

# Natural and Nature-Based Features to Enhance the Resilience of Coastal Systems: Post-Sandy Recovery Efforts

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US Army Corps of Engineers  
**BUILDING STRONG**



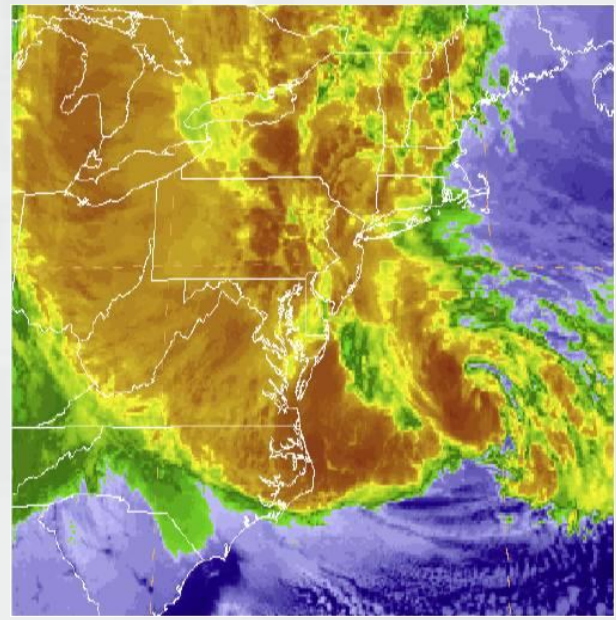
# Team Acknowledgement

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# Background

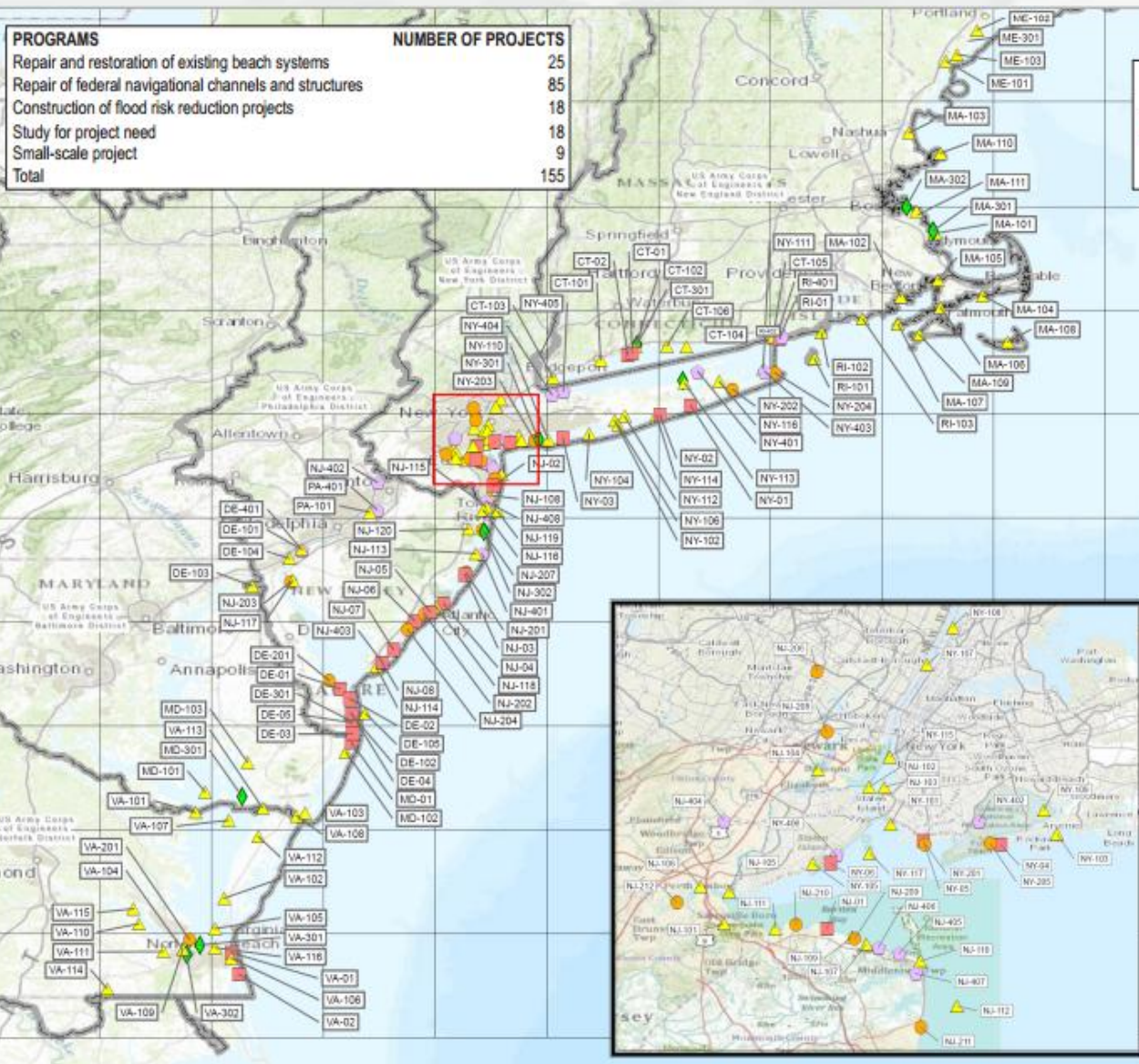
- Hurricane/Post-Tropical Cyclone Sandy moved to the U.S. Atlantic Ocean coastline 22-29 October 2012
- Affected entire U.S. east coast: 24 States from Florida to Maine; New Jersey to Michigan and Wisconsin
- Areas of extensive damage from coastal flooding: New Jersey, New York, Connecticut
- Public Law 113-2 enacted 29 January 2013



# The Disaster Relief Appropriations Act of 2013

PROGRAMS	NUMBER OF PROJECTS
Repair and restoration of existing beach systems	25
Repair of federal navigational channels and structures	85
Construction of flood risk reduction projects	18
Study for project need	18
Small-scale project	9
<b>Total</b>	<b>155</b>

■ Near-Term Coastal Restoration    
 ▲ Operations and Maintenance    
 ● Authorized But Not Yet Constructed    
 ◆ Coastal Storm Damage Reduction Studies    
 ◆ Continuing Authorities Program

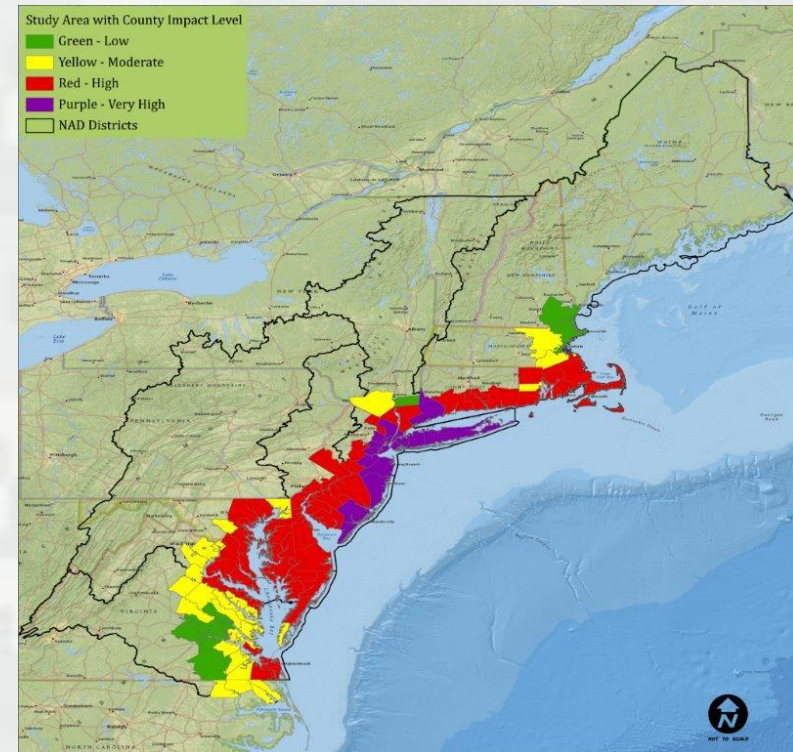


Map ID	Project Name	Map ID	Project Name
CT-05	Project Beach, West Haven, CT Public	PA-01	Port Matineck, NJ
CT-02	Woodmont Beach, Milford, CT Public	PA-02	Little Beach, NJ
CT-131	Belmont Harbor, CT	PA-03	Seaside Park, Ocean City, NJ
CT-101	New Haven Harbor, CT O&M	PA-04	Seaside Park, Ocean City, NJ
CT-103	Hamden Harbor, CT	PA-05	Seaside Park, Ocean City, NJ
CT-104	Clinton Harbor, CT O&M	PA-06	Seaside Park, Ocean City, NJ
CT-105	Yorke Management Bay, RI O&M	PA-07	Seaside Park, Ocean City, NJ
CT-106	Montic Clock, New Haven, CT O&M	PA-08	Seaside Park, Ocean City, NJ
CT-107	Rockaway Inlet to Lanes	PA-09	Seaside Park, Ocean City, NJ
CT-108	Rockaway Inlet to Swamy, DE	PA-10	Seaside Park, Ocean City, NJ
CT-109	Delaware Coast Protection, DE	PA-11	Seaside Park, Ocean City, NJ
CT-110	Delaware Coast Protection, DE	PA-12	Seaside Park, Ocean City, NJ
CT-111	Delaware Coast Protection, DE	PA-13	Seaside Park, Ocean City, NJ
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CT-197	Delaware Coast Protection, DE	PA-99	Seaside Park, Ocean City, NJ
CT-198	Delaware Coast Protection, DE	PA-100	Seaside Park, Ocean City, NJ

# North Atlantic Coast Comprehensive Study

- Collaborative development of a **Risk Reduction Framework** for the 31,000 miles of coastline affected by Hurricane Sandy.
- 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
- \$19M study submitted to Congress in January 2015

## NACCS



# Green Infrastructure (e.g. Living Shorelines)

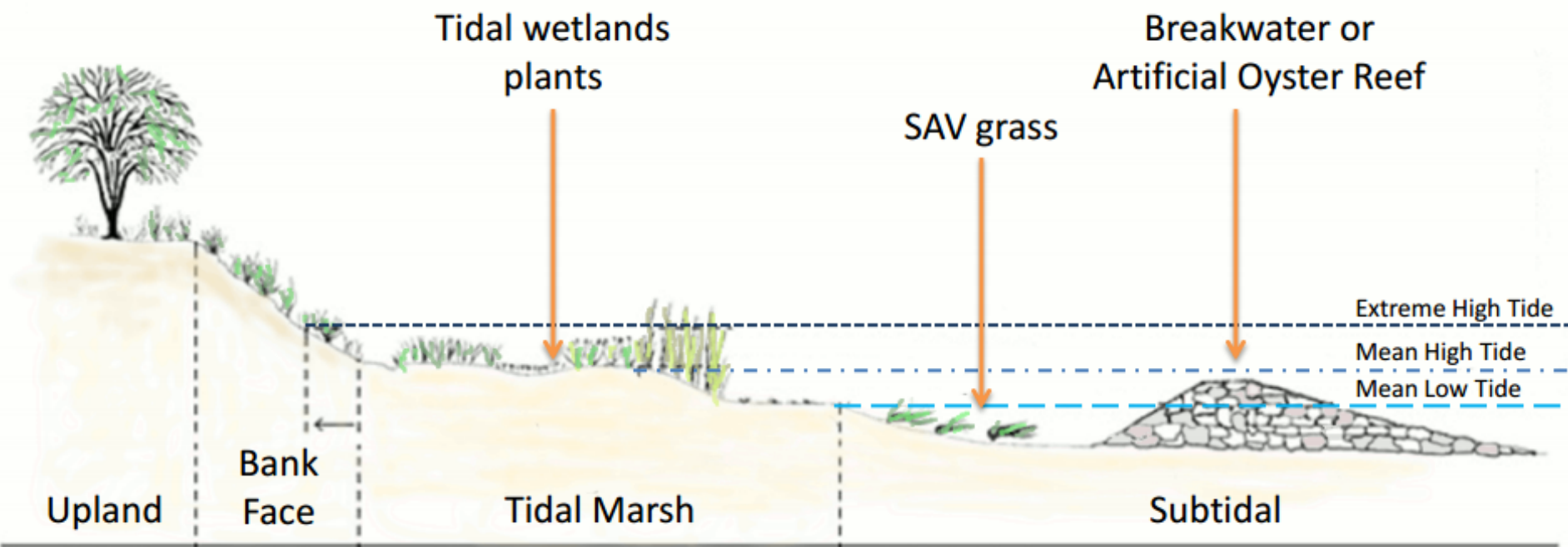





Image adapted from Burke Environmental Associates



# Coastal Risk Reduction & Resilience Measures

Measure	Definition	Effect	Examples
<b>Natural</b>	Created through the action of biochemical and physical processes operating in nature	Shoreline erosion control, wave and surge attenuation, especially in low-energy environments; additional resilience benefits; performance difficult to quantify	Barrier islands, dunes, reefs, wetlands, and riparian corridors 
<b>Nature-Based</b>	Products of planning, engineering design, and construction incorporating natural processes that contribute to coastal risk reduction and resilience	Shoreline erosion control, wave and surge attenuation, especially in low-energy environments; performance difficult to quantify	
<b>Non-Structural</b>	Products of public policy, management and regulatory practices; may include pricing schemes, planning, engineering design, and construction	Modify or avoid the impacts of the hazard (vs. modifying the hazard); quantifiable performance	Structure acquisitions or relocations, flood proofing of structures, implementing flood warning systems, flood preparedness planning, land use regulations, development restrictions within the greatest flood hazard areas, elevated development, managed retreat, evacuation, buyout and leaseback 
<b>Structural</b>	Products of planning, engineering design, and construction	Shoreline erosion control, wave and surge attenuation, reduced flooding; quantifiable performance	Levees, storm surge barrier gates, seawalls, groins, revetments, and near-shore breakwaters 

# Natural and Nature-Based Infrastructure at a Glance

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



## Dunes and Beaches

### Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer

### Performance Factors

- Berm height and width
- Beach Slope
- Sediment grain size and supply
- Dune height, crest, width
- Presence of vegetation

## Vegetated Features:

### Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV)

### Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer
- Increase infiltration

### Performance Factors

- Marsh, wetland, or SAV elevation and continuity
- Vegetation type and density

## Oyster and Coral Reefs

### Benefits/Processes

- Break offshore waves
- Attenuate wave energy
- Slow inland water transfer

### Performance Factors

- Reef width, elevation and roughness

## Barrier Islands

### Benefits/Processes

- Wave attenuation and/or dissipation
- Sediment stabilization

### Performance Factors

- Island elevation, length, and width
- Land cover
- Breach susceptibility
- Proximity to mainland shore

## Maritime Forests/Shrub Communities

### Benefits/Processes

- Wave attenuation and/or dissipation
- Shoreline erosion stabilization
- Soil retention

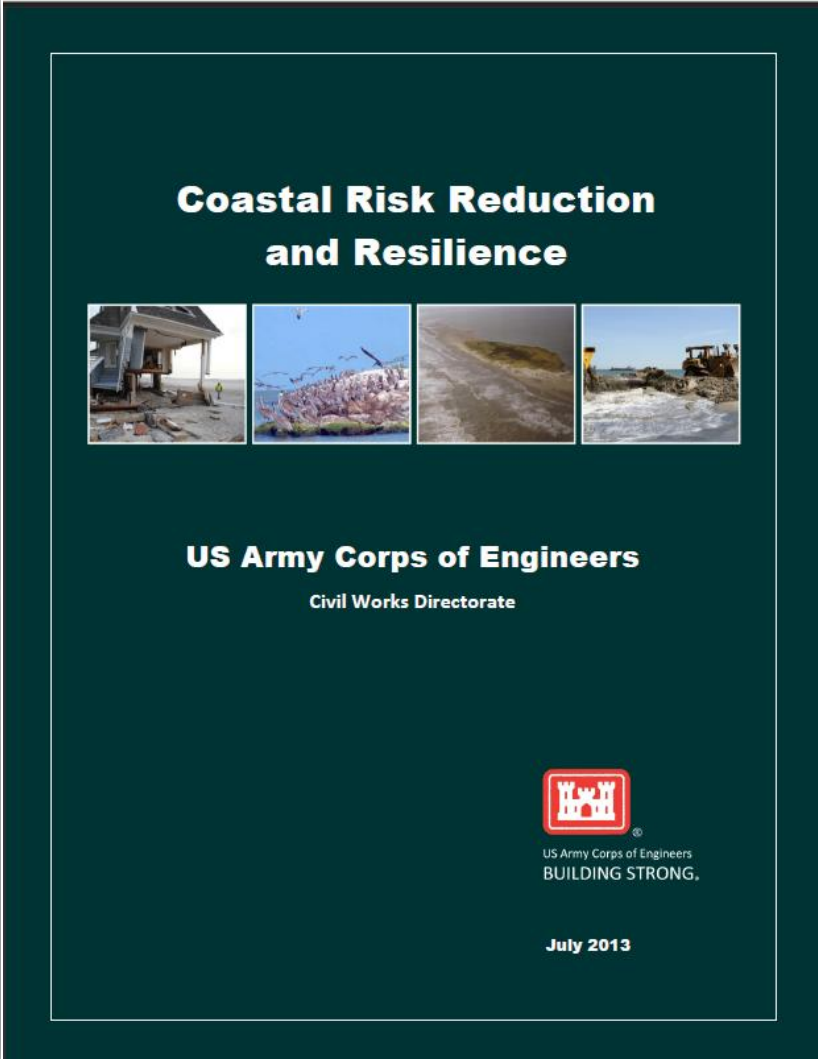
### Performance Factors

- Vegetation height and density
- Forest dimension
- Sediment composition
- Platform elevation




# Coastal Risk Reduction and Resilience


The USACE planning approach supports an **integrated approach** to reducing coastal risks and increasing human and ecosystem community resilience through a combination of **natural, nature-based, non-structural and structural measures**. This approach considers the engineering attributes of the component features and the dependencies and interactions among these features over both the short- and long-term. It also considers the **full range of environmental and social benefits** produced by the component features.



**Coastal Risk Reduction  
and Resilience**



**US Army Corps of Engineers**  
Civil Works Directorate

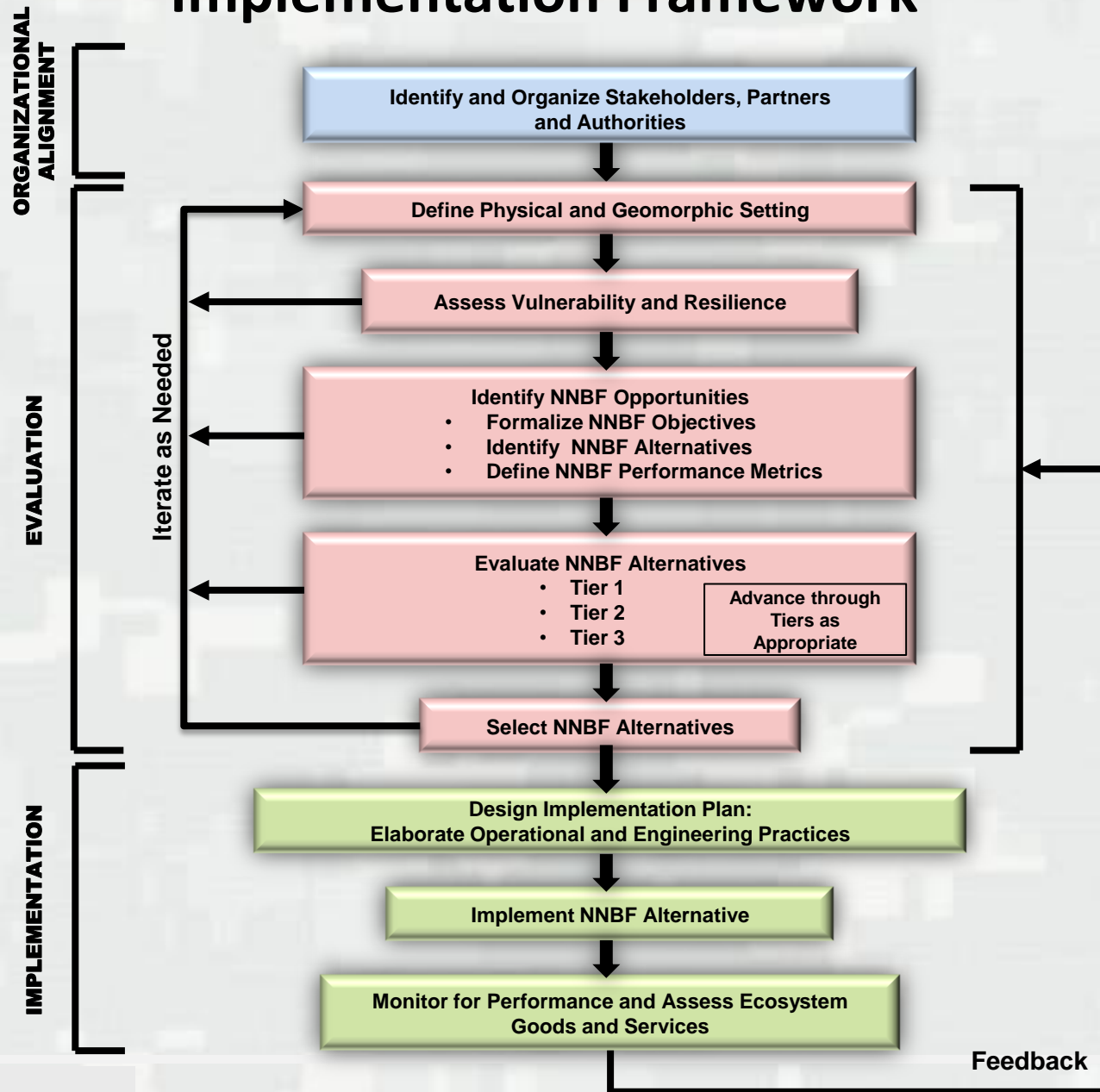


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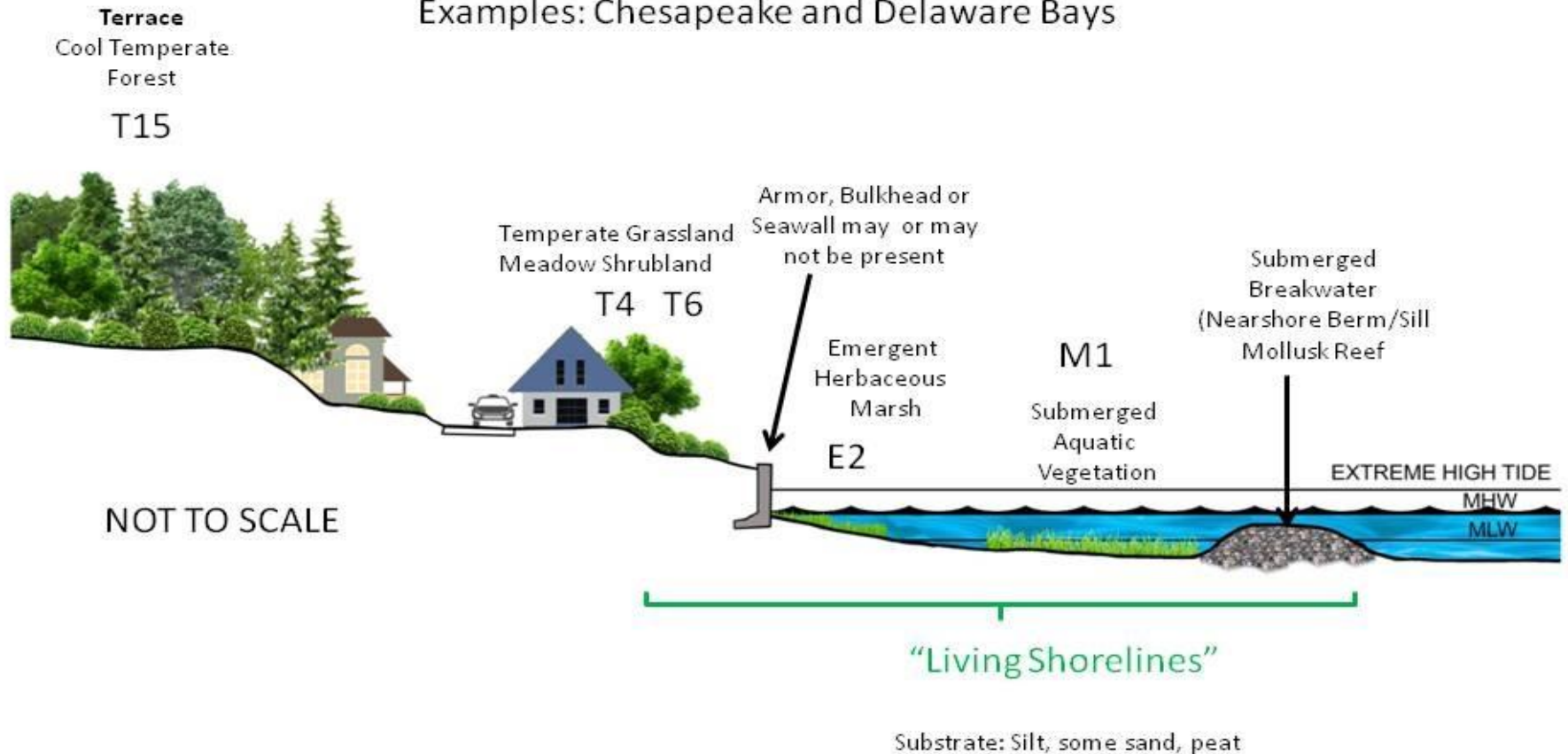
# Natural and Nature-Based Features Evaluation and Implementation Framework



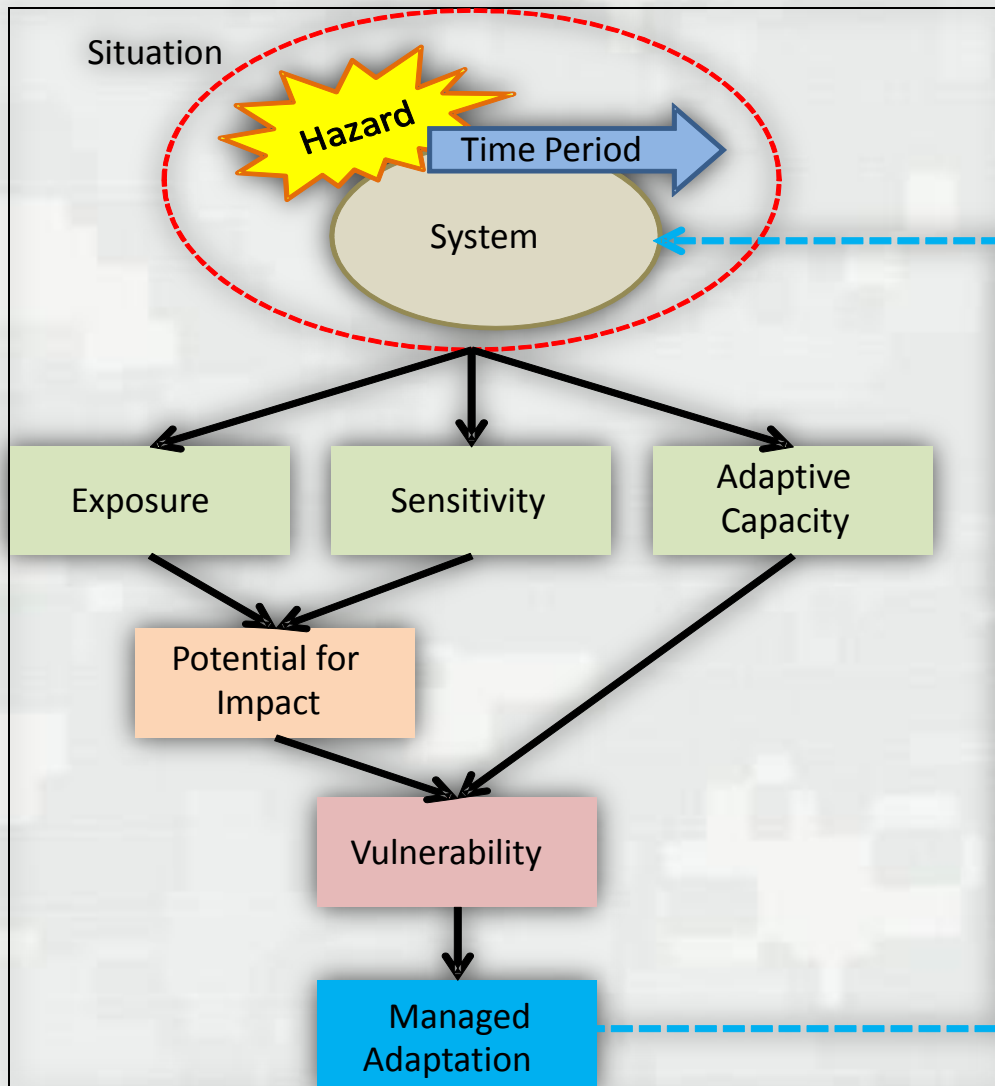
# Classification System

## 1 A 1-1. Drowned River Valley

Examples: Chesapeake and Delaware Bays



# Vulnerability



***Vulnerability: Degree to which a system is susceptible to, and unable to cope with, adverse effects from a hazard; vulnerability is a function of the character and magnitude of a hazard to which a system is exposed, its sensitivity, and its adaptive capacity.***

**Vulnerability factors:**

- **Internal**
- **External**
- **Socioeconomic**
- **Biophysical**

**Metrics must consider *EXPOSURE*, *SENSITIVITY*, and *ADAPTIVE CAPACITY* of a system.**



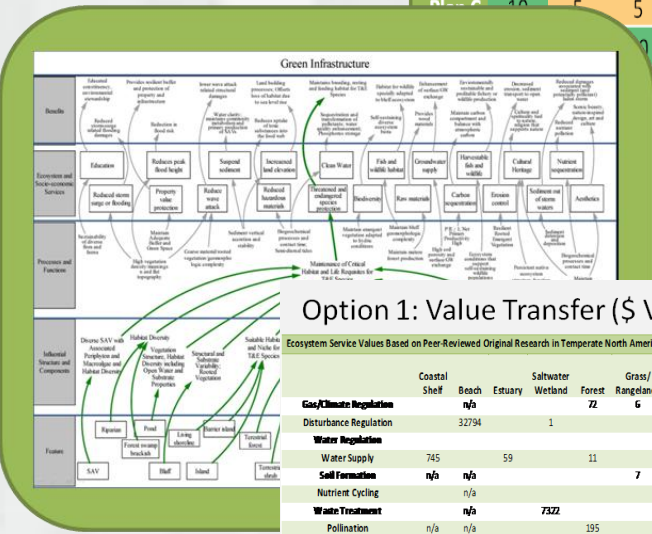
# 21 Ecosystem Goods and Services Associated with NNBF

1. Aesthetics - appreciation of natural scenery (other than through deliberate recreational activities), Inspiration for culture, art and design
2. Biological diversity (biodiversity)
3. Carbon sequestration
4. Clean water provisioning (sediment, nutrients, pathogens, salinity, other pollutants)
5. Commercial harvestable fish and wildlife production
6. Cultural heritage and identity - sense of place and belonging, spiritual and religious inspiration
7. Education and scientific opportunities (for training and education)
8. Erosion protection and control (water and wind, any source)
9. Habitat for fish and wildlife provisioning (nursery, refugium, food sources, etc.)
10. Increase or maintain land elevation, land-building, sediment source reduction
11. Keeping unwanted sediments out of storm waters
12. Nutrient sequestration or conversion
13. Property value protection
14. Provision and storage of groundwater supply
15. Raw materials production (timber, fiber and fuel, etc.)
16. Recreation - opportunities for tourism and recreational activities
17. Reduce hazardous or toxic materials in water or landscape
18. Reduce storm surge and related flooding
19. Reduce the peak flood height and lengthen the time to peak flood
20. Reduce wave attack
21. Threatened and Endangered species protection

# 3 Levels of Performance 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		
		B1	B2	B3	B4	B5	Mean	Wtd
Plan A		10	8	5	1	0	4.8	49
Plan B		10	10	0	0	0	4	30
Plan C		10	5	5	9	7	7.2	102
Plan D		10	10	10	8	5	7.8	115
Plan E		10	10	10	10	10	7	115
Plan F		10	10	10	10	10	7	115
Plan G		10	10	10	10	10	7	115
Plan H		10	10	10	10	10	7	115
Plan I		10	10	10	10	10	7	115
Plan J		10	10	10	10	10	7	115
Plan K		10	10	10	10	10	7	115
Plan L		10	10	10	10	10	7	115
Plan M		10	10	10	10	10	7	115
Plan N		10	10	10	10	10	7	115
Plan O		10	10	10	10	10	7	115
Plan P		10	10	10	10	10	7	115
Plan Q		10	10	10	10	10	7	115
Plan R		10	10	10	10	10	7	115
Plan S		10	10	10	10	10	7	115
Plan T		10	10	10	10	10	7	115
Plan U		10	10	10	10	10	7	115
Plan V		10	10	10	10	10	7	115
Plan W		10	10	10	10	10	7	115
Plan X		10	10	10	10	10	7	115
Plan Y		10	10	10	10	10	7	115
Plan Z		10	10	10	10	10	7	115



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
<b>Gas/Climate Regulation</b>					72	6						404
<b>Disturbance Regulation</b>		32794		1						106		7
<b>Water Regulation</b>								7162				
<b>Water Supply</b>		745	59		11			1396	492	2310		
<b>Soil Formation</b>		n/a	n/a			7						
<b>Nutrient Cycling</b>												
<b>Waste Treatment</b>							7322					
<b>Pollination</b>		n/a	n/a		195			10		n/a		
<b>Biological Control</b>												
<b>Habitat/Refugia</b>			438	277	1110			6				
<b>Aesthetic/Recreation</b>	17651	364	31	156	1	18	1889	428	1047	2562		5

Option 2: Ecosystem Production Functions



Literature, and Meta-analysis Studies in Temperate North America/Europe (2012 \$/ac\*yr)

	Forest	Grass/Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/Barren
Forest	65	4		161			404	
				4397		106		7
		2		3590				
	196			1856	492	2310		
	6	4				n/a		
	53	53		1006				
	195	16	10			n/a		
	2	14	14					
	1110			999	136			
	147	1	18	1680	428	1047	2562	
	1			1070				5

**72 individual performance metrics identified for NNBF**



# Decision Framework

Objective	Performance Metric	Measure	Alternative Performance			
			1	2	3	4
Developed by Stakeholders Impacts	Average annual damages avoided	Selected for Tier (Section 3) & Informed by NNBF Performance (Sections 1&2)	Formulated Using NNBF Descriptions (Section 1)			
	Recovery time					
	Employment impacts	% of workforce unemployed				
Sustain Ecosystem Services Generated by Coastal Systems	Fish & wildlife habitat provision	Habitat Quality Index	Determined Using Best Available Data/Tools			
	Maintain water quality	WQ Index				
Promote Resilient Coastal Communities	Population	No. residents				
	Vulnerability to coastal storms	Exposure + Sensitivity				

Developed From Performance & Vulnerability Metrics (Section 2)

Developed by Stakeholders

Selected for Tier (Section 3) & Informed by NNBF Performance (Sections 1&2)

Formulated Using NNBF Descriptions (Section 1)

Determined Using Best Available Data/Tools



# Performance Evaluation Case Studies

## 1. Proof of concept analysis

- Quantify benefits of environmental restoration projects using an ecosystem goods and services (EGS) analysis framework

## 2. Hurricane Sandy case study

- Use extreme event to improve understanding of restoration effectiveness & benefits

## 3. Focused on two general types of services:

- Flood damage Reduction
- Wildlife Habitat (emphasis on T&E species)

## 4. 3 Study Sites

- Jamaica Bay
- Cape May Meadows
- Cape Charles South





# Moving Forward. . .

- Organize and expand science and engineering understanding regarding NNBF
  - Reduce uncertainties regarding design and performance
  - Differences among types of NNBF
  - Dynamic performance of NNBF
- Integrating expertise both within and across organizations
  - Planning, designing, constructing, monitoring , and maintaining NNBF

