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US ARMY CORPS OF ENGINEERS NORTH ATLANTIC COAST COMPREHENSIVE STUDY

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ABSTRACT: The United States is experiencing a trend toward increased frequency, high magnitude storm events such as Hurricanes Katrina and Rita in 2005, and storms of large areal extent creating larger damage areas as evidenced by the size of Hurricane Irene in 2011and Hurricane Sandy in 2012, Given the reality of sea level rise as a probable future condition, the Disaster Relief Appropriation Act of 2013 (P.L. 113-2) recognized the need to comprehensively evaluate the existing and planned measures to reduce the flooding risk from tidally-influenced storm surges as well as other alternatives for areas at risk to future storm damages. The legislation directed the US Army Corps of Engineers to undertake a Comprehensive Study of the Sandy impacted areas in the North Atlantic Division (Maine to Virginia) to be conducted in coordination with other Federal agencies, and State, Local, and Tribal officials to ensure consistency with other recovery plans being developed. The goal of the North Atlantic Coast Comprehensive Study is advance coastal storm risk reduction strategies for vulnerable coastal populations considering future sea level rise and climate change scenarios. This discussion will describe the current status of the Comprehensive Study and ongoing collaborations, and the process leading to the January 2015 submission to Congress.

Key Words: Sandy, Coastal Storm Risk Management, Climate Change

1. INTRODUCTION.

On January 29, 2013, the Disaster Relief Appropriations Act, 2013, Public Law 113-2 (US Government 2013), was enacted to assist in the recovery in the aftermath of the hybrid cyclone-nor'easter known as Hurricane Sandy. The Act directed 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 of Engineers*…" (the region extending from Maine to Virginia). The study area includes the 10 northeast States and the District of Columbia that were impacted by Hurricane Sandy. In response to a Congressional mandate to respond to Hurricane Sandy, the purpose of the North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk (NACCS) is to develop strategies accessible to all stakeholders that reduce the risk from, and make the North Atlantic region more resilient to, future storms and impacts of sea level rise. Hurricane Sandy could have been more devastating in as much as existing infrastructure prevented some $1.9 billion in damages (USACE 2012). The NACCS will help the region to prepare NOW for future storms, climate change (and sea level change), population increases, and other relevant factors.

2. UNDERTAKING THE US ARMY CORPS OF ENGINEERS NORTH ATLANTIC COAST COMPREHENSIVE STUDY

2.1 HURRICANE SANDY

Hurricane Sandy was an extraordinary storm, particularly in the coastal areas extending from Cape May, NJ to Montauk Point, NY. Peak water levels indicate that Hurricane Sandy was at least greater than a 200 year event (1 in 200 annual exceedance probability), greatly exceeding project design levels. This resulted in damages throughout the New York City metropolitan area. Beyond the New York Bight, including New Jersey, along the north shore of Long Island, NY, Connecticut, Rhode Island, southern Massachusetts, and the Atlantic coasts of Delaware and Maryland, storm tides, although still significant, were considerably lower, typically a 20 to 30 year event. Farther away, in Massachusetts north of Cape Cod, New Hampshire, and Maine to the north and the Chesapeake Bay coastline of Maryland and Virginia to the south, Hurricane Sandy was less than a 10 year event (US Army Corps of Engineers 2013b).

The Congressional response to the devastation in the wake of Hurricane Sandy represents a need to address as a regional system the vulnerability of populations at risk in coastal regions in the U.S. Army Corps of Engineers (USACE) North Atlantic Division. Along with a recent increase in high magnitude storm events such as Hurricanes Katrina and Rita in 2005, and recent storms with larger areal extents creating larger damage areas as evident by the size of Hurricane Irene in 2011 and Hurricane Sandy in 2012, as well as the reality of sea level rise as a probable future condition, there is a need to comprehensively evaluate the existing and planned measures to reduce the flooding risk from tidally influenced storm surges as well as other alternatives for areas at risk to future storm damages. The Comprehensive Study will take into account the many interagency plans and strategies that were undertaken both prior to and after Hurricane Sandy pertaining to adaptation and the need to be resilient in the face of climate change and sea level rise. As the Study is currently under review, this discussion will focus on the result of an initial evaluation of project performance which forms the foundation of the Study and the analytic tools and collaborative process employed in developing the Comprehensive Study.

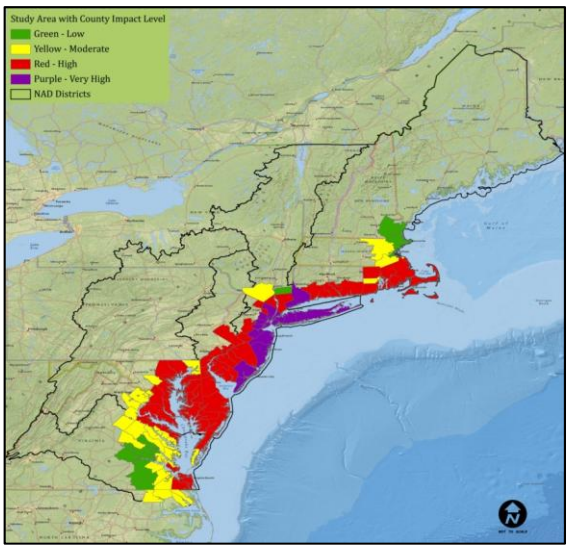

Figure 1: Study Area of the North Atlantic Coast Comprehensive Study

In the aftermath of 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 impacted by Hurricane Sandy and document the economic impacts related to storm surge, intense rainfall, and high winds. The areas of greatest impacts were in New York and New Jersey. The Study Area Map (Figure 1) provides a color-coded overview of the damages using the following criteria:

- Very High (Purple): County population greater than 10,000 exposed to surge.
- High (Red): County population of 500 to 10,000 exposed to surge, or modeled wind damages

greater than $100M, or precipitation greater than 8 inches.
- Moderate (Yellow): County population of 100 to 500 exposed to surge, or modeled wind damages of $10 to $100M, or precipitation of 4 to 8 inches.
- Low (Green): No storm surge impacts, or modeled wind damages less than $10M, or precipitation less than 4 inches.

The development of the Risk Reduction Framework will include examples of its application to this high impact area. Following 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. This effort which culminated in the *Hurricane Sandy Rebuilding Strategy (*Hurricane Sandy Rebuilding Task Force 2013) has changed the physical and cultural landscape of the impacted areas and has altered the social and political awareness of the potential impacts from future storms.

3. UNDERTAKING THE US ARMY CORPS OF ENGINEERS NORTH ATLANTIC COAST COMPREHENSIVE STUDY

The Comprehensive Study is based on the *"Infrastructure Systems Rebuilding Principles"* advanced by National Oceanic and Atmospheric Administration and the U.S. Army Corps of Engineers (2013). The purpose of the *Rebuilding Principles* were to improve long-term performance of coastal rebuilding and restoration actions undertaken through the Infrastructure Systems Recovery Support Functions under the National Disaster Recovery Framework following Superstorm Sandy by implementing Executive Order 11988 and these consistent principles on a regional scale that anticipate a changing environment; integrate economic, social, and environmental resiliency and sustainability; and promote long term community protection. The three Principles are: 1) Work together in a collaborative manner across multiple scales of governance (i.e., local, State, Tribal, and Federal) and with relevant entities outside 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; 2) Improve coastal resilience by pursuing a systems approach that incorporates natural, social, and built systems as a whole; and 3) Promote increased recognition and awareness of risks and consequences among decision makers, stakeholders, and the public.

The Comprehensive Study takes into account the many interagency plans and strategies that were undertaken both prior to and after Hurricane Sandy pertaining to adaptation and the need to be resilient in the face of climate change and sea level rise. However, the USACE recognizes that more comprehensive protection can only be realized when individuals and government agencies at non-federal and Federal levels collectively recognize, understand, and act to manage and effectively reduce risks attributed to threats posed by flooding and coastal storms (US Army Corps of Engineers 2013b).

3.1 North Atlantic Coast Comprehensive Study (NACCS) Engagement and Communication Strategy

An Engagement and Communication Strategy was prepared to provide a consistent approach for planning, integrating and executing all communication associated with the NACCS. The 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.

Table 1. Requests for Information and Verification

Requested Input	Date	Purpose
State Verification of Post-Sandy Landscape Letter	May 23, 2013	Request State confirmation of post-Sandy projects and anticipated projects such that future exposure and vulnerability can be properly assessed.
NACCS Public Web site 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 non-governmental stakeholders	June 6, 2013	Provide general background; request post-Sandy data or regional strategies, as well as a point of contact.
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-Sandy conditions, as well as most vulnerable areas.
Federal Register Notice	October 4, 2013	Solicit peer-reviewed data.
United South and Eastern Tribes (USET) Tribal Meeting, NC	October 28–31, 2013	Present the NACCS and solicit input.
Tribal Coordination Webinars	December 17, 2013	Answer questions and solicit input.

Interagency points of contact and subject matter experts were asked in early 2013 to assist in preparing the scope for the NACCS and to be engaged in data gathering and development of analyses as part of the NACCS. Table 1 summarizes the input requested. Interagency subject matter experts were also embedded in various sub-teams (engineering, environmental, coastal storm risk reduction measures, sea level rise, etc.) supporting the study. Interagency subject matter experts were also embedded in various sub-teams (engineering, environmental, NNBF, sea level rise, etc.) supporting the study.

An Interagency Collaboration Webinar Series was developed in response to agency requests to be part of the development of the NACCS, to provide stakeholders an overview of how a particular topic was being considered within the context of the study, and to solicit early feedback and additional information to refine the analyses. Table 2 lists the webinars by topic. Following the webinar presentations, an extensive question and answer period was used to share information and allow for discussion among participants. All webinar materials were posted on the NACCS Web site:
www.nad.usace.army.mil/CompStudy
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Webinar Topic	Date	Purpose
Natural and Nature-Based Features	July 30, 2013	Provide an overview of how green/nature-based infrastructure is being applied to the NACCS and obtain relevant input or data from interagency partners.
Ecosystem Goods and Services	August 29, 2013	Introduce a framework for the evaluation of ecosystem goods and services produced from NNBF risk reduction measures.
Numerical Modeling and Sea Level Rise	September 12, 2013	Provide information on the NACCS effort for Numerical Engineering Modeling of Future Scenarios, which will compute the joint probability of Hurricane Sandy and historical coastal storm forcing parameters from Maine to Virginia.
Vulnerability Assessments	September 25, 2013	Provide information on the NACCS effort related to the development of coastal vulnerability metrics, coastal flooding exposure assessment, and problems, needs, and opportunities identification.
Institutional Barriers and Policy Challenges	December 2013	Provide preliminary results of policy challenges to comprehensive coastal storm risk management, including the use of NNBF, identified through personal interviews and literature reviews.
Comprehensive Validation of Draft NACCS Analyses	March 2014	Describe the compilation of analyses based on all prior coordination and NACCS development, and solicit validation of data use, data gaps, etc. Two overview webinars and three webinars focusing on specific topics associated with the NACCS will be offered..
Adaptive Management	March 2013	Discuss the importance of adaptive management as it relates to future implementation of projects.

Tribes represent an important stakeholder group and are included in many of the coordination efforts. In addition to the engagements and forums described above, USACE tribal liaisons contacted tribal groups. Liaisons regularly communicated with the tribal entities, and used webinars, to ensure they were fully aware of and integrated into the study efforts. USACE representatives attended the United South and Eastern Tribes (USET) Meeting in October 2013 and plan to attend To Bridge a Gap in spring 2014.

The NACCS includes various media engagements, including interviews with The Weather Channel, Newsday, and PBS Nova, to name a few. A complete listing of media, political, local, and regional engagements can be found in the Agency Coordination/Collaboration Supporting Documentation Appendix (Appendix W). These engagements and panel sessions provided another opportunity to share information about the NACCS, expose stakeholders to the Web site, and provide input to the Study. Additional in-person working meetings were held to assess the State of the science and determine future needs and best approaches to be used in the NACCS.

3.2 Hurricane Sandy Performance Evaluation Study

The Hurricane Sandy Performance Evaluation Study (US Army Corps of Engineers 2013a), an accelerated portion of the Comprehensive Study which has already been submitted to Congress, identified several recommendations to improve project performance, including:

• Delivery of more comprehensive protection to affected coastal areas requires a broader approach to the investigation and planning of flood and coastal storm damage reduction projects that includes consideration of potential flooding of back-bay reaches of barrier islands among other concerns.
• Provision of increased levels of flood risk reduction may increase the cost of projects, so evaluation of such projects will be based on economic benefits, as well as other factors such as reduced risk of mortality and capacity for a resilient recovery.
• The data for evaluating project performance, including measurements of water levels, nearshore waves and currents, coastal winds, and pre- and post-storm topographic and bathymetric surveys, is not available for all projects.
• The complexities associated with securing real estate easements continues to be a challenge with providing a comprehensive system of coastal storm damage risk reduction.
• Permit conditions and environmental construction windows designed to reduce or avoid impacts to endangered or threatened species limit the duration of dredging that can occur with a given year. Furthermore, environmental considerations may increase the level of effort required to identify and select borrow source sites, and may restrict site selection to Federal navigation channels even when borrow areas can be found closer to the project that would have lower borrow material transportation costs.
• Different communities value different aspects of the benefits that coasts provide, and maintaining those benefits may conflict with and challenge the Corps' flood and storm damage reduction mission. Reconciling these differences can be difficult.
• Projects should consider how to address the impacts of back-bay flooding of barrier islands to provide more comprehensive protection or identify the residual risks to ensure public and agency awareness.
• The efficacy of natural and engineered dunes in reducing risks of coastal storm damages should be evaluated. Some projects with high storm berms or those backed by significant dunes generally performed better than projects involving a berm alone.
• A broader range of project benefits should be considered to more accurately evaluate the impacts of extreme storm and flooding events. These include community resilience and recovery which would be enhanced by explicitly protecting critical infrastructure and basic services.
• The Corps should identify a limited number of strategically located projects at which to collect nearshore wave/current and coastal wind data, in coordination with other Federal, state and local agencies and partners; it should also conduct regular surveys of those projects (such as before storm season and after significant storms).
• Projects need to include an adaptive management plan or strategy for changing the design within the authorization to respond to external factors, such as changes in local weather patterns or sediment transport, shifts in development trends or public tolerance for storm risks, or changes in coastal flood risks due to climate change. In addition, coastal flood risk analysis technologies are improving at a remarkable rate. Both external factors and changing risk analysis and modeling can lead to changes in project planning, design and nourishment/ maintenance. There should be a streamlined institutional mechanism that allows changes in project dimensions during the life of the project. Design Standards should allow for flexible use of renourishment material, perhaps based on a volume-of- fill standard, which would allow for adaptive management of the beachfill design features over time to reflect changes in coastal forcing events.
• Use of regional sediment management practices could supplement coastal protection and regional planning with various Federal and non-Federal agencies and stakeholders could be conducted to identify and analyze sand resources.

3.3 The Coastal Storm Risk Management Framework

The goals of the Comprehensive Study are to (1) provide risk reduction strategies to subjected vulnerable coastal populations, and (2) promote coastal resilient communities to ensure a sustainable and robust coastal landscape system, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable population, property, ecosystems, and infrastructure. The Comprehensive Study will include

a coastal framework as well as storm suite modeling, coastal GIS analysis, and related evaluations, for the affected coastlines. The study will identify existing green/nature-based infrastructure, include an evaluation of the performance of green/nature-based infrastructure during Hurricane Sandy and other recent storms, and consider the performance of green/nature-based infrastructure in reducing the impacts of coastal storm flooding, as well as other impacts at a larger scale and as a system.

The Comprehensive Study is being developed by a USACE enterprise team. This team will be led by the USACE Coastal Storm Damage Reduction Planning Center of Expertise and will comprise planners and engineers from North Atlantic Division districts, the USACE Engineer Research and Development Center, and the USACE Institute for Water Resources, incorporating other USACE resources and expertise as appropriate.

3.4 Evaluation of Sea Level Change and Extreme Water Levels

Rising sea levels and climate change are expected to have a profound effect on the coastal region 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. Relative sea level rise will not only inundate larger coastal areas, but will also be a driver of change 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 relative sea level rise. 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. Additional services provided by coastal habitats would also be affected.

The NACCS addresses sea level change in accordance with the recently-updated guidance document USACE Engineer Circular (EC) 1165-2-212, *Sea-Level Change Considerations for Civil Works Programs* (USACE 2011). The USACE Sea Level Change EC 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* due to local/regional land uplift. In the case of the NACCS, relative sea levels are rising throughout the entire study area. The USACE EC specifies a method for developing relative sea level change (RSLC) scenarios to be used in developing the range of plausible future conditions in the planning process. In addition, NOAA recently recommended its own set of sea level change scenarios in a report entitled *Global Sea Level Rise Scenarios for the US National Climate Assessment* (NOAA 2012). The NACCS considers scenarios from both documents. The USACE EC also specifies a risk-based framework for evaluation of RSLC impacts to projects in the presence of other forces (in this case erosion, storm surge, riverine flooding events, etc.).

The Engineering Technical Letter contains specific methods to address RSLC in the context of the USACE Coastal Storm Risk Management and Flood Risk Management missions. These documents are used to guide sea level change considerations within the NACCS. RSLC is also incorporated into the hydrodynamic modeling effort, which is ongoing in parallel to the NACCS risk reduction framework efforts. Recent climate research (IPCC 2007, 2013) predicts continued or accelerated global climate change for the 21st century and possibly beyond, which will cause a continued change in global mean sea level. RSLC scenarios have been developed by USACE (2011) and NOAA (2012) for use in assessing the future impacts of sea level change on the natural environment and human infrastructure. The application of these RSLC scenarios for the NACCS is outlined below. The global sea level rise during the past several thousand years has been due to the inter-glacial warming period that followed the last ice age. This 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).

Local/regional land uplift (rise) and subsidence (fall) can contribute to higher or lower local RSLCs. In some locations, although not within the study area, localland uplift is great enough to offset global mean sea level rise to create a condition of local, relative sea level fall. The overall objective of RSLC estimates is to place long-term sea level changes into a local/regional context that is relevant for determining local impacts from changing sea levels.

The current USACE guidance on development of RSLC (USACE 2011) outlines the development of three scenarios: Low, Intermediate, and High. The Low scenario is an extrapolation of the historical sea level trends based on existing tide gauge station data.The Intermediate and High scenarios correspond to sea level rise scenarios developed by the National Research Council (NRC 1987). All three of these USACE RSLC scenarios are evaluated in the NACCS.

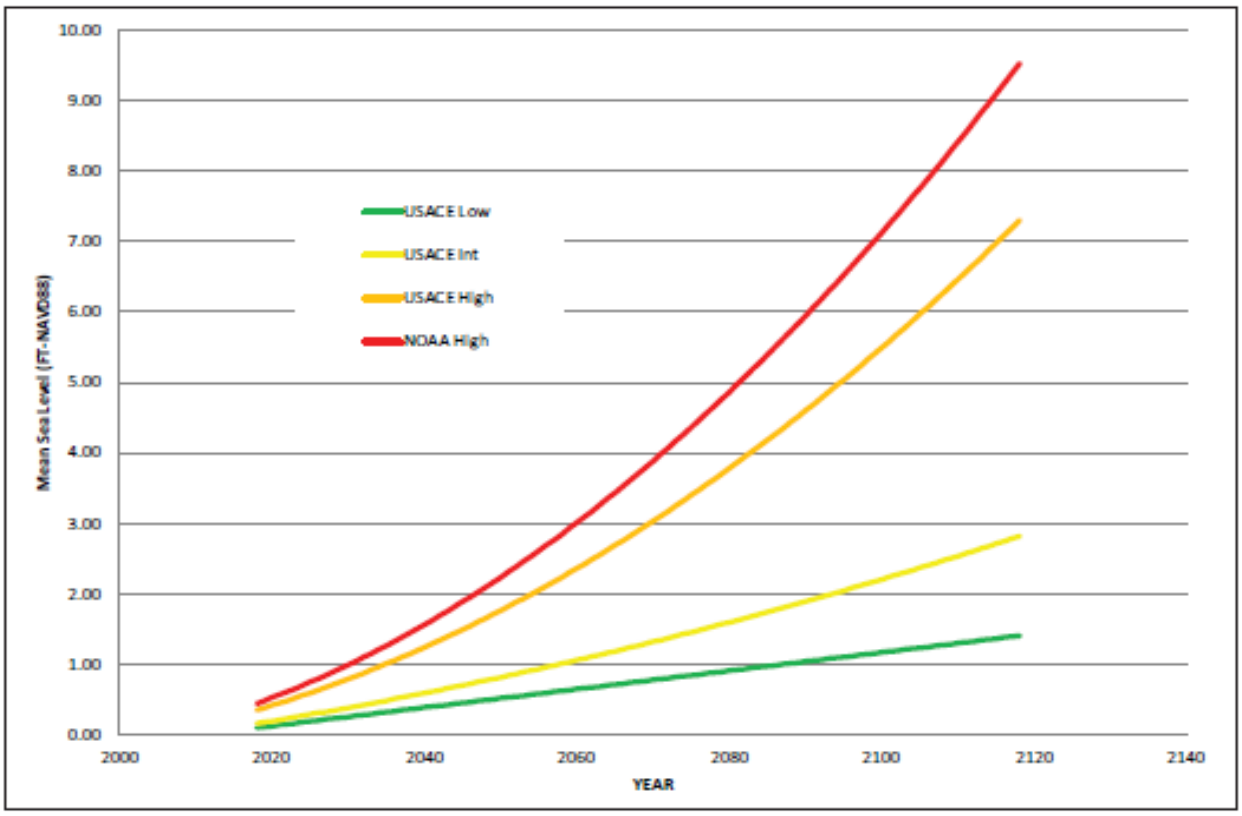

Figure 2: Sea level rise* evaluated for the years 2018, 2068, 2100** and 2118
Relative sea level change for Sandy Hook, NJ for USACE and NOAA scenarios

* SLR evaluated using both USACE's Engineer Circular (EC) 1165-2-212 (low, intermediate high) and NOAA 's highest SLR scenarios

** Intergovernmental Panel on Climate Change (2007) scenario

The Coastal Storm Risk Management Framework includes evaluations of strategies in response to increased risk from coastal storms and sea level rise. Subsequent analyses at a community specific scale should incorporate climate change adaptation planning when considering projected future vulnerabilities and not necessarily existing vulnerabilities. Climate change will impact coastal forces, primarily sea level change. Not only would effects of climate change result in sea level change, or more specifically sea level rise, but also extreme water levels. Furthermore, climate change could result in changes to storm surge and rainfall/runoff. Complex interactions between alluvial and tidally influenced tributaries will change. The combination of extreme water levels and RSLC (some areas of the NACCS study area will likely experience variations in the effects of sea level change due to relative effects of land and tidal processes) will vary across the study area. Furthermore, the coastal landscape responses will vary across the study area because of the myriad of geomorphological and land use characteristics.

Flood frequency, erosion/sedimentation, and environmental responses will depend on site and regional characteristics. Thus, subsequent analyses at a community-specific scale must consider the various components of long-term climate change adaptation and the various strategies and corresponding measures for projected vulnerabilities. This approach will allow communities to consider the appropriate

short-term response to address existing levels of exposure and vulnerability and avoid the need to reinvest in a different solution based on the rate of sea level change over time. Further development of this topic will be included in the final report delivered to Congress.

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