United States Government Accountability Office

Report to Congressional Requesters

March 2019

ARMY CORPS OF ENGINEERS

Consideration of Project Costs and Benefits in Using Natural Coastal Infrastructure and Associated Challenges

Accessible Version

GAO-19-319

GAO Highlights

Highlights of GAO-19-319, a report to congressional requesters

March 2019

ARMY CORPS OF ENGINEERS

Consideration of Project Costs and Benefits in Using Natural Coastal Infrastructure and Associated Challenges

Why GAO Did This Study

The Corps constructs water resources projects to reduce risks to coastal communities from storm damage, among other things. These projects can involve building hard structures, such as seawalls, to protect against flooding and wave damage. The Corps and some state and local agencies are increasingly considering using natural infrastructure, such as wetlands, to reduce risks from coastal storms and flooding.

GAO was asked to review the uses, costs, and benefits of natural coastal infrastructure for the Corps' coastal storm and flood risk management projects. This report describes (1) how the Corps considered costs and benefits for selected projects that used natural infrastructure and (2) challenges the Corps faces in developing cost and benefit information for using natural infrastructure and steps taken to address them.

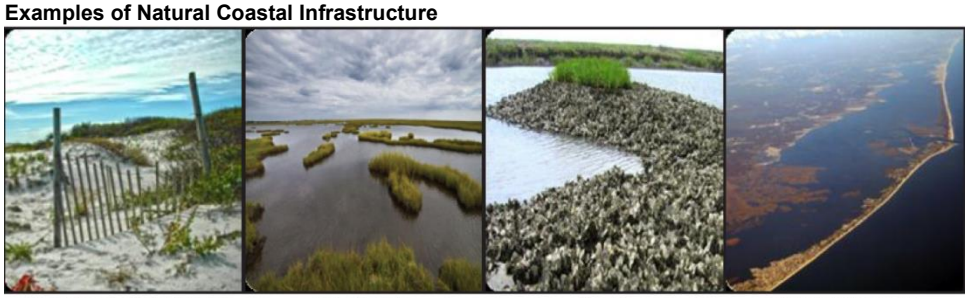
GAO reviewed Corps guidance; obtained information on projects that used natural infrastructure and received funding from fiscal years 2012 through 2017; randomly selected eight coastal storm and flood risk reduction projects from the Atlantic, Gulf, and Pacific coasts; and reviewed each project's planning documentation and economic analyses. Findings from these projects are not generalizable to all Corps' projects. GAO also reviewed economic literature, reviewed Corps documents related to the use of natural infrastructure, and interviewed Corps officials and stakeholders with experience in using natural infrastructure.

View GAO-19-319. For more information, contact Anne-Marie Fennell at (202) 512-3841 or fennella@gao.gov.

What GAO Found

The U.S. Army Corps of Engineers (Corps) typically identified project costs and damage reduction benefits for the eight projects using natural infrastructure that GAO reviewed. In selecting projects, the Corps is to conduct economic analyses of project alternatives, which may include hard structures, natural infrastructure, or a combination, to compare their costs and benefits. Corps guidance states that for coastal storm and flood risk management projects it is to select the alternative determined to have the maximum net benefits (benefits minus project costs). The Corps calculated project costs for the eight projects, such as planning, design, construction, and maintenance costs. It calculated damage reduction benefits for seven projects by estimating reduced damages to existing structures in the project area, including to homes and commercial buildings. Corps guidance allows the economic analysis to also include incidental benefits of a project, and four projects incorporated recreational benefits of alternatives, such as increases in recreational visits because beaches would be larger. The Corps did not include other types of incidental benefits, such as environmental or other social benefits, for the eight projects. Corps documentation for one project identified environmental benefits of constructing wetlands as part of the project, such as improving ecosystems and filtering water. However, Corps officials said they did not incorporate these benefits into the economic analysis because the benefits could not be monetized.

Examples of Natural Coastal Infrastructure



Beaches and dunes | Wetlands | Reefs | Barrier islands

Source: U.S. Army Corps of Engineers. | GAO-19-319

The Corps faces challenges in developing cost and benefit information for some types of natural infrastructure and has initiated steps to address this. For example, a 2015 Corps report identified knowledge gaps in understanding how natural coastal infrastructure, such as wetlands, may perform during coastal storms. These knowledge gaps make it challenging for the Corps to develop cost and benefit information for some natural infrastructure alternatives and compare them to other alternatives, such as those that use hard infrastructure. The Corps recognizes the need to obtain additional data to better develop cost and benefit information and has begun taking steps to do so. For example, in 2018, the Corps initiated a project to help identify natural infrastructure knowledge gaps and prioritize key areas for research. The Corps plans to incorporate information gathered from this project into a strategic plan that is intended to help inform research funding decisions for fiscal year 2020, according to a Corps official.

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Abbreviations

Corps	U.S. Army Corps of Engineers
NOAA	National Oceanic and Atmospheric Administration
Planning Guidance	U.S. Army Corps of Engineers *Planning Guidance Notebook*
Principles and Guidelines	U.S. Water Resources Council's 1983 *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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March 28, 2019

The Honorable Tom Carper
Ranking Member
Committee on Environment and Public Works
United States Senate

The Honorable Sheldon Whitehouse
United States Senate

Coastal areas are home to a considerable portion of the U.S. population, with about 40 percent of the population living in coastal shoreline counties and contributing to the production of $8.3 trillion of goods and services annually.[1] Coastal storms and flooding pose significant risks to coastal communities and may cause substantial property damage. For example, according to the National Oceanic and Atmospheric Administration (NOAA), the three largest hurricanes during the 2017 Atlantic hurricane season caused an estimated $265 billion in damage in the United States. Moreover, according to the U.S. Global Change Research Program's 2018 Fourth National Climate Assessment, damage to coastal areas from extreme weather events combined with rising sea levels threaten approximately $1 trillion in national wealth held in coastal real estate.[2]

State and local governments have primary responsibility for managing U.S. coastlines, but the federal government plays a key role in implementing projects to reduce coastal risks from storms and floods. In particular, the U.S. Army Corps of Engineers (Corps), within the

[1]National Oceanic and Atmospheric Administration, Office for Coastal Management, *Economics and Demographics*, accessed November 15, 2018, https://coast.noaa.gov/states/fast-facts/economics-and-demographics.html.

[2]D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.), *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Washington, D.C.: U.S. Global Change Research Program, 2018). In February 2013, we placed Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks on our High-Risk List. In our High-Risk Report, we identified a number of areas in which the federal government faces fiscal exposure from climate change risks, including its role as the owner and operator of extensive infrastructure and federal property vulnerable to climate impacts. GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others*, GAO-17-317 (Washington, D.C.: Feb. 15, 2017).

Department of Defense, constructs water resources projects to help reduce the risks from coastal storms and flooding as well as to meet other objectives,[3] including restoring ecosystems and maintaining navigation throughout the nation's ports and waterways. For decades, the Corps has used hard infrastructure (e.g., seawalls and levees) as well as beaches and dunes to help reduce the risks from coastal storms and flooding.[4] The Corps also helps to repair infrastructure damaged by natural disasters. For example, in response to natural disasters in 2017, the Corps allocated approximately $645 million in supplemental appropriations for emergency repairs for flood control and coastal risk reduction projects.[5]

Over the last several years, some federal, state, and local governments, as well as nongovernmental organizations and academia, have increasingly supported using natural infrastructure as an alternative to hard infrastructure for reducing risks in coastal areas. Natural infrastructure includes (1) natural features that may provide coastal risk reduction and that are created over time by physical, biological, geologic, and chemical processes operating in nature or (2) nature-based features created by human design, engineering, and construction to provide specific services, such as coastal storm risk reduction.[6] Natural infrastructure may involve using a variety of natural features, including beaches, dunes, wetlands, reefs, and aquatic vegetation. Natural features can also be combined with hard infrastructure to create a hybrid approach for reducing the risks to coastal areas from coastal storms and flooding. Studies have shown that using natural features, such as wetlands and marshes, can help reduce the risks to coastal communities from storms

[3]The Corps' water resources projects meet one or more of the following objectives: (1) coastal storm risk management, (2) flood risk management, (3) navigation, (4) ecosystem restoration, (5) hydroelectric power generation, (6) water storage, and (7) recreation.

[4]According to a 2014 National Academy of Sciences report, the Corps had been using beaches and dunes for several decades and this usage has increased over time. See National Research Council, Committee on U.S. Army Corps of Engineers Water Resources Science, *Engineering and Planning: Coastal Risk Reduction, Reducing Coastal Risk on the East and Gulf Coasts* (Washington, D.C.: The National Academies Press, 2014).

[5]This estimate includes 81 projects for coastal and inland areas in 16 states and Puerto Rico, according to a Corps July 2018 budget document.

[6]The Corps generally refers to natural infrastructure as natural and nature-based features. This report focuses on the potential use of natural infrastructure in marine coastal environments in the contiguous United States, excluding freshwater coasts, such as the Great Lakes.

and flooding and provide other benefits, such as support for fisheries, recreational opportunities, and carbon sequestration.[7]

You asked us to review the uses, costs, and benefits of natural coastal infrastructure for the Corps' coastal storm and flood risk management projects. This report describes (1) how the Corps considered costs and benefits for selected projects that used natural infrastructure and (2) challenges the Corps faces in developing cost and benefit information for using natural infrastructure and steps taken to address them.

To describe how the Corps considered costs and benefits for selected projects that used natural infrastructure, we reviewed Corps guidance on its process for planning water resources projects. We also obtained descriptive information—such as the location, purpose, and types of infrastructure used for projects—from each of the Corps' coastal districts[8] that used natural infrastructure and had expenditures from fiscal years 2012 through 2017.[9] We compiled this information into a list of 179 projects and analyzed it to select specific projects for further review. From this list, we excluded projects without a coastal storm or flood risk

[7]See, for example, National Research Council, *Coastal Risk Reduction*; Craig E. Landry, *Coastal Erosion as a Natural Resource Management Problem: An Economic Perspective, Coastal Management* (2011); and U.S. Department of Agriculture/Economic Research Service, *Targeting Investments to Cost Effectively Restore and Protect Wetland Ecosystems: Some Economic Insights* (2015).

[8]The Corps does not have a centralized database with information on projects that use natural infrastructure. Corps officials said that as of November 2017 they were beginning to develop approaches for tracking projects that use natural infrastructure in response to reporting requirements in section 1184(c) of the Water Infrastructure Improvements for the Nation Act. Pub. L. No. 114-322, § 1184(c), 130 Stat. 1628, 1679 (2016).

[9]Corps officials stated that the Corps has constructed projects using natural infrastructure, such as beaches, for decades. We requested information on projects using natural infrastructure that had expenditures from fiscal years 2012 through 2017. The list of projects that the Corps provided included projects that may have begun construction or completed initial construction before 2012. The list included projects with different objectives related to the Corps' business lines of coastal storm risk management, flood risk management, ecosystem restoration, and navigation.

reduction objective.[10] This resulted in 79 projects with coastal storm and flood risk management objectives. To select specific projects for further review, we then categorized projects by Corps district to identify districts with the highest number of coastal storm and flood risk management projects. We separated districts by their coastlines (Atlantic, Gulf, and Pacific) and selected the district on each coastline with the highest number of projects.[11] For each selected district, we randomly selected two projects with a coastal storm and flood risk management objective for review, for a total of eight projects (see table 1).[12]

Table 1: Selected Corps Projects to Manage Coastal Storm or Flood Risks

Coast	Corps district	Project name
Atlantic	New York	Atlantic Coast of New York, East Rockaway Inlet to Rockaway Inlet and Jamaica Bay (Jamaica Bay)
Atlantic	New York	Union Beach, New Jersey (Union Beach)
Atlantic	Philadelphia	Lower Cape May Meadows - Cape May Point (Lower Cape May)
Atlantic	Philadelphia	Townsends Inlet to Cape May Inlet (Townsends Inlet)
Gulf	Jacksonville	Sarasota County Florida Hurricane and Storm Damage Reduction Project Lido Key (Lido Key)
Gulf	Jacksonville	Manatee County Florida Cedar Hammock (Wares Creek)

[10]Corps projects with navigation and ecosystem restoration objectives may use natural infrastructure. However, we excluded these projects because Corps planning processes for these business lines do not specifically analyze or document benefits of risk reduction for these projects. For example, an ecosystem restoration project to restore a wetland may provide erosion or storm protection benefits, but the Corps does not estimate or formally consider these benefits in its project planning. In addition, we excluded a small number of projects from Puerto Rico as well as several projects that we identified after further review that did not use natural infrastructure.

[11]About 75 percent of the projects that the Corps identified were on the Atlantic coast, and therefore we chose two districts on the Atlantic coast (and one district each from the Gulf and Pacific coasts) to account for the distribution of projects. For the Jacksonville District, we identified the county in which each project was located and determined whether the county was on the Gulf or Atlantic coast. We divided the Jacksonville District into two components, one for each coast, to identify and categorize projects.

[12]For the Corps' Los Angeles District, we obtained documentation for one project, but the other selected projects in the district were early in the planning process and as a result did not have documentation for review. Therefore, we selected a project from the Seattle District, which had the next highest number of projects on the Pacific Coast in order to review two projects from that coast.

Coast	Corps district	Project name
Pacific	Los Angeles	Encinitas - Solana Beach Coastal Storm Damage Reduction Project (Encinitas-Solana Beach)
Pacific	Seattle	Shoalwater Bay Shoreline Erosion Flood And Coastal Storm Damage Reduction Shoalwater Bay Indian Reservation (Shoalwater Bay)

Source: GAO analysis of the U.S. Army Corps of Engineers' (Corps) water resources planning documentation. | GAO-19-319

For each of the eight projects, we obtained and analyzed information on (1) the location and purpose of the project, (2) how the Corps identified and considered project alternatives, and (3) the economic analysis conducted. For example, to analyze the Corps' economic analysis, we reviewed the types of costs and benefits the Corps analyzed for each project, and whether the Corps used standard approaches of economic analysis outlined in the agency's guidance, such as comparing project results to expected conditions without the project. We interviewed Corps officials at the districts with knowledge of the projects and relevant Corps policies. In addition, we interviewed nonfederal sponsors for three projects with planning documentation issued since 2007 (10 years prior to our review) for their perspective on how the Corps considered the costs and benefits for the projects.[13] The findings from our analysis of the eight selected projects are not generalizable to all Corps projects with coastal storm and flood risk management objectives, but provide illustrative examples of how the Corps considers the costs and benefits for a geographically diverse range of randomly selected projects that used natural infrastructure. See appendix I for more information about the eight projects we reviewed.

To describe challenges in developing cost and benefit information for using natural infrastructure, we conducted a literature review, reviewed Corps documents related to the use of natural infrastructure, and interviewed Corps officials and stakeholders with experience in using natural infrastructure. To conduct the literature review, we searched the ProQuest, Scopus, Organisation for Economic Co-operation and Development, and the World Bank databases for economic articles using search terms such as coastline, natural infrastructure, and green infrastructure. Our initial searches identified 98 studies that we reviewed to determine if they were (1) published after 2010, (2) peer reviewed, and (3) focused on analyzing the economic costs and benefits associated with using natural infrastructure for coastal storm and flood risk reduction in

[13]We selected these nonfederal sponsors because their planning documentation was the most recently issued of the eight projects.

the United States. Based on the application of these criteria, we identified six studies that met our selection criteria for in-depth assessment. To review these studies, we compared their assessment of benefits and costs of using natural coastal infrastructure with relevant federal guidelines and leading practices established by the Office of Management and Budget, GAO, and others. Specifically, we assessed the extent to which the studies included the elements of an economic analysis as defined in GAO's Assessment Methodology for Economic Analysis[14] and consistent with Office of Management and Budget Circular A-94.[15] Based on our review, we determined that the six studies are sufficiently reliable for purposes of this report.

In addition, we reviewed Corps documents identifying challenges associated with using natural infrastructure.[16] We also interviewed Corps officials with experience in researching natural infrastructure and constructing projects about any challenges related to using natural infrastructure. Finally, we interviewed a nongeneralizable selection of stakeholders to obtain additional perspectives on any challenges related to identifying the costs and benefits of using natural infrastructure. We identified stakeholders from our review of economic literature. Specifically, stakeholders we interviewed included officials from NOAA's Office for Coastal Management and researchers from the University of California Santa Cruz, the University of Minnesota, the Environmental Defense Fund, and The Nature Conservancy. To identify any steps the Corps has taken to address these challenges, we interviewed Corps officials from the Civil Works Directorate and the Engineer Research and Development Center about the agency's initiatives and obtained

[14]GAO, *Assessment Methodology for Economic Analysis*, GAO-18-151SP (Washington, D.C.: April 2018). The methodology provides a framework for assessing the sufficiency of economic analyses, including cost-benefit and cost-effectiveness analyses. GAO developed this methodology by synthesizing economic concepts identified in federal and international agency guidance and by consulting with experts on economic analysis.

[15]Office of Management and Budget, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* OMB Circular No. A-94 (October 1992).

[16]See, for example, Todd S. Bridges, Paul W. Wagner, Kelly A. Burks-Copes, Matthew E. Bates, Zachary A. Collier, Craig J. Fischenich, Joe Z. Gailani, Lauren D. Leuck, Candice D. Piercy, Julie D. Rosati, Edmund J. Russo, Deborah J. Shafer, Burton C. Suedel, Emily A. Vuxton, and Ty V. Wamsley, *Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience*, ERDC SR-15-1 (U.S. Army Corps of Engineers, Engineer Research and Development Center, January 2015).

supporting documentation, where available.[17] In identifying challenges associated with natural coastal infrastructure, we recognize that the Corps may face other challenges in certain situations that we did not identify through our document review, literature review, or interviews.

We conducted this performance audit from July 2017 to March 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform our audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Coastal communities face hazards from coastal storms and flooding that can cause loss of life, property damage, and damage to the environment. More specifically, coastal communities face threats from erosion and damages from waves, wind, and storm surges. For example, during Superstorm Sandy in 2012, shoreline water levels rose across the East Coast, causing billions of dollars in property damage to homes and businesses.[18] These threats can be exacerbated by several factors, including sea level rise and commercial and residential development, according to Corps documents on coastal risk reduction and resilience. For example, rising sea levels increase the risks from regular tidal flooding and coastal storms and new construction along coastlines can increase the number of people and buildings at risk from the storms.

The Corps constructs projects to help reduce the risks from coastal storm hazards and mitigate erosion, wave damage, and flooding, which may

[17]The Corps' Civil Works Directorate is responsible for implementing water resources projects. The Engineer Research and Development Center conducts research to support the Civil Works program, among other Department of Defense programs.

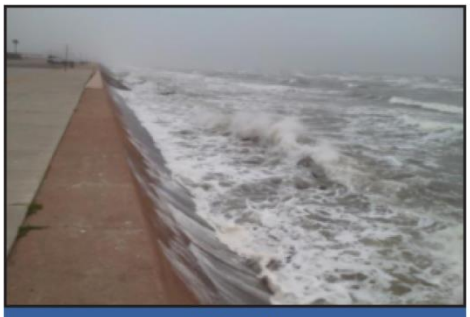
[18]According to NOAA's estimates, Superstorm Sandy resulted in approximately $65 billion in economic damages. National Oceanic and Atmospheric Administration, National Hurricane Center, *Costliest U.S. Tropical Cyclones Tables Updated*, accessed January 15, 2019, https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf.

include the use of hard structures.[19] The Corps has decades of experience developing projects that use hard structures, such as revetments, seawalls, and storm surge barriers, to reduce the risks from coastal storm hazards, according to a 2014 report by the National Academy of Sciences (see fig. 1).[20]

Figure 1: Examples of Hard Infrastructure the Corps May Use for Coastal Storm and Flood Risk Reduction

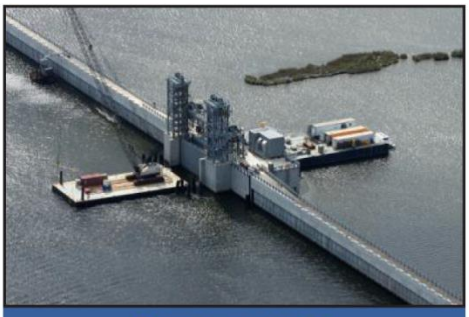
Revetment

Revetments are onshore structures typically used to reduce risks of erosion on shorelines.



Seawall

Seawalls are onshore structures built parallel to the shore that can reduce risks of waves overtopping the shore and flooding land behind the seawall.



Storm surge barrier

Storm surge barriers are typically used with levee systems to reduce the risks of stormwater moving up waterways (e.g., the entrance to a bay) and causing flooding.

Source: U.S. Army Corps of Engineers (Corps) documents. | GAO-19-319

Natural infrastructure can also be designed and developed for coastal storm and flood risk reduction purposes. Natural infrastructure can involve several types of natural features that have the potential to reduce risks to coastal areas from storms (see fig. 2). Diverse natural features occur in different areas of the United States. For example, some areas along the Florida Gulf Coast are host to mangroves—coastal wetlands found in tropical and subtropical regions—that can reduce the impacts of high energy waves from storm surges. The extent to which natural infrastructure can reduce risks to coastal areas from storms and flooding depends on the types of natural features being used. For example, underwater vegetation, such as seagrass, has less capacity to reduce

[19]According to a Corps document on coastal risk reduction, nonstructural measures can also be used to reduce risk from coastal hazards. For example, nonstructural measures that can reduce the consequences of flooding include establishing flood warning systems, regulating flood plain management, establishing flood preparedness plans, or relocating existing structures.

[20]National Research Council, *Coastal Risk Reduction*.

wave energy than a coral reef, which is a hard underwater structure, according to scientific studies.

Figure 2: Examples of Natural Infrastructure the Corps May Use for Coastal Storm and Flood Risk Reduction

Beaches and dunes

Beaches have the potential to reduce risks from coastal storms because their sloping bottoms cause waves to break, thereby dissipating wave energy.

Wetlands

Wetlands have the potential to decrease the speed of waves from coastal storms and reduce the risks of inland flooding.

Reefs

Reefs, including coral and oyster reefs, can serve as barriers causing waves to break, thereby dissipating wave energy.

Source: U.S. Army Corps of Engineers (Corps) documents. | GAO-19-319

According to a 2014 National Academy of Sciences report, in addition to reducing the risks of storms and flooding for coastal communities, projects using natural infrastructure may provide other benefits, depending on the type of natural feature associated with the project.[21] Among other things, natural infrastructure has the potential to enhance commercial and recreational fisheries and create recreational opportunities. For example, natural infrastructure may support fish habitats, which could enhance a commercial or recreational fishery. In addition, wetlands may improve habitats for birds, which could enhance bird watching activities. Similarly, replenishing beaches may provide more beach area for individuals to use for recreational activities, and provide nesting habitat for birds and sea turtles.

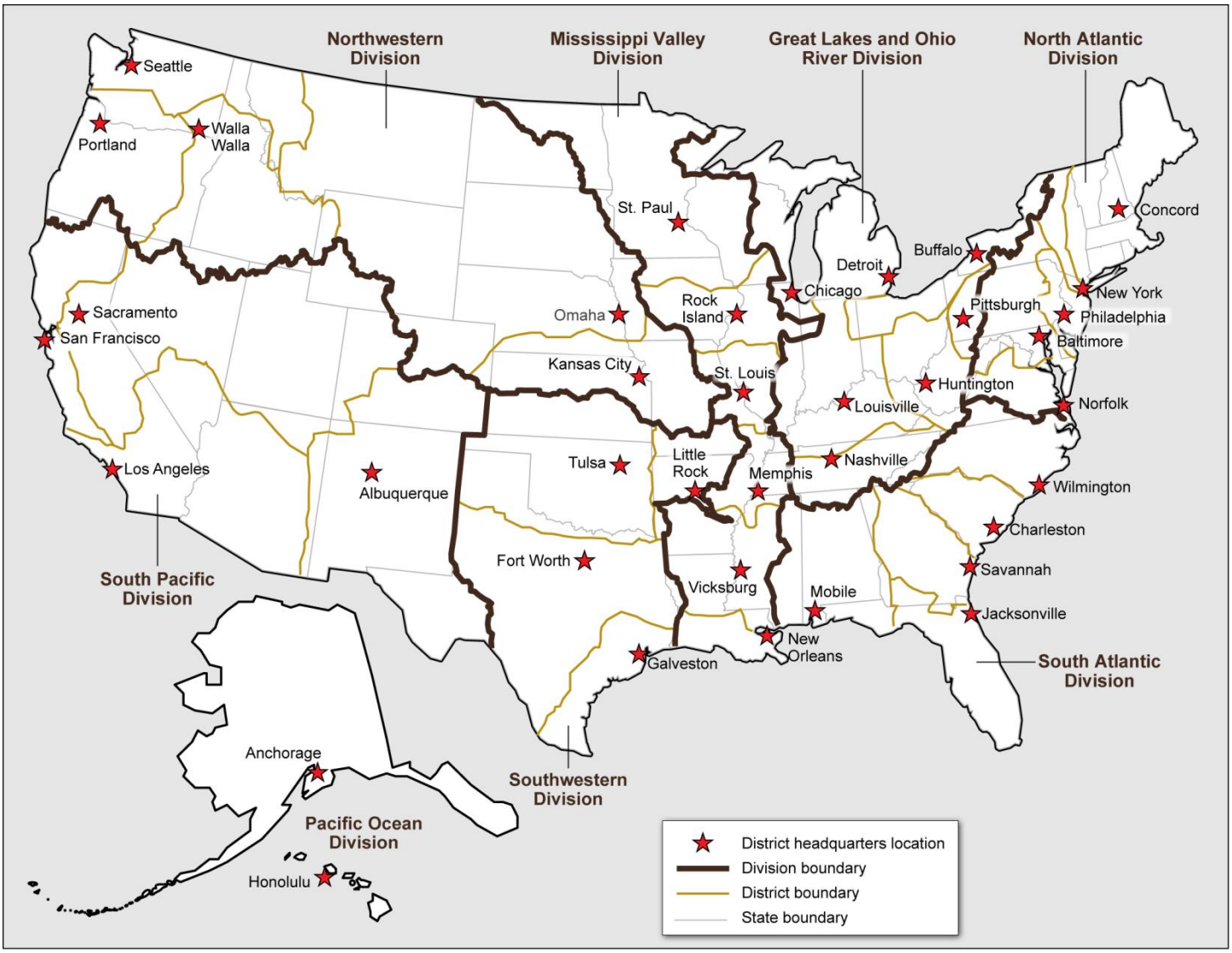
[21]National Research Council, *Coastal Risk Reduction*.

Corps Organization

The Corps' Civil Works program—responsible for water resources projects—is organized in three tiers: a national headquarters in Washington, D.C.; eight regional divisions; and 38 districts (see fig. 3).[22]

[22]According to Corps officials, the agency has developed water resources projects using natural infrastructure to meet different water resources objectives (i.e., coastal storm and flood risk management, ecosystem restoration, and navigation). Our review focused on projects with coastal storm and flood risk management objectives.

Figure 3: Map of U.S. Army Corps of Engineers Divisions and Districts



Sources: GAO analysis of U.S. Army Corps of Engineers data; Map Resources (map). | GAO-19-319

Corps headquarters primarily develops the policies and guidance that the agency's divisions and districts carry out as part of their oversight responsibilities for the water resources projects under the Corps' purview. Corps districts are responsible for planning, engineering, constructing, and managing water resources projects in their districts, including projects that consider or use natural infrastructure.

The Corps has several programs and initiatives related to using natural infrastructure for water resources projects. For example, the Engineer Research and Development Center, the research organization within the Corps, manages a portfolio of research related to water resources projects that includes research focused on flood risk management and coastal systems. The Corps also has an initiative called Engineering With Nature®, which the Corps' scientists and engineers developed to facilitate using sustainable practices in Corps projects.

The Corps' Water Resources Project Planning Process

The Corps develops water resources projects, including coastal storm and flood risk management projects, in conjunction with nonfederal sponsors, such as state and local governments. According to Corps guidance, the planning process for these projects begins with a nonfederal sponsor identifying a problem and approaching the Corps to help develop a solution. Upon statutory authorization for a study and appropriations to fund it, the Corps and the nonfederal sponsor enter into an agreement to conduct a feasibility study for a potential project. Nonfederal sponsors are to participate in the planning process, as well as remain involved through project design, construction, and post-project operations and maintenance. For example, for projects where the Corps constructs hard infrastructure, such as a seawall, the nonfederal sponsor is to assume responsibility for monitoring and maintenance costs associated with the seawall after its construction. In contrast, for a project that involves replenishing a beach, the Corps and the nonfederal sponsor usually share the cost of replenishment for a specific period of time, typically 50 years.[23]

The U.S. Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (Principles and Guidelines) outline the standards and procedures that the Corps is to follow for planning water resources projects, including those with coastal storm and flood risk management

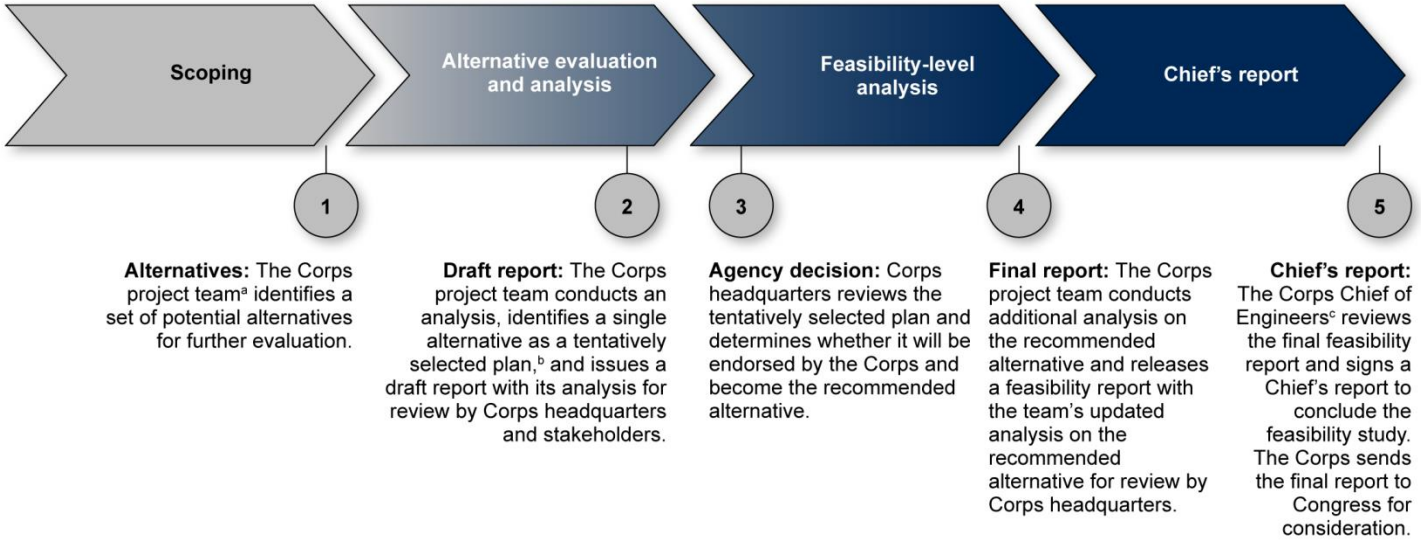
[23]Beach projects are considered to be ongoing construction projects during replenishment, and the Corps typically shares the costs with the nonfederal sponsors as those of ongoing construction projects, according to the Corps' *Planning Guidance Notebook*.

objectives.[24] The Principles and Guidelines establish that the federal objective of water resources projects is to contribute to national economic development while protecting the nation's environment. The Corps implements the planning process outlined in the Principles and Guidelines by conducting feasibility studies for proposed water resources projects. The Corps' Planning Guidance Notebook (Planning Guidance)[25] provides detailed guidance on how to implement the general process outlined in the Principles and Guidelines for planning water resource projects. The Corps' feasibility study process includes four major phases and five milestones, as shown in figure 4.

[24]U.S. Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Mar. 10, 1983). At the time it was developed, the planning approach applied to the Corps, the Bureau of Reclamation, the Tennessee Valley Authority, and the Soil Conservation Service. Section 2031 of the Water Resources Development Act of 2007 required the Secretary of the Army to issue revisions to the Principles and Guidelines to ensure that they addressed certain considerations. In March 2013, the Council on Environmental Quality issued an update to the Principles and Guidelines, called the Principles and Requirements, and the council issued interagency guidelines in December 2014. Together the Principles, Requirements, and Guidelines revise and replace the 1983 Principles and Guidelines. However, the Corps has continued to use the original 1983 Principles and Guidelines because conference reports and explanatory statements accompanying the Corps' annual appropriations from fiscal years 2014 through 2019 have directed it to do so.

[25]U.S. Army Corps of Engineers, *Planning Guidance Notebook*, ER 1105-2-100 (Apr. 22, 2000).

Figure 4: Corps Feasibility Study Phases and Milestones



Source: GAO analysis of U.S. Army Corps of Engineers (Corps) documentation. | GAO-19-319

Notes: This figure describes the Corps' SMART (Specific, Measurable, Attainable, Risk Informed, Timely) Planning process for conducting feasibility studies for water resources development projects adopted in 2012.

[a]Corps project teams typically include officials from the cognizant Corps district and other offices and representatives of the nonfederal sponsor. The project team is supported by other Corps district, division, and headquarters officials, as well as technical experts.

[b]A tentatively selected plan is the project alternative identified by the Corps project team as meeting the project objectives. A tentatively selected plan undergoes further review before the Corps endorses it as a recommended alternative.

[c]The Chief of Engineers, a military officer, oversees the Corps' Civil Works operations and reports on civil works matters to the Assistant Secretary of the Army for Civil Works.

The Corps initiates a feasibility study by forming a project team, comprising Corps engineers, economists, planners, and other specialists, to conduct the study. The Corps project team begins with a scoping phase that specifies the problem, such as the potential for coastal storm and flood damage, and identifies opportunities for a project to address the problem. The project team then inventories conditions in the project area, including physical, economic, and social conditions, and forecasts how these conditions may change over the life of a potential project. As it continues the scoping phase, the project team identifies various measures that could address the problem, such as replenishing an existing beach or constructing a seawall. The project team then develops potential individual measures or combinations of measures (e.g., beach replenishment and seawall construction) into an initial list of alternatives.

Since 2016, the Corps has been required by statute to consider natural infrastructure in certain circumstances.[26]

With its initial list of alternatives, the Corps project team is to then evaluate each alternative by (1) comparing it to the scenario of proceeding with no project; (2) applying criteria established in the Principles and Guidelines;[27] (3) identifying beneficial and adverse effects of each alternative; and (4) considering other relevant factors, such as compliance with environmental requirements. To identify beneficial and adverse effects of each alternative, the Corps uses four general categories established in the Principles and Guidelines, as shown in table 2. The Corps' Planning Guidance states that project teams should evaluate alternatives using the four categories of analysis, but the evaluation from two categories—National Economic Development and Environmental Quality—must be included in each feasibility study. According to the Planning Guidance, evaluating projects' potential costs and benefits through these categories of analysis provides a basis for determining which alternatives should be eliminated from consideration, modified, or selected for further analysis. This evaluation can eliminate alternatives that do not meet planning objectives and may narrow the initial list of alternatives to a final list for more detailed analyses and comparison. Corps officials stated that the process of evaluating alternatives can be iterative and is project specific.

[26]In December 2016, a law was enacted requiring the Corps to consider, as appropriate, natural features, nature-based features, and nonstructural measures in feasibility studies for flood risk management, hurricane and storm damage reduction, and ecosystem restoration projects if the nonfederal sponsor, such as a state or local government, consents. Water Infrastructure Improvements for the Nation Act, Pub. L. No. 114-322, § 1184(b), 130 Stat. 1628, 1679 (2016) (*codified at* 33 U.S.C. § 2289a(b)). In October 2018, a law was enacted requiring the Corps to consider the use of traditional and natural infrastructure alternatives, alone or in conjunction, if those alternatives are practicable in carrying out a feasibility report for flood risk management or hurricane and storm damage risk reduction projects. America's Waster Infrastructure Act of 2018, Pub. L. No. 115-270, § 1149(c), 132 Stat. 3765, 3787 (2018) (*classified to* 33 U.S.C. § 2282 Note). In addition, the law requires the Corps to consider a natural feature or nature-based feature in a project to restore and protect an aquatic ecosystem or estuary in certain circumstances. Pub. L. No. 115-270, § 1149(a), 132 Stat. 3765, 3787 (2018) (*codified at* 33 U.S.C. § 2330(e)).

[27]The Principles and Guidelines identify four criteria (i.e., acceptability, effectiveness, efficiency, and completeness) for evaluating each alternative.

Table 2: Categories of Analysis the U.S. Army Corps of Engineers Uses for Evaluating Potential Water Resource Project Alternatives

Category name	Purpose
National Economic Development	Identifies a project's contributions to net national economic output of goods and services in monetary terms.
Environmental Quality	Identifies nonmonetary effects on significant natural and cultural resources expected as a result of a project, such as changes in habitat quality and quantity.
Regional Economic Development	Identifies changes in the distribution of regional economic activity, such as regional employment, that may result from each project alternative.
Other Social Effects	Identifies potential effects of project alternatives relevant to the planning process, but that are not reflected in the other three categories of analysis, such as community impacts, health and safety, energy conservation, and others.

Source: U.S. Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. | GAO-19-319

The Corps project team then is to conduct detailed analyses of its final list of alternatives to compare them to each other and select a recommended alternative. The project team includes the recommended alternative in a draft report with its analysis. The draft report is made available for review and comment by nonfederal sponsors, federal and state agencies, and other stakeholders. The project team incorporates comments into the report, as appropriate, and determines whether the agency will endorse the recommended alternative. The project team finalizes its feasibility study after internal review. The Corps then prepares a report summarizing the proposed plan—known as the Chief's report—and submits it to Congress for consideration and potential authorization.

The Corps Typically Identified Project Costs and Damage Reduction Benefits for Selected Projects That Used Natural Infrastructure

Based on our review of Corps guidance and eight selected projects that used natural infrastructure, we found that the Corps typically identified project costs and damage reduction benefits in selecting the alternative, although for some projects it also considered additional benefits, such as recreational benefits. Once a Corps project team develops a final list of alternatives in conducting a feasibility study for a particular project, the project team is to conduct an economic analysis for each alternative. This analysis allows the team to compare costs and benefits directly across

the alternatives, including alternatives using natural infrastructure, hard infrastructure, or a combination of the two. Specifically, the project team is to develop estimates for each project alternative's net economic benefits—benefits minus costs—to identify and select the project alternative with the maximum net benefits. The Corps' Planning Guidance states that the Corps shall select coastal storm and flood risk management projects determined to have the maximum net benefits.

Our review of Corps guidance and eight selected projects identified the following costs and benefits that the Corps generally incorporated into its economic analyses:

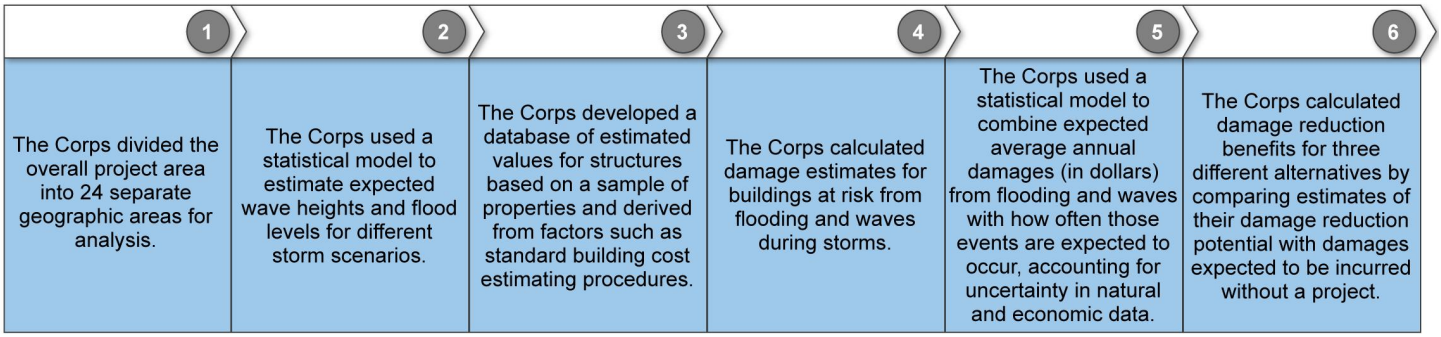
- **Project costs**. According to the Corps' Planning Guidance, project costs include three categories: implementation costs, other direct costs, and associated costs.[28] Implementation costs, for example, include planning and design, construction, construction contingency, operations, maintenance, repair, and other costs necessary to implement a project. The eight selected projects that we reviewed included analyses of project costs, which mostly focused on implementation and interest costs. For example, the costs for the Corps' Jacksonville District Lido Key project included initial construction costs (i.e., beach construction and hard infrastructure designed to reduce shore currents), future beach replenishment costs (i.e., operations related to placing material on beaches to replenish eroding shores), and monitoring costs (e.g., measurement of beach fill, sediment type, and habitat quality).
- **Damage reduction benefits**. Reducing damages to existing structures, including homes and commercial buildings, is the primary benefit the Corps considers when identifying benefits for coastal storm risk management project alternatives, according to the Corps' Planning Guidance.[29] The guidance outlines general steps for estimating damage reduction benefits, which are to be calculated and

[28]The Corps' Planning Guidance defines implementation costs as the direct expenditures to develop a project. Other direct costs include the costs of resources directly required for a project that is not paid for with implementation funds, such as interest on costs incurred during construction and the value of donated land. Associated costs are costs necessary to achieve project outputs for which no project expenditure is made, such as private sector construction of transmission lines to deliver energy for a hydropower project.

[29]According to the Corps' Planning Guidance, expected annual damages include the value of erosion and storm damage losses over the life cycle of the project. A project alternative's damage estimate comes from subtracting the expected benefits without any project from the expected benefits that the Corps estimated.

included in each coastal storm and flood risk management alternative's economic analysis. In seven of the eight projects we reviewed, the Corps analyzed damage reduction benefits as part of its economic analysis.[30] For example, the Corps' project team for the New York District Union Beach project determined the potential damage reduction benefits of each alternative by estimating the alternative's potential to reduce (1) damages to coastal property from flooding and waves, (2) public emergency spending, and (3) administrative costs for the National Flood Insurance Program (see fig. 5).[31]

Figure 5: Key Steps for Estimating Expected Damage Reduction Benefits for the Corps' Union Beach Coastal Storm Risk Management Project



Source: GAO analysis of U.S. Army Corps of Engineers (Corps) guidance and project documents. | GAO-19-319

Note: In its September 2003 feasibility report for the Union Beach project, the Corps' New York District recommended using a combination of hard infrastructure and beaches along the New Jersey coastline. This project used a process outlined in Corps guidance to estimate damage reduction benefits. Specifically, Corps guidance identifies eight steps for estimating damage reduction benefits. The first two steps—identifying the overall project area and defining the problem—were scoping steps that precede the actual analysis and therefore are not included in this figure.

[30]One of the eight projects, the Seattle District's Shoalwater Bay project, did not estimate damage reduction benefits because federal law requires that the project be constructed if, among other things, the Corps determines it is a cost-effective means of providing erosion protection and ecosystem restoration. Pub. L. No. 106-541, § 545, 114 Stat. 2572, 2675 (2000), *as amended by* Pub. L. No. 110-114, § 5153, 121 Stat. 1041, 1256 (2007). Therefore, the Corps used a cost-effectiveness analysis to identify the recommended plan, which did not estimate monetary damage reduction benefits.

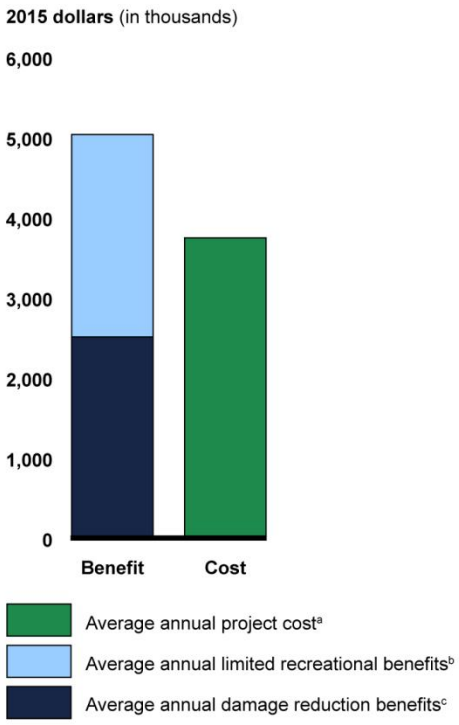
[31]According to the Corps' feasibility study for this project, the Borough of Union Beach participated in the National Flood Insurance Program and had 943 structures whose owners maintained flood insurance. Any policyholders in the area protected by the project would no longer be required to maintain insurance, resulting in reduced administrative costs for the Federal Emergency Management Agency, which administers the program. In addition, the original 2003 feasibility study included the avoided administrative costs, but a subsequent limited reevaluation report in 2017 excluded the administrative costs from the analysis because of a change in Corps policy.

We also found that for some selected projects, the Corps identified and incorporated additional benefits into the projects' economic analyses, including the following:

- **Incidental recreational benefits**. Corps project teams may include in the economic analysis recreational benefits that stem directly from the project alternative but that are incidental to the primary purpose of damage reduction, according to the Corps' Planning Guidance. Specifically, Corps project teams may include recreational benefits, such as increases in recreational visits because beaches are larger in their economic analysis of project alternatives, but recreational benefits are limited to no more than 50 percent of the total economic benefits used to justify an alternative (i.e., demonstrate that an alternative has greater benefits than costs). After an alternative has been economically justified, the team can use the full estimated recreational benefits with the damage reduction benefits to select the alternative with maximum net benefits. In our review of eight projects, we identified four projects where the Corps project team included recreational benefits in its economic analysis for the project alternative that was selected. For one such project, the Los Angeles District's Encinitas-Solana Beach project, the Corps' economic analysis showed that the selected project alternative had lower damage reduction benefits than project costs. However, when the Corps added recreational benefits—as allowed by Corps policy—the combined annual damage reduction and recreational benefits resulted in the alternative having greater benefits than costs (see fig. 6).[32]

[32]The approach of using limited recreational benefits is consistent with the Corps' water resources planning guidance. However, the nonfederal sponsors of the Encinitas-Solana Beach project said that as of December 2018 the project had not received appropriations for construction. Recreational benefits in conjunction with damage reduction benefits were used to justify the project by the Corps, but the nonfederal sponsors indicated that the Office of Management and Budget did not include recreational benefits in its review of the project, which affected its eligibility for inclusion in the President's budget request. Corps officials explained that the criteria for recommending a project be authorized differ from those for inclusion in the President's budget request.

Figure 6: Average Annual Expected Costs and Benefits of the Selected Alternative for the Corps' Encinitas-Solana Beach Project



Source: GAO analysis of U.S. Army Corps of Engineers (Corps) data. | GAO-19-319

Note: In its April 2015 feasibility report for the Encinitas-Solana Beach project, the Corps' Los Angeles District recommended using beach replenishment along the Encinitas and Solana Beach coastlines in California. The recommended alternative for this project would produce recreational benefits, some of which were included in the project's total benefits estimated in the Corps' feasibility study, as allowed by Corps guidance. The Corps used fiscal year 2015 price levels and a discount rate of 3.375 in developing its annual expected costs and benefits. The estimates represent average annual expected costs and benefits of the recommended alternative for the project at the time the feasibility report was finalized in April 2015.

[a]Average annual project costs represent the estimated dollar cost to implement the project throughout its life cycle.

[b]Average annual limited recreational benefits represent the estimated increased recreational activity and associated dollar benefits allowed by Corps policy.

[c]Average annual damage reduction benefits represent the estimated avoided damages in dollars.

- **Other direct incidental benefits**. The Corps may also consider other direct incidental benefits in its economic analysis, as appropriate, according to the Principles and Guidelines. In our review of eight projects, we identified three projects that included estimated incidental benefits aside from recreational benefits. The three projects included economic benefits associated with reduced maintenance costs for local communities, whose expenses for maintaining local beaches would decline after the Corps projects were constructed. Other than

these reduced maintenance costs, the Corps did not include other types of direct incidental benefits, such as environmental or other social benefits, in the economic analyses for the eight projects we reviewed. According to Corps officials, some project alternatives using natural infrastructure may provide direct incidental benefits that are not included in the economic analysis, such as environmental and social benefits. For example, the draft feasibility study for the New York District's Jamaica Bay project states that natural infrastructure can provide direct incidental benefits, such as improving ecosystems, filtering water, and improving aesthetics. The Corps acknowledged these incidental benefits and their importance to communities in its draft feasibility study, but did not incorporate these benefits into its economic analysis because they could not be monetized, according to Corps district officials. Corps headquarters officials said incidental benefits that cannot be monetized in the economic analysis are considered in the planning process through the evaluation of other Principles and Guidelines categories.

Two reports published by the National Academy of Sciences stated that when assessing project alternatives, the Corps primarily uses qualitative measures to assess benefits that are difficult to monetize but that relegates such effects to secondary status compared to the monetized estimates of costs and benefits.[33] Moreover, a 2004 National Academy of Sciences report found that the Principles and Guidelines outlines a process that focuses on the effects that can be monetized, which does not allow for full consideration of a project's total economic effects.

Nonetheless, for three of the eight projects we reviewed, we found that the Corps modified its approach in selecting the use of natural infrastructure as part of the recommended alternative. For instance, for the Encinitas-Solana Beach project, the Corps granted an exception to its planning process and recommended a locally preferred plan. In certain circumstances, Corps project teams can deviate from the Corps' Planning Guidance that calls for the Corps to select the project alternative with the

[33]See National Research Council, *Coastal Risk Reduction*, 7. Also see, National Research Council, Committee to Assess the U.S. Army Corps of Engineers Methods of Analysis and Peer Review for Water Resources Project Planning, *Analytical Methods and Approaches for Water Resources Planning* (Washington D.C.: National Academies Press, 2004).

maximum net benefits.[34] Corps headquarters officials said that requesting such an exception is the primary method the agency uses for recommending a project alternative that does not meet the Corps maximum net benefits requirement for a project focused solely on coastal storm or flood risk management. For the Encinitas-Solana Beach project, the California Coastal Commission found that the Corps' proposed alternative with the maximum net benefits was inconsistent with the mission of California's coastal management program to protect and enhance the state's coastal environment.[35] In particular, the Commission had concerns about the size of the project and the amount of sand to be added to the beach under the proposed alternative, as well as the potential adverse effects on a nearshore natural reef and marine resources. In response, the Corps' Los Angeles District worked with the project's nonfederal sponsors to address the commission's concerns and revised the project by reducing its size and potentially lessening its environmental impacts.[36] The commission approved the revised project alternative in November 2013.

The Corps' Planning Guidance also allows projects with multiple objectives to incorporate other analyses in selecting a recommended alternative. For the Philadelphia District's Lower Cape May project, ecosystem restoration was the project's primary objective, but it also had a coastal storm risk management objective. According to the project's feasibility study, the project focused on protecting and restoring a freshwater marsh that was being flooded with salt water from storms because of continued beach erosion. The Corps used a cost-effectiveness analysis to meet the primary objective, which compared

[34]According to the Planning Guidance, projects may deviate from the alternative with the maximum net benefits if requested by the nonfederal sponsor and approved by the Assistant Secretary of the Army for Civil Works. Project plans with such alternatives requested by the nonfederal sponsor are referred to by the Corps as the locally preferred plans. The Assistant Secretary of the Army for Civil Works can grant exceptions if there are federal, state, local, or international concerns.

[35]Under the Coastal Zone Management Act, federal agency activities within or outside the coastal zone that affect land, water use, or natural resources of the coastal zone must be carried out in a manner consistent to the maximum extent practicable with the enforceable policies of an approved state coastal management program. Federal consistency allows states with approved coastal zone management programs to review federal actions—including agency activities, permits, financial assistance, and outer continental shelf activities—that might affect the state's coastal uses or resources.

[36]Reducing the size of the project decreased the coastal storm damage reduction benefits it may provide, according to Corps officials.

environmental measures (e.g., the number of acres of habitat restored) with the costs of different alternatives.[37] In addition, this project included a beach component to protect the marsh from saltwater intrusion. In the process of designing beach alternatives, the Corps project team conducted a damage reduction benefit analysis to determine an optimal size for the beach that would provide the greatest net damage reduction benefit to nearby communities. This analysis helped inform the Corps decision to select a beach design option that met the project's primary objective of protecting the ecosystem, while also providing the most incidental damage reduction benefits to local communities, according to Corps district officials.

For the third project, the New York District's Jamaica Bay project, the Corps incorporated natural features into the project, although it did not directly include the economic benefits of these features in its economic analysis. For the project, the Corps project team recommended an alternative that was designed to address frequent flooding within Jamaica Bay at three locations. The project team incorporated wetlands into the design at one location, along with hard infrastructure. The nonfederal sponsors of the project told us that they advocated for the inclusion of these natural features, where appropriate, because of their risk reduction and ecological benefits. In response to the interests of nonfederal sponsors, the Corps project team developed and recommended the alternative incorporating hard infrastructure, such as floodwalls, along with coastal wetlands.[38] The Corps did not include the risk reduction benefits from the wetlands in the economic analysis, but the draft feasibility study noted that the project was economically justified based on the monetary benefits of the hard infrastructure alone and that the wetlands provided additional benefits that could not be monetized.[39]

[37]Ecosystem restoration projects generally follow the same planning process as projects with other objectives. However, the ecosystem restoration projects use a different type of economic analysis to select the recommended alternative—cost-effectiveness analysis. This project's cost-effectiveness analysis compares the estimated costs of the project in dollars with estimated acres of wetland that the project would restore.

[38]Corps guidance states that adverse effects of project alternatives on fish and wildlife habitat should be mitigated, if appropriate. According to the draft feasibility report for this project, wetlands were incorporated into the project to meet the environmental mitigation needs of the project by replacing habitat that would be affected by the construction of hard infrastructure with coastal wetlands.

[39]The Corps had not finalized the feasibility report for the Jamaica Bay project as of January 2019.

The Corps Faces Challenges in Developing Cost and Benefit Information for Some Types of Natural Infrastructure and Has Initiated Steps to Address Them

Based on our literature review, agency documentation, and interviews with Corps officials and other stakeholders, we found that the Corps faces challenges developing cost and benefit information for some natural infrastructure to help inform the process for selecting project alternatives and conducting economic analyses in feasibility studies. Specifically, these challenges related to (1) assessing the performance of some types of natural infrastructure and (2) monetizing the social and environmental benefits associated with using natural infrastructure. The Corps recognizes the need to obtain additional data to better develop cost and benefit information for some types of natural coastal infrastructure, and it has begun taking steps to do so.

Challenge in Assessing the Performance of Some Types of Natural Infrastructure

Information is not readily available on the performance of some types of natural features in reducing coastal storm and flood damages, which makes it challenging for the Corps to develop cost and benefit information for these features and compare them to other alternatives, such as those that use hard infrastructure. For example, Corps headquarters officials said that—in contrast to beaches and dunes—there are significant knowledge gaps about the extent to which wetlands, reefs, and subaquatic vegetation can reduce the risks associated with coastal storms by, for example, moderating wave heights and flooding. In addition, there are knowledge gaps about how these natural features will change over time and how any changes might affect the long-term performance of the features.[40]

[40]In particular, one academic researcher we interviewed said that having a clear understanding about how natural features affect risks associated with coastal storms is a key first step in assessing the economic effects of using these features; however, such information is generally lacking for natural features.

A Corps report from January 2015 also identified knowledge gaps in understanding how some natural infrastructure, such as wetlands, may perform during coastal storms or floods.[41] According to the report, wetlands may reduce storm surge, but in some instances water can be redirected, potentially causing a storm surge increase elsewhere. Corps officials noted that all structures—whether natural or hard—change over time, requiring maintenance and repair, but said that natural infrastructure may change more dramatically than hard infrastructure and over a shorter period of time. For example, a healthy wetland could restore itself and reduce maintenance costs after a major storm or require the Corps to take action to restore the wetland after the storm event, which could increase the costs of maintaining the wetland. Corps officials also stated that there are knowledge gaps regarding whether wetlands can absorb major storm surges and how these features would perform in the event of recurring coastal storms in a short period of time. Specifically, natural features may be damaged during intense storms (e.g., wetlands can erode and vegetation may be stripped apart), which may degrade the long-term performance of the features.

Because the Corps does not have information on performance for some natural features, it has been unable to update engineering guidance to include the use of some natural features, according to Corps officials. A Corps headquarters official explained that the agency must first develop a broader understanding of how some natural features, such as wetlands, perform under various coastal storm scenarios over time before it can begin to develop design guidance for using these features for coastal storm protection and flood risk management projects.

A Corps headquarters official said that the agency recognizes the need to obtain additional information on natural infrastructure and has initiated steps to address the challenge related to developing information on the performance of some types of natural infrastructure. In particular, in October 2016, the Engineer Research and Development Center began collaborating with several entities, including other federal agencies,[42] international partners, academic institutions, and nongovernmental organizations, to develop guidelines for using some types of natural infrastructure. According to the scoping document, this effort is to entail

[41]U.S. Army Corps of Engineers, *North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk, Main Report, Final Report* (January 2015).

[42]Federal agencies include NOAA and the U.S. Fish and Wildlife Service.

developing guidelines to support various phases of building natural infrastructure projects, including conceptualization, design, engineering, construction, and maintenance. According to the Corps official, an anticipated key output from the international effort includes developing information on defining performance for different types of natural infrastructure features and options for measuring performance depending on project objectives. The final product is expected to include chapters with information on analyzing natural infrastructure benefits and related monitoring, maintenance, and adaptive management issues, among others.

The Corps official stated that the guidelines will not be official Corps guidance or policy, but Corps project teams and other practitioners can use the guidelines as a resource for identifying best practices in planning projects and assessing potential alternatives. For example, the guidelines will include case studies illustrating design and engineering concepts for certain types of natural features. The guidelines are scheduled for publication in March 2020.

The Corps has also developed a separate internal initiative to help fill knowledge gaps regarding how some natural features' performance can provide benefits relevant to flood risk management, among other benefits. Specifically, the Corps' Engineering With Nature® Initiative is focused on sharing natural infrastructure best practices that are emerging, and communicating the information to staff in the Corps' district offices and other key stakeholders. According to a Corps official, the goal of this initiative, among other things, is to help familiarize the Corps' district staff with existing natural infrastructure information and relevant case studies. The Corps' Galveston and Philadelphia Districts have projects that may incorporate natural infrastructure. For example, the Galveston District is considering opportunities through the Coastal Texas study[43] to use natural features, such as barrier islands, wetlands, and reefs, in combination with hard infrastructure (e.g., levees), to reduce the risks from storms and floods. Similarly, the Corps' Philadelphia District is

[43]Through the Coastal Texas study, the Corps is developing a plan to determine the feasibility of developing projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration in the coastal areas of Texas. The plan is intended to identify methods for protecting, conserving, and restoring wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, and erosion. The draft feasibility study was released for public review and comment in October 2018. The Corps expects to release the final feasibility study in 2021.

considering a plan to design, construct, and evaluate natural features as part of the New Jersey Back Bays Storm Flood Risk Management study.[44]

In addition, in 2018, the Corps' coastal working group initiated a project within the Corps to help identify natural infrastructure knowledge gaps and prioritize key areas for research based on requests for information received from Corps' districts.[45] The Corps plans to incorporate information gathered from this project into a strategic plan that is intended to help inform research funding decisions for fiscal year 2020, according to a Corps official.

Challenge in Monetizing Environmental and Social Benefits

Our review of economic literature identified challenges in estimating the total economic benefits associated with using natural infrastructure features. Several studies noted that data for conducting economic analyses are not readily available. For example, one study noted that there is insufficient information on how restoring wetlands might affect the survival of certain endangered species. Such information is needed, according to the study, to provide insight on the extent to which such features might generate economic benefits. Another study noted that because projects that combine natural features with more traditional structures (i.e., hybrid projects) are relatively new, less is known about their effectiveness or their costs and benefits. Finally, according to another study, estimating recreational benefits associated with natural habitats, such as coastal marshes, can be difficult because there is insufficient information about the extent to which the public visits those sites.

[44]The New Jersey Back Bays Storm Flood Risk Management study resulted from the larger North Atlantic Coast Comprehensive study, which identified nine high-risk areas on the Atlantic coast for further in-depth analysis. The purpose of the study is to investigate coastal storm risk management strategies and solutions to reduce damages from coastal flooding affecting population, critical infrastructure, property, and ecosystems. The study is to consider the full array of structural, nonstructural, and natural and nature-based features, according to Corps documents. The draft feasibility study is scheduled to be released for public review and comment in March 2020.

[45]According to a Corps official, the coastal working group was organized in 2005 and is a community of practice focusing on coastal issues. The group is an advisory board composed of senior-level coastal engineers, planners, scientists, and researchers from Corps headquarters, divisions, districts, and research labs.

In the eight projects we reviewed, Corps project teams did not estimate incidental benefits other than recreational benefits or through avoiding maintenance costs for coastal storm and flood risk management projects. As previously discussed, environmental and social benefits are considered incidental benefits, and Corps guidance indicates that they do not have to be included in the economic analysis. On the other hand, when assessing potential alternatives of coastal storm and flood risk management projects in its feasibility studies, the Corps can quantify or describe the benefits qualitatively and consider these effects during the planning process, outside of the economic analysis. For example, the Corps has measures to quantify changes in habitat, such as number of acres of wetlands restored. The Corps can also qualitatively describe habitat benefits for specific species. However, these nonmonetized benefits may not affect the selection of the recommended alternative, which is generally based on the monetized net benefit estimates of each proposed alternative.

The Corps has begun developing a process for identifying, describing, and considering a broader array of potential benefits when assessing natural infrastructure alternatives for specific projects. Specifically, a June 2017 memorandum from the Corps' Director of Civil Works indicated that projects with coastal storm and flood risk management objectives as well as other objectives should consider social and environmental benefits in the formulation, design, and implementation of projects within existing legislation and Corps policy. A Corps headquarters official said that the agency is not attempting to monetize all potential benefits but is considering options for accounting for potential benefits other than through the traditional monetary assessments of costs and economic benefits. A Corps headquarters planning group is currently working on developing an initiative that would identify a process for using a flexible approach for considering the social and environmental effects of natural infrastructure for coastal storm and flood risk management projects. For example, project teams may have the option of determining whether to incorporate nonmonetized social and environmental benefits, such as enhancing public safety in coastal communities, into the decision-making process for selecting the recommended alternative. The Corps official stated that the agency has begun working on developing guidance for this initiative and expects to issue the guidance in calendar year 2019.

Agency Comments

We provided a draft of this report for review and comment to the Department of Defense. The department provided technical comments, which we incorporated as appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, the Secretary of Defense, the Chief of Engineers and Commanding General of the U.S. Army Corps of Engineers, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions regarding this report, please contact me at (202) 512-3841 or fennella@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to the report are listed in appendix II.

Anne-Marie Fennell
Director, Natural Resources and Environment

Appendix I: Selected Projects with Coastal Storm and Flood Risk Management Objectives Using Natural Infrastructure

This appendix presents information on the eight projects that we selected for review with coastal storm and flood risk management objectives that the U.S. Army Corps of Engineers (Corps) constructed and that included natural infrastructure. We randomly selected eight projects across Corps districts on the Atlantic, Gulf, and Pacific coasts. In seven of the eight projects, the Corps recommended alternatives with either beaches or dunes as the type of natural features to be used for coastal storm and flood risk reduction (see table 3). According to several Corps district officials we interviewed, alternatives featuring beaches are often most appropriate because other natural features, such as wetlands, would not survive the impacts of the high-energy storm waves in open ocean coastal areas where these projects are located.

Table 3: Types of Natural and Hard Infrastructure Included in the Recommended Alternative for Eight Selected Corps Projects with Coastal Storm and Flood Risk Management Objectives

Corps district	Project name	Natural infrastructure	Hard infrastructure	Natural features included for other purposes[a]	Project status as of January, 2019
New York	Jamaica Bay	Beaches and dunes Wetlands[b]	Floodwalls, bulkheads, seawalls, and groins[c]	None	Ongoing feasibility study[d]
New York	Union Beach	Beaches and dunes	Revetments,[e] terminal groins,[c] levees, and floodwalls	None	Beginning initial construction[f]
Philadelphia	Lower Cape May	Beaches and dunes	None	Ecosystem restoration of a wetland	Ongoing beach replenishment[g]
Philadelphia	Townsends Inlet	Beaches and dunes	Seawalls	Ecosystem restoration of a separate beach area, including tree plantings	Ongoing beach replenishment[h]

Corps district	Project name	Natural infrastructure	Hard infrastructure	Natural features included for other purposes[a]	Project status as of January, 2019
Jacksonville	Lido Key	Beaches	Groins[c]	None	Beginning initial construction[l]
Jacksonville	Wares Creek	None[j]	Concrete walls supporting an enlarged channel	Grass lining along creek line	Operations and maintenance[k]
Los Angeles	Encinitas-Solana Beach	Beaches	None	None	Feasibility study complete[l]
Seattle	Shoalwater Bay	Beaches and dunes	None	None	Ongoing beach replenishment[m]

Source: GAO analysis of the U.S. Army Corps of Engineers' (Corps) water resources planning documentation. | GAO-19-319

Notes: This table refers to the recommended alternatives presented in Corps planning documentation for eight projects with objectives to reduce risks from coastal storms and flooding.

[a]The Corps may construct natural features for other purposes aside from coastal storm and flood risk damage reduction, such as ecosystem restoration. This does not include natural features installed as part of environmental mitigation plans in project design.

[b]This project included the construction of wetlands and other natural features within Jamaica Bay that could reduce risks from smaller more frequent storms. However, the economic benefits of the natural features were not assessed in dollar terms for this project. Instead, these features were included as environmental mitigation—steps the Corps took to reduce the environmental impact of projects.

[c]Groins are structures designed to reduce shore currents and retain sediment on the shoreline.

[d]The New York District published a draft report in August 2018, which had not been finalized as of January 2019. District officials stated that they expected a Chief's report to be submitted in July 2019.

[e]Revetments are stone or concrete structures to reduce risks to shore structures from erosion due to waves.

[f]The New York District executed a project partnership agreement with the nonfederal sponsor in January 2018 to begin construction of the project. Construction is scheduled to begin in August 2020.

[g]The Philadelphia District completed initial construction in 2007 and has conducted ongoing beach replenishments (i.e., operations related to placing material on beaches to replenish eroding shores). The third beach replenishment was completed in 2017.

[h]The Philadelphia District completed initial construction in 2009 and has conducted ongoing beach replenishments, completing the third replenishment in 2017.

[l]The Jacksonville District is beginning initial construction on this project after receiving funding in fiscal year 2018 and is planning to award a contract in July 2019.

[j]The Manatee County Florida Cedar Hammock (Wares Creek) project involved deepening an existing creek channel to reduce the risk of flooding. The selected plan involved constructing walls to deepen the channel and installing grass lining on the channel. According to Corps district officials, the grass-lined channel provided a natural feature but was not designed as the primary risk reduction feature.

[k]The Jacksonville District completed construction in 2016 and turned the project over to the nonfederal sponsor in September 2016 to operate and maintain it.

[l]The Los Angeles District submitted the Chief's report in April 2016 to complete the feasibility study. This project was authorized in section 1401(3) of the Water Infrastructure Improvements for the Nation Act. Pub. L. No. 114-322, § 1401(3), 130 Stat. 1628, 1713 (2016). However, the nonfederal sponsors of the Encinitas-Solana Beach project said that as of December 2018 the project had not received appropriations for construction. Recreational benefits in conjunction with damage reduction benefits were used to justify the project by the Corps, but the nonfederal sponsors indicated that the Office of Management and Budget did not include recreational benefits in its review of the project, which affected its eligibility for inclusion in the President's budget request. Corps officials explained that the criteria for recommending a project be authorized differ from those for inclusion in the President's budget request.

[m]The Seattle District completed construction in December 2013, and the beach was reestablished in September 2018 under emergency authority, according to district officials.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Anne-Marie Fennell, (202) 512-3841 or fennella@gao.gov

Staff Acknowledgments

In addition to the contact named above, Alyssa M. Hundrup (Assistant Director), Leo Acosta (Analyst-in-Charge), Mark Braza, Eric Charles, Timothy Guinane, and Jeanette Soares made key contributions to this report. Important contributions were also made by John Delicath and Sara Sullivan.

Appendix III: Accessible Data

Data Tables

Accessible Data for Figure 1: Examples of Hard Infrastructure the Corps May Use for Coastal Storm and Flood Risk Reduction

Category	Category description
"Revetment"	"Revetments are onshore structures typically used to reduce risks of erosion on shorelines."
Seawall	"Seawalls are onshore structures built parallel to the shore that can reduce risks of waves overtopping the shore and flooding land behind the seawall."
Storm Surge Barrier	"Storm surge barriers are typically used with levee systems to reduce the risks of stormwater moving up waterways (e.g., the entrance to a bay) and causing flooding."

Accessible Data for Figure 2: Examples of Natural Infrastructure the Corps May Use for Coastal Storm and Flood Risk Reduction

Infrastructure	Example of Protection
Beaches and dunes	Beaches have the potential to reduce risks from coastal storms because their sloping bottoms cause waves to break, thereby dissipating wave energy.
Wetlands	Wetlands have the potential to decrease the speed of waves from coastal storms and reduce the risks of inland flooding.
Reefs	Reefs, including coral and oyster reefs, can serve as a barriers causing waves to break, thereby dissipating wave energy.

Accessible Data for Figure 5: Key Steps for Estimating Expected Damage Reduction Benefits for the Corps' Union Beach Coastal Storm Risk Management Project

Step	Union Beach step
1	The Corps divided the overall project area into 24 separate geographic areas for analysis.

Step	Union Beach step
2	The Corps used a statistical model to estimate expected wave heights and flood levels for different storm scenarios.
3	The Corps developed a database of estimated values for structures based on a sample of properties and derived from factors such as standard building cost-estimating procedures
4	The Corps calculated damage estimates for buildings at risk from flooding and waves during storms.
5	The Corps used a statistical model to combine expected average annual damages (in dollars) from flooding and waves with how often those events are expected to occur, accounting for uncertainty in natural and economic data.
6	The Corps calculated damage reduction benefits for three different alternatives by comparing estimates of their damage reduction potential with damages expected to be incurred without a project.

Accessible Data for Figure 6: Average Annual Expected Costs and Benefits of the Selected Alternative for the Corps' Encinitas-Solana Beach Project

Category	Average Annual Damage Reduction Benefits	Average Annual Recreational Benefits	Average Annual Project Costs
Benefit	2,527	2,527	n/a
Cost	n/a	n/a	3,763

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