Executive Summary

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

Todd S. Bridges, Paul W. Wagner, Kelly A. Burks-Copes, Matthew E. Bates, Zachary A. Collier, Craig J. Fischenich, Joe Z. Gailani, Lauren D. Leuck, Candice D. Piercy, Julie D. Rosati, Edmond J. Russo, Deborah J. Shafer, Burton C. Suedel, Emily A. Vuxton, and Ty V. Wamsley

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## Executive Summary

*Natural, nature-based, nonstructural,* and *structural* are terms used to describe the full array of measures that can be employed to support coastal resilience and risk reduction (U.S. Army Corps of Engineers (USACE) 2013). By definition, *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. Conversely, *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). An integrated approach to coastal resilience and risk reduction will employ the full array of measures, in combination, to support coastal systems and communities. In order to pursue an integrated approach to coastal resilience, the North Atlantic Coast Comprehensive Study (NACCS) formed a team to develop a framework for identifying and evaluating opportunities for integrating natural and nature-based features (NNBF) (USACE 2015).

NNBF can be used to enhance the resilience of coastal areas threatened by sea level rise and coastal storms. For example, beaches are natural features that can provide coastal storm risk reduction and resilience where their sloping nearshore bottom causes waves to break—dissipating wave energy over the surf zone. Dunes that back a beach can act as physical barriers that reduce inundation and wave attack to the coast landward of the dune. Coastal wetlands can attenuate waves and stabilize sediments, thereby providing coastal storm protection.

Nature-based features are acted upon by processes operating in nature, and as a result, generally must be maintained by human intervention to provide the functions and services for which they were built. Coastal systems are naturally dynamic, and NNBF respond in many ways to storms—with some responses being temporary and others permanent. Storm effects on wetlands often include erosion, stripped vegetation, and salinity burn—all of which can decrease long-term productivity. Storms, however, also introduce mineral sediments that contribute to long-term sustainability with respect to sea level rise.

In addition to providing engineering functions related to reducing risks from coastal storms, NNBF can provide a range of additional ecosystem services, including those supporting coastal ecosystems and communities. A true systems approach to coastal risk reduction and resilience requires consideration of the full range of functions, services, and benefits produced by coastal projects and NNBF. These include benefits related to commercial and recreational fisheries,

tourism, provisioning of clean water, habitat for threatened, endangered, and sensitive species (TES), and support for cultural practices. Developing a more complete understanding of the ecosystem goods and services provided by the full range of coastal features, individually and in combination, will help to inform plan formulation and benefit determination for risk reduction strategies.

Knowledge about the performance of natural, nature-based, nonstructural, and structural features varies, as do the methods to calculate and measure performance. The dynamic behavior and response of NNBF to threats such as coastal storms and development can affect their performance with respect to system-level risk reduction and resiliency objectives. Moreover, it is important to design nature-based features in such a way that they will establish and/or re-establish natural processes and become as self-sustaining as possible. Federal investment in the use of NNBF intended to provide ecosystem goods and services, including coastal risk reduction and resiliency, should be based upon solid scientific and engineering evidence about the function and performance of these features. As with structural measures, some nature-based features will require routine maintenance and these costs should be factored into analyses.

## Purpose of this Study

The purpose of this study was to fill knowledge gaps and produce relevant information to support the identification, evaluation and integration of NNBF with structural and non-nonstructural measures in order to support coastal risk reduction and resilience. Developing a comprehensive framework was viewed as an important next step in coordinating the advancement of NNBF among the many organizations and stakeholders engaged in the management of coastal systems. The framework includes a range of activities relevant to the use of NBF and is divided into three categories of activities: Organizational Alignment, Evaluation and Implementation. Steps in the framework are enumerated here and briefly described below:

1. Classifying, mapping and characterizing NNBF,
2. Developing vulnerability metrics,
3. Developing performance metrics,
4. Assessing and ranking proposed alternatives,
5. Considering sediment as a resource for NNBF,
6. Monitoring and assessing NNBF to support adaptive management, and
7. Considering policy challenges and implications.

## Classification, Mapping, and Feature Characterization

A classification system was developed for NNBF that applies two existing systems that are widely used both nationally and internationally. The first is a geomorphologic classification system of coastline types based on Shepard (1973), and illustrated in the Coastal Engineering Manual (USACE 2002). For each of the geomorphologic classes present within the study area, one or more profiles were generated to illustrate the typical arrangement of geomorphic features, including those potentially identified as NNBF. The profiles can be used to illustrate the types of NNBF that could be expected to occur or be used in the landscape, as well as how combinations of multiple features could be applied to increase the level of coastal protection afforded. Geomorphic features typical of each coast type are described in detail. Many features are coincident and/or provide similar functions in the landscape and are described together. The driving processes that describe each feature are identified; information on processes is detailed separately to avoid repetition. These processes (e.g., wave attack, erosion, sediment transport, changes in sea level, glaciation) also continue to act on and shape NNBF in the coastal environment. Understanding these processes will be important to engineers and scientists involved in the design and construction of NNBF. Morphological and physical attributes of each feature type are tabulated for each coast type.

The approach applied to NNBF is the U.S. National Vegetation Classification (USNVC) (Grossman 1998). This system delivers a comprehensive *single-factor* approach to hierarchical classification of ecological communities based on vegetation. A major advantage of this system is that geospatial mapping layers are available for the study area, and detailed descriptions of the plant communities are available for each State through the State Natural Heritage programs. The detailed descriptions of the plant community associations can be used in a variety of ways. For example, knowledge of the species composition and structural characteristics of the vegetation can be used to estimate the degree of surface roughness and impedance to the flow of water during storm events. The descriptions of the species associations can also be used as a planting guide to select the most appropriate suite of plant species for the NNBF under consideration. Mapping layers of the vegetation classes can also be used to identify NNBF characteristics in relation to conservation and preservation goals.

## Approach for Developing Coastal Vulnerability Metrics

Coastal areas of the U.S. are threatened by erosion and damage due to storm waves, wind, and surge. Evaluation of the role of NNBF, in the context of coastal zone management and storm damage risk reduction, requires the assessment of vulnerability in natural and human environments. Vulnerability is conceptualized in many different ways and depends on the scientific background of those assessing vulnerability. Here is defined an approach to assessing vulnerabilities in order to identify beneficial applications of NNBF.

A comparison was made of previous approaches to assessing vulnerability, which demonstrated the subjective nature of developing vulnerability metrics. The various approaches differ in how vulnerability is measured as they depend on the purpose of the vulnerability assessment, the spatial and temporal scale for which the assessment is being conducted, the specific coastal characteristics for the area of interest, and data availability. Metrics can be both quantitative and qualitative. While qualitative metrics are non-numerical, they may still reflect measurable characteristics such as the relative resistance of a given landform to erosion. Comprehensive approaches recognize that overall vulnerability is determined by physical coastal characteristics (e.g., geology, elevation), coastal forcing (e.g., tide range, wave height, storm frequency), and socioeconomic characteristics (e.g., Pop, cultural heritage, land use). Finally, it is also recognized that assessment of vulnerability can be improved through process parameterization or modeling.

Vulnerability is a function of the hazard to which a system is exposed, the sensitivity of the system to the hazard, and the system's adaptive capacity. A satisfactory conceptual approach for identifying and defining meaningful metrics must consider all three of these components to be complete. The approach that was developed was designed to ensure a set of metrics is developed for a complete assessment of vulnerability for a wide range of systems and hazards at multiple scales, with specific emphasis on NNBF.

Metrics for application in assessing vulnerability for multiple coastal landscapes are developed. The vulnerability of anything on the landscape is directly linked to natural coastal landscape and NNBF vulnerability. The metrics developed are specifically intended for assessing relative vulnerability of coastal landscapes along the northern Atlantic coast, understanding how NNBF influence vulnerability of a coastal landscape, and understanding vulnerability of specific NNBF. The metrics presented are not all of equal importance, nor are they mutually exclusive. The actual selection of metrics to apply for a given vulnerability assessment will depend on many factors, most notably the purpose and scale of the vulnerability assessment and data availability.

## Performance Metrics for Ecosystem Goods and Services Generated by NNBF

Identifying appropriate and effective applications of NNBF will be guided by the benefits and services these features can provide. A comprehensive set of relevant performance metrics for NNBF was developed, expressed in terms of ecosystem goods and services, that can be used to characterize (either qualitatively or quantitatively) the benefits generated by these features. Twenty-one ecosystem-based goods and services were developed along with 72 quantitative performance metrics that capture a full suite of social, environmental, and economic benefits generated by 30 NNBF and structural features, implemented individually and in combination, to promote flood risk reduction and improve ecosystem resilience. A general methodology was developed to qualitatively analyze these services for NNBF applications.

Each NNBF (e.g., dune-swale complex) was decomposed into its critical components (i.e., physical characteristics such as soils and vegetative properties), and the ecosystem functions and processes associated with these components were linked through causal pathways to the goods or services the feature would provide (e.g., aesthetics, habitat provisioning, wave-attack reduction). From there, benefits were derived (e.g., scenic beauty, TES protection, flood risk reduction) and a metric for each line of evidence was developed (e.g., vegetative cover visible to local community, habitat suitability indices, and flood-prone-area reduction).

Three methodologies were developed to analyze ecosystem goods and services for NNBF applications. A matrix was developed aligning NNBF with the various services they provide, and a qualitative ranking system was produced to elicit stakeholder preferences with regards to NNBF applications. A second, semi-quantitative method was developed to expose lines of evidence linking features to benefits through causal pathways. This approach can be operationalized in the future using scientific evidence and quantifications to measure recovery plan performance with respect to NNBF inputs. The third approach focused on the development of quantifiable metrics using readily available geographic information system (GIS)-based data to characterize landscape-level performance of NNBF using a variety of geoprocessing techniques documented in the relevant scientific literature. In addition, a Benefit Transfer table was developed using literature-based values in order to provide an alternative means for characterizing the goods and services in a quantitative fashion.

## Framework for Assessing and Ranking NNBF Alternatives

A flexible, tiered evaluation framework was developed for analyzing the contribution of NNBF to system resilience, while accounting for other services generated by NNBF. The framework uses a structured decision-making process, performance metrics, and available data to guide the identification of appropriate applications of NNBF. The tiers of analysis, beginning with evaluation based on expert elicitation, will progress through stages employing greater levels of quantitative and engineering analysis. Each successive tier is more quantitative (to resolve uncertainties) and can build on previous tiers. The framework is compatible with alternative screening, prioritization, and benefit and cost analyses, depending on the tier. The framework includes how to use stakeholder preferences, how consequence tables can be derived consistently across the tiers, and the inherent characteristics that make the framework suitably appropriate and flexible. The evaluation framework includes processes for engaging stakeholder preferences regarding objectives in order to explore trade-offs among alternative configurations and uses of NNBF. The framework can be used to assess NNBF in a categorical fashion, as specific projects, or as groups of projects reflecting a particular alternative. NNBF alternatives, alone or in combination with structural features, are evaluated against an explicit set of the performance metrics. Performance may be determined using the expert opinion (in the first tier of analysis) or through application of detailed modeling and technical analyses (in subsequent tiers of analysis), or through a combination of inputs. Thus, the framework can be implemented, initially, with limited information and can be progressively applied through stages employing greater levels of quantitative and engineering analysis. A narrative describing how the approach applies, how to use stakeholder preferences and how the consequence tables can be derived at each of three tiers, and the inherent characteristics that make the framework suitably appropriate and flexible is presented using several examples.

## Regional Sediment Management (RSM) to Support NNBF

A life-cycle RSM strategy for placing dredged sediments beneficially in the study area was developed to support and sustain the use and value of NNBF. The intent was to have a means for comprehensively developing dredging and placement options in a technically appropriate and consistent manner in the context of stakeholder objectives. Relevant information and input was gathered from SMEs in the field of dredging and sediment management. A case-study application was developed using data and information from Long Island Sound (LIS).

Beneficial use of dredged material has been a long-established practice within the study region. In the context of this practice, the developed strategy defines and distinguishes practices related to strategic placement of sediment, natural systems approaches, and Engineering with Nature (EWN). The results of a detailed literature review served as the basis for identifying and inventorying past best practices, underpinning technical information, and using evaluation tools to support the development of a Screening Methodology for Strategic Placement (SMSP). Field site visits to the region were used to gain firsthand information about current practices and to engage SME on dredging operational practices.

The initial phase of the SMSP methodology concerns the identification of NNBF opportunities, which includes the following steps:

- identification of coastal geomorphic landscape features
- condition assessment of features
- assessment of the benefit of dredged sediment applicability
- identification of dredging/placement techniques compatible with the settings.

Next, navigation channel Operations and Maintenance (O&M) sediment sources were estimated. This involved forecasting shoaling and dredging requirements, assessing the properties of materials to be dredged, and identifying dredging/placement techniques compatible with dredged sediments. With the foregoing information sets prepared, technically defensible options were inventoried for sediment source matching with beneficial use placement opportunities. A dredging/placement technique library was created and was related to forecasts of dredging/sediment placement activities in order to identify compatibilities.

A case-study application of the SMSP was developed for Long Island Sound (LIS) in order to produce an example of strategic placement designs and costs for sediments that are forecasted to be dredged. In a separate effort, stakeholders engaged through the New England District of USACE had collaborated to define a set of problems, needs, and opportunities for dredged-material management in the region. Through this engagement, performance objectives, constraints, driving scenarios, and potential dredged-sediment management measures were summarized to inform the demonstration.

Optimization of dredged-sediment management options with respect to life-cycle performance and cost was analyzed using an existing USACE modeling tool (D2M2[1]). Using existing data and following the themes of the prior stakeholder preference elicitation, this tool was used to perform a trade-off analysis. The LIS case-study application of the SMSP was developed to provide a template for scoping comprehensive analyses that could be performed over the entire study area. Key elements along the path to wider application of the SMPS include the following:

- *bench-scale* testing the methodology for engaging stakeholders to identify dredged-sediment sources and placement options at multiple locations in the Study Area
- critically review bench-scale testing of the engagement methodology
- refine the method based on critical review
- apply refined method for the entire NACCS study area.

## Ecosystem Service Benefits of Existing NNBF – A Hurricane Sandy Case Study

An evaluation of ecosystem goods and services (EGS) produced by three coastal ecosystem restoration sites (Jamaica Bay, NY; Cape May Meadows, NJ; and Cape Charles, VA) within the study area was performed. The sites were distributed to provide geographic coverage of the study area; the sites also differed in terms of their objectives and construction details. To examine performance during extreme events, when some benefits of coastal ecosystem restoration would be expected to be at their peak, outcomes in restored and un-restored areas during Hurricane Sandy were compared. For all analyses, available data was used, including data that had been collected to document Hurricane Sandy impacts. The results of the evaluation indicate that the benefits provided by these projects were moderate to substantial in nature, particularly in terms of beneficial effects on rare species habitats and property value enhancements. The results of the evaluations indicate that with relatively cost-effective analysis methods, the changes in ecosystem goods and services as a result of ecological restoration projects can be quantified in terms that are meaningful to the public. Further, some of those changes could be translated into social values using damage costs avoided and benefit-transfer methods. The case-study evaluations allowed the identification of opportunities for improving and strengthening monitoring and performance evaluation of NNBF.

## Institutional Barriers and Opportunities Related to NNBF

Advancing practice related to NNBF will involve making changes to institutional practices across Federal, State, and local government levels, as well as other organizations. In order to inform the efforts of the NACCS, a workshop was conducted with the purpose of assessing the policy challenges that exist that may impair the implementation and use of NNBF to create coastal resilience and reduce coastal risk. Specifically, the identification of the policy challenges that exist within and among Federal agencies that have a role in the implementation of these

[1] http://el.erdc.usace.army.mil/dots/models.html

features was sought. Thirty-four individuals from the Bureau of Ocean Energy Management, CDM Smith, the Department of Homeland Security (DHS), the USACE, the U.S. Environmental Protection Agency (USEPA), the U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service (USFS), the U.S. Geological Survey (USGS), HR Wallingford, the National Park Service (NPS), the National Ocean and Atmospheric Administration (NOAA), the National Wildlife Federation (NWF), and the Water Institute of the Gulf participated in the workshop.

Several opportunities for addressing the challenges were identified and categorized as follows:

*Science, Engineering, and Technology*

1. Create NNBF demonstration projects to learn the best practices and uses of NNBF.
2. Generate a compilation of information on the ecosystem goods and services provided by NNBF.
3. Develop risk and resiliency performance metrics for NNBF.
4. Initiate a wiki-type repository of knowledge adjacent to a data portal that could include contact information of people involved in NNBF efforts in different organizations and agencies.

*Leadership and Institutional Coordination*

1. Improve regional coordination through existing mechanisms such as Silver Jackets, NOAA's Sea Grant, and U.S. Department of Agriculture (USDA) extension offices.
2. Utilize public/private partnerships to implement NNBF.
3. Initiate the development of guidance and policies to achieve robust coordination and data sharing among resource and planning agencies.
4. Incorporate NNBF into existing decision support and communication tools.
5. Leverage partnerships and funding to promote NNBF in support of community resilience.
6. Develop a guidebook with information on NNBF that could be implemented during the recovery process following a disaster.

*Communication and Outreach*

1. Develop a policy digest with relevant definitions of NNBF, as well as the authorities, roles, and responsibilities of Federal, State, and local agencies that have jurisdiction or interest in the implementation of NNBF.
1. Form an NNBF community-of-practice.

## Looking Forward

U.S. coastlines provide social, economic, and ecological benefits to the nation, but are especially vulnerable to risks from the combination of changing climate and geological processes and continued urbanization and economic investment. NNBF can help reduce coastal risks as a part of an integrated approach that draws together the full array of coastal features that contribute to enhancing coastal resilience. By employing sound science and engineering practices, collaborating organizations will be able to identify timely opportunities, formulate and evaluate robust alternatives, and implement feasible approaches for making use of NNBF to enhance the resilience of social, economic, and ecological systems in coastal environments.