Developing Socio-Economic Metrics to Measure DOI Hurricane Sandy Project and Program Outcomes

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Prepared for:
National Fish and Wildlife Foundation
1133 15th Street NW
Suite 1100
Washington, DC 20005

Submitted by:
Abt Associates
4550 Montgomery Avenue
Suite 800 North
Bethesda, MD 20814

Tables

Acronyms

ACCSP	Atlantic Coastal Cooperative Statistics Program
ACS	American Community Survey
ADCIRC	ADvanced CIRCulation Model
AWQC	Ambient Water Quality Criteria
BEA	Bureau of Economic Analysis
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CEQ	Center for Environmental Quality
CRS	Community Rating System
DOI	Department of the Interior
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information Systems
HEC-RAS	Hydrologic Engineering Centers River Analysis System
MEG	Metrics Expert Workgroup
MRIP	Marine Recreational Information Program
NFIP	National Flood Insurance Program
NFWF	National Fish and Wildlife Foundation
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWR	National Wildlife Refuge
OSTP	Office of Science, Technology, and Policy
SAFIS	Standard Atlantic Fisheries Information System
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Executive Summary

The Department of Interior (DOI) allocated $340 million for projects that promote improvements in community and ecological system resilience. These funds were distributed internally among bureaus and externally through the National Fish and Wildlife Foundation (NFWF). With a total of 162 resilience focused projects, DOI initiated a process to establish criteria for evaluating project success and to establish metrics that quantify changes in resilience resulting from project actions at multiple scales. To that end, DOI convened a team of Federal experts to comprise the metrics expert group (MEG). This team developed performance metrics to measure changes in ecological resilience resulting from the DOI-sponsored projects, and determined that a separate analysis was needed for the development of socio-economic metrics. This report builds on the MEG ecological metrics and incorporates metrics to address potential socio-economic impacts resulting from the DOI-sponsored projects. Combined, the metrics identified by the MEG and this report will be used to evaluate the results of the DOI projects, individually and across larger scales. Such evaluative efforts will inform best practices, address knowledge gaps, sustain and enhance improvements in coastal resilience, and further community competence and empowerment.

1. Introduction

In the wake of Hurricane Sandy, a number of Federal, State, Non-Governmental, and academic efforts formed to address recovery and enhance coastal resilience along the northeastern U.S. coast. Recommendation 22 of the Sandy Rebuild Strategy, for example, states "*to develop a consistent approach to valuing the benefits of green approaches to infrastructure development and develop tools, data, and best practices to advance the broad integration of green infrastructure*." Related, the Council on Environmental Quality (CEQ) drafted policy guidance in 2015 recommending that ecosystem goods and services become increasingly incorporated in agency plans and policies, and the Office of Science, Technology and Policy (OSTP) released a research agenda to support coastal resilience and promote the establishment of consistent methodologies and metrics. Such groups have collectively recognized the difficulty with developing metrics to assess and quantify changes in resilience, as well as relating changes in ecological systems with that of community resilience. At the same time, Federal agencies are increasingly interested in using social sciences to demonstrate how restoration and resilience projects affect local economies and overall well-being.

The Department of Interior (DOI) allocated $340 million for projects that promote improvements in community and ecological system resilience, including projects that advance science to inform management decisions and to obtain essential data for baselining conditions and trends in coastal processes. These funds were distributed internally among bureaus and externally through the National Fish and Wildlife Foundation (NFWF). With 162 total resilience focused projects, DOI initiated a process to establish criteria for evaluating project success and to establish metrics that quantify changes in resilience resulting from project actions at multiple scales. However, measuring project success, especially within the three-year timeframe, requires ease of data collection, data management for sharing and summarizing, and early detection in changes to resilience. DOI convened a metrics expert group (MEG) to develop performance metrics for ecological systems and data management. The MEG adopted the definition of resilience established by the White House Exec. Order 13653, "*the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.*" This definition of resilience also includes improved scientific and socio-economic understanding that can inform mitigation and restoration practice, decrease model uncertainty, and support more resilient management decisions.

The MEG identified and organized metrics by the natural and artificial coastal features most affected by Hurricane Sandy along the northeast coast. The associated core metrics have the ability to indicate changes in resilience at these features. In particular, the MEG identified a range of project benefits provided by each coastal feature, performance metrics to assess success at achieving project objectives, and key standard protocols to perform given measures. The MEG determined that additional analysis was needed for the development of socio-economic metrics, and Abt Associates provided support to DOI and NFWF by expanding the work of the MEG ecological performance metrics to include socio-economic metrics. These socio-economic metrics were developed to provide measures of community well-being and resilience resulting from the DOI resilience projects.

This report summarizes our efforts over a three month timeframe to understand and characterize the DOI investment portfolio; document the activities and state of knowledge across project leads, DOI staff, and leading experts; develop socio-economic metrics for the habitat and activities of existing and future coastal resilience efforts; associate methodologies with the socio-economic metrics, including criteria to inform selection; and examine the application and integration of the socio-economic and ecological metrics from project, region, and programmatic scales.

Measures and methodologies to address community resilience are broad and therefore less established than ecological metrics. For example, the 2012 National Academies Committee on Increasing National Resilience to Hazards and Disasters concluded that methodologies to document community resilience and changes in resilience resulting from planning and investments are currently lacking (NAS, 2012). Our efforts began with a thorough literature review of the existing disparate efforts to assess community well-being and metric frameworks. The literature review informed categorization of resilience measures and shaped the organization of the socio-economic metrics presented in this report. These metrics are organized into four resilience categories – Human Health and Safety, Property and Infrastructure Protection and Enhancement, Economic Resilience, and Community Competence and Empowerment. This organization was also informed by a number of interviews with DOI bureaus, internal and externally funded project leads, and well-known social science and coastal resilience experts. The remarkable number of projects across DOI in response to Sandy provides a valuable opportunity to develop accurate and sensitive measures to detect change as well as to document the relationship between ecosystem resilience and community resilience. With 162 resilience focused projects, our team reviewed each proposal and project summary to ensure the habitat, primary objectives, and stated measures were incorporated. Further, all project outcomes were cross-referenced with potential resilience goals, wherein 16 resilience goals total may be achieved across the relevant project outcomes.

We identified over 200 socio-economic metrics. Metrics are summarized in tabular format according to their resilience goals for ease of identification and understanding. This report provides a description of the resilience category in relation to the definition and principles of resilience (e.g., anticipate, prepare, adapt, withstand, respond, recover) and provides a narrative description of the metrics within each of the four resilience categories. A suite of metrics is offered for each combination of 1) ecological or biophysical project outcomes and 2) desired or potential resilience goals. This suite provides a range of measures increasing in detail and complexity (e.g., narrative, semi-quantitative, quantitative modeling, benefit valuation). Methodologies and the recommended data and tools are provided for each metric, and we present a scheme to coordinate methodologies of varying degrees of difficulty and detail with the appropriate metrics. We recognize that while a set of relevant metrics may vary across projects, there could be a "core" of basic metrics that are applicable across a wide array of projects and relatively easy to construct.

A final objective of this study was to develop a framework to assess the socio-economic benefits of the DOI Sandy resilience projects by assigning metrics to each project. Review of each project revealed multiple layers of characteristics and parameters – habitat, anticipated project benefits, likely contributions to resilience, and ecological outcomes. The framework developed here is based on the assignment of one to several project activities to each project, and provides a flexible and repeatable approach to use with future studies. A project activity is defined as the high-level summary of the primary goals, actions, or objectives of a project, and includes, for example, habitat restoration data, mapping and modeling green infrastructure, and ecological resilience planning. There are 11 total project activities defined for the 162 resilience projects. The project activities are mapped to the suites of metrics across each of the resilience categories. These metrics suites are the recommended measures of effectiveness and socio-economic benefits across the DOI resilience projects. Using one or more of the metrics in each of the suites will provide narrative, qualitative, and quantitative details on how the DOI resilience projects have improved coastal resilience for the communities within their region of impact. The rationale behind this framework and the testing scenarios to validate the approach are described in the report. We also provide a review of the advantages and disadvantages of using this approach and other manual approaches based on project characteristics. These metrics and methodologies are described in this report, and were made available to NFWF and DOI in a comprehensive matrix with an accompanying user guide.

While this study was conducted over a brief period of time, our report also remarks on the contribution of the socio-economic metrics to the evaluation of the impacts of the DOI projects on coastal resilience. In particular, we discuss considerations for cumulative measures and emergent effects in regards to the regional contributions to resilience.

2. Project Categorization

Our effort to develop socio-economic metrics began with a screening-level review of the 162 DOI Hurricane Sandy Coastal Resiliency programs and projects (resilience projects). The goal of this initial review was to identify critical project characteristics that could be used to categorize projects. In turn, being able to categorize the projects was critical for establishing a representative subset of projects that would undergo a more in-depth review through interviews to help develop and review potential metrics. We ultimately categorized the reviewed proposals according to the location, budget, primary activities (e.g., Community Resilience Planning, Habitat Restoration, Grey Infrastructure), and environmental feature (e.g., beach, nearshore, riverine).

In particular, a project's primary activity quickly emerged as a critical characteristic that could be used to distinguish and thus categorize the proposals. Characterizing and categorizing projects in this manner allowed our team to (1) ensure that the metrics we identified and described are appropriate to the portfolio of projects; (2) select interviewees who covered a range of project types and locations; and (3) ultimately link projects, based on their primary activities, to the types of metrics that would best assess a project's socio-economic resilience outcomes. In this section, we provide summary information about the projects funded by DOI, the development of project categories used to group similar projects, and the role of the project categories in shaping our analysis.

Project activity refers to the primary actions of a project, as described in its grant proposals.

Project outcome refers to the final impact or intended impact of a project on its location. It roughly corresponds to ecosystem services.

Resilience category refers to the overarching organization for the impacts of the projects on community resilience.

Resilience goals refer to the specific socio-economic benefits associated with each resilience category.

2.1 Project Activity Categories

During the initial review process, we recorded keywords and outcomes from the proposals and project descriptions. For example, we documented key terms from the NFWF proposal sections: *Activities and Outcomes*, *Project Goals*, and *Return on Investment*. For the U.S. Fish and Wildlife Service (FWS), we documented the "*National disaster recovery framework support functions*" and terms from the project goals and summary sections. For all DOI Sandy Resilience projects we listed all project outcomes, which we then reviewed and grouped into 11 overall project activity categories. The final project activity categories are presented in Table 1.

Dredge work to drain flooded marsh at Prime Hook National Wildlife Refuge (Richard Weiner)

These project activities create a framework for understanding the project outcomes, but they operate at a higher scale. The project activities reflect the perceived prioritization of project goals and the primary focus of a project. This is further illustrated in Section 7, with the testing of the metric assignment to project categories. We assigned each project to one or more project activity. In particular, 99 projects are assigned to one project activity, and 63 projects have between two to five assigned project activities. The majority of the projects are assigned between one and three activities. Table 2 provides an example from the summary spreadsheet that lists the activities assigned to each project. For example, a project may be primarily focused on Habitat Restoration, but a good portion of the proposal or project description includes efforts to inform Community Resilience Planning.

Table 1. Project activity categories defined for the DOI resilience projects.

Project Activity	Definition
Community Resilience Planning	Analyzing and planning for resilience efforts that focus on human capital and built infrastructure.
Contaminant Assessment or Remediation	Examining or addressing water and soil contamination already in existence or as a potential threat from storms.
Critical Infrastructure Assessment or Protection	Protecting or assessing critical infrastructure.
Data, Mapping, and Modeling	Collecting data of ecological, biophysical or natural resources; coastal mapping; modeling coastal flooding scenarios.
Ecological Resilience Planning	Planning for ecological resilience or analyzing ecological resilience needs of ecosystems and/or regions.
Green Infrastructure Planning and Implementation (living shorelines, etc.)	Planning for or implementing green infrastructure projects including oyster reefs, living shorelines, and urban-focused projects. Only applied when the projects mentioned green infrastructure specifically or referred to the outcome of wetland restoration on storm surge, waves, or inundation.
Grey Infrastructure (dams, culverts, berms)	Removing, repairing, or implementing grey infrastructure elements for water control, including dam removal, culvert removal or repair, and actions associated with berms.
Habitat Restoration	Restoring species or vegetation habitats.
Impact or Vulnerability Assessments	Understanding the impacts of storms to communities, ecosystems, habitats, and species, and assessing vulnerability and risks for ecological and human communities.
Public Access	Planning for or creating opportunities for public access.
Sand Resource Identification or Assessment	Assessing sand resources for beach renourishment, but not direct beach nourishment or restoration actions.

Table 2. Example of table recording project activities assigned to each project. The full list of projects and mapped activities is provided in Appendix A.

Project Activity Categories													
Funding Org. and Id. Number	**Project Title**	**Grey Infras.**	**Green Infras.**	**Data, Map. & Model**	**Hbt. Rest.**	**Sand Resource Id. or Assess.**	**Eco. Resil. Plan.**	**Comm. Resil. Plan.**	**Impct. or Vuln. Assess. or Plan.**	**Contain. Asses. or Remed.**	**Crit. Infras. Assess. or Protect.**	**Public Access**
NFWF-41739	Reusing Dredged Materials to Enhance Salt Marsh in Ninigret Pond (RI)				x							
NFWF-41766	Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts			x	x		x	x	x			
NFWF-41787	Restoring Bellamy River's Fish Passage and Reducing Flooding Through Removal of Two Fish Barriers (NH)	x										
NFWF-41795	Strengthening Sachuest Bay's Coastal Resiliency (RI)	x			x							x

The percentage of grant funding across projects and the count of projects were also considered (Table 3). However, the information from the funding is less straight forward due to the multiple project activities assigned to may projects (e.g. the referenced objectives and outcomes) and the difference in cost across project activities (e.g. construction versus planning). Nonetheless, the percentage of all grant funding for each project activity (as a standalone activity assigned to a project) and the project counts by category are summarized in Table 3. We assigned 63 of the DOI resilience projects to more than one project activity category, and these projects make up 52% of the total grant funding. The total count for a project activity across all of the projects—both projects with only one activity and those with multiple activities—is presented in the last column of Table 3. Considering this total count across project activities, Habitat Restoration (49 of 162) and Data, Mapping, and Modeling (across 60 projects) are the two most frequently proposed project activities.

Table 3. Project Activity categories broken out by the percentage of funding when a project was assigned with just one activity implemented, number of projects assigned with only one activity implemented, and projects with multiple activities under multiple activity categories

Project Activity Category	Percentage of Grant Funding for Standalone Projects with One Activity Implemented	Projects Assigned that have only One Activity Implemented	Projects with Multiple Activities under Multiple Activity Categories
Community Resilience Planning	0.5%	2	19
Contaminant Assessment or Remediation	2%	3	4
Critical Infrastructure Assessment or Protection	Does not appear as a standalone	Does not appear as a standalone	3
Data, Mapping, and Modeling	14%	40	60
Ecological Resilience Planning	0.1%	1	13
Green Infrastructure Planning and Implementation (living shorelines, etc.)	1%	6	33
Grey Infrastructure (dams, culverts, berms)	5%	12	26
Habitat Restoration	16%	11	49
Impact or Vulnerability Assessments	7%	11	24
Public Access	Does not appear as a standalone	Does not appear as a standalone	5
Sand Resource Identification or Assessment	1%	13	13

2.2 Measurements

The NFWF project descriptions and proposals were reviewed to capture the anticipated measurements of project outcomes. This information was taken only from NFWF projects from the *Monitoring and Measuring Performance* and *Work Plan* sections because projects from the Bureau of Safety and Environmental Enforcement (BSEE), Bureau of Ocean Energy Management (BOEM), NPS, USGS, and FWS did not have a similar section to evaluate for the planned measurement of project outcomes.

Vegetation Data Collection (Erika Nicosia)

The majority of the NFWF projects reported no explicit plans to measure socio-economic outcomes of the project (Table 4). Where socio-economic measurements were mentioned in the project proposals, they tended to be relatively simplistic or inconsistent (e.g., a count of volunteers at a public event, a survey of volunteers). This provided a context for the type of metrics that projects were already considering and a jumping off point for our own metric development by indicating a possible minimum level of metric types. It also demonstrated the need for comprehensive socio-economic metrics that are reliable and repeatable.

Table 4. Qualitative review of socio-economic measures from NFWF projects.

Socio-Economic Measurement Level	Count of NFWF Projects
None	29
Low (basic counts)	13
High (mentions survey or analysis)	12

While many NFWF projects will inform the measurement of socio-economic benefits by providing measurements of the ecological and biophysical outcomes of a project, the current efforts to measure socio-economic benefits are inconsistent and infrequent. This gap demonstrates the need for robust socio-economic metrics that are applied to projects using a standardized and repeatable method. A full list of the measurement categories used and their definitions can be found in Appendix B.

2.3 Environmental Features and Organization

We also examined the environmental features across the projects. These features reflect where projects are located or the types of changes anticipated as a result of the funded activity (e.g., restoration of a wetland). The environmental feature categories used to summarize the projects

Table 5) were determined by reviewing each project proposal abstract or summary. The categories correspond to general features that we noted across the projects, and have not been rolled into higher-order categories or mapped to the feature categories of the DOI Metrics Expert Workgroup (MEG) ecological metrics.

The environmental feature categories also help reflect the scale of a project. For example, if a project occurs throughout an entire bay region, the scale of the project is reflected by identifying the environmental feature as the bay, rather than the individual natural features that make up the bay. As a result, we assigned each project to a single environmental feature category. While specific habitats and project sites are prevalent, there are also a number of projects occurring at larger ecological and human scales.

Restored beach and dunes offering protection to NASA facility (NASA)

Table 5. Environmental feature categories for all DOI resilience projects.

	Project Activity Categories										
Habitats	Comm.Resil. Plan.	Contam. Assess. or Remed.	Crit. Infra. Assess. or Protect	Data, Map., and Model.	Eco. Resil. Plan.	Grn Infra. Plan. & Imp.	Grey Infra.	Hab. Rest.	Impact or Vul. Assess.	Public Access	Sand Res. Id. or Assess.
Bay				14	2				7		
Beach/dune	1						1	3			
Beach/dunes and offshore				2							13
Beach/dunes and wetland	3		1	1	3	2	2	8	1	1	
Coastal plain								1			
Coastal upland and wetland						2		3		2	
Community/regional	11	3	1	26	3	7	2	2	12		
Forest					1						
Groundwater				3							
Riparian	1			1	1	1	14	5			
Shoreline	1	1		2		10	1	6		1	
Submerged				6							
Wetland	2		1	4	2	10	6	19	4	1	
Wetland, floodplain, and riparian						1		1			
Wetland, forest, and riparian				1	1			1			

3. Literature Review

At the study's onset we conducted a literature review to capture relevant information on coastal resilience, metric frameworks, disaster response, and related socio-economic evaluations. The literature review also informed identification of experts, federal agencies and programs, and communities to interview throughout this study. Additionally, we reviewed and documented metric frameworks for compilation and to inform the socio-economic metric framework. Metric frameworks we reviewed included those of the National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency (FEMA), U.S. Army Corps of Engineers (USACE), leading research institutions, and non-governmental organizations (NGOs) within the United States. The literature review also captured exceptional or innovative metric studies. We identified additional resources during interviews with the project leads and resilience experts.

The publication search for peer-reviewed sources used electronic search engines including Google Scholar, EBSCO, and JSTOR. A review of important grey literature through keyword searches on google.com identified reports by agencies, NGOs, and research institutions. We identified additional sources from citations in the compiled review. We found applicable articles in journals such as *Environmental and Resource Economics*, *Journal of Homeland Security and Emergency Management*, and *Journal of Water Resources Planning and Management*. The count of sources by document type is provided in Table 6.

Table 6. Count of sources reviewed.

Document Type	Count
Peer-Reviewed Article	57
Government Report	26
NGO Report	17
Book	1
Thesis	1

All sources we reviewed for the study are compiled as an annotated review in an Excel table, which is provided as a separate deliverable (Appendix 2, Metrics Matrix and Project Analysis). The sources are categorized according to document type, keywords, and application to this study (e.g., metric methodology, metric framework, soil contamination protocol). The annotation for each source describes key points as well as how we applied the information to our report. The Excel table also features columns for author, title, year, source, and full citation for each source.

While the literature review informed all aspects of the study, the literature review particularly informed the metric framework design in terms of relevant resilience categories, causal chain mapping, and the development of a methodology best suited to fully define socio-economic metrics for the DOI resilience projects.

3.1 Resilience Categories

Our review identified 17 metric framework studies, wherein each framework presents a categorization as a means to organize metrics. The socio-economic resilience metrics that we present in this report reflect the ecological outcomes compiled across all 162 DOI resilience projects. We supplement the results of our review of the projects with information we identified through the literature and interviews, and resulted in our proposed metric categories of Human Health and Safety, Property and Infrastructure Protection and Enhancement, Economic Resilience, and Community Competence and Empowerment. Organizing metrics into overarching categories assists in the development of the metrics by ensuring that each metric (1) is linked to a final socio-economic benefit and (2) resonates with the definition used in this report for coastal resilience.

We define the resilience categories below:

- **Human Health and Safety**. The socio-economic benefits in the category of human health and safety are those resulting from reduced risks or threats of injury, casualty, or sickness. Reducing these risks or improving health outcomes allows populations to better *withstand* and *recover from* disaster, which is directly related to resilience. These metrics measure the impact of DOI resilience projects' changes to the natural environment. In contrast, the impact of DOI resilience projects on planning efforts and emergency management or communication tools is measured using metrics grouped under the community competence and empowerment heading because the ultimate outcome of interest is the use of the planning efforts or tools by communities, rather than the intended reach of the project efforts.
- **Property and Infrastructure Protection and Enhancement**. This category is also associated with the reduction of risk (similar to Human Health and Safety), yet these metrics consider impacts on the physical structural elements of a community. Damaged property or interrupted services from community infrastructure pieces such as roads or emergency services all impair the ability of a community to *withstand*, *respond to*, or *recover from* natural disasters.
- **Economic Resilience**. Metrics measuring economic resilience address the direct and indirect impact of a DOI resilience project on the improvement in a community's economic sectors to *withstand* and *recover from* disasters. Some of the metrics measure the reduced impact of a storm event on economic sectors, while others examine improvements to the robustness of important economic sectors resulting from a project. In both cases, a stronger economic sector through protections or enhancements will improve resilience.
- **Community Competence and Empowerment**. Metrics included in Community Competence and Empowerment are, for the most part, measurements of improvements in resilience-related behavior of institutions, communities, and individuals. The socio-economic impact of a project that produces a new tool or set of data, for example, can be evaluated by improvements to hazard mitigation plans for a federal, state, or local government. While the possible types of project outcomes in the community competence and empowerment category are diverse, the resilience outcomes and thus the metrics are relatively narrow and are focused on proxy, indirect, and direct measures of behavior.

3.2 Causal Chain Framework

To identify and develop relevant socio-economic metrics for the DOI Sandy resilience projects, we referenced literature that develops "*theories of change*" across the project activities defined in this report. In particular, the *theories of change* developed here are modifications of existing 'causal chains' designed to explicitly link ecological restoration with societal benefits through changes in biophysical processes and conditions (*e.g.* Olander et al. 2015; Wainger and Mazzotta 2011; National

Ecosystem Services Partnership 2014). An example is mapped in Exhibit 1, wherein the causal chain illustrates how a resource management action (wetland restoration) reverberates through the biophysical and socio-economic systems. In this example, a common project outcome - acres of restored wetland - is linked to a change in socio-economic resilience through the project's ecological and biophysical outcomes.

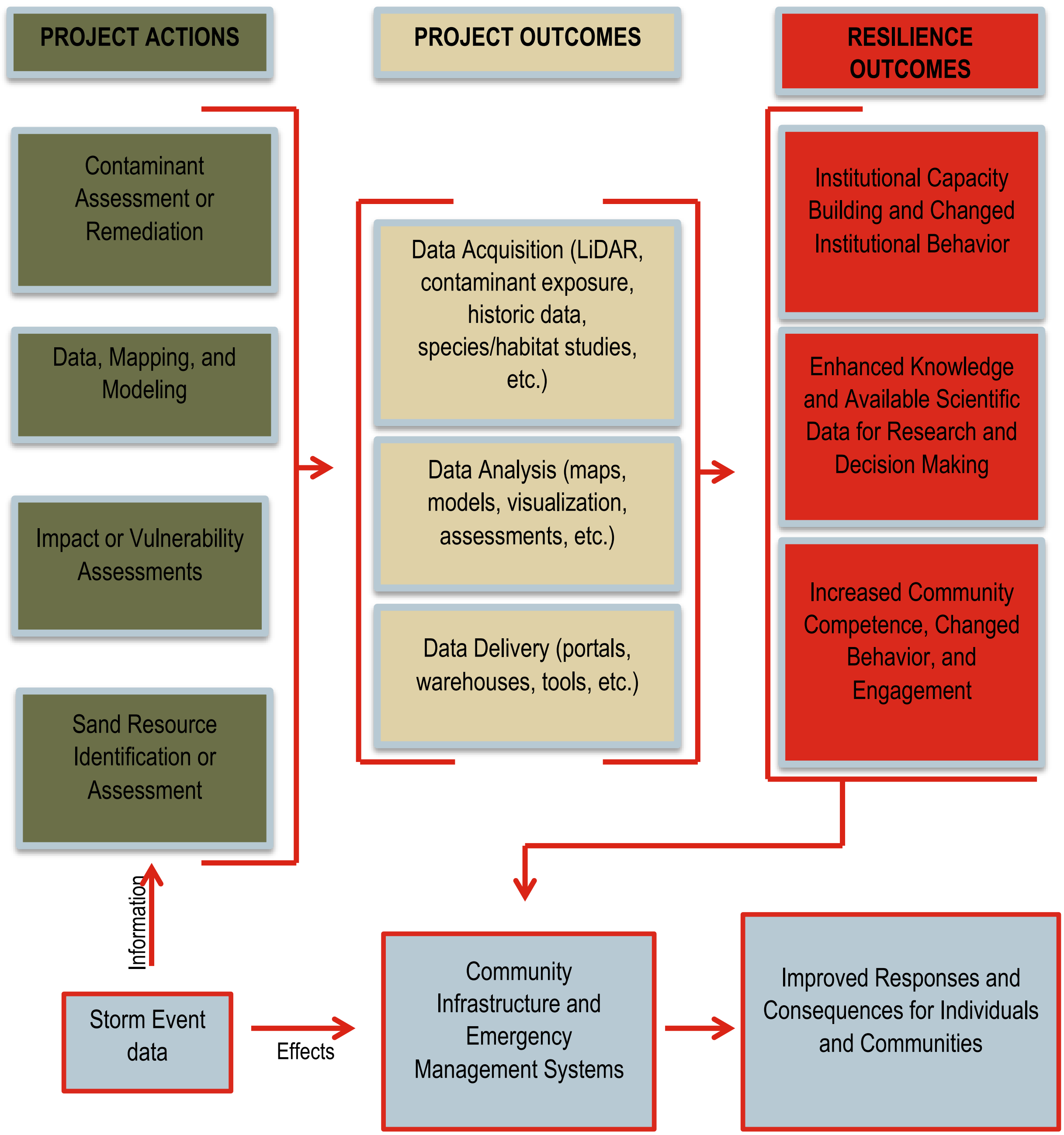
We used causal chains to ensure that (1) our metrics captured the activities and outcomes of the DOI Sandy resilience projects and (2) the metrics were linked to final societal benefits represented by socio-economic values. We reviewed and summarized the actions of all 162 DOI Sandy resilience projects. We then linked these actions to project outcomes through further review of the project proposals, literature review, and interviews. Finally, we determined the appropriate resilience goal for each of the project outcomes, again using literature review and interviews.

Importantly, as more links must be included in a causal chain in order to identify the societal benefit, the uncertainty in the relationship between the project outcomes and societal benefits increases accordingly (e.g., Olander et al. 2015).

Exhibit 1. Causal chain linking project actions to end resilience goal

Projects without a direct biophysical or ecological outcome are also able to be mapped to coastal resilience. For projects with impacts that are measured using metrics in the Community Competence and Empowerment resilience category, especially those that are primarily focused on data acquisition, analysis, and delivery, the ultimate socio-economic benefit is reflected in improved emergency management systems. This mapping process is shown in Exhibit 2.

Exhibit 2. Mapping projects with data outcomes to community resilience.



4. Interviews

We conducted interviews with a number of persons from different agencies, organizations, and expertise to further inform the socio-economic metric development. The structure of these interviews varied from open-ended to semi-structured conversations where participants were first provided with an interview guide or draft metrics material to help prepare responses to interview questions and to consider potentially relevant information to provide. In this section we summarize the interviews conducted and the findings.

4.1 Interview Methodology

To develop socio-economic metrics sufficient for assessing socio-economic resilience outcomes of post-Hurricane Sandy investments made by DOI and NFWF, we conducted a range of interviews with DOI and NFWF program staff, project leads for funded projects, and experts in constructing socio-economic metrics for resilience assessment. Our interviews with each of these groups had distinct aims and methodologies, each of which is described more fully below.

4.1.1 Program Staff Interviews

We conducted interviews with key staff responsible for awarding, overseeing, and administering the DOI and NFWF Hurricane Sandy resilience projects. We conducted these "program staff" interviews in the first weeks of the project to improve understanding of:

- The genesis of the need for socio-economic metrics and this project to develop Hurricane Sandy socio-economic metrics.
- The RFP release and subsequent project and/or proposal review and selection process for the resilience projects funded.
- How the socio-economic metrics will be used.
- Who will be collecting the socio-economic data.
- What a successful end product of this Hurricane Sandy socio-economic metric project looks like across the programs.

These interviews also solicited recommendations for key resources and experts to inform the metric development. The program staff interviews were semi-structured, in that we used an interview guide to steer the conversation, but we did not ask all questions in each interview based on the course of the conversation. Summaries of each of the interviews are provided as a separate document. We conducted interviews with the following program staff:

- National Fish and Wildlife Foundation: Candace Leong, Christina Kakoyannis, Mandy Chesnutt
- U.S. Fish and Wildlife Service: Dr. Rick Bennett, Lia McLaughlin
- U.S. Geological Survey: Dr. Pete Murdoch, Dr. Holly Weyers, Dr. Daniel Hippe, Dr. Carl Shapiro
- National Park Service: Dr. Charlie Roman
- U.S. Bureau of Ocean Energy Management: Dr. Jeff Reidenauer

4.1.2 Interviews with Project Leads

Interviews with project leads for funded projects were conducted from mid-September through late October 2015. The project lead interviews focused on developing information in the following areas:

- The nature of a given project's intervention/restoration goal
- The potential socio-economic outcomes of the intervention/restoration goal
- Whether the project was already collecting socio-economic metric data, and, if so, what data
- Potential synergies with other projects
- The socio-economic data that project leads would prioritize and collect.

These interviews were also semi-structured. We developed and shared interview guides prior to each interview. As with the program staff interviews, we allowed conversations with project leads to flow naturally; as a result, we did not ask all questions from the guide in each interview. Table 7 provides a summary of the project leads with whom interviews were completed along with some details of the specific DOI resilience project.

Table 7. Summary of project lead interviews, and project characteristics considered to ensure a variety of interviews across the project activities and habitats.

Grant Project (Funding Agency)	State	Interviewee	Project Activity	Project Habitat
Aquatic Connectivity and Flood Resilience: West Britannia and Whittenton Dam Removals, Mill River, Taunton, MA Connectivity (FWS)	MA	Eric Derleth, Assistant Supervisor, Partners for Fish and Wildlife, U.S. Fish & Wildlife Service, New England Field Office	Grey Infrastructure (dams, culverts, berms)	Riparian
Increase Resilience of Beach Habitat at Pierce's Point, Reed's Beach, and Moore's Beach (FWS)	NJ	Eric Schrading, Project Leader, U.S. Fish & Wildlife Service, New Jersey Field Office	Habitat Restoration	Beach/dune
Prime Hook National Wildlife Refuge Coastal Tidal Marsh/ Barrier Beach Restoration (FWS)	DE	Al Rizzo, Project Leader, Coastal Delaware NWR Complex	Habitat Restoration	Beach/dune and wetland
Increasing Water Management Capability at Great Dismal Swamp National Wildlife Refuge (NWR) to Enhance its Resiliency for Wildlife and People (FWS)	VA	Chris Lowie, Acting Refuge Manager, Chesapeake Marshlands National Wildlife Refuge Complex	Grey Infrastructure (dams, culverts, berms); Habitat Restoration	Wetland
Removal of 10 Dams in Massachusetts (NFWF)	MA	Tim Purinton, Director, Mass Division of Ecological Restoration	Grey Infrastructure (dams, culverts, berms); Ecological Resilience Planning	Riparian

Grant Project (Funding Agency)	State	Interviewee	Project Activity	Project Habitat
(1) Creating Green Infrastructure Resiliency in Greater Baltimore and Annapolis Watersheds (NFWF) (2) Increasing Salt Marsh Acreage and Resiliency for Blackwater National Wildlife Refuge (NFWF)	MD	Erik Jon Meyers, Vice President, The Conservation Fund	(1) Green Infrastructure Planning and Implementation; Data, Mapping, and Modeling; Community Resilience Planning (2) Habitat Restoration	(1) Community/ regional (2) Wetland
Building Green Infrastructure into Community Policies (NFWF)	RI	Pamela Rubinoff, Senior Coastal Manager, University of Rhode Island	Green Infrastructure Planning and Implementation (living shorelines, etc.); Community Resilience Planning	Community/ regional
Incorporating Green Infrastructure Resiliency in the Raritan River Basin (NFWF)	NJ	Christopher Obropta, Associate Extension Specialist, Office of Research and Sponsored Programs, Rutgers University	Green Infrastructure Planning and Implementation (living shorelines, etc.)	Community/ regional
Strengthening Marshes Creek Through Green and Grey Infrastructure (NFWF)	NJ	Dr. Qizhong (George) Guo, Professor, Rutgers University	Grey Infrastructure (dams, culverts, berms); Green Infrastructure Planning and Implementation (living shorelines, etc.); Habitat Restoration	Wetland
Building Ecological Solutions to Coastal Community Hazards (NFWF)	NJ	Elizabeth Semple, Manager, New Jersey Department of Environmental Protection	Green Infrastructure Planning and Implementation (living shorelines, etc.); Community Resilience Planning	Community/ regional
Ausable Watershed Flood Mitigation and Fish Passage Restoration (NFWF)	NY	Michelle Brown, Conservation Scientist, The Nature Conservancy	Grey Infrastructure (dams, culverts, berms)	Riparian
Reusing Dredged Materials to Enhance Salt Marsh in Ninigret Pond (NFWF)	RI	Caitlin Marie Chaffee, Policy Analyst, RI Coastal Resources Management Council	Habitat Restoration	Wetland
Improving Northeast Coast Storm-Related Data Interpretation and Accessibility (NFWF)		Cassie Stymiest, Program Manager, Northeastern Regional Association of Coastal and Ocean Observing Systems	Data, Mapping, and Modeling	Community/ regional

Grant Project (Funding Agency)	State	Interviewee	Project Activity	Project Habitat
Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts (NFWF)	MA	Christopher Hilke, Program Manager, National Wildlife Foundation	Data, Mapping, and Modeling; Habitat Restoration; Ecological Resilience Planning; Community Resilience Planning; Impact or Vulnerability Assessments	Beach/ dunes and wetland
Enhancing Mill River's Flood Resiliency and Habitat Corridor (NFWF)	CT	Milton Puryear, Executive Director, Mill River Collaborative	Data, Mapping, and Modeling; Habitat Restoration; Community Resilience Planning	Riparian
Ecological response of Great South Bay to the Fire Island Breach (NPS)	NY	Patti Rafferty, Coastal Ecologist, National Park Service, Northeast Region	Data, Mapping, and Modeling; Impact or Vulnerability Assessments	Bay
Submerged habitat mapping (Cape Cod, Fire Island, Gateway, Assateague) (NPS)	NY, MA, NJ, MD	Monique LaFrance, Oceanographer, University of Rhode Island	Data, Mapping, and Modeling	Submerged
Groundwater studies (Fire Island, Gateway, Assateague) (NPS)	NY, NJ, MD	Dr. Amanda Babson, Coastal Climate Adaptation Coordinator, National Park Service, Northeast Region	Data, Mapping, and Modeling	Groundwater
Ecological response of Great South Bay to the Fire Island breach (NPS)	NY	Dr. Christopher Gobler, Professor, Stony Brook Univ	Data, Mapping and Modeling; Impact or Vulnerability Assessments	Bay
Coastal Hazards Information and Decision Support Portal (USGS)		Dr. E. Robert Thieler, Research Geologist, USGS	Data, Mapping, and Modeling	Community/ regional

4.1.3 Expert Interviews

We conducted expert interviews throughout the 11-week study to inform and review the draft socio-economic metrics, and to ensure that these metrics reflect the current state of the art and science. Therefore, the interview objectives changed during the study. Early expert interviews primarily solicited recommendations for key resources pertaining to information or examples of relevant socio-economic metrics and data sources. These early expert interviews also included discussions on the importance and applicability of broad metric categories (e.g., to assess socio-economic outcomes of changes in nuisance flooding[1]). Mid-study interviews typically consisted of providing experts with a draft of the metric table ("metrics matrix"), and the objective was to solicit feedback regarding gaps and inconsistencies in the overall metric framework or specific socio-economic metrics. Finally, expert interviews near the end of the metric development and methodology review helped to refine our findings and presentation of the socio-economic metrics. We also asked experts to respond to the proposed methodologies and data sources for metric construction, as well as the feasibility of using

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[1] Nuisance flooding is defined as flood events that occur at least every year, typically resulting from King Tides.

existing off-the-shelf models and data sets. The expert interviews were informal, and we did not develop or use any interview guides. During the study, we interviewed the following experts:

- Dr. Kelly Burks-Copes, Research Ecologist, U.S. Army Engineer Research and Development Center
- Hannah Safford, SINSI Fellow, The White House Office of Science and Technology Policy
- Katherine Johnson, Ph.D. Candidate, University of Maryland Department of Anthropology
- Lisa Auermueller, Watershed/Outreach Coordinator, Jacques Cousteau National Estuarine Research Reserve, N.J. Agricultural Experiment Station, Rutgers University
- Barry Pendergrass, Office of Planning and Development, New York Department of State
- Darlene Finch, Mid-Atlantic Regional Coordinator, National Oceanic and Atmospheric Administration Coastal Services Center
- Dr. Susan Durden, Economist, U.S. Army Corps of Engineers Institute for Water Resources
- Keely Maxwell, Anthropologist, U.S. Environmental Protection Agency
- Elizabeth Schuster, Environmental Economist, The Nature Conservancy

In addition to these interviews, Dr. Lisa Wainger of the University of Maryland contributed her expertise in developing and applying socio-economic metrics to assess outcomes from a wide range of natural resource management programs as an expert consultant on this project.

4.2 Interview Findings

4.2.1 Program Staff Interview Findings

The program staff interviews were foundational to establish project context across the agencies and further understanding of the goals of each agency with respect to using the socio-economic metrics and coupling them with the ecological metrics. A brief summary of the general findings from the program staff interviews include the following observations:

- **The nature and extent of the links between anticipated project outcomes and potential socio-economic resilience vary among granting entities.** All program staff interviews identified a clear link between anticipated project outcomes and resilience as defined by DOI. However, the DOI resilience definition is broad enough that the resulting socio-economic outcomes could be very direct or indirect. This variation in the explicit and implicit relation to socio-economic outcomes is related to the solicitation and project selection process across the agencies and NFWF. Specifically, NFWF staff clarified that an emphasis on projects with a direct link to socio-economic improvements was a criterion for selection. In contrast, each DOI agency staff member suggested that different project aspects of resilience were more important, including for example, provision of direct ecological outcomes (FWS), development of scientific information (NPS) and models (USGS), and evaluation of resources to support future use (BOEM).
- **Projects funded are not required to monitor socio-economic related outcomes**. Whereas the project solicitation processes (i.e., requests for proposals) recognized the importance for project proposals to speak to potential socio-economic benefits, NFWF and the DOI agencies did not require proposals to conduct or describe a plan to monitor or evaluate the socio-economic benefits highlighted in the proposal. In contrast, most project-level monitoring focused on assessing project progress as measured in changes in biophysical and ecological metrics.

- **<u>Program staff are interested in a range of potential metrics.</u>** Program staff indicated preference to see and consider a range of metrics and the relative strengths and weaknesses for each. In particular, program staff are typically interested in the availability of data and the level of effort and expertise for measures and the ability of a metric to convey information to stakeholders. Such information will inform the tradeoffs involved in selecting socio-economic metrics to evaluate projects, and the metrics that can be used across project activities and scales.
- **<u>Ultimate use of socio-economic metric data.</u>** Program staff confirmed that socio-economic data will likely be used in the evaluation of the DOI Hurricane Sandy Resilience investments. As such, staff developed potential evaluation questions that the socio-economic metrics, once fully developed, could help answer. We used these questions to guide our work.
- **<u>Program staff desire information to support multi-project assessments.</u>** Program staff expressed a clear interest in receiving metrics and methodologies to evaluate projects' outcomes at multiple geographic scales. However, multiple staff also mentioned that it would be ideal if our report both (1) helped the project leads identify the types of metrics appropriate for their projects and (2) spurred project leads or their partners to begin collecting some of the data necessary for metrics construction on their own.

4.2.2 Interview Findings from Project Leads

We invested the bulk of our interview effort in interviews with project leads to capture their in-depth knowledge of the biophysical, social, and economic context and potential outcomes of their projects. We interviewed 17 project leads between September 24 and December 4, 2015. Interview counts represent the number of interviews, which typically included more than one person in an interview session. We selected interviewees to provide a representative mix across DOI agencies, geographic regions, and project types (e.g., dam/culvert removal, shoreline habitat restoration, green infrastructure, coastal resilience planning). Table 8 summarizes the interviews with project leads by key themes.

Table 8. Key themes from project lead interviews.

Interview Theme	Summary of Interviewee Responses
Potential socio-economic resilience outcomes of projects	• *Most commonly discussed:* recreation (fishing, boating, birding), property values, flood risk reduction, tourism, public safety, water quality. • *Discussed by a small subset of interviewees:* community education, urban redevelopment, fire risk reduction, regional partnerships for improved planning efforts, science and data tools, transfer of knowledge
Specific plans to measure socio-economic benefits of projects	• Very few projects had plans to directly measure outcomes in terms of socio-economic resilience. Projects leads are aware of general socio-economic outcomes though. • Most DOI project leads expressed a clear focus on improving the ecological functioning in project areas or developing an understanding of natural resources and systems with socio-economic outcomes as ancillary to their core focus. • A small subset of dam removal projects (sometimes combined with Habitat Restoration) are assessing changes in floodplains post-intervention, and a small subset of projects are measuring the outcomes of restoration on carbon storage and job creation. • Projects implementing online portals and warehouses for data or other online tools commonly used or planned on relying on Google analytics for simple

Interview Theme	Summary of Interviewee Responses
	measures.
Socio-economic data that project leads would find most useful (even if not collected by them)	• Links between restoration actions and tourism/site visitation. • Tracking changes in recreational fishing quality (e.g., catch rates, fish size, species caught) and related visitation after dam or culvert removal. • Green infrastructure and the value to water quality benefits. • National Park visitation rates at specific sites (e.g., beaches, fishing sites) after storms to observe how visitation changes during a "natural recovery" process (could serve as a baseline for comparisons with restoration interventions). • Changes in patterns of investment in blighted urban areas after restoration projects are implemented (speaks to whether restoration can help spur development). • The value of actionable science and data delivery. • Effectiveness of community resilience planning at local and regional level for long-lasting changes.
Geographical proximity to other Sandy resilience projects (gauge of potential cross-project synergies)	• Ability of nearby projects or regional projects and the socio-economic linkages of the project outcomes.
Effects on vulnerable populations (e.g., poor, elderly, or infirm people, recent immigrants)	• Beneficial to economically depressed area. • Does not appear to be a focus of the portfolio

While one can draw many inferences from the information provided in the summaries in Table 8, we highlight a selection of key findings below.

- **DOI project leads are less focused on socio-economic outcomes.** While each DOI project addresses elements of the resilience definition, the focus is rarely on socio-economic outcomes. The extent of this focus varies by agency. For example, FWS projects typically have an "ecology first" emphasis, including restoration of natural systems with an ancillary recognition of a project's potential to also provide socio-economic resilience. In contrast, NPS projects are generally oriented towards developing information to characterize baseline ecological conditions; USGS projects typically focus on development of natural system models; and BOEM projects complete assessments to support future resource management decisions with a direct link to human activity (e.g., beach renourishment).
- **NFWF project leads are more explicitly focused on socio-economic outcomes.** NFWF project leads generally have a clearer vision of how their projects may contribute to socio-economic resilience in nearby communities; this is true even though many projects have a primary project activity and focus on improving coastal ecological resilience (much like the DOI project leads). However, while most NFWF project leads more readily recognized and touted their projects potential for socio-economic resilience effects, it was similarly rare for them to be directly measuring such effects. As with the DOI project leads, NFWF project leads whose projects are Habitat Restoration based were focusing their monitoring plans on measuring changes in ecological outcomes; they did not often move beyond conceptual or theoretical links between ecological outcomes and socio-economic resilience effects. When community benefits were a primary focus of a project, project leads were considering how to link their efforts to socio-

economic resilience benefits. They often felt, however, that they did not have the capacity to complete a thorough review of those benefits.

- **Project leads commonly cited a subset of socio-economic resilience effects.** While the DOI resilience investment has the potential to provide a range of socio-economic resilience benefits, project leads most commonly cited a select few during discussions of the possible links between projects and socio-economic outcomes. These included enhanced opportunities for recreational boating and fishing, reduced flood levels and/or residence time, improved water quality, higher property values, and improved safety from a reduced flood hazard.
- **Most projects expect modest outcomes on nearby infrastructure.** While project leads often mentioned reduced coastal flooding as a key benefit, few interviewees seemed motivated by a need to protect nearby businesses or housing. Some project leads noted the potential for reduced damage to a few nearby structures, but this issue was often noted as a secondary benefit. While the protection of housing, businesses, or other real estate did not seem to be a central focus of most projects, a significant subset of project leads noted that their interventions would likely reduce the frequency and duration of nearby road flooding and closures. In some cases, interviewees noted that the affected road was critical for evacuation, so keeping roads open was important for safety. In other projects, roads were noted as important for recreational access, tourism, or commuting.
- **Significant cross-project socio-economic synergies are not likely.** Very few projects are geographically or physically inter-connected or closely juxtaposed. Therefore, significant socio-economic synergies are not likely to be evident across the investment portfolio. This obviates the need for metrics that would detect such synergies.
- **The exposure of disadvantaged populations or emergency-related infrastructure (e.g., cell towers, hospitals) is not generally relevant to the grant portfolio.** Few project leads we interviewed anticipated project outcomes relevant to elderly, disabled, or low–income persons in the area affected by their projects. While vulnerable populations and emergency related infrastructure was not a focus for the majority of projects, these demographic details and infrastructure components should be considered when measuring the socio-economic impacts of the projects (NIST 2010; Jepson and Colburn 2013; (Cutter 1996; Cutter et al. 2000).

Overall, the project lead interviews ***confirmed a strong nexus between explicitly funded project activities and potential socio-economic benefits*** that could result from their project. However, our interviews also indicated that ***little is being done to monitor for these types of outcomes***, though such an effort would is welcomed. Such an effort should target a subset of projects that provide representative coverage of key geographic regions and interventions of interest, rather than trying to be truly comprehensive across the portfolio of grants.

4.2.3 Expert Interview Findings

As noted above, we did not intend to use our expert interviews to develop standalone findings to share in this report. Rather, these interviews sought to identify literature and conceptual ideas, and to solicit input on early drafts of our list of socio-economic resilience metrics. We integrated expert-suggested government and non-government reports and peer-reviewed literature on existing socio-economic resilience frameworks into our review and methodology development). Our mid- to late-project interviews consisted of favorable reviews of the draft metric table, though experts suggested the removal of the ecological resilience category metric from our resilience category. Many experts suggested that ecological resilience effects are more appropriately captured through the ecological metrics. Experts also suggested including metrics for measuring damages resulting from nuisance flooding, as property damages from annual or more frequent flooding could exceed one-time property damages from major storms.

In two cases, experts were skeptical about the relevance of some metrics (i.e., improved human health and safety from reducing risk of wildfire, and reduced damage to farmland from saltwater intrusion) that we had included based on interviews with project leads. Although we agree that these metrics may not be applicable to a wide range of projects, we have retained them based on their relevance to the set of projects examined in this study.

Long Beach Island Coastal Storm Damage Reduction Project, New Jersey (Tim Boyle)

Experts also provided their state of knowledge on other programmatic research approaches and measures to evaluate investments in coastal resilience. For example, USACE performs physical modeling to assess relative outcomes of varying storm intensities for given landscape configurations. Experts also commented on the applicability of existing methods and tools to measure socio-economic benefits and contributions to resilience. In addition, one socio-economic indicator expert emphasized that no more work is needed on metric development as many frameworks have already been carefully developed; instead, what is most needed is more application of those frameworks to real world projects.

5. Socio-Economic Metrics

The DOI Hurricane Sandy resilience projects were not all required to provide for immediate environmental or conservation outputs and outcomes, but rather to enhance or provide for coastal resilience to future storm damages. To assess and communicate the value of these projects, changes in coastal resilience need be conveyed in metrics that reflect their *social relevance*.

To that end, we developed a suite of socio-economic metrics to provide for a robust assessment of the DOI resilience projects regarding the contribution to community well-being or socio-economic resilience. As discussed in the Introduction, resilience is in part informed and scoped by Executive Order 13653,

> "… The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." (76 FR 3821, p. 66824).

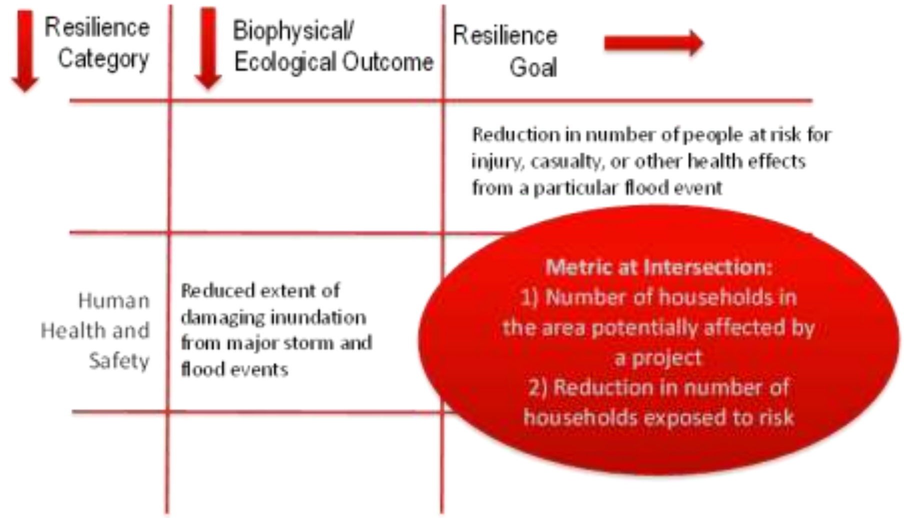
The socio-economic metrics and organizational structure (hereafter "metric framework") that we designed for this project are based on the three information-gathering tasks discussed in the above sections: project proposal review and categorization, literature review, and interviews with various stakeholders, leaders, and experts. The socio-economic metric identification process was iterative, including continued input from the information-gathering tasks and internal reviews with NFWF and DOI technical leadership.

In this section, we describe the metrics that can be applied to measure and monitor socio-economic contributions to coastal resilience. The metrics are organized by the four overarching resilience outcome categories listed in Section 3.2:

- Human Health and Safety
- Property and Infrastructure Protection and Enhancement
- Economic Resilience
- Community Competence and Empowerment

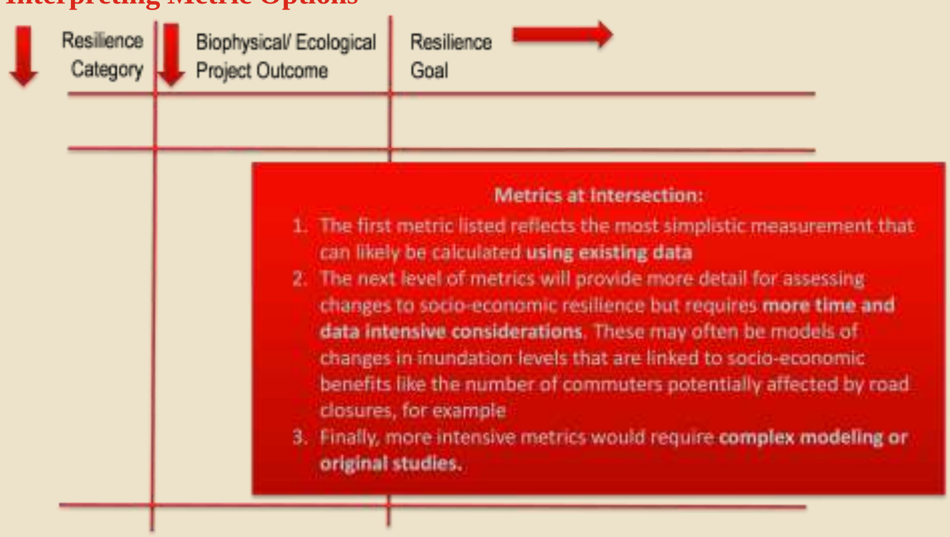
The metrics are summarized in tabular format according to the identified resilience goals (see Exhibit 3). There are 16 resilience goals in total with each one unique to the resilience category it falls under. The resilience goals were developed through review of the project proposals, interviews with project leads, program staff, and experts, and the literature review. Each resilience category section below begins with an introductory description of the resilience category's relation to the definition and principles of resilience (e.g., anticipate, prepare, adapt, withstand, respond, recover). This narrative description also includes an overview of potential resilience goals that may be achieved through the relevant project outcomes.

Exhibit 3. Metrics are provided at the intersection of project outcomes and resilience goals.



There are many options for measuring and communicating the effects of ecological enhancements resulting from the DOI Sandy resilience projects on socio-economic resilience. These options range from simple metrics based on qualitative descriptions or semi-quantitative information (e.g., number of households residing in the project vicinity) to metrics based on complex environmental modeling (e.g., changes in the expected property damage from a 1% flood event). Within each intersection of project outcomes and resilience goals, we will number the possible metrics in order of increasing difficulty. While a set of relevant metrics may differ across projects, there could be a “core” of basic metrics that are applicable across a wide array of projects and relatively easy to construct. The Methodology section provides a scheme to coordinate methodologies of varying degrees of difficulty or detail.

Interpreting Metric Options



5.1 Human Health and Safety

5.1.1 Introduction

> Project Activities:
>
> - Contaminant Assessment or Remediation
> - Green Infrastructure Planning and Implementation (living shorelines, etc.)
> - Grey Infrastructure (dams, culverts, berms)
> - Habitat Restoration

The safety and quality of life for people at risk of exposure to a natural hazard is directly related to resilience as part of a community's ability to withstand disasters (National Institute of Standards and Technology [NIST] 2010). Improved human health and safety is a co-benefit of many of the DOI Sandy resilience projects that enhance or restore landscape features to improve wildlife habitat or enhance environmental quality (e.g., reducing water and soil contamination, and improving water quantity in a wetland to reduce risk of wildfire). These co-benefits may exist even if they are not the original reason for the project. The box lists project types that are associated with human health and safety as a resilience outcome. These project types are based on the project categorization analysis from our review of the project proposals. We provide them as an example of the type of project actions that have resilience co-benefits.

5.1.2 Metrics

The human health and safety metrics highlight the human dimensions of projects and consider community demographics that are indicative of community resilience (e.g., presence of low-income population or a large percentage of retirees) (Jepson and Colburn 2013). The core metrics applicable to human health and safety are summarized in tabular form in Exhibit 4. These metrics fall under two resilience goals:

- The **reduction in exposure to flood hazard** from a particular flood event. This metric is determined by the resilience goal to reduce the number of households exposed to acute flooding hazards, and should be measured for major flood events (i.e., flood events with annual probabilities of 0.2%, 1%, 2%, and 5%) as well as flood events associated with more frequent, chronic nuisance flooding.
- The **reduction in exposure to other environmental hazards**, such as contaminated soil, water, and particulate matter. These metrics reflect the number of households expected to benefit from reduced health risk resulting from improved environmental quality and restoration activities. For example, the human health metric for a project that improves water quality could measure the change in number of households or recreational users exposed to unsafe levels of pathogens in surface water.

Exhibit 4. Metrics for human health and safety.

Metrics for Human Health and Safety		Resilience Goals: Reduction in number of people at risk for injury, casualty, or other health effects from a particular flood event	Resilience Goals: Reduction in number of people at risk for negative effects from contaminated water, soil, mosquito-borne disease, and wildfire
		Metrics[a]	
Biophysical and Ecological Outcomes	Reduced extent of damaging inundation from major storm and flood events[b]	1. Number of households in the area potentially affected by a project 2. Reduction in number of households exposed with the project as compared to without	
	Reduced hazard of nuisance flooding[c]		1. Number of households in the area potentially affected by a project 2. Reduction in number of households exposed with the project as compared to without
	Improved water quality		1. Reduction in number of households exposed to water-borne disease with the project as compared to without
	Improved water management and fire control		1. Reduction in number of households exposed to smoke and particulate matter with the project as compared to without
	Reduced soil contamination		1. Reduction in number of households exposed to a toxic pollutant with the project as compared to without
	Increased % native vegetation		1. Increase in number of households benefiting from reduced likelihood of West Nile Virus transmission
	Improved fish and shellfish habitat, increased fish and shellfish abundance and diversity		1. Increase in number of households with improved access to seafood

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list

b. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.

c. Nuisance flooding is defined as flood events that occur at least every year.

5.2 Property and Infrastructure Protection and Enhancement

5.2.1 Introduction

Physical infrastructure is an important aspect of coastal resilience because interruptions to surface transportation and emergency services resulting from flooded or damaged roads and bridges create significant disruption in businesses' and individuals' activities (e.g., food supply). Additionally, power outages and disruptions to water supply can limit the ability of critical services such as hospitals to perform their primary functions (NIST 2010). These damages to residential and commercial property create economic losses that impact and disrupt local economies and people directly. Minimizing potential disruption to critical infrastructure from storms and nuisance flooding, ensuring that critical services can perform their primary functions, and reducing economic losses can make a community more resilient by making it easier to restore pre-storm conditions. In addition, the

Property and Infrastructure consists of:

- Residential and commercial properties
- Cultural and heritage sites (e.g., historically designated houses, churches, community centers)
- Power, fuel/gas/energy, water, and sewer utilities
- Emergency services (e.g., fire, police)
- Health services
- Communication services
- Food supply
- National Guard bases
- Roads, highways, rail lines
- Bridges
- Transportation hubs (e.g., public transit, airports)
- Ports

DOI Sandy resilience projects may enhance the value of nearby properties. For example, water quality improvements and increases in vegetated open space and beach width have been shown to commonly increase values of nearby properties (Mazzotta et al. 2014; Ranson 2012; Gopalakrishnan et al. 2011). Much like the Human Health and Safety resilience category, Property and Infrastructure Protection and Enhancement is closely associated with projects that enhance community resilience by improving or restoring landscape features. The improvement to resilience often comes through reduced exposure to damaging inundation for various property and infrastructure components, as well as the enhancement of property through improved natural amenities and environmental quality.

5.2.2 Metrics

Physical infrastructure corresponds to the built environment such as residential, commercial, and cultural buildings and essential systems (e.g., transportation, utilities, health care, food supply, and communications) (NIST 2010). The metrics for property and infrastructure protection and enhancement fall into two main groupings:

- The **reduction in the amount of property and critical infrastructure exposed** to a potentially damaging inundation from a particular flood event. This metric is defined as the change in the quantities of the property and infrastructure components (e.g., number of buildings or road miles) exposed to damaging inundation from major flood events (i.e., flood events with annual probabilities of 0.2%, 1%, 2%, and 5%) as well as flood events associated with nuisance flooding that occurs at least every year. See Exhibit 5 for core metrics for these resilience goals.
- The **enhancement of residential and commercial properties** from changes in available natural amenities and environmental quality, including installation of green infrastructure, increase in beach width, and improvements in water quality and wildlife habitat. See Exhibit 6 for core metrics for these resilience goals.

Exhibit 5. Metrics for Property and Infrastructure Protection

Metrics for Property and Infrastructure Protection		Resilience Goals		
		Reduction in number of residential, commercial, cultural, and heritage properties at risk to potentially damaging inundation	Reduction in miles of roads, highways, and rail lines at risk to potentially damaging inundation	Reduction in number of critical service facilities[b] at risk to potentially damaging inundation
		Metrics[a]		
Biophysical and Ecological Outcomes	Reduced extent of damaging inundation from major storm and flood events[b]	1. Reduction in number of properties exposed to flood event with the project as compared to without 2. Reduction in percentage of total residential and commercial property value expected to be damaged in floods with the project as compared to without 3. Property value of residential and commercial properties exposed to a flood event with and without project 4. Reduction in flood insurance premiums or change in the Community Rating System (CRS) rating of the National Flood Insurance Program (NFIP) as the result of project 5. Tax base increase attributed to residential and commercial properties exposed to a flood event with and without project 6. Reduction in expected damages to properties from floods with the project as compared to without	1. Reduction in miles of transportation infrastructure exposed to a flood event, leading to a decrease in accessibility, with the project as compared to without. 2. Reduction in number of users potentially affected due to exposed transportation infrastructure 3. Avoided repair/replacement cost to transportation infrastructure exposed to a flood event 4. Avoided days of closure of transportation infrastructure 5. Avoided losses from closures or delays	1. Reduction in number of critical service and utility facilities exposed to a flood event with the project as compared to without 2. Reduction in number of users or customers potentially affected due to disruption of critical services or utilities 3. Avoided days of closure or disruption of critical services or utilities 4. Avoided losses from closures or delays
	Reduced hazard of nuisance flooding[c]			

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list.
b. Critical service facilities include power, fuel/gas/energy, water, and sewer utilities, emergency services, health services, communication services, food supply, National Guard bases, and transportation hubs.
c. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.
d. Nuisance flooding is defined as flood events that occur at least every year.

Exhibit 6. Metrics for Property and Infrastructure Enhancement

Metrics for Property and Infrastructure Enhancement		Resilience Goals: Enhancement of property and infrastructure components from improved natural amenities — Metrics[a]
Biophysical and Ecological Outcomes	Improved water quality	1. Number of residential, commercial, cultural, and heritage properties benefiting from improvement 2. Increase in property value of residential and commercial properties benefiting from improvement 3. Tax base increase or change attributed to residential and commercial properties benefiting from improvement 4. Increase in property value of residential and commercial properties benefiting from improvement (benefit transfer approach or original study)
	Reduced soil contamination	
	Reduced beach erosion; increased beach width; restored dunes	
	Improved vegetation cover; increase in vegetated area	
	Improved fish and shellfish habitat, increased fish and shellfish abundance and diversity	
	Improved amenities	

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list.

5.3 Economic Resilience

5.3.1 Introduction

> Vulnerable economic sectors:
>
> - Tourism and recreation infrastructure
> - Fishing, shellfishing, and aquaculture
> - Coastal-based businesses within FEMA NFIP flood hazard areas
> - Agricultural land within FEMA flood hazard areas or impacted by saltwater intrusion
>
> Source: NIST (2010); NOAA (2013).

Communities that primarily rely on a single employment sector susceptible to exposure to flood hazard (e.g., tourism and recreation, or commercial fishing) are likely to be less resilient and have difficulty with changing conditions and disruptions (EO 13653 2015; NIST 2010; NOAA 2013). Although the DOI resilience projects have fewer outcomes with direct effects on economic resilience, many of the projects may provide benefits to economic sectors vulnerable to flood hazard because of their impacts on tourism, recreation, fishing, shellfishing, aquaculture, and other local or regional business interests. Economic resilience metrics focus on the impacts of projects on the economic sectors and factors that are critical for local economies and, if relevant, regional economies (NOAA 2013; Pendleton 2010). For example, fishing communities may be more vulnerable to natural disasters because of their dependence on a single economic sector (NOAA 2013). Therefore, considering effects on reducing potential damages from flood hazard to the working waterfront in fishing communities would be particularly important.

5.3.2 Metrics

The metrics for economic resilience follow groupings similar to those for property and infrastructure protection and enhancement, with metrics either being associated with the reduction of the effect of damaging inundation and nuisance flooding or the enhancement resulting from project outcomes:

- The **reduction in the value and percentage of local or regional economic output affected by inundation** from a particular flood event or nuisance flooding. Economic sectors that are particularly vulnerable to flood hazards include tourism and recreation, commercial fishing, shellfishing, aquaculture, and agriculture (see Exhibit 7).
- The **enhancement of local and regional economies** from project outcomes, including improved opportunities for tourism and recreational activities, and improved conditions for fishing, shellfishing, and aquaculture (see Exhibit 8).

Exhibit 7. Metrics for Economic Resilience and Exposure to Flood Hazard

<table>
<tr><th colspan="2" rowspan="3">Metrics for Economic Resilience and Reduction to Exposure to Inundation</th><th colspan="4">Resilience Goals</th></tr>
<tr><th>Reduction in quantity of tourism and recreational infrastructure at risk to flood hazard</th><th>Reduction in quantity of commercial fishing, shellfishing, and aquaculture infrastructure at risk to flood hazard</th><th>Reduction in the share of agricultural land and output at risk to flood hazard</th><th>Reduction in share of local and regional economic output at risk to flood hazard</th></tr>
<tr><th colspan="4">Metrics[a]</th></tr>
<tr><td rowspan="2">Biophysical and Ecological Outcomes</td><td>Reduced extent of damaging inundation from major storm and flood events[b]</td><td rowspan="2">1. Reduction in number of buildings (e.g., hotels and summer rentals), recreational facilities, and amenities exposed to flood hazard
2. Reduction of number of visitors affected
3. Avoided user days lost
4. Avoided replacement cost
5. Avoided economic losses (lost revenue)</td><td rowspan="2">1. Reduction in number of boat launches, warehouses, fishing vessels, and aquaculture leased bottom exposed to damage or disruption
2. Reduction of number of potentially jobs affected by flood event
3. Avoided work days lost
4. Avoided replacement cost
5. Avoided economic losses (lost revenue)</td><td rowspan="2">1. Reduction in number of acres exposed to flood hazard or increased salinity
2. Avoided economic losses (lost revenue)</td><td rowspan="2">1. Reduction in number of businesses affected by a flood event
2. Reduction of percentage of local economic output potentially exposed to damage or disruption
3. Reduction of number of jobs potentially affected by a flood event
4. Avoided economic losses (total value and % of local output)</td></tr>
<tr><td>Reduced hazard of nuisance flooding[c]</td></tr>
</table>

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list

b. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.

c. Nuisance flooding is defined as flood events that occur at least every year.

Exhibit 8. Metrics for Economic Resilience and Natural Amenities Enhancement

<table>
<tr><th colspan="2" rowspan="3">Metrics for Economic Resilience and Natural Amenities Enhancement</th><th colspan="3">Resilience Goals</th></tr>
<tr><th>Enhancement of tourism and recreational infrastructure at risk to flood hazard</th><th>Enhancement of fishing, shellfishing, and aquaculture business</th><th>Enhancement of local and regional economic output</th></tr>
<tr><th colspan="3">Metrics[a]</th></tr>
<tr><td rowspan="5">Biophysical and Ecological Outcomes</td><td>Improved fish/shellfish habitat; increased fish abundance and diversity; improved water quality</td><td>1. Number of recreational fishing/shellfishing sites and areas in project's vicinity
2. Number of recreational users living within distance of using the site
3. Number of anglers/users visiting the affected sites; Number of fishing permits
4. Increase in fish/shellfish abundance and harvest or catch rates</td><td>1. Area of aquaculture leased bottom in project's vicinity
2. Number of commercial fishing/shellfishing permits holders affected by project
3. Increases in commercial fishing/shellfishing revenues
4. Avoided number of days of shellfish bed of closures (acres/days)
5. Increases in commercial species harvest</td><td>1. Number of related businesses affected
2. Percentage of local economic output affected</td></tr>
<tr><td>Improved amenities – presence of observation platforms, boardwalks, etc.; changes to amenity accessibility</td><td rowspan="4">1. Number of businesses or tourism and recreational properties within project's vicinity
2. Number of recreational sites with new or improved amenities and accessibility
3. Number of recreational users living within distance of using the site
4. Number of visitors or users affected
5. Increases in tourism revenues</td><td rowspan="4"></td><td></td></tr>
<tr><td>Improved vegetation cover; increase in vegetated area</td><td>1. Avoided cost of navigational waterways dredging</td></tr>
<tr><td>Improved avian and terrestrial species habitat and biodiversity</td><td></td></tr>
<tr><td>Reduced beach erosion; increased beach width; restored dunes</td><td>1. Avoided cost of beach re-nourishment
2. Avoided cost of navigational waterways dredging</td></tr>
</table>

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list.

5.4 Community Competence and Empowerment

5.4.1 Introduction

Resilient communities are those that possess a set of capabilities necessary to better adapt, survive, and recover when confronted with extreme disasters (NIST 2010). These capabilities might include the following to improve community responses to disasters:

- Community competence, or the ability of communities to affect positive change in advance

Community Empowerment project outcomes:

- Data, mapping, modeling
- Green infrastructure planning
- Community resilience planning
- Risk characterization
- Storm impact assessment
- Vulnerability assessment

of and in response to disasters (NIST 2010)

- Existence of collaborative relationships
- Community engagement
- Emergency plans (up to date and complete)

Approximately 19 of the 162 projects explicitly target community resilience as a goal, and 60 of the projects place a significant priority on Data, Mapping, and Modeling efforts that would also have an impact on institutional capacity and community competence (see Section 2.1). Many of these projects create data, tools, or other products that improve a community's ability to plan for, withstand, and recover from a disaster. Habitat Restoration projects also have the potential to provide opportunities for community engagement and volunteering as an ancillary benefits. Projects that explicitly focus on community resilience and those that indirectly affect it through the collection of scientific data or a restoration project require specific metrics to fully understand their impacts on community competence, collaborative behavior, decision making and other critical factors affecting communities' vulnerability to disasters (Jepson and Colburn 2013). Project activities with planning, tools, and science outcomes associated with Community Competence and Empowerment are listed in Exhibit 9. Projects with biophysical and ecological outcomes associated with Community Competence and Empowerment are listed in Exhibit 10.

5.4.2 Metrics

Metrics for Community Competence and Empowerment must be applicable to a wide range of project outcomes, including projects with outcomes that empower communities through the opportunities for engagement and dissemination of best resource management practices and projects that are primarily focused on improving community resilience through improved planning, partnerships, engagement, and creation of transferable best disaster mitigation practices or new knowledge (e.g., data collection and analysis). The latter project category has not been represented in the other resilience metrics.

Projects such as those categorized as having Data, Mapping, and Modeling or Community Resilience Planning outcomes certainly have field-based effects in the long term, but this connection is difficult to measure because of the large number of steps, data, and assumptions needed to connect new scientific information to lives saved in a storm event, for example. Instead, we recommend measuring changes in behavior that can be more directly attributed to these project outcomes and provide a more reliable measurement of impact.

Projects that produce improved plans, data, maps, or models, and projects with biophysical and ecological outcomes that also have community engagement aspects or develop best practices can be measured using metrics that correspond to four resilience goals:

- Increased institutional capacity, which is the ability of institutions to plan, withstand, and recover from disasters
- Enhanced knowledge, which improves the ability of individuals, community groups, and institutions to strengthen relationships and efficiently plan for emergency management, restoration, and mitigation efforts
- Increased community competence and engagement with projects producing planning, tools, and scientific products, which indicates a community's investment in planning processes and its ability to use the project outputs for improved behavior

- Increased community competence and engagement with projects producing biophysical and ecological outcomes, which indicates a community's level of investment in local projects and its ability to use the project outputs for improved behavior.

Exhibit 9. Metrics for Community Competence and Empowerment—Projects with Planning, Tools, and Science Outcomes

Metrics for Institutional and Community Resilience for Planning, Tools, and Science Outcomes		Resilience Goals: Increased institutional capacity	Resilience Goals: Enhanced knowledge	Resilience Goals: Increased community competence and engagement for projects other than restoration
		Metrics[a]		
Project Outcomes	Improved community comprehensive planning, mapping, and zoning efforts	1. Increase in participation or ranking of NFIP's CRS program 2. Number of stakeholder/end user groups involved in development and implementation of project 3. Increase in number of communities with comprehensive plans, hazard planning, and emergency communication plans that meet minimum or best practice standards 4. Responsiveness to stakeholders/end user groups involved in development and implementation (i.e., engagement with stakeholders through meetings, responses to comments, incorporation in to decision making process, etc.)	1. Increase in number of partnerships across institutions, governments, and community groups 2. Increase in number of regional partnerships 3. Creation of improved best practices for planning and mitigation for other regions, projects, institutions 4. Increase in number of planning and mitigation plans for the transfer and communications of best practices 5. Uptake of best practices for planning and mitigation by other organizations 6. Increased regional actions and lasting planning coordination as the result of project 7. Increased speed of delivery of services and improvement of quality of services because of information provided by project 8. Reduced cost or savings to implementing new projects elsewhere because of information provided by project	1. Increase in number of repeat volunteers at events 2. Increase in number of households participating in public planning sessions or project run events 3. Increase in number of households making changes to own property (e.g. people storm proofing/or fitting houses to meet Federal Emergency Management Agency Base Flood Elevation (FEMA BFE); people raising elevation/increasing freeboard of buildings) 4. Increase in number of households aware of risk reduction tools like early warning systems, evacuation routes, etc. 5. Increase in number of households aware of community needs during disaster response (e.g. households aware of which neighbors need assistance during a disaster)
	Improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards			
	Improved hazard mitigation planning, actions, or capital expenditures			

	Increased quality and diversity of data acquisition, including datasets, maps, and models Increased quality and diversity of data analysis, including datasets, maps, and models Increased quality and diversity of data delivery for datasets, maps, and models (i.e. portals, visualization, etc.)	1. Increase in number of communities and other institutions accessing project products or tools 2. Provision of technical assistance/training to communities or stakeholders as part of the project 3. Number of stakeholder/end user groups involved in development and implementation of project 4. Number of communities instituting on-the-ground efforts or investments as the result of projects 5. Number of communities and other institutions using project information to make emergency decisions 6. Responsiveness to stakeholders/end user groups involved in development and implementation (i.e., engagement with stakeholders through meetings, responses to comments, incorporation in to decision making process, etc.)	1. Increase in number of tailored or gap-filling plans, datasets, maps, or models for specific communities 2. Increase in number of partnerships across institutions, governments, and community groups 3. Creation of improved best practices for other projects, institutions 4. Creation of science or tools that can be used by other organizations and leveraged for additional research goals 5. Increase in number of planning and mitigation plans for the transfer and communications of best practices Uptake of best practices by other organizations 6. Use of science or tools by other organizations or stakeholders and analyzed by user type (public, decision makers, researchers, etc.) 7. Increased speed of delivery of services and improvement of quality of services because of information provided by project 8. Reduced cost or savings to implementing new projects elsewhere because of information provided by project	1. Increase in number of households making changes to own property (e.g. people storm proofing/or fitting houses to meet FEMA BFE; people raising elevation/increasing freeboard of buildings) 2. Increase in number of households aware of risk reduction tools like early warning systems, evacuation routes, etc.

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list

Exhibit 10. Metrics for Community Competence and Empowerment—Projects with Biophysical or Ecological Outcomes

<table>
<tr><th colspan="2" rowspan="2">Metrics for Institutional and Community Resilience for Biophysical or Ecological Outcomes</th><th colspan="2">Resilience Goals</th></tr>
<tr><th>Increased community engagement and well-being resulting from restoration projects</th><th>Enhanced knowledge</th></tr>
<tr><th colspan="2"></th><th colspan="2">Metrics[a]</th></tr>
<tr><td rowspan="6">Biophysical and Ecological Outcomes</td><td>Improved fish/shellfish habitat; increased fish abundance and diversity; improved water quality</td><td rowspan="6">1. Number of educational, outreach, and volunteer events held by the project
2. Number of sites with enhanced activities (i.e. educational programs, recreational programs, etc.)
3. Number of researchers, volunteers, and students engaged in project
4. Number of community groups involved in project
5. Increase in number and percentage of schools with access to natural resources
6. Increase in number and percentage of local residents spending time outdoors due to project</td><td rowspan="6">1. Increase in number of partnerships across institutions, governments, and community groups
2. Creation of improved best practices for other projects, institutions
3. Creation of science or tools that can be used by other organizations and leveraged for additional research goals
4. Increase in number of planning and mitigation plans for the transfer and communications of best practices Uptake of best practices by other organizations
5. Use of science or tools by other organizations or stakeholders and analyzed by user type (public, decision makers, researchers, etc.)
6. Reduced cost or savings to implementing new projects elsewhere because of information provided by project</td></tr>
<tr><td>Improved amenities—presence of observation platforms, boardwalks, etc.; changes to amenity accessibility</td></tr>
<tr><td>Improved vegetation cover; increase in vegetated area</td></tr>
<tr><td>Improved avian and terrestrial species habitat and biodiversity</td></tr>
<tr><td>Reduced beach erosion; increased beach width; restored dunes</td></tr>
<tr><td>Improved fish/shellfish habitat; increased fish abundance and diversity; improved water quality</td></tr>
</table>

a. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring relative to each individual list

6. Methods for Estimating Socio-Economic Metrics

The socio-economic metrics developed as potentially applicable to assess the resilience project impacts is quite extensive given the diversity of ecological and resilience objectives and outcomes. For example, the original review of project proposals and the anticipated outcomes produced 79 unique descriptions of the actions taken by projects. This section presents methodologies for metrics estimation, organized by the four resilience categories and the intersection of the socio-economic resilience goal and the project outcome, as shown in Exhibit 3.

Each metric can be estimated using one or more methodologies, such that evaluators and those implementing monitoring plans for a given project may tailor an assessment based on project activities and the existing or developing data and resources. We define the simplest methodologies as those that require the minimum information needed to describe and/or communicate project accomplishments (e.g., qualitative description of resilience impact at the project level). More detailed methodologies are then defined as those providing quantitative site and community characteristics, indicative of the potential magnitude of project benefits (e.g., number of recreational users affected by beach restoration). More complex methodologies require analytical or numerical modeling to further quantify the potential socio-economic benefits of the resilience projects (e.g., estimate changes in avoided economic damages for a 1%-chance flood) and frequently rely on existing literature to establish changes in baseline or relationships between ecological or biophysical outcomes and socio-economic benefits.

Common methodologies to perform the measures include spatial analysis using Geographic Information Systems/Science (GIS), and counts of community and environmental features, dose-response modeling, and socio-economic surveys. Each of the methodology options for each resilience category is described in the individual sections below. The methodologies presented here include options to assess and tailor measures for a given project goal, stated measurements, and the available resources. Whenever possible, any ongoing data collection that projects are completing for their own monitoring efforts is recommended for use in applying the methodologies.

We adopted the following coding scheme to indicate these different levels of effort, data requirements, and expertise required to implement a particular method:

Low – Relatively low level of effort, relies on publicly available data or data collected by project leads. Little to no specialized expertise is required beyond GIS and simple data manipulation. This approach is more likely to produce screening level results that provide basic information (e.g., change in number of residential buildings potentially exposed to flood hazard) but not allow for detailed estimates of change (e.g., the expected value of avoided damages from a particular flood event).

Medium – Medium level of effort, relies on publicly available models and data and/or data collected by project leads. Requires specialized expertise and understanding of methods commonly used in human health and environmental hazard modeling and ecosystem service analysis and valuation. This approach would produce more refined or detailed results; for example, quantitative results based on existing data or economic valuations that rely on existing literature. For example, benefit transfer approaches used for estimating changes in property value from environmental enhancement resulting from improved natural amenities rely on published studies, publicly available data, and well accepted methods that are relatively easy to use in metric development but require expertise in resource valuation.

High – Resource and data intensive, relies on complex environmental modeling tools, requires specialized expertise and/or access to the relevant software. This approach would result in state-of-the-art estimates. In some cases, an approach may not be resource intensive but data is not available or is difficult to obtain. Approaches that require primary data collection and result in comprehensive site- and project-specific estimates are generally more time and resource intensive than those that rely on publicly available data. However, in some cases existing models and data may allow implementation of complex analyses using low to medium level of effort. Therefore, assessment of the baseline data availability is a necessary step in selecting the appropriate methodology.

For each of the resilience categories—Human Health and Safety, Property and Infrastructure Protection and Enhancement, Economic Resilience, and Community Competence and Empowerment—we review in tabular form the resilience goals, project outcomes, and metrics presented earlier with the addition of the possible methodologies. We then discuss how to determine the ecological or biophysical effects of the project (e.g. the project outcomes) and how to determine the population affected by the project. Finally, we present in-depth discussions of how the different methodologies can use the measurements of the ecological or biophysical effects and the affected population to determine the project's ultimate impact on the socio-economic resilience goal. Note that options are presented as low, medium, or high.

6.1 Human Health and Safety

The methodologies for human health and safety measures range from a proxy measurement of reduced number of households exposed to risk using the National Flood Insurance Program's Community Rating System (NFIP CRS) to spatial overlays of basic estimates of affected area and affected population (e.g., low) to more rigorous modeling techniques that examine changes in inundation levels and risk. Methodologies associated with Human Health and Safety are listed in Exhibit 11 with their associated socio-economic resilience goals, project outcomes, and performance metrics.

Exhibit 11. Methodologies for Human Health and Safety

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Reduction in number of people at risk for injury, casualty, or other health effects from a particular flood event	Reduced extent of damaging inundation from major storm and flood events[b] and reduced hazard of nuisance flooding[c]	Number of households in the area potentially affected by a project or reduction in number of households exposed with the project compared to without	• Low: A community's ranking or participation in the NFIP's CRS program • Medium: Existing literature that demonstrate the link between the project actions and biophysical change partnered with an estimation of affected population • High: Model the effects of the project using a spatial overlay of the extent and depth of inundation with and without the project using SLOSH, ADCIRC, HEC-RAS, and related models.

Exhibit 11. Methodologies for Human Health and Safety

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Reduction of people at risk for negative effects from contaminated water, soil, mosquito-borne disease, and wildfire	Improved water quality	Reduction in number of households exposed to water-borne disease with the project compared to without	• Low: Information from existing literature to discuss potential changes in human health risk associated with the projects qualitatively. • Medium: A simplified approach to estimating potential changes in human health risk from exposure to contaminated water. This approach relies on comparison of the before and after- project water concentrations to the human health-based ambient water quality criteria (AWQC) limits (U.S. EPA 2015a). • High: More sophisticated approaches to evaluating changes in health risk involve using dose-response functions to estimate changes in individual's health risk from exposure to various pollutants (e.g., pathogens). • High: Avoided incidence of adverse human health effects associated with exposure to ecological and biophysical changes.
	Improved water management and fire control	Reduction in number of households exposed to smoke and particulate matter with the project compared to without	
	Reduced soil contamination	Reduction in number of households exposed to a toxic pollutant with the project compared to without	
	Increased % native vegetation	Number of households benefiting from reduced likelihood of West Nile Virus transmission	
	Improved fish and shellfish habitat; increased fish and shellfish abundance and diversity	Increase in number of households with improved access to seafood	

a. Methodology options: Green – low level of effort; Blue – medium level of effort; Red – high level of effort
b. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.
c. Nuisance flooding is defined as flood events that occur at least every year.

In addition to measuring the impact of projects on the overall community population, human health and safety metrics should be applied to show how changes in exposure to flood hazard might affect vulnerable populations or neighborhoods where a high percentage of the population is vulnerable. These populations tend to fare worse during disasters and may bear a disproportionate share of the impact of a disaster (Jepson and Colburn 2013). Key factors that affect an individual's resilience include educational attainment, marital status, annual income, age, gender, race/ethnicity, and English proficiency (Cutter 1996; Cutter et al. 2000). When measuring the effect of a project on a population, therefore, a project should determine the distribution of that population's vulnerability characteristics. We suggest that measurements of vulnerable populations report on low-income households, retirees, children ages 0 to 5, and people with low English proficiency.

6.1.1 Methods and Data for Estimating Biophysical Changes

To link project outcomes to impacts on Human Health and Safety, the ecological or biophysical changes from a project must be estimated or measured. Project-collected data should be used whenever possible, but when relevant data are not collected by the projects themselves they can be supplemented by sources such as FEMA NFIP flood hazard data and Hazus datasets, local, county, and state GIS, and additional field data. FEMA flood maps most commonly provide the 0.2% and 1% flood events, though local and state agencies may have additional flood event or mapping information.

Additionally, the inundation extent for different flood events can be modeled using such tools as ADCIRC or SLOSH (coastal) or HEC-RAS (riverine). Such modeling approaches can be further applied to estimate changes in inundation with and without project conditions, though this approach is considered as extensive modeling and resources. For example, specific studies such as Georgiou et al. (2012) or Barbier et al. (2013) have been used to connect project actions such as wetland restoration, beach nourishment, and dune restoration with changes in the spatial distribution of wave height or water storage to identify households that may benefit from project actions. Careful consideration should be given to applicability of a particular study based on compatibility of the project location, resource characteristics, and resource management scenarios between the original study and the project site.

Water-based debris removal at Forsythe National Wildlife Refuge (Ryan Hagert)

Other improvements in environmental quality that are likely to affect human health require measurements of water quality, pollutant levels in soil, and air quality (i.e., particulate matter from wildfire). Many of these measurements will come directly from projects, which are measuring these environmental outcomes as indicators of project success. Additional measurements may need to be collected for projects that focus on enhancing wildlife habitat and thus do not consider other environmental quality data (e.g., water quality) to be high-priority measurements. Spatial overlays can also be used for these ecological and biophysical outcomes to determine the total area affected by a project, especially if a specific measurement of improvement is not possible. For projects affecting fire risk in wetlands, for example FWS's Increasing Water Management Capability at Great Dismal Swamp NWR to Enhance Resiliency for Wildlife and People, changes in water storage and quantity will need to be measured either through estimations based on literature or the project itself.

6.1.2 Methods and Data for Estimating Affected Populations

The methods to calculate the number of households benefiting from reduced exposure to flood hazard require spatial overlay of areas expected to be inundated with and without the project together with household location data. Inundation extent data were discussed above, and the U.S. Census provides data on the number of households per Census block. There are several approaches to assess household exposure to flooding, including: (1) assuming even distribution within a Census block where exposure is equivalent to the percent of the block inundated (e.g., 10% of a block inundated means 10% of the population flooded; or (2) assuming population distributed only on land areas identified as urban (e.g., using the National Land Cover Dataset) (Taylor and Lorie 2014). Many localities have more precise data on the locations of households from property tax databases or other datasets that provide more precise estimates of exposure to flood hazards. A count of the number of households within an estimated affected area (e.g., an X-meter buffer zone from a project or number of households within a floodplain before and after project implementation can also be used).[2]

Demographic data relevant to population vulnerability are available from the U.S. decennial Census and the American Community Survey (ACS).The ACS, for example, provides data on household income, disability, and similar vulnerability associated characteristics (American Community Survey 2014). As with population and number of households, these data are provided at the Census block level; cities or local agencies may have more precise data on these demographic characteristics. GIS can be used to overlay demographic characteristics with the area affected by a project to determine possible impacts on vulnerable populations. When using Census block data, assumptions about even spatial distribution must be made; more precise data may not require this assumption and can provide more precise results.

Estimating the number of households benefitting from enhanced environmental quality depends on the nature of improvement and the population expected to benefit from the improvement (e.g., households residing in the vicinity of the site and/or recreational users). In general, this analysis involves two steps:

- Identifying the geographic area of project outcome based on published literature or data provided by project leads.
- Estimating the number of households or resource users present in the relevant geographic area.

For example, the relevant number of individuals benefitting from reduced exposure to contaminated soil is likely to include households residing within a walking distance from the contaminated area. The analysis would involve using GIS to estimate a buffer zone around the project (e.g., 0.5 miles) and identifying the number of households residing in the buffer zone based on the U.S. Census database.

If a project results in water quality improvements in recreational areas and is thus expected to reduce health risk to recreational users, the number of potential beneficiaries could be determined by collecting visitation data to the recreational site (e.g., number of beach users) or using publicly available data. For example, NOAA's Marine Recreational Information Program (MRIP) site survey data can be used to estimate the number of recreational fishing trips to the coastal fishing sites (NOAA NMFS MRIP). State or county-level beach visitation data, fishing license data, and data on the number of anglers and angling trips from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (e.g., U.S. FWS 2011) could also be used to determine the number of beneficiaries. If subsistence fishing is present in the restoration area, collection of site-specific information may be necessary to estimate the number of beneficiaries since data on the extent of subsistence fishing are not widely available.

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2 If inundation information is not available or cannot be estimated, for example for projects outside of targeted geographies that do not include reduction in flood hazard as a primary goal, a count of households within an estimated affected area (e.g., an x meter buffer zone from a project) or the number of households within a floodplain map can be used to create an estimate of the benefits of the project.

Unless primary data on the number of recreational users are collected, recreation trip data need to be combined with information from the published literature to determine how far recreational users are likely to travel for their activities and how the presence of substitute recreational sites may affect their behavior and thus number of trips taken to the site affected by a restoration project. For example, based on data from the National Survey on Recreation and the Environment, about 80 percent of all water-based recreation occurs with 100 miles of the users' homes (Viscusi et al. 2008). Models from existing literature could be used to determine effects of substitute sites (e.g., Bergstrom & Cordell 1991).

Estimating the population affected by the wildfire may require assembling geospatial data (i.e., satellite images of the smoke plume) on the areas historically affected by the wildfire smoke and overlaying the plume boundaries with the U.S. Census data.

6.1.3 Estimating Changes in Health Risks

Methods potentially applicable to assessing changes in health risk resulting from the projects range from a qualitative assessment to using existing models. Selection of the appropriate approach for evaluating changes in human health risk should be based on data and resource availability as well as the importance of a particular issue in the community.

The following methods and data sources are recommended for estimating changes in the risk for injury, casualty, or other health effects from a particular flood event:

- Low: Use the project information to locate the community benefiting from project efforts and determine if the community is participating in the FEMA/NFIP Community Rating System, a voluntary program for recognizing and encouraging community floodplain management activities exceeding the NFIP's minimum standards. For participating communities, flood insurance premium rates are discounted. Use changes in a community's ranking or participation in the NFIP's CRS program as a proxy to indicate improved adaptation for the overall community. Qualitatively measure the benefits of the project by estimating the geographic area and the number of households associated with the changes in the NFIP's CRS program.
- Medium: Demonstrate the causal link between the project actions and biophysical change to inundation level, wave attenuation, etc., using the example methods described above. Quantify these benefits to also determine the affected geographic area and population. This can provide an estimate of the number of individuals at reduced risk of injury or casualty, or the negative health effects from a project without modeling changes in inundation levels.
- High: Analytically or numerically model the effects of the project by producing a specific hindcast or forecast of the extent and depth of inundation with and without the project using SLOSH, ADCIRC, HEC-RAS, and other similar models. Use the estimate of the affected geographic area calculation to determine the number of affected individuals.

The following methods and data sources are recommended for estimating the changes in risk for adverse health effects from contaminated water, soil, mosquito-borne disease, and wildfire:

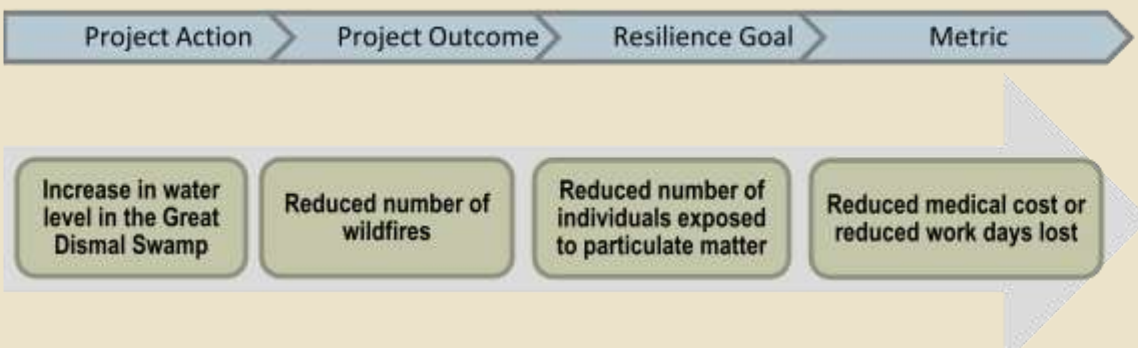
- Low: Use information from existing literature to discuss potential changes in human health risk associated with the projects qualitatively. For example, Allan et al. (2008) provide evidence of reducing the risk of transmission of the West Nile Virus resulting from increased avian diversity in the area, and the effect of the diversity is represented by the change in the per capita human incidence of West Nile Virus by county. Ezenwa et al. (2007) provide evidence of reducing West Nile Virus prevalence through increased wetland vegetative area as demonstrated by infection rates among mosquitoes. U.S. decennial Census tract data can provide an estimate of the population within walkable distance of the improved site who will benefit from these types of projects.

- Medium: Use a simplified approach to estimating potential changes in human health risk from exposure to contaminated water. This approach relies on comparison of the before- and after-project water concentrations to the human health-based ambient water quality criteria (AWQC) limits (U.S. EPA 2015a). This analysis provides a measure of the change in cancer and non-cancer health risk by comparing the number of sites and pollutants exceeding health-based AWQC in the affected waterbody before and after completion of the projects.
- High: More sophisticated approaches to evaluating changes in health risk involve using dose-response functions to estimate changes in an individual's health risk from exposure to various pollutants (e.g., pathogens). Data and methodologies for conducting human health risk assessment are described in detail in the EPA's risk assessment guidelines (U.S. EPA 2015b).
- High: Avoided incidence of adverse human health effects associated with reduced exposure to particulate matter in the areas affected by smoke from wildfire could be estimated using EPA's BenMAP-CE (U.S. EPA 2015c).

Increasing Water Management Capability at Great Dismal Swamp NWR to Enhance its Resiliency for Wildlife and People

This FWS project covers the 110,000 acre Great Dismal Swamp National Wildlife Refuge, which incurred damage from wildfires and hurricanes during the past two decades that affected water and land management. The objective of this project is to alleviate these stresses by improving control of water levels and water management. Two of the ecological outcomes anticipated are reduced fire vulnerability of carbon-rich peat soils to drought events and reduced wildfire smoke impacts on public health and the tourism in the surrounding urban areas. Multiple socio-economic benefits are associated with these two project outcomes, but a major benefit from this project is its impact on human health.

An assessment of the project's impact on human health would start by estimating the relationship between the increased water levels at the Great Dismal Swamp and the reduction in risk of wildfires using existing literature. The potentially affected population can be calculated with geospatial data of the area and historical data on plume direction and boundaries. A simple estimate of those potentially protected by a reduction in occurrences of wildfires can be provided by an overlay of the plume with data from the American Community Survey or a more complex calculation can be based on avoided incidence of adverse human health effects associated with reduced exposure to particulate matter in the areas affected by smoke from wildfire could be estimated using EPA's BenMAP-CE (U.S. EPA 2015c). The measurement of socio-economic benefit can end there, or the reduced medical cost or reduced work days lost can be calculated.



6.2 Property and Infrastructure Protection and Enhancement

The broad methodology categories for property and infrastructure protection and enhancement mirror those presented for human health and safety with the exception of the addition of a hedonic valuation method to assess changes in property value resulting from the project activity. In this section, we discuss how to determine the ecological or biophysical effects of the project and the affected population, and then provide details on how to apply the different methodologies. Methodologies associated with Property and Infrastructure Protection and Enhancement are listed in Exhibit 12 with their associated socio-economic resilience goals, project outcomes, and performance metrics.

Exhibit 12. Methodologies for Property and Infrastructure Protection and Enhancement, mapped to resilience goals, project outcomes, and core metrics.

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Reduction in number of residential, commercial, cultural, and heritage properties at risk to potentially damaging inundation	Reduced extent of damaging inundation from major storm and flood events[b] and reduced hazard of nuisance flooding[c]	Reduction in number of properties exposed, reduction in percentage of total residential and commercial property value exposed, increase in property value, increase in tax base attributed to properties, reduction in expected damages	• Low: Use changes in a community's ranking or participation in the NFIP's CRS program as a proxy to indicate improved protection of infrastructure. • Medium: Demonstrate the link between the project actions and increased protection to infrastructure functionality by using one of the methods described for estimating biophysical change. • High: Model the effects of the project using a spatial overlay of the extent and depth of inundation with property and infrastructure components with and without the project using Hazus-MH.
Reduction in miles of roads, highways, and rail lines at risk to potentially damaging inundation		Reduction in number of miles exposed, reduction in number of users affected, avoided damage cost, avoided days of closure or disruption	
Reduction of critical service facilities at risk to potentially damaging inundation		Reduction in number of critical service and utility facilities exposed, reduced in number of users or customers affected, avoided loss of critical service and utility facilities, avoided days of closure or disruption	
Property enhancement from improved amenities	Improved water and soil quality, reduced soil contamination, restored beaches, dunes, improved fish and shellfish habitat; increased fish and shellfish abundance and diversity, improved vegetative cover, and improved amenities	Number of residential, commercial, cultural, and heritage properties benefiting, property value of residential and commercial properties, tax base attributed to residential and commercial properties benefiting, increase in property value of residential and commercial properties benefiting	• Low: Spatial overlay with the estimated of affected area and properties • Medium: Demonstrate the link between the project actions and increased protection to infrastructure functionality by using one of the methods described for estimating biophysical change. • High: Actual changes in property values resulting from environmental quality improvements can be estimated based on an original hedonic valuation study.

a. Methodology options: Green – low level of effort; Blue – medium level of effort; Red – high level of effort
b. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.
c. Nuisance flooding is defined as flood events that occur at least every year.

Property and infrastructure protection and enhancement measures should be conducted for geographic areas that show landscape-level or ecological changes affecting property. Metrics should also highlight the infrastructure components that are critical to community survival and functioning, for example evacuation routes, roads or highways that are the only access for communities, hospitals, police stations, power stations, and water treatment plants.

The customer and user base for the utility and critical services metrics should also be reviewed to show how changes affect the vulnerable populations considered in the human health and safety section.

The effect of projects on hospitals, fire stations, police, and National Guard bases should also be considered.

6.2.1 Methods and Data for Estimating Biophysical Changes

In order to measure the metrics for property and infrastructure protection and enhancement, the biophysical change caused by the project must be calculated at the appropriate geographic scale and for the outcome of interest. When project leads collect data to evaluate or model the outcome of the project on floodplain changes, the resulting data should be used as the biophysical input for this assessment. When projects do not collect this data, FEMA Hazus-MH datasets, local, county, and state GIS, and additional on-site collection can supplement existing data. Generally, FEMA flood maps include only the 0.2% and 1% events; therefore, local and state data will be needed for other flood events.

Determining the biophysical changes follows the same methodology used for human health and safety metrics. The areal extent of inundation for different flood events must be modeled using tools such as SLOSH, HEC-RAS, and other similar models. These tools can be used to produce a spatial overlay of inundation with and without the project. Established literature such as Georgiou et al. (2012) or Barbier et al. (2013) could be used to connect project actions such as wetland restoration, beach nourishment, or dune restoration with changes in the spatial distribution of wave height or water storage.

Projects that enhance natural amenities can rely on determining the affected area based on local information supplied by project leads or distance calculations based on existing resource valuation literature.

6.2.2 Methods and Data for Estimating Affected Area

Once the biophysical change has been determined, a geographic area with affected properties, infrastructure components, users, and customers must be calculated. For property and infrastructure protection and enhancement, the affected area definition uses the same methods as for human health and safety but counts property and infrastructure components, not households.

FEMA's Hazus General Building Stock database provides a Census block-level inventory of residential and non-residential buildings, including structural characteristics that are crucial for estimating damages. As with population analysis, analysis relying on this data requires assumptions about spatial distribution of buildings within each Census block. More precise data can come from local agencies, including planning offices, and tax assessor offices. Similarly, Hazus includes databases of the locations of civil infrastructure, such as roads and bridges, and critical facilities, such as hospitals and police stations, but more detailed and up-to-date information may be available from local agencies.

Users of other critical services can be assumed to be the populations within a determined distance of the critical service facility. For example, users affected by a disruption in police services would be those within the community radius of the police station. These calculations can be done using spatial analysis and existing GIS layers. If relying on FEMA's Hazus-MH, that methodology should be followed to ensure that the appropriate scales are available.

Calculations of affected areas relevant to transportation outcomes rely on GIS data layers to determine the miles of roads, highways, railways, bridges, and transportation hubs. Evacuation route information can be obtained from FEMA-funded Hurricane Evacuation Studies or local emergency response plans. State and local transportation planning departments collect and model traffic data that may be used to estimate the number of people potentially affected when roads or bridges are exposed to flooding. Water utility affected area and population served data for both drinking water and wastewater can be obtained from each local utility. Power utility market area will be determined in a similar manner except for the use of U.S. Energy Information Administration databases and local sources of information for customer and user data. It is worth noting that many of these data are considered sensitive because of potential homeland security implications and there may be restrictions on obtaining and publishing the data.

Cultural and heritage sites can be identified using federal, state, or local GIS layers (e.g., USGS Geographic Names Information System 2015; Census TIGER/Line® Shapefiles 2015; National Park Service 2015)—for example to locate historic districts, churches, and community centers—or through community services to identify and prioritize specific sites.

When considering property enhancement, the primary beneficiaries will be owners of the residential and commercial properties located in the vicinity of green infrastructure or amenity enhancements projects. The appropriate distance for identifying residential and commercial properties potentially affected by the projects can be determined based on existing economic literature. For example, an increase in small, vegetated open space (e.g., green infrastructure) may increase property values within a 500-meter radius from the green space area (Mazzotta et al. 2014). Contaminated soil may affect property values within 200 feet to up to a 3-mile radius (Kaufman 2006; Alberini 2010; McCluskey 2001). An increase in beach width and dune restoration may also benefit adjacent properties (Ranson 2012; Gopalakrishnan et al. 2011).

6.2.3 Estimating Changes in Property and Infrastructure Resilience

The final step to measure increased resilience for property and infrastructure components is to bring together estimates of the biophysical changes, the affected area, and the number of users or population served. An additional step could be taken to determine the change in expected property damage from a particular flood event, property value enhancement from restoration projects, and the effect on the tax base.

The following methods and data sources are recommended for estimating the changes in the expected property damage:

- Low: Use changes in a community's ranking or participation in the NFIP's CRS program as a proxy to indicate improved protection of infrastructure. Quantify the benefits using one of the previously described methods for determining the affected geographic area, infrastructure components, and/or population. This will provide an estimate of the number of households and/or a quantitative measure of infrastructure components benefiting from the project (e.g., number of road miles no longer exposed to inundation during a particular flood event).

- Medium: Demonstrate the link between the project actions and increased protection to infrastructure functionality by using one of the methods described for estimating biophysical change. Quantify the benefits using one of the previously described methods for determining the affected geographic area and population. See an example application of this approach in Section 6.1.3. This approach can provide an estimate of the number of users benefiting from a project (e.g., number of commuters affected by potential road closures) and more detailed metrics (such as avoided commuting time as a result of commuters being required to use alternate routes).
- High: Model the effects of the project using a spatial overlay of the extent and depth of inundation with property and infrastructure components with and without the project using Hazus-MH. This can provide an estimate of affected properties and infrastructure components, and it can be used to estimate dollar damages as result of flood inundation under different scenarios. These damage estimates can be used to assess potentially avoided damages associated with a project.

The following methods and data sources are recommended for estimating changes in property values from environmental quality or natural amenity enhancement:

- Low: Use the estimate of the affected area to determine the number of affected properties and the property value within that spatial overlay. Assess potential benefits to property owners qualitatively based on available literature.
- Medium: Overlay the area affected by the project with the sum of housing units in the Census tracts intersecting the area affected by the project and use the present-day median home values from the American Community Survey to determine the property tax contributions to the town from that area with and without the project (American Community Survey 2014). To determine the project's effect on property values, use a benefit transfer approach to estimate an increase in property values from the environmental quality improvements or natural amenity enhancement.[3] Existing literature can be used to estimate changes in property values from a variety of ecological improvements resulting from the projects, including an increase in open space (e.g., Mazzotta 2014; Neumann et al. 2009) or wetland area (e.g., Mahan et al. 2000; Boyer & Polasky 2004; Bin & Polasky 2005), water quality improvements (e.g., Bin & Czakowski 2013; Artell 2014; Poor et al. 2007; Leggett & Bockstael 2000), reduction in soil contamination (e.g., Brasington 2005; Alberini 2010; Bible 2002), reduction in flood risk (e.g., Braden & Johnston 2004; Daniel, Florax, & Rietveld 2009), increase in beach width (e.g., Ranson 2012), and dune restoration (Gopalakrishnan et al. 2011).

[3] Benefit transfer is a common and well-accepted approach to adapting benefit values first estimated in one context to a second context that is similar, but for which time or data prevent a new, ground-up economic study (Freeman, 2003; U.S. EPA, 2010; U.S. Office of Management and Budget, 2003). Developing benefit transfers involves three key steps recommended in the U.S. Environmental Protection Agency (EPA)'s *Guidelines for Economic Analysis* (U.S. EPA 2010), including: (1) detailing the ecological metric (e.g., change in vegetated open space) for which value estimates are desired, (2) selecting studies from existing economic research that match the ecological metric, and (3) transferring values.

- High: Actual changes in property values resulting from environmental quality improvements can be estimated based on an original hedonic valuation study.[4] This approach is resource intensive and can only be implemented by a resource economist with expertise in developing hedonic price models and possesses strong econometric skills. Moreover, the effect of restoration projects on property values will not be detectable immediately. The advantage of this approach is that it will provide estimates of property value effects specific to the ecological improvements resulting from the projects.

The removal of White Rock dam on the lower Pawcatuck River (Scott Comings)

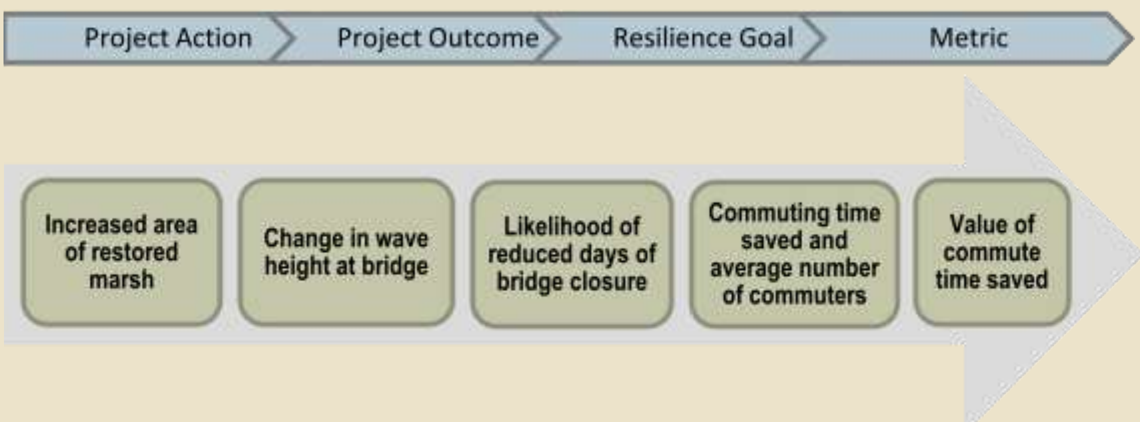
[4] The hedonic method allows for the indirect valuation of non-market benefits by utilizing market transactions for differentiated goods to observe the tradeoffs individuals make based on a specific characteristic. Rosen (1974), Freeman (2003), and Greenstone and Gallagher (2008) provide detail on developing hedonic models. Such studies, however, may not be easy to implement because they would require assembling a large datasets, including property sales data (including detail on property characteristics), geospatial characteristics (e.g., distance to the nearest beach or road), community characteristics, environmental quality, and other natural amenities.

Jamaica Bay, Boroughs of Brooklyn and Queens, New York City

A U.S. Army Corps of Engineers marsh restoration project was anticipated to have positive effects on the Cross Bay Bridge in Jamaica, but the exact effect has not yet been measured (Wainger et al. 2015). A number of socio-economic metrics or methodologies could be used to evaluate the effect, but resource constriction guided the selection of the metric and protocol (Wainger et al. 2015).

The evaluating team chose a metric that allowed for a direct connection to be made between the outcome of the project on biophysical aspects of the bay and the socio-economic benefits without requiring intense geophysical modeling. The metric chosen was total time cost per day of bridge closure, and the outcome of the restored marshes was measured as a threshold. The team determined that the project did have a positive effect on the protection of the bridge but did not determine the exact level of that protection.

Wainger et al. (2015) collected socio-economic information on commuting time and additional time required if the bridge was closed. The market size of affected users was broken out by rush hour and non-rush hour users (Wainger et al. 2015). The additional driving time required if the bridge was closed was multiplied by the market size to determine the total time cost per day of bridge closure (Wainger et al. 2015).



6.3 Economic Resilience

Changes in economic resilience can be measured in a number of different ways, and the specific methodology used will be heavily dependent on the metric chosen and community-specific concerns (e.g., heavy reliance on tourism industry). While spatial overlays can be used to determine a rough estimate of beneficiaries, socio-economic effects can be estimated more precisely through modeling of the biophysical changes and measurements of avoided economic losses. In this section, we present the project outcomes, metrics, and possible methodologies for measuring economic resilience effects, discuss how to determine the ecological or biophysical effects of the project and the affected population, and then provide details on how to apply the different methodologies. Methodologies associated with Economic Resilience are listed in Exhibit 13 with their associated socio-economic resilience goals, project outcomes, and performance metrics.

Exhibit 13. Methodologies for Economic Resilience

<table>
<tr><th>Socio-Economic Resilience Goals</th><th>Project Outcomes</th><th>Performance Metrics</th><th>Possible Methodologies[a]</th></tr>
<tr><td>Reduction of local and regional economic output at risk to flood hazard</td><td rowspan="4">Reduced extent of damaging inundation from major storm and flood events[b] and Reduced hazard of nuisance flooding[c]</td><td>Reduction in number of businesses affected, reduction in percent of local economic output potentially exposed, reduction in number of jobs affected, avoided economic losses</td><td rowspan="4">• Low: Spatial overlay with the estimated of affected area and market area or infrastructure as a percentage of the population now protected
• Medium: Model the effects of the project using a spatial overlay of the extent and depth of inundation with economic components with and without the project using Hazus-MH or other models</td></tr>
<tr><td>Reduction of tourism and recreational infrastructure at risk to flood hazard</td><td>Reduction in number of buildings, recreational facilities, and amenities exposed, reduction in number of visitors affected, avoided user days lost, avoided replacement cost, avoided economic losses</td></tr>
<tr><td>Reduction of commercial fishing, shellfishing, and aquaculture infrastructure at risk to flood hazard</td><td>Reduction in number of boat launches, warehouses, fishing vessels, and aquaculture leased bottom exposed, reduction in number of jobs affected, avoided work days lost, avoided replacement cost, and avoided economic losses</td></tr>
<tr><td>Reduction of agriculture land at risk to flood hazard</td><td>Reduction in number of acres exposed, and avoided economic losses</td></tr>
<tr><td>Enhanced tourism and recreational opportunities</td><td rowspan="3">Improved Water Quality, restored beaches, dunes, improved fish and shellfish habitat, increased fish and shellfish abundance and diversity, species habitat, and vegetative cover, and improved amenities</td><td>Number of businesses, recreational sites and areas in project's vicinity, number of users affected, change in recreational fish/shellfish abundance and harvest/catch rates, and tourism revenues potentially affected</td><td rowspan="3">• Low: Spatial overlay with the estimated of affected area and market area, the percent of the total county's economic output benefiting from the project enhancement, and the value of the different economic sector outputs enhanced by the project.
• Medium: Model estimated biophysical or geographic changes and determine avoided costs or increased revenue</td></tr>
<tr><td>Enhanced fishing, shellfishing, and aquaculture opportunities</td><td>Area of aquaculture leased bottom in project's vicinity, number of commercial fishing/shellfishing permits holders affected, avoided number of days of shellfish bed of closures (acres/days), potential increase in commercial species harvest, increase in commercial fishing/shellfishing revenues</td></tr>
<tr><td>Enhanced agricultural land</td><td>Acres of affected farmland and value of the potentially affected agricultural output</td></tr>
</table>

Exhibit 13. Methodologies for Economic Resilience

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Increase in local and regional economic output		Number of related businesses affected, percent of local economic output affected, avoided cost of beach re-nourishment, and avoided cost of navigational waterways dredging	

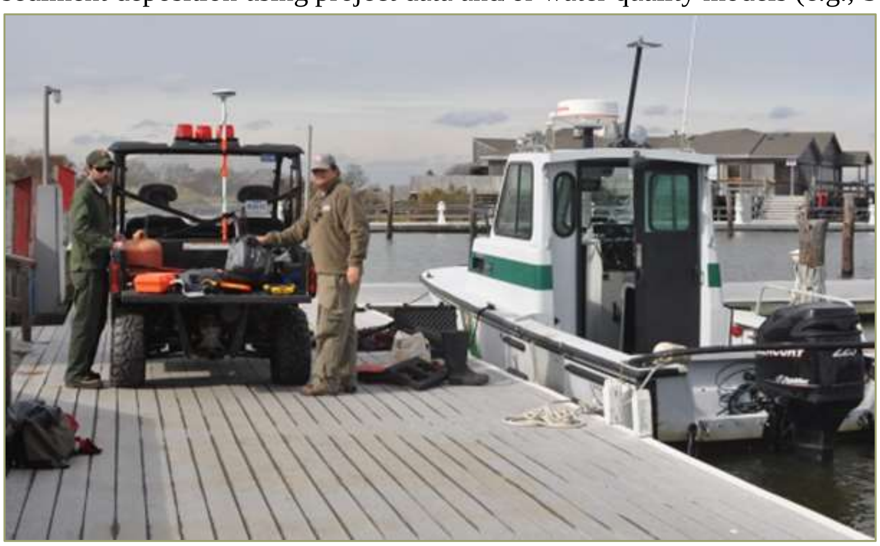
a. Methodology options: Green – low level of effort; Blue – medium level of effort; Red – high level of effort.
b. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.
c. Nuisance flooding is defined as flood events that occur at least every year.

As with the other categories, each metric can be applied to multiple subgroups to determine the distribution of effects of a project on different economic sectors or components, including tourism, recreation, fishing, shellfishing, and aquaculture.

6.3.1 Methods and Data for Estimating Biophysical Changes

The same combination of modeling and spatial analysis presented in Section 6.1 and Section 6.2 should be used to estimate a project's biophysical change. Additional modeling may be needed to determine salt water intrusion, changes in commercial and recreational harvest, and erosion and sedimentation rates. When applicable, additional modeling of salt water intrusion and erosion can be done using existing methodologies:

- **Salt water intrusion:** This analysis required a groundwater model that simulates density-dependent flow to evaluate salt water intrusion into aquifers (e.g. SUTRA; MOCDENS).
- **Sedimentation:** This analysis would involve identifying surface waters affected by the project that require dredging (e.g., navigational waterways and reservoirs) and estimating changes in sediment deposition using project data and/or water quality models (e.g., SWAT 2015).



Preparing for beach surveys at Fire Island (USGS)

NOAA's National Marine Fisheries Statistics data (e.g., NOAA 2014) can be used to identify commercial and recreational species of interest. Although NOAA regularly collects data on commercial landings and recreational catch, attributing changes in commercial and recreational fisheries harvest to the restoration projects in question may not be possible. A trophic transfer approach can be used to approximate the potential for a commercial and recreational fishing harvest increase resulting from wetland or other habitat restoration because more exact methods of assessing effects of restoration projects on commercial landings and recreational catch require detailed quantitative data and significant modeling expertise. Trophic transfer approach is based on web connectivity between primary production, in this case primary production in wetland habitat, and the production of resident and transient fish (Kneib 2003; McCay & Rowe 2003). The approach provides a simplified method to approximate potential commercial and recreational fishing benefits when fish sampling data are not available to support a more refined analysis. Fish production per acre of wetland habitat can be estimated by tracking biomass through four trophic levels. A trophic conversion occurs between each step due to losses of energy due to metabolic processes with only a fraction of production transferring to the subsequent level. Similarly, habitat productivity functions from available literature can be used to estimate changes in commercial and recreational harvest from restoration in oyster reefs and submerged aquatic vegetation.

6.3.2 Methods and Data for Estimating Affected Areas or Populations

Methods for estimating the affected properties and infrastructure related to tourism and recreation (e.g., hotels, summer rentals, and recreational facilities) and commercial fishing and shellfishing (e.g., working waterfront and aquaculture) are described in detail in the Property and Infrastructure Protection and Enhancement section (Section 6.2). Agricultural land potentially exposed to flood hazard can be identified based on the National Land Cover Database and GIS analysis.

Methods and data sources for estimating the number of potentially affected recreational users and tourists are referenced in the Human Health and Safety section (Section 6.1), including data on recreational fishing and beach visitations.

Data necessary to estimate the extent of commercial fishing in a local community and potential effects on this sector from exposure to flood hazard include the number of fishing permits, pounds and value of commercial landings, and number of dealers for commercial fishing. State- and port-level data are provided by NOAA (NOAA 2014). County-level information can be obtained from the SAFIS data warehouse of the Atlantic Coastal Cooperative Statistics Program (ACCSP 2014).

Data on economic outputs by county and economic sector (e.g., tourism, recreation, and commercial fishing), municipal costs (including dredging), and the makeup of local economies can be derived from the U.S. Bureau of Economic Analysis Regional Economic Accounts (U.S. BEA 2014). Publicly available data should be supplemented wherever possible by data from the relevant state, county, and local governments.

6.3.3 Estimating Changes in Economic Resilience

The final step to measure increased economic resilience is to bring together the biophysical changes, affected geographic area, and population to determine the change in economic resilience.

The following methods and data sources are recommended for estimating the changes in economic resilience and exposure to inundation:

- Low: Use the estimated geographic area to determine the number of tourism, recreation, fishing, shellfishing, and aquaculture infrastructure components potentially exposed to flood hazard from a particular flood event, the percentage of the total county infrastructure for a given economic sector potentially exposed to flood hazard, the number of local jobs, and the value of the economic sector output. All metrics are estimated with and without the project to determine incremental changes to economic resilience from the project.
- Medium: Using site-specific biophysical data and economic data, model the outcomes of various flooding scenarios on the relevant properties and infrastructure components and the associated flood losses in Hazus-MH. This can provide an avoided loss value for the effects of the project on tourism, fisheries, and agricultural infrastructure.

The following methods and data sources are recommended for estimating project-related enhancement effects for economic sectors vulnerable to exposure to flood hazards:

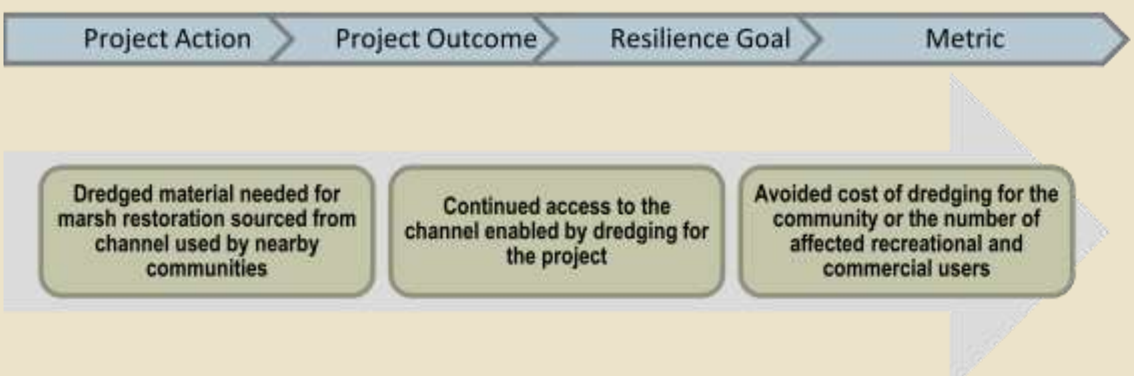
- Low: Use the estimated affected area to determine the affected tourism, recreation, fishing, shellfishing, aquaculture, and agriculture components benefiting from the project enhancement, the percentage of the total county economic output benefiting from the project enhancement, and the value of the different economic sector outputs enhanced by the project. This includes the number of recreational users, revenues per sector, and local jobs. All metrics are estimated with and without the project to determine the incremental changes to economic resilience from the project.
- Medium: Use estimated changes in sedimentation of navigational waterways and reservoirs in conjunction with estimates of the cost of dredging to determine cost savings to local municipalities; use changes in saltwater intrusion rates to agricultural land to determine the avoided revenue losses because of the project; use predicted changes in commercial fishing harvest from improved habitat productivity (wetland, oyster reefs, submerged aquatic vegetation) and the per-pound value of species of interest to estimate changes in commercial fishing revenues.

Although it is possible to estimate changes in the number of recreational visits resulting from improved recreational opportunities using primary studies of recreational behavior, such studies require significant resources and strong expertise in developing recreational survey instruments and modeling recreational behavior. Similarly, economic outcomes from increased number of recreational visits to the area affected by the projects can be estimated based on recreational expenditure data (either available from existing studies or collected), and change in the number of visits before and after the project.

Reusing Dredged Materials to Enhance Salt Marsh in Ninigret Pond (RI)

This NFWF project is restoring 30 acres of salt marsh and creating two additional marsh restoration designs in the Salt Ponds Region in south Rhode Island. The project is intended to strengthen the marsh's resiliency and serve as a model to similar restoration projects throughout the state. The goals of this project are heavily targeted toward ecological coastal resilience, but there are still socio-economic benefits that should be accounted for when assessing this type of restoration effort. While an obvious benefit is the potential reduction of risk of inundation, more indirect resilience goals should also be considered in any assessment. In the case of this project, the dredging materials come from a local channel. The dredging of the channel is not a primary goal of the project, but it does produce important socio-economic benefits for the surrounding communities by maintaining access to the breachway for boaters.

An assessment would begin by verifying that the project does, in fact, require the dredging of a channel used by the community. The population using the channel would then be estimated using data for recreational, tourism, and commercial users. The final impact on resilience can be shown as either the avoided cost to the communities for the dredging to maintain the channel or the number of recreational and community users affected. Both of these outcomes are related to resilience because they indicate a strengthened economic base, which then affects a community's ability to recover from a disaster.



6.4 Community Competence and Empowerment

The process to identify inputs for the methodologies used for Community Competence and Empowerment metrics differ from the previous section in that the project outcomes of interest are not field based. Instead, the focus is on changes in individual, community, and institutional structure and behavior. The relevant methodologies range in complexity from a simple count of participants to survey methods intended to assess behavior change. In this section, we present the project outcomes, metrics, and possible methodologies for Community Competence and Empowerment, discuss how to determine the outcomes and the affected population, and then provide details on how to apply the different methodologies. Methodologies associated with Community Competence and Empowerment are listed in Exhibit 14 with their associated socio-economic resilience goals, project outcomes, and performance metrics.

Exhibit 14. Methodologies for Community Competence and Empowerment

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Increased institutional capacity	Improved community comprehensive planning, mapping, and zoning efforts; improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards	Increase in number of participants or ranking of NFIP's CRS program	• Low: Identify communities within the appropriate geographic area whose participation or ranking in the NFIP's CRS program has changed after the implementation of the project • Low: Use project data and information from local planning offices to measure number of appropriate events, plans, and other efforts of stakeholder engagement • Medium: Conduct interviews with representatives from relevant institutions to assess changes in institutional capacity • High: Conduct a survey within the affected area to evaluate changes in institutional capacity and tie to cost or time savings
		Number of stakeholder/end user groups involved in development and implementation of project	
		Increase in number of communities with comprehensive plans, hazard planning, and emergency communication plans that meet minimum or best practice standards	
		Responsiveness to stakeholders/end user groups involved in development and implementation	
	Increased quality and diversity of data acquisition, including datasets, maps, and models; increased quality and diversity of data analysis, including datasets, maps, and models; increased quality and diversity of data delivery, including for datasets, maps, and models	Increase in number of communities and other institutions accessing project products or tools	
		Provision of technical assistance/training to communities or stakeholders as part of the project	
		Number of stakeholder/end user groups involved in development and implementation of the project	
		Number of communities instituting on-the-ground efforts or investments as the result of projects	
		Number of communities and other institutions using the project information to make emergency decisions	
		Responsiveness to stakeholders/end user groups involved in development and implementation	
Increased community engagement for projects beyond restoration	Improved community comprehensive planning, mapping, and zoning efforts; improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards	Increase in number of repeat volunteers at events	• Low: Use project data and information from local planning offices to measure number of appropriate events and plans • Medium: Conduct interviews with representatives from
		Increase in number of households participating in public planning sessions or project run events	
		Increase in number of households making changes to own property	
		Increase in number of households aware of risk reduction tools like early warning systems, evacuation routes, etc.	

Exhibit 14. Methodologies for Community Competence and Empowerment

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
		Increase in number of households aware of community needs during disaster response (e.g. households aware of which neighbors need assistance during a disaster)	relevant institutions to assess changes in community competence and tie to cost or time savings • High: Conduct a survey within the market area to evaluate changes in community competence and tie to cost or time savings
	Increased quality and diversity of data acquisition, including datasets, maps, and models; increased quality and diversity of data analysis, including datasets, maps, and models; increased quality and diversity of data delivery, including for datasets, maps, and models	Increase in number of households making changes to own property	
		Increase in number of households aware of risk reduction tools like early warning systems, evacuation routes, etc.	
Enhanced knowledge	Improved community comprehensive planning, mapping, and zoning efforts; improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards	Increase in number of partnerships across institutions, governments, and community groups	• Low: Use project data and information from local planning offices to measure number partnerships, plans, and resulting actions • Medium: Conduct interviews with representatives from relevant institutions and end users to assess changes and tie to cost or time savings
		Increase in number of regional partnerships	
		Creation of improved best practices for planning and mitigation for other regions, projects, institutions	
		Plans for the transfer and communication of best practices for planning and mitigation	
		Uptake of best practices for planning and mitigation by other organizations	
		Increased regional actions and lasting planning coordination as the result of project	
		Increased speed of delivery of services and improvement of quality of services because of information provided by project	
		Reduced cost or savings to implementing new projects elsewhere because of information provided by project	
	Increased quality and diversity of data acquisition, including datasets, maps, and models; increased quality and diversity of data analysis, including	Increase in number of tailored or gap-filling plans, datasets, maps, or models for specific communities	
		Increase in number of partnerships across institutions, governments, and community groups	
		Creation of improved best practices for other projects, institutions	

Exhibit 14. Methodologies for Community Competence and Empowerment

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
	datasets, maps, and models; increased quality and diversity of data delivery, including for datasets, maps, and models	Creation of science or tools that can be used by other organizations and leveraged for additional research goals	
		Plans for the transfer and communications of best practices	
		Uptake of best practices by other organizations	
		Use of science or tools by other organizations or stakeholders and analyzed by user type	
		Increased speed of delivery of services and improvement of quality of services because of information provided by project	
		Reduced cost or savings to implementing new projects elsewhere because of information provided by project	
	Improved water quality, restored beaches, dunes, improved fish and shellfish habitat, increased fish and shellfish abundance and diversity, species habitat, and vegetative cover, and improved amenities	Increase in number of partnerships across institutions, governments, and community groups	
		Creation of improved best practices for other projects, institutions	
		Creation of science or tools that can be used by other organizations and leveraged for additional research goals	
		Plans for the transfer and communications of best practices	
		Uptake of best practices by other organizations	
		Use of science or tools by other organizations or stakeholders and analyzed by user type	
		Reduced cost or savings to implementing new projects elsewhere because of information provided by project	
Increased community engagement with restoration projects	Improved water quality, restored beaches, dunes, improved fish and shellfish habitat, increased fish and shellfish abundance and diversity, species habitat, and vegetative cover, and improved amenities	Number of educational, outreach, and volunteer events held by the DOI-funded project	• Low: Use project data to determine the number of training and educational events held, the number of attendees or volunteers at the events, the number of researchers, students, and community groups involved in the project • Medium: Determine the number of schools within
		Number of sites with enhanced activities	
		Number of researchers, volunteers, and students engaged in project	
		Increase in number of community groups involved in project	
		Increase in number and percentage of schools with access to natural resources	
		Increase in number and percentage of local residents spending time outdoors due to project	

Exhibit 14. Methodologies for Community Competence and Empowerment

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
		Number of researchers, volunteers, and students engaged in project	the community affected by the project and measure the number of schools and students who now have access to improved natural resources as a result of the project • High: Conduct a survey to determine how community residents' behavior and interaction with the natural resource affected by the project has changed since implementation of the project
		Increase in number of community groups involved in project	
		Increase in number and percentage of schools with access to natural resources	
		Increase in number and percentage of local residents spending time outdoors due to project	

a. Methodology options: Green – low level of effort; Blue – medium level of effort; Red – high level of effort.

Community Competence and Empowerment metrics should also be assessed whenever possible for the outcomes on vulnerable populations. For example, attendance at a project event, a simple metric, should be broken down by the socio-demographic characteristics of attendees whenever possible. The demographics of the community where the event is being held could act as a proxy measurement of vulnerability, or socio-demographic characteristics could be collected at the event. Community organizations that should be considered when measuring effects on community institutions include educational organizations, non-profits, and civic groups. Federal, state, and local emergency response services should be considered when a metric is measuring outcomes that affect federal, state, and local governments; state and local land use and planning departments; and federal, state, and local elected officials. Metrics used for Community Competence and Empowerment projects should also include measures of vulnerable populations as a percentage of the total population potentially impacted by planning efforts.

6.4.1 Methods and Data for Estimating Project Changes

Fifty-three percent of all projects include activities associated with Community Competence and Empowerment. While some of these projects produce only planning tools, data, maps, or models, many are also associated with projects with biophysical or ecological outcomes. For example, of the 49 projects with an objective of Habitat Restoration, 17 also include significant efforts to address Ecological Resilience Planning, Community Resilience Planning, Impact or Vulnerability Assessments, or Critical Infrastructure Assessment or Protection. However, the impact of interest for the projects with this suite of metrics is their outcomes on Community Competence and Empowerment and not the ecological impacts. For that reason, the site of the project needs to be identified, but additional measurements of the ecological or biophysical outcome are not required.

6.4.2 Methods and Data for Estimating Affected Geographic Area and Population

The affected population for these projects should also be determined by the geographic area of the intended reach of the project. For a data collection project occurring at a regional level, for example, the affected geographic area will be the communities located within that region that may potentially benefit from the project's goals. Specific area and characteristics of the communities affected by a project, such as number of schools, can be gathered from state GIS layers. The number of students can be estimated from population statistics from the American Community Survey or for individual schools from state data. The presence of community organizations can be provided by state GIS layers or local information collection. Other components, such as the number of Green Infrastructure grants or projects, should be provided by the DOI Sandy resilience project.

The USGS Coastal Change Hazards Portal provides information on wave and storm surges, and pictures of coastal hazards.

6.4.3 Estimating Changes in Community Competence and Empowerment

The final step is to assess and describe changes to Community Competence and Empowerment resulting from each project. Improvements in institutional capacity will enhance communities' ability to prepare for disasters, reduce their impact, and to better recover from a disaster through planning or relationship building with other institutions or the community. This includes better emergency planning, emergency communications, community awareness and support, and other types of community planning efforts.

The following methods and data sources are recommended for estimating the changes in Community Competence and Empowerment:

- Low: Identify communities within the appropriate market area whose participation or ranking in the NFIP's CRS program has changed after the implementation of the project. Applicable CRS actions fall under three of the four CRS categories: public information; mapping and regulations; and warning and response (NFIP 2013). Depending on the project's resilience goal, it should be assessed based on its actions within the appropriate CRS category.
- Low: Use project data and information from local planning offices to measure the number of public planning events; the number of households, individuals, and community groups participating in planning processes; the number of partnerships across governments and nongovernmental institutions; the number of new datasets, models, and maps; and the number of communities adopting plans for green infrastructure, hazard mitigation, and risk communication. In the case of community comprehensive plans, the assessment would have to account for the long interval most communities have between releasing new plans. Whenever possible, assess the quality of these efforts and whether they meet best practice standards and fill gaps in existing knowledge or resources. This method can be used to asses institutional capacity and community competence.

- Medium: Conduct interviews with representatives from relevant institutions and stakeholder groups, for example local agencies and NGOs, to assess whether a project contributed to institutional capacity or community competence. For example, interviewees can be asked questions regarding whether institutions and communities developed or updated pre-existing emergency response plans, mutual aid agreements, stakeholder engagement efforts, communication strategies, zoning laws, and other elements of effective pre-disaster mitigation efforts and emergency response and recovery planning that help ensure resilience in case of natural disaster. The results of the interviews can also be used to approximate how the project efforts contribute to cost or time savings through expert elicitation of expected values.
- High: Conduct a survey within the market area of residents or users of project-produced tools, data, and science to evaluate the contribution of the project to institutional capacity or enhanced knowledge. These types of surveys can be used to evaluate changes in Community Competence and Empowerment, including local agencies, NGOs, residents' acceptance of flood mitigation practices, community engagement, and development of helping behavior (e.g., neighbors knowing other neighbors who would need assistance during an evacuation), problem-solving skills, and other necessary behavioral changes. The results of the survey can also be used to determine how the project efforts contribute to cost or time savings through expert elicitation of expected values that are then tied to survey results.

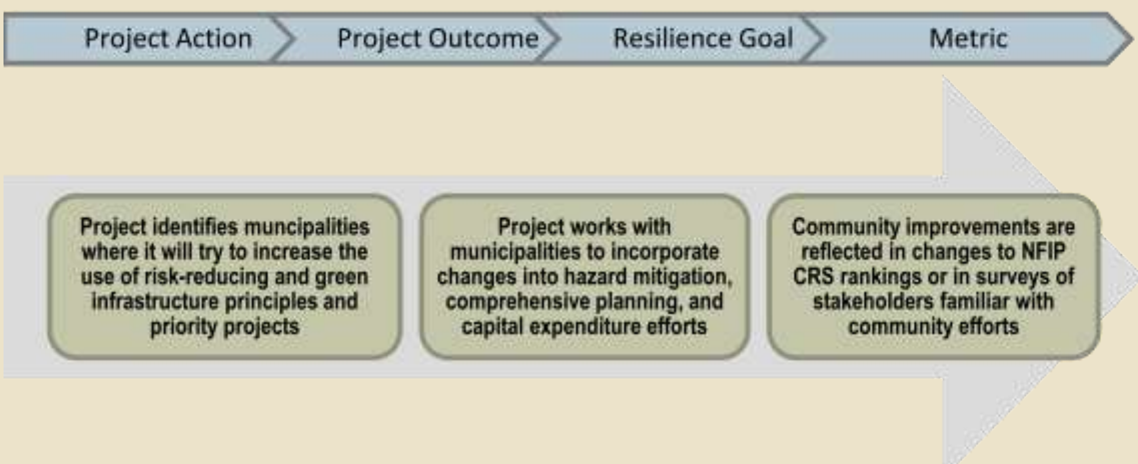
The following methods and data sources are recommended for estimating the changes in a community's opportunities for engagement through restoration activities:

- Low: Use the appropriate project data to determine the number of training and educational events held, the number of attendees or volunteers at the events, and the number of researchers, students, and community groups involved in the project.
- Low: Determine the number of schools within the community affected by the project and measure the number of schools and students who now have access to improved natural resources as a result of the project.
- High: Conduct a survey to determine how community residents' behavior and interaction with the natural resources affected by the project has changed since implementation of the project.

Creating a Regional Framework for Coastal Resilience in Southern Connecticut

This NFWF project establishes a regional framework for coastal resilience for ten municipalities that run along the entire central coast of Connecticut. The municipalities will integrate green infrastructure principles, prioritize projects, and contribute to a regional coastal resiliency plan. This project is addressing resilience through planning efforts at the institutional and community level rather than through on-the-ground restoration efforts. These types of project outcomes affect resilience goals of increased institutional capacity and improved community competence and engagement. The project outcomes are the tools, planning documents, data, maps, and models produced by a project, or the physical changes when community members are involved in the implementation of a restoration project. As the MEG report included measures of quality for these types of outcomes, the socio-economic metrics measure how a project strengthens a community and increases its ability to plan for, withstand, and recover from a disaster.

This project includes a number of planning outcomes, one of which is the integration of green infrastructure principles and priority projects into the hazard mitigation, comprehensive planning, and capital expenditure efforts of ten targeted municipalities. To assess the impact of the project on socio-economic benefits, the municipalities benefiting from the efforts of improved planning, jurisdictional boundaries, and important community institutions should be identified. The NFIP CRS ranking for these municipalities can then be used as a proxy for measuring the direct impact of the project, or a survey of relevant stakeholders can be conducted to determine the extent of changes in hazard mitigation, comprehensive planning, and capital expenditure efforts resulting from the project.



7. Analysis of Projects

The metrics and methodologies presented in Sections 5 and 6, Socio-economic Metrics and Methodology, were developed to provide a toolbox for assessing the socio-economic benefits of the projects. A critical next step is developing a framework to assign these metrics to each of the projects. Review of each project revealed multiple layers of characteristics and parameters—project activity, habitat, secondary project benefits, and ecological outcomes. The project activity categories described in Section 2, Project Categorization, provide the most appropriate and flexible approach to map and assign metrics to individual projects based on the categorical goal and objective. This section presents a framework for assigning the metrics, wherein the metrics are mapped to the project activities for each of the four overall resilience categories.

7.1 Mapping Project Activities to Metrics

As discussed in Section 2, descriptions of the different actions taken by the projects were recorded and eventually rolled up into 11 project activity categories (Table 9). A total of 99 out of 162 projects were assigned one activity, and 63 projects had two to five activities. The project proposals and any additional materials associated with these multi-activity projects were reviewed extensively to determine the appropriate activity categories. The assignment of different activity categories was qualitative and based on the projects' self-reported descriptions of methodology, funding, and measurements.

We then mapped the different project outcomes, described in Section 5 as informing the development of the metrics, to the project activities (Table 9). This was done to ensure that the actions as defined qualitatively at a high level appropriately captured the possible endpoints associated with the projects. Once the relationship between the activity categories and the project outcomes was confirmed, the activity categories were then mapped to the four resilience categories to provide a quick way to identify relevant metrics for individual or groups of projects. A high level summary of this crosswalk is provided in Table 10, while the specific recommended suites of metrics are provided in the Metrics Matrix and Project Analysis Excel workbook (Appendix 2).

Recall from the *project activity* definitions (Table 1) and the overall *resilience* (Section 5), that a project's expected, proposed, and desired *objectives and outcomes* both of these categories (*activities* and *resilience category*). This approach addresses points where a user may want to enter this metric decision framework (e.g., I have a of…; The action implemented can be described as . . .; My agency mission is health safety…). Further, there exists built-in cross-walking and quality control with this framework. Another way to consider this is that the project outcomes are summarized activities, yet project activities may fall into multiple resilience categories (

Table 10).

Table 9. Project outcomes (ecological, biophysical, and planning) mapped to the 11 project activity categories objectives.

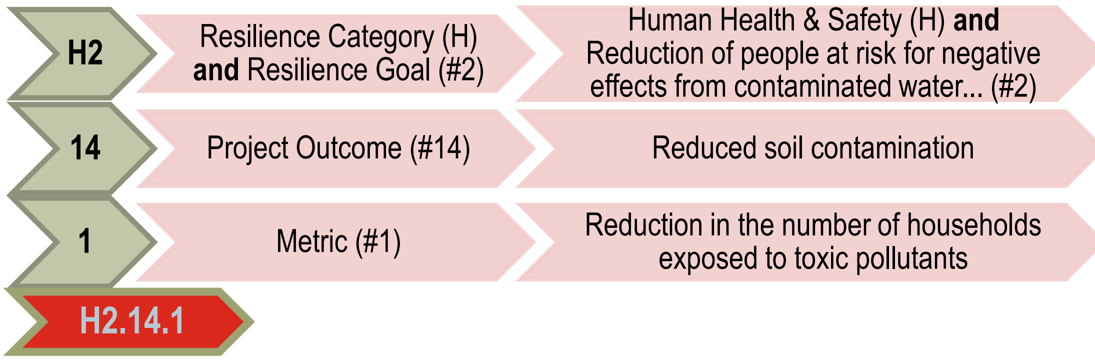
Outcomes / Objectives	Community Resilience Planning	Contaminant Assessment or Remediation	Critical Infrastructure Assessment or Protection	Data, Mapping, and Modeling	Ecological Resilience Planning	Green Infra. Planning and Implementation (living shorelines, etc.)	Grey Infra. (dams, culverts, berms)	Habitat Restoration	Impact or Vulnerability Assessments	Public Access	Sand Resource Identification or Assessment
Improved avian and terrestrial species habitat and biodiversity						x		x			
Improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards	x								x		
Improved fish and shellfish habitat; increased fish and shellfish abundance and diversity						x	x	x			
Improved hazard mitigation planning, actions, or capital expenditures	x		x		x				x		
Improved natural amenities, including observation platforms, boardwalks, etc.; changes to amenity accessibility								x		x	
Increased quality and diversity of data acquisition, including datasets, maps, and models	x	x	x	x					x		x
Increased quality and diversity of data analysis, including datasets, maps, and models	x	x	x	x					x		x
Improved community comprehensive planning, mapping, and zoning efforts	x		x		x				x		
Improved vegetative cover; increase in vegetated area; increased percentage of native vegetation						x		x			
Improved water management for fire control								x			
Improved water quality		x						x			
Increased community engagement and wellbeing resulting from restoration projects								x		x	
Reduced beach erosion; increased beach width; restored dunes						x		x			
Reduced extent of damaging inundation from major storm and flood events			x			x	x	x			
Reduced hazard of nuisance flooding			x			x	x	x			
Reduced soil contamination		x									

Table 10. Project activity categories mapped to each relevant resilience category.

Project Activity	Resilience Categories			
	Human Health and Safety	Property and Infrastructure Protection and Enhancement	Economic Resilience	Community Competence and Empowerment
Community Resilience Planning				●
Contaminant Assessment or Remediation	●	●		●
Critical Infrastructure Assessment or Protection		●		●
Data, Mapping, and Modeling				●
Ecological Resilience Planning				●
Green Infrastructure Planning and Implementation (living shorelines, etc.)	●	●	●	●
Grey Infrastructure (dams, culverts, berms)	●	●	●	●
Habitat Restoration	●	●	●	●
Impact or Vulnerability Assessments				●
Public Access		●	●	●
Sand Resource Identification or Assessment			●	●

With the framework established, each project ***outcome*** (ecological, biological, or planning) can be cross walked across the socio-economic resilience goals for a given resilience category. In the accompanying Metrics Matrix and Project Analysis Excel workbook (Appendix 2) each project ***outcome*** is assigned a unique numerical code and the resilience outcome is assigned a unique numerical code. The metrics identified in the tables (Section 5.3) are further classified as the third variable that occurs at the intersection of a project ***outcome*** and the socio-economic resilience goal, for a total of over 200 metrics. In addition, each project ***activity*** has one or more of these combinations of identification numbers that identifies the recommended socio-economic metrics for that activity. For example, a project with the defined ***activity*** of "Community Resilience Planning" is expected to have outcomes that are associated with the Community Competence and Empowerment resilience category. Metrics under this resilience category are therefore recommended for any project assigned the ***activity*** of "Community Resilience Planning." One recommended metric for this project activity is *"Increase in participation or ranking of National Flood Insurance Program's Community Rating System (NFIP's CRS) program,"* which falls into resilience goal code C1 (increased institutional capacity), project outcome code 1 (improved comprehensive plan), and metric code (1). When the full suite of metrics is applicable, the identification number would end with the project outcome code. Exhibit 15 provides another example of the metrics reference code scheme.

Exhibit 15. Example - Navigation through the socio-economic metrics reference code scheme. Metrics may refer to the intersection of a suite of metrics based on a Resilience Goal and Project Outcome (e.g., H2.14) or a specific metrics at that intersection (e.g., H2.14.1).



We performed this process of identifying metrics by project activity, informed by the project and resilience outcomes for each resilience category. The product is a recommended suite of metrics for each project activity for a given resilience category, shown in Table 11 and in Appendix 2, the Metrics Matrix and Project Analysis workbook under the tab "Metrics for Project Activities."

In summary, each DOI project is assigned one or more project activity. The project activity provides the means to determine the appropriate metrics to measure the socio-economic benefits of each project. A user guide for using the project activity category in conjunction with the metrics described in Section 5 and the methodologies described in Section 6 is provided as a separate deliverable (Appendix 1).

Table 11. Assignment of metrics to each project activity across the resilience categories.

	Recommended Suites of Metrics for Resilience Categories			
Project Activity Categories	**Health and Human Safety Metric Suites**	**Property and Infrastructure Protection and Enhancement Metric Suites**	**Economic Resilience Metric Suites**	**Community Competence and Empowerment Metric Suites**
Community Resilience Planning				C1.2; C1.4; C1.7; C2.2; C2.4; C2.7; C4.2; C4.4; C4.7
Contaminant Assessment or Remediation	H2.10; H2.14	P4.10; P4.14	E5.3; E6.3; E7.3	C1.6; C1.15; C1.16; C2.6; C2.15; C2.16; C4.6; C4.15; C4.16
Critical Infrastructure Assessment or Protection		P1.12; P1.13; P2.12; P2.13; P3.12; P3.13	E4.12	C1.2; C1.4; C1.6; C1.7; C1.15; C1.16; C4.6; C4.15; C4.16
Data, Mapping, and Modeling				C1.6; C1.15; C1.16; C2.6; C2.15; C2.16; C4.6; C4.15; C4.16
Ecological Resilience Planning				C1.6; C1.15; C1.16; C2.6; C2.15; C2.16; C4.6; C4.15; C4.16
Green Infrastructure Planning and Implementation (living shorelines, etc.)	H1.12; H2.3; H2.8; H2.10; H2.13	P1.12; P1.13; P2.12; P2.13; P3.12; P3.13; P4.5; P4.8; P4.10; P4.11	E1.12; E1.13; E2.12; E2.13; E3.12; E3.13; E4.12; E4.13; E5.1; E5.3; E5.5; E5.8; E5.11; E6.3; E7.3; E7.8; E7.11	C1.4; C1.7; C2.4; C2.7; C3.1; C3.3; C3.5; C3.8; C3.11; C4.3; C4.5; C4.8; C4.11
Grey Infrastructure (dams, culverts, berms)	H1.12; H2.3; H2.13	P1.12; P1.13; P2.12; P2.13; P3.12; P3.13; P4.11	E3.12; E3.13; E4.12; E4.13; E5.3; E5.11; E6.3; E7.3; E7.8; E7.11	C1.4; C1.7; C2.4; C2.7; C3.3; C3.11; C4.3; C4.11
Habitat Restoration	H1.12; H2.3; H2.8; H2.9; H2.10; H2.13	P1.12; P1.13; P2.12; P2.13; P3.12; P3.13 ; P4.5; P4.8; P4.10; P4.11	E3.12; E3.13; E4.12; E4.13; E5.1; E5.3; E5.5; E5.8; E5.11; E6.3; E7.3; E7.8; E7.11	C3.1; C3.3; C3.5; C3.8; C3.11; C4.1; C4.3; C4.5; C4.8; C4.11
Impact or Vulnerability Assessments				C1.2; C1.4; C1.6; C1.7; C1.15; C1.16; C2.2; C2.4; C2.6; C2.7; C2.15; C2.16; C4.2; C4.4; C4.6; C4.7; C4.15; C4.16
Public Access		P4.5	E5.5; E6.5; E7.5	C3.1; C3.5; C4.5
Sand Resource Identification or Assessment				C1.6; C1.15; C1.16; C2.6; C2.15; C2.16; C4.6; C4.15; C4.16

7.2 Testing

The effectiveness of the approach to assign metrics by project category and resilience category was tested against randomly selected DOI resilience projects. Results from four tests on NFWF- and FWS-funded projects are presented below. We selected NFWF and FWS projects for testing because the proposals and project summaries provide extensive information on the actions, goals, and proposed measurements of outcomes. We designed the testing to evaluate two essential elements:

1. Ensure that the projects are being assigned the appropriate project activity(s) that reflect the project objectives and outcomes.
2. Ensure that the recommended suite of metrics assigned provides for meaningful measure of the socio-economic benefits for a given project.

Testing revealed that the assignment of project activity(s) and the resulting recommended metrics meet both of these goals. Due to the extensive detail and number of metrics assigned to the four testing projects, two examples are provided here to illustrate the framework approach and the testing results.

We reviewed proposals for each test project to assess if and how well the project activity categories align with the defined project actions and potential resilience outcomes. We identified the specific project objectives and outcomes and then compared them against the definitions of the assigned project activity(s). Next, testing focused on whether or not the recommended metrics provide meaningful measures of the expected socio-economic outcomes of the projects. We assessed the suitability of the metric by reviewing project descriptions and assigning metrics solely based on that review. We then compared these metrics with the suite of metrics recommended by the project categorization process.

Test 1. USFWS-32 Resilience of the Tidal Marsh Bird Community to Hurricane Sandy and Assessment of Restoration Efforts

The *Resilience of the Tidal Marsh Bird Community to Hurricane Sandy and Assessment of Restoration Efforts* project is funded by FWS. This project will provide clear resolution of the severity and spatial distribution of Sandy's impacts, estimating current, unaided marsh resilience, and developing a multi-metric tool to evaluate the conservation value of tidal marshes and the cost effectiveness of alternative restoration approaches. Review of the proposal did not reveal any specific or explicit planned socio-economic measures.

Using the project activity assignment process described in Section 2, Project Categorization, this project was assigned as follows:

- **Data, Mapping, and Modeling.** Collecting data of ecological, biophysical or natural resources; coastal mapping; modeling coastal flooding scenarios.
- **Impact or Vulnerability Assessments.** Understanding the impacts of storms to communities, ecosystems, habitats, and species, and assessing vulnerability and risks for ecological and human communities.

To determine whether or not the activity categorization framework aligns with the project actions and potential resilience outcomes described in the proposal, we reviewed the proposal and identified the following themes in the project's proposal:

- Assess habitat damage and wildlife impacts
- Assess biological effectiveness of recovery actions
- Assess demographic impacts on the most threatened species
- Develop a multi-metric tool to evaluate the conservation value of tidal marshes and the cost effectiveness of alternative restoration approaches

Each of these objectives from the proposal aligns with the assigned project activities, with most of the objectives mapping to the Impact or Vulnerability Assessment category. The multi-metric tool relies on collected data, maps, and models to provide insight into conservation, mitigation, and resilience and can therefore be considered part of the Data, Mapping, and Modeling objective.

The next level of testing assesses if the metrics recommended through the project activity process provide meaningful measures to capture the complete socio-economic benefits, as related to resilience. Here, we compared the suite of metrics mapped to Data, Mapping, and Modeling and Impact or Vulnerability Assessments to the metrics identified in the metric tables and from review of the project outcomes and objectives. The individual project review assigned metrics by finding the intersection of the closest matching project outcomes in the Metrics Matrix and the possible resilience goals (Appendix 2).

The project activity approach recommends 13 different suites of metrics for Data, Mapping, and Modeling and Impact or Vulnerability Assessments. The metrics fall under the resilience goals of "Increased institutional capacity," "Increased community competence and engagement for project beyond restoration," and "Enhanced knowledge."

The project outcomes included in the recommended suites of metrics are "Improved communication plans, including emergency communication plans and communication tools for mitigation, risks, and hazards," "Improved hazard mitigation planning, actions, or capital expenditures," "Increased quality and diversity of data acquisition, including datasets, maps, and models," "Improved community comprehensive planning, mapping, and zoning efforts," "Increased quality and diversity of data analysis, including datasets, maps, and models," and "Increased quality and diversity of data delivery, including for datasets, maps, and models."

We found that the suite of metrics assigned by the project activity process provides a broad range of metric types. The project proposal is largely focused on the ecological outcomes of its effort. While these ecological outcomes can also provide socio-economic benefits, the benefits are somewhat narrow. The project activity approach has the advantage of drawing attention to the range of socio-economic metrics available, and therefore presents the possible socio-economic benefits related to resilience efforts that may not otherwise be measured.

Test 2. 41766 NFWF Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts

The *Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts* is a NFWF-funded project to restore and enhance the Great Marsh's wetlands and dunes. By means of restoration projects, assessments, and coastal resilience plans, the project is anticipated to provide for reduced local municipality vulnerability to disasters. The project proposal indicated that the project will perform a low level of socio-economic measurements.

Using the project activity categorization approach from Section 2, this project was assigned five project activities. This is one of the highest numbers of assigned activities out of all the projects, which indicates that this is a project with a broad range of project outcomes and a diverse set of potential resilience outcomes. The Project Activities for this project are:

- Data, mapping, and modeling
- Habitat restoration
- Ecological resilience planning
- Community resilience planning
- Impact or vulnerability assessments

To determine whether or not the Project Activity process aligns with appropriate project outcomes and potential resilience goals, we reviewed the project's proposal and found the following themes:

- Beach habitat quality improvements
- Erosion control (fencing)
- Riparian restoration (eelgrass)
- Wetland restoration
- Volunteer participation
- Research
- Outreach/education/technical assistance
- Economic benefits (number of jobs created)[5]
- Management or governance planning
- Surveys, ecological and risk screening models, and prioritization of high-risk infrastructure[6]

Mapping of the project objectives to the assigned project activities illustrates that the metric assignment framework is accurately capturing the substance of the projects (Table 12).

Table 12. Mapping of the project activity categories identified for the test NFWF project with the actual objectives and outcomes listed in the proposal.

Project Activity Categories	Individual Project Objectives and Outcomes
Data, Mapping, and Modeling	• Surveys, ecological and risk screening models, and prioritization of high-risk infrastructure
Habitat restoration	• Beach habitat quality improvement • Erosion control • Riparian restoration • Wetland restoration

[5] This is not included in the table of individual activities because the socio-economic metrics here are not intended to measure the direct economic impact of the projects through their jobs created.

[6] The project activity Critical Infrastructure Assessment or Protection was not assigned to this project because it is a component of larger Impact or Vulnerability assessments and Planning Processes.

Project Activity Categories	Individual Project Objectives and Outcomes
Ecological Resilience Planning	• Research
Community resilience planning	• Outreach/education/technical assistance • Volunteer participation • Management or governance planning
Impact or vulnerability assessments	• Surveys, ecological and risk screening models, and prioritizing high risk infrastructure

Given the number of project activities assigned to this project, it follows that the project also has an extensive number of recommended metrics across all four of the resilience categories (e.g., Human Health and Safety, Property and Infrastructure Protection and Enhancement, Economic Resilience, and Community Competence and Empowerment). The comparison of metrics assigned through the project activity process with those assigned individual review of the project mirrored the results of the first test. However, the framework developed in this effort provides for a larger range of possible metrics, and therefore provides an opportunity to tailor the metrics to the specific project while decreasing the likelihood of not measuring a possible socio-economic benefit.

7.3 Discussion

For all of the projects we examined in this testing exercise, the majority of the metrics individually assigned to a project were included in the suites of metrics recommended by the project categorization process. The categorization process provides more metrics as recommended for review than when the metrics are assigned individually by project. This is unsurprising given that the project activity categories provide a large bin of metric suites. The methodology selection presented in Section 6 provides a means to narrow down the appropriate metrics and methodology. Whereas the recommended metrics provided by the project activities are broader and less focused than the individual "by hand and table" project outcome approach, this framework ensures that all potential resilience outcomes are considered, even when the project itself does not identify the resilience outcome as a stated goal.

The testing process also exemplifies the importance of following the recommended process for selecting metrics and methodologies as described in Section 6. The process ensures that measures will be tailored to reflect the appropriate level of detail desired by an assessment and allowed by available resources; for example, a project that considers changed behavior as one of its results. This pre-existing interest in a relatively high level of detail for a socio-economic outcome may mean that the resources and data necessary for one of the more detailed metrics are available for an assessment.

8. Summary

The socio-economic metric framework presented in Section 5 is based on the DOI Hurricane Sandy resilience goals as well as causal chain mapping. This mapping follows the general program results chain for the DOI investment portfolio (Exhibit 16), wherein a series of project activities generate habitat and other outcomes that minimize adverse future storm impacts, which in turn will also provide or increase resilience for both human communities and ecological systems. The goal of the socio-economic metrics is to provide a systematic framework to evaluate the outcomes of an individual project, group of projects, or the full portfolio of DOI investments. In this section, we describe some of the practical and technical considerations that will help DOI and NFWF staffs successfully proceed with project and programmatic evaluations.

Exhibit 16. Example logic model scenario for evaluation of programmatic success.

The socio-economic metrics, in combination with the MEG ecological metrics, play an important role in understanding project outcomes that are most tangible to people and directly affect their quality of life. However, agency missions and other driving forces may require using a combination of ecological and socio-economic metrics to fully address performance tracking as part of an evaluation. Thus, before metrics are selected for project or program evaluation, some key considerations need to be addressed including:

- **The goal of the evaluation.** An evaluation of coastal resilience may focus on any number of potential combinations of ecological and social outcomes; clarifying key evaluation and performance goals will be essential to the effective selection of appropriate metrics.
- **The target audience of the evaluation.** There are a wide range of potential audiences for an evaluation (e.g., policymakers, resource managers, general public); identifying which audiences are being addressed by an evaluation can help clarify the goals to guide metric choices.
- **The scale of the evaluation.** Outcomes can be evaluated at the project-scale, for a suite of projects (e.g., habitat or project objective), within a specific geographic region, or across the entire portfolio. While evaluations typically focus on more than one scale, understanding the relative importance of each scale and how goals may vary across scales will affect metric and methodology selection.
- **Resources available for the evaluation.** Financial and other constraints (e.g., staff time, delivery date for final products) are a critical constraint on an evaluation, and will shape the number and type of metrics chosen.

- **The definition of a project's outcome area.** Socio-economic outcomes from a project will be realized by discrete populations; how these affected parties are identified has the potential to shape the metric selection and methodologies.

The answers to these questions will help to focus the metric analysis where it can best represent the project, programs, or cumulative effects, given the resources available.

8.1 Scaling of Metrics

While the majority of the metric framework has focused on project-scale assessment, evaluating project success to achieve the intended goal will require some analysis at a range of scales (e.g., project, habitat, and region). The most relevant evaluation questions for each scale typically differ, which means that the metrics used to answer those questions are also likely to change. In addition, as the scale of the evaluation area increases, it will become more difficult to identify and distinguish the outcome of an individual project from other environmental, economic, political, and social factors. For example, assessing the outcome of a restoration project to reduce the risk of flooding at nearby structures may involve use of the metric "Reduction in number of properties exposed to flood event with project" to quantify the socio-economic benefit of a project. However, this metric is not relevant to analyze the outcomes of a geographically clustered suite of projects in a region. Specifically, it is unlikely that outcomes of any one project, or even all projects combined, will have a discernible effect on flood risk at a regional scale.

An aerial photo of the breach at Old Inlet, Fire Island National Seashore (Charles Flagg)

Project-scale effects can be assessed and aggregated to larger geographies when effects are additive. Such aggregation requires similar metrics across projects and normalizing metrics by people or area analyzed. Aggregation may involve one of three approaches:

- **A comprehensive assessment.** In an ideal world, all potential socio-economic benefits would be characterized across all projects quantitatively using the same types of metrics and methodologies. This would characterize accomplishments and represent them in terms of people served, property protected, educational goals achieved, and similar "countable" outcomes.

- **Targeted case studies.** Case studies can provide representative information. The cases may be selected to be a representative sample of the key project activities or even more narrowly focused on one specific project objective. Where possible, results for case study projects would be transferred to similar projects to estimate effects for a larger set of projects. For example, if one assumes that similar interventions will lead to similar types of outcomes, one could apply the metrics developed under a case study to similar projects based on project area affected, similarity of socio-demographics, the number of projects implemented, or other factors.
- **Limited, but consistent, data collection across all projects.** Another option is to gather uniform metrics (using identical methodologies) for a subset of socio-economic outcomes of interest. This would allow one to tally outcomes across all relevant projects, but the coverage of outcomes would necessarily be incomplete and this approach could underrepresent benefits of projects with diverse goals.

8.2 Synergies and Emergent Effects at the Regional Scale

A complementary approach to evaluating and summing individual project effects is to take a regional approach to assess cumulative or emergent effects at broad scales. Regional-scale effects may be distinct from project-scale effects or may simply be more substantial or meaningful versions of the project-level effects, due to synergism and other factors.

Some socio-economic effects cannot be measured effectively at the project scale. Consider that if a jurisdictional goal was to create a walkable environment, putting in 10 feet of sidewalk in one project would not have an appreciable effect on walkability. However, the cumulative effect of zoning changes, green infrastructure development, and multiple sidewalk-building projects conducted by many agencies could create the desired walkability. Adding up feet of sidewalk added by all projects funded by one agency would be a *leading indicator* of walkability, but would not fully capture this effect. Further, a completely different analysis method would be needed to assess whether the area had reached a tipping point at which a substantial proportion of people felt it was desirable and safe to walk, instead of drive.

Consider a regional economic vibrancy example. A component of socio-economic resilience is the willingness to invest in a community and rebuild after damage or economic downturns. Economic research has revealed that communities with higher levels of amenities tend to be more resilient to such shocks, particularly rural communities (e.g., Johnson and Rasker 1995). The relevant amenities include scenic beauty, recreational opportunities, quality of housing stock, cultural richness, sense of community, crime, and quality of public services, among others. All of these amenity (or quality of life) factors could be influenced by individual projects, but some socio-economic effects can only be measured at the scale of the economic area that represents areas of connected regional economic activity. Given this relationship, changes in long-term economic vibrancy in the face of climate change could be inferred by social metrics, measured at the regional scale, that assess people's level of commitment to their community and the overall availability of scenic and recreational options.

Ultimately, the combination of metrics and methods selected for an evaluation will reflect the responses to the previously identified considerations in this section.

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Appendix A: Project Activities Assigned to Resilience Projects

Funding Org. and Id. Number	Project Title	Gry. Infras.	Gn. Infras.	Data, Map. & Model	Hbt. Rest.	Sand Resource Id. or Assess.	Eco. Resil. Plan.	Comm. Resil. Plan.	Impct. or Vuln. Assess. or Plan.	Contain. Asses. or Remed.	Crit. Infras. Assess. or Protect.	Public Access
NFWF-41739	Reusing Dredged Materials to Enhance Salt Marsh in Ninigret Pond (RI)				x							
NFWF-41766	Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts			x	x		x	x	x			
NFWF-41787	Restoring Bellamy River's Fish Passage and Reducing Flooding Through Removal of Two Fish Barriers (NH)	x										
NFWF-41795	Strengthening Sachuest Bay's Coastal Resiliency (RI)	x			x							x
NFWF-41812	Preventing Erosion and Restoring Hydrology in the Pine Barrens (NJ)				x							

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NFWF-41931	Developing Self-Sustaining Oyster Population in Jamaica Bay (NY)		x									
NFWF-41991	Increasing Seven Mile Island's Beach Resiliency (NJ)				x			x				
NFWF-42019	Restoring Bronx River Shoreline at Starlight Park (NY)		x		x					x		
NFWF-42279	Building Ecological Solutions to Coastal Community Hazards (NJ)		x					x				
NFWF-42442	Strengthening Sunken Meadow State Park's Resiliency (NY)		x		x							x
NFWF-42551	Green Infrastructure in Accomack and Northampton Counties (VA)		x					x				
NFWF-42671	Enhancing Seven Communities, Ecosystems, and Infrastructure Resiliency by Removing Seven Fish	x					x					

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	Barriers (MA)											
NFWF-42697	Building Green Infrastructure into Community Policies (RI)		x					x				
NFWF-42714	Transforming Hoboken's Block 12 into a Green Infrastructure Asset (NJ)		x									x
NFWF-42874	Ausable Watershed Flood Mitigation and Fish Passage Restoration (NY)	x										
NFWF-42878	Assessing Coastal Impoundment Vulnerability and Resilience in the Northeast								x			
NFWF-42942	Increasing Salt Marsh Acreage and Resiliency for Blackwater National Wildlife Refuge (MD)				x							
NFWF-42956	Strengthening Coney Island's Resiliency through Green Streets (NY)		x									

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NFWF-42957	Designing a Daylighting Plan to Improve Harlem River's Water Quality and Resiliency (NY)				x							
NFWF-42958	Restoring Spring Creek Park's Salt Marsh and Upland Habitat (NY)		x		x							
NFWF-42959	Rejuvenating Sunset Cove's Salt Marsh and Upland Habitat (NY)		x		x							x
NFWF-42984	Enhancing Mill River's Flood Resiliency and Habitat Corridor (CT)			x	x			x				
NFWF-43006	Wetland Restoration in Suffolk County (NY)				x							
NFWF-43095	Reusing Dredged Material to Restore Salt Marshes and Protect Communities (NJ)		x		x			x	x			
NFWF-43129	Creating Green Infrastructure Resiliency in Greater Baltimore and Annapolis Watersheds		x	x				x				

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	(MD)											
NFWF-43281	Restoring Delaware Bay's Wetlands and Beaches in Mispillion Harbor Reserve and Milford Neck Conservation Area				x		x	x				
NFWF-43290	Developing a Design that Will Enhance Liberty State Park's Marshes and Upland Habitats (NJ)				x							x
NFWF-43308	Developing a Green Infrastructure Plan and Network for the Lafayette River Watershed (VA)		x		x							
NFWF-43322	Enhancing Wampanoag Tribe of Gay Head's Land Resiliency in Martha's Vineyard (MA)				x						x	
NFWF-43378	Restoring Fish Runs and Fragmented Trout Populations by Removing a Fish Barrier (CT)	x										

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NFWF-43429	Creating a Resilient Delaware Bay Shoreline in Cape May and Cumberland Counties (NJ)		x		x		x	x				
NFWF-43752	Creating a Three Dimensional Wetland Model for the Bombay Hook National Wildlife Refuge (DE)			x								
NFWF-43759	Reducing Flood Impacts and Restoring Habitat in the Brandywine River Watershed (PA)		x		x							
NFWF-43834	Increasing Community and Ecological Resiliency by Removing a Patapsco River Fish Barrier (MD)	x										
NFWF-43849	Developing Coastal Resiliency Regional Models (VA)			x	x		x					
NFWF-43861	Creating a Natural Resource Resiliency Assessment and Action Plan (RI)						x					

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NFWF-43931	Strengthening Marshes Creek Through Green and Grey Infrastructure (NJ)	x	x		x							
NFWF-43932	Improving and Quantifying Wetlands’ Potential to Reduce Storm Surge Impacts (VA)		x		x		x	x	x			
NFWF-43939	Restoring Newark Bay's Wetlands (NJ)		x		x							
NFWF-43986	Strengthening Monmouth Beach's Marshes and Dunes (NJ)		x		x							
NFWF-44017	Developing Rhode Island's Coastal Resiliency Program			x								
NFWF-44020	Developing a Green Infrastructure Plan for Chester City (PA)		x									
NFWF-44022	Reconnecting and Restoring the Allegany Reservoir (NY)				x							

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NFWF-44068	Restoring Over One Hundred Wetland Acres in Great Egg Harbor Bay (NJ)		x		x							
NFWF-44109	Replenishing Little Egg Harbor's Marshes and Wetlands (NJ)		x		x							
NFWF-44140	Improving Coastal Resiliency through Community Engagement (OH, RI)						x	x				
NFWF-44157	Repairing Infrastructure and Designing Wetland and Beach Restoration Plans along the Central Delaware Bayshore	x			x							
NFWF-44167	Protecting North Beach's Salt Marsh and Emergency Route (MD)		x		x						x	
NFWF-44193	Incorporating Green Infrastructure Resiliency in the Raritan River Basin (NJ)		x									

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NFWF-44199	Designing a Plan to Reuse Dredged Rock to Protect the Boston Harbor Shoreline (MA)		x									
NFWF-44212	Improving Northeast Coast Storm-Related Data Interpretation and Accessibility			x								
NFWF-44225	Improving Shinnecock Reservation's Shoreline Habitats (NY)		x		x							
NFWF-44245	Developing a Resiliency Management Plan for Pawcatuck River Watershed (CT, RI)							x				
NFWF-44271	Creating a Regional Framework for Coastal Resilience in Southern Connecticut							x				
BLM-BLM	Seedbanking for Resiliency Project				x							
BSEE-BSEE	Improve Resilience of the Ohmsett Facility								x			

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USGS-GS1-1a	Establish a Sandy Region Coastal National Elevation Database (CoNED)			x								
USGS-GS1-1b	Topographic surveys (LiDAR) for impact area assessment and reconstruction			x								
USGS-GS1-1c	Delivery Systems for Hazards, Topographic and Bathymetric Elevation Data			x								
USGS-GS1-2a	Coastal Mapping Products & Impact Assessments: Pre- and post-storm mapping of coastal impacts and vulnerability			x								
USGS-GS1-2b	Impacts to and Vulnerability of Coastal Beaches: Develop coastal impact forecast models			x								
USGS-GS1-2c	Coastal Hazards Information and Decision Support Portal			x								

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USGS-GS1-3a	Storm Surge Response, Data Collection, and Data Delivery			**x**								
USGS-GS1-3b	Storm Tide Monitoring Networks and Data Analysis			**x**								
USGS-GS1-4a	Ecological Contaminant Exposures									**x**		
USGS-GS1-4b	Human Contaminant Exposures									x		
USGS-GS1-5a	Assess storm impact to wetland integrity and stability to assist recovery decisions								x			
USGS-GS1-	Assess storm impact to waterfowl and migratory								x			

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5b	birds to support conservation											
USGS-GS1-5c	Assess coast-wide storm impacts to forest habitats in coastal parks and refuges								x			
USGS-GS1-5d	Develop data-driven models and ecological monitoring networks to support recovery and resilience			x								
USGS-GS2-1A	Topographic Surveys for Priority Watershed and Ecological Assessments			x								
USGS-GS2-2A	Barrier Island and Estuarine Wetland Physical Change Assessment								x			
USGS-GS2-2B	Linking Coastal Processes and Vulnerability – Fire Island Regional Study								x			
USGS-GS2-2C	Coastal Vulnerability and Resource Assessment, Delmarva Peninsula								x			

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USGS-GS2-2D	Estuarine Response to Storm Forcing								x			
USGS-GS2-3A	Enhance Storm Tide Monitoring, Data Recovery, and Data Display Capabilities			x								
USGS-GS2-3B	Storm Surge Science Evaluations to Improve Models, Vulnerability Assessments, and Storm Surge Predictions			x								
USGS-GS2-4A	Mapping, measuring, and predicting vulnerability from contaminant hazards from Hurricane Sandy and other storms in the Northeast Coastal zone									x		
USGS-GS2-5A	Evaluating Ecosystem Resilience								x			
USGS-GS2-5D	Forecasting Biological Vulnerabilities			x								
USGS-GS-82	Topographic Surveys: Lidar Elevation Data			x								

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BOEM-M13AC00012	Ecological Function and Recovery of Biological Communities within Dredged Ridge-Swale Habitats and in the South-Atlantic Bight			x								
BOEM-M13AC00031	Natural Habitat Association and the Effects of Dredging on Fish at the Canaveral Shoals, East-central Florida			x								
BOEM-M14AC00001	Sand Needs and Resources Offshore New York					x						
BOEM-M14AC00002	Post Hurricane Sandy Offshore New Jersey Sand Resources Investigations					x						
BOEM-M14AC00003	Delaware Offshore Sand Resource Investigation					x						
BOEM-M14AC00004	Modernizing the ROSS database and a review and synthesis of existing geophysical data from selected areas on the			x								

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	outer continental shelf (OCS Region) along Florida's central Atlantic coast.											
BOEM-M14AC00005	Geospatial Sand Resource Assessment for Georgia Coastal Recovery and Resiliency					x						
BOEM-M14AC00006	Sand Resources Needs Assessment at Critical Beaches on Massachusetts					x						
BOEM-M14AC00007	Conversion of Maryland's Offshore Mineral Resources Data for GIS Applications and Baseline Acoustic Seafloor Classifications of Offshore Borrow Areas					x						
BOEM-M14AC00009	Assessing sand resources for North Carolina: inventory, needs assessment and reanalysis for post-Hurricane Sandy recovery and future resilience					x						

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BOEM-M14AC00010	Assessment of Offshore Sand and Gravel for Beach Nourishment in New Hampshire					x						
BOEM-M14AC00011	Identification of Sand/Gravel Resources in Rhode Island Waters While Working Toward a Better Understanding of Storm Impacts on Sediment Budgets					x						
BOEM-M14AC00012	South Carolina Offshore Sand Resources: Data Inventory, Digital Data Conversion, and Needs Assessment					x						
BOEM-M14AC00013	Assessment of Offshore Sand Resources for Virginia Beachfront Restoration					x						
BOEM-M14AC00013	EXPLORATION AND HABITAT CLASSIFICATION: TOOLS FOR BUILDING RESILIENCY IN MAINE					x						

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BOEM-M14PC00006	Geological and Geophysical Data Acquisition: Inventory of Potential Beach Nourishment and Coastal Restoration Sand Sources on the Atlantic Outer Continental Shelf					x						
BOEM-M15PS00030	Propagation Characteristics of High-Frequency Sounds Emitted During High-Resolution Geophysical Surveys: Open Water Testing			x								
NPS	Mitigate Impacts from Artificial Groin to Jacob Riis Beach to Restore Habitats and Recreation Resources				x							
NPS-14	Sub-project: Detecting water quality regime shifts in Jamaica Bay			x								
NPS-14	Sub-project: Health and Resiliency of Salt Marshes in Jamaica Bay			x			x					

Funding Org. and Id. Number	Project Title	Gry. Infras.	Gn. Infras.	Data, Map. & Model	Hbt. Rest.	Sand Resource Id. or Assess.	Eco. Resil. Plan.	Comm. Resil. Plan.	Impct. or Vuln. Assess. or Plan.	Contain. Asses. or Remed.	Crit. Infras. Assess. or Protect.	Public Access
NPS-14	Sub-project: Monitoring and Evaluation of Restoration and Resilience: Jamaica Bay Unit Shoreline and Geomorphology			x								
NPS-14	Sub-project: Acidification, hypoxia, and algal blooms: Barriers to current and future ecosystem restoration and climate change resilience in Jamaica Bay			x								
NPS-14	Sub-project: Restoration of Jamaica Bay fringing habitats: post-Sandy status and new approaches for a resilient future			x			x					
NPS-14	Sub-project: The Jamaica Bay Observing system: Process studies and groundwork for Long-term Ecosystem Research and Resilience			x								

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NPS-14	Sub-project: Coastal Adaptation Impacts on Jamaica Bay Water Quality, Waves and Flooding			x								
NPS-14	Sub-project: Visionmaker Jamaica Bay: Evaluation and synthesis of community generated adaptation strategies to enhance resilient ecosystems in Jamaica Bay, NY			x				x				
NPS-14	Sub-project: Science and Resilience Institute at Jamaica Bay: Coordination of DOI and NPS Sandy Resilience Projects			x								
NPS-14	Sub-project: The environmental history of Jamaica Bay: A foundational monograph			x								
NPS-14 (subproject broken out)	Main project: Support for the Science and Resilience Center											

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NPS-23	Develop Breach Management Plans for Coastal National Seashores to Maximize Ecological Benefits						x	x			x	
NPS-27	Dyke Marsh Restoration to Promote Resource Protection from Storm Response and Adaptation to Sea Level Rise		x		x							
NPS-3	Sub-project: Modification to Acquisition Coordination, Compilation, Data Management and Change Analysis of LiDAR and Other Geospatial Data Collected Pre- and Post-Hurricane			x				x				
NPS-3	Sub-project: Field Technician Support for Elevation Mapping of NPS Salt Marshes and other sites for Sea Level Rise Planning and Post- and Future Storm Evaluation			x								

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NPS-3	Sub-project: Collection of High Resolution Topographical data and development of metrics associated with superstorm sandy impacts, recovery, and coastal geomorphological resiliency			x								
NPS-3	Sub-project: Tide-Telemetry and Coastal-Flood-Warning System Fire Island National Seashore			x				x				
NPS-3	Sub-project: Modeling salt marsh condition and resiliency in four National Parks based local sea level rise predictions to assist park managers in understanding local conditions and to develop mitigation strategies			x			x					
NPS-3 (subprojects broken out)	Main project: Acquire high-resolution elevation data to improve storm surge forecasting and											

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	mitigation planning											
NPS-35	Sub-project: Assessing the response of juvenile and adult hard clams to the new breach in Great South Bay: Post-Hurricane Sandy study			x					x			
NPS-35	Sub-project: Assessing the response of the Great South Bay plankton community to Hurricane Sandy			x					x			
NPS-35	Sub-project: Assessing the response of the Great South Bay estuarine fauna to Hurricane Sandy: focus on nekton utilization of seagrass habitats			x					x			
NPS-35	Sub-project: Effects of storm induced barrier breach on community assemblages and ecosystem structure within a temperate lagoonal estuary (post Hurricane Sandy)			x					x			

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NPS-35	Sub-project: Impact of Hurricane Sandy on the Fire Island National Seashore (FIIS) Water Quality and Seagrass Resources			x					x			
NPS-35	Sub-project: Assessing the response of indicator bacteria in Great South Bay to Hurricane Sandy			x					x			
NPS-35	Sub-project: Science Communication (videos)							x	x			
NPS-35	Sub-project: Continuation of post-Hurricane Sandy physical monitoring of the Old Inlet breach, Fire Island National Seashore: Phase Two (summer 2014 – summer 2016)			x					x			
NPS-35 (subprojects broken out)	Evaluate ecological impacts of breaching on estuarine habitats											
NPS-49	Sub-project: Assess Groundwater Resources at Assateague Island			x								

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	National Seashore											
NPS-49	Sub-project: Assess Groundwater Resources at Fire Island National Seashore			x								
NPS-49	Sub-project: Assess Groundwater Resources at Sandy Hook Unit of Gateway National Recreation Area			x								
NPS-49 (subprojects broken out	Assess Groundwater Resources to Adapt to Climate Change in Mid Atlantic National Seashores											
NPS-72	Sub-project: Post-Hurricane Sandy Submerged Marine Habitat Mapping, Fire Island National Seashore			x								
NPS-72	Sub-project: Post-Hurricane Sandy -- Submerged Marine Habitat Mapping: A Foundation for Enhancing			x								

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	Resilience to Climate Change and other Stressors at the Gateway National Recreation Area											
NPS-72	Sub-project: Submerged Marine Habitat Mapping: A Foundation for Enhancing Resilience to Climate Change and Other Stressors			x								
NPS-72	Sub-project: Submerged Marine Habitat Mapping, Cape Cod National Seashore: a post-Hurricane Sandy study			x								
NPS-72 (subprojects broken out)	Submerged Marine Habitat Mapping: A foundation for enhancing resilience to coastal storms and other climate change drivers											
USFWS-1	Salt Marsh Restoration and Enhancement at Seatuck, Wertheim and Lido Beach National Wildlife Refuges, Long				x							

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	Island, New York											
USFWS-10	Round Hill Salt Marsh Restoration Project, Dartmouth MA	x			x							
USFWS-11	Muddy Creek Wetland Restoration Project, Chatham MA	x			x							
USFWS-15	Prime Hook National Wildlife Refuge Coastal Tidal Marsh /Barrier Beach Restoration				x							
USFWS-17	Building a predictive model for submerged aquatic vegetation prevalence and salt marsh resiliency in the face of Hurricane Sandy and sea level rise			x								
USFWS-21	Aquatic Connectivity and Flood Resilience in CT and RI: Removing the White Rock and Bradford Dams and Assessing the Potter Hill Dam Fishway on the Pawcatuck River & Removing the Shady Lea	x										

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	Mill Dam in North Kingstown											
USFWS-24	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Tidal Wetland Habitats and Species in the Face of Storms and Sea Level Rise								x			
USFWS-30	A Stronger Coast: Three USFWS Region 5 multi-National Wildlife Refuge projects to increase coastal resilience and preparedness			x								
USFWS-31	Fog Point Living Shoreline Restoration, Martin NWR		x		x							
USFWS-32	Resilience of the Tidal Marsh Bird Community to Hurricane Sandy and Assessment of Restoration Efforts			x					x			
USFWS-33	Parker River Tidal	x			x							

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	Restoration Project											
USFWS-34	Aquatic Connectivity and Flood Resilience in VA: Replacing the Quantico Creek Culvert in Dumfries	x			x							
USFWS-37	Restoring Coastal Marshes in NJ NWRs	x	x		x							
USFWS-43	Restoring resiliency to the Great Marsh; Parker River NWR, MA	x			x							
USFWS-50	Increasing Water Management Capability at Great Dismal Swamp NWR to Enhance its Resiliency for Wildlife and People	x			x							
USFWS-51	Aquatic Connectivity and Flood Resilience: Pond Lily Dam Removal, West River, New Haven, CT	x										
USFWS-53	Aquatic Connectivity and Flood Resilience: Hyde Pond Dam Removal, Whitford Brook, Mystic,	x										

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	CT											
USFWS-57	Hail Cove Living Shoreline Restoration, Eastern Neck NWR		x		x							
USFWS-6	Increase Resilience of Beach Habitat at Pierce's Point, Reed's Beach, and Moore's Beach, New Jersey	x			x							
USFWS-63	Collaboratively Increasing Resiliency and Improving Standards for Culverts and Road-Stream Crossings to Future Floods While Restoring Aquatic Connectivity	x		x								
USFWS-64	Coastal Barrier Resources System Comprehensive Map Modernization - Supporting Coastal Resiliency and Sustainability following Hurricane Sandy			x								

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USFWS-65	Protecting Property and Helping Coastal Wildlife: Enhancing Salt marsh and Estuarine Function and Resiliency for Key Habitats on Impacted Wildlife Refuges from Rhode Island to southern Maine	x	x		x							
USFWS-67	Decision Support for Hurricane Sandy Restoration and Future Conservation to Increase Resiliency of Beach Habitats and Species in the Face of Storms and Sea Level Rise			x			x		x			
USFWS-68	Aquatic Connectivity and Flood Resilience: Flock Process Dam Removal, Norwalk River, Norwalk, CT	x										
USFWS-76	Living Shoreline-Oyster Reef Restoration and Construction at Chincoteague NWR, VA		x		x							

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USFWS-77	Gandy's Beach Shoreline Protection Project, NJ		x									
USFWS-79	Aquatic Connectivity and Flood Resilience: Norton Mill Dam Removal, Jeremy River, Colchester, CT	x										
USFWS-85	Ferry Point, Nanticoke River – Pocomoke Sound Marsh Enhancement				x							
USFWS-89	Aquatic Connectivity and Flood Resilience in MD: Removing the Centreville Dam in Centreville and the Bloede Dam in Catonsville	x										
USFWS-9	Aquatic Connectivity and Flood Resilience: West Britannia and Whittenton Dam Removals, Mill River, Taunton, MA Connectivity	x										
USFWS-94	Aquatic Connectivity & Flood Resilience in NJ: Removing the Hughsville Dam in Pohatcong & Restoring the Wreck Pond Inlet and Dune in Sea Girt	x										

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	and Spring Lake											

Appendix B: NFWF Socio-Economic Measures

NFWF Project Measurements and Definitions

Measurement Type	Definition	Project Count
Socio-economic	Measurements of project social or economic effects, ranging from google analytics information to program evaluations	24
Vegetation	Measurements and monitoring of vegetative cover, diversity, native vegetation percentages, etc.	12
Soil Quality and Sedimentation	Direct measurements of soil quality and monitoring or modeling of sedimentation	6
Avian and Terrestrial Species	Measurements of avian and terrestrial species presence and diversity through observation or other methods	6
Aquatic Vertebrate Species	Measurements of vertebrate aquatic species presence and diversity through observation or other methods	2
Water Quality and Aquatic Habitats	Direct and indirect measurements of water quality and aquatic habitats through observation, invertebrates, and other methods	15
Structural surveys	Evaluation of built environments and infrastructure through as-built surveys and other methods	6
GIS	Observation of changes in habitat cover, species presence, and other spatial characteristics through GIS	2
Storm Water	Measurements and observation of storm water run-off	3
Baseline Data Collection	Measurements and collection of data focused on the creation of baseline data rather than measurements of change	4
Flooding, Inundation, and Storm Buffer	Direct and indirect measurements of changes in flooding, inundation, and the creation of storm buffers through observation, modeling, and other methods	16

NFWF Projects and Reported Measures

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-41739	Reusing Dredged Materials to Enhance Salt Marsh in Ninigret Pond (RI)				x		x					x
NFWF-41766	Coastal Resiliency Planning and Ecosystem Enhancement for Northeastern Massachusetts	x	x									
NFWF-41787	Restoring Bellamy River's Fish Passage and Reducing Flooding Through Removal of Two Fish Barriers (NH)						x	x				
NFWF-41795	Strengthening Sachuest Bay's Coastal Resiliency (RI)		x					x	x			x
NFWF-41812	Preventing Erosion and Restoring Hydrology in the Pine Barrens (NJ)						x	x			x	
NFWF-41931	Developing Self-Sustaining Oyster Population in Jamaica Bay (NY)					x	x					
NFWF-41991	Increasing Seven Mile Island's Beach Resiliency (NJ)	x			x		x					

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-42019	Restoring Bronx River Shoreline at Starlight Park (NY)									x		
NFWF-42279	Building Ecological Solutions to Coastal Community Hazards (NJ)	x										
NFWF-42442	Strengthening Sunken Meadow State Park's Resiliency (NY)	x	x		x							
NFWF-42551	Green Infrastructure in Accomack and Northampton Counties (VA)	x										
NFWF-42671	Enhancing Seven Communities, Ecosystems, and Infrastructure Resiliency by Removing Seven Fish Barriers (MA)						x	x			x	
NFWF-42697	Building Green Infrastructure into Community Policies (RI)	x									x	
NFWF-42714	Transforming Hoboken's Block 12 into a Green Infrastructure Asset (NJ)	x								x		x
NFWF-42874	Ausable Watershed Flood Mitigation and Fish Passage Restoration (NY)					x	x	x				x

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-42878	Assessing Coastal Impoundment Vulnerability and Resilience in the Northeast	x										
NFWF-42942	Increasing Salt Marsh Acreage and Resiliency for Blackwater National Wildlife Refuge (MD)				x				x			x
NFWF-42956	Strengthening Coney Island's Resiliency through Green Streets (NY)	x								x		
NFWF-42957	Designing a Daylighting Plan to Improve Harlem River's Water Quality and Resiliency (NY)											
NFWF-42958	Restoring Spring Creek Park's Salt Marsh and Upland Habitat (NY)						x					
NFWF-42959	Rejuvenating Sunset Cove's Salt Marsh and Upland Habitat (NY)		x				x				x	
NFWF-42984	Enhancing Mill River's Flood Resiliency and Habitat Corridor (CT)											x

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-43006	Wetland Restoration in Suffolk County (NY)	x										x
NFWF-43095	Reusing Dredged Material to Restore Salt Marshes and Protect Communities (NJ)	x		x								x
NFWF-43129	Creating Green Infrastructure Resiliency in Greater Baltimore and Annapolis Watersheds (MD)	x										
NFWF-43281	Restoring Delaware Bay's Wetlands and Beaches in Mispillion Harbor Reserve and Milford Neck Conservation Area	x	x	x								
NFWF-43290	Developing a Design that Will Enhance Liberty State Park's Marshes and Upland Habitats (NJ)	x										
NFWF-43308	Developing a Green Infrastructure Plan and Network for the Lafayette River Watershed (VA)	x										
NFWF-43322	Enhancing Wampanoag Tribe of Gay Head's Land Resiliency in Martha's Vineyard (MA)	x						x				

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-43378	Restoring Fish Runs and Fragmented Trout Populations by Removing a Fish Barrier (CT)						x					
NFWF-43429	Creating a Resilient Delaware Bay Shoreline in Cape May and Cumberland Counties (NJ)	x		x			x					x
NFWF-43752	Creating a Three Dimensional Wetland Model for the Bombay Hook National Wildlife Refuge (DE)											
NFWF-43759	Reducing Flood Impacts and Restoring Habitat in the Brandywine River Watershed (PA)						x					x
NFWF-43834	Increasing Community and Ecological Resiliency by Removing a Patapsco River Fish Barrier (MD)	x	x	x	x							x
NFWF-43849	Developing Coastal Resiliency Regional Models (VA)	x	x				x					
NFWF-43861	Creating a Natural Resource Resiliency Assessment and Action Plan (RI)	x										

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-43931	Strengthening Marshes Creek Through Green and Grey Infrastructure (NJ)		x									
NFWF-43932	Improving and Quantifying Wetlands' Potential to Reduce Storm Surge Impacts (VA)		x									x
NFWF-43939	Restoring Newark Bay's Wetlands (NJ)		x		x							
NFWF-43986	Strengthening Monmouth Beach's Marshes and Dunes (NJ)											x
NFWF-44017	Developing Rhode Island's Coastal Resiliency Program											
NFWF-44020	Developing a Green Infrastructure Plan for Chester City (PA)	x										x
NFWF-44022	Reconnecting and Restoring the Allegany Reservoir (NY)			x			x					
NFWF-44068	Restoring Over One Hundred Wetland Acres in Great Egg Harbor Bay (NJ)											x
NFWF-44109	Replenishing Little Egg Harbor's Marshes											

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
	and Wetlands (NJ)											
NFWF-44140	Improving Coastal Resiliency through Community Engagement (OH, RI)	x										x
NFWF-44157	Repairing Infrastructure and Designing Wetland and Beach Restoration Plans along the Central Delaware Bayshore		x				x					
NFWF-44167	Protecting North Beach's Salt Marsh and Emergency Route (MD)											
NFWF-44193	Incorporating Green Infrastructure Resiliency in the Raritan River Basin (NJ)											
NFWF-44199	Designing a Plan to Reuse Dredged Rock to Protect the Boston Harbor Shoreline (MA)											
NFWF-44212	Improving Northeast Coast Storm-Related Data Interpretation and Accessibility	x										
NFWF-44225	Improving Shinnecock Reservation's Shoreline Habitats (NY)		x	x								

Funding Org. and Id. Number	Project Title	Socio-economic	Vegetation	Soil Quality and Sedimentation	Avian and Terrestrial Species	Aquatic Species (non-invertebrates)	Water Quality and Aquatic Habitats	Structural surveys	GIS	Storm Water	Baseline Data Collection	Flooding, Inundation, and Storm Buffer
NFWF-44245	Developing a Resiliency Management Plan for Pawcatuck River Watershed (CT, RI)											
NFWF-44271	Creating a Regional Framework for Coastal Resilience in Southern Connecticut	x										