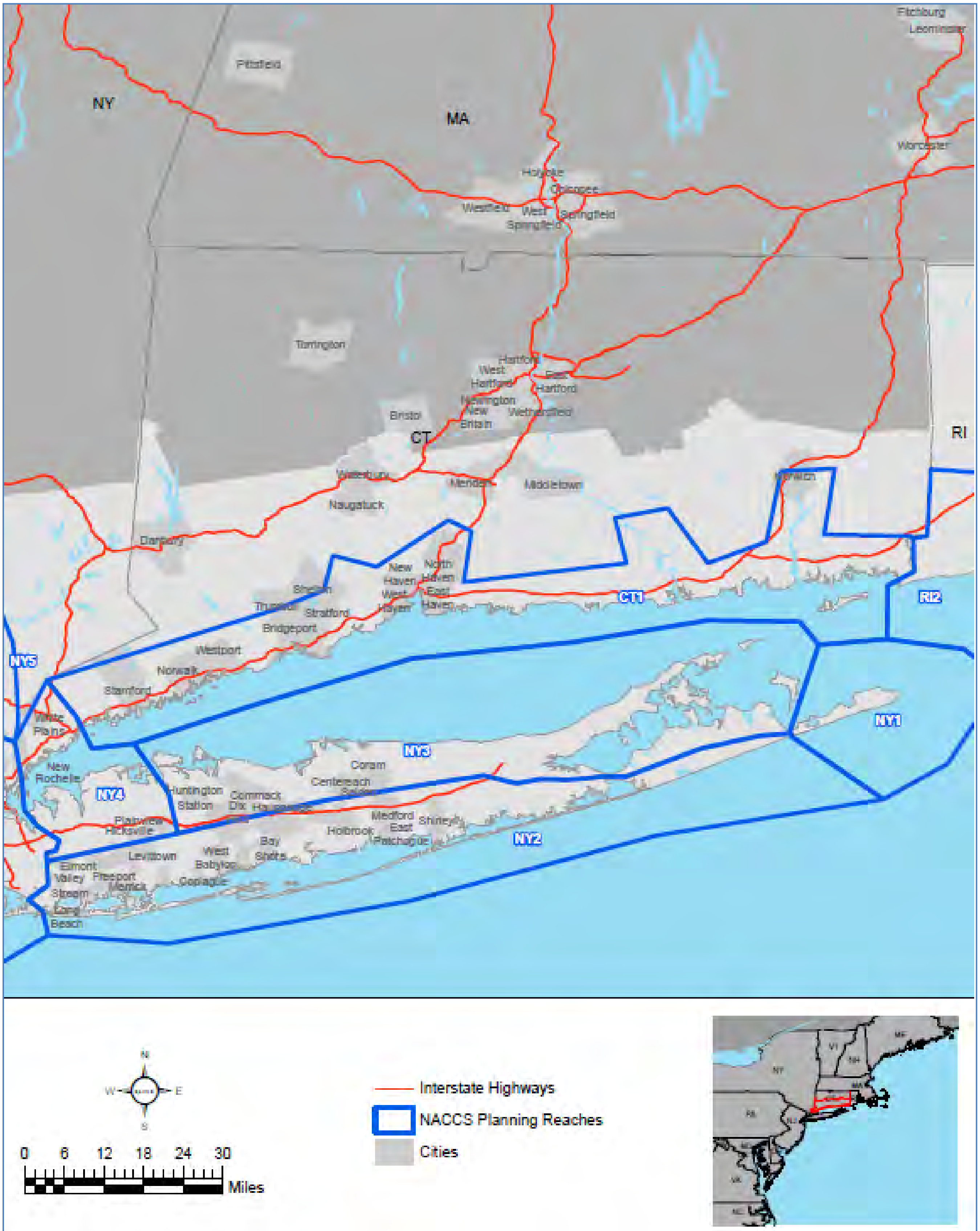


Figure 1. Planning Reaches for the State of Connecticut

There is one planning reach in Connecticut, designated as CT1. CT1 is the entire coast of the state. This reach includes all of the state's more densely populated coastal municipalities including: New Haven, Milford, Stratford, Bridgeport, Norwalk, and Stamford. Several of these cities contain significant ports that are critical to the local and regional economy. There are also several other smaller coastal communities that are included in this reach but are no less impacted by coastal storms. Fishers Island, though part of the State of New York, was included in this reach and its subsequent analysis.

III. Existing and Post-Sandy Landscape Conditions

III.1 Existing Conditions

The existing conditions are the conditions immediately after the landfall of Hurricane Sandy. This existing conditions analysis includes consideration of the population, supporting critical infrastructure, environmental conditions, inventory of existing CSRM projects and associated project performance during Hurricane Sandy, the 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.

Only the Stamford Hurricane Protection Barrier in Stamford, CT 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.

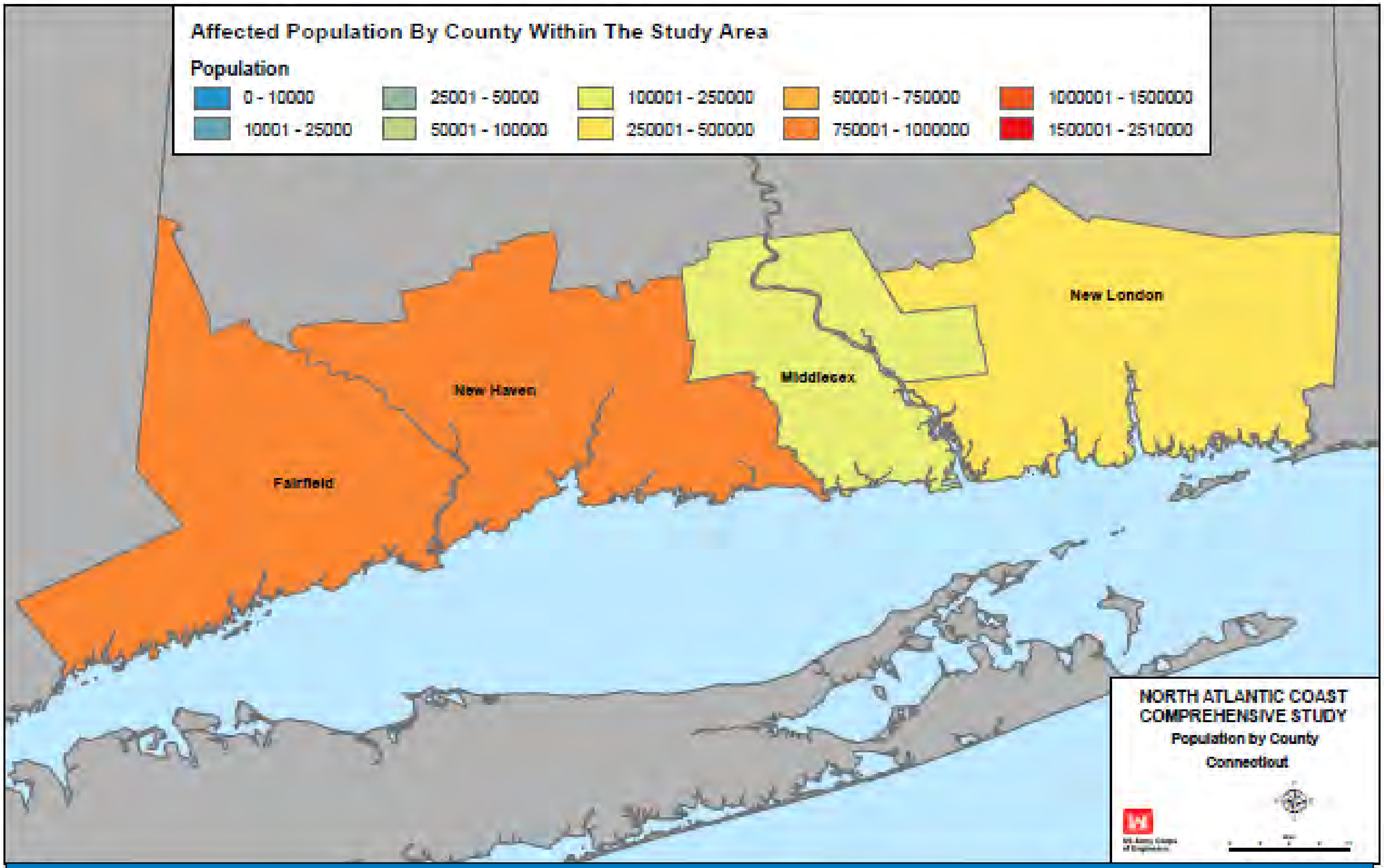


Figure 2. Affected Population by Hurricane Sandy for the State of Connecticut (2010, U.S. Census Data)

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

County	Population
Fairfield	916,829
New Haven	862,477
Middlesex	165,676
New London	274,055
Total Population Affected	**2,219,037**

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.

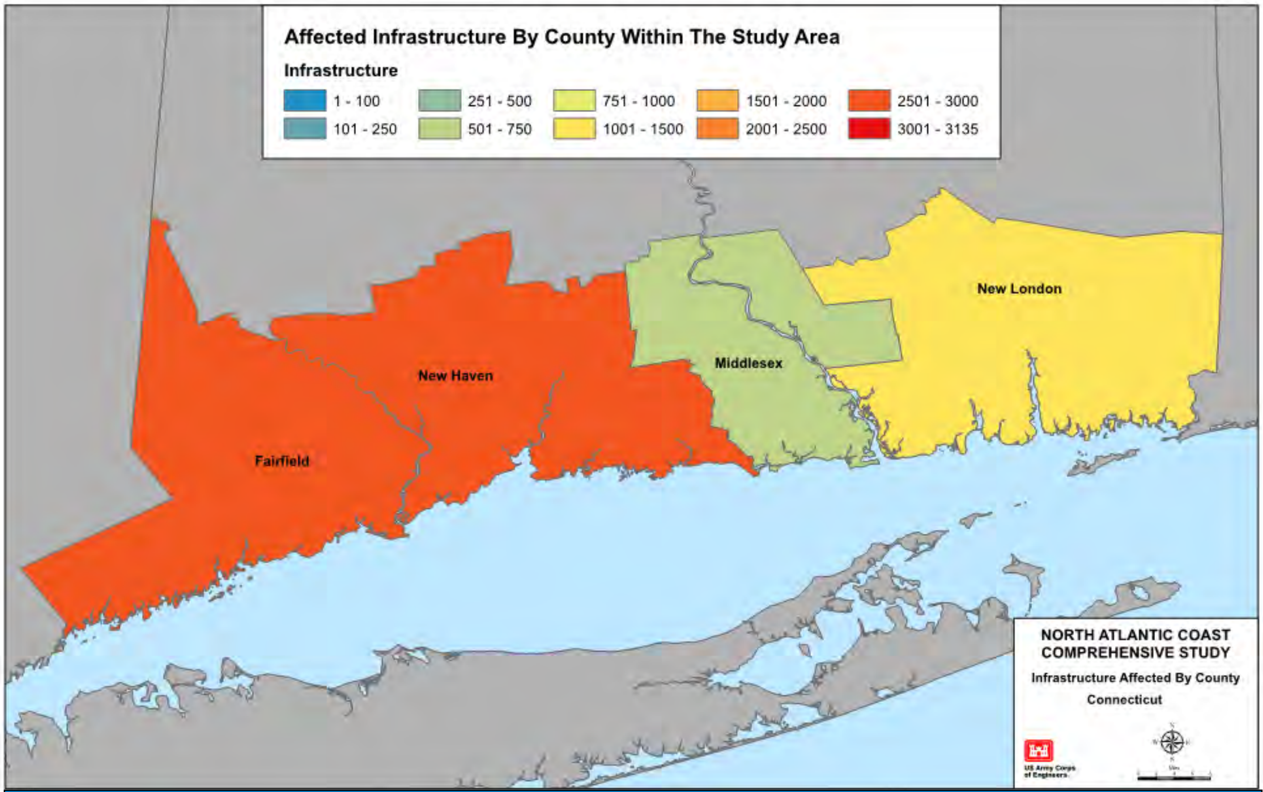


Figure 3. Affected Infrastructure by Hurricane Sandy for the State of Connecticut

Table 2. Affected Infrastructure Elements by Hurricane Sandy

County	Infrastructure
Fairfield	2,560
Middlesex	723
New Haven	2,637
New London	1,252
Total Infrastructure Affected	**7,172**

A detailed discussion of the environmental and cultural resources existing condition 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 or constructed.

USACE has identified 37 Federal projects in Connecticut that are included in the post-Sandy landscape condition; 13 of which are CSRM projects and 24 are navigation projects (NAV) (Figure 4). A complete list of existing USACE projects within the entire study area is presented in Appendix C – Planning Analyses.

The post-Sandy landscape condition also includes active (at the time of the landfall of Hurricane Sandy) state and local communities' CSRM projects in the State of Connecticut. Some of these projects may have been damaged during Hurricane Sandy. USACE understands that Connecticut 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 current lack of resources to commence new CSRM efforts at this time, USACE has made the assumption that the states' post-Sandy landscape conditions will be the pre-Sandy condition. Connecticut was queried with regard to the statement's accuracy in a May 23, 2013 letter. The Connecticut Office of Long Island Sound Programs (OLISP) indicated via email correspondence (June 26, 2013) that the agency agrees with the statement's accuracy. They further stated that they do not have any sizable projects that they are looking to accomplish other than some beach nourishment projects which would provide additional resilience and protection.

Connecticut OLISP provided the USACE information regarding 97 CSRM projects that were a mix of bulkheads, seawalls, retaining walls, dikes and revetments (Figure 5). These are strictly state owned projects. No information was available regarding the specific level of protection afforded by these projects.

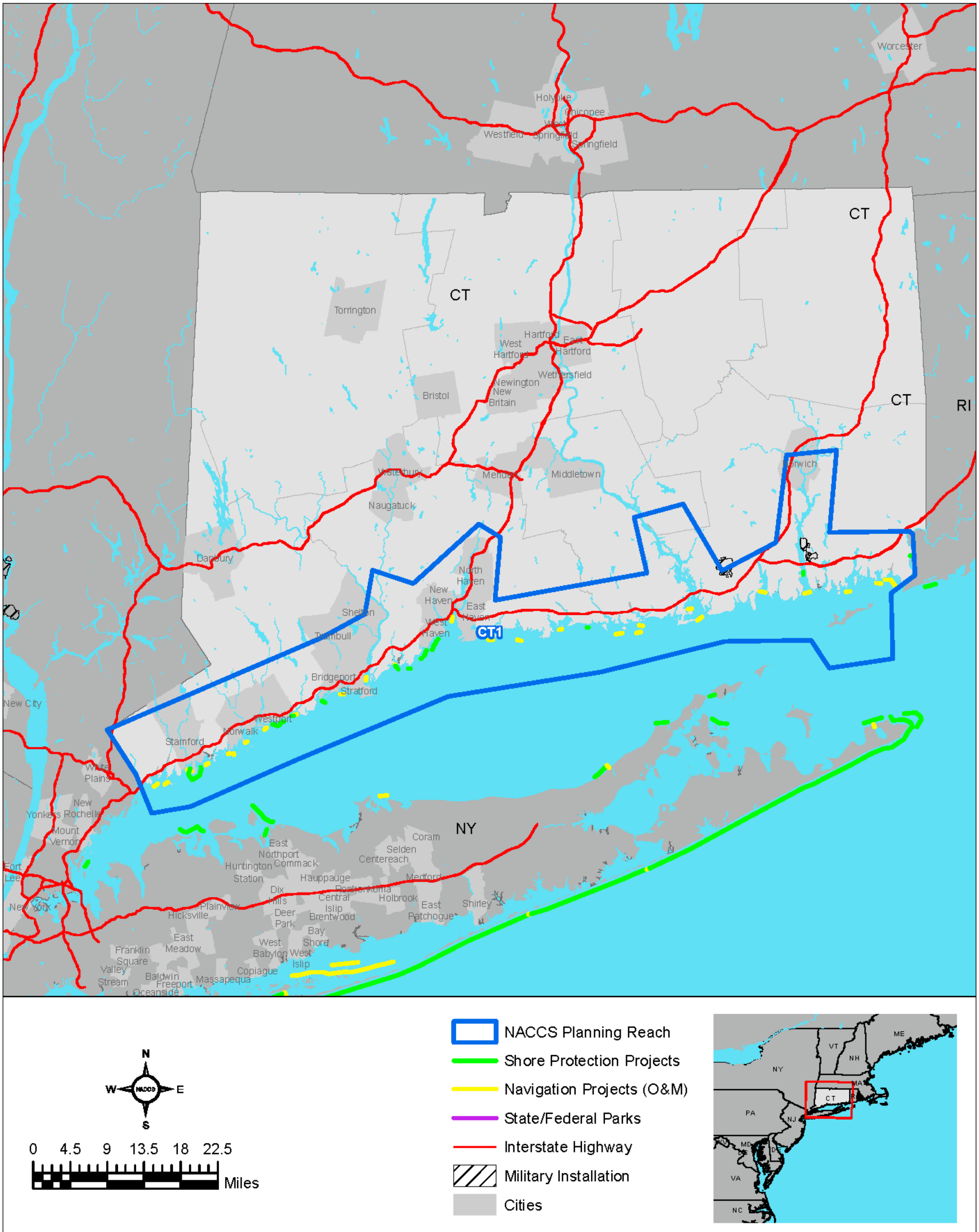


Figure 4. Federal Projects included in the Post-Sandy Landscape Condition

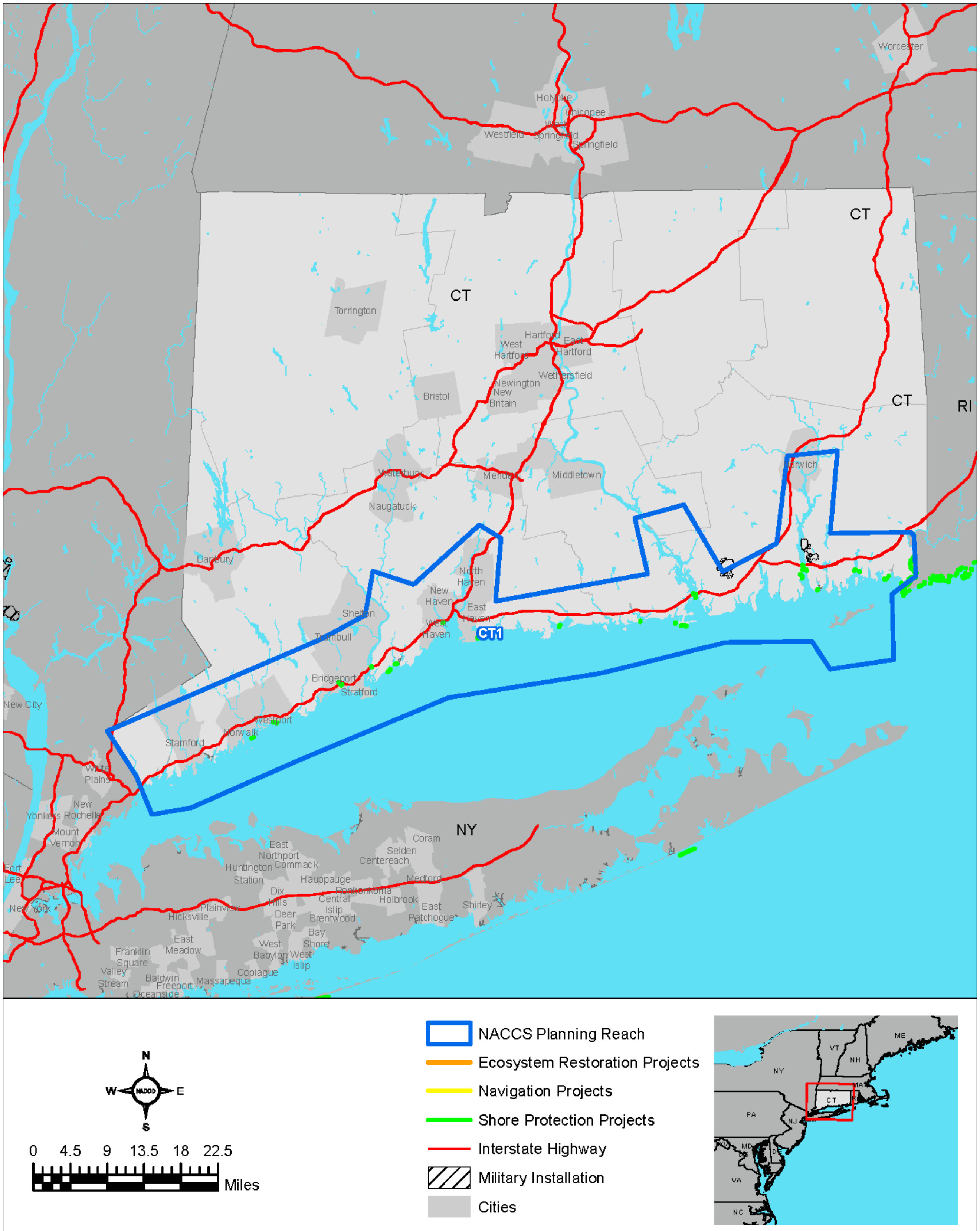


Figure 5. State Projects Included in the Post-Sandy Landscape Condition

Sea Level Change

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

The State of Connecticut has not officially adopted any SLC scenario. One of the initial tasks of the newly established Connecticut Institute for Resilience and Climate Adaptation is to develop future sea level estimates that are applicable to Long Island Sound.

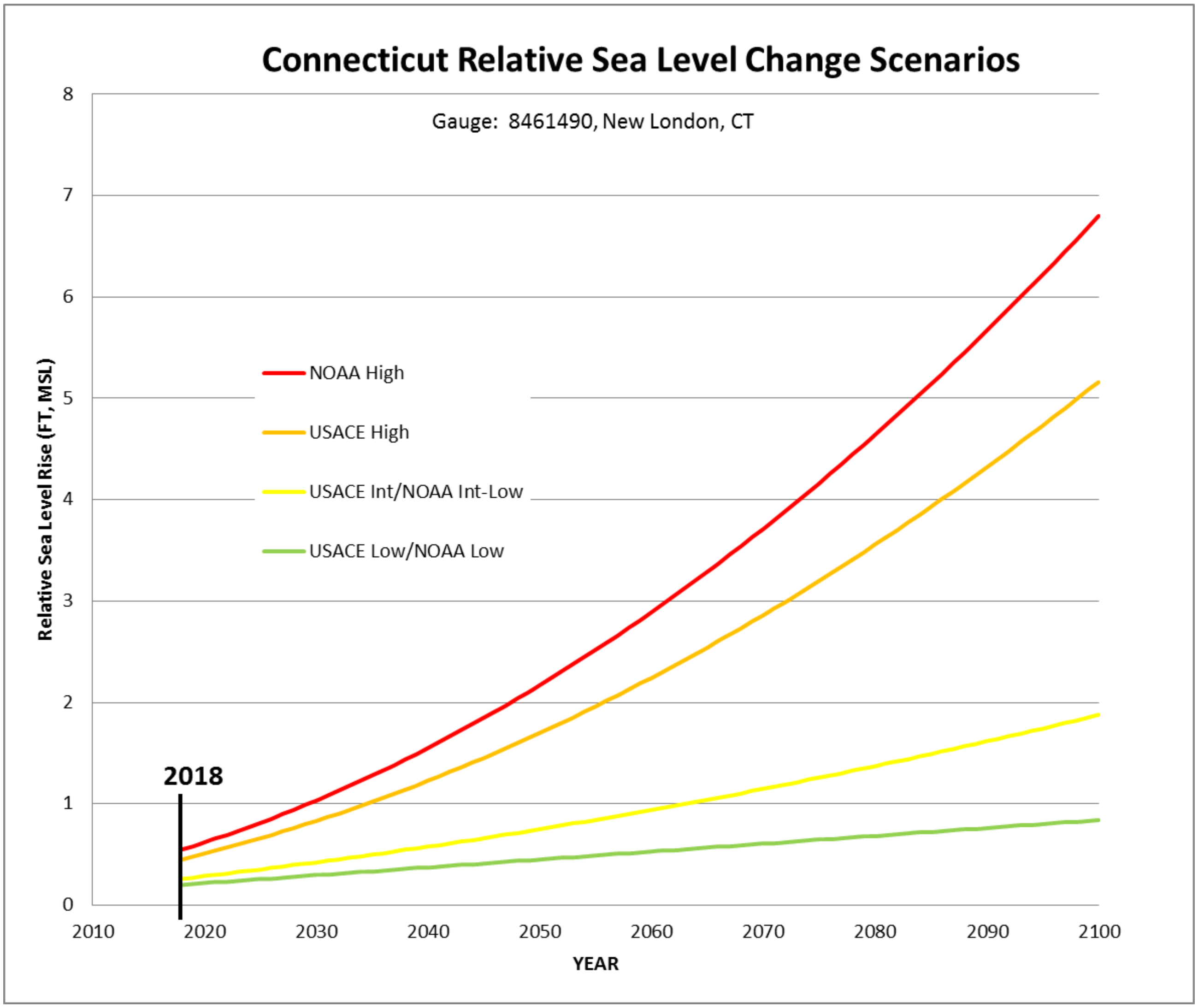


Figure 6. Relative Sea Level Change for Connecticut for USACE and NOAA Scenarios.

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

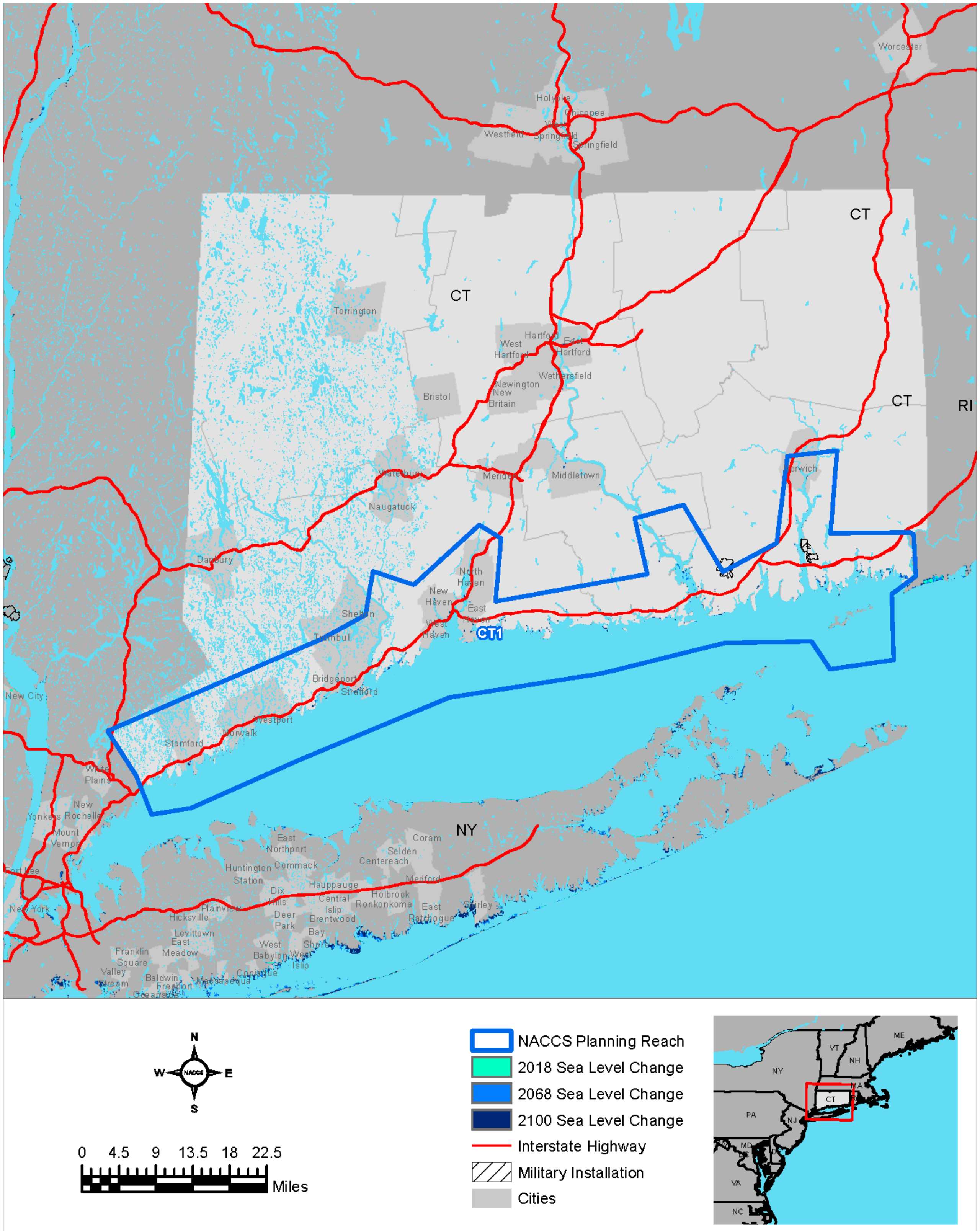


Figure 7. USACE High Scenario Future Mean Sea Level Mapping for the State of Connecticut

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 CT. Changes to environmental and cultural resources and social vulnerability characteristics will not be considered as part of the overall forecasted exposure index assessment. Discussions of likely future impacts with respect to SLC on environmental and cultural resources will be considered in the Environmental and Cultural Resources Conditions Report. Additional information related to the forecasted population and development density is included in Appendix C – Planning Analyses.

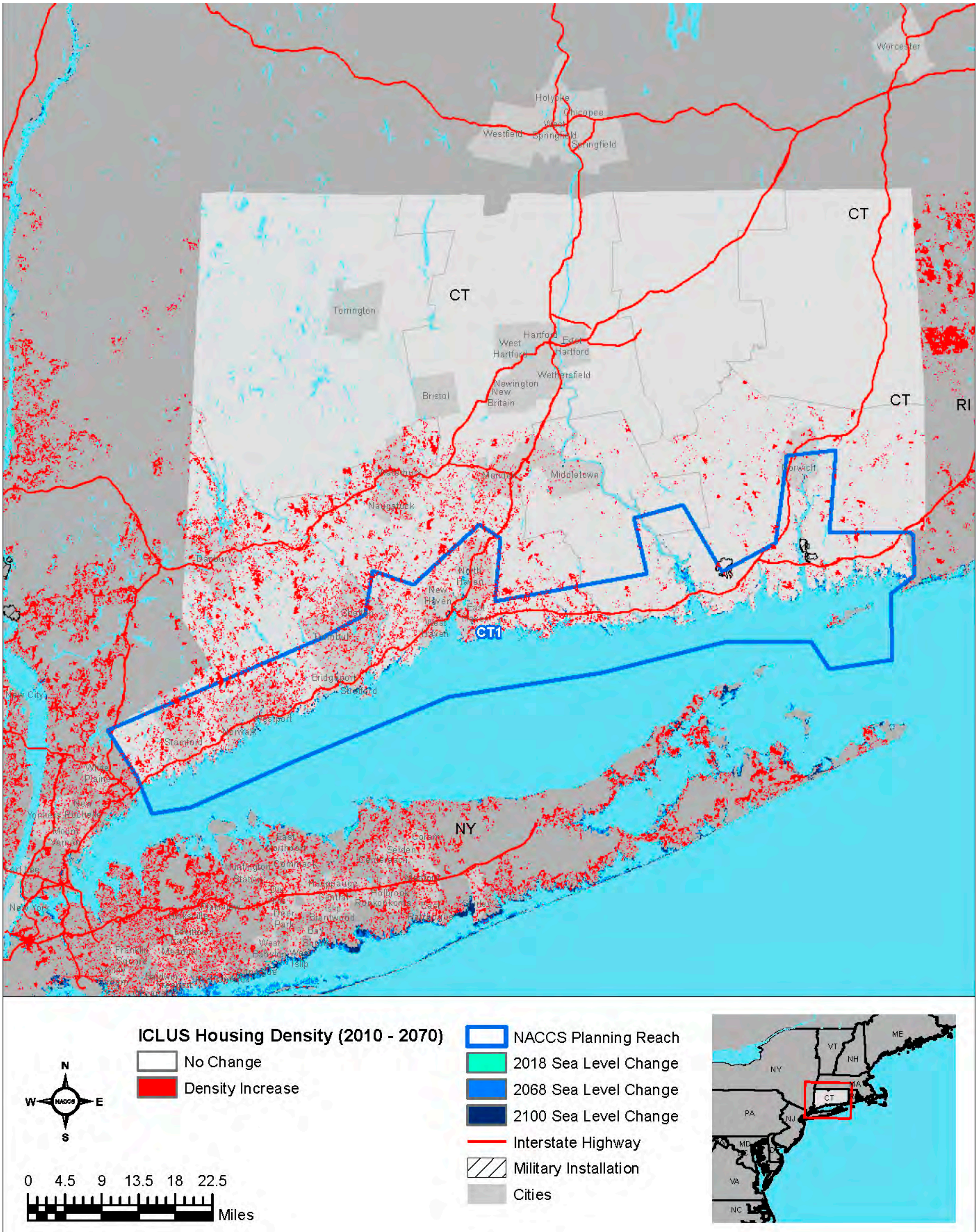


Figure 8. USACE High Scenario Future Mean Sea Level Inundation and Forecasted Residential Development Density Increase for the State of Connecticut

Extreme Water Levels

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

Figure 10 presents the approximate 1 percent floodplain plus 3 feet for the same area to illustrate areas exposed to projected inundation levels, which are closely aligned with the USACE High scenario for projected SLC by year 2068. Areas between the Category 4 and 1 percent plus 3 feet 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 flooding in any given year). The purpose of the 10 percent floodplain is to consider the possibility of surge reduction related to some natural and nature-based features (NNBF) management measures such as wetlands, living shorelines, and reefs.

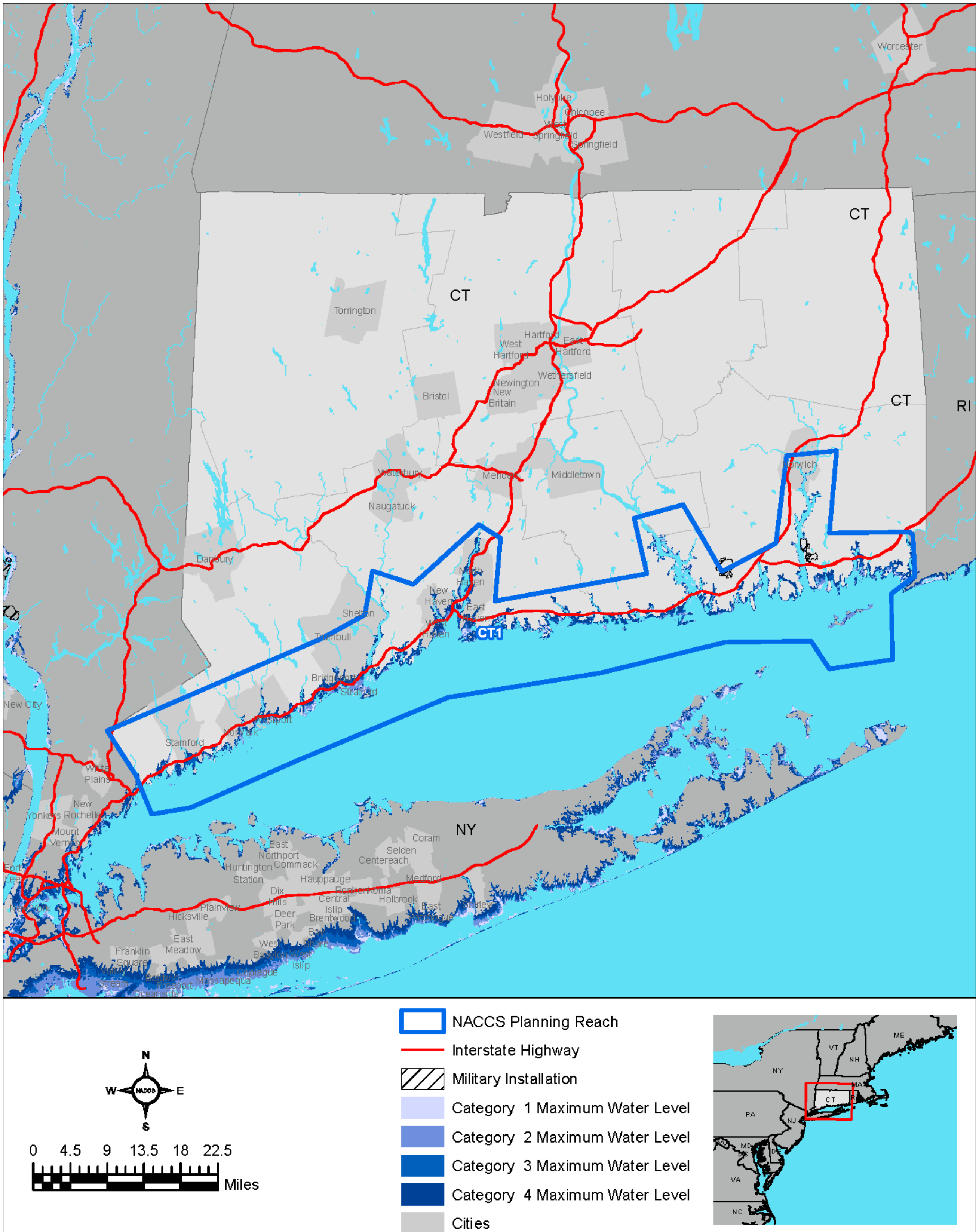


Figure 9. Impacted Area Category 1 - 4 Water Levels for the State of Connecticut

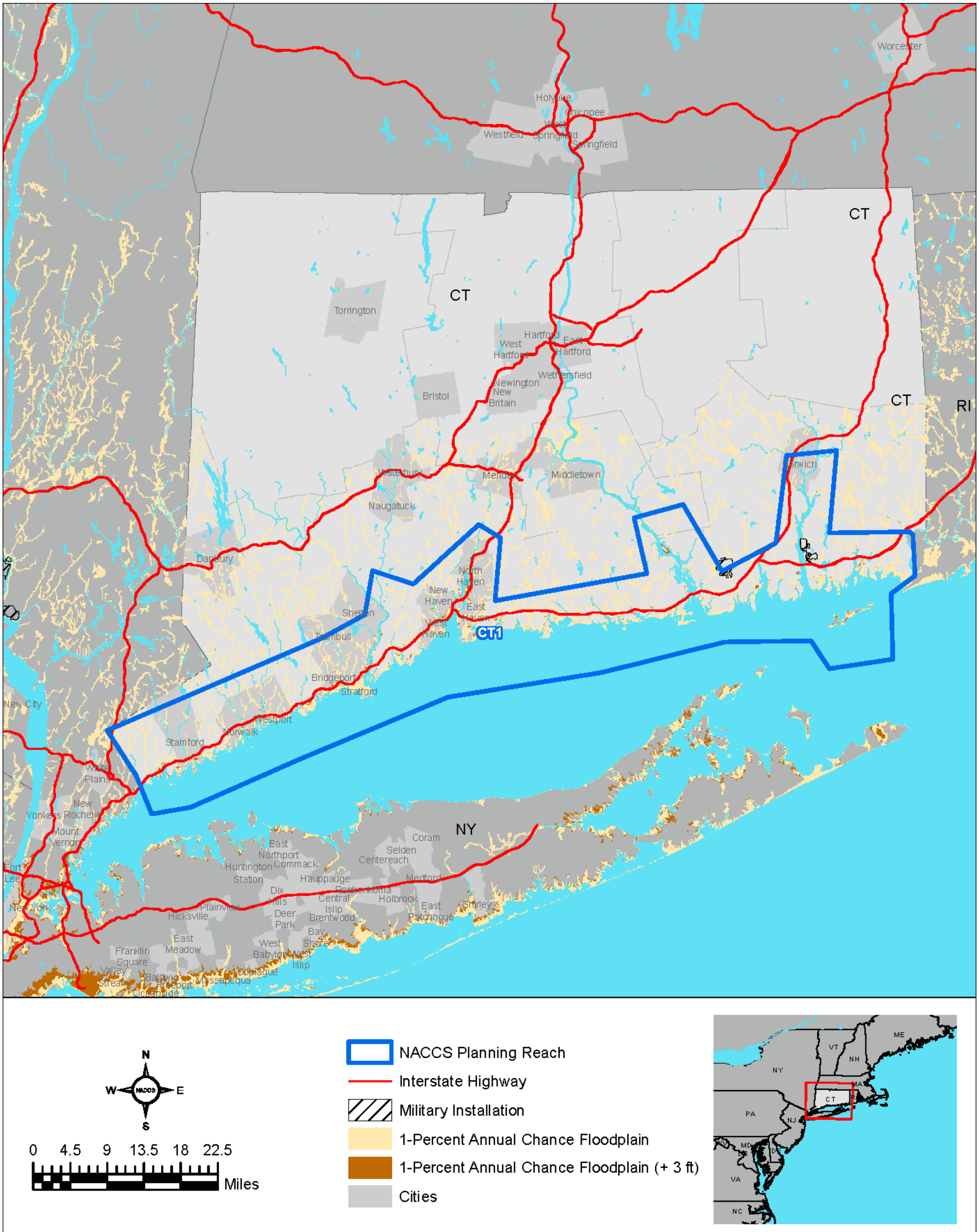


Figure 10. Impacted Area 1 Percent + 3 feet Water Surface for the State of Connecticut

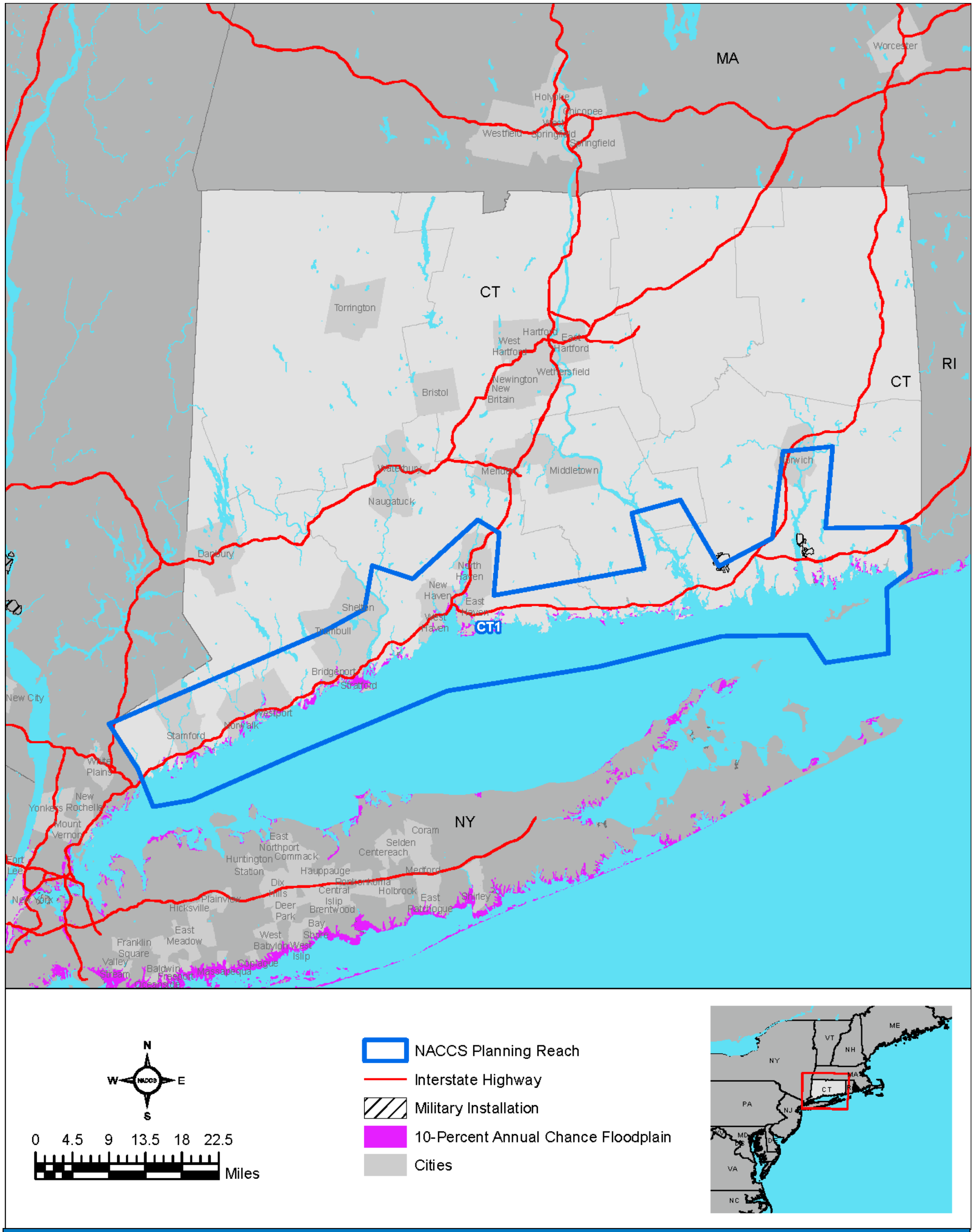


Figure 11. Impacted Area 10 Percent Water Surface for the State of Connecticut

Environmental Resources

Some of Connecticut's beach and dune habitat is adjacent to highly developed areas. Beaches have a limited distribution and position along the coast in Connecticut. However, beaches and vegetated dunes provide an important buffer between coastal waters and infrastructure. Sea level and climate change can have significant impacts to this buffer if nothing is done to protect this habitat.

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 SLC. 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. In many areas this will eliminate or reduce habitat for beach and dune dependent species such as horseshoe crabs, and nesting habitat for birds such as piping plovers, terns, and foraging habitat of small beach organisms found within or on the sandy substrate or beach wrack for birds.

Coastal wetlands have the potential to adapt and keep pace with SLC 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. SLC 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. Coastal wetlands adjacent to human development or seawalls that block natural wetland migration paths will be inundated. In addition, these wetlands will generally be unable to accrete at a pace greater or equal to relative SLC, so a change in sea level will cause a net loss of marsh acreage. Plants and wildlife dependent on this habitat will be impacted. The supportive nursery functions of these coastal marshes for ecologically and recreationally important finfish will be impaired by the changes in condition and availability of this habitat.

Freshwater tidal marshes further upstream along major rivers such as the Connecticut River will be lost or converted. This will occur when increases in salinity in the estuaries move upstream and the lack of suitable adjoining areas to accommodate upland migration is experienced. The alteration in the amplitude and timing of annual spring freshets and lower summer flows will also reduce the extent and complexity of these highly productive interfaces between land and water and the ecological functions these marshes provide (storm buffering, flood storage, fish nurseries, water filtering, and biodiversity).

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 as a result of the effects of SLC.

Climate change is expected to have an impact on Connecticut's major commercially grown shellfish species (i.e., Eastern oyster and hard clam), primarily from increased water temperatures. Although these species are predicted to adapt to the increased temperatures and even experience faster growth, the increased water temperature could also lead to increased disease prevalence. It is also predicted that in the coming decades, ocean acidification, due primarily from increased carbon dioxide, could negatively affect shellfish larvae and juveniles jeopardizing future populations.

The abundance and distribution of cold water coastal species is expected to decline and warm water species to increase with increased water temperatures. Coldwater freshwater species already in decline include brook trout, brown trout and slimy sculpin; saltwater species in decline include winter flounder, American lobster, and longhorn sculpin, and anadromous species in decline are the rainbow smelt and tomcod.

Offshore islands in Long Island Sound are unique landscape features that face the same threats as other coastal and estuarine aquatic habitats. The loss or inundation of these islands as a result of SLC would have negative implications for the breeding success of shorebirds, haul out sites for marine mammals, and important stopover sites for migratory species along the Atlantic Flyway to feed and rest during their annual migrations.

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.

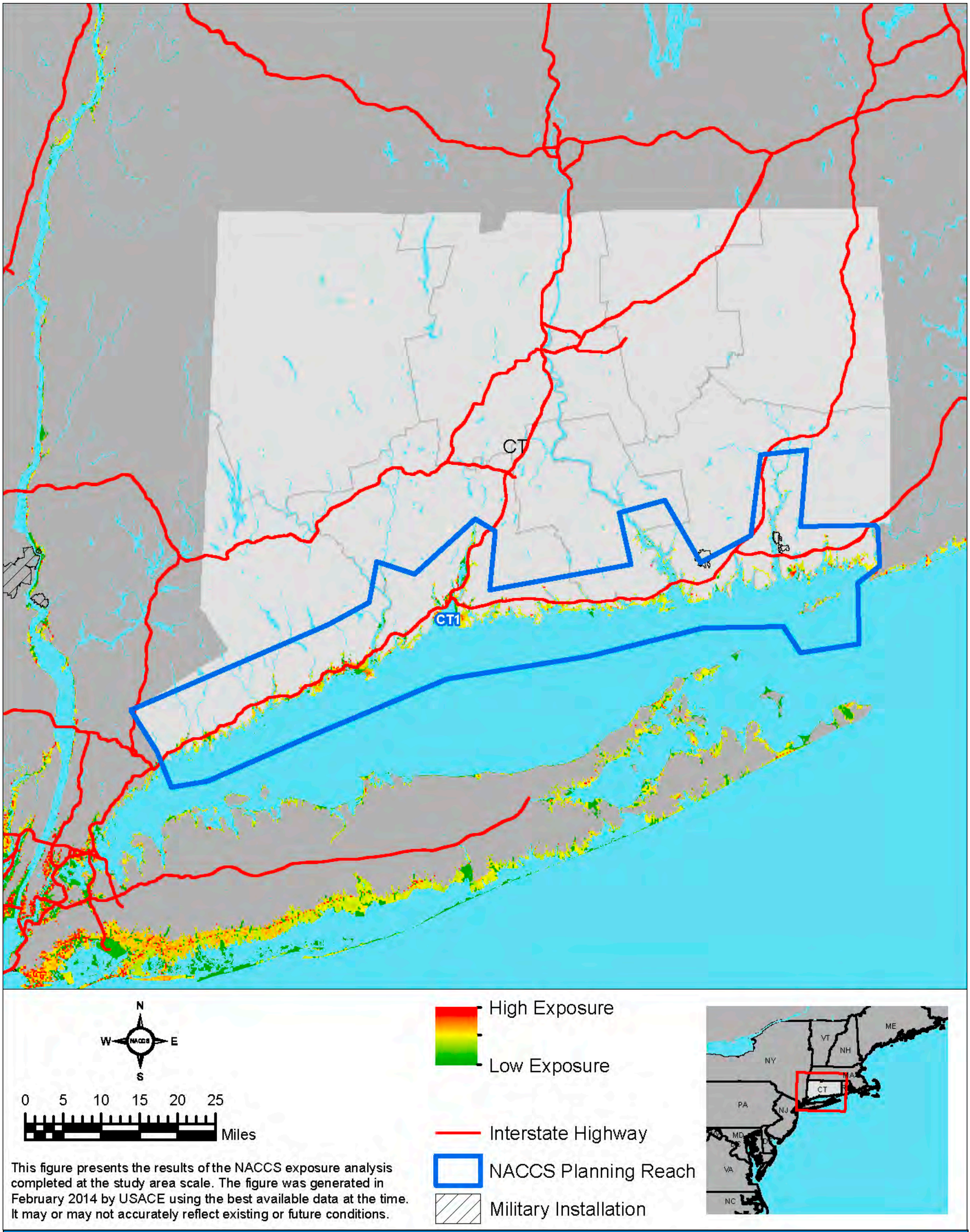


Figure 12. Population and Infrastructure Exposure Index for the State of Connecticut

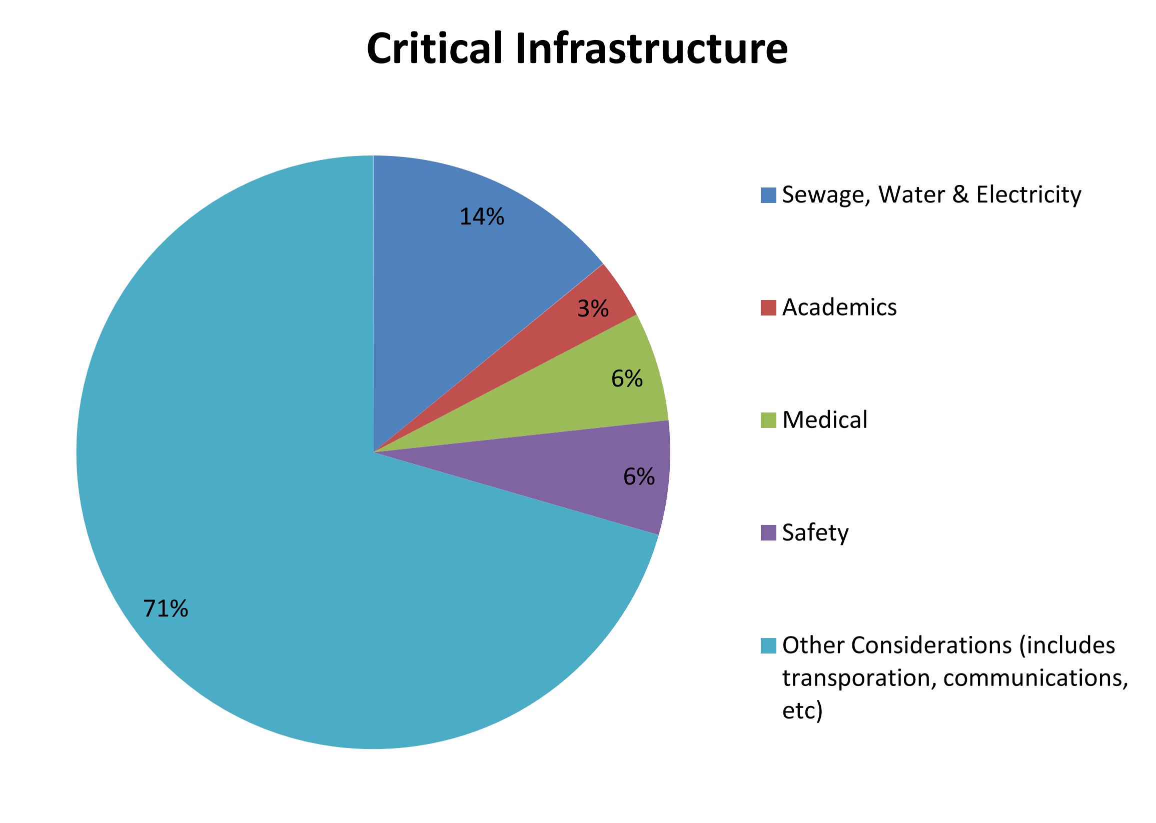


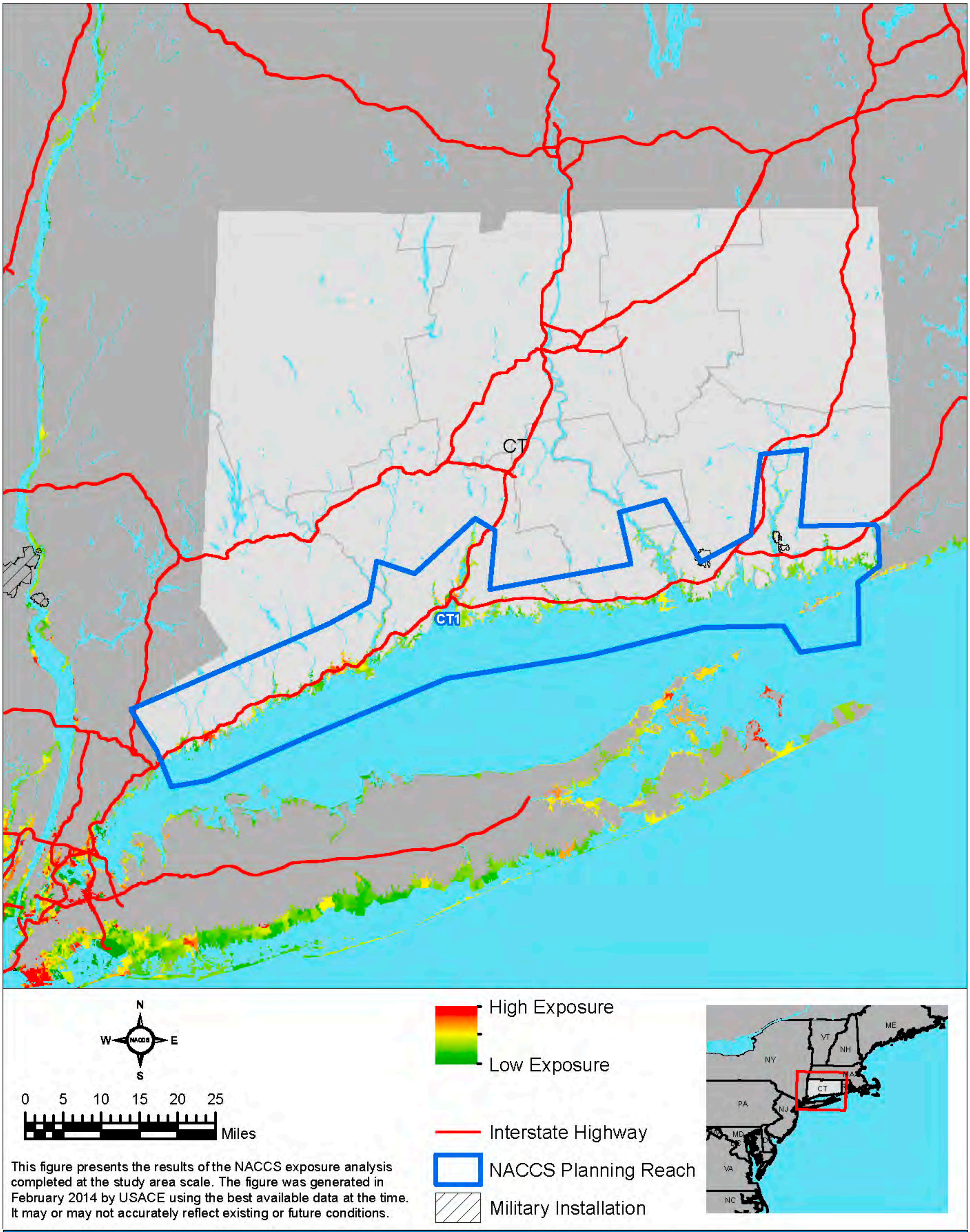
Figure 13. Vulnerable Infrastructure Elements Within the Category 4 MOM Inundation Area in the State of Connecticut.

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

Social Vulnerability Characterization Index

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

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



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

Figure 14. Social Vulnerability Index for the State of Connecticut

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 Connecticut.

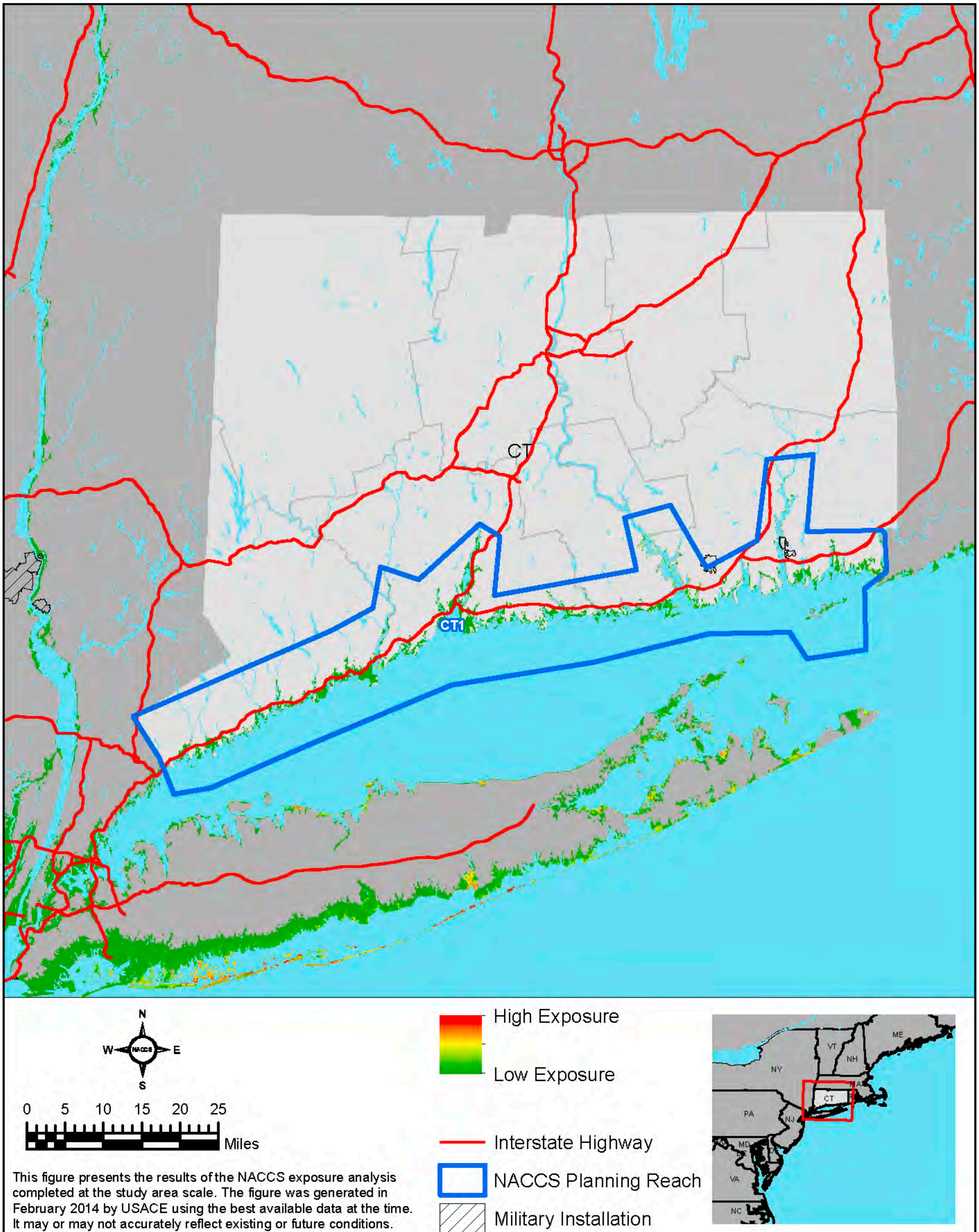
Reach: CT 1

Based on the social vulnerability analysis, 27 areas were identified within this reach as areas with relatively high social vulnerability. These areas were located within census tracts 703, 706, 445, 709, 710, 711, 712, 713, 714, 716, 720, 215, 218.02, 736, 221, 222, 738, 739, and 740 (Fairfield County, CT), and 1423, 1424, 1425, 1402, 1405, 1406, 1404, and 1408 (New Haven County, CT). The areas in census tracts 703, 709, 710, 711, 712, 713, 714, 716, 720, 215, 218.02, 736, 221, 222, 738, 739, 1423, 1424, 1425, and 1404 were identified as vulnerable mainly due to a considerable percent of the population being non-English speakers. The areas in census tracts 703, 709, 712, 716, and 739 also have a large percent of the population below the poverty level. The areas in tracts 706, 740, 1402, and 1406 have a large percent of the population below the poverty level as well. The areas identified in tracts 703, 712, 714, 716, 738, 1425, 1402, 1405, and 1406 have large portion of the population who are under the age of 5. The areas in tracts 706, 445, 218.02, 221, 740, 1402, and 1408 have a large percent of the population over 65 years old.

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



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

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

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

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

Reach: CT1

This analysis resulted in approximately 950 acres of High (orange) Environmental and Cultural Resources Exposure index areas in planning reach CT1.

Bluff Point, Goshen Cove, Griswold Point, Hammonasset Point, Long Beach, Lynde Point, Milford Point, Morse Park, Norwalk Islands, and Ram Island form roughly 930 acres of CBRS in this environmental and cultural resources exposure index area. The Stewart B. McKinney National Wildlife Refuge provides nearly 1,100 acres of USFWS protected area in these exposure areas. Slightly over 49 acres of habitat is available for piping plovers and red knots habitat. Cochenoe Island and Ram Island provide colonial nesting waterbird habitat in this exposure index area. About 6 acres of park land, with slightly more State Park than city/county park, are located within this high environmental and cultural resources exposure index area.

More shoreline is fine-grained mud and organics (approximately 24 acres) compared to the coarse grained sands and gravels (approximately 14 acres) shoreline in this high environmental and cultural resources exposure index area. Over 840 acres of tidal emergent marsh, one acre of seagrass, and one acre of freshwater emergent marsh can be found in this environmental and cultural resources exposure index area.

Within the state of Connecticut, two historic sites are within Reach CT1 environmental and cultural resources exposure index area, the Lynde Point Lighthouse and Norwalk Island Lighthouse. This planning reach is the coastal areas of the state along Long Island Sound. Additionally, there are roughly 950 acres of cultural resources buffer in the high environmental and cultural resources exposure index area in planning reach CT1.

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 Connecticut.

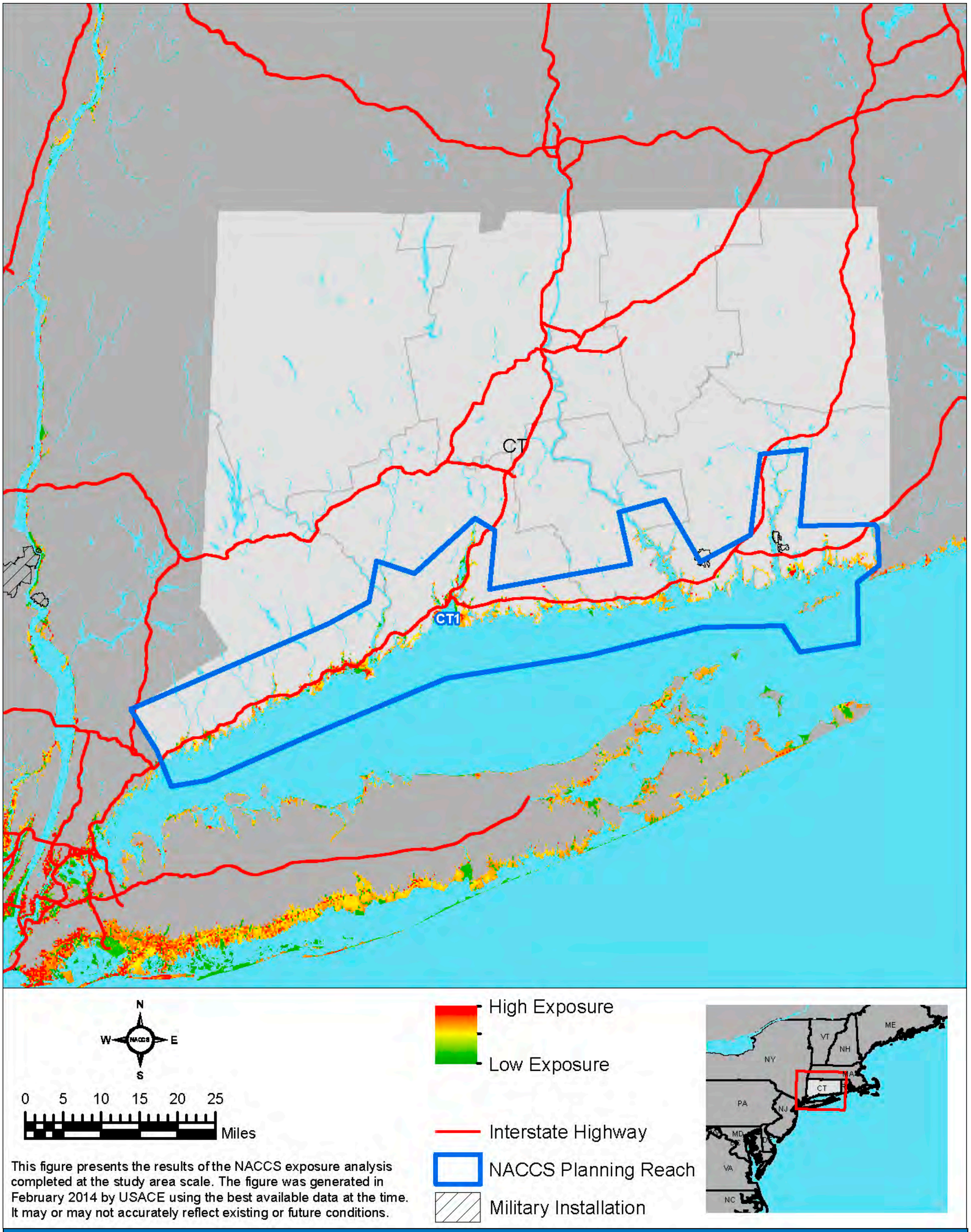


Figure 16. Composite Exposure Index for the State of Connecticut

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 Connecticut.

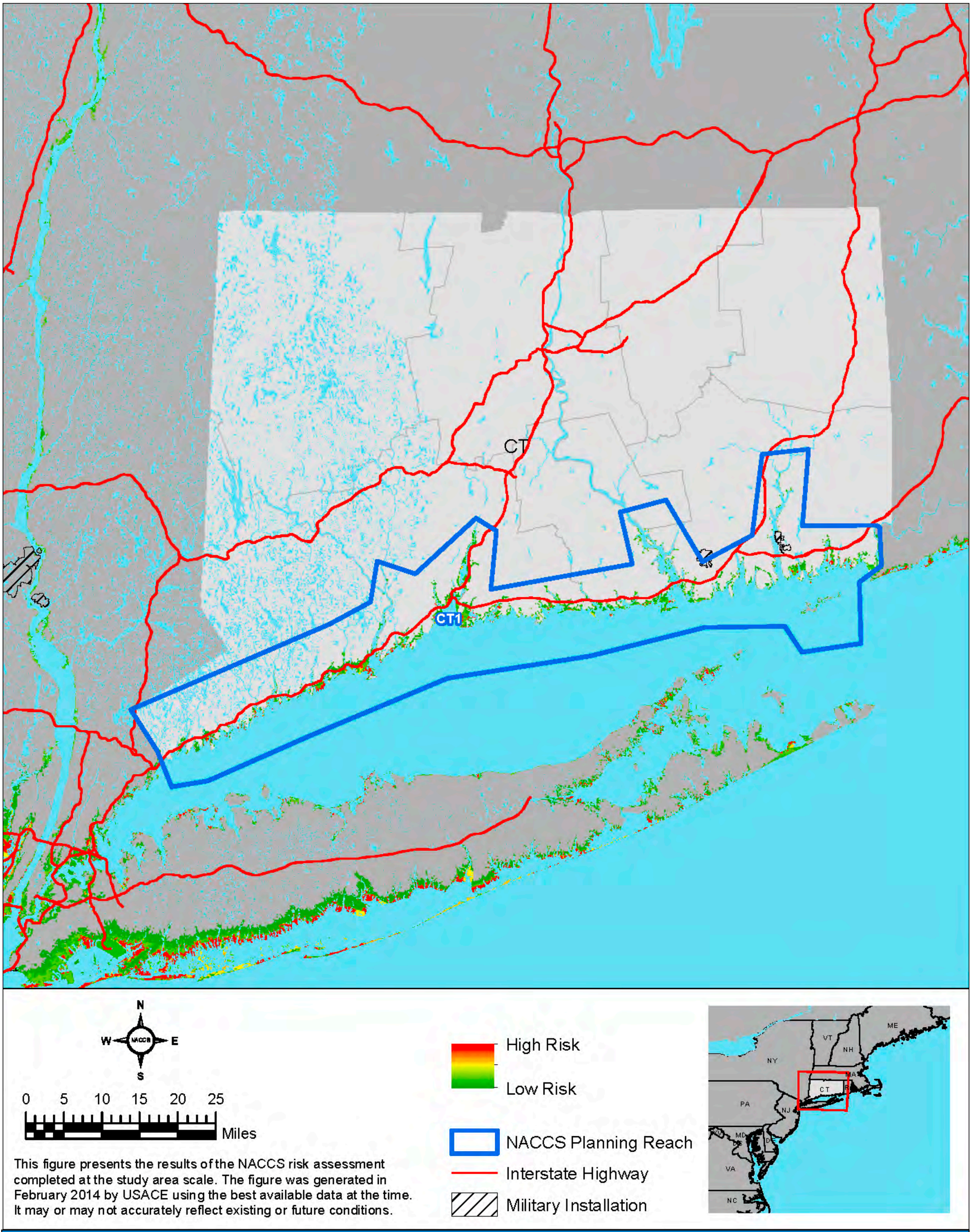


Figure 17. Risk Assessment for the State of Connecticut

IV.3 NACCS Risk Areas Identification

Applying the risk assessment to the State of Connecticut identified 15 areas for further analysis. These locations are identified on Figure 18 and are described in more detail below.

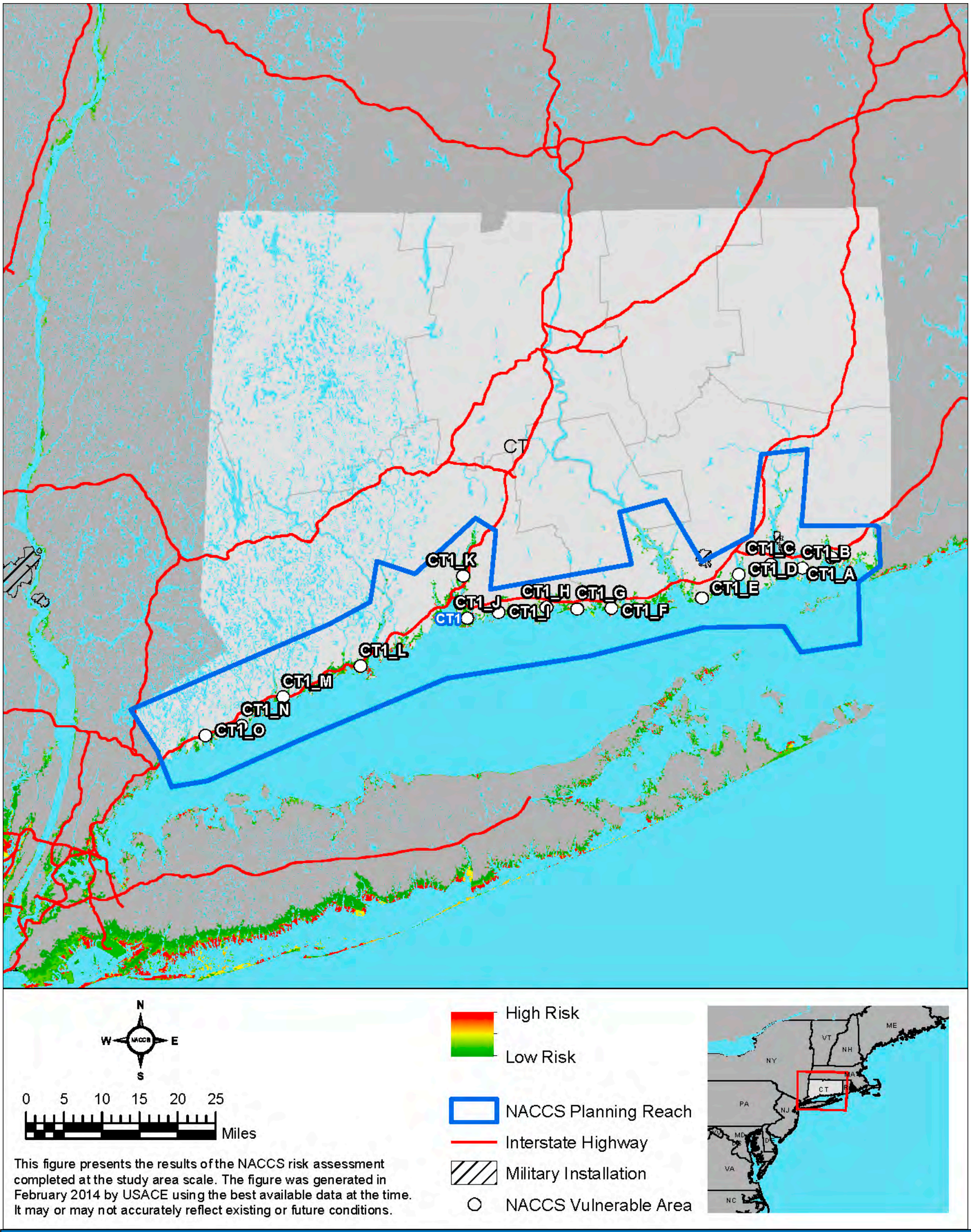


Figure 18. Reach CT1 Risk Areas

Reach: CT1

The shoreline of Connecticut Reach 1 (Figure 18) is classified as a mixture of wetlands, urban areas, and some beaches and estuaries. Half of the coastline (east of New Haven, CT), tends to be less developed than the western half of the state where more of the coastal cities are located. The reach contains several USACE coastal flood risk management projects, and an extensive 1 percent floodplain.

Fifteen areas of high exposure were identified in this reach and are described in this section. Many of the identified areas center on fairly dense urban areas of the cities of New Haven, West Haven, Milford, Stratford, Bridgeport, Norwalk and Stamford (site of an existing hurricane barrier). There are also less populated exposure areas located in the towns of Stonington, Groton, Old Saybrook, Westbrook, Clinton, Guilford and Branford.

CT1_A: Stonington to Mystic

This area of high exposure encompasses the waterfront area of the town of Stonington, including Stonington Harbor, east to the village of Mystic and its harbor. There are several pockets of dense residential development along this portion of the coast that are vulnerable to storm surge inundation. The two harbors also include a fair amount of commercial development and boating infrastructure. Municipal infrastructure is also of concern including some major roads.

CT1_B: Groton

This area of high exposure involves the coastal area consists of the between the developed sections in Groton called Noank, Groton Long Point and the Baker's Cove area. Again, pocketes of residential development are extremely vulnerable here. The Groton Airport is also within this exposure area.

CT1_C: New London

This area of high exposure consists of the inundated industrial and commercial area around Shaw Cove in New London. There is a small hurricane barrier here but it only protects up to a Category 1 storm surge. Impacts would include damage to commerical, industrial, bething areas, and city services (wastewater treatement) as well as some residential structures in the downton area.

CT1_D: Waterfor/East Lyme

Niantic Bay includes significant commercial, residential, and port development in the Niantic and Millstone sections of town. Route 156 connects the two towns in this area of high exposure. The Millstone Nuclear Power Plant, the state's only nuclear power generating facility, is located on the east side of the bay and is adjacent to the area of high exposure.

CT1_E: Old Lyme

Between Hatchett Point and Griswold Point in Old Lyme there are two pockets of residential development that have been identified as being extremely vulnerable to a surge event. Hundreds of residential properties are in this area of high exposure including all of the municipal and state infrastructure (Route 156) associated with them.

CT1_F: Old Saybrook to Madison

This low lying area of high exposure is fairly large and encompasses the coastal portions of Old Saybrook, Westbrook, Clinton, and the Hammonasset area of Madison. The area of high exposure includes large numbers (thousands) of residential and commerical property including the downtown centers of Old Saybrook, Westbrook and Clinton. Fairly significant commerical/recreational ports exist in Westbrook and Clinton. Routes 1, 154 and the Hammonasset Connector are important infrastructure in this area of high exposure that may be impacted.

CT1_G: Madison

This area of high exposure runs from the Hammonsasset area of Madison to the East River. It includes significant pockets of residential development and its supporting infrastructure (local roads and utilities).

CT1_H: Guilford

Between downtown Guilford and the coast there are pockets of residential and commercial development, including their supporting municipal infrastructure, that were determined to be significant enough to be listed as an area of high exposure. The area includes Guilford Harbor and state roads Route 146 and 1.

CT1_I: Branford

This area of high exposure extends from the Seaview Avenue area of Branford to Lindsey Cove. It includes several densley populated areas as far inland as Route 1 as well as Branford Harbor and the downtown area. Many commercial facilities fall within this area including several recreational boating marinas. The town's wastewater treatment facilities are in the area of high exposure as well. Several important local and state roads (e.g. Route 146 and 1) are included in the area of high exposure.

CT1_J: East Haven

This area of high exposure encompasses most of the coastal zone of East Haven from the Farm River on the east side to Morris Cove in New Haven Harbor. The area reaches inland as far as Route 1 and includes possibly thousands of residential properties, some fairly significant commercial properties (Proto Drive and Commerce Street), the New Haven Airport, and much municipal property and infrastructure.

CT1_K: New Haven

The area of high exposure identified for this stretch of coastline includes the cities of New Haven and West Haven. This area of high exposure is the first of several densely populated and developed portions of the coastline in Connecticut that would be subject to very significant damage if a Sany-like event were to hit. This area begins at the Morris Cove on the east side of New Haven Harbor and terminates at the Prospect Beach area in West Haven. The area extends as far inland as Sackett Point Road along the Quinnipiac River. There are several thousand residential, commercial, industrial, and municipal structures located in this area of high exposure. New Haven Harbor is surrounded with many petroleum and bulk cargo based industries that rely heavily on the port for moving those products. The area includes two major interstate highways, Routes 95 and 91, that are critical to the region for moving traffic. There are many important rail lines that run through this area as well. There are several wastewater treatment facilites located here that are subject to inundatioin.

CT1_L: Milford – Fairfield

This area of high exposure is the largest stretch of contiguous impacted coastline in the Connecticut reach. It begins at the Point Beach area of Milford and ends at Southport village in Fairfield. It includes the cities of Milford, Stratford, Bridgeport, and Fairfield. All of these communities were hard hit during

Hurricane Sandy. The area of high exposure extends inland beyond the Route 95 corridor and includes many state and local roaways. Major ports in the area include Milford Harbor, Stratford Harbor, and Bridgeport Harbor. There are thousands of residential, commercial, industrial, and municipal structures located in this area of high exposure. Bridgeport Harbor is surrounded with many petroleum and bulk cargo based industries that rely heavily on the port for moving those products. There are several wastewater treatment facilites located here that are subject to inundatioin as well as state and local parks, Sikorsky Airport in Stratford, and a major rail line that connects the New York City area to the northeast region.

CT1_M: Westport - Norwalk

This area of high exposure includes the coast line fom the Sherwook Island Park area of Westport to the west side of Norwalk Harbor, including the wastewater treatment facility at Manresa Island. The area extends up the Saugatuck River in Westport just past Route 1 and up the Norwalk River in Norwalk to Cross Street. Again, these communities were hard hit during Hurricane Sandy. The area of high exposure extends inland beyond the Route 95 corridor and includes many state and local roaways. Norwalk Harbor is a major port in the area. There are hundreds if not thousands of residential, commercial and municipal structures located in this area of high exposure. Norwalk Harbor includes some industry but not nearly at the level as the two previous areas of high exposure. There are several wastewater treatment facilites located here that are subject to inundatioin as well as a major rail line that connects the New York City area to the northeast region.

CT1_N: Darien

This area of high exposure begins just after Wilson Cove in west Norwalk and ends in Scott Cove in Darien. It encompasses a fairly dense pocket of residential development that extends to Chasmars Pond and includes all of the associated municipal infrastructure.

CT1_O: Stamford-Greenwich

The area of high exposure in this sub-reach begins at Long Neck Point in Darien and extends to Cos Cob Harbor in Greenwich. The area extends into downtown Stamford, past Route 1, as the existing hurricane barrier there only protects up to a Category 2 hurricane storm surge. The area of high exposure extends inland beyond the Route 95 corridor (in some places past Route 1) and includes many state and local roaways. There are hundreds if not thousands of residential, commercial and municipal structures located in this area of high exposure. Stamford Harbor includes some industry but it, as well as Cos Cob, is dominated by marinas. There are several wastewater treatment facilites located here that are subject to inundatioin as well as a major rail line that connects the New York City area to the northeast region.

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 19 presents the location and extent of each shoreline type in the State of Connecticut. Table 3 summarizes the measures' applicability based on shoreline type. It is assumed non-structural measures could be considered in all geographic contexts, subject to further evaluation at a smaller scale.

Additionally, a conceptual analysis of geographic applicability of NNBF measures 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 considered were 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 20 presents the location and extent of NNBF measures based on additional screening criteria. Additional information associated with the methodology and results of the analysis is presented in Appendix C – Planning - Analyses. Table 4 displays a summary of shoreline type by length by reach for the State of Connecticut. The lengths of shoreline type on an individual reach basis are provided on Figure 21.

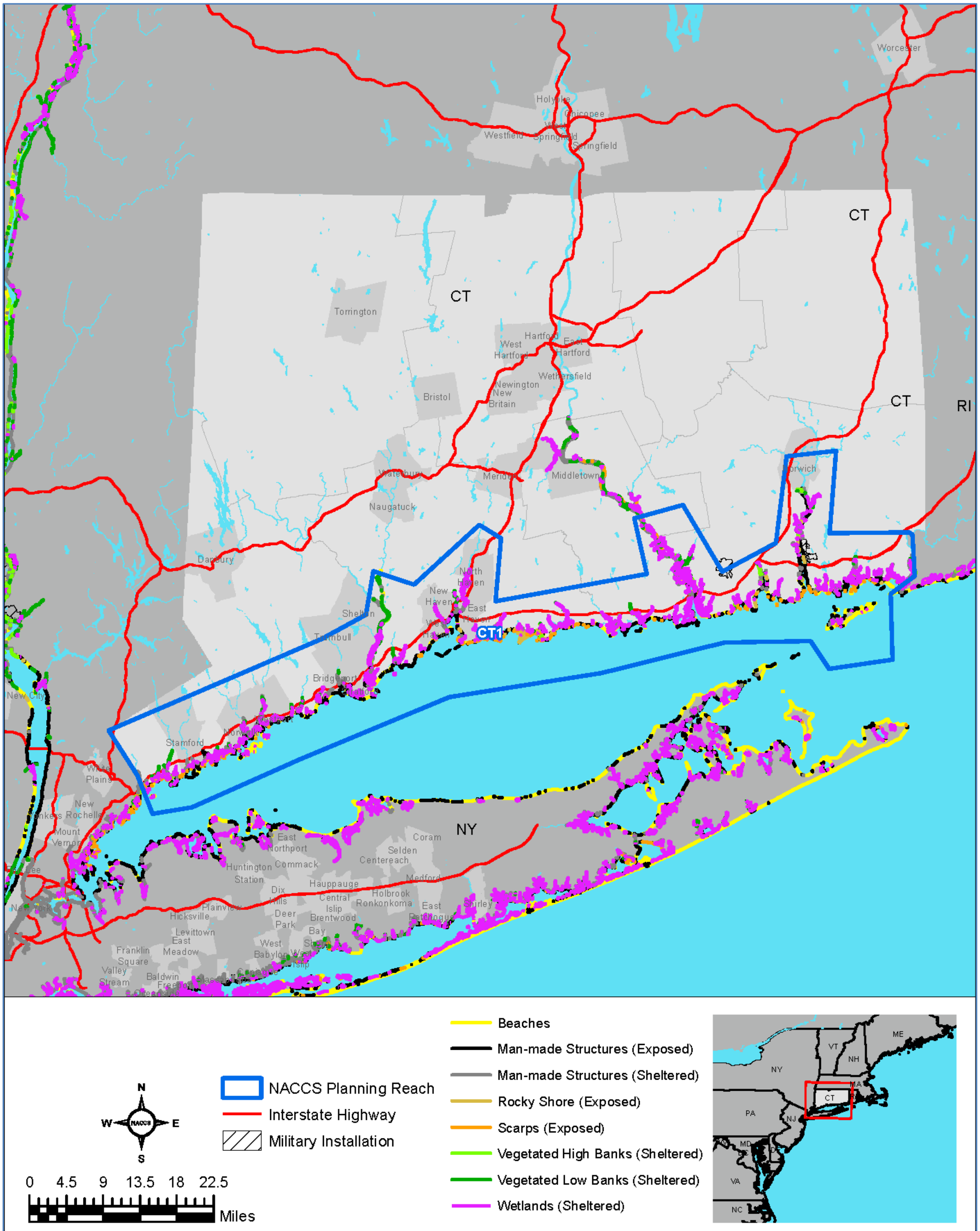


Figure 19. Shoreline Types for the State of Connecticut

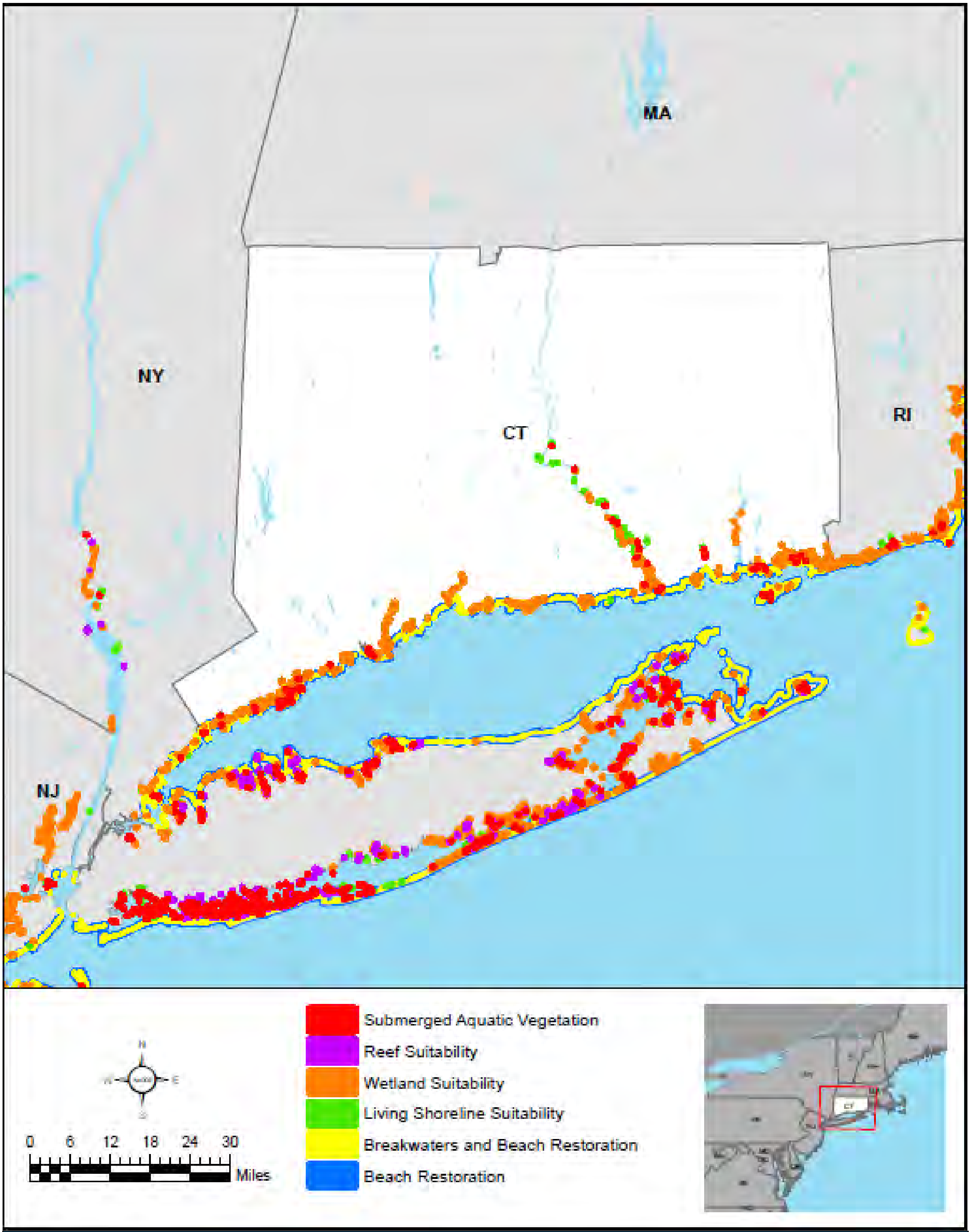


Figure 20. NNBF Measures Screening for the State of Connecticut.

Table 3. Structural and NNBF Measure Applicability by NOAA-Environmental Sensitivity Index (ESI) Shoreline Type

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

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

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

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

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

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

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
CT1_A	8,091	12,171	19,561	29,009	716	1,415	106		71,069
CT1_B	14,710	6,753	12,026	42,805	133	675	921	1,690	79,713
CT1_C	417	8,914	7,094	999	413		687		18,524
CT1_D	2,513	5,321	2,394	1,378			189		11,795
CT1_E	766	276							1,042
CT1_F	35,087	25,639	30,970	320,010		329	1,457	1,742	415,234
CT1_G	4,917	3,991		22,397	162	2,748		50	34,265
CT1_H	505	1,068	1,692	19,423		188			22,876
CT1_I	2,369	7,470	9,348	49,126	2,255	1,142	443	218	72,371
CT1_J	3,336	3,220	3,821	62,020	276	688	960		74,321
CT1_K	12,590	11,634	31,454	165,448	94	408		18,181	239,809
CT1_L	37,157	42,530	63,380	406,350				17,850	567,267
CT1_M	9,579	21,290	50,469	106,547	572	226	2,702	13,939	205,324
CT1_N	2,389	2,394	13,470	13,519	1,987	131		443	34,333
CT1_O	16,652	39,053	36,386	47,714		9,826	87	5,819	155,537
Grand Total	**151,078**	**191,724**	**282,065**	**1,286,745**	**6,608**	**17,776**	**7,552**	**59,932**	**2,003,480**

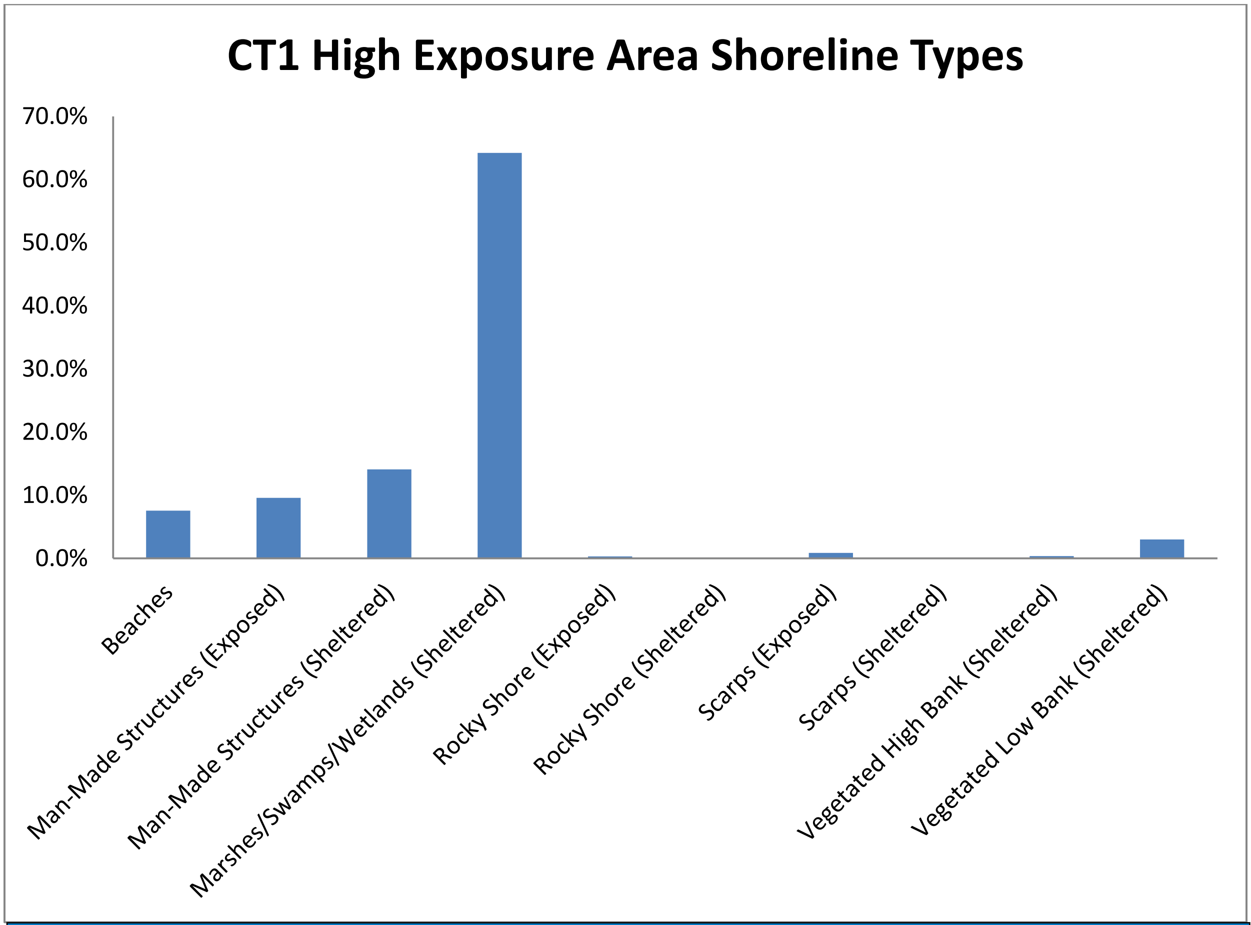


Figure 21. CT1 Shoreline Types

V.2 Cost Considerations

Conceptual design and parametric cost estimates were developed for the various coastal storm risk management measures were representative, concept designs were developed for each measure together with quantities and parametric costs (typically per linear foot of shoreline) based on a combination of available cost information for existing projects and representative unit costs for all construction items (e.g., excavation, fill, rock, plantings) based on historical observations. Additional information on the various measures is included in Appendix C – Planning Analyses.

VI. Tier 1 Assessment Results

Table 5 presents the results of the State of Connecticut 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 Connecticut Risk Areas

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
CT1_A	Beaches	High	1	3	2								
CT1_A	Manmade Structures (Sheltered)	High					3	2	1				
CT1_A	Rocky Shore (Exposed)	Low										1	
CT1_A	Scarps (Exposed)	Low				2				1			
CT1_A	Wetlands (Sheltered)	Low								1	3	4	2
CT1_B	Beaches	High	1	3	2								
CT1_B	Manmade Structures (Sheltered)	High					3	2	1				
CT1_B	Rocky Shore (Exposed)	Low										1	
CT1_B	Scarps (Exposed)	Low				3				1		2	
CT1_B	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_B	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_B	Wetlands (Sheltered)	Low								1	3	4	2
CT1_C	Beaches	High	1	3	2								
CT1_C	Manmade Structures (Sheltered)	High					3	2	1				
CT1_C	Rocky Shore (Exposed)	Low										1	
CT1_C	Wetlands (Sheltered)	Low								1	3	4	2
CT1_D	Beaches	High	1	3	2								
CT1_D	Manmade Structures (Sheltered)	High					3	2	1				
CT1_D	Wetlands (Sheltered)	Low								1	3	4	2
CT1_E	Beaches	High	1	3	2								
CT1_F	Beaches	High	1	3	2								
CT1_F	Manmade Structures (Sheltered)	High					3	2	1				

Table 5. Comparison of Measures within Connecticut Risk Areas

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
CT1_F	Scarps (Exposed)	Low				3				1		2	
CT1_F	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_F	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_F	Wetlands (Sheltered)	Low								1	3	4	2
CT1_G	Beaches	High	1	3	2								
CT1_G	Rocky Shore (Exposed)	Low										1	
CT1_G	Scarps (Exposed)	Low				3				1		2	
CT1_G	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_G	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_G	Wetlands (Sheltered)	Low								1	3	4	2
CT1_H	Beaches	High	1	3	2								
CT1_H	Manmade Structures (Sheltered)	High					3	2	1				
CT1_H	Scarps (Exposed)	Low				3				1		2	
CT1_H	Wetlands (Sheltered)	Low								1	3	4	2
CT1_I	Beaches	High	1	3	2								
CT1_I	Manmade Structures (Sheltered)	High					3	2	1				
CT1_I	Rocky Shore (Exposed)	Low										1	
CT1_I	Scarps (Exposed)	Low				3				1		2	
CT1_I	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_I	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_I	Wetlands (Sheltered)	Low								1	3	4	2

Table 5. Comparison of Measures within Connecticut Risk Areas

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
CT1_J	Beaches	High	1	3	2								
CT1_J	Manmade Structures (Sheltered)	High					3	2	1				
CT1_J	Rocky Shore (Exposed)	Low										1	
CT1_J	Scarps (Exposed)	Low				3				1		2	
CT1_J	Wetlands (Sheltered)	Low								1	3	4	2
CT1_K	Beaches	High	1	3	2								
CT1_K	Manmade Structures (Sheltered)	High					3	2	1				
CT1_K	Rocky Shore (Exposed)	Low										1	
CT1_K	Scarps (Exposed)	Low				3				1		2	
CT1_K	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_K	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_K	Wetlands (Sheltered)	Low								1	3	4	2
CT1_L	Beaches	High	1	3	2								
CT1_L	Manmade Structures (Sheltered)	High					3	2	1				
CT1_L	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_L	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_L	Wetlands (Sheltered)	Low								1	3	4	2
CT1_M	Beaches	High	1	3	2								
CT1_M	Manmade Structures (Sheltered)	High					3	2	1				
CT1_M	Rocky Shore (Exposed)	Low										1	
CT1_M	Scarps (Exposed)	Low				3				1		2	

Table 5. Comparison of Measures within Connecticut Risk Areas

Risk Areas	Shoreline	RR	Beach Restoration with Dunes	Beach Restoration with Breakwaters	Beach Restoration with Groins	Shoreline Stabilization	Deployable Floodwall	Floodwall	Levee	Living Shoreline	Wetlands	Reefs	SAV Restoration
CT1_M	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_M	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_M	Wetlands (Sheltered)	Low								1	3	4	2
CT1_N	Beaches	High	1	3	2								
CT1_N	Manmade Structures (Sheltered)	High					3	2	1				
CT1_N	Rocky Shore (Exposed)	Low										1	
CT1_N	Scarps (Exposed)	Low				3				1		2	
CT1_N	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_N	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_N	Wetlands (Sheltered)	Low								1	3	4	2
CT1_O	Beaches	High	1	3	2								
CT1_O	Manmade Structures (Sheltered)	High					3	2	1				
CT1_O	Scarps (Exposed)	Low				3				1		2	
CT1_O	Vegetated Low Banks (Sheltered)	High						2	1				
CT1_O	Vegetated Low Banks (Sheltered)	Low				2				1			
CT1_O	Wetlands (Sheltered)	Low								1	3	4	2

VII. Tier 2 Assessment of Conceptual Measures

As part of the NACCS Tier 2 analysis for the State of Connecticut and in coordination with Connecticut Department of Energy and Environmental Protection (CT DEEP), the Fairfield – Milford complex was selected as an example area to further evaluate flood risk as part of the CSRM Framework. Defined as Area CT1_L, the area includes the inundated shoreline of the towns of Fairfield, Bridgeport, Stamford and Milford. The example area represents an area within the State of Connecticut at risk to coastal flooding. This area was selected for additional analysis due to the lack of existing projects as well as the overall need for enhanced coastal resilience to surrounding communities.

As demonstrated in Table 6, this area of high risk was subdivided into 25 subregions. Each subregion offers a unique set of CSRM measures which may act as an example for similar geomorphic settings in the State of Connecticut by state and local agencies, and non-profit organizations.

Table 6. Tier 2 Example Area Relative Cost/Management Measure Matrix for the State of Connecticut

Subregion Strategy CT1_L											
				Risk Management Strategies (CT)							
				Preserve			***Accommodate***			***Avoid***	
	Existing Coastal Flood Risk Management Projects			Structural Measures (100yr +3')		Regional/ Gates (500yr)	NNBF (10yr)	Non-Structural (10yr)		Acquisition (10-year floodplain)	
Revised Polygon	Description	Existing Project -2018 Post Sandy	Estimated LOP	Description	Cost Index	Description	Description	Description	Cost Index	Description	Cost Index
CT1_L_1	N/A	None	N/A	No. Few properties; won't support a 100-yr LOP project.	N/A	N/A	N/A	Floodproofing	1.00	Acquisition and Relocation	0.49
CT1_L_2	N/A	None	N/A	No. Primarily a golf course.	N/A	N/A	N/A	No	N/A	No	N/A
CT1_L_3	N/A	None	N/A	No. Engineer report indicates 100-yr LOP along Pine Creek not possible due to impacts to private property.	N/A	N/A	N/A	Floodproofing	0.59	Acquisition and Relocation	1.00
CT1_L_4	N/A	None	N/A	No. Engineer report indicates 100-yr LOP along Pine Creek not possible due to impacts to private property.	N/A	N/A	N/A	Floodproofing	0.64	Acquisition and Relocation	1.00

CT1_L_5	N/A	None	N/A	Yes, the town has come up with a plan for an engineered dike to protect a large portion of this flood prone portion of town.	0.19	N/A	N/A	Floodproofing	0.60	Acquisition and Relocation	1.00
CT1_L_6	N/A	None	N/A	No	N/A	N/A	N/A	Floodproofing	0.87	Acquisition and Relocation	1.00
CT1_L_7	N/A	None	N/A	No. Industrial waterfront seems to be fairly elevated and/or doesn't lend itself to structural solutions. Other property too spread out.	N/A	N/A	N/A	Floodproofing	0.83	Acquisition and Relocation	1.00
CT1_L_8	N/A	None	N/A	No	N/A	N/A	N/A	Floodproofing	6.72	Acquisition and Relocation	0.15
CT1_L_9	N/A	None	N/A	No. Industrial waterfront seems to be fairly elevated and/or doesn't lend itself to structural solutions. Other property too spread out.	N/A	N/A	N/A	Floodproofing	1.00	Acquisition and Relocation	0.94
CT1_L_10 & CT1_L_6	N/A	None	N/A	Yes, possible wall or small earthen dike to protect municipal WWTP in Stratford. Industrial waterfront in Bridgeport seems to be fairly elevated	0.01	N/A	N/A	Floodproofing	0.33	Acquisition and Relocation	1.00

				and/or doesn't lend itself to structural solutions.							
CT1_L_11	N/A	None	N/A	No.	N/A	N/A	N/A	No	N/A	No	N/A
CT1_L_12	N/A	None	N/A	No. Airport and industrial area surrounded by water.	N/A	N/A	N/A	Floodproofing	0.45	Acquisition and Relocation	1.00
CT1_L_13	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	0.65	Acquisition and Relocation	1.00
CT1_L_14	N/A	None	N/A	No. Marsh/park area.	N/A	N/A	N/A	Floodproofing	0.59	Acquisition and Relocation	1.00
CT1_L_15	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	0.59	Acquisition and Relocation	1.00
CT1_L_16	N/A	None	N/A	Combination beach fill/dune along shore. Protection level may be limited due to space and viewscape. Flanking protection may also be required on the west side.	1.00	N/A	N/A	Floodproofing	0.14	Acquisition and Relocation	0.24
CT1_L_17	N/A	None	N/A	No. Marsh/park area.	N/A	N/A	N/A	Floodproofing	1.00	Acquisition and Relocation	0.22

CT1_L_18	N/A	None	N/A	Combination beach fill/dune project along shore. Protection level may be limited due to space and viewscape. Flanking protection may also be required on the west side.	0.53	N/A	N/A	Floodproofing	0.63	Acquisition and Relocation	1.00
CT1_L_19	N/A	None	N/A	No.	N/A	N/A	N/A	No	N/A	No	N/A
CT1_L_20	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	0.59	Acquisition and Relocation	1.00
CT1_L_21	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	1.00	Acquisition and Relocation	0.22
CT1_L_22	N/A	None	N/A	No. Mostly marsh area	N/A	N/A	N/A	Floodproofing	1.00	Acquisition and Relocation	0.25
CT1_L_23	N/A	None	N/A	No. Many properties already have seawalls or revetments. 100-yr protection unlikely due to space and viewscape.	N/A	N/A	N/A	Floodproofing	0.67	Acquisition and Relocation	1.00
CT1_L_24	N/A	None	N/A	No.	N/A	N/A	N/A	Floodproofing	0.59	Yes	1.00
CT1_L_25	N/A	None	N/A	Beach fill/dune project along shore. Protection level may be limited due to viewscape or space.	0.29	N/A	N/A	Floodproofing	0.59	Yes	1.00

Table 6 presents the results of the Tier 2 analysis. The Tier 2 analysis evaluates the relative costs associated with risk management measures included in the three primary strategies: avoid, accommodate, and preserve for CSRM 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 3, such as high for a 1 percent flood plus three feet and low for a 10-percent-annual-chance flood. The cost index was derived from parametric unit cost estimates divided by the highest parametric unit cost of all the management measure in the area. The higher the cost index the greater the relative costs. This enables the users to compare the measures associated with the risk management strategy in order to evaluate affordability and ultimately leading to an acceptable level of risk tolerance. The combination of measures leading to a selection of a plan as described in the NACCS Framework would further quantify risk reduction, and evaluate and compare the change in the risk based on the total cost of the plan. This would be completed at a smaller scale, Tier 3, which would be able to incorporate refined exposure and vulnerability, and evaluation or other risk management measures, as well as refined costs.

VIII. Focus Area Analysis Summary

One Focus Area Analysis (FAA) has been developed for the State of Connecticut, the “Connecticut Coastal Flood Risk Management and Storm Damage Assessment”. The purpose of the Focus Area Analysis are to: 1) identify problems, needs and opportunities for improvements relating to CSRM and related purposes, 2) determine if there is an interest in conducting further study, and 3) to identify potential non-Federal sponsor(s) to cost share in future investigations.

The study area is located along the coast of Connecticut. The entire southern edge of the state forms the shore of Long Island Sound; a narrow estuary of the Atlantic Ocean stretching for approximately 160 miles of bays, coves and promontories as shown on Figure 22 below. Specific analysis was conducted on one of the hardest hit areas; the town of Fairfield in Fairfield County.

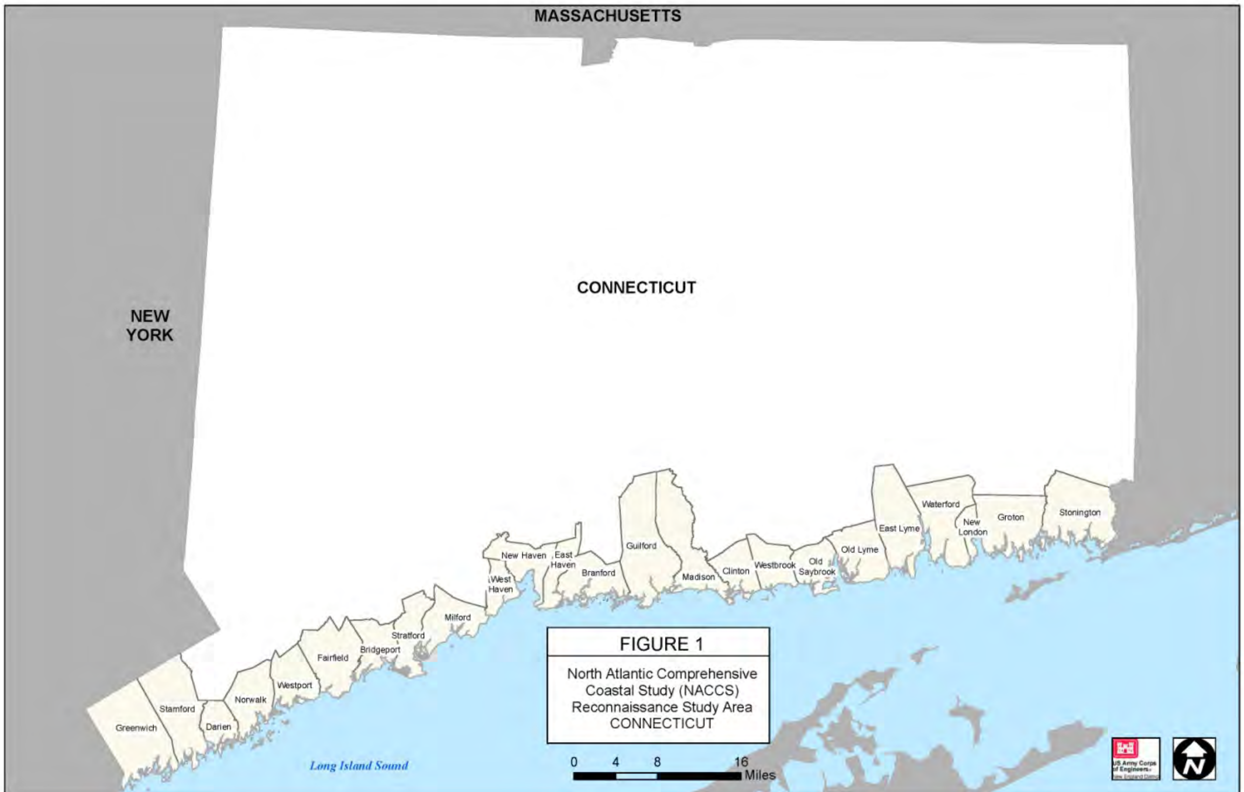


Figure 22. Connecticut focus area analysis boundary

IX. Agency Coordination and Collaboration

IX.1 Coordination

Visioning Meeting Summary - A visioning meeting conducted by the USACE New England District was held at the offices of the Connecticut Department of Energy and Environmental Protection in Hartford, CT on Friday, February 28, 2014. Attendees included representatives from state, county and local community agencies and representatives and non-profit organizations. Dialogue centered on coastal resilience in the wake of Hurricane Sandy. Specific discussion topics included identifying coastal storm risk at the community level, solutions to that risk, and identifying pertinent policy changes and legislative solutions that could improve coastal resilience.

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.

The New England District reguested feedback with respect to the preliminary problem identification and exposure mapping in a letter dated September 4, 2013. To date, the District has received no response. However, state contacts did indicate by email on October 3, 2013 that the Fairfield -Milford area were greatly impacted by Hurricane Sandy and should be included in the risk mapping. The areas in question are covered by site CT1_L.

IX.2 Related Activities, Projects, and Grants

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

Federal Efforts

The Department of the Interior received $360 million in appropriations for mitigation actions to restore and rebuild national parks, national wildlife refuges, and other Federal public assets through resilient coastal habitat and infrastructure. In August 2013, the Department of the Interior (DOI) announced that USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grant Program which will support projects that reduce communities' vulnerability to the growing risks from coastal storms, SLC, flooding, erosion and associated threats through strengthening natural ecosystems that also benefit fish and wildlife (NFWF, 2013). The Hurricane Sandy Coastal Resiliency Competitive Grants Program will provide approximately $100 million in grants for 46 proposals to those states that were affected by Hurricane Sandy. States affected is defined as those states with disaster declarations as a result of the storm event. The grants range from $100,000 to $5 million and requests for proposal were due by January 31, 2014. More information on the program can be found at www.nfwf.org/HurricaneSandy, and the full list of projects can be found at http://www.nfwf.org/hurricanesandy/Documents/doi-projects.pdf. Table 7 presents the list of specific Federal projects and plans proposed for the State of Connecticut that have been identified to date. Figure 23 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 Connecticut			
Agency	State	Proposal	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	CT	Pond Lily Dam Removal, West River, New Haven	$661,500
USFWS/DOI	CT	Hyde Pond Dam removal, Whitford Brook, Groton	$551,250
USFWS/DOI	CT	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Beach Habitats and Species in the Face of Storms and Sea Level Rise	$1,750,000
USFWS/DOI	CT	Flock Process Dam removal, Norwalk River, Norwalk	$970,000
USFWS/DOI	CT	Norton Mill Dam Removal, Colchester	$727,650
USDA/NRCS	CT	NRCS will provide $2.6 million to purchase floodplain easements on 34 acres in the Old Field Creek salt marsh and 12 homes along Blohm, May, and Third Avenues to mitigate flooding during future storms and provide relief to residents.	$2,600,000
HUD	CT	Grantees will be required to identify unmet needs for housing, economic development and infrastructure and may use this allocation to address those unmet needs. Grantees will be required to incorporate a risk assessment in their planning efforts to ensure long term resilience.	$137,820,000
NOAA	NY/NJ /CT/RI	Activity 1: Install water level stations and collect water level, and ellipsoidal data in NY, NJ, CT, and RI to refine VDatum models to support hydro and shoreline surveys from Rhode Island to New Jersey (CO-OPS) Activity 2: Establish GPS Observations for determining Geodetic to Ellipsoid Relationships at Historic Tidal Gauge Sites (NGS)	

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

Agency	State	Proposal	Cost
DOI/NFWF/City of Stamford	CT	Increase Mill River's flood resilience and re-creating a habitat corridor in Stamford, Connecticut. Project will eradicate invasive species, replant native flora, and remove 15 properties from the one percent flood risk area.	$3,750,000
DOI/NFWF/CT	CT	Remove a hazardous and unused fish barrier in Enfield, Connecticut. Project will restore 7.7 miles of diadromous fish runs, reunite brook trout populations, and reduce flood hazards.	$2,800,000
DOI/NFWF/SCRCOG	CT	Establish a Regional Framework for Coastal Resilience for ten municipalities that run along the entire central coast of Connecticut. The municipalities will integrate green infrastructure principles, prioritize projects, and contribute to a Regional Coastal Resiliency Plan.	$700,000
DOI/NFWF/Wood River Watershed Association	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.	$720,000

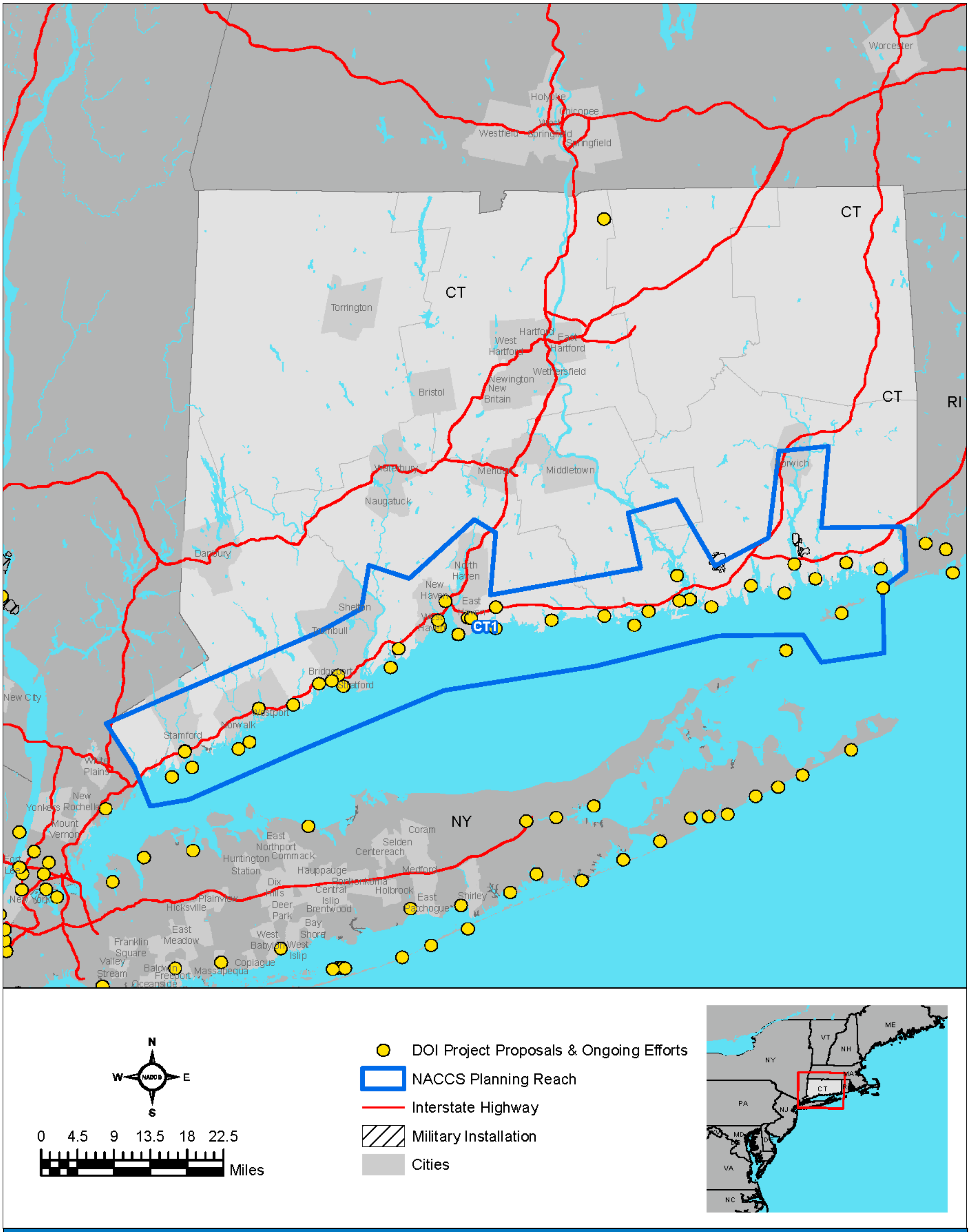


Figure 23. Department of the Interior Projects for the State of Connecticut

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

The USACE is working with several partners including NOAA, FEMA, The Nature Conservancy, The Conservation Fund and academic institutions such as University of Rhode Island, Virginia Institute of Marine Sciences and the University of New Orleans to institute the Systems Approach to Geomorphic Engineering (SAGE) Program. The goals of this program are to pursue and advance a large-scale comprehensive view of coastal landscape change and use integrated methods for coastal landscape transformation to slow/prevent/minimize mitigate impacts to coastal communities and shorelines through an innovative approach to coastal landscape resilience. The next steps for the SAGE Program are to establish regional communities of practice within each of the demonstration pilots, identify areas of need within the demo sites, and determine potential solutions for the areas of need within each of the demo sites.

NOAA is working to complete various data collections activities as part of the PL 113-2 funding allocations within the National Ocean Service, National Marine Fisheries Service, and the National Weather Service, including mapping, modeling resilience, and technical assistance (NOAA, 2013). Mapping activities include aerial photogrammetry surveys, hydrographic surveys, integrated ocean and coastal mapping using light and radar (LIDAR) (in coordination with U.S. Geological Survey [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 tools 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 also 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 here
http://www.recovery.gov/Sandy/whereisthemoneygoing/Pages/DisasterReliefPrograms.aspx.

The U.S. 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 Program (CDBG). To be eligible to receive funds, each grantee must conduct a comprehensive risk assessment to address climate change impacts, changes in development patterns and population, and incorporate resilience performance standards identified in the Hurricane Sandy Rebuilding Strategy. More information can be found at http://portal.hud.gov/hudportal/HUD?src=/sandyrebuilding. In Connecticut, $149 million of CDBG funds were made available for areas affected by Hurricane Sandy.

Region 1 of the EPA has developed a compilation of studies and projects that they and the New England states believe will advance emergency preparedness and resilience. The initiative is called the Region 1 Resiliency Portfolio "Advancing Resilient Communities and Water Infrastructure". Projects aimed at advancing resilience will result in long-term benefits, including reduction in emergency wastewater bypasses and boil water orders, less reliance on energy grids, and economic savings and public health benefits from expedited cleanups.

In addition to the Hurricane Sandy Rebuilding Task Force discussed in the Overview section of this State Appendix, the HUD has allocated approximately $1 billion for recovery actions including Rebuild by Design to rebuild areas affected by Hurricane Sandy through CDBG. The purpose of the Rebuild by Design initiative is to consider innovative and implementable solutions to address risk of future climate events. By creating a competition, the effort brings together experts from various fields to develop opportunities for resilience and innovation as part of the rebuilding process in areas with extensive impacts from Hurricane Sandy in Connecticut, New Jersey, and New York. Three geographical categories were identified: City, Shore, and Region. Ten projects were selected by HUD Secretary Shaun Donovan to proceed into a design phase. Final designs were shared with Federal and public stakeholders in April 2014. The winning design solutions will be selected by HUD in mid-2014. These solutions may be implemented with disaster recovery grants from HUD in addition to other sources of public and private sector funding. More information on the initiative and the various designs that were submitted for consideration for the competition is available at http://www.rebuildbydesign.org/.

Resilient Bridgeport comprises place-specific design solutions ranging from upland green streets to coastal wetland park buffers. In Bridgeport's South End, the plan proposes elevating Singer Street, building a waterfront berm in Seaside Park, and establishing offshore breakwaters. The proposed South End Resilience Education and Community Center would serve the neighborhood's 12,600 residents with community-driven programming, ranging from workforce training and a fresh food co-op to a healthcare clinic, senior activities center, and childcare. In an emergency, the center could provide shelter capacity for 1,500 people, using self-sufficient utilities.

Other Federal projects and efforts conducted within the agencies' mission areas in response to Hurricane Sandy not associated with PL 113-2 are discussed below.

Under the National Response Plan, the U.S. Department of Homeland Security calls for the establishment of a Joint Field Office (JFO) as one of the principal NRP organizational elements designed to implement the new single, comprehensive approach to domestic incident management. The JFO is a temporary Federal multiagency coordination center established locally at a central location to coordinate Federal, state, local, tribal, nongovernmental and private-sector organizations with primary responsibility for activities associated with threat response and incident support. Hurricane Sandy JFOs were established in Connecticut, New York, and New Jersey.

Structures of Coastal Resilience (SCR) is a Rockefeller Foundation-supported project dedicated to studying and proposing resilient designs for urban coastal environments in the North Atlantic region. Four design teams from Princeton, Harvard, the City College of New York, and University of Pennsylvania are developing both general strategies and features for coastal protection and site-specific design in the study regions: Narragansett Bay RI, Jamaica Bay NY, Atlantic City NJ, and Norfolk VA.

On February 4, 2013, the Federal Transit Administration (FTA) announced the availability of $2 billion in emergency aid funds to transit agencies affected by Hurricane Sandy, through its new Emergency Relief Program. The projects are being implemented with resilient features so that the infrastructure will not need to be replaced when the next storm occurs.

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 reduction in Connecticut were considered in the development of this state narrative and are listed in Table 8.

Table 8. Federal and State of Connecticut Sources of Information

Resource	Source/Reference	Subject	Key Findings Synopsis
CT Coastal Management Manual	http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323814&deepNav_GID=1622	CZM Policy	The Coastal Management Manual was developed as a tool for coastal land use agents, boards and commissions, as well as developers, consultants and individuals, to use in understanding how to apply the standards and policies of the Connecticut Coastal Management Act.
CT Natural Hazards Mitigation Plan	http://www.ct.gov/deep/cwp/view.asp?A=2720&Q=325652	Hazard Mitigation	This Plan represents the State of Connecticut's efforts to approach mitigating the effects of natural disasters on a multi-hazard basis, and shifts from a disaster-response driven system to one based on effective hazard mitigation planning.
Coastal Hazards in CT	http://www.ct.gov/deep/lib/deep/long_island_sound/coastal_hazards/ct_coastal_hazards.pdf	Coastal Hazards and Climate Change	The Connecticut Department of Energy and Environmental Protection Office of Long Island Sound Programs produced a report in 2010 that synthesizes a multitude of coastal hazard and climate change documents.
The Changing Demographics of Connecticut 1990-2000	http://www.ctdatahaven.org/reports/five_cts.pdf	Socioeconomics	The Center for Population Research at the University of Connecticut developed this study of demographic changes in the state for the years 1990-2000. Though somewhat dated, the report may still have some use.
CT Maps & Photographs	http://www.cteco.uconn.edu/	Maps and GIS Data	University of Connecticut website that houses the most recent digital data for the state
CT Maps & Photographs	http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898&deepNav_GID=1707	Maps and GIS Data	CT DEEP website that provides maps and GIS downloads for public use.
CT Population Projections 2015-2025	http://ctsdc.uconn.edu/projections.html	Population Projections	The Connecticut State Data Center at the University of Connecticut provides near term projections for every town in the state at this site.
CT Five-Year Strategic Floodplain Management Plan	http://www.floods.org/PDF/5_Year_Plans/5yr_CT.pdf	Floodplain Management	CT DEEP's five year floodplain management plan was developed for the years 2004-2009. A more recent plan was not found.
Living on the Shore - Shore Protection	http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323806	Coastal Planning	CT DEEP's website that provides people living on the shore with resources for shore protection.
CT Habitats	http://clear.uconn.edu/tools/habitats/index.htm	Coastal Resources	A University of Connecticut website that describes the primary coastal habitats and resources in CT as well as provides useful links to others reports regarding resources in Long Island Sound.

Resource	Source/Reference	Subject	Key Findings Synopsis
Article describing new Resiliency Institute in Groton	http://www.governor.ct.gov/malloy/cwp/view.asp?A=4010&Q=538668	Coastal Resiliency Planning	Governor Malloy recently launched the Institute for Community Resiliency and Climate Adaptation at the UConn's Avery Point Campus in Groton. The new research center will strengthen efforts to help residents, communities, and businesses better prepare for the impacts of more severe weather and rising sea levels.
Adaption Subcommittee to the Governor's Steering Committee on Climate Change. (January 2010)	http://www.ct.gov/deep/lib/deep/climatechange/impactsofclimatechange.pdf	Coastal Resiliency Planning	Lays out the impacts of climate change on Connecticut agriculture, infrastructure, natural resources, and public health.
Atlantic Coast Joint Venture. (January 2005)	http://www.acjv.org/maps/ct_waterfowl_web_map.pdf.	Coastal Resources	Map showing various coastal waterfowl focus areas in Connecticut.

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http://www.nfwf.org/HurricaneSandy/Pages/home.aspx

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

http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323814&deepNav_GID=1622

http://www.ct.gov/deep/cwp/view.asp?A=2720&Q=325652

http://www.governor.ct.gov/malloy/cwp/view.asp?A=4010&Q=538668

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http://www.floods.org/PDF/5_Year_Plans/5yr_CT.pdf

http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323806

http://clear.uconn.edu/tools/habitats/index.htm

http://www.ct.gov/deep/lib/deep/long_island_sound/coastal_hazards/ct_coastal_hazards.pdf

ATTACHMENT A

Focus Area Analyses Report

ATTACHMENT A

Connecticut Coastal Flood Risk Management and Storm Damage Assessment

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1. Authority

This investigation is being conducted as 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 PL113-2 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 focus area analysis along the Connecticut 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 Connecticut 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 Connecticut. The entire southern edge of the state forms the shore of Long Island Sound; a narrow estuary of the Atlantic Ocean stretching for approximately 160 miles of bays, coves and promontories as shown in Figure 1 below. Specific analysis was conducted on one of the hardest hit areas; the town of Fairfield in Fairfield County.

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

   2nd Congressional District – Rep. Joseph Courtney
   3rd Congressional District – Rep. Rosa L. DeLauro
   4th Congressional District – Rep. James A. Himes

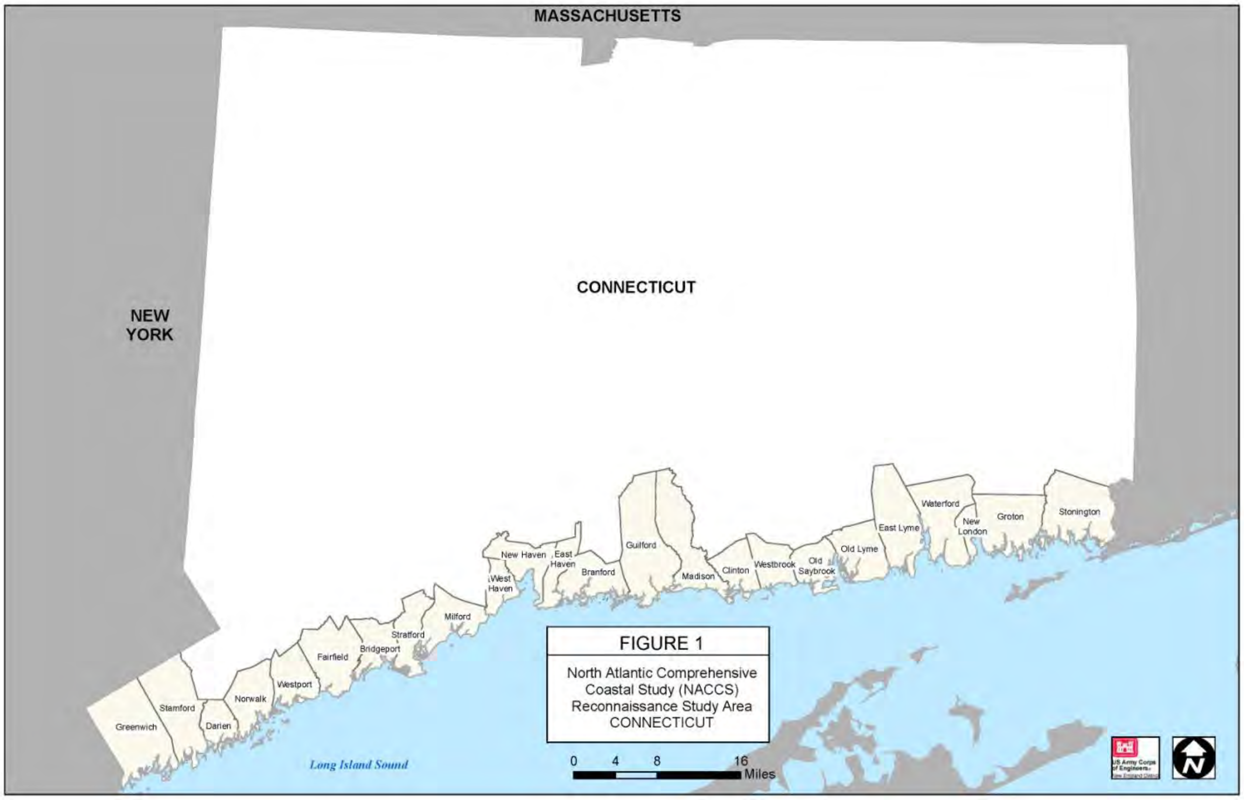

Figure 1. Connecticut Reconnaisance Study Area

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) **Tidal-Flood Management, West Central Connecticut, Reconnaissance Report (June 1988).** The report determined a Federal interest in pursuing flood risk reduction measures in the towns of Milford, located in New Haven County; and Westport and Fairfield, located in Fairfield County. The recommendation to elevate 36 homes above the FEMA Flood Insurance Study base flood elevation in the town of Milford was authorized in 1994 and completed in July 2004. Recommendations for projects in Fairfield County did not progress to Feasibility Level analysis.

b. Existing Projects

1) **Stamford Hurricane Barrier.** The Barrier Project extends from the West Branch eastward across the East Branch of Stamford Harbor, in the City of Stamford, Fairfield County, CT. Construction of the Barrier was authorized under the Flood Control Act of 1960 and was completed in 1969. It consists of a 90-foot wide navigation opening closed by a large flap gate operated by a hydraulic cylinder system. The project also consists of pumping stations, dikes, and concrete flood walls and provides protection from coastal storms and hurricanes to approximately 600 acres of commercial, industrial, and residential property in the city.

2) **Woodmont Beach, Milford, CT, Shore Protection and Erosion Control Project**. The project was authorized by House Document No. 203, 83rd Congress, 1st session, July 6, 1953. The modified project was adopted under authority contained in Section 103 of the 1962 River and Harbor Act, as amended. The project involved the direct placement of sand fill, along 1,500 feet of beach to form a 50 foot wide berm at elevation 11.0 mean low water (MLW) and a dry beach area approximately 100-feet wide above MHW. Groins were also constructed and mitigation was provided to replace rocky habitat for Blue Mussels.

3) **Prospect Beach, West Haven, CT, Shore Protection and Erosion Control Project.** Initial authorization was provided in RHA of 1954 (3 September 1954). The modified project was adopted under authority contained in Section 103 of the 1962 River and Harbor Act, as amended. The project was constructed between 1992 and 1995 and consists of a level beach berm with an average width of 50 feet at elevation of 12 feet above mean low water with a relatively flat 1 on 15 seaward slope. This shore protection project provides a usable dry beach width of about 130 feet shoreward of the mean high waterline. The authorized beach erosion control project involved the placement of approximately 113,000 cubic yards of suitable sand fill along 4,500 feet of shoreline.

4) **Sea Bluff Beach, West Haven, CT, Shore Protection and Erosion Control Project.** The project was authorized by the Chief of Engineers on November 6, 1989 under authority contained in Section 103 of the 1962 River and Harbor Act, as amended. The project was constructed between October 1990 and January 1991 and consists of a 50-foot wide level beach berm at elevation of 12 feet above mean low water with a 15H:1V seaward slope. This provides a usable dry beach width of about 120 feet shoreward of the mean high waterline. The project involved the placement of approximately 14,300 cubic yards of sand fill along 1,000 feet of shoreline, and the reconstruction of an existing rock groin structure located at the southwest end of the beach.

5) **Gulf Beach, Milford, CT, Shore Protection and Erosion Control Project.** Authorized by the River and Harbor Act of September 3, 1954. The beach erosion control project consists of the 1,200 foot southern jetty at the entrance to Milford Harbor (Wepawaug River), and a 50 foot berm with 1 vertical and 36 horizontal beach slope to mean high water.

6) **Point Beach, Milford, CT, Hurricane and Storm Damage Reduction Project.** The project was authorized under the special continuing authority contained in Section 103 of the River and Harbor Act of 1962. The decision document for the project is dated September 1994. It is a nonstructural project that elevated 36 homes in Milford, CT above the Flood Insurance Study's base flood elevation.

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 Connecticut 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 coast of Connecticut forms the northern shore of the Long Island Sound Estuary while Long Island, NY creates the southern shore. The coast runs generally east to west, but there are many beaches and headlands along the coast that have westerly or easterly exposures. The mouths of the Housatonic, Connecticut, and Thames Rivers are located on Connecticut's southern coast. These rivers provide sediment that nourishes beaches along the coast, and provide the freshwater that makes Long Island Sound an estuary.

Due to the east-west orientation of the southern shore in relation to the Atlantic Ocean, Connecticut is particularly vulnerable to storm surge flooding when winds from the northeast to east-southeast direction are greater than 30 mph and last for more than 12 hours; continuing through an astronomical high tide. 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).

Table 1 below presents a list of Disaster declarations made by the Federal Emergency Management Agency (FEMA). Connecticut has had fourteen (14) storm-related emergency declarations involving coastal flooding and damages since 1954.

Table 1. FEMA Disaster Declarations

Disaster Number	Date	Incident Description	Declaration Type
4087	10/27/2012	Hurricane (Sandy)	Major Disaster
4023	8/27/2011	Hurricane (Irene)	Major Disaster
1904	3/12/2010	Severe Storms & Flooding	Major Disaster
1700	4/15/2007	Severe Storms & Flooding	Major Disaster
1619	10/14/2005	Severe Storms & Flooding	Major Disaster
3246	9/19/2005	Hurricane (Katrina)	Major Disaster
1302	9/06/1999	Tropical Storm/Hurricane (Floyd)	Major Disaster
972	12/10/1992	Coastal Flooding/Winter Storm	Major Disaster
916	8/19/1991	Hurricane (Bob)	Major Disaster
747	9/27/1985	Hurricane (Gloria)	Major Disaster
711	5/27/1984	Severe Storms & Flooding	Major Disaster
661	6/14/1982	Severe Storms & Flooding	Major Disaster
42	8/20/1955	Hurricane (Diane)	Major Disaster
25	9/17/1954	Hurricane (Carol)	Major Disaster

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

Presented below in Figure 2 is the floodplain inundation for the town of Fairfield and the two neighboring towns. A Category 2 hurricane corresponds to a storm event with a .01 probability of occurrence (100-yr return interval). A Category 4 hurricane corresponds to a storm event with a .002 probability of occurrence (500-yr return interval).

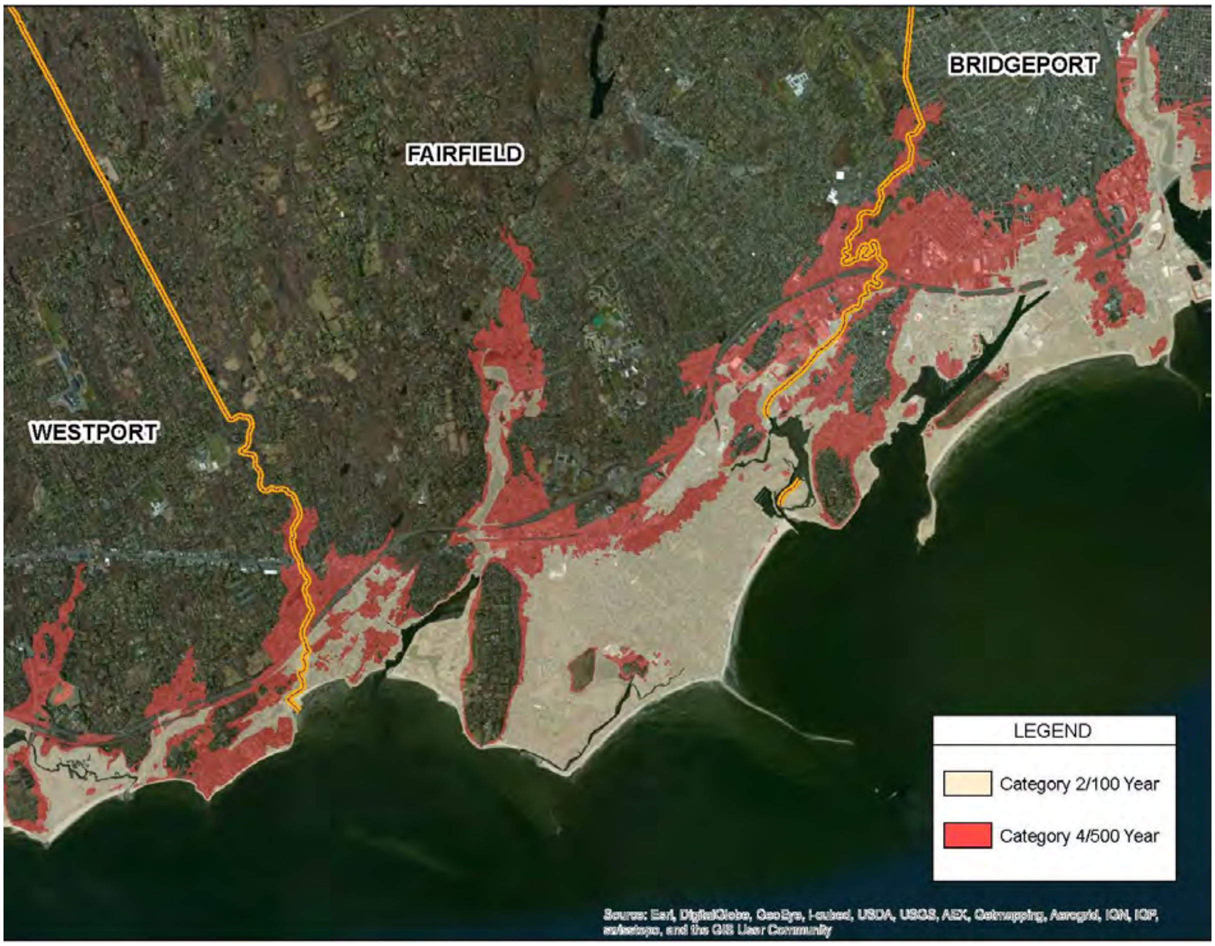

Figure 2. Inundation Area for CAT 2 & 4 Hurricanes

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, Connecticut has experienced approximately 30 hurricanes throughout recorded history with 15 occurring in the 20th century (NOAA).

The most notable storm to hit Connecticut was the hurricane of September 21, 1938, also known as the Long Island Express. This storm was still classified as a Category 3 hurricane even after it crossed long Island and made landfall again on the Connecticut coast during high tide. The storm brought major devastation to the State, with 125 deaths in Connecticut and damage estimated at $53 million in 1938 dollars (CTDEP, 2009), which equates to $1.4 billion in 2013 dollars (adjusted using average CCI & IPD). Property damage on the coast of Connecticut accounted for 42% of the total damages (CTDEP, 2009).

Another major hurricane occurred on September 14, 1944; Injuries, deaths, and damages were less than the 1938 hurricane due to better warnings and fewer structures because of a lack of rebuilding after the 1938 hurricane. Seven people were killed and damages were between $3 million and $5 million in 1944 dollars ($64 to $106 million in 2013 dollars).

Ten years later, Hurricane Carol hit Connecticut resulting in 65 deaths in New England and $460 million in property damage in 1954 dollars ($5.1 billion in 2013 dollars) (Wikipedia). Hurricane Carol arrived on August 31, 1954 shortly after high tide. Even though the storm arrived after high tide, surge levels ranged from five to eight feet across the west shore of Connecticut and from 10 to 15 feet from the New London area eastward. (NOAA) Coastal communities from central Connecticut eastward were devastated. Entire coastal communities were nearly wiped out in New London, Groton, and Mystic, Connecticut. The storm also destroyed nearly 40% of the apple, corn, peach, and tomato crops from eastern Connecticut to Cape Cod, Massachusetts (Vallee & Dion, 1997).

Hurricane Gloria was a Category 2 hurricane when it made landfall at Westport Connecticut on September 27, 1985. Fortunately, the storm arrived at low tide and storm surges, although between 4.5 feet and 5.5 above normal, were lower than they would have been at high tide (Grammatico, 2002). The entire causeway in the Fenwick section of Old Saybrook was under water at the height of the hurricane, while several fishing piers near New Haven were also destroyed.

Connecticut received an indirect strike from Hurricane Bob on August 19, 1991. Damage in the state was estimated around $49 million ($86 million in 2013 dollars), including $4.5 million ($8 million in 2013 dollars) in crop damage. The highest storm surge was five ft. in New London. Despite being primarily localized to the east, Bob was responsible for six deaths in the region, all in Connecticut (CTDEP, 2009).

Hurricane Irene made landfall on the Connecticut 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 flooded streets blocking access to emergency vehicles and evacuation routes in several low-lying communities. About 1,500 residents sought shelter at evacuation centers, including more than 700 from the coastal town of Bridgeport. Twenty homes in East Haven were destroyed and five others damaged beyond repair by flooding and storm surge (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 Connecticut coastline due to Hurricane Sandy.

Hurricane Sandy

Hurricane Sandy's arrival on October 29, 2012 during high tide inundated the Connecticut coastline with storm surge in excess of 11 feet in some locations as well as six to 10 foot waves on top of the surge. Coastal Flood Warnings and mandatory evacuations were in effect for more than 360,000 people from coastal towns and low lying areas. At least three people died in coastal towns. Inland cities and towns saw widespread power failures, with more than 600,000 people without power. Residents who did not heed evacuation orders were trapped in their homes and had to be evacuated. Local fire departments performed a total of 144 rescues, while the Connecticut National Guard supported 73 missions, including 6 life-saving rescue efforts (State of CT, 2013).

The Stamford Hurricane Protection Barrier was closed to reduce potential flooding in Stamford, saving an estimated $26,000,000 in flood damage. Water levels at the Hurricane Barrier exceeded all recorded storms dating back to 1893. Preliminary data indicates Hurricane Sandy resulted in flooding close to, or at, the one hundred year storm level from East Haven to Greenwich. A review of state records indicates that in a significant portion of the State’s coastal area, Hurricane Sandy exceeded the 1938 Hurricane, becoming the most severe storm in Connecticut history (State of CT, 2013).

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. Telecommunications across the State were crippled by the storm. Cellular transmission sites were disabled or damaged and communications and cable companies brought in hundreds of generators in order to address critical issues such as the loss of 911 dispatch networks.

Flooding and power outages caused raw sewage discharges at treatment plants and pumping stations in seven cities, contaminating flood waters. Bridgeport officials said 15 to 20 million gallons of partially treated sewage from two plants were discharged into the Long Island Sound.

Airports were either closed entirely or were reduced to limited service. The MetroNorth New Haven Line, Amtrak Intercity and Shore Line East commuter rails were all shut down. On October 31, when New York Harbor was closed to all shipping traffic, fuel barges could not supply fuel terminals in New Haven and Bridgeport. Fuel supply was also impeded as hundreds of gas stations were closed due to the power outages. The State’s Department of Consumer Protection reported that at the peak of Hurricane Sandy’s impact on the fuel distribution system, 866 out of 1,493 gas stations were without power and residents were unable to obtain gas, or waited in long lines at the few open stations. Residents not only from Connecticut but from heavily affected communities in bordering New York State, such as Port Chester, Rye and White Plains, came to Connecticut in search of fuel, placing a heavy demand on an already low fuel supply (State of CT, 2013).

More than $283 million dollars in federal disaster grants, loans and insurance settlements is supporting the ongoing Connecticut recovery from Hurricane Sandy. Over 12,000 Connecticut residents in the counties of Fairfield, Middlesex, New Haven and New London, and in the Mashantucket Pequot and Mohegan Tribal Nations located within New London County, signed up for federal disaster assistance in the aftermath of Sandy. More than 6,000 properties were inspected for damage claims (FEMA, 2013).

More than $12.6 million was approved for housing assistance, including short-term rental assistance and home repair costs. Another $1 million was approved to cover other essential disaster-related needs, such as medical and dental expenses and lost personal possessions. $42.8 million in low-interest disaster loans for homeowners, renters, businesses and private nonprofit organizations has been approved by the U.S. Small Business Administration and $22,200 in Disaster unemployment Assistance has also been approved (FEMA, 2013).

FEMA’s website reports the National Flood Insurance Program (NFIP) has paid more than $242.5 million for more than 6,156 flood insurance claims. Federal aid also included more than $13.7 million in

Individual Assistance grants paid directly to eligible individuals and families to meet basic needs for housing and cover other essential disaster-related expenses (FEMA, 2013).

In addition to NFIP claims, $76 million in Public Assistance (PA) for storm-related damage to publicly-owned infrastructure has been identified. The federal share of that portion of the recovery is $57 million, or 75 percent, with the remainder paid by state and local government. 220 eligible PA applicants have submitted 425 of an estimated 660 projects, and more than $7.04 million in federal PA grants has been obligated to date (FEMA, 2013).

The Disaster Relief Appropriations Act of 2013 (PL. 113–2) allocated $5.4 billion dollars of Community Development Block Grant disaster recovery (CDBG–DR) funds for the purpose of assisting recovery in the most impacted and distressed areas declared a major disaster due to Hurricane Sandy. The Department of Housing and Urban Development (HUD) allocated $71.8 million dollars to the State of Connecticut to assist the State's recovery from Hurricane Sandy, particularly in the most impacted counties of Fairfield and New Haven counties (CT Dept. Economic and Community Development, 2013).

Figures 3 through 8 below show damage in towns east of the Fairfield study area.

Figure 3. Cosey Beach, East Haven

Figure 4. Bayview Beach, Milford

Figure 5. Bayview Beach, Milford

Figure 6. Bridgeport Airport

Figure 7. Woman surveys damage next to smoldering ruins of house that burned to the ground because firefighters could not get through flooded streets

Figure 8. Chalker Beach, Old Saybrook

Fairfield, CT

The Town of Fairfield had the largest volume of damaged homes in Fairfield County. At least 893 single family homes were affected in the town. Fairfield is a 31.3 square mile town situated on Long Island Sound. Much of the damage to the town was the result of wind and storm surge along the coastal areas and included both primary and secondary homes, particularly within the area between Fairfield Beach and Shoal Point (Cover photo). Fairfield's total population in 2011 was 59,078. Over nineteen percent (19.6%) of the population is elderly. Fairfield's estimated median household income in 2011 was $118,476. Fairfield's homeownership rate in 2011 was 85.4%. The current estimated median house or condo value is $450,100, down from $521,000 in 2009 (State of CT, 2013). Figures 9 through 13 below show flooding and damages in the Fairfield area.

Figure 9. Backshore properties in Fairfield, CT

Figure 10. Reef Road, Fairfield

Figure 11. Fairfield Beach Road

Figure 12. Fairfield Beach Road

Figure 13. Fairfield Beach Road

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; and
- 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 as part of the 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 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 Connecticut.

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, Fairfield. The team decided to calculate the total damages that could occur across all probable storm events for the floodplain area extending along the shoreline from a point approximately 1,000 feet west of Pine Creek, running east to Ash Creek. This site was chosen as it is a concentrated area of residential 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 Connecticut and 2010 LIDAR from the US Geological Survey (USGS).
- 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 Fairfield.
- Developing a stage-frequency curve for the Fairfield area using the most recent FEMA Flood Insurance information.
- Developing an overall damage-frequency curve 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 2 below.

Table 2. Without Project Damages by Event – Fairfield, CT

Probability	Recurrence Interval (Years)	$000's
0.5	2	$4,646.6
0.2	5	$12,515.3
0.1	10	$29,056.3
0.04	25	$88,554.7
0.02	50	$121,831.8
0.01	100	$246,879.7
0.004	250	$304,186.2
0.002	500	$370,307.3

The expected annual damages to structures, across all storm frequencies, for the Fairfield area are estimated to be $17,484,900 in the without-project condition. There are approximately 2,519 residential and 235 commercial properties in the study area. This total is broken down by damage category in the following table. 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 3 below.

Table 3. Expected Annual Damages for Fairfield Beach Area, Fairfield, CT

Category	Without Project	With Project	Project Benefits
Residential	$13,366,480	$3,328,970	$10,037,510
Commercial	$4,118,410	$514,720	$3,603,690
Total	$17,484,890	$3,843,690	$13,641,200

A combination beach fill and floodwall (reinforced concrete over sheeting) or earthen dike was considered for the damaged areas along Fairfield Beach. The Fairfield project would consist of approximately 9,000 feet of newly created beach/dune sand fill. The beach fill will have a dune elevation of 13 feet NAVD88 with a dune width of 20'. The berm will be at elevation 6' NAVD88 with a width of between 30' and 40' for the fill areas. The initial beach fill volume will be 128,000 cubic yards and the renourishment volume will be 82,000 cubic yards with a renourishment interval estimated at every 8 years. Cost estimates were based on trucking the sand in from a local source.

Two flanking flood walls will be constructed to protect the backshore neighborhood and businesses. Starting at the southwest end of the floodplain, the project would include approximately 5,500 feet of flood wall along Old Dam Road, a tide gate and navigation structure across Pine Creek and another floodwall approximately 4,000 feet long in the Jennings Beach-Ash Creek area. Both flood walls will tie into high ground with the top of the walls set at elevation of 12 feet NAVD88. 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 $15,720,320. 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%, a 50 year project life, and the capital recovery factor of 0.00457, yields an annual cost of $1,092,705. Annual benefits are $13,641,200, therefore, the benefit to cost ratio for this alternative would be 10.06 with annual net benefits of $12,285,100.

5.8 Conclusions

In addition to the measure described above, other alternatives that should be analyzed in a feasibility 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 Connecticut Department of Energy and Environmental Protection. However, none of the coastal communities or other pertinent state agencies 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 will be developed.

8. Views of Other Resource Agencies

Due to the funding and time constraints of the focus area analysis, 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.

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