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Environmental Projects in Urban Areas: Analysis to Support Project Planning and Budgeting for the US Army Corps of Engineers

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Boyd's research emphasizes collaborations between ecologists and economists in order to guide decisions that affect natural resources. His work considers how natural systems contribute to economic wealth and social wellbeing and how policies can be designed to protect and enhance valuable ecosystem goods and services.

Boyd works closely with diverse partners from government, NGO, and private sector institutions and emphasizes close collaboration between decision-makers and academic researchers to generate science that is useful and practical in real world settings. He serves on US EPA Science Advisory Board and other government and private advisory panels including the boards of the Ecological Society of America, American Rivers, and the Monterey Institute's Center for the Blue Economy.

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Shabman's current work balances time spent in research with advisory activities in order to have a direct bearing on the design and execution of water and related resources policy. His ongoing work focuses on protocols for water development projects and ecosystem restoration programs, design of market-like environmental management programs, and increasing the effectiveness of national flood risk management and disaster aid programs.

About the Project

This report describes US Army Corps of Engineers project planning and budget justification practices for funding environmental improvement projects. Corps environmental improvement projects include dredge material handling for beneficial use, inclusion of natural and nature-based features in storm reduction projects, and aquatic ecosystem restoration. The report describes why Corps planning and budgeting practices do not consider ecosystem services benefits, such as water quality improvement and recreation, when considering funding for projects in urban areas. This is the case even though these benefits tend to be highest in areas of greatest population density, such as the lower Hudson River Estuary in New York and New Jersey. Leonard Shabman and James Boyd from Resources for the Future were asked by the **Hudson River Foundation** to propose ways to cost-effectively report on a wider array of benefits in ways that might be used in Corps budget decisionmaking and by the government and non-government organizations that must pay for shares of the cost of Corps projects. While this report focuses on USACE decisionmaking, there are applications for other federal, state, and local agencies as well. The results will be used by the Foundation and its partners in the New York-New Jersey Harbor & Estuary Program (HEP) to inform research needs and project justification.

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About RFF

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Sharing Our Work

Executive Summary

This report describes the planning and budget justification practices of the US Army Corps of Engineers (USACE) for coastal and estuarine environments, distinguishing between three distinct mission areas: Inland Waterways and Harbor (IWH) development; Coastal Storm and Flood Risk Management (CSFRM); and Aquatic Ecosystem Restoration (AER). The report identifies challenges to the inclusion of ecosystem goods and services (EGS) analysis in decisionmaking by the Corps, specifically in urban environments.

The report finds that bringing analysis of EGS into Corps' planning and budget decisionmaking is constrained by the relatively narrow scope of defined purposes served by each mission area. In effect, there are often restrictions on the kinds of benefits that can be considered when recommending or justifying a plan for federal funding. Even if EGS were to be considered, limits on study duration and funding for analysis are likely to narrow the detail of EGS analyses.

Within these general constraints, opportunities exist for introducing EGS analyses into each of the mission areas:

- EGS analyses in the IWH mission area can help the USACE rapidly evaluate the benefits of "beneficial reuse of dredged material" in order to encourage partners to pay the incremental costs of projects and project features that exceed the federal standard for reuse.
- Similarly, in the CSFRM mission area, the ability to measure "incidental" EGS benefits might help motivate local cost-share partners to support "natural and nature-based feature" (NNBF) projects that offer a similar degree of storm protection as non-NNBF alternatives.
- Consideration of urban EGS benefits under the AER mission area is possible but would likely require changes in the AER program. Corps' AER projects are expected to recreate habitat in "nationally significant ecosystems," which tend to be located away from urban areas. Analysis of mission-specific benefits from AER or IWH (for example, flood risk reduction) or EGS benefits (for example, water quality improvement) to justify an AER investment in urban areas would require further exploration of special congressional authorizations that would allow the Corps to (1) formulate and evaluate specific urban projects, or (2) develop programmatic permission for a new urban-centric business line that could consider a wider range of project benefits.

In light of these opportunities, but also with an eye to practical analytical approaches, the report recommends research to develop benefit indicators for EGS. Benefit indicators can be developed relatively quickly and cheaply to quantify things like the number of people benefiting from enhanced EGS, the scarcity of EGS in a particular community, and the number or value of properties enhanced by environmental

improvement projects. Benefit indicators can be used to communicate the scope and significance of EGS to non-Corps budget authorities who may be able to fund projects that do not meet the Corps' budget justification criteria, and to rank aquatic ecosystem restoration projects that have met the national significance test.

The report also proposes six sequential research and development activities that can produce benefit indicators for use in the Hudson Raritan Estuary, and describes how benefit indicators can be used to make the case and secure funding for urban area estuary improvement projects.

These activities include identification of project alternatives and opportunities, stakeholder demand for specific EGS improvements, assessment of biophysical relationships that link specific projects to changed EGS outcomes, and institutional analysis of pertinent regulatory authorities and funding streams. Based on the insight of stakeholders in the Hudson Raritan Estuary, several specific benefit indicators were discussed during a workshop held at the offices of the Hudson River Foundation on May 13, 2019. Notes from that workshop are included as Appendix A.

Contents

1. Introduction

This report responds to the Hudson River Foundation's interest in the use of ecosystem goods and services (EGS) analysis to justify and secure funding for ecosystem restoration projects in urban settings—and more specifically in the Hudson Raritan Estuary (HRE). The US Army Corps of Engineers (USACE, or the Corps) and partners (including the Hudson River Foundation and the New York–New Jersey Harbor and Estuary Program) have identified 12 target ecological characteristics and hundreds of potential restoration projects in the region in a Comprehensive Restoration Plan.[1]

This report focuses on the legal and administrative context in which EGS analysis is or could be deployed by the Corps in project planning and budgeting decisionmaking. Of particular note, the report recognizes that the Corps categorizes its programs into three principal mission areas and focuses on the potential use of EGS analysis in each area.[2] For this report we label the mission areas as follows: 1) Inland Waterways and Harbors (IWH); 2) Coastal Storm and Flood Risk Management (CSFRM); and 3) Aquatic Ecosystem Restoration (AER). The report also makes recommendations for the development of EGS research plans pertinent to Corps' planning and budget decisionmaking in the HRE. The emphasis on the Corps resulted from discussions at a 2017 workshop hosted by the Hudson River Foundation that identified Corps' decisionmaking—with its associated requirements for stakeholder and cost-share partners participation in decisionmaking—as a focus of interest.

1.1. Approach

To undertake this analysis, the principal investigators undertook the following approaches:

- Reviewed Corps' planning and budget guidance and spending patterns.
- Conducted interviews by phone, in-person, and via email exchange during 2017 and 2018. The interviews explored Corps' interest in EGS analysis and refined the understanding of Corps' planning and budgeting practices. Interviews with non-Corps entities supplemented the Corps interviews.
- Attended activities (meetings in Galveston, New York City, and at the Institute for Water Resources) hosted by the Corps where presentations were made on planning and budgeting practices. Informal discussions with attendees, as well as facilitated discussions at the workshops, provided insights into Corps' practices and the possible role of EGS analysis.

1.2. Ecosystem Services: A Corps-Centered Perspective

1.2.1. What are Ecosystem Services?

Corps projects alter, and then manage, hydrologic and geomorphic conditions in a watershed or estuary to secure mission-specific services. These mission-specific services include marine transportation (IWH);[3] allowing economic activity to be located in areas where the risk of flooding is reduced (CSFRM);[4] and restoring aquatic habitat conditions (relative to a previous condition) for species of national concern (AER).[5]

The Corps will continue to make future investments and management decisions in managed watersheds and estuaries, but the agency recognizes its planning needs to consider how it defines EGS. This recognition is evident in its general policy guidance and in its research and development programs.[6] In the Corps context, attention to EGS means that a new Corps project (or operation and management of existing projects) might look beyond traditionally provided services to recognize that a project can increase the suitability of a riparian area for fish reproduction (habitat enhancement) or make water-contact recreation less of a health risk (water quality improvement).

The academic literature uses the term "ecosystem services" and the Corps has adopted the term EGS. The difference is more than semantic. Those who advocate for greater attention to ecosystem services, without reference to the Corps, often focus on how natural systems (i.e., natural capital)—for example, watersheds that are minimally altered by human activity or that can be restored to some pre-alteration condition—may provide a whole array of services valued by people. Protection of these natural systems may lead to increases in food; timber; drinking water; water for irrigation; transportation; scenic beauty; and populations of species for recreational, ethical, or cultural enhancement; as well as protection from harm (for example, wetlands in a watershed may hold water and reduce downstream flood stages).

The Corps would categorize some of these as the mission-specific services already recognized in project planning and operations and would consider other services to be EGS, falling outside of their current mission area emphasis. The Corps uses EGS to describe an expansion of the scope of considerations, beyond its mission-specific services, in planning and justifying a project for funding. Importantly, the Corps would allow for the possibility that its projects of any type can yield or can be used (operated or maintained) to increase EGS in heavily altered as opposed to "natural" watersheds. We use the terms ecosystem services and EGS interchangeably in this report; however, whichever term is used, the Corps' perspective on EGS is our focus.

1.2.2. Environmental Improvement Projects (EIPs)

The Corps uses different terms in the different mission areas to describe its projects that might increase EGS analysis:

- AER mission area—the Corps uses the term "restoration" to describe projects that replicate previous hydrologic or geomorphic conditions in a watershed.
- CSFRM mission area—the Corps uses the term "natural and nature based features" (NNBF) to describe actions that reduce flood hazard through actions that are not traditional "hard" infrastructure, such as seawalls, levees, and storm barriers. NNBFs might include oyster reefs, seagrass beds, or tidal wetlands. The Corps does include beach nourishment and dune creation as NNBFs.
- IWH mission area—the Corps uses the term "beneficial use" when describing disposal alternatives for dredge material, generally to mean any dredge disposal approach that seeks to secure non-transportation benefits and is more costly than meeting federal standard for dredge material disposal.

The Corps uses many different terms to describe its "environmental" activities and programs. Given the focus of this report, we use the general term "environmental improvement project" (EIP) to describe any Corps actions intended to increase EGS analysis (as described above) relative to the future without Corps action.

1.3. Report Objectives

1. Describe and assess the Corps' decision criteria for selecting a preferred project alternative for Corps funding of EIPs within the three principal Corps' mission areas, to include any anti-urban bias.
2. Propose a strategy for the Hudson River Foundation to prioritize research on EGS analysis that will be acceptable for use by the Corps and other restoration funders.

1.4. Report Structure

The report assumes that readers are familiar with Corps' planning and budgeting practices. Readers who are not familiar with Corps' practices should refer to Appendix B, which provides an overview of the Army Corps of Engineers' decisionmaking process.

The main report has two main sections. The next section addresses Objective 1 and describes the challenges of bringing EGS analysis to Corps' decisionmaking in an urban context. This is followed by a section addressing Objective 2, describing a research strategy to increase the likelihood of Corps' adoption of EGS analysis and to increase the likelihood of funding EIPs in urban settings.

2. Bringing Ecosystems Services Analysis to Corps' Decisionmaking: General Observations

There are three general constraints on the conduct and then use of EGS analysis in Corps' planning and budget justification. Constraints that cut across the mission areas are discussed first, followed by a discussion of how the constraints manifest themselves in each mission area.

2.1. Primary and Incidental Benefits

When making a budget decision, the Corps considers some benefits of its projects as "primary" and others as "incidental." **Primary benefits** are directly related to specific mission areas. Other benefits, even if reported in a planning document, are considered **incidental** when making a budget allocation.

EGS analysis—by design—expands the benefits considered in project evaluation in all three mission areas. In fact, many of those interviewed for this report used the term "policy compliant" to characterize forms of analysis that would be acceptable given current agency practices.

While Corps' planning guidance does not limit planning purposes (the problems and opportunities addressed) or what benefits might be calculated, the distinction between primary and incidental benefits is important. If incidental benefits might not be considered in the budget decision, this dictates the scope of planning for each mission area and the benefits that get assessed. One possible exception might be in the case of measured and reported incidental benefits to gain potential cost-share support by other partners in a project; for instance, state government, local government, corporate partners, or philanthropies.

2.2. Constraints on Study Time and Resources Limit Interest in EGS Analysis

The agency has made a commitment to expedited construction planning. This includes what the Corps calls "3X3X3," which has been extended to include risk informed planning (RIP).[7] "3X3X3" means that a planning study can cost no more than $3 million, take no more than 3 years, and must have 3 concurrent levels of review. A study that exceeds those time or cost limits requires an approved exemption by the Assistant Secretary of the Army for Civil Works; a study over $6 million requires approval by the Office of Management and Budget (OMB) and congressional notification. One feature of RIP is the requirement to report analytical uncertainties and their implications for project selection.

The common theme is that plans will be prepared and recommendations for action will be made in a timely manner and that the reports will be transparent and easily interpreted by decisionmakers.

This means that the scope and details of any EGS analyses will be constrained by the time and financial resources available for project planning, especially if the analysis is about incidental as opposed to primary benefits.

2.3. Limited Construction and OMRRR Budget Funds Limit Interest in EGS Analysis

Over the past several decades, the Corps' annual appropriations have decreased in inflation-adjusted terms, even as money from trust funds supported by user fees dedicated to the IWH mission area have become available. In effect, this means that appropriations from general tax revenues have fallen even more dramatically.

Meanwhile, the share of the annual appropriation going to the budget for operations, maintenance, repair, replacement, and rehabilitation (OMRRR) has increased while funds for studies, construction, and programmatic budgets have decreased. In fact, more than 50 percent of the annual budget now is dedicated to OMRRR.

The current construction budget hovers around $1 billion, or about 20 percent of the $5–6 billion annual appropriation. Also, recent emphasis within the construction budget on Corps' infrastructure repair and rehabilitation has displaced investment in new projects—adding to year-over-year declines in available new investment funds. Finally, some of these construction funds are dedicated to IWH mission. In summary, construction funding for new flood and coastal projects and AER mission projects is limited and declining.

Three emergency supplemental budget allocations after Hurricane Katrina (about $15 billion), Hurricane Sandy (about $7 billion) and after the 2017 hurricane season (about $17 billion) have significantly expanded funds available for CSFRM project construction in anticipation of future storms. These supplemental funds focus on the CSFRM mission and projects in locations most affected by the storms, although projects in locations distant from the storms' effects have also received funding.

Even with the emergency supplemental funding, the costs for currently authorized projects far exceed the funds available for construction. The result is significant competition for project funding within and among mission areas. The Corps' budget process creates (at least in concept) sub-budgets by mission area. EGS benefits must be paid for with funds from within a given mission area. The Corps will not allocate budget funds from one mission area to pay for actions that provide benefits for another mission area.

3. Bringing EGS Analysis to Corps' Decisionmaking: Mission-Specific Reflections

Each Corps' mission area, for construction and OMRRR, has its own separate planning practices and budget justification criteria that 1) provide context for understanding if there is an anti-urban bias in the Corps' process; 2) affect whether a broader recognition of EGS would change plan formulation, evaluation, or plan recommendations; and 3) influence whether expanded use of EGS analysis would influence Corps' budgeting practices.

This section provides an elaboration of the planning and budgeting practices within the different mission areas in order to provide the context for describing barriers to the use of EGS analysis in Corps' construction planning.

3.1. IWH and Beneficial Use of Dredged Material

3.1.1. Problems and Opportunities

For harbor deepening and maintenance, the purpose is to achieve (or maintain, if a project is in place) transportation cost savings while meeting the federal standard for disposal of any dredged material. The federal standard calls for disposal of material in the least-cost way, subject to compliance with environmental laws and regulations.[8] This standard is an elastic concept (as opposed to a numeric threshold), defined for a specific place by the USACE with input from project partners and federal and state resource agencies. Beneficial use, as noted earlier, refers to dredge material placement that creates benefits incidental to the IWH mission.

3.1.2. Formulation of Alternatives

If a construction project to increase channel width or depth is being formulated and evaluated, alternatives such as riding tides, light loading, off-loading to smaller ships, or even using an alternative port might all be considered.

Within OMRRR, a dredging team identifies channels to be maintained and the material needed to be removed to maintain channel depths. Baseline alternatives for meeting the federal standard may involve side-casting or moving the material to a nearby confinement area.

The baseline alternative is identified when the Corps makes budget decisions on dredge material disposal in its operations and maintenance sections, when planning for a specific project, or under the Continuing Authorities Program.

Using the material to build up beaches and dunes for storm damage reduction, building wetlands in near-shore and open-water areas for habitat creation (and maybe recreational use), or landfill capping are deemed beneficial use projects. The ecological and social benefits of such projects are incidental, not primary, to the IWH mission area.[9] While IWH teams are open to requests for beneficial use of material from non-Corps entities, including other federal agencies, the incremental costs of beneficial use projects must be paid for by others.

Among the barriers to getting beneficial use plans formulated, even if there is a partner willing to pay, is the documentation that needs to be completed given the short time frames in which the material has to be dredged and then deposited. In addition, resource agencies often focus on disposal being consistent with their resource protection regulations and less so on securing a particular stream of EGS benefits.

The Continuing Authorities Program process has a longer lead time, allowing for better alignment of the timing of the dredging with beneficial use of the material (e.g., to build wetlands; one example was use of dredged material to build a marsh island at the Rockaway Inlet).

3.1.3. Evaluation

Primary benefits in the IWH mission area are transportation time and cost savings, reported in dollar equivalents. Vessel safety also might be considered a primary benefit, but design criteria (e.g., channel width) are used more often to assure a tolerable risk (likelihood and consequences) of vessel accidents. Dredged material handling, including possible beneficial uses of the material, is considered a cost for such projects. Benefits that can be realized if additional costs above the federal standard[10] are incurred are deemed incidental.

Beneficial use typically involves added costs above those necessary to meet the federal standard. Whether in construction or OMRRR, the incremental cost for any beneficial use must be paid from somewhere other than the Corps' IWH budget. These costs need to be justified to the entity making the spending decision (e.g., port authority, local government, or other federal agency).

The costs for the dredged material alternative might address a problem or seize an opportunity in the CSFRM or AER mission areas. If so, that beneficial use needs to be justified with the evaluation criteria that apply to that mission and that are budgeted (as well as cost-shared) according to polices govern that (non-IWH) mission area. For example, dredged material for the deepening of the approaches to the Port of Baltimore was used to rebuild the eroding Poplar Island in the Chesapeake Bay. That use was authorized as an AER project, justified under AER criteria, and cost-shared according to AER requirements.

3.1.4. Decision Criteria and Preferred Alternatives

There is no anti-urban bias in using dredged material for an EIP within construction or in OMRRR. If a beneficial use is selected for a project and that beneficial use happens to be (or be part of) the federal standard or base plan option for the project—because it is the least costly alternative that is consistent with sound engineering practices and meets all federal environmental requirements—the costs of that beneficial use are assigned to the navigational purpose of the project and are shared with the non-federal sponsor.

If a beneficial use is selected for a project, and that beneficial use is not the federal standard option, the costs for the beneficial use option are divided into two categories for the purpose of determining the federal and non-federal sharing ratios. First, the costs assigned to the navigational purpose of the project (i.e., the amount it would have cost to implement the federal standard option) are shared with the non-federal sponsor. Second, the costs beyond the navigational purpose costs (termed "incremental costs") are shared on a different basis, depending on the type of beneficial use. In fact, to the extent urban areas have non-federal partners who are financially well off (e.g., ports and local governments), beneficial use may be more likely in urban areas.

However, it is not likely that costs in excess of meeting the federal standard will be paid from the IWH budget. We note that the 2014 Water Resources Reform and Development Act (Section 1038) calls on the Corps to reevaluate the federal standard to recognize beneficial uses. However, the effect of such a change would be to shift the costs from beneficial use proponents to the Corps' IWH construction or OMRRR budget (budgets that are stretched thin)—and to do so for what the Corps deems "incidental" benefits. Also, if an IWH project were proposed for construction, a change in the federal standard would add costs to serve "incidental" benefits, in effect reducing the benefit–cost ratio used for budget justification. Short of a congressional directive with specific and detailed analytical requirements on how to change the federal standard, it is not likely to be changed to accommodate EGS that are deemed incidental benefits.[11]

EGS analysis might be useful to build support among non-Corps budget entities for beneficial uses and to encourage them to pay the incremental cost above the federal standard. The possibility that non-Corps entities would accept and use EGS benefit indicators when making budget decisions is an area for HRF research that we will discuss below.

3.2. CSFRM and NNBFs

3.2.1. Problems and Opportunities

The purpose of this mission area is to reduce storm damage and erosion in high-energy coastal wave and surge settings. The Corps will treat other purposes, such as recreational use of beaches, as incidental.

3.2.2. Formulation of Alternatives

The agency is most comfortable formulating alternatives when it has a high confidence in the predictions of the effectiveness of the action. For reduced storm damage, the Corps has particular confidence in gates; seawalls, (i.e., "hard" infrastructure projects); beach and dune creation as a NNBF; and property and population relocation.

After Hurricane Sandy, NNBFs were proposed for inclusion in plan formulation. A post-Sandy report defined NNBFs as actions such as oyster reef construction, sea-grass bed establishment, and wetlands creation/recreation in addition to beach and dune creation. In fact, there is increased popular and professional discussion of NNBFs for storm and erosion risk management that has reached the point of congressional directives to require federal agencies to consider NNBFs as an alternative for coastal storm damage reduction.[12] Specific language in the 2016 Water Resources Development Act (Section 1184) directed the Corps to consider NNBFs in plan formulation.[13] This congressional direction was restated in subsequent authorization legislation[14]

In response to Section 1184, the Corps issued guidance requiring expanded consideration of NNBFs during the plan formulation step. The guidance suggests that NNBFs can be combined with different combinations of hard infrastructure measures to create a broader range of alternatives when developing a risk management plan for coastal storms and floods. The resulting alternatives to be evaluated will include (at least in principle) an "all NNBF" alternative at one extreme, an "all hard" alternative at the other, and mixes of the two between the extremes. How far this formulation process can be taken will be limited by study time and budget.

3.2.3. Evaluation

The 1184 guidance did not change how the formulated project alternatives, (whether they include NNBFs or not) are to be evaluated and justified for funding. The primary benefits of storm damage reduction are avoided repair and replacement costs for physical assets (i.e., avoided damages). The benefits measure relies on models of stage/surge and associated velocity from different coastal storms. The water level and velocity are translated to estimates of physical damage and then the costs to repair and replace what was damaged. Models are used to predict how any alternative, including NNBFs, might reduce the resulting surge stage and velocity and thereby reduce damages.

In the CSFRM mission area, primary benefits are the avoided costs of repairing and replacing existing assets reported in dollar equivalents and used in the reported benefit cost ratio and net benefits calculation. Reductions in life safety risk also might be a primary benefit. In urban areas, a minimal tolerable level of residual risk—often called a level of protection (LOP)—might be a target. The cost for any project—whether "traditional" (a seawall or beach or building elevation) or an NNBF (such as

an oyster reef or wetlands to reduce storm surge)—must be justified by its primary benefits. Any other benefits realized from that project are considered incidental. A special case exists for beach nourishment, in which recreation benefits for increased beach use attributed to the larger beach can be up to 50 percent of the benefits evaluated. However, these recreation benefits may not carry the same importance as storm damage reduction benefits within the Corps' budget justification process.

3.2.4. Decision Criteria and Preferred Alternatives

There is no anti-urban bias in the CSFRM mission. On one hand, the more people and assets that are exposed, the more likely it is that a Corps project will be justified. On the other, if the effectiveness of NNBFs compared to "hard" infrastructure is viewed as more uncertain, the density of urban area populations and assets could strengthen the argument against implementing NNBFs.[15,16]

If the Corps and the community want to secure a certain level of protection against coastal storms—with, say, 98 percent likelihood—then a likely alternative will be a seawall with the height needed to meet that target. However, there are planning approaches where CSFRM planning practices could justify projects that include NNBFs. One possibility would be when project designers include an NNBF feature as integral to a specific project alternative, thus avoiding the need to incrementally justify the NNBF. For example, the still-developing Jamaica Bay plan includes four projects in Back Bay areas, where project design engineers found an equivalent effectiveness between a seawall and a berm with a fronting wetland (an NNBF approach). This design conclusion allowed the Corps' district to compare the options for a wall versus a berm/wetlands based on cost-effectiveness.[17]

Another situation is when NNBFs might save on project costs and raise (or at least not lower) the net benefits of flood risk reduction. For example, we were told in an interview that as the Staten Island seawall design was being fine-tuned, the wall was realigned to avoid a wetlands area and allow for some restoration of the wetlands site. That realignment reduced mitigation costs and, in so doing, increased the project's net benefits.[18] In other words, cost savings from mitigation efforts justified the seawall realignment to allow for wetlands restoration.

A third scenario is also possible. The 1184 guidance (and previous guidance) refers to the locally preferred alternative. Suppose an alternative with NNBFs involves only a modest compromise with an expected flood return frequency target (say it achieves a 450-year but not a 500-year target), and that reduction is acceptable to the Corps (which it might be) and to local interests that would benefit from NNBFs beyond flood risk reduction. In such a hypothetical scenario, the Corps might be willing to accept this locally preferred plan and recommend it for budgeting, but only if non-Corps entities pay for any incremental costs.

3.3. The Effectiveness and Reliability of NNBFs

We emphasize that if an NNBF increases the uncertainty of meeting a target—even if it is expected to meet the target[19]—the Corps will resist its inclusion, even if the NNBF generates other benefits.

The Corps believes the effects of NNBFs on coastal storm hazards (e.g., wave height dissipation, reduced storm surge, and still water-elevation and/or reduced erosion) are highly site-specific and less predictable while modeling capability remains in development. As one example, the effects of oyster reefs or seagrass on surge elevation depends on multiple storm characteristics, including the direction from which the storm approaches, size of the storm (areal extent), wind speed, time of high tide, and other factors. This means that the effectiveness of an NNBF will be depicted as a statistical distribution of possible effects—not a single effect for all storms. That distribution will be compared to a corresponding (but usually far tighter) distribution of outcomes associated with conventional, "hard" alternatives. Current modeling platforms (certified Corps models and models in the broader research community) can report the central value of avoided damages but, in general, such models produce a wide range of possible values.[20] At present, the Corps attention to NNBFs is still being vetted in its research organizations.[21]

Any quantification of NNBF effectiveness and reliability will receive significant scrutiny from the Corps. An issue for NNBF advocates is that rule-of-thumb generalizations[22] and even site- specific academic research studies[23] about NNBF effectiveness must be complemented by far more robust and extensive quantification if NNBFs are to successfully compete against traditional protection alternatives.

The Corps' concern with effectiveness stems from its statutory responsibility to protect life and property (i.e., the problem used to justify spending). From the Corps' perspective, it—rather than diverse advocates of NNBFs—is politically, legally, and ethically responsible for project performance should NNBF features fail to perform as expected.

3.4. Aquatic Ecosystem Restoration

3.4.1. Problems and Opportunities

In the AER mission area, relevant problems and opportunities relate to restoration of hydrologic or geomorphic features of the aquatic ecosystem. More specifically, the 2007 Water Resources Development Act states that: "It is the policy of the United States that all water resources projects should […] protect the environment by: […] protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems." This aligns with earlier (and still in effect) Corps' guidance (ER-1165-2-501) that says the AER mission is "to restore significant ecosystem function, structure, and dynamic processes that have been degraded.

[...] The intent of restoration is to partially or fully reestablish the attributes of a naturalistic, functioning, and self-regulating system." In practice, return to a "reference condition" defines project opportunities. The reference condition is a state variable (metric) that describes a pre-alteration condition in the area or a similar watershed. According to planning guidance, "examples of possible metrics [that] may be used include habitat units, acres of increased spawning habitat for anadromous fish, stream miles restored to provide fish habitat, increases in number of breeding birds, increases in target species, and diversity indices."

3.4.2. Formulation of Alternatives

The formulation of alternatives begins by focusing on hydrology or geomorphology. The Corps expects projects to restore the "natural hydrologic signature" of an ecosystem, including the timing, magnitude, duration, and rates of change of flow, water levels, and surface/subsurface exchange processes" and to restore the resource's "natural geomorphic structure (e.g., channel form, substrate composition) and processes (e.g., erosion, sediment transport, and channel migration)."

3.4.3. Evaluation

Primary benefits in the AER mission area are expressed in biophysical terms, usually related to a project's contribution to the life cycle of nationally significant species or communities of species. A frequently used metric is habitat units. Any benefits—whether monetized (e.g., flood damage reduction as in the CSFRM mission) or non-monetized (e.g., enhanced recreational opportunities for low- to moderate-income (LMI) households)—are deemed incidental.

The valuation process is termed "cost-effectiveness incremental cost analysis" (CE-ICA). There are five components to a CE-IC analysis.

- First: an outcome metric is selected. As noted above, there are numerous possible metrics; in practice, the Corps often chooses a measure of habitat units for a particular species.[24]
- Second: the analyst calculates the present value of the costs for each alternative.
- Third: alternatives are screened based on cost-effectiveness. Those that are not cost-effective (same outputs, for a higher cost) are dropped from further consideration.
- Fourth: the alternatives that remain are arrayed from the least cost to the highest cost, and the additional cost from moving to the next highest cost alternative is calculated. This is the incremental cost. As costs increase, the additional habitat units that result from that added cost are reported.
- Fifth: a combination of quantitative evidence and qualitative argument is used to define when the cost of the next added increment of (in this case) habitat units is less than their incremental value to society. Making the case for an increment of spending becomes harder as the incremental costs increase.[25]

3.4.4. Decision Criteria and Preferred Alternatives

AER funding prioritizes areas of special recognition (higher priority is given to projects that directly support broader restoration efforts, such as the Comprehensive Everglades Restoration Plan or the Great Lakes Restoration Initiative) and to special status species (recovery of species under the Endangered Species Act, state laws, or international agreements). Also, priority is given to projects that have a clear nexus to offsetting the effects on hydrology and geomorphology of past Corps projects. These motivations for AER spending support projects representing the bulk of the AER budget.

The AER mission of the Corps is about restoration (where the Corps has been the cause of the alteration) of nationally significant habitats.[26] For that reason, there is a marked anti-urban bias within the AER mission, because urban areas usually cannot meet these project-selection criteria. That bias is unintended but is a logical outcome of the mission history and definition.[27]

Moreover, any effort to alter this state of affairs by broadening the AER mission to include additional EGS benefits is likely to meet with political resistance. The AER mission area's focus on nationally significant habitats aligns it with "nature for nature's sake" advocates and provides a source of restoration funding driven by ecological aims rather than broader social goals. Were AER projects to compete on broader EGS criteria (provision of recreational, aesthetic, or flood damage benefits), it is a near certainty that AER funds would shift toward more urban restoration settings and away from the "nationally significant habitat" areas that are its current focus.

That said, within a specific watershed area there may be a list of AER projects that all meet the minimum project justification criteria. Additional EGS analyses to expand the benefits considered may be used to rank these equally acceptable projects; in effect, EGS could serve as a "tie breaker" analysis.[28]

4. A Research Strategy for Bringing EGS Analysis to Corps' Decisionmaking

In this section, we provide a short primer on what EGS analysis requires. The presumption is that the Corps could use socioeconomic evaluation of any EGS (many of which would be deemed "incidental") in order to evaluate EIP project alternatives (Element 5 of the Corps' planning process). Built into the primer are recommendations for specific HRF activities as it develops an ecosystem services research program. To the extent possible, we use concepts and terminology consistent with the Corps' planning model.

Evaluation of ecosystem services involves two types of linked analyses. The first is biophysical analysis, typically in the form of models that link ecological, hydrologic, and geomorphic processes that are the result of watershed structure (both human and natural capital). The models predict how actions (formulated plans) make changes in those capital assets and can lead to different biophysical conditions and to a vector of ecosystem services relative to the future-without-action condition. Socioeconomic valuation of changes in ecosystem services relies on the underlying biophysical models. For that reason, we begin with a framework to guide biophysical analysis and make specific recommendations for biophysical analysis relevant to the HRE.

4.1. Biophysical Analysis of Ecosystem Goods and Services

Ecosystems—because they are "systems"—are composed of multiple, interlocking biophysical processes and features. Thus, in almost all cases, actions trigger a variety of changed biophysical outcomes mediated by the system as a whole. Accordingly, EGS analysis involves the depiction and quantification of multiple cause-and-effect relationships. Consider the cascade of effects from a stormwater wetland that sequesters nutrients. Sequestration alters riparian water chemistry, which alters riparian vegetation, which alters gastropod abundance, which alters a broader food web and the abundance of multiple species. In principle, each step in this causal chain is quantifiable and is represented in a statistical or mathematical process model. A goal of EGS analysis is to model the relevant system of relationships—**ecosystem production analysis**—to predict the changes in biophysical results (e.g., changes in bird populations and diversity) and the social benefits that result (e.g., from bird watching).

It deserves emphasis that models must recognize spatial and inter-temporal relationships. They are spatial because of movement (e.g., air circulates; water flows; species migrate; seeds, pollen, and juvenile organisms disperse) and because ecological production can exhibit non-linearities in scale and configuration (e.g., edge effects, minimum forage and reproductive requirements). They are inter-temporal

because of the reproduction, forage, and growth of species lags between the storage and release of water, erosion, and other dynamic processes.

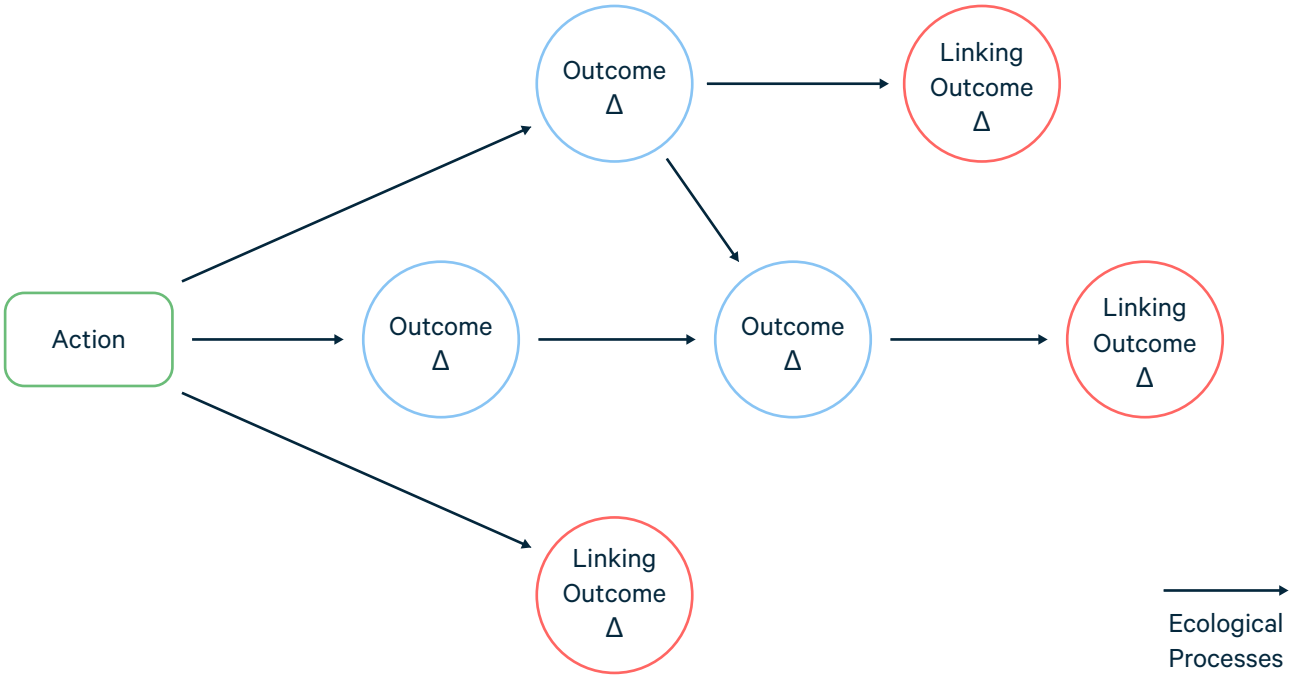
A goal of modeling is clarification of what biophysical changes will happen, as well as where and when. These changes allow for the prediction of what we will call **linking outcomes**: biophysical outcomes closely linked to social outcomes. Linking outcomes are understandable to lay audiences and convey (as directly as possible) ecological changes so that agencies and the lay public can judge the value of such changes relative to costs. As noted earlier, alternatives can trigger a very wide variety of ecosystem changes, with a correspondingly wide set of possible outcome measures (e.g., vectors of water quality parameters, benthic measures, and habitat characteristics). Linking outcomes are a subset of these measures: those that best enable stakeholder evaluation and economic analysis.

There is no black-and-white test of what constitutes a linking outcome. However, certain principles can guide their identification. One useful test is whether interpretation of an ecological metric requires a scientific background or familiarity with technical jargon. Chemical measures (e.g., nitrogen, phosphorus, and dissolved oxygen concentrations); indices (e.g., biotic integrity, habitat suitability); and biomass, productivity, tropic, and energy measures all require such a background. To be clear, these measures are all important to the understanding of ecosystem production and may have salience in agency decisionmaking. For example, the Corps uses habitat units to describe benefits in its AER program, even though habitat units are not easily interpreted by lay audiences.[29] The Corps uses return frequency and residual risk (i.e., levels of protection) as one way to judge alternatives in its CSFDM program area, but the terms are often misunderstood by the general public. Because these terms can be difficult to interpret without a scientific or engineering background, however, they make the bridge to social and economic analysis difficult—if not impossible.

Modeling can predict linking outcomes. Consider the example above, which predicted how a wetland can change ambient water chemistry, aquatic vegetation, gastropod abundance, and fish abundance. That simple (and incomplete) production framework relates a set of "technical" or "intermediate" inputs (e.g., dissolved oxygen levels, aquatic vegetation) to an ultimate outcome (e.g., fish abundance). In any such causal chain, the ultimate biophysical outcome, rather than inputs to that outcome, is a candidate for a linking outcome. Of course, this raises the question of "when do we stop building the chain of causation?" The answer is: if the decision analysis requires valuation of a biophysical outcome that directly matters to stakeholders, we need to predict a linking outcome. For example, can we stop our analysis with gastropod abundance—or should we go further? This depends on the social context and stakeholders involved. In the rare context where snail harvests are of primary social importance, indicators of their abundance are sufficient for social analysis. In most other contexts, however, fish and shellfish will be of primary importance, in which case quantification of their abundance is needed.

Another way to convey the importance of linking outcomes is to think about the evidence needed if dollar values are to be attached to ecosystem services.[30] That evidence can take a wide variety of forms (both formal and informal) but often involves talking to or measuring the behavior of stakeholders—some of who may lack technical, quantitative knowledge of the ecosystem producing the services.[31] Consider the most informal procedure, where stakeholders are convened to rank, prioritize, or simply reflect on ecosystem changes. If presented with only proxies for what directly matters to them, they are (in effect) being asked to "quantify"—for themselves—the causal relationship between proxies and the outcomes they actually understand and value. Lay audiences are not suited for this task. As a result, they may misrepresent the underlying casual effect (in magnitude and even direction). Ecological outcomes that we can see, smell, hear, taste, and touch are in general more likely to influence behavior (and directly matter to welfare) than "unexperienced" outcomes. Note that these kind of outcomes—precisely because they are directly experienced—are more likely to be linking outcomes than are more technical scientific measures. Figure 1 depicts an ecological production system and the key elements within it.

Figure 1. An Ecological Modeling System



Implementation of an EIP action will trigger changes in multiple ecological outcomes (outcome Δs). Linking outcome Δs can either be directly related to the action or are related to the action via intermediate causal relationships. Linking indicators are the endpoints of these causal chains. Ecosystem services valuation is served by prediction of the relationship between an action and linking outcome Δs. A modeling system both

describes and then can be used to quantify the relationship between EIP actions and multiple biophysical outcome Δs that are amenable to social and economic analysis. Consider Table 1, a provisional list of EIP actions in the HRE.

Table 1. Restoration-Relevant Actions

Beach, living breakwater, and sand bar creation or replenishment	Removal of impervious surface
Oyster reef	Aquatic catch management (e.g., harvest limits) & restocking
Wetland creation or restoration (coastal and inland)	Septic system upgrades
Oyster reef creation or restoration	Relocation of people and assets, so the previously occupied area is allowed to "naturalize"
Submerged aquatic vegetation restoration	CSO upgrades
Afforestation	Tighter point source release requirements (e.g., via waterbody reclassification)
Constructed swales and bioretention areas	Removal of contaminated sediments (via dredging)
Riparian vegetation restoration	Contaminant isolation (via capping)
Fish passage construction	Stream bank stabilization
Invasive species removal	Avoided boat groundings or contaminant spills (via navigational restrictions)

This (likely incomplete) list represents actions that could be taken in order to address perceived problems and opportunities in the estuary.[32] Table 2 provides a provisional list of linking outcomes relevant to communities surrounding the estuary.

Table 2. Beneficial Ecological Outcomes (Linking Outcome Δs)

Reduction in frequency, height, force, and duration of storm surge	Increased land area accessible for recreation
Increased abundance of recreationally, culturally, and commercially important (multiple, species-specific)	Increase in navigable water area
Increased abundance of threatened and endangered species (multiple, species-specific)	Increase in aesthetically desirable land cover features (e.g., tree cover, other natural open space)
Reduction in probability or severity of negative human health impacts (via water, air, soil vectors)	Improved water clarity and odor
Reduction in heating degree days, energy use	Reduced pollutant loads to water treatment facilities
Carbon sequestered	Reduction in peak flows to CSO systems
Avoided saltwater intrusion to residential and commercial wells and agricultural activities	

While the list may be incomplete, these outcomes represent candidate problems and opportunities likely to be understandable and directly relevant to individuals in the NYC area.

EGS analysis is often thought of as "mostly about the valuation." As the discussion above shows, that is a mistake. In fact, much of the work associated with EGS analysis involves the construction of models that relate natural resource management actions to changed biophysical outcomes. Moreover, the analysis undertaken to value ecosystem services is contingent on the form and specifics of the available underlying biophysical analysis. For these reasons, and with reference to Tables 1 and 2, we recommend the following activities.

4.1.1. Research Activity 1: Review of Candidate Restoration Actions

- This review would benefit most from the involvement of local restoration practitioners and environmental regulators.
- Purpose: To validate the list presented in Table 1, amend as needed, prioritize based on HRF's mission and interests, and provide more specificity to the actions.[33] The broader purpose is to inform and help set priorities for subsequent ecological analysis.

4.1.2. Research Activity 2: Review of Candidate Linking Outcomes

- This review would benefit from nontechnical perspectives on the problems and opportunities most salient to communities surrounding the estuary (e.g., community representatives and environmental advocates), as well as from government agency representatives with concrete management objectives.
- Purpose: To validate the list presented in Table 2, amend as needed, and develop more specific outcome metrics.[34] Again, a broader purpose is to inform and help set priorities for subsequent ecological analysis.

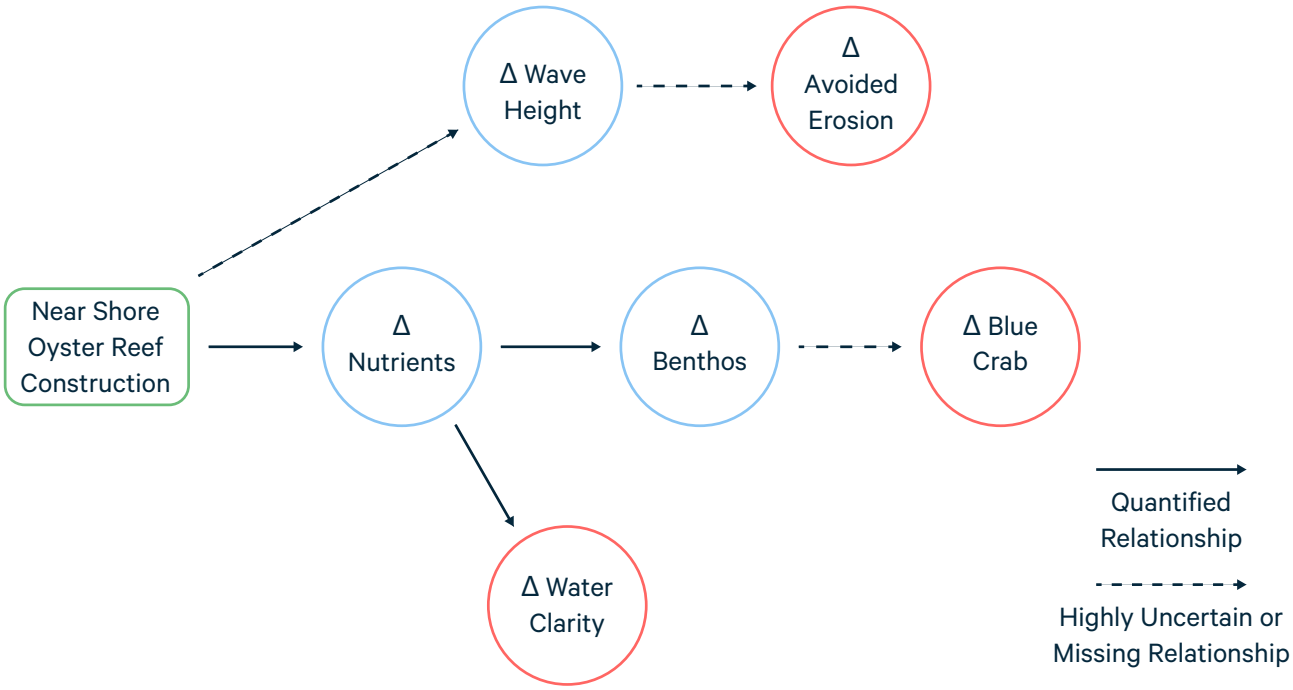
4.1.3. Research Activity 3: Develop Conceptual Models and Conduct Causal Knowledge Gap Analysis

- This activity requires input from a diverse set of scientists with expertise relating to the estuary as a system of land, water, and species interactions.
- Purpose: To assess the ability to predict how alternative actions lead to specific linking outcomes. Also, to identify knowledge gaps that, if filled, would allow for such prediction.

Activity 3 involves, first, the conceptual development of multiple causal frameworks relating EIP actions to linking outcomes. Second, using the causal framework, the activity involves identifying data, models, and existing literature available to quantify some or all of the relationships in the causal framework.

Consider the following hypothetical example—participants would be asked first: "What are the linking outcome effects of wetlands construction?" Second: "What intermediate processes and outcomes lead to or alter that relationship? Third: "Does the existing science (e.g., expert opinion and statistically valid studies) permit quantification of the linkages so that a model can be constructed?" Fourth: "What are the key uncertainties and how do those manifest themselves in confidence bands around the model predictions of the linking outcomes?" The result might look something like Figure 2 (though a real example would involve more elements).[35]

Figure 2. An Example Model Framework



One causal chain might relate oyster reef size, location, and features to stage reductions for storms of different strengths approaching from different directions. That analysis could be extended to predict reduced coastal erosion. Another causal chain might relate the reef construction to the near-shore nitrogen cycle, changes in various benthic biota, and subsequent improvements in blue crab abundance. A third might relate nutrient loadings to water clarity and odor.

With such a conceptual framework, participants can address the question of quantification. It is common for some (but not all) steps in the causal chain to be backed by empirical analysis. Some relationships can be quantified and immediately useful in model construction. For others, uncertainty and error bands may be significant. For example, the effect of oyster reefs on stage height remains an area of scientific uncertainty, which could discourage the Corps' use of current empirical estimates in its evaluation. Identification of gaps and uncertainties is a key goal of Activity 3. Gap analysis helps set priorities for subsequent analysis (e.g., original research, model development, deeper exploration of existing literature, and expert elicitation).

Finally, the activity can highlight the likely magnitude and uncertainty (in biophysical terms) of the model predictions.[36] We stress that assessment of uncertainty can be particularly important when nature-based actions and features are being evaluated against conventional "hard" engineering and construction alternatives. One reason that conventionally engineered actions (e.g., seawalls and beaches) are currently emphasized by Corps' evaluation practices is that the Corps believes predictions of their effectiveness are relatively certain.

HRF-supported research might increase confidence in how NNBFs produce storm reduction services. However, this research area might not be the best use of limited HRF funds since it is now a major topic in the scientific literature.[37]

Instead, HRF might seek advice on how to better predict non-flood reduction linking outcomes if NNBFs were paired with other CSFRM alternatives (such as water quality and species-related improvements). Such prediction capacity, perhaps combined with valuation studies (see next section), might encourage cost-sharing partners or other entities to include NNBFs in locally preferred CSFRM plans and pay for their incremental costs.

In summary, Activity 3 helps structure discussion of the state of available and relevant estuarine science and a longer-term research agenda to support biophysical modeling. This activity also plays a key role in the economic, social, and institutional analysis of ecosystem services, to which we now turn.

4.2. Economic Analysis of Ecosystem Goods and Services

4.2.1. Monetary Valuation

We now turn to the ways in which ecological production analysis, frameworks, and linking indicators can be deployed to derive the economic, social, and institutional implications of EIP actions. This section introduces three additional suggested research planning activities—all of which build and are conditional upon completion of activities 1, 2, and 3 above.

We begin with an overview of economic methods to monetize the benefits (or costs) of ecological change (i.e., economic valuation).[38] The following points should be kept in mind. First, dollar-based benefit measures are not the only way to inform decision makers and the public about the benefits of an EIP action.[39] Social science uses a variety of techniques—from monetary valuation methods, to opinion polls, to less formal stakeholder group consultations—to elicit public preferences for ecosystem goods and services. Second, economists advocate the use of people's "willingness to pay" (WTP) as the appropriate conceptual framework to reflect peoples' preferences for a change in environmental conditions. This is also the conceptual framework used by the Corps for its valuation of alternatives. We will use the terms "WTP" and "economic valuation" as synonyms. There are several tools, or methods, for economic valuation. The choice of a particular method depends on a variety of factors including who benefits, how they are benefited, and data availability.[40] In effect, linking outcome Δs become inputs to those techniques, as they are outcomes that (by design) are meaningful to and interpretable by the public and social scientists.

Economic valuation is a way to depict something's importance or desirability. Economic values can be thought of as rankings, weights, or priorities expressed via common metric—dollars. Economists measure values by methods designed to reveal

an individual's WTP for a beneficial ecological outcome (or their WTP to avoid a detrimental outcome).[41] Expressed in monetary terms, these individual WTP values can be aggregated to derive a social benefit measure.[42] The "benefit analysis" in cost–benefit analysis—as practiced by economists and government agencies, including the Corps—refers to WTP analysis.

As discussed above, agencies such as the Corps do not measure or report WTP for all effects of their actions. For example, the WTP of shippers for increased navigation channel depth is a primary benefit for the Corps' decisionmaking in the IWH mission area and is monetized. However, the loss of WTP to commercial fishers for a degradation in fish habitat from the same dredging is not monetized via WTP analysis. Instead, the costs of measures to offset the loss of lost benefits (mitigation costs) is added to the cost side of the benefit–cost report.

As a practical matter, technically credible (to professional economists) WTP measurement demands time, extensive data, sophisticated methods, and expertise. At times, WTP measurements can be challenged based on a study or method's technical credibility. Challenges to benefits analysis may also be made on conceptual grounds—for example, by questioning the assumption of fixed and well-formed preferences, or assumptions about the effect of income on individual preferences and the weighting of those preferences.

How is WTP measured? In general, the approach is to examine the actual or simulated behavior of individuals (their choices) in order to infer WTP.

Hedonic price valuation methods examine the prices people pay for things that have environmental features (controlling for many other features that affect prices). For example, when people purchase a home near an aesthetically pleasing river or shoreline, home prices reflect that environmental amenity. The price premium of living near the ocean, having a mountain view, or being in close proximity to urban parks can be measured via statistical analysis of land prices, where the premium due to those features is isolated for the land price by statistically controlling for other factors that affect real estate value. Evidence of environmental WTP value can also be inferred from voter choices to incur costs to support prohibitions on drilling, development, and other land use changes—or voting to approve tax increases to fund natural land acquisition.

Travel cost methods examine the costs people are willing to bear to enjoy natural resources. When we spend time and money to enjoy nature, we are revealing something about its value to us. If we are willing to bear those costs, we must value the experience, enjoyment, or use of the resource more than that cost. The travel cost method requires data and analysis linking the number of trips to a site to its quality, size, or location. Changes in these attributes can be valued if there is a perceptible change in the number, length, or cost of trips taken to the site. However, the amount spent on the recreational experience, including travel, is not a direct measure of benefits.

Another technique is to examine costs avoided. The Corps uses avoided cost to value benefits in its CSFDM mission area. Avoided cost can be used to value natural capital. Consider a wetland that is shown, by modeling or other evidence, to prevent a specific amount of sediment and nutrient runoff into an adjacent water body. The avoided cost of a water treatment facility built to control those same pollutants is one way to measure the benefit of preserving the wetlands. Avoided cost is a measure of the wetlands benefit under three conditions: 1) there is evidence of a WTP for the limitations on sediments and nutrients (for example, without the wetlands water quality standards might be violated); 2) that the avoided water treatment facility alternative was the least cost way to reduce the pollutants (for example, maybe diverting the water to a nearby wetland would be less costly); and 3) the wetland can achieve the same reduction in pollutant loads.

Another valuation approach, the stated preference method, presents people with hypothetical scenarios that ask them to choose (in a survey format) between ecosystem goods or services and something with a clear dollar value, such as an increase in property tax. These methods are more structured than opinion polling. They are also often the only way to estimate certain benefits for which there is little or no behavioral evidence (e.g., existence values). Nevertheless, stated preference methods are controversial because people's choices are undisciplined by the need to spend their own money—which, in principle, may lead them to overstate their WTP. Care must also be given to clearly defining and isolating the goods or services in question and framing the choice problem in a way that does not bias people's responses.

Is one of these methods better than the others? Put differently, can analysts use a single valuation method to capture the benefits of a restoration action? The answer is no. Specific valuation methods apply to distinct kinds of ecosystem benefits and the various types of individuals who enjoy them. Consider hedonic valuation. It only captures benefits (a) enjoyed by property owners and (b) that affect the value of property. Or consider an increased fish population in the estuary—the benefits to recreational anglers would be calculated with different methods and data (e.g., travel cost methods) than the benefits to commercial fishermen (where more conventional market-based data and methods could be deployed). As noted earlier, most ecological actions lead to multiple changes in linking ecological outcomes and affect multiple classes of beneficiaries. Accordingly, comprehensive benefit analysis typically requires the use of multiple methods and forms of evidence.

4.2.2. Non-Monetary Benefit Indicators

A potentially more practical alternative to monetary WTP analysis is the collection and communication of non-monetary WTP benefit indicators. Benefit indicators are countable features of the physical and social landscape that may be intuitively meaningful indications of environmental and social of value.[43] They can also provide useful "distributional" information (e.g., related to fairness concerns) by depicting who

is likely to benefit and where. Environmental benefit indicators are relatively simple measures to develop and represent a practical middle ground between no economic analysis and monetary valuation.

Consider two broad categories of benefit indicators:

- *Population Indicators* can be used to reflect the size and characteristics of specific populations benefiting from proximity to an ecological feature or EIP.
- *Asset Indicators* can be used to reflect the number and market value of homes, businesses, and public infrastructure (e.g, roads, parks, etc.) protected or enhanced by ecological features or EIPs.

In general, the larger the population benefiting from an ecological feature or EIP, the greater its value; the larger the market value protected or enhanced by the feature, the greater its value.

Population indicators can be used to reflect the fact that, all else equal, a park with the possibility of 10,000 visitors a year is more recreationally valuable than a park likely to receive only 100 visitors a year. Or, for other examples, that open space viewable by 500 homeowners is more valuable than open space viewable by only 50 homeowners, or that an aquifer's value as a source of drinking water is greater the larger the number of households with current or possible future access to the aquifer.

Similarly, asset indicators can be used to reflect the fact that a coastal wetland predicted to reduce flood stages for a property worth $10 million is more valuable than a similar one reducing flood stages for property worth $1 million.

A variety of geospatially delineated population and asset indicator data is available from federal, state, and municipal sources.[44] Relevant population data goes beyond that collected by the US Census and can include, for example, data on commercial fishing activities, transportation (e.g., commuting patterns), tourism, and recreational activity. Relevant asset data can come from local property tax assessments and physical real estate inventories.

In order to develop informative population and asset indicators, several things should be kept in mind. First, there is often more than one population benefiting from a given restoration action. Accordingly, a typical EIP will be valued by several relevant populations. Using the example from Figure 2, the reef project affects at least three distinct populations: property owners benefiting from flood protection, fishermen benefiting from increased crab abundance, and recreators benefiting from improved coastal water quality. Second, each population will have its own spatial delineation. Again, referring to the example, the population of affected property owners is defined spatially by hydrological factors, the population of fishermen is defined by their access to the estuary and the location of crab populations, and the population of affected recreators is defined by physical proximity and access to the site.

In general, when these indicators are developed, care should be given to how population-specific "access and proximity" are defined. Aesthetic benefits may rely on only visual proximity, for example, whereas recreational benefits rely on physical access.[45]

A third category of benefit indicator is also potentially relevant to decision-making and social benefit evaluation:

- *Scarcity Indicators* can be used to reflect the importance of ecological features to specific populations in specific locations.

The scarcer a natural resource or ecosystem service, the more valuable it is, all else equal. A beach where water-contract recreation is possible will be more valuable if there are few alternatives beaches. Is it the only swimmable bay in the area, or one of many? The same holds true of parks and open space. Are these land uses scarce or plentiful? Scarcity indicators can be used to reflect the fact that the first acre of public greenspace in a neighborhood is worth more than the 500th acre of greenspace; or that the first square mile of navigable water area is worth more than the 50th.

Substitutes for the service can also be important to analyze. If water flows in a stream are reduced, but there are alternative groundwater sources for irrigation or drinking, the value of the stream water—all else equal—will be lower than if there are no substitute water sources. Scarcity measures can be constructed at various scales (e.g. scarcity within a neighborhood, county, or region). They can also be targeted at various beneficiary populations in order to analyze distributional impacts. For example, is the resource scarce to a particular neighborhood or sociodemographic group? With enough geographic detail, analysis can be used to identify how benefits are distributed across and within communities—geographically and demographically. This allows environmental choices to be compared in terms of fairness, justice, and political salience.

Example Benefit Indicators

To illustrate specific benefit indicators and how they might vary depending on particular biophysical outcomes of interest consider the following examples.

Example 1: If the outcome of interest is an increase in land area where erosion is avoided, the following benefit indicators can help communicate the benefits of that outcome and help target areas where the benefit would be greatest.

I_1 = # and/or $ value of residential properties less subject to erosion
I_2 = demographic household features (e.g., vulnerability metric)
I_3 = # and/or $ value $ value of commercial properties protected
I_4 = $ value of public infrastructure protected

Example 2: If the outcome of interest is a water quality improvement (e.g., better clarity, better odor, reduced risk of illness), the following benefit indicators can help communicate the benefits of that outcome and help target areas where the benefit would be greatest.

I_1 = # of water quality beneficiaries (via direct contact or not)
I_2 = demographic features of those beneficiaries
I_3 = presence/absence/abundance of "substitute" waterbodies
I_4 = presence/absence/abundance of access opportunities (e.g., parks, promenades, boat ramps, and beaches)

Combined with ecological modeling, benefit indicators can provide decisionmakers and stakeholders with a richer understanding of who benefits from restoration actions and how socially important those benefits are likely to be. They are relatively simple and transparent way to introduce valuation information into decisionmaking.

In the context of Corps' planning, several arguments support the development of benefit indicators:

- Benefit indicators allow for a rapid value assessment to overcome time constraints imposed on decisionmaking (e.g., as in the IWH beneficial use context)
- Benefit indicators can help rank AER projects when multiple projects meet a national threshold
- Benefit indicators might resonate with non-Corps stakeholders and motivate non-Corps funding contributions to projects analyzed by the Corps. For example, benefit indicators can be prepared quickly and might build support from non-Corps budget authorities to pay the incremental cost of NNBFs.

Consider the biophysical analysis described earlier. Because ecological production analysis, frameworks, and linking indicators describe what is beneficial and to whom, where, and when, they are central to the identification of appropriate economic valuation methods and data. Accordingly, if valuation is desirable or necessary, we recommend the following activities conditional on completion of Activities 1, 2, and 3.

4.2.3. Research Activity 4: Develop WTP Valuation Methods, Data, and Benefits Gap Analysis

- This activity requires input from economists with expertise in market and non-market valuation and data.
- Purpose: To assess the ability to monetize ecological benefits related to restoration actions. Also to identify knowledge gaps that, if filled, would allow for such quantification.

4.2.4. Research Activity 5: Assess Agency and Stakeholder interest in EGS Benefit Indicators Analysis

- This activity requires input from agency staff and stakeholders familiar with their regulatory, planning, and political decision criteria, as well as from local data practitioners (e.g., geographic information systems specialists from agencies or NGOs). The activity might include pilot development of benefit indicators for one or more EIPs in order to assess data availability for population, asset, and scarcity indicators.
- Purpose: To define benefit-specific populations and affected assets as well as specific demographic populations of interest, and assess data availability for population, asset, and scarcity indicators.

Tools to Quantify and Predict Ecosystem Services Responses

Our recommendation is to develop causal frameworks—in part to identify quantitative modeling needs, both in terms of biophysical and socioeconomic assessment. With those frameworks identified, analysts can search for existing research and modeling tools that allows model parameters and outcomes to be quantified. Of course, one alternative is to conduct original, in situ, empirical analysis (for example, of the effect of storm barriers on wave attenuation in New York Harbor and the corresponding reductions in property damage). However, original research is both expensive and time consuming.

Two alternatives to original, location-specific research should be noted. First, are open-source ecosystem assessment tools that allow for relatively quick assessment of biophysical relationships. Consider the best known of these tools, the Natural Capital Project's Integrated Valuation of Ecosystem Services and Tradeoffs tool (InVEST). InVEST inputs "alternative management choices" to models that then generate mapped "ecosystem service outputs." Modeling capability is available for 18 service categories. In this sense, InVEST is well-suited to the kinds of quantification we propose.

However, the tool's capabilities should be qualified somewhat. First, most of the models generate only biophysical outputs, meaning they do not generate economic or social benefit measures.[46] For example, InVEST's coastal vulnerability model produces a "qualitative estimate of exposure in terms of a Vulnerability Index," it does not produce damage avoidance benefits. As another example, the nutrient delivery ratio model generates nutrient export predictions for watershed outlets, it does not generate benefits or costs associated with that export. Similarly, the habitat quality model generates a habitat rarity measure, not the social benefits of habitat restoration or protection. Second, and as these examples demonstrate, the model outputs do not usually correspond to what we have referred to as linking outcomes. That is, they do not generate outcomes that are easy to interpret in social or economic terms. Putting a social value on changes in a coastal vulnerability index, nutrient deliveries, or rarity index will remain a challenge unless additional biophysical analysis is available to translate those outcomes into linking outcomes.

Second, the developers intentionally designed the tools to be broadly and generally applicable, rather than detailed and accurate in specific contexts. Consider again the coastal vulnerability model. As the developers clearly note, "the model does not take into account coastal processes that are unique to a region, nor does it predict long- or short-term changes in shoreline position or configuration."[47] For some audiences and applications, therefore, the models may entirely miss features considered to be important to the modeling of outcomes. It is unlikely, for example, that the Corps would rely on InVEST's coastal hydrology modeling in lieu of its own modeling capabilities, or that the National Oceanographic and Atmospheric Administration (NOAA) would adopt InVEST's habitat model to assess critical habitat needs. Another InVEST feature is that its depictions of alternative management choices are corresponding coarse. The choice is typically a land use pattern across various scenarios.

Those caveats aside, InVEST model suites are a useful and informative input to discussions of what kind of biophysical science is needed, the state of existing science, and the kinds of data available to quantify biophysical production relationships pertinent to EGS analysis. Moreover, because they are open-source and clearly documented they are convenient resources for analysts in the early stages of model development.

The second alternative to original, location-specific research is benefit transfer analysis. Benefit transfer analysis is the application of dollar benefit values found in one study to other locations, thus avoiding the need for time-consuming and costly new valuation research. However, the transfer of valuations from one ecological and social context to another is problematic, because ecosystem values are highly dependent on location. Benefit transfer involves statistical methods designed to control for similarities and differences in spatial context and adjust the transferred valuation accordingly. It is therefore a relevant strategy to consider, but not as simple as conducting a literature review and applying "known values" to a different ecological and social context.

4.3. Using EGS Analysis to Expand Support for Urban EIPs

EIPs can trigger a variety of changed ecological outcomes involving multiple cause-and-effect relationships. A consequence is that the benefits of restoration actions are distributed across various jurisdictional and stakeholder interests. The "distribution of interests," combined with regulatory and budgets constrained to support narrow agency mission stovepipes can be a significant barrier to restoration action and funding.

One way to overcome the barrier is to assemble coalitions to coordinate analysis, political support, and funding. Ecological production frameworks can help identify coalitions, communicate collective stakeholder benefits and responsibilities, and (perhaps) motivate cost-share contributions.

To see how this would work in a hypothetical example see Figure 3.

Figure 3. Example Jurisdictional and Stakeholder Analysis

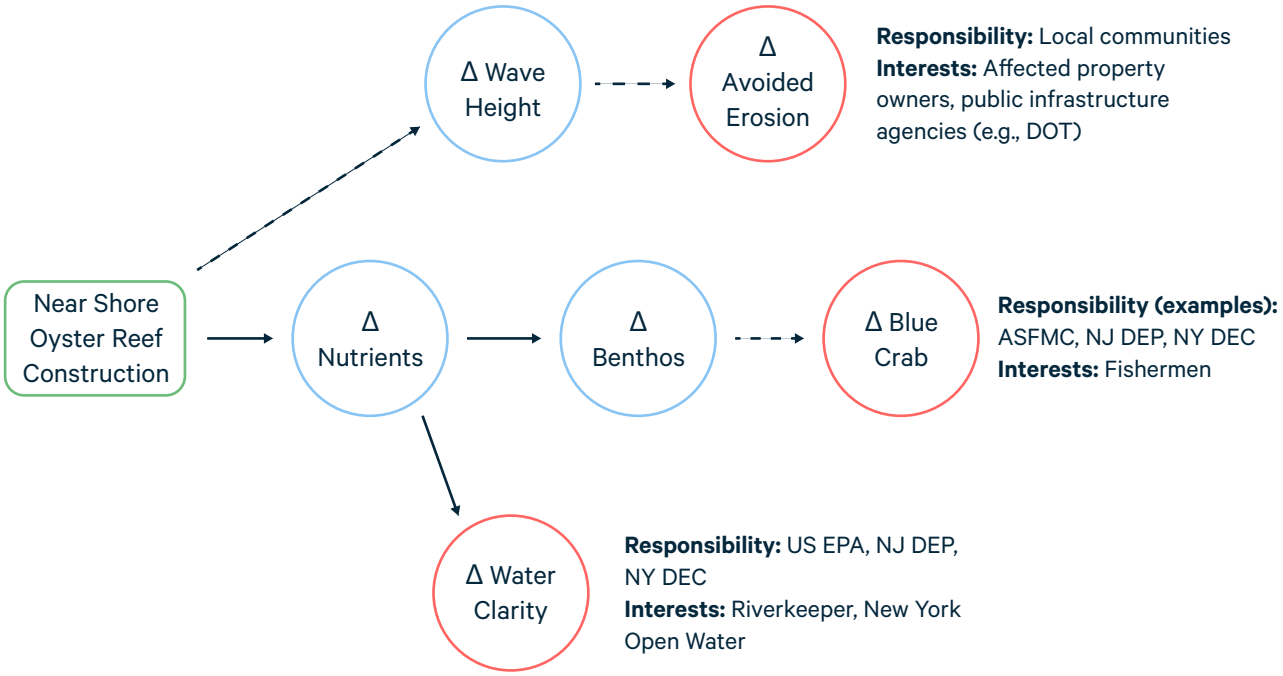


Figure 3 reproduces and annotates the simple production framework presented earlier (Figure 2). The annotations relate changed ecological outcomes to jurisdictional responsibilities and stakeholder interests. (The annotations are merely illustrative and are certainly incomplete.)

The example illustrates how a single restoration action can trigger outcomes affecting, and affected by, multiple mission agencies and stakeholder interests. A challenge is that a single agency or mission area within an agency may be solely responsible for the costs of restoration and required to justify those costs based on only one component of the benefits generated (e.g., flood protection benefits). This can lead to "incorrect" project choice and approval decisions from a social perspective, since the project's other benefits are missing from the agency's decision calculus.

One way to address the problem is to supplement lead agency funding with cost contributions from agencies and interests associated with the project's other beneficial outcomes. We do not want to overstate the ability to overcome barriers associated with stove-piped budget authority and constrained financial resources. However, jurisdictional and stakeholder analysis linked to ecological production frameworks is one way to identify and explore such cost-share opportunities.

Funding aside, jurisdictional and stakeholder analysis linked to ecological production frameworks can be a useful tool to help identify and organize coalitions supportive of restoration actions.

4.3.1. Research Activity 6: Conduct a Jurisdiction and Stakeholder Analysis

- This activity requires input from local practitioners and stakeholders familiar with the regulatory, planning, and political landscape across which ecosystem effects will arise.
- Purpose: To identify the range of stakeholder interests affected by restoration actions and government agencies with responsibility for affected natural resources.

4.3.2. Policy Analysis Option: Prepare and Advocate WRDA Language to Promote EIPs in Urban Areas

As noted earlier, modification of the AER program via an expansion of what the program considers to be "primary benefits" (i.e., expansion to include EGS benefits with the potential to increase funding for urban EIPs) is unlikely. However, an alternative strategy is to direct the Corps, in future WRDA language, to stand up a new mission focused on urban EIPs and to authorize "multi-mission" studies.

First, Congress would authorize the Corps to create a new "urban area (rivers and estuaries) estuary improvement program" (UAEIP). WRDA language might define the purpose of the UAEIP mission area as restoration of "historically compromised" ecosystem services in urban settings. Primary benefits for this mission could be the full suite of EGS, especially those relevant to urban settings. For example, water quality

and recreational use could be stressed, in addition to the current focus on commercial and property protection services in the CSFRM mission area and habitat enhancement in the AER mission area.

To move forward, this opportunity requires legal and institutional research to develop a detailed proposal for an UAEIP structure. Key elements of such a program structure include practices associated with each Corps' planning step, budget justification criteria, and cost-sharing rules.[48]

Regarding evaluation, the WRDA could direct the Corps to still evaluate and justify projects using the "federal objective,"[49] but might affirm that some benefits could be monetized while others can be reported in non-monetary terms, including benefit indicator-type assessments. The acceptable evaluation framework could be described as an adaptation of the CE-ICA. For example, imagine evaluation of an urban wetland rehabilitation EIP. The Corps could calculate monetary flood damage reduction benefits, using its standard methods. These monetized benefits could be subtracted from implementation costs, and the net costs would be used for a CE-ICA where non-monetized benefit metrics (benefit indicators), and perhaps other objectives, might be used to justify incremental costs.

Second, recall that limits on inclusion of EIPs in plan formulation are often the result of narrow mission authorities. For the CSFRM mission area only, storm damage reduction benefits are considered a "primary" concern. The AER mission focuses on nationally significant habitat benefits, which may not exist in urban areas. Use of the federal standard to define a baseline for dredged material use in the IWH mission area often makes analysis and selection of beneficial use impractical. If Congress authorized Corps' planning for multiple missions, including a new UAEIP, the barriers in each mission area to including EIPs in planning could be reduced and budgeting would be less tied to each mission area.

An existing example of multi-mission project planning and budgeting (although not technically authorized as "multi-mission") is a project in Hamilton City, California. The problem focus was initially on flood damage reduction. Initial efforts to justify the project in the CSFRM project mission found that its costs exceeded benefits. During the planning process, the Corps identified an alternative that addressed the flooding problem, but also seized an AER restoration opportunity. The plan allocated project costs to both the CSFRM and AER missions. The monetized flood risk reduction benefits justified the costs allocated to CSFEM while the habitat unit benefits justified the AER allocated costs.[50]

4.3.3. Research Activity 7: Policy Paper on Expanded Corps' Missions and Study Authorities

- Conduct a policy analysis that has three separable, but sequential, activities.
    - First support a report to document Corps' precedents, motivations, and current status of specific projects or programs that might offer lessons for a UAEIP. Two examples might include background on the Section 594 authority and the Urban Rivers Restoration Initiative.
    - Second, based on lessons learned from the first activity, host a stakeholder workshop to focus on opportunities for (and barriers to) a programmatic multi-mission authority for Corps' planning to include budgeting to promote urban EIPs nationally. The same convening should develop model language for project-specific authorizations for urban area EIPs.
    - Based on the second activity, a decision will be made to facilitate and then participate in a stakeholder advocacy process to promote a programmatic multi- mission UAEIP, or to adapt the model language to seek individual project authorizations directed to the HRE.
- Purpose: To advance support for urban EIPs within the Corps' portfolio of projects.

Appendix A. Workshop Notes (May 13, 2019)

Ecosystem Service Analyses Likely to Best Demonstrate Environmental Improvement Benefits

The Hudson River Foundation convened a group of key stakeholders to help identify activities that are likely to have the greatest biophysical impact and whose impacts can be modeled/quantified. The workshop then assumed that there is a quantifiable environmental impact, and with that assumption in mind discussed EGS socioeconomic metrics that would be most likely to be deployed in planning and used in Corps' budget decisionmaking for the IWH, CSFRM, and AER projects in the region. Based on this discussion, the following specific activities and observation are a guide for deeper exploration going forward.

Storm Surge and Flood Attenuation

- General
  - Ecological goods and services analyses may have the greatest likelihood of use in CSFRM projects.
  - Confidence in NNBFs in reducing storm surge is limited, although grey structures don't always perform as expected—and may fail.
  - The Corps' planning focus is generally for large events, not frequent nuisance flooding events, even if flood risk perception studies indicate that the latter is a greater concern of area residents.
- Biophysical modeling
  - Force, frequency, and depth are considered in most models.
  - Erosion and wave action [more typical benefits from an NNBF] are not easily modeled at a reasonable cost.
  - Data needs: seasonality to vegetation cover, changes over time, sustainability
  - Some work on reduction of frequency and impacts was done for the marsh islands.
- Social benefit indicators
  - Monetary
    - Avoided damages data are well regarded
    - Avoided mitigation costs for NNBF
    - Avoided cost of buyout program as source of value
  - Non-monetary
    - People at risk
    - Disruption of services (e.g., roadway flooding/traffic implications)

Species/Habitat (Discussion centered on dam removal/fish ladders)

- General
  - Big difference between dam removal and fish ladders
  - Removal has some negative effects—due to contaminated sediment and cultural values
- Biophysical modeling
  - USACE has model for habitat units by fish passage
  - Miles of connectivity is another measure
  - Habitat equivalency areas (HEA)/resource equivalency analysis (REA) from NOAA
- Social benefit indicators
  - Number of school groups
  - Visitors to facility

Species/Habitat (Discussion centered on salt marshes)

- General
  - Showing social values not critical for decisionmakers—they consider more habitat to be better and not a difficult argument to make
- Biophysical modeling
  - Habitat equivalency analysis/resource equivalency analysis from NOAA
  - Unclear about ability to relate production of alewife and other local forage species to game fish production or essential fish habitat.
  - Limited data on population—Essential Fish Habitat analysis does not always account for whole lifespan/habitat needs
  - The Corps models for fish may not be capable of predicting changes in population from a specific EIP
  - Consider mummichog abundance as a proxy as they spend life in marsh
  - Difficulty in scaling benefits of fish habitat
  - Carbon sequestration
- Social benefit indicators
  - Difficult to know about fishing as there is no marine license
  - Recreational birding as a possibility
  - Health benefits of contaminant remediation that is likely part of restoration
  - Habitat per capita—recognizing that many people would view habitat as having an intrinsic value
  - Sequestration of carbon as offset to emission reduction

Recreation

- General
  - Generally familiar and not challenging to make argument given unmet recreational demand
  - Density of population is the fundamental variable—everything else is just a detail, though definition of relevant population is an open question (spatial boundaries, inclusion of residents versus commuters versus other transient beneficiaries)
- Biophysical modeling
  - Have acreage and shoreline miles of waterfront parks
  - Population characteristics are simple
- Social benefit indicators
  - Enjoyment hours
  - Visitors (challenging for whole region/parks with less capacity, although use of anonymized cell phone data is growing)
  - Program visitors (e.g., we have boathouse data)
  - Intensity/capacity of stewardship activity from the US Forest Service Stewardship Mapping and Assessment Project

Appendix B. Corps' Decisionmaking: Some Basics[51]

B.1. New Start Planning

B.1.1. Authorities and Partners

The Corps has "programmatic" study authorities, but for larger projects the Corps requires a congressionally granted authorization to spend money on a project study, what the Corps call planning (investigations).[52]

A cost-share partner must pay a prescribed amount (or provide in-kind services) to most studies, the exception being studies for inland waterway improvements.

A study will result in a feasibility study report that includes information used by the administration to decide if a proposed project is worthy of being recommended to Congress for authorization for construction. Congress may also use the report as a basis for construction authorization, independent of the administration.

B.2. New Start Construction

Once authorized for construction, the Corps, OMB, and Congress rely on that same analysis, or an updated version, when making a budget allocation toward a new construction start. For projects that move to construction, a cost-share partner must also agree to pay a share of construction costs (the inland waterways trust fund acts as the cost-share partner for those projects). The preferences of the cost share partner influence the scope of the study and the alternative recommended for construction.

B.3. Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRRR)

For the CSFRM and AER missions, once construction is deemed complete, a project is turned over to a non-federal entity, most often the entity that served as the cost-share partner, for long-term stewardship (e.g., responsibility for OMRRR).

Corps-owned and operated projects include dams, inland waterways, dredged harbors, flood protection works in the lower Mississippi Valley, and a limited number of storm and flood risk management projects elsewhere in the nation. The annual Corps budget (exclusive of emergency supplemental appropriations) includes funds for OMRRR at Corps-owned facilities,[53] or for repairs to projects that qualify for federal funding for repairs.

B.4. Planning to Make a New Start Recommendation

The section discusses the six planning elements that result in a recommendation for construction authorization. The planning elements are described as if they follow in sequence, but steps are applied interactively, especially among elements three, four, and five (outlined below).

B.4.1. Element 1. Define Problems and Opportunities

A problem is a socially unacceptable level of the primary service within a mission area at the current time or in the future without any action by the Corps. This includes a high probability of flood damages in the CSFRM mission area, high or increasing shipper cost in the IWH mission area, or a less-supportive condition of aquatic habitat for one or more species relative to pre-disturbance condition. An opportunity is an expectation of increased services, relative to current or expected without action conditions, if an action is taken (e.g., an increase in waterborne freight movements as a result of dredging). The Corps also refers to problems and opportunities as the planning "purpose."

B.4.2. Element 2. Predict Future without Action Conditions

The baseline for measuring benefits and costs of any action is a prediction of the future without action levels for the identified services of concern. Corps planners use certified [54] models or prediction, unless Corps reviewers grant an exemption. Prediction model development is discussed further under element four, and then later in the report.

B.4.3. Element 3. Formulate Alternatives

Alternative plans include different mixes of separable actions predicted to affect future levels of the watershed services relative to baseline levels (i.e., without action). The Corps requires that all alternatives must be as follows:

- Complete (all components of the action necessary to provide the intended service are included in the plan);
- Effective (expected to work with "tolerable" level of model prediction uncertainty);
- Efficient (cost-effective;[55] there is no other action that can provide the same service flow for less cost); and
- Acceptable (meets legal and regulatory compliance requirements, and has support among cost share entities and the public).

B.4.4. Element 4. Predict Future with Action Conditions

Prediction requires models, and the preference is for Corps-certified models. Corps planners translate conceptual models into empirical models (statistical or mathematical process models). Empirical models may be complex and require significant amounts of data, or may be simplified in order to reduce data requirements.

Models predict how implementation of formulated alternatives will change future watershed services (those identified as a problem or opportunity). For example, models can be used to predict future waterborne commerce, flood damages, acres of habitat, and species populations relative to future conditions if the action is not taken. Models can also be used to predict changes in environmental features (watershed structure, processes, and functions) to establish environmental mitigation requirements (most often in order to replicate lost ecological structure and processes).

B.4.5. Element 5. Evaluate and Compare Plans

Evaluation requires models of the biophysical system that can predict how alternative actions affect the watershed or estuary's structure, function, and derived services. This step can also include analysis of economic benefits via valuation studies. Valuation is the development of metrics (reported as dollars or in nonmonetary units) that Corps decisionmakers use to judge the benefits of changes in service levels for comparison with expenditures required to implement the plan. Evaluation and comparison typically involve the elements described below.

Costs

Costs are the government expenditures (federal and non-federal) required to implement, operate, and maintain a project over its lifetime. If a project imposes opportunity costs (i.e., forgone societal benefits), those costs are considered project costs. If there are adverse effects on habitat, plans identify actions needed to avoid and then mitigate those effects, and the mitigation costs are added to project costs. From a practical standpoint, mitigation costs typically arise from the costs to comply with environmental laws and regulations or the costs of project features designed to avoid adverse effects on beneficiaries of existing projects.

Monetized and Nonmonetized Benefits

Note that primary benefits in the IWH and CSFRM areas are reported in dollar terms. Following standards derived from the economics literature, the Corps conceptually defines benefits as the beneficiaries' "willingness to pay" (WTP; i.e., how much income a person would be willing to give up to have an increment of a service rather than go without that increment. By this definition, ability to pay (i.e., income level) is also considered when measuring benefits in monetary terms. Individual WTP is summed over all beneficiaries to report total benefits.

In practice, the primary benefits for some services, such as in the IWH and CSFRM missions, are accepted and reported as monetized WTP measures. In the AER mission area primary benefits are reported as physical units.

Incremental Justification

In each mission area, agency analysts apply the logic of incremental justification, whereby a specific project alternative's incremental increase in costs (relative to the next least-costly alternative) is compared to the incremental benefits it generates. Incremental justification means that additional dollars for a separable project feature must be justified by the benefits that feature produces. Examples of additional (i.e., incremental) project features include adding a public overlook to a wetlands creation project; hardening coastline in a way that provides 125-year (rather than 100-year) storm protection; or increasing the number of habitat units created at a project site.

B.4.6. Element 6. Identify and Recommend a Preferred Alternative

The Corps has its own internal criteria for making a project recommendation. For the IWH and CSFRM missions the most recognized criterion is that the present value (at a specified discount rate) of monetized benefits must exceed the present value of project costs. For the AER mission, a nonmonetary metric (usually habitat units) describes project benefits, allowing projects to be ranked on the basis of "habitat units per dollar of expenditure."

The benefit–cost comparison of project alternatives is organized around meeting the "federal objective," defined as making a "contribution to national economic development (NED) consistent with protecting the nation's environment, pursuant to environmental statutes, applicable executive orders, and other federal planning requirements."[56] AER projects have an exemption for meeting the federal objective. However, as noted, the federal objective has to be met using only primary benefits (e.g., those typically expressed as habitat units).

The Corps reports can provide analyses other than NED and include them in one of three other accounts. Analyses in an environmental quality account might report biophysical measures of particular environmental outcomes (e.g., changes in nutrient concentrations). The regional economic development account reports on contributions to job creation or changes in tax revenue.[57] The account for other social effects reports how costs and benefits distribute across and within communities—geographically and demographically—as well as including other measures relevant to the decision not in any of the other three accounts.

The cost-sharing entity may prefer a different alternative, and the Corps' planning report might include other analyses that non-Corps entities use to identify its own preferred plan. However, any incremental costs for a cost-share partners preferred plan, in excess of costs for the plan that meets the federal objective, are paid by the cost-share partner.

B.5. Planning for OMRRR of Corps-Owned Projects

Projects owned and operated by the Corps include dams, inland waterways (locks, dams, and channels), harbor approach channels, flood protection works in the lower Mississippi Valley, and a limited number of storm and flood risk management projects elsewhere in the nation. The OMRRR budget is limited to use at these Corps-owned projects, and the Corps is developing an asset management approach to OMRRR planning, for all planning except dam safety and major rehabilitation (defined by costs exceeding $20 million). Budget decisions for major rehabilitation follow the six-element planning process. This is also true for the dam safety program—although for dam safety, the focus is on the possibility of a dam overtopping and/or breaching, and life safety risk is the primary problem to be addressed.[58]

However, the OMRRR planning process follows the logic of the six-element planning process, although many of the elements are based on professional judgment more than analytical models.[59] Each project has reliability expectations based on its design, and performance expectations (e.g., expected benefit stream) from that design consistent with the original authorization. Reliability might be about the ability of a lock to operate without constant repair, or about the frequency of sedimentation in a navigation channel. Each field office assesses the condition of the facilities under its jurisdiction, first focusing on reliability. If there is a concern for reliability, the analysis then turns to the consequences for the intended project users (beneficiaries).

At this point, the actual use of the asset in a future-without-action condition becomes the focus. Consider the IWH, which demands most of the OMRRR funds, aside from dam safety. If an authorized harbor channel depth will not be maintained and shipping costs will rise, then there may be a problem that calls for a consideration of dredging, traffic management (e.g., riding tides), or some other alternative. However, if a shipping channel has an authorized controlling depth, but if few boats traveling a channel require that depth, then there is no problem and no alternatives might be considered.[60]

Continuing with the harbor dredging example, a dredging alternative would be formulated. If the costs are deemed "reasonable" (including meeting the federal standard for dredge material handling) and the channel is deemed to support "high-value" traffic, then the dredging alternative would be a preferred plan.

B.6. Budgeting

B.6.1. Construction Budget Justification Criteria

At present, when proposing projects to fund under a budget constraint, OMB requires the Corps to rank IWH and CSFDRM projects by benefit–cost ratio of 2.5 (based on primary benefits). However, in recent years, IWH and CSFDRM new starts have had benefit–cost ratios less than that (but above 1, based on primary benefits) when those

projects also provided significant environmental or lifesaving benefits.[61] In the AER business line, OMB has ranked projects by cost per habitat unit (in dollar terms), as long as the AER project is supporting "nationally significant" species or ecosystems.

B.6.2. Budgeting for OMRRR

The OMRRR budget is built from the bottom up based on requests from Corps' field offices. As budget requests pass from field offices to headquarters, priorities are set so that the aggregated total funding request fits into a limited OMRRR budget.

After the complete annual budget is in place for the Corps, OMRRR funds are distributed to the field units. However, during the time between building the case for the OMRRR budget and receiving the funds, conditions in the watershed may have changed, Therefore, the field units have significant discretion to deciding where to spend OMRRR funds.

Notes

1 **https://www.hudsonriver.org/article/hrecrp**

2 **https://www.publications.usace.army.mil/Portals/76/Publications/Miscellaneous/FY_2015_USACE_Annual%20CW_Financial_Report.pdf**

3 Shipping channels are dredged to a reliable depth to support marine transportation, in coastal areas, for example.

4 Storm and flood risk management results from structures are built to hold water, redirect flows, or resist storm surge as well as providing other services. For example, water supply reliability is increased by reservoirs that store water in wet periods to be used in dry periods. Hydroelectric power production can be realized at a navigation locks and dam complex, or as a reservoir is operated.

5 Recent years have brought attention to the unintentional effects of human activity, such as when changes to a river's flow regime changes the composition of fish and wildlife species that live in the watershed. In urban areas, land use changes driven by project-stimulated economic activity can accelerate runoff of nutrients and sediments. Contaminants can cause changes in the water itself, making recreation with water contact a health risk. Sediments fill in riparian areas and river channels, and combined with contaminant runoff, can compromise the life cycles of valued fish and wildlife species.

6 For example, see: **https://floodplainlawblog.lexblogplatformthree.com/wp-content/uploads/sites/475/2017/06/Advancing-CW-Project-Delivery_21Jun17-Memo.pdf.** Several published and unpublished reports and memoranda describe EGS analysis and the Corps possible interest in EGS, but none of the results or recommendations have been incorporated in planning or budgeting practice. For example, see: **http://www.nad.usace.army.mil/Portals/40/docs/ComprehensiveStudy/August%202013%20Webinar/8-27-13%20Task%202B%20EGS%20Perf%20Metrics%20-%20Burks-Copes%20V3.pdf**

7 See: **https://planning.erdc.dren.mil/toolbox/smart.cfm?Section=9&Step=1** and

https://planning.erdc.dren.mil/toolbox/library/FactSheets/RiskInformedPlanningFactSheet_Nov2017.pdf

8 **https://www.epa.gov/cwa-404/role-federal-standard-beneficial-use-dredged-material**

9 **https://www.publications.usace.army.mil/portals/76/publications/engineermanuals/em_1110-2-5025.pdf**

10 The Federal standard is the dredged material display option that has the lowest cost consistent with meeting sound engineering practice and compliance with environmental regulations.

11 The Congress authorized, and the Corps created, a beneficial use pilot programs, soliciting and ranking beneficial use projects in priority. However, at this time there are no funds to implement the priority pilot projects.

12

https://www-cdn.law.stanford.edu/wp-content/uploads/2015/04/FEMA_Analysis_Nature-BasedStrategies_Formatted_Combined.pdf

https://www.eenews.net/greenwire/2018/05/21/stories/1060082253

13 Recently the Government Accountability Office (GAO) issued a report on whether USACE planning gives adequate attention to NNBF actions. **https://www.gao.gov/assets/700/698019.pdf**

14 Section 1149 of the 2018 authorization legislation reinforces Section 1184 and appears to expand the coverage to the AER mission. The text of Section 1149 reads: "This section directs the Secretary to consider, with the consent of the non-Federal interest, a natural feature or nature-based feature when conducting a project to restore and protect an aquatic ecosystem or estuary, pursuant to section 206 of WRDA 1996. In carrying out a feasibility report for flood risk management or hurricane and storm damage risk reduction, the Secretary shall consider and may include the use of both traditional and natural infrastructure alternatives."

15 NNBFs might be successful if there are few fixed assets exposed and few people who either can readily move out of harm's way after a storm warning or can be permanently moved as part of the plan. In this situation, the uncertain effectiveness of the NNBF is of less concern because of the limited consequences of NNBF non-performance. However, such a plan would need to be planned and then justified as an AER and CSFRM project, and the costs of protecting assets and populations would be a cost of the AER project.

16 Another competitive disadvantage of NNBF in an urban environment is their relatively large geographic footprint. Most NNBF rely on a fairly large spatial area to function most effectively (e.g., the 20+ miles of marshland south of New Orleans). In urban environments, real estate is often a key cost driver of project benefit–cost ratios. For this reason, NNBF are often at a relative disadvantage in high-cost urban environments.

17 At this time, there is an assumption, not a clear demonstration, that the storm damage reduction benefits exceed projects costs and are equivalent between the alternatives.

18 **http://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/South-Shore-of-Staten-Island/**

19 Generally, the lower the return frequency/larger the storm, the less likely NNBFs will contribute to meeting a storm surge reduction target, given uncertainty.

20 Also, NNBFs may take time to become effective, so there is a lag between the investment and the realized effectiveness, putting aside model uncertainties (wetlands need to develop, as do oyster reefs). This lag will reduce the present value benefits when compared with the benefit calculation for a gate or seawall.

21 **https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/3442/**

22 A recent news article cited NOAA fisheries as making this general statement, "15 feet of marshland can absorb about 50 percent of a wave's energy". **http://www.staugustine.com/news/20180831/st-augustine-officials-in-talks-with-dutch-researchers-on-sea-level-rise-solutions**

23 **https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newyork/climate-energy/natural-infrastructure-study-at-howard-beach.xml**

24 In the IWH and CSFDR mission areas, monetary measures of benefits are used to justify the incremental costs, but not in AER. In AER, the Corps is only interested in habitat metric (and maybe storm reduction) services—so has no interest in predicting other services that might be realized.

25 This is what EPA and other agencies call "knee of the curve" justification.

26 One person interviewed used the term "natural heritage" to describe what is meant by "significant," suggesting an analogy to how cultural world heritage sites are unique and of special value.

27 There are "small" stand-alone and independently justified AER projects that may not rise to national significance for funding. This set of projects would, for example, include Liberty State Park. Outside of Hurricane Sandy emergency supplemental finds, few projects in the Hudson River area even received investigation funds for feasibility studies in 2015–16 budget: Hudson River habitat restoration, NY ($52K in 2016); HRE lower Passaic

River, NY and NJ ($52K in 2015); HRE Hackensack meadows, NY and NJ ($202K in 2015). These are extremely small amounts of funding. In FY 2016 and 2015, only one AER project in NY/NJ received construction funds: Lower Cape May Meadows, NJ ($7.4M in 2016). More generally, AER study budgets are generally going down nationwide. FY19 has only one AER general investigation study.

28 A Corps supported research paper on this possibility has been reviewed and is in draft form. McKay, et.al, 2019, Incorporating multiple lines of evidence in urban stream restoration decision-making, in Review, Anthropocene.

29 Many restoration practitioners rely upon habitat units because they are well understood within the restoration community and are relatively easy to quantify. However, habitat units are only a rough proxy for what directly matters to people (e.g., species abundance), are not easily interpretable by lay audiences, and are thus difficult to value economically.

30 "Willingness to pay" for ecosystem services is the conceptual standard employed by the Corps to measure these values.

31 An exception would be the use of engineering estimates of avoided costs as a way to measure benefits. The Corps measures the benefits of flood damage reduction as the present value of future avoided repair and replacement costs, implicitly assuming (in effect) that willingness to pay is just equal to the avoided costs, although other measurement methods (e.g., land price analysis, surveys, voting behavior) may generate different benefit estimates.

32 The left column corresponds to what might be referred to as "natural capital" actions, while the right column corresponds to regulatory or constructed "built capital" actions. In our view, the distinction between the two types is not particularly important since both categories of action can address Corps objectives ("problems and opportunities").

33 For example, instead of referring generically to "oyster reef restoration," more detail could be provided about oyster types, reef engineering features, and location.

34 For example, health impacts could be distinguished by type and whether or not they are triggered by pollutants or pathogens.

35 The Corps NNBF report provides additional illustrations. **https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/3442/**

36 We note, however, that a "small" ecological change (in biophysical terms) does not necessarily imply a small change in economic terms. Nor does a "large" change in biophysical terms imply a large economic benefit.

37 **https://www.sciencedirect.com/science/article/pii/S0272771418301057?via%3Dihub**

38 We emphasize that the economic value of natural resources and ecological systems goes well beyond the value of consuming natural resources such as water, lumber, and food. It also includes the value associated with non-consumptive natural resource uses (e.g., for aesthetic or recreational enjoyment); the intrinsic value of protecting nature for its own sake; and the bequest value of passing a healthy environment along to our descendants.

39 See discussion of non-monetary benefit indicators below.

40 WTP methods can be used to measure both the benefits of what people believe to be an environmental improvement or what people believe to be the benefits foregone from an environmental harm.

41 WTP is not the same thing as what people actually pay (i.e., prices).

42 As an aside, we note that economic methods should not—and cannot—be used to measure the value of entire ecosystems. Rather, they are used to measure the incremental benefit of ecosystem changes triggered by specific actions, which we defined earlier as

"outcome Δs."

43 Benefit indicators are proxies for WTP. However, they tell us nothing about the underlying preferences for goods and services. Thus, they provide some information relating to WTP, but by themselves do not allow for monetary valuation.

44 As argued earlier, ecological production analysis and linking outcomes should be spatially and temporally explicit. This is also true of their associated benefit indicators. Location- and time-specific benefit indicators help us understand the larger social and physical landscape so that we can better assess the relative importance of particular services in particular places.

45 As an example, recreational fishery enhancements in locations closer to public water access (e.g., ramps, docks, and public parks) may be more valuable than enhancement in more inaccessible areas.

46 See the InVEST User's Guide at http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/

47 For a comparison of InVEST and another ecosystem services modeling platforms' outputs, see Bagstad, Kenneth J., Darius J. Semmens, and Robert Winthrop. 2013. "Comparing Approaches to Spatially Explicit Ecosystem Service Modeling: A Case Study from the San Pedro River, Arizona," in Ecosystem Services, volume 5 (September): 40–50.

48 An analogy is the Corps' Section 594 that provides the authority to assist public entities with design and construction of environmental infrastructure projects. The authority includes wastewater treatment and related facilities; sewer outflow; water supply; storage treatment and related facilities; and other water resource protection and development efforts. **https://www.lrh.usace.army.mil/Missions/Civil-Works/Current-Projects/Env-Infrastructure-for-Ohio-594-Program-/**

49 Also, evaluation that focused on EIPs for disadvantaged communities could be required.

50 **http://www.chicoer.com/restoration-project-key-to-new-j-levee-construction**

51 For an extended discussion of many of the points summarized in this section see: **https://www.everycrsreport.com/reports/R41243.html**

52 Planning funds are provided though annual appropriation or through an emergency supplemental appropriation.

53 When rehabilitation costs exceed $20 million, the funds must be allocated from the construction budget.

54 **https://planning.erdc.dren.mil/toolbox/mobile/current.cfm?Title=Model%20Certification&ThisPage=ModelCert&Side=No** The model certification process might constrain innovation and adoption of new methods but, at the same time, can protect the agency analysts from the being questioned by project critics about the validity of model results.

55 Costs are financial expenditures made by a government entity, a private entity, or a combination in order to secure benefits; cost-effectiveness means that the alternative has the lowest expenditure necessary to achieve a single, measurable goal (such as acres of restored wetland, or level of flood protection).

56 The term "national economic development" can be misleading. The actual measurement of benefits is conceptually based on WTP. Changes in national economic development (increase in GDP, for example) are not how benefits are to be measured.

57 Economic development analysis typically relies on a different set of tools (e.g., input-output models) and data than the "benefit analysis" described above. There is an opportunity for evaluation and comparison to be based on other objectives, but as will be noted, the focus on the "federal objective" and the particular criteria used in the AER mission limit what is considered for budgeting.

58 **https://www.usace.army.mil/Missions/Civil-Works/Dam-Safety-Program/**

59 This is a highly general description of the Corps asset management approach still under development. **https://operations.erdc.dren.mil/pdfs/assetmgmt-brochure.pdf**

60 A similar example could be developed for locks and dams or for Corps-owned levees.

61 Funding through an emergency supplemental appropriation may trigger use of different criteria for project selection, and no cost-share partner may be required. However, the implementation guidance for Sandy investigations ("Applicable Policies and Guidance-Except as otherwise noted") says "Ongoing studies will be undertaken in accordance with existing CW policies and guidance and incorporate SMART planning."