Natural Infrastructure Supporting Ecosystem Goods and Services

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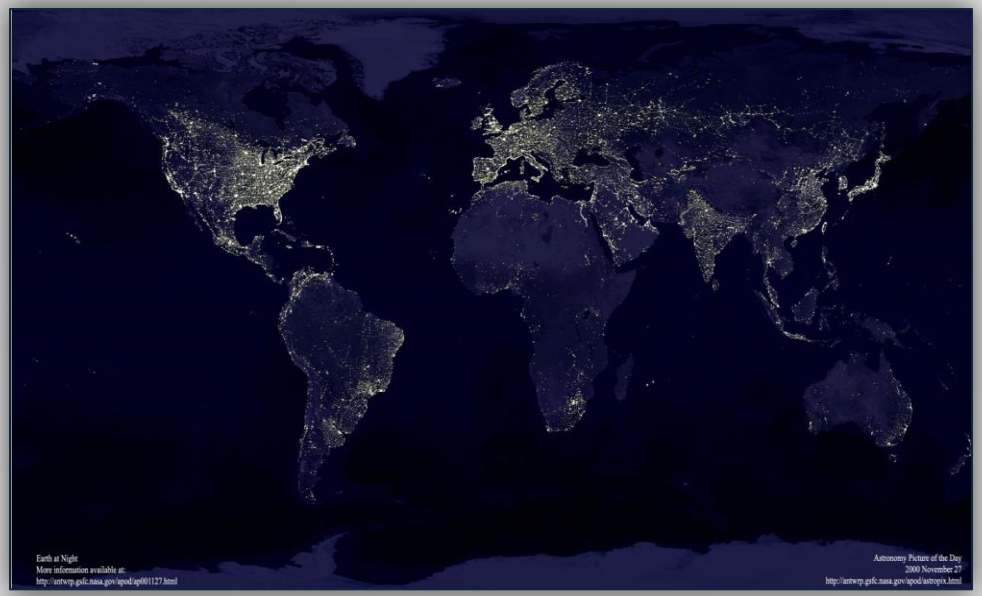
21 May 201


Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap001127.html
Astronomy Picture of the Day
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Coastal Communities: Vital to U.S. and International Economies

- ✓ 45 percent of the U.S. national gross domestic product is contributed by coastal communities.
- ✓ 51 million jobs
- ✓ Coastal habitats help reduce impacts of floods, storms, and climate change on coastal communities by absorbing water, wave energy, and other stressors.

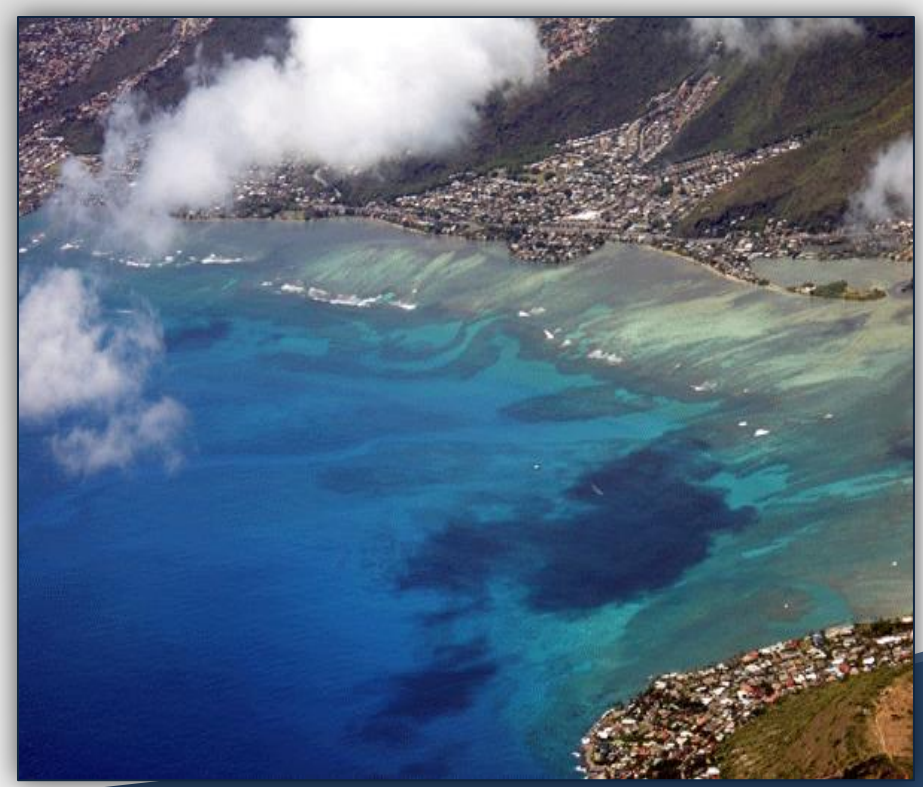
Green/Gray Infrastructure: Working with Mother Nature

Systems Approach to Geomorphic Engineering (SAGE)

- Merging green and gray solutions with wisdom gained from good science, coupled with foresight and good judgment.
- A systems approach – looking at an entire coastal system, operating as a whole, not just single component in isolation

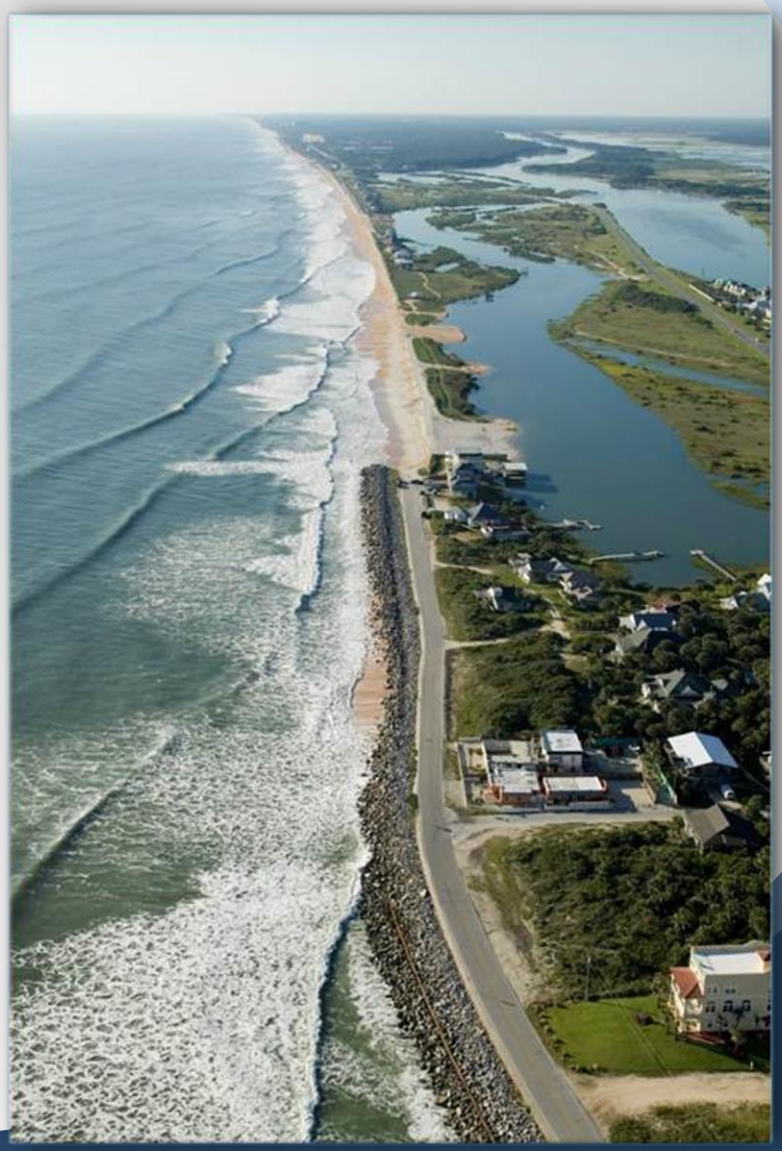
SAGE Vision

Extensive use of effectively combined *engineered* ‘soft’ (or green) living shoreline approaches and ‘hard’ (or gray) structures that provide innovative solutions to support the *adaptation* of ecosystems and *transformation* of coastlines contributing to robust/resilient coastal ecosystems, communities and economies.



Characteristics of a SAGE Approach

- Living shorelines
- Hybrid green **and** gray solutions
- Regional scales
- Landscape transformation with ecosystem adaption



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Information Needs for SAGE Approaches

- Under what circumstances can the natural environment provide coastal protection?
- What affects an ecosystem's ability to provide protection?
- Can we value the suite of ecosystems services for cost-benefit analyses?
- What are the maintenance costs?

Introducing Green Infrastructure for Coastal Resilience

- Learn fundamental green infrastructure concepts and practices that can play a critical role in making coastal communities more resilient to natural hazards.
- Learn about a range of natural assets and green infrastructure approaches that can improve coastal community resilience

Linking the Coastal and Marine Ecological Classification Standard (CMECS) to Ecosystem Services: An application to the US Gulf of Mexico

Cristina Carollo, Rebecca J. Allee & David W. Yoskowitz

(1) Classify habitat types (ecological units) within the northern Gulf of Mexico according to the CMECS structure;

(2) Identify ecosystem services those habitat types might provide; and

(3) Rank those services within each habitat type.

Table 2. Classification of ecosystem services (modified from Farber et al. 2006) provided by Gulf of Mexico ecological units as determined by workshop participants.

	Definition	Coastal and marine examples
Regulating/balance services	Maintenance of essential ecological processes and life support systems for human well-being	
Biological interactions	Species interactions	Keystone species. Starfish keeping a tidal pool in balance
Climate balance	Regulation of local to global climate processes	Influence of the ocean on temperature and precipitation
Gas balance	Regulation of the chemical composition of the atmosphere and the oceans	Sequestration of atmospheric carbon dioxide in the ocean
Hydrological balance	Movement, storage, and flow of water through the biosphere	Evapotranspiration and modulation of the drought-flood cycle
Nutrient balance	Maintenance of major nutrients within acceptable bounds	Bivalves (oysters and mussels) reduce water column nutrients; phytoplankton and primary productivity; clean water
Pollutant attenuation	Removal or breakdown of non-nutrient compounds and materials	Sequestration of heavy metals in sediments
Soil and sediment balance	Erosion control and sediment retention	Sediment stabilization, creation of shell hash and sand as shells break down
Water quality	Filtering of biotic and abiotic substances	Marsh, mangrove, seagrass, and oyster reefs removing sediment and excess nutrients and clarifying water
Hazard moderation	Dampening of environmental fluctuation and disturbance	Protection from hurricane storm surge by barrier islands and wetlands
Provisioning services	Provisions of natural resources and raw materials	
Air supply	Production of oxygen	Phytoplankton production of oxygen in the ocean
Food	Provisioning of edible plants and animals for human consumption	Commercial and subsistence harvesting of shellfish and finfish
Water quantity	Retention and storage of freshwater	Coastal freshwater wetlands providing drinking water. Desalination of seawater for human consumption
Medicinal resources	Biological and chemical substances for use in drugs and pharmaceuticals	Antibiotic molecules in deep ocean sediments. Toxins provided by coral reefs
Ornamental resources	Resources for fashion, handicraft, jewelry, decoration, worship, and souvenirs	Belt buckles and ornamental construction from shells
Raw materials	Materials for building and manufacturing. Fuel and energy. Soil and natural fertilizers	Road base, chicken calcium supplement, cosmetics from bivalves. Wave energy
Cultural services	Enhancing emotional, psychological, and cognitive well-being	
Aesthetic and existence	Sensory enjoyment of the natural environment	Enjoying a view of the ocean. Protecting marine mammals
Recreational opportunities	Opportunities for rest, refreshment, and recreation	Fishing, bird watching
Science and education	Use of natural areas for scientific and educational enhancement	Research about oysters and natural reefs provide metrics for restoration
Spiritual and historic	Spiritual and historic sites and information	Oyster middens of Native Americans, seafood festivals

Operationalizing Ecosystem Services for Restoration

TEXAS A&M UNIVERSITY CORPUS CHRISTI | HARTE RESEARCH INSTITUTE FOR GULF OF MEXICO STUDIES

PHASE I: IDENTIFICATION

Step 1: Establish human well-being and biophysical needs

Task 1: Human and biophysical needs are identified.

Task 2: Ecosystem services addressing human needs are determined.

Task 3: A link between ecosystem services and human well-being is established.

Step 2: Define ecological and socioeconomic goals and objectives

Task 1: Basic ecosystem and socioeconomic information is gathered.

Task 2: Overall ecological and socio-economic goals of the conservation project are defined.

Task 3: Specific objectives to accomplish the overall goals of the project are set.

Step 3: Acquire baseline information

Step 4: Identify project alternatives

PHASE II: ANALYSIS

Step 5: Perform trade-off analyses

Task 1: Criteria used to compare project alternatives are identified.

Task 2: A suite of project alternatives is selected for possible implementation.

Step 6: Analyze the legal framework

Step 7: Choose project alternative to implement

PHASE III: IMPLEMENTATION AND EVALUATION

Step 8: Implement the selected project alternative

Step 9: Monitor and measure performance

Task 1: Establish monitoring plan.

Task 2: Measure project performance.

Step 10: Adjust

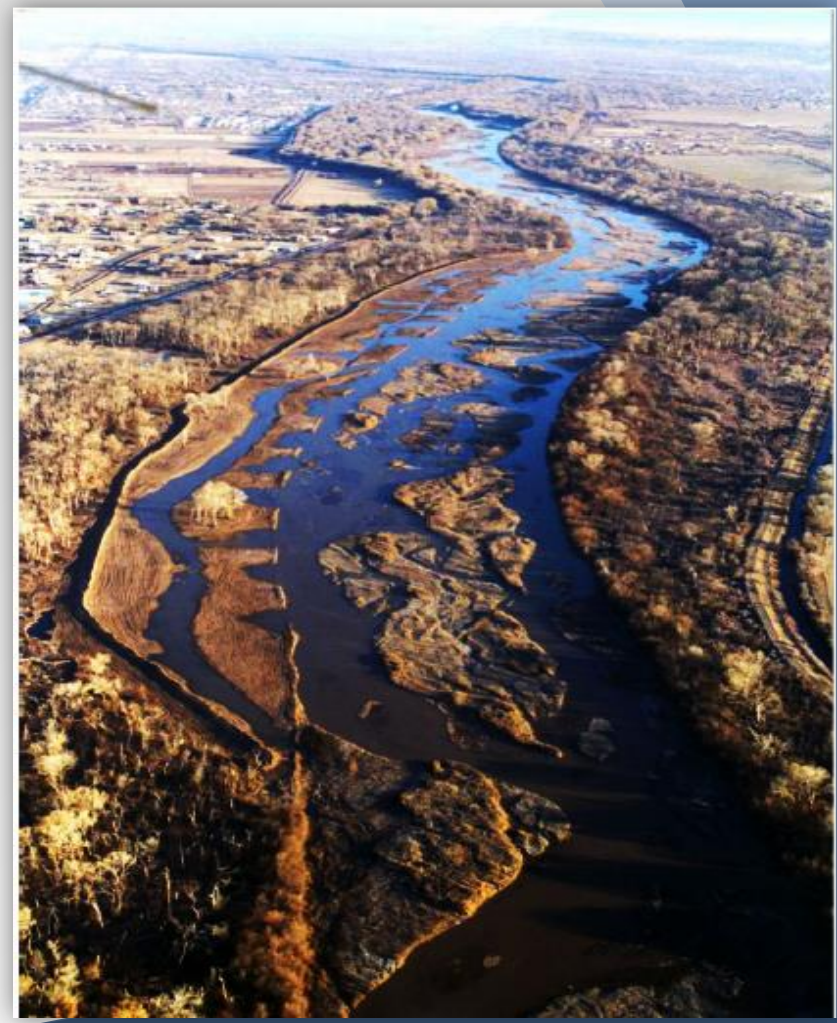
Step 11: Communicate project results

Selected Coastal Ecosystems and Ecosystem Services: Ecosystem Services Provided

Beaches	Dunes	Salt Marshes/Estuaries
Storm protection	Storm protection	Storm protection
Tourism and recreation	Tourism and recreation	Water purification
Erosion control	Erosion control	Fisheries maintenance
	Water catchment	Carbon sequestration
	Wildlife maintenance	Tourism and recreation
	Carbon sequestration	

New Planning & Operational Paradigm

- USACE projects are not isolated, but rather exist at the ***interface*** of population centers and their supporting waterways
- The USACE planning approach supports an ***integrated approach*** to reducing flood risks and improving coastal resilience
- ***Full array of measures***: natural, nature-based, non-structural and structural.
- And a ***full range of*** benefits

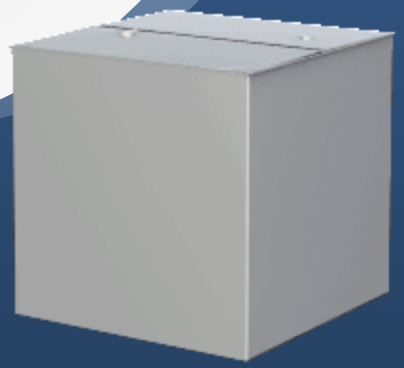


Key Definitions

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:

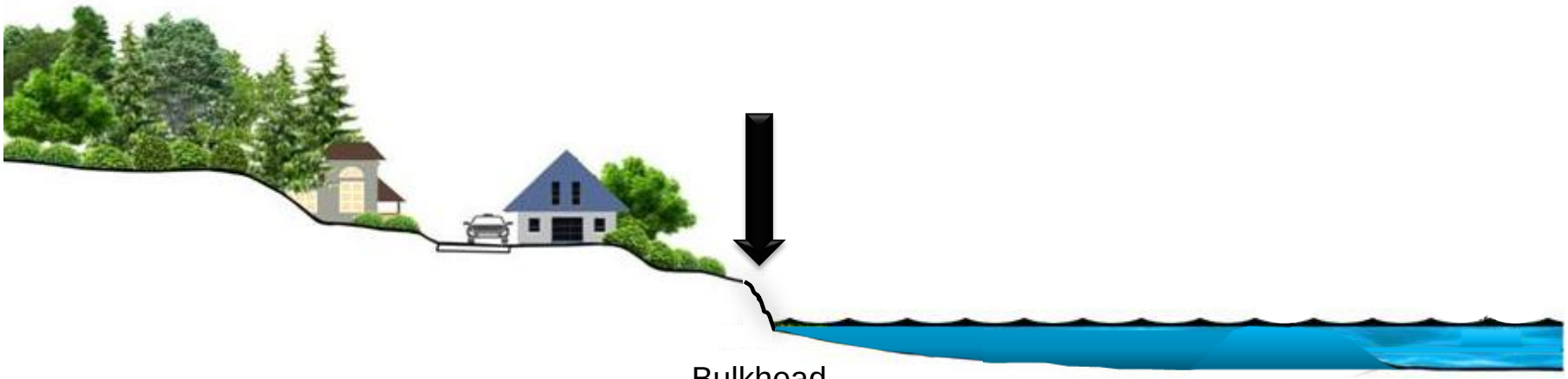
1. EGS can be derived from either built or natural capital (or a combination of the two)
2. Their value is simply a way to depict their importance or desirability to the consumers.
3. The ability of ecosystems to provide goods and services is dependent on critical ecosystem processes tied to structure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



Integrated Approach:

Considers the *full array of measures* and accounts for the *full array of benefits*

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

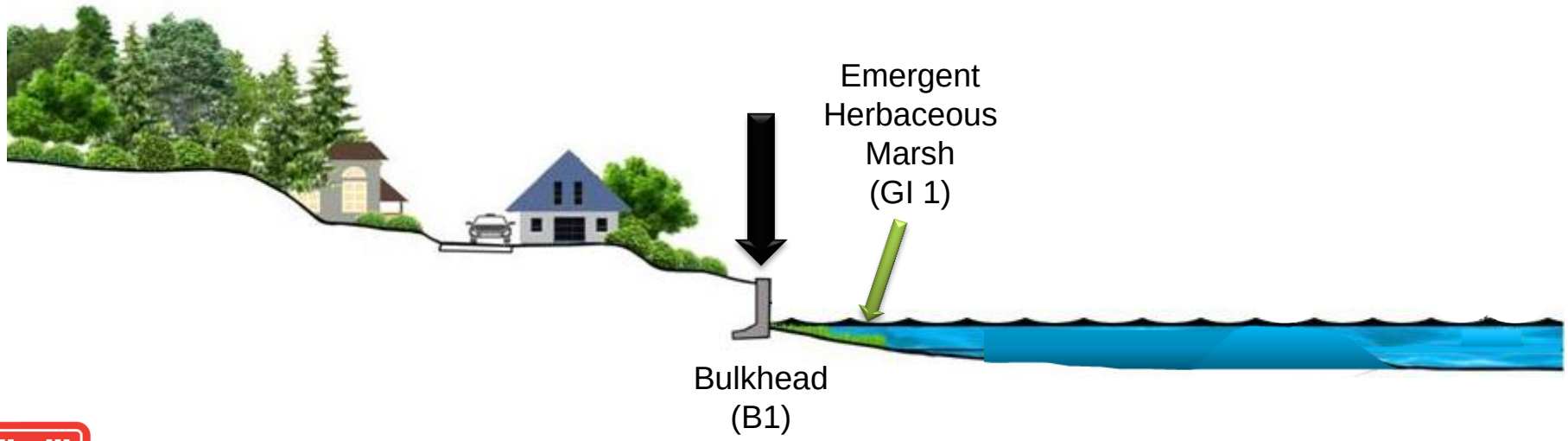


Bulkhead
(B1)

Integrated Approach:

Considers the *full array of measures* and accounts for the *full array of benefits*

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



Integrated Approach:

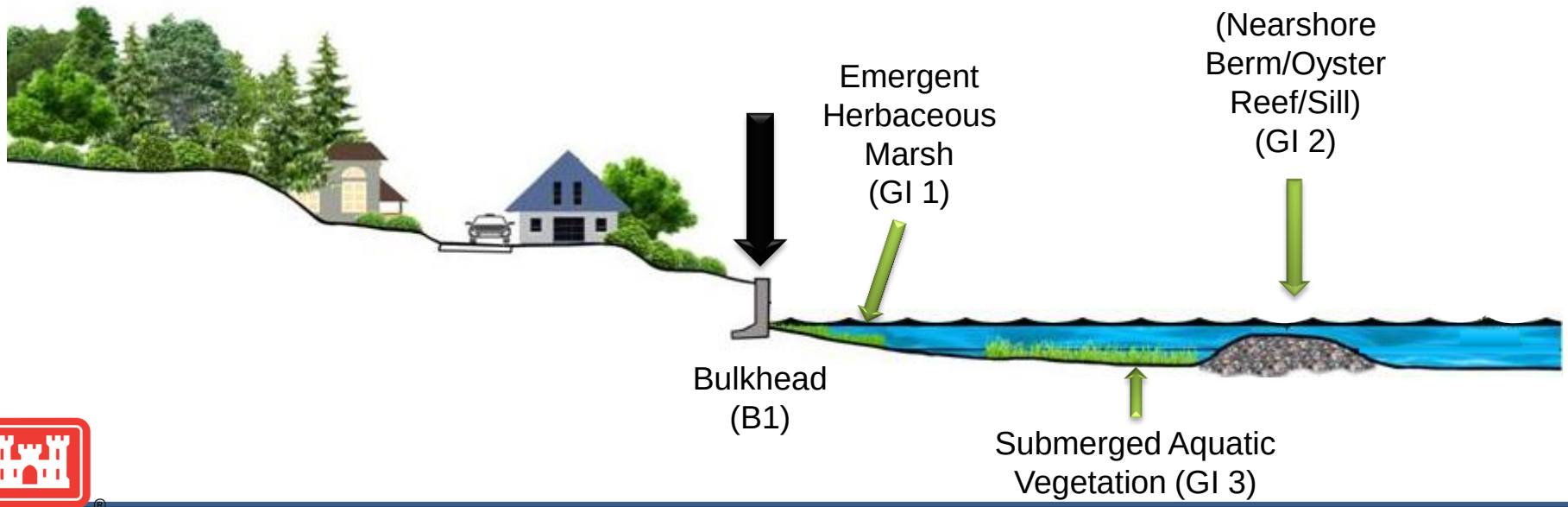
Considers the *full array of measures* and accounts for the *full array of benefits*

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

Integrated Approach:

Considers the *full array of measures* and accounts for the *full array of benefits*

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



Food for Thought . . . .

How can we account for non-monetizable EGS?

What about using Ecosystem Production Functions?

How will we handle trade-offs between monetizable and non-monetizable benefits?

How can we capture EGS from a systems perspective?

How should we define service area?

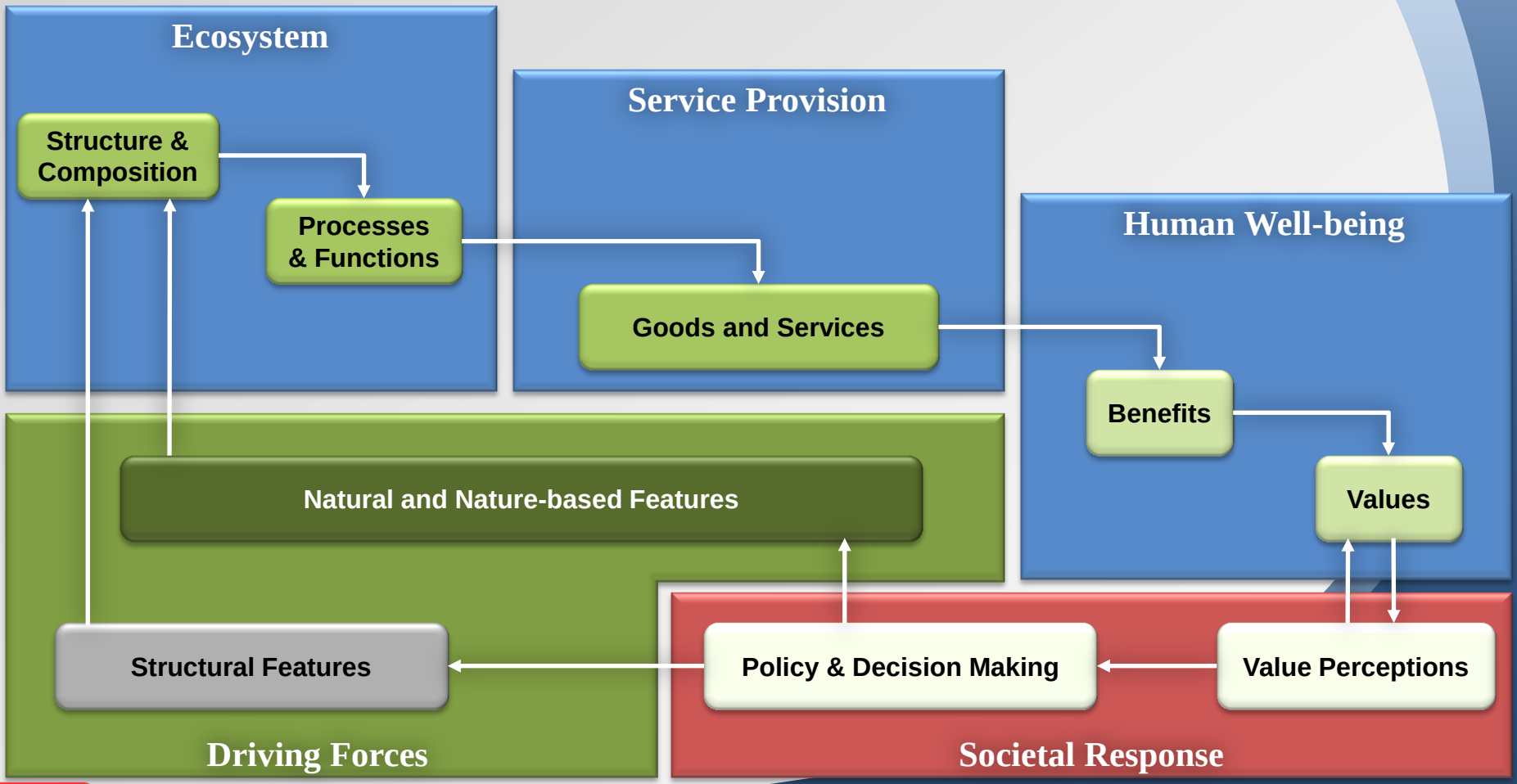
How can we account for competing EGS?

How will we distinguish between Intermediate vs. Final EGS?

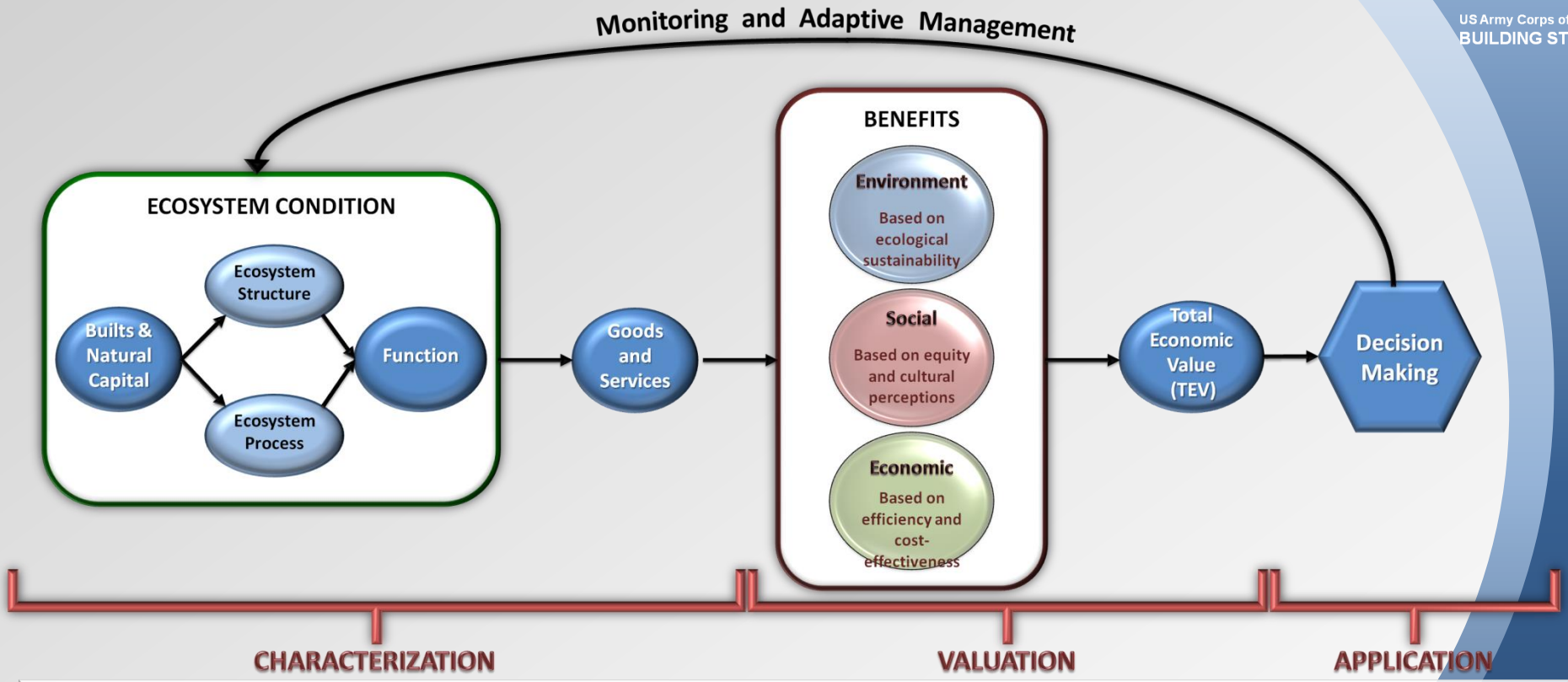
How can we address blended solutions?

If we agree that structural features can produce EGS, then how do we tackle solutions that have EGS generated by a blended solution?

Ecosystem goods and services production



Soup to Nuts Accounting



Built & Natural capital are comprised of features on the landscape (e.g., wetlands, dunes, beaches, breakwaters, reefs, etc.) that interact (i.e., through ecosystem processes such as nutrient cycling and carbon sequestration) performing functions (i.e., water purification, waste assimilation, wave attenuation formation, etc.) that generate services humans can either directly or indirectly utilize (i.e., clean water, flood protection, erosion control, storm surge protection, recreation, etc.).

What USACE operations and management needs to do is characterize these services, determine their environmental, social, and economic values, then perform tradeoffs to establish a total economic value (TEV) that can be used to measure performance in decision-making. Monitoring will trigger adaptive management that revisits the characterization and valuation processes over the life of the project.

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.

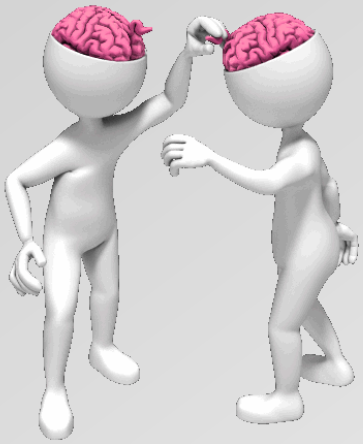
They articulate the exact information that will be collected, modeled, elicited from experts, or otherwise developed and presented to decision makers to characterize plan performance and engineering designs.

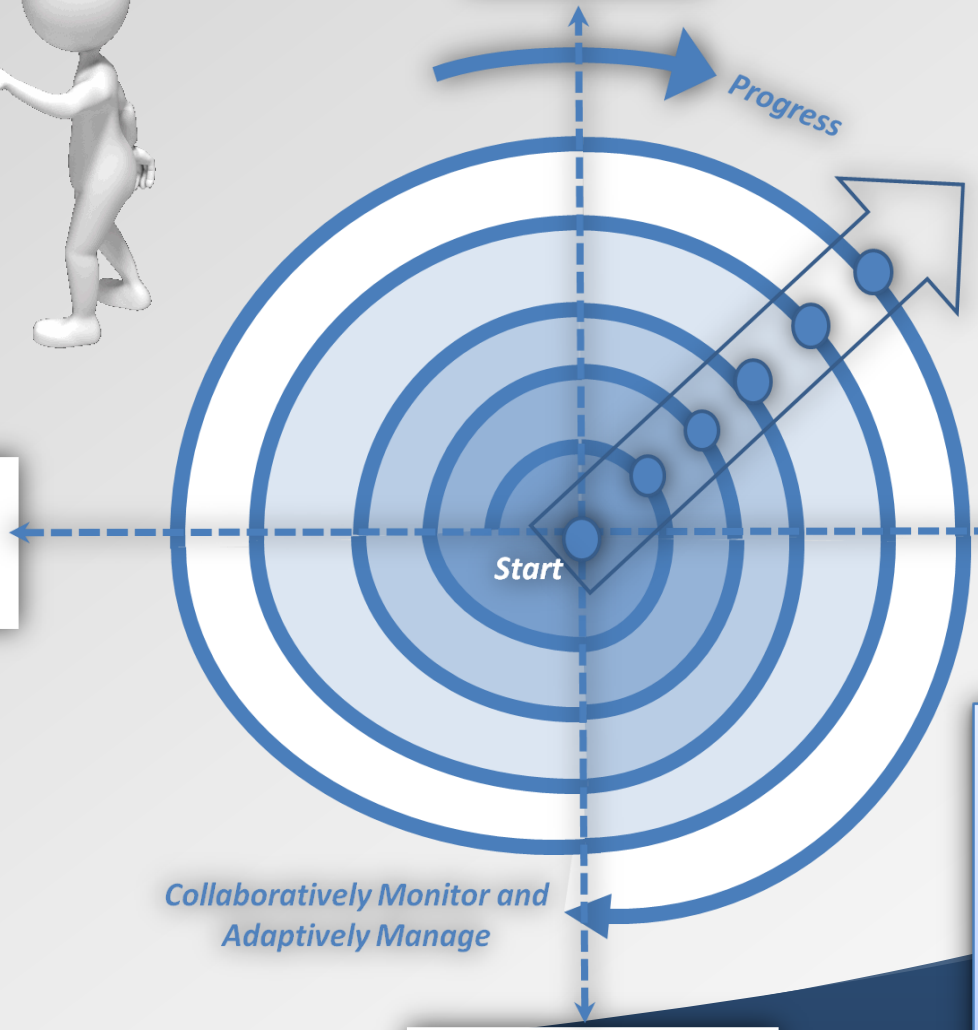
They must provide the ability to distinguish the relative degree of ecosystem response (conveyed in terms of impacts or benefits) across alternatives and designs, either qualitatively or quantitatively, in ways that make sense and will help decision makers consistently and transparently compare alternatives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

Good performance metrics are:

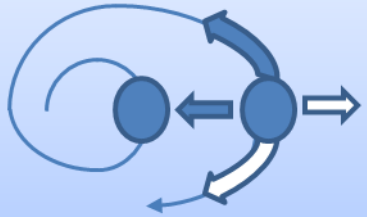
- Complete and concise
- Transparent and unambiguous
- Accurate
- Direct
- Understandable
- Operational

Spiral Framework in Action





Reflexive Prototyping



Reflect on outcome

Learn and adapt

The development path of the conceptual model

Interactive team meetings

The process of capacity building and raising awareness

Feature List - NACCS Case Study

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Natural and Nature-based Features

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

Ecosystem Goods & Services List

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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

Services Table Approach

NNBF FEATURE: Beach (sand, gravel, cobble)					
Influential structure and components	**Processes, functions**	**Ecosystem and Socioeconomic Services**	**Benefits**	**Performance Metric**	**Data sources**
Characteristic Intertidal Substrate	Geomorphologic diversity and natural ecosystem components	Aesthetics - appreciation of natural scenery (other than through deliberate recreational activities), Inspiration for culture, art and design	Scenic beauty, nature-inspired design, art and culture	log(Feature Size) x population density in Plan Reach	C-CAP, Census
Substrate Type and Cross-Sectional and Longitudinal Distribution	series of ecosystem elements that that support a variety of native biota	Biological diversity (biodiversity)	self-sustaining diverse ecosystem biota	log(Feature Size) * Landfire veg cover * ((25 - % imp cover in 100-m radius)/15 [max = 1, min = 0])	C-CAP, Landfire, NLCD
Characteristic Intertidal Substrate	persistent native ecosystem structure, function and dynamic processes	Cultural heritage and identity - sense of place and belonging, spiritual and religious inspiration	culture and spirituality tied to nature, religion that supports nature	log(Feature Size) x population density in Plan Reach	C-CAP, Census
Substrate Type and Cross-Sectional and Longitudinal Distribution	variety of ecosystem types with balanced processes	Education and scientific opportunities (for training and education)	educated constituency, environmental stewardship	log(Feature Size) x (population density in Plan Reach + # schools in 10 km radius)/2	C-CAP, Census, Schools layer
Substrate Type and Cross-Sectional and Longitudinal Distribution	attenuation of erosive processes	Erosion protection and control (water and wind, any source)	decreased erosion, sediment transport to open water	Feature size x Landfire veg cover x Prop Native x veg height/perc slope	USGS Landfire, 10-m NED

Tiered Application Approach

Level 1 – Qualitative characterization of performance

- –2013 Workshop Exercise
  - 48 instruments returned (76% Response Rate)
    - 8 Academics
    - 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	
Reduce wave attack	80.0	26.8	100	0	7%	90	
Erosion protection and control	78.6	24.7	100	15	7%	85	
Reduce the peak flood height and lengthen the time to peak flood	75.9	29.3	100	0	7%	90	
Habitat for fish and wildlife provisioning	69.9	32.4	100	0	6%	90	
Threatened and Endangered species protection	66.6	32.4	100	0	6%	80	
Clean water provisioning	64.7	31.3	100	0	6%	75	
Biological diversity	64.3	32.0	100	0	6%	70	
Recreation	61.2	27.4	100	5	5%	60	
Property value protection	56.8	33.3	100	0	5%	70	
Reduce hazardous or toxic materials in water or landscape	55.9	32.3	100	0	5%	60	
Nutrient sequestration or conversion	52.6	31.2	100	0	5%	60	
Increase or maintain land elevation and land-building	52.2	32.6	100	0	5%	50	
Education and scientific opportunities	49.1	31.3	100	0	4%	50	
Commercial harvestable fish and wildlife production	48.7	32.8	100	0	4%	50	
Aesthetics	47.6	28.8	100	0	4%	50	
Provision and storage of groundwater supply	47.4	31.2	100	0	4%	50	
Carbon sequestration	46.8	30.1	100	0	4%	50	
Maintain background suspended sediment in surface waters	45.0	26.6	80	0	4%	50	
Cultural heritage and identity	44.3	29.1	100	0	4%	50	
Raw materials production	22.3	25.6	100	0	2%	10	

Tiered Application Approach

Level 1 – Qualitative characterization of performance

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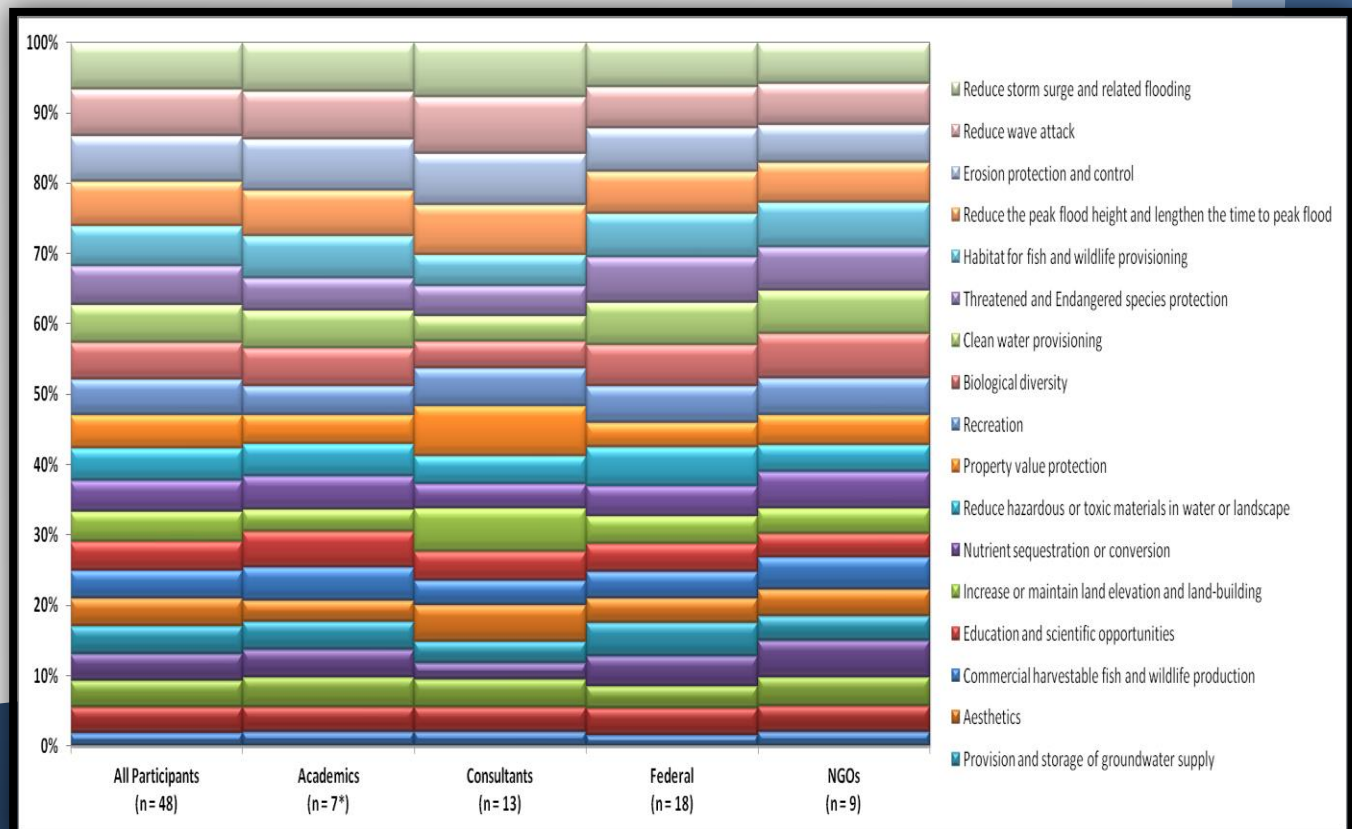

Tiered Application Approach

Level 1 – Qualitative characterization of performance

Level 2 – Semi-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
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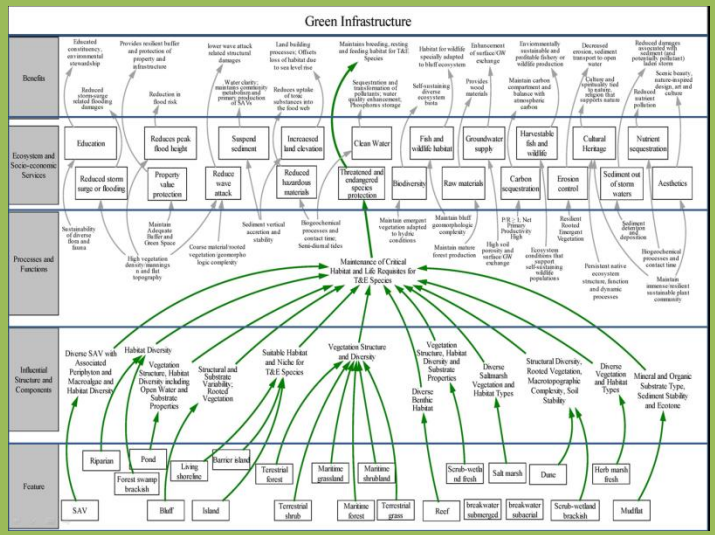
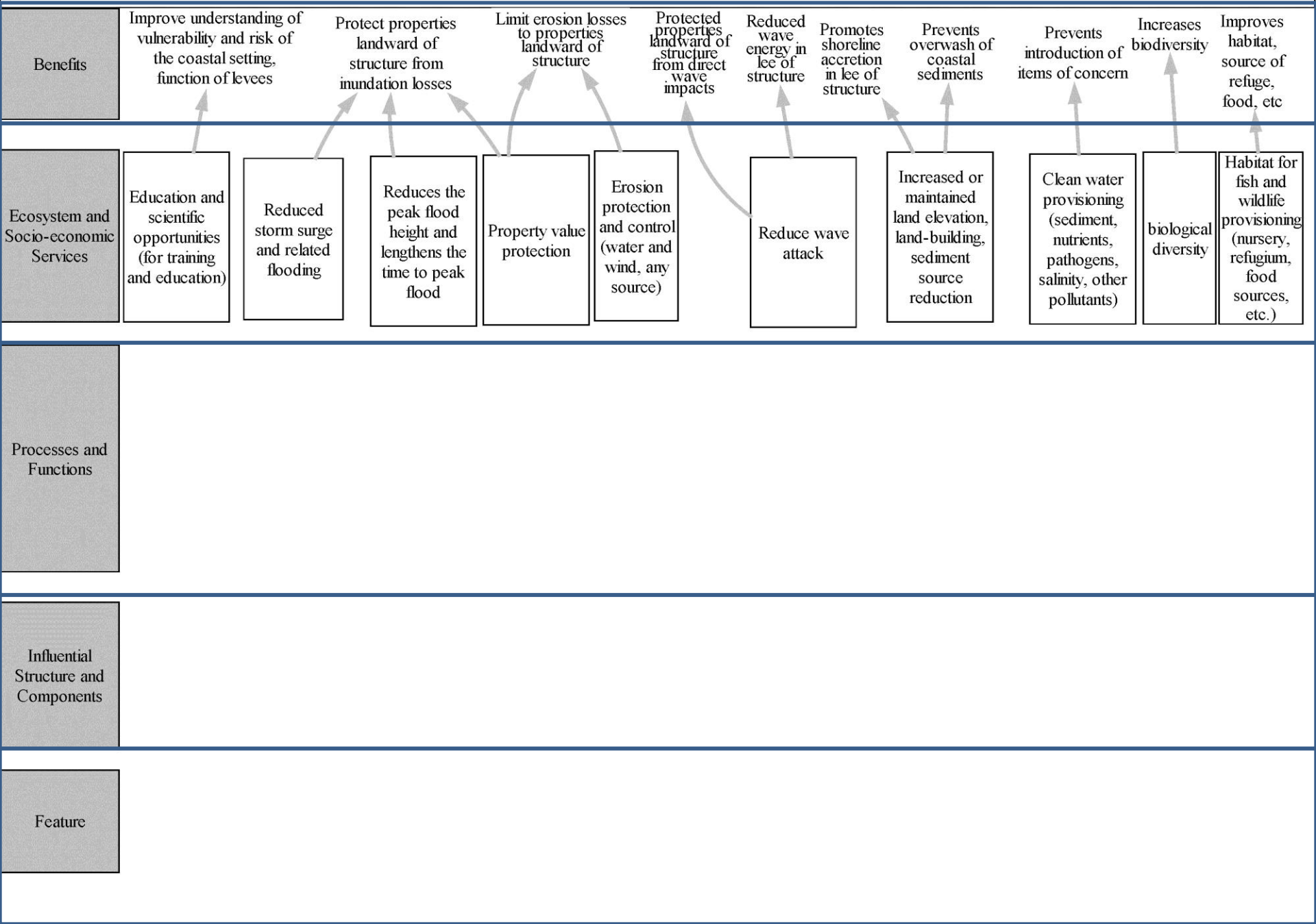
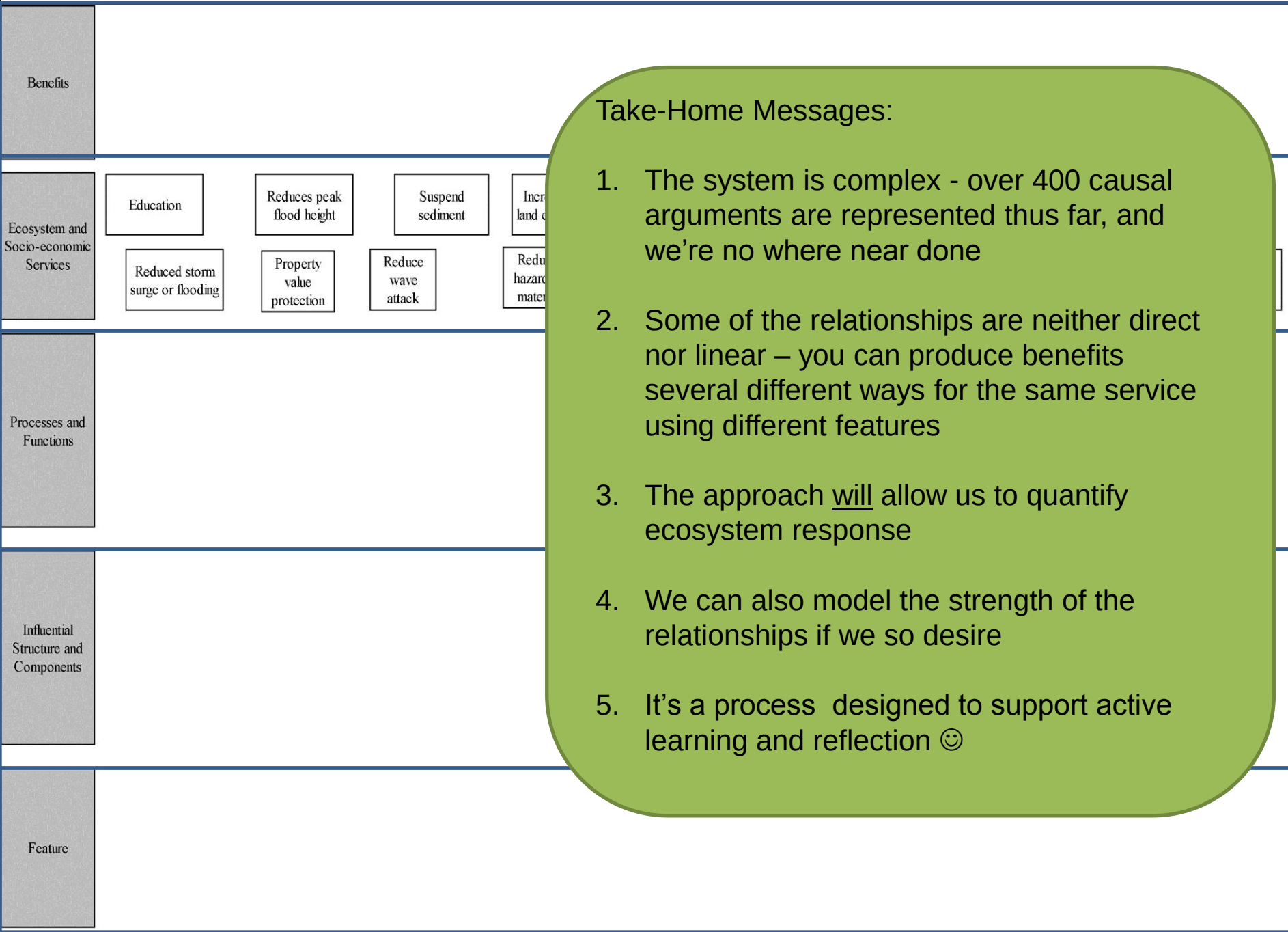


Structural Features



Natural and Nature-Based Features



Take-Home Messages:

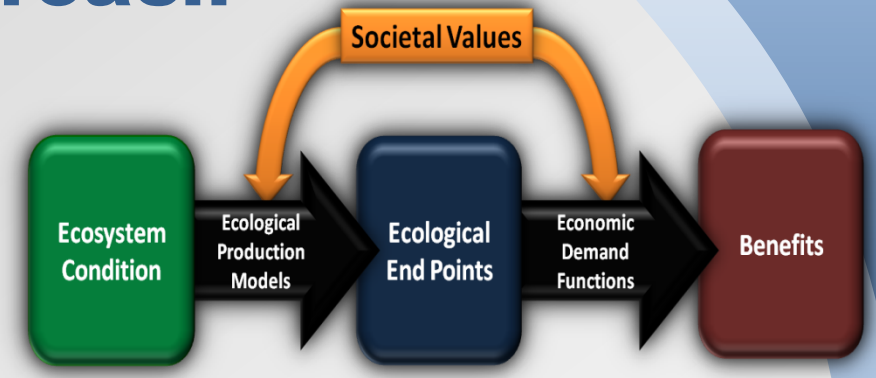
1. The system is complex - over 400 causal arguments are represented thus far, and we're no where near done
2. Some of the relationships are neither direct nor linear – you can produce benefits several different ways for the same service using different features
3. The approach will allow us to quantify 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

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		

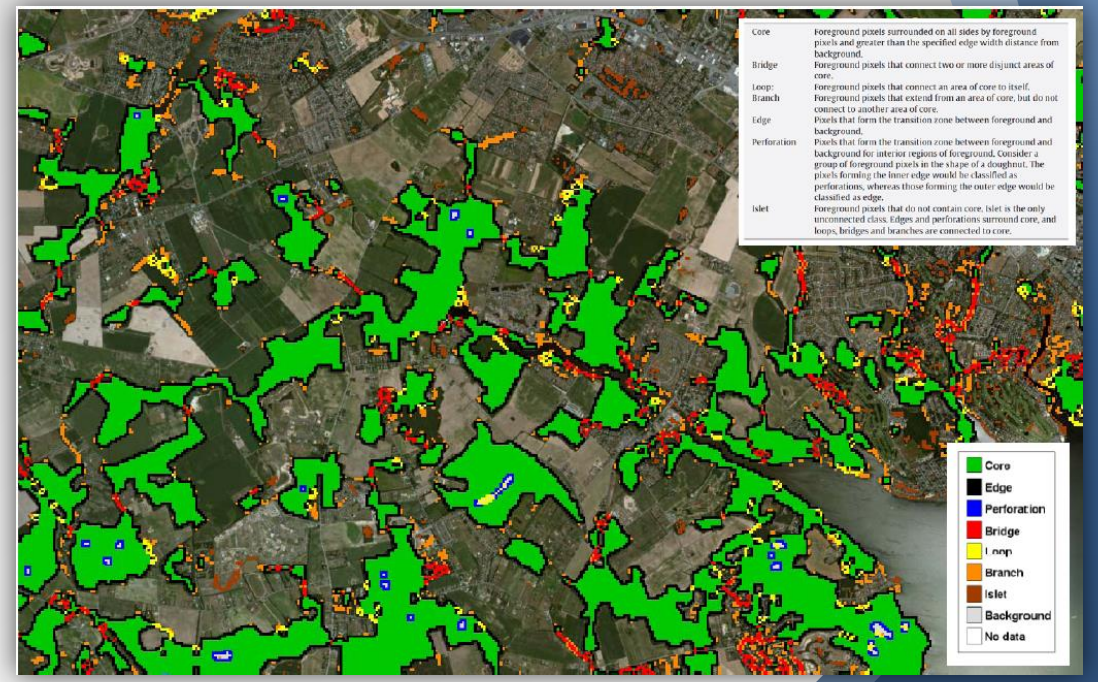
Tiered Application Approach

Level 1 – Qualitative characterization of performance

Level 2 – Semi-quantitative characterization of performance

Level 3 – Quantitative characterization of performance

Option 2: Ecosystem Production Functions



We're at the frontier. . .

What's important to remember:

- What can the USACE, NOAA, and their stakeholders consider to address flood damage reductions and promote resiliency (structural vs. nature-based vs. blended)?
- How effective will these solutions be?
- Are they cost effective?

What's important to recognize:

- Nature-based solutions and the goods and services they could provide are at the frontiers of science and engineering, and the answers to these questions are uncertain.
- Stakeholder perceptions and values will play a significant role in the use of both nature-based solutions and the accounting of their benefits to the society at large.

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