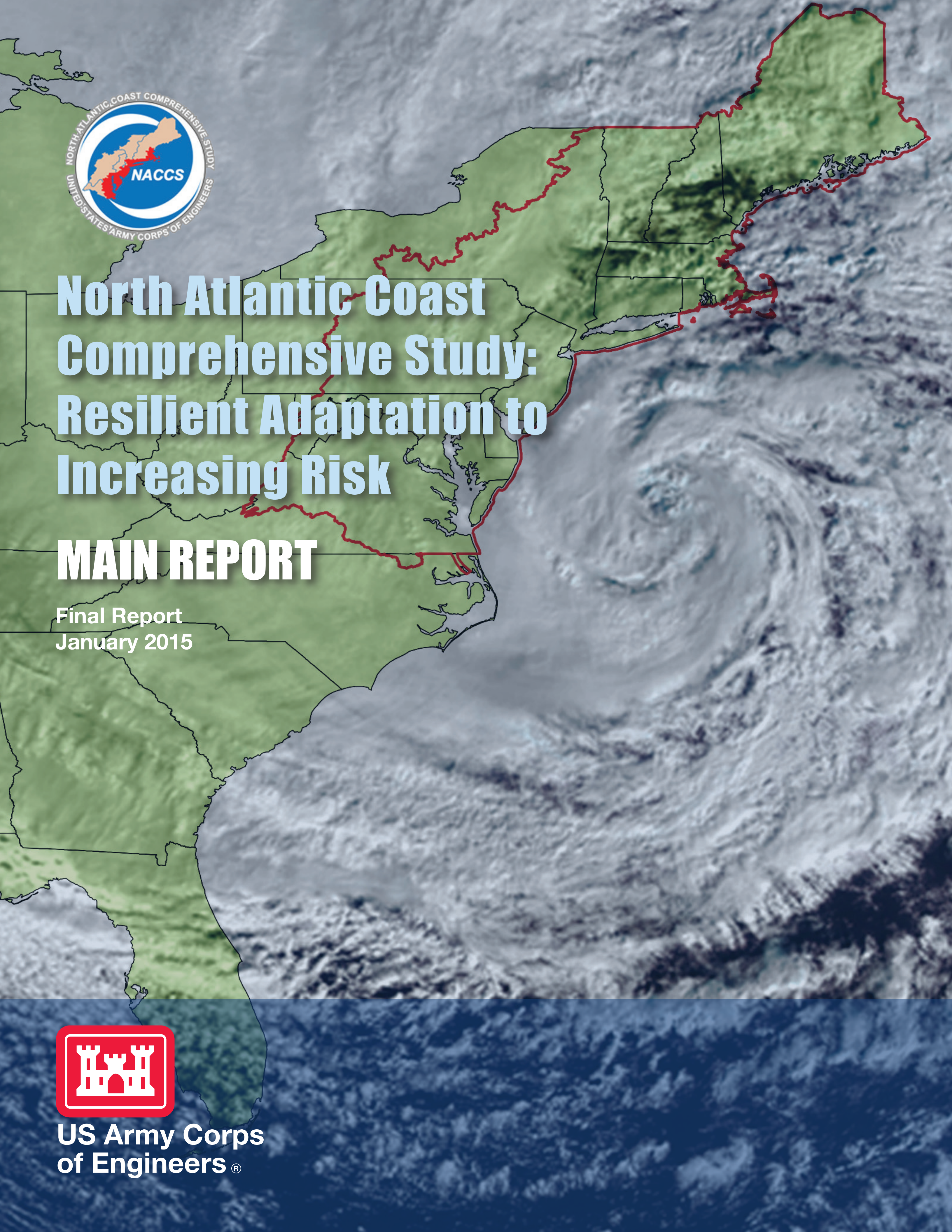

North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

MAIN REPORT

Final Report
January 2015

US Army Corps of Engineers®

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Preface

TOUGH CHOICES

The North Atlantic Coast is a dynamic environment that supports densely populated areas encompassing trillions of dollars of largely fixed public, private, and commercial investment. Hurricane Sandy made us acutely aware of our vulnerability to coastal storms and the potential for future, more devastating events due to changing sea levels and climate change. Changing sea levels represent an inexorable process causing numerous, significant water resource problems such as: increased, widespread flooding along the coast; changes in salinity gradients in estuarine areas that impact ecosystems; increased inundation at high tide; decreased capacity for stormwater drainage; and declining reliability of critical infrastructure services such as transportation, power, and communications. Addressing these problems requires a paradigm shift in how we work, live, travel, and play in a sustainable manner as the extent of the area at very high risk of coastal storm damage expands. This report provides some optimism about the short-term future through the collaborative and multifaceted adaptation measures proposed. However, a realistic view of the long-term challenges facing the area makes it clear that integrated solutions that promote sustainable communities and ecosystems will be needed. Civic and business leaders and citizens must innovate and create solutions that reduce the loss of life, the economic impacts, and the personal devastation that results from coastal storms, while still supporting continued economic growth and opportunities for all. We have begun to take clues from communities and ecosystems which have successfully adapted over time to changing conditions, by expanding from traditional structural risk reduction measures to include more emphasis on nonstructural, natural, and nature-based systems. Given current and projected sea level and climate change trends, some of our built environment will become unsustainable for the human systems presently located there. Coastal communities face tough choices as they adapt local land use patterns while striving to preserve community values and economic vitality. In some cases, this may mean that, just as ecosystems migrate and change functions, human systems may have to relocate in a responsible manner to sustain their economic viability and social resilience. Absent improvements to our current planning and development patterns that account for future conditions, the next devastating storm event will result in similar or worse impacts.

FUTURE OUTLOOK

While the disastrous results of Sandy remain fresh in the North Atlantic coastal communities, we must continue with a clear focus on the storm-related science, community planning and other measures that can reduce the risks of natural disasters over the short-term and the long-term. As the storm recedes from memory, we should resist the temptation to return to "business as usual" and remain focused on the "new normal" of change that represents a responsible and effective response to the dynamic coastal environment. In the longer term, communities should pursue opportunities to reduce exposure to risks in coastal zones in ways that support improvements in economic, social, and environmental conditions (e.g., preparedness, resilience, and floodplain management). This report represents a start in the direction of the new paradigm that accounts for new and changing conditions – this will need the attention and commitment of public, private and commercial interests in order to succeed. We need to continually improve our plans for climate preparedness and resilience in order to reduce vulnerability through adaptation to climate change (USACE 2014a).

The NACCS is closely aligned with many interagency plans and strategies including the recent National Research Council (NRC) report entitled Reducing Coastal Risk on the East and Gulf Coasts (NRC 2014). The report explores and challenges many existing policies and new approaches, for all levels of government that guide coastal storm risk management decisions and actions. http://www.nap.edu/catalog/18811/reducing-coastal-risk-on-the-east-and-gulf-coasts

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Executive Summary

OVERVIEW

Hurricane Sandy originated in the southwestern Caribbean Sea on October 22, 2012 (Blake et al. 2013). On October 29, 2012, the remnants of Hurricane Sandy in the form of a post-tropical cyclone made landfall near Brigantine, NJ. Because of its tremendous size and timing during high tide, the storm drove a catastrophic surge of water into densely developed areas of New Jersey and New York. As a result, there was considerable loss of life, extensive damage to development, and massive disruption to communities.

On January 29, 2013, President Obama signed into law the Disaster Relief Appropriations Act, of 2013 (Public Law 113-2), to assist in the recovery in the aftermath of Hurricane Sandy. Public Law 113-2, Chapter 4, directed the U.S. Army Corps of Engineers (USACE) as follows:

Provided further, That using up to $20,000,000 of the funds provided herein, the Secretary shall conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps: Provided further, That an interim report with an assessment of authorized Corps projects for reducing flooding and storm risks in the affected area that have been constructed or are under construction, including construction cost estimates, shall be submitted to the Committees on Appropriations of the House of Representatives and the Senate not later than March 1, 2013: Provided further, That an interim report identifying any previously authorized but unconstructed Corps project and any project under study by the Corps for reducing flooding and storm damage risks in the affected area, including updated construction cost estimates, that are, or would be, consistent with the comprehensive study shall be submitted to the appropriate congressional committees by May 1, 2013: Provided further, That a final report shall be submitted to the appropriate congressional committees within 24 months of the date of enactment of this division: Provided further, That as a part of the study, the Secretary shall identify those activities warranting additional analysis by the Corps, as well as institutional and other barriers to providing protection to the affected coastal areas: Provided further, That the Secretary shall conduct the study in coordination with other Federal agencies, and State, local and Tribal officials to ensure consistency with other plans to be developed, as appropriate: Provided further, That using $500,000 of the funds provided herein, the Secretary shall conduct an evaluation of the performance of existing projects constructed by the Corps and impacted by Hurricane Sandy for the purposes of determining their effectiveness and making recommendations for improvements thereto: Provided further, That as a part of the study, the Secretary shall identify institutional and other barriers to providing comprehensive protection to affected coastal areas and shall provide this report to the Committees on Appropriations of the House of Representatives and the Senate within 120 days of enactment of this division…

REPORTS SUBMITTED TO CONGRESS

First Interim Report, Second Interim Report, Performance Evaluation Study and Comprehensive Study available at: http://www.nad.usace.army.mil/CompStudy.

The Water Resources Reform and Development Act of 2014 (Section 3026 and the Joint Explanatory Statement of the Committee of Conference), signed by President Obama on June 10, 2014, provided further clarification to USACE.

PURPOSE

Devastation in the wake of Hurricane Sandy revealed a need to address the vulnerability of populations, infrastructure, and resources at risk throughout more than 31,200 miles of the North Atlantic coastal region. This study can be used by States and local communities to identify their flood risk, and plan and implement strategies in collaboration with others, to reduce that risk now and into the future. Such risk management can include nonstructural and structural strategies, ranging from the wise use of floodplains and evacuation planning to natural and nature-based features (NNBF) and blended solutions.

THE GOALS OF THE NACCS ARE TO:

- **Provide a risk management framework**, consistent with the National Oceanic and Atmospheric Administration (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 manage risk to vulnerable populations, property, ecosystems, and infrastructure.

WHAT IS THE NACCS?

The North Atlantic Coast Comprehensive Study (NACCS) provides a step-by-step approach, with advancements in the state of the science and tools to conduct three levels of analysis (available at http://www.nad.usace.army.mil/CompStudy). Tier 1 is a regional scale analysis (completed as part of this study), Tier 2 would be conducted at a State or watershed scale (conceptual Tier 2 evaluations were completed in each State and the District of Columbia and can be found in State and District of Columbia Analyses Appendix), and Tier 3 would be a local-scale analysis that incorporates benefit-cost evaluations of coastal storm risk management plans.

QUICK FACTS

- Floods are the most common and costly hazard affecting communities and the hazard that is most predictable (FEMA 2013a).
- Concepts of resilience include: anticipate (prepare, avoid); resist (withstand); recover (bounce back); and adapt (evolve, transform).

Using the tiered analyses will enable communities to understand and manage their short-term and long-term coastal risk in a systems context. The NACCS addresses the coastal areas defined by the extent of Hurricane Sandy's storm surge in the District of Columbia and the States of New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, and Virginia. Maine was not included in the study because minimal impacts from storm surge were documented as part of the Federal Emergency Management Agency's (FEMA's) Modeling Task Force (MOTF) Hurricane Sandy Impact Analysis. Additionally, the USACE Hurricane Sandy Coastal Projects Performance Evaluation Study included an assessment of 13 USACE coastal storm risk management projects in northern Massachusetts and Maine, and noted that Hurricane Sandy was generally less than a 20 percent flood with negligible damages to project features. Based on minimal impacts and the authorization language that defined the study area as areas affected by Hurricane Sandy, Maine was not included as part of the NACCS study area. Regardless, as the Maine coastline is primarily affected by nor'easters and periodically by tropical storms and hurricanes, stakeholders and communities could apply the study results to address coastal storm risk as well as utilize the various products generated as part of the NACCS.

Managing short-term and long-term risk across local, regional, Tribal, State, and Federal agencies, nongovernmental organizations (NGOs), academia, business, and industry requires collaboration, data sharing, overcoming barriers, advancing the state of the science, and developing new partnerships and incentives for a renewed era of coastal storm risk management and action. Comprehensive action and monitoring to assess system responses are imperative to increase resilience and manage risk from future storms and a changing climate, including sea level change. ***Resilience*** as defined by the Infrastructure Systems Rebuilding Principles (established by NOAA and USACE) is the ability to adapt to changing conditions and withstand and rapidly recover from disruptions due to disasters.

The Infrastructure Systems Rebuilding Principles (NOAA and USACE 2013), which were developed following Hurricane Sandy, provide the foundation for a framework to address flood risk to vulnerable coastal populations and include:

- Working together in a collaborative manner across multiple levels of governance (including Federal, Tribal, State, and local) and with relevant entities outside of the government to develop long-term strategies that promote public safety, protect and restore natural resources and functions of the coast, and enhance coastal resilience;
- Improving coastal resilience by pursuing a systems approach that incorporates natural, social, and built systems as a whole; and

- Promoting increased recognition and awareness of risks and consequences among decision-makers, stakeholders, and the public.

The NACCS is not a major Federal action and does not include designs, evaluations for specific projects, or National Environmental Policy Act (NEPA) documentation.

FINDINGS, OUTCOMES, AND OPPORTUNITIES

Key findings, outcomes, and opportunities of the NACCS include the following:

- Flood risk is increasing for coastal populations and supporting infrastructure.
- Improved land use, wise use of floodplains, responsible evacuation planning, and strategic retreat are important and cost-effective actions.
- Communities should adopt combinations of solutions, including nonstructural, structural, natural and nature-based, and programmatic measures to manage risk, where avoidance is not possible.
- Communities must identify their acceptable level of residual risk to plan for long-term, comprehensive, and resilient risk management.
- Many opportunities exist to improve risk management, including enhancing collaboration, building new partnerships, and strengthening pre-storm planning.
- Addressing coastal risk requires collaboration among local, regional, Tribal, State and Federal entities, NGOs, academia, business, and industry.
- Resilience can be encouraged through the use of a coastal storm risk management framework and continued commitments to advance the state of the science with respect to sea level and climate change, storm surge modeling, ecosystem goods and services, and related themes.
- Strategic and comprehensive monitoring is required to fully assess and adapt the coastal system to avoid future damages. Monitoring information must be made available to the public in a timely manner that allows rapid decision-making by public and private partners.
- Pre-disaster planning and mitigation can save communities approximately 75 percent of post-storm costs (NRC 2014).

COASTAL STORM RISK MANAGEMENT FRAMEWORK FOR VULNERABLE COASTAL POPULATIONS

The Coastal Storm Risk Management Framework (the Framework) is a process to address flood risk to vulnerable coastal populations and was developed to be customizable. The Framework is intended to be implemented at smaller watershed scales by incorporating State and local priorities, refined data sets, and site-specific analyses.

Specifically, the Framework (Figure ES-1) guides users in identifying existing and future risks and vulnerabilities, comparing risk management measures, and considering a full array of solutions. In addition to the Framework itself, technical products by USACE and others are provided for each step of the process (Table ES-1).

Metropolitan Transit Authority employees worked around the clock to remove seawater from a flooded subway tunnel in Manhattan, NY on November 5, 2012

Source: http://www.theatlantic.com/infocus/2012/11/hurricane-sandy-the-long-recovery/100405/

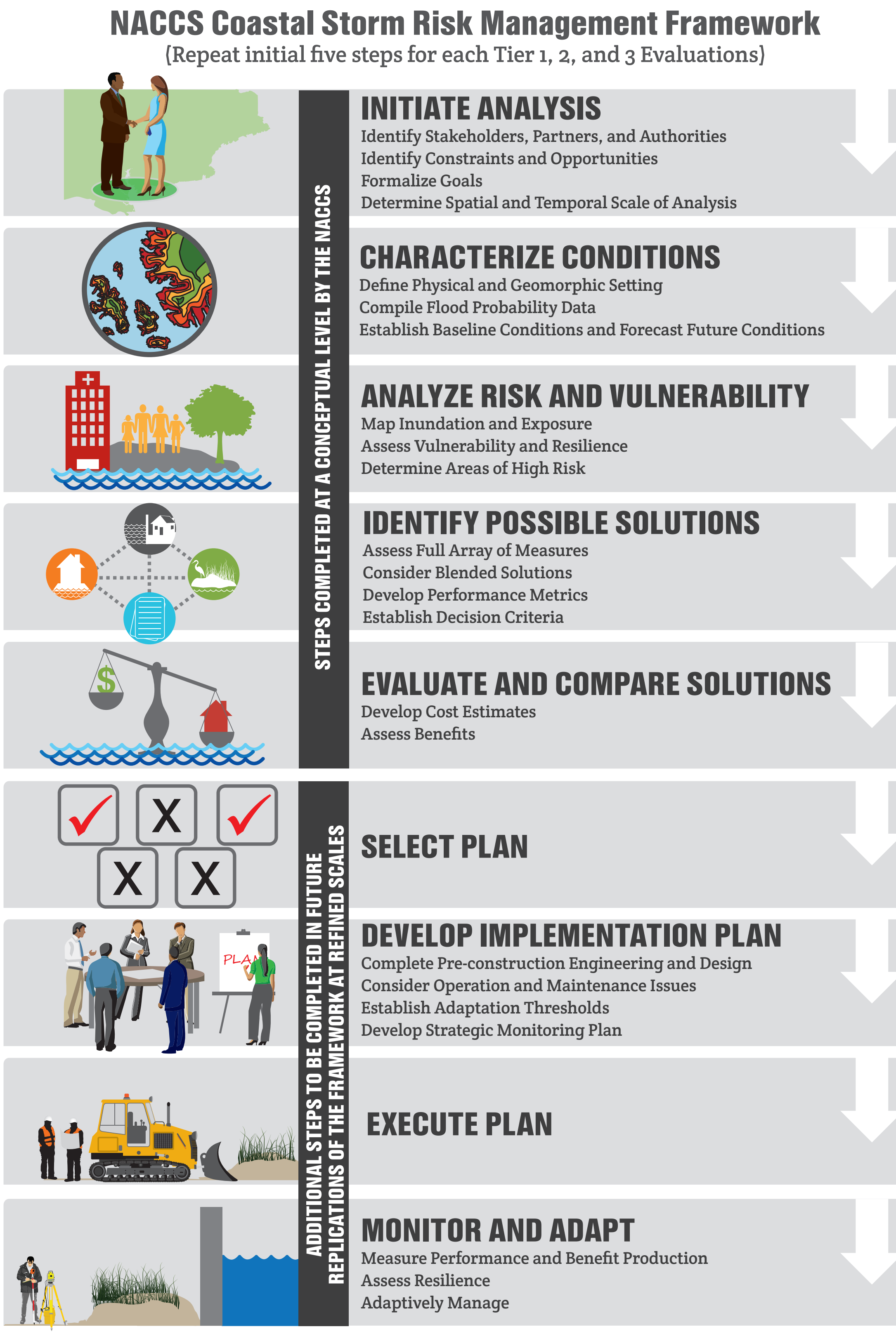


Figure ES-1. NACCS Framework Steps

Table ES-1. NACCS Framework and Products

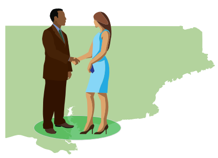
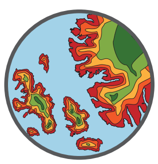
Framework Step	Technical Products[1] Advanced by the NACCS to Further the State of the Science	Value Added
Initiate Analysis 	Visioning Sessions Report & Focus Area Analyses	Identifies specific problems, needs, and opportunities for each focus area.
	Institutional & Other Barriers Report	Identifies six themes and each theme's institutional and other barriers, successes, and opportunities for action. Results are documented in the NACCS Main Report and also in the NACCS Institutional and Other Barriers Report.
	Collaboration Report	Documents outreach conducted throughout the course of the study.
Characterize Conditions 	GIS Geodatabase[2]	Includes data layers derived from the NACCS in a central location that can be used for additional analyses.
	Environmental & Cultural Resources Conditions Report	Provides a comprehensive report of environmental and cultural conditions for the North Atlantic Region. This information can be used in future National Environmental Policy Act (NEPA) documentation or environmental studies.
	USFWS Planning Aid Report	Provides a report of environmental conditions, including species and habitat considerations for the North Atlantic Region.
Analyze Risk and Vulnerability 	Storm Surge Modeling	Provides information about future storms and climate change, which will inform future studies and analyses.
	Barrier Island Sea Level Rise Inundation Assessment Report	Provides an example to complete an assessment of flood risk to a barrier island and back bay and vulnerability to the impacts of sea level change.
	Extreme Water Levels Report	Provides current and future extreme water levels for each of the NACCS sea level change scenarios for the 1, 0.1, 0.04, 0.02, 0.01, and 0.002 percent events for all 23 tide gages along the North Atlantic coastline of sufficient record length.
Identify Possible Solutions 	NNBF Report and Brochures	Advances the science on NNBF strategic placement, how these features can be applied, and the benefits they provide. Includes the technical report, Use of Natural and Nature-Based Features for Coastal Resilience (Bridges et al. 2015), as well as user-friendly consolidated brochures.
	Conceptual Regional Sediment Budget	Identifies the sources and sinks for sediment. Also identifies opportunities for the strategic placement of dredged material for NNBF.
	State and District of Columbia Analyses Appendix	Provides State by State chapters that discuss each State and District's post Hurricane Sandy landscape, sea level change considerations, and vulnerability assessment.
	Vulnerability Decision Tree	Provides a question tree that guides local users through the exposure and vulnerability assessment criteria and weightings.

Table ES-1: NACCS Framework and Products (continued)

Framework Step	Technical Products[1] Advanced by the NACCS to Further the State of the Science	Value Added
Identify Possible Solutions 	Coastal Program Guide	Provides detailed information on coastal storm risk management programs, including their authority, types of grants available, point of contact information, goals, etc.
	Measures Infographics	Displays various risk management measures discussed in the NACCS and depicts graphically how the measures work.
Evaluate and Compare Solutions 	Enhanced Depth-Damage Functions for Coastal Storms	Provides generic coastal depth-damage curves for the region, as well as a report documenting the relationship of secondary and tertiary impacts.

[1] Products are available at http//www.nad.usace.army.mil/CompStudy

[2] The NACCS GIS Geodatabase product can also be utilized as part of the Analyze Risk and Vulnerability Step

GIS = Geographic Information Systems

NNBF = Natural and Nature-Based Features

USFWS = U.S. Fish and Wildlife Service

The NACCS applies steps 1–5, described below, at the regional (Tier 1) scale. More detailed information is provided in the Planning Analyses Appendix. Using the Tier 2 and Tier 3 evaluations, communities can proceed sequentially through Steps 1–9 of the Framework.

Step 1. Initiate Analysis

When applying the Framework, identifying a range of stakeholders and interested parties early in the process is important. In addition, determining the temporal and spatial scale of the analysis will guide collection of the necessary data sets, refine the goals and constraints of the analysis, and reveal other opportunities or objectives to be considered. Given the many entities and funding mechanisms potentially involved in the planning or implementation of coastal actions, understanding the criteria (i.e., time constraints, special requirements, real estate, operation and maintenance responsibilities, etc.) of the agencies and programs involved is critical. Through collaboration and careful planning, these criteria can be considered early and integrated successfully.

The NACCS study area encompasses 10 States and the District of Columbia. As required by Public Law 113-2 and Section 3026 of the Water Resources Reform and Development Act of 2014, stakeholder outreach included Federal and State agencies; Coastal Zone Management teams; Tribal liaisons; NGOs; industry; and academia, including historically black colleges and universities, Tribal colleges, and universities, and other minority serving institutions. These stakeholders provided local knowledge of the study area, participated in multiple panel discussions, and assisted with website development to solicit and share information. They were an invaluable asset to the NACCS. Coordination among these experts and interested parties should continue during any further analyses.

Step 2. Characterize Conditions – Existing and Future

More than 31,200 miles of coastal shoreline were delineated into 39 planning reaches based on State boundaries, shoreline types, geomorphic features, and extent of existing or planned risk management projects. Based on coordination with a diverse set of agencies, the post-Hurricane Sandy landscape considers population and supporting infrastructure, environmental and cultural resources, and existing and planned coastal storm risk management efforts. The study also considers existing and future inundation and sea level change. For the Tier 2 and Tier 3 evaluations, this information can be refined and aligned with State Coastal Zone Management Programs.

KEY ELEMENTS OF THE NATIONAL COASTAL ZONE MANAGEMENT PROGRAM

http://coast.noaa.gov/czm/

- Protecting natural resources;
- Managing development in high hazard areas;
- Giving development priority to coastal-dependent uses;
- Providing public access for recreation; and
- Coordinating the State and Federal actions.

The National Coastal Zone Management Program administered by NOAA is a voluntary Federal-State partnership for protecting, restoring, and responsibly developing our Nation's diverse coastal communities and resources. All 10 States within the NACCS study area have approved coastal zone management programs (District of Columbia does not participate) to address a wide range of existing and future issues, including coastal development, water quality, public access, habitat protection, energy facility siting, ocean governance and planning, coastal hazards, and climate change. These programs provide States the flexibility to design planning and implementation actions that best address their unique coastal challenges, laws, and regulations.

Step 3. Analyze Risk and Vulnerability

Significant new technical information has been developed as a result of Hurricane Sandy. Localities must know what locations and resources are at risk of coastal flooding. This knowledge can directly affect evacuation planning and emergency response, the siting of future development, and the implementation of adaptation planning.

Analyses defining the extent of inundation for different storm events were developed, as well as inundation from forecasted sea level change scenarios, for the study area. *Understanding WHERE the flood hazard exists is critical*. Three exposure indices were used for population density and infrastructure, social vulnerability, and environmental and cultural resources located within the floodplains. In addition, the three individual indices were combined to create a composite exposure index. *Understanding WHAT is exposed to flood hazard is critical*. The composite exposure index was combined with the probability of inundation to illustrate the flood risk along the coastline. *Understanding HOW FREQUENTLY these areas are exposed to flood hazards is critical*. The NACCS risk assessment and National Hurricane Program's Hurricane Evacuation Studies provide State-specific information for Tier 2 and Tier 3 evaluations.

THE NATIONAL HURRICANE PROGRAM

Conducts assessments and provides tools and technical assistance to State and local agencies in developing hurricane evacuation plans.

http://www.fema.gov/region-iii-mitigation-division/national-hurricane-program/

Step 4. Identify Possible Solutions – Risk Management Measures by Shoreline Type

State and local decision-makers play an integral role in choosing and implementing solutions that address near-term and long-term visions for their communities. Lessons learned following Hurricanes Katrina and Rita (2005) led to mitigation projects, implemented through the Coastal Community Resilience program (http://coastal.la.gov/project-content/ccrp/), that focus on incorporating nonstructural projects into coastal storm risk management planning, such as elevating structures, floodproofing structures, and voluntary acquisition or relocation. Effective coordination between local officials, policymakers, NGOs, community groups, and citizens supports the implementation of initiatives that will manage risk to people, homes, and businesses.

Structural, nonstructural, NNBF, and programmatic coastal storm risk management measures were gathered from a wide range of stakeholders and experts. These measures were evaluated to identify those most appropriate for different shoreline types, such that available resources can be directed to those measures most likely to succeed and/or provide the greatest coastal resilience. A shoreline type was assigned to each shoreline in the study area using a classification dataset developed by NOAA.

Step 5. Evaluate and Compare Solutions – Systems Approach for Resilient Adaptation

The current approach to coastal storm risk management includes a myriad of individual projects to address independent problems. The dynamics, complexity, and risks germane to coastal systems cannot be adequately addressed by incrementally building a patchwork of solutions. A systems approach to coastal storm risk management is a cornerstone of the NOAA and USACE Infrastructure Systems Rebuilding Principles.

Site-specific solutions can produce benefits and consequences to the region, or system, and vice versa. The NACCS presents a range of solutions and an evaluation of the potential reduction in risk compared to the relative cost of the strategies and measures. The Framework identifies the strategies and measures that provide the greatest risk reduction for the lowest cost. *Understanding the full array of measures and the relative cost of pursuing certain levels of risk reduction is critical*. This transparent and transferable process does not prohibit consideration of additional measures and relative costs. Combinations of risk management measures, including floodplain and evacuation planning, managed retreat, buyouts, NNBF, and structural solutions are some of the ways to adapt to future sea level and climate change.

Holistically evaluating and comparing solutions based on future visioning, short-term and long-term costs and financing strategies, environmental and cultural resources, the economy, and much more will ensure that investments in our communities and along our coastline are strategic and forward-thinking.

INSTITUTIONAL AND OTHER BARRIERS

Public Law 113-2 directed an evaluation of institutional and other barriers to providing comprehensive coastal storm risk management. Six overarching themes were identified based on the views of coastal stakeholders on frequent or high-impact issues, each with specific institutional challenges, successes, and opportunities for action. These themes are consistent with the plans of others and identify opportunities for action as indicated in Table ES-2.

INTEGRATED COASTAL INVESTMENTS

The NACCS, through extensive collaboration, streamlines the risk management planning process for the North Atlantic communities and others undertaking coastal storm risk management initiatives. Partners representing the public and local communities, State and Federal agencies, Tribal entities, regional bodies, NGOs, academia, and industry can use the information and products presented in the NACCS to pursue a more resilient and sustainable coastline considering site-specific vulnerabilities and future sea level change. The NACCS products will also save time and resources when the Framework is implemented at smaller scales.

ACTIVITIES WARRANTING ADDITIONAL ANALYSIS

Many areas of uncertainty and opportunities to collaborate remain, particularly with respect to technical and scientific advancements, risk communication, and institutional alignment and financing. The NACCS identified nine high-risk areas of the North Atlantic Coast that warrant additional analyses by USACE to address coastal flood risk. No USACE cost-shared studies addressing these areas were ongoing at the time of the NACCS analyses:

- Rhode Island Coastline
- Connecticut Coastline
- New York–New Jersey Harbor and Tributaries
- Nassau County Back Bays, NY
- New Jersey Back Bays
- Delaware Inland Bays and Delaware Bay Coast
- City of Baltimore, MD
- The District of Columbia
- City of Norfolk, VA

Table ES-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
1. Risk/Resilience Standards	Develop consistent definitions for risk, vulnerability, resilience, and related terms and conduct research, as necessary, to develop design standards for resilience, performance metrics, a resilience scorecard, and other standards[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) Presidential Policy Directive 8, National Preparedness
	Conduct a national vulnerability study of constructed USACE coastal storm risk management projects	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop a national strategy for coastal storm risk management	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop regional and watershed-based plans, including a broad base of benefits, benefit quantification, and multi-objective approaches[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
2. Communication and Outreach	Conduct coastal storm risk management visioning sessions with the public[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Continue to develop information and programs to educate the public about flood vulnerabilities, flood risk, residual risk, blended solutions, and pre-disaster and evacuation planning[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop a community of practice[2] for Natural and Nature-Based Features (NNBF)[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)
3. Risk Management	Strengthen and enforce floodplain management policies	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Simplify the complicated network of coastal programs for communities[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)

Table ES-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action (continued)

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
4. Science, Engineering, and Technology	Improve research, coordination, and collection of pre- and post-storm data collection (e.g., climate and sea level change), including more rigorous instrumentation and monitoring for adaptive management, with USGS and others[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a) *The President's Climate Action Plan* (Executive Office of the President 2013)
	Develop better design and implementation guidance for NNBF for use in coastal storm risk management, including effects on long-term maintenance	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Compile information on ecosystem goods and services provided by NNBF[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)
5. Leadership and Institutional Coordination	Re-evaluate and complete authorized or planned projects in a comprehensive systems approach[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Increase coordination between Federal, State, local, and Tribal governmental agencies with responsibility for coastal management to foster mutual understanding of roles and responsibilities and to foster consistency between Federal programs affecting coastal management[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a) Presidential Policy Directive 8, National Preparedness
	Support national adaptation planning[1]	*Federal Actions for a Climate Resilient Nation* (ICCATF 2011) *National Climate Change Adaptation Strategy* (CEQ 2010) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)

Table ES-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action (continued)

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
6. Local Planning and Financing	Apply lessons learned following Hurricanes Katrina, Rita, Sandy, and other coastal storms to provide integrated coastal storm risk management approaches[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)
	Create new tax and market-based incentive programs to encourage resilient local action	Hurricane Sandy Coastal Projects Performance Evaluation Study (USACE 2013a)
	Explore innovative financing options and timetables for Federal and non-Federal partnerships to sustain long-term operation, maintenance, monitoring, and adaptive management	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Leverage public-private partnerships as part of community financing strategies	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)

[1] NACCS contributed toward reducing this barrier and introducing this opportunity for action.

[2] A community of practice is a group of individuals who practice and share an interest in a major functional area.

Hurricane Sandy revealed where the vulnerabilities exist, now and into the future. With projected population increases, climate change, and existing barriers to comprehensive coastal storm risk management, the risk to populations and infrastructure will continue to increase. Local municipalities were the first to feel the impacts of Hurricane Sandy and are also the first line of defense in hazard mitigation planning. As stated in Reducing Coastal Risk (NRC 2014),

"Every dollar spent before an event saves four to five dollars in reconstruction costs after."

Local governments can lead a new era of coastal storm risk management through intensive and proactive pre-storm initiatives. Local governments must commit to wise land use planning and zoning, use of floodplains, and evacuation planning. Integration of a common coastal storm risk management framework, evaluations of blended solutions and adaptation, and collaborative, strategic investments in coastal storm risk management will facilitate resilient, thriving communities. Our citizens, our businesses, and our local and regional economies cannot afford to wait.

"Floods are 'acts of God,' but flood losses are largely acts of man."

– Gilbert White, known as the father of floodplain management

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I. Purpose

On January 29, 2013, President Obama signed into law the Disaster Relief Appropriations Act of 2013, Public Law 113-2, to assist in recovery in the aftermath of Hurricane Sandy. The Act directs the Secretary of the Army to "…*conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas that were affected by Hurricane Sandy within the boundaries of the North Atlantic Division of the Corps*…." The study area includes the District of Columbia and the 10 States that were impacted by Hurricane Sandy: New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, and Virginia.

The purpose of the North Atlantic Coast Comprehensive Study (NACCS) is to identify flood risk and plan and implement strategies, in collaboration with others, to reduce that risk now and in the future. Action is needed to reduce the risk from, and make the North Atlantic region more resilient to, the impacts of future storms and sea level change. Hurricane Sandy could have been more devastating. Initial "damages prevented" estimates shortly after the storm suggest that existing coastal storm risk management infrastructure prevented some $1.9 billion in damages (USACE 2012). The NACCS will help the region to prepare now for future storms, climate change (including sea level change), and other increasing risks.

THE GOALS OF THE NACCS ARE:

- Provide a risk management framework, consistent with National Oceanic and Atmospheric Administration (NOAA) / U.S. Army Corps of Engineers (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 manage risk to vulnerable populations, property, ecosystems, and infrastructure.

BACKGROUND

Hurricane Sandy originated as a late season hurricane in the southwestern Caribbean Sea on October 22, 2012 (Blake et al. 2013). The storm made landfall in Jamaica on October 24, 2012, as a Category 1 hurricane and strengthened to a Category 3 hurricane in eastern Cuba on October 25, 2012. While over the Bahamas, it weakened to a tropical storm, but grew considerably in size. The system strengthened to a Category 1 hurricane while it moved northward, parallel to the coast of the southeastern United States (Figure I-1). The storm continued to increase in size to a diameter of more than 1,000 nautical miles, making it the largest diameter storm recorded in the Atlantic basin. On October 29, 2012, the remnants of Hurricane Sandy in the form of a post-tropical cyclone made landfall near Brigantine, NJ.

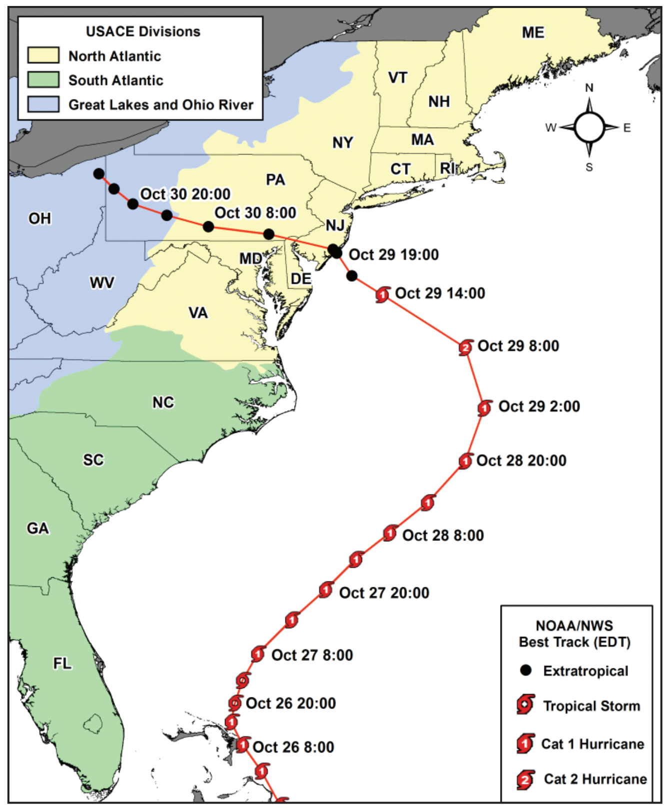

Figure I-1. Hurricane Sandy Track, October 26 – 29, 2012

The storm drove a catastrophic storm surge into the New Jersey and New York coastlines. National Ocean Service tide gages at Kings Point on the western end of Long Island Sound and the Battery on the southern tip of Manhattan measured storm surges of 12.65 feet and feet above normal tide levels, respectively (Blake et al. 2013). Storm surge is an abnormal rise of water above normal tide levels generated by the storm whereas storm tide is the total observed water level during the storm due to the combination of surge and astronomical tide (NOAA 2013a). This surge was accompanied by powerful and damaging waves, especially along the coast of central and northern New Jersey, Staten Island, and southern-facing shores of Long Island. With the landfall of Hurricane Sandy coinciding with high tide, tide gages in the New York City area measured record storm tides. These storm tides resulted in flood depths of as much as 9 feet in Manhattan, Staten Island, and other low-lying areas within the New York Metropolitan Area (Blake et al. 2013).

With estimated damages of $65 billion, Hurricane Sandy is the second costliest hurricane in the Nation's history and the largest storm of its kind to hit the U.S. east coast. Twenty-six States were impacted by Hurricane Sandy, with Major Disaster declarations issued in 13 (NOAA 2013b).

HURRICANE SANDY QUICK FACTS

$65 billion in damages and economic losses

159 total fatalities caused by the storm

8.5 million customers without power

650,000 homes damaged or destroyed

13 States with Major Disaster declarations

(HSRTF 2013a)

In the aftermath of Hurricane Sandy, the Federal Emergency Management Agency (FEMA) Modeling Task Force (MOTF) developed a Total Damage (Composite Surge / Precipitation / Wind Map) County Impact Analysis to define the area affected by Hurricane Sandy and document widespread economic impacts related to storm surge, intense rainfall, and high winds. Figure I-2 provides a color-coded overview of impacts using the following criteria:

- Very High (Purple): County population greater than 10,000 experienced storm surge flooding impacts.
- High (Red): County population of 500 to 10,000 experienced storm surge impacts, or modeled wind damages greater than $100 million, or precipitation greater than 8 inches.
- Moderate (Yellow): County population of 100 to 500 experienced storm surge impacts, or modeled win damages of $10 to $100 million, or precipitation of 4 to 8 inches.
- Low (Green): No storm surge impacts or modeled wind damages less than $10 million or precipitation less than 4 inches.

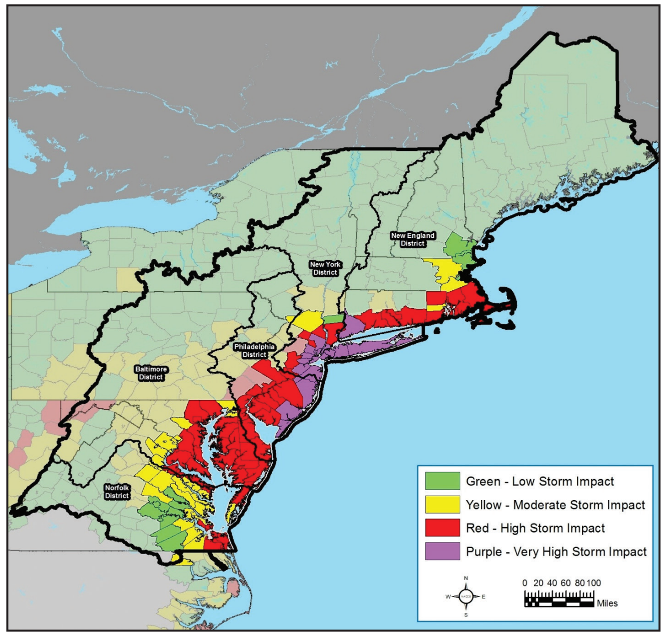

Figure I-2. Areas Impacted by Hurricane Sandy with Highlighted Counties Included in NACCS Study Area (FEMA MOTF 2013)

The FEMA MOTF data for the post-Hurricane Sandy impact analyses are available online at https://content.femadata.com/GISData/MOTF/Hurricane%20Sandy/.

New York and New Jersey were the most seriously impacted States, with the greatest damages and the most fatalities occurring in the New York Metropolitan Area. New York had 48 direct fatalities, followed by 12 in New Jersey, 5 in Connecticut, 2 each in Pennsylvania and Virginia, and 1 each in New Hampshire, West Virginia, and Maryland (Blake et al. 2013). Authorities ordered mandatory evacuations in areas vulnerable to storm surge throughout the region, affecting more than 500,000 people, including 370,000 in New York City alone. By October 31, 2012, 8.5 million customers were without power and approximately 20,000 residents were in shelters across the region. At least 650,000 houses were either damaged or destroyed as a result of the storm, with the vast majority of the damage caused by storm surge and/or waves. Many of the 8.5 million customers who lost power remained without power for weeks or even months in some areas. Telecommunications were seriously affected, with approximately 25 percent of cell towers across all or part of 10 States and the District of Columbia out of service. Extensive flooding and lack of power shut down business and commerce for several days, including the New York Stock Exchange, which closed for 2 days.

OVERVIEW OF THE NACCS

A key product developed as part of the NACCS is the Coastal Storm Risk Management Framework (the Framework). The NOAA/USACE Infrastructure Systems Rebuilding Principles, which were developed following Hurricane Sandy (NOAA and USACE 2013), provide the foundation for the Framework and include:

- Working together in a collaborative manner across multiple scales of governance (including Federal, Tribal, State, and local) and with relevant entities outside of the government to develop long-term strategies that promote public safety, protect and restore natural resources and functions of the coast, and enhance coastal resilience;
- Improving coastal resiliency by pursuing a systems approach that incorporates natural, social, and built systems as a whole; and
- Promoting increased recognition and awareness of risks and consequences among decision-makers, stakeholders, and the public.

The Framework and supporting analyses offer a coastal storm risk management methodology for stakeholders to increase resilient planning and adapt to increasing risk. This methodology includes risk, exposure, and vulnerability analyses and results in long-term coastal management strategies. The NACCS presents the results of large-scale risk and exposure assessments for the NACCS study area using the Framework, as well as various risk management measures and opportunities for multi-agency action and further evaluation.

The Framework also describes the methodology to evaluate risk, exposure, and vulnerability to flood hazards at a smaller, State- and community-level scale. Developing and implementing comprehensive coastal storm risk management solutions is a shared responsibility. The Framework addresses increasing risk as a system of strategies and measures to manage coastal storm risk and promote resilience.

The NACCS provides:

- An analysis of sea level and climate change scenarios, and a discussion of how those scenarios might affect coastal populations, infrastructure, ecosystems, and implementation of risk management strategies;
- Significant advancements in coastal hydrodynamic modeling, economic benefit pools, and analyses of natural and nature-based features (NNBF);
- A list of areas warranting further analysis; and
- A list of institutional and other barriers to providing "protection to affected coastal areas".

In response to specific provisions included in Public Law 113-2, USACE prepared and submitted two interim reports to Congress. Public Law 113-2 also required an evaluation of the performance of existing projects constructed by USACE and affected by Hurricane Sandy. The First and Second Interim Reports and the Hurricane Sandy Coastal Projects Performance Evaluation Study are available online at www.nad.usace.army.mil/CompStudy.

The study area's 31,200 miles of coastline was delineated into 39 planning reaches (Figure I-3) considering State boundaries, predominant shoreline types, and other features. Maine was not included in the Framework analyses because minimal impacts from storm surge were documented as part of the FEMA MOTF Hurricane Sandy Impact Analysis. Additionally, the USACE Hurricane Sandy Coastal Projects Performance Evaluation Study included an assessment of 13 USACE coastal storm risk management projects in northern Massachusetts and Maine, and noted that Hurricane Sandy was generally less than a 20 percent flood with negligible damages to project features. Based on minimal impacts and the authorization language that defined the study area as areas affected by Hurricane Sandy, Maine was not included as part of the NACCS study area. Regardless, as the Maine coastline is primarily affected by nor'easters and periodically by tropical storms and hurricanes, stakeholders and communities could apply the Framework to address flood risk as well as utilize the various products generated as part of the NACCS.

Figure I-4 depicts the overall process and timeline of the NACCS. As shown, the study was conducted in three major phases. Phase 1 identified the people, property, and environmental and cultural resources at risk to coastal flooding, as well as the measures available to potentially manage coastal storm risk. Phase 2 involved extensive interagency collaboration and refinement of the analyses. Phase 3 included the internal agency reviews and final refinements prior to the submittal to Congress in January 2015. The internal review process included numerous staff from the five USACE North Atlantic Division Districts, North Atlantic Division, USACE Headquarters, the Office of the Assistant Secretary of the Army for Civil Works, the Office of Management and Budget, and the Council on Environmental Quality (CEQ). Other Federal agencies provided valuable input and comments as part of the NACCS refinements during Phase 3. These agencies included the U.S. Department of the Interior (DOI), National Park Service, U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), NOAA, and FEMA.

For general communication purposes, the term "coastal storm risk management" as used in this report applies to terms used in typical USACE and other Federal and State reports, including, but not limited to, shore protection, flood risk management, hurricane and storm damage reduction, and coastal storm damage reduction.

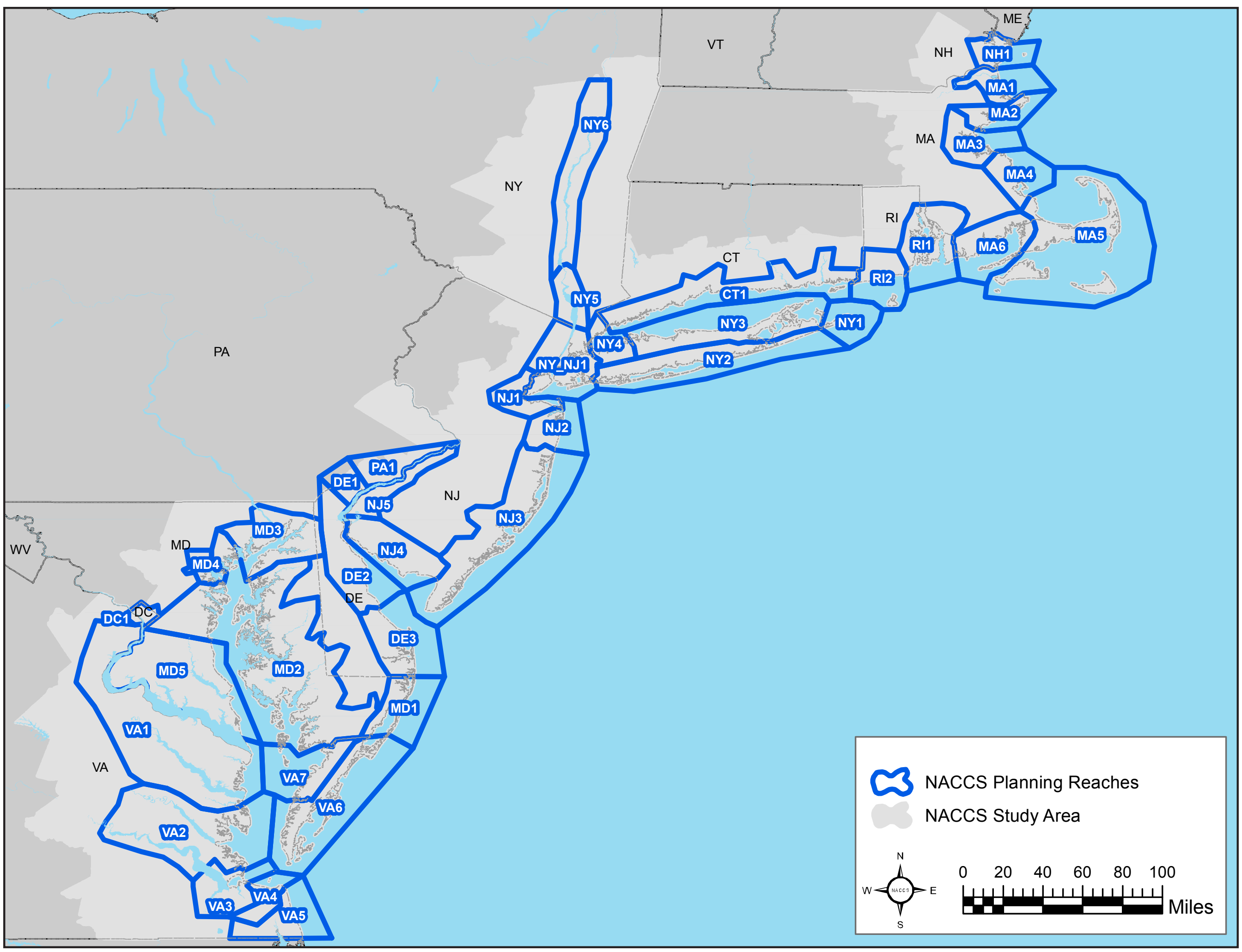

Figure I-3. NACCS Planning Reaches

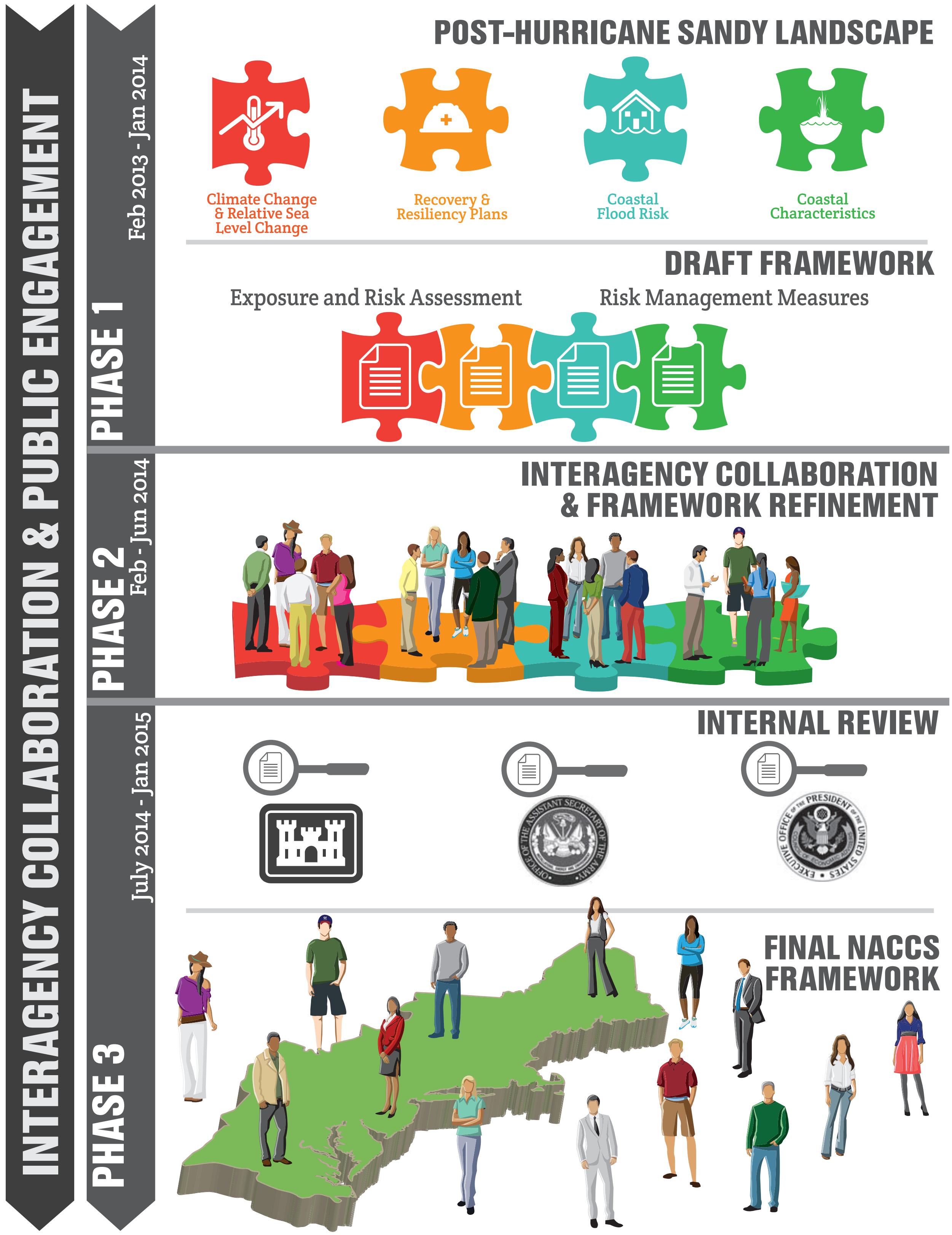

Figure I-4. NACCS Process Flowchart

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II. Findings, Outcomes, and Opportunities

Findings, outcomes, and opportunities were identified as part of the NACCS using an intensive, collaborative approach that included a number of Federal and State agencies, nongovernmental organizations (NGOs), and tribes, as well as alignment with ongoing and planned actions.

FINDINGS

The NACCS is based on the study and examination of a great amount of new information pertaining to all facets of coastal storm risk management. The following conclusions emerged from this effort.

Addressing coastal storm risk is a shared responsibility

Developing and implementing comprehensive **coastal storm risk management solutions is a shared responsibility** among Federal, State, regional, and Tribal entities; NGOs; academia; business and industry; local governments; and the public. Addressing coastal storm risk requires responsible evacuation planning and rethinking approaches to land use and use of floodplains, systems planning, risk communication, Federal and State assistance programs, cost sharing, and related local, regional, State, and Federal policies, as well as coordination with private land owners during implementation of coastal storm risk management solutions.

Vulnerability and residual risk continue to increase in the North Atlantic region

Numerous **populations, infrastructure, local and regional economies, ecosystems**, and other significant assets in the North Atlantic region are increasingly vulnerable to coastal storm damage and impacts from sea level change. Areas most vulnerable include those with high populations and urban areas. Risk communication is critical to convey existing and potential future risk.

Improved coastal storm risk management measures are needed

Employing three primary strategies—**avoid, accommodate, and preserve**—coastal communities should consider a system of **comprehensive, resilient, and sustainable** coastal storm risk management measures. The system should include a **combination of measures** (structural, NNBF, and nonstructural measures) to form **resilient, redundant, robust, and adaptable strategies** and measures (Figure II-1) that promote life safety based on local site conditions and societal values.

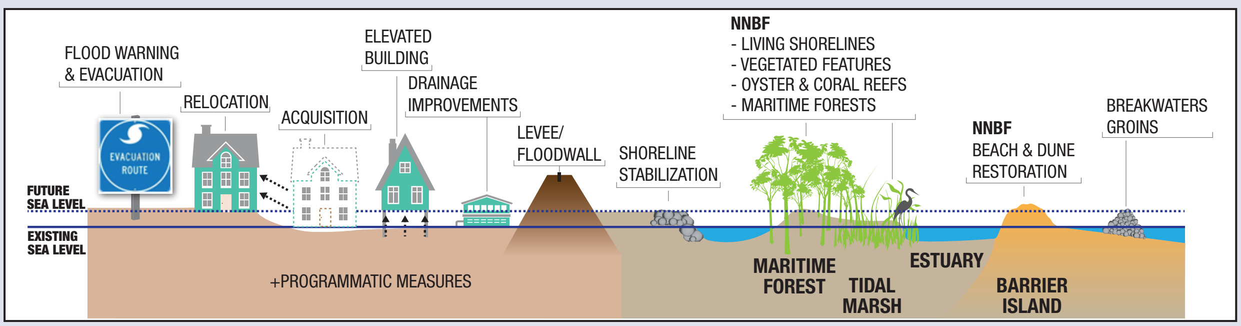

Figure II-1. Combinations of Adaptable Measures That May Be Used to Improve Redundancy, Robustness, and Resilience Associated with Coastal Flood Risk Management (not to scale)

Sea level change is affecting the nature of fluvial and coastal flooding interactions

One of the important data gaps identified by the NACCS is how sea level change will affect communities and their existing stormwater infrastructure. Sea level change will alter the ability of streams and rivers to convey rainfall to coastal bays and estuaries and may increase the frequency and severity of inland and coastal flooding from rainfall.

Interior, low-lying shorelines are susceptible to small changes in water levels

Low-lying areas with large populations and/or critical infrastructure are particularly vulnerable to sea level change.

OUTCOMES

The NACCS provides products, strengthened relationships, and outcomes to assist in coastal storm risk management planning. The outcomes outlined below represent a high level of cooperation at all levels of government that will facilitate implementation of future coastal storm risk management actions.

Coastal Storm Risk Management Framework	**The Coastal Storm Risk Management Framework** was applied to one example area in each State and the District of Columbia (State and District of Columbia Analyses Appendix) to identify vulnerable areas and communities and strategies for comprehensive pre-disaster planning, risk management, and resilience. Further, the Framework itself is transferable to other vulnerable areas, such as the South Atlantic and Gulf of Mexico coasts where storm surge and sea level change are major threats.
A common framework leading to best practices and validation of solutions	Partners and stakeholders can implement near-term demonstration projects using the **common framework** presented in this study. These projects will support the development of valuable **best practices** and expertise to **validate solutions** aimed at reducing coastal flooding risk and promoting resilient measures.
Interagency collaboration	**Interagency collaboration** has strengthened the dialogue on resilient approaches and will continue to inform coastal storm risk management planning and implementation.
Advanced the state-of-the-science	NACCS technical products **advanced the state-of-the-science**. These products are available for coastal storm risk management and planning, and can be used to revisit the scope and purpose of authorized USACE projects. Ongoing studies, plans, and design efforts can immediately utilize the NACCS outcomes/products/tools, including all projects identified in First and Second Interim Reports and the Performance Evaluation Study.[1] The analyses and technical products will inform and could potentially **expedite future investigations**. Further, the NACCS products can be used for other vulnerable areas, such as the South Atlantic and Gulf of Mexico coasts where storm surge and sea level change are major threats.

[1] In response to specific provisions included in Public Law 113-2, USACE prepared and submitted two interim reports to Congress.

What remains of a home in the Rockaways in Queens, NY after one of many fires caused by Hurricane Sandy

Source: Brandon Beach, USACE

OPPORTUNITIES

NACCS identifies and emphasizes a number of opportunities to increase coastal resilience. These opportunities, which include some nontraditional approaches to coastal storm risk management, are outlined below.

Identify acceptable levels of risk	**Communities and agencies must identify their acceptable level of residual risk** to plan for long-term, comprehensive, and resilient risk management. Existing programs for technical assistance include, but are not limited to, the USACE Floodplain Management Services and interagency Silver Jackets Programs.
Encourage dynamic collaboration	As knowledge of climate change, relative sea level change, and risk assessments continues to evolve, **dynamic and collaborative partnerships at the Federal, State, local, and Tribal levels are critical to mitigating future risk**.
Develop creative incentives	Developing **creative incentives** is necessary to spearhead the use of an array of resilient measures. Such incentives include, but are not limited to, enhanced cost sharing for evacuation, floodplain, and pre-storm planning; prioritized funding for initiatives with diverse partnerships or for areas demonstrating wise use of floodplains; and similar efforts.
Promote public-private partnerships[1]	**Public-private partnerships** should be explored to strengthen the resilience of coastal communities and their supporting economies, environments, and infrastructure.
Focus and prioritize limited resources	A **prioritized plan, including a system of coastal storm risk management infrastructure and supporting authority and policies**, may be considered to help focus limited resources on solutions and strategies that reduce damages to critical infrastructure. Redundant features that incorporate resilience of methods and materials to address storm risk should be considered based on the benefits and costs of the additional investment.
Rebuild with redundancy and robustness to increase resilience	**Rebuilding with redundancy and robustness** will increase resilience during more frequent, lower magnitude storm events and potentially more extreme storms.
Improve implementation of Natural and Nature-Based Features (NNBF)	Opportunities exist in the North Atlantic coastal region to integrate Federal and State data to **improve implementation of NNBF and blended solutions where appropriate**.
Quantify the economic value and services produced by NNBF	There is a need to **quantify the collateral economic value and services** produced by NNBF, including coastal storm risk management, ecosystem goods and services, and their contributions to system resilience to further the science of overall benefits that NNBF serve for coastal communities.
Provide for strategic monitoring and adaptive coastal storm risk management	Policy development and planning and designing of coastal storm risk management features should incorporate input from strategic monitoring efforts. Input from strategic monitoring will bolster **flexibility and adaptive management** of existing and future coastal storm risk management projects, including the USACE projects referenced in the First and Second Interim Reports.

OPPORTUNITIES (CONTINUED)

Continue analyses in focus areas	**Nine high-risk focus areas (Figure II-2) identified in the NACCS warrant additional analysis**: Rhode Island Coastline; Connecticut Coastline; New York – New Jersey Harbor and Tributaries; Nassau County Back Bays, NY; New Jersey Back Bays, NJ; Delaware Inland Bays and Delaware Bay Coast, DE; City of Baltimore, MD; the District of Columbia; and the City of Norfolk, VA.
Relay transparent and actionable information	Comprehensively **monitor coastal conditions** and **provide actionable information** to regional, State, local, and public entities to facilitate shared solutions and increase awareness of coastal conditions.

[1]Public-private partnerships generally refer to relationships between the public sector and a private entity for the financing, design, construction, renovation, management, operation, and/or maintenance of public infrastructure and/or the provision of public services (Abt Associates 2014).

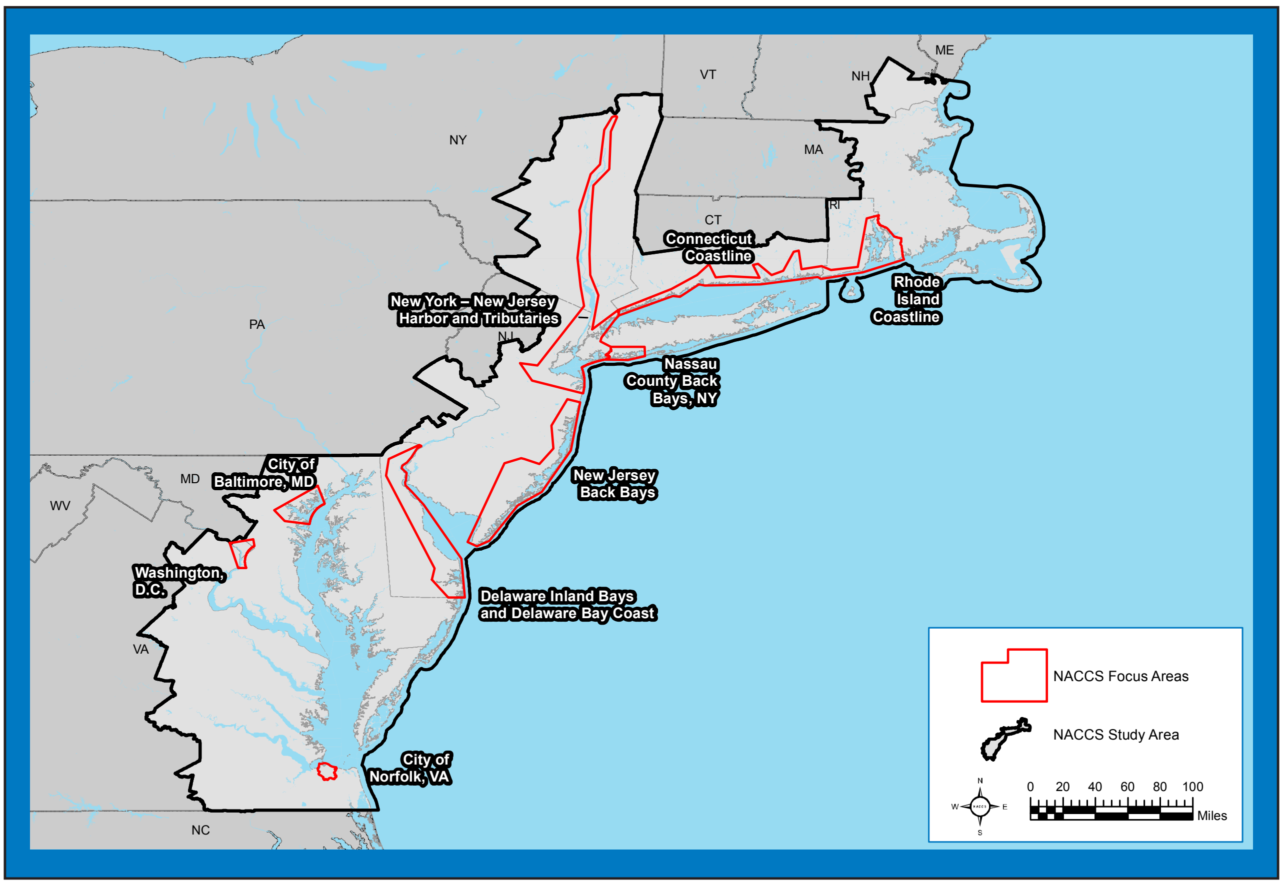

Figure II-2. NACCS Focus Areas

III. Interagency Alignment and Consistency with Other Plans

Throughout the development of the NACCS, significant resources were dedicated to coordination and collaboration with others. The study is consistent with, and was conducted in collaboration with, Federal, NGO, Tribal, State, and local partners. Public Law 113-2, Chapter 4 specified: "… that the Secretary shall conduct the study in coordination with other Federal agencies, and State, local, and Tribal officials to ensure consistency with other plans to be developed, as appropriate…." In the scoping stages of the study, an Engagement and Communication Strategy was prepared to provide a comprehensive framework for planning, integrating, and executing all communication associated with the NACCS.

Goals of the engagement and communication strategy were to:

- Increase the understanding of the purpose and expected outcomes of the NACCS;
- Receive input and feedback from stakeholders;
- Facilitate open communication among agencies, tribes, congressional interests, media, and the public by keeping them informed about the status of the NACCS; and
- Provide a forum to deliver a consistent message to diverse audiences that include Federal, State, Tribal, and nongovernmental stakeholders.

STAKEHOLDER INPUT AND DIALOGUE

Interagency points of contact and subject matter experts were identified in early 2013 to assist in preparing the scope of the study and engage in data gathering and development of analyses as part of the NACCS. Table III-1 lists the requested input. Interagency subject matter experts were also embedded in various subteams (engineering,

Table III-1. Requests for Information and Verification

Requested Input	Date	Purpose
State Verification of Post-Hurricane Sandy Landscape Letter	May 23, 2013	Request State confirmation of post-Hurricane Sandy projects and anticipated projects such that future exposure and risk can be properly assessed.
NACCS Public website and News Release	May 28, 2013	Provide background, status, technical information, subscribers list, and opportunity to provide input on resiliency measures.
NACCS Formal Initiation Letter to Federal, State, Tribal and Nongovernmental Stakeholders	June 6, 2013	Provide general background and request post-Hurricane Sandy data or regional strategies, as well as a point of contact information.
Federal Register Notice	June 19, 2013	Notify stakeholders of the NACCS and opportunities for input.
State Historic Preservation Officers Letter	August 1, 2013	Request review and validation of cultural resources characterization.
State, Tribes, and Subject Matter Expert Verification of Exposure Analyses Letter	September 4, 2013	Request review and validation of exposure mapping and methodology.
State Verification/Input on State Appendices	October 1, 2013	Request review and verification of existing State and post-Hurricane Sandy conditions, as well as most vulnerable areas.
Federal Register Notice	October 4, 2013	Solicit peer-reviewed data.
Tribal Coordination Webinars	December 17, 2013	Answer questions and solicit input.
United South and Eastern Tribes (USET) Tribal Meeting, ME	June 1, 2014	Present the NACCS and solicit input.

environmental, NNBF, sea level change, etc.) supporting the NACCS. Details on agency representation and public engagements are included in the Agency Collaboration Report located at http://www.nad.usace.army.mil/CompStudy.

An Interagency Collaboration Webinar Series provided stakeholders with an overview of the topics being considered in the NACCS, which resulted in early feedback used to refine the analyses. The webinars provided an opportunity for stakeholders to ask questions and obtain answers, as well as for discussion among participants. Webinar attendance ranged from 70 to 130 participants each, depending on the topic, and webinars were recorded for future reference. Table III-2 lists the webinars by topic. All webinar materials are posted on the NACCS website: http://www.nad.usace.army.mil/CompStudy.

Floating Debris in the Battery Park Underpass in lower Manhattan, NY on November 2, 2012

Source: http://www.army.mil/media/270702

Table III-2. Interagency Collaboration Webinar Series

Webinar Topic	Date	Purpose
Natural and Nature-Based Features (NNBF)	July 30, 2013	Provide an overview of how NNBF infrastructure is being applied to the NACCS and obtain relevant input or data from interagency partners.
Ecosystem Goods and Services	August 29, 2013	Introduce the processes necessary to evaluate ecosystem goods and services produced from NNBF coastal storm risk management measures.
Numerical Modeling and Sea Level Rise	September 12, 2013	Provide information on the NACCS effort to develop numerical models for evaluating future scenarios and determining the probability of future Hurricane Sandy events based on historical coastal storm forcing parameters.
Exposure and Risk Assessments	September 25, 2013	Provide information on the NACCS effort related to the development of coastal risk metrics, coastal flooding exposure assessment, and problems, needs, and identification of opportunities.
Institutional Barriers and Policy Challenges	December 19, 2013	Provide preliminary results of policy challenges to comprehensive coastal storm risk management, including the use of NNBF, as identified through personal interviews and literature reviews.
Comprehensive Collaboration of Draft NACCS Analyses	March-April 2014	Describe the compilation of analyses based on all prior coordination and NACCS development, and solicit validation of data, data gaps, etc. Included one overview webinar and three webinars focusing on specific topics associated with the NACCS.
Regional Sediment Management and a Systems Approach to Coastal Flood Risk Management and Resilience	June 24, 2014	Describe the results of the conceptual sediment management budget for the Atlantic Ocean and major estuarine reaches within the North Atlantic Division of the U.S. Army Corps of Engineers, case studies associated with regional sediment management and NNBF, and discussion of a systems approach as well as public-private partnerships to address coastal storm risk and promote resilience.
General Overview of the NACCS	August 14, 2014	Present the results of the NACCS draft report, with a focus on the Coastal Storm Risk Management Framework, technical products supporting the Framework, and a systems approach and resilience accounting for potential future impacts from each level change and climate change. The discussion was also intended to align with The Infrastructure Security Partnership's Regional and Infrastructure Resilience Committee's three strategic objectives, which include: • Facilitate education and knowledge transfer; • Advance operational and functional resilience of communities and the built environment through regional and State partnerships; and • Enable existing and new partnerships for regional, State, local, and private sector collaboration in achieving resilience planning and improvements, advocating critical infrastructure security and resilience, and incorporating resilience management into an effective lifecycle risk management model.

Table III-3 presents in-person working meetings that occurred to address the state of the science and determine future needs and best approaches. A series of visioning sessions were held in the focus areas that are identified and described in the State and District of Columbia Analyses Appendix. The purpose of these meetings was to continue dialogue with the States and other stakeholders to develop a shared vision to address coastal storm risk and promote resilience. These meetings reaffirmed that coastal storm risk management is a reality faced by many stakeholders throughout the study area. For the majority of the meetings, three general topics were discussed, including vulnerability, potential solutions, and institutional/policy change related to coastal storm risk. For each particular topic, participants were asked a question in a small group and then asked to provide written responses. On the topic of vulnerability, the question posed to the groups was, "How is your community (or agency/organization) most vulnerable to coastal storm risk?" The overwhelming majority of responses listed aging infrastructure as the top vulnerability, and natural systems and resources as the second most common vulnerability. The other two topics included discussion of potential solutions to those vulnerabilities and institutional/policy changes that could potentially increase coastal resiliency. The most common responses and themes for both topics were related to "community scale" and "building scale" measures. The community scale measures included proper zoning and land use regulations, floodplain management to limit development and redevelopment after a disaster, as well as community retreat. A summary of the participant responses and the most prominent common themes identified during the visioning and partnering meetings is included in the State and District of Columbia Analyses Appendix. Additionally, more information about NACCS coordination efforts can be found in the Interagency Coordination and Collaboration Report, located on the NACCS website (http://www.nad.usace.army.mil/CompStudy).

Various media outlets, including The Weather Channel, Newsday, and PBS Nova, featured the NACCS in interviews with NACCS team members. These engagements and panel sessions provided more opportunities to share information about the NACCS, expose stakeholders to the website, and provide input.

Tribes represent an important stakeholder group and were included in many of the coordination efforts. Existing communication channels between USACE District Tribal liaisons and tribes were enlisted in addition to the engagements and forums described above. Liaisons regularly participated in webinars and communicated with the Tribal entities to ensure they were fully aware of and integrated into the study efforts. USACE representatives attended the United South and Eastern Tribes (USET) Meetings in October 2013 and June 2014. The Water Resources Reform and Development Act of 2014 directed the USACE to extend coordination efforts beyond Federal and State agencies, NGOs, and tribes, to also include historically black colleges and universities (HBCUs). In July 2014, 27 HBCU, tribal college, and university stakeholders received the NACCS draft report for review and comment.

Collaboration opportunities and data-sharing discussions occurred during the NACCS efforts. Coordination meetings and discussions with various NGOs and their various committees took place as various post-Hurricane Sandy efforts initiated in earnest in 2013, including discussions with the Conservation Fund, the Nature Conservancy, the Audubon Society, the Association of State Floodplain Managers, and the American Shore and Beach Preservation Association. In addition, USACE coordinated with State Historical Preservation Offices across the study area. Cultural resources and other national/historic places along the North Atlantic Coast may also be at risk to coastal flood peril and impacts from sea level change. The USACE coordination and collaboration effort completed as part of the NACCS with a myriad of stakeholders serves a foundation for future collaboration efforts needed to meet the ongoing challenge to address coastal storm risk and promoting resilient communities.

Table III-3. Technical Working Meetings

Topic	Date	Purpose
North Atlantic Coast Comprehensive Study Numerical Engineering Modeling of Future Scenarios Meeting	June 12–13, 2013, Polytechnic Institute of New York University	Develop models for coastal flooding, storm surge, wave systems, and climate change.
Reducing Risk and Building Resiliency following Hurricane Sandy	June 26–27, 2013, Stevens Institute of Technology	Develop strategies to reduce risk and increase the resilience of communities affected by Hurricane Sandy in 2012.
Policy Challenges to Using Natural and Nature-Based Features (NNBF) for Risk Reduction and Resiliency	November 20, 2013, U.S. Army Corps of Engineers Institute for Water Resources	Identify institutional barriers and policy challenges to implementing NNBF to support comprehensive risk reduction and resilience.
Technical Considerations in Using NNBF to Support Coastal Resilience and Risk Reduction	November 22–23, 2013, Hall of States, Washington, DC	Share diverse approaches and best practices, and receive input on evaluating NNBF, performance metrics for goods and services produced, knowledge gaps, etc.
Focus Area Visioning Sessions (7 Visioning Sessions and 2 Partnership Meetings)	January–March 2014	Continue dialogue with the States and other stakeholders to develop a shared vision for resiliency in response to risk and exposure, building on the previous discussions and information compiled to date.

Additional information on working meetings can be found on the NACCS website (http://www.nad.usace.army.mil/CompStudy).

INTERAGENCY ALIGNMENT

Table III-4 lists various agencies and organizations that participated during the study. Coordination and alignment initiatives included presentations, working meetings, and webinars.

Table III-4. Interagency, NGO, and Tribal Alignment Initiatives

Agency	Alignment Initiative(s)
Connecticut, Massachusetts, New Hampshire, and Rhode Island Coastal and Environmental State Agencies	Participated in NACCS working meetings and webinars and reviewed interim analyses and processes.
Conservation Fund and Audubon Society	Presented and aligned the Saving the Salt Marshes of Blackwater National Wildlife Refuge (NWR) report with the NACCS.
U.S. Environmental Protection Agency (EPA)	Coordinated with various subject matter experts, participated in NACCS working meetings and webinars, and reviewed interim products.
Federal Climate Partners for the Mid-Atlantic and the New England Federal Partners	Participated in briefings on the development of the NACCS.
Federal Emergency Management Agency (FEMA)	Coordinated with subject matter experts, attended NACCS working meetings and webinars, and reviewed interim products analyses.
Joint Field Offices (New York and New Jersey)	Provided the recovery support strategies to help align risk management strategies and measures with the NACCS.

Table III-4. Interagency, NGO, and Tribal Alignment Initiatives (continued)

Agency	Alignment Initiative(s)
Maryland Department of the Environment (MDE)	Participated in a presentation of innovative uses of green/nature-based features at a technical working meeting.
Maryland and District of Columbia Silver Jackets[1] Teams	Participated in NACCS working meetings and webinars and reviewed interim analyses and processes.
Mid-Atlantic Regional Ocean Council	Coordinated with subject matter experts and reviewed interim analyses.
National Fish and Wildlife Foundation (NFWF)	Provided the post-Sandy report, *Assessing the Impacts of Hurricane Sandy on Coastal Habitats* (NFWF 2012) to aid in the development of the environmental conditions.
National Oceanic and Atmospheric Administration (NOAA)	Embedded a NOAA team member on the Communications and Community Visioning Sessions. Reviewed sea level change analyses, participated in modeling working meeting, coordinated on use of Geographic Information System (GIS) data, and provided the Community Resiliency Survey for reference in the NACCS report.
New York City	Presented *A Stronger, More Resilient New York* to the NACCS team. The NACCS is consistent with the strategies presented in the New York City report.
NOAA–Urban Waters Initiative	Shared preliminary data on exposure areas such that the U.S. Department of the Interior (DOI) could align urban waters criteria and grant funding to vulnerable areas.
North Atlantic Landscape Conservation Cooperative – DOI / U.S Fish and Wildlife Service (USFWS) / North Atlantic Landscape Conservation Cooperative (NALCC)	Attended a briefing on the NACCS and participated in interagency validation, by reviewing analyses and confirming that they align with the organization's understanding of the topic.
Northeast Regional Ocean Council	Participated in NACCS working meetings and webinars.
The Nature Conservancy (including State offices)	Previewed Coastal Resilience 2.0 and validated alignment between the tool and the NACCS products.
United South and Eastern Tribes (USET)	Participated in the October 2013 USET meeting. Offered an opportunity to present the NACCS to the Culture & Heritage and Natural Resources committees of USET at the June 2, 2014, meeting. Participated in review of the NACCS.
U.S. Department of Housing and Urban Development (HUD) Task Force	Provided the Task Force Report, so that the U.S. Army Corps of Engineers (USACE) could align actions identified in the *Hurricane Sandy Rebuilding Strategy* Report into the NACCS.
U.S. Department of Transportation (DOT)	Participated in the June 2013 NACCS measures working meeting.
USFWS	Produced a Planning Aid Report for the NACCS and hosted an NNBF Webinar in coordination with USACE.
USFWS – Hurricane Sandy Coastal Resiliency Competitive Grant Program	Coordinated with NACCS team to ensure requests for funding were not for duplicative efforts or for data collection occurring as part of NACCS.
U.S. Geological Survey (USGS)	Provided the USGS Coastal Vulnerability Index for use in the NACCS risk assessment and GIS data coordination.

[1]The Silver Jackets program provides an opportunity to consistently bring together multiple State, Federal, and sometimes Tribal and local agencies to learn from one another and apply their knowledge to reduce flood risk.

Figure III-1 presents the various interagency initiatives, strategies, and reports with which the NACCS is consistent.

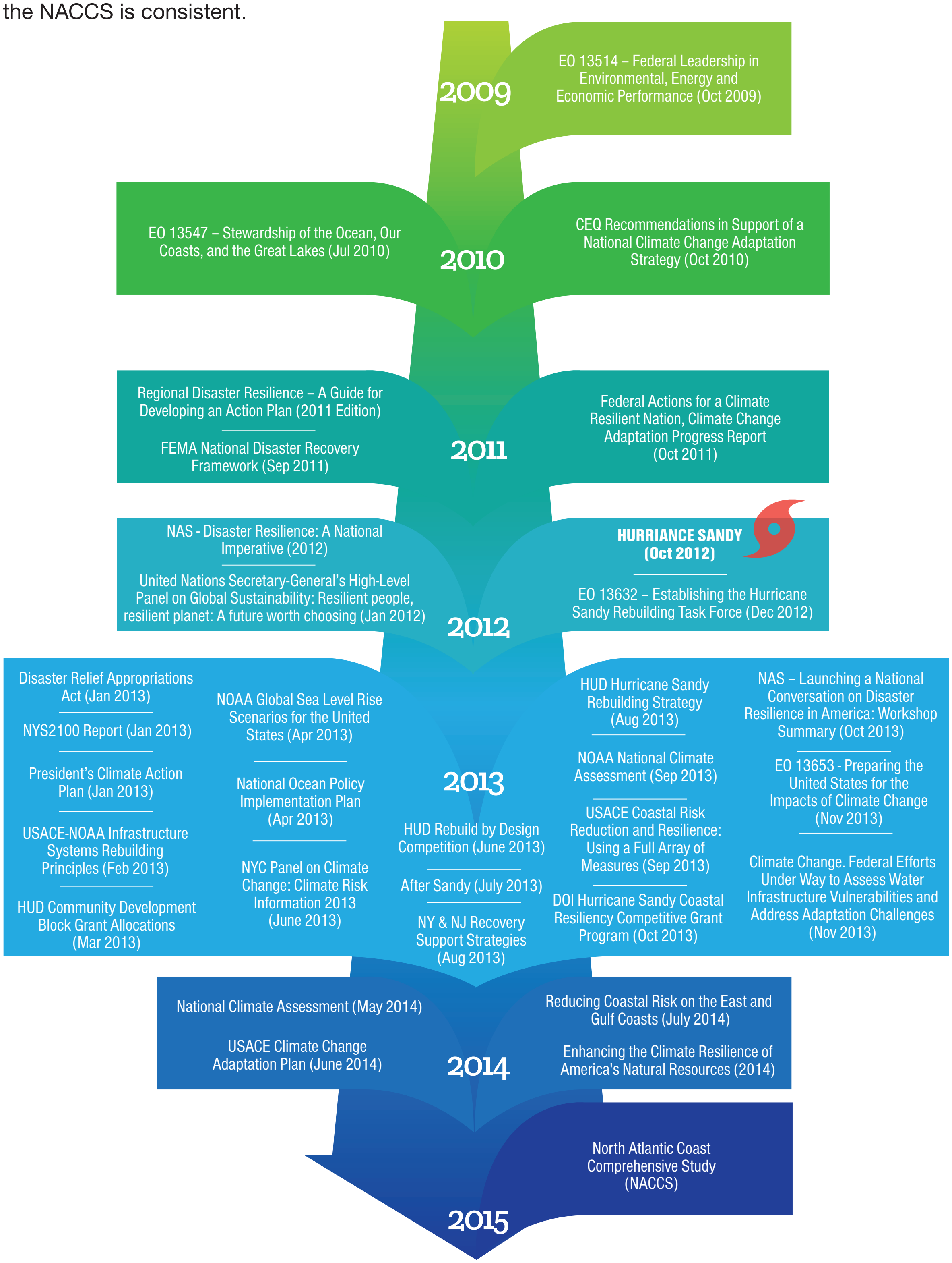

Figure III-1. NACCS Alignment with Interagency Plans and Strategies

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For a typical feasibility study leading to an agency recommendation, the USACE plan formulation process includes identifying problems and opportunities, forecasting future conditions, identifying solutions, and evaluating and comparing solutions to determine a recommended plan for action or implementation. Such a plan would evaluate coastal storm risk within the context of forecasted future conditions and potential effects of sea level change and would include estimates of damage associated with flood inundation, wave action, and erosion. Additional investigation and evaluation of strategies, solutions, and plans at a smaller scale would be required for and should also be considered more broadly within a systems perspective. The NACCS is not a typical USACE feasibility study. Rather, the NACCS developed technical products and the Framework that presents the steps to assist with the identification of coastal storm risk, exposure, vulnerability, and the coastal storm risk management strategies and measures to reduce risk and promote resilience.

OVERVIEW OF THE FRAMEWORK

The Framework is a three-tiered evaluation (Figure IV-1). Tiers 1, 2, and 3 are defined by different scales, objectives to address flood risk, and stakeholders for input and feedback. The NACCS presents a large-scale application of the Framework in the evaluation of risk and exposure for the North Atlantic Coast study area (Tier 1). For consistency across State boundaries, national datasets were used to complete the Tier 1 evaluation. These datasets include the USGS National Hydrography Dataset and 10-meter digital elevation model, NOAA's Environmental Sensitivity Index data (shorelines), the Homeland Security Infrastructure Program Gold data layers, USFWS National Wetland Inventory, The Nature Conservancy Ecoregional Priorities, and the U.S. Census Data. Given the scale, the datasets are likely not as refined as State or local datasets, which is why the steps are repeated as part of a Tier 2 (State and large watershed scale) and Tier 3 (local and small watershed scale) evaluation. Furthermore, the NACCS application of the Framework does not include steps 6 through 9, which require refined datasets and analysis as well as refined objectives and constraints for evaluation at a smaller scale (Tier 2 and/or Tier 3).

In Tier 2 and Tier 3, the Framework steps are repeated and adapted to a smaller, community-specific scale, incorporating refined datasets and societal value for exposure, risk, and vulnerability assessments. Example Tier 2 evaluations were completed for nine States in the study area and the District of Columbia to present applications of the Framework at a smaller scale. A Tier 2 evaluation example is not included for the Commonwealth of Pennsylvania. The example Tier 2 evaluations do not include refined exposure and risk assessments. Rather, the Tier 1 exposure and risk assessments were used with refined assumptions only related to coastal storm risk management measures. The results of the example Tier 2 evaluations are presented in the State and District of Columbia Analyses Appendix.

A Tier 3 evaluation would likely include a benefit- to-cost ratio analysis leading to the selection of a plan. The Framework can also be used in anticipation of future storms and for climate change adaptation planning. Long-term flood risk and vulnerability should be considered when addressing current flood risk and vulnerability solutions.

The following paragraphs provide an overview of the Framework steps that were completed as part of the NACCS. This section describes the steps in general and is followed by sections with more detailed discussion. Presentation of the results of the Tier 1 application of the Framework represents an evaluation of flood risk, including storm surge, erosion, and wave action, and does not include an evaluation of potential impacts from wind or interior drainage analyses.

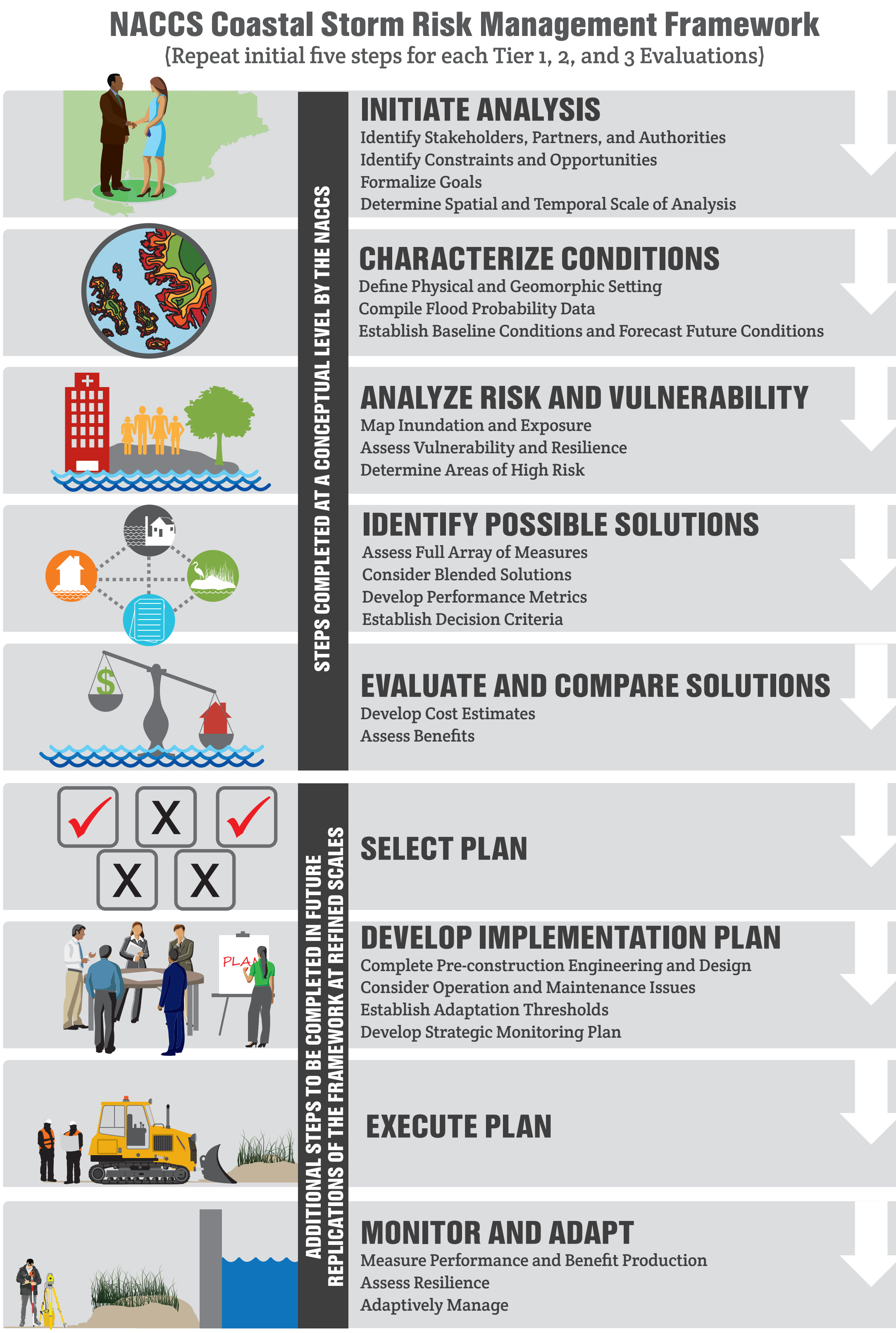
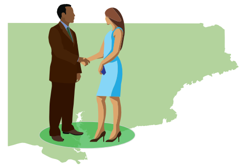


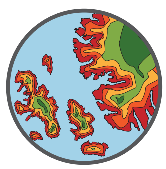
Figure IV-1. Coastal Storm Risk Management Framework

Initiate Analysis



In early 2013, interagency points of contact and subject matter experts were identified to assist in preparing the scope for the NACCS and to be engaged in data gathering and development of analyses. Various individuals associated with the National Disaster Recovery Framework Joint Field Offices (established in New York and New Jersey following Hurricane Sandy) were among the many points of contact and subject matter experts. Numerous Federal and State agency representatives involved in coastal storm risk management activities as well as Silver Jackets Teams in several of the study area States also engaged in the process. In preparation of the scope, various interagency stakeholders provided feedback on the goals, opportunities, and constraints.

Characterize Conditions



More than 31,200 linear miles of coastal shoreline were delineated into 39 planning reaches as shown in Figure I-3. The reach delineations are based on State boundaries, similar shoreline types, similar geomorphic features, and the extent of existing or planned coastal storm risk management projects. Forecasting the post-Hurricane Sandy landscape involved identifying the status of existing and planned coastal storm risk management efforts anticipated by 2018 as well as the future inundation conditions, taking into account climate change and relative sea level change over a 100-year time horizon.

Analyze Risk and Vulnerability

Risk is an overarching concept that considers hazard, exposure, performance of coastal storm risk management features, subsequent consequences, and vulnerability. The NACCS defines risk of coastal flood peril using flood inundation mapping. Exposure to flood peril is defined as the presence of people, infrastructure, and/or environmental resources (receptors) affected by potential coastal flooding. Vulnerability is defined as the degree to which a system's receptors or assets are susceptible to, and unable to cope with, the adverse effects of coastal flooding over a period of time. Vulnerability is a function of the character and magnitude of a hazard (i.e., coastal storm flooding) to which the community is exposed; the sensitivity of the population, infrastructure, and environmental resources in the community; and the capacity of the community to recover and regain full functionality or design capacity. The NACCS presents a large scale evaluation of coastal storm risk for the North Atlantic coastline. This assessment identifies coastal flood hazards and proposes a method by which to identify and evaluate measures that could reduce or manage the risk. The extent of the flood hazard and what is exposed to the flood peril help further define the problems and opportunities. The Framework provides a process to identify the flood hazard from coastal storms, forecasted impacts from sea level and climate change, and various assets exposed to the flood hazard, as well as a process to assess vulnerability.

Identify Possible Solutions – Coastal Storm Risk Management Strategies and Measures

Structural, nonstructural, NNBF, and programmatic measures were evaluated to determine which may be applicable to the different shoreline types. Shorelines throughout the study area were assigned shoreline types using available Geographic Information System (GIS) mapping.

Evaluate and Compare Solutions

As indicated by the NACCS Findings in Section II, improved coastal storm risk management measures are needed throughout the study area. The Tier 1 evaluation included cost-efficiency analyses that compared the potential reduction in risk to the relative costs of the measures. In coordination with State stakeholders, example areas were identified to present a refined application of the Framework. This second stage refinement, or the Tier 2 evaluation, within each State demonstrates how individual measures may be combined to provide more comprehensive risk management and more resilient communities. The State and District of Columbia Analyses Appendix includes the risk assessments for each of the reaches.

Further site-specific analyses would constitute Tier 3 local evaluations.

Illustration of Framework Application

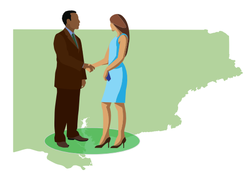
Because of the extensive damage that occurred as a result of Hurricane Sandy in highly developed areas of the New York and New Jersey metropolitan area, the following sections detail the application of the NACCS Tier 1 Framework for the NY_NJ1 Reach, with particular focus on the Jamaica Bay and Rockaway Peninsula (NACCS Risk Area NY_NJ1_I).

Although the Tier 1 evaluation identifies some areas as having relatively higher vulnerability, the methodology presented by the Framework is applicable for subsequent analyses to all coastal communities of the North Atlantic Coast, as well as other coastal areas like the South Atlantic or Gulf Coasts.

Based on an evaluation and comparison of solutions, Framework users select a coastal storm risk management plan, which includes provisions for implementation of adaptation strategies as well as subsequent monitoring and adaptive management. These last four steps are applicable to a detailed Tier 2 or 3 evaluation and not the regional Tier 1 application.

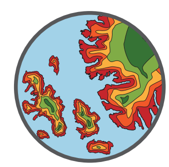
The following sections provide a detailed description of the initial five framework steps applied in the NACCS as part of a Tier 1 evaluation.

INITIATE ANALYSIS



Public Law 113-2 provided authority and appropriated funding for USACE to initiate analyses associated with the NACCS. Numerous points of contact and subject matter experts were identified as part of the stakeholder identification process and for further collaboration. Stakeholders expressed interest in collaborating with USACE and assisted with the development of the NACCS goals, identification of constraints and opportunities, and the determination of the spatial and temporal scale of analyses as part of the scoping process. The collaboration effort completed as part of the NACCS would continue as part of subsequent Tier 2 or Tier 3 evaluations, as well as other ongoing initiatives.

CHARACTERIZE CONDITIONS – THE POST-HURRICANE SANDY LANDSCAPE



The Planning and State and District of Columbia Analyses Appendices, as well as the *NACCS Environmental and Cultural Resources Conditions Report*, describe existing conditions of the NACCS study area.

Hurricane Sandy Response in New York and New Jersey

Following Hurricane Sandy, Federal, State, and local government agencies and NGOs initiated a major response and recovery effort to repair, replace, and restore homes, industry, and critical infrastructure under the National Disaster Recovery Framework developed by FEMA. This effort has changed the physical and cultural landscape of the impacted areas and has altered the social and political awareness of the potential impacts of future storms.

On January 29, 2013, President Obama signed the Disaster Relief Appropriations Act (Public Law 113-2), which provided approximately $50 billion in funding to support rebuilding. That Act made available $16 billion in Community Development Block Grant (CDBG) funds (later reduced to $15.18 billion due to sequestration) for necessary expenses related to disaster relief, long-term recovery, restoration of infrastructure and housing, and economic revitalization in the most impacted and distressed areas resulting from a major disaster declared pursuant to the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1974 (42 U.S.C. 5121 et seq.) due to Hurricane Sandy and other eligible events in calendar years 2011, 2012, and 2013.

> $3.8 billion was provided to more than 270,000 individuals and 3,900 businesses through Small Business Administration recovery loans and FEMA Individual Assistance.

On May 13, 2013, HUD approved the State of New Jersey's CDBG-DR Action Plan for an initial $1.83 billion for housing and business recovery programs. HUD allocated an additional $1.46 billion on May 30, 2014.

On February 6, 2013, HUD allocated $5.4 billion in CDBG Disaster Recovery funding to five states and New York City, representing the first round of CDBG grants from the Disaster Relief Appropriations Act of 2013 signed into law by President Obama on January 29. On October 28, 2013, HUD allocated a combined $5.1 billion through a second round of recovery funds to five states and New York City. On May 30, 2014, HUD announced a third round of grant funding, totaling more than $2.5 billion, to help four states and New York City continue recovering from Hurricane Sandy. In these three allocations, HUD awarded $4.42 billion to New York State, $4.21 billion to New York City, $4.17 billion to New Jersey, $159 million for Connecticut, $29 million for Maryland, and nearly $20 million for Rhode Island. Each grantee was required to submit an action plan describing the unmet recovery needs from Hurricane Sandy and the planned use of the funds.

In recognition of the rebuilding challenges facing the region, President Obama signed Executive Order 13632 on December 7, 2012, creating the Hurricane Sandy Rebuilding Task Force (HSRTF), and designated the Secretary of HUD, Shaun Donovan, as Chair. President Obama charged the Task Force with identifying and working to remove obstacles to resilient rebuilding while taking into account existing and future risks and promoting the long-term sustainability of communities and ecosystems in the Hurricane Sandy-affected region.

In August 2013, the HSRTF released the Hurricane Sandy Rebuilding Strategy. This strategy established guidelines for the investment of Federal funds for the recovery of the impacted region. These funds are to be used for recovery and to build back smarter and stronger with the following outcomes in mind:

- Align this funding with local visions for rebuilding.
- Cutting red tape and getting assistance to families, businesses, and communities efficiently and effectively, with maximum accountability.
- Coordinate the efforts of the Federal, State, and local governments to ensure a region-wide approach to rebuilding.
- Ensuring the region is rebuilt in a way that makes it more resilient – that is, better able to withstand future storms and other risks posed by a changing climate.

INCORPORATING REDUNDANCY WILL ENHANCE REGIONAL RESILIENCE:

"We also need to design and plan for more redundancy [in] our transportation system, to enhance regional resilience so that when one part of the system goes down, other parts can pick up the slack. We could see the importance of this in the reaction to Hurricane Sandy."

– John Porcari, former Deputy Secretary, U.S. Department of Transportation, in November 6, 2013, briefing to the U.S. House of Representatives, Subcommittee on Emergency Management, Intergovernmental Relations, and the District of Columbia

The Disaster Relief Appropriations Act allocated $13.1 billion (later reduced by $650 million due to sequestration) to the U.S. Department of Transportation (DOT) and $10.2 billion to the Federal Transit Administration for a new Public Transportation Emergency Relief Program. On November 6, 2013, John Porcari, Deputy Secretary, DOT, addressed the U.S. Senate, highlighting the agency's role in recovery, rebuilding, and improving resilience. Mr. Porcari proposed building transportation systems that are more resilient in the face of high winds and storm surges and that provide transportation agencies with better information, new designs, and tools to enhance the resilience of their infrastructure and the ability to address problems in a regional way. A sample of specific initiatives related to resiliency and redundancy are highlighted below:

- November 2014 – The Federal Transit Administration announced the selection of $3.592 billion in public transportation resilience projects in the area impacted by Hurricane Sandy. Projects were selected subsequent to a December 2013 notice of funding availability and competitive process;
- Gateway Project – an initiative to expand rail capacity from New Jersey into New York Penn Station; and
- River-to-River Rail Resiliency – an initiative to manage risk to the East River Tunnels and Penn Station, which are used by the Metropolitan Transportation Authority Long Island Rail Road as well as Amtrak and New Jersey Transit.

Hurricane Evacuation Planning and Floodplain Management

Avoiding flood risk is important to effectively address coastal storm risk to communities. Evacuation planning addresses flood risk avoidance. Various evacuation studies have identified potential hurricane storm surge inundation, evaluated evacuation routes, and identified locations of hurricane shelters and hospitals outside the potential hurricane surge areas. Despite such evacuation planning, some residents do not heed evacuation warnings and orders, such as the many residents of the New York City Housing Authority who chose to shelter in place during Hurricane Sandy (City of New York 2013).

Hurricane evacuation studies identify the potential inundation possibilities for worst case storm events to identify segments of communities to evacuate. The studies evaluate the appropriate evacuation routes to maximize the efficiency of evacuation efforts prior to the storm event. Evacuation planning is a necessary part of emergency management preparations for coastal storms (among other hazard mitigation strategies for communities) to avoid having people stranded in areas experiencing direct damage from coastal storms. With increasing and aging populations in coastal communities, evacuation planning and ways to encourage residents residing in flood prone areas will continue to be an increasingly important measure to address coastal storm risk. Some States and New York City host websites devoted to evacuation that include online viewers of coastal storm risk and flooding, such as New York City's http://maps.nyc.gov/hurricane/. However, effective local floodplain management could potentially reduce the risk of flood peril even before the next storm event occurs. Communities at risk of flood peril have the regulatory authority to address local land use, zoning, and building codes to avoid siting development in floodplains. Additional information on hurricane evacuation studies is included in the State and District of Columbia Analyses Appendix.

Coastal Storm Risk Management Projects

The post-Hurricane Sandy physical landscape reflects major investments by governments and NGOs to restore and expand coastal storm risk management projects. In response to the Disaster Relief Appropriations Act, the USACE prepared the following three reports to document the status of various projects:

- First Interim Report, USACE projects that are constructed or under construction (March 11, 2013);
- Second Interim Report, USACE projects authorized but not constructed and projects under study (May 30, 2013); and
- *Hurricane Sandy Coastal Projects Performance Evaluation Study* of constructed USACE coastal storm risk management projects (November 6, 2013).

The purpose of the First Interim Report was to provide the Committees on Appropriations of the House of Representatives and Senate with an assessment of authorized constructed projects and projects under construction. The purpose of the Second Interim Report to was to list previously authorized but unconstructed USACE projects as well as any potential USACE project under study by USACE to address coastal storm flooding risks. Table IV-1 provides a summary of the current and anticipated USACE projects in the high-impact States of New York and New Jersey. The table presents how the results of the two interim reports were incorporated into the USACE post-Hurricane Sandy landscape, identifying those existing projects, projects under construction when Hurricane Sandy occurred, authorized but unconstructed projects that would be funded for construction under Public Law 113-2, USACE investigations that were underway when Hurricane Sandy occurred that may lead to a determination of Federal interest to pursue construction authorization and appropriations, and those USACE projects that were not included in the First and Second Interim Reports.

The Hurricane Sandy Coastal Projects Performance Evaluation Study identified numerous USACE projects that did not eliminate the flood risk associated with Hurricane Sandy in the New York–New Jersey metropolitan area, but did reduce damage despite the fact that the storm tides and waves that Hurricane Sandy generated exceeded the design of the projects. Projects that were intended to provide coastal storm risk management, including seawalls, levees, and closure gates to prevent inundation, provided effective damage reduction. However, in many locations, heavily developed areas on the bayside of many projects (and non-project areas)

Table IV-1. Current and Anticipated USACE Projects in New York and New Jersey

PROJECT	Constructed Projects (From Interim Report[1])	Projects Under Construction (From First Interim Report)	Authorized but Unconstructed Projects (From Second Interim Report)	Projects Under Study[2,5] with High Probability of Implementation[3] (From Second Interim Report)	Projects not Included in Public Law 113-2 (First and Second Interim Reports)
Asharoken, NY (CAP S 103)[4]					Constructed
Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, NY (FIMP)			X		Constructed
Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, NY (FIMP): West Of Shinnecock Inlet Interim[6]		X			
Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, NY (FIMP): Westhampton Interim[6]					Constructed
Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, NY (FIMP): Fire Island to Moriches Interim[6]			X		
Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, NY (FIMP): Downtown Montauk Interim[6]			X		
Atlantic Coast of New York City, East Rockaway Inlet to Jones Inlet, NY (Rockaway)			X		
Atlantic Coast of New York City, East Rockaway Inlet to Rockaway Inlet, NY (Rockaway)[6]	X		X		
Atlantic Coast of New York City, Rockaway Inlet to Norton Point, NY (Coney Island)[6]			X		
Fire Island and Shores Westerly to Jones Inlet, NY (Gilgo Beach)	X				
Hashamomuck Cove, NY				X	
Jamaica Bay, Marine Park & Plumb Beach, NY					Unconstructed
Mattituck Inlet, NY (CAP S 111)					Constructed
Montauk Point, NY[6]			X		
Oakwood Beach, NY (CAP S 103)	X				
Orchard Beach, NY					Constructed
Orient Harbor, NY State Road 25 (CAP S 14)					Constructed
Point Lookout/Jones Inlet, NY (CAP S 204)					Constructed
Plumb Beach, NY (CAP S 204)					Constructed
Joseph G. Minish Waterfront Park and Historic Area, NJ[6]			X		
Passaic Main Stem, NJ			X		
Passaic River Tidal Protection Area, NJ[6]			X		
Port Monmouth, NJ[6]			X		

Table IV-1. Current and Anticipated USACE Projects in New York and New Jersey (continued)

PROJECT	Constructed Projects (From Interim Report[1])	Projects Under Construction (From First Interim Report)	Authorized but Unconstructed Projects (From Second Interim Report)	Projects Under Study[2,5] with High Probability of Implementation[3] (From Second Interim Report)	Projects not Included in Public Law 113-2 (First and Second Interim Reports)
Raritan Bay and Sandy Hook Bay: Keansburg, East Keansburg, and Laurence Harbor, NJ	X				
Sandy Hook to Barnegat Inlet, NJ (Elberon to Loch Arbour)[6]			X		
Sandy Hook to Barnegat Inlet, NJ (Sea Bright to Ocean Township and Asbury Park to Manasquan)[6]		X			
South River, Raritan River Basin, NJ[6]			X		
Union Beach, NJ[6]			X		
Barnegat Inlet to Little Egg Harbor Inlet, NJ			X		
Brigantine Inlet to Great Egg Harbor Inlet, NJ (Absecon)[6]	X		X		
Brigantine Inlet to Great Egg Harbor Inlet, NJ (Brigantine Island)	X				
Cape May Inlet to Lower Township, NJ	X				
Delaware Bay Coastline, Oakwood Beach, NJ[6]			X		
Delaware Bay Coastline, Reeds Beach and Pierces Point, NJ					Unconstructed
Delaware Bay Coastline, Villas, and Vicinity, NJ					Unconstructed
Great Egg Harbor Inlet to Peck Beach, NJ	X				
Great Egg Harbor Inlet to Townsends Inlet, NJ[6]			X		
Hereford Inlet to Cape May Inlet, NJ				X	
Lower Cape May Meadows/Cape May Point, NJ					Constructed
Manasquan Inlet to Barnegat Inlet, NJ[6]			X		
Townsends Inlet to Cape May Inlet, NJ	X				

[1] Jamaica Bay Natural/Nature-Based Features will be evaluated for coastal storm risk management in the Rockaway-Jamaica Bay General Re-evaluation Report effort. Jamaica Bay sites that are screened from the Rockaway-Jamaica Bay General Re-evaluation Report would be advanced via the regular Civil Works program and be included in the Hudson Raritan Estuary Feasibility Study.

[2] Projects under study may be constructed with Public Law 113-2 funds if the Office of the Assistant Secretary of the Army (Civil Works) determines the recommended project is technically feasible, economically justified, and environmentally acceptable and if there are sufficient Public Law 113-2 funds to complete initial construction of the project.

[3] For projects with high probability of implementation, the estimate of 5 years to complete construction is acceptable for regional planning purposes.

[4] CAP = Continuing Authorities Program

[5] There are other ongoing USACE projects to address coastal storm risk that will not be completed by the year 2018 and are not included in this list.

[6] Project identified as a General or Hurricane Sandy Limited Reevaluation Report (HSGRR/HSLRR) in PL 113-2, Disaster Relief Appropriations Act

were subject to back bay flooding and widespread inundation damage, primarily because the storm tide propagated through inlets. Projects in these areas were not authorized or formulated to comprehensively manage flood risks from the back bay. As noted in Section II, these bayside areas remain at risk of future flooding and impacts from sea level change. Moreover, risk communication is extremely important for local communities that may have existing coastal storm risk management infrastructure in place. As noted in the *Hurricane Sandy Coastal Projects Performance Evaluation Study*, infrastructure projects could experience storm conditions that exceed the design capacity, resulting in potential failure. Effective operation and maintenance; redundant flood risk management measures, such as elevating structures and floodproofing; and evacuation planning could assist those areas landward of the project to address life safety concerns should a project or a feature of a project fail to perform as designed.

In addition to the information in the interim reports and Performance Evaluation Study, data provided by various States, counties, and local municipalities were instrumental in developing an inventory of existing coastal storm risk management projects and studies. Navigation, ecosystem restoration, and economic development efforts were also included in the inventory of projects if they were related to coastal resilience or represented significant social and economic investments in the Nation's coastlines. Letters were mailed to Federal, State, Tribal, and non-governmental agencies in June 2013.

Figure IV-2 presents the inventory of existing USACE and State coastal storm risk management, coastal ecosystem restoration, and navigation projects for the study area. A more detailed discussion of Federal and State projects is provided in the State and District of Columbia Analyses Appendix, which includes input received from State, Tribal, and non-government agencies in response to the request for information made in June 2013. The Coastal Systems Portfolio Initiative Technical Review document presents additional project information on a project-by-project basis. Additional information related to the USACE projects included in the Coastal Systems Portfolio Initiative is available online at http://cspi.usace.army.mil/.

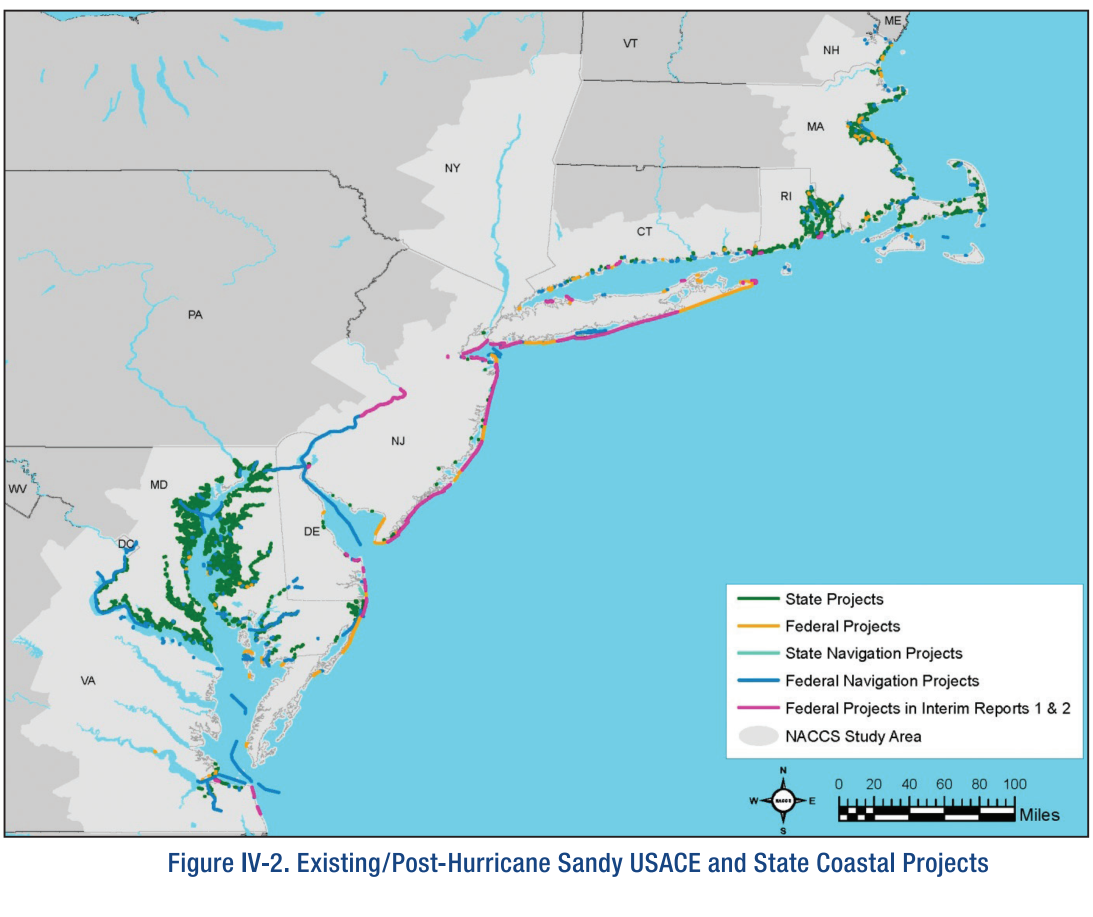


Figure IV-2. Existing/Post-Hurricane Sandy USACE and State Coastal Projects

As part of the post-Hurricane Sandy landscape, additional coastal storm risk management and resilience projects will be constructed using funds made available by Congress under Public Law 113-2. In August 2013, the DOI announced that the USFWS and the National Fish and Wildlife Foundation (NFWF) would assist in administering the Hurricane Sandy Coastal Resiliency Competitive Grants Program. The program will support projects that reduce communities' vulnerability to the growing risks from coastal storms, sea level change, flooding, erosion, and associated threats by strengthening natural ecosystems that also benefit fish and wildlife (NFWF 2013). The Hurricane Sandy Coastal Resiliency Competitive Grants Program has already provided approximately $100 million in grants for 46 proposals to those States that were affected by Hurricane Sandy. Additional information is included in the Planning Analyses Appendix.

The authorized, but unconstructed projects presented in the Second Interim Report include a design for a coastal storm risk management project as part of a recommended plan in each project's USACE decision document authorized by Congress. Within the scope and scale of the project design, modifications to incorporate features to address resilience, sea level change, and adaptation would be considered further as part of subsequent plans and specifications for the project.

Within the high-impact area of New York and New Jersey, extensive investments have been made in coastal storm risk management projects over the past five decades. These projects were designed and implemented individually with different goals and design criteria. Although coastal storm risk is managed along much of the Atlantic Ocean coast of New York City and Long Island by Federal projects, risk management improvements to these shorelines should be identified to enhance future resilience. In addition, portions of the New York and New Jersey Harbor and the Nassau County back bays are at risk and have a limited number of coastal storm risk management projects. Extensive damages from Hurricane Sandy in the New York–New Jersey area occurred as a result of back bay flooding in areas without constructed USACE coastal storm risk management projects as well as along the Atlantic Ocean coastline where water levels exceeded the design of USACE coastal storm risk management projects (USACE 2013a). In New Jersey, coastal storm risk is managed along the Atlantic Ocean coast by a number of Federal coastal storm risk management projects. However, the low-lying areas of tidal rivers, back bays, and Delaware Bay coasts have a limited number of coastal storm risk management projects.

Future Landscape Change

The landscape in the study area is constantly changing. Unfortunately, many of the past decisions affecting coastal storm risk have resulted in measures that are not readily adaptable to this changing landscape. The Framework facilitates a flexible approach that can be adapted to changing conditions or societal needs. Changes in socioeconomic, environmental, cultural, and related conditions will certainly alter coastal risks and resilience, likely in ways difficult to foresee. This uncertainty reinforces the need for adaptable strategies to accomplish the NACCS goals.

As indicated by the NACCS Findings in Section II, vulnerability and residual risk continue to increase in the North Atlantic Region as a result of the following:

- Relative sea level is increasing throughout the study area, which when coupled with fluvial flooding, increases the areas exposed to storm surge and increases the frequency of flooding.
- Shorelines are changing in response to relative sea level change and sediment deficits and excesses. Historic erosion patterns are likely to continue or accelerate.
- Atlantic Hurricanes may increase in intensity; however, climate science projections for intensity and intense hurricane numbers suggest relatively large uncertainty (NOAA 2012b).
- The population in the study area is increasing (U.S. Census Bureau 2012). The population and communities depend on infrastructure to support economic development and critical infrastructure to maintain functionality of established society. Existing infrastructure is at risk of damage from a coastal storm.
- The population in the study area is getting older. Older populations are more vulnerable during a storm.
- The extent and size of coastal storm risk management projects will increase. Many communities will respond to increased risk by

implementing projects and programs in developed areas with blended solutions, including a combination of traditional storm risk management projects, NNBF, managed retreat, and/or elevation of structures.

- Ports and the infrastructure that support waterborne commerce activities are at risk to coastal flood damages. Waterborne commerce and cargo is forecasted to increase along North Atlantic ports with the expansion of the Panama Canal. Existing and future infrastructure to support port activities, including navigation features, are at risk of coastal storm damage and impacts of sea level change.

The HSRTF announced on April 4, 2013, that all Hurricane Sandy-related rebuilding projects funded by Public Law 113-2 must meet a single uniform coastal storm risk management standard of 1 foot above the best available and most recent base flood elevation (BFE) information provided by FEMA, unless local standards are more restrictive. The NACCS incorporates this principle to consider the uncertainty of sea level and climate change. The NACCS uses evaluation scenarios for years 2018, 2068, and 2100 to consider long-term water level changes associated with sea level and climate change (the various scenarios consider impacts of climate change that would result in accelerated sea level change). The Framework also considers future population forecast scenarios for a 50-year planning horizon (2068) and projected sea level change inundation mapping.

Anticipated Impacts from Sea Level Change and Extreme Water Levels

Rising sea levels and climate change are expected to have a profound effect in the study area. Impacts will likely include shoreline retreat from erosion and inundation, increased frequency and magnitude of storm-related flooding, temperature changes, and saltwater intrusion into the estuaries and aquifers (EPA 2009a). Relative sea level change will not only inundate larger coastal areas, but will also be a driver of changes in habitat and species distribution, as will other effects of climate changes, such as increased sea surface temperatures. Additionally, the presence of developed shorelines behind many of these habitats will prevent natural barrier island overwash and migration landward in response to sea level change. Habitat changes may be structural or functional; species that depend on coastal habitats for feeding, nesting, spawning, protection, and other activities could be severely impacted if this critical habitat is converted or lost. The future without-project conditions of coastal habitats in the study area and their dependent species are discussed in more detail in the State and District of Columbia Analyses Appendix. Additional data on climate change, coastal impacts, and resilience for use by communities, businesses, and citizens is available at http://www.data.gov/climate/.

Relative Sea Level Change

Global mean sea level change over the past several thousand years is a result of the inter-glacial warming period that followed the last ice age. This warming period has caused the global mean sea level change to stabilize at an approximate rate of +1.7 millimeters per year during the 20th century (IPCC 2007, 2013). The global mean sea level change rate is expected to accelerate over the next century as a result of increases in ocean water temperatures and the rate of polar ice loss (IPCC 2014).

Local/regional land uplift (rise) and subsidence (fall) can contribute to higher or lower local relative sea level change. Variable rates of subsidence have been observed throughout the NACCS study area. These subsidence rates create relative sea level change rates that are significantly higher than the global mean sea level change rate.

The NACCS addresses sea level change in accordance with the recently-updated guidance document USACE Engineer Regulation (ER) 1100-2-8162, *Incorporating Sea Level Change in Civil Works Programs* (USACE 2013b). The USACE Sea Level Change ER refers to sea level change (rather than sea level rise) because it is meant to be applicable in all areas—including those locations where local relative sea levels are falling as a result of local/regional land uplift. Relative sea levels are rising throughout the entire NACCS study area.

The USACE ER specifies relative sea level change scenarios to be used in climate change planning and outlines the development of three relative sea level change scenarios: Low, Intermediate, and High. The USACE High scenario forecasts sea level change based on a combination of polar and glacial ice loss and ocean warming. The USACE Intermediate scenario is based primarily on ocean warming. The

USACE Low scenario is a linear extrapolation of the historical sea level change records. All three of these USACE relative sea level change scenarios are evaluated in the NACCS.

In addition, Global Sea Level Rise Scenarios for the US National Climate Assessment, a joint report by NOAA, U.S. Geological Survey, Department of Defense Strategic Environmental Research and Development Program, and USACE, recommends sea level change scenarios (NOAA 2012a). NOAA outlines four relative sea level change scenarios: Low, Intermediate Low, Intermediate High, and High. The Low and Intermediate Low NOAA scenarios are identical to the USACE Low and Intermediate scenarios, respectively. The NOAA Intermediate High falls between the USACE Intermediate and High scenarios and the NOAA High scenario is greater than the USACE High scenario. The NOAA and USACE scenarios incorporate the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report global mean sea level change projections and are consistent with the latest IPCC, Fifth Assessment Report predictions. The USACE Comprehensive Evaluation of Projects with Respect to Sea-Level Change, which is available online at http://www.corpsclimate.us/ccaceslcurves.cfm, provides additional information and a sea level change curve calculator for USACE and NOAA sea level change scenarios. Additionally, the NOAA Coastal Services Center, Digital Coast includes a sea level change online viewer, http://coast.noaa.gov/digitalcoast/tools/slr, that presents a range of potential impacts from different scenarios of inundation.

The NACCS uses the USACE Low, Intermediate, and High scenarios and the NOAA High scenario. These four scenarios are shown, starting in the year 2018, in Figure IV-3 for the Sandy Hook, NJ, NOAA tide gage, located in the center of the high-impact areas of New York and New Jersey. As indicated by the NACCS Findings in Section II, vulnerability and residual risk continue to increase in the North Atlantic region as a result of projected rise in future sea levels, regardless of the scenario considered.

Future Sea Level

The USACE Low, Intermediate, and High scenarios and NOAA High scenario were developed for the 26 NOAA gage locations across the study area that have measurement records equal to or greater than 40 years, as shown in Figure IV-3. A record length of 40 years or greater significantly decreases the erroneous sea level trends associated with decadal scale

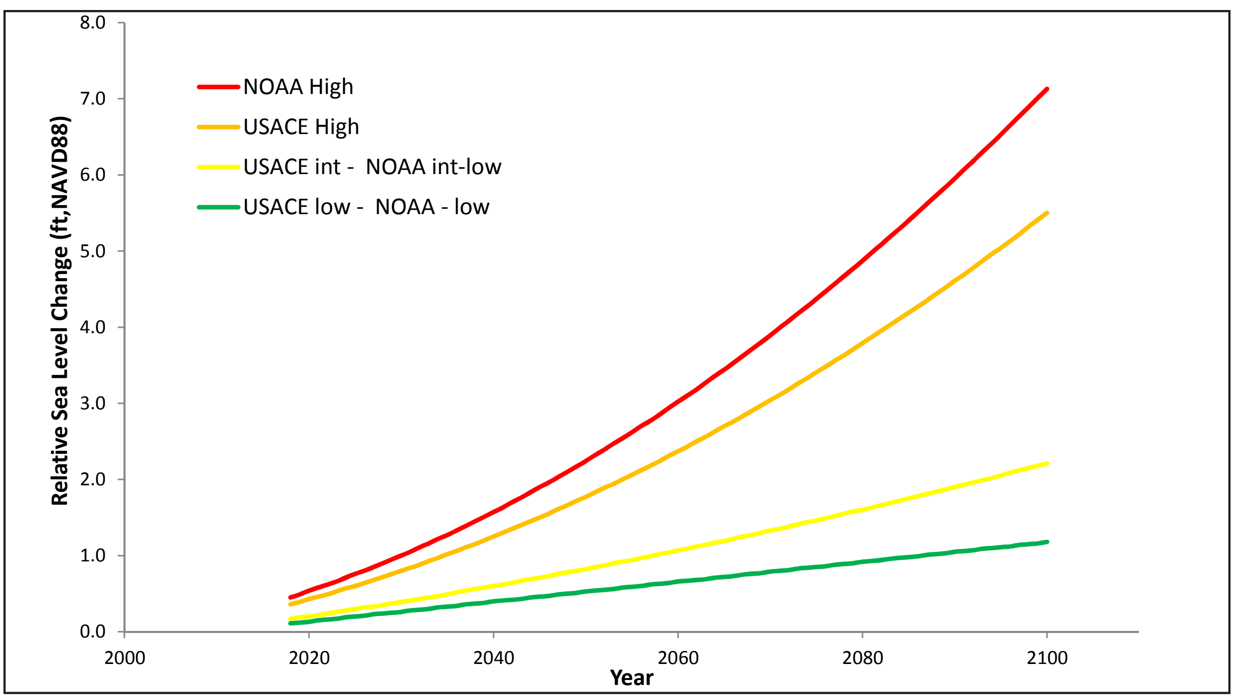


Figure IV-3. Relative Sea Level Change for Sandy Hook, NJ for USACE and NOAA Scenarios

variations in water level that are not associated with long-term mean sea level change (USACE 2013b).

The future relative mean sea level was computed for three time horizons: 2018, 2068, and 2100. For the purposes of the study, post-Hurricane Sandy USACE projects were assumed to be completed 5 years following Public Law 113-2 appropriations for construction by 2018. The year 2068 represents a 50-year, post-construction period of project performance. The year 2100 is commonly presented in science literature about sea level change as an endpoint; few projections are provided after that time. Because USACE engineering technical letter 1100-2-1 requires the consideration of a 100-year time horizon, the curves have been extrapolated beyond 2100, to 2118. However, to be consistent with various stakeholders, the analyses presented in the NACCS identify the planning horizon to year 2100. The base year was set at 1992 for all calculations, which corresponds to the midpoint of the currently used National Tidal Datum Epoch of 1983–2001. Future relative sea levels have been converted to the North American Vertical Datum of 1988 (NAVD88) at each long-term NOAA gage location in accordance with ER 1110-2-8160, *Engineering and Design: Policies for Referencing Project Evaluation Grades to Nationwide Vertical Datums* (USACE 2009b), and EM 1110-2-6056, *Standards and Procedures for Referencing Project Evaluation Grades to Nationwide Vertical Datums* (USACE 2010b). Variable rates of subsidence and local sea surface elevations associated with changes in the gulfstream have been observed within the NACCS study area, particularly in Maryland and Virginia where relative sea level change rates are the greatest (Boon et al. 2010 and Eggleston and Pope 2013). Figure IV-4 illustrates the relative sea level changes for the USACE High scenario; as shown, the maximum relative sea level changes are expected to occur in Virginia and Maryland with a generally declining trend of relative sea level change toward the north.

Table IV-2 shows future mean sea level estimates for Sandy Hook, NJ. Figure IV-5 shows areas for Reach NY_NJ1 that would be below mean sea level at three

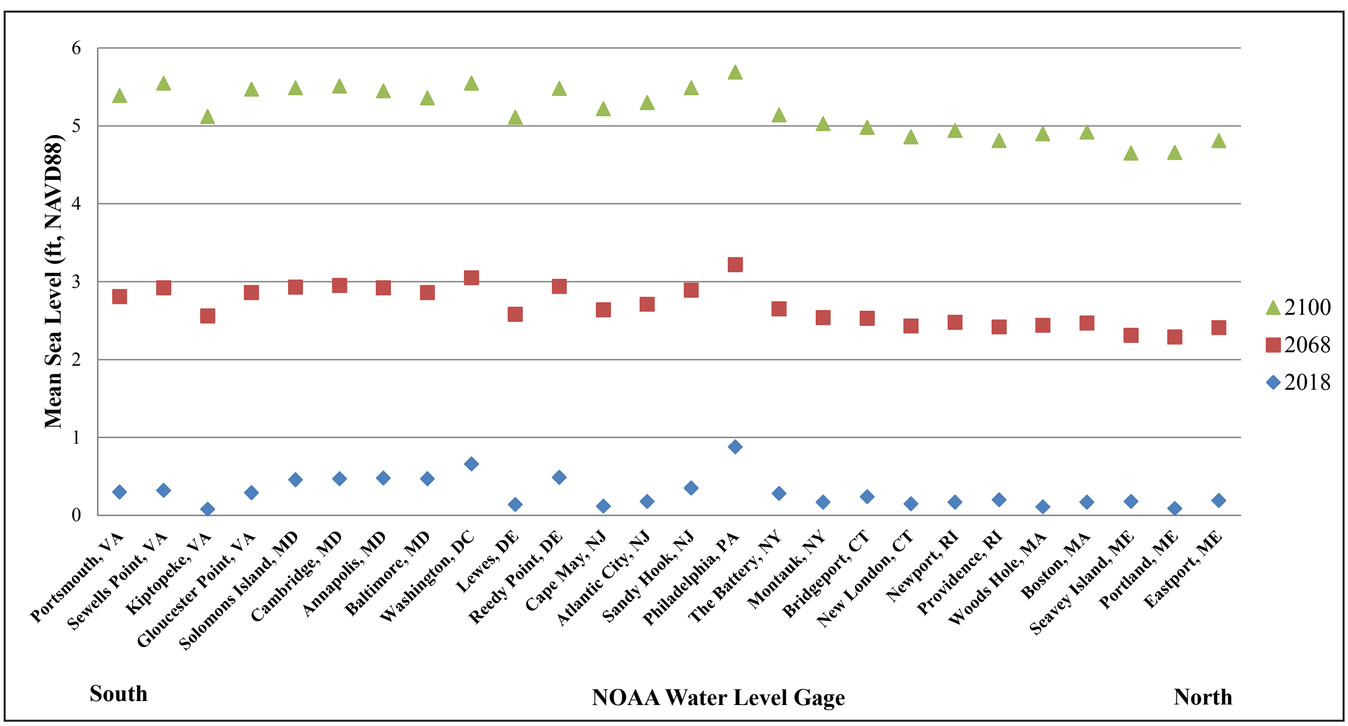


Figure IV-4. USACE High Scenario Mean Sea Levels for NOAA Gage Stations future times (2018, 2068, and 2100) based on the USACE High scenario. A complete set of future sea level tables for each scenario and time is presented in the Engineering Appendix. Sea level change mapping for the respective States is presented in the State and District of Columbia Analyses Appendix. Various

Federal and State agencies also have completed analyses to evaluate forecasted change in sea level, including USGS, which is completing similar analyses to USACE and NOAA. Additionally, some States have adopted regulatory policies for infrastructure projects based on similar analyses and forecasts. The State and District of Columbia Analyses Appendix includes additional information for each State's respective sea level change analyses completed.

Table IV-2. Future Mean Sea Level Scenarios (feet, above NAVD88) at Sandy Hook, NJ

Year	USACE Low / NOAA Low (feet above NAVD88)	USACE Int / NOAA Int-Low (feet above NAVD88)	USACE High (feet above NAVD88)	NOAA High (feet above NAVD88)
2018	0.1	0.2	0.4	0.5
2068	0.8	1.3	2.9	3.7
2100	1.2	2.2	5.5	7.1

NAVD88 = North American Vertical Datum of 1988

Marblehead, Massachusetts during Hurricane Sandy on October 29, 2012

Source: Photo by Brian Birke, Flickr.com, October 29, 2012

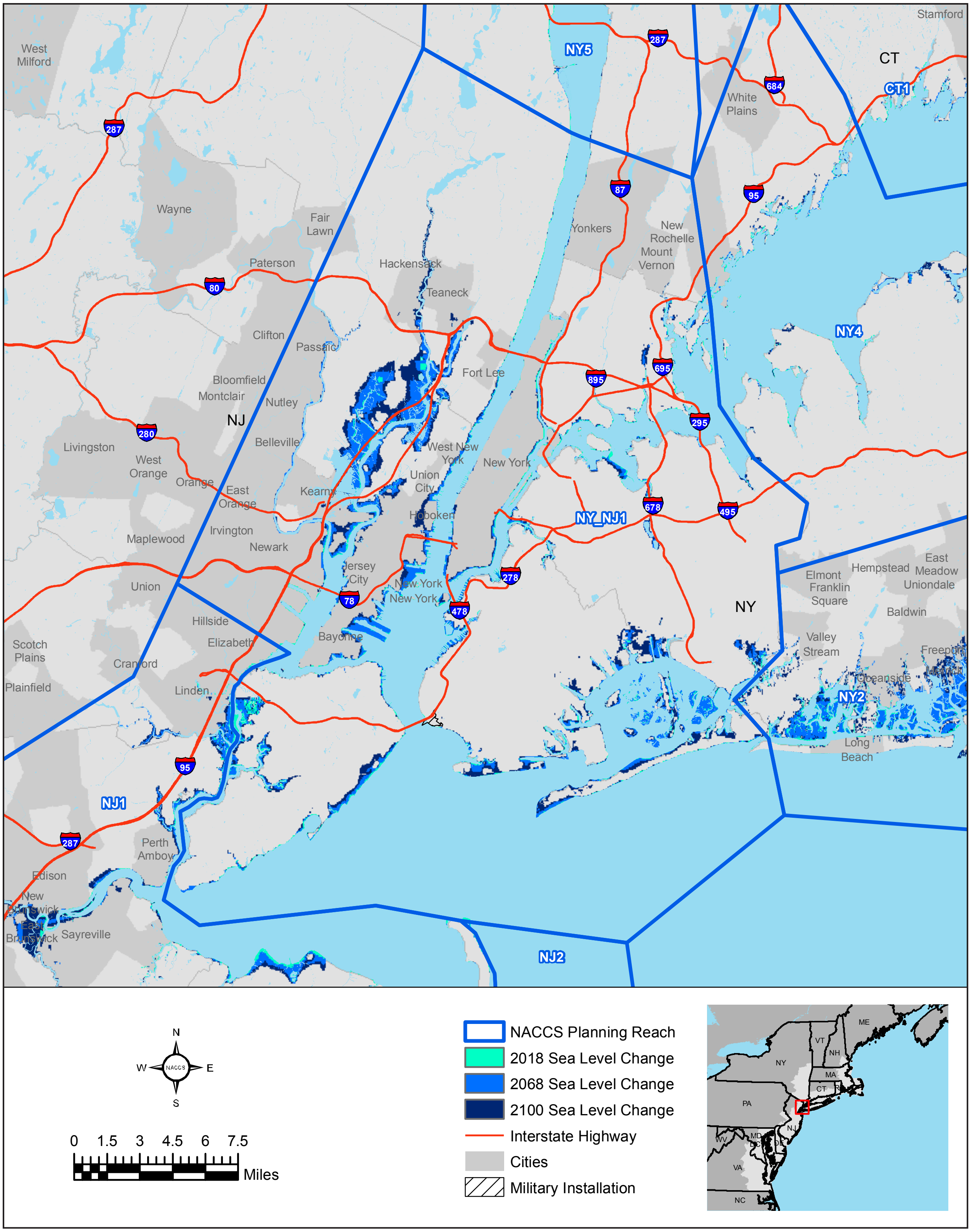


Figure IV-5. USACE High Scenario Future Mean Sea Level Mapping for Reach NY_NJ1

Population and Development Density Forecast

In most urban and suburban counties in the North Atlantic Region, the total population will likely increase by 2070. For the more rural areas or areas with agriculture as the predominant land use, such as the lower Eastern shore of Maryland and Virginia and southern Virginia's western shore, the total population will likely decrease by 2070. Coastal storm risk and residual risk will continue to increase in the region with an increasing population density as indicated by the NACCS Findings in Section II.

Inferences related to the future population and residential development increase by 2070 were evaluated using information and datasets generated as part of the U.S. Environmental Protection Agency's (EPA's) Integrated Climate and Land Use Scenarios (ICLUS) (EPA 2009b). The ICLUS data was used to derive the percent increase or decrease in total population between the 2010 Census data and the ICLUS 2070 total population projection. The residential density development forecast was then compared to the NACCS sea level change mapping for the USACE High Scenario. Figure IV-6 presents the USACE High scenario inundation and the increase in residential development forecast derived from EPA's ICLUS data.

The residential density development was computed at a national level and compared to the residential density at a smaller scale, which could potentially introduce changes in the resolution of the outputs. Some of the residential density increases were in areas of open space, as designated by the ICLUS model input parameters, but that are not developable, such as a cemetery. Similarly, local planning considerations to account for relative sea level change that may prohibit future development along the coast could not be incorporated into the ICLUS model. More refined analyses at a smaller scale, similar to the NACCS tiered approach, would be appropriate to account for such considerations.

The Environmental and Cultural Resources Conditions Report, prepared as a technical product as part of NACCS, presents a summary of each State's (and District of Columbia) information on existing coastal and cultural resource characteristics, habitat impacts from Hurricane Sandy, and future environmental conditions. A Planning Aid Report for the North Atlantic Region, prepared by the USFWS, is included with the Environmental and Cultural Conditions Report. This organization is intended to facilitate State-level use of the final document, for study and project reports, and National Environmental Policy Act (NEPA) documentation by others. Users can easily locate and review, and reproduce in hard copy, the information that pertains to their interests.

For subsequent analyses of a range of future conditions, population at risk and potential life safety concerns will help to determine the extent and severity of the flood problems, needs, and opportunities in order to evaluate and compare adaptation strategies and coastal storm risk management measures. Considering the analyses of likely future population increases and development density, potential issues to be addressed include failure of existing coastal storm risk management projects and infrastructure from, for example, breaching; the inability of the existing stormwater management infrastructure to handle an extreme event (in combination with relative sea level change inundation and potential future precipitation patterns as a result of climate change); closure of evacuation routes and inability of first responders to access areas inundated by flood waters; and loss of utilities and emergency services that support communities. Addressing these life safety issues will help to refine the areas at risk and the measures used to manage flood risk.

Extreme Water Levels

Storm-induced coastal flooding is primarily caused by combinations of rainfall, storm surge, and waves from both tropical cyclones (tropical storms and hurricanes) and extra-tropical storms (nor'easters). For the North Atlantic coastline of the United States, astronomical tides strongly influence the frequency and severity of coastal flooding. In some locations, tides create significant nuisance flooding even in the absence of storm activity. Increases in relative sea level has the potential to worsen coastal storm flood risk as well as create or worsen nuisance flooding from normal rainfall events and astronomical tides.

The NACCS quantifies existing and future storm conditions for use in assessing risk and measures to increase resilience from coastal flooding. Potential future climate change is included in the analysis. This work was performed by the USACE Engineer Research and Development Center (ERDC) and is

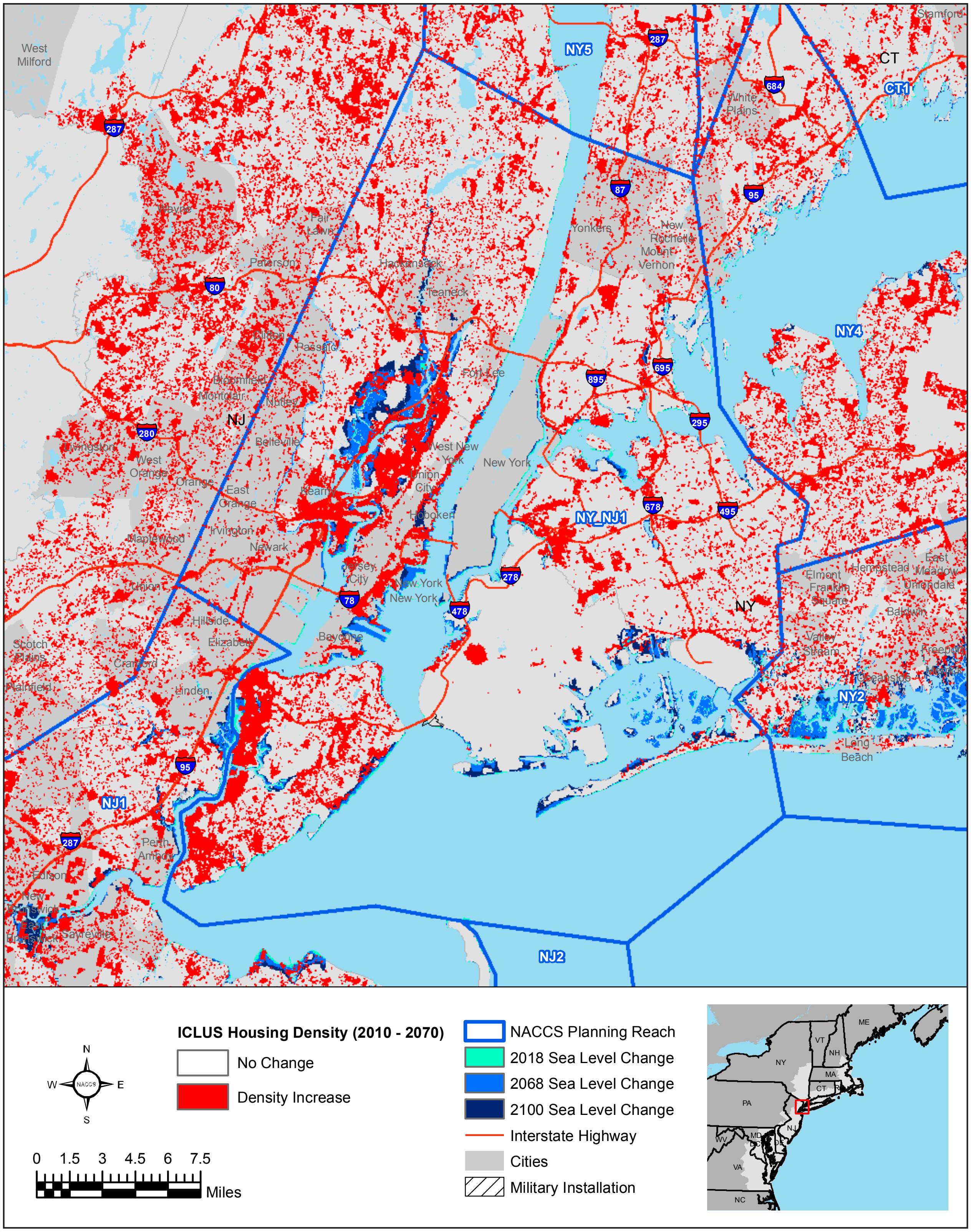


Figure IV-6. USACE High Scenario Future Mean Sea Level and Future Development Mapping for Reach NY_NJ1 detailed in Technical Report TR-14-7 (Nadal-Caraballo and Melby 2014). ERDC conducted rigorous regional statistical analysis and detailed high-fidelity numerical hydrodynamic modeling for the North Atlantic coastal region to quantify coastal storm wave, wind, and storm-driven water level extremes.

The extent of coastal flood hazard was determined using readily available 1 percent flood mapping from FEMA, preliminary 10 percent flood values from the ERDC extreme water level analysis, and the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) modeling conducted by NOAA. The purpose of the various inundation datasets was to identify, assess, and communicate flood risk at the regional scale. The inundation mapping represents varying levels of probability and corresponds with other agencies' regulatory and planning efforts.

SLOSH modeling of hurricane intensities is categorized by the Saffir-Simpson hurricane wind scale and includes other characteristics of hurricanes that can vary considerably along the coast, such as pressure, size (radius of maximum winds), forward speed, and track data to create a model of the wind field which drives the storm surge. The SLOSH model outputs support hurricane evacuation studies. The storm surge 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 storm surge during a landfall during different tide scenarios (i.e., high or mean tide for NY). Although the SLOSH storm surge mapping is not referenced to a specific probability of occurrence (unlike FEMA flood mapping, which presents the 0.2 percent and 1 percent flood zones) nor does it include wave heights, the flooding from a worst-case Category 4 hurricane making landfall during high tide represents an extremely low probability of occurrence but high-magnitude event.

The use of the SLOSH model MOM was necessary based on the large spatial extent of the study area and because it is currently the most advanced storm surge model available for the entire study area. The extent of the Category 4 MOM represents the maximum storm tide levels caused by extreme hurricane scenarios across the region, and, therefore, provides a reasonable approximation of the most extreme flooding extent. Figure IV-7 presents the SLOSH hydrodynamic modeling inundation mapping associated with Categories 1 through 4 hurricanes used for evacuation modeling in Reach NY_NJ1.

FEMA's National Flood Insurance Program (NFIP) bases the availability of flood insurance on communities' adoption and enforcement of floodplain management ordinances relative to the BFE. The BFE is the computed elevation to which floodwater is anticipated to rise during the base flood. The base flood is the flood having a 1 percent chance of being equaled or exceeded in any given year and is used by the NFIP and local floodplain management authorities for the purposes of requiring the purchase of flood insurance and regulating new development (http://www.fema.gov/national-flood-insurance-program/base-flood). Flood insurance and building ordinances for communities participating in the NFIP reference the BFE for new or substantial renovations or new mortgages on home sales. Although flood insurance requirements and building ordinances are tied to the BFE, they are not always tied to first floor elevation. For example, in V-zones presented on FEMA Flood Insurance Rate Maps (FIRMs), the reference to the building codes is to the lowest horizontal structural member. Local jurisdictions can adopt more stringent building codes than FEMA's minimum requirements to participate in the NFIP.

Furthermore, in April 2013, the Hurricane Sandy Presidential Task Force established a Hurricane Sandy coastal storm risk management standard of the 1 percent flood plus 1 foot for buildings. This is a minimum standard applicable to federally funded recovery and rebuilding investments under Public Law 113-2, including USACE vertical infrastructure and nonstructural retrofitting projects. The USACE formulates its project recommendations for coastal storm risk management projects based on an evaluation of an array of alternatives and the benefits and costs of each increment of work for these alternatives. However, for the purposes of the NACCS Tier 1 evaluation and to use a conservative assumption, the 1 percent flood inundation mapping plus 3 feet was used to evaluate structural coastal storm risk management measures (including NNBF measures, such as beaches and dunes) as well as to generate parametric unit cost estimates for structural risk management measures.

Figure IV-8 presents areas for Reach NY_NJ1 that are exposed to the 1 percent flood as well as the NACCS assumption of the 1 percent flood plus a 3-foot relative sea level change allowance. The 3-foot allowance is closely aligned with the USACE/NOAA High scenario for projected relative sea level change by year 2068 as well as New York City's recent recommendations (City of New York 2013). The 1 percent flood inundation mapping was obtained from effective and preliminary FIRMs available from FEMA's Map Service Center (http://msc.fema.gov/portal) and GeoPLATFORM (http://fema.maps.arcgis.com/home/). The sources and dates of the data incorporated into the NACCS Tier 1 evaluation are included in the Planning Analyses Appendix. FEMA's Special Flood Hazard Area and the computation of the BFE include wave heights. The SLOSH Category 2 (MOM) floodplain was used as a surrogate for the 1 percent flood plus 3 feet. For more refined studies, more detailed analyses to address risk and uncertainty should be considered. The purpose of presenting the Category 4 MOM and the 1 percent flood plus 3 feet floodplain is to illustrate residual risk to promote enhanced risk communication. Subsequent and more refined analyses would more accurately define residual risk associated with various coastal storm risk management measures accordingly.

Figure IV-9 presents the limit of the current 10 percent floodplain (an area with a 10 percent or greater chance of being flooded in any given year). The 10 percent floodplain was delineated using the stage- frequency analyses completed for NOAA gages across the entire study area (Appendix A). The purpose of the 10 percent floodplain is to consider the coastal storm risk management performance of various NNBF risk management measures with respect to storm surge. Although NNBF may provide multiple benefits and contribute to resilient coastlines and communities, some NNBF measures are not likely to offer coastal storm risk management with respect to storm surge for extreme events. Sea level change was not accounted for as part of the 10 percent floodplain, because for various NNBF coastal storm risk management measures, such as wetlands or living shorelines, adaptive management to mean sea level conditions would be required. Consistent with NACCS opportunities in Section II, there are significant opportunities for adaptive management in this regard.

Houses devastated by Hurricane Sandy in Mantoloking, NJ on November 26, 2012

Source: https://www.flickr.com/photos/usacenad/8228204866/

TERMS USED TO DESCRIBE THE CHANCE OF A COASTAL OR RIVERINE FLOOD

Floods are often defined according to their likelihood of occurring in any given year at a specific location. The most commonly used definition is the "100-year flood." This refers to a flood level or peak that has a 1 in 100, or 1 percent chance of being equaled or exceeded in any year (i.e., 1 percent "annual exceedance probability"). Therefore, the 100-year flood is also referred to as the "1 percent flood," or as having a "recurrence interval" or "return period" of 100 years.

A common misinterpretation is that a 100-year flood is likely to occur only once in a 100-year period. In fact, a second 100-year flood could occur a year or even a week after the first one. The term only means that that the average interval between floods greater than the 100-year flood over a very long period (say 1,000 years) will be 100 years. However, the actual interval between floods greater than this magnitude will vary considerably.

In addition, the probability of a certain flood occurring will increase for a longer period of time. For example, over the life of an average 30-year mortgage, a home located within the 100-year flood zone has a 26 percent chance of being flooded at least once. Even more significantly, a house in a 10-year flood zone is almost certain to be flooded at least once (96 percent chance) in the same 30-year mortgage cycle. The probability (P) that one or more of a certain-size flood occurring during any period will exceed a given flood threshold can be estimated as

$$P = 1 - \left[1 - \frac{1}{T}\right]^n$$

where T is the return period of a given flood (e.g., 100 years, 50 years, 25 years) and n is the number of years in the period. The probability of flooding by various return period floods in any given year and over the life of a 30-year mortgage is summarized in the following table.

Return Period (years)	Chance of flooding in any given year	Percent chance of flooding during 30-year mortgage
10	10 in 100 (10%)	96%
50	2 in 100 (2%)	46%
100	1 in 100 (1%)	26%
500	0.2 in 100 (0.2%)	6%

Because of the potential confusion, recent USACE guidance documents and policy letters recommend use of the annual exceedance probability terminology instead of the recurrence interval or return period terminology. For example, one would discuss the "1-percent-annual-exceedance-probability flood" or "1-percent-chance-exceedance flood," which may be shortened to "1 percent flood" as opposed to the "100-year flood." This report uses the short form "1 percent flood."

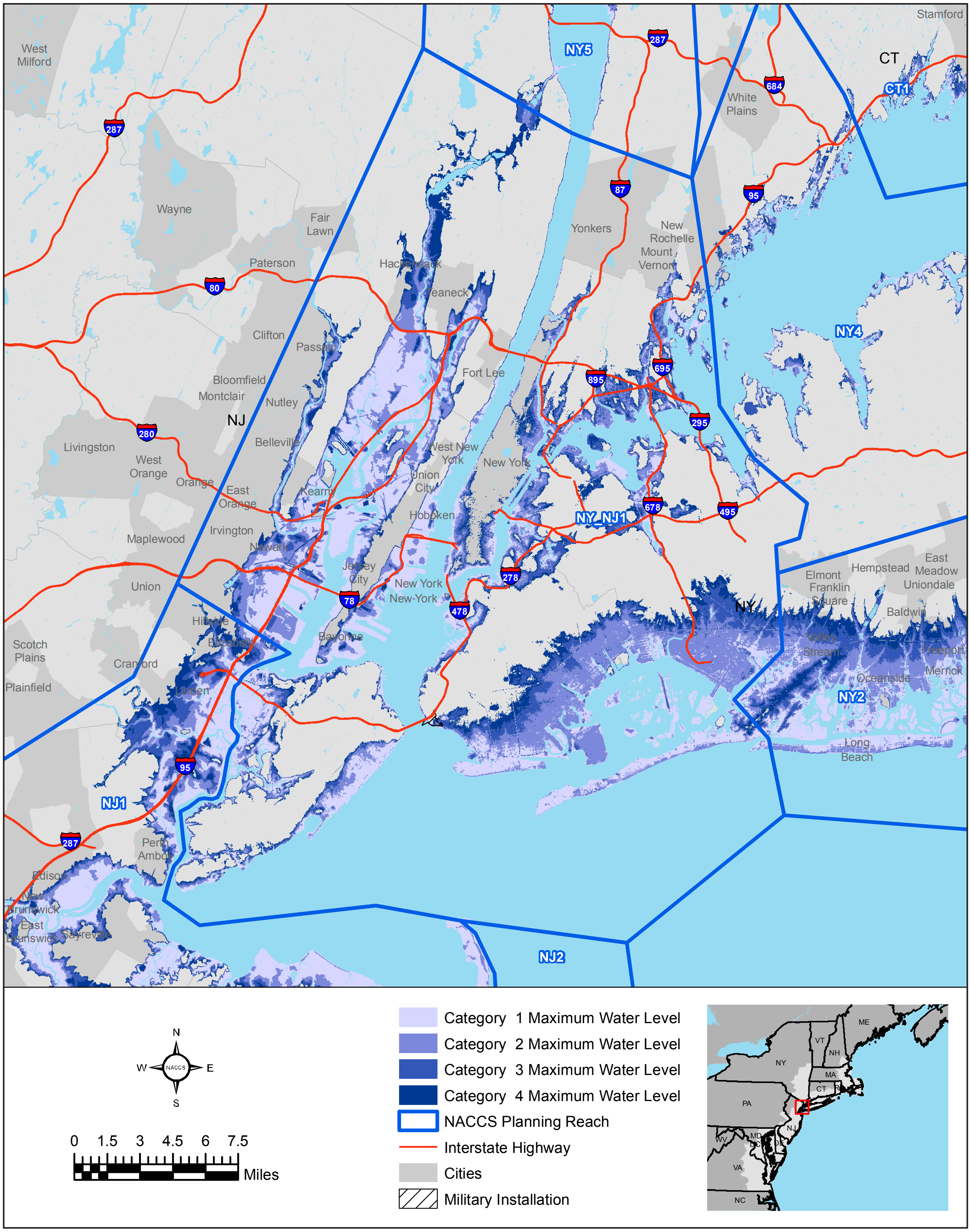


Figure IV-7. Reach NY_NJ1 NOAA SLOSH Model Very High Impact Area Category 1–4 Water Levels

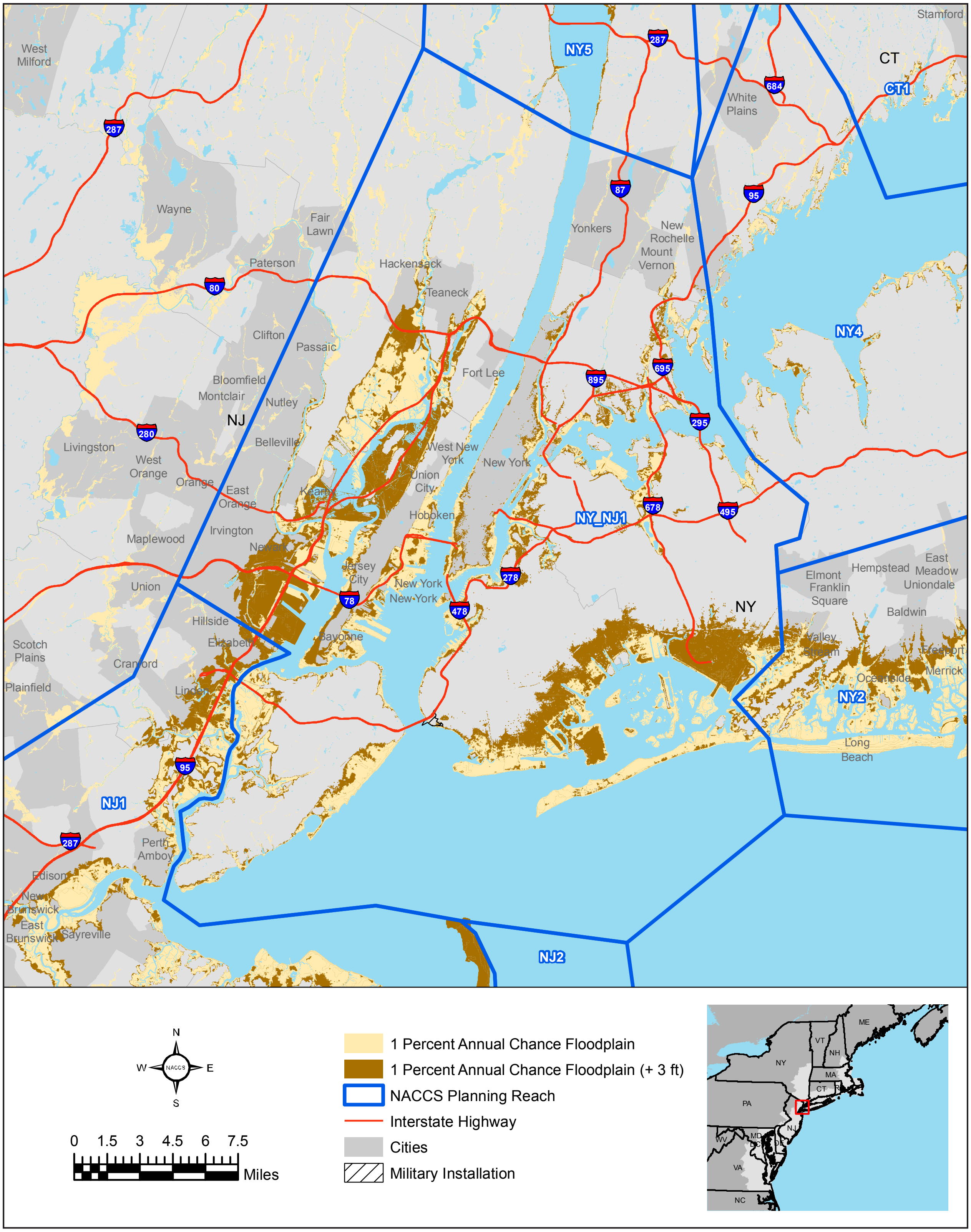


Figure IV-8. Reach NY_NJ1 Very High Impact Area NACCS 1 Percent Flood + 3-foot Floodplain

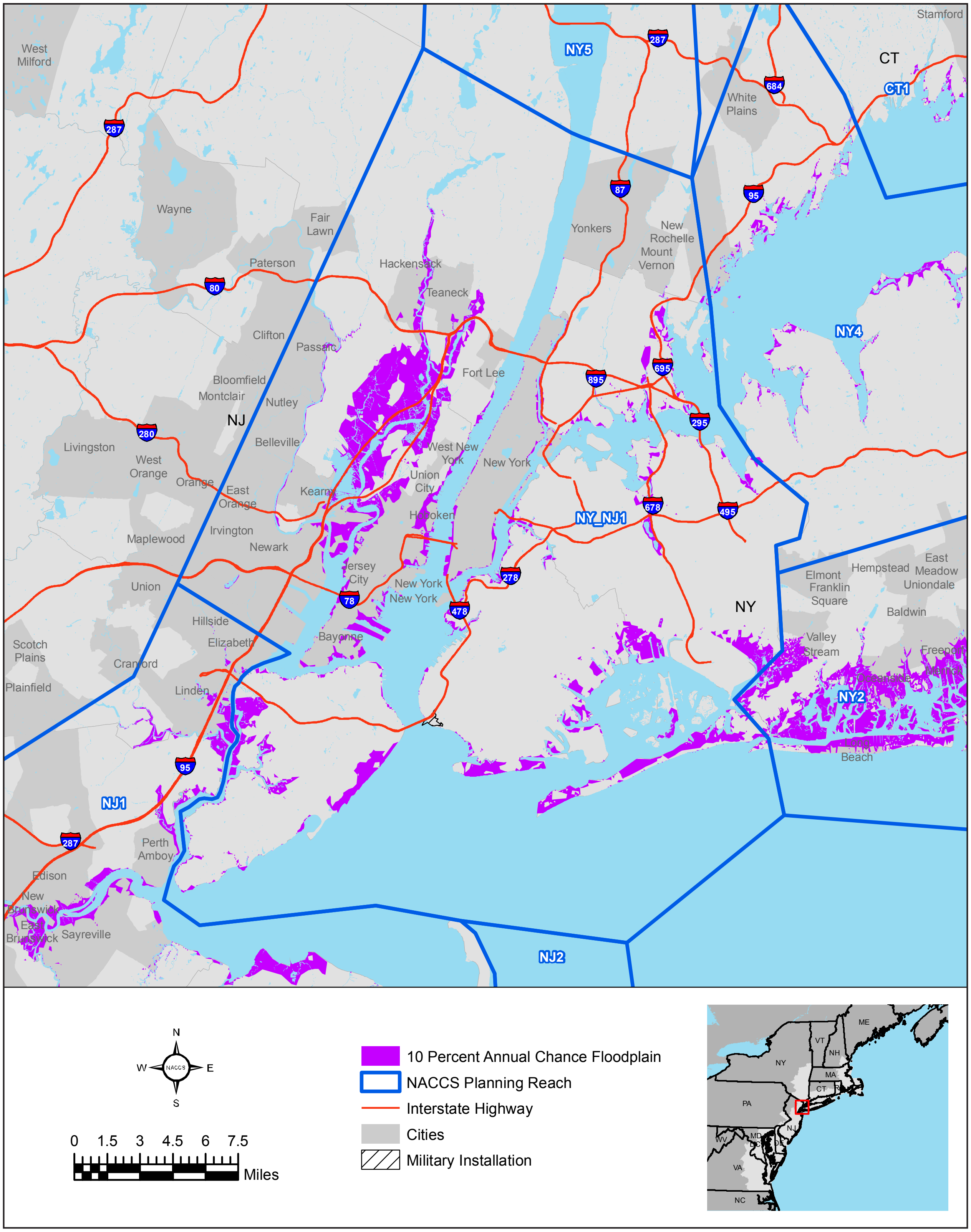


Figure IV-9. Reach NY_NJ1 Very High Impact Area NACCS 10 Percent Floodplain

Numerical Modeling

Completed as a technical product in parallel to the development of the Framework, the NACCS modeling efforts included the latest atmospheric, wave, and storm surge modeling and extremal statistical analysis techniques. Previously, only regional SLOSH models existed for the study area, along with a myriad of local models causing discrepancies in contiguous detailed model results with respect to water surface elevations. The NACCS modeling methodology for computing winds, waves, and water levels involves the application of a suite of high-fidelity numerical models within the Coastal Storm Modeling System (CSTORM-MS). The statistical analysis was performed using the Joint Probability Method with Optimum Sampling by Bayesian Quadrature (JPM-OS-BQ) and traditional joint probability techniques as was also applied in recent FEMA Risk Mapping, Assessment, and Planning (Risk MAP) (FEMA 2012) and USACE studies (IPET 2009). The NACCS study produced nearshore wind, wave, and water level estimates and the associated marginal and joint probabilities. This study did not include engineering calculations, such as wave runup, nearshore morphology change, sediment transport, and probabilistic analysis of riverine stage or overland flooding.

Over 1,100 production storms were designed (synthetic storms) or selected (historical storms), simulated, analyzed, and incorporated into the Coastal Hazards database. The suite of storms included 1,050 synthetic tropical storms and 100 historical extratropical events. The synthetic tropical storms were developed to populate the statistical parameter space as part of the project design process. The development of synthetic tropical storms focused on: 1) the discretization of the marginal distributions for each of the hurricane parameters; 2) the development of the hurricane track paths; and 3) development of the along-track variations of hurricane parameters. Because of the extremely large number of simulations and the massive amount of model-generated results from these simulations, a method was developed to automate the simulation process to best utilize human and computational resources. A semi-automated production script was developed to set up and perform CSTORM-MS simulations, visualize and archive model results, and prepare a summary report as part of the quality control process. This automation speeds up the simulation process and reduces the potential for human error. Prior to production, the numerical models applied to the NACCS study (WAM [Wave Prediction Model], STWAVE [Steady State Spectral Wave], and ADCIRC [Advanced Circulation Model]) were validated for a set of historical tropical and extratropical storm events.

For the joint probability of coastal storm forcing, the standard-of-practice is to develop a joint probability of nearshore waves, water levels, winds, overland flooding, river flow, and any other parameters of interest. The statistical approaches for estimating the joint probability of coastal storm response, such as surge and waves, have also been greatly improved within USACE studies as well as FEMA Risk MAP studies. For recent similar USACE and FEMA studies, planetary boundary layer numerical models are used to generate wind and pressure fields that are then used to drive high-fidelity storm surge and wave hydrodynamic models. Waves and water levels are modeled to the nearshore area for historical storm events and/or synthetic events to define a robust statistical population of project storm forcing. Present approaches include the JPM-OS-BQ technique for hurricanes and more traditional joint probability techniques for extra-tropical storms. Products from this work incorporated into the Coastal Hazards database include simulated winds, waves, and water levels for approximately 1,050 synthetic tropical events and 100 extratropical events computed at over 3 million computational locations. A smaller number—18,000 locations—save the same information at higher frequency for more convenient/concise data handling. These storm events are determined to span the range of practical storm probabilities. The water levels are modeled in such a way that the effects of storm surge, waves, tide, and sea level change can be assessed.

The NACCS storm simulation suite and statistical analysis helps to close gaps in data required for coastal storm risk management analyses by providing statistical wave and water level information for the entire North Atlantic coast, while providing a cost savings compared to developing the ocean coastal storm hazard data for individual local projects. The statistical database can potentially be revised based on estimates of future climatology. The CSTORM-MS platform contains the raw model data (winds, waves, and water levels) as well as processed data (visualization products and statistics) and is available through the Internet-based Coastal Hazards System, and linked to the NACCS website http://www.nad.usace.army.mil/CompStudy. These data will be available for engineering analyses and project design for coastal projects from Maine to Virginia for a spatially complete model domain for the entire North Atlantic coastline.

ANALYZE RISK AND VULNERABILITY

The concept of risk includes the components of hazard, exposure, performance of a system with coastal storm risk management features (if applicable), subsequent consequences, and vulnerability. Exposure and risk assessments evaluate risk from the flood hazard along the North Atlantic Coast as a system, incorporating the natural, social, and built systems as referenced in the NOAA/USACE Infrastructure Systems Rebuilding Principles. As such, the exposure and risk assessments make use of the planning process that allows stakeholders to highlight risk areas by evaluating three criteria: population and infrastructure, social vulnerability factors of the population, and environmental and cultural sensitivities.

Exposure is defined as the presence of people, infrastructure, and/or environmental resources (receptors) in areas subject to potential coastal flooding. A higher density of people, infrastructure, and/or environmental resources produces relatively higher exposure to coastal flood hazards. Three separate exposure indices were developed—population density and infrastructure, social vulnerability characterization, and environmental and cultural resources—to represent exposure to flood inundation within the footprint of the Category 4 MOM floodplain. The Category 4 MOM represents the maximum hurricane water level values from severe storm events and provides a reasonable approximation of extreme flooding extent within the study area. Risk of coastal flood peril was estimated using flood inundation mapping in combination with the exposure.

The extent of flooding, as presented in Figure IV-7 through Figure IV-9, was used to delineate the areas included in the exposure and risk assessments. The purpose of the exposure assessment is to identify, in geographical terms, a relative range of characteristics to define the consequences of a coastal storm flooding event. The exposure assessment was completed by creating a composite exposure index. A composite exposure index is an instrument for communicating relative exposure to coastal flooding hazards for the natural and developed systems, taking into consideration all three criteria: population and infrastructure, social vulnerability factors of the population, and environmental and cultural sensitivities. The characteristics of population density and infrastructure, social vulnerability, and environmental and cultural resource sensitivities were incorporated into the exposure index using GIS spatial data layers. The data layers utilized national datasets to provide consistency across the study area, which covers 10 States and the District of Columbia.

Areas with relatively higher composite indices were used to identify segments of the coastline for further evaluation by the respective States and the District of Columbia (State and District of Columbia Analyses Appendix). The flexibility of the Framework facilitates the analysis of site-specific characteristics. When completing this step of the Framework, the assumptions should be revisited and refined GIS datasets should be incorporated. If the Framework is applied and refined at the State and community level, decision-makers should adjust the indices to reflect the values and goals of the respective communities. When stakeholders adjust the indices, the individual data layers should also be analyzed as necessary. The Economics and Social Analyses Appendix presents more information on the theory of the exposure index. The Planning Analyses Appendix presents information on the development of the exposure index.

Performance of the system, or how the system reacts to a hazard and associated consequences, requires further analysis as part of the Tier 2 and Tier 3 evaluations to be completed with refined objectives, constraints, and datasets for smaller geographic regions. Similar to performance and consequences, vulnerability also requires further analysis as part of the Tier 2 and Tier 3 evaluations that include data-intensive analyses. The technical report *Use of Natural and Nature-Based Features for Coastal Resilience* includes additional details related to the development of coastal vulnerability metrics to assess vulnerability and resilience metrics (Bridges et al. 2015). The standards, policies, and guidance of the participating agencies establish the study requirements and stakeholders refine objectives and constraints.

NACCS Exposure Assessment

Although a myriad of factors or criteria can be used to identify exposure, the NACCS Tier 1 evaluation focused on the following categories and criteria:

- Population Density and Infrastructure: Population density includes 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.
- Social Vulnerability Characterization: Social vulnerability characterization includes certain segments of the population that may have more difficulty preparing for and responding to coastal flood events.
- Environmental and Cultural Resources: The environmental and cultural resources exposure captures important habitat and selected cultural resources that would be affected by storm surge and erosion.

Population Density and Infrastructure Index

Population and population density was identified as a measure of the coastal flood exposure. In addition to identifying population, an objective of the NACCS is to identify coastal storm risk management to critical infrastructure. Critical infrastructure was identified through the Homeland Security Infrastructure Program using principles associated with an engineering reconnaissance process described in the Department of the Army Field Manual 3-34.170, Engineer Reconnaissance (2008). The Army developed the sewage, water, electricity, academics, trash, medical, safety, and other considerations (SWEAT-MSO) assessment process to provide immediate feedback concerning the status of the basic services necessary to sustain a population. The post-hurricane recovery time includes the time it takes to restore interruptions in basic infrastructure services, which may be used as a measure of how resilient a community is following a storm event.

The evaluation of critical infrastructure considered a wide range of facilities, including large facilities, such as power plants, ports, and airports that serve large regional populations; moderate-sized facilities, such as water and wastewater treatment plants, that may serve an entire community; and smaller facilities, such as gas stations and pharmacies that serve specific neighborhoods. The Planning Analyses Appendix provides a discussion of how these different facilities were weighted in the analysis. Figure IV-10 depicts the overall population density and infrastructure exposure index for Reach NY_NJ1. This index reflects a weighted summation of the population density and infrastructure that could be exposed to coastal flooding.

Social Vulnerability Characterization Index

The 2010 U.S. Census data was used to develop the social vulnerability characterization. The overarching goal is to quantify populations that are more at risk from storm impacts. Age, income, and non-English speaking populations were considered important factors in social vulnerability. The Economics Analyses Appendix includes additional information on the development of the social vulnerability characterization exposure index. Figure IV-11 provides a depiction of the social vulnerability characterization exposure index for Reach NY_NJ1.

Environmental and Cultural Resources Index

Environmental and cultural resources were evaluated as they relate to exposure to the Category 4 MOM. Data from national databases, such as the National Wetlands Inventory and The Nature Conservancy Ecoregional Assessments, and data provided by the 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 to assess resource exposure. Properties with restricted locations, typically archaeological sites, and certain other properties were omitted from the analysis. Figure IV-12 presents the results of the environmental and cultural resources exposure index for Reach NY_NJ1.

Composite Exposure Index

The three independent exposure indices were weighted and summed to develop one composite index to convey overall exposure. Because the focus of the NACCS is on managing risk to vulnerable coastal populations and the infrastructure that supports it, the population density and infrastructure exposure index was weighted higher than the social vulnerability characterization and environmental and cultural resources indices. Population density and infrastructure was assigned a weight of 80 percent, social vulnerability characterization was assigned a weight of 10 percent, and environmental and cultural resources exposure was assigned a weight of 10 percent. In consultation with others (States, District of Columbia, agency webinars, and subject matter experts), the weighting for the Tier 1 evaluation composite index was selected to provide a greater emphasis on population and infrastructure as an illustrative example of the application of the Framework at the regional scale.

In addition, when critical infrastructure is damaged and services are interrupted, as demonstrated by Hurricane Sandy in the densely developed areas of New York and New Jersey, the entire population is affected. As noted previously, the Framework could be adjusted to meet specific objectives by applying refined datasets and/or resetting index weights. A sensitivity assessment was performed to evaluate changes when the composite index weights are adjusted to shift emphasis to either social vulnerability or environmental and cultural resources. More information on the development of the exposure indices and the sensitivity analysis is included in the Economics Analyses and Planning Analyses Appendices. Figure IV-13 depicts a sample composite exposure index for Reach NY_NJ1.

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 3 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 3 feet extent, and the 1 percent plus 3 feet to the Category 4 MOM inundation extent. FEMA 1 percent flood mapping is not available in all regions throughout the study area; therefore, the 1 percent plus 3 feet floodplain was defined as the Category 2 MOM instead. This process was completed for the composite exposure assessment in order to generate the new data presented as the NACCS risk assessment. Figure IV-14 depicts the results of the risk assessment for Reach NY_NJ1. The data were symbolized to present areas of relatively higher risk, which, based on the analysis, correspond 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.

NACCS Risk Areas Identification

The risk assessment for Reach NY_NJ1 identified 17 locations as having relative higher risk. These locations, labeled areas NY_NJ1_A through NY_NJ1_Q are identified on Figure IV-15 and listed in Table IV-3. Because of scale limitations, the risk areas are presented in Figure IV-17 as point locations and may not specifically correspond with the map symbology presenting the areas of relatively higher risk.

Additional information, including the description of each risk area, is included in the corresponding New York chapter of the State and District of Columbia Analyses Appendix.

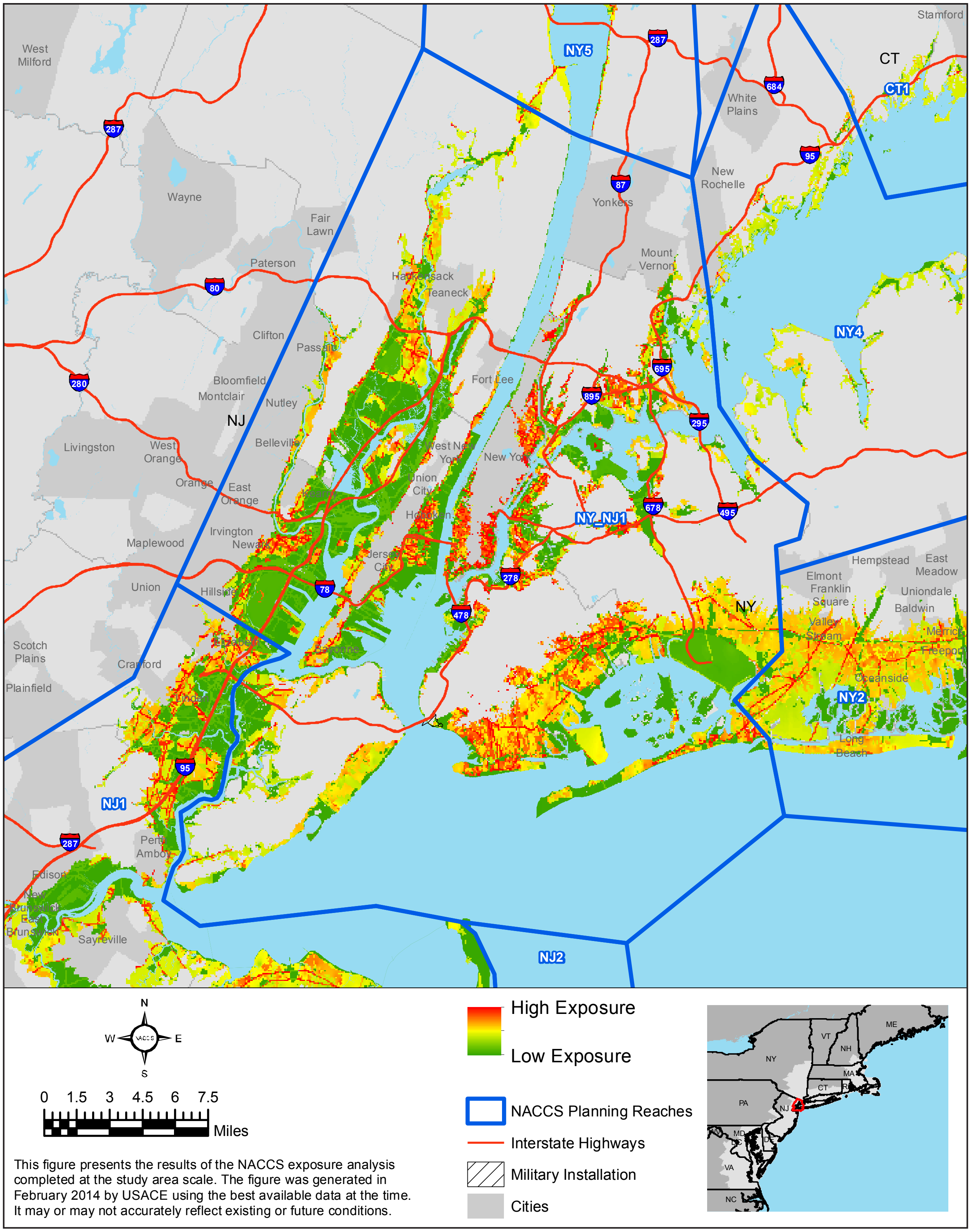


Figure IV-10. Reach NY_NJ1 NACCS Tier 1 Evaluation Population and Infrastructure Exposure Index

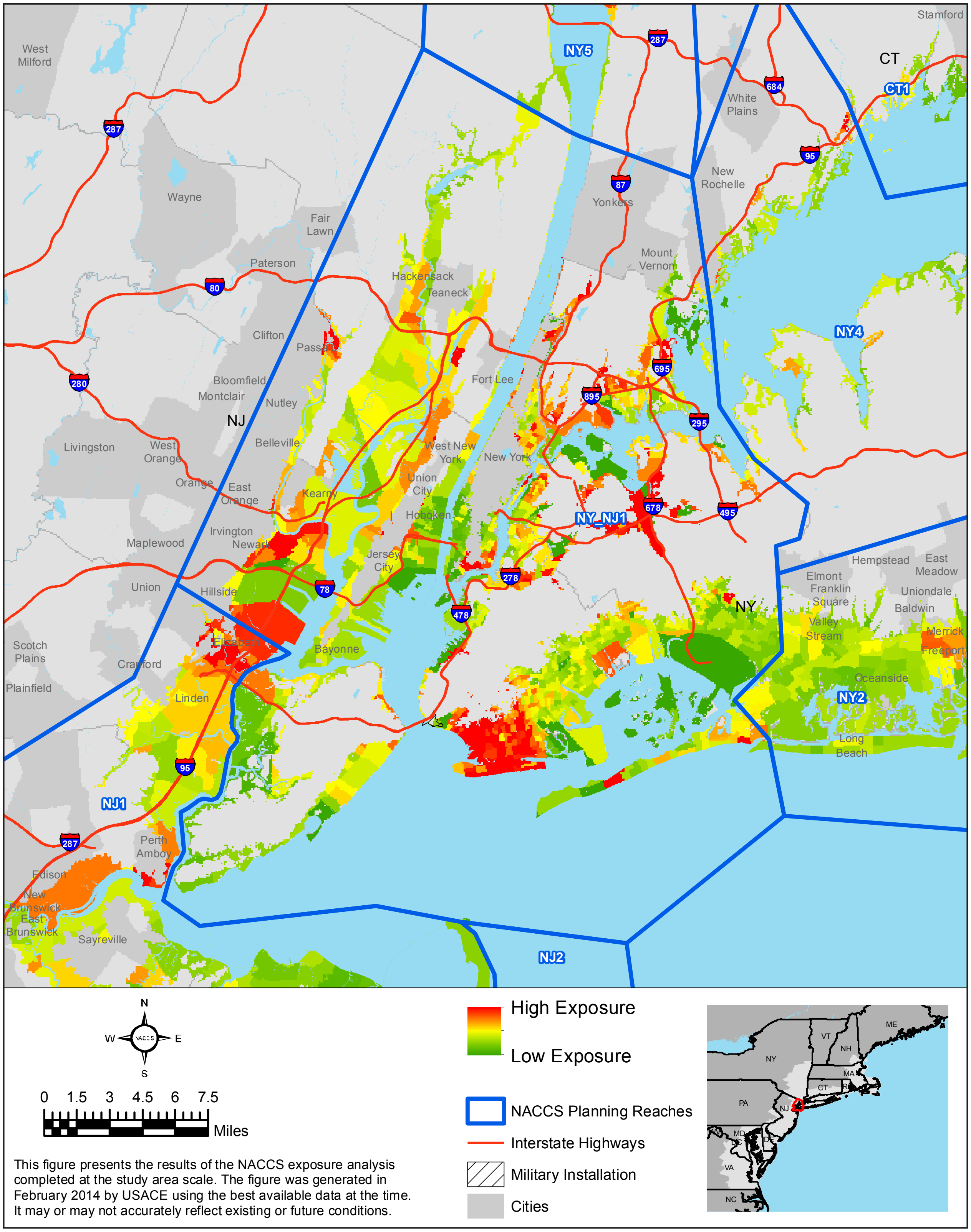


Figure IV-11. Reach NY_NJ1 NACCS Tier 1 Evaluation Area Social Vulnerability Characterization Exposure Index

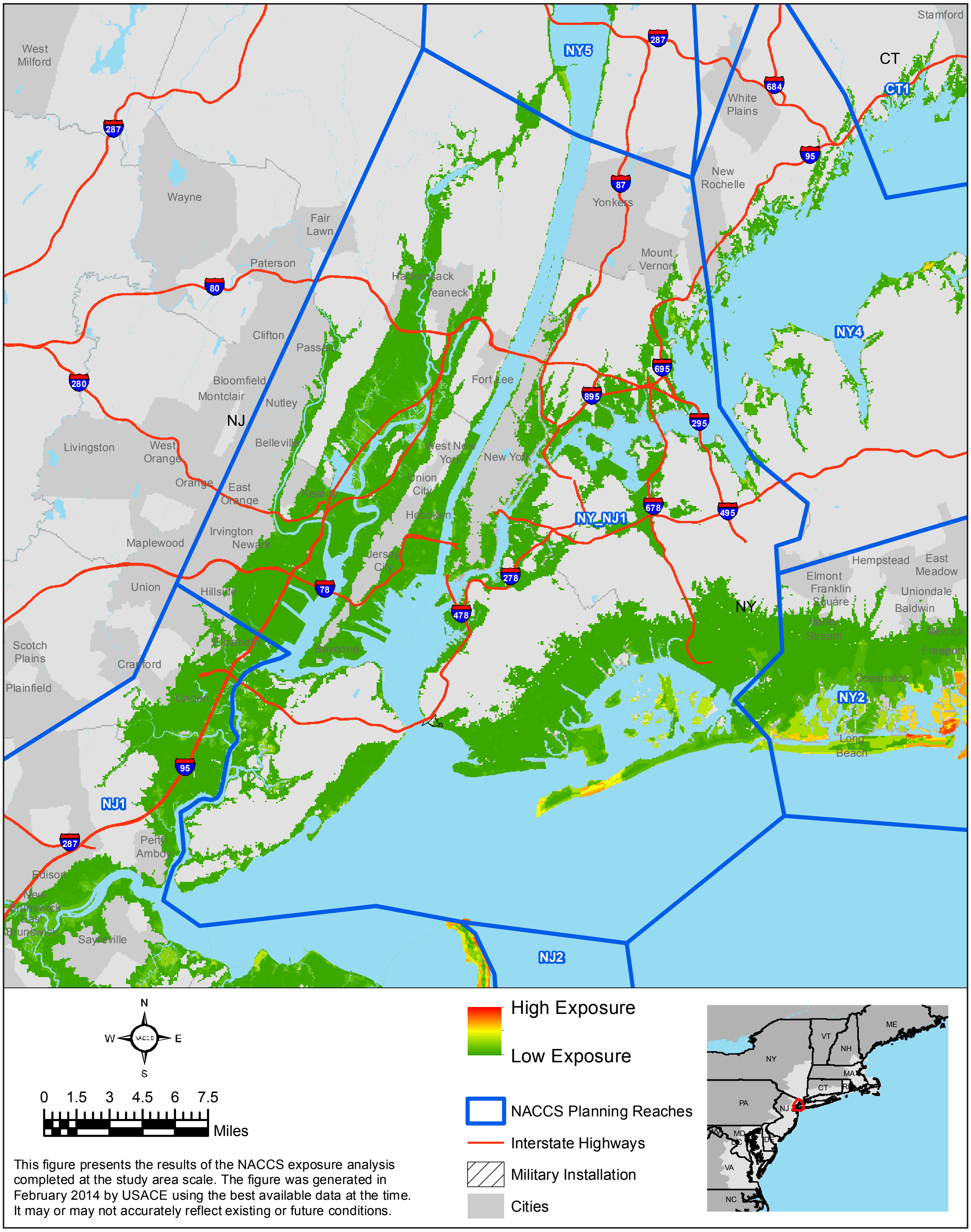


Figure IV-12. Reach NY_NJ1 NACCS Tier 1 Evaluation Environmental and Cultural Resources Exposure Index

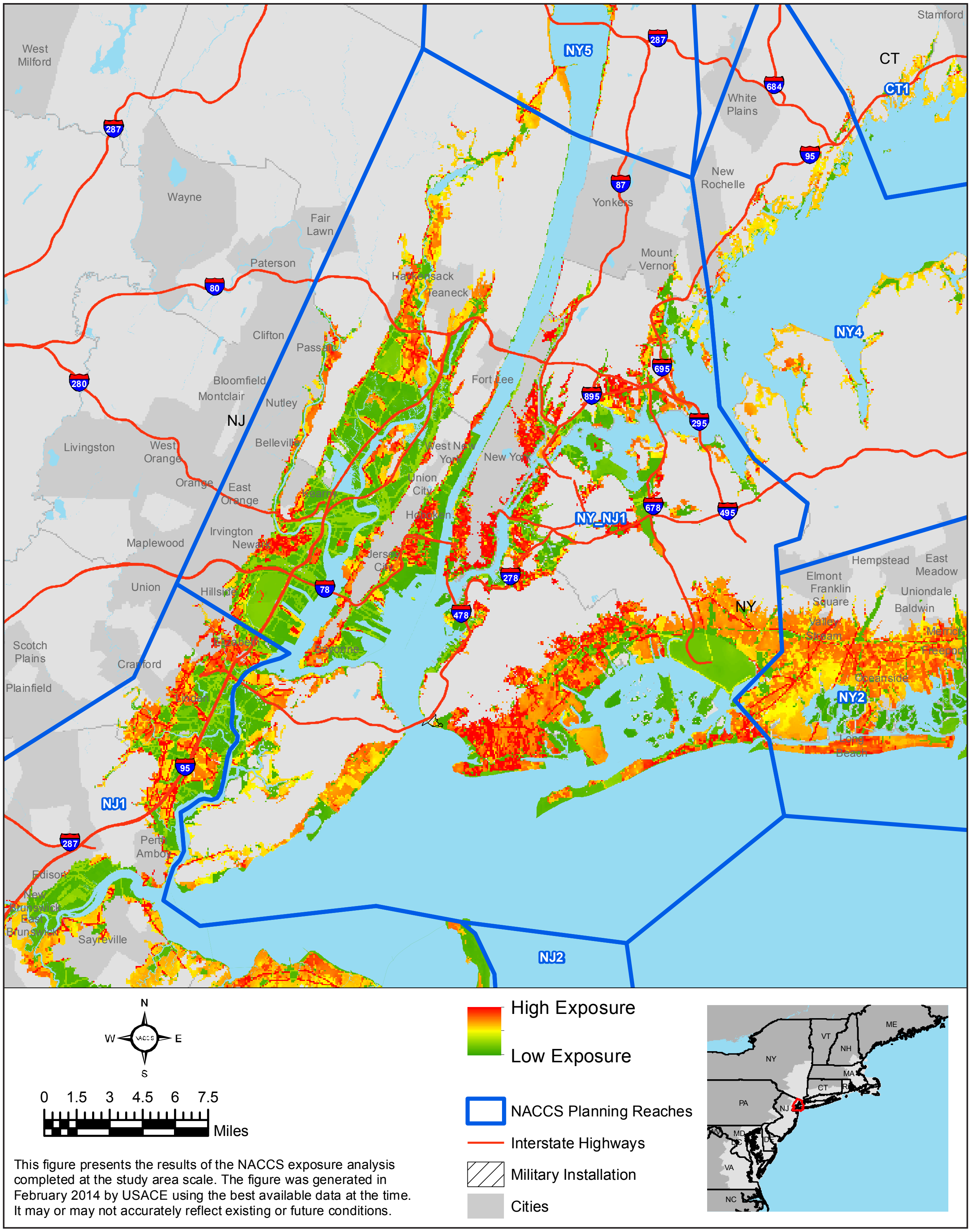


Figure IV-13. Reach NY_NJ1 NACCS Tier 1 Evaluation Composite Exposure Index

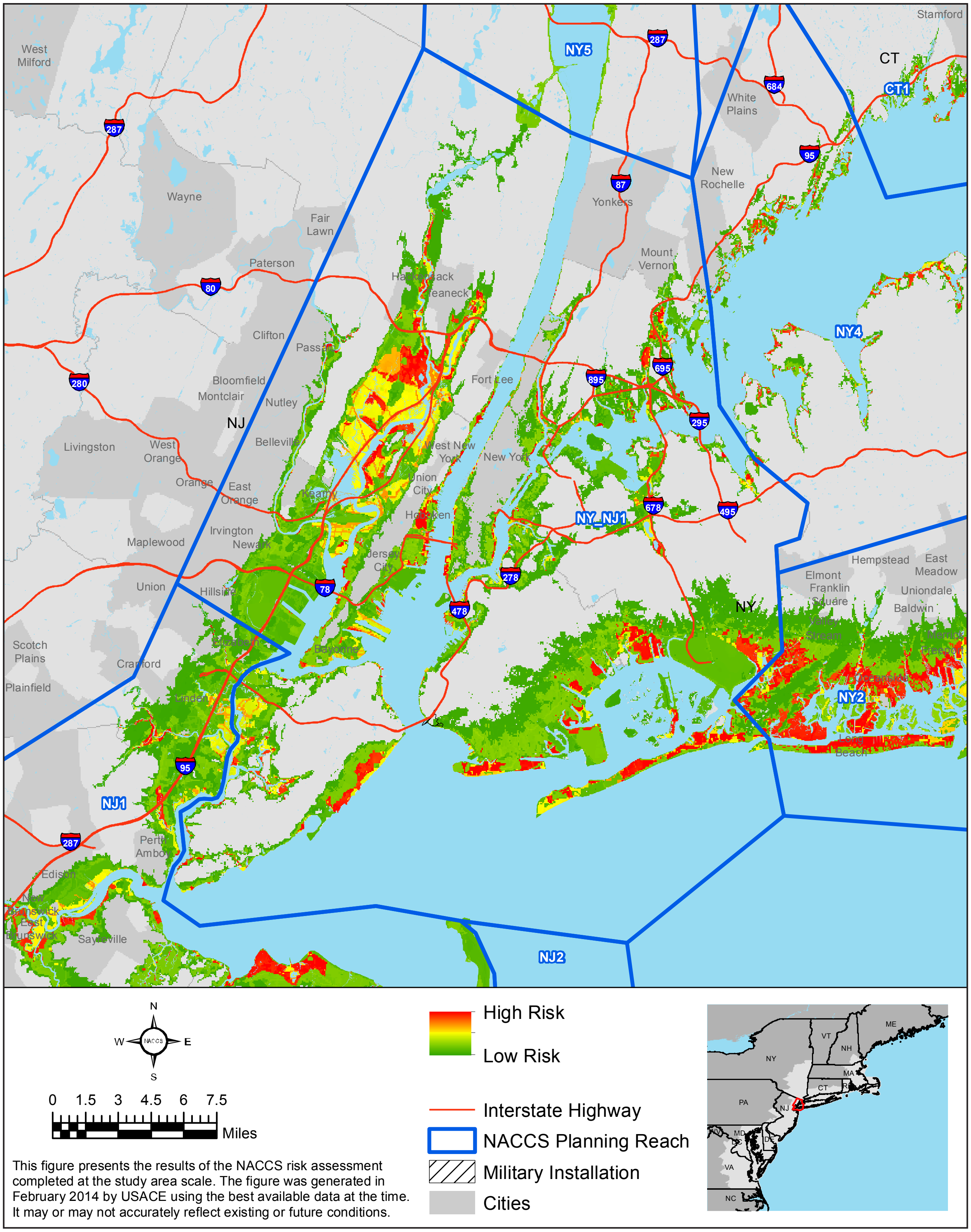


Figure IV-14. Reach NY_NJ1 NACCS Tier 1 Risk Evaluation

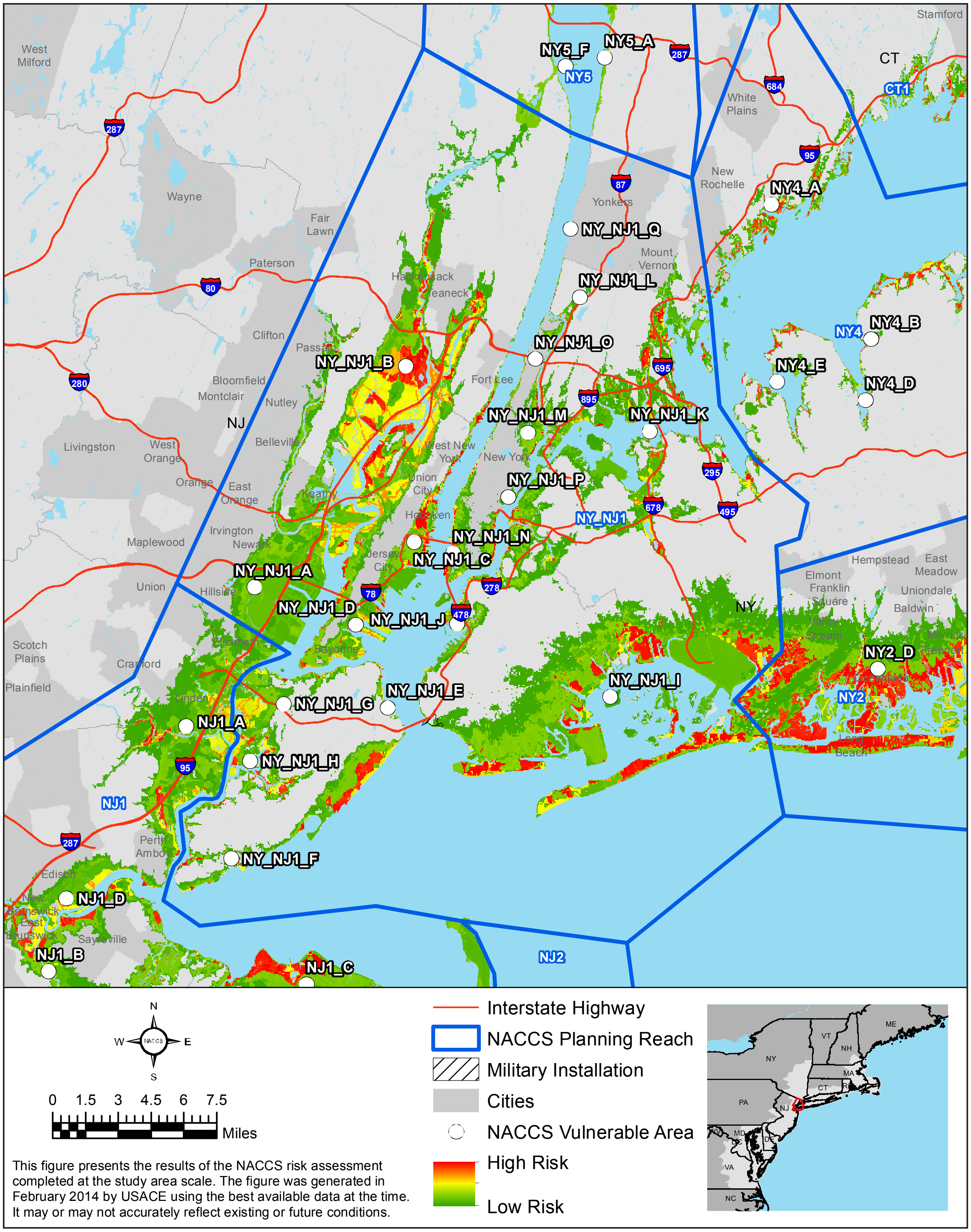


Figure IV-15. Reach NY_NJ1 NACCS Tier 1 Evaluation Risk Areas

Table IV-3. List of NACCS Risk Areas within Reach NY_NJ1 with Relative Higher Risk

Label	Location
NY_NJ1_A	Lower Passaic River
NY_NJ1_B	Hackensack River, Hackensack Meadowlands
NY_NJ1_C	Hudson Waterfront of New Jersey (Jersey City to Edgewater)
NY_NJ1_D	City of Bayonne
NY_NJ1_E	Rosebank to St. George on Staten Island (North Shore of Staten Island)
NY_NJ1_F	South Shore of Staten Island
NY_NJ1_G	New Brighton to Mariners Harbor (North Shore of Staten Island)
NY_NJ1_H	West Shore of Staten Island
NY_NJ1_I	Southern Brooklyn and Queens – Jamaica Bay and the Rockaway Peninsula
NY_NJ1_J	Brooklyn and Queens western waterfront
NY_NJ1_K	Northern Queens and the Bronx
NY_NJ1_L	Marble Hill and the Spuyten Duyvil
NY_NJ1_M	Harlem, East Harlem, and the Upper East Side
NY_NJ1_N	Mid and Lower Manhattan
NY_NJ1_O	Hudson River Shoreline of Upper Manhattan
NY_NJ1_P	East River Shoreline of Mid-Manhattan
NY_NJ1_Q	Hudson River Waterfront of Yonkers

The area NY_NJ1_I, Southern Brooklyn and Queens – Jamaica Bay and the Rockaway Peninsula, was selected to illustrate the application of the Framework as part of a Tier 2 evaluation because it includes a wide range of problems, needs, and opportunities. The area experienced extensive flooding from Hurricane Sandy, particularly along the back bay area of Jamaica Bay, as well as the USACE coastal storm risk management projects along the Atlantic Ocean coastline. The State and District of Columbia Analyses Appendix includes discussions for other State and District of Columbia risk areas.

The NY_NJ1_I risk area encompasses southern Brooklyn and Queens in the City of New York, including the neighborhoods of Coney Island, Brighton Beach, Sheepshead Bay, Marine Park, Flatlands, Canarsie, Howard Beach, Far Rockaway, and Breezy Point. The neighborhoods of Coney Island, Brighton Beach, and the Rockaway Peninsula were fully inundated during Hurricane Sandy. In Breezy Point, 130 homes were destroyed and another 50 homes damaged by a fire caused by salt water contacting live electrical wires. The storm's winds fanned the flames and flood waters impeded first responders from controlling it. Rockaway Peninsula lost 1.5 million cubic yards of sand from its beaches and dunes during Hurricane Sandy. Residents in this area were without electricity and other utilities for weeks following the storm. The number of structures in this area with flood damage from Hurricane Sandy was in the thousands. In addition to dense residential and commercial development, this risk area also contains John F. Kennedy International Airport, the Metropolitan Transit Authority A-train subway line, portions of the Gateway National Recreational Area, the historic Floyd Bennett Field, Jacob Riis Park, and Jamaica Bay itself, one of the largest remaining wetland complexes in the New York Metropolitan Area.

IDENTIFY POSSIBLE SOLUTIONS – COASTAL STORM RISK MANAGEMENT STRATEGIES AND MEASURES

The Framework presents structural (including NNBF), nonstructural, and programmatic measures to address coastal storm risk, along with a conceptual and qualitative evaluation of risk management capacity and parametric unit costs. The information presented in the Framework related to coastal storm risk management measures is intended to provide users with useful information to evaluate community-specific risk management measures as well as an opportunity to derive order of magnitude cost considerations. Subsequent analyses could then consider further the full array and combinations of measures as part of a systems approach and broader strategy to manage flood risk. Subsequent sections of this report discuss the systems approach to coastal storm risk management.

As indicated by the NACCS Findings in Section II, improved coastal storm risk management measures are needed, ideally utilizing an integrated approach that combines the full array of measures. The built components of coastal systems can include both nature-based and engineered structures that support a range of objectives, including erosion control and coastal storm risk management (e.g., seawalls, levees), as well as infrastructure providing economic and social functions (e.g., navigation channels, ports, harbors, residential housing). Nonstructural measures focus on elevation, relocation, flood warnings, and preparedness. Natural features are created through the action of physical, geological, biological, and chemical processes over time. In contrast to natural features, nature-based features are created by human design, engineering, and construction (in concert with natural processes) to provide specific services, such as coastal storm risk management and other ecosystem services (e.g., habitat for fish and wildlife). Nature-based features are acted upon by processes operating in nature and, as a result, generally must be maintained by human intervention to sustain the functions and services for which they were built.

Measures Compilation and Aggregation Process

The first step in compiling and aggregating measures is developing an initial suite of coastal storm risk management measures to reduce the risk to coastal populations and increase resiliency. The USACE convened a 2-day working meeting on June 26–27, 2013, at the Stevens Institute of Technology in Hoboken, NJ, with representatives from Federal, State, and local governments, as well as academia, NGOs, and private industry, to discuss the full array of potential measures. A master list of all the measures identified was compiled at the conclusion of this meeting, then edited and filtered for duplication and consistency with study goals and objectives, and finally augmented based on a literature review. The aggregated measures were then organized into three categories: structural, nonstructural, and NNBF. Some NNBF measures were identified for both the NNBF and structural categories because of their storm surge reduction potential. Additionally, programmatic measures were organized under the nonstructural category. Figure IV-16 illustrates this process to compile and aggregate measures.

> **Natural, nature-based, nonstructural, and structural** are terms used to describe the full array of measures that can be employed to provide increased coastal resilience and risk reduction (USACE 2013c).

Structural Measures

Structural coastal storm risk management measures are engineering solutions to manage flood risk and reduce damage from coastal storms. Typical structural solutions include levees, floodwalls, beaches, and dunes, which are intended to physically limit flood water inundation from causing damage. The actual level of risk reduction associated with these measures can vary significantly depending on the specific application. At site-specific locations, the design considerations and corresponding assumptions for structural measures will vary. Furthermore, the level of risk reduction associated with USACE coastal storm risk management projects is based on a benefit to cost evaluation as opposed to a specific risk reduction standard. In general, structural measures such as revetments, bulkheads and seawalls all share the disadvantage of being potential wave reflectors that can erode a beach fronting a structure. Depending on the design specifics and the characteristics of the particular site, negative impacts such as induced flooding and short to long-term negative

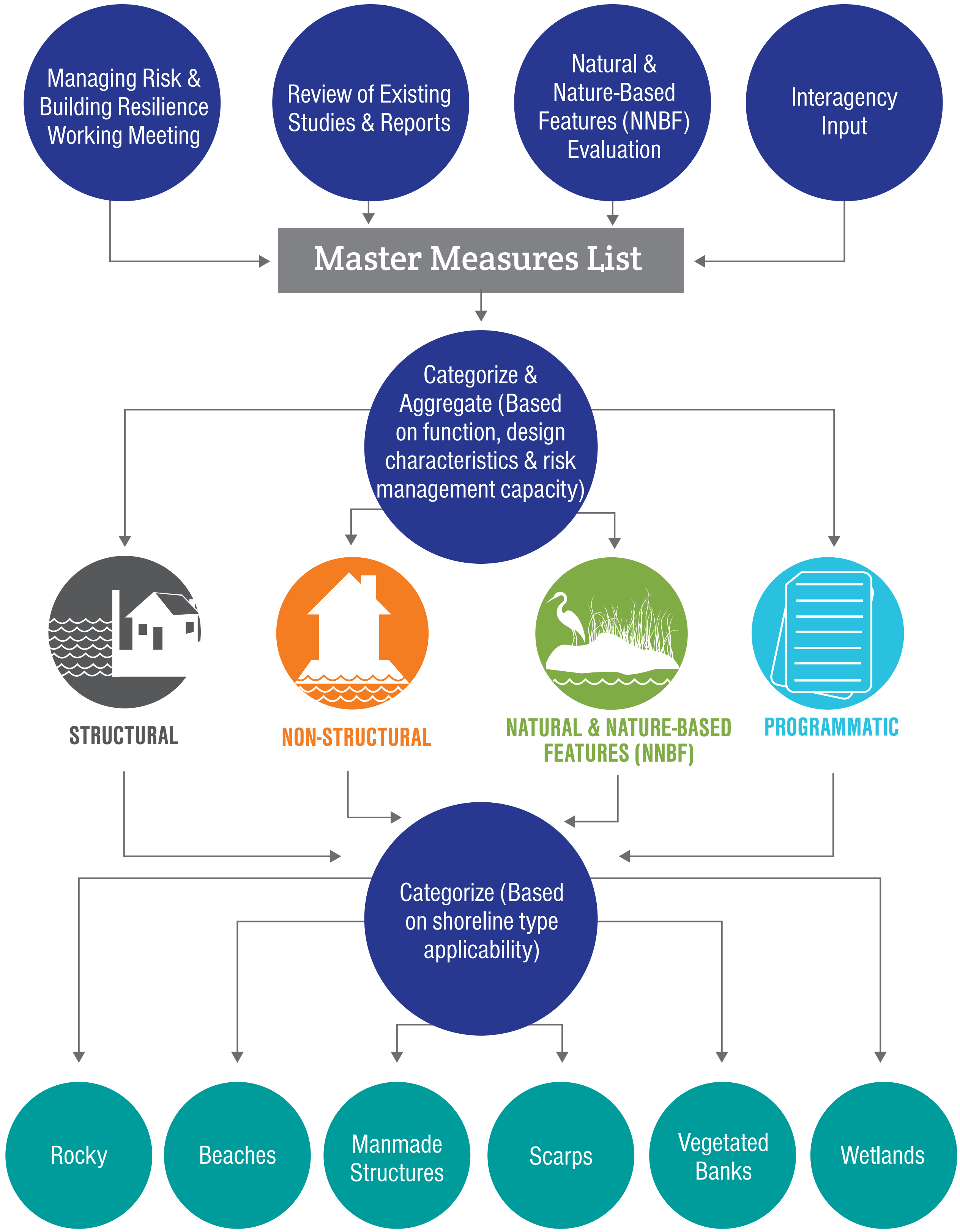


Figure IV-16. Measures Compilation and Aggregation Process environmental impacts can also be associated with structural measures.

Although many of the structural measures generally correspond to standard coastal storm risk management strategies, specific applications are not constrained to the usual solutions. Opportunities for innovative designs, technologies, materials, etc., should be considered when evaluating specific application of any of these measures. Furthermore, implementing innovative combinations of standard measures is key to managing coastal storm risks and increasing resilience. For example, shoreline stabilization measures, such as seawalls and revetments, can work effectively with beach restoration when designed to be exposed to waves only during extreme events to provide an additional line of defense without interrupting non-storm coastal processes (USACE 2013c).

NNBF Measures

NNBF measures have been useful in enhancing the resilience of coastal areas threatened by sea level change (Borsje et al. 2011) and coastal storms (Gedan et al. 2011; Lopez 2009). For example, beaches are natural features that can provide coastal storm risk management and resilience where their sloping nearshore bottom causes waves to break—dissipating wave energy over the surf zone. These breaking waves often form offshore bars that help to dissipate waves farther offshore. Dunes that back a beach can act as physical barriers that reduce inundation and wave attack to the coast landward of the dune. Although dunes may erode during a storm, they often provide a sediment source for beach recovery following storms. Engineered beaches and dunes can provide functions that are similar to natural beaches and dunes and represent nature-based infrastructure specifically designed and maintained to provide coastal storm risk management. Strategic placement of offshore sediment is critical for these measures. These NNBF often require beach nourishment to mitigate ongoing erosion and other natural processes.

Dense vegetation and the shallow water within wetlands can slow storm surge advance somewhat and can reduce the surge in some cases or slow its arrival time landward (Wamsley et al. 2009 and 2010). However, when storm surges increase water levels above the height of the vegetation, low-lying vegetation, such as sea grasses and salt marshes, have less of an effect on mitigating storm surges (Koch et al. 2009). Coastal storm risk management does not solely consist of surge reduction. Wetlands can also dissipate wave energy (Gedan et al. 2011; Tschirky et al. 2001). The magnitude of these effects depends on the specific characteristics of the wetlands, including the type of vegetation, its rigidity and structure, and wetland extent and position relative to the storm track (Tschirky et al. 2001). Although wetlands may reduce storm surge propagation in some instances, water can be redirected, potentially causing a local storm surge increase elsewhere, similar to sea walls/other structural interventions. Furthermore, engineered, constructed, and natural wetlands can enhance the adaptive capacity of the coastal system under future conditions including climate and sea level change.

ADAPTATION AND ADAPTIVE CAPACITY IN RESPONSE TO INCREASING RISK

Adaptive capacity describes a system's ability to evolve, either naturally or through engineered maintenance activities, to preserve or enhance the system's valued functions. In the future coastal landscape, adaptation and adaptive capacity of coastal storm risk management measures will become more and more critical to vulnerable communities and populations. Specifically, with current literature documenting increases in storm intensity and frequency, and impacts from sea level change, the coastal landscape can be expected to change considerably in the future (IPCC 2007, 2013). The NACCS sea level change analyses presents potential scenarios of sea level change for 2018, 2068, and 2100; the results reinforce the concept of coastline migration and inundation over time. Coastal communities and populations must be prepared to adjust or adapt to these changing conditions. Furthermore, adaptive management costs of measures must accounted for to allow migration, particularly in a developed area where real estate costs are high or pose a barrier to migration.

As indicated by the NACCS Opportunities in Section II, improved implementation of NNBF throughout the study area is a significant opportunity to increase resilience and manage risk. Moreover, NNBF performance and characterization of ecosystem goods and services derived from NNBF implementation remain key knowledge gaps that should be addressed by interagency research teams in the immediate future.

Nonstructural Measures

Nonstructural coastal storm risk management measures include acquisition and relocation, building retrofits, flood warning and evacuation planning, and programmatic considerations, such as land use and floodplain management and zoning. Additionally, conservation planning actions, including acquisition and the establishment of perpetual easements to increase the total acreage of undeveloped land and open space, to convert existing areas of privately-owned and existing buildable properties into natural habitat along the coast could reduce risk by removing properties and people from potential direct damages from future coastal storm events (NRC 2014). Programmatic measures include floodplain management and zoning, which could also include rescission of building permits following a storm event for structures in a floodplain regulated by the local jurisdiction that are substantially damaged during a flood event. Nonstructural management measures in general are intended to reduce the consequences that flooding would have to assets exposed to flood peril, as opposed to a structural measure that alters the characteristics or the probability of the flood peril to occur (USACE 2014b). Operation and maintenance costs of nonstructural measures are typically low, and are usually sustainable over long-term planning horizons (USACE 2014c).

The Planning Analyses Appendix includes additional information on the description of coastal storm risk management measures, including benefits, impacts, and other considerations.

Measure Categorizations and Comparisons

Once the measures were aggregated into specific types, the respective coastal storm risk management capacity, as well as the measures' function to promote resilience within a system and their adaptive capacity over time was evaluated. The coastal storm risk management measures were characterized by the degree to which they could 1) manage coastal storm damage (through reductions in flooding, waves, or erosion), 2) produce multiple benefits in addition to coastal storm risk management, and 3) promote resilience and adaptive capacity. Based on these criteria, Table IV-4 presents the measures categorized as high, medium, low, and none. This evaluation of the coastal storm risk management functions is based on professional experiences from previous coastal storm investigations. It was intended to present a qualitative assessment of the function, performance, utility, and resilience attributes of the various measures. Table IV-4 is intended to highlight that while a measure may not have a singular high designation for risk management potential, it may be quite useful in adaptive capacity and promoting resilience in the system. Subsequent analyses could provide more refined and quantitative evaluations of the measures' coastal storm risk management capacity, other benefits, and resilience and adaptive capacity, including a range of possible metrics for evaluation at smaller scales.

A section of boardwalk at the base of Lincoln Boulevard destroyed during Hurricane Sandy in Long Beach, NY

Source: http://www.theatlantic.com/infocus/2012/11/hurricane-sandy-the-long-recovery/100405/

Table IV-4. Coastal Storm Risk Management and Resilience Attributes Associated with the Full Array of Measures

Aggregated Measure Type[1]	Category[2]	Coastal Storm Risk Management Function			Multi-Benefits[3]	Resilience
		Flooding	Wave Attenuation	Erosion		Adaptive Capacity[4]
Acquisition (building removal) and relocation[5]	Non-STR	High	High	High	High	High
Building retrofit (e.g., floodproofing, elevating structures, relocating structures, ringwalls)	Non-STR	High	Low	Low	Low	Low
Enhanced flood warning and evacuation planning (early warning systems, emergency response systems, emergency access routes)	Non-STR	Low	None	None	Low	High
Land use management/ conservation and preservation of undeveloped land, zoning, and flood insurance	Non-STR	Medium	None	None	High	Medium
Deployable floodwalls	STR	Medium	None	None	None	Low
Floodwalls and levees	STR	High	Low	None	Low	Low
Shoreline stabilization (seawalls, revetments, bulkheads)	STR	Low	High	High	Low	Low
Storm surge barriers	STR	High	Medium	None	Low	Low
Barrier island preservation and beach restoration (beach fill, dune creation)	STR/NNBF	High	High	Medium	High	High
Beach restoration and breakwaters	STR/NNBF	High	High	High	High	Medium
Beach restoration and groins	STR/NNBF	High	High	High	High	Medium
Drainage improvements (e.g., channel restoration, water storage/retention features)	STR/NNBF	Medium	Low	Medium	Medium	Low
Living shorelines	STR/NNBF	Low	Medium	Medium	High	High
Overwash fans (e.g., back bay tidal flats/fans)	NNBF	Low	Medium	High	Medium	High
Reefs	NNBF	Low	Medium	Medium	High	High
Submerged aquatic vegetation	NNBF	Low	Low	Low	High	Medium
Wetlands	NNBF	Low	Medium	Medium	High	High

1 *An extensive list of management measures was compiled as part of the NACCS Measures Working Meeting in June 2013. The measures presented here represent an aggregated list of the categories of measures and corresponding conceptual parametric unit cost estimates.*

2 *STR = structural measure, Non-STR = nonstructural measure, and NNBF = Natural and Nature-Based Features measure. Multiple measures are listed if the aggregated measure type is made up of a combination of measures.*

3 *Multi-benefits focus on socioeconomic contributions to human health and welfare above and beyond the risk management benefits already highlighted in this table (i.e., flooding, wave attenuation, etc.). These benefits could include increased recreational opportunities, development of fish and wildlife habitat, provisioning of clean water, production of harvestable fish or other materials, etc.*

4 *Adaptive capacity is the assessment of a measure's ability to adjust with changing conditions and forces (including sea level change) through natural processes, operation and maintenance activities, or adaptive management, to preserve the measure's function.*

5 *Acquisition, relocation, and buyouts do not actually prevent flooding and erosion but remove the population and associated development from its effects.*

In addition to providing engineering functions related to managing risks from coastal storms, integrated solutions can provide a range of additional ecosystem services. A true systems approach to coastal storm risk management and resilience requires consideration of the full range of functions, services, and benefits produced by coastal projects and blended solutions. These include benefits related to commercial and recreational fisheries, tourism, clean water, habitat for threatened and endangered species, and support for cultural practices.

As an example of a blended solution, breakwaters manage risk of shoreline erosion by attenuating wave energy and can provide additional recreational opportunities, valuable aquatic habitat, and carbon or nutrient sequestration with wetlands incorporated into the design. Natural features, such as coastal wetlands, forests, or oyster reefs, provide environmental and social benefits and can also contribute to coastal storm risk management or resilience. NNBF, such as engineered beaches and dunes, or ecosystem restoration projects involving coastal wetlands, forests, or oyster reefs, can provide a range of environmental and social benefits, including those related to coastal storm risk management. Nonstructural measures may reduce social vulnerability due to changing sea levels and coastal storms and can also allow for wetland migration over time or support increased socioeconomic benefits associated with recreation.

Developing a more complete understanding of the engineering functions, multiple benefits, and adaptive capacity provided by the full range of coastal features will help to inform development and application of coastal storm risk management strategies. Some benefits are complementary, such as wetland restoration that increases habitat and wave attenuation, while others are conflicting, such as dune creation for coastal storm risk management that competes with viewshed concerns. As sea level and climate change influence the coastal environment, taking a comprehensive view of the functions and benefits will provide important information for decision-making that supports resilient coastal systems.

Knowledge about the performance of NNBF, nonstructural, and structural features varies, as do the methods to calculate and measure performance. Factors contributing to this varied knowledge include the diversity of objectives, the threats under consideration (e.g., a particular range or frequency of coastal storms), and technical information that is available for describing the relevant processes and functions. By employing a tiered approach to addressing coastal storm risk management (incorporating the steps of the Framework), various components of the system could then be identified for further analyses, perhaps leading to more detailed designs of features composing the system.

Coastal systems are naturally dynamic, and integrated measures will respond in many ways to storms—with some responses being temporary and others permanent. Storm effects on wetlands often include erosion, stripped vegetation, and salinity burn, all of which can decrease long-term productivity. However, storms can also introduce mineral sediments that contribute to the long-term sustainability of wetlands with respect to sea level change. The long- term consequences for wetland systems depends on many factors, including pre-storm landscape structure (including wetland extent and relationship to other natural and built features), proximity of the wetland to a storm track, and the meteorological conditions that persist following a hurricane (e.g., salinity burn effects are reduced if high precipitation occurs during or after the storm).

Storms provide the greatest source of coastal change on barrier islands due to storm surge and strong waves. Surging water and stronger waves can erode barrier island beaches and, if the surge is high enough, result in overwash, breaching, or back bay flooding, thereby reducing the coastal storm risk management function of the islands.

The dynamic behavior and response of NNBF to threats, such as coastal storms and development, can affect their performance with respect to system-level coastal storm risk management and resilience objectives. For NNBF, such as engineered beaches and dunes, this variation can be addressed through effective planning and engineering to maintain the desired level of service.

Although some literature suggests that coastal features (e.g., wetlands, barrier islands) can reduce surge and waves, this conclusion has sometimes been based on limited data. Consequently, characterizations of coastal storm risk management benefits vary widely based on anecdotal, qualitative, and quantitative information (Wamsley et al. 2009). The actual ability of wetlands to provide coastal storm risk management from storms is complex and depends on many factors, including storm intensity, track, speed, and the surrounding local bathymetry and topography (Resio and Westerlink 2008). However, there are methods for including these complexities and the interactions of storms with NNBF that make use of more quantitative analytical approaches (Anderson et al. 2011, Cialone et al. 2008, Suzuki et al. 2012, Yao et al. 2012).

Applicability by Shoreline Type

The measures were further categorized according to the shoreline type for which they are best suited considering typical application opportunities, constraints and best professional judgment. Shoreline types were derived from the NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA n.d.). This categorization is summarized in the Planning Analyses Appendix and State and District of Columbia Analyses Appendix.

A conceptual evaluation was conducted on the geographic applicability of the NNBF measures presented in Table IV-4, including beach restoration, beach restoration with breakwaters/groins, living shorelines, reefs, submerged aquatic vegetation, and wetlands. The GIS operations used for the NNBF screening analysis are described in the technical report *Use of Natural and Nature-Based Features in Coastal Systems* (Bridges et al. 2015). In addition to shoreline type, the analysis considered habitat type, impervious cover, water quality, and topography/bathymetry. Further evaluation of the results would be required for applicability to a smaller scale using more refined datasets. Additional information associated with the methodology and results of the analysis is presented in the Planning Analyses Appendix.

Coastal Storm Risk Management Strategies and Full Array of Measures

Coastal systems provide important social, economic, and ecological benefits to the Nation. However, our coasts are vulnerable to the influence of a combination of factors, including storms, changing climate, geological processes, and the pressures of ongoing development and urbanization. The overarching strategy to increase coastal resilience and reduce vulnerability can be achieved by 1) instituting land use changes over time to adapt to impacts that increase risks; 2) accommodating potential changes, such as climate variability, sea level change, etc., to preserve the natural and built environment over time; and 3) employing coastal storm risk management measures to manage and reduce flood damage to property and infrastructure. In addition to policy and programmatic efforts to manage risk, the NACCS Coastal Storm Risk Management Framework builds on three common adaptation categories used by the climate adaptation communities in the United States and internationally: avoid (sometimes termed "retreat"), accommodate, and preserve (sometimes termed "protect") (Dronkers, J. et al. 1990; USACE 2014c).

These three strategies can include a variety of structural (including NNBF), nonstructural, and programmatic coastal storm risk management measures, and combinations thereof, that provide risk management and adaptation options to coastal communities to address increasing flood risk over time. Given the uncertainty associated with climate science and the corresponding impacts to sea level change, planning scenarios should be factored into the decision-making process when evaluating coastal storm risk management strategies, as well as risk management measures. Subsequent sections of this report provide additional discussion on climate change adaptation planning, including key concepts, tiered adaptation planning, and a systems approach.

Design Considerations

A Design Standards and Criteria Team was formed to examine existing coastal engineering design standards and criteria, as required by Public Law 113-2:

…that efforts using these funds shall incorporate current science and engineering standards in constructing previously authorized Corps projects designed to reduce flood and storm damage risks and modifying existing Corps projects that do not meet these standards, with such modifications as the Secretary determines are necessary to incorporate these standards or to meet the goal of providing sustainable reduction to flooding and storm damage risks.

Table IV-5 presents the post-Hurricane Sandy design criteria identified by the Design Standards and Criteria Team. These criteria informed the coastal storm risk management levels assigned to measures. Table IV-6 presents suggested levels of coastal storm risk management. Actual risk management levels may vary depending on site-specific conditions.

Table IV-6 summarizes the conceptual design criteria that were used in evaluating costs and risk management for the various coastal storm risk management measures. The design criteria included a "+3 feet" allowance for the structural measures to account for uncertainty associated with future sea level change forecasts. This 3-foot allowance is consistent with the USACE High scenario for projected sea level change by year 2068, as well as post-Hurricane Sandy design guidance developed by other agencies. Most structural measures and NNBF features such as beach fill and dune creation were assumed to be designed to a 1 percent flood elevation plus a 3-foot allowance for future sea level change. Storm surge barriers were assumed to be designed to a 0.2 percent flood elevation plus the same 3-foot allowance for future sea level change.

For other NNBF measures (not including the beach restoration [beach fill, dune creation] measures presented in Table IV-4), the design criteria of the 10 percent flood was assumed for risk management potential. This design criteria was assumed for concept design purposes, although the opportunity for surge reduction would ultimately be dependent on site-specific criteria, such as geographical location, local tidal variance, geomorphological conditions, etc. In addition, the allowance for future sea level change increase was not considered for the 10 percent floodplain because NNBF risk management measures would depend on tidal influences to maintain their functionality (e.g., wetlands and living shorelines). Adaptive management considerations with respect to sea level and climate change would be required for NNBF management measures.

Buildings are typically elevated (nonstructural measure) one foot above the 1 percent flood to account for risk and uncertainty. However, as part of floodplain ordinances and building codes, some coastal communities have, or are enacting, more stringent elevation requirements of up to 3 feet above

Table IV-5. Post-Hurricane Sandy Design Criteria of Other Agencies

Agency	Criteria
NYC Special Initiative for Rebuilding and Resilience (2013)	FEMA Base Flood Elevation (BFE) + 3 feet
U.S. Department of Housing and Urban Development–Hurricane Sandy Rebuilding Task Force (2013)	FEMA Base Flood Elevation (BFE) +1 feet

Table IV-6. Conceptual Design Criteria of NACCS Risk Management Measures

Measure Type	Criteria[1]
Structural (not barriers)[2]	1 percent flood elevation + 3-foot sea level change allowance
Storm Surge Barriers	0.2 percent flood elevation + 3-foot sea level change allowance
Natural and Nature-Based Features	10 percent flood elevation
Nonstructural (floodproofing and buyouts)	1 percent flood elevation + 3-foot sea level change allowance

[1] *Criteria are for conceptual NACCS design only, and may not be consistent with existing USACE or other Agency analysis or design guidance.*

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

the 1 percent flood as a result of the magnitude and impact of Hurricane Sandy, and the uncertainty regarding the rate of sea level change. Therefore, for the purposes of this analysis, the more conservative requirement of 3 feet above the 1 percent flood was used as the nonstructural design elevation.

Cost Considerations

Conceptual design and parametric cost estimates were developed for the various coastal storm risk management measures. They are representative of typical conditions and do not account for reach or site-specific variations in ground level, tidal range, or storm water levels. 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 historical unit costs for all construction items (e.g., excavation, fill, rock, plantings). Project timeframes represent a 50-year project life, unless otherwise noted. For those measures that require substantial operations and maintenance requirements, such as a beach and dune project, periodic operation and maintenance assumptions were specifically noted. Each measure presented in Appendix C that includes a parametric unit cost estimate includes a line item noting operations and maintenance costs to annualize costs over a 50-year project life, which was then used to derive the unit cost. Table IV-7 presents the parametric unit costs associated with coastal storm risk management measures. Additional information on the various measures is included in the Planning Analyses Appendix. For Tier 2 and Tier 3, the conceptual designs and associated costs would be adjusted for variability in design parameters, including local design water levels, labor and materials, and more refined estimates of operations and maintenance costs. Considerations of costs associated with real estate, including real estate acquisitions, rights of way, or other easements, would need to be considered as well.

Aerial view of New Jersey coast during a search and rescue mission, Oct. 30, 2012

Source: http://en.wikipedia.org/wiki/Hurricane_Sandy
U.S. Air Force photo by Master Sgt. Mark C. Olsen

Table IV-7. NACCS Risk Management Measures Parametric Unit Cost Estimates

Aggregated Measure Type[1]	Total Estimated First Construction Cost per Unit[2]	Total Estimated Annual Average Cost per Unit[3]	Units
Acquisition (building removal) and relocation	$349,000	$14,900	Building
Building retrofit (floodproofing)	$100,000	$4,200	Building
Building retrofit[4] (elevating structures)	$192,000	$8,200	Building
Building retrofit (ringwalls – commercial/ apartment building)	$3,680,000	$157,000	Building
Building retrofit (ringwalls – industrial building)	$4,840,000	$206,000	Building
Land use management/zoning and flood insurance[5]	Varies	Varies	
Deployable floodwalls	$5,500	$250	feet
Floodwalls[6]	$5,300	$240	feet
Levee	$1,600	$80	feet
Shoreline stabilization (seawalls, revetments, bulkheads)	$4,800	$250	feet
Storm surge barriers	Varies	Varies	
Beach restoration (beach fill, dune creation)	$3,500	$490	feet
Beach restoration and breakwaters	$9,200	$610	feet
Beach restoration and groins	$7,400	$530	feet
Drainage improvements[5] (e.g., channel restoration, water storage/retention features)	Varies	Varies	
Living shorelines	$1,400	$70	feet
Overwash fans (e.g., back bay tidal flats/fans)	$2,400	$100	feet
Reefs	$4,800	$200	feet
Submerged aquatic vegetation	$2,400	$100	feet
Wetlands[7]	$565,000	$26,900	acre

1 *An extensive list of management measures was compiled as part of the NACCS Measures Working Meeting in June 2013. The measures presented here represent an aggregated list of the categories of measures and corresponding conceptual parametric unit cost estimates.*

2 *Regional factors, such as materials, labor, and fuel, may affect overall costs. The total construction cost estimates must take into account more localized costs of these factors as part of the development of project cost estimates.*

3 *Includes operations and maintenance costs for all measures as well as periodic renourishment costs for beach restoration measures.*

4 *The range of costs to elevate structures can vary considerably.*

5 *Costs could not be developed due to scale of the NACCS study.*

6 *The concept design identified for the floodwall category consists of a concrete structure. These structures might also require closure structures including stoplogs, miter gates, swing gates, or roller gates, which were not included in the development of the parametric unit cost estimate. A simple steel sheetpile I-wall may be more economical.*

7 *An annual average cost of $120 per foot was used in the Tier 1 evaluation assuming a nominal wetland width (i.e., dimension perpendicular to the shoreline) of 200 feet.*

EVALUATE AND COMPARE SOLUTIONS

As part of the Framework Tier 1 evaluation, an initial screening of potentially applicable measures for each risk area was performed as part of the exposure and risk assessment. After identifying the shoreline types and measures applicable by shoreline type, the corresponding shoreline lengths within the risk areas were computed. Next, the qualitative assessment of risk management potential and the parametric unit costs were used to complete an evaluation of the measures. For those areas of the coast that were not specifically identified as a risk area as part of the Tier 1 exposure and risk assessment, local communities and stakeholders could use the information presented in the Framework to quickly develop similar comparisons. The Economics Analyses Appendix provides additional discussion of the evaluation of measures, and corresponding risk management and costs. The results of the Tier 1 evaluation and comparison of solutions are included in the State and District of Columbia Analyses Appendix.

Because the study area covered 10 States and the District of Columbia, the Tier 1 evaluation required the use of consistent national datasets that were available across the entire study area, which decreased the level of detail and granularity. For example, in some areas of rather homogenous shorelines, such as beaches or urban areas, only a few measures are likely to be applicable. The number of measures with the lowest parametric unit cost that may be applicable for the shoreline type and that provide the same level of qualitative risk management potential is limited. The scale and corresponding level of detail necessary for decision-makers to determine the appropriate risk management strategy and specific measures to employ requires further analysis as part of the aforementioned Tier 2 and Tier 3 evaluations. The subsequent analyses should also consider the range of future, long-term scenarios associated with climate change adaptation planning to adequately address and account for risk-based planning analyses.

Evaluating and comparing various risk management solutions in the context of climate change and climate change adaptation planning is critical. Consistent with the *National Climate Assessment: Climate Change Impacts in the United States*, the Framework consideration of climate change presents a risk-based, scenario-planning approach to address uncertainties and improve the ability to anticipate thresholds and tipping points (Melillo et al. 2014). Long-term planning would assist with the development of effective strategies and adaptation efforts to address risk from future flood hazards exacerbated by forecasted sea level change.

Climate Change Adaptation Planning

The combination of extreme weather, such as storms like Hurricane Sandy, and climate change scenarios results in "climate extremes" that create risks to coastal areas and may be significantly greater in the future. Changing sea levels also result in changes to less extreme events by increasing the frequency of nuisance flooding (NOAA 2014). In addition, these climate impacts would interact with other simultaneous social and environmental changes to produce a substantially different future risk regime.

In the United States, the U.S. Global Research Program, National Research Council (NRC), NOAA, and USACE are among those advocating the use of scenario-based approaches to project future sea level changes (Mellilo et al. 2014, NRC 1987, NRC 2012b, NOAA 2012a, USACE 2013b, USACE 2014a, USACE 2014d). In fact, USACE guidance first addressed changing sea levels in a 1986 letter of instruction, which was followed by a 2000 requirement for sensitivity analyses to differing rates of change, and subsequently a multiple-scenario approach (USACE 2014d).

According to Moser et al., the multiple-scenario approach "acknowledges uncertainty by considering an array of futures based on different potential values of key uncertainties. In this context, plans are formulated that both address each of the possible futures but also are robust in achieving the desired objectives regardless of the future" (2008). The scenario approach allows communities and decision-makers to consider a range of potential future climate conditions and their associated levels of impacts (USACE 2014a). Effective use of scenarios enables decisions to be made despite climate change uncertainty. The ultimate goal of climate change adaptation would be to reduce the impacts from climate change and to promote community and ecosystem resilience. The Framework incorporates climate change adaptation considerations associated with future coastal storm risk and vulnerability.

Key concepts related to climate change adaptation in coastal settings are presented in the technical report *Use of Natural and Nature-based Features for Coastal Resilience* (Bridges et al. 2015). Key concepts incorporated in the NACCS include the following:

- Climate change means that natural forces would change in the future; this nonstationarity requires consideration of a future that may be substantially different than the past. There is considerable uncertainty associated with future climate change (USACE 2014a, 2014d).
- Uncertainty exists not only with regard to sea level change and wider climate change, but also with regard to landscape responses, such as flooding, erosion, environmental impact, socioeconomic changes, and human responses, such as future policy and programmatic changes, that could influence how communities respond to climate changes (USACE 2014d).
- Climate change scenarios do not project future conditions exactly, but they describe potential future conditions, which are then used to evaluate decisions under a variety of potential future outcomes (USACE 2014d).
- Adaptation plans include both current actions and future actions that are implemented when critical climate change and/or vulnerability thresholds occur in the future (USACE 2014a, 2014d).
- A recurring/iterative approach to climate change planning allows decision-makers to leverage future advancements in climate science and policy as well as evaluate the performance of coastal storm risk management measures that have already been implemented as part of their climate change adaptation strategy (USACE 2014d).
- Adaptation plans consider the full range of coastal storm risk management measures: structural (including natural and nature based), nonstructural, and programmatic (USACE 2013c, 2014d), and can include combinations of structural, nonstructural, and natural and nature-based measures that are implemented simultaneously or in phases over time.
- Future performance and alternative adaptation measures are important considerations during coastal storm risk management systems planning and design (USACE 2014d).

Prior to the rise of concerns regarding climate change, decisions regarding coastal risk were generally based on the assumption that the climate would be stable—that a given location would see the same weather patterns in the future that it had seen in the past. As such, forecasts of future conditions were typically based on a significant body of measured historical data on the climate at the site and the historical responses to that climate. This stationary climate resulted in a decision-making environment based on a single future condition that assumed low uncertainty with respect to future forcing conditions (sea level, waves, tides, surges, storms). Low uncertainty thus led to a "predict-then-act" paradigm that decision-makers have become accustomed to (NAS 2010).

Given the current and potential future rates of sea level change and land subsidence in the NACCS study area, assuming stationary conditions is not realistic. Climate change scenarios indicate that future coastal forces and associated impacts may be far outside the realm of past experience (Melillo et al. 2014, NOAA 2012a, NAS 2010, and USACE 2014d). For this reason, USACE coastal storm risk management planning relies on climate change scenarios rather than simple extrapolation of past climate observations (USACE 2013b, 2014d).

Climate change scenarios incorporate a higher level of uncertainty through the use of a range of potential future coastal risks. Sea level change is relatively well understood, but climate impacts to storms are still emerging. For this reason, coastal storm risk management strategies must include periodic/ongoing review and revision to incorporate new science and climate scenarios as they develop.

In the face of highly uncertain outcomes associated with climate change, coastal storm risk management decisions based solely on a single most probable or likely outcome can lead to inaction, poor project performance or maladaptation (NOAA 2012a, USACE 2014d). This uncertain future suggests a transition to an "explore-then-test" decision context (NAS 2010) in which multiple scenarios are evaluated and coastal storm risk management measures are judged by their adaptability and function across the full range of future risks. USACE (2014d) recommends a tiered approach to the assessment of sea level change on project alternatives and project performance using three scenarios of sea level change.

Tiered Adaptation Planning

Decision-making under uncertainty requires a tiered, iterative approach whereby an early, screening-level analysis provides a preliminary outline of the landscape responses to climate change (USACE 2010a, 2014d). One of the primary benefits of the screening level analysis is that it illuminates relevant variables and uncertainties and is the first chance to evaluate potential measures and alternatives. The NACCS includes a Tier 1 level evaluation of sea level change scenario impacts and measures and strategies for coastal storm risk management.

USACE has developed specific guidance in regards to sea level change (USACE 2013b, 2014d) that is scenario-based. Scenario-based analysis establishes the range of expected future landscape responses, rather than a single most likely future condition. USACE (2014a) scenario-based adaptation planning concentrates on establishing critical thresholds (e.g., sea level change, flooding frequency) at which future actions would take place (e.g., initiate construction of flood walls, elevation of structures, building code revisions, marsh construction).

The Framework follows a tiered approach in which a screening level (Tier 1) evaluation is performed to evaluate broad and approximate impacts from climate change. This process scopes a Tier 2 evaluation that evaluates specific measures against the full range of scenarios on a regional geographic scale. Adaptation alternatives can then be developed to include multiple measures applied at varying thresholds of risk or impact.

A Systems Approach to Climate Change Adaptation

The geophysical setting, existing and future levels of risk exposure, desired level of risk reduction, environmental constraints, cost, and other factors would all influence the development of adaptation strategies (USACE 2014d).

As described elsewhere in this report, a risk management strategy would, in most cases, consist of multiple individual measures that work together as a coastal storm risk management strategy.

Adaptation strategies that look far into the future would require that decision-makers consider a geographic extent over which coastal adaptation would occur. In many cases, this would include areas landward of what has traditionally been considered the coastal zone that may not currently be significantly threatened by coastal storms or sea level change but that could be an important component of adaptation (USACE 2014d). Additionally, gravity-driven stormwater systems could become inundated by increases in mean sea level and perform below their designed capacity (Mellilo et al. 2014). Drainage problems are being experienced in the mid-Atlantic areas and in the Chesapeake Bay in particular because sea level is rising at a faster rate than other areas of the Atlantic Coast (Boesch et al. 2013). The NACCS sea level change analyses corroborate this trend. As a result, further consideration of potential changes in precipitation patterns should be evaluated in low-lying areas associated with both tropical and extra-tropical events as well as in areas farther inland that represent the estuarine and freshwater tidal interface with riverine conditions. This is because poor drainage associated with stormwater design capacity exceeded by rising sea levels could exacerbate flooding conditions and increase flood risk. In low-lying areas and reaches of the Hudson, Delaware, and Chesapeake Bays and their tributaries, increases in mean sea level coupled with riverine flooding could pose increasing flood risk to those communities farther landward.

In addition to coastal storm risk management measures to be implemented at the outset of the planning process, determining those measures that appear the most promising for future implementation and establishing current actions that would facilitate their future use is also important. For example, retreat from threatened coastal areas might require room for a natural marsh habitat to move landward with rising sea levels or retreat from a populated barrier island might require relocation of communities. Adaptation plans must also take into account other, non-climate related environmental changes and the associated uncertainties (Mellilo et al. 2014).

Application of the Framework and Other Considerations

Table IV-8 summarizes the first five steps associated with the Framework and includes supporting data and references for completing each step.

The detailed Tier 3 evaluation would consider combinations of measures for comparison of alternative plans and could incorporate a benefit - cost analysis. Additional characteristics or metrics beyond risk assessment and parametric cost estimates should be explicitly considered at this level of analysis and the best available data should be used. Tier 3 evaluation should also consider other metrics associated with risk, vulnerability, and exposure, including more refined site-specific datasets addressing sensitivity and adaptive capacity. In addition, the evaluation should consider the resilience, including rapid recovery, of critical infrastructure, focusing more protection on infrastructure that is slow to recover (e.g., hospitals) compared to those that rapidly recover (e.g., portions of airports without buildings). Various metrics associated with evaluation of management measures objectives, such as risk reduction (life safety), damage reduction, feasibility, and impacts should also be incorporated.

Hurricane Sandy flooding, Crisfield, MD on October 30, 2012

Source: http://en.wikipedia.org/wiki/Hurricane_Sandy
The National Guard - Maryland National Guard

Table IV-8. Supporting Data and References for Completing the First Five Steps Associated with the NACCS Coastal Storm Risk Management Framework

Steps	Tier 1 (NACCS/ Regional Level)	Tier 2/Tier 3 (State/Local Level Replication)	Appropriate Data Sources/ References (Not an Exhaustive List)
Initiate Analysis	Initiate Analysis	Initiate Analysis	Federal Emergency Management Agency (FEMA) Hazard Mitigation Planning Points of contact U.S. Army Corps of Engineers (USACE) Districts NACCS Coastal Program Guide NACCS Visioning Session Silver Jackets NACCS Risk Assessment Decision-Making Questioning and Metric Development Methodology
Characterize Conditions	Inventory existing conditions and forecast future conditions of the study area • Collect data • Select a planning horizon (25, 50, 100 years) • Utilize existing plans and studies • Consider environmental conditions and cultural resources • Consider changes in population and supporting infrastructure • Consider climate change and sea level change scenarios	Inventory existing conditions and forecast future conditions of the study area • Collect refined geographic data (bathymetry, topography, land use, environmental/habitat, etc.) • Collect refined coastal hazard data (storm surge, waves, rainfall, etc.) • Consider local policies and other local data	ER 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs (https://www.flseagrant.org/wp-content/uploads/USACE_SLR_guidance_ER_1100-2-8162.pdf) ETL 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf) NACCS Geodatabase NACCS Storm Database Focus Area Assessments and Visioning Session Reports USACE Sea Level Change Curve Calculator http://www.corpsclimate.us/ccaceslcurves.cfm National Oceanic and Atmospheric Administration (NOAA) Digital Coast (Coastal Services Center) (http://coast.noaa.gov/digitalcoast/tools/slr) U.S. Geological Survey National Climate Change Viewer (http://www.usgs.gov/climate_landuse/clu_rd/nex-dcp30.asp) NACCS Depth-Damage Functions (including HEC-FIA [Hydrologic Engineering Center Flood Impact Analysis] for coastal investigation) Sea Level Affecting Marshes Model (SLAMM) State Plans/Geographic Information System (GIS) data Hurricane Evacuation Studies Bureau of Labor and Statistics Employment and Wages in Flood Zones (http://www.bls.gov/cew/hurricane_zones/home.htm and http://www.bls.gov/cew/hurricane_zones/maps.htm)

Table IV-8. Supporting Data and References for Completing the First Five Steps Associated with the NACCS Coastal Storm Risk Management Framework (continued)

Steps	Tier 1 (NACCS/ Regional Level)	Tier 2/Tier 3 (State/Local Level Replication)	Appropriate Data Sources/ References (Not an Exhaustive List)
			Coastal Barrier Resources System Mapper (http://www.fws.gov/CBRA/Maps/Mapper.html) U.S. Geological Survey iCoast (http://www.climatecentral.org/) Climate Central (http://www.climatecentral.org/) Surging Seas Sea Level Rise Assessment Tool (http://sealevel.climatecentral.org/) USGS monitoring/modeling of onshore and nearshore coastal storm characteristics USGS Coastal Vulnerability Index (http://marine.usgs.gov/coastalchangehazards/ and http://pubs.usgs.gov/of/1999/of99-593/index.html) FEMA National Flood Hazard Layer and Community Identification database U.S. Department of Interior, Northeast Climate Center (http://www.doi.gov/csc/northeast/science.cfm) New Jersey Adapt http://www.njadapt.org/home.html
Analyze Risk and Vulnerability	Identify problems and opportunities through exposure and risk assessments • Map inundation and exposure • Multiply exposure by the chance of inundation to present risk (GIS exercise)	Identify problems and opportunities through exposure and risk assessments • Alter exposure index metrics and weights as appropriate • Consider how existing projects reduce exposure and vulnerability • Perform more detailed analysis/ modeling of coastal responses to sea level change and storms • Evaluate existing and planned coastal storm risk management infrastructure design capacity and performance as well as risk associated with potential failure	ER 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs (https://www.flseagrant.org/wp-content/uploads/USACE_SLR_guidance_ER_1100-2-8162.pdf) ETL 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf) NACCS Exposure Assessment NOAA Digital Coast (Coastal Services Center) (http://coast.noaa.gov/digitalcoast/tools/slr) Social Vulnerability Index Northeast Climate Science Center Research & Decision Support Framework (https://www.sciencebase.gov/catalog/item/5012eb2fe4b05140039e03e0) U.S. Energy Information Administration Flood Vulnerability Assessment Map (http://www.eia.gov/special/floodhazard/) Coastal Resilience Mapping Portal (http://maps.coastalresilience.org/network/)

Table IV-8. Supporting Data and References for Completing the First Five Steps Associated with the NACCS Coastal Storm Risk Management Framework (continued)

Steps	Tier 1 (NACCS/ Regional Level)	Tier 2/Tier 3 (State/Local Level Replication)	Appropriate Data Sources/ References (Not an Exhaustive List)
Identify Possible Solutions	Identify possible solutions (risk management measures) • Identify the shoreline types within the study area • Pull forward measures that are applicable to the shoreline types in the study area (structural, nonstructural, NNBF)	Identify possible solutions (risk management measures) • Consider existing projects and whether retrofits are feasible • Consider adaptability of measures Adopt systems approach; combine measures into coastal storm risk management strategies	ETL 1100-2-1, Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf) Using the Full Array of Measures Publication (http://www.corpsclimate.us/docs/USACE_Coastal_Risk_Reduction_final_CWTS_2013-3.pdf) State measures matrices and shoreline type display (State and District of Columbia Analyses Appendix) FEMA's Floodproofing Manual for Non-Residential Structures Institute for Water Resources' (IWR's) Systems Approach to Geomorphic Engineering (SAGE) (http://www.iwr.usace.army.mil/Missions/Coasts/ProgramsandInitiatives.aspx)
Evaluate and Compare Solutions	Evaluate and relatively compare measures – coastal storm risk management strategies and measures using a systems approach • Identify the change in risk that implementing each applicable measure could provide • Divide the change in risk by the parametric cost for each applicable measure • Consider long-term vulnerabilities associated with sea level change inundation and forecasted changes in acceleration associated with climate change • Identify the process leading to the development of a quantitative metric to measure change in resilience by implementing an array of solutions (management measures)	Evaluate and relatively compare measures • Create smaller scale reaches (if needed) • Consider how existing projects can be enhanced or replicated in other areas • Consider how coastal storm risk system (existing and new features) work together • Consider available site-specific information (i.e., land use, existing State/ local plans) • Assess the resilience of the community by completing a detailed risk assessment that evaluates exposure, sensitivity, and adaptive capacity of the community • Consider climate change adaptation plan • Address existing risk while considering the long-term forecasted risk to sea level change inundation	USACE project listings/GIS layers State project listings/GIS layers NOAA Resilience Index (Mississippi and Alabama) (http://masgc.org/assets/uploads/publications/662/coastal_community_resilience_index.pdf) NOAA Digital Coast (Coastal Services Center) (http://coast.noaa.gov/digitalcoast/tools/slr) Climate Central's Surging Seas Risk Finder for New England (http://sealevel.climatecentral.org/) IWR's SAGE (http://www.iwr.usace.army.mil/Missions/Coasts/ProgramsandInitiatives.aspx) Lincoln Institute of Land Policy's Policy Focus Report: Lessons from Sandy

A variety of strategies and combinations of coastal storm risk management measures will be required to effectively manage coastal storm risk to vulnerable populations along the North Atlantic coastline. These measures are needed to create a coastline resilient to future changes in climate, sea level, and coastal storms, as well as populations such that our communities, infrastructure, economy, investments, national security, ecosystems, and livelihoods can be sustained. The risk of flood peril to humans and infrastructure would be effectively reduced to zero if they were not exposed to inundation during a flood event. However, in numerous areas of the North Atlantic Coast that have considerable infrastructure and large populations as part of long- established communities, managed retreat and relocation is not likely to be a viable option as a short-term strategy to address flood risk and sea level change. Furthermore, avoiding may never be a viable strategy if the current NFIP policy that transfers part of the cost of siting assets and communities in flood-prone areas to taxpayers is maintained. However, in some coastal communities, sea level change may cause inundation resulting in a tipping point and lead to changes in effective coastal storm risk management strategies. Considerations of the appropriate strategies— avoid, accommodate, and preserve—and further evaluation of the corresponding actions are required. Decision-makers can use the Framework to evaluate flood risk and the ability or willingness of communities to adapt to increasing coastal storm risk over time.

Several States and communities are already adopting policies and guidelines to consider increases in water surface elevations and require that the construction of infrastructure and structures consider increased future risk. Local jurisdictions must adopt minimum lowest floor elevation requirements to participate in the NFIP. Minimum policy and design requirements must be adjusted to align with a community's acceptable level of risk and corresponding sensitivity and adaptive capacity in response to a flood event. As indicated by the NACCS Opportunities in Section II, communities that are already partaking in incentives to manage risk have the opportunity to become more creative in encouraging innovative solutions to managing flood risk. The Community Rating System provides incentives to communities to adopt more stringent floodplain management ordinances above and beyond the minimal requirements to participate in the NFIP. To address the next storm, minimum building requirements could be increased.

As indicated by the NACCS Opportunities in Section II, States and communities need to determine what they consider an acceptable level of risk, taking into account sea level change and willingness or ability to adapt to the likelihood of increased vulnerability over time.

REDUNDANCY WITHIN A COASTAL STORM RISK MANAGEMENT SYSTEM WITH AN EMPAHASIS ON CRITICAL INFRASTRUCTURE WILL PROMOTE RESILIENCE

Compartmentalization of flood risk and modularity within communities to ensure continuity of operations of critical infrastructure must also be considered for site-specific coastal storm risk management measures to increase resilience following a storm event. Broader concepts with respect to community resilience presented in the *Regional Disaster Resilience: A Guide for Developing an Action Plan* are incorporated as part of the Framework (The Infrastructure Security Partnership 2011).

As indicated by the NACCS Findings in Section II, improved coastal storm risk management measures are needed and should include consideration of redundant risk management measures for critical infrastructure, such structural measures that reduce damage from waves and nonstructural measures, such as elevation and/or floodproofing of mechanical or electrical equipment, that reduce the risk and vulnerability. Resilience could also be incorporated by waterproofing electrical components and switches as another redundant feature.

Robust and redundant measures also provide greater risk management when high-magnitude events occur in series, such as Hurricane Rita following Hurricane Katrina in the Gulf of Mexico in 2005. Much of the North Atlantic Coast is lined with existing beach nourishment and/or dune coastal storm risk management projects and may not be able to perform as designed should two high- magnitude events occur in series over a short time. As described in the *Hurricane Sandy Coastal Projects Performance Evaluation Study*, disruption of planned maintenance and renourishment activities, and accelerated degradation of project conditions caused by coastal storms can affect the project's capacity to deliver expected coastal storm risk management benefits.

When applying the Framework for subsequent Tier 2 or Tier 3 evaluations, shared waters must be managed without regard to political boundaries. Changes in sea level, water quality, sediment transport, and habitats often have regional impacts and require regional solutions. For inland waters, the Susquehanna River Basin Commission, the Delaware River Basin Compact, and the Interstate Commission on the Potomac River Basin strike Compact are examples of commissions established by Congress in recognition that managing these shared waters without regard to political boundaries is in the Federal interest. Although the NACCS Framework can be utilized by State and local governmental entities, applying the Framework to the entire coastal system, which includes shared waters, would also be beneficial. USACE, which has served a leadership role on river basin commissions and in watershed partnerships, could potentially provide technical assistance through various standing authorities such as the Planning Assistance to States Program. Public-private partnerships to establish innovative financing opportunities, particularly in areas of shared waters, are gaining traction to better leverage resources to address the common goals of managing flood risk and promoting resilient and sustainable coastal communities.

INTERAGENCY COLLABORATION IS REQUIRED TO ADDRESS INCREASING COASTAL STORM RISK

Ongoing interagency collaboration among government agencies at all levels, along with other stakeholders and academia, will help overcome institutional barriers and guide an interagency response for the broader coastal system.

NACCS FRAMEWORK EXAMPLES

The NACCS Tier 1 evaluation of the study area over nine States and the District of Columbia was a large scale evaluation to address flood risk, which required national level datasets for consistency. At a smaller scale, finer details could be incorporated into the Framework steps as part of Tier 2 and Tier 3 evaluations. The NACCS includes several examples of Tier 2 evaluations presenting the various concepts included in the analyses to address increasing coastal storm risk and promoting resilience. Two are highlighted in the following sections.

The first example includes a basic Tier 2 evaluation for the Jamaica Bay and Rockaway Peninsula (NY-NJ1-I) risk area. The analysis is still based on the Tier 1 NACCS composite exposure and risk assessments, but it also includes refined assumptions related to the application and design of coastal storm risk management measures as well as a cost index, a normalized parametric estimate of the costs. Specifically, as part of the Tier 1 evaluation, one generic design and cost were developed for each measure type and then various measures were selected based on their applicability to shoreline type. In the Tier 2 evaluation, local shoreline configuration, ground elevations, and design water levels were also considered to develop measure designs and parametric cost estimates.

The purpose of this analysis was to showcase an example of the Framework for each of the 10 States and the District of Columbia included in the study area. In addition, Tier 2 examples were completed for each State and the District of Columbia to demonstrate the concepts presented in the Framework. The results of each of the Tier 2 example are presented in the State and District of Columbia Analyses Appendix. For specific Tier 2 applications of the Framework by coastal communities, the exposure, risk, and potential vulnerability and resilience assessments would be updated or completed in addition to refining the adaptation strategies and corresponding coastal storm risk management measures. In addition, more refined costs would be developed to more effectively address the comparability of the risk management strategies and corresponding coastal storm risk management measures necessary to establish a plan for implementation.

The second example presented herein is an evaluation of the increasing flood risk posed by sea level change to barrier islands and the back bays, including a focus on back bay flooding risks. The purpose of this analysis was to highlight the potential impacts that coastal communities may experience as a result of the impacts associated with sea level and climate change.

NACCS Tier 2 Example No. 1: Jamaica Bay and Rockaway Peninsula (NY_NJ1_I Risk Area)

The NACCS Tier 1 assessment as part of the Framework is a relative evaluation. This level of analysis should be considered a first approximation, which requires much more detail before any decisions can be made for implementation. The Tier 2 assessment constitutes a slightly finer analysis. For example, this level of analysis incorporates existing coastal storm risk management projects as well as other planned activities. Decision-makers could use the information obtained from the Tier 2 assessment to assist with general discussions of the appropriate flood risk management strategies, such as avoid, accommodate, and preserve, which could then lead into a Tier 3 evaluation of the various risk management measures to consider as part of the strategy. The Tier 3 evaluation would likely include site-specific analyses of risk management measures as well as benefit-cost analyses.

This section presents the application of the Framework Tier 2 evaluation for Jamaica Bay and Rockaway Peninsula (NY_NJ1_I risk area). As part of the Tier 2 evaluation, the NY_NJ1_I risk area was further divided into 15 subareas to generally identify those areas appropriate for the various coastal storm risk management strategies - avoid, accommodate, and preserve – along with applicable structural (including NNBF), and non-structural coastal storm risk management measures. For each of the subareas identified, coastal storm risk management measures were selected based on general knowledge and available data, including shoreline type and the aggregated coastal storm risk management measures matrix, topography, extent of development from online aerial photography, and flood inundation mapping. The purpose of this iterative process was to reevaluate the Tier 1 evaluation at a smaller scale while considering existing coastal storm risk management projects and planned projects. The Jamaica Bay and Rockaway Peninsula evaluation incorporates general strategies and specific project proposals in NYC's PLANYC: A Stronger, More Resilient New York Report, NY Rising Community Reconstruction Plans, New York State Plans, and ongoing USACE studies and projects into the evaluation. Additionally, by dividing the risk area into subareas, the combination of measures included in the Tier 1 evaluation could be generally re-evaluated considering regional and local coastal storm risk management measures, including a storm surge barrier across Rockaway Inlet.

Coastal storm risk management measures were considered based on applicability to the shoreline types in the measures matrix. The analysis considered ongoing USACE projects located in the risk area, including East Rockaway Inlet to Rockaway Inlet (Rockaway) identified in the First Interim Report and the Atlantic Coast of New York City, Rockaway Inlet to Norton Point NY (Coney Island) identified in the Second Interim Report.

The Jamaica Bay and Rockaway Peninsula Tier 2 evaluation considered two preservation coastal storm risk management strategies. The first consisted of local coastal storm risk management measures, such as dune and beach fill along the ocean shorelines, and revetments, seawalls, levees, and floodwalls along interior bay shorelines. This strategy was developed considering existing constructed projects such as USACE's Coney Island coastal storm risk management beach fill project, as well as others that will be constructed in the near term, such as beach fill and groins along Sea Gate's ocean shoreline as part of USACE's Coney Island coastal storm risk management project, USACE's Rockaway coastal storm risk management project, and the New York State Department of Environmental Conservation natural infrastructure project at Spring Creek in Howard Beach. The second strategy was a regional coastal storm risk management strategy that included combining more robust ocean shoreline protection measures with a storm surge barrier across Rockaway Inlet and a number of NNBF measures within Jamaica Bay that would mitigate the effects of frequent flooding locally. These NNBF measures are consistent with proposed projects presented in the NY Rising Community Reconstruction plans as well as other ongoing USACE efforts, such as the Jamaica Bay Ecosystem Restoration Feasibility Study.

The Jamaica Bay and Rockaway Peninsula Tier 2 evaluation also considered an accommodation strategy, including NNBF and non-structural measures. There are significant opportunities for improved implementation of NNBF in this area. NNBF opportunities include wetland restoration, maritime forests, oyster reefs/breakwaters, natural re-contouring of existing grades, natural berm construction, etc. as part of an accommodation strategy together with nonstructural measures, such as elevating and floodproofing structures.

Table IV-9. Tier 2 Example No. 1: Jamaica Bay and Rockaway Peninsula (NY_NJ1_I Risk Area) – Relative Costs[1] for Various Coastal Storm Risk Management Strategies

Subarea	Coastal Storm Risk Management Strategies									
	Avoid		Accommodate				Preserve			
	Acquisition (10% flood elevation)		NNBF (10% flood elevation)		Non-Structural Measures (1% flood elevation plus 3 feet)		Structural Measures (1% flood elevation plus 3 feet)		Regional/ Gates Structural Measures (0.2% flood elevation plus 3 feet)	
	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index	Description	Cost Index
Coney Island – Sea Gate	N/A	N/A	N/A	N/A	N/A	N/A	"Strengthen" to 1 % flood design level	0.45	“Strengthen” to 0.2 % flood design level	1.00
Coney Island & Brighton Beach	N/A	N/A	N/A	N/A	N/A	N/A	“Strengthen” to 1 % flood design level	0.35	"Strengthen" to 0.2 % flood design level	1.00
Manhattan Beach	Acquisition and Relocation	1.00	N/A	N/A	Floodproofing	0.42	Groins + Beach Restoration	0.48	Coastal dike/ floodwall	0.72
Rockaway West	Acquisition and Relocation	1.00	N/A	N/A	Floodproofing	0.42	Beach Restoration	0.19	Beach restoration + buried seawall	0.40
Rockaway East – Ocean	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Beach restoration + buried seawall	1.00
Coney Island Creek	Acquisition and Relocation	1.00	NNBF	0.01	Floodproofing	0.42	Revetment	0.04	Tidal barrier and wetlands (PLANYC)	0.08
Jamaica Bay – Brooklyn Shoreline	Acquisition and Relocation	1.00	NNBF	0.01	Floodproofing	0.42	Levee/ Floodwall	0.24	NNBF	0.01
Howard Beach	Acquisition and Relocation	1.00	NNBF	0.07	Floodproofing	0.42	2018 Existing Conditions plus Levee/ Floodwall	0.86	NNBF	0.07
JFK Airport	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rockaway East – Bay	Acquisition and Relocation	1.00	NNBF	0.03	Floodproofing	0.42	Levee/ Floodwall	0.72	NNBF	0.03
Rockaway West – Bay 1	Acquisition and Relocation	0.22	N/A	N/A	Floodproofing	0.09	Levee/ Floodwall	1.00	N/A	N/A
Floyd Bennett Field – National Park Service	N/A	N/A	NNBF	1.00	N/A	N/A	N/A	N/A	NNBF	1.00
Marsh Islands	N/A	N/A	NNBF	1.00	N/A	N/A	N/A	N/A	NNBF	1.00
Broad Channel	Acquisition and Relocation	0.15	NNBF	0.01	Floodproofing	0.06	Levee/ Floodwall	1.00	N/A	N/A

[1] *Cost indices are based parametric costs estimates.*

Finally, the Jamaica Bay and Rockaway Peninsula Tier 2 evaluation considered an avoid risk management strategy comparable to managed retreat. Specific measures as part of this strategy consisted of the acquisition and relocation of structures in areas subject to frequent flooding defined using the 10 percent floodplain.

Table IV-9 presents the results of the Tier 2 evaluation. The results illustrate relative changes in risk associated with the various measures associated with the three adaptation strategies along with a cost index range (no specific cost estimates for measures are included).

The design level and potential risk management associated with each coastal storm risk management measure correspond to the qualitative evaluation of measures presented in Table IV-4, such as high for a 1 percent flood plus 3 feet and low for a 10 percent flood. The cost index was derived from parametric cost estimates divided by the highest parametric cost of all the coastal storm risk management measures in each subarea. The higher the cost index, the greater the relative costs. The combination of measures leading to a selection of a plan, as described in the Framework, would further quantify risk management and evaluate and compare the change in the risk based on the total cost of the plan. This effort would be completed as part of a Tier 3 evaluation and would incorporate refined exposure and vulnerability data, and evaluation of other risk management measures and costs.

Future Outlook

Accepting certain levels of risk, making cultural changes, planning for the future, creating public-private partnerships and incentive programs, and implementing measures and combinations of measures to address coastal storm risk management of risk areas will be driven by regional coordination between Federal, State, local, and tribal officials. Regional coordination should occur through an interagency stakeholder group, chartered to periodically review, evaluate, and coordinate development and implementation of coastal storm risk management features and programs. Close coordination by these groups will help ensure buy-in by all affected constituents and assist communities in becoming more resilient to future storm events. Regional coordination will help guide efficient spending to optimize coastal storm risk management and help align Federal, State, and local decision-makers to achieve multiple goals.

There are a number of ongoing efforts by New York City, State, and Federal government to repair damage from Hurricane Sandy and to restore beaches and natural features through a wide range of risk management measures within Reach NY_NJ1_I in Coney Island and Rockaway.

Federal Initiatives and Funding – DOI and USACE

In October 2011, the DOI and New York City entered into an agreement regarding Jamaica Bay. The agreement established a formal partnership between the National Park Service and the New York City Department of Parks and Recreation to collaborate in four areas: effective management of park lands, science and restoration of Jamaica Bay, access and transportation to park lands around Jamaica Bay, and engagement of New York City youth with hands-on science programs and fun public service projects to promote recreation, stewardship, and “green” careers.

In a press release on October 24, 2013, DOI committed an investment of $162 million for restoration and research projects to build resilience by restoring natural features along shorelines, including the New York–New Jersey Harbor. In addition to its 2011 agreement with New York City, an investment of $3.6 million of the DOI funding was allocated to the National Park Service’s Jamaica Bay Science and Resilience Center to support research on resilience in urban coastal ecosystems.

The USACE East Rockaway Inlet to Rockaway Inlet (Rockaway) and the Atlantic Coast of New York City, Rockaway Inlet to Norton Point (Coney Island) projects have been restored to their original design profile, pursuant to Public Law 113- 2, through the USACE Flood Control and Coastal Emergencies program. The USACE is re-evaluating the Rockaway Project to identify whether there are cost-effective alternatives to provide additional coastal storm risk management, including NNBF. As indicated by the NACCS Opportunities in Section II, the USACE is considering opportunities for improved implementation of NNBF in this project.

In Jamaica Bay, the USACE, in partnership with New York City Department of Environmental Protection, is re-evaluating the Jamaica Bay Environmental Restoration Feasibility Study, a draft plan that considers eight potential environmental restoration sites, to re-create natural streams, restore tidal marshes, and plant coastal forests and other uplands to better manage risk to neighborhoods and natural resources. An early draft of this plan will be revised to better highlight the coastal storm risk management features of these projects and to include new techniques.

Several additional studies and projects in the risk area are pending funding, including the Manhattan Beach and Sheepshead Bay Reconnaissance Study.

Statewide Actions – New York State

The New York Rising Program was established by Governor Andrew M. Cuomo to provide assistance to communities damaged by Hurricane Sandy, Hurricane Irene, and Tropical Storm Lee. Under the New York Rising umbrella, the Office of Storm Recovery was created in June 2013 to centralize recovery and rebuilding efforts in storm-affected municipalities throughout New York State, including New York City. In support of the State of New York's recovery from the impacts of Hurricane Sandy, HUD allocated $2,097,000,000 of CDBG-DR funds in November 2013 (http://stormrecovery.ny.gov/action-plans-and-amendments). In close collaboration with local and community leaders in these areas, the Office of Storm Recovery continues to work to respond to communities' most urgent rebuilding needs while also identifying long-term and innovative solutions to strengthen the State's infrastructure and critical systems for the future.

New York Rising programs include the Housing Recovery program, which provides homeowners with assistance for home repairs/rehabilitation, mitigation, elevation, and buyouts; the Small Business program, which includes small business grants of $50,000 or more and low-interest loans for businesses recovering from the storms; and the Community Reconstruction Program, which provides assistance through a community-driven initiative to develop distinct comprehensive recovery plans that increase resilience and economic development in the regions affected by the three storms. Table IV-10 provides a summary of funding allocations to the Southern Brooklyn and Queens risk area communities under the Community Reconstruction Program.

Rebuilding efforts within the listed communities exemplify application and challenges of various initiatives. Rebuilding efforts and design criteria will draw on new risk information provided by FEMA (revised FIRMs) and potential coastal storm risk management based on current USACE studies. Buildings will be constructed or retrofitted in accordance with FEMA and New York City standards to minimize vulnerability and reduce flood insurance

Table IV-10. NY Rising Community Reconstruction Program Funding Allocation

Community	Eligibility
Belle Harbor	$10,400,000
Breezy Point	$16,500,000
Brighton Beach	$4,200,000
Broad Channel	$6,100,000
Coney Island	$6,100,000
Far Rockaway	$5,500,000
Gerritsen Beach	$6,700,000
Manhattan Beach	$5,400,000
Neponsit	$3,700,000
New Howard Beach	$9,300,000
Old Howard Beach	$9,100,000
Rockaway	$16,800,000
Roxbury	$3,000,000
Seagate	$3,500,000
Sheepshead Bay	$6,700,000
Total	**$113,000,000**

premiums, and repetitive loss structures will be considered for acquisition and relocation—both in close coordination with local floodplain administrators.

Local Initiatives – New York City

The former mayor of New York City, Michael Bloomberg, convened the Special Initiative for Rebuilding and Resiliency (SIRR) and charged it with analyzing the impacts of Hurricane Sandy on the City's buildings, infrastructure, and people; assessing the risks the City faces from climate change in the mid term (2020s) and long term (2050s); and outlining strategies for increasing resiliency citywide (City of New York 2013). The *PLANYC: A Stronger, More Resilient New York* report compiled by the SIRR addresses the need for improved coastal storm risk management measures.

The PLANYC report's recommendations for this area integrate the USACE Coney Island and Rockaway projects. These coastal storm risk management projects are part of the system of coastal storm risk management measures.

NACCS Tier 2 Example No. 2: Barrier Island and Back Bay Example

Based on the documented impacts from Hurricane Sandy and the NACCS sea level change evaluation, barrier islands, back bay areas, and embayments along the North Atlantic Coast, including the coastlines of New York, New Jersey, Delaware, Maryland, and Virginia are at a risk from the impacts of sea level change and a corresponding increase in flood risk. Additionally, the back bays of barrier islands to the bay side of beaches and dunes as well as other areas of the North Atlantic Coast including embayments and harbors are at risk of storm surge and tidal flooding via barrier island inlets. The following example is included to illustrate one approach for evaluating potential impacts of storms and sea level change and the identification of appropriate coastal storm risk management strategies.

Long Beach Island, New Jersey was identified for the NACCS Barrier Island and Back Bay Example to present an illustrative example of how a beach and dune system would perform based on sea level change inundation scenarios as well as the impacts of coastal flooding from back bay areas. This example is not intended to evaluate the actual coastal storm risk and consequences.

Submergence Assessment

An initial simple submergence assessment was applied to bands of sea level against the elevation of the island to identify the area that would be lost at varying levels without levees or flood walls and assuming full hydraulic connectivity. The assessment was based on a digital terrain model with a resolution of 6 feet and analyzed into 1 foot bands of ground height.

Figure IV-17 shows the resulting percentage loss in land area compared with the four sea level change scenarios considered in the NACCS. As previous studies have shown, this kind of analysis indicates significant loss of land for just a one foot increase in relative sea level, with only the large beach berm and dune systems on the Atlantic Ocean escaping much of the inundation. The analysis was completed for several barrier islands and the results were broadly similar for each. The results confirm the vulnerability of back bays and the lack of a comprehensive coastal storm risk management solution.

Storm Inundation Analysis

The storm inundation analysis emphasizes the sensitivity of the island to a relatively modest rise in sea level. In particular, risk of the island road network to back bay flooding, even during relatively modest storms, could affect access. Although less than 20 percent of the road network is flooded during such annual storms and only to an average depth of about a foot, just a one foot increase in relative sea level increases the percentage to about 70 percent, with some roads flooded up to 4 feet. With an increase of 3 feet in relative sea level the road network becomes unusable.

The risk of property to increased damage increases with sea level change. As part of the storm inundation analysis, annual damages were estimated based on market valuations of structures in the different zones of the island, including ocean front, ocean block, ocean side, bay side, and bay front. The costs were normalized to present the concept of increasing risk and corresponding damages associated with future storm events (excluding wave attack and erosion because the analysis used only depth-damage relationships) coupled with sea level change.

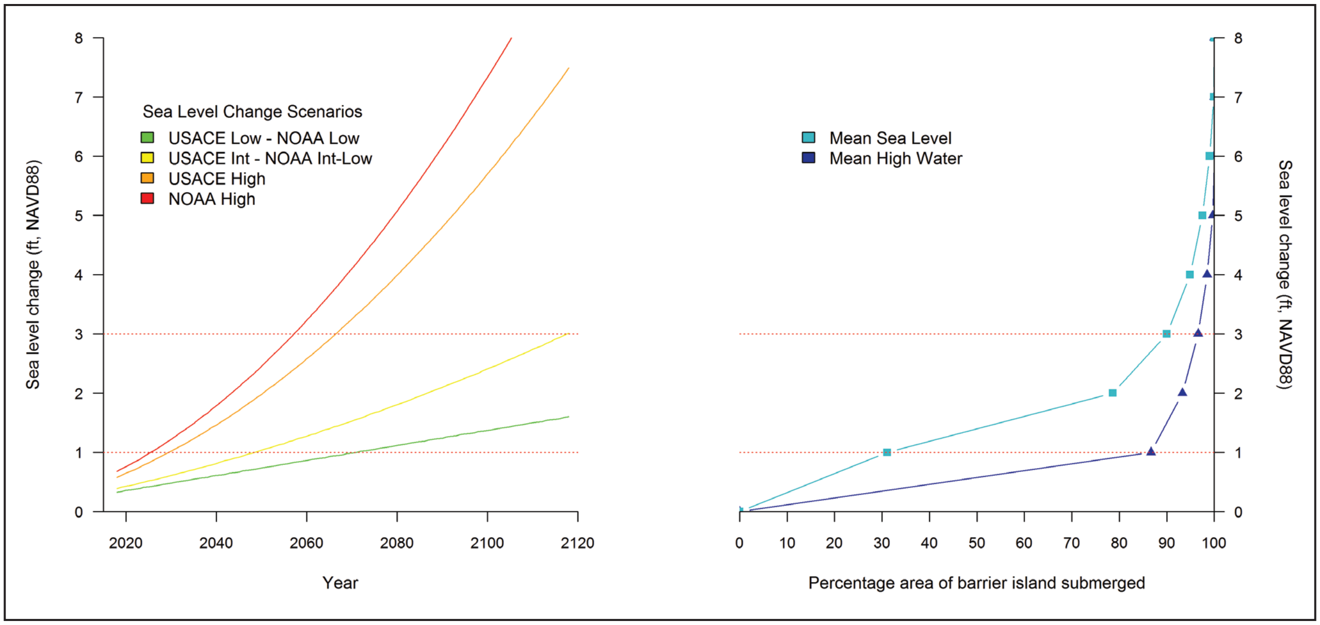


Figure IV-17. Submergence due to Sea Level Change

Implications of Analysis for Adaptation

The analysis suggests that the beach berm and dune system can be maintained in a relatively robust condition even with an increase of 6 feet in relative sea level. Coastal storm risk management efforts should instead focus on back bay flooding. Combinations of the following measures could be considered instead:

- Comprehensive back bay risk management. Maintenance of leisure access for boating will be important where bulkheads already exist; new (or elevated) bulkheads could be considered. Stepped features may be possible. For locations where natural beaches exist, terraced features incorporating ecological components could be considered. In both cases, paths for access and viewing are possible.
- Modifications to drainage systems. Structural coastal storm risk management measures alone would not solve all the flooding problems because during high water events, flooding can occur by water backing up the drainage systems. Flap valves or sluices would, therefore, need to be installed on all outfalls. Significant rainwater storage would also be required, possibly located within modified features.
- Elevation measures. Property elevation remains a valuable tool to limit damage in the event of flooding. Elevation of the road network to improve access could be considered, but would require proper drainage and rainwater storage located beneath such elevated roads.

Table IV-11 presents the storm analysis stage and the description of the various analyses completed as part of the NACCS barrier island and back bay example.

Table IV-11. Storm Analysis Stages

Storm Analysis Stage	Description
Scenario assumptions	Because the issues with barrier islands are primarily associated with the amount rather than the rate of sea level change, future scenarios were examined following 1 foot, 3 foot, and 6 foot increases as opposed to selecting one of the specific sea level change rate scenarios discussed in Section IV. The increased water levels also affect the wave heights, both to a limited extent in conditions offshore (e.g., in 30 feet of water) but more significantly in the near-shore conditions where the wave breaking occurs. Here, as nearshore wave heights become strongly dependent on the available water depth, the generation of greater water depths by increases in mean sea levels lead to correspondingly increased nearshore wave heights. For each scenario, extreme wave and water level conditions for the 100, 10, 3, 1, and 0.1 percent flood events were examined. Calculations were also performed for two response scenarios: one where defenses and dune systems were raised in line with sea level and the other where no such improvements were included.
Extreme waves and water levels	The analysis uses offshore waves based on data from the National Data Buoy Center at the nearest available offshore location. A record length of 24.9 years was available, which included 139 events (including Hurricane Sandy) where the significant wave height exceeded 13 feet. Equivalent coincident water levels used in the analysis were based on recorded sea level data, using Monte Carlo simulation to fill any data gaps and a joint probability distribution of waves and water levels obtained. Wave heights were transformed to the nearshore taking into account wave refraction and breaking and then the data was analyzed to obtain estimates of extreme wave heights. Because there is a relatively low tidal range on the North Atlantic Coast, a strong correlation exists between the most extreme waves and hurricane or other significant storm surges.
Beach/dune profile response	A DUROS+ empirical dune model (van Rijn 2013) was used to validate field data obtained before and after Hurricane Sandy (Stockton 2012) and to predict beach-dune profile response, using a representative uniform sediment size of 0.152 millimeters. The predicted run-up (exceeded by 33 percent of the waves) necessary for the empirical model was calculated using van Rijn (2008) with results ranging from 6.5 feet for the 100 percent flood event to 8.7 feet for the 0.1 percent flood event. In the sea level change scenarios with nourishment, these results barely changed. In the sea level change scenarios without nourishment, greater cut-back of the dunes occurs, but as relative sea levels continue to increase, the cut back of the dune crest seems to reach a threshold beyond which further erosion does not occur. Instead, under extreme conditions, further erosion is focused on the submerged part of the beach profile.
Dune overtopping calculations	The EurOtop manual (Pullen et al. 2007) was used to assess overtopping rates based on the modeled beach berm and dune profile and wave heights at the toe of the beach and taking account of the crest height, toe level, and a simplified structure slope. Large overtopping rates can be maintained over a large part of the tidal cycle and, hence, overtopping rates were calculated over a full tidal cycle. Because of the significant variation in beach berm and dune profiles, a sensitivity analysis was conducted and found several orders of magnitude difference in overtopping rates depending on which beach berm and dune profile was selected. This issue could have been explored further, but in practice the inundation of the island is dominated by inflows from the back bay.

Table IV-11. Storm Analysis Stages (continued)

Storm Analysis Stage	Description
Inundation modeling (ocean & bay shorelines)	The computational mesh for the flood spreading model RFSM-EDA (Jamieson et al. 2012a and 2012b) was made up of relatively small irregular polygons impact zones to capture the inundation spreading across the narrow barrier island. Discharge boundary conditions were applied using the dune overtopping rates on the ocean shore and a water level on the bayshore, which represented the average sea level over the 24 hours that follow the peak of the event. Plots for different sea level change scenarios were created and indicated the proportions of the whole island, and of the road network, that would be inundated by different flood depths. The proportions of inundation are slightly higher for the case of the road network reflecting lower ground elevations for the roads than for the property parcels.
Flood risk analysis	The total impacts of flooding for each scenario (return period, sea level change), were calculated by combining the maximum flood depths with a depth-damage function in each grid cell based on those used in Hazus/HEC-FIA (Hydrologic Engineering Center Flood Impact Analysis). Property values were based on average property and structure prices for different zones across the width of the island.

Flooding on 11th Street, Ocean City, NJ

Source: Photo by USACE team, taken on October 31, 2012
https://www.flickr.com/photos/philadelphiausace

INNOVATIVE ACTIONS TO PROMOTE RESILIENT COASTAL COMMUNITIES

As part of an initiative of the HSRTF administered by HUD, the Rebuild by Design competition provided incentives to plan coastal landscape systems to better withstand the impacts of the next coastal storm (HSRTF 2013a). The competition tasked 10 teams with investigating opportunities to promote resilient communities, ultimately leading to the design of a solution that may receive HUD disaster recovery funds for implementation (HSRTF 2013b).

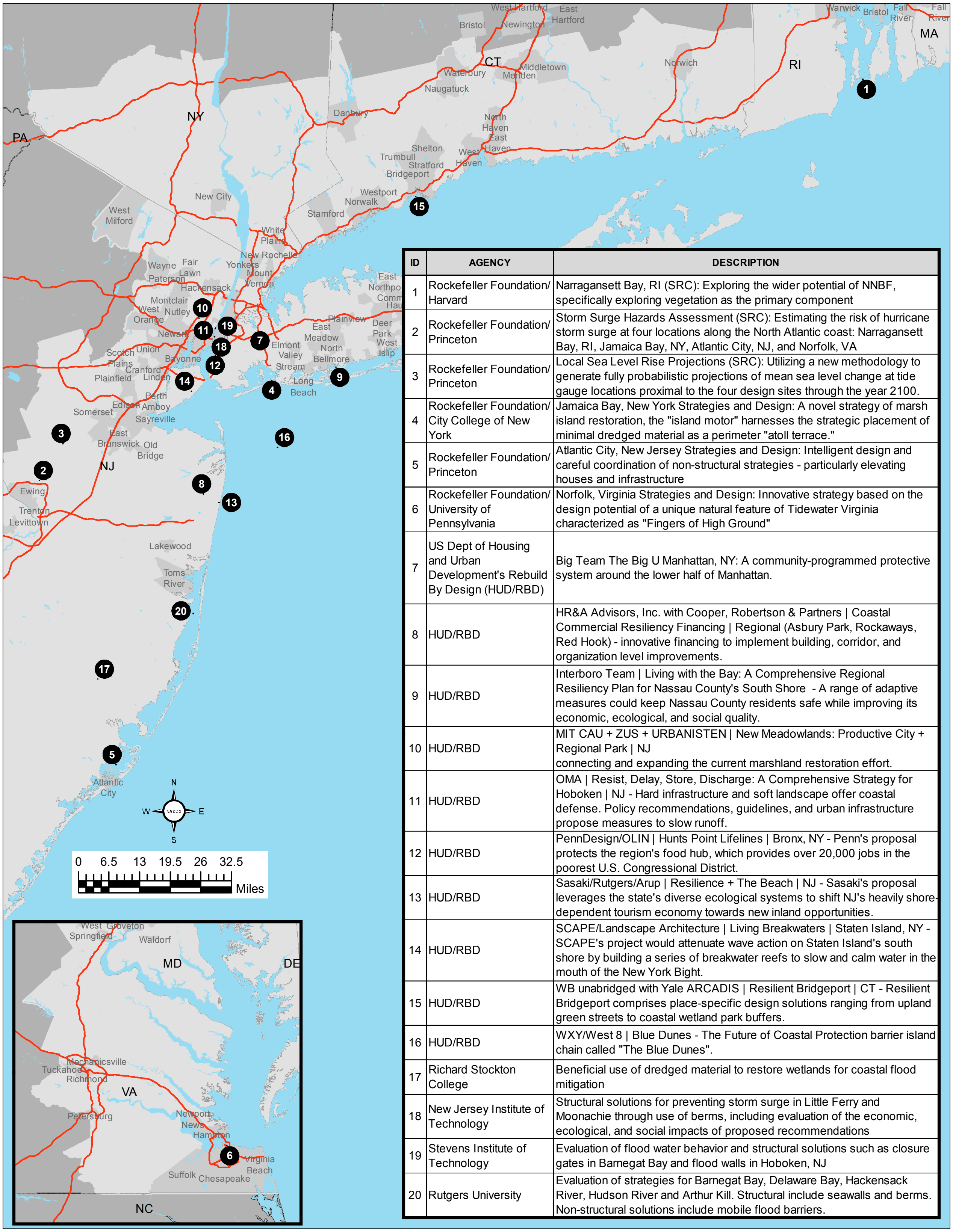
In addition to its support for the Rebuild by Design initiative, the Rockefeller Foundation also supports the Structures of Coastal Resilience (SCR) and 100 Resilient Cities Centennial Challenge (Rockefeller Foundation 2014). The SCR project will study and propose resilient designs for urban coastal environments. The project team includes engineers and scientists from Princeton University, Harvard University, the City College of New York, and the University of Pennsylvania, who will investigate strategies and coastal storm risk management measures in four regions along the North Atlantic Coast: Narragansett Bay, RI; Jamaica Bay, NY; Atlantic City, NJ; and Norfolk, VA. As part of the SCR, Princeton will develop a probabilistic projection of forecasted mean sea level change, which is a different method than the USACE and NOAA sea level change projections.

The 100 Resilient Cities Centennial Challenge is an initiative to enable 100 cities to better address the increasing shocks and stresses of the 21st century. The City of New York, NY, and the City of Norfolk, VA, were among the 100 cities selected from six continents, each of whom will be receiving technical support from the Rockefeller Foundation over the next 3 years to address the challenges of recurrent coastal flooding and sea level change.

Other initiatives and projects are ongoing through the New Jersey Department of Environmental Protection in collaboration with six New Jersey universities, including Richard Stockton College of New Jersey, the New Jersey Institute of Technology, Stevens Institute of Technology, Rutgers University, Monmouth University, and Montclair State University. The projects will identify opportunities for structural, NNBF, and nonstructural solutions to address coastal storm risk. Additionally, NGOs are implementing innovative projects and other initiatives. The Conservation Fund, the Audubon Society, and the Nature Conservancy, to name a few, obtain grant funding for implementation of natural features, which contribute to resilient coastal systems. Their projects include a number of opportunities for improved implementation of NNBF. Figure IV-18, while not all inclusive, presents a snapshot of the locations of innovative projects and initiatives.

Inlet Section of Atlantic City, NJ after Hurricane Sandy

Source: http://www.wunderground.com/blog/JeffMasters/why-did-hurricane-sandy-take-such-an-unusual-track-into-new-jersey



ID	AGENCY	DESCRIPTION
1	Rockefeller Foundation/ Harvard	Narragansett Bay, RI (SRC): Exploring the wider potential of NNBF, specifically exploring vegetation as the primary component
2	Rockefeller Foundation/ Princeton	Storm Surge Hazards Assessment (SRC): Estimating the risk of hurricane storm surge at four locations along the North Atlantic coast: Narragansett Bay, RI, Jamaica Bay, NY, Atlantic City, NJ, and Norfolk, VA
3	Rockefeller Foundation/ Princeton	Local Sea Level Rise Projections (SRC): Utilizing a new methodology to generate fully probabilistic projections of mean sea level change at tide gauge locations proximal to the four design sites through the year 2100.
4	Rockefeller Foundation/ City College of New York	Jamaica Bay, New York Strategies and Design: A novel strategy of marsh island restoration, the "island motor" harnesses the strategic placement of minimal dredged material as a perimeter "atoll terrace."
5	Rockefeller Foundation/ Princeton	Atlantic City, New Jersey Strategies and Design: Intelligent design and careful coordination of non-structural strategies - particularly elevating houses and infrastructure
6	Rockefeller Foundation/ University of Pennsylvania	Norfolk, Virginia Strategies and Design: Innovative strategy based on the design potential of a unique natural feature of Tidewater Virginia characterized as "Fingers of High Ground"
7	US Dept of Housing and Urban Development's Rebuild By Design (HUD/RBD)	Big Team The Big U Manhattan, NY: A community-programmed protective system around the lower half of Manhattan.
8	HUD/RBD	HR&A Advisors, Inc. with Cooper, Robertson & Partners | Coastal Commercial Resiliency Financing | Regional (Asbury Park, Rockaways, Red Hook) - innovative financing to implement building, corridor, and organization level improvements.
9	HUD/RBD	Interboro Team | Living with the Bay: A Comprehensive Regional Resiliency Plan for Nassau County's South Shore - A range of adaptive measures could keep Nassau County residents safe while improving its economic, ecological, and social quality.
10	HUD/RBD	MIT CAU + ZUS + URBANISTEN | New Meadowlands: Productive City + Regional Park | NJ connecting and expanding the current marshland restoration effort.
11	HUD/RBD	OMA | Resist, Delay, Store, Discharge: A Comprehensive Strategy for Hoboken | NJ - Hard infrastructure and soft landscape offer coastal defense. Policy recommendations, guidelines, and urban infrastructure propose measures to slow runoff.
12	HUD/RBD	PennDesign/OLIN | Hunts Point Lifelines | Bronx, NY - Penn's proposal protects the region's food hub, which provides over 20,000 jobs in the poorest U.S. Congressional District.
13	HUD/RBD	Sasaki/Rutgers/Arup | Resilience + The Beach | NJ - Sasaki's proposal leverages the state's diverse ecological systems to shift NJ's heavily shore-dependent tourism economy towards new inland opportunities.
14	HUD/RBD	SCAPE/Landscape Architecture | Living Breakwaters | Staten Island, NY - SCAPE's project would attenuate wave action on Staten Island's south shore by building a series of breakwater reefs to slow and calm water in the mouth of the New York Bight.
15	HUD/RBD	WB unabridged with Yale ARCADIS | Resilient Bridgeport | CT - Resilient Bridgeport comprises place-specific design solutions ranging from upland green streets to coastal wetland park buffers.
16	HUD/RBD	WXY/West 8 | Blue Dunes - The Future of Coastal Protection barrier island chain called "The Blue Dunes".
17	Richard Stockton College	Beneficial use of dredged material to restore wetlands for coastal flood mitigation
18	New Jersey Institute of Technology	Structural solutions for preventing storm surge in Little Ferry and Moonachie through use of berms, including evaluation of the economic, ecological, and social impacts of proposed recommendations
19	Stevens Institute of Technology	Evaluation of flood water behavior and structural solutions such as closure gates in Barnegat Bay and flood walls in Hoboken, NJ
20	Rutgers University	Evaluation of strategies for Barnegat Bay, Delaware Bay, Hackensack River, Hudson River and Arthur Kill. Structural include seawalls and berms. Non-structural solutions include mobile flood barriers.

Figure IV-18. Locations of Innovative Projects and Initiatives in Coastal Communities

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V. Systems Approach to Coastal Storm Risk and Resilience

The risks in coastal areas have been managed using a patchwork of measures, but experience has proven that coastal risks require a more comprehensive and integrated strategy, given the dynamics and complexities of the coastal environment. The patchwork approach has developed over time for a variety of reasons—government agencies with different missions, line-item budgeting in project authorizations and funding appropriations, land use and zoning, private interests, and other reasons.

After Hurricane Sandy, NOAA and USACE collaborated on developing the publication *Infrastructure Systems Rebuilding Principles* (NOAA and USACE 2013), which outlines the unified focus of these Federal Agencies to use a systems approach to coastal storm risk management. A systems approach to coastal storm risk management is a cornerstone of the rebuilding principles.

A systems approach entails taking a broad view of causes, objectives, and interactions among processes and actions to manage the risk in coastal systems. A systems approach to coastal storm risk management addresses the following aspects of coastal areas:

- Coastal processes occur over large geographic areas. For example, major storms affect regional geographic areas, and coastal response is forced by processes occurring on watershed scales.
- Geological and other physical processes that occur over long periods of time affect coastal areas. Examples are worldwide sea-level change, regional subsidence or uplift, changes in storm frequency and severity, and changes in precipitation patterns.
- Focusing on one process in a linked system can have negative effects. For instance, building a structural seawall to manage risk to a single oceanfront property can result in erosion on adjacent properties and loss of habitat throughout the area. On a larger scale, even a seawall that is built to manage risk to an entire community can leave many properties exposed to flooding from inlets, bays, and estuaries.
- The coastal environment is dynamic, and environmental, economic, and social interactions are complex. Coastal areas are affected by regional issues and patterns, such as climate change; species migration patterns and habitat availability; laws, regulations, and policies; economic investments; and changes in populations.
- Managing coastal storm risks involves dealing with competing objectives from numerous stakeholders, including Federal, State, Tribal, and local governments; NGOs; business and industry; and the public.

Implementation of a systems approach has the following advantages:

- Thinking and planning on a system scale inherently involves coordination of multiple decision-makers, stakeholders, and the public, which means that potentially contentious issues can be acknowledged upfront, and group understanding and consensus can be attained early in the process of developing solutions.
- Sound science and engineering that build on lessons learned can be applied to the development, design, evaluation, and implementation of solutions. For example, as part of the NACCS, USACE through ERDC, as part of the numerical modeling effort, is developing a state-of-the-art database of storm waves and surge, incorporating future sea level change.
- As identified in the NACCS Opportunities in Section II, using a systems approach enables optimization of resources.

Applying a systems approach to managing coastal storm risk provides for more reliable performance of infrastructure, lowering risks, and increasing system resilience. Intentional alignment of engineering and natural systems maximizes benefits to support vulnerable populations and natural assets and minimizes unintended negative consequences. Future damage will be reduced, promoting the ability of the region, economy, and most importantly, communities to rapidly recover from impacts of the next coastal disaster and to optimize the economic benefits. The intentional alignment and evaluation of the interconnected components of the system require a prioritized plan, which could be developed using the steps presented in the Framework. With constrained budgets and the need for alternative and innovative financing opportunities like public-private partnerships, the plan would necessitate identifying the strategies and solutions that would benefit the partnership and overall resilience of the community.

A systems approach to managing coastal storm risk should include adaptation planning, monitoring, redundancy, and modularity.

ADAPTATION PLANNING

Planning for adaptations to potential changes in the climate using scenarios should include actions that will be implemented when critical climate change and/or vulnerability thresholds are met.

Evaluating “low-regret” measures (measures that are beneficial even in the absence of climate change) that provide both present and future benefits is a productive approach considering the current climate and the range of future climate scenarios. Low-regret measures are effective starting points for climate change adaptation because they address both current and future vulnerabilities. These measures may have a wide range of benefits, may be highly adaptable across different future scenarios, and may minimize the taxpayer burden by avoiding the cost of capital improvements that cannot be retrofitted and would need to be replaced if changes in the climate require modification. Adaptation planning should also include a consideration of removing or modifying existing structures such as bulkheads, groins, jetties, revetments, and riprap that no longer serve their intended purpose of managing coastal storm risk and have become erosional features.

Scenario planning strategies should be developed to include cost-effective measures that will achieve the objectives of both communities and regions. An iterative approach to scenario planning allows decision-makers to leverage advancements in science and policy in the future.

Because there are many unknowns in future storms, precipitation patterns, and sea level change, resilient systems must include a consideration of the potential for extreme events and ancillary conditions that have not been experienced previously. Planning for the unknown means that system solutions need to be designed and monitored so they can be readily adapted as needed.

Resilient adaptation to increasing risk, or the ability to adapt to changing and increasingly perilous conditions and to withstand and rapidly recover, requires a systems approach and a combination of strategies and measures. A combination of measures to effectively decrease exposure and/or sensitivity to flood hazard results in a relative increase in resilience. This relationship can be quantified to define a metric to measure the change in a community’s resilience by implementing various pre-storm strategies and measures. The technical report, *Use of Natural and Nature-based Features for Coastal Resilience*, (Bridges et al. 2015) presents additional information on incorporating the measurement of resilience based on changes in vulnerability into scenario planning.

Managing a coastal system to reduce the risk of storm damage and increase resilience includes strategic monitoring of the system and making information on the condition of the system available to stakeholders and the public. The information will help Federal, State, local, and homeowners make decisions on where investments are needed.

Monitoring coastal systems also allows for proactively managing risks to weak links and repairing failed portions of the coastal storm risk management system. An example of a weak link in a coastal barrier island system is a narrow, low portion of the island that is vulnerable to breaching during a storm. Proactive coastal storm risk management could involve adding width to the island in that area, adding a living shoreline on the bay-shore to reduce long-term erosion, or making sand available and obtaining permits a priori to close a breach if it occurs.

As indicated by the NACCS Opportunities in Section II, redundant features in a coastal storm risk management system ensure that if one or more components of the system are damaged, alternatives are available to ensure that the system does not fail. An example of redundancy is three bridges on a barrier island that can all be used for evacuation; if one bridge is inaccessible, the other two will allow evacuation off the island.

A modular system is a system in which the same coastal storm risk management features are dispersed throughout the geographical extent of the coastal system. The redundant coastal storm risk management features can be prioritized to avoid indirect damage as a result of direct damage to one component of the coastal system. Prioritizing the features requires identifying the critical components that, if damaged, will decrease the resilience of the system. For example, electric grid substations that provide electricity to the coastal system and that are damaged by flooding may lead to indirect damage (loss of electricity) to the community.

Successful coastal storm risk management and resilient coastal solutions combine and integrate approaches across the full array of measures, including structural, nonstructural, and NNBF, in a variety of redundant combinations to support resilient coastal communities and a robust, sustainable coastal landscape.

EXAMPLES OF A SYSTEMS APPROACH TO MANAGING COASTAL RISK

This section presents examples from the New Jersey and Florida coastlines to illustrate a systems approach to managing coastal risk.

Enhancing and Managing Risk to the New Jersey Coastal NNBF

The U.S. Army ERDC; USACE District, Philadelphia; Forsythe National Wildlife Refuge (NWR); and HR Wallingford (HRW) among others including USGS are working on a variety of projects designed to improve the resilience of the New Jersey coastline by enhancing and managing risk to existing NNBF using a systems approach. The projects have various funding sources and objectives, but all are designed to improve the resiliency of the New Jersey coast.

Figure V-1 is a map and conceptual diagram showing the interconnectedness of the coastal system. The resilience of the New Jersey coast is a function of the individual features in the system and the interaction between the features.

Dune Grass Planting on Long Beach Island, New Jersey

Source: http://www.buylbi.com/lbirealestate/dune-grass-planting-on-long-beach-island-new-jersey/

The projects are as follows:

- Management of navigation channels and sediments along the New Jersey Intracoastal Waterway. ERDC and USACE Philadelphia District examined placement options for the required dredging of the New Jersey Intracoastal Waterway that would enhance existing NNBF near the navigation channel. Although regulatory and logistical constraints will determine the placement, all options included a consideration of the enhancement of the resilience of the coastal system.
- Ecosystem restoration and enhancement in response to relative sea level change at the Forsythe NWR. ERDC and Forsythe NWR are planning a variety of ecosystem restoration and enhancement projects intended to increase the resilience of the refuge's ecological resources, including restoring and enhancing salt marshes and impoundments and developing long-term plans for monitoring and adaptation in response to future disasters, sea level change, and anthropogenic changes in the system.
- Sea level change vulnerability and adaptation measures for barrier coasts - the analyses conducted as part of the NACCS Tier 2 Example No. 2: Barrier Island and Back Bays Example. A barrier island evaluation method was completed to predict the erosion and overtopping response of dune-beach systems to sea level change using Long Beach Island, NJ. The methodology can be used to examine the impacts of proposed policy decisions for managing barrier island and back bay systems on submergence and increasing flood risk over time.

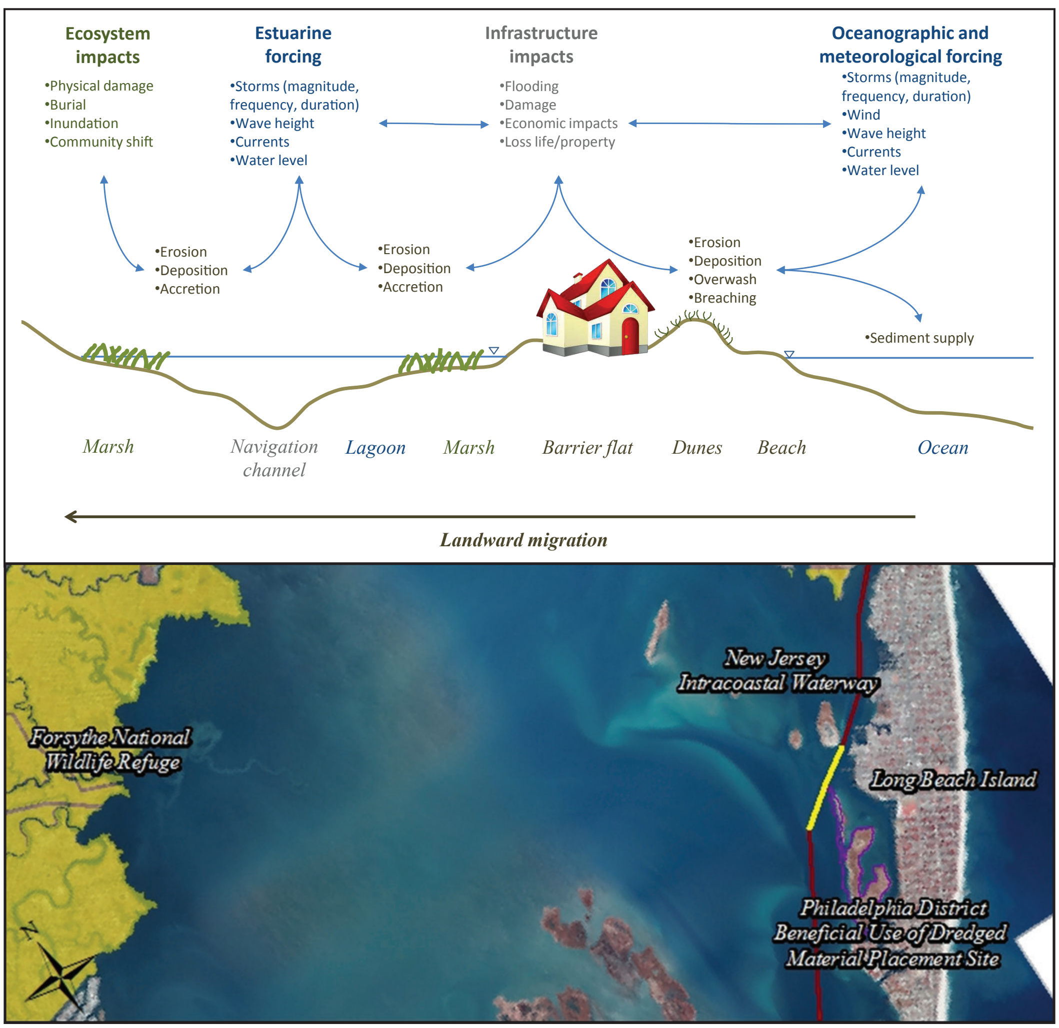

Figure V-1. Conceptual Diagram and Map Showing the Interconnectedness of a Coastal System (Bridges et al. 2015)

Using a systems approach can ensure that all of the ongoing activities on the New Jersey coastline are increasing system resiliency and reducing the vulnerability to future disasters despite the individual, and sometimes competing, interests of each project.

Regional Sediment Management in Northeast Florida

The regional sediment management activities in the USACE District, Jacksonville, for Nassau and Duval Counties in northeast Florida illustrate the benefits of a systems approach (Hodgens and Neves 2014).

Coastal processes and anthropogenic activities in the region are complex and interconnected (see Figure V- 2) and include:

- Two deep-draft Federal harbors
- Two deep-draft Navy harbors
- Two intracoastal waterways
- Two Federal coastal storm risk management projects
- Locally funded coastal storm risk management project
- Two natural inlets

Net sediment transport is from north to south in this region, although there are reversals downdrift of the coastal inlets as well as complex interactions between the inlets, river systems, estuaries, and waterways. As a result of these complex sediment transport patterns, beaches downdrift of coastal inlets have eroded, sand is needed on beaches to create dunes and berms, and fine sediments are needed in estuaries and bays for habitat creation.

The systems approach has been largely realized by connecting dredging activities at the Federal and Navy navigation channels with the coastal storm risk management and NNBF needs of the adjacent beaches, estuaries, and bays. By recognizing the region as an interconnected coastal system, aligning existing authorities and funding streams, obtaining permitting proactively, and fostering collaborative planning, the USACE Jacksonville District has coordinated the dredging and placement activities, reduced costs, and increased the coastal resilience of the region.

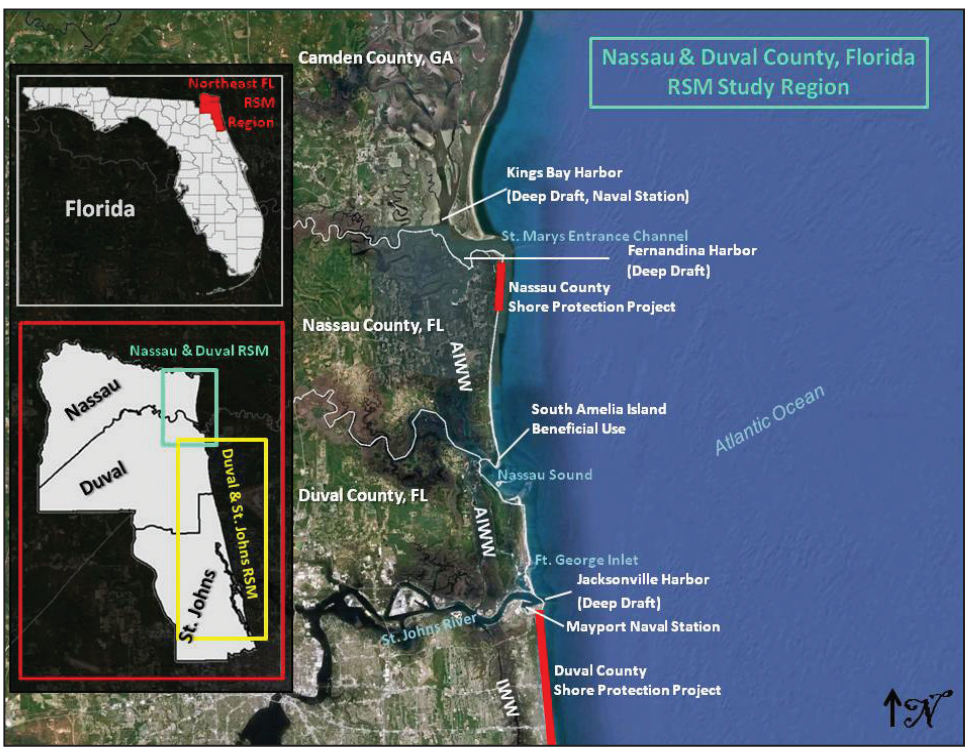

Figure V-2. Coastal Processes and Anthropogenic Activities in Nassau and Duval Counties, FL (Hodgens and Neves 2014)

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VI. Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action

The Disaster Relief Appropriations Act of 2013, Public Law 113-2, states that as part of the investigations, "… the Secretary shall identify those activities warranting additional analysis by the Corps, as well as institutional and other barriers to providing protection to the affected coastal areas …"

COASTAL POLICY LANDSCAPE

To frame the issues of coastal storm risk management in the context of the policy landscape, the NACCS goals of community resilience and coastal storm risk management must be understood. Resilience is defined in the Hurricane Sandy Rebuilding Strategy report as "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" (HSRTF 2013a).

Recent literature (NRC 2014 and Aerts et al. 2014) suggests that the future of resilience in coastal communities could be tied to the concept of shared responsibility. The concept calls for a whole community effort by Federal, State, Tribal, local, and individual stakeholders to understand, assess, and prepare for current and future risks.

Figure VI-1 illustrates that significant coastal storm risk management can be achieved through nonstructural measures, such as zoning, building codes, risk communication, and evacuation plans. A combination of nonstructural measures, floodproofing, wise use of floodplains, managed retreat, and insurance can further reduce the residual risk.

In Figure VI-1, the left-most bar represents the initial risk faced by a community. Moving to the right, each bar shows the actions and policies (structural, nonstructural, and NNBF) that can be used to manage and reduce the initial risk. The entities that are responsible for the actions and policies are also shown (Federal, State, and local governments and homeowners and business owners). The right-most bar shows that risk cannot be completely eliminated.

Hundreds of policies and programs influence coastal storm risk management and the achievement of community resilience. Table VI-1 is a list of the significant Federal acts, Presidential Policy Directives, Executive Orders, and one program that affects long-term recovery and coastal resilience in the Hurricane Sandy-affected areas. State and local governments and programs and policies related to land use, zoning, and building codes heavily influence coastal storm risk management and are too numerous to list.

Since Hurricane Katrina and Hurricane Sandy, many Federal and State agencies have been trending toward supporting a more prepared and resilient Nation.

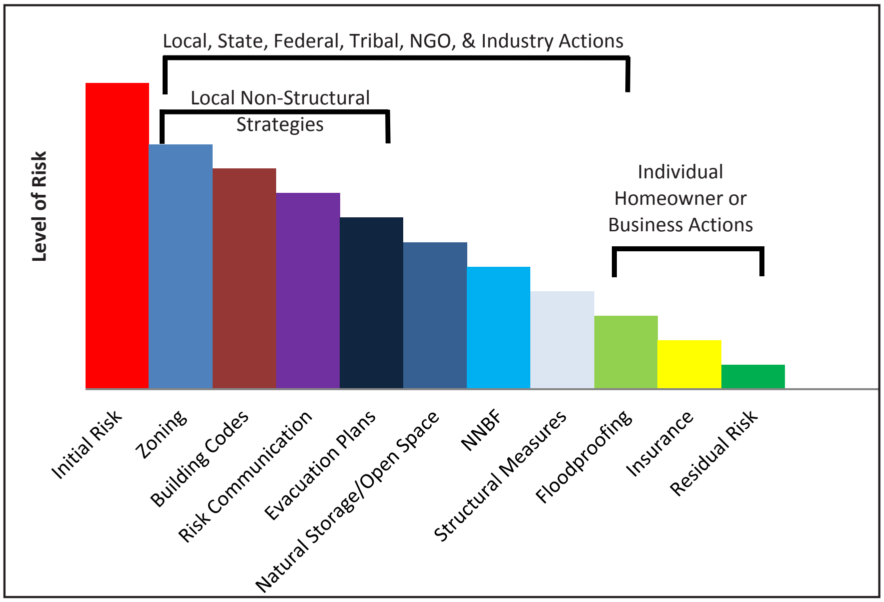

Figure VI-1. Coastal Storm Risk Management Measures (Source: NRC 2013, modified by USACE)

Table VI-1. Federal Acts, Programs, PPDs, and Executive Orders That Affect Coastal Storm Risk Management in Areas Affected by Hurricane Sandy

Title	Purpose
Biggert-Waters Flood Insurance Reform Act of 2012	Long-term reauthorization and reform of the NFIP. Raised insurance rates on certain properties that had been previously discounted in order to achieve actuarial soundness and included provisions for evaluating future risk
Grimm-Waters-Richmond Flood Insurance Affordability Act (2014)	Delays rate increases for some property types until an affordability assessment and new maps are completed
Community Development Block Grant Disaster Recovery Program (2013)	Appropriated funds for necessary expenses related to disaster relief, long-term recovery, restoration of infrastructure and housing, and economic revitalization in the most impacted and distressed areas resulting from a major disaster declared pursuant to the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1974 (42 U.S.C. 5121 et seq.) due to Hurricane Sandy and other eligible events in calendar years 2011, 2012, and 2013
Coastal Zone Management Act of 1972	Appropriated Federal funds to 34 State programs through NOAA to “preserve, protect, develop, and where possible, to restore or enhance the resources of the nation’s coastal zone”
Disaster Relief Appropriations Act of 2013	Appropriated funds and set guidance for recovery and rebuilding after Hurricane Sandy
PPD-8, National Preparedness (2011)	Directed the development of a national preparedness goal that would include national planning frameworks for protection, prevention, mitigation, response, and recovery
National Disaster Recovery Framework (FEMA 2013c) and National Mitigation Framework (FEMA 2014b)	Two of the five planning frameworks required by PPD-8
PPD-21, Critical Infrastructure Security and Resilience	Mandated that critical infrastructure be hazard resilient
Post-Katrina Emergency Reform Act of 2006	Provided funding for FEMA Risk Mapping, Assessment, and Planning
FY2010 Department of Homeland Security Appropriations Act	Appropriated funding for FEMA Risk Mapping, Assessment, and Planning
Water Resource Development Acts (1974 through 2007)	Authorized major water resource projects and provided for updating planning guidance and a national vulnerability assessment and strategy
Executive Order 11988, Floodplain Management (1977)	Required Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains
Coastal Barrier Resources Act (1982)	Identified and mapped undeveloped coastal barriers with the intention of discouraging development in areas vulnerable to storm damage and therefore minimizing the loss of human life, wasteful expenditures, and damage to natural resources

FEMA = Federal Emergency Management Agency
NOAA = National Oceanic and Atmospheric Administration
NFIP = National Flood Insurance Program
PPD = Presidential Policy Directive

Figure VI-2. Risk Management Process (NRC 2012a, used with permission)

Figure VI-2 outlines a risk management process that can be used by decision-makers and policymakers to manage risk and build resilience. The process is an adaptive cycle beginning with hazard identification and risk assessment, continuing with strategy development and implementation, and concluding with policy development and adjustment.

OPPORTUNITIES FOR ACTION

Institutional and other barriers, opportunities for action, and successes in reducing or eliminating the barriers were identified by analyzing relevant reports and interagency webinars and by interviewing key players at the local, State, and Federal levels. The identification of barriers was based on two criteria: the frequency of which the institutional barrier was mentioned and the severity of the impact/consequences of the barrier on coastal storm risk management and/or resilience.

The following six themes in the barriers emerged from the analysis:

- Theme 1: Risk/Resilience Standards
- Theme 2: Communication and Outreach
- Theme 3: Risk Management
- Theme 4: Science, Engineering, and Technology
- Theme 5: Leadership and Institutional Coordination
- Theme 6: Local Planning and Financing

The themes, opportunities for action, and successes are described in the following sections.

Theme 1: Risk/Resilience Standards

Opportunities for Action

- Standardize the definitions of risk, vulnerability, resilience, and related terms. Conduct research, as necessary, to develop design standards for resilience, performance metrics, a resilience scorecard, and other design issues.
- Conduct a national vulnerability study.
- Develop a national strategy for coastal storm risk management and/or a national coastal policy. The NRC report (2012a) and others have called for a national policy; therefore, NACCS is consistent and aligned with these references. A national policy would set the vision, and Coastal Zone Management plans would be examples of documents that would implement the vision.
- Develop regional and watershed-based plans, including a broad base of benefits, benefit quantification, and multi-objective approaches.

The challenges related to risk and resilience standards contribute to confusion and misperception of the real risks, including residual risk and long-term sustainable options to recover from Hurricane Sandy and to mitigate future risk. Some project design levels (2 percent flood, 1 percent flood), or the 1 percent flood standard for FIRMs, represent conditions that may not be appropriate considering all the economic, social,and environmental consequences of a large natural disaster in a region. Nor do these conditions or standards consider future risks to provide long-term comprehensive planning scenarios.

Further, there is general agreement that such standards should be national in scope, or at least regional, to avoid creating perverse incentives for developers to “shop” for lenient standards and disincentives for communities to adopt more stringent standards (ASFPM 2013; NRC 2012a). Finally, Smith and Grannis (2013) and information obtained in interviews suggest that some agency programs may restrict the ability of communities to use Federal grant program funds for coastal storm risk management improvements to infrastructure or facilities damaged in disasters.

Successes

A number of policies and reports have identified initiatives for meeting the challenges associated with establishing and implementing better standards for risk and resilience. These policies and initiatives serve to:

- Provide a more holistic approach to coastal storm risk management and community resilience.
- Embrace collaborative and integrated water resources planning and management opportunities.
- Form interagency and intergovernmental teams.
- Set standards for risk and resilience.

The following national initiatives are underway that support strategy integration and standard setting:

- In 2013, CEQ released Principles and Requirements for Federal Investments in Water Resources.
- (CEQ 2013) pursuant to the Water Resources Development Act of 2007 (33 U.S.C.) to supersede the 1983 *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (U.S. Water Resources Council 1983). CEQ (2013) sets a Federal objective for all key Federal agencies with water resource missions to maximize public benefits that encompass environmental, economic, and social goals. Although CEQ (2013) has yet to be implemented at the agency level, the requirement of a multi-objective focus in water resource investments is promising.
- President Obama’s Climate Action Plan (Executive Office of the President 2013), along with Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, require federally funded projects to reflect a consistent approach that accounts for relative sea level change and other factors affecting coastal storm risk.
- The HSRTF recommended that a minimum coastal storm risk management standard be adopted during recovery for major Federal investments. The standard sets the rebuilding standard for Federal investments involving vertical construction as 1 foot above the best available and most recent BFE information provided by FEMA, unless local standards are more restrictive. This standard and

even more stringent standards have already been adopted by some States and local communities in the North Atlantic region.

Additionally, Federal agencies have provided guidance to inform resilience planning. The USACE guidance on relative sea level change and accompanying relative sea level change calculator are included (Engineering Regulation [ER] 1100-2-8162, Dec 2013, "Incorporating Sea Level Change in Civil Works Programs").

- The Federal Interagency Floodplain Management Task Force (FIFMTF) identified as a priority the need to develop or update the national strategic vision for floodplain management that was established in the *Unified National Program for Floodplain Management* (FIFMTF 1994).
- As discussed in Theme 5, the Mitigation Framework Leadership Group (MitFLG) has been established under Presidential Policy Directive (PPD) 8, National Preparedness, to serve as a Federal leadership forum to promote preparedness.

There are also important non-Federal initiatives that look at national risk. New York State identified the need to promote planning and development criteria for integrated decision-making for capital investments across agencies (NYS 2100 Commission 2012). In October 2013, Michael Bloomberg, then-Mayor of the City of New York, announced an initiative called Risky Business to prepare the Nation for extreme weather events such as Hurricane Sandy. The initiative evaluates the risks imposed by climate change on the entire U.S. economy and will help individuals, communities, and the Nation understand and prepare for risk (Bloomberg Philanthropies 2013).

Theme 2: Communication and Outreach

Opportunities for Action

- Conduct coastal storm risk management visioning sessions with the public and with help from programs such as NOAA's National Sea Grant College Program.
- Working with NOAA's National Sea Grant College Program, continue to develop information and programs to educate the public about flood vulnerabilities, flood risk, residual risk, blended solutions, pre-disaster and evacuation planning, and similar issues.
- Develop a community of practice for NNBF, a group of individuals who practice and share an interest in a major functional area.

Communication and outreach about NNBF should:

- Focus on NNBF definitions, key concepts, and costs and benefits, particularly how these features can increase the resilience of a community, ecosystem, or local economy.
- Target Federal, State, and local levels of government, as well as private interests and homeowners who determine the type of project to implement on their property.
- Include working with coastal communities to help them consider potential future changes, such as demographic changes, and the implications of climate change, such as relative sea level change, and determine how to incorporate and use NNBF in these considerations.
- A critical aspect of managing risk and creating resilient communities is communicating risk to local officials, community leaders, and decision-makers who are responsible for land use, evacuation planning, and implementation of mitigation measures. Public acceptability of coastal storm risk management measures, the difficulty individuals and communities have in understanding their own risk, and a lack of community engagement about coastal storm risk management options have all been cited as barriers to implementing good coastal management strategies.
- In many areas, mitigation measures for homes such as floodproofing, elevation, and managed retreat are considered adverse options and may be prevented by legacy zoning or building codes. This issue is sometimes the result of a miscommunication of standards. For instance, many homeowners believe the 1 percent flood is an unlikely event, and particularly if such an event has just occurred, they believe is not likely to happen again soon. Additionally, beachfront property owners and local officials have sometimes resisted community coastal storm risk management projects because of perceived negative impacts on views and access.

- Similar communication and outreach challenges were identified by participants of the November 2013 “Policy Challenges to Using NNBF for Risk Reduction and Resiliency” working meeting. Participants noted that NNBF remains a nebulous concept for many, including decision-makers and others with responsibility for implementing coastal projects.

Successes

NOAA’s Sea Grant College Program is a network of 33 Sea Grant programs in universities and colleges located in every coastal and Great Lakes State, Puerto Rico, Lake Champlain, State, and Guam. The program is a trusted source of information on conservation and practical use of coasts and marine areas. After Hurricane Sandy, the Sea Grant programs in the Northeast played a key role in disseminating information, educating the public on Federal and State programs, and providing important scientific information on coastal restoration and climate change (NOAA 2014).

On a more local level, under the EPA’s National Estuary Program, the Barnegat Bay Partnership is 1 of 28 congressionally designated National Estuary Programs throughout the United States working to improve the health of nationally significant estuaries. A partnership of Federal, State, county, municipal, academic, business, and private stakeholders in the Barnegat Bay Partnership watershed program supported the Hurricane Sandy Federal Recovery Support Strategy, including its mission of “research, educate and restore” to provide outreach and education to New Jersey (Barnegat Bay Partnership 2014).

Theme 3: Risk Management

Opportunities for Action

- Strengthen and enforce floodplain management policies.
- Simplify the complicated network of coastal programs for communities.

Federal policies can inform and incentivize good land use zoning and building codes, but State, local, and Tribal communities have the authority to implement them. Communities can choose not to participate in the NFIP, not adopt the minimum floodplain standards set by the program, and forfeit the availability of flood insurance through the program. Further, even though homes may be eligible for buyouts under various Federal grant programs, homeowner participation is voluntary.

The strategies that communities develop and the laws and ordinances they adopt reflect the tolerance they have for managing their risks. Perceived or real impacts to the local tax basis make it difficult for decision-makers to implement effective zoning and code laws. Changes to land use and building codes can potentially drive down the value of an existing property over the short term and stimulate “takings” lawsuits, even while they may provide a sustainable solution to the community for managing flood risk, creating a double-edged sword for decision-makers and property owners.

Although many issues were identified, six key subthemes of coastal storm risk management emerged:

- Great concern and political interest in the impacts of rising insurance rates and new flood risk maps on low- and moderate-income populations. The repeal of portions of the Biggert-Waters Flood Insurance Reform Act is a manifestation of the concern. One alternative is the establishment of voucher systems to provide assistance to lower income groups (Pirani and Tolkoff 2014).
- Balancing old and newly emerging floodplain management ordinances on land use and building codes with an urgent need to move forward.
- Integrating the requirements and applications of Federal dollars for rebuilding infrastructure with local recovery plans.
- Lack of capacity, capability, and sometimes willingness at the local level for resilience planning.
- Pressure to rebuild infrastructure quickly and expedite regulatory reviews and requirements for environmental and historic preservation.
- Compassion-driven approaches to disaster recovery that are short-sighted and that avoid the tough issues in risk management and building resiliency.

Successes

Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region (HSRTF 2013a) contains numerous recommendations for addressing some of the programmatic issues listed previously. The task force encouraged communities and homeowners to promote existing programs, such as the Institute for Business and Home Safety's program for Fortified Homes, embrace green building practices, and adopt the latest International Building Code and International Residential Code.

The task force also suggested establishing a Hurricane Sandy Regional Infrastructure Permitting and Review team to help expedite the review of the most complex infrastructure projects. The recommendation follows the intent of Executive Order 13604, *Improving Performance of Federal Permitting and Review of Infrastructure Projects* (2012), which recommends the establishment of regional teams to keep communications open with Federal and State permitting officials.

Based on a task force recommendation, States have adopted amendments through Coastal Zone Management programs to include climate change in coastal development and revitalization plans and encouraged "soft approaches" to coastal storm risk management projects.

In addition, several States also supported the policy for using advisory base flood elevations (ABFEs) plus additional elevations to address risk and uncertainty associated with forecasted relative sea level change scenarios to build back more resilient communities. ABFEs are computed by FEMA following a storm event that exceeded the effective BFE. The purpose of ABFEs is to assist communities in their rebuilding efforts while new FIRMs are being completed (FEMA 2014a).

The NFIP Community Rating System has helped communities reduce their insurance premiums by incentivizing good floodplain management; however, some communities fail to enforce proper floodplain management standards.

Many community efforts have been focused on regional approaches to resilience. The National Disaster Recovery Framework and the National Mitigation Framework have helped to institutionalize regional approaches and capacity building.

Some initiatives, such as Rhode Island's Center for Coastal Adaptation and Resilience, are intended to provide "extension service," one-on-one type assistance to communities and homeowners to understand risk and risk management approaches.

Theme 4: Science, Engineering, and Technology

Opportunities for Action

- Improve research, coordination, and collection of pre- and post-storm data (e.g., relative sea level change, climate change) and data standards, including more rigorous instrumentation and monitoring for adaptive management, with USGS and others.
- Develop better design guidance for NNBF and use in coastal storm risk management, including effects on long-term maintenance.
- Compile information on ecosystem goods and services provided by NNBF (USACE 2013d).

Successful comprehensive coastal storm risk management incorporates sound science, engineering, and technology practices. Critical gaps, including risk and uncertainly, still exist (and will remain, in some cases) in climate change, environmental enhancement and risk management, NNBF, blended solutions, watershed and integrated water resource management solutions, and decision-support tools and data.

Data gaps and uncertainties exist in critical areas, including climate change; social science of coastal areas; NNBF production functions; ecosystem goods and services; and wave, wind, and elevation data. Baseline condition data are needed in many of these areas, as well as improved process modeling and engineering methods that are informed by data collection and experimental studies. All of the data gaps and uncertainties constitute important areas for additional research and development. Enhanced relative sea level change and storm models are also necessary to meet data needs.

The study of ecosystem goods and services has acute and specific data needs. Although NNBF can provide a wide range of ecosystem goods and services, the kinds and extents of ecosystem goods and services provided by different NNBF are generally poorly understood. Some believe it is hard to describe and quantify the secondary and tertiary benefits of NNBF. There are also perceptions that benefits that are difficult to monetize are less reliable in their performance or in decision criteria. Policies to inform benefit-cost valuations of the ecosystem goods and services provided by NNBF are needed, as well as direction on how to monetize benefits provided by NNBF.

> Assessment of NNBF performance and characterization of ecosystem goods and services remains a key knowledge gap that can be addressed by interagency teams.

There are also numerous uncertainties regarding the performance, timing, and scale of NNBF needed to provide coastal storm risk management and decrease storm damages. More information is needed on NNBF performance to effectively compare and integrate NNBF with structural and nonstructural measures. The lifecycle costs needed to operate and maintain NNBF are also uncertain. Finally, many threats, including relative sea level change and climate change also have unknown effects on the performance of NNBF, though it must be acknowledged that the effects of relative sea level change and climate change on structural coastal storm risk management features may also be unknown.

Adaptive management is an important requirement for many coastal storm risk management alternatives and in particular will be critical for implementing and maintaining NNBF Further, although NEPA requirements present an opportunity to improve project design and gather stakeholder input and ensure that scientifically sound approaches are considered, it was cited as occasionally delaying the implementation of adaptive coastal storm risk management measures. Adaptive management can be accommodated through NEPA with a tiered or programmatic approach, which should be used to overcome these issues if they arise. Additionally, the use of adaptive management approaches may mean that projects that are phased in over time do not initially meet the required standards (local, State or Federal), which could result in penalties. In some municipalities, existing policies hamper the application of adaptive management because the municipalities may be penalized for reporting results that are below expectations.

Successes

A number of positive technology and data advances have been achieved. Following Hurricane Sandy, NOAA, in partnership with FEMA and the USACE, created a set of map services to help communities, residents, and other stakeholders consider risks from future relative sea change in planning for reconstruction. The services are endorsed by the U.S. Global Change Research Program and are available on its website at http://www.globalchange.gov/what-we-do/assessment/coastal-resilience-resources.

The Nature Conservancy has been partnering with many governmental, nongovernmental, and academic entities to develop guidelines for nature-based designs (see http://www.nature.org/media/climatechange/building-coastal-resilience.pdf) and recently released a coastal resilience mapping tool to help communities evaluate alternatives (see http://maps.coastalresilience.org) (Mathison 2012).

Engineering with Nature (http://el.erdc.usace.army.mil/ewn/) is a USACE initiative defined as the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes.

The Systems Approach to Geomorphic Engineering (SAGE 2014) is another initiative led by USACE, NOAA, and FEMA that engages a diverse set of experts and partners to develop and apply innovative alternatives to coastal resilience using both natural and nature-based (green) and structural (gray) elements.

The HSRTF and HUD, in partnership with The Rockefeller Foundation, launched an initiative called Rebuild by Design in June 2013 as a multi-stage design competition to develop innovative, implementable, and regionally-scalable proposals that promote resilience in the Hurricane Sandy-affected region. In October 2014, HUD allocated a total of $930 million toward implementation of seven projects originating from the competition (six winning projects and one finalist project).

The extensive rebuilding effort following Hurricane Sandy presented an opportunity for homeowners and businesses to adapt to increasing flood risk. Participation in the NFIP requires that communities adopt and enforce floodplain ordinances that meet or exceed FEMA requirements to reduce the risk of flooding, including building permits that require the lowest floor elevation (for A-Zone) or lowest structural horizontal member (for V-Zone) to be at or above the BFE (1 percent flood) according to FEMA's floodplain management regulations available at http://www.fema.gov/floodplain-management/floodplain-management-requirements.

Developed in collaboration with FEMA, NOAA, and the U.S. Global Change Research Program, the USACE sea level change calculator provides four scenarios (USACE/NOAA Low, USACE/NOAA Intermediate, USACE High, and NOAA High) to present the elevations based on the potential future sea level change scenarios above the BFE obtained from FEMA's Preliminary FIRMs published after Hurricane Sandy. The tool is available at http://www.corpsclimate.us/ccaceslcurves.cfm.

Theme 5: Leadership and Institutional Coordination

Opportunities for Action

- Re-evaluate and complete authorized or planned projects using a comprehensive systems approach.
- Increase coordination between Federal, State, Tribal, and local governmental agencies with responsibility for coastal storm risk management to foster a mutual understanding of roles and responsibilities and consistency between Federal programs affecting coastal management.
- Support national adaptation planning.

Two of the more significant challenges identified from the analyses are the complexity of institutional governance and the need for coordination and leadership at all levels. There are at least 9 Federal agencies with responsibilities for various parts of coastal storm risk management and 16 Congressional subcommittees responsible for authorization of programs and appropriation of funds for coastal storm risk management. Increasing Federal intra- and interagency coordination could help ensure consistent implementation of Federal projects and programs affecting coastal storm risk management. Likewise, increasing coordination between these Federal agencies and the State, Tribal, and local tribal governmental agencies with responsibility for coastal storm risk management could promote mutual understanding of each entity's roles and responsibilities in policy-making, data sharing, and planning and regulatory reviews.

Improved coordination among government agencies, academia, nongovernmental entities, and others is needed to determine where NNBF could best be used to manage risk throughout an entire region. Organizations serving this capacity include the Northeast Regional Ocean Council, Northeast Regional Association Coastal Ocean Observing Systems, Mid-Atlantic Regional Council on the Ocean, and MAFPO. Federal agencies NNBF are not practical in all instances, but a broad understanding and characterization of the landscape can facilitate their use. Land use planning and zoning policies often do not encourage and sometimes limit the use of NNBF. Informing local governments about the benefits of NNBF and working with them to institute policies that allow for NNBF, while promoting resilient communities, could alleviate this problem. The promotion of a holistic or integrated community strategy and decision-making process would facilitate collaboration among communities on how to achieve resilience through measures that include NNBF.

Successes

Under PPD-8, both the National Disaster Recovery Framework and the National Mitigation Framework have functions that support integration of programs and community engagement. As part of the National Mitigation Framework, the MitFLG was established to coordinate interagency policies for disaster reduction. Additionally, the FIFMTF developed a focused work plan to improve coordination, collaboration, and transparency among Federal agencies (FIFMTF 2013).

Further opportunities lie in continuing support of the regional body to enhance local leadership and ensure consistency of implementation efforts with the NACCS, State, and local/community master plans. For example, under its Community Development Block Grant disaster recovery grants made to Hurricane Sandy disaster recovery grantees, HUD encouraged grantees to consult with a Regional Coordination Working Group and agreed to consider the group's views prior to approving an action plan for the use of funds by a CDBG disaster recovery grantee. HUD stated that the goal of this effort was ‘to promote a regional and cross-jurisdictional approach to resilience in which neighboring and states come together to: identify interdependencies among and across geography and infrastructure systems; compound individual investments towards shared goals; foster leadership; build capacity; and share information and best practices on infrastructure resilience (Federal Register 2014).

Additionally, the programs of multiple Federal agencies have provisions that disincentivize development in hazardous areas. For example, the Department of the Interior’s Coastal Barrier Resources Act restricts Federal spending on undeveloped coastal barrier islands. Additionally, the Steering Committee on Federal Infrastructure Permitting and Review has been established to lead the development of a plan, released in May 2014, for modernizing the Federal permitting and review process for major infrastructure projects to reduce the time and uncertainty for such projects and to ensure that appropriate environmental and other safeguards are accommodated (Steering Committee 2014).

Theme 6: Local Planning and Financing

Opportunities for Action

- Apply lessons learned from post-Hurricanes Katrina, Rita, Sandy and other coastal storms to provide integrated coastal storm risk management approaches.
- Create new tax and market-based incentive programs to encourage resilient local action.
- Explore innovative financing options and timetables for Federal and non-Federal partnerships to sustain long-term operation, maintenance, monitoring and adaptive management.
- Leverage public-private partnerships as part of community financing strategies.

The issue of funding and resources was an often repeated challenge mentioned during the interviews conducted as part of this analysis. Beyond budgets and staffing, policies and authorities can cause unintended economic stressors, limit the ability to pool resources or incentivize good coastal storm risk management, or make executing programs difficult within a certain period of time or at a particular geographic scale. The key challenges that were identified are as follows:

- Investing in preparing for and mitigating future disasters provides a much higher return to taxpayers than investing in disaster recovery. For example, the Government Accountability Office concluded in 2007 that a comprehensive strategic framework establishing joint strategies and leveraging resources across agencies for addressing natural hazard mitigation to reduce or eliminate long-term risks to life and property would provide greater benefit than disaster recovery (GAO 2007). Similarly, a benefit-cost analysis performed by the National Institute of Building Sciences found that a dollar invested in mitigating the effects of natural hazards saved society an average of $4 in disaster recovery costs (National Institute of Building Sciences 2005). The challenge is that Federal government has increasingly funded post-disaster recovery as opposed to pre-disaster mitigation opportunities.
- Project decisions are often too focused on least cost or benefit-cost ratio, limiting the consideration of environmental benefits or other regional and local benefits.

Additionally, examples from the Louisiana Coastal Protection and Restoration effort illustrate formulation and evaluation processes for adding nonstructural components into an integrated coastal storm risk management program (USACE 2009a). As this report indicates:

Nonstructural measures were formulated with the primary goal of managing risk to the population and assets of South Louisiana. The development of applicable measures was based on two primary sources of risk: storm surge velocity and inundation. Findings support that nonstructural measures perform well across all the metrics considered for the LACPR evaluation. They are efficient and effective in managing risk from storm surge, as well as from other sources of flooding. Nonstructural measures bear few operational and maintenance costs and have little or no environmental mitigation requirement (USACE 2009a).

Challenges to USACE projects that were identified in the *Hurricane Sandy Coastal Performance Evaluation Study* (USACE 2013a) include limited consideration of issues in coastal watersheds such as impacts in back bays and concurrent flooding and limited consideration of the interrelationship of coastal features. Older local ordinances and building codes may encourage or require armored shorelines over NNBF, taking choices away from landowners.

SUMMARY

The institutional landscape and hierarchy of decision-makers, policymakers, and those who enforce the decisions is complex. The six institutional and other barriers identified in NACCS are consistent with challenges identified in other recent initiatives. Opportunities for action are summarized such that decision-makers and policymakers across all levels of government, NGOs, and the private sector can come together as a coastal community committed to coastal storm risk management and resilience. Table VI-2 presents a summary of the barriers, their consistency with others, and opportunities for action.

Table VI-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
1. Risk/Resilience Standards	Develop consistent definitions for risk, vulnerability, resilience, and related terms and conduct research, as necessary, to develop design standards for resilience, performance metrics, a resilience scorecard, and other standards[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) Presidential Policy Directive 8, National Preparedness
	Conduct a national vulnerability study of constructed USACE coastal storm risk management projects	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop a national strategy for coastal storm risk management	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop regional and watershed-based plans, including a broad base of benefits, benefit quantification, and multi-objective approaches[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)

Table VI-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action (continued)

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
2. Communication and Outreach	Conduct coastal storm risk management visioning sessions with the public[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Continue to develop information and programs to educate the public about flood vulnerabilities, flood risk, residual risk, blended solutions, and pre-disaster and evacuation planning[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Develop a community of practice[2] for Natural and Nature-Based Features (NNBF)[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)
3. Risk Management	Strengthen and enforce floodplain management policies	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Simplify the complicated network of coastal programs for communities[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
4. Science, Engineering, and Technology	Improve research, coordination, and collection of pre- and post-storm data collection (e.g., relative sea level change, climate change), including more rigorous instrumentation and monitoring for adaptive management, with USGS and others[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a) *The President's Climate Action Plan* (Executive Office of the President 2013)
	Develop better design and implementation guidance for NNBF for use in coastal storm risk management, including effects on long-term maintenance	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Compile information on ecosystem goods and services provided by NNBF[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)

Table VI-2. Summary of Institutional and Other Barriers to Achieving NACCS Goals and Opportunities for Action (continued)

Barrier Theme	Opportunities for Action	Consistent with Plans by Others
5. Leadership and Institutional Coordination	Re-evaluate and complete authorized or planned projects in a comprehensive systems approach[1]	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Increase coordination between Federal, State, local, and Tribal governmental agencies with responsibility for coastal management to foster mutual understanding of roles and responsibilities and to foster consistency between Federal programs affecting coastal storm risk management[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a) *Reducing Coastal Risk on the East and Gulf Coasts* (NRC 2014) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a) Presidential Policy Directive 8, National Preparedness
	Support national adaptation planning[1]	*Federal Actions for a Climate Resilient Nation* (ICCATF 2011) *National Climate Change Adaptation Strategy* (CEQ 2010) *Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
6. Local Planning and Financing	Apply lessons learned following Hurricanes Katrina, Rita, Sandy, and other coastal storms to provide integrated coastal storm risk management approaches[1]	*Hurricane Sandy Rebuilding Strategy – Stronger Communities, A Resilient Region* (HSRTF 2013a)
	Create new tax and market-based incentive programs to encourage resilient local action	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Explore innovative financing options and timetables for Federal and non-Federal partnerships to sustain long-term operation, maintenance, monitoring. and adaptive management	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)
	Leverage public-private partnerships as part of community financing strategies	*Hurricane Sandy Coastal Projects Performance Evaluation Study* (USACE 2013a)

[1] NACCS contributed toward reducing this barrier and toward this opportunity for action.

[2] A community of practice is a group of individuals who practice and share an interest in a major functional area.

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VII. Activities Warranting Additional Analysis

The NACCS provides the baseline knowledge to continue the dialog with vulnerable coastal communities and evaluate plans to address the future challenges these communities face. Other analyses, using the technical products from NACCS, which include measures and socioeconomic and environmental benefit analyses, could be pursued to contribute further to coastal storm risk management strategies.

The NACCS Framework and accompanying technical analyses, which advance the state-of-the-science, are significant steps forward in aligning coastal practitioners and streamlining decision-making to support diverse and resilient management in a systems context. There remain many areas of uncertainty and opportunities for collaboration: from conducting research and development to overcoming policy challenges to educating others on the Framework and the full array of measures for managing risk to vulnerable coastal populations. Activities warranting additional analysis have been identified, as directed by the Disaster Relief Appropriations Act of 2013, and are summarized in the following sections.

TECHNICAL AND SCIENTIFIC ANALYSES

Additional technical analyses are needed to advance the incorporation of resilience, risk and uncertainty, and sea level and climate change adaptation planning into site-specific coastal design and construction, including the following:

- Detailed risk, exposure, and vulnerability analyses (i.e., application of the Framework using technical advancements of the NACCS) to support long-term planning decisions about when and where to transition strategies between avoid, accommodate, and preserve. Opportunities exist to conduct more detailed analyses for the nine focus areas identified in this report (see Figure II-2).
- Site-specific analyses to demonstrate potential coastal storm risk management benefits from blended solutions, NNBF, and other innovative approaches.
- Documentation of best practices for coastal storm risk management and resilience and validation (monitoring and adaptive management data) of success.
- Additional system-wide and regional sediment budget investigation to address navigation, NNBF, and sand sources in the region.
- Reliable prediction of storm severity and landfall locations 72 hours or more prior to landfall are needed to gain public confidence and streamline evacuation of coastal regions.
- Analysis of ecosystem goods and services of NNBF.

RISK COMMUNICATION AND COLLABORATION

Effective and ongoing communication of coastal storm risk is required among various Federal, State, Tribal, and local governments as well as NGOs, academia, private industry, and the public. Examples of actions to be taken include:

- Local risk communication approaches and techniques to assist in sharing and understanding applicable analyses, models, measures, and actions that could be taken to manage and reduce risk.
- Dynamic and cohesive education and communication about current risks, community risk and resilience self-assessments, and acceptable levels of risk in the future due to the impacts of sea level and climate change.

INSTITUTIONAL AND FINANCING

Additional coordination is needed to overcome challenges and complexities associated with land-use policy and permitting actions, as follows:

- Develop policies, guidance, and incentive programs based on state-of-the-art science (e.g., land use, wise use of floodplains, zoning, pre-storm planning, and nonstructural measures are cost-effective measures supporting coastal resilience).
- Explore innovative financing and public-private partnership models for integrated water resources management. These approaches, when established

carefully, can present an efficient allocation of resources, be consistent with the Federal role in infrastructure investment, and support long-term sustainability and local economies.

- Develop prioritized plans for coastal storm risk management to focus limited resources.
- Streamline and align regulatory and planning reviews, data sharing, and resources across agencies.

COASTAL STORM RISK

Nine areas of the North Atlantic Coast were identified as warranting additional analyses to address coastal storm risk. The areas are listed below. A Focus Area Report for each area is provided as an attachment to the State and District of Columbia Analyses Appendix.

- Rhode Island Coastline
- Connecticut Coastline
- New York-New Jersey Harbor and Tributaries
- Nassau County Back Bays, NY
- New Jersey Back Bays
- Delaware Inland Bays and Delaware Bay Coast
- City of Baltimore, MD
- The District of Columbia
- City of Norfolk, VA

Through extensive collaboration, planning efforts for the North Atlantic Coast in coastal storm risk management and resilience, as well as potential impacts from forecasted relative sea level change, have been streamlined for USACE and other stakeholders. Federal, State, Tribal, and local stakeholders and NGOs, academia, and industry can use the information and products presented in the NACCS to implement the vision of more resilient and sustainable coastal communities. Hurricane Sandy revealed that that North Atlantic Coast is vulnerable to the impacts of coastal flooding. Future projections of increasing relative sea level change as a result of impacts of climate change present a range of possible future conditions, all of which indicate increasing risk.

The NACCS was a 2-year study that was initiated in response to a catastrophic event—Hurricane Sandy. The risk of similar events may increase over time with exacerbated impacts of relative sea level change and climate change; therefore, coastal communities must begin to consider long-term coastal storm risk now. Some communities have already begun addressing the issue, such as in New York City.

Considerations for an adaptation strategy to avoid, accommodate, or preserve could be incorporated into coastal storm risk management planning activities. Short-term and long-term adaptation strategies include evacuation planning. Permanent relocations and re-siting of regional critical infrastructure that supports the population as part of a long-term planning effort to avoid flood peril could also be considered across the North Atlantic Coast, where appropriate, based on a community's objectives and constraints.

For coastal communities that intend to adopt an adaptation strategy to accommodate or preserve, planning will be an ongoing effort by various stakeholders over a number of years. For example, any new plan to incorporate or modify existing coastal storm risk management projects into the landscape would require planning, design, construction, monitoring, and adaptive management. The timeframe to implement solutions could be years, including the time necessary to plan a risk management solution; coordinate the solution with various stakeholders including the public; evaluate the benefits, costs, and impacts; design the solution; and then implement it. Strategic monitoring of the coastline will be necessary to measure how well investments perform and increase resilience as well as to inform an adaptive management strategy.

Addressing coastal storm risk is a shared responsibility. It will require communities and local governments to effectively plan for the populations to avoid the impacts of future storms, as well as Federal, State, Tribal, and local governments, NGOs, academia, and private industry to provide support as appropriate. The NACCS Framework enables the development of solutions to address the coastal storm risk to vulnerable coastal populations. To promote resilience and sustainable coastal communities, integrated water resources planning to address the increasing risk must occur now.

VIII. Definitions and Acronyms

DEFINITIONS

Accommodate – An adaptation category that allows individuals and communities to adapt to sea level changes and other impacts as they occur over time. This strategy could include traditional nonstructural measures, such as elevation, floodproofing, and ring walls, along with improved implementation of NNBF measures.

Adaptive Capacity – Assessment of a measure's ability to adjust through natural processes, operation and maintenance activities, or adaptive management, in such a way as to preserve the measure's function.

Adaptive Management – Decision-making process that promotes flexible decision-making that can be adjusted in the face of risks and uncertainties, such as those presented by climate change, as outcomes from management actions and other events become better understood through monitoring and improved knowledge.

Advisory Base Flood Elevations (ABFEs) – Following large storm events, such as Hurricane Sandy, FEMA performs an assessment to determine whether the 1 percent flood event, shown on effective FIRMs adequately reflects the current flood hazard. In some cases, because of the age of the analysis and the science used to develop the FIRMs, FEMA determines that there is a need to produce ABFEs. ABFEs are provided to communities to support recovery to make the communities more resilient to future storms (FEMA 2013b).

Avoid – An adaptation category, sometimes termed "retreat," that seeks to avoid increasing impacts through traditional nonstructural activities, such as acquisition, to convert land to open space, providing natural infrastructure risk reduction benefits, but also could include other strategies, such as NNBF measures.

Coastal Storm Risk Management Framework – Suite of coastal storm risk management strategies, measures, and parametric costs that provides a basis for further analyses and potential implementation at a future stage. The framework manages risk to reduce damage and promotes resilience to populations in areas of the USACE North Atlantic Division vulnerable to storm surge-induced flooding.

Consequence – Amount of harm caused by a hazard.

Cost Index Range – Range of values taken by the cost index. The cost index for measure X is the normalized parametric estimate of the unit cost of producing measure X. The idea of a parametric cost estimate is to produce, for each type of measure, an equation of the relationship between the scale of production of the measure and the total cost to produce that scale.

Ecosystem – A dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems.

Ecosystem Services – Benefits people obtain from ecosystems and the attributes and outputs of ecosystems that create value for human users. Ecosystem services are derived from ecosystem processes, such as nutrient cycling, climate regulation, and maintenance of biodiversity. The tangible items or intangible commodities generated by self-regulating or managed ecosystems whose composition, structure, and function are composed of natural, nature-based, and/or structural features that produce socially valued benefits that can be used either directly or indirectly to promote human well-being.

Exposure – Presence of people, infrastructure, and/or environmental resources (receptors of the hazard) affected by the coastal storm flooding hazard. A higher density of people, infrastructure, and/or environmental resources produces relatively higher exposure to coastal storm flood hazard.

Hazard – Circumstance that increases the likelihood of danger or peril to life, property, or assets.

Measure – See Risk Management Measure.

Mitigation – Capabilities necessary to reduce loss of life and property and damage to natural resources or ecosystem services by lessening the impact of disasters. Mitigation capabilities include, but are not limited to, community-wide risk management projects, efforts to improve the resilience of critical infrastructure and coastal ecosystems, risk management for specific vulnerabilities from natural hazards or acts of terrorism, and initiatives to manage future risks after a disaster has occurred to reduce damages.

Natural Features – Elements that are created and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature.

Nature-Based Features – Elements that mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal storm risk management.

Nonstructural Measures – Complete or partial alternatives to structural measures, including modifications in public policy, management practices, regulatory policy, and pricing policy. Nonstructural measures essentially reduce the consequences of flooding as compared to structural measures, which may also reduce the probability of flooding.

Performance – How a system reacts to a hazard according to a specific set of metrics.

Planning Reach – Planning segment with an area smaller than State jurisdictions based on existing natural and manmade coastal features, including shoreline type, USACE coastal storm risk management project extent, and the 1 percent flood (100-year flood) floodplain, from which risk management and resilient coastal community decisions can be made.

Preserve – An adaptation category, sometimes termed "protect," that focuses on preserving the function or reliability of the given economic, social, and/or environmental system that is adversely affected by climate change (e.g., navigation channels continue to function reliably, coastal storm risk management measures continue to manage and reduce risk), and may include structural, nonstructural, NNBF, and combinations of each as appropriate.

Recovery – Capabilities necessary to assist communities affected by an incident to recover effectively, including, but not limited to, rebuilding infrastructure systems; providing adequate interim and long-term housing for survivors; restoring health, social, and community services; promoting economic development; and restoring natural and cultural resources.

Redevelopment – Rebuilding degraded, damaged, or destroyed social, economic, and physical infrastructure in a community, State, or Tribal lands to create the foundation for long-term community development, health, and resiliency.

Redundancy – Duplication of critical components of a system with the intention of increasing reliability of the system, usually in the case of a backup or fail-safe.

Residual Risk – Flood risk that remains after all efforts to manage and reduce the risk are completed. Residual risk is the exposure to flood peril remaining after other known risks have been countered, factored in or eliminated.

Resilience – Ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies.

Response – Capabilities necessary to save lives, manage risks to property and the environment, and meet basic human needs after an incident has occurred.

Restoration – For the purposes of the NACCS, restoration includes not only returning a physical structure, essential government or commercial services, or a societal condition back to a former or normal state of use through repairs, rebuilding, relocation, or reestablishment, but also the restoration of natural and ecological systems and processes that are linked with and contribute to the resiliency of physical infrastructure and coastal economies.

Risk – Function of the probability of occurrence of some event (i.e., frequency with which it occurs) and the consequences of the event. Risk is an overarching concept that includes the components of hazard, exposure, vulnerability, performance, and subsequent consequences. For the purposes of the NACCS, hazard, exposure, and vulnerability are addressed in the risk assessment. At the NACCS study area scale for plan formulation purposes, risk was further defined as the function of exposure to the coastal flood hazard and the probability that the hazard will occur.

Risk Management Measure – Feature or activity that can be implemented at a specific geographic site to address risk.

Risk Management Strategy – Set of related features or activities that can be considered alone or in combination to manage risk.

Robustness – Ability of a system to continue to operate correctly across a wide range of operational conditions (the wider the range of conditions, the more robust the system), with minimal damage, alteration or loss of functionality, and to not fail catastrophically outside that range.

Sensitivity – Potential of a system's valued attributes or functions to be affected (either positively or negatively) by the changes caused by a hazard.

Strategy – See Risk Management Strategy.

Structural Measures – Measures that are intended to prevent flooding by altering the flow of floodwater and include constructing levees or dams or modifying a waterway's channel.

Sustainability – Meeting the needs of the present without compromising the ability of future generations to meet their own needs.

System – Integrated whole of the natural and built environments that can be defined geographically, technically, and politically.

Vulnerability – Degree to which a system's receptors or assets are susceptible to, and unable to cope with, the adverse effects of coastal storm flood hazard over a period of time or temporal reference. More broadly, vulnerability to coastal storm flood hazard is a function of the exposure of receptors or assets to the hazard, the sensitivity of the receptors or assets within the system to the hazard, and adaptive capacity of the receptors or assets within the system to recover from and withstand the reoccurrence of the coastal flood event. Given the expansive scale of the NACCS, probability of occurrence is used as the only measure of the receptors' or assets' sensitivity to the coastal flood hazard, and adaptive capacity was not assessed.

ACRONYMS

ABFE	Advisory Base Flood Elevation
ADCIRC	Advanced Circulation Model
BFE	Base Flood Elevation
CAP	Continuing Authorities Program
CDBG-DR	Community Development Block Grant Disaster Recovery
CEQ	Council on Environmental Quality
CSTORM-MS	Coastal Storm Modeling System
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EC	Engineering Circular
EPA	U.S. Environmental Protection Agency
ER	Engineer Regulation
ERDC	Engineer Research and Development Center
FEMA	Federal Emergency Management Agency
FEMA MOTF	Modeling Task Force
FIFMTF	Federal Interagency Floodplain Management Task Force
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
HBCUs	Historically Black Colleges and Universities

HEC-FIA	Hydrologic Engineering Center Flood Impact Analysis [model]
HSRTF	Hurricane Sandy Rebuilding Task Force
HUD	U.S. Department of Housing and Urban Development
ICLUS	Integrated Climate and Land Use Scenarios
IPCC	Intergovernmental Panel on Climate Change
JPM-OS-BQ	Joint Probability Method with Optimum Sampling by Bayesian Quadrature
IWR	Institute for Water Resources
MDE	Maryland Department of the Environment
MitFLG	Mitigation Framework Leadership Group
MOM	Maximum of Maximum
NACCS	North Atlantic Coast Comprehensive Study
NALCC	North Atlantic Landscape Conservation Cooperative
NAVD88	North American Vertical Datum of 1988
n.d.	no date
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFWF	National Fish and Wildlife Foundation
NGO	Nongovernmental Organization
NNBF	Natural and Nature-Based Features
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWR	National Wildlife Refuge
PPD	Presidential Policy Directive
Risk MAP	Risk Mapping, Assessment, and Planning
SAGE	Systems Approach to Geomorphic Engineering
SCR	Structures of Coastal Resilience
SIRR	Special Initiative for Rebuilding and Resiliency
SLAMM	Sea Level Affecting Marshes Model
SLOSH	Sea, Lake , and Overland Surges from Hurricanes
STWAVE	Steady State Spectral Wave
SWEAT-MSO	Sewage, Water, Electricity, Academics, Trash, Medical, Safety, and Other Considerations

USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USET	United South and Eastern Tribes
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAM	Wave Prediction Model

A debris engineer with USACE inspects a house devastated by Hurricane Sandy in Queens, NY on November 30, 2012.
Source: https://www.flickr.com/photos/usacenad/8248944721/in/photostream/

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