North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

USFWS SCIENCE SEMINAR SERIES
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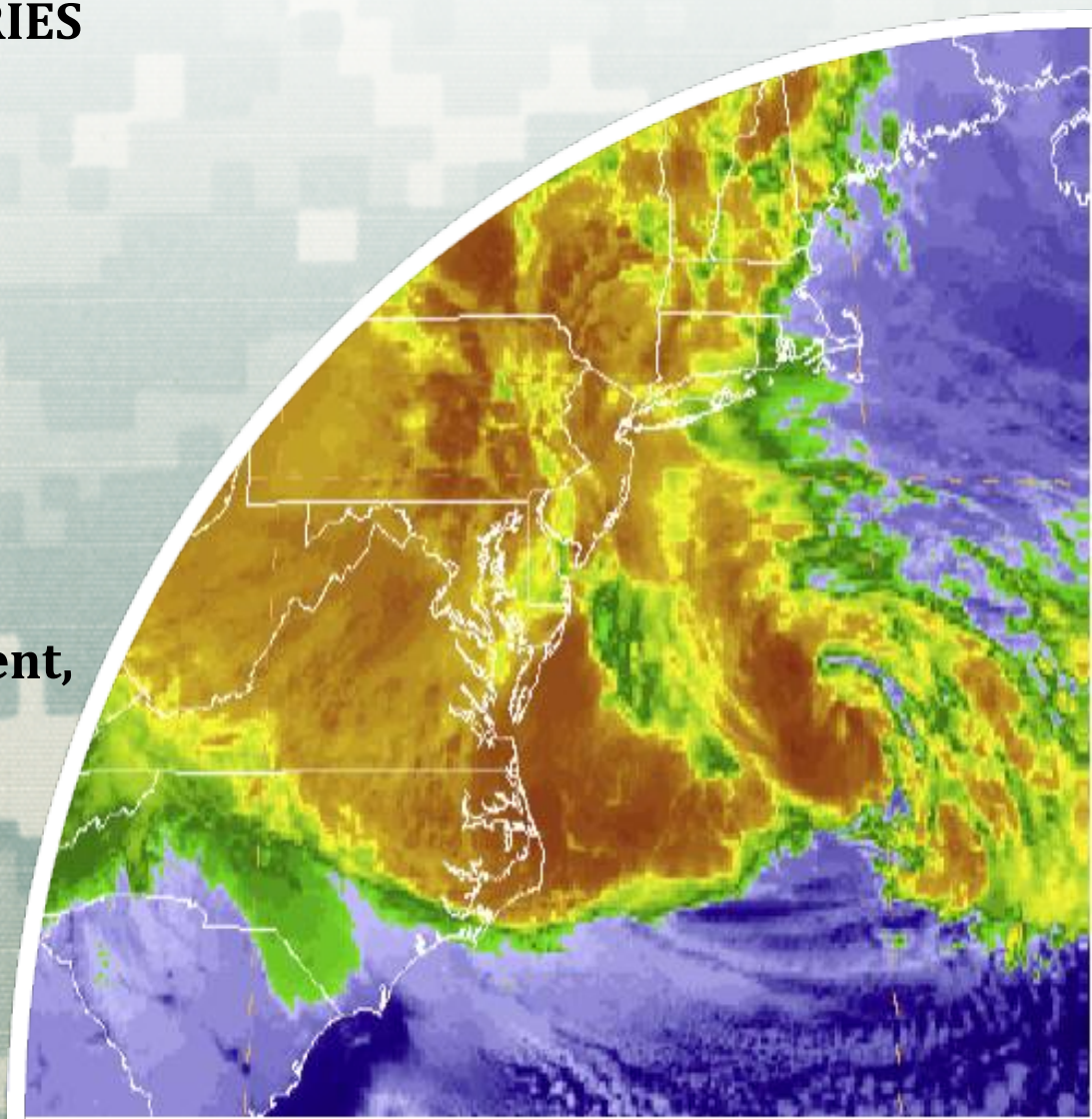

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Outline

- Background
- Findings, Outcomes, and Opportunities
- Coastal Storm Risk Management Framework
  - Flood Hazard, Exposure, and Risk Assessment
  - Risk Management Measures
- Technical Products Supporting the Framework
  - Environmental and Cultural Resources Conditions Report
    - USFWS Planning Aid Report
  - Use of Natural and Nature-Based Features for Coastal Resilience Report

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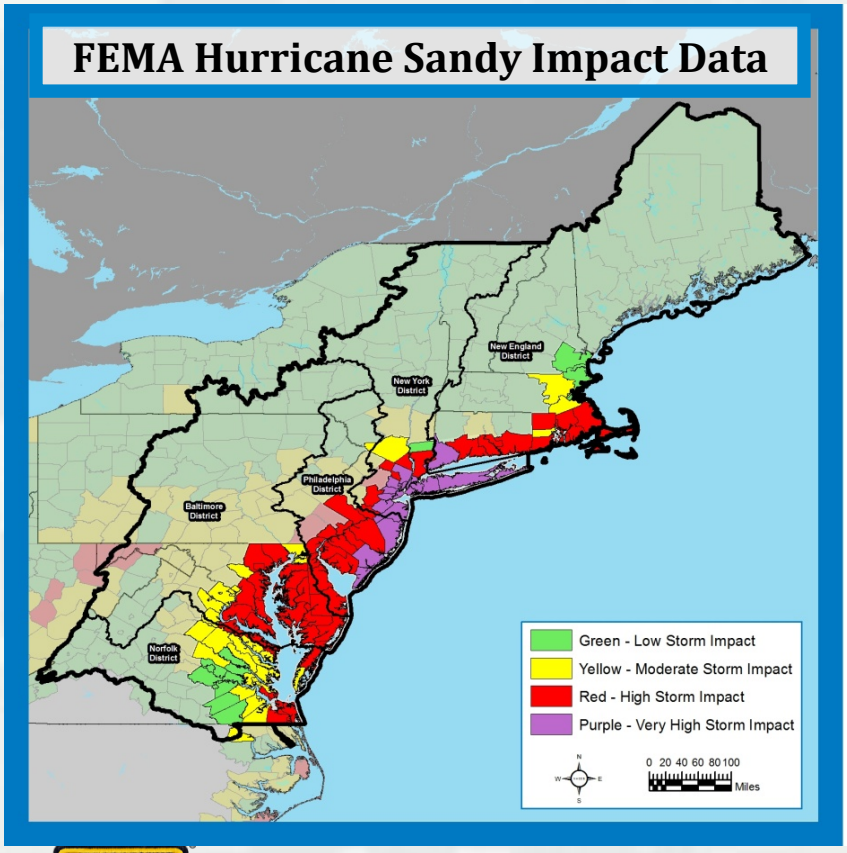
Background

"… 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…"

- Completed Jan 2015



Goals

- Provide a **Risk Management Framework**
- 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

- Developed a **comprehensive plan** to address vulnerable coastal communities and applied it at the study area scale (Tier 1)
- Formalized and **consistent approach/framework** for more detailed, site specific coastal evaluations
- **Integration** of state-of-the-science techniques and collaboration
- Interagency collaboration
  - Interagency stakeholder validation and input
  - Interagency Collaboration Webinar Series
  - Stakeholder review and validation
- Equip and link a broad audience and all levels of government with data, tools, and other stakeholders to make **INFORMED coastal risk management decisions**

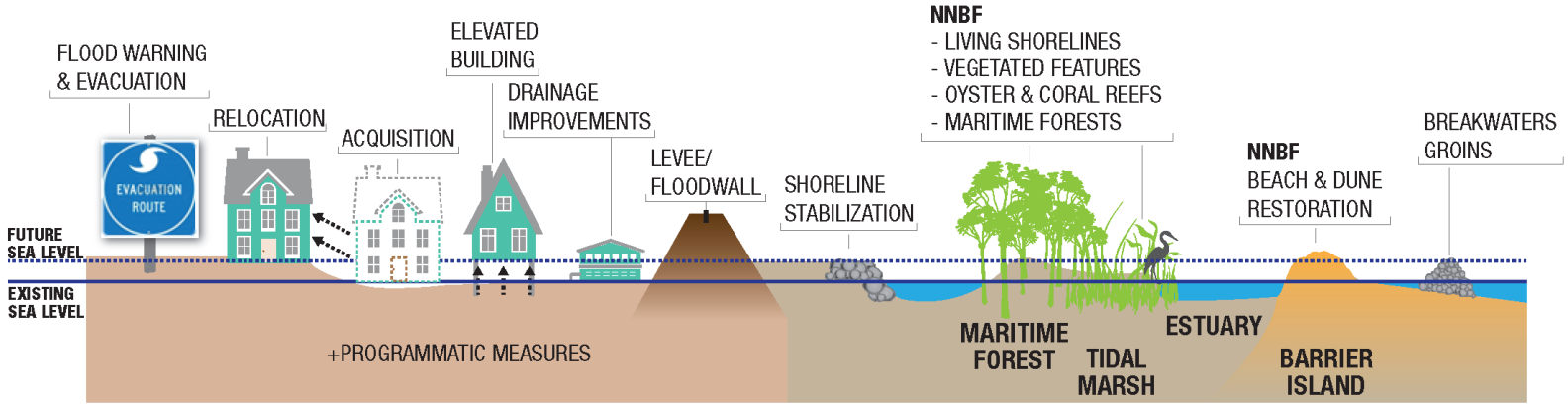
www.nad.usace.army.mil/CompStudy

➢ NACCS is *not*:

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

Findings

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



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Opportunities

- Mitigate future risk with **improve pre-storm planning**
- Identify acceptable **flood risk at a community** and state scale
- **Prioritize** critical infrastructure
- **Rebuild with redundancy**
- Encourage design **flexibility and adaptive management**
- Advance efforts in the nine 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

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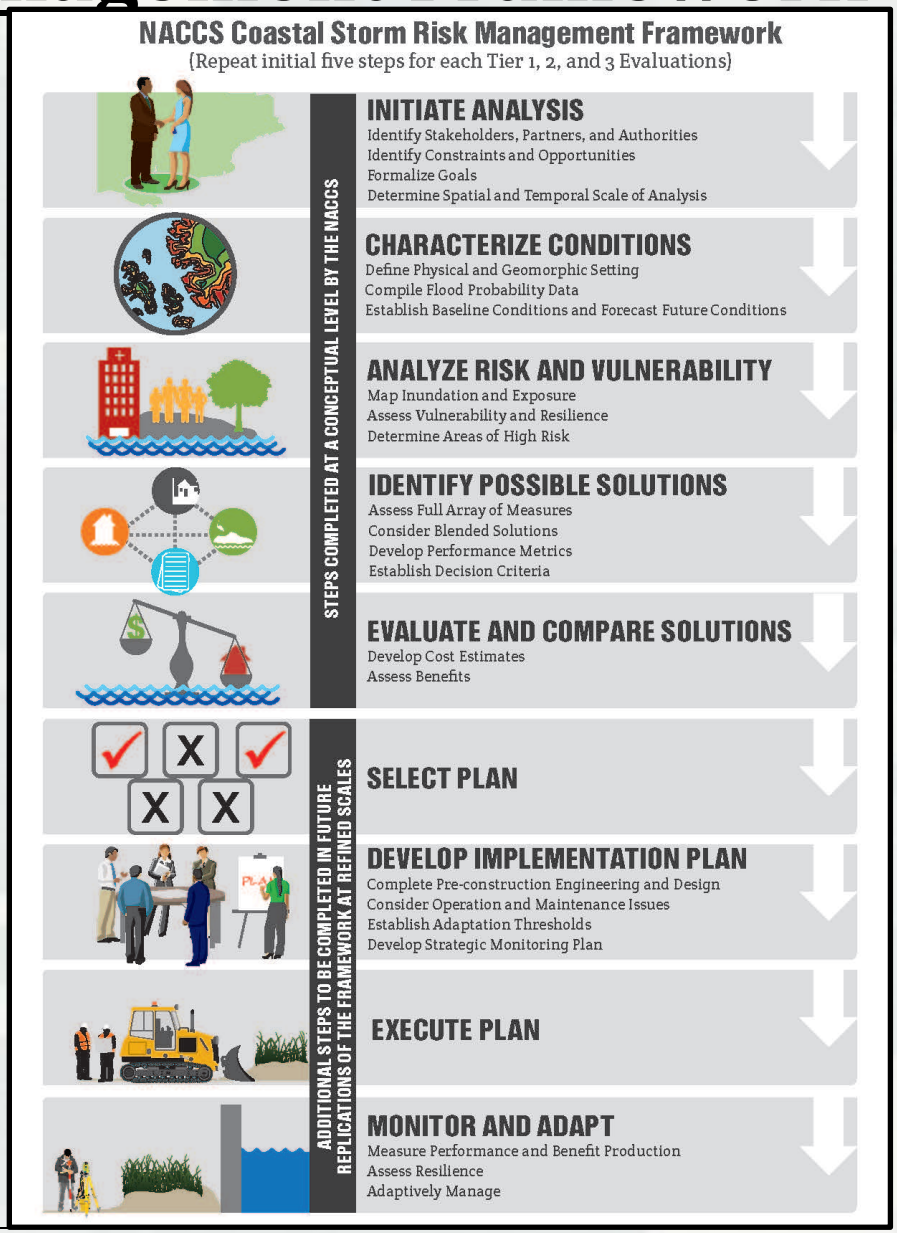
Coastal Storm Risk Management Framework

- **Where** is the flood risk?
  - Flood inundation mapping
- **Who and what** is exposed to flood risk?
  - Exposure, Risk, and Vulnerability
- What are the **appropriate strategies** and management measures to manage flood risk?
  - Avoid (sometimes termed "retreat"), accommodate, preserve (sometimes termed "protect")
  - Structural (including NNBF), non-structural, programmatic
- 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

- 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



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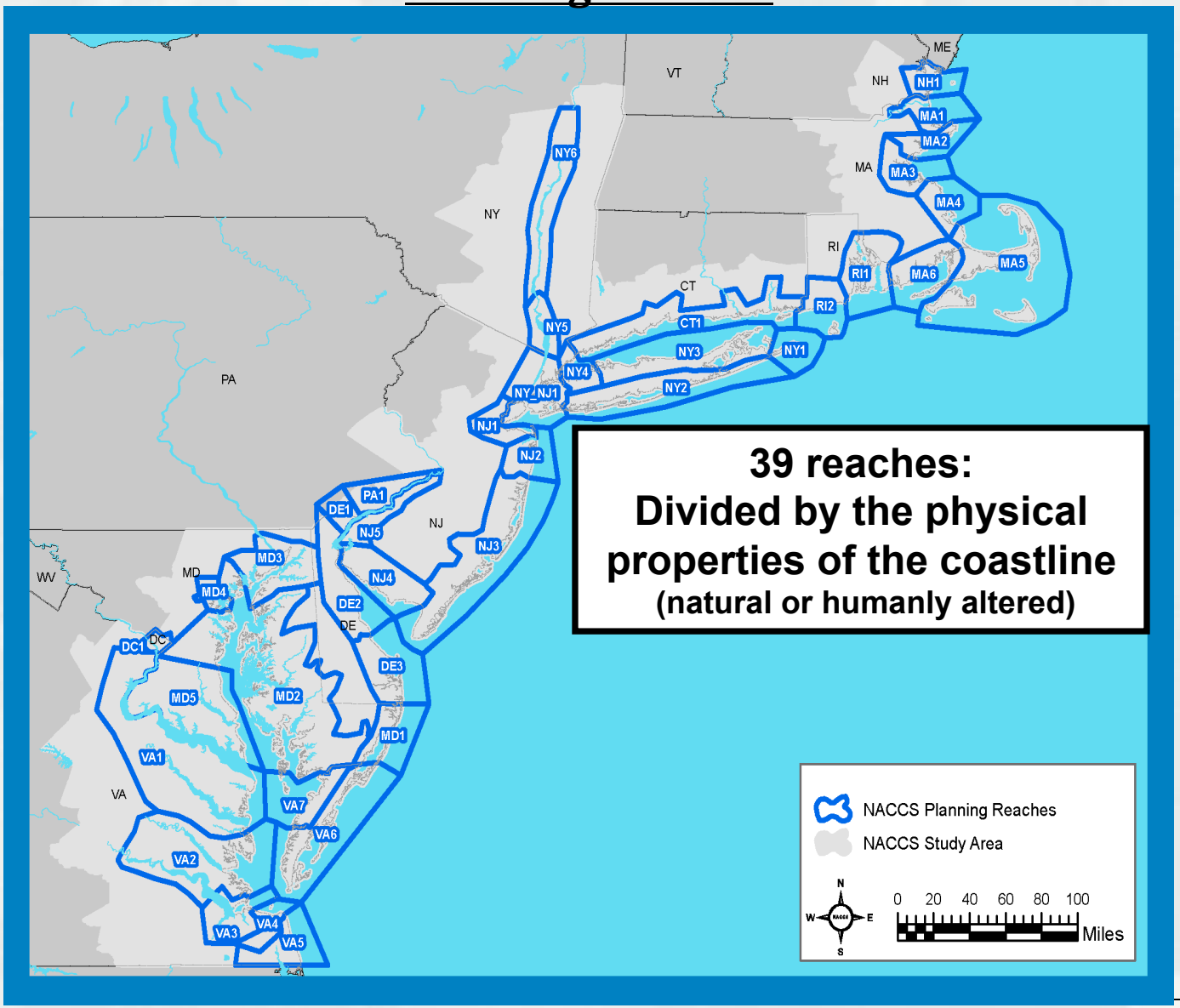
Coastal Storm Risk Management Framework

Planning Reaches



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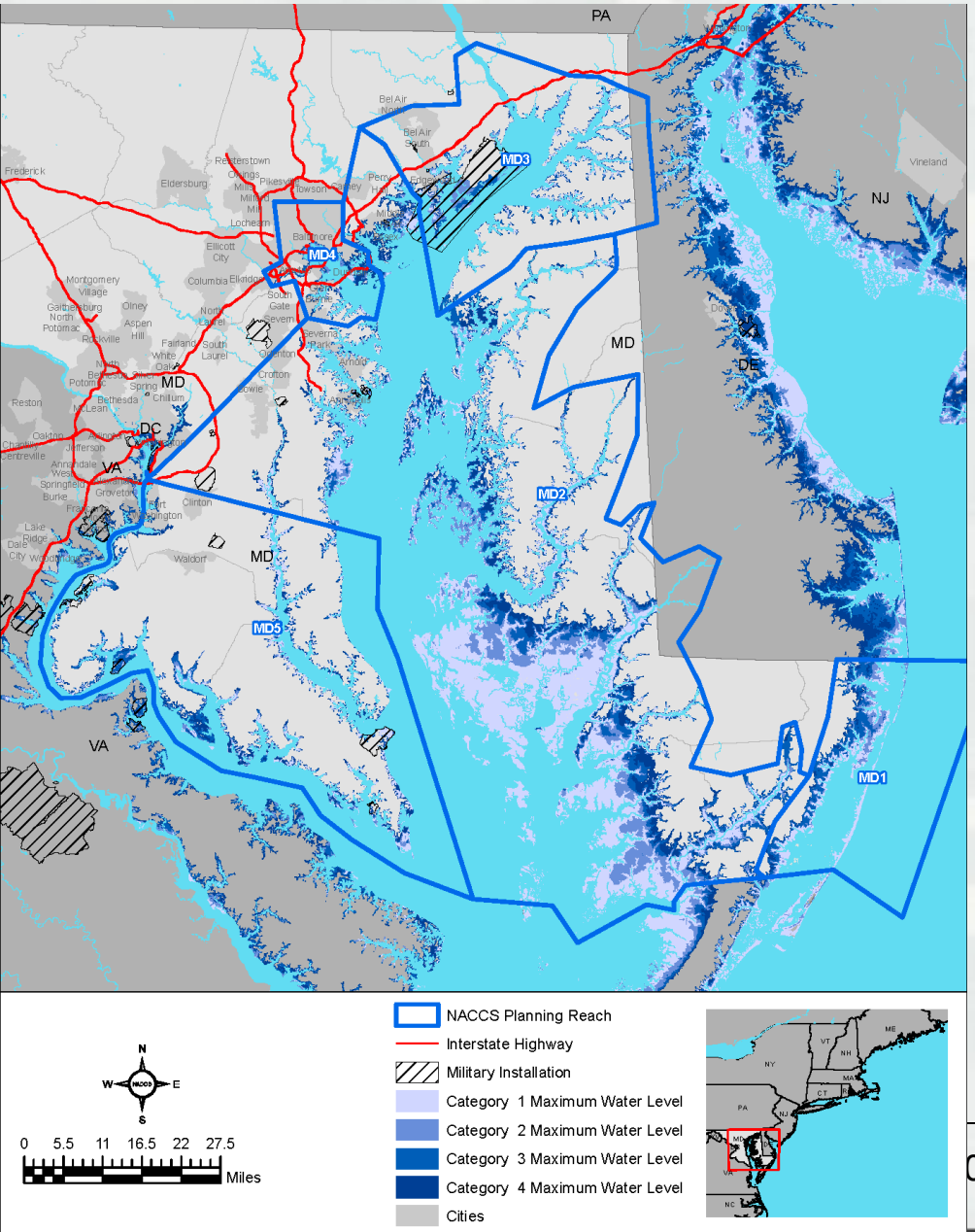
Coastal Storm Risk Management Framework

Existing/Future Conditions: Probability of Flooding



Widest Extent of Inundation

Hurricane Events Category 1-4

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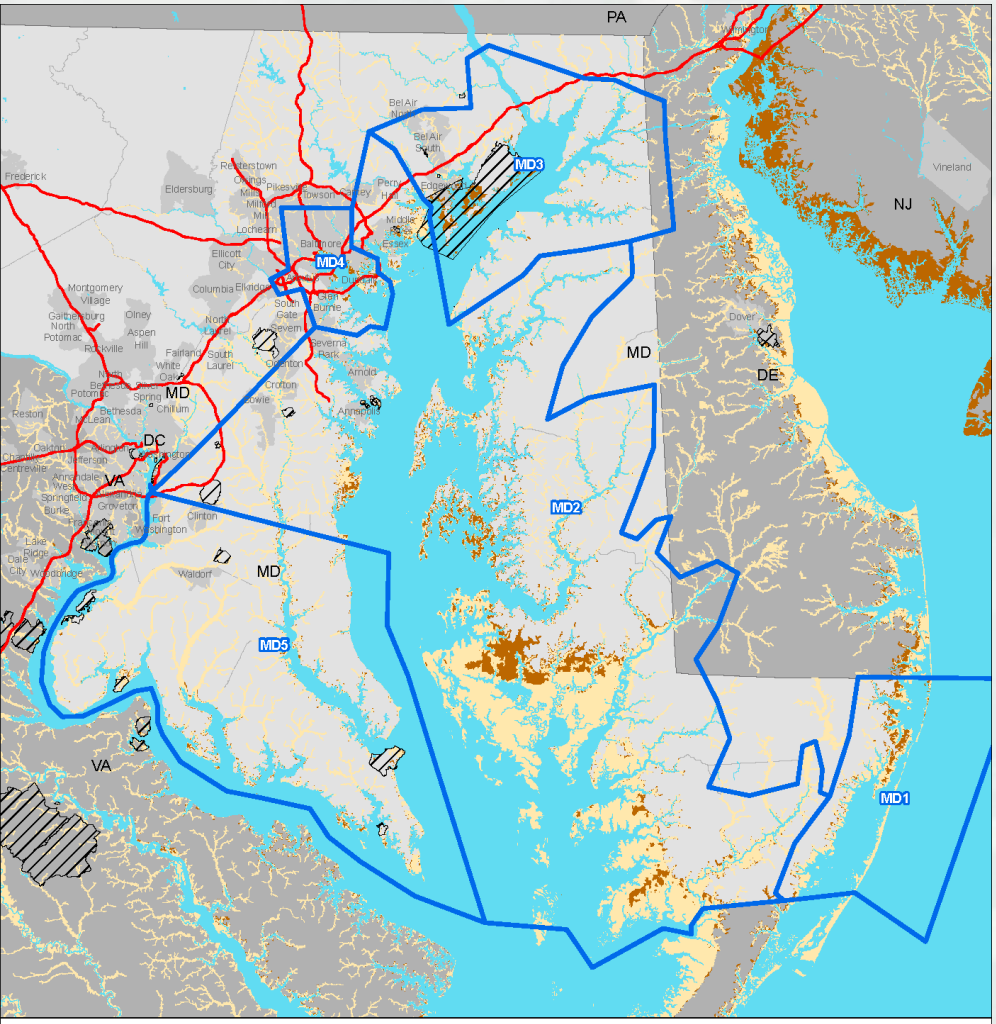
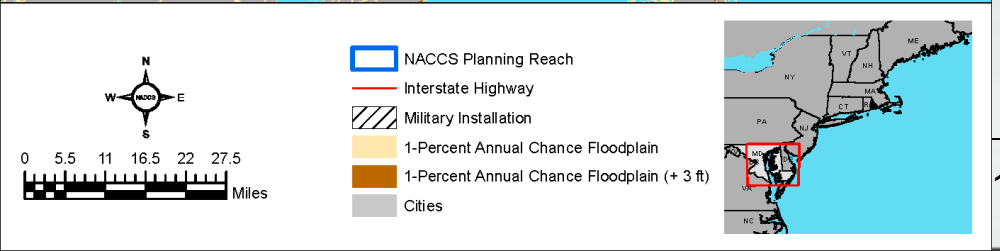
Coastal Storm Risk Management Framework

Existing/Future Conditions: Probability of Flooding





Extent of Inundation

1- Percent Floodplain

See Coastal Hazard System for updated, high-fidelity extreme water levels, including the 1-percent flood elevation at various save point locations: https://chs.erdc.dren.mil

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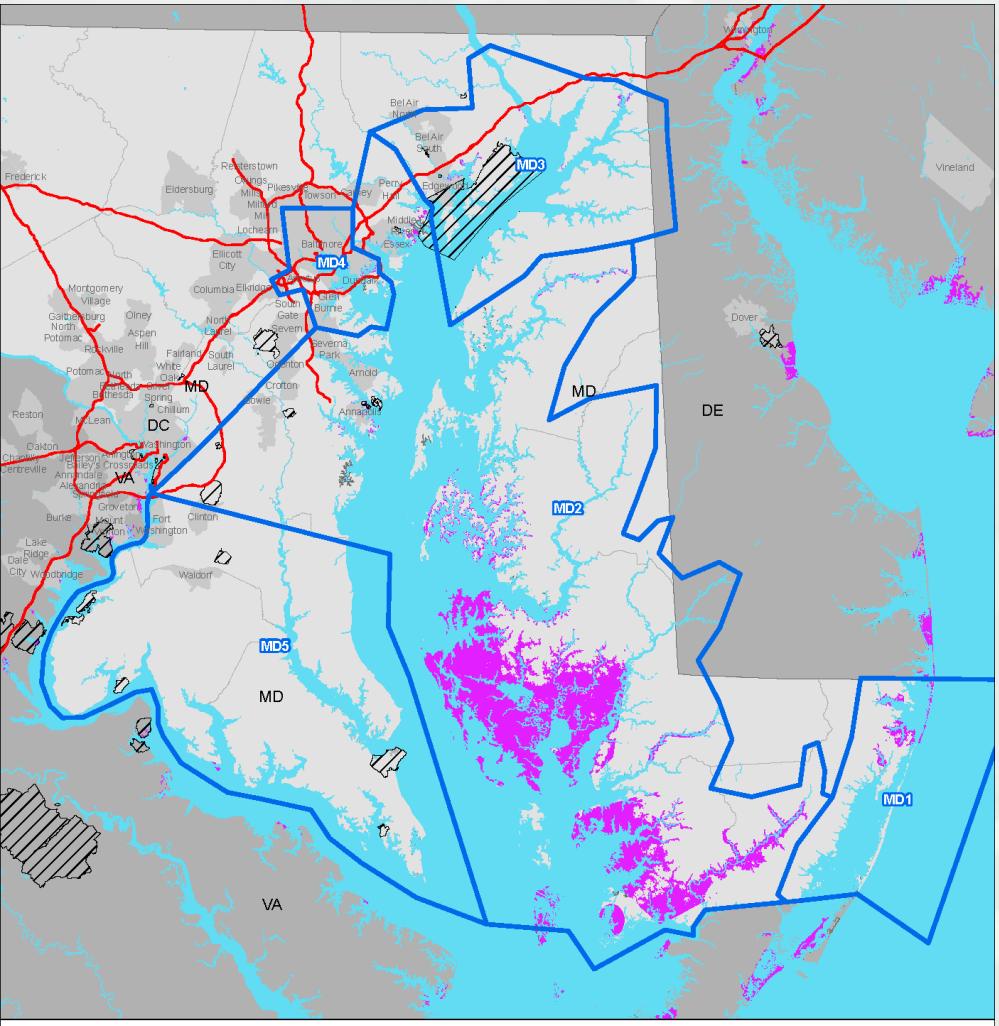
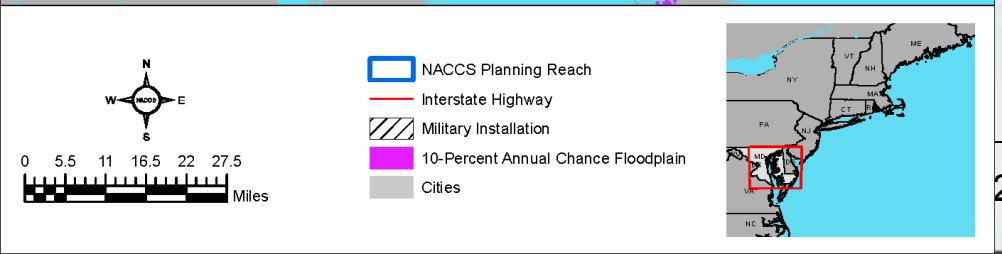
Coastal Storm Risk Management Framework

Existing/Future Conditions: Probability of Flooding



Extent of Inundation

10-Percent Floodplain

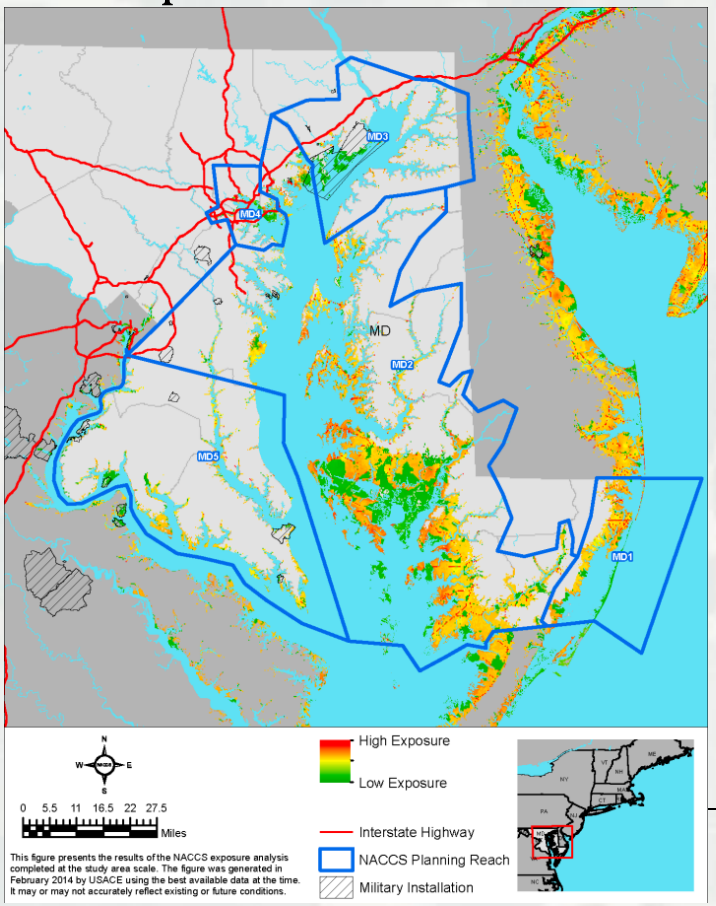


See Coastal Hazard System for updated, high-fidelity extreme water levels, including the 10-percent flood elevation at various save point locations: https://chs.erdc.dren.mil

Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

- **Coastal Flood Hazard**
  - SLOSH CAT1-4 Maximum of Maximum
  - FEMA DFIRM
  - 10-percent-annual chance



- **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**

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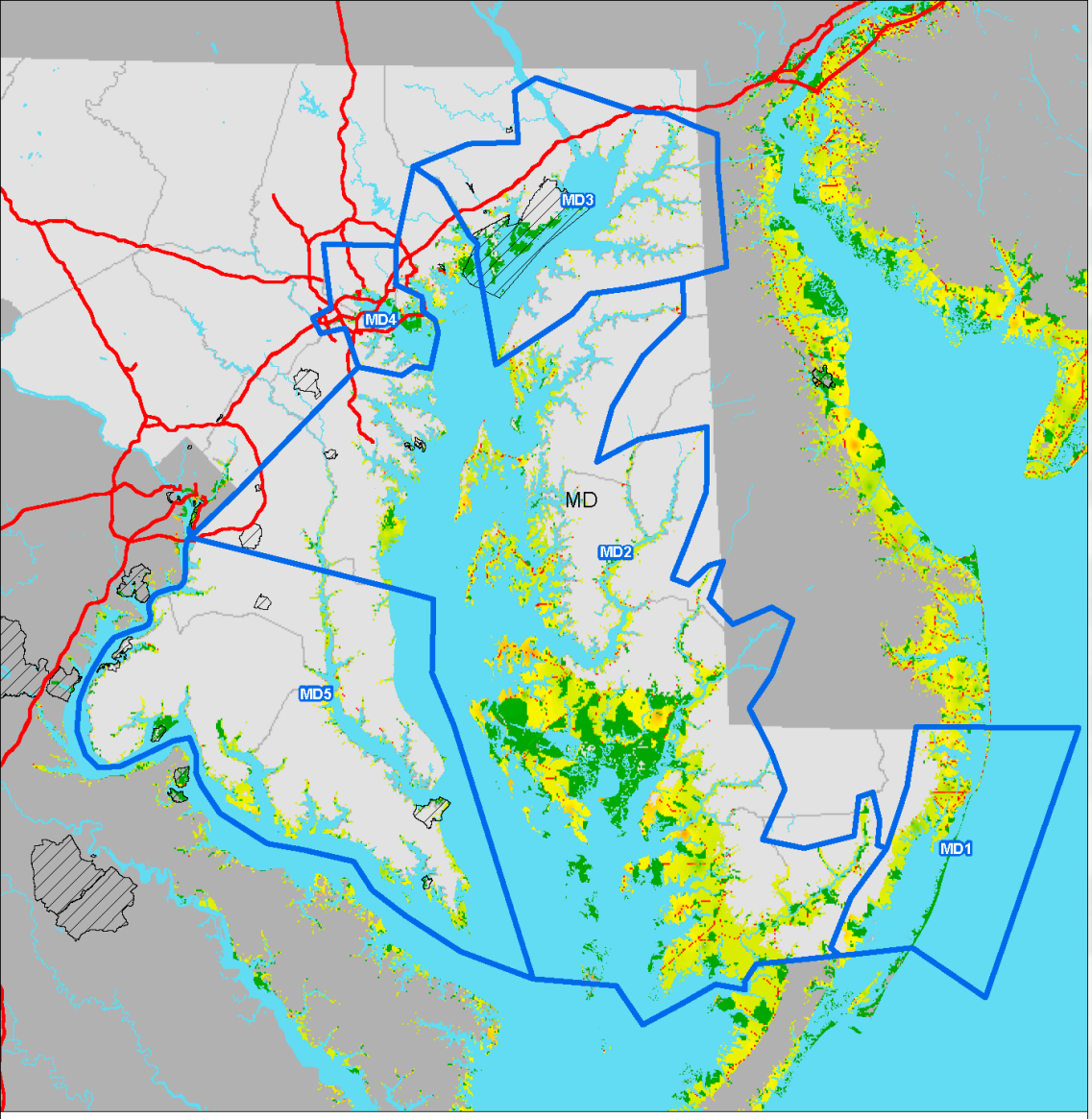
Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

Population and Infrastructure Exposure Index



N
W E
S

0 5.5 11 16.5 22 27.5 Miles

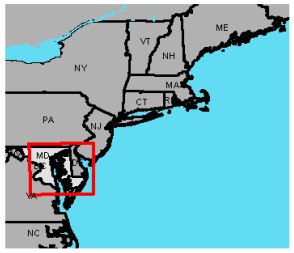
High Exposure

Low Exposure

Interstate Highway

NACCS Planning Reach

Military Installation



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.

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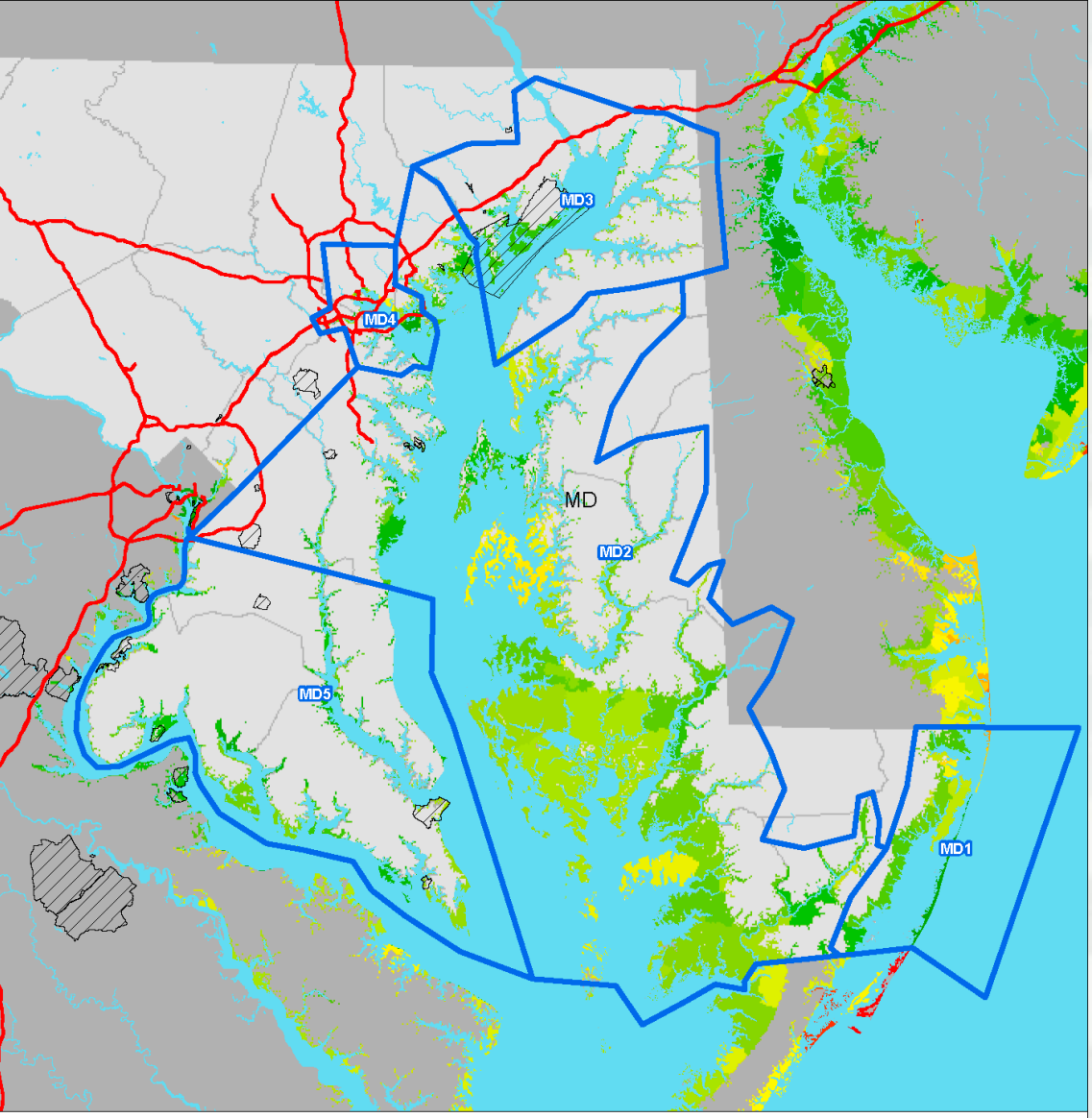
Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

Social Vulnerability Characterization Exposure Index



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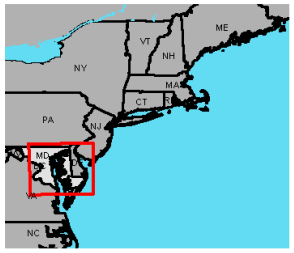

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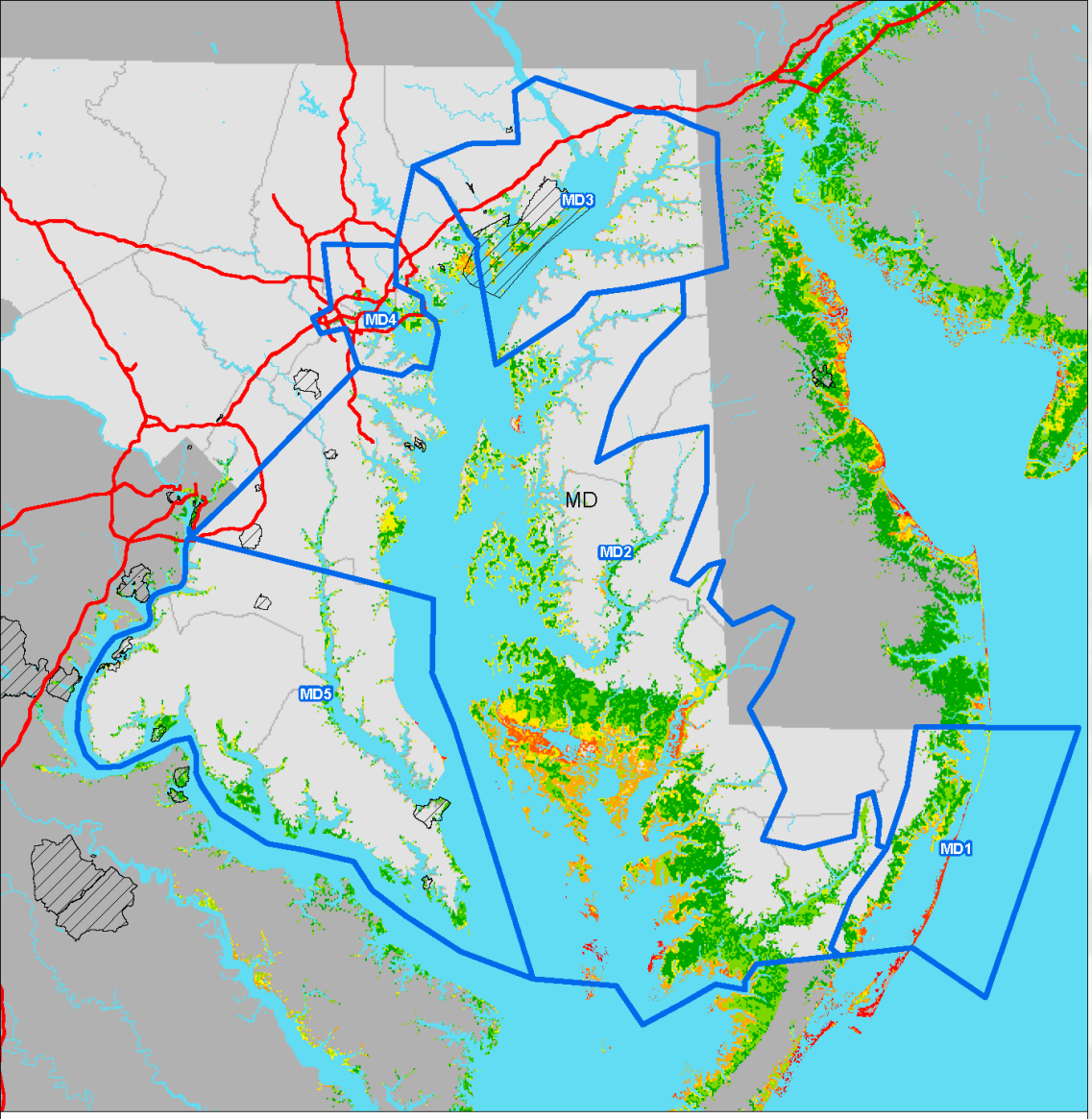
Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

Environmental and Cultural Exposure Index



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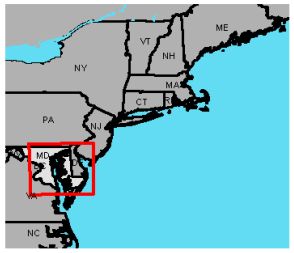
Miles

High Exposure
Low Exposure

Interstate Highway
NACCS Planning Reach
Military Installation



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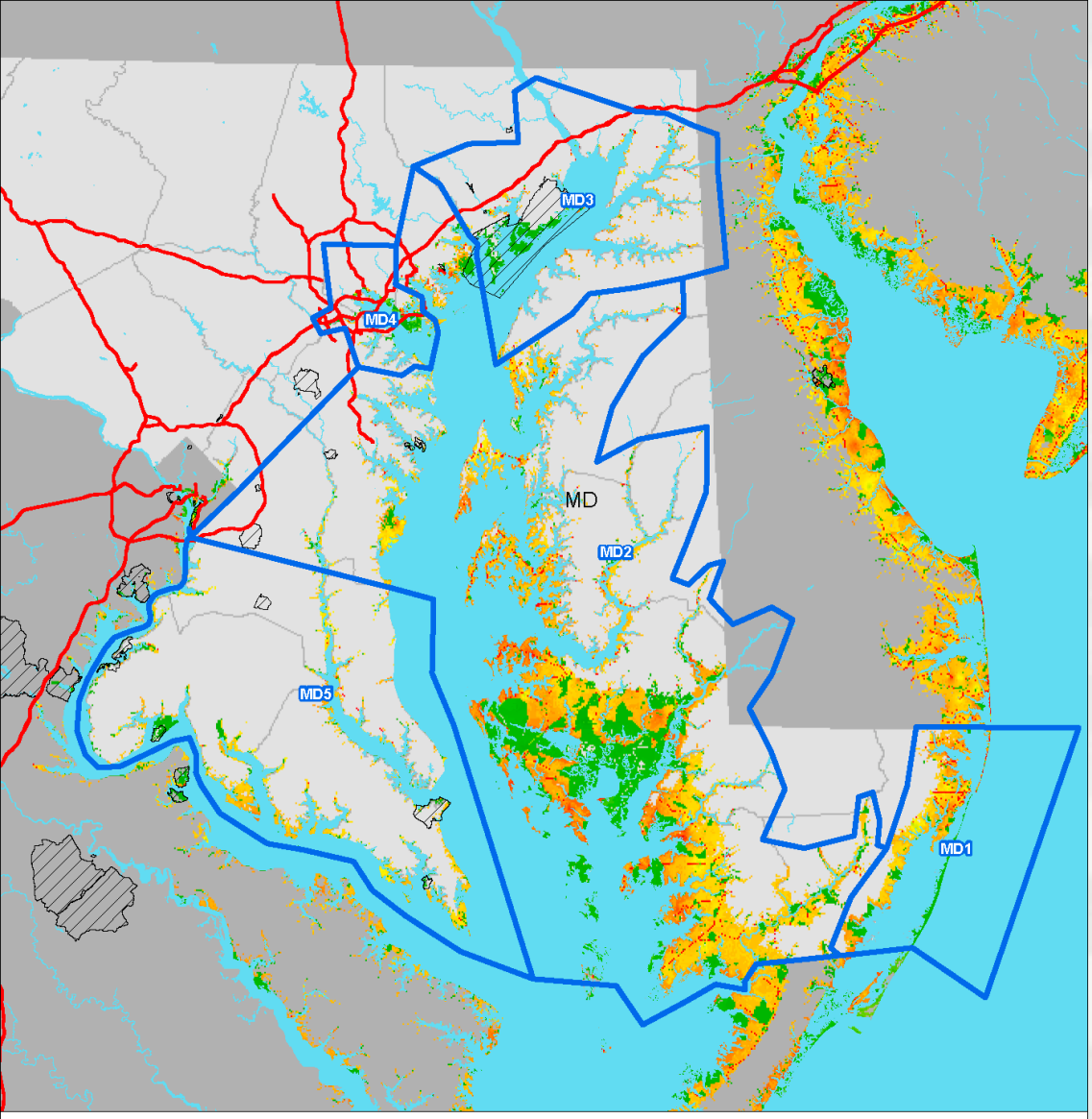
Coastal Storm Risk Management Framework

Flood Exposure & Risk Assessment

Composite Exposure Index



N
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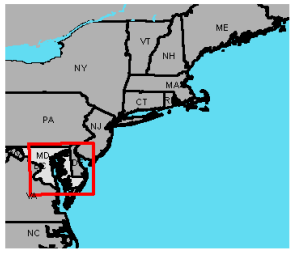
0 5.5 11 16.5 22 27.5
Miles

High Exposure
Low Exposure

Interstate Highway
NACCS Planning Reach
Military Installation



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Coastal Storm Risk Management Framework

Flood Exposure and Risk Assessment

- Greater risk based on proximity to flooding source
- Risk
  - Determine probability of the flood to occur times the consequences (exposure)
  - Multiply value in each pixel of the composite exposure grid by the probability of flooding
- Additional metrics to be considered at finer scales

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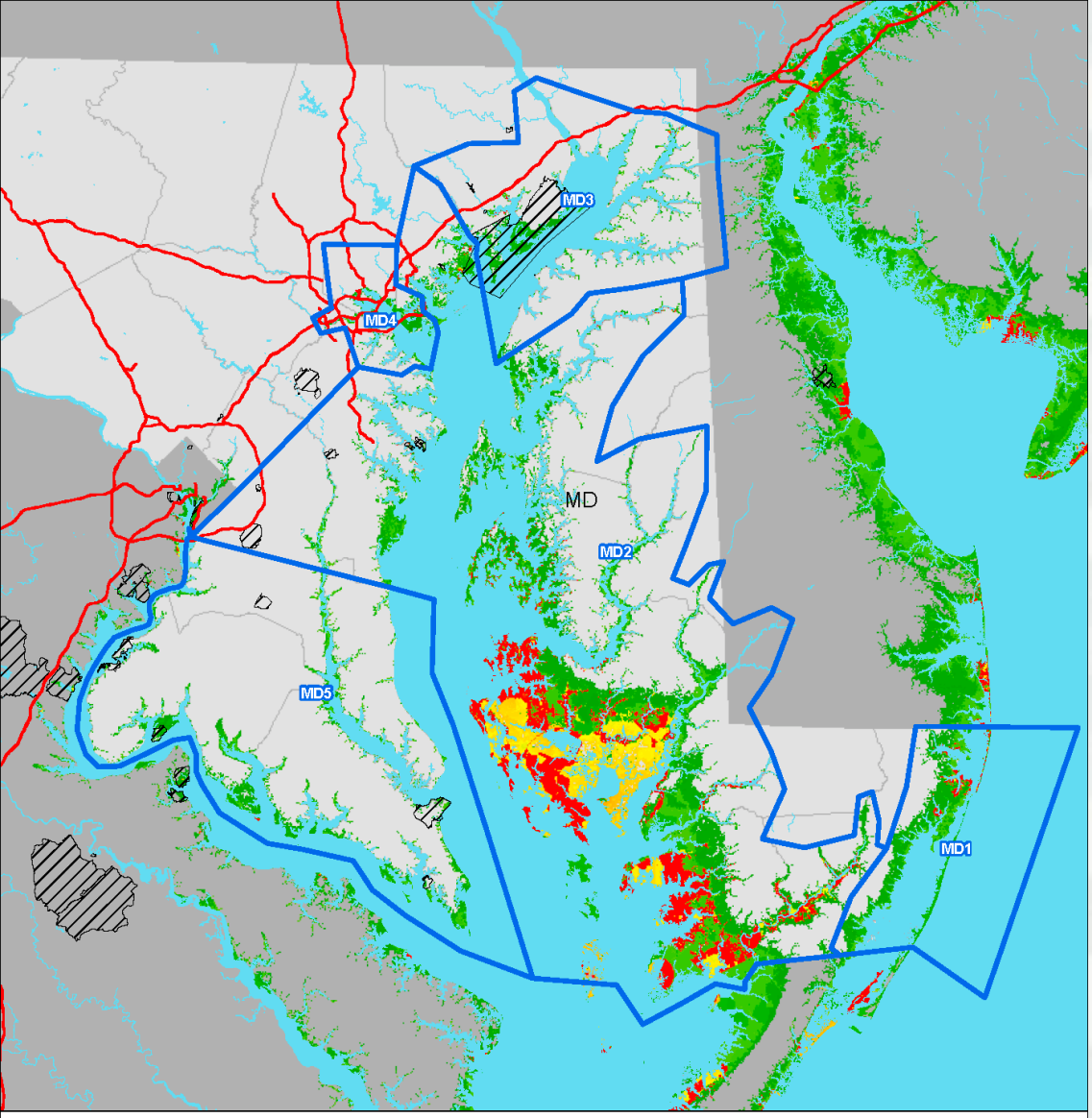
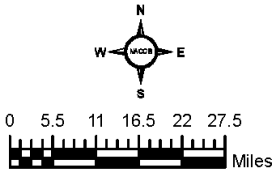
Coastal Risk Management Framework

Flood Exposure and Risk Assessment





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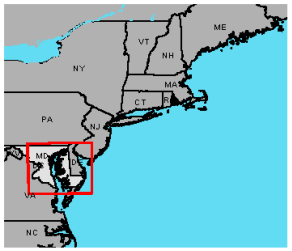
High Risk

Low Risk

NACCS Planning Reach

Interstate Highway

Military Installation



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Coastal Storm Risk Management Framework

Existing/Future Conditions: Sea Level Change

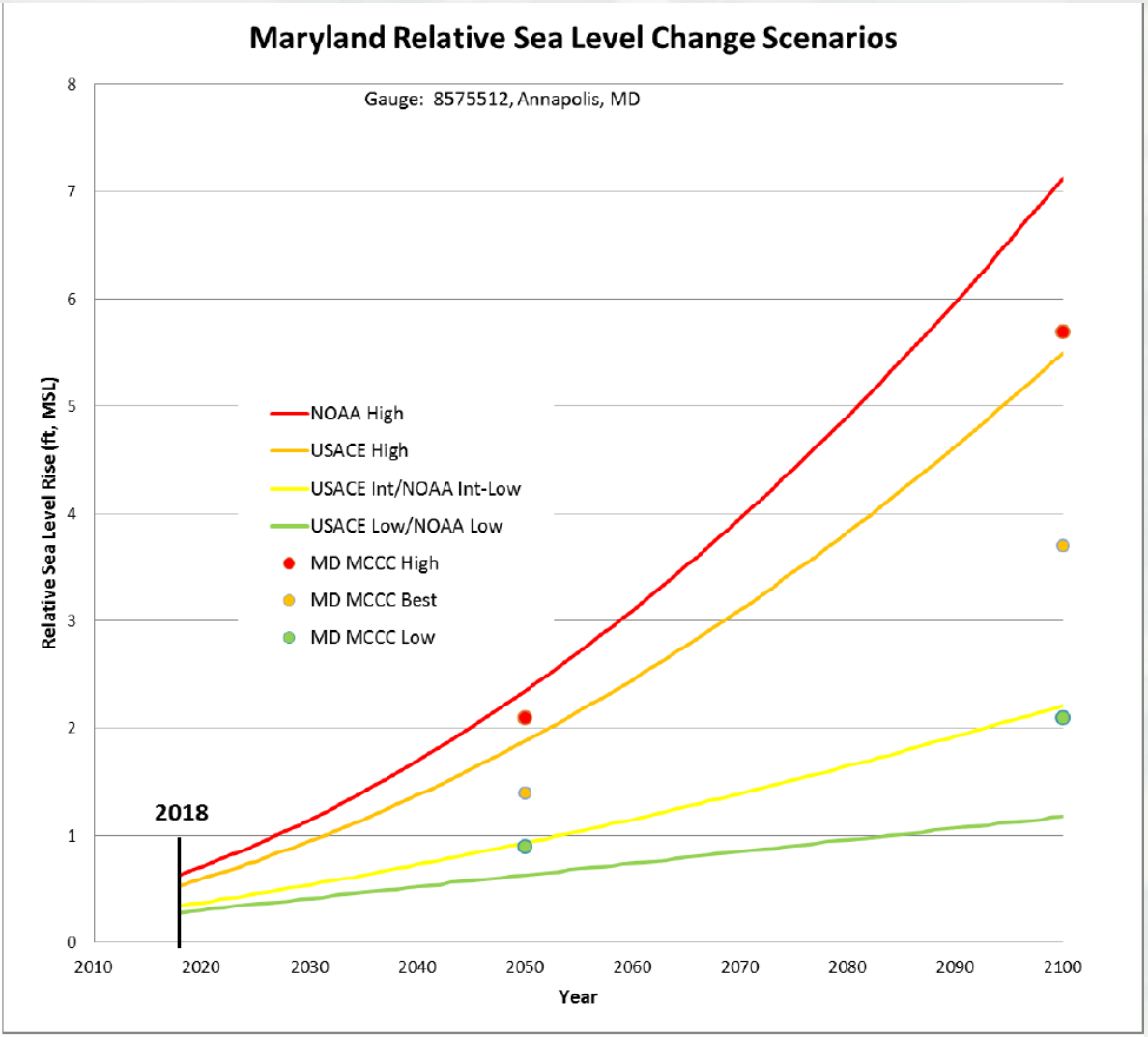


Figure 6. Relative Sea Level Change for Annapolis, MD for USACE and NOAA Scenarios and the State of Maryland.

- Evaluations for:
  - Current (2018)
  - 50-years (2068)
  - 2100

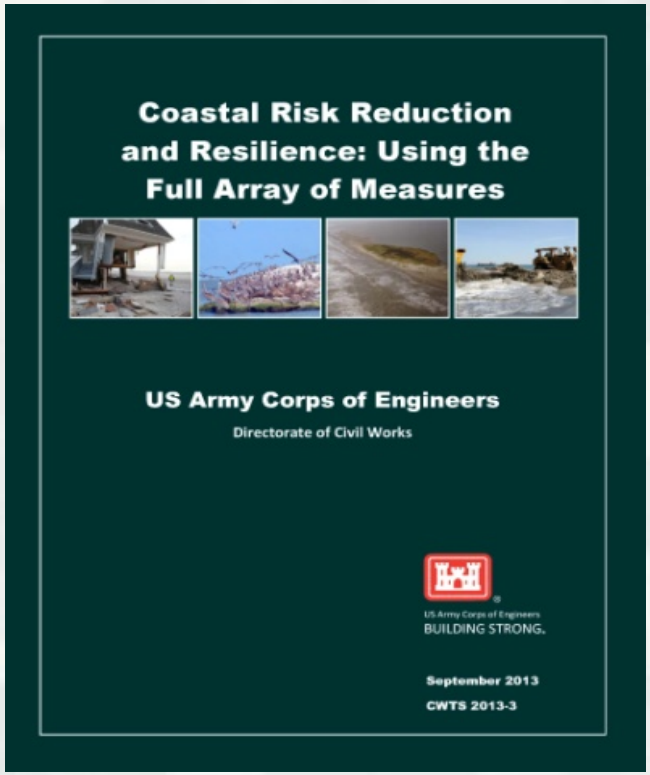
  (Intergovernmental Panel on Climate Change)

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

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.)

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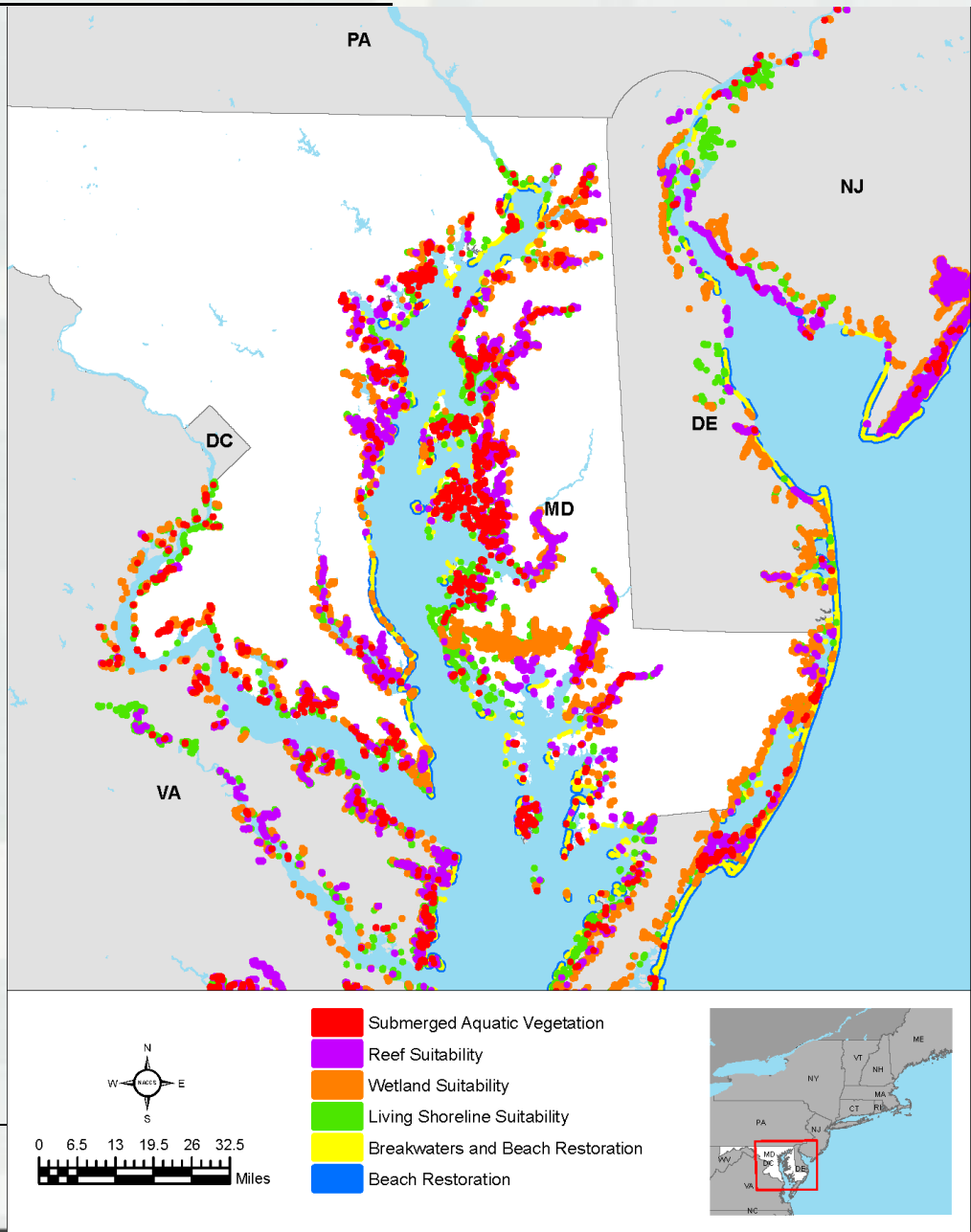
Coastal Storm Risk Management Framework:

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



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
  - Non-stationarity – the future may be substantially different than the past
  - Uncertainty – climate change and sea level change
    - Consideration of a range of possible future scenarios
    - Precipitation patterns and effects farther inland may result in increasing risk
    - Adaptive management

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Technical Products Supporting the Framework

NACCS Coastal Storm Risk Management Framework

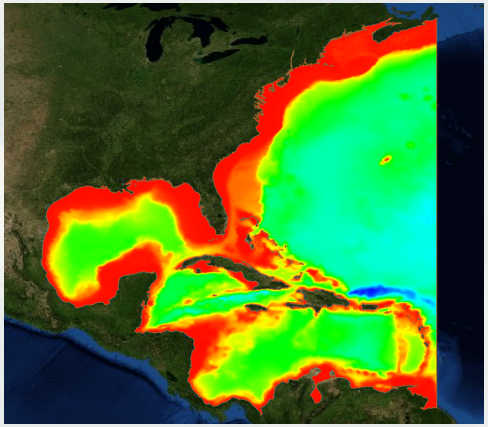
STEPS COMPLETED AT A CONCEPTUAL LEVEL BY THE NACCS

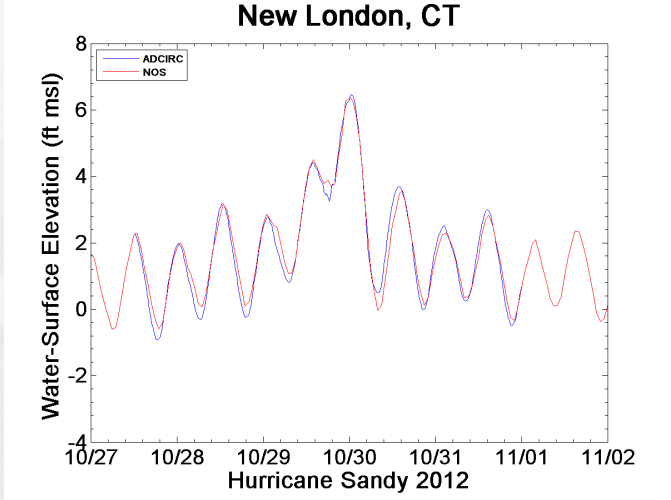
	Technical Products Advanced by NACCS to Close Identified Data Gaps
INITIATE ANALYSIS Identify Stakeholders, Partners, and Authorities Identify Constraints and Opportunities Formalize Goals	• Visioning Sessions Report & Focus Area Analyses • Institutional & Other Barriers Report
CHARACTERIZE EXISTING CONDITIONS Define Physical and Geomorphic Setting Compile Flood Probability Data Establish Baseline Conditions	• NACCS GIS Geodatabase • Environmental & Cultural Resources Conditions Report
ANALYZE VULNERABILITY AND RISK Map Inundation and Exposure Assess Vulnerability and Resilience Determine Areas of High Risk	• Storm Suite Modeling • NACCS GIS Geodatabase • NACCS Barrier Island Sea Level Rise Inundation Assessment Report
IDENTIFY POSSIBLE SOLUTIONS Assess Full Array of Measures Consider Blended Solutions Develop Performance Metrics Establish Decision Criteria	• Natural & Nature-Based Features Report • Conceptual Regional Sediment Budget • State Appendix • Vulnerability Decision Tree
EVALUATE AND COMPARE SOLUTIONS Develop Cost Estimates Assess Benefits	• Enhanced Depth-Damage Functions for Coastal Storms

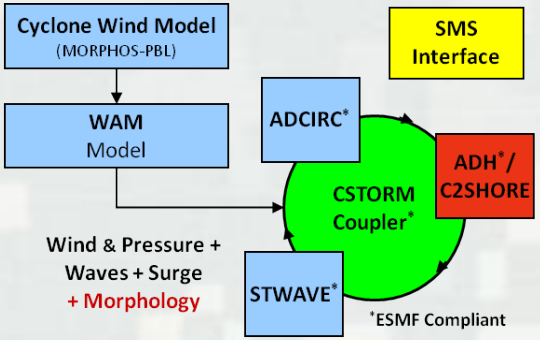
Several products, planning tools, and models were developed to assist decision makers in going through the Coastal Storm Risk Management Framework

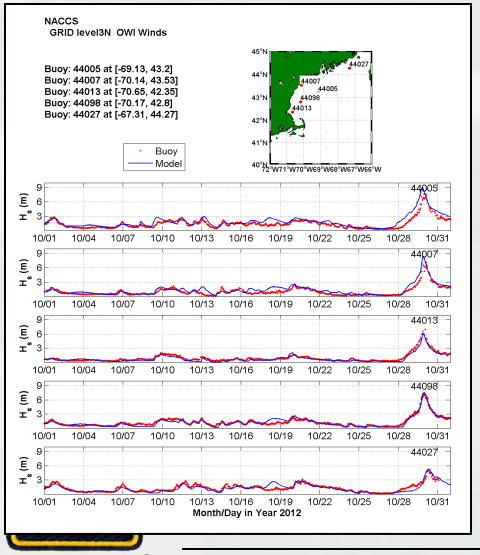
Technical Products Supporting the Framework

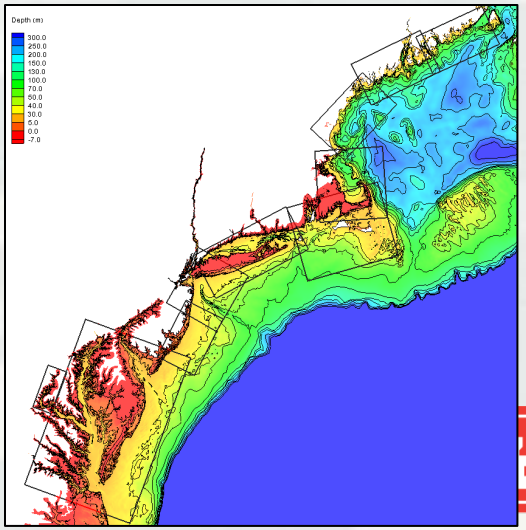
High-Fidelity Modeling

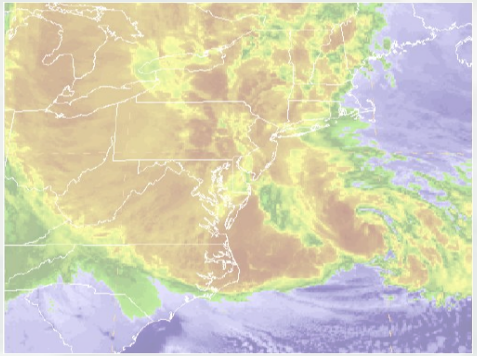






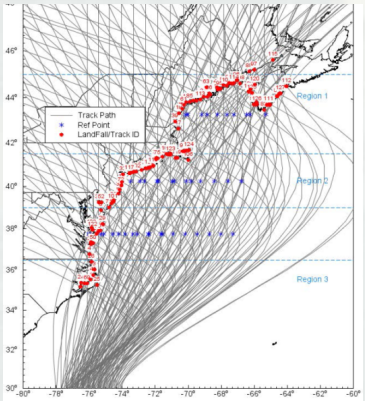






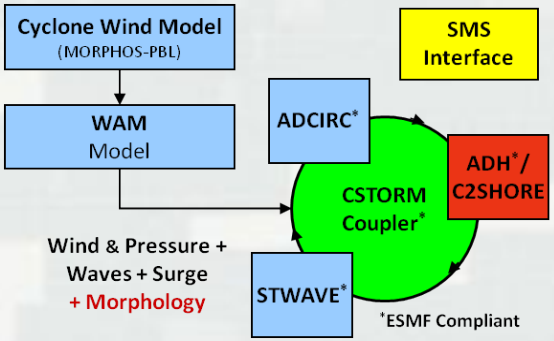
1050 synthetic tropical storms
100 historical extratropical storms

1150 simulation storm suite

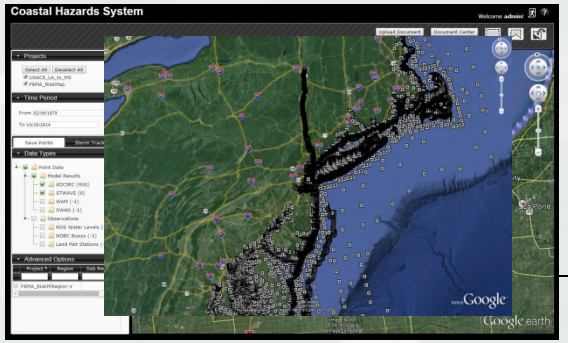


Base | **With Tide/River Inflow** | **With Tide/River Inflow/SLC**

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

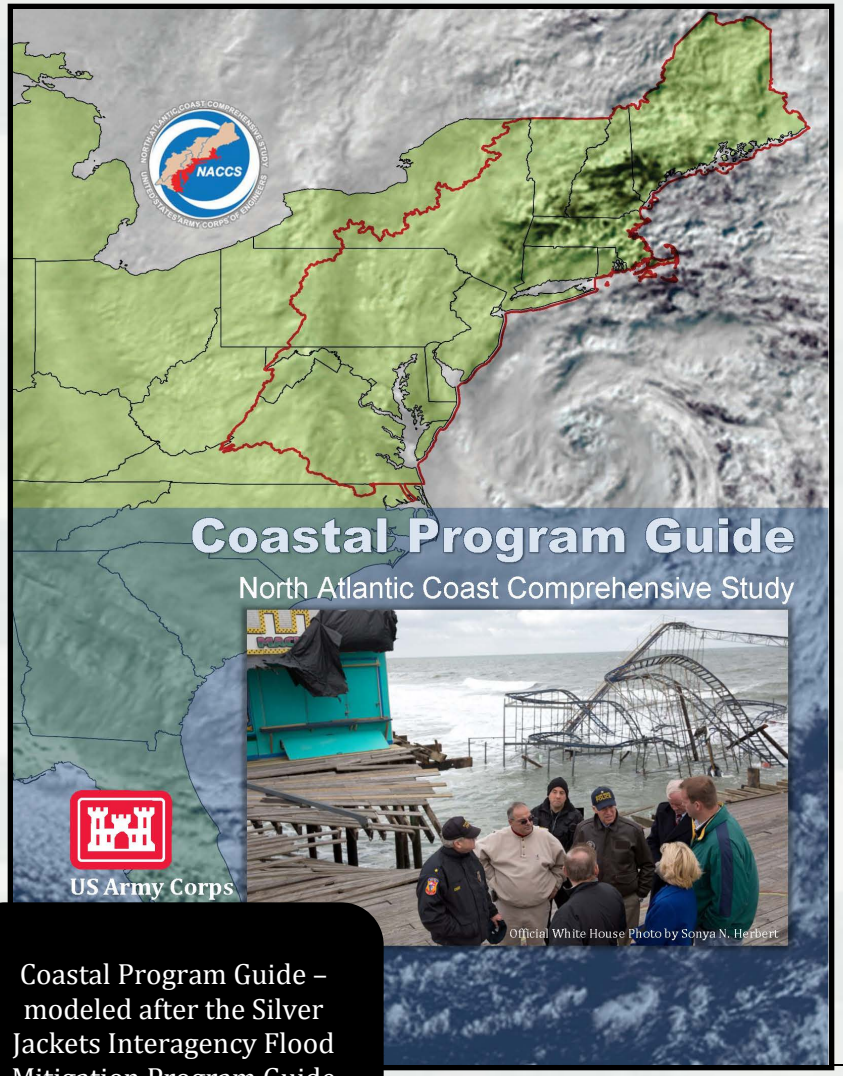


3450 storms simulated x ~19000 save point locations
Model results, time series plots, and statistics available through
The Coastal Hazards System
https://chs.erdc.dren.mil



Technical Products Supporting the Framework

Coastal Program Guide



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

U.S. Fish and Wildlife Planning Aid Report

FWS Planning Aid Report to USACE modified to support the NACCS

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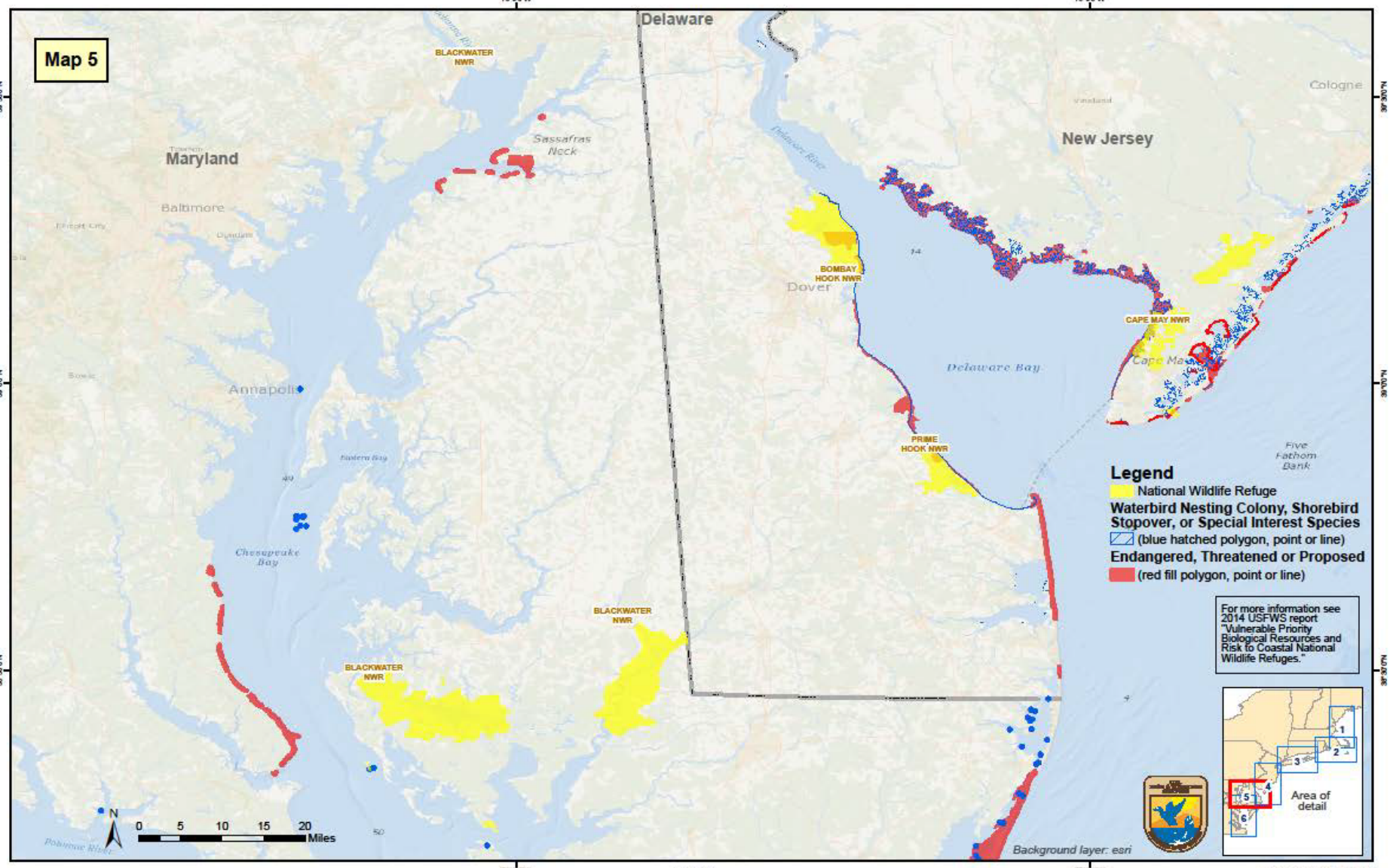
Sea Level Change

- Effects on
  - Tidal marshes
  - Ocean coasts
  - Estuarine and coastal bay shorelines
  - Estuarine and coastal bays aquatic habitats
- Conclusion
  - Tidal marshes, ocean coasts, estuarine shorelines and estuarine aquatic habitat will be affected by accelerated SLR
  - Effects on natural functioning ecosystems is complicated because of their dynamic nature
  - Will increase coastal retreat and wetland loss
  - Uncertainty in forecasting effects on species is greater because of need to consider specific species-habitat relationships and interactions between species

Vulnerable Resources and Wildlife Refuges

- Changes in coastal habitats as a result of SLR and storm activity will have important consequences for biological resources
- Effects on T&E species particular concern
- Waterbird nesting and concentration areas especially vulnerable
- NWRs along coast at risk and steps being taken to reduce risk
- Report focuses on resources and refuges most at risk
- Covers Virginia through Maine

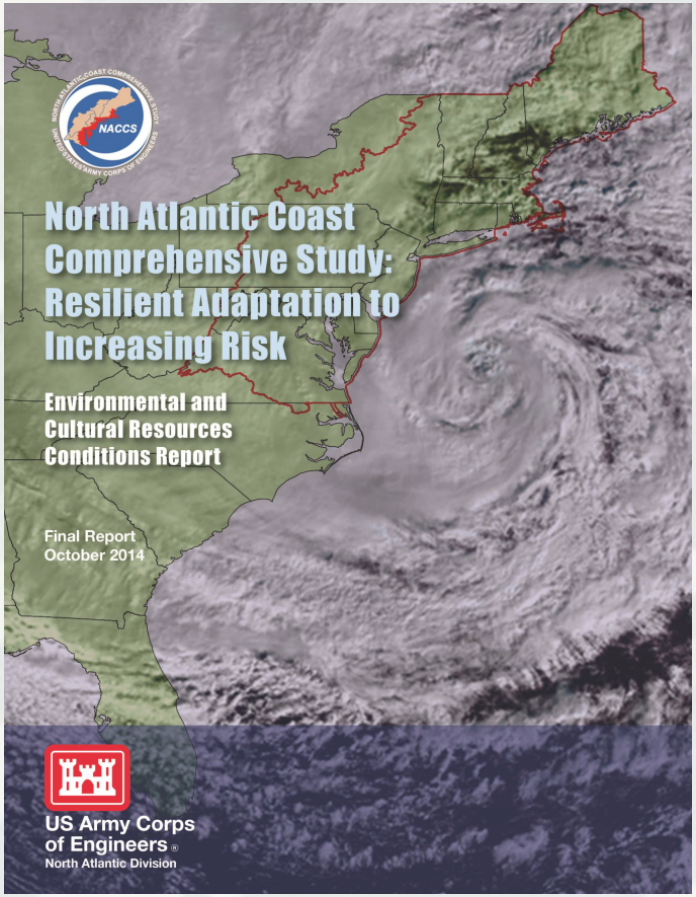
Example – Summary Map



BHouston 2 April 2014 Map #568

NACCS – Environmental and Cultural Resources Conditions Report

- Contains information on existing coastal and cultural resource characteristics, habitat impacts from Hurricane Sandy, and future environmental conditions
- Coastal habitat include area between open water and developed or agricultural lands
- Impacts occur over time as terrestrial habitats are converted to open water
- Other possible impacts of climate change i.e. storm frequency and intensity considered
- Existing conditions includes implementation action through 2018



NACCS – Environmental and Cultural Resources Conditions Report

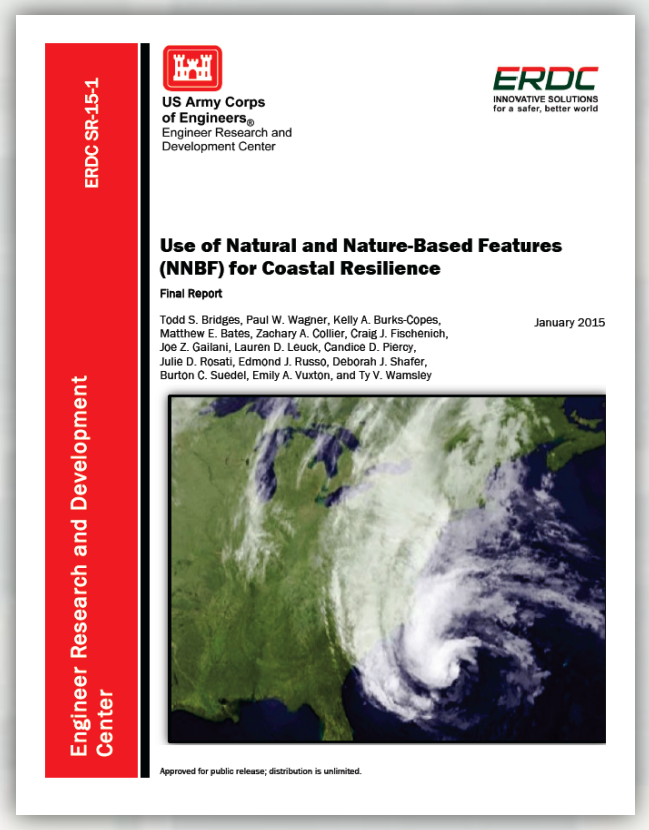
- Separate chapter on Cultural and Tribal Resources

- Information
  - Presented as bulleted list of details
  - Can be extracted to support project NEPA compliance documents or other reports
  - Presented by state, specific location, habitat type, and/or species

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

Technical Products Supporting the Use of NNBF to Promote Coastal Resiliency

- 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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Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience

Final Report

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January 2015

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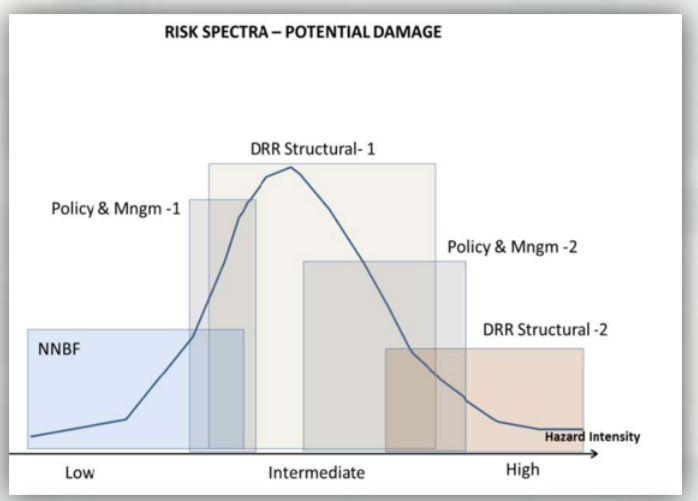
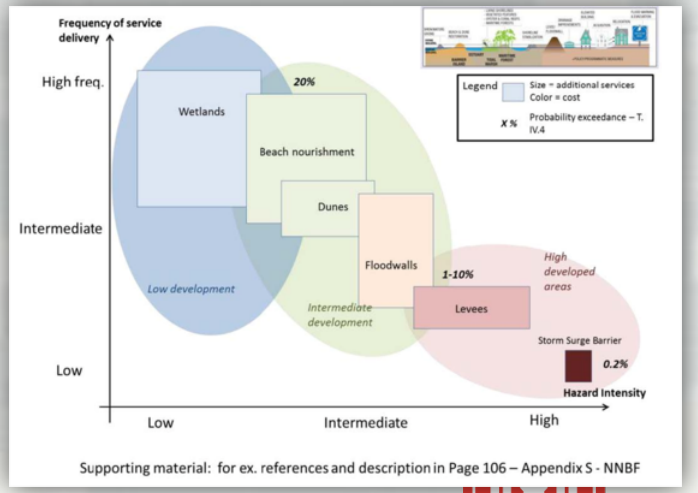
Natural and Nature-Based Features at a Glance

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
Benefits/Processes Breaking of offshore waves Attenuation of wave energy Slow inland water transfer	**Benefits/Processes** Breaking of offshore waves Attenuation of wave energy Slow inland water transfer Increased infiltration	**Benefits/Processes** Breaking of offshore waves Attenuation of wave energy Slow inland water transfer	**Benefits/Processes** Wave attenuation and/or dissipation Sediment stabilization	**Benefits/Processes** Wave attenuation and/or dissipation Shoreline erosion stabilization Soil retention
Performance Factors Berm height and width Beach slope Sediment grain size and supply Dune height, crest, and width Presence of vegetation	**Performance Factors** Marsh, wetland, or SAV elevation and continuity Vegetation type and density	**Performance Factors** Marsh, wetland, or SAV elevation and continuity Vegetation type and density	**Performance Factors** Marsh, wetland, or SAV elevation and continuity Vegetation type and density	**Performance Factors** Marsh, wetland, or SAV elevation and continuity Vegetation type and density



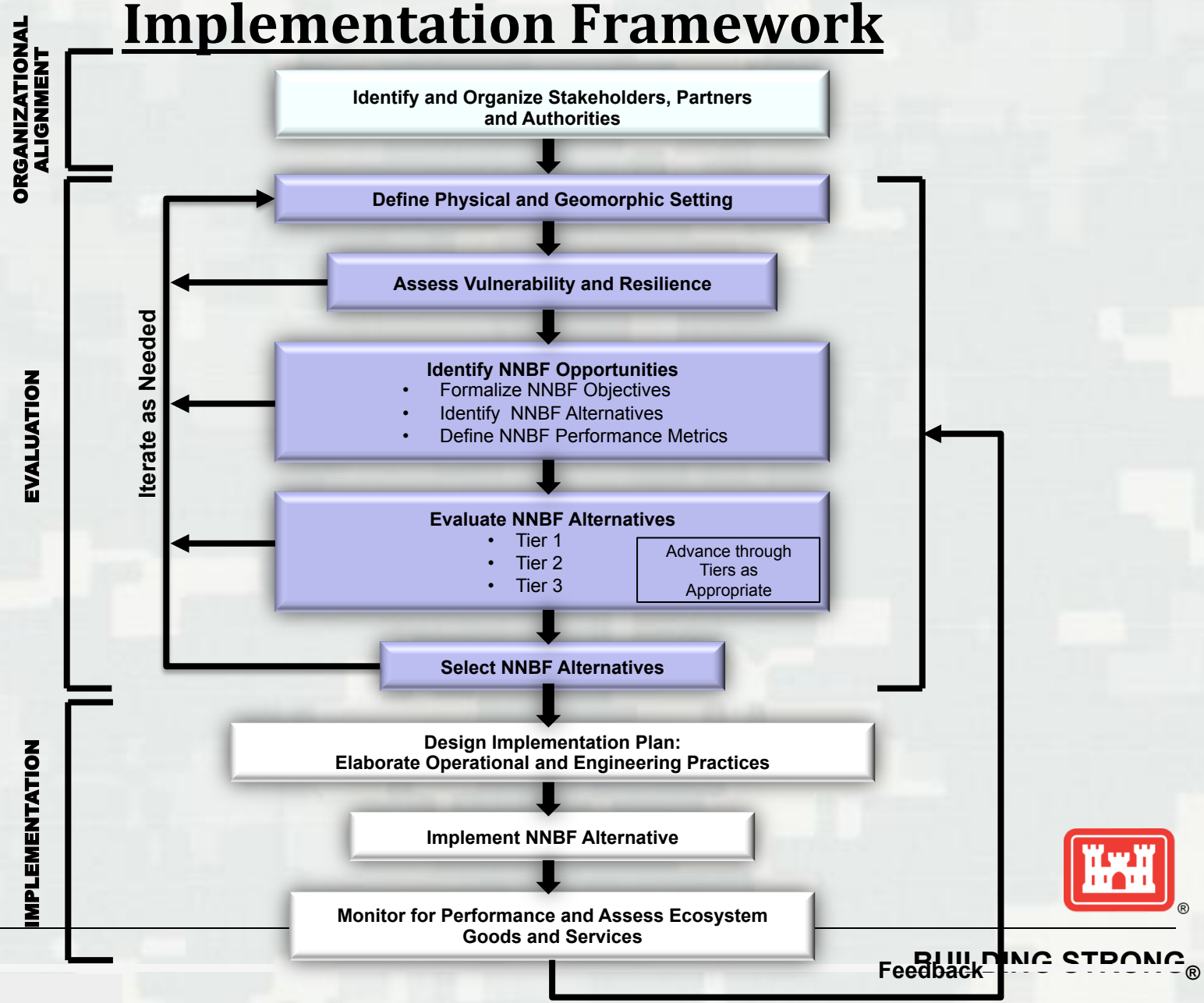


Supporting material: for ex. references and description in Page 106 – Appendix S - NNBF

http://www.corpsclimate.us/ccacrrr.cfm

Reguero et al. 2014 (in press)

Natural and Nature-Based Features Evaluation and Implementation Framework



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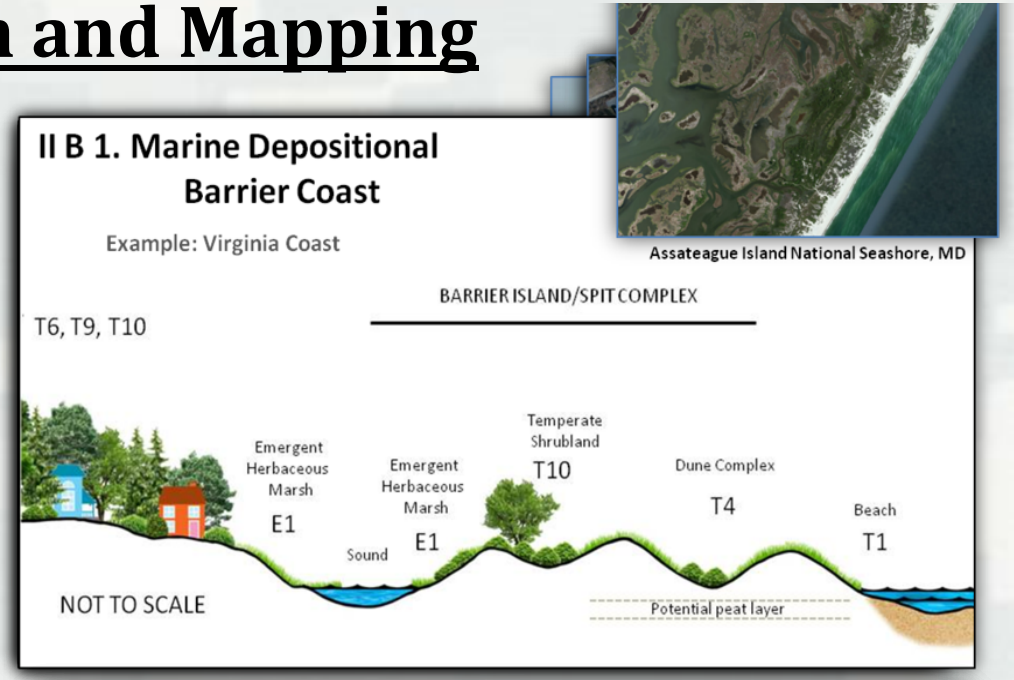
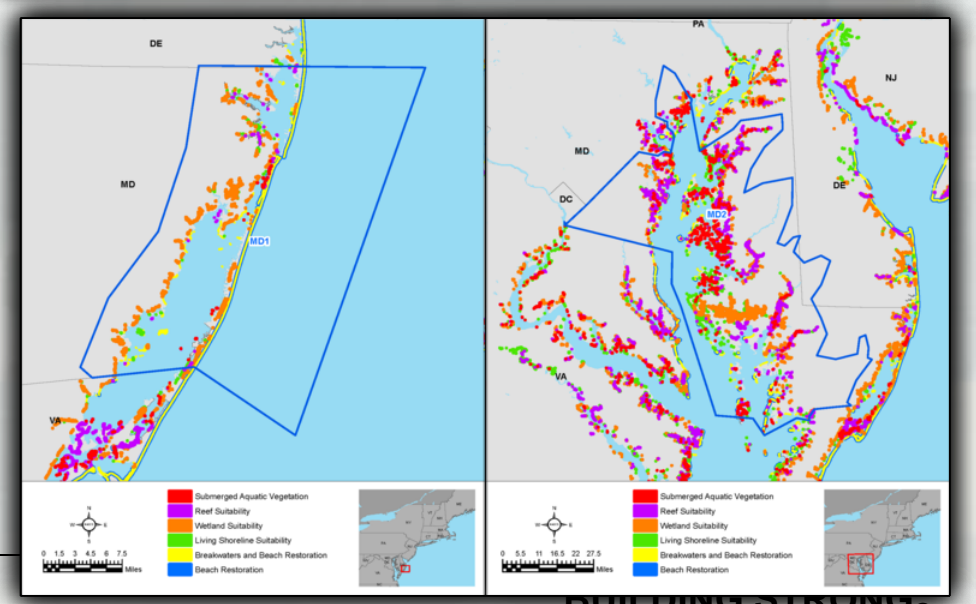
NNBF Characterization and Mapping

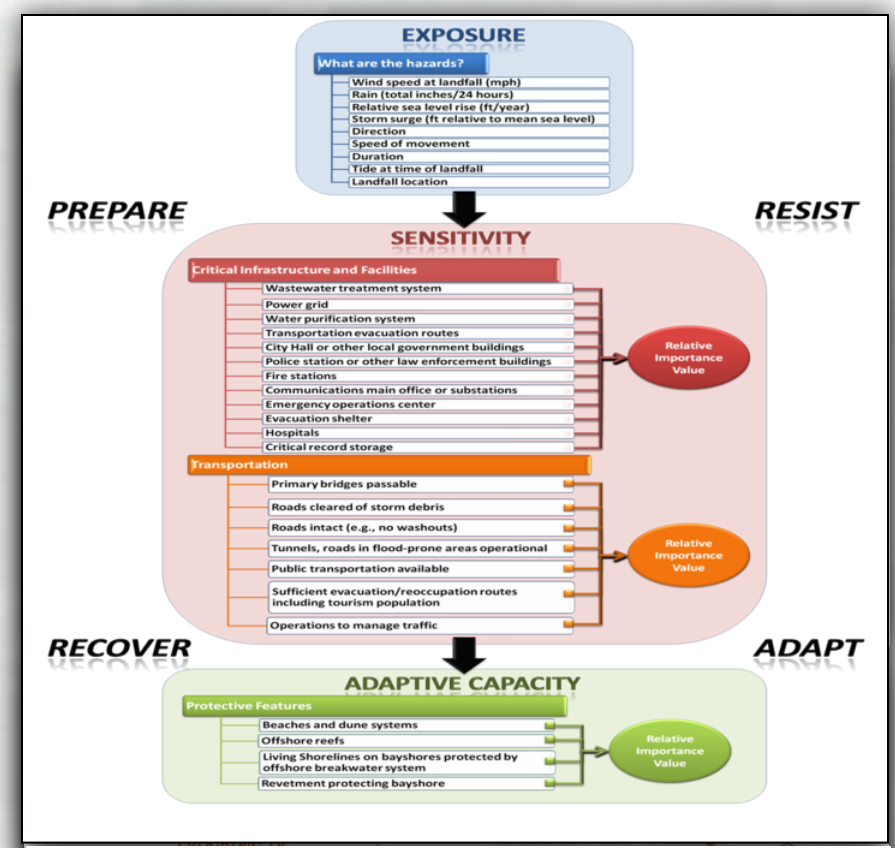
- **Characterization** geomorphological & vegetative cross sections
- **Form and function** processing
- **System-wide** mapping
- **Cost** derivations



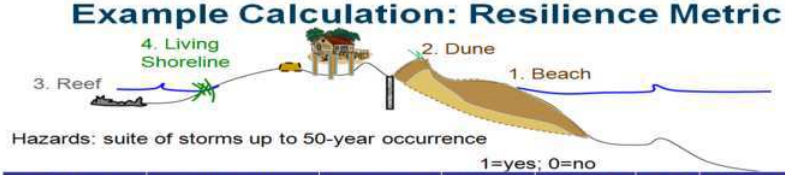


NNBF Vulnerability and Resilience

- **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



Example Calculation: Resilience Metric



Hazards: suite of storms up to 50-year occurrence

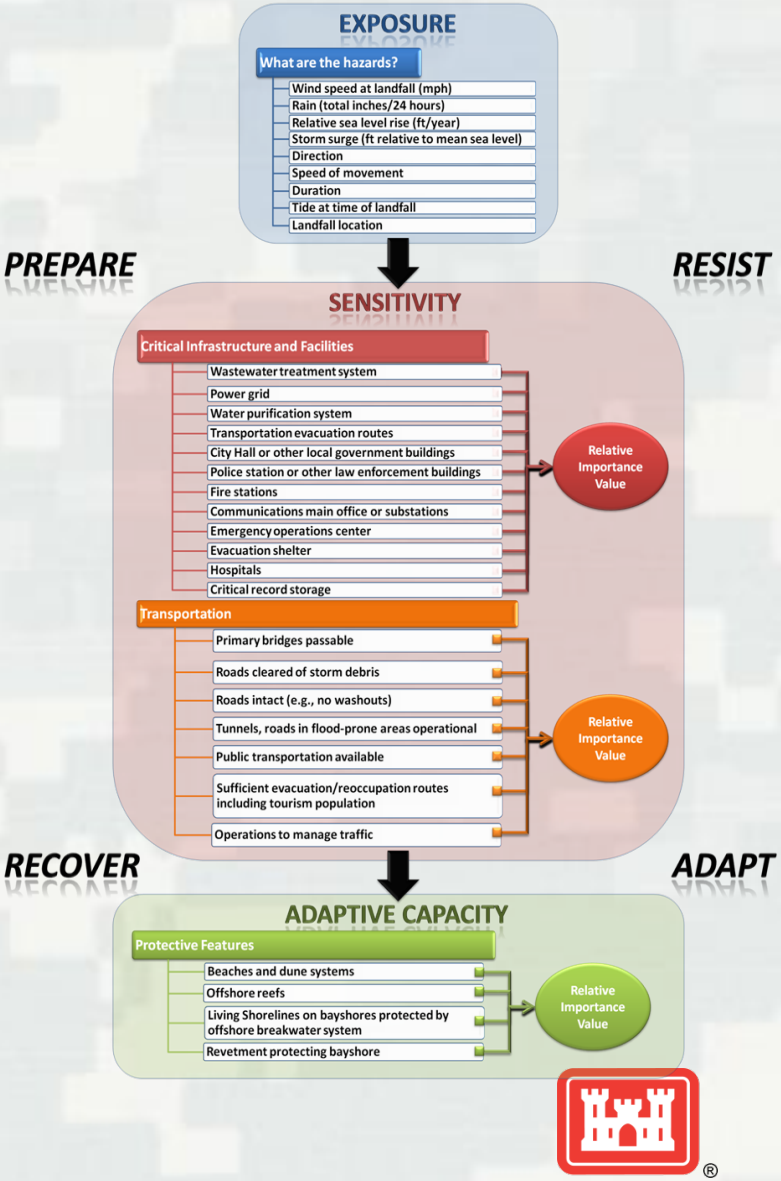
1=yes; 0=no

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 =$\{\Sigma(F+R)*W\}/2$ = (2*0.25+1*0.3+1*0.2+0*0.25)/2=						**50%**

Systems Approach, Vulnerability, 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



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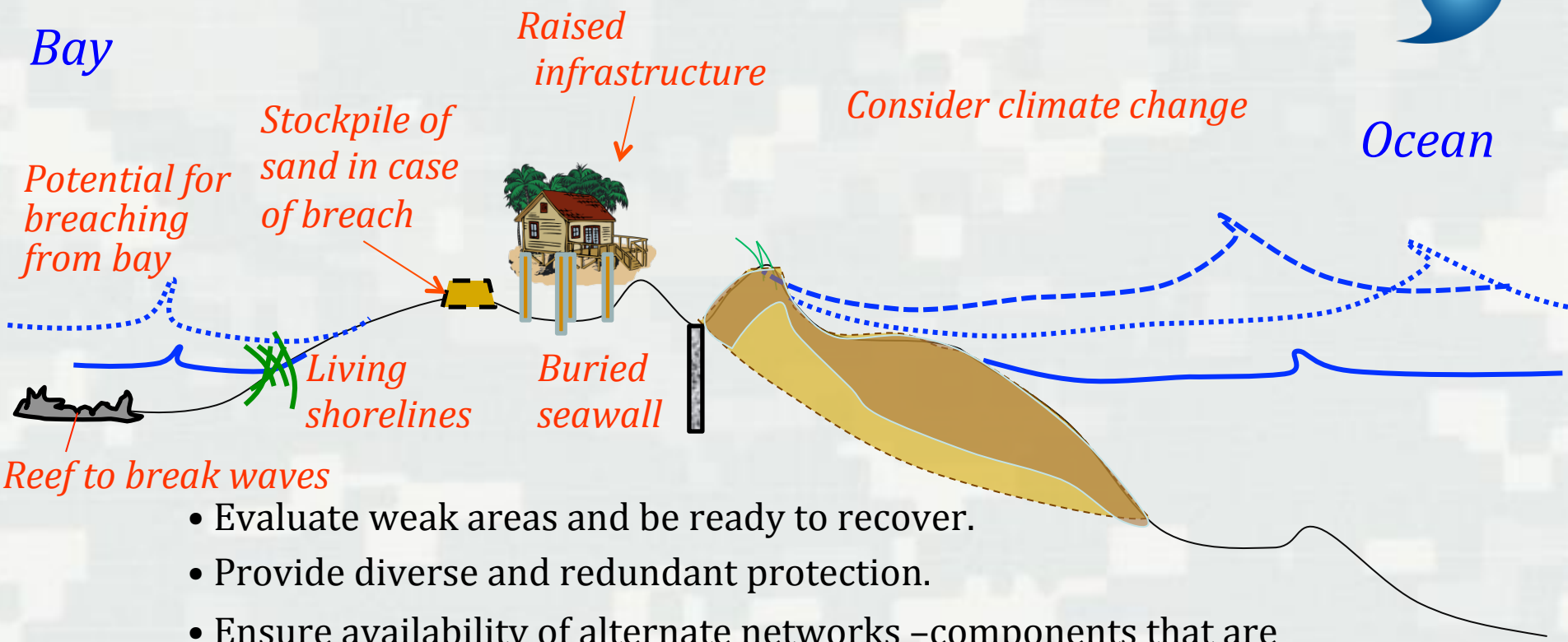
What is a resilient coastal system?

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).
- Compartmentalize risk.
- Provide accessible information for rapid decision-making.

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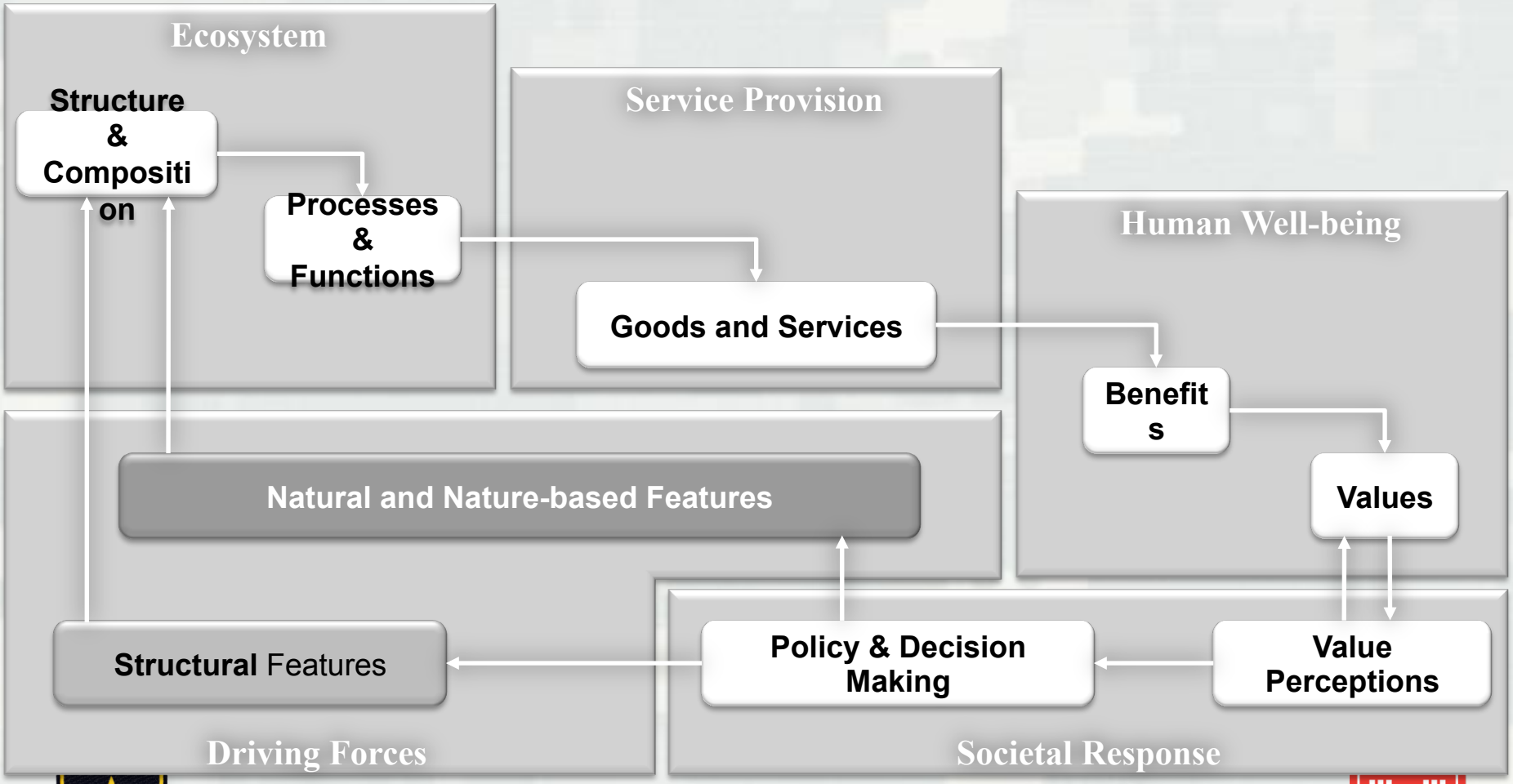
Performance can be characterized by the production of ecosystem goods and services….



Services Table Approach

Influential Structures and Components	Processes and/or Functions	Services	Benefits	Metric Components*
Characteristic Beach Substrate	Natural Ecosystem Components	Aesthetics Recreation	Scenic Beauty, Tourism dollars	Population Density, Public Beaches, Appropriate Width
	Ecosystem Support for Self-sustaining Wildlife Populations	Biodiversity T&E Species protection	Self-Sustaining, Diverse Ecosystem Biota, Biological Heritage	Vegetative Cover, Impervious Cover, Dimensions and Feature Boundaries, T&E Use
Substrate Type and Spatial Distribution	Ecosystem Roughness (Break Waves, Reduce Velocity)	Erosion Protection and Control	Decreased Erosion, Decreased Open Water Sediment Loading	Vegetative Cover, Dimensions and Feature Boundaries
Substrate Type, Beach Slope, Topography	Ecosystem Structure (Flood Attenuation, Diversion)	Reduce Wave Attack Reduce Storm Surge & Flooding	Reduced Structural Damages Reduced Flooding Damages	Dimensions and Feature Boundaries, Height and Width
Substrate Type & Vertical Accretion	Sediment Detention & Deposition	Maintain Background Suspended Sediment	Reduced Damages From Polluted Water	

Tiered Application Approach

- **Level 1** – Qualitative characterization of performance
- **Level 2** – Semi-quantitative characterization of performance
- **Level 3** – Quantitative characterization of performance

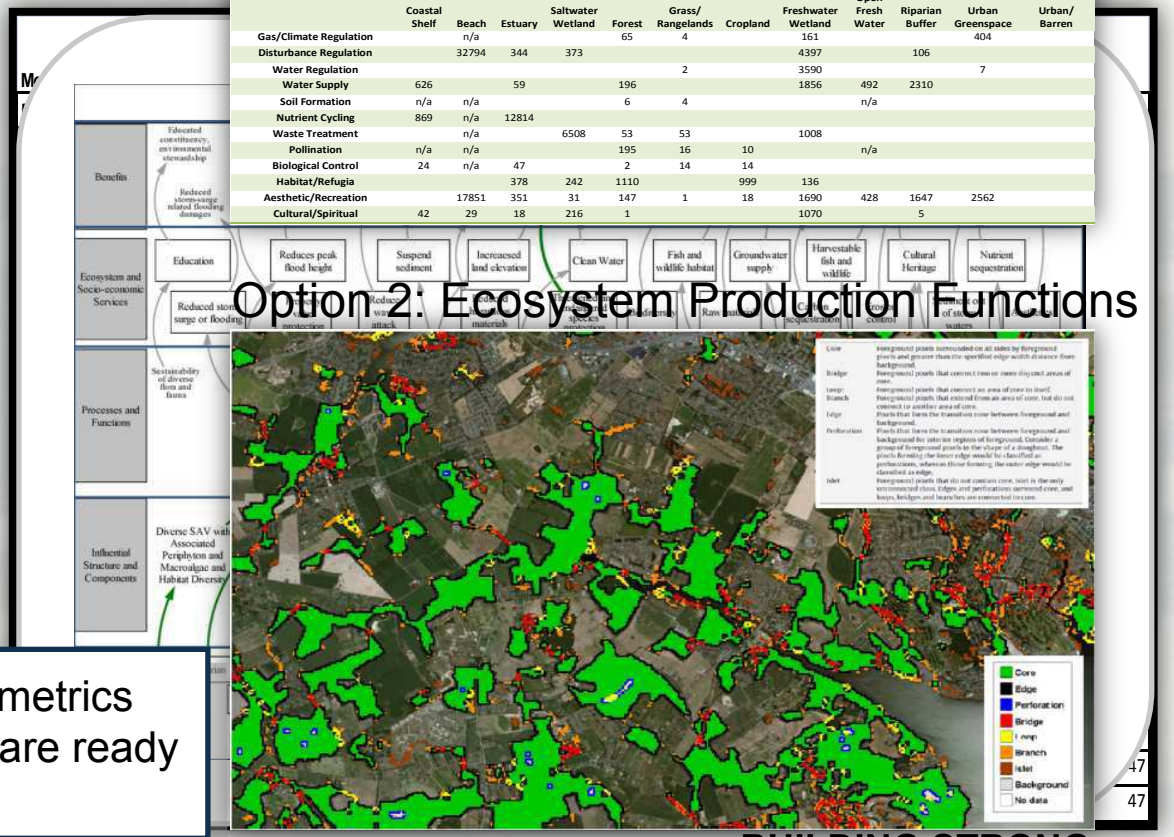
Option 1: Value Transfer ($ Value per acre)

Ecosystem Service Values Based on Peer-Reviewed Original Research in Temperate North America/Europe (2012 $/(ac*yr))

	Coastal Shelf	Beach	Estuary	Saltwater Wetland	Forest	Grass/ Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/ Barren
Gas/Climate Regulation		n/a			72	6					404	
Disturbance Regulation		32794		1						106		
Water Regulation								7162			7	
Water Supply	745		59		11			1396	492	2310		
Soil Formation	n/a	n/a				7			n/a			
Nutrient Cycling		n/a										
Waste Treatment		n/a		7322								
Pollination	n/a	n/a			195		10		n/a			
Biological Control		n/a										
Habitat/Refugia			438	277	1110			6				
Aesthetic/Recreation		17851	364	31	156	1	18	1889	428	1647	2562	
Cultural/Spiritual		29		216						5		

Ecosystem Service Values Based on Peer-Reviewed Original Research, Grey Literature, and Meta-analysis Studies in Temperate North America/Europe (2012 $/(ac*yr))

	Coastal Shelf	Beach	Estuary	Saltwater Wetland	Forest	Grass/ Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/ Barren
Gas/Climate Regulation		n/a			65	4		161			404	
Disturbance Regulation		32794	344	373				4397		106		
Water Regulation						2		3590			7	
Water Supply	626		59		196			1856	492	2310		
Soil Formation	n/a	n/a			6	4			n/a			
Nutrient Cycling	869	n/a	12814									
Waste Treatment		n/a		6508	53	53		1008				
Pollination	n/a	n/a			195	16	10		n/a			
Biological Control	24	n/a	47		2	14	14					
Habitat/Refugia			378	242	1110		999	136				
Aesthetic/Recreation		17851	351	31	147	1	18	1690	428	1647	2562	
Cultural/Spiritual	42	29	18	216	1			1070		5		



Option 2: Ecosystem Production Functions

72 individual performance metrics have been developed and are ready for deployment!

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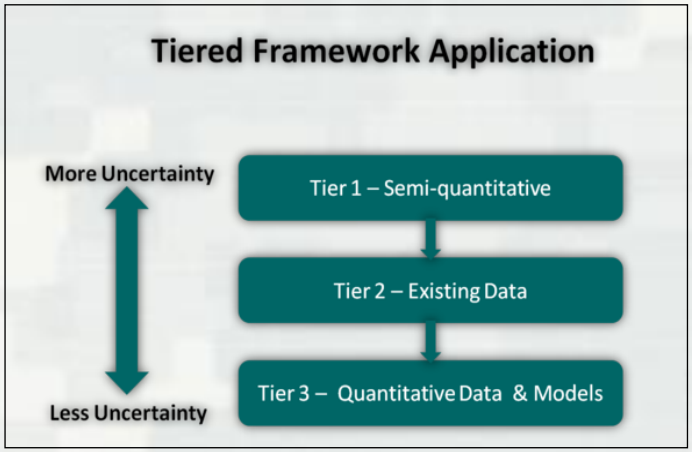
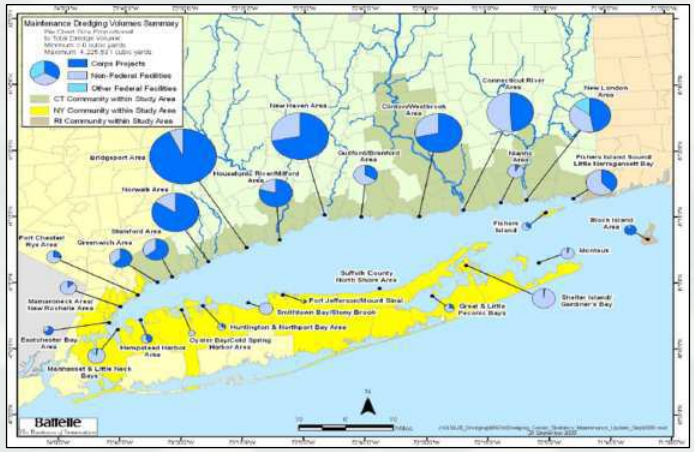
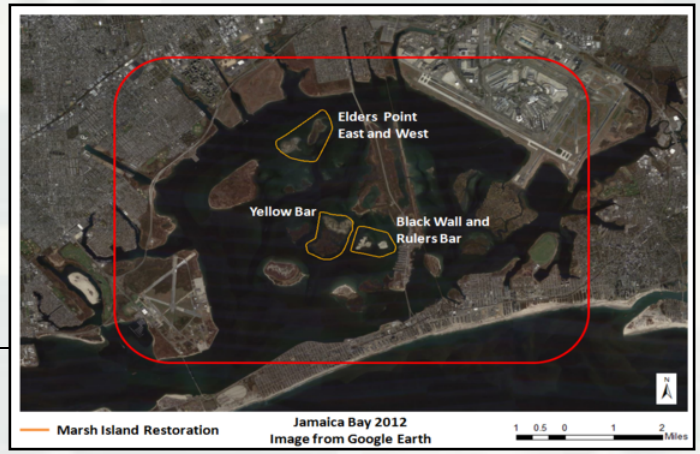
Putting NNBF into Practice

- **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

- **Underlying Themes:**

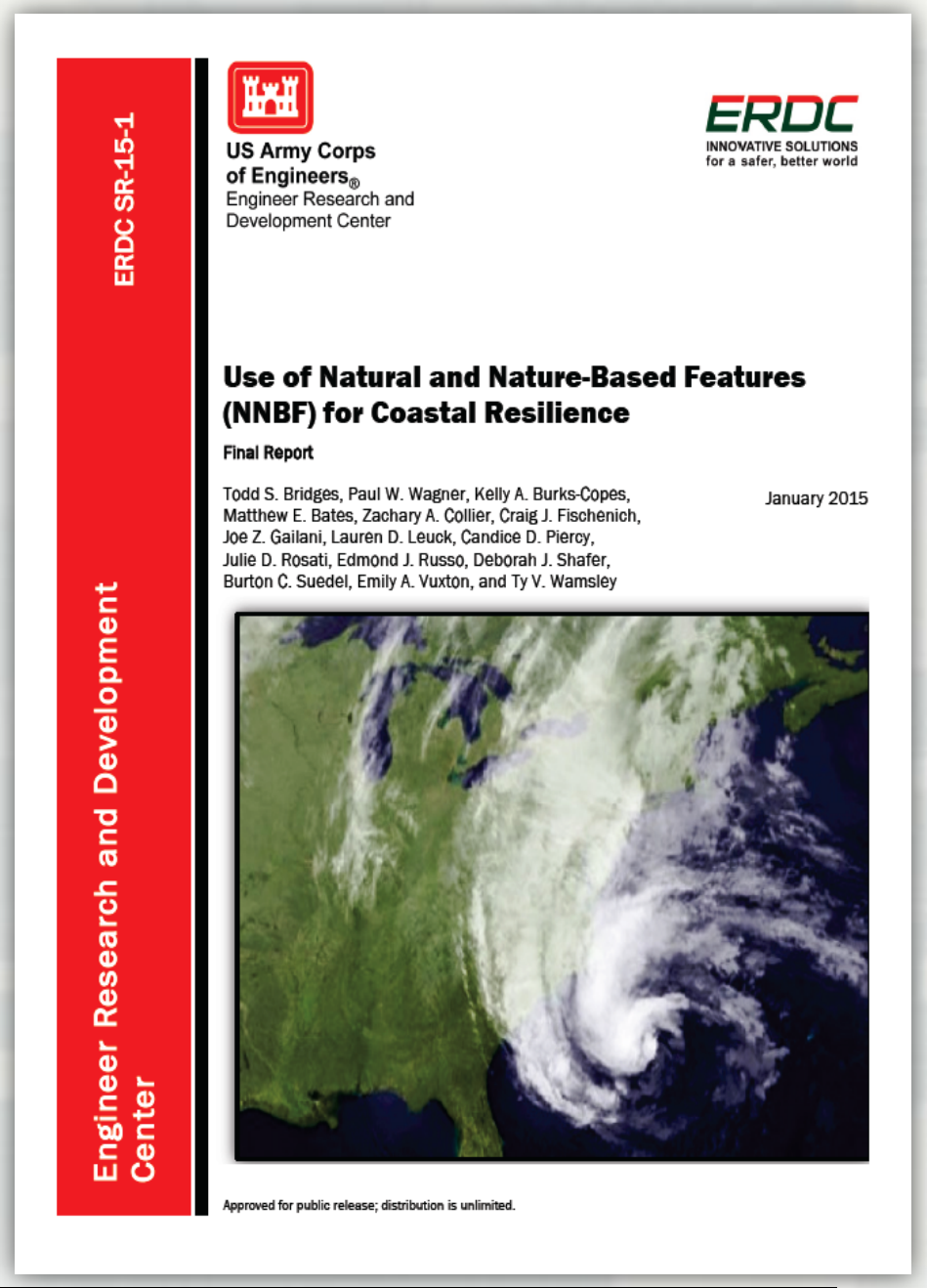
1. **Science, engineering, and technology**
   Knowledge and data deficiencies pose significant challenges for the development of guidance and policies for the evaluation and implementation of NNBF

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

Report Conclusions

- **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



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http:// www.EngineeringWithNature.org

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Ongoing and Future Activities

- NNBF Work Group
  - NWF, USFWS, USACE, NOAA, USGS, USEPA, TNC, TPL, CRMC, MD-DNR
- Focused R&D and field demonstrations
  - USACE Engineering with Nature (EWN) program
  - Regional Sediment Management (RSM) program
  - Systems Approach to Geomorphic Engineering (SAGE)
  - R&D coordinated across USACE business lines: Flood & Coastal, Navigation, Ecosystem Restoration
- Collaboration with others, e.g., TNC and Science for Nature and People, NJ-DNR NFWF project
- Hurricane Sandy Comprehensive Study Focus Areas
- Need: decision-making case studies

Q&A Session

More information is available at http://www.nad.usace.army.mil/CompStudy.aspx