

North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

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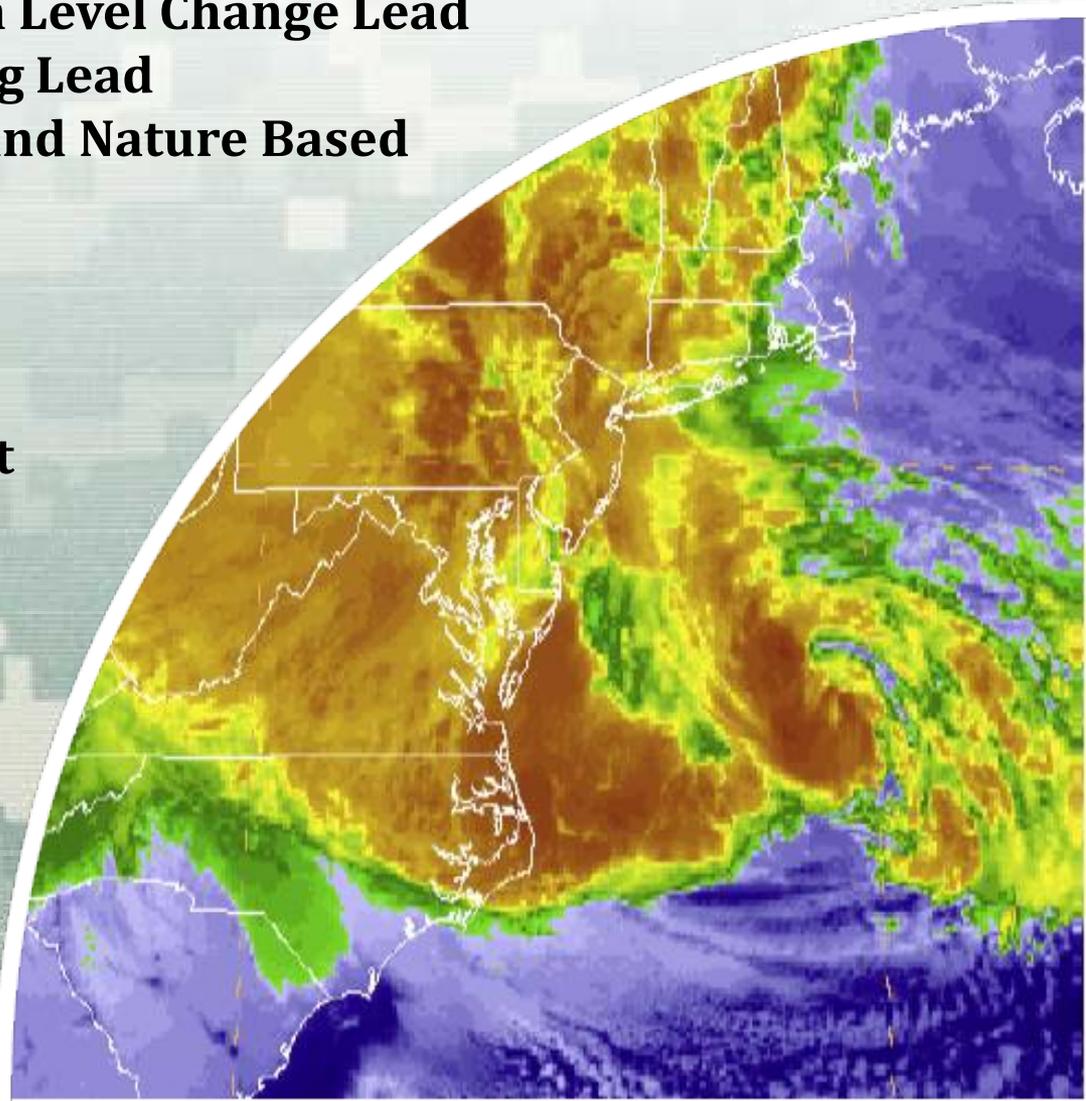
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**National Planning Center for
Coastal Storm Risk Management
U.S. Army Corps of Engineers**

2 February 2015



Outline

- Background
- Interagency Collaboration
- Findings, Outcomes, and Opportunities
- Coastal Storm Risk Management Framework
 - Existing and Future Conditions
 - Flood Exposure and Risk Assessment
 - Risk Management Measures
- Climate Change and Adaptation
- Technical Products Supporting the Framework
- Systems Approach and Resilience
- Institutional and Other Barriers
- Summary



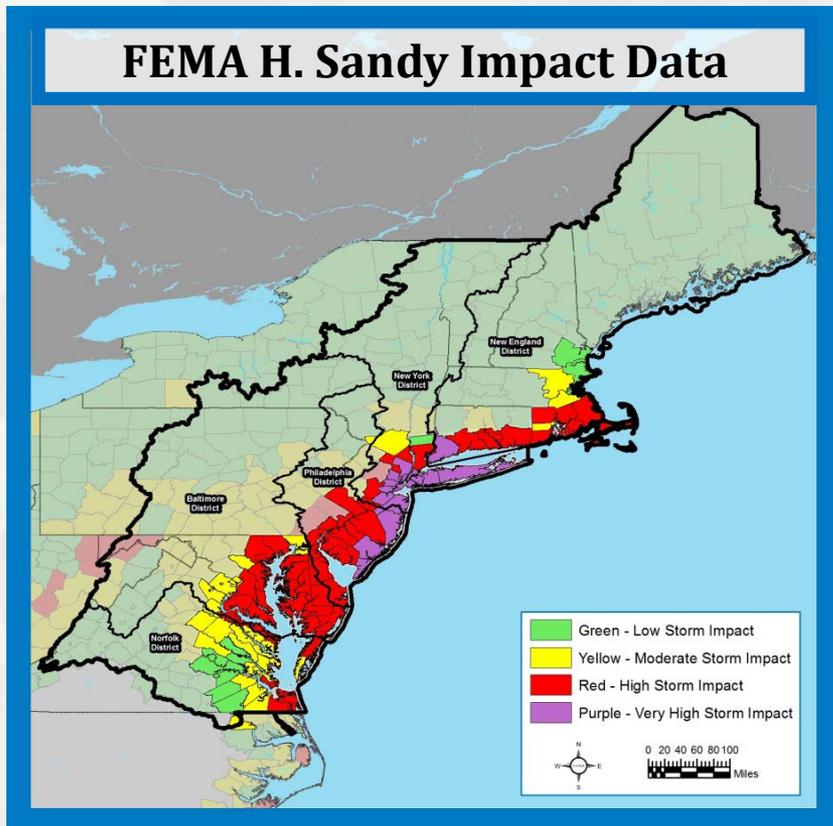
Background

“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...” (*\$19M after sequestration)

Goals

➤ Complete by Jan 2015

- Provide a **Risk Management Framework**, consistent with USACE-NOAA Rebuilding Principles
- Support **Resilient Coastal Communities** and robust, sustainable coastal landscape systems, considering future sea level rise and climate change scenarios, to reduce risk to vulnerable population, property, ecosystems, and infrastructure



Background

➤ End State

- Address the legislative direction for a **comprehensive plan** to address vulnerable coastal communities
- Formalized and **consistent approach/framework** for more detailed, site specific coastal evaluations
- **Integration** of state-of-the-science techniques and collaboration
- Equip and link a broad audience and all levels of government with data, tools, and other stakeholders to make **INFORMED coastal risk management decisions**

www.nad.usace.army.mil/CompStudy

➤ NACCS is *not*:

- A decision document authorizing design and construction
- A NEPA document evaluating impacts of any specific solution
- A USACE-only application



Interagency Collaboration

➤ **Interagency and Tribal Input**

- Formal and informal letters and email
- Technical working meetings
- Tribal webinars and meeting participation
- Panel discussions and meetings upon request
- Subject Matter Experts embedded in team and via outreach
- Federal Register notices
- Public website with subscribe list and opportunity for input on resilience
- OMB Legislative Review Memorandum with Federal Agencies

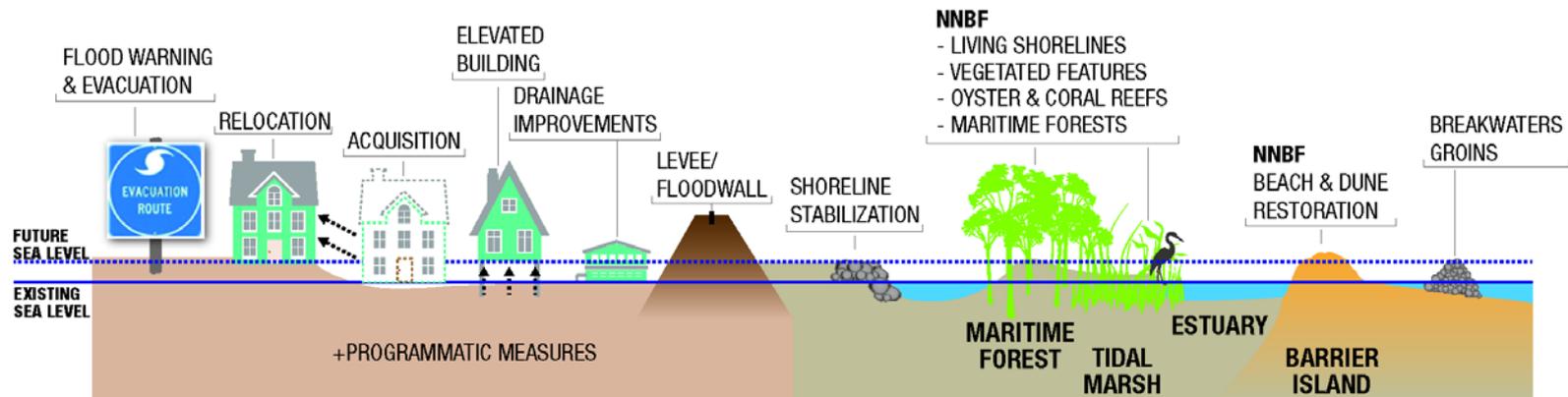
➤ **Interagency Webinar Collaboration Series**

- Webinar 1 (30 July 2013) Green/Nature Based Infrastructure
- Webinar 2 (29 August 2013) Ecosystem Goods and Services
- Webinar 3 (12 September 2013) Numerical Modeling and Sea Level Rise
- Webinar 4 (25 September 2013) Vulnerability Assessments
- Webinar 5 (19 December 2013) Policy Challenges and Other Barriers
- Webinar 6 (24 June 2014) Regional Sediment Management and Systems Approach



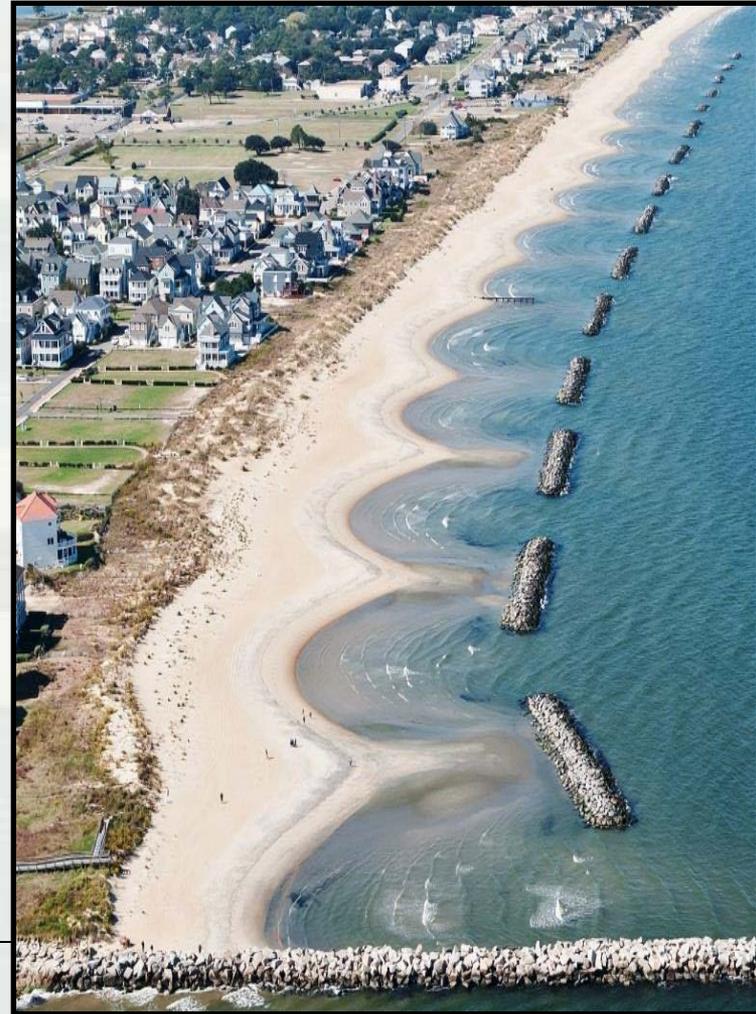
Findings

- **Shared** responsibility of all levels of Government and partnerships
- Rethink approaches to **adapting to risk**
- Resilience and sustainability must consider a **combination and blend** of measures



Outcomes

- **State-by-State Risk Management Frameworks informing, strengthening and catalyzing the focus on regional resilience, redundancy and robustness in coastal planning and implementation**
- **System-wide framework of solutions and best practices**
- **Interagency and Regional alignment with others**
- **Advanced the Science and closed data gaps**



Opportunities

- Mitigate future risk with **improved pre-storm planning**
- Identify acceptable **flood risk at a community** and state scale
- **Prioritize** critical infrastructure
- **Rebuild with redundancy**
- Develop **creative incentives** to promote use of resilience measures
- Utilize a **collaborative regional governance structure**
- Develop **Public-Private Partnerships** for coastal risk management
- Integrate **natural-based features** in coastal risk management systems
- Encourage design **flexibility and adaptive management**
- Advance efforts in the 9 focus areas:

1) Rhode Island Coastline

2) Connecticut Coastline

3) Nassau County Back Bays, NY

4) New York -New Jersey

Harbor and Tributaries

5) New Jersey Back Bays

6) Delaware Inland Bays and

Delaware Bay Coast

7) City of Baltimore, MD

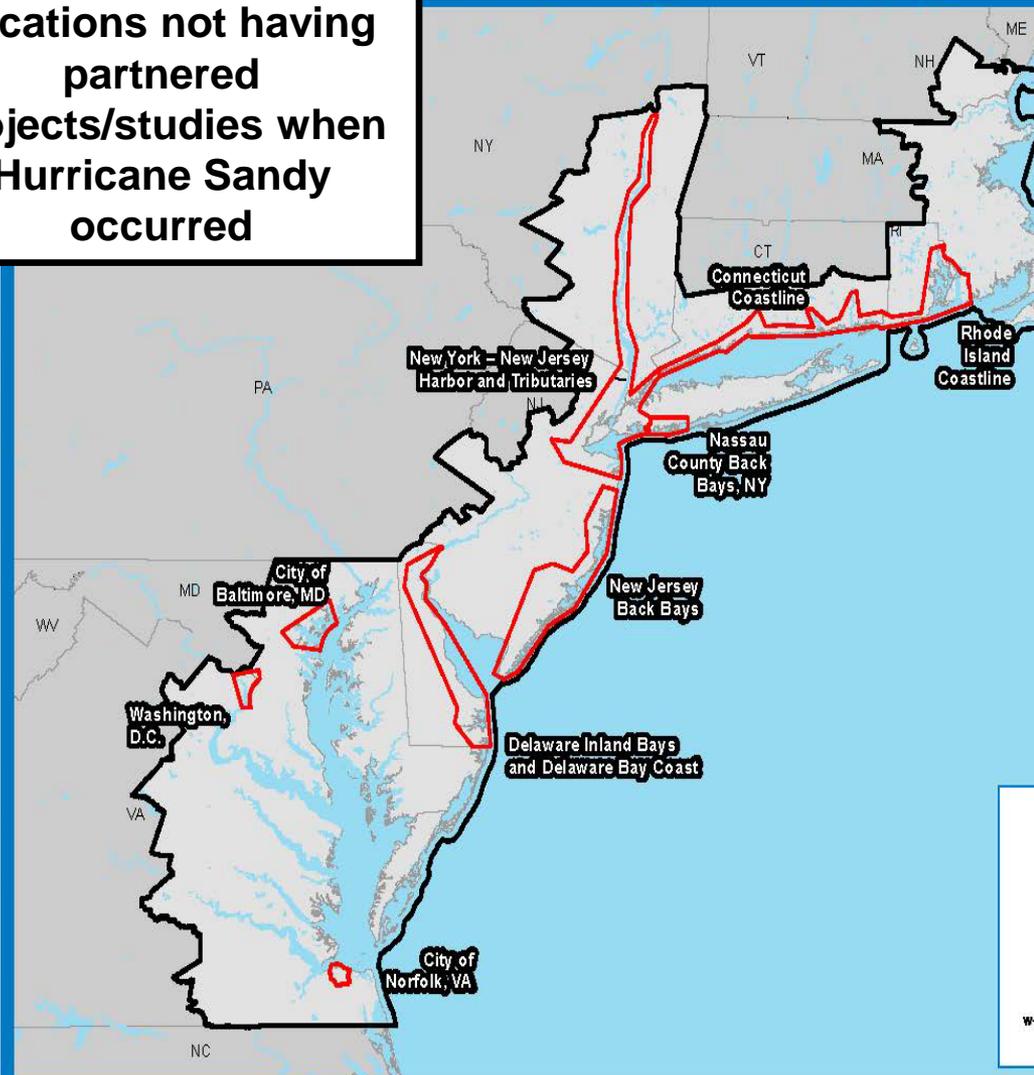
8) Washington, D.C.

9) City of Norfolk, VA



Areas Warranting Additional Analysis

**9 Focus Areas:
Locations not having
partnered
projects/studies when
Hurricane Sandy
occurred**



1. Rhode Island Coastline
2. Connecticut Coastline
3. New York - New Jersey Harbor and Tributaries
4. Nassau County Back Bays, NY
5. New Jersey Back Bays
6. Delaware Inland Bays and Delaware Bay Coast
7. City of Baltimore, MD
8. Washington, D.C.
9. City of Norfolk, VA



Coastal Storm Risk Management Framework

- Who and what is exposed to flood risk?
- Where is the flood risk?
- What are the appropriate strategies and measures to reduce flood risk?
- What is the relative cost of a particular strategy compared to the anticipated risk reduction?
- What data are available to make RISK INFORMED decisions?
- How can the science be advanced/data gaps closed through the NACCS?



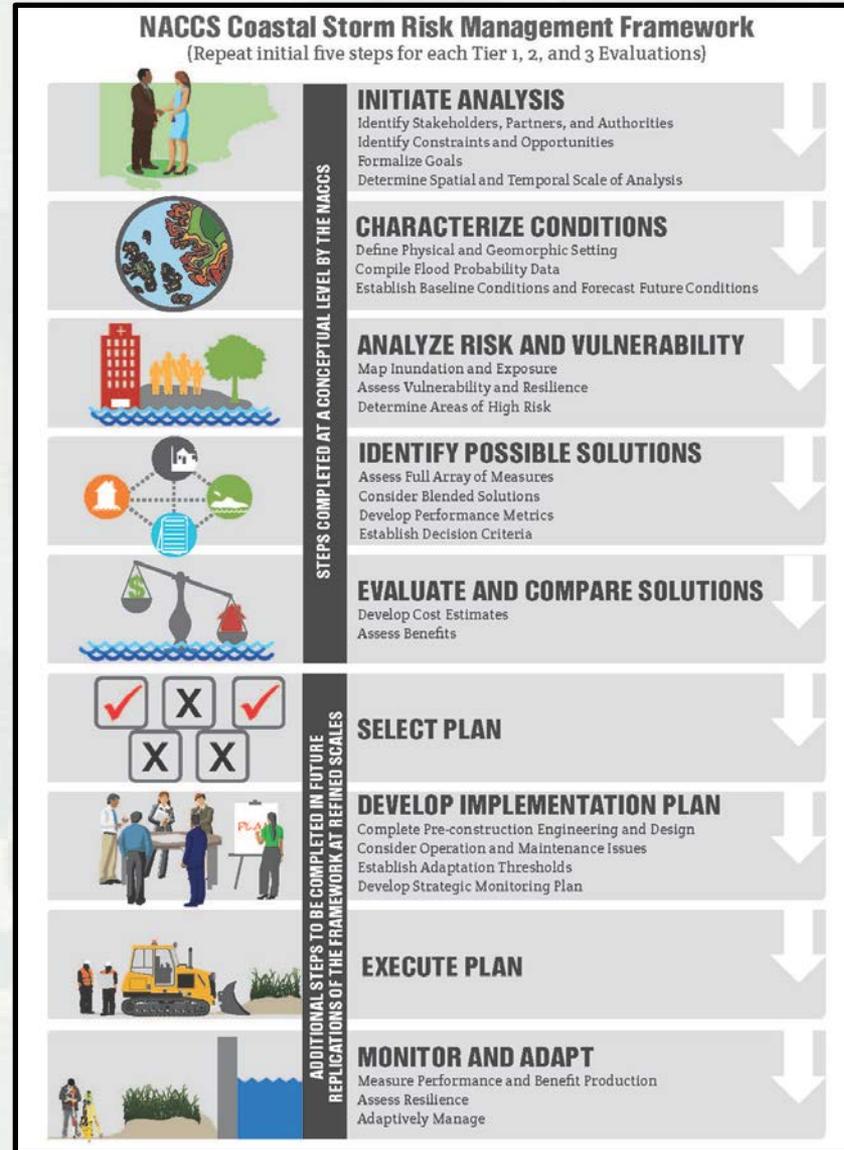
Coastal Storm Risk Management Framework

➤ Managing coastal storm risk is a shared responsibility and requires:

- Shared tools
- Common methodology that all parties can follow together to assess risk and identify solutions

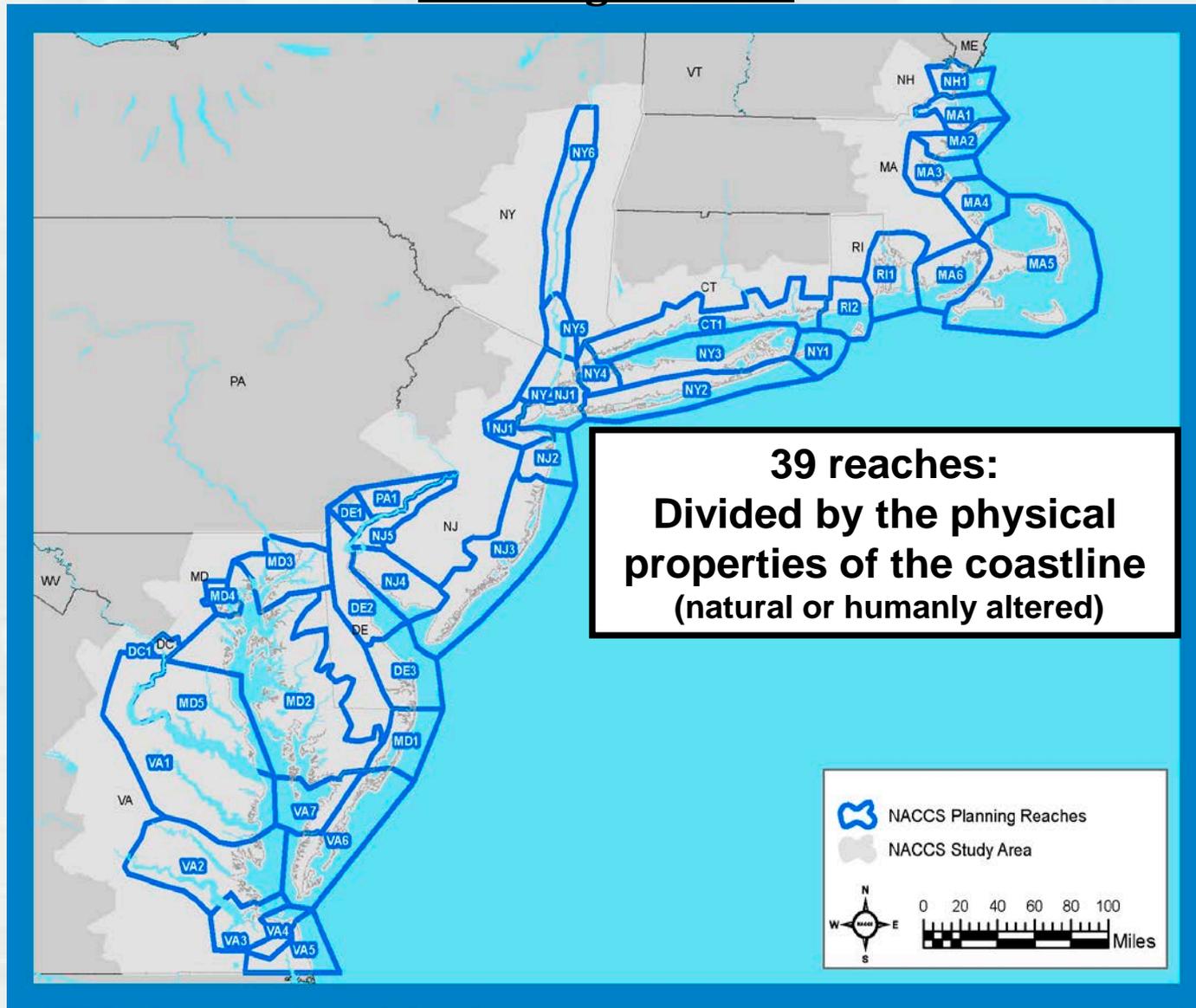
➤ The framework is:

- A 9-step process
- Customizable for any coastal area or watershed
- Repeatable at state and local scales
- Transferable to other areas of the country



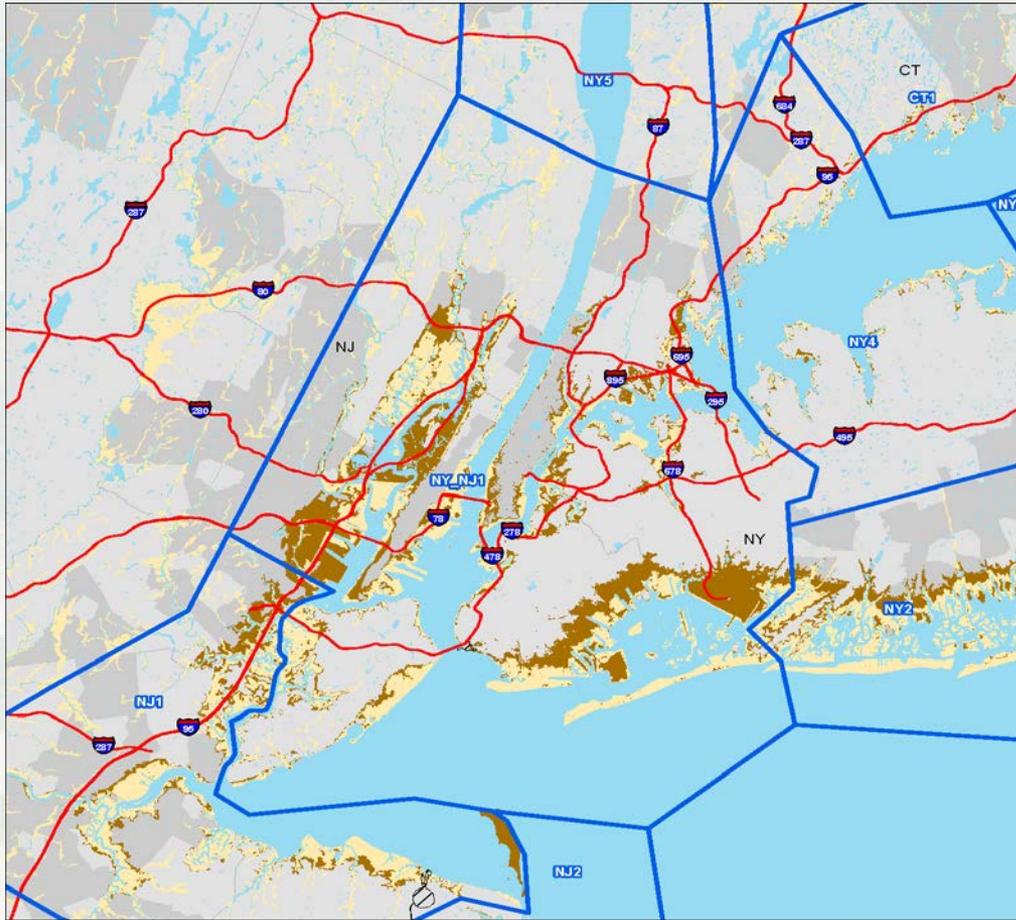
Coastal Storm Risk Management Framework

Planning Reaches



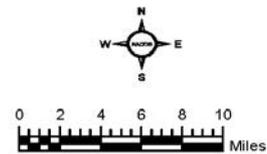
Coastal Storm Risk Management Framework

Existing/Future Conditions: Probability of Flooding



Extent of
Inundation

1- Percent
Annual Floodplain

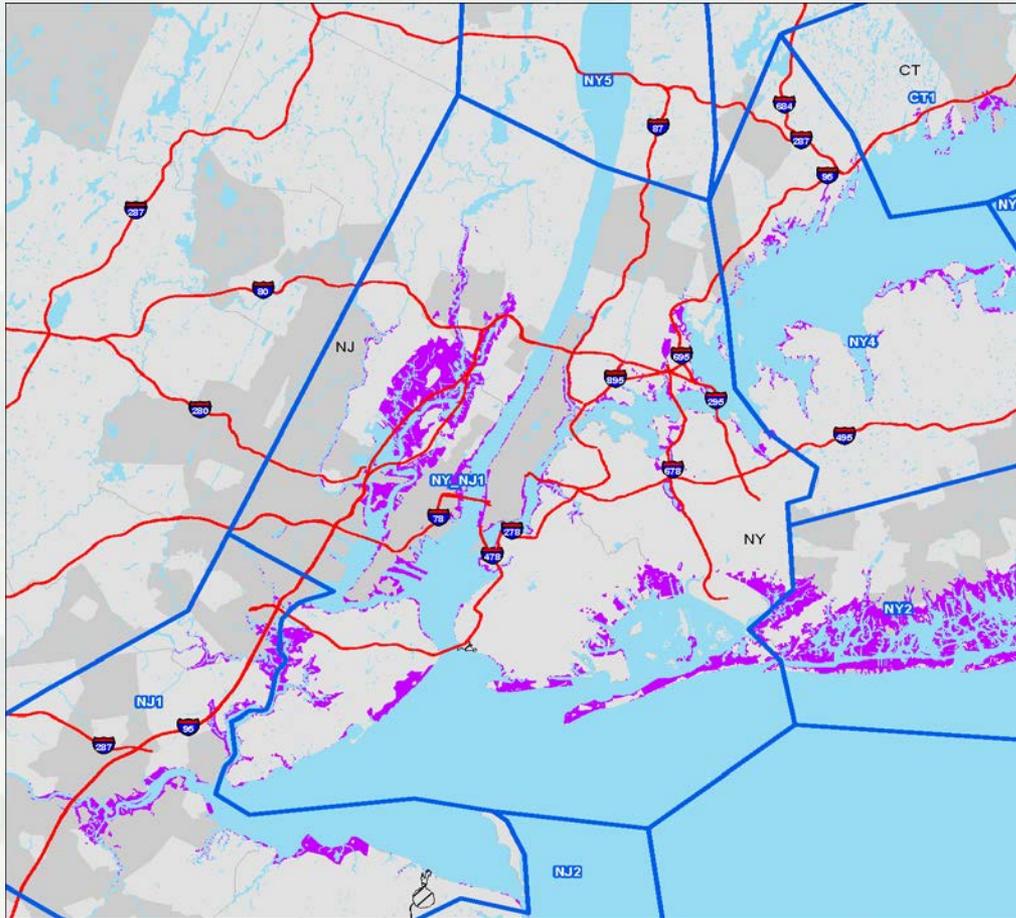


- NACCS Planning Reach
- 1-Percent Annual Chance Floodplain
- 1-Percent Annual Chance Floodplain (+ 3 ft)
- Interstate Highway
- ▨ Military Installation
- Cities



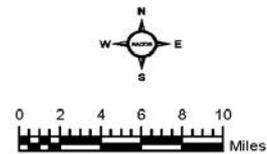
Coastal Storm Risk Management Framework

Existing/Future Conditions: Probability of Flooding



Extent of
Inundation

10-Percent
Annual Floodplain



- NACCS Planning Reach
- 10-Percent Annual Chance Floodplain
- Interstate Highway
- Military Installation
- Cities



Coastal Storm Risk Management Framework

Existing/Future Conditions: Sea Level Rise

➤ Evaluations for:

- Current (2018)
- 50-years (2068)
- 2100 (International Panel on Climate Change)

➤ SLR evaluation:

USACE Engineer Circular 1100-2-8162 (low, intermediate, high scenarios) and NOAA 's highest

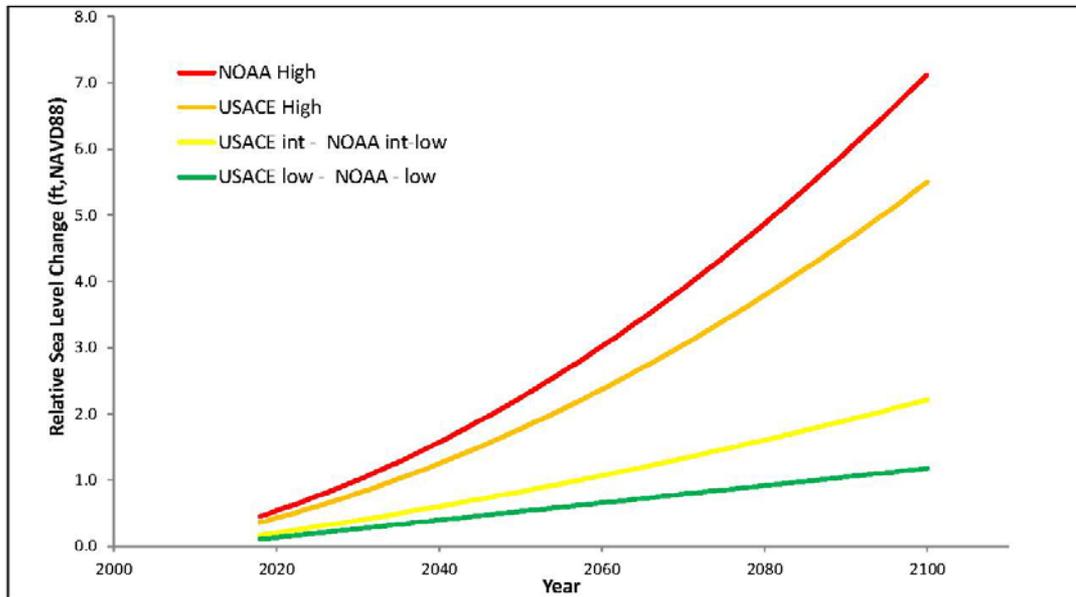


Figure IV-3. Relative Sea Level Change for Sandy Hook, NJ for USACE and NOAA Scenarios



Coastal Storm Risk Management Framework

Existing/Future Conditions: Trends

➤ **Climate and Sea Level Change**

- Sea level is increasing throughout the study area
- Shorelines are changing in response to sea level change
- Historic erosion patterns will continue and accelerate

➤ **Socioeconomic Trends**

- Population is aging (i.e. more difficult to evacuate/relocate during flooding)
- Population is increasing in coastal zone (more people exposed to flooding)
- Importance of operating channels and ports will become more critical to regional and national economy

➤ **Environmental Trends**

- Habitats subject to more stress with population increase, climate change, and other effects

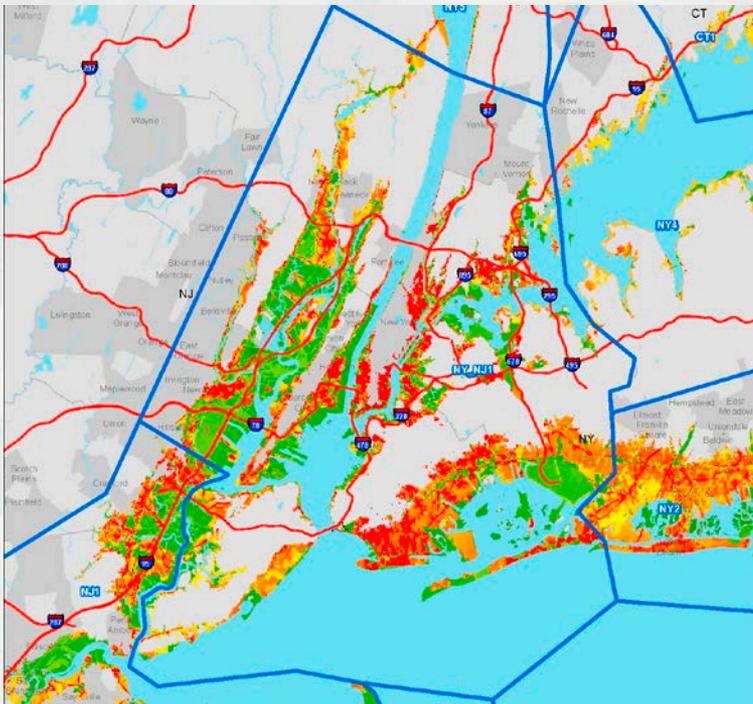


Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

➤ Coastal Flood

- SLOSH CAT1-4 Maximum of Maximum
- FEMA DFIRM
- 10-percent-annual chance
- SLR Inundation (USACE high)



➤ Exposure Indices

- **Population density and infrastructure** (number of people and infrastructure in communities subject to flooding)
- **Socioeconomic groups** (populations that may have more difficulty preparing and responding to flooding)
- **Environmental & Cultural** (critical habitat, wetlands and other areas that maintain resiliency during flooding; key cultural resources subject to flooding)
- **Composite**

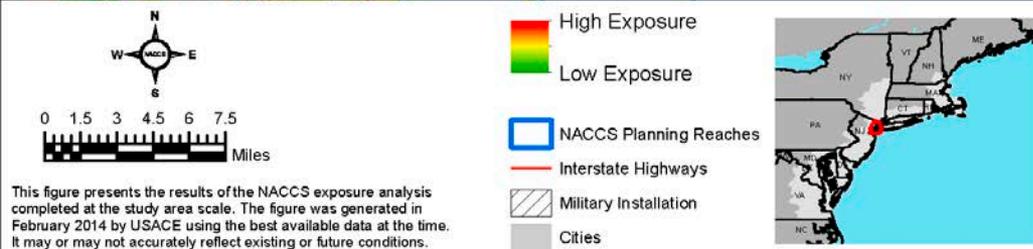
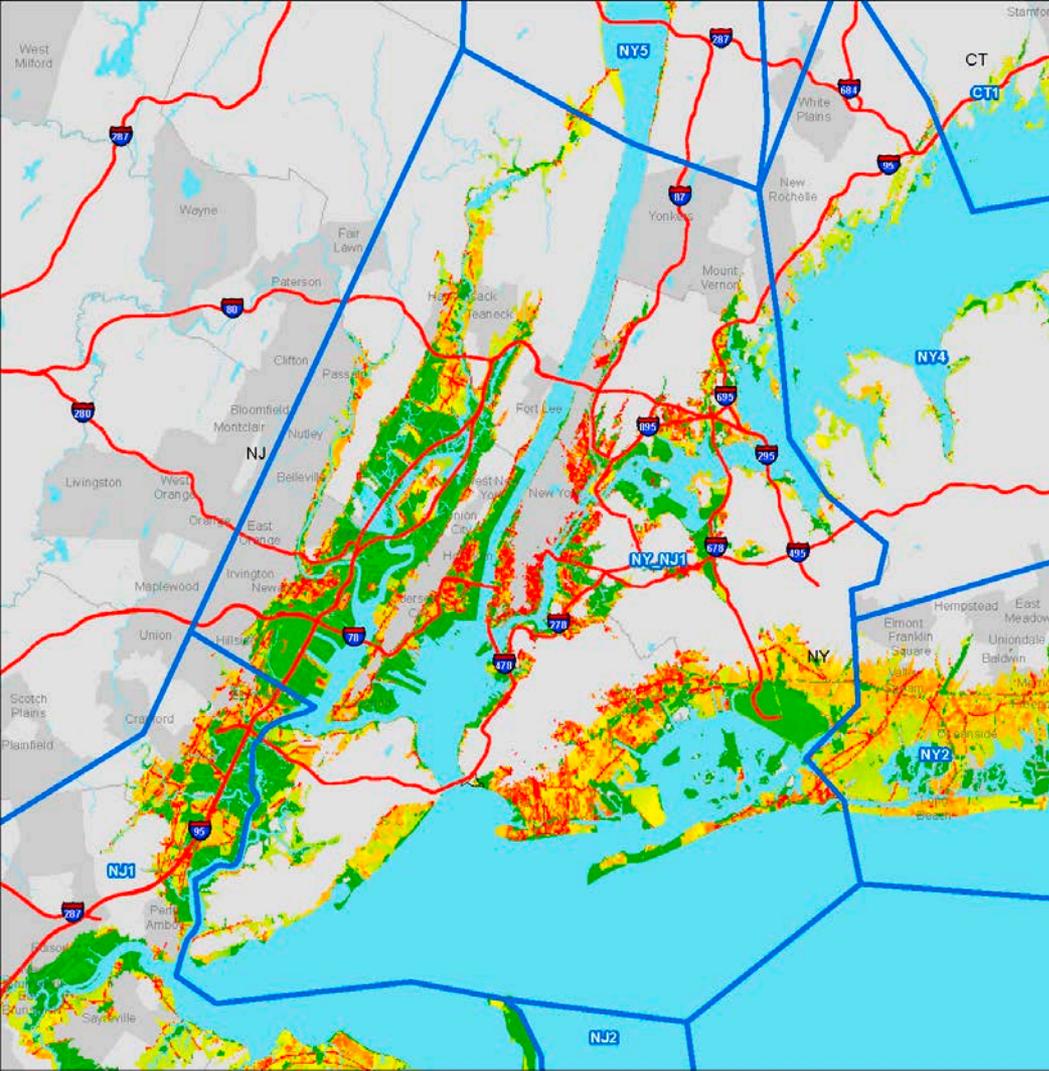
➤ Mapping

- Flood Hazard
- Relative Exposure Index
- Relative Risk Index



Coastal Storm Risk Management Framework Flood Exposure & Risk Assessment

Population and Infrastructure Exposure Index

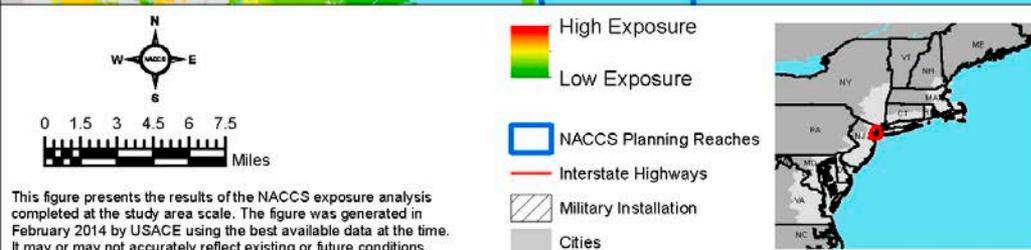
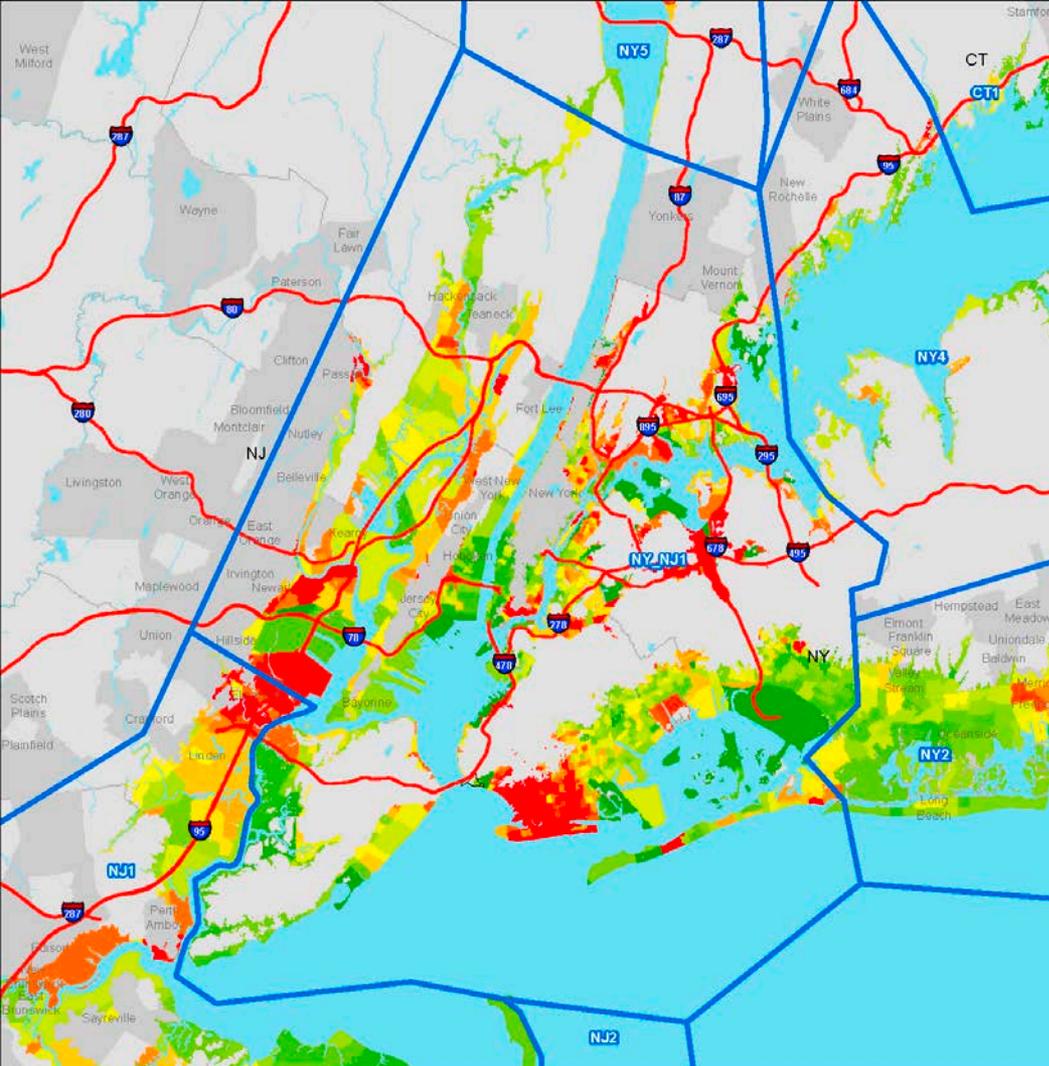


This figure presents the results of the NACCS exposure analysis completed at the study area scale. The figure was generated in February 2014 by USACE using the best available data at the time. It may or may not accurately reflect existing or future conditions.



Coastal Storm Risk Management Framework Flood Exposure & Risk Assessment

Social
Vulnerability
Characterization
Exposure Index

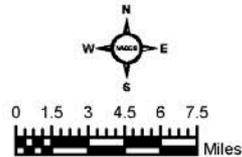
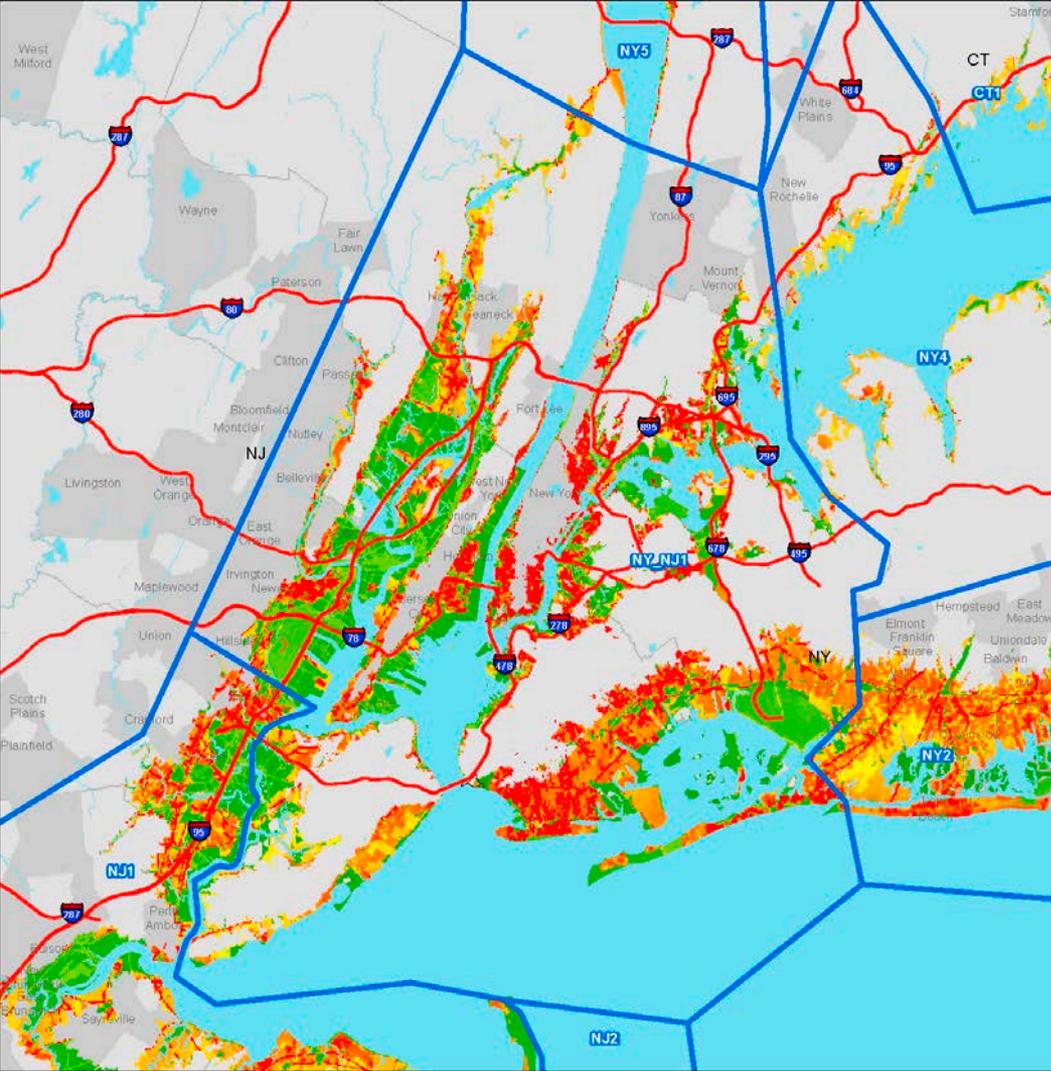


This figure presents the results of the NACCS exposure analysis completed at the study area scale. The figure was generated in February 2014 by USACE using the best available data at the time. It may or may not accurately reflect existing or future conditions.



Coastal Storm Risk Management Framework Flood Exposure & Risk Assessment

Composite Exposure Index



-  High Exposure
-  Low Exposure
-  NACCS Planning Reaches
-  Interstate Highways
-  Military Installation
-  Cities



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



Coastal Storm Risk Management Framework

Flood Exposure and Risk Assessment

- Greater risk based on proximity to flooding source

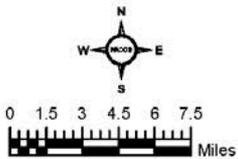
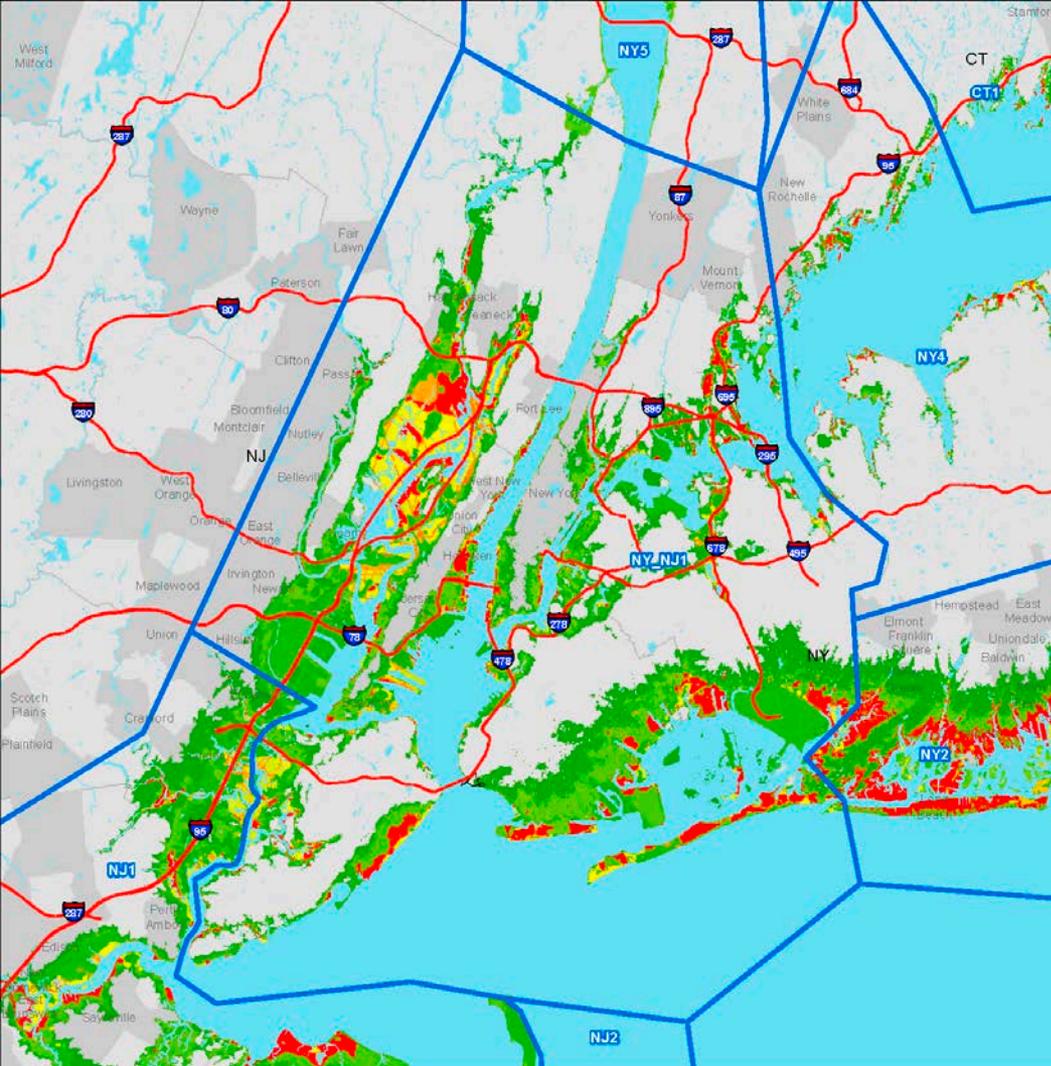
- Exposure
 - Determine probability of flooding
 - Multiply value in each pixel of the composite exposure grid by the probability of flooding

- Additional metrics to be considered at finer scales



Coastal Risk Management Framework

Flood Exposure and Risk Assessment



-  High Risk
-  Low Risk
-  Interstate Highway
-  NACCs Planning Reach
-  Military Installation
-  Cities



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

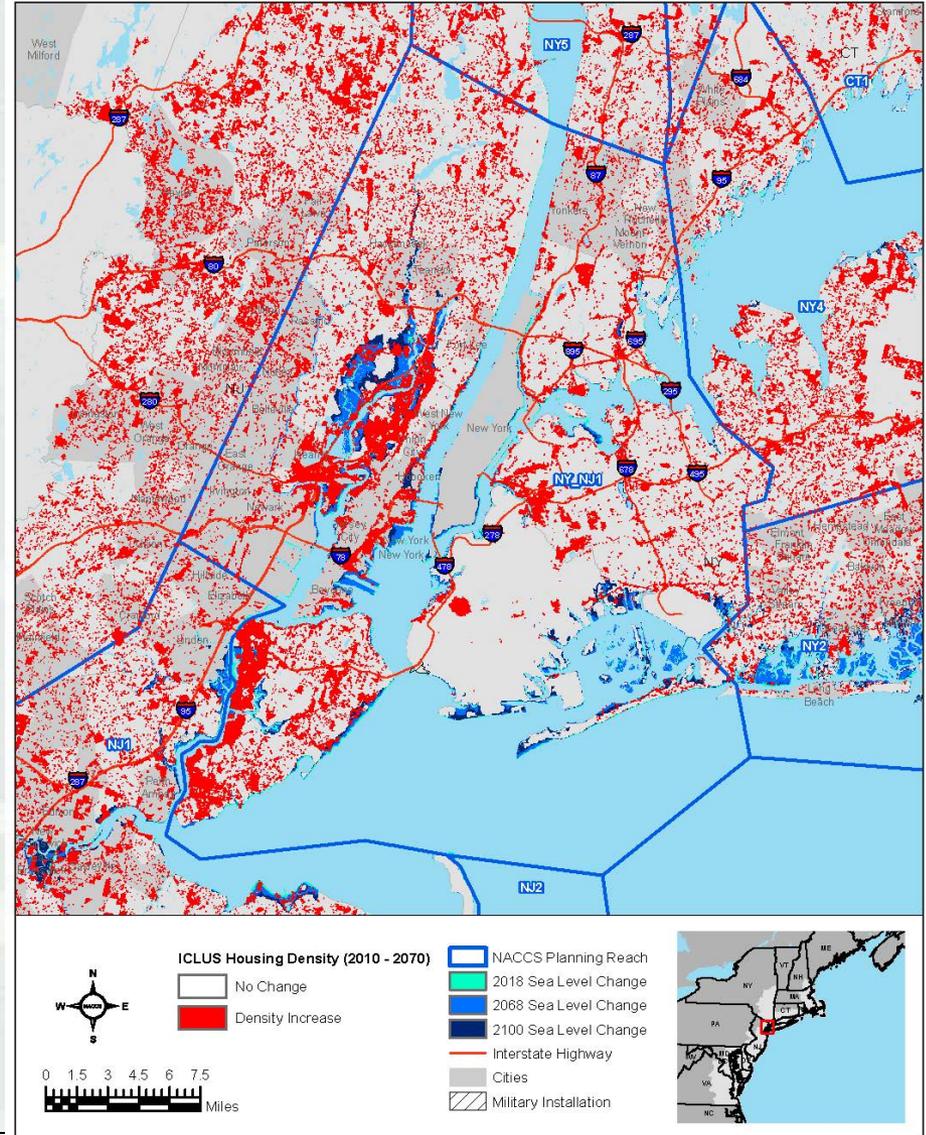


Coastal Storm Risk Management Framework

Flood Exposure and Risk Assessment

Forecasted Population and Sea Level Rise

- Presents percent change in county populations from 2010 to 2070 and 2018, 2068, 2100 SLR conditions
- EPA Integrate Climate and Land Use Scenarios data & B2 storyline
- B2 storyline is conservative:
 - Assumes moderate rates for economic development, fertility and mortality, and migration



Coastal Storm Risk Management Framework:

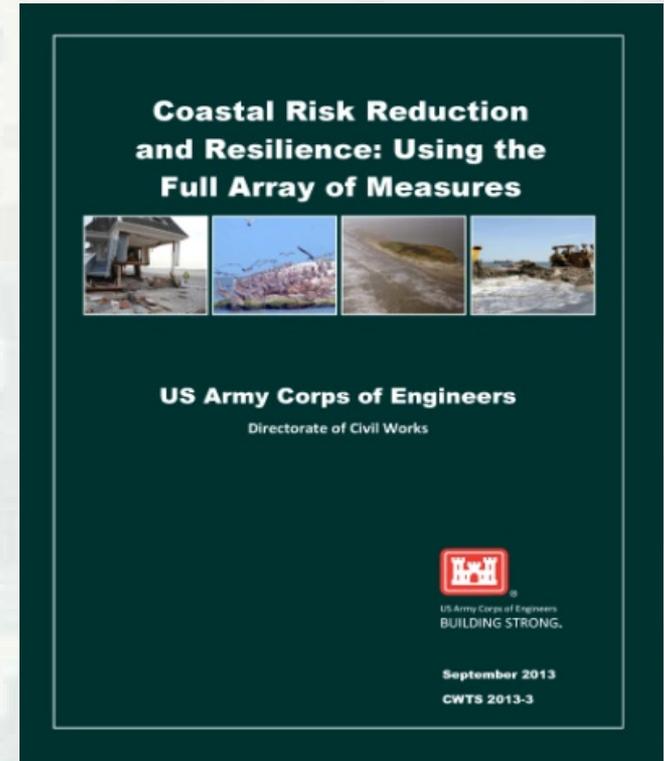
Risk Management Measures

➤ **Structural**

- Storm surge barriers
- Levees, breakwaters, shoreline stabilization
- Natural and Nature-Based Features (e.g., beaches and dunes, living shorelines, wetlands, oyster reefs, SAV restoration)

➤ **Non-Structural** (e.g., floodproofing, acquisition and relocation, flood warning, etc.)

➤ **Programmatic** (e.g., floodplain management, land use planning, State/municipal policy, natural resources, surface water management, education, flood insurance programs, etc.)



Coastal Storm Risk Management Framework:

Risk Management Measures

Tier 1 Analysis

- Initial Screening
- Aggregated Measures
- Evaluated Applicability of Measures given Shoreline Type Classification
- Tiers 2/3 Analysis to be conducted by Stakeholders

Table VIII-2. Structural and NNBF Measure Applicability by NOAA-ESI Shoreline Type

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

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

² Beaches and dunes are also considered NNBF.

³ Submerged aquatic vegetation is not associated with any particular shoreline type. It is initially assumed to apply to wetland shorelines.

⁴ Overwash fans may apply to the back side of barrier islands, which are not explicitly identified in the NOAA Environmental Sensitivity Index Shoreline Classification dataset.



Coastal Storm Risk Management Framework:

Risk Management Measures



Natural and Nature-Based Features

- Natural landscapes or engineered ecosystems, and blended solutions
- Intrinsically dynamic, adaptive, and potentially more resilient than built systems
- Hurricane Sandy Rebuilding Strategy Recommendations 19-22

Closing Data Gaps

- Evaluate performance during Sandy
- Identify storm resilient features
- Provide tools for benefit evaluation
- Integrate NNBF coastal storm risk management benefits as part of coastal risk management systems



Coastal Storm Risk Management Framework:

Risk Management Measures

GENERAL COASTAL RISK REDUCTION PERFORMANCE FACTORS:
 STORM INTENSITY, TRACK, AND FORWARD SPEED; SURROUNDING LOCAL BATHYMETRY AND TOPOGRAPHY



Dunes and Beaches	Vegetated Features	Oyster and Coral Reefs	Barrier Islands	Maritime Forests/Shrub Communities
<p>Benefits/Processes</p> <ul style="list-style-type: none"> Breaking of offshore waves Attenuation of wave energy Slow inland water transfer 	<p>Benefits/Processes</p> <ul style="list-style-type: none"> Breaking of offshore waves Attenuation of wave energy Slow inland water transfer Increased infiltration 	<p>Benefits/Processes</p> <ul style="list-style-type: none"> Breaking of offshore waves Attenuation of wave energy Slow inland water transfer 	<p>Benefits/Processes</p> <ul style="list-style-type: none"> Wave attenuation and/or dissipation Sediment stabilization 	<p>Benefits/Processes</p> <ul style="list-style-type: none"> Wave attenuation and/or dissipation Shoreline erosion stabilization Soil retention
<p>Performance Factors</p> <ul style="list-style-type: none"> Berm height and width Beach slope Sediment grain size and supply Dune height, crest, and width Presence of vegetation 	<p>Performance Factors</p> <ul style="list-style-type: none"> Marsh, wetland, or SAV elevation and continuity Vegetation type and density 	<p>Performance Factors</p> <ul style="list-style-type: none"> Marsh, wetland, or SAV elevation and continuity Vegetation type and density 	<p>Performance Factors</p> <ul style="list-style-type: none"> Marsh, wetland, or SAV elevation and continuity Vegetation type and density 	<p>Performance Factors</p> <ul style="list-style-type: none"> Marsh, wetland, or SAV elevation and continuity Vegetation type and density

Natural and Nature-Based Features



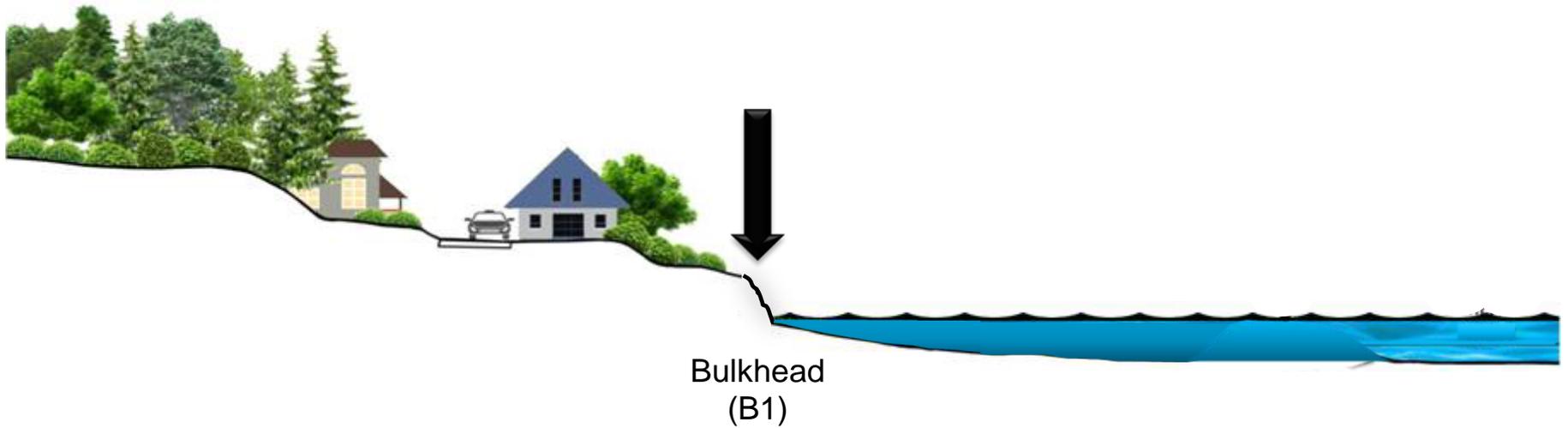
Coastal Storm Risk Management

Framework:

Risk Management Measures

Integration of Measures

	SB1	NBI 1	NBI 2	NBI 3	ALL
S1	✓				
S2	✓				
S3					
S4					
S5					
S6					



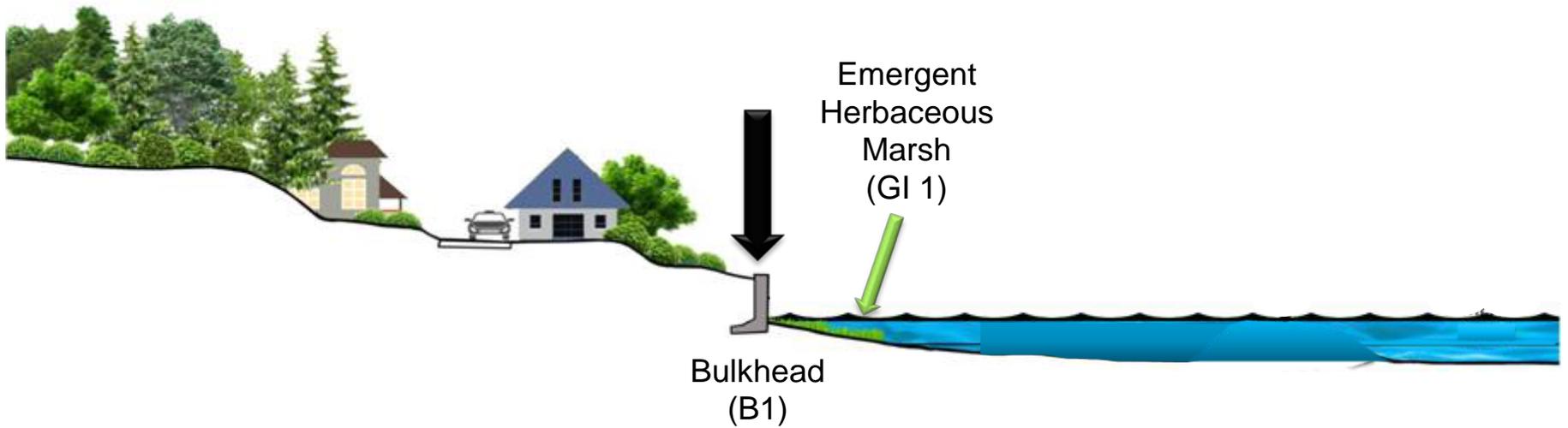
Coastal Storm Risk Management

Framework:

Risk Management Measures

Integration of Measures

	SB1	NBI 1	NBI 2	NBI 3	ALL
S1	✓				
S2	✓				
S3					
S4					
S5		✓			
S6		✓			



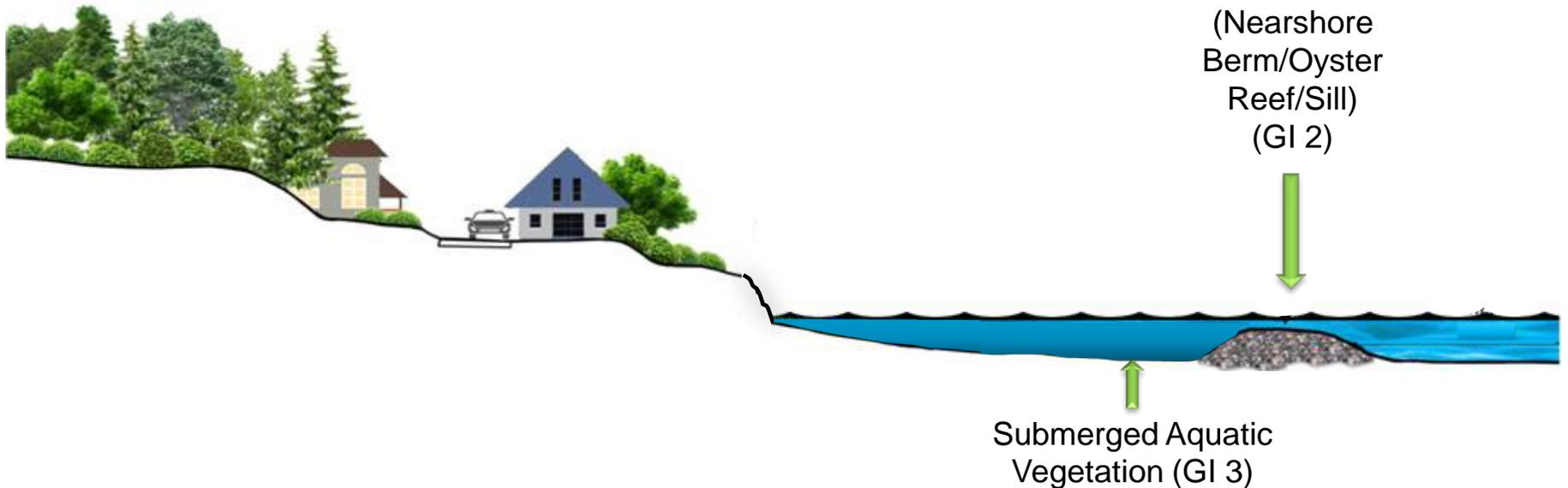
Coastal Storm Risk Management

Framework:

Risk Management Measures

Integration of Measures

	SB1	NBI 1	NBI 2	NBI 3	ALL
S1	✓		✓		
S2	✓		✓	✓	
S3			✓		
S4				✓	
S5		✓	✓		
S6		✓		✓	



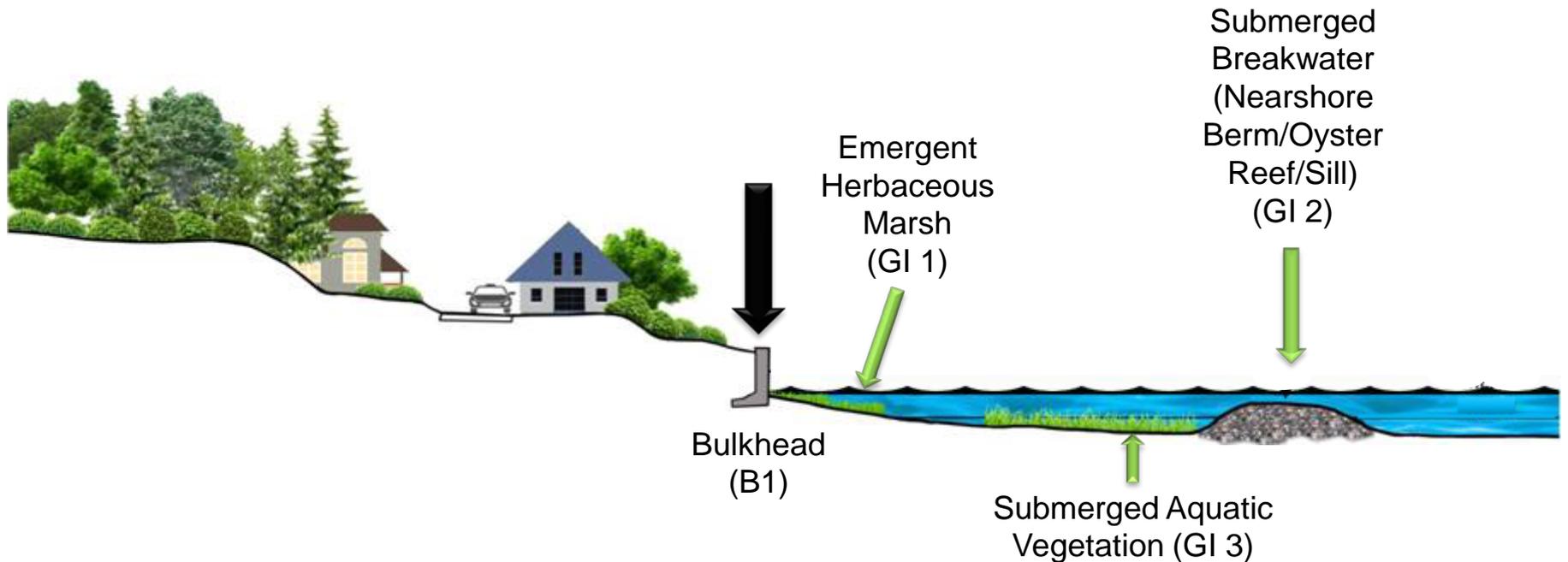
Coastal Storm Risk Management

Framework:

Risk Management Measures

Integration of Measures

	SB1	NBI 1	NBI 2	NBI 3	ALL
S1	✓		✓		✓
S2	✓		✓	✓	✓
S3			✓		✓
S4				✓	✓
S5		✓	✓		✓
S6		✓		✓	✓



Coastal Storm Risk Management Framework:

Risk Management Measures

Natural and Nature-Based Features GIS Mapping

- Conceptual analysis of geographic applicability of NNBF measures
- Data layers and other screening criteria
 - NOAA Environmental Sensitivity Index Shoreline Classification dataset (NOAA, 2002)
 - Habitat type
 - Impervious cover
 - Water quality
 - Topography/bathymetry
- State appendix contains results

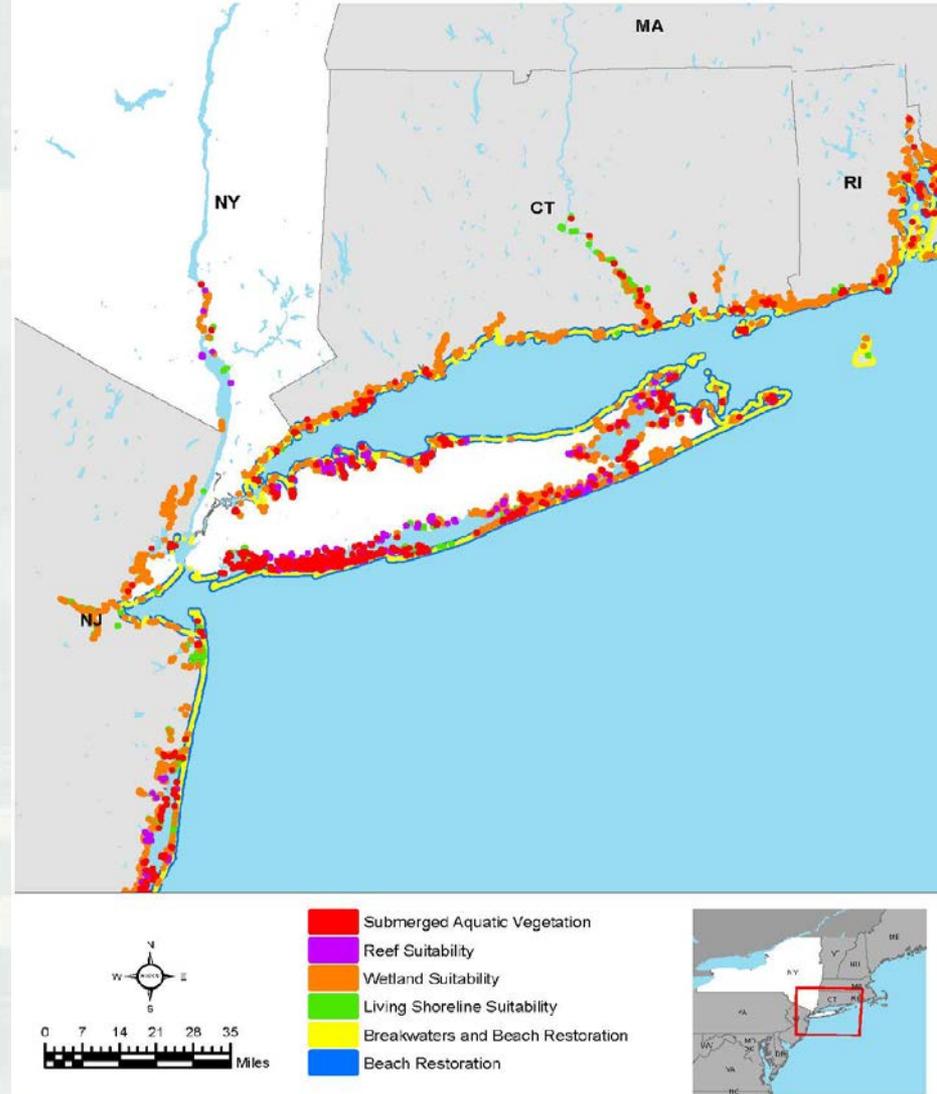


Figure 28. NNB Measures Screening for the State of New York.



Parametric Unit Costs (Tier 1)

➤ 14 Parametric Unit Costs Developed

- Existing observations
- Typical quantities
- E&D, Contingency, S&A, and O&M
- Average annual cost per foot

➤ Generic Design

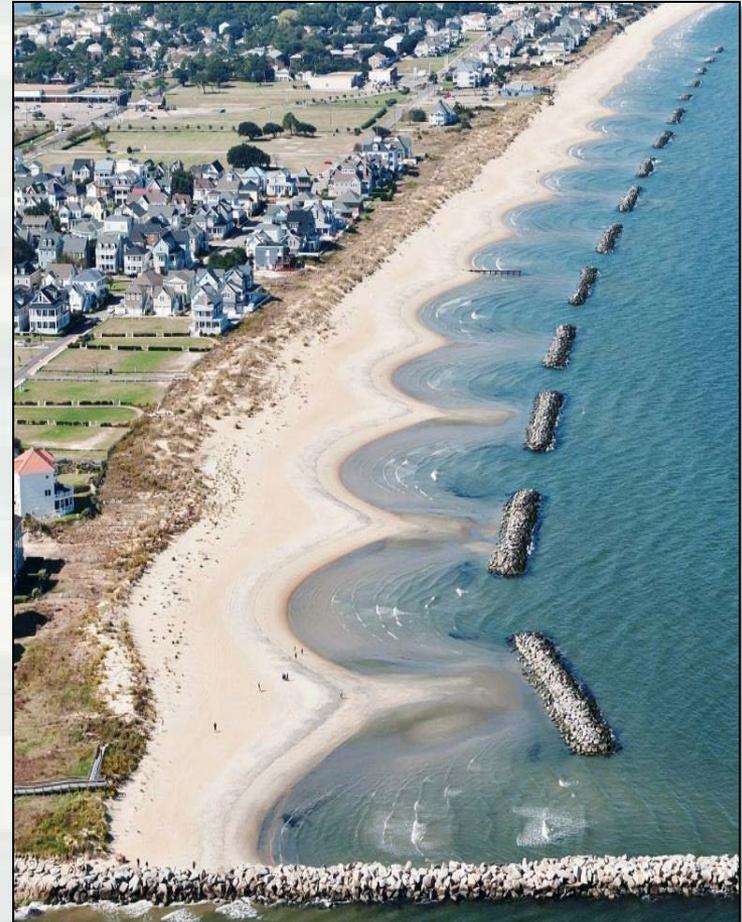
➤ Benefits, Impacts and Other Considerations

➤ Storm Surge Barriers

- First Cost Construction Estimates for 36 potential sites using world-wide observations

➤ Non-Structural

- Elevation
- Ringwalls (Industrial and High Density Residential)



Parametric Unit Costs (Tier 2)

- **Parametric Unit Cost Estimates Developed for Example Areas**
 - Existing observations
 - Typical quantities
 - E&D, contingency, S&A, and O&M
- **Refined Lengths**
- **Heights Based on 100-year +3 ft (equation allows calculation based on other heights)**
- **Cost Index Presentation**



Incorporation of Climate Change into NACCS

- Evaluated USACE and NOAA relative sea level change scenarios at 26 NOAA WL gage locations across NAD/NACCS study area
- Comparisons of NACCS and state and local SLC scenarios
- GIS mapping of relative sea level change in 50 and 100 years with projected future development densities
- Statistical analysis of historical and future extreme water levels with sea level change
- NACCS Flood Risk and SLC
- Climate change adaptation planning concepts



NACCS Relative Sea Level Rise Scenarios

- ❑ USACE (2014) ER 1100-2-8162: *Incorporating Sea-Level Change in Civil Works Programs*
- ❑ NOAA (2012): *Global Sea Level Rise Scenarios for the US National Climate Assessment*
- ❑ Computed for 26 Locations from VA to ME, NOAA long term water level stations

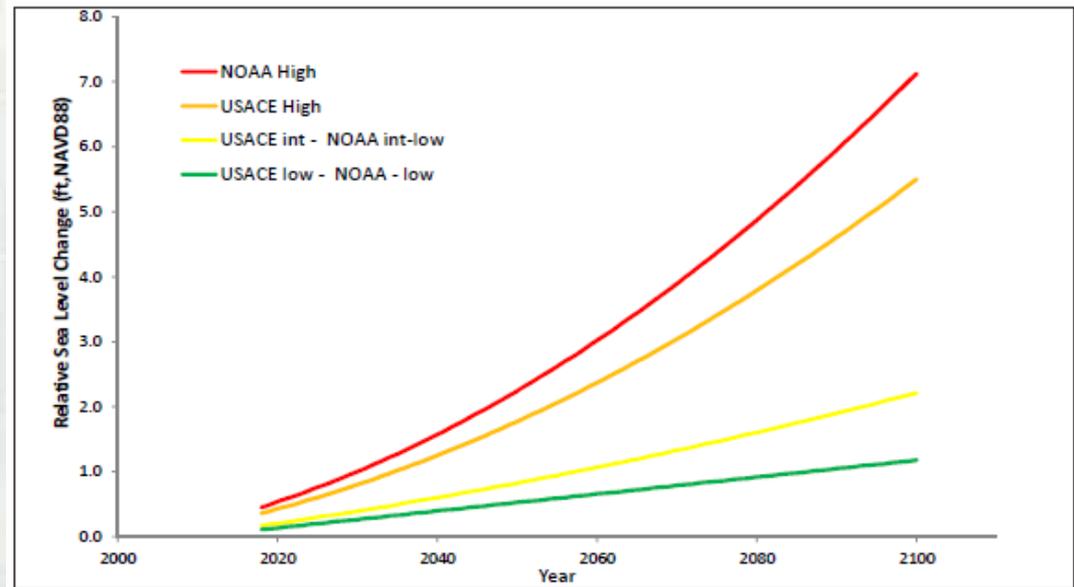


Figure IV-3. Relative Sea Level Change for Sandy Hook, NJ for USACE and NOAA Scenarios

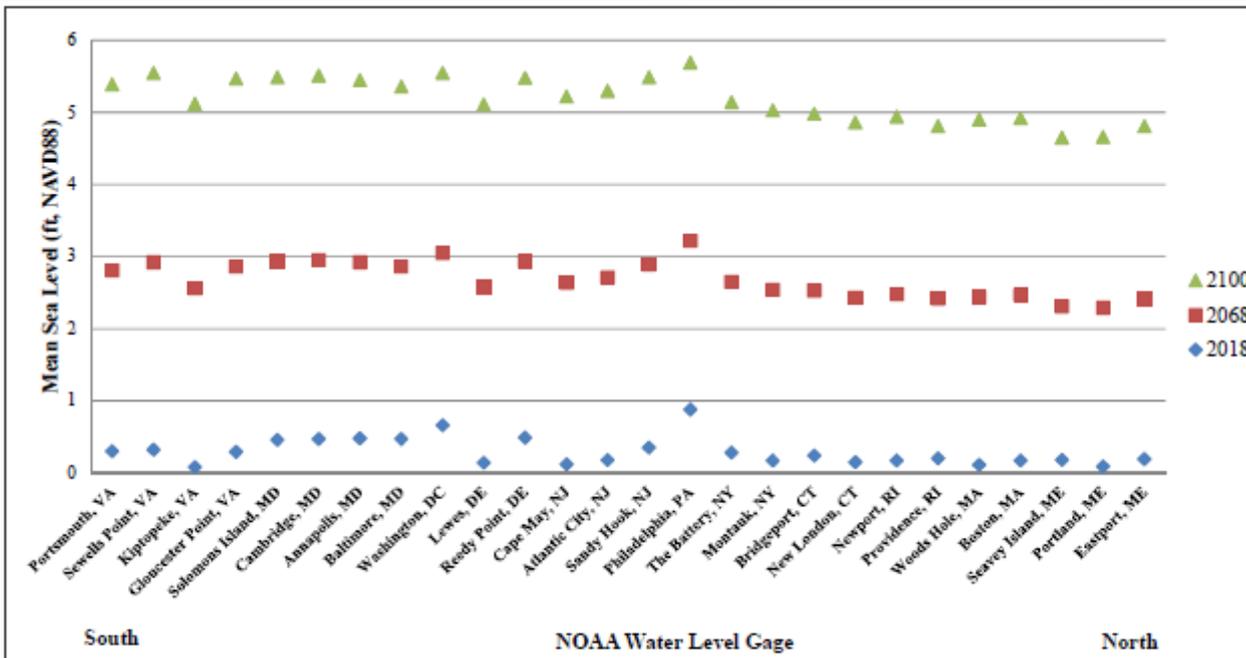
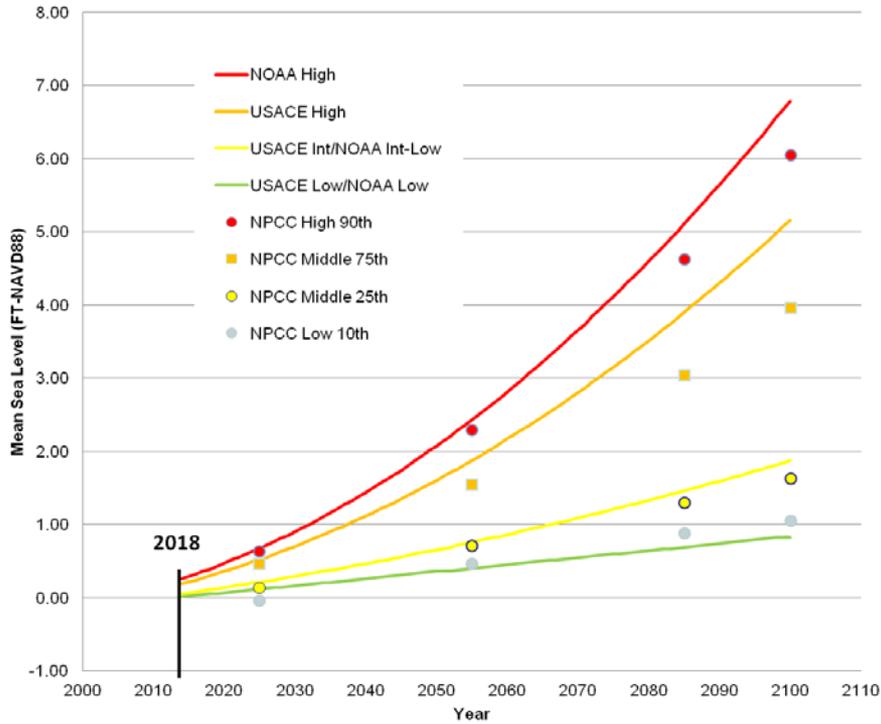


Figure IV-4. USACE High Scenario Mean Sea Levels for NOAA Gage Stations

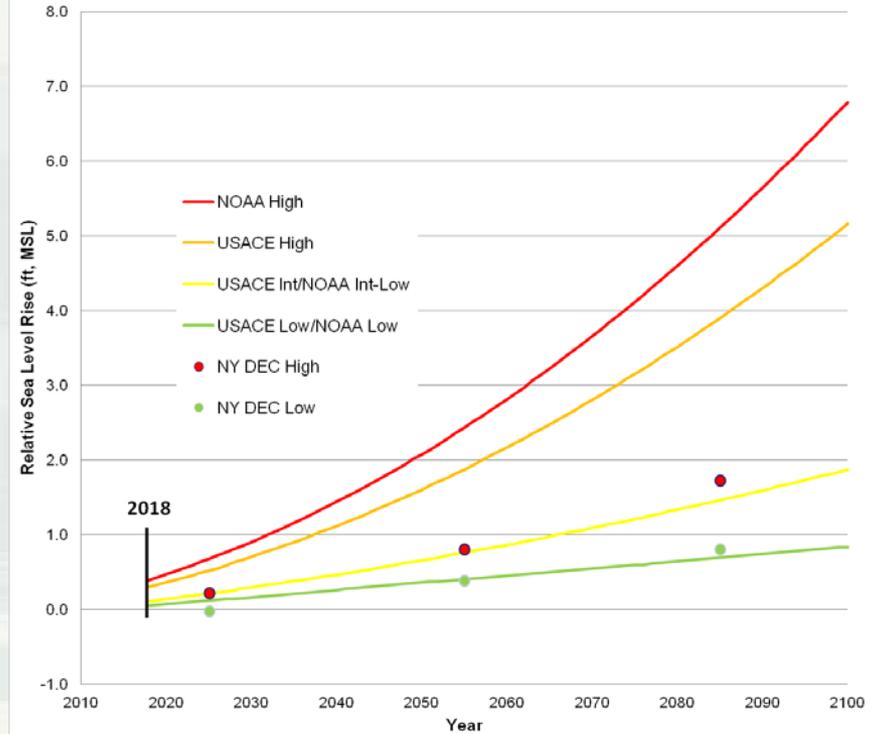


Comparison of NACCS and State SLC Scenarios

New York City, NY Relative Sea Level Rise Scenarios



New York State Relative Sea Level Rise Scenarios



SLC Impacts and Density of Development

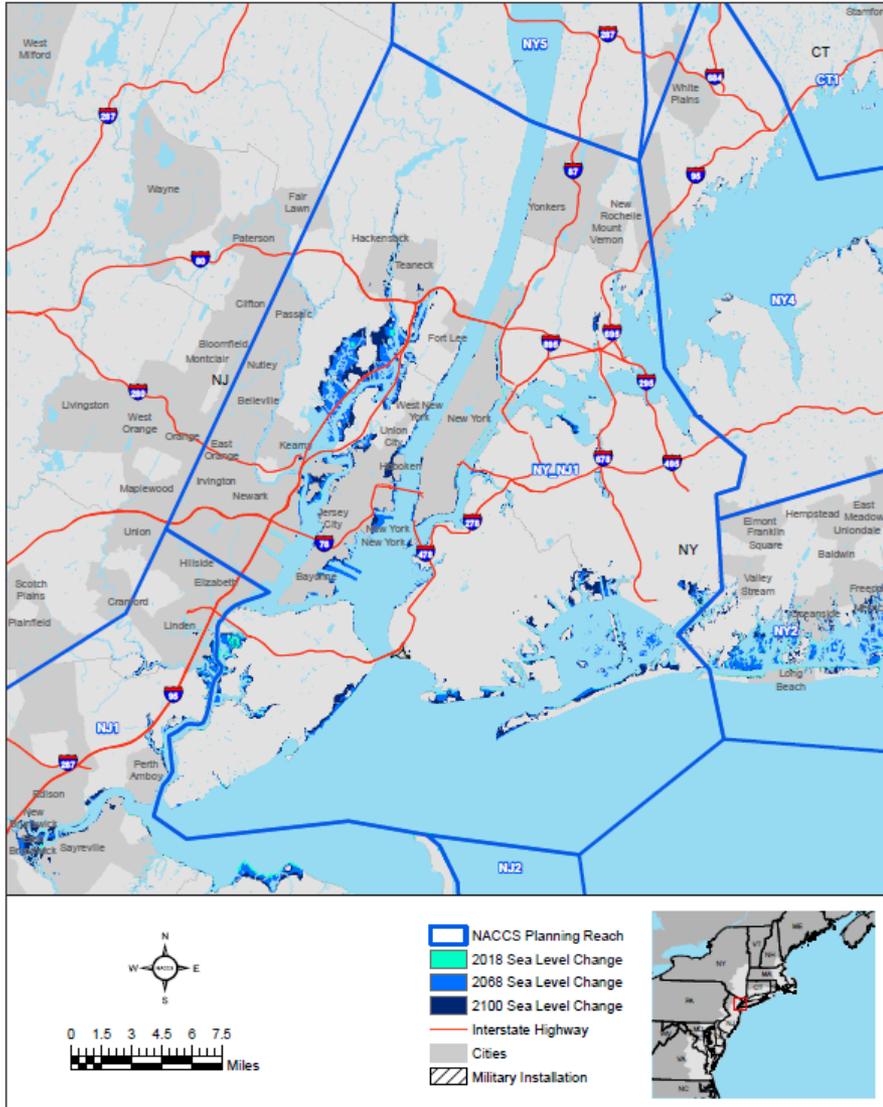
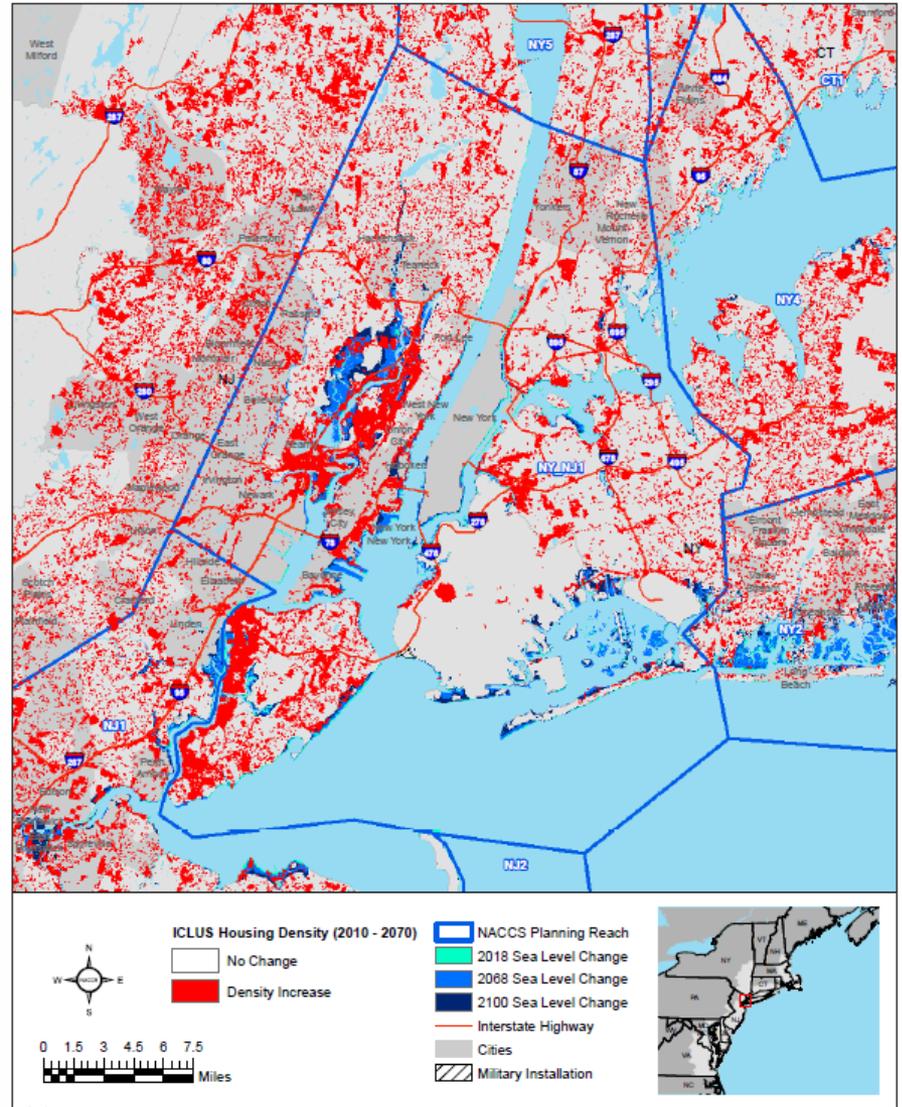


Figure IV-5. USACE High Scenario Future Mean Sea Level Mapping for Reach NY_NJ1



40 Figure IV-6. USACE High Scenario Future Mean Sea Level and Future Development Mapping for Reach NY_NJ1

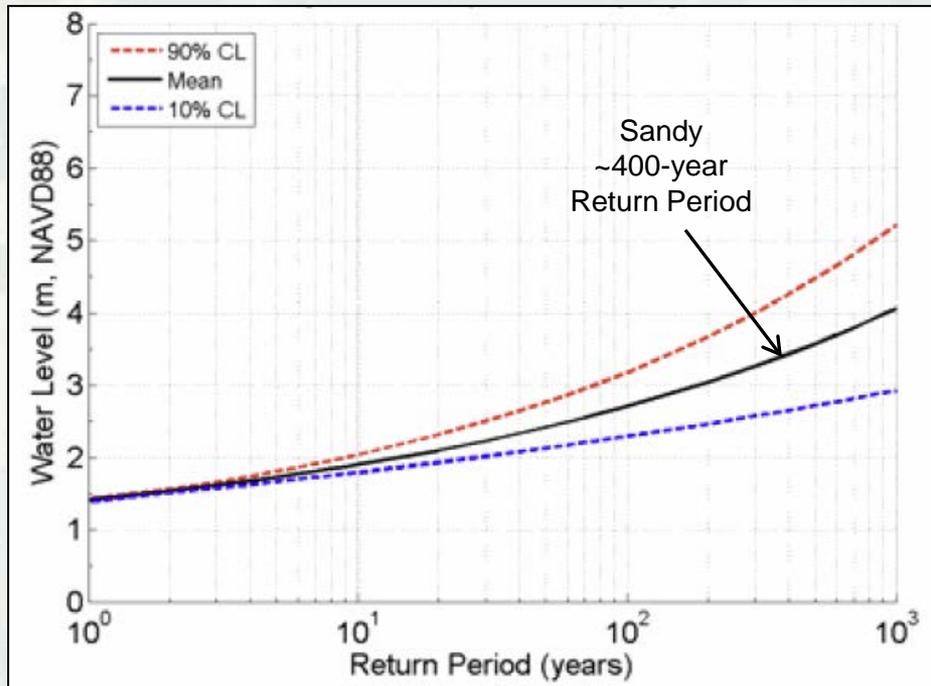
ERDC Extreme Water Levels with SLC

TR-14-7

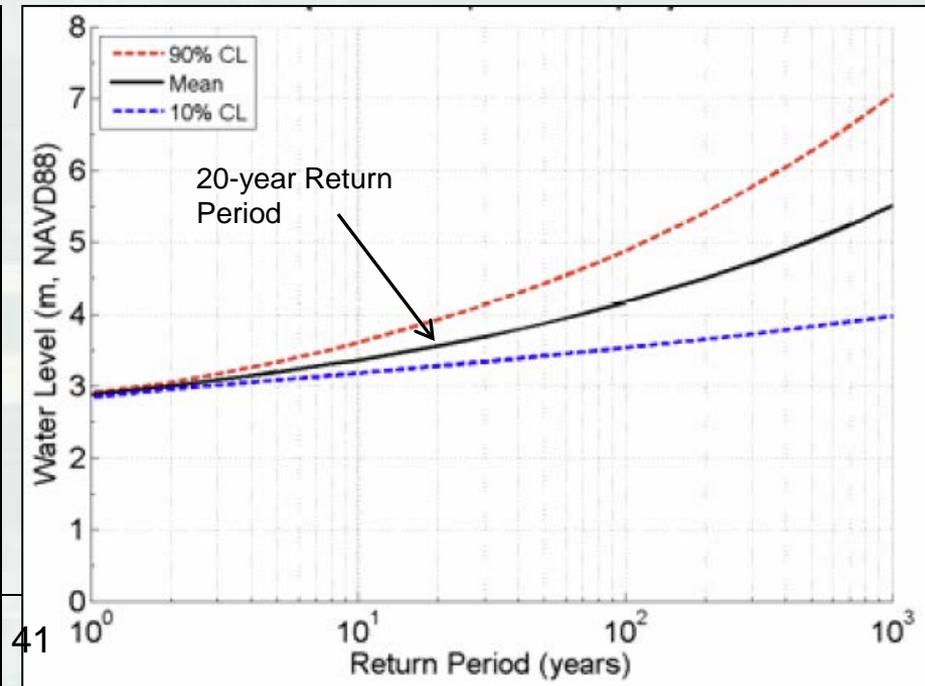
Statistical analysis of historical extreme water level measurements across NAD AOR

- ❑ Relative sea level rise scenarios + historical extreme water levels = future extreme water level exceedance probability
- ❑ 23 NOAA water level stations with sufficient data quality/quantity
- ❑ Used for NACCS 10% exceedance Storm Surge Mapping
- ❑ Used for validation of NACCS CSTORM numerical modeling
- ❑ <http://el.erd.c.usace.army.mil/elpubs/pdf/trel14-7.pdf>

Historical Extreme Water Level (Sandy Hook, NJ)



USACE 'High' Relative Sea Level Rise, 100 years (Sandy Hook, NJ)



NACCS Flood Risk with SLC

- 1% annual exceedance probability flood inundation elevation + 3' used for NACCS Tier 1 risk management measures/parametric costs
- Closely aligned with USACE High scenario in 2068 and with NYC recent recommendations
- 1% inundation obtained from FEMA FIRMs
- 1% + 3' obtained from FEMA SLOSH Category 2 (MOM) floodplain
- 10% annual exceedance water levels obtained from ERDC EWL analysis

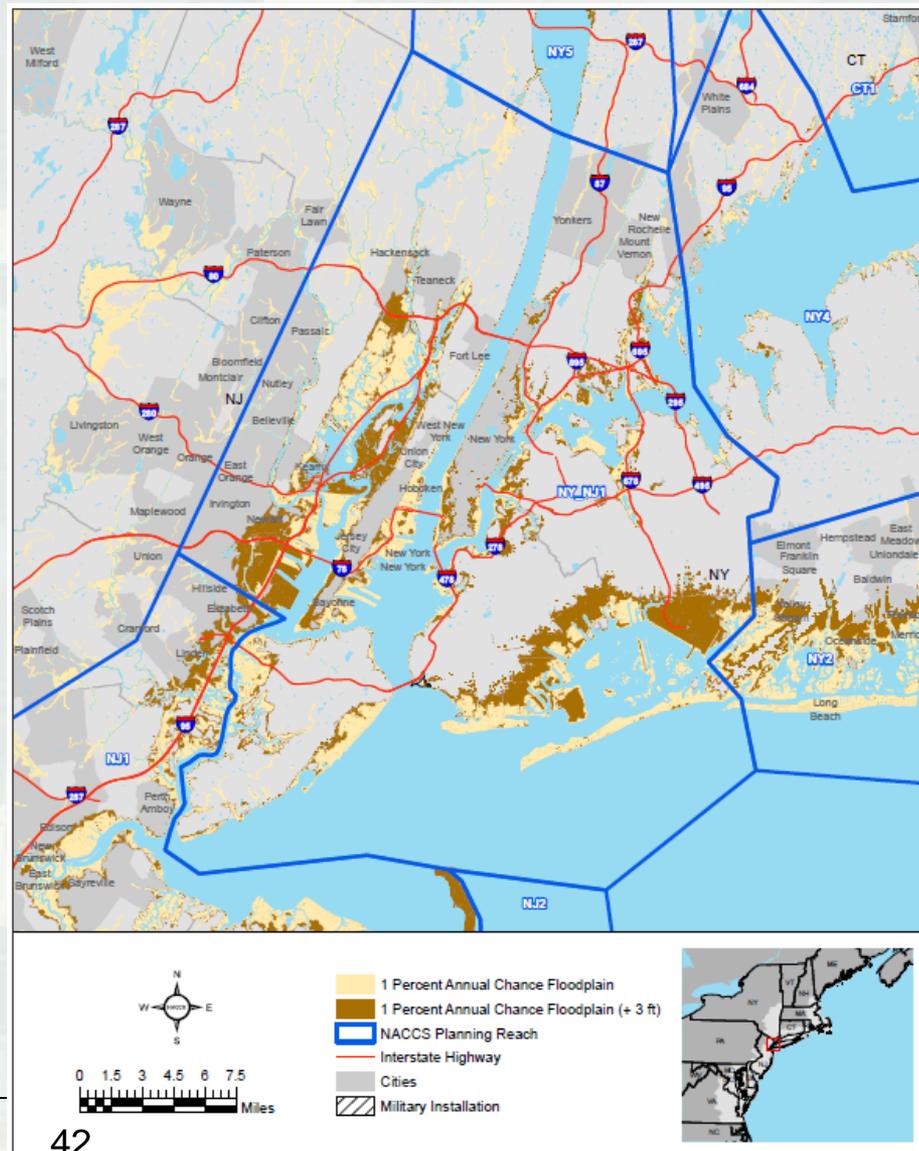


Figure IV-8. Reach NY_NJ1 Very High Impact Area NACCS 1 Percent Flood + 3-foot Floodplain



NACCS Technical Products

NACCS Coastal Storm Risk Management Framework



INITIATE ANALYSIS

Identify Stakeholders, Partners, and Authorities
Identify Constraints and Opportunities
Formalize Goals



CHARACTERIZE EXISTING CONDITIONS

Define Physical and Geomorphic Setting
Compile Flood Probability Data
Establish Baseline Conditions



ANALYZE VULNERABILITY AND RISK

Map Inundation and Exposure
Assess Vulnerability and Resilience
Determine Areas of High Risk



IDENTIFY POSSIBLE SOLUTIONS

Assess Full Array of Measures
Consider Blended Solutions
Develop Performance Metrics
Establish Decision Criteria



EVALUATE AND COMPARE SOLUTIONS

Develop Cost Estimates
Assess Benefits

STEPS COMPLETED AT A CONCEPTUAL LEVEL BY THE NACCS

Technical Products Advanced by NACCS to Close Identified Data Gaps

- Visioning Sessions Report & Focus Area Analyses
- Institutional & Other Barriers Report

- NACCS GIS Geodatabase
- Environmental & Cultural Resources Conditions Report

- Storm Suite Modeling
- NACCS GIS Geodatabase
- NACCS Barrier Island Sea Level Rise Inundation Assessment Report

- Natural & Nature-Based Features Report
- Conceptual Regional Sediment Budget
- State Appendix
- Vulnerability Decision Tree

- Enhanced Depth-Damage Functions for Coastal Storms

Several products, planning tools, and models were developed to assist decision makers in going through the Coastal Storm Risk Management Framework



Technical Products Supporting the Framework

Depth-Damage Functions

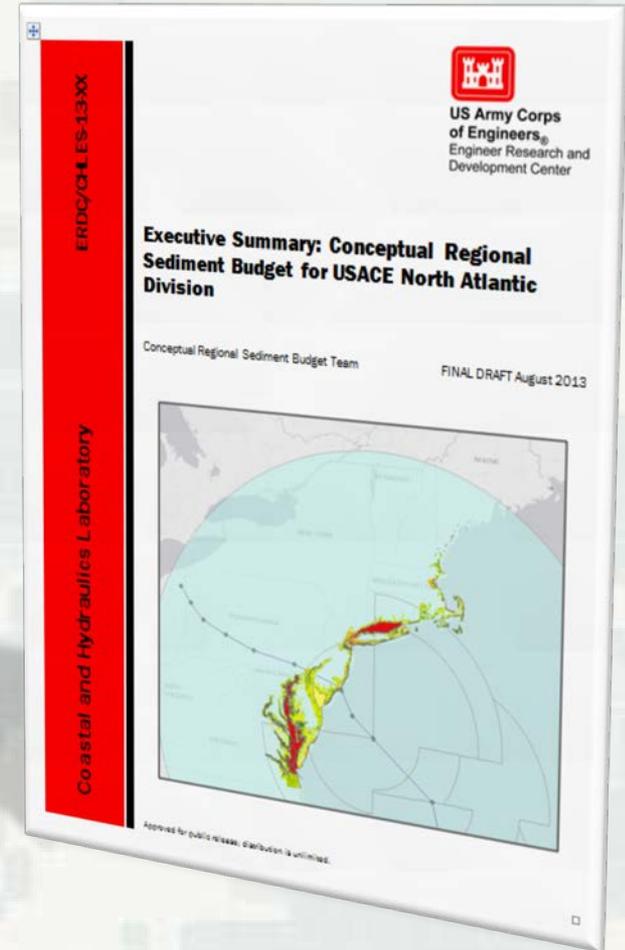
- **Assessment of Damages to Structures and Their Contents**
 - Coastal focus; existing curves focus on fluvial flood events
 - Closed a data gap of being appropriate to densely populated metropolitan areas with significant portions of their populations living in high-rise apartment buildings
- **Loss of Life Projection**
 - Coastal focus
 - Emphasis on obstacles to evacuation
- **Emergency Costs**
 - Builds on the framework of New Orleans efforts
- **Secondary and Tertiary Effects**
 - Effects that occur as a result of direct primary damages that are not typically identified (*e.g.* lost work/school days)
 - If not for the primary damages caused by the storm, the second and third effects would not have occurred



Technical Products Supporting the Framework

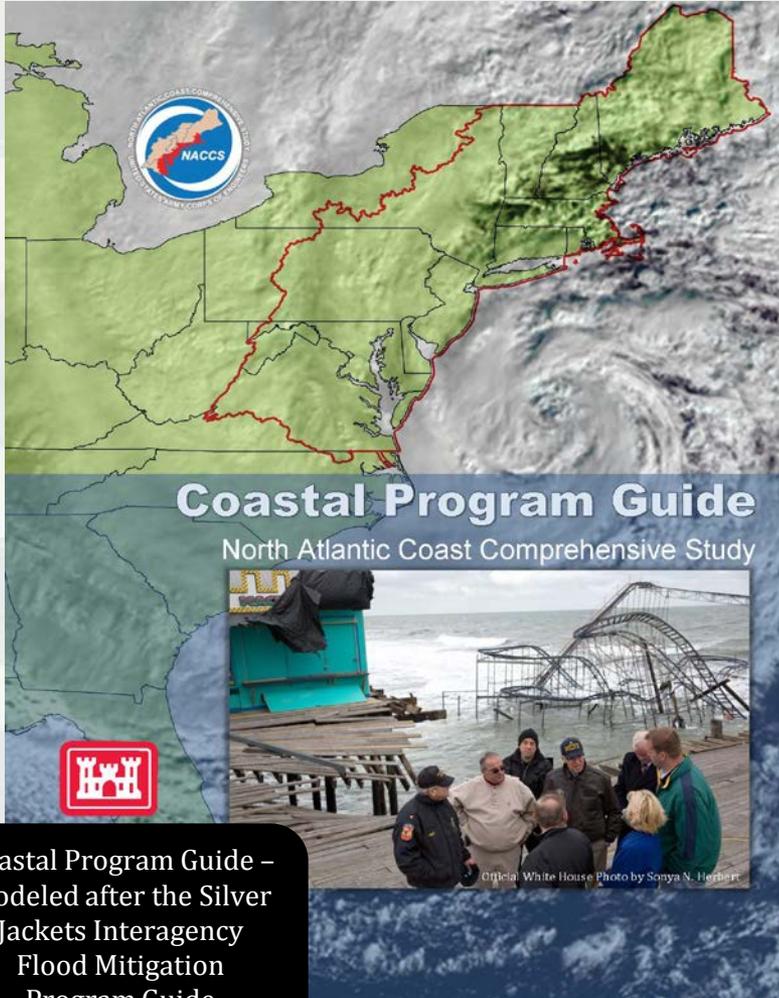
Conceptual Regional Sediment Budget

- Visualizes magnitude and direction of sediment transport
- Includes dredging data from Dredging Information System and placement site (if available)
- Based on existing knowledge or morphology
- Extends from Virginia to Maine
- Visualized in ERDC's Sediment Budget Analysis System Web Portal; overlain with Exposure/Risk/Vulnerability (ERV) database



Technical Products Supporting the Framework

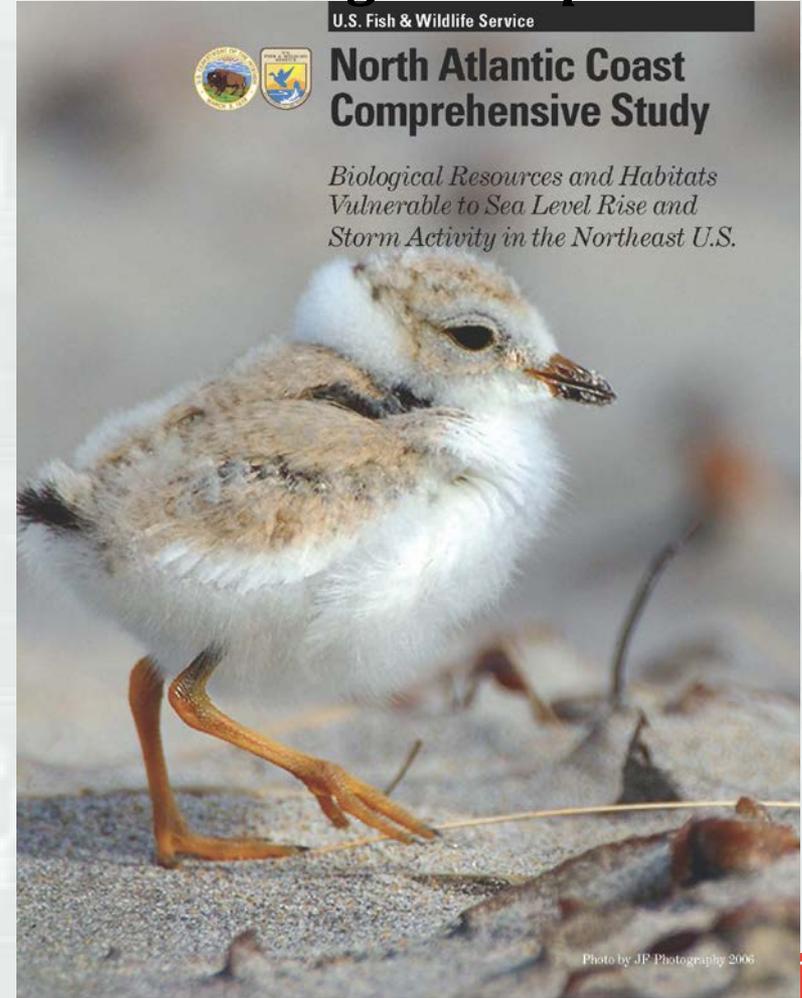
Coastal Program Guide



Coastal Program Guide – modeled after the Silver Jackets Interagency Flood Mitigation Program Guide



US Fish and Wildlife Planning Aid Report



Technical Products Supporting the Framework

Numerical Modeling and Statistics

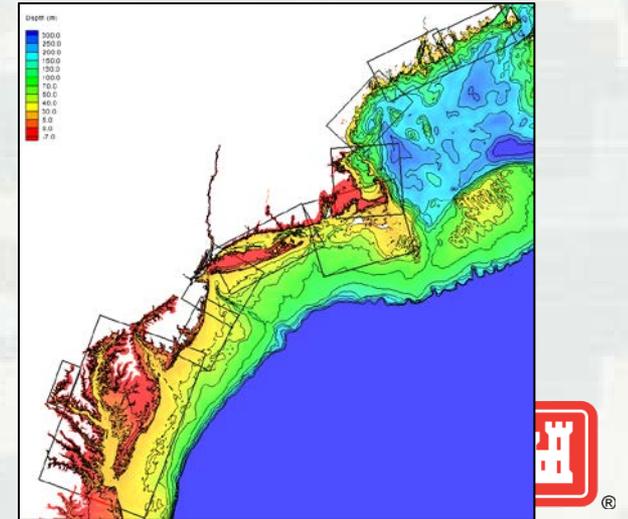
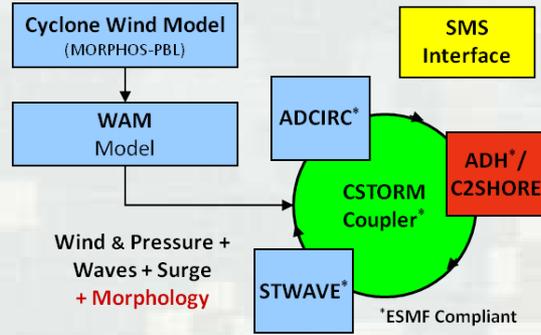
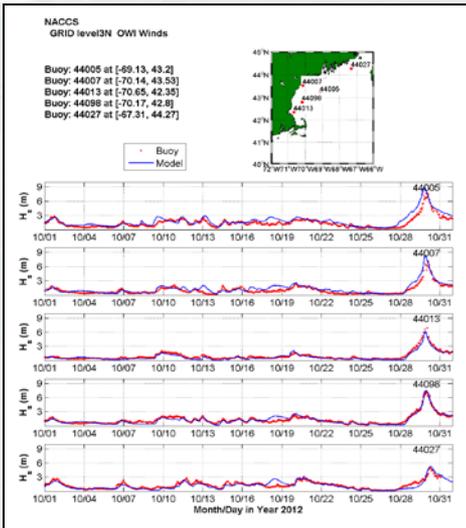
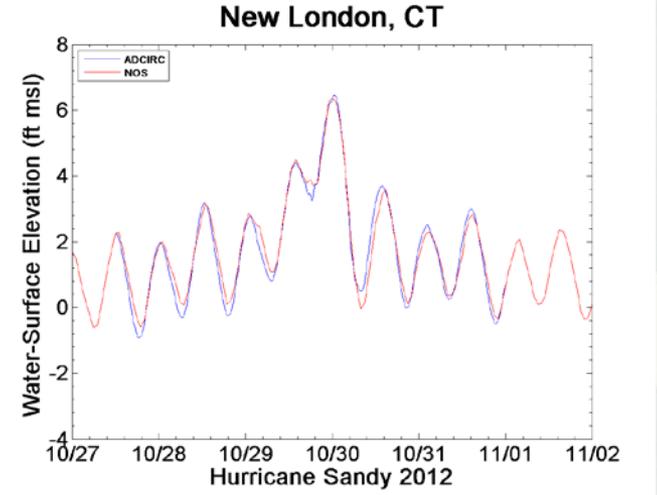
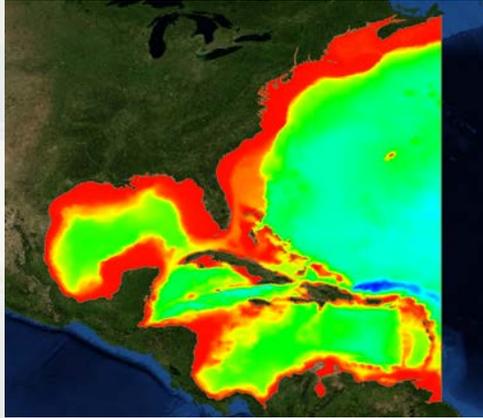
The NACCS modeling and statistical analysis study is a regional study covering the east coast of the United States from Maine to Virginia with the goal of quantifying the coastal storm hazard throughout the region and to provide an environmental forcing database for use in project design and evaluation as well as a wide range of other planning studies such as vulnerability assessments, resiliency studies, and critical infrastructure evaluations.

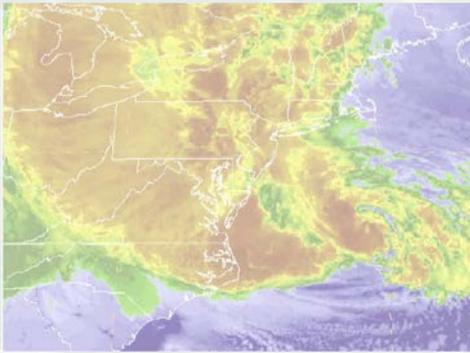
Products will include Wave, wind, water level, meteorological data, Storm characteristics (track, Rmax, Cp, VF, etc), and Statistics of peak responses



Technical Products Supporting the Framework

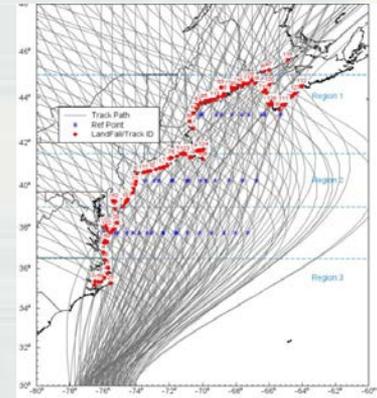
High-Fidelity Modeling





1050 synthetic tropical storms
100 historical extratropical storms

1150 simulation storm suite

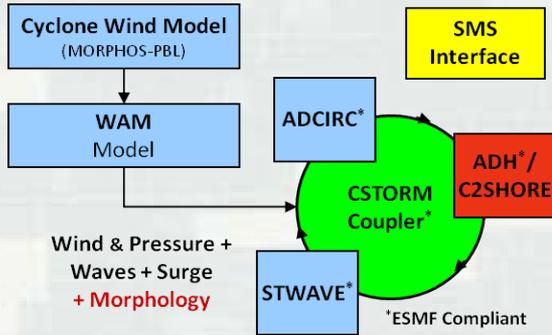


Base

With Tide/River Inflow

With Tide/River Inflow/SLC

3450 storms simulated with CSTORM-MS Production System developed for NACCS



3450 storms simulated x ~19000 save point locations
Model results, time series plots, and statistics
available through

The Coastal Hazards System

<https://chs.erdc.dren.mil>



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Technical Products Supporting the Framework

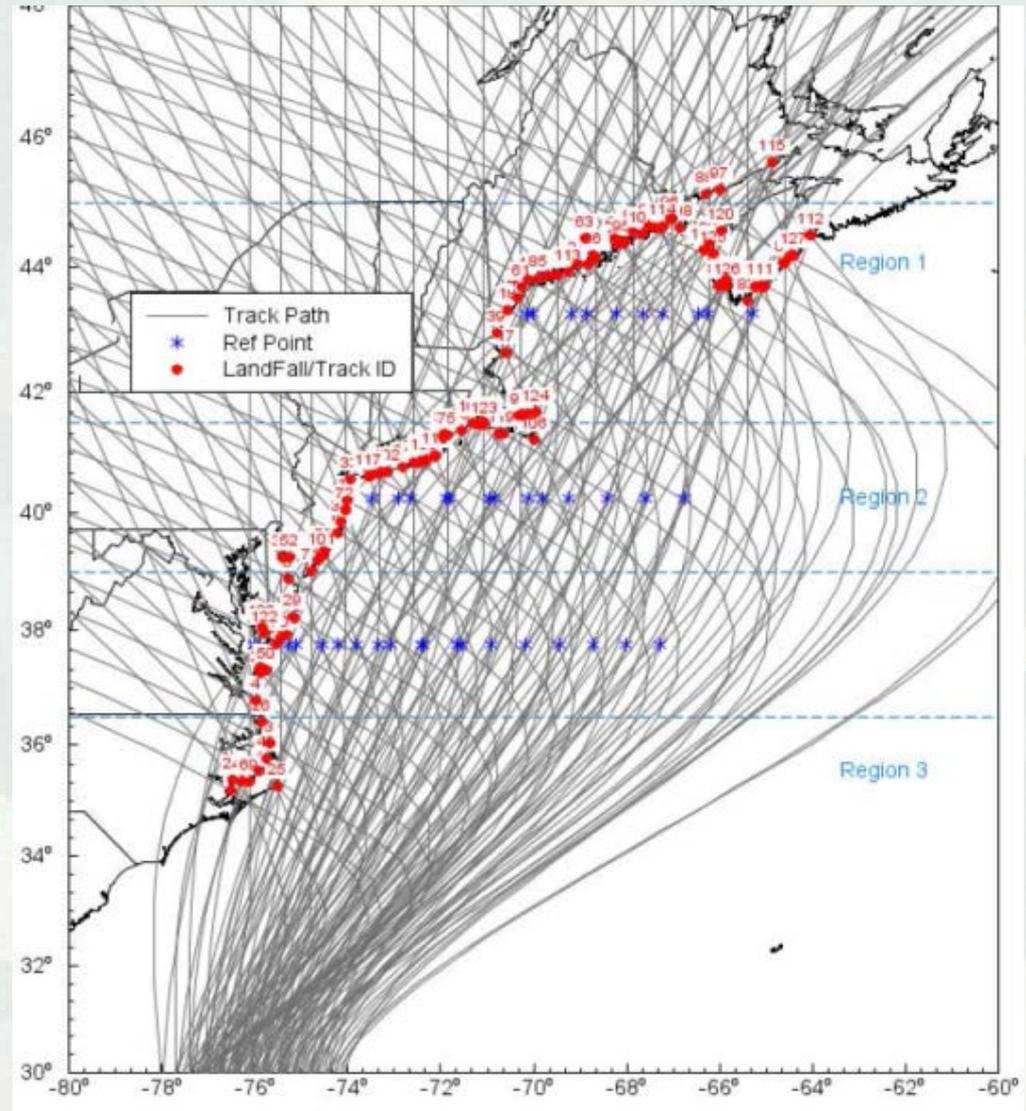
Results: Flood-Hazard Statistics

Historical Storms

Synthetic Storms

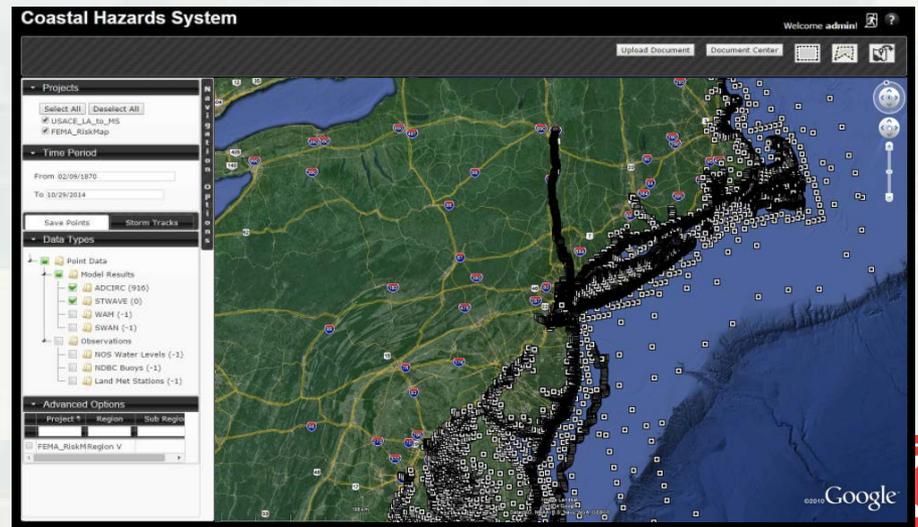
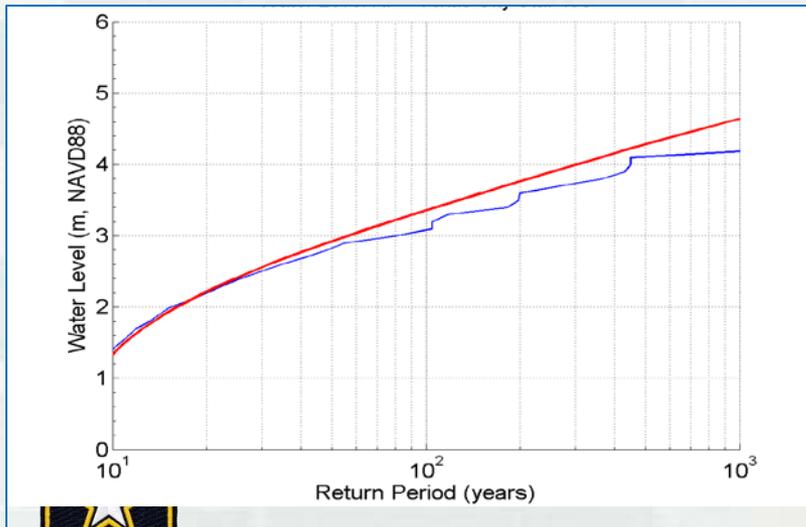
- Radius to maximum winds
- Central pressure
- Forward speed
- Track
- Landfall location

State-of-the-art statistical methodology JPM-OS



Technical Products Supporting the Framework Benefits

- **Data Products**: serve the coastal engineering and management communities 10+ years
- **Economies of Scale**: spatial extent/quantity of reusable data from regional model
- **Relevance**: technical advancements post-Katrina; enterprise modeling and analysis methods; USACE engineering guidance update



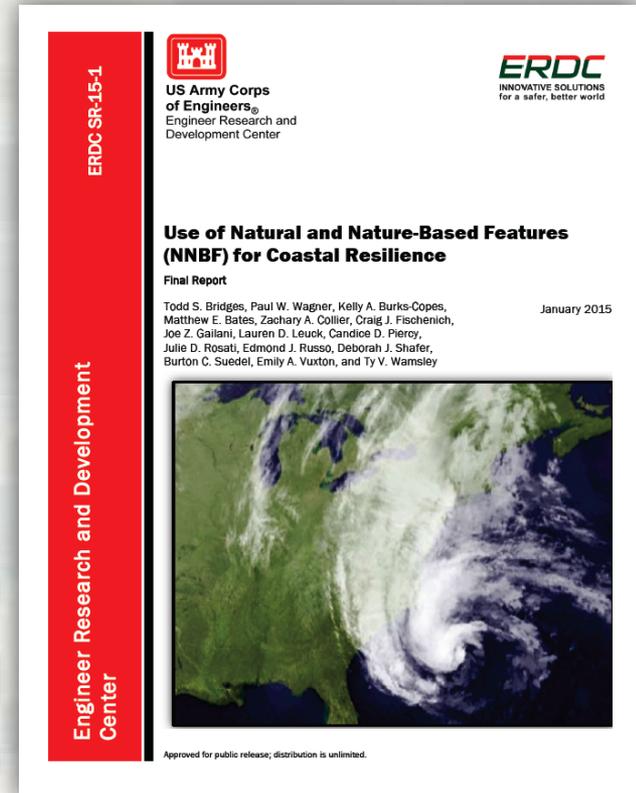
Technical Products Supporting the Use of NNBF to Promote Coastal Resiliency

Dr. Kelly A. Burks-Copes

Kelly.A.Burks-Copes@usace.army.mil

- What are NNBF and how can they contribute?
 - ▶ Characterization
 - ▶ Data Integration and Metrics for NNBFs
 - ▶ Evaluation and Case Studies
 - ▶ Policy Implications and Path Forward
- Get the entire report (480 pages):

- www.nad.usace.army/CompStudy and/or
- www.EngineeringWithNature.org



NACCS Natural and Nature-Based Features: Multi-Disciplinary Team

Project Leaders:

- Paul Wagner (IWR)
- Todd Bridges (EL)

Task Leaders:

- Kelly Burks-Copes (EL)
- Craig Fischenich (EL)
- Edmond Russo (EL)
- Deborah Shafer (EL)
- Ty Wamsley (CHL)

Study Team Members:

- Scott Bourne (EL)
- Pam Bailey (EL)
- Kate Brodie (EL)
- Zach Collier (EL)
- Sarah Miller (EL)
- Patrick O'Brien (EL)
- Candice Piercy (EL)
- Bruce Pruitt (EL)
- Burton Suedel (EL)
- Lauren Dunkin (CHL)
- Ashley Frey (CHL)
- Mark Gravens (CHL)
- Linda Lillycrop (CHL)
- Jeff Melby (CHL)
- Andy Morang (CHL)
- Cheryl Pollock (CHL)
- Jane Smith (CHL)
- Jennifer Wozencraft (CHL)
- Emily Vuxton (IWR)
- Jae Chung (IWR)
- Michael Deegan (IWR)
- Michelle Haynes (IWR)
- Lauren Leuck (IWR)
- David Raff (IWR)
- Lisa Wainger (U. Maryland)
- Sam Sifleet (U. Maryland)

I'd rather be managing
a large coastal hazard
risk assessment study



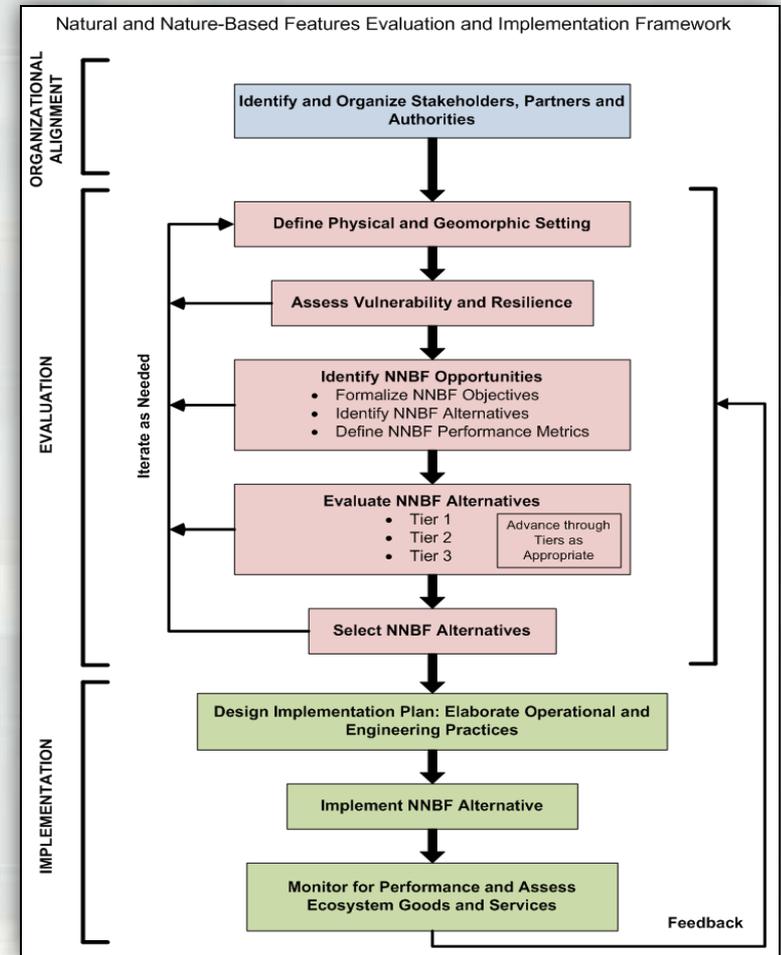
The daydreams of cat herders



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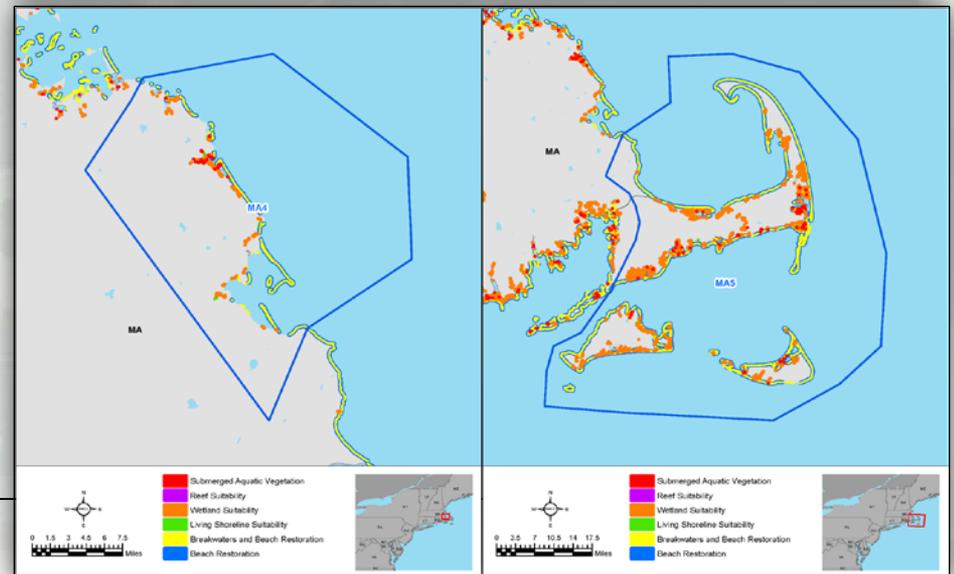
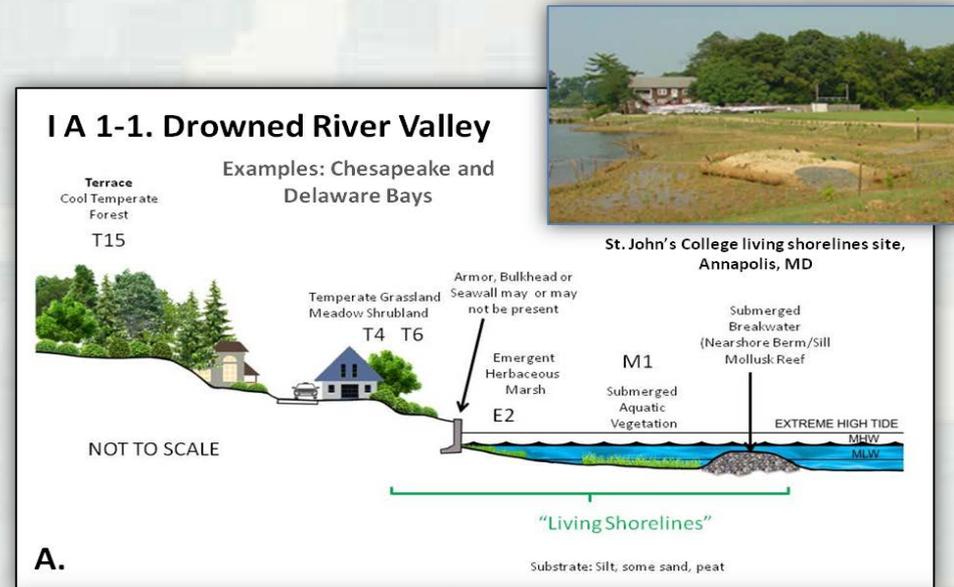
NNBF Integration from an Engineer's Perspective

- Integrated Planning and Implementation Framework
 - ▶ Organization alignment
 - ▶ Evaluation
 - ▶ Implementation
- With an impetus on sustainability, resilience and adaptive management



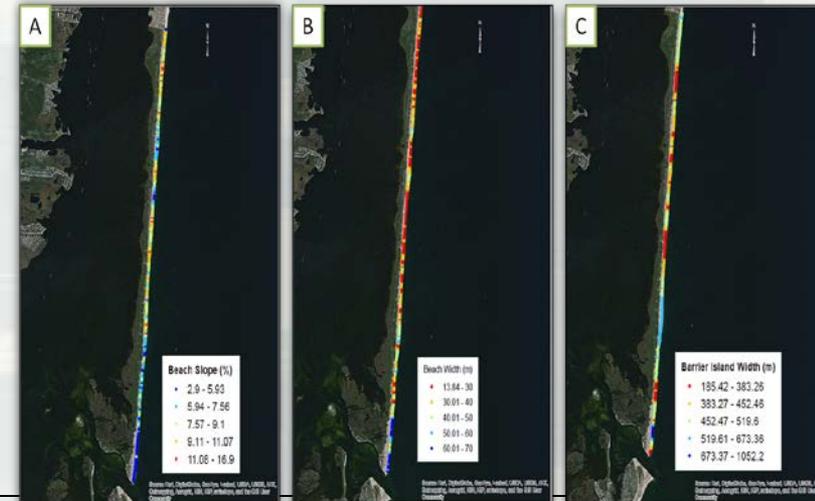
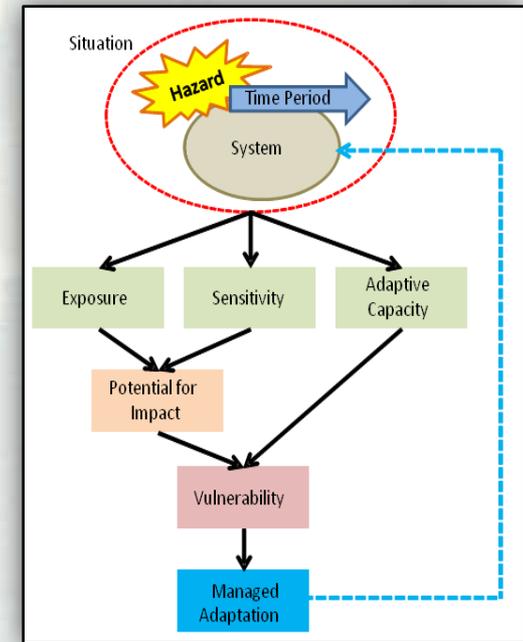
NNBF Characterization and Mapping

- Cross-sectional Characterization (geomorphological and vegetative)
- Processes the drive form and function
- System-wide Mapping
- Associated costs



NNBF Vulnerability and Resilience

- Definitions – what do we mean?
- How can we assess vulnerability of NNBF?
 - ▶ Suggested metrics
 - ▶ Assessment protocol
- How can we enhance resilience with NNBF and quantify the return on investment?
 - ▶ Community self assessments



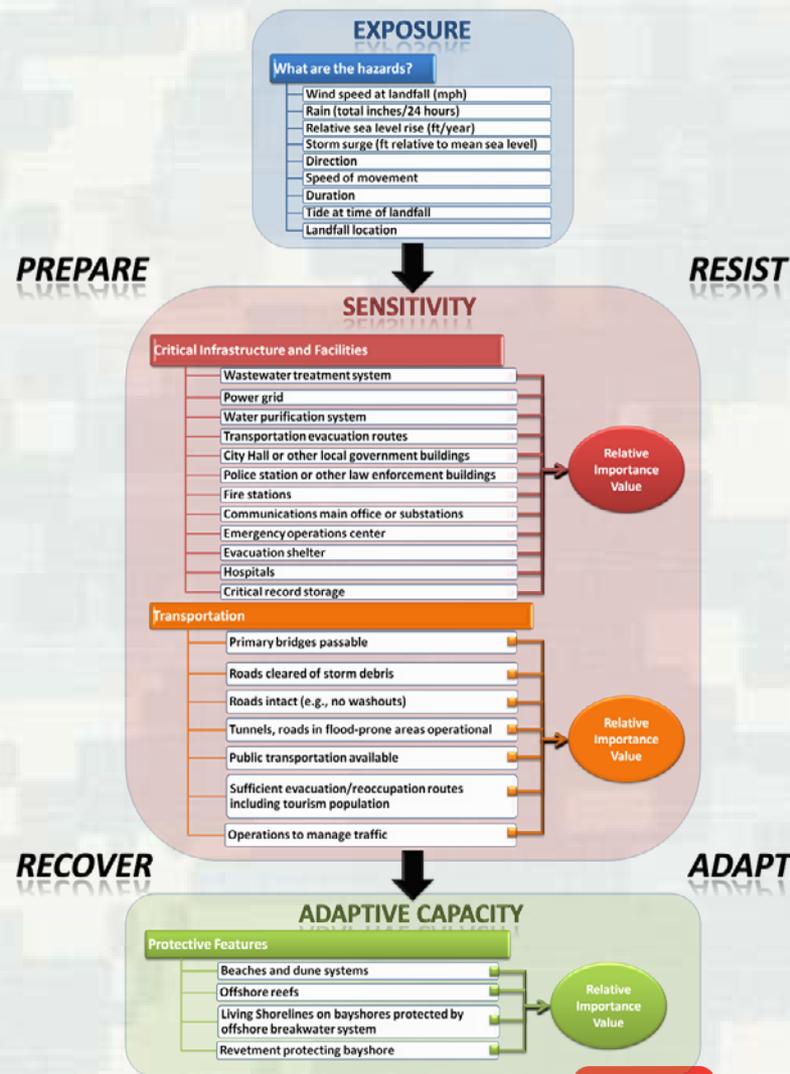
Systems Approach and Resilience

Capturing a Community's Sense of Vulnerability

➤ **Community resilience** is the capability to **anticipate** risk, **limit** impact, and **bounce back** rapidly through survival, adaptability, evolution, and growth in the face of turbulent change

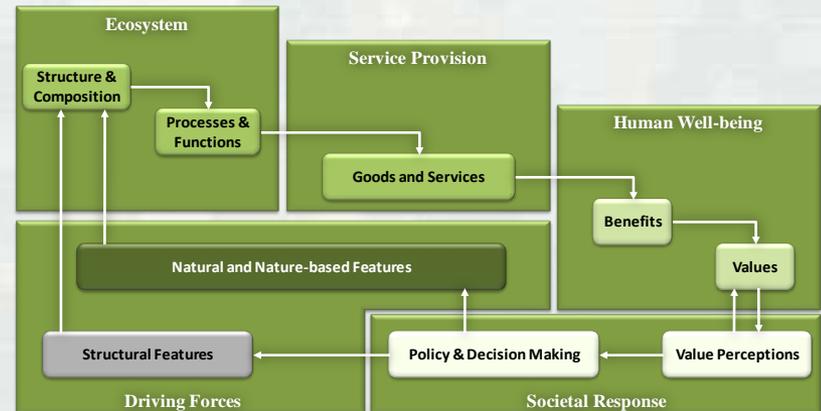
➤ **Self-Assessment Steps:**

1. Define spatial and temporal boundaries
2. Identify benchmark and future storms
3. Identify critical infrastructure and facilities and a recovery goal for each
4. Identify transportation issues
5. Identify protective features
6. Calculate the overall community resilience rating

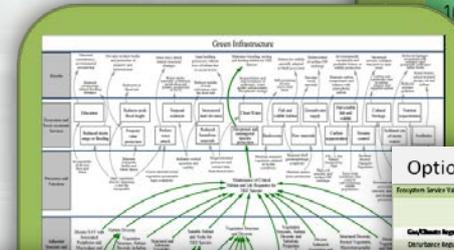


NNBF Performance Metrics

- Ecosystem Goods and Services
- Tiered Metrics
 - ▶ **Level 1** – Qualitative characterization of performance
 - ▶ **Level 2** – Semi-quantitative characterization of performance
 - ▶ **Level 3** – Quantitative characterization of performance



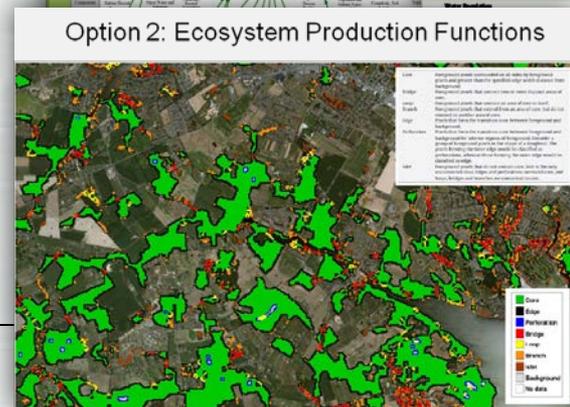
	Wt	1	2	4	3	5	Mean	Wtd
	B1	B2	B3	B4	B5			
Plan A	10	8	5	1	0	4.8	49	
	10	10	0	0	0	4	30	
		5	5	9	7	7.2	102	
		10	10	8	5	7.8	115	
		5	5	10	10	7	115	



Option 1: Value Transfer (\$ Value per acre)

Ecosystem Service Value Based on Peer-Reviewed Original Research in Temperate North America (Temper 2012 \$/ha*yr)

Category	Coastal Wetland	Shrubland Wetland	Forest Wetland	Rangeland Wetland	Open Forest Wetland	Open Freshwater Wetland	Riparian Wetland	Urban Wetland	Urban Wetland
Coastal Wetland	30794								
Shrubland Wetland		1							
Forest Wetland			762						
Rangeland Wetland				11					
Open Forest Wetland					7				
Open Freshwater Wetland						262			
Riparian Wetland							1196		
Urban Wetland								2310	
Urban Wetland									404

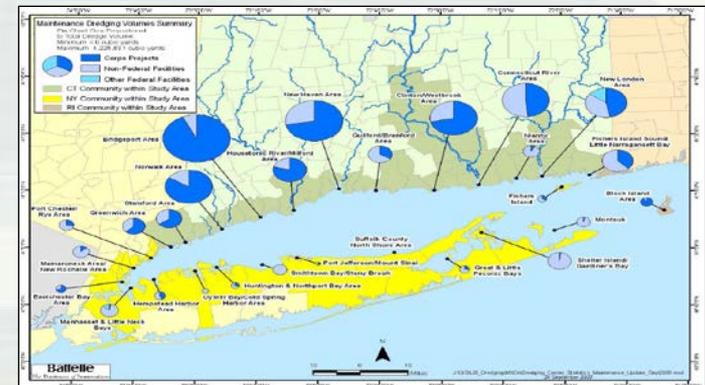
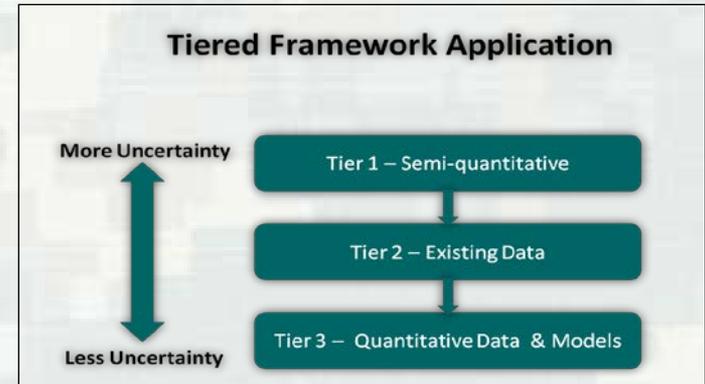


72 individual performance metrics identified for NNBF



Putting NNBF into Practice

- Evaluation Framework
 - Ever-increasing levels of data integration and evaluation
- Regional Sediment Management
 - Consider sediment as a source for NNBF
 - Case study – Long Island Sound D2M2 Application
- Ecosystem Goods and Services Assessment Case Studies
 - Jamaica Bay, Cape May Meadows, and South Cape Charles



NNBF Policy Implications

■ Workshops produced Underlying Themes:

1. **Science, engineering, and technology** - Knowledge and data deficiencies pose significant challenges for the development of guidance and policies for the evaluation and implementation of NNBF
2. **Communication and outreach** - NNBF remain a nebulous concept for many, including decision makers and others with the responsibility to implement coastal projects . . . there is a need for better communication and information sharing on NNBF
3. **Leadership and institutional coordination** - NNBF are not practical in all instances, but a broad understanding and characterization of the landscape can facilitate their use



Research Targets to Advance the NNBF Practice

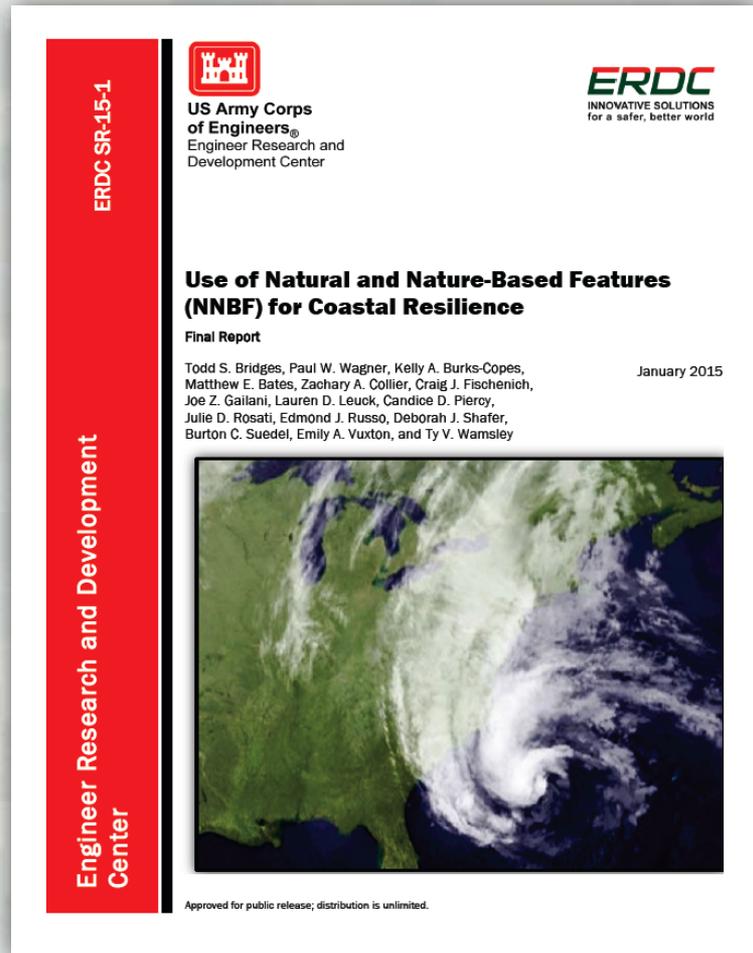
- **Advance understanding** of important, fundamental processes
 - ▶ E.g., sediment transport through wetlands, environmental goods and services provided by engineered features, engineering performance of NNBF
- **Improved modeling** systems that engage users, stakeholders and decision-makers
 - ▶ E.g., rapidly deployed, visual interfaces to engage stakeholders in the process, amenable to “what if” evaluation
- **Reliable, cost-efficient monitoring technologies** for measuring system evolution and infrastructure/feature performance
- **Demonstration/pilot project opportunities** to innovate, evaluate, and learn at relevant field scales
 - ▶ Facilitating necessary collaboration
 - ▶ Evolving organizational culture and practice
 - ▶ Producing credible evidence of success
- **Policy analysis** supporting Engineering With Nature (EWN) and the use of NNBF
 - ▶ Projecting benefits and costs
 - E.g., NNBF are expected to be more dynamic than “hard” infrastructure. How does this affect nature of benefits streams and factors such as O&M?
 - Resolving trade-offs with regards to habitat switching



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NNBF Path Forward

- **Organize and expand science** and engineering related to natural processes and features
- **Reduce uncertainties** regarding performance to support design
- **Develop** methods for integrating NNBF with other measures
- **Consider and emphasize** the dynamic nature of natural systems
- **Integrate expertise** across disciplines and organizations
- **Deploy demonstration projects** to develop facts and evidence that fuel the “power of the story” to persuade



www.nad.usace.army/CompStudy



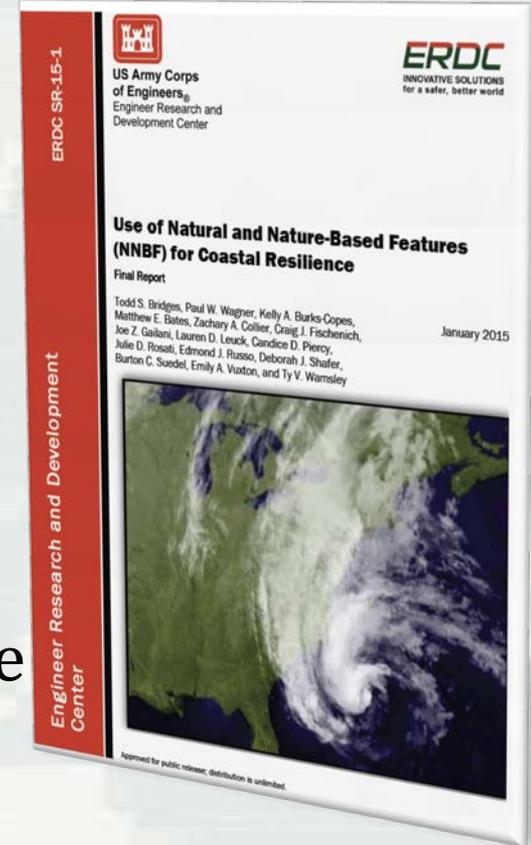
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Community Self-Assessment of Resilience

Julie Dean Rosati

Julie.D.Rosati@usace.army.mil

- What is resilience?
 - ▶ Key Actions
 - ▶ Timeline
 - ▶ Aspects of Engineering, Ecological & Community Resilience
- How do we quantify resilience?
- Community Self-Assessment of Resilience
http://el.erd.c.usace.army.mil/ewn/news_files/17839-report.pdf
- Measures to Increase Resilience

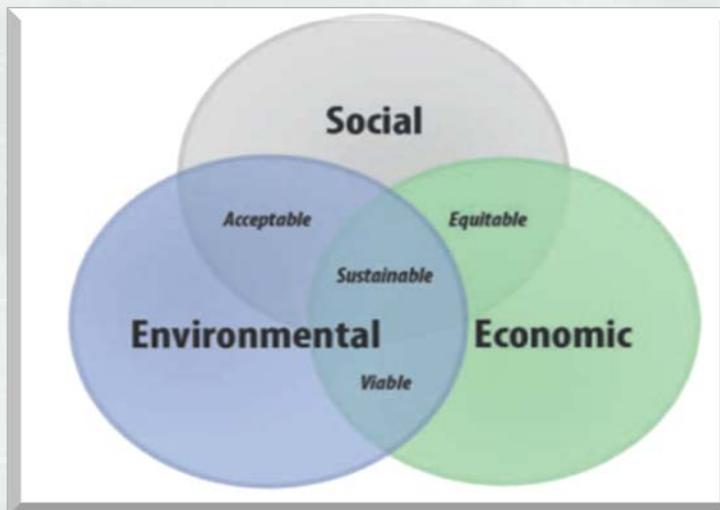


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Systems Approach and Resilience

Why a Systems Approach?

- Coastal change occurs over large temporal and spatial scales
- Complex social, economic, and environmental interactions
- Multiple/competing stakeholder objectives
- A Systems Approach:
 - ➔ *Takes broad view of interactions & objectives to develop potential solution sets*
 - ➔ *Intentionally aligns engineering and natural systems*



*Restoration of Deer Island, MS
Barrier Island and Marsh*



Definitions of Resilience

Study	Definition
American Society of Civil Engineers (2006) http://www.asce.org/Content.aspx?id=8478	"Resilience refers to the capability to mitigate against significant all-hazards risks and incidents and to expeditiously recover and reconstitute critical services with minimum damage to public safety and health, the economy, and national security."
National Disaster Recovery Framework, Strengthening Disaster Recovery for the Nation (FEMA 2011) http://www.fema.gov/media-library/assets/documents/24647?fromSearch=fromsearch&id=5124	A resilient community has ... "an improved ability to withstand , respond to and recover from disasters."
The Infrastructure Security Partnership and Society of Military Engineers (SAME). "Understanding Resilience – Disaster Resilience Begins with You" (2012) http://tisp.org/tisp/2012/08/21/understanding-resilience-disaster-resilience-begins-with-you/	Disaster Resilience is... "the capacity to withstand and recover rapidly with limited damage."
Disaster Resilience: A National Strategy (2012) http://www.nap.edu/read/13127/chapter/1	"Resilience is the ability to withstand , recover from , and more successfully adapt to adverse events."
Hurricane Sandy (2013) http://portal.hud.gov/hudportal/HUD?src=/main/region/2013/08/21/hurricane-sandy-resilience-a-national-strategy.ppt	"The ability to prepare for, respond to, withstand and recover rapidly from disruptions."
Infrastructure Resilience: A National Strategy (2013) http://coastalmgmt.org/Portals/0/Infrastructure%20Resilience%20Principles.pdf	"Ability to withstand conditions and withstand and recover from disruption due to..."
Coastal Risk Reduction: A National Strategy (2013) http://www.cerf.gov/Portals/0/Coastal%20Risk%20Reduction%20Strategy%202013-3.pdf	"Ability to withstand conditions and withstand and recover from disruption due to..."
Urban Land Institute and Adaptability (2013) http://www.uli.org/Portals/0/Urban%20Land%20Institute%20and%20Adaptability%20Documents/Afterschool%20Resilience.pdf	"The capacity of individuals, communities, and organizations to withstand and recover from a disaster event."
Presidential Executive Order on Climate Change (2013) http://www.whitehouse.gov/the-press-office/2013/04/01/eo-13526-climate-change-resilience	"Resilience means the capacity to withstand , respond to, and adapt to changing conditions and conditions."
Rockefeller Foundation (2013) http://www.rockefellerfoundation.org/blog/city-resilient	"The capacity of individuals, communities, and organizations to survive , adapt , and grow in the face of changes, even catastrophic changes."
Community and Regional Resilience Institute (CARRI) (2013) http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf	"Community resilience is the capacity to mitigate risk, limit impact, and bounce back rapidly through survival, adaptability , evolution , and growth in the face of turbulent change"
U.S. Army Corps of Engineers Safety of Dams, Policy and Procedures, ER 1110-2-1156 (2014) http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf	"The ability to avoid , minimize, withstand , and recover from the effects of adversity, whether natural or manmade, under all circumstances of use."
Intergovernmental Panel on Climate Change Fifth Assessment Report, "Climate Change 2014: Impacts, Adaptation, and Vulnerability" (2014) http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Glossary_FGD.pdf	"The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function , identity, and structure, while also maintaining the capacity for adaptation , learning, and transformation "

Key words:

Prepare

Resist

Recover

Adapt

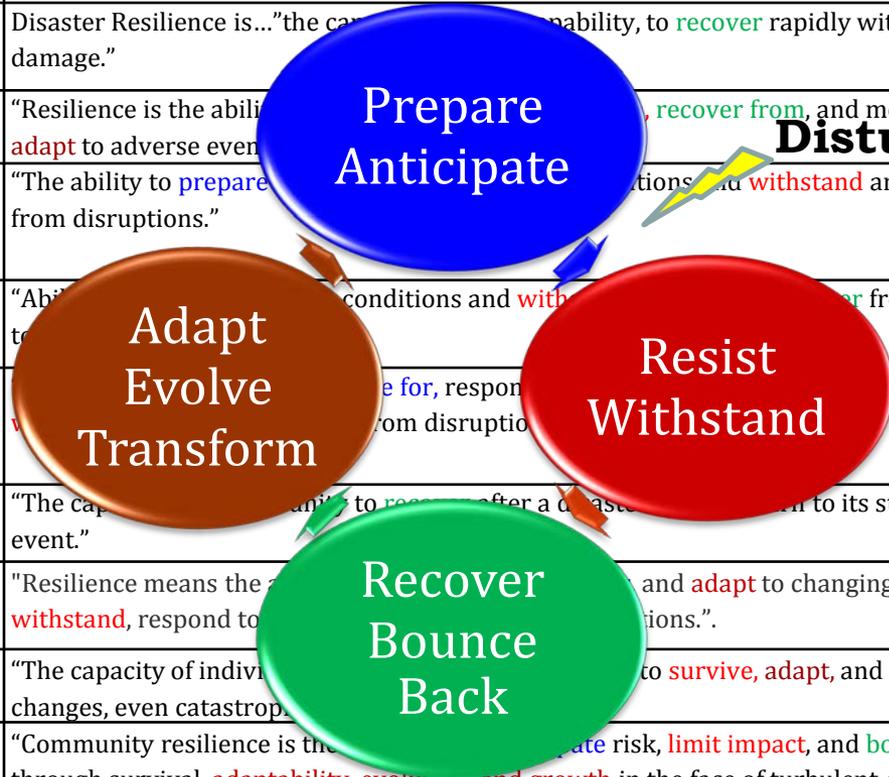
Prepare
Anticipate

Adapt
Evolve
Transform

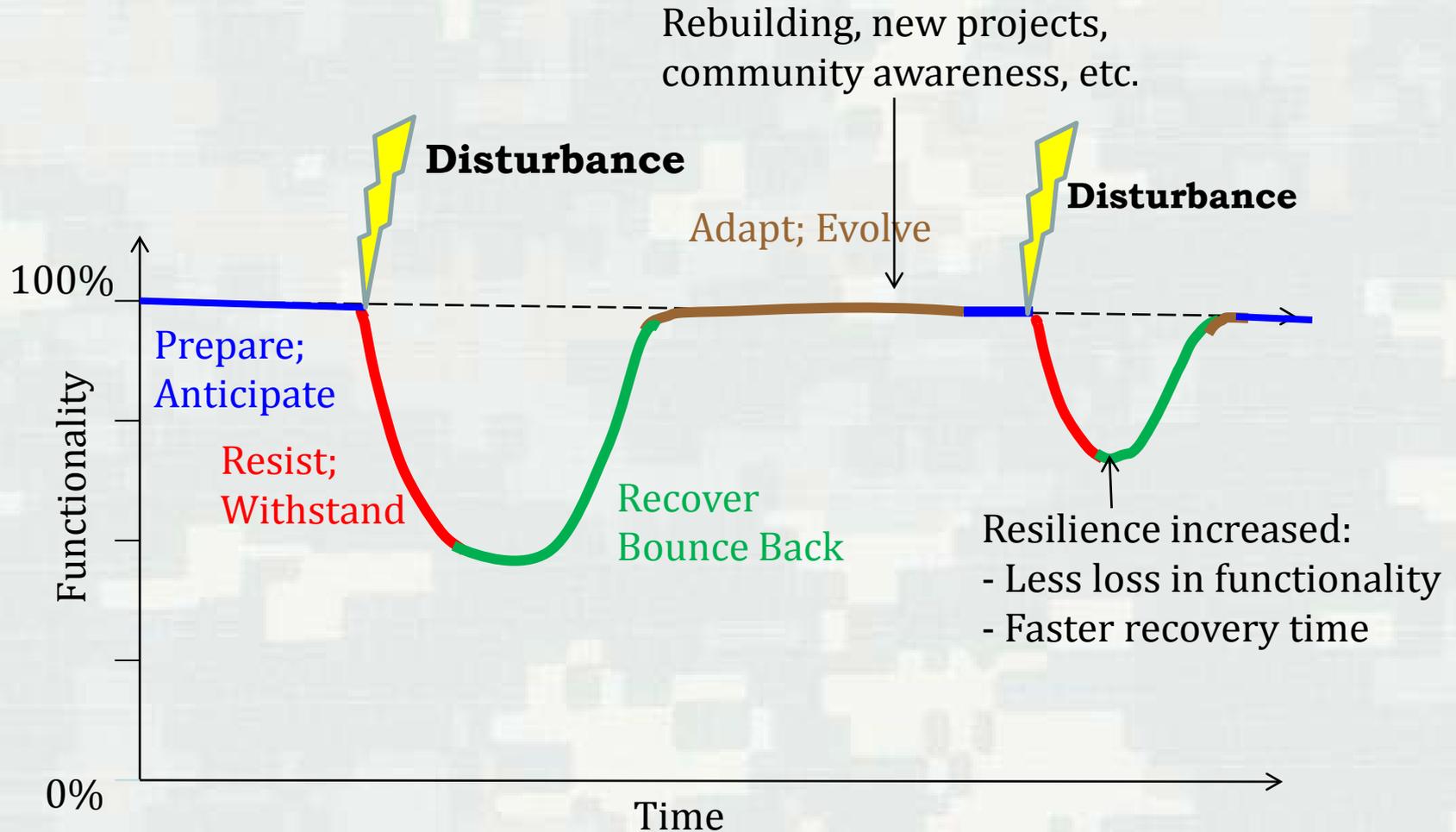
Resist
Withstand

Recover
Bounce
Back

Disturbance



Resilience Timeline



Resilience -

Many studies with similar definitions



Engineering (USACE)

The ability of a system to **anticipate**, **resist**, **recover**, and **adapt** to achieve *functional* performance under the stress of disturbances through time.

Engineering Resilience:

- Reliable performance
- Range of design forcing
- *Most engineered systems do not naturally adapt*



Ecological (Walker et al. 2004)

The capacity of a system to **absorb disturbance** and **reorganize** while **undergoing change** so as to still **retain** essentially the **same function**, structure, identity, and feedbacks.

Ecological Resilience:

In general, changes must be gradual for successful adaptation



Community (CARRI 2013)

Capability to **anticipate** risk, **limit impact**, and **bounce back** rapidly through survival, **adaptability**, **evolution**, and **growth** in the face of turbulent change.

Community Resilience:

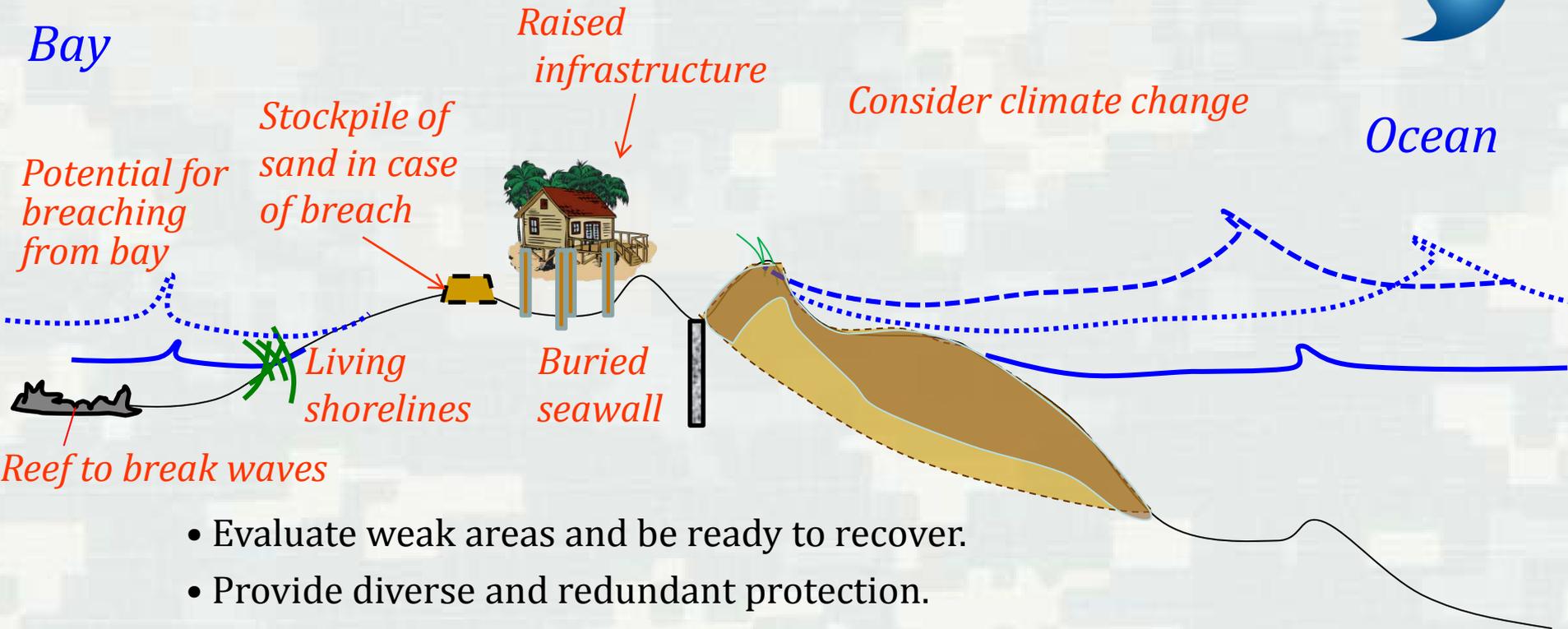
Humans have the capacity to learn and make conscious decisions to avoid future losses



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What is a resilient coastal system?

Example barrier island cross-section



- Evaluate weak areas and be ready to recover.
- Provide diverse and redundant protection.
- Ensure availability of alternate networks –components that are independent of, and complement each other (e.g., multiple evacuation routes).

- Provide accessible information for rapid decision-making.



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How do we calculate resilience?

1. Functional Objective:

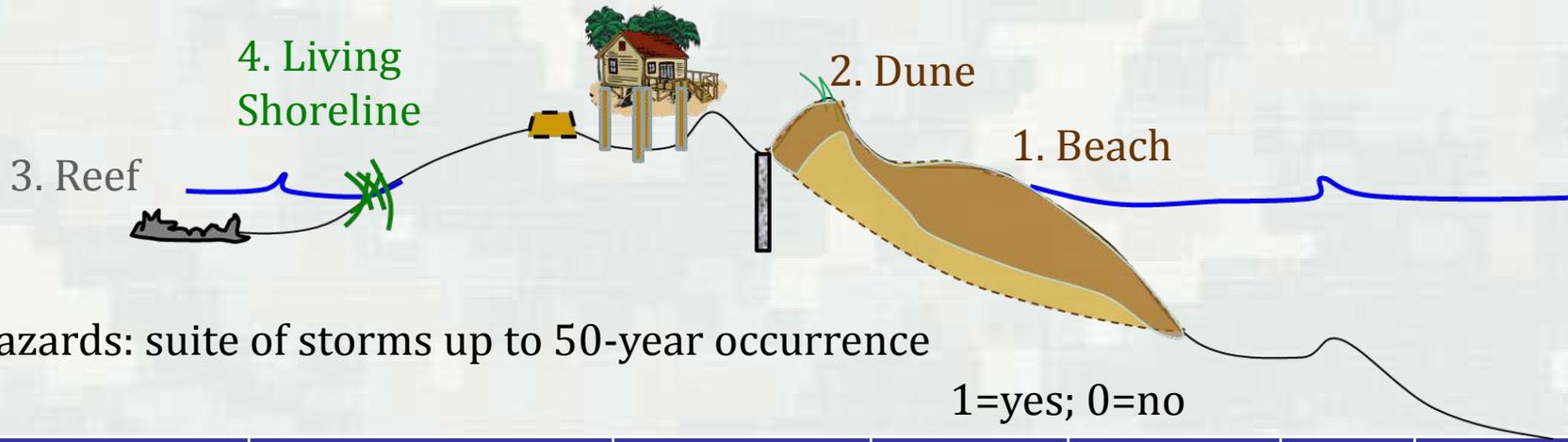
*How do we want the system to perform? Was the system **Prepared** to **Resist** damage?*

2. Recovery Objective:

*Was the system able to **Recover** and **Adapt** within a desired timeframe?*



Example Calculation: Resilience Metric



Critical Element	Functional Obj, F	Recovery Obj, R	Was F met?	Was R met?	F+R	Weighting, W
1. Beach	Prevent surge	3 mos	1	1	2	0.25
2. Dune	Prevent overtopping	3 mos	0	1	1	0.3
3. Reef (bay)	Reduce erosion by 10%	6 mos	0	1	1	0.2
4. Living Shoreline (bay)	Reduce erosion by 30%	6 mos	0	0	0	0.25
Resilience Metric = {S(F+R)*W}/2 = (2*0.25+1*0.3+1*0.2+0*0.25)/2=						50%

Measures to Increase Resilience

Prepare, Anticipate:

- Consider likely and rare future scenarios
- Establish early warning and evacuation plans
- Establish multiple evacuation routes
- Maintain/improve projects
- Educate state, local, individuals
- Evaluate weakest links in system and prepare to recover these as rapidly as possible
- Update resilience assessments

Adapt, Evolve, Transform, 'Bounce Forward':

- Modify evacuation and response plans
- Improve to reduce future damages
- Provide incentives for raising residential and critical infrastructure in vulnerable areas



Resist, Withstand:

- Ensure critical features are in good condition
- Relocate critical infrastructure as needed
- Monitor system performance and community response



Recover, Bounce Back:

- Repair damaged systems
- Assess and document system performance
- Implement mitigation measures and improvements



Institutional and Other Barriers

- Six themes presented with Policy Challenges, Successes, Opportunities for Action
 - 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
- Aligned with Project Performance Evaluation Report and Hurricane Sandy Rebuilding Strategy



Coastal Resilience Integration

9 Focus Area
Integrated
Strategies

USACE-Sponsor Feasibility Studies and/or
Comprehensive Plans; Technical Assistance

USACE-Sponsor Design and
Construction

NACCS Products: Geospatial Database; Numerical Modeling of Extreme Water Levels; Economic Depth-Damage Functions; Environmental and Cultural Resources Conditions Report; Conceptual Regional Sediment Budget; Vulnerability, Resilience, Natural and Nature-Based Features Assessment and Metric Development

Integration of Strategic Coastal Investments

State
Implementation
of Ongoing & Planned Risk
Reduction

Ongoing USACE Activities

- *Vulnerability Assessments, Resilience and Climate Change Adaptation Planning
- *Technical Assistance to States and installations; Public-Private Partnership initiatives
- *Limited & General Reevaluation Reports
- *Continuing Authorities Program and Operation & Maintenance activities
- *Flood Control and Coastal Emergency projects
- *National Hurricane Program

Regional Partnerships & Collaboration

Housing and Urban Development (HUD)
Northeast Regional Ocean Council (NROC)
Sandy Regional Infrastructure Resilience Coordination (SRIRC)
Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS)
Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS)
Department of Interior – NFWF Grants
Chesapeake Bay Resilience Co-Lead
Rebuild By Design and more...

2013

2015

73

2020

2025

Summary

NACCS Saves Communities Time and Money when Planning for Resilient Adaptation to Increasing Risk!

- Consistent coastal framework – transferable
- New tools (closed data gaps)
- Integration with other stakeholders and *their* tools
- Able to be used by **all** (federal, state, regional, local, tribal, NGO, industry, academia, etc.)
- More robust, risk-informed decision-making



Q&A Session

