

# Performance Metrics for Ecosystem Goods and Services Generated in the Post-Sandy Environment

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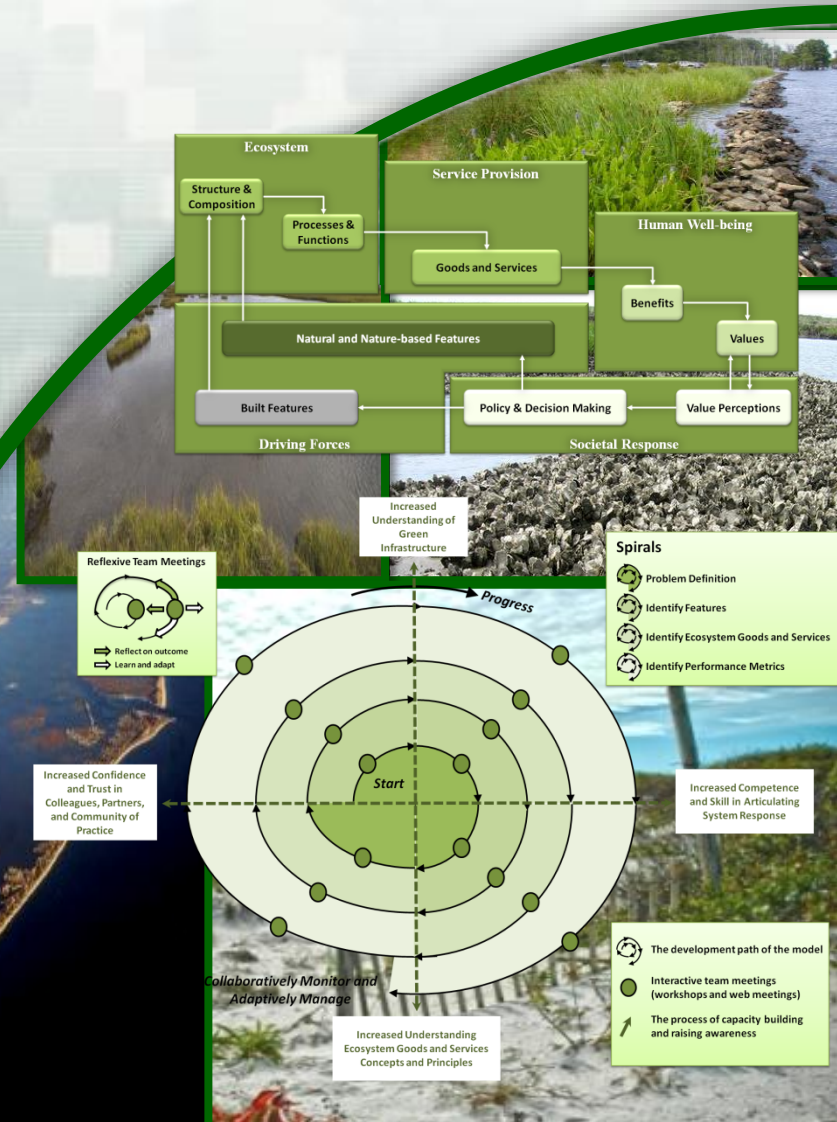
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Alexandria, VA, USA

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Baltimore, MD, USA

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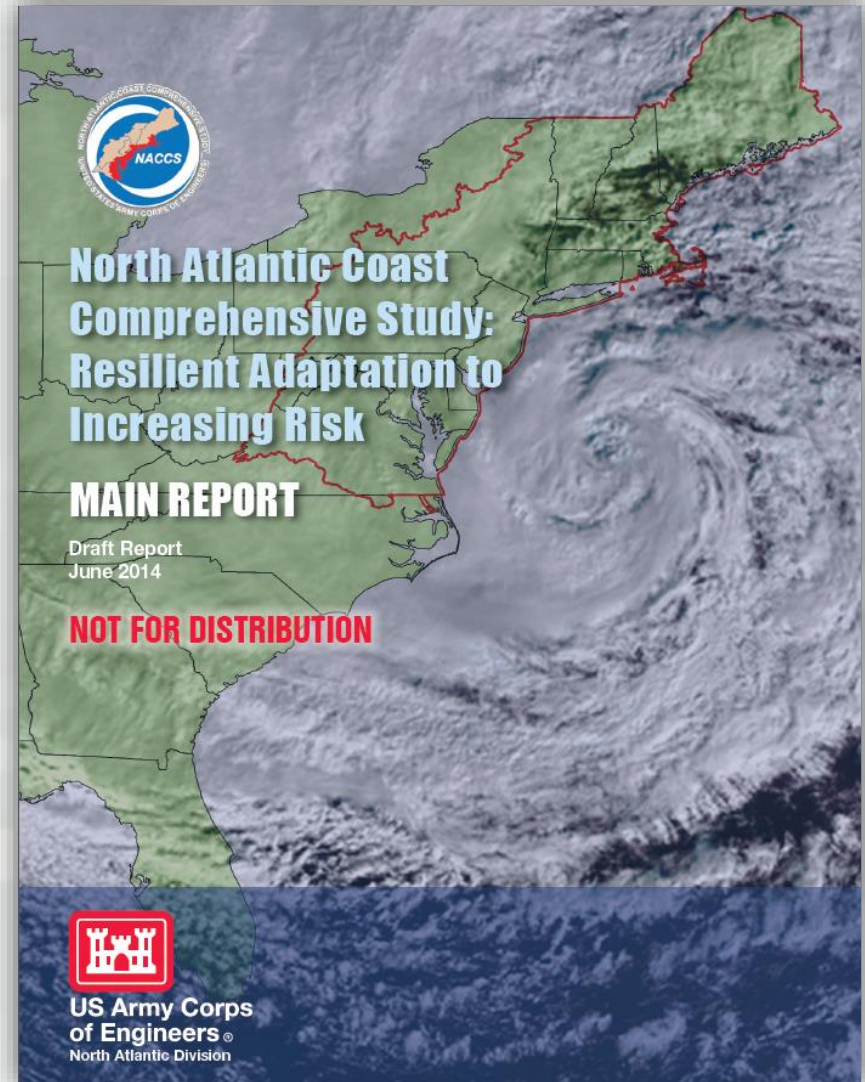
US Army Corps of Engineers  
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# North Atlantic Coast Comprehensive Study (NACCS)

- **Who** and what is exposed to flood risk?
- **Where** is the flood risk?
- **What** are the appropriate strategies and measures to reduce flood risk and how do they align with each other and other regional plans?
- **What** is the relative cost of a particular measure compared to the anticipated risk reduction?
- **What** data are available to make a RISK INFORMED decision?
- **What** data gaps exist/can be closed through the NACCS?

**Final report** is undergoing internal agency reviews now, and will be released in **January 2015**





# Multiple Lines of Defense

**Natural features** are created and evolve over time through the actions of physical, biological, geologic, and chemical processes operating in nature. 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.

**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).

## Coastal Risk Reduction and Resilience: Using the Full Array of Measures



US Army Corps of Engineers

Civil Works Directorate



US Army Corps of Engineers  
BUILDING STRONG.

August 2013

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

Improved coastal storm risk management measures are needed

Employing three primary strategies—**protect, accommodate, and retreat**—coastal communities should consider a system of **comprehensive, resilient, and sustainable** coastal storm risk management measures. The system should include a **combination of measures** (structural, NNBf, and nonstructural measures) to form **resilient, redundant, robust, and adaptable strategies** and measures that are tailored to enhance life safety, local site conditions, and societal values.

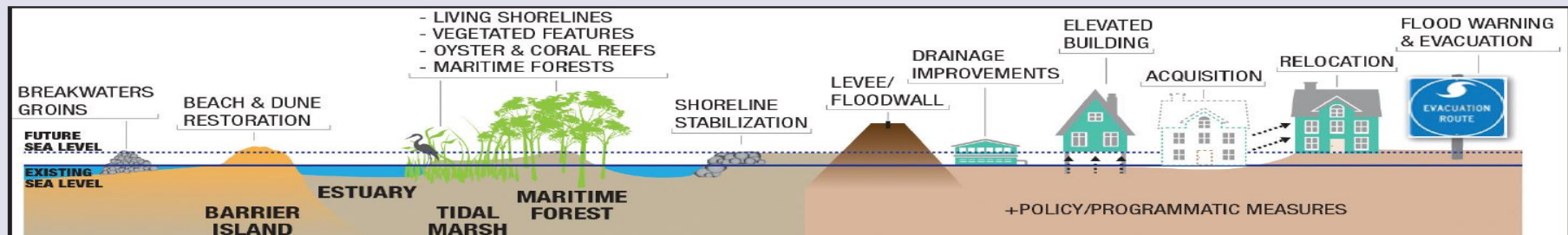


Figure II-1. Combinations of measures may be used to improve redundancy and resilience associated with coastal flood risk management.

# Use of Natural and Nature-based Features (NNBF) for the NACCS

**Task 1: Characterize** Natural and Nature-Based Feature(NNBF)  
Contribution to Resilience and Risk Reduction

**Task 1A: Define** resilience with respect to NNBFs

**Task 1B: Identify** characteristics of natural systems

**Task 1C: Identify** categories of NNBF that contribute to resilience

**Task 2: Data Integration** and Metrics for NNBFs

**Task 2A: Data** integration

**Task 2B: Develop** performance metrics for NNBF

**Task 2C: Develop** vulnerability metrics

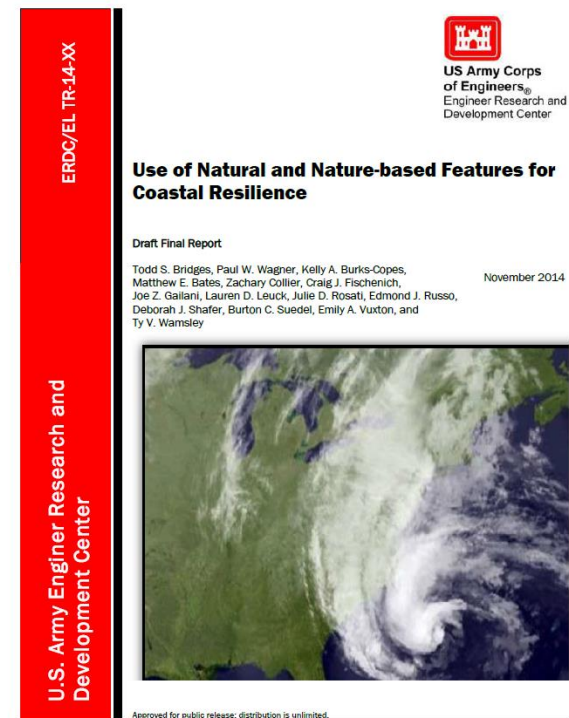
**Task 3: Evaluation** Framework for NNBF

**Task 3A: Develop** evaluation framework

**Task 3B: Apply** the NNBF evaluation framework

**Task 3C: Demonstrate** of ecosystem goods & services assessment

**Goal:** Assist the USACE Baltimore District in obtaining **scientifically defensible justification** to incorporate **Natural and Nature-Based Features (NNBF)** into the District's current management portfolio and acquire the necessary knowledge and methodologies to integrate NB into **tactical** and **strategic** planning initiatives in a post-Sandy planning environment.



Bridges et al. 2014 (in press)



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

## Project Leaders:

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

## Task Leaders:

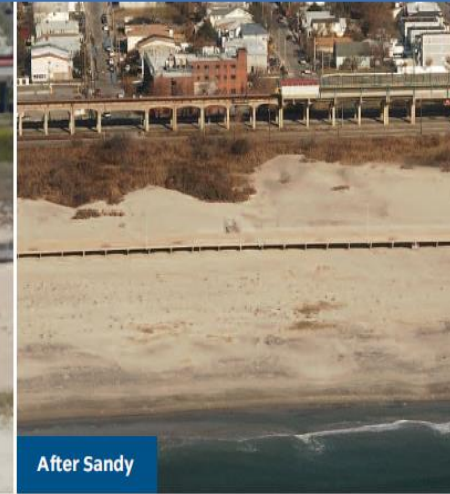
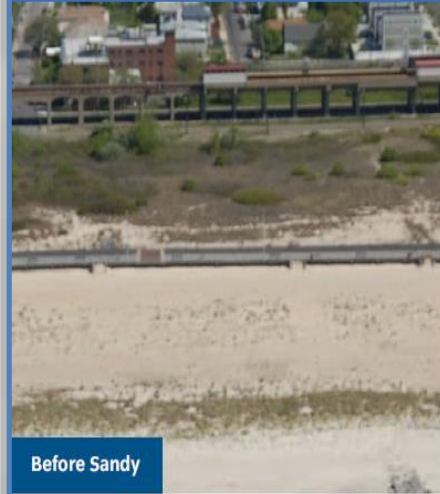
- Kelly Burks-Copes (EL)
- Craig Fischenich (EL)
- Edmond Russo (EL)
- Deborah Shafer (EL)
- Ty Wamsley (CHL)

## Study Team Members:

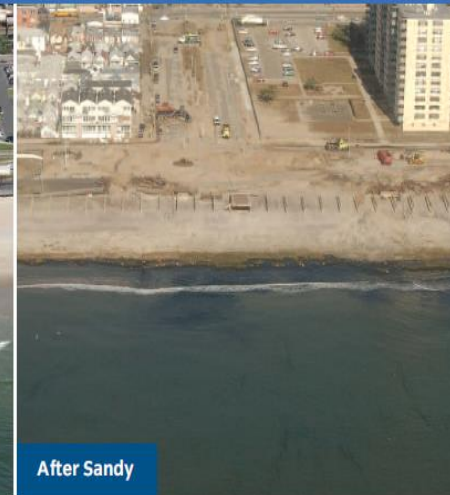
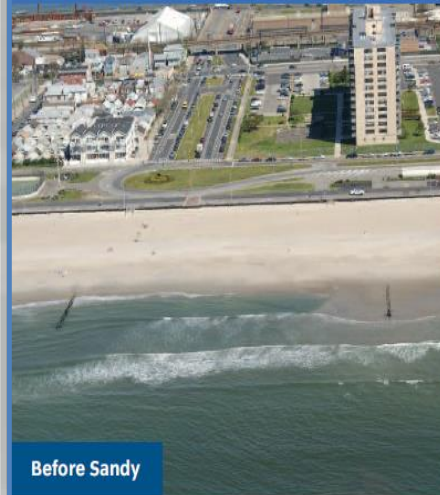
- Scott Bourne (EL)
- Pam Bailey (EL)
- Kate Brodie (EL)
- Zach Collier (EL)
- Sarah Miller (EL)
- Patrick O'Brien (EL)
- Candice Piercy (EL)
- Bruce Pruitt (EL)
- Burton Suedel (EL)
- Lauren Dunkin (CHL)
- Ashley Frey (CHL)
- Mark Gravens (CHL)
- Linda Lillycrop (CHL)
- Jeff Melby (CHL)
- Andy Morang (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)

### Dune Protection on the Rockaway Peninsula

#### With Dune (Beach 56th Street)



#### Without Dune (Beach 94th Street)



# Natural and Nature-Based Infrastructure 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

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Marsh, wetland, or SAV elevation and continuity

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Marsh, wetland, or SAV elevation and continuity

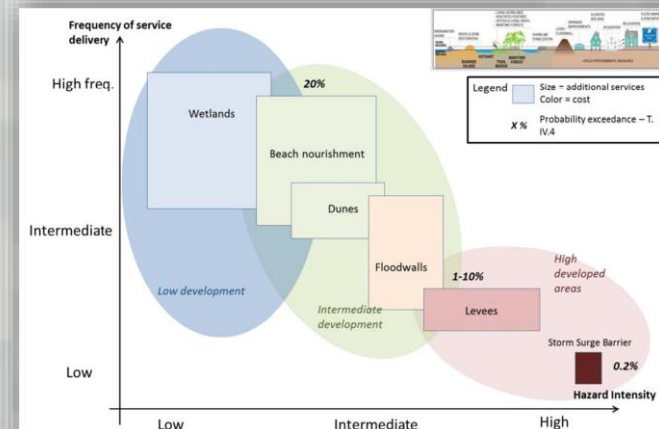
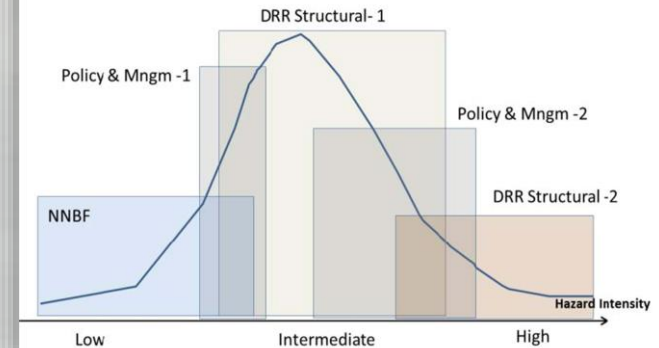
Vegetation type and density

### Performance Factors

Marsh, wetland, or SAV elevation and continuity

Vegetation type and density

## RISK SPECTRA – POTENTIAL DAMAGE



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)



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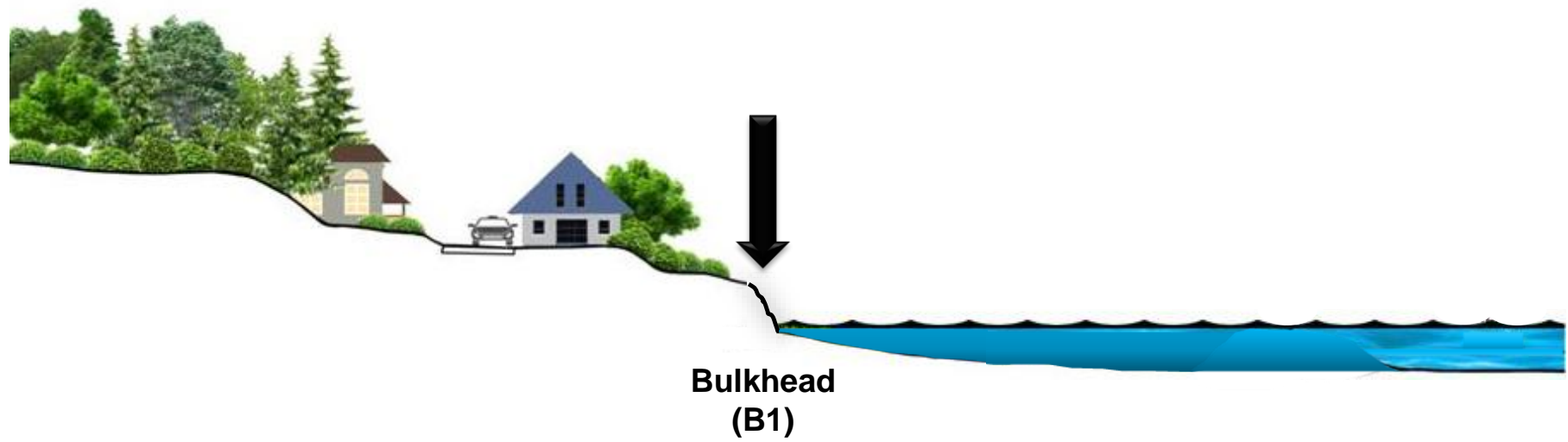
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# Plan Comparisons



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

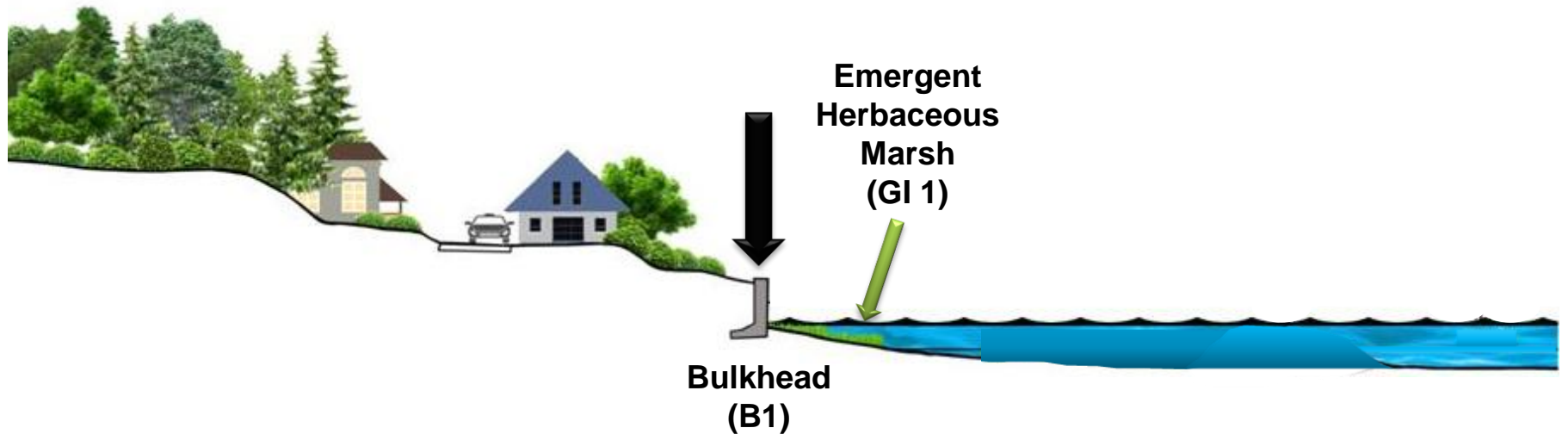


# Plan Comparisons

Plans

Services

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

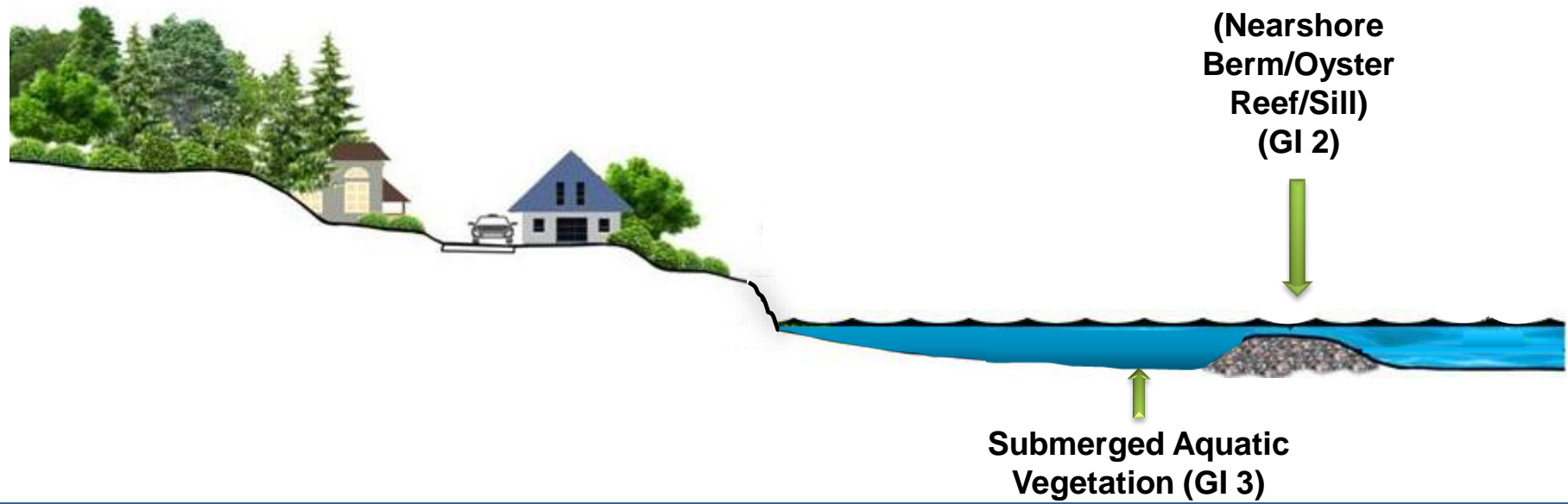




# Plan Comparisons



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

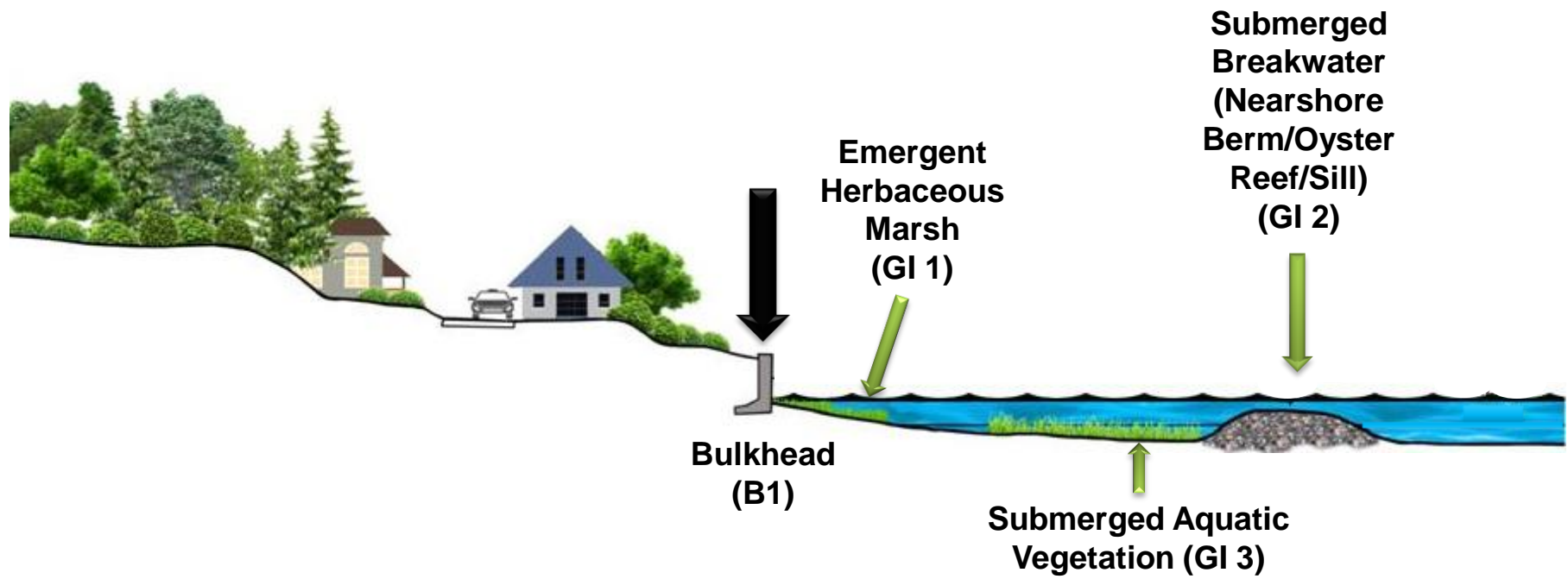


# Plan Comparisons

Plans

Services

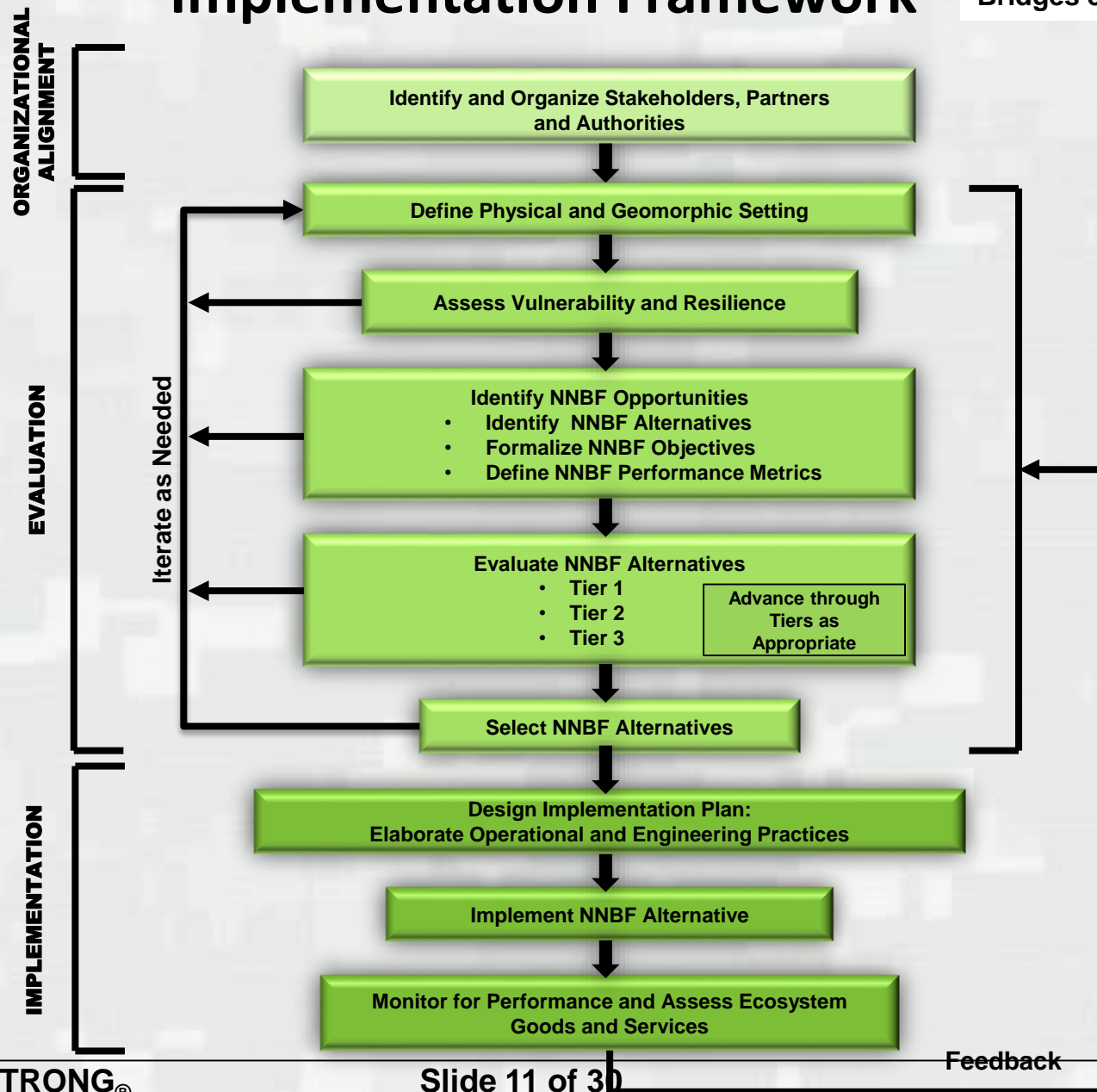
	SB1	NNBF 1	NNBF 2	NNBF 3	ALL
S1	✓		✓		✓
S2	✓		✓	✓	✓
S3			✓		✓
S4				✓	✓
S5		✓	✓		✓
S6		✓		✓	✓



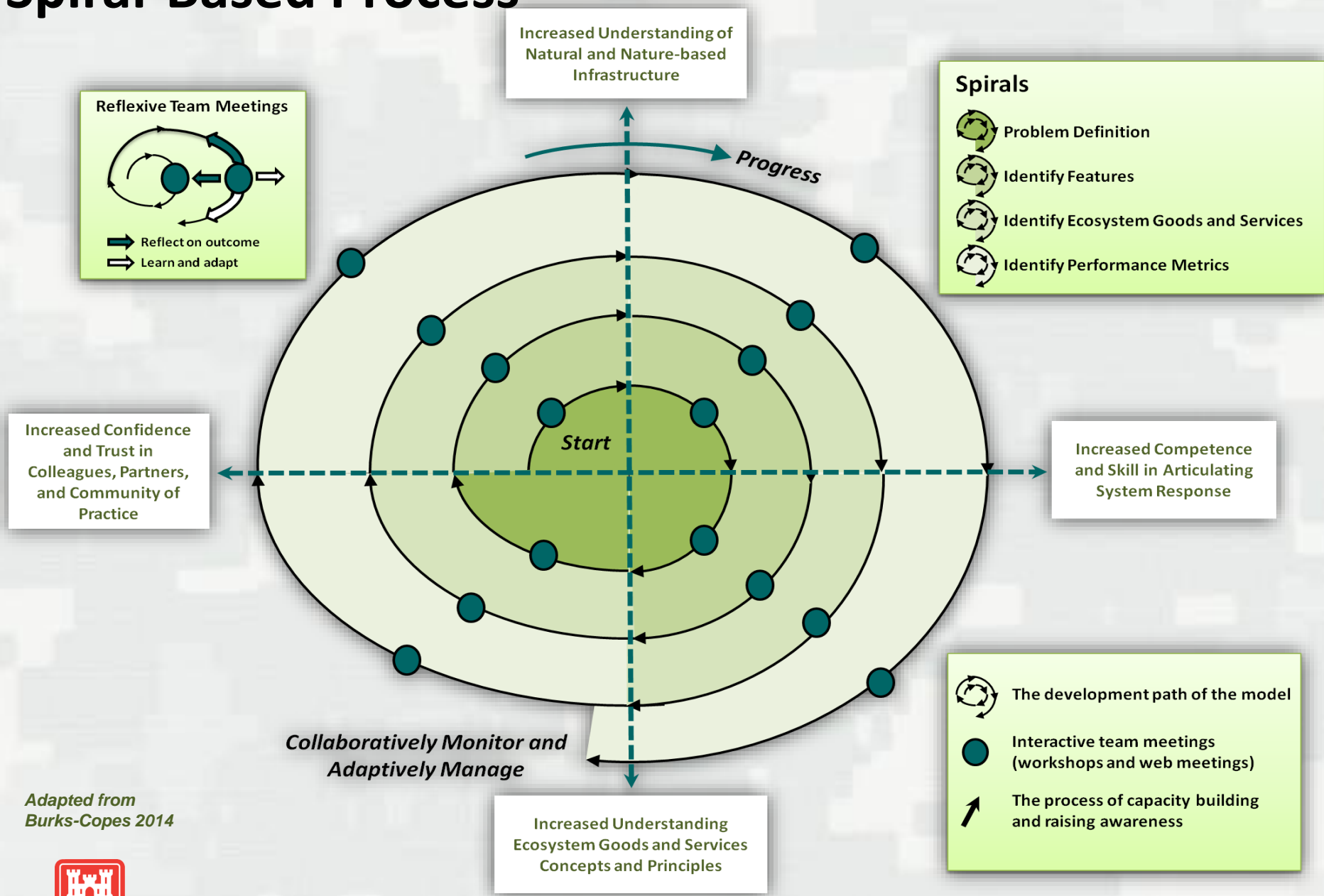


# Natural and Nature-Based Features Evaluation and Implementation Framework

Bridges et al. 2014 (in press)



# Spiral-Based Process



Adapted from  
Burks-Copes 2014





# Goal of this effort . . . .

- **How do we measure coastal resilience?**
  - **Blended solutions** (gray and green infrastructure) will produce a **full array of benefits**
  - We must identify and develop **metrics** to measure their performance and success
  - We can focus on the production of **ecosystem goods & services (EGS)** to get there
  - **Ecosystem Production Functions** offer a non-monetized, scalable approach
  - **Trade-offs** between monetizable and non-monetizable benefits must be anticipated & handled transparently
  - How do we define the **service area**?
  - How do we account for **competing** EGS?
  - How do we determine **Intermediate vs. Final EGS**?



# 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 a 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

# 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.

Bridges et al. 2014 (in press)



# NNBF List (30 Total)

## Natural and Nature-based Features

- |  |  |
|--|--|
| 1. Beach (sand, gravel, cobble)                      | 10. Maritime forest  |
| 2. Mudflat / sandflat                                | 11. Submerged aquatic vegetation (seagrass, other - fresh or saline) |
| 3. Bluff (any material, if sand assume eroding dune) | 12. Riparian buffer  |
| 4. Dune / swale complex                              | 13. Emergent herbaceous marsh / wetland (fresh)                      |
| 5. Salt marsh (emergent herbaceous)                  | 14. Shrub-scrub wetlands (fresh)                                     |
| 6. Shrub-scrub wetlands (brackish)                   | 15. Flooded swamp forest (fresh)                                     |
| 7. Flooded swamp forest (brackish)                   | 16. Pond   |
| 8. Maritime grassland                                | 17. Terrestrial grassland  |
| 9. Maritime shrubland                                | 18. Terrestrial shrubland  |
|  | 19. Terrestrial forest   |

## Natural and Nature-based Complexes

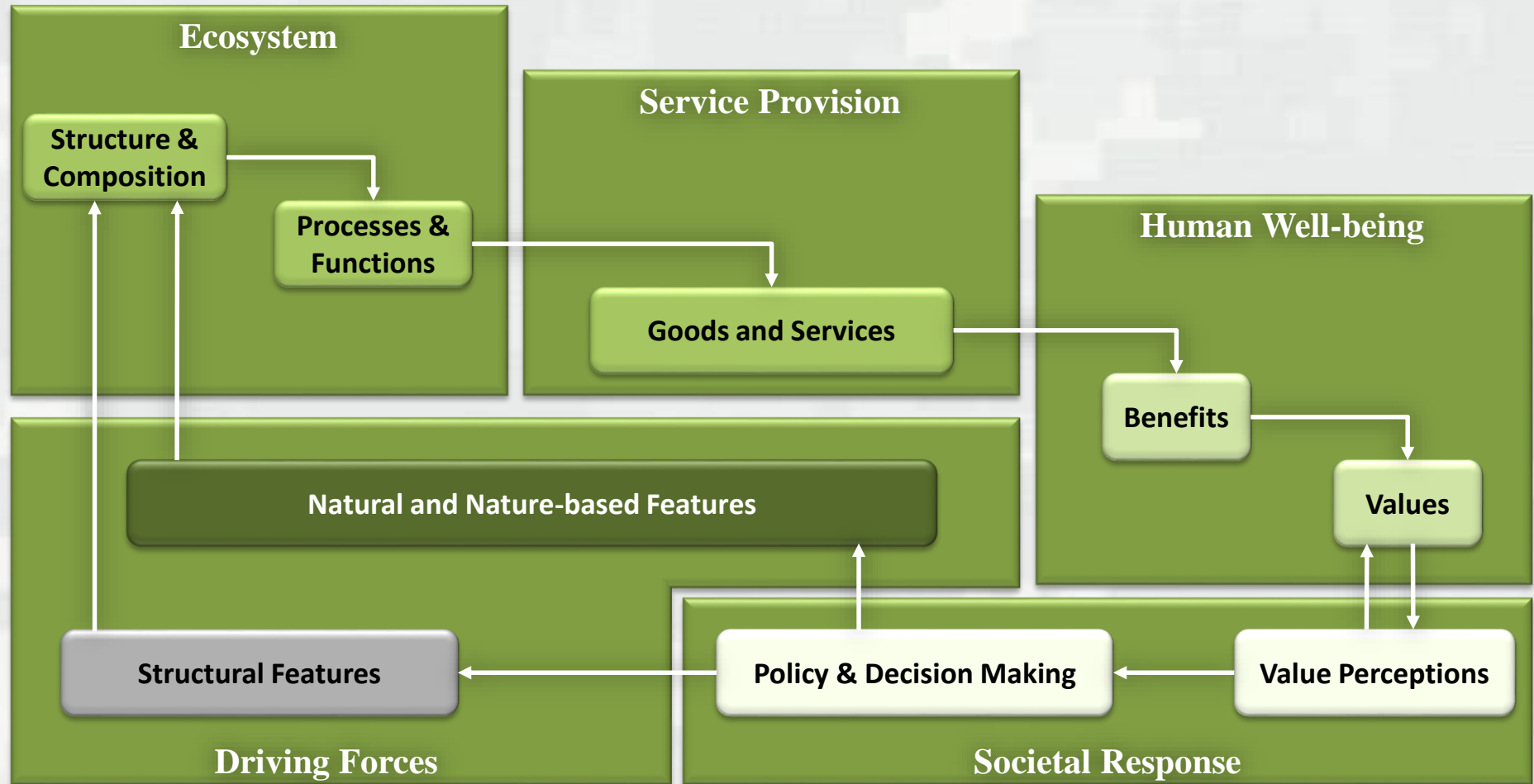
- 20. Reef, intertidal or submerged (also see breakwater)
- 21. Breakwater, subaerial or emergent (nearshore berm, sill, reef, can contain oysters, rock, shells, mussels, SAV, emergent or herbaceous vegetation)
- 22. Breakwater, submerged (nearshore berm, sill, artificial reef - if containing living organisms or plants, see reef)
- 23. Island (can include one or more of beach, dune, breakwater, bluff, marsh, maritime forest, other veg)
- 24. Barrier island (can include one or more of beach, dune, breakwater, bluff, marsh, maritime forest, other veg)
- 25. Living shoreline (vegetation w/ sills, benches, breakwaters, etc.)

## Built Features

- 26. Levee
- 27. Storm surge barrier
- 28. Seawall / revetment / bulkhead
- 29. Groin
- 30. Breakwater



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



# EGS List (21 Total – Presented Alphabetically)

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. Maintain background suspended sediment in surface 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

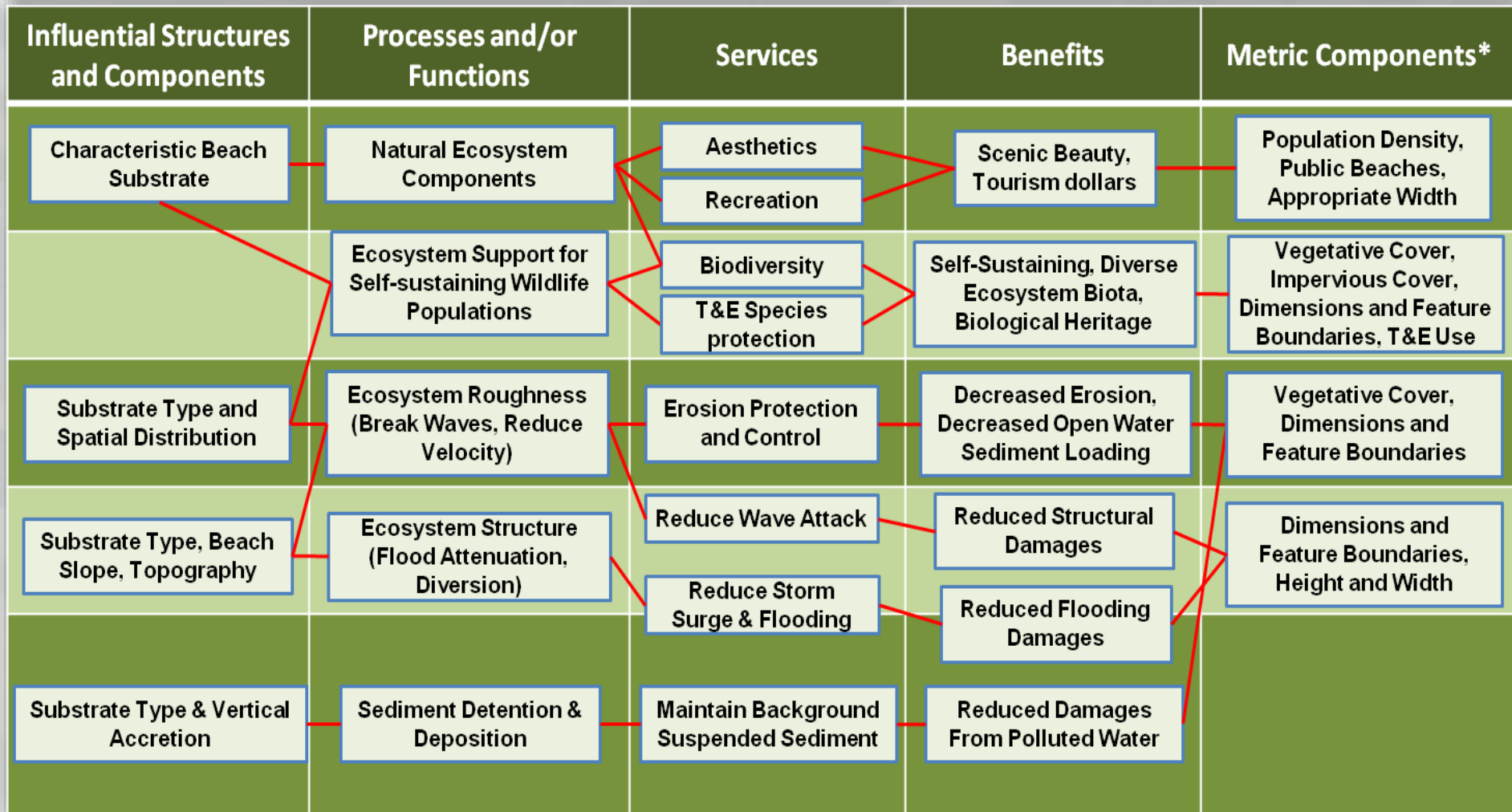
# Services Table Approach

*For a Given NNBF Feature or Complex*

Influential Structures and Components	Processes and/or Functions	Services	Benefits	Metrics
What are we looking at? What components comprise the feature?	How does each component function? Mechanisms, Processes	What service does each function provide?	What product(s) does the service produce that is valued?	How can that benefit be measured?
Component 1	Function 1	Service	Benefit 1	Metric 1
	Function 2		Benefit 2	Metric 2
Component 2	Function 3	Service 2	Benefit 3	Metric 3
			Benefit 4	Metric 4
				Metric 5



# Beaches for example . . . . .



\*Metrics data, mathematical functions and data sources discussed in Appendix E of the White Paper.



# Tiered Application Approach

## • **Level 1** – Qualitative characterization of performance

– 2013 Workshop Exercise

### • 48 instruments returned (76% Response Rate)

- 8 Academics (1 illegible)
- 13 Consultants
- 18 Federals
- 9 NGOs

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	6	10	10	8	5	7.8	115
Plan E	5	5	5	10	10	7	115
Plan F	7	7	3	4	7	5.6	80

Metric	Average	Stdev	Max	Min	Relative Mean	Median	n
Reduce storm surge and related flooding	81.2	25.9	100	0	7%	95	47
Reduce wave attack	80.0	26.8	100	0	7%	90	47
Erosion protection and control	78.6	24.7	100	15	7%	85	47
Reduce the peak flood height and lengthen the time to peak flood	75.9	29.3	100	0	7%	90	47
Habitat for fish and wildlife provisioning	69.9	32.4	100	0	6%	90	47
Threatened and Endangered species protection	66.6	32.4	100	0	6%	80	47
Clean water provisioning	64.7	31.3	100	0	6%	75	47
Biological diversity	64.3	32.0	100	0	6%	70	47
Recreation	61.2	27.4	100	5	5%	60	47
Property value protection	56.8	33.3	100	0	5%	70	47
Reduce hazardous or toxic materials in water or landscape	55.9	32.3	100	0	5%	60	47
Nutrient sequestration or conversion	52.6	31.2	100	0	5%	60	47
Increase or maintain land elevation and land-building	52.2	32.6	100	0	5%	50	47
Education and scientific opportunities	49.1	31.3	100	0	4%	50	47
Commercial harvestable fish and wildlife production	48.7	32.8	100	0	4%	50	47
Aesthetics	47.6	28.8	100	0	4%	50	47
Provision and storage of groundwater supply	47.4	31.2	100	0	4%	50	47
Carbon sequestration	46.8	30.1	100	0	4%	50	47
Maintain background suspended sediment in surface waters	45.0	26.6	80	0	4%	50	47
Cultural heritage and identity	44.3	29.1	100	0	4%	50	47
Raw materials production	22.3	25.6	100	0	2%	10	47



# Tiered Application Approach

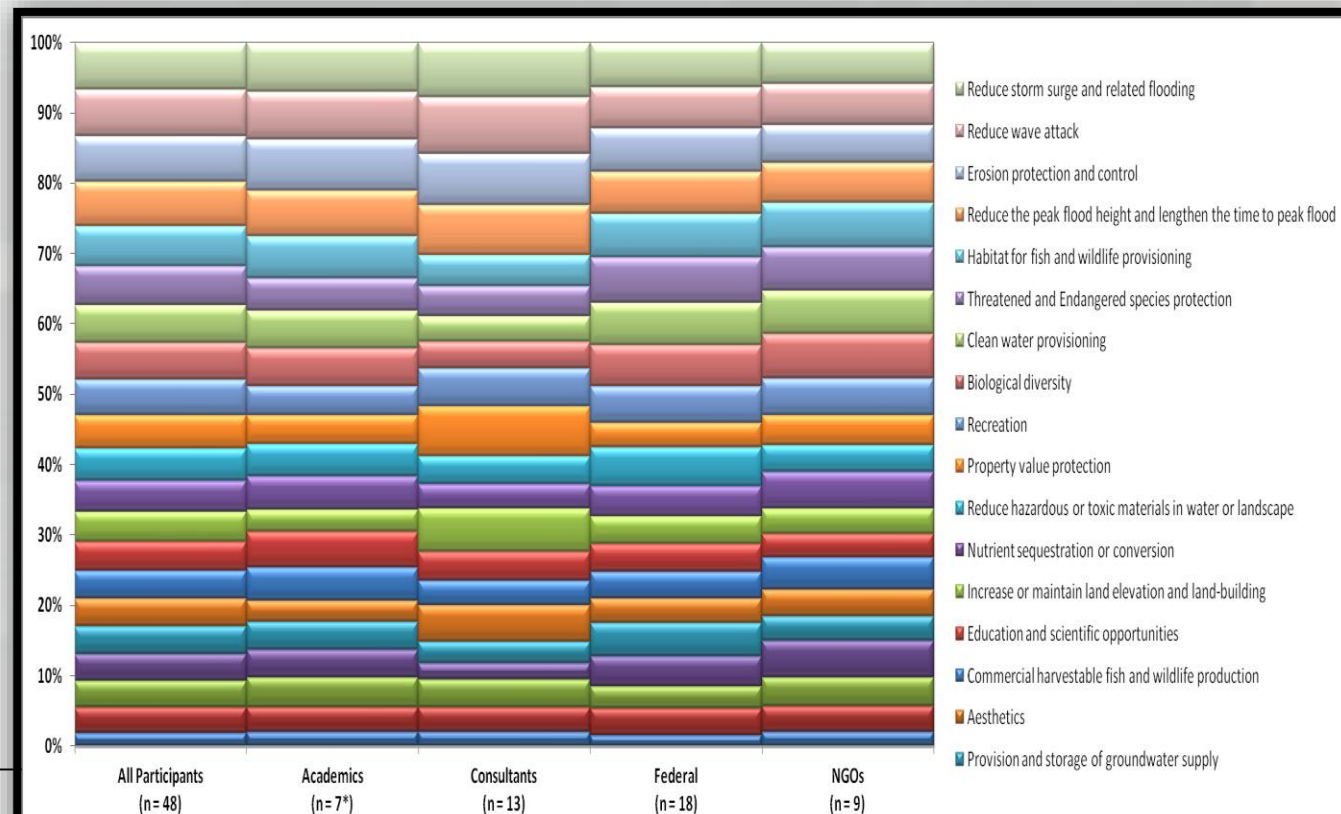
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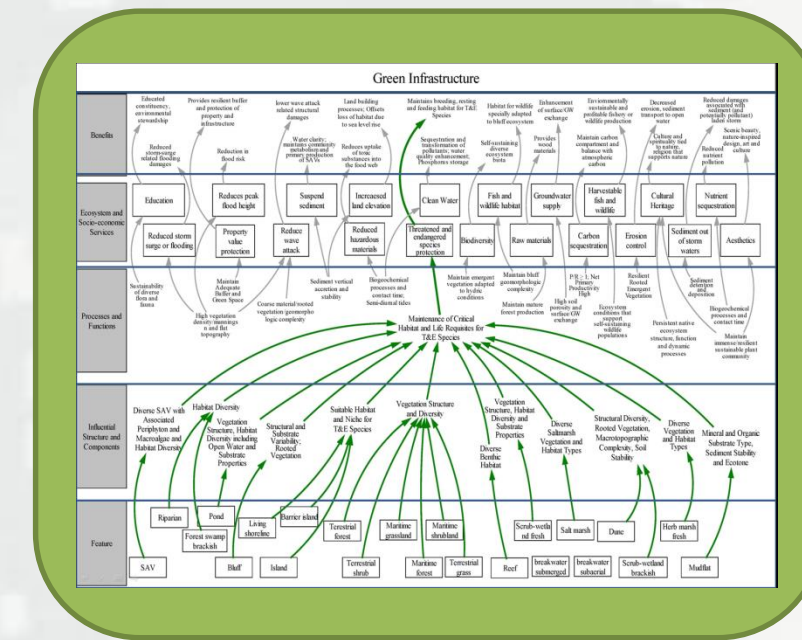
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Plan D	6	10	10	8	5	7.8	115
Plan E	5	5	5	10	10	7	115
Plan F	7	7	3	4	7	5.6	80



# Define Requirements for Applications

- Sync with Task 3A & 3B
  - Tiered Approach
    - **Level 1** – Qualitative characterization of performance
    - **Level 2** – Semi-quantitative characterization of performance

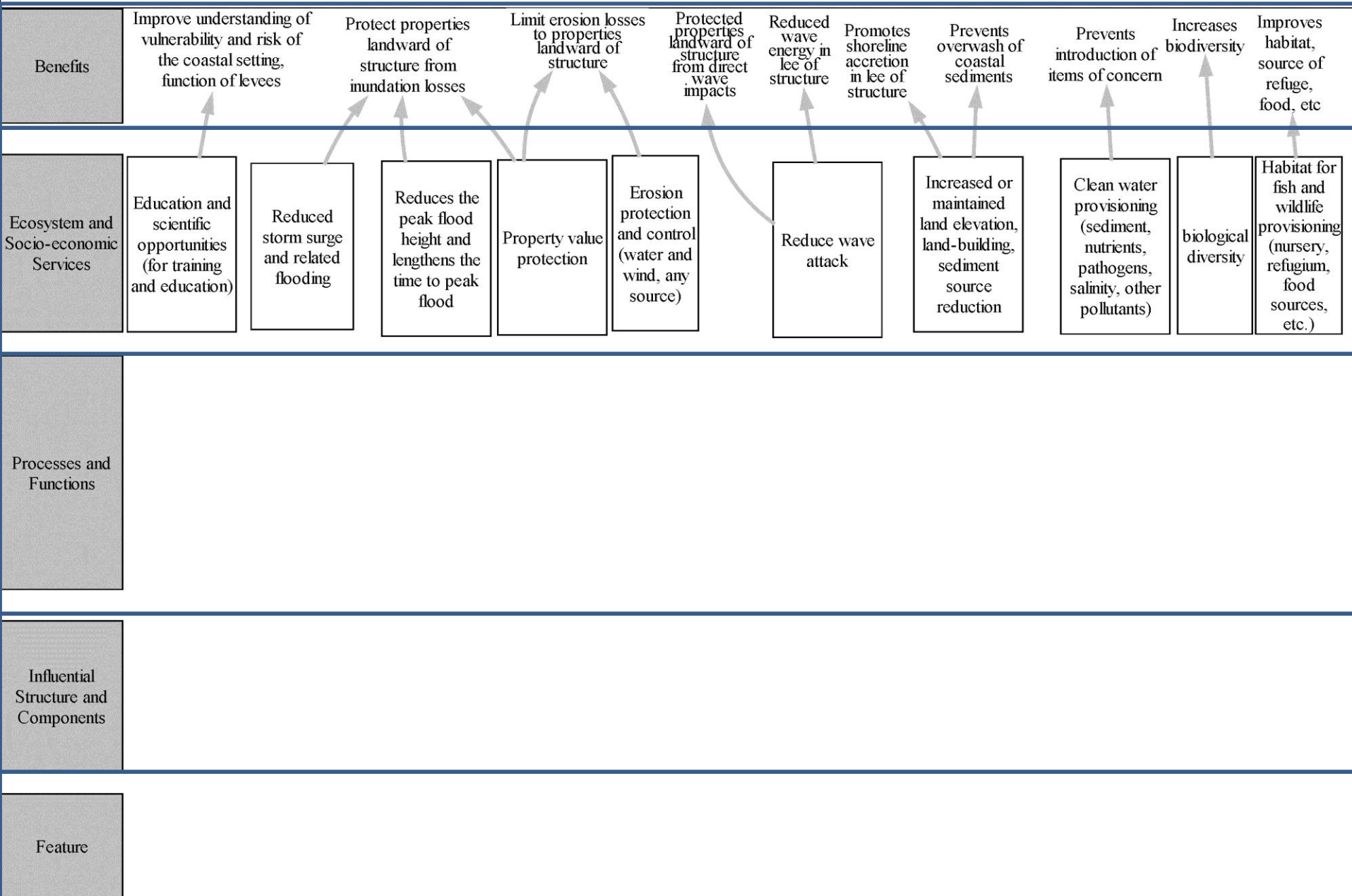
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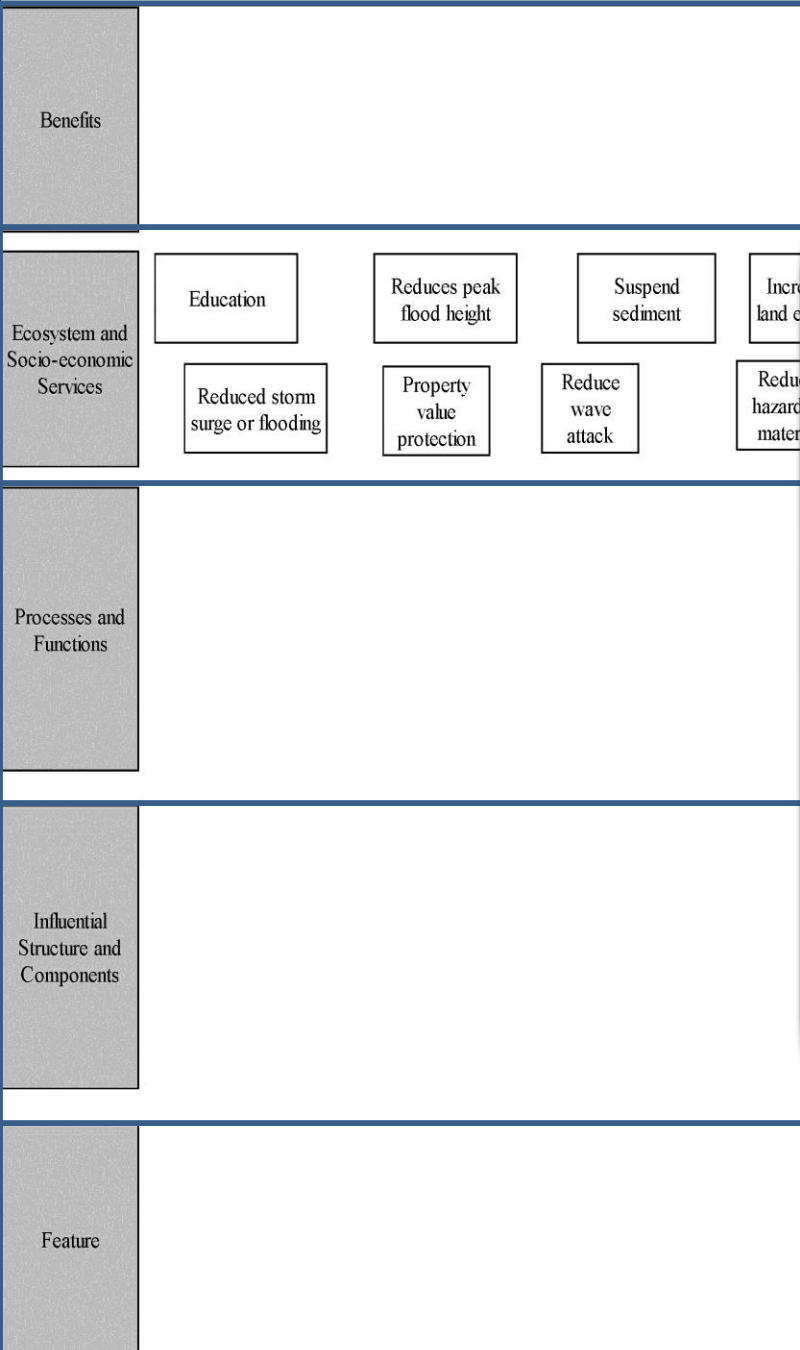




# Structural Features

Bridges et al. 2014 (in press)



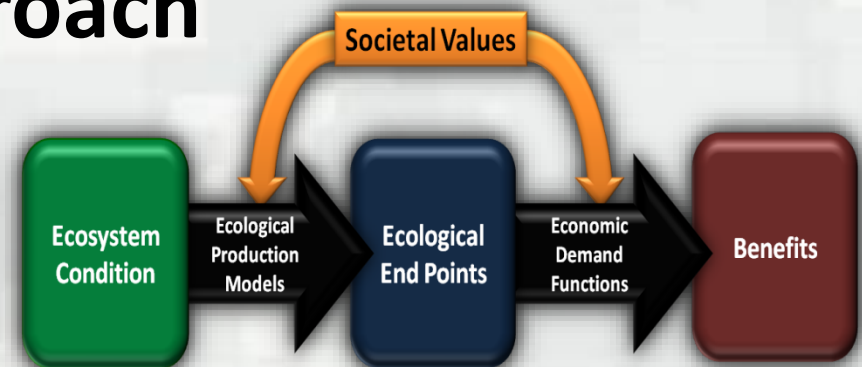


## Take-Home Messages:

1. The system is complex - over 400 causal arguments are represented thus far, and we're no where near done
2. Some of the relationships are neither direct nor linear – you can produce benefits several different ways for the same service using different features
3. The approach will allow us to quantify ecosystem response
4. We can also model the strength of the relationships if we so desire
5. It's a process designed to support active learning and reflection 😊

# Tiered Application Approach

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



**Ecosystem production functions** are one option to quantify the capacity of the blended solutions to supply ecosystem goods and services to humans based on ecosystem condition



Tools like **tradeoff flowers** can be utilized extensively to transparently communicate decisions involving ecosystem services to upper management, their partners, their stakeholders, and ultimately to the public



# Define Requirements for Applications

- Sync with Task 3A & 3B
  - Tiered 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)

	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		

	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			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		





# Define Requirements for Applications

- Sync with Task 3A & 3B

- Tiered Approach

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

## Option 2: Ecosystem Production Functions



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



# Point of Contact

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