Use of Natural and Nature-Based Features to Enhance the Resilience of Coastal Systems

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13 November 2013

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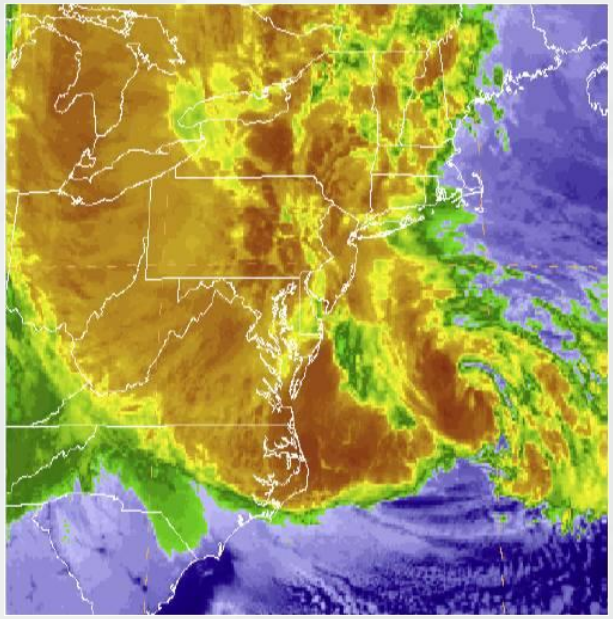

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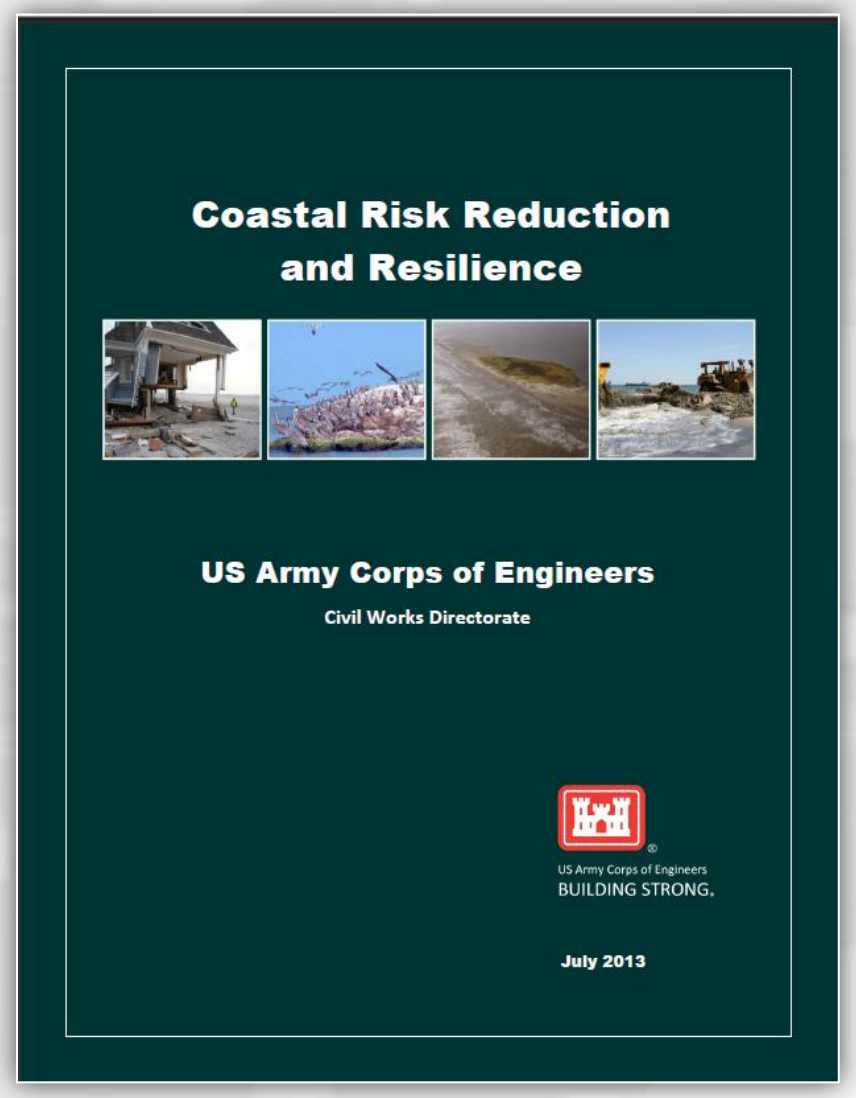
Coastal Risk Reduction and Resilience

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.*



Key Definitions

Natural and Nature-Based Features

Natural features are created and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. Nature-based features are those that may mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal risk reduction.

The built components of the system include nature-based and other structures that support a range of objectives, including erosion control and storm risk reduction (e.g., seawalls, levees), as well as infrastructure providing economic and social functions (e.g., navigation channels, ports, harbors, residential housing). Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, dunes, beaches, wetlands, and maritime forests. The relationships and interactions among the natural and built features comprising the coastal system are important variables determining coastal vulnerability, reliability, risk, and resilience.

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

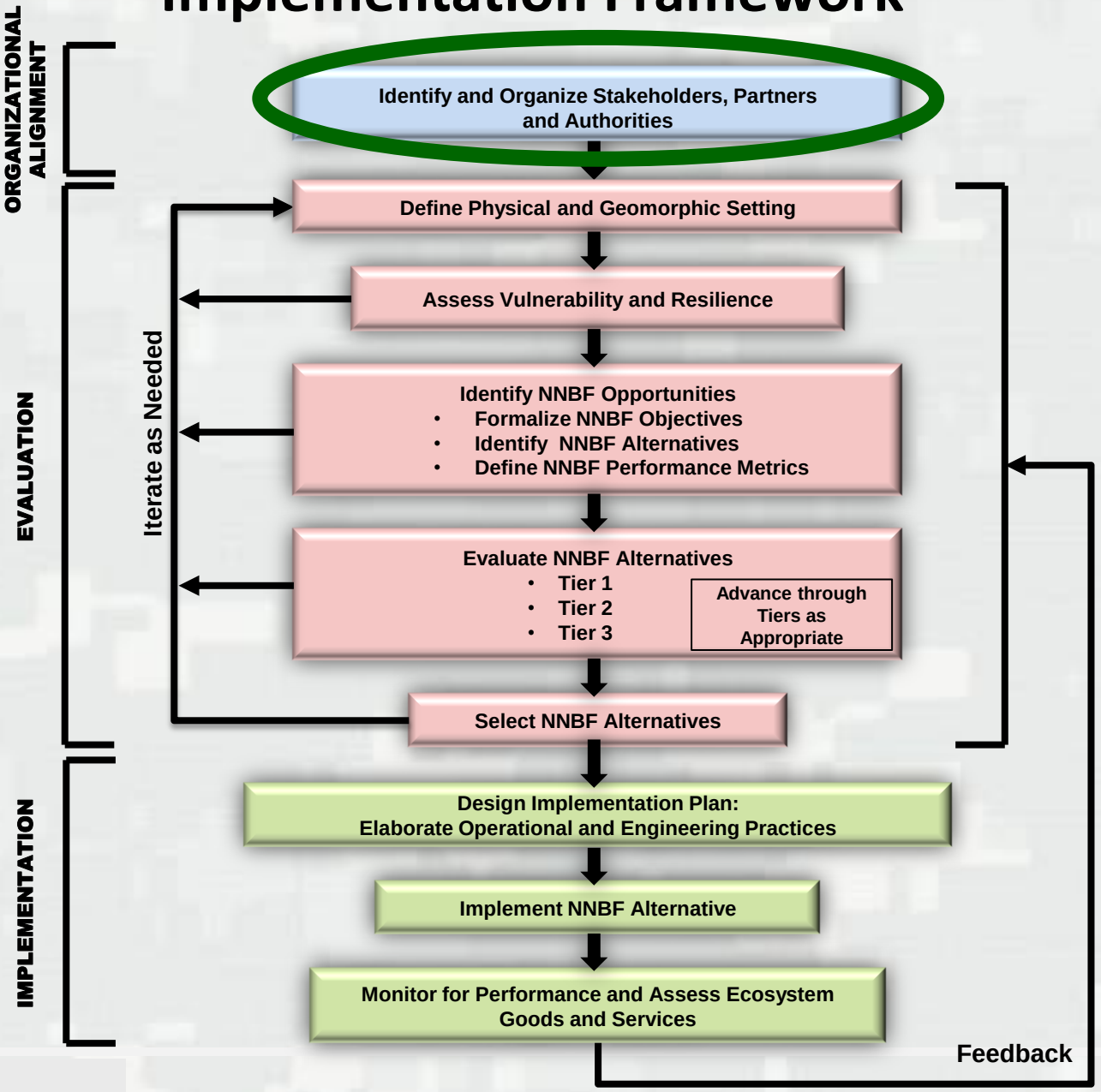
Vegetation height and density

Forest dimension

Sediment composition

Platform elevation

Natural and Nature-Based Features Evaluation and Implementation Framework

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The Nature
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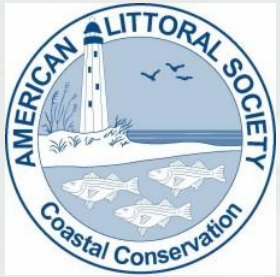
AMERICAN LITTORAL SOCIETY
Coastal Conservation


NATIONAL
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NOAA
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NATURAL RESOURCES


D·E·M


MASSACHUSETTS OFFICE OF
COASTAL ZONE MANAGEMENT


THE PORT AUTHORITY
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Authorities

Coastal Zone Management Act

Fish and Wildlife Conservation Act

Clean Water Act

Water Resources Development Acts

National Historic Preservation Acts

Marine Protection, Research and Sanctuaries Act

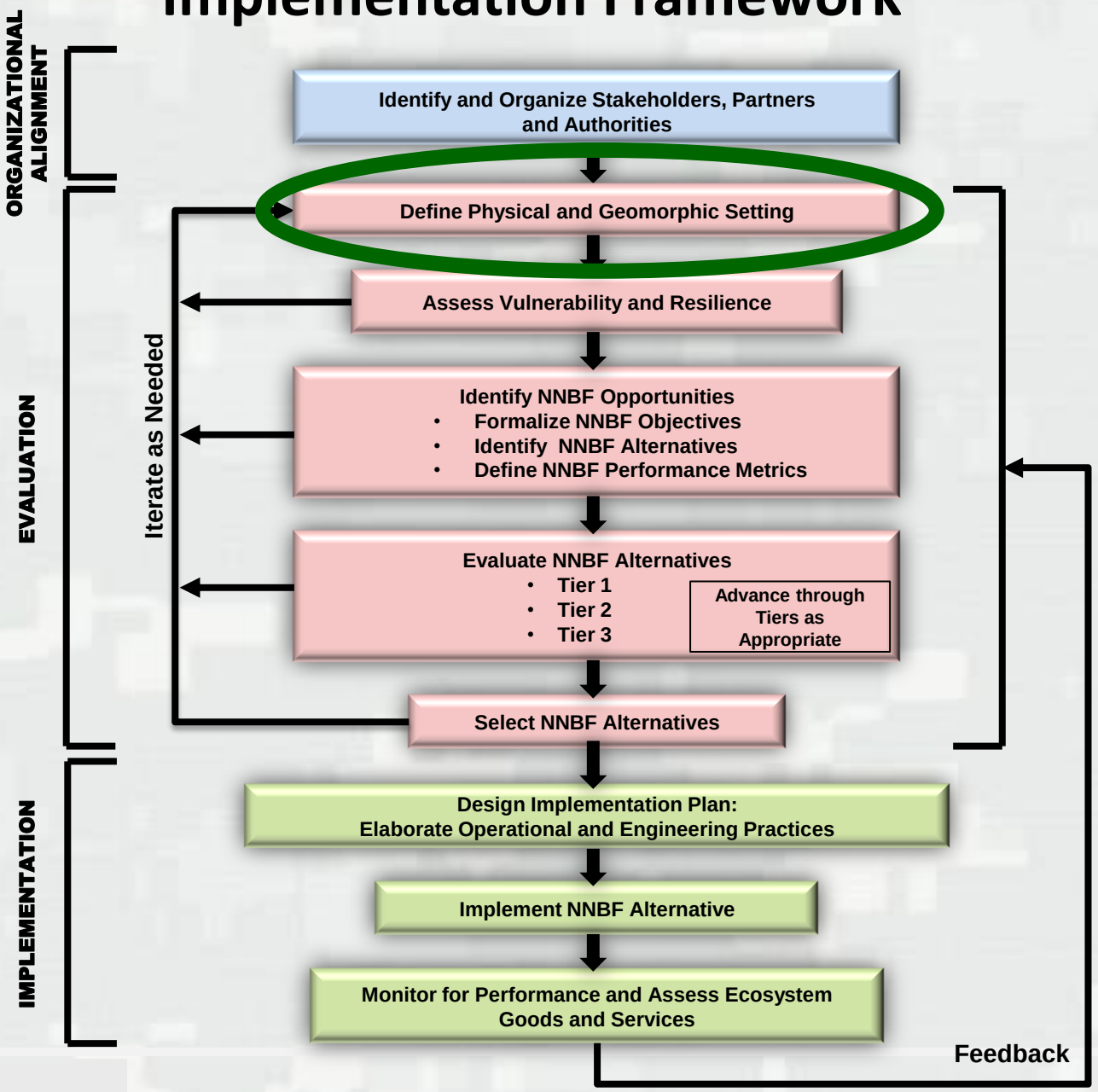
Sustainable Fisheries Act

National Environmental Policy Act

Endangered Species Act

Etc., Etc., Etc.

Natural and Nature-Based Features Evaluation and Implementation Framework



Define Physical and Geomorphic Setting

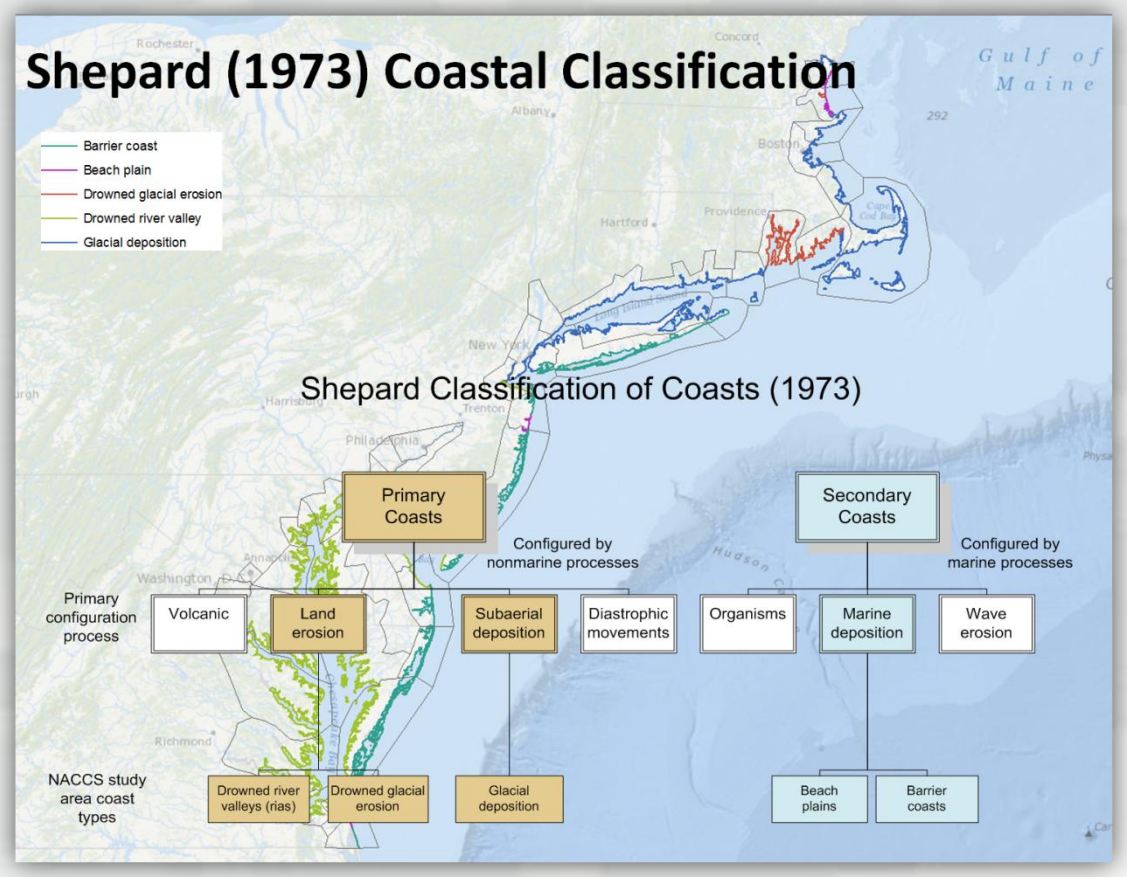
Applying a Classification System for Coastal NNBFs

Approach:

Combine the Coastal Geomorphological Classification

(Shepard 1948, 1963, 1973) with the National Vegetation Classification System

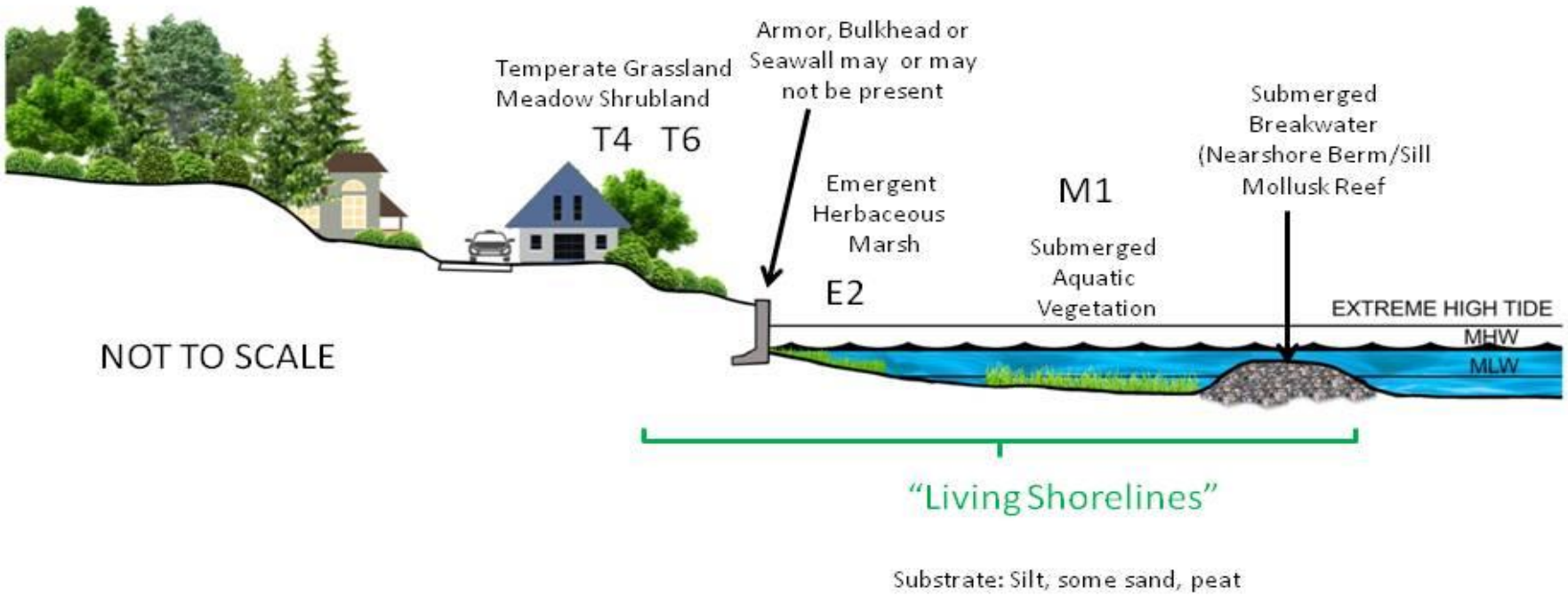
(Anderson et al. 1998)



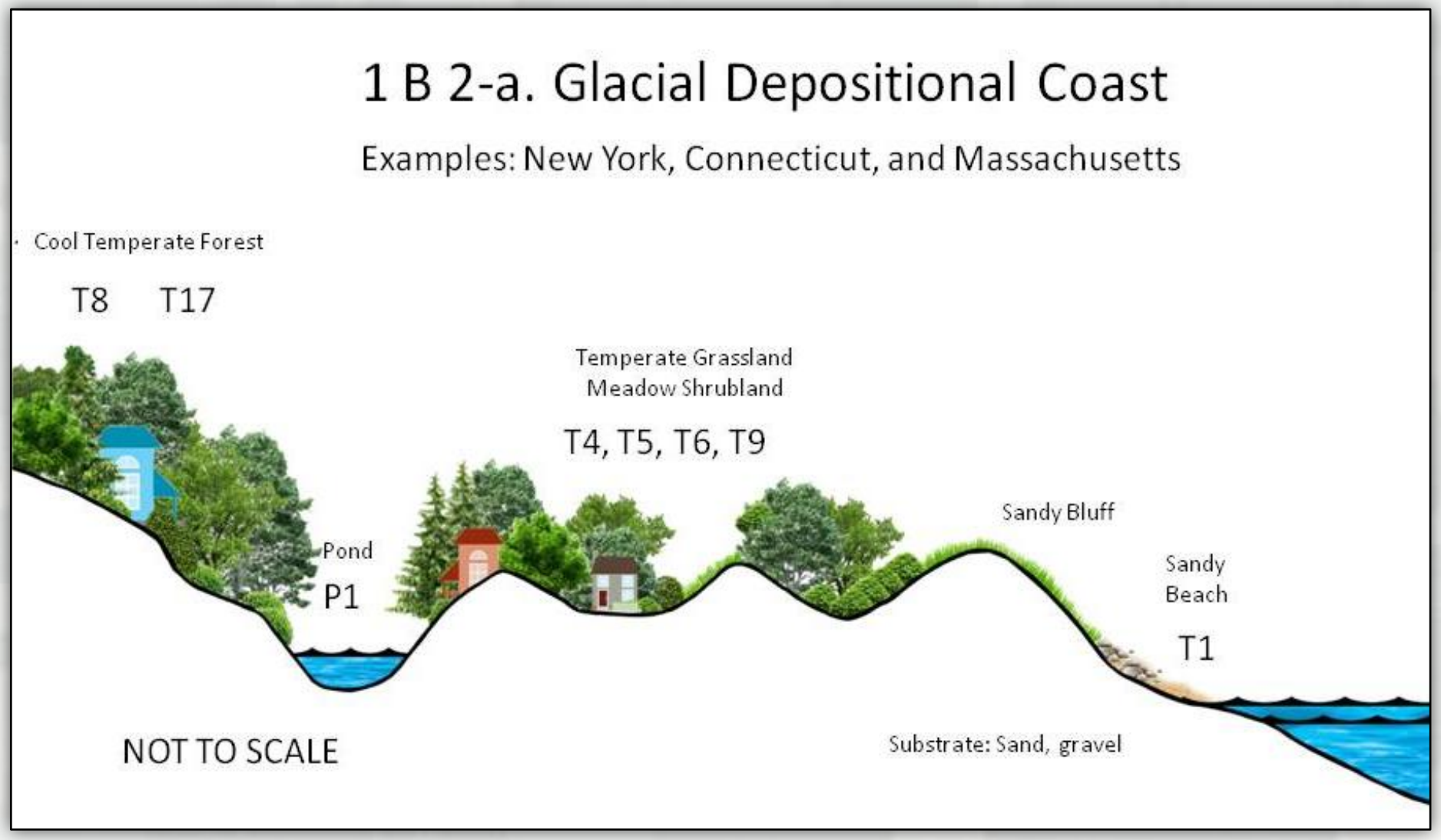
Combined Profiles

1 A 1-1. Drowned River Valley

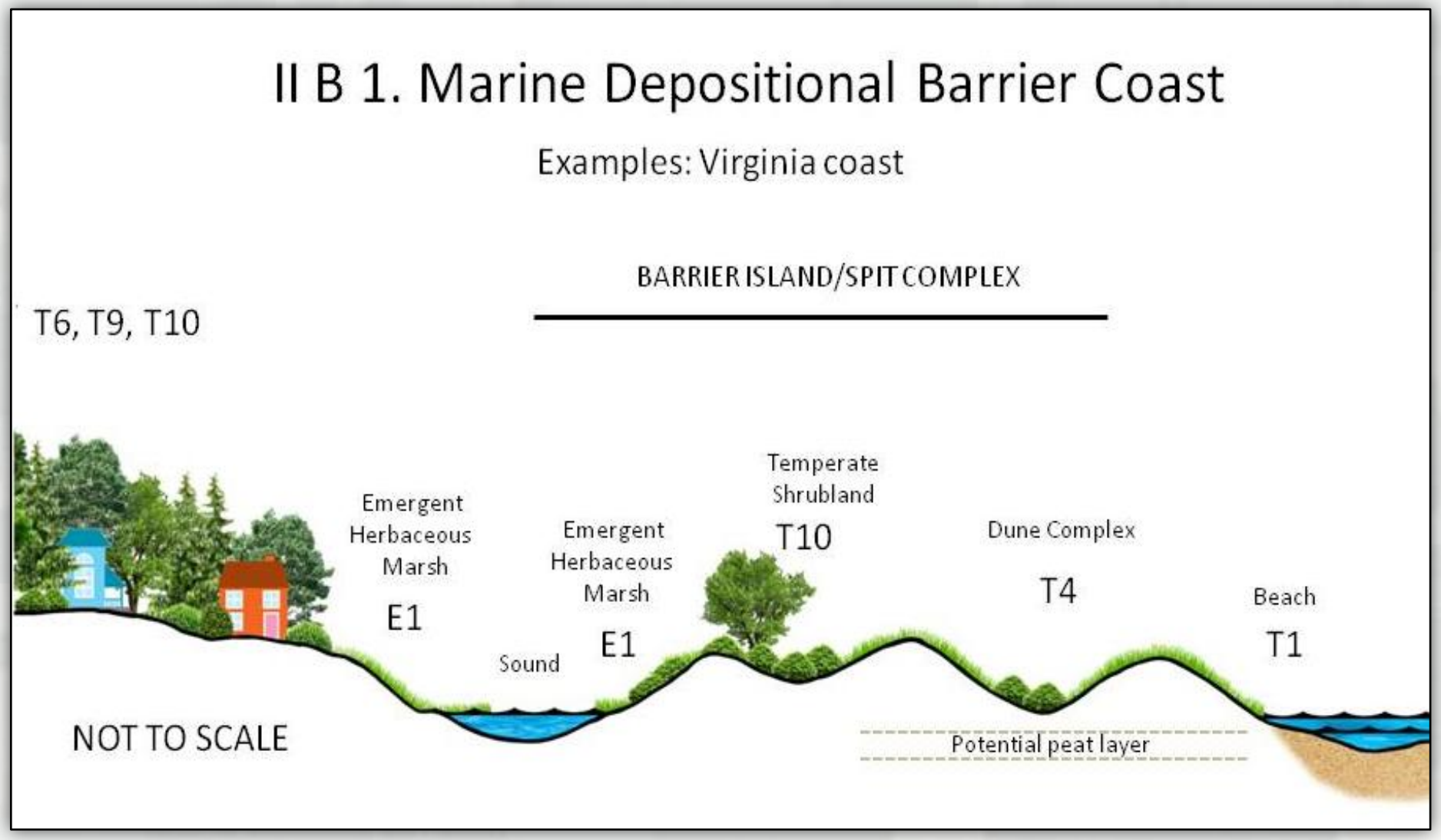
Examples: Chesapeake and Delaware Bays



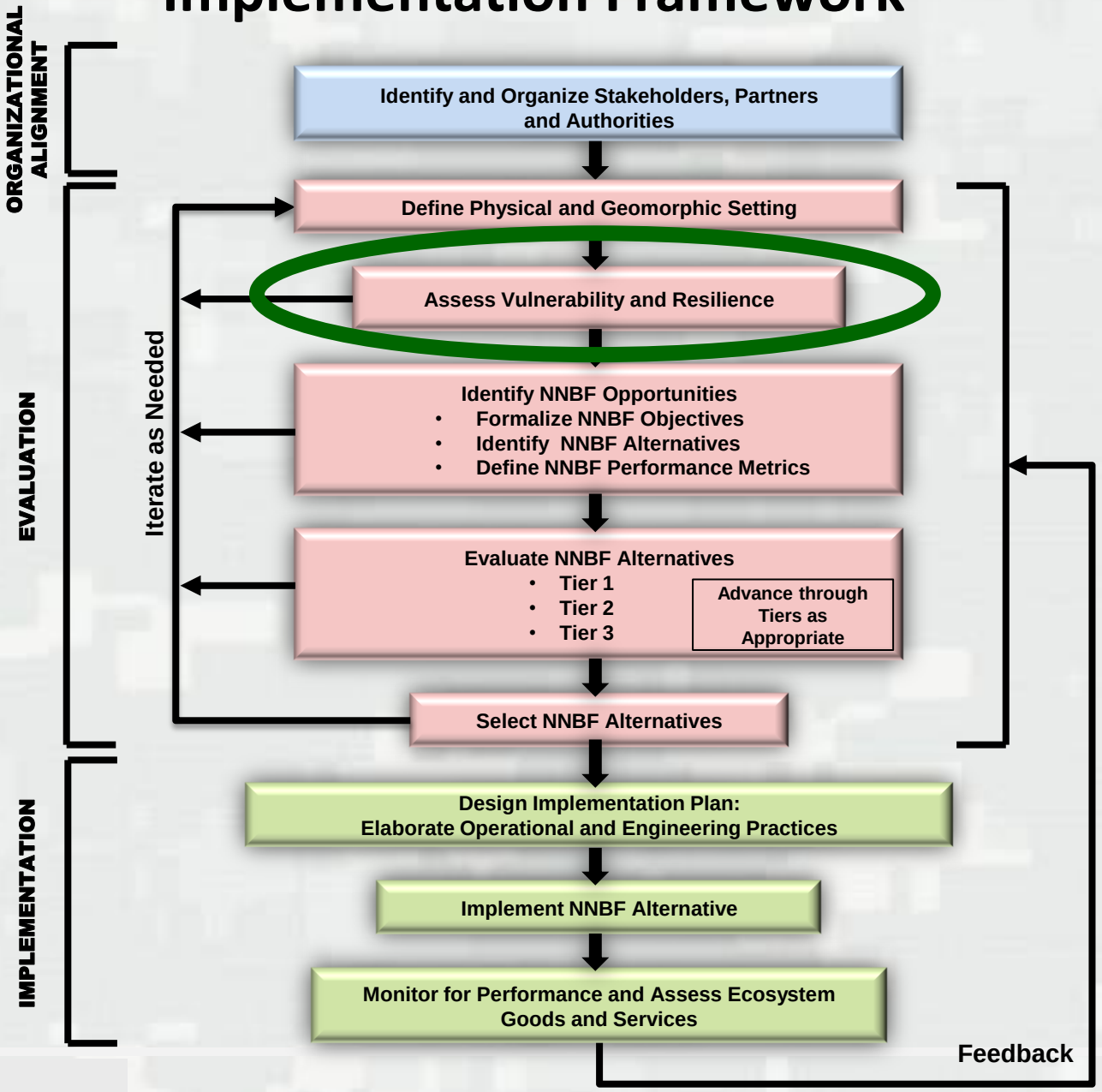
Combined Profiles



Combined Profiles



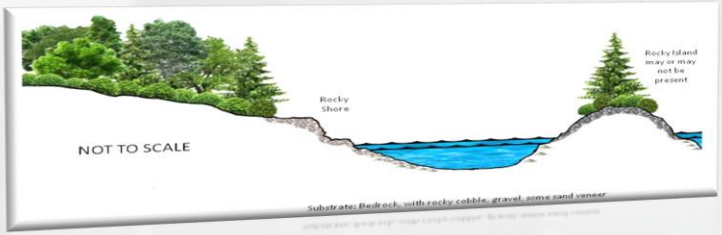
Natural and Nature-Based Features Evaluation and Implementation Framework

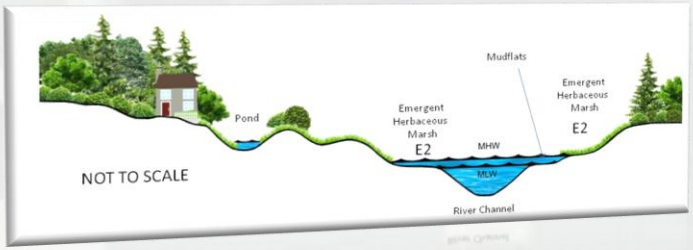


Vulnerability

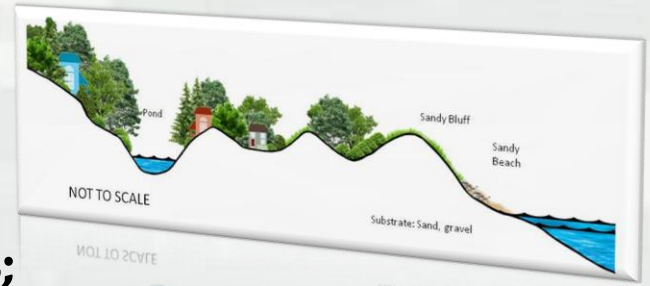
NACCS

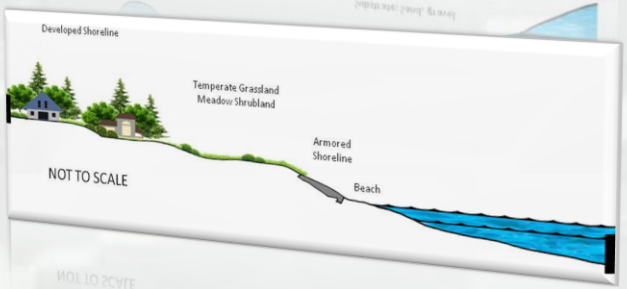
Vulnerability of Nature-Based Features in the Coastal Zone





Relative vulnerability of coastal landscapes; how nature-based features affect vulnerability

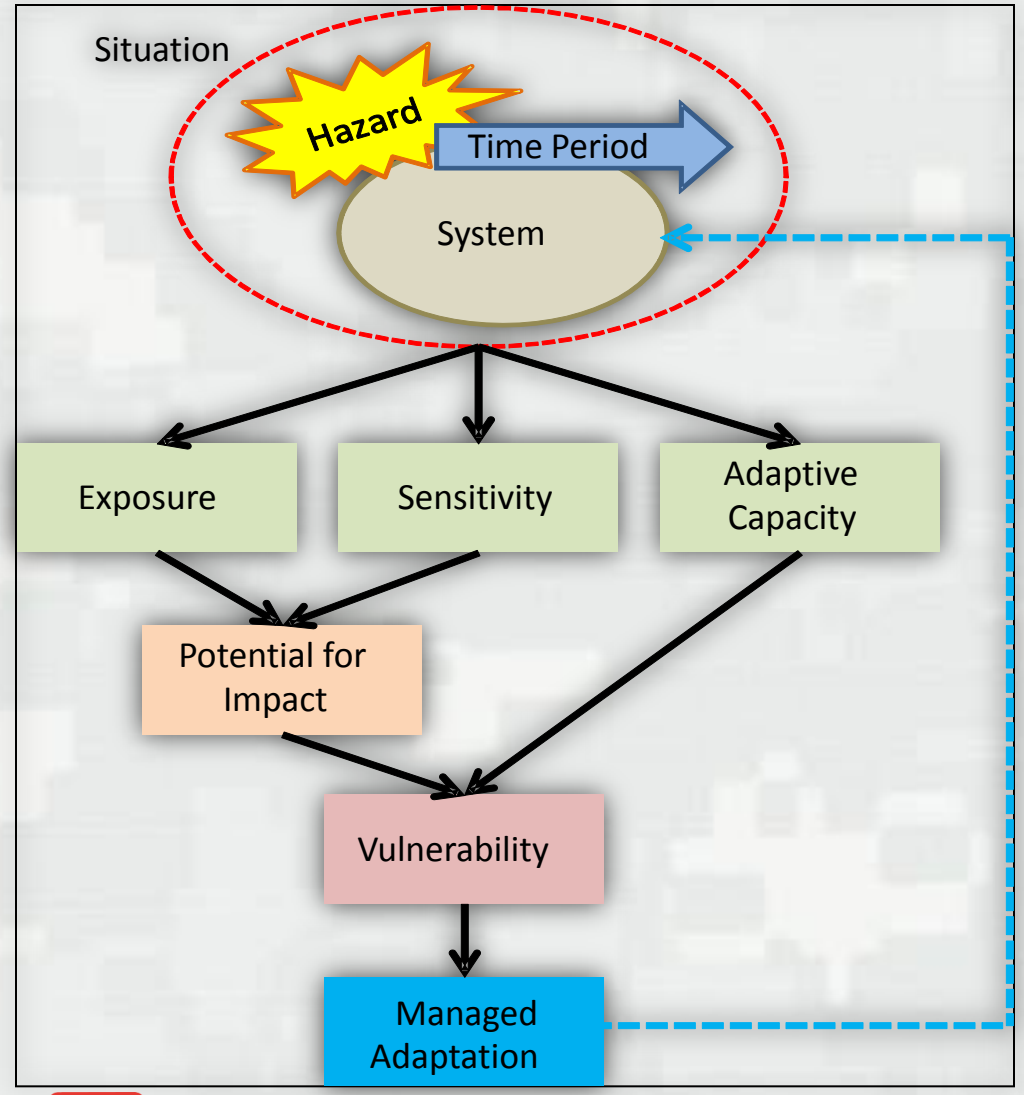




***Vulnerability*: Degree to which a system is susceptible to, and unable to cope with, adverse effects from a hazard; vulnerability is a function of the character and magnitude of a hazard to which a system is exposed, its sensitivity, and its adaptive capacity.**

Wamsley et al. 2013 (in review)

Assess Vulnerability



Vulnerability factors:

- **Internal** – properties of the vulnerable system or community itself
- **External** – factors outside the vulnerable system
- **Socioeconomic** – relate to economic resources, distribution of power, social institutions, cultural practices, etc.
- **Biophysical** – properties investigated by the physical sciences

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

Example Vulnerability Factors Relevant to NNBF

Valued System Functions	Vulnerability Factors		
	Exposure	**Sensitivity**	**Adaptive Capacity**
Coastal Storm Damage Reduction	• Water level (Surge) • Tide range • Wave height (Waves) • Wave period (Waves) • Wave runup (Waves) • Beach and nearshore slope • Storm duration • Storminess	•Median sediment grain size (Sediment type) •Berm width (Beach berm) •Dune height (Dune) •Dune or dune field width (Dune) •Dune or dune field volume (Dune) •Presence of vegetation (Vegetation type) •Dune sediment compaction	•Long-term shoreline change (Longshore transport processes and Sediment supply) •Emergency beach action plan •Beach re-nourishment interval •Community wealth •Tourist beach recreation use •Sediment type •Dune or dune field volume (Dune)
Beach recreation	•Water level (Surge) •Wave height (Waves) •Wave period (Waves) •Tide range •Beach slope •Storm duration •Storminess	•Median sediment grain size (Sediment type) •Berm width (Beach berm) •Dune or dune field volume (Dune)	•Long-term shoreline change (Longshore transport processes and Sediment supply) •Beach re-nourishment interval •Community wealth •Tourist beach recreation use •Sediment type •Dune or dune field volume (Dune)

Resilience

The ability of a system to resist, recover and/or adapt to the stresses of adverse events

- **Engineering:** resist damage, or return to a prior relatively stable state following a disturbance.
- **Ecological:** resist damage, or self-organize into a new configuration after disturbance.
- **Community/Social:** learn and adapt to avoid loss in functionality; develop new functions in response to disturbance.

Schultz et al. (2012)

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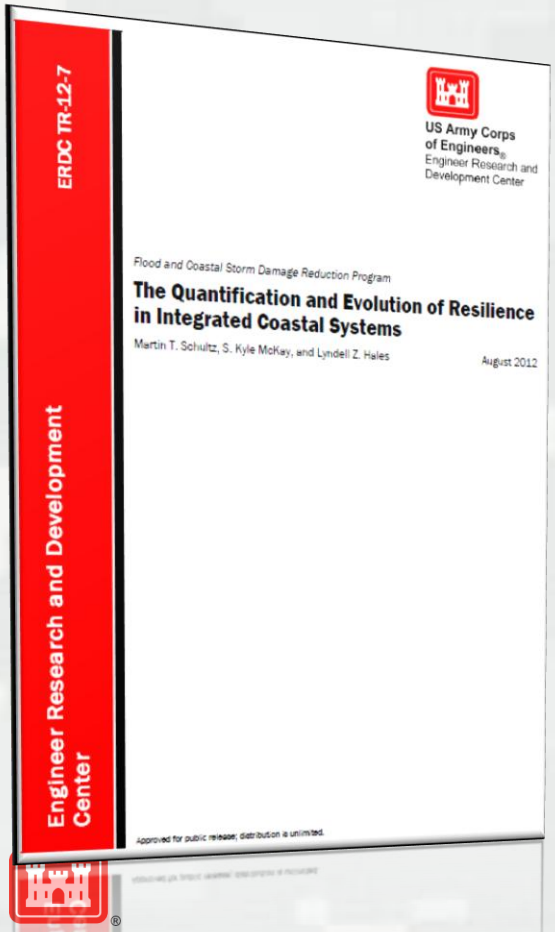
Resilience

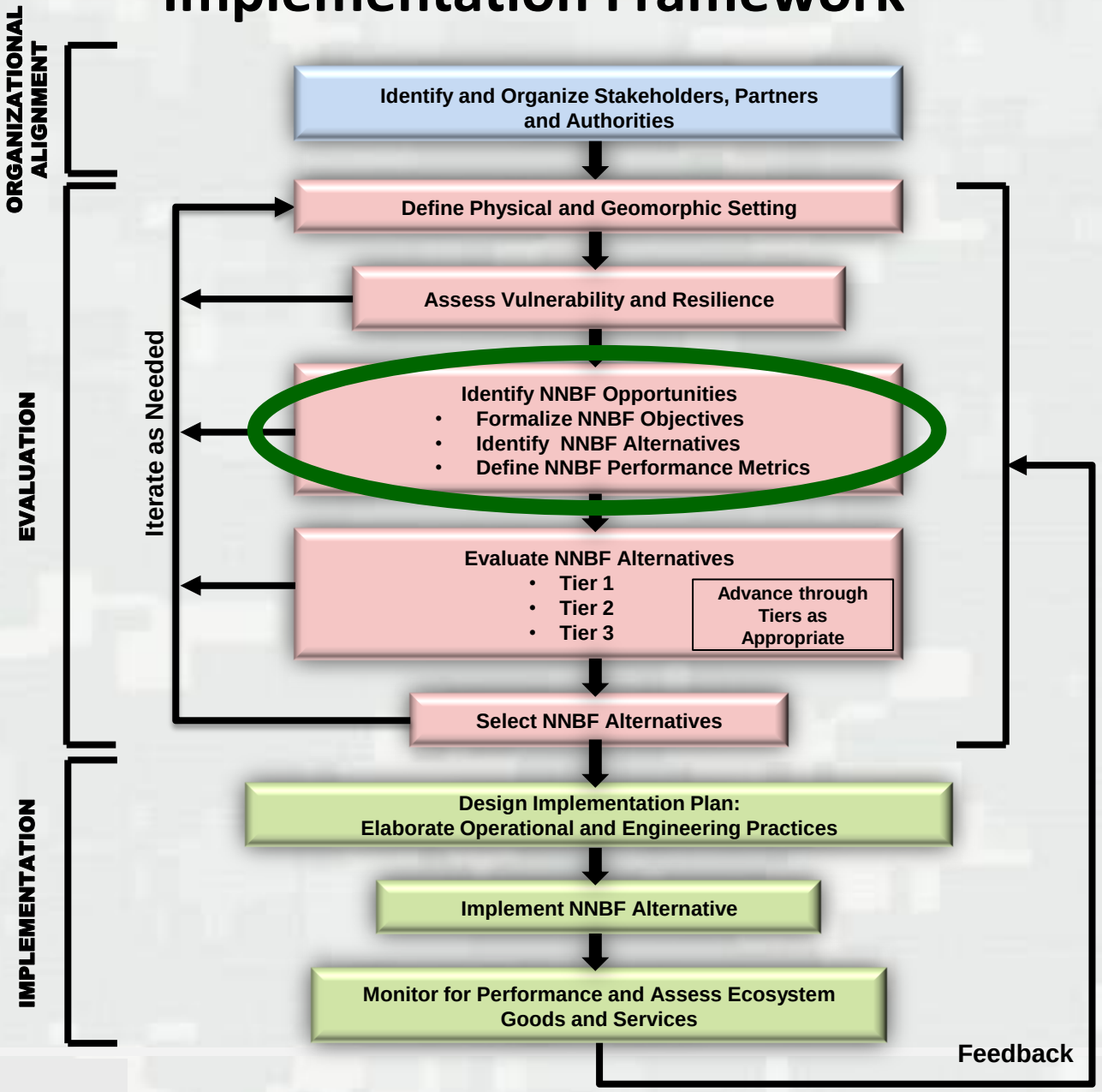
Civil Works

Framework to <u>quantify</u> resilience for Integrated Coastal Systems (ICS)



- **Focus on functional performance of engineered projects.**
- **Incorporates multiple projects in the ICS.**
- **Develops a quantified measure of resilience based on speed and magnitude of restoring functionality or service following a disturbance.**
- **Functionality/service can be restored via natural processes and/or human maintenance.**
- **Not limited by mission area.**

Natural and Nature-Based Features Evaluation and Implementation Framework



Key Definitions

Ecosystem Goods and Services are tangible items or intangible commodities generated by self-regulating or managed ecosystems whose composition, structure, and function are comprised of natural, nature-based and/or structural features that produce socially valued benefits that can be utilized either directly or indirectly to promote human well-being.

Key Take-home points:

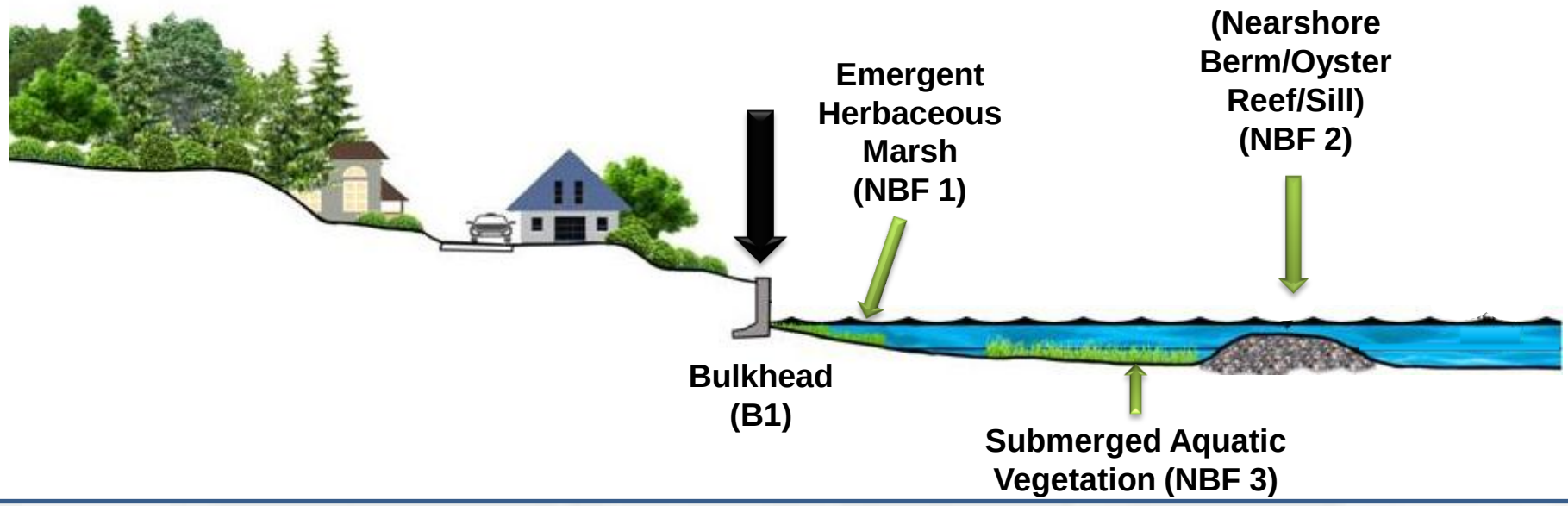
1. EGS can be derived from either built or natural capital (or a combination of the two).
2. Their value is simply a way to depict their importance or desirability to the consumers.
3. The ability of ecosystems to provide goods and services is dependent on critical ecosystem processes tied to structure and function either alone or in concert.

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

Metrics – Services to NBI Matrix

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



Key Definitions

Performance Metrics are **specific** measures of production or indicators of system response that can be used to **consistently** estimate and report the anticipated **consequences** of an alternative plan with respect to particular planning and engineering objectives.

They articulate the exact information that will be collected, modeled, elicited from experts, or otherwise developed and presented to decision makers to characterize plan performance and engineering designs.

They must provide the ability to **distinguish** the relative degree of ecosystem response (conveyed in terms of impacts or benefits) **across alternatives and designs**, either qualitatively or quantitatively, in ways that make sense and will help decision makers consistently and transparently compare alternatives and designs.

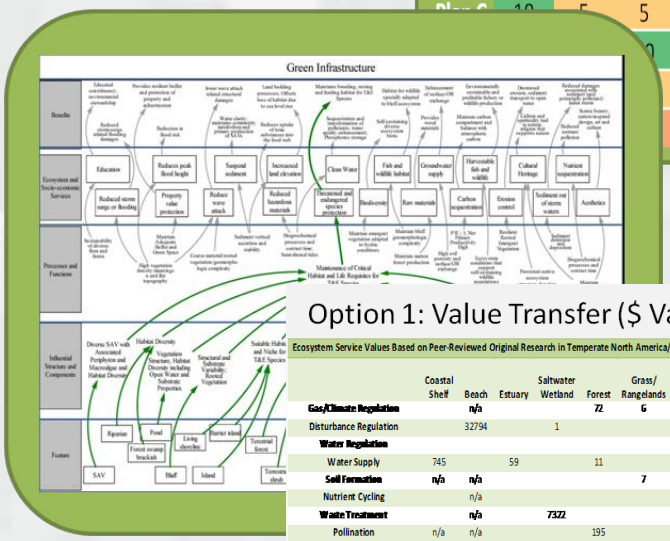
Good performance metrics are:

- Complete and concise
- Transparent and unambiguous
- Accurate
- Direct
- Understandable
- Operational

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
			5	9	7	7.2	102
				8	5	7.8	115
				10	10	7	115
				4	7	5.6	80



Option 1: Value Transfer ($ Value per acre)

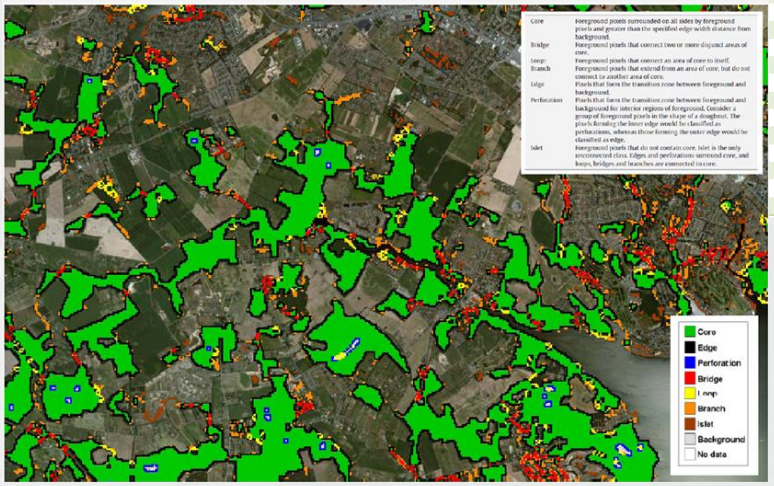
Ecosystem Service Values Based on Peer-Reviewed Original Research in Temperate North America/Europe (2012 $/(ac*yr))

	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	
										5		

Option 2: Ecosystem Production Functions

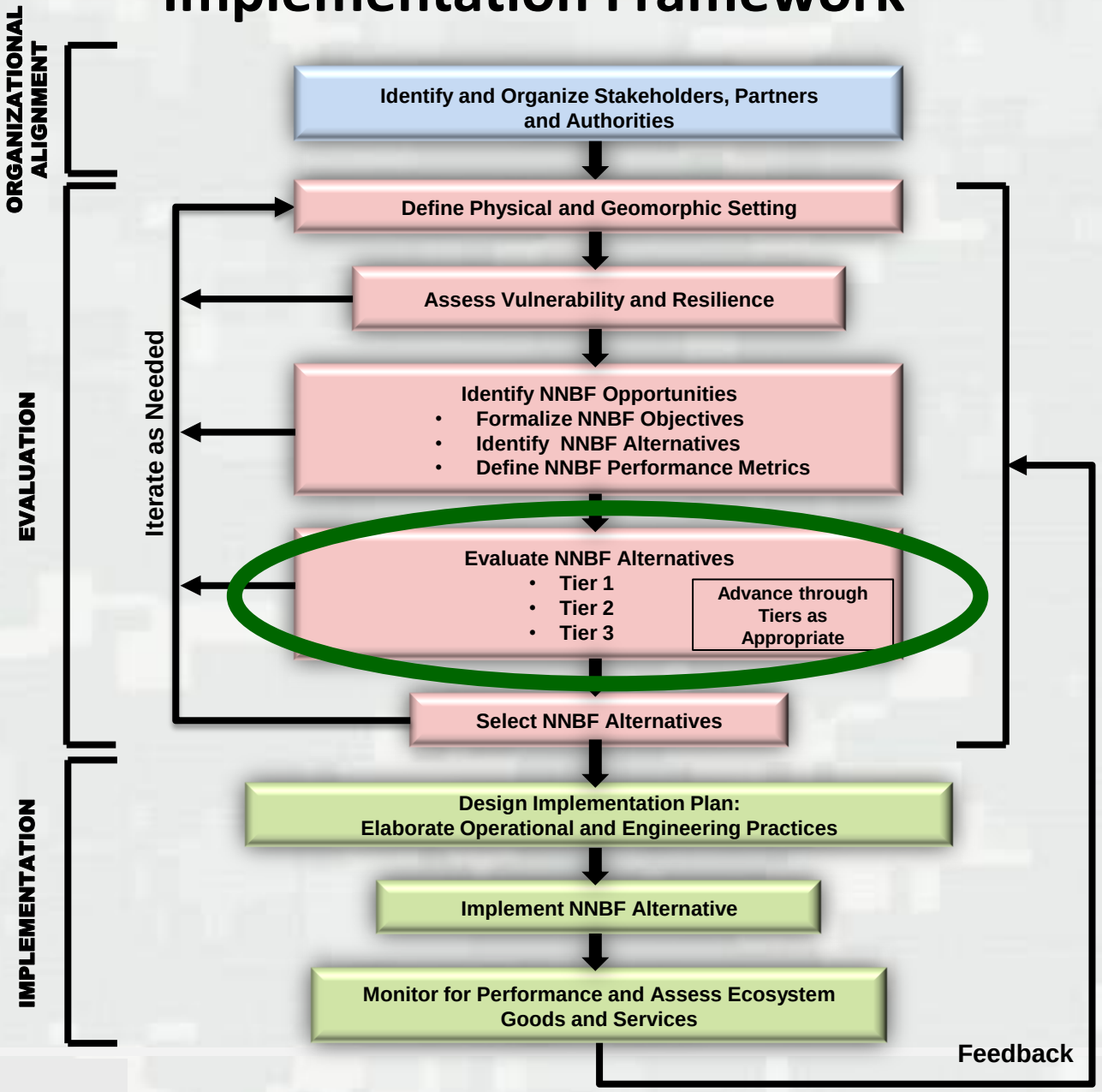
Literature, and Meta-analysis Studies in Temperate North America/Europe (2012 $/(ac*yr))

Forest	Grass/ Rangelands	Cropland	Freshwater Wetland	Open Fresh Water	Riparian Buffer	Urban Greenspace	Urban/ Barren
65	4		161			404	
			4397		106		
	2		3590			7	
196			1856	492	2310		
6	4			n/a			
53	53		1008				
195	16	10		n/a			
2	14	14					
1110		999	136				
147	1	18	1690	428	1647	2562	
1			1070		5		

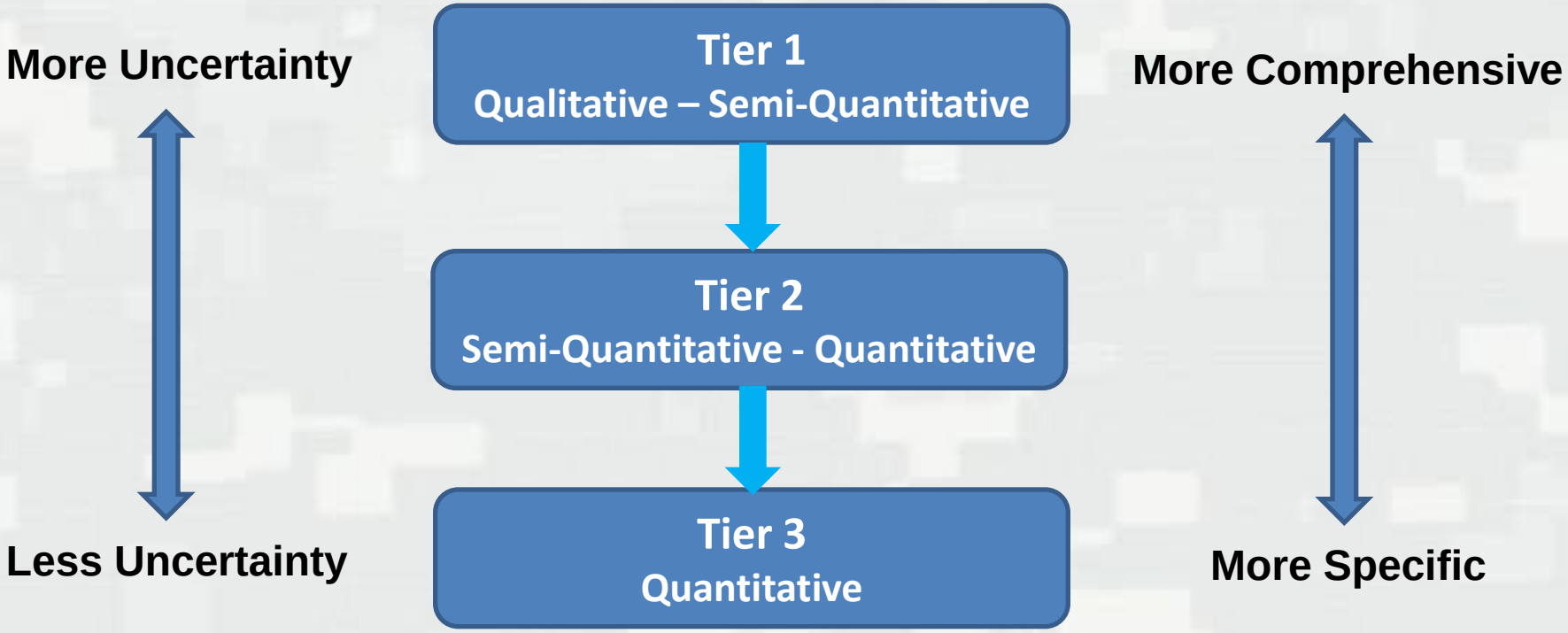


72 individual performance metrics identified for NNBF

Natural and Nature-Based Features Evaluation and Implementation Framework



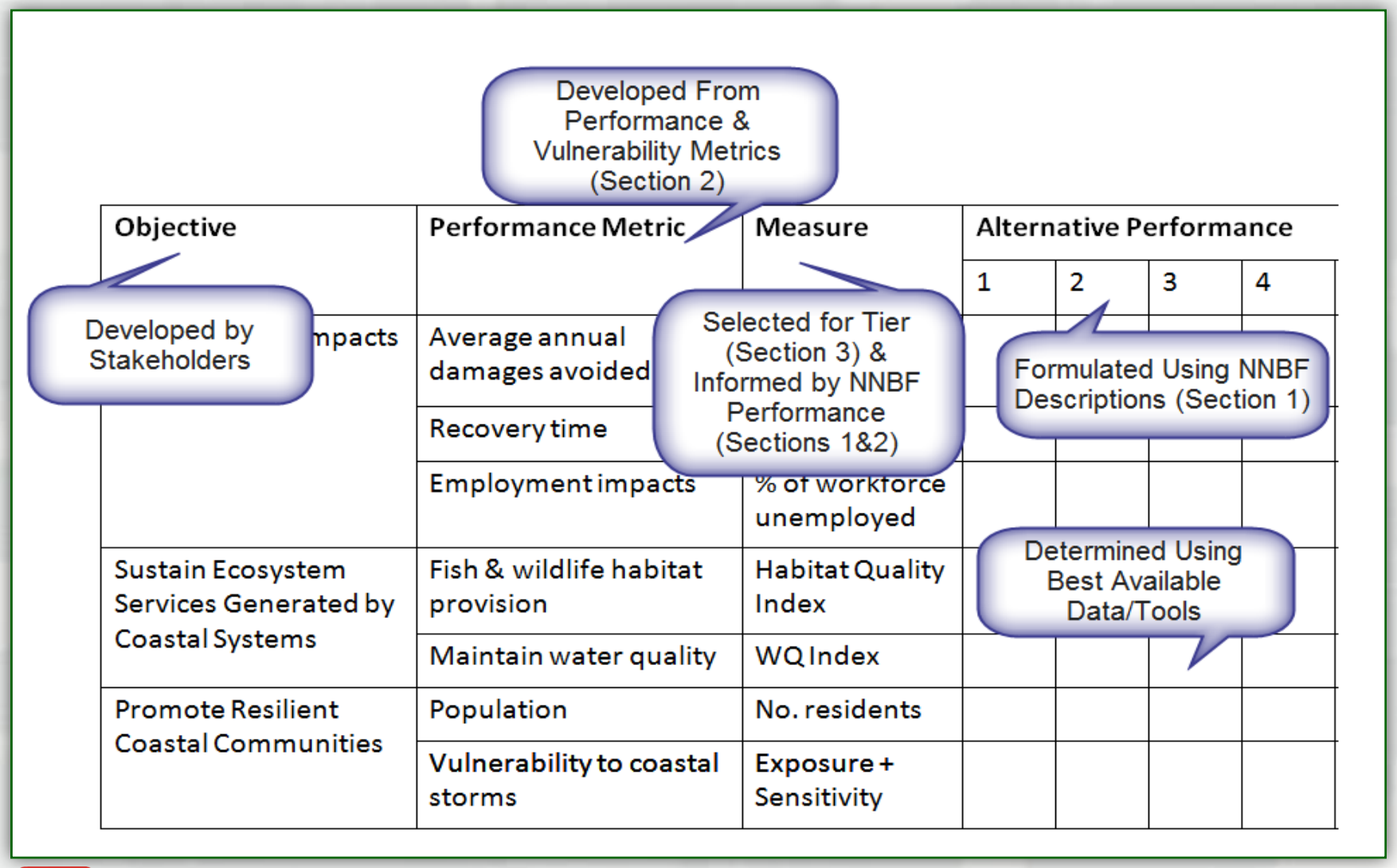
Tiered Evaluation Framework



Framework Implementation

- Objectives and associated metrics serve as the **primary** evaluation criteria
- Decision options (i.e., categories of NNBF, specific NNBF projects, or alternatives consisting of groups of NNBF projects and non-structural and structural measures) are **evaluated against** metrics
- Criteria that measure performance **relative to** the objectives will depend on the Tier
- **Weights** can be applied to the objectives
- **Opportunities** for swing-weighting, value of information assessments, and other decision support may be exercised

Basic Construct



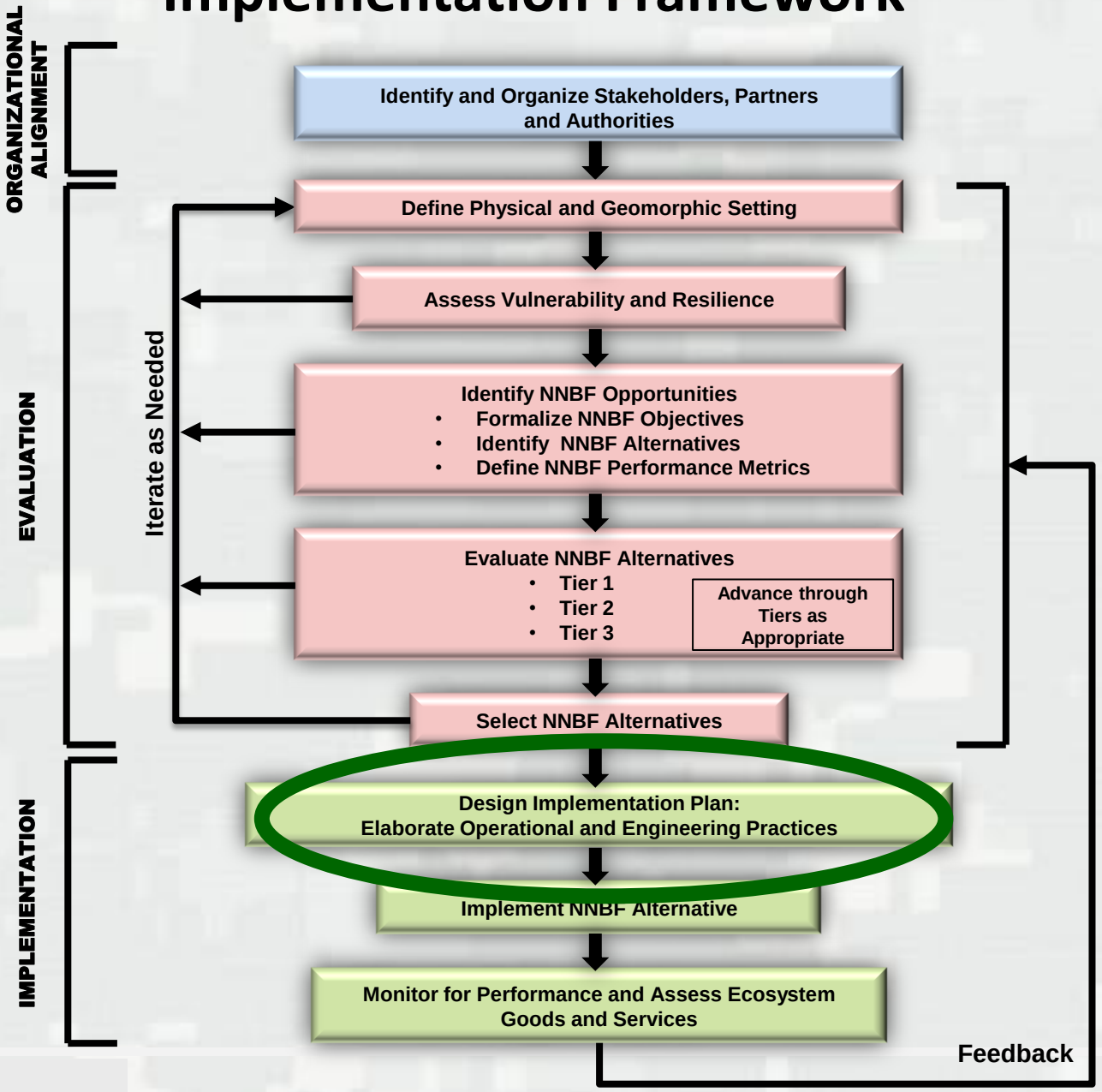
Objective	Performance Metric	Measure	Alternative Performance			
			1	2	3	4
mpacts	Average annual damages avoided					
	Recovery time					
	Employment impacts	% of workforce unemployed				
Sustain Ecosystem Services Generated by Coastal Systems	Fish & wildlife habitat provision	Habitat Quality Index				
	Maintain water quality	WQ Index				
Promote Resilient Coastal Communities	Population	No. residents				
	Vulnerability to coastal storms	Exposure + Sensitivity				

Tier 3 Assessment

- More quantitative measures, generally involving numerical analysis
- Greater resolution in the "alternative" under consideration

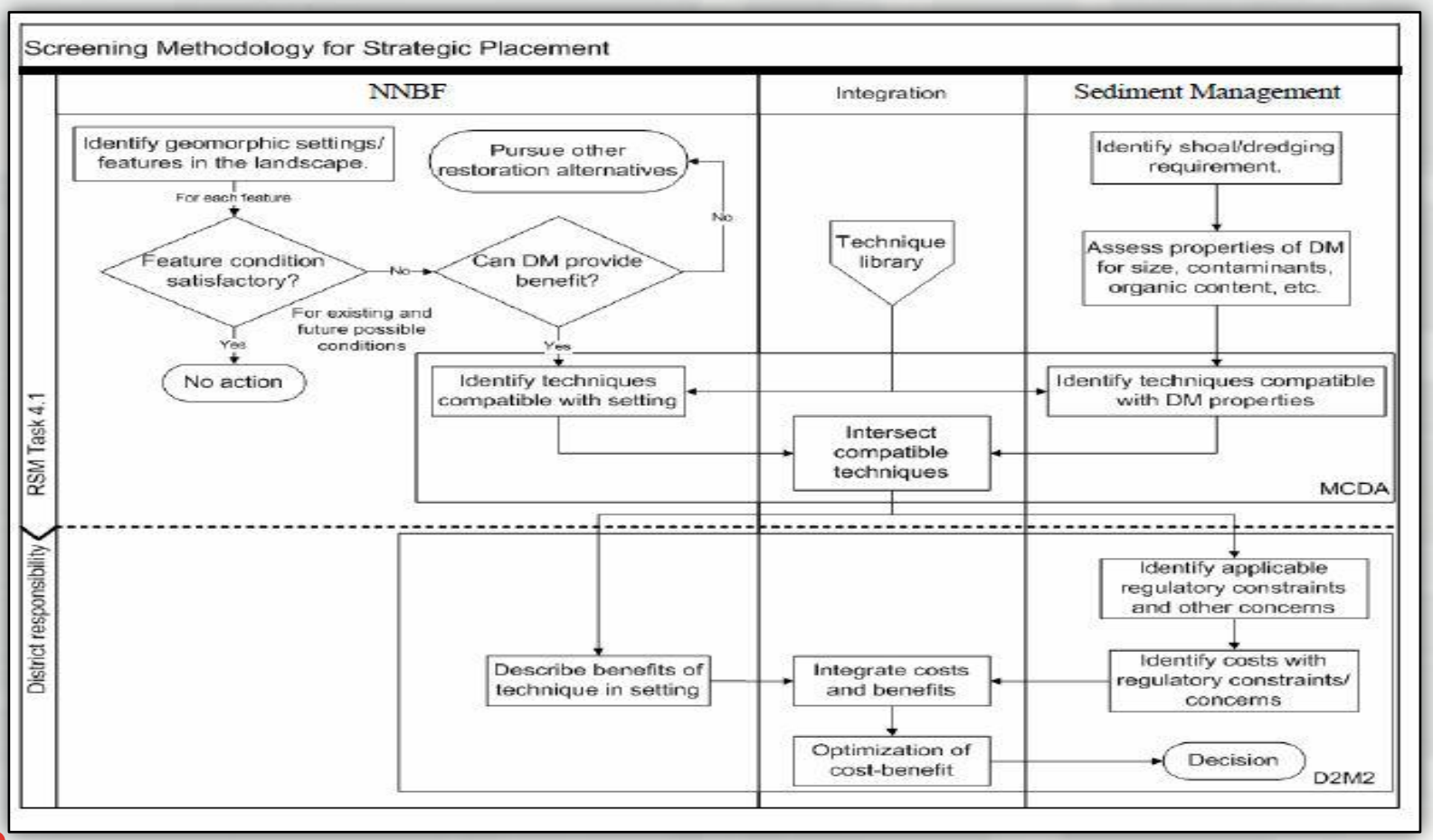
Objective Information	Performance Metric	Measure	Consequences				
			No Action Alternative	Structural Feature (breakwater)	NNBF (Oyster Reef)	Structural Feature + NNBF (Breakwater + Oyster Reef)	Structural Feature + NNBF (Seawall + Living Shoreline)
Objective Category Vulnerability **Objective** Contribution of NNBF to reducing coastal vulnerability	Storm protection	Peak water level (m), maximum wave height (m), (Average Annual Damages Avoided $M)	2.1,0.5 ($0)	2.1,0.3 ($1)	1.7,0.3 ($2)	1.7,0.2 ($2.2)	1.4,0.2 ($2.3)

Natural and Nature-Based Features Evaluation and Implementation Framework



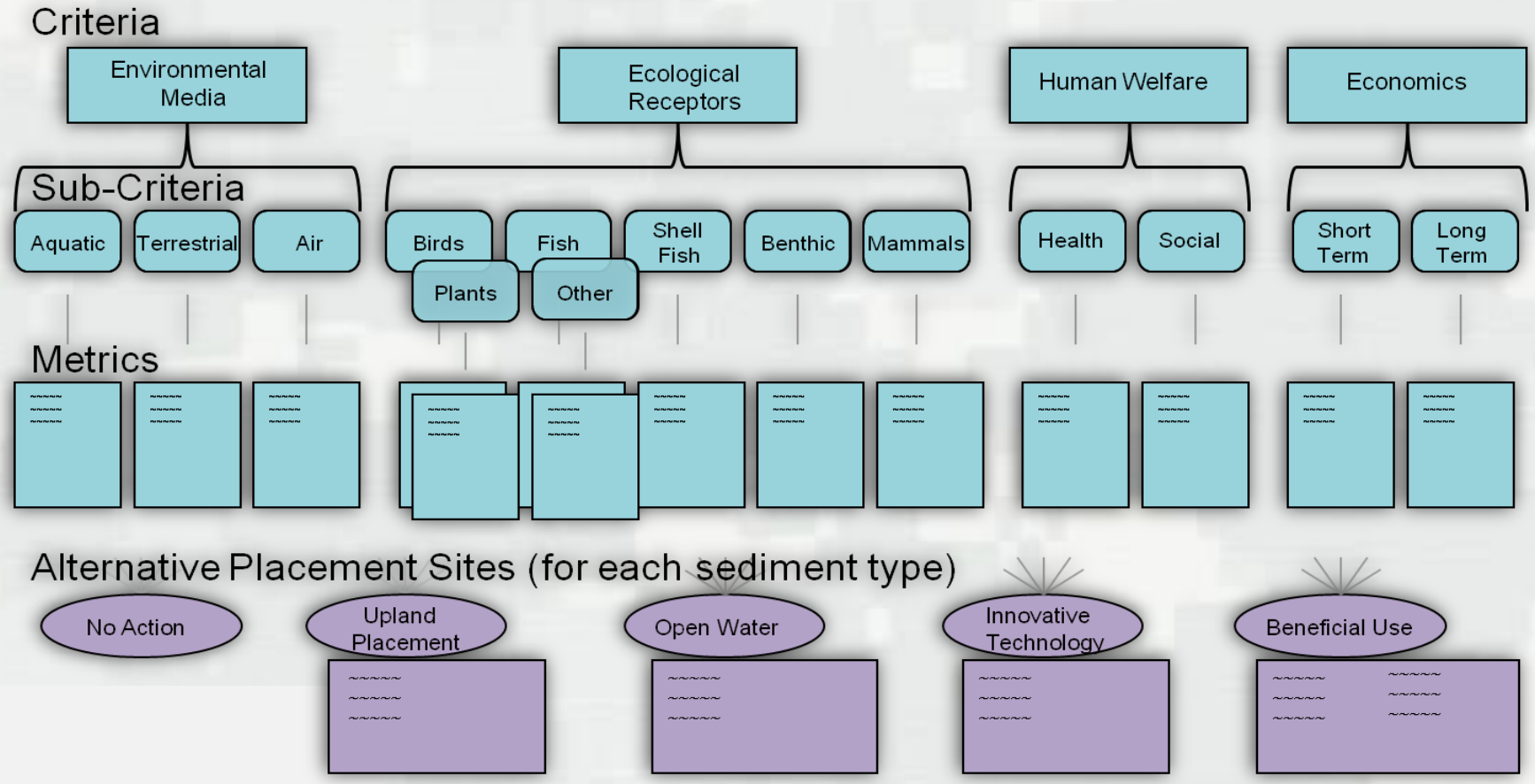
Managing Sediment Resources for NNBF: Beneficial Use of Dredged Materials

Linking need, opportunity, and operational practice

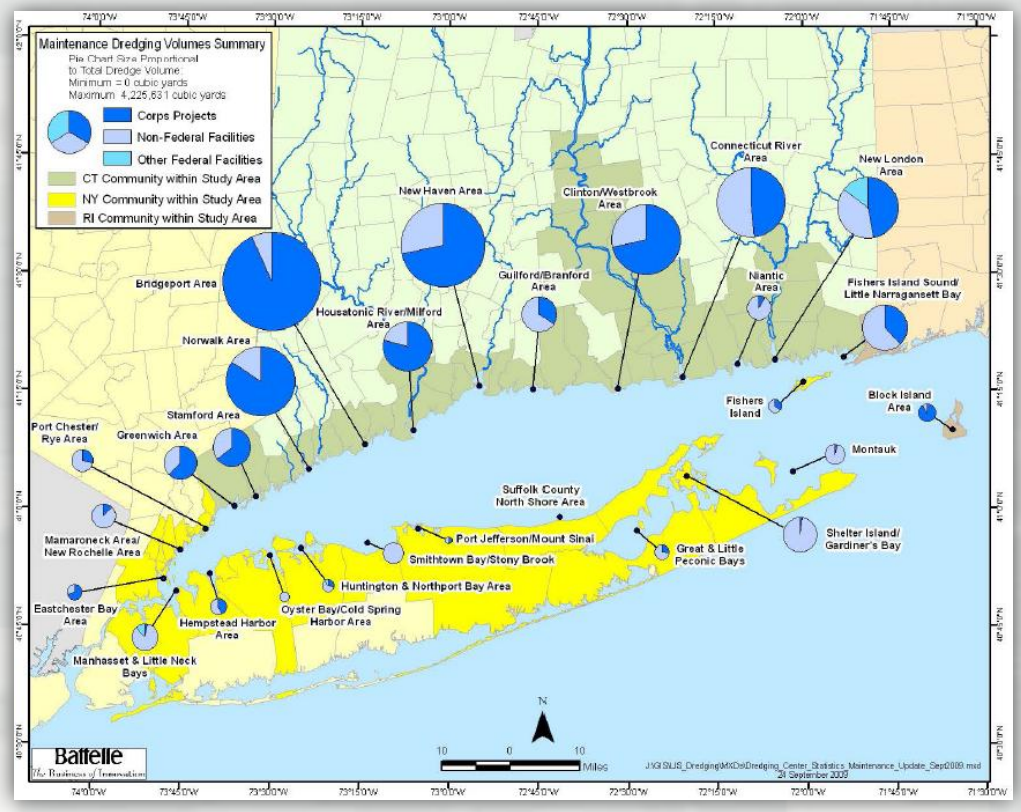


Decision Model Application to Long Island Sound

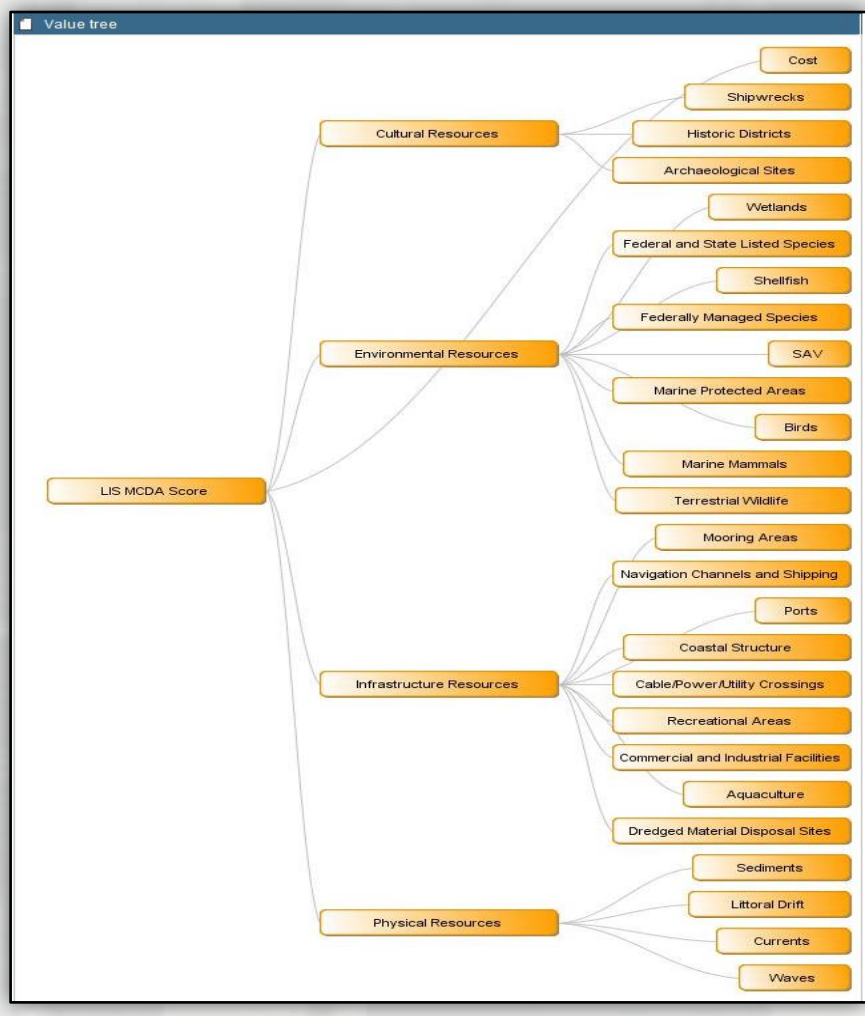
- **A MCDA decision framework was collectively developed by stakeholder representatives involved in the Long Island Sound Dredged Materials Management Plan Working Group**
- **Through group discussion and individual interviews, this approach incorporates stakeholder objectives and concerns into the decision process**



D2M2 Vignette – Long Island Sound

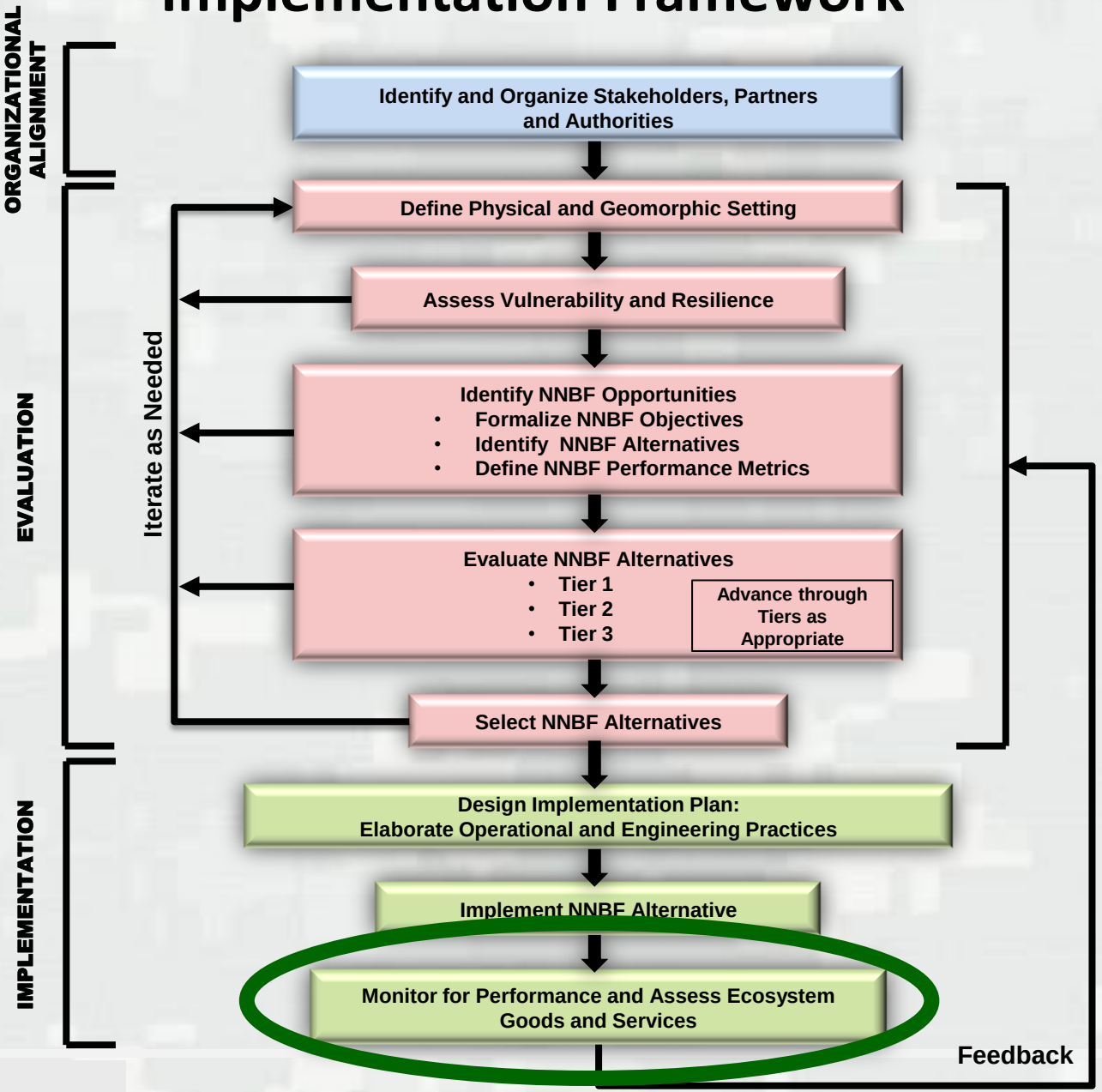


Map of the LIS region identifying regional dredging centers and projected dredging needs for a 30 year time horizon



MCDA Value Tree of costs and impact criteria.

Natural and Nature-Based Features Evaluation and Implementation Framework



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