



National Park Service Beach Nourishment Guidance (Second Edition)

Natural Resource Report NPS/NRSS/GRD/NRR—2023/2515



ON THE COVER

Left: An aerial image of Indiana Dunes National Park (NPS). Upper right: American oystercatcher (*Haematopus palliatus*) with chicks at Fire Island National Seashore (NPS). Center right: Beach nourishment work at Indiana Dunes National Park with a tracked excavator (NPS). Lower right: Railroad vine (*Ipomoea pes-caprae*) at Padre Island National Seashore (NPS).

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Contents

	Page
Figures.....	vii
Tables.....	ix
Appendices.....	ix
Executive Summary	xi
Beach Nourishment Project Steps	xi
Basis of Design.....	xii
NPS Policy and Guidance	xii
Sediment Properties for Beach Nourishment	xii
Nearshore Sediment Placement.....	xii
Offshore Borrow Areas	xiii
Project Design Considerations to Reduce Environmental Impacts.....	xiii
Monitoring Program	xiii
Laws, Policies and Regulations.....	xiii
Case Studies	xiv
Acknowledgments.....	xv
Acronyms and Abbreviations.....	xvii
Introduction.....	1
Purpose	1
Topics Covered.....	2
Disclaimer	2
Beach Nourishment Project Steps.....	5
Step 1: Characterize the Physical System	5
Step 2: Define Objectives and Metrics.....	6
Step 3: Design and Permitting.....	7
Step 4: Project Execution	8
Step 5: Monitoring and Adaptive Management	8

Contents (continued)

	Page
Basis of Design	9
Short- and Long-Term Viability.....	9
Climate Change and Resilience.....	9
Local and Regional Projections for Sea Level Rise	9
Defining Management Thresholds for Sea Level Rise.....	10
Holistic Adaptation Planning	11
Nourishment as a Long-Term Adaptation Strategy.....	11
Consideration of Coastal Processes.....	12
Longshore Current.....	12
Hydrodynamic Forcing.....	12
Seasonal Forces	13
Significant Storms	13
Cost Considerations.....	13
Potential Alternatives to Beach Nourishment	14
NPS Policy and Guidance	17
Preservation of Natural Systems	17
Restoration of Human-Disturbed Systems	18
Wetland Policy	19
Wetland Excepted Actions	20
Floodplain Policy.....	21
Revegetation and Landscaping.....	22
Borrow Pits and Dredge Spoil Areas.....	22
Biological Resource Management.....	23
Legal Authority and Jurisdiction	23
Climate Change Guidance	23
Sea Level Rise and Storm Surge Guidance	25

Contents (continued)

	Page
Sediment Properties for Beach Nourishment.....	27
Grain Size Compatibility	27
Overfill Factor Compatibility	30
Sediment Color Compatibility.....	31
Composite Mineralogy	32
Organic Content.....	32
Sediment Contamination	32
Foreign Matter	33
Selecting Native Material for Compatibility Analysis	33
Nearshore Sediment Placement	35
Offshore Borrow Areas.....	37
Project Design Considerations to Reduce Environmental Impacts	39
Turbidity.....	39
Placement Design	39
Placement Geometry	39
Volume	41
Coverage.....	41
Compaction	43
Construction	43
Equipment Considerations.....	43
Project Timing and Time of Year Restrictions.....	43
Minimizing Impacts on Biological Resources	44
Benthic Macroinvertebrates.....	45
Birds	49
Sea Turtles	50
Fish, Seagrass, and Corals	51

Contents (continued)

	Page
Dune Vegetation.....	52
Other Biological Resources.....	53
Managing Invasive Species	53
Monitoring Program.....	55
Seasonality.....	56
Frequency	56
Duration.....	57
Monitoring Components.....	57
Topographic Surveys.....	58
Visual Beach Inspections	59
Sediment Samples	60
Turbidity Monitoring.....	60
Aerial Photography.....	60
Bathymetric Surveys	60
Waves, Currents, and Water Level Measurements.....	61
Biological Monitoring	61
Permits and Regulations	67
Literature Cited	69

Figures

	Page
Figure 1. Longshore current mechanisms (adapted from Linham and Nicholls 2010: Figure 4.3).....	12
Figure 2. Beach nourishment was implemented at Assateague Island National Seashore, Maryland to mitigate some of the sediment lost from the beach since the construction of the Ocean City Inlet jetties.....	18
Figure 3. Erosion threatens historic Fort Massachusetts on the north shore of West Ship Island in Gulf Islands National Seashore, Mississippi, pictured here pre-nourishment, April 2002 (BOB WEBSTER).....	19
Figure 4. Prisoner’s Harbor on Santa Cruz Island, Channel Islands National Park, California where wetlands have been degraded due to previous or ongoing human actions (NPS/KEVIN NOON).	20
Figure 5. Close-up image of beach sand, Golden Gate National Recreation Area, California (USGS/PATRICK BARNARD).....	27
Figure 6. Grain size distribution curves from a restoration project in Gulf Islands National Seashore, Mississippi (adapted from USACE 2010a: Figure 3.c).	28
Figure 7. Map of existing and proposed nearshore placement areas at Beaufort Inlet, North Carolina. Shackleford Banks, a barrier island to the east of the inlet, is part of Cape Lookout National Seashore (USACE 2016b: Figure 3).....	36
Figure 8. Excavator placing sediment along the Lake Michigan shoreline, Indiana Dunes National Lakeshore, Indiana (NPS).	40
Figure 9. Sand slurry pipeline at Gateway National Recreation Area, New Jersey.....	42
Figure 10. Ghost crab at Padre Island National Seashore, Texas (NPS).	47
Figure 11. A federally listed threatened and endangered species, a piping plover (<i>Charadrius melodus</i>) chick, in Cape Cod National Seashore, Massachusetts.	58
Figure 12. Conceptual dune-beach profile showing the juxtaposition of water level, topographic features, and the identification of the neap high-tide swash line (Psuty et al. 2010: upper part of Figure 3).	58
Figure 13. Bathymetric change from 1974 to 2009 at Beaufort Inlet, North Carolina, adjacent to Cape Lookout National Seashore (adapted from USACE 2016b: Figure 3-18).	61
Figure 14. Kemp’s ridley sea turtle (<i>Lepidochelys kempii</i>), a federally listed endangered species, Padre Island National Seashore, Texas (NPS).	63

Figures (continued)

	Page
Figure C-1. Cape Hatteras National Seashore, North Carolina, with areas of likely sediment management indicated (NPS).	106
Figure C-2. Hopper-style dredge (COASTAL SCIENCE & ENGINEERING, INC. [CSE]).	108
Figure C-3. Aerial of onshore beach nourishment setup depicting elbow pipe (CSE).	109
Figure C-4. Ground-based perspective of beach nourishment onshore setup (CSE).	109
Figure D-1. Aerial image looking south showing the Ocean City Inlet and eroded Assateague Island at the top of the image (INTEGRATION AND APPLICATION NETWORK/JANE THOMAS; https://ian.umces.edu/media-library/aerial-view-of-the-ocean-city-inlet-from-isle-of-wight-bay/ , CC BY-SA 4.0).	117
Figure D-2. Location map of the North End Restoration Project, Assateague Island National Seashore, Maryland (Schupp et al. 2007: Figure 1).	118
Figure D-3. Proposed dredging at the Ocean City inlet. Borrow locations for Assateague long-term sand management project are shown as black polygons (USACE 2022: Figure 3-1 [mislabeled 2-1]).	119
Figure D-4. 2D sediment transport modeling shows shoaling in blue shaded areas and scouring in red shaded areas for the proposed action.	120
Figure D-5. Monitoring data illustrated that the shoreline section directly onshore of the sediment placement site became highly and unnaturally accretional, signaling the need for a change in placement site at Assateague Island National Seashore (Schupp et al. 2007: Figure 3).	122
Figure D-6. Unexpected conditions led to a loss of overwash processes and a sheltered island interior at Assateague Island National Seashore, fostering vegetation succession and dune growth (NPS).	123
Figure D-7. A hopper dredge placing sediment on and just seaward of the nearshore bar at Assateague Island National Seashore.	124
Figure E-1. Location of Perdido Key, Gulf Islands National Seashore, and 2011 sediment placement area near Perdido Key, Florida (Gailani et al. 2019: Figure 7).	127
Figure E-2. Average profiles (based on seven profiles) within the nourishment area, Gulf Islands National Seashore, Florida (after Work and Dean 1992: Figure 10).	129

Tables

	Page
Table 1. US standard sieve sizes (King and Galvin 2002).....	29
Table 2. US Army Corps of Engineers' Coastal Engineering Manual recommended grain size compatibility limits (Gravens et al. 2008).	30
Table 3. Florida and North Carolina state requirements for beach nourishment sediment.....	30
Table A-1. Information sources for state/territory beach nourishment policies.....	83
Table B-1. Summary of policy recommendations.....	103

Appendices

	Page
Appendix A: State and Territory Beach Nourishment Policies	83
Appendix B: Summary—Sediment Placement Regulations of US Coastal States and Territories.....	101
Appendix C: Case Study—Cape Hatteras National Seashore, North Carolina	105
Appendix D: Case Study—North End Restoration Project, Assateague Island National Seashore, Maryland.....	117
Appendix E: Case Study—Perdido Key, Gulf Islands National Seashore, Florida.....	127

Executive Summary

Sandy coastal areas (including coastal dunes, beaches, and submerged intertidal and nearshore areas) are naturally dynamic ecosystems. These areas experience accretion, erosion, dune and island migration, overwash, and other processes as sediments are transported by the wind, waves, tides, and currents. If these natural physical processes are disrupted, the beach ecosystem may transform, become unstable, or disappear completely over time. Human development of coastal areas, sea level rise, and increasing frequency and intensity of coastal storms are examples of coastal change that interfere with sediment transport and therefore threaten the stability of coastal ecosystems. Beach nourishment is a nature-based engineering strategy that artificially delivers sand (a size of sediment) to a coastal ecosystem to lessen the disruption of sediment supply. Generally, beach nourishment is intended to mitigate erosion, protect infrastructure and buildings, and/or to restore habitat. The National Park Service (NPS) has produced an updated guidance manual that provides a consistent approach to beach nourishment based on sound coastal science and engineering. The goal of this updated guidance is to provide information on this method to protect and preserve the beaches and associated resources of the National Park System.

Beach Nourishment Project Steps

A beach nourishment project generally follows five steps: (1) characterize the physical system; (2) define objectives and metrics; (3) design and permitting; (4) project implementation; (5) monitoring and adaptive management.

Characterizing the physical system confirms that the site is a strong candidate for beach nourishment and builds a case for anticipated maintenance requirements, as effective nourishment is typically a long-term, iterative undertaking. Recommended outputs during this phase are a conceptual model of the site, a sediment budget, and a habitat assessment. Assuming compliance with the National Environmental Policy Act of 1969 (NEPA) has already been completed, the management team should consult the relevant NEPA document to determine whether additional analysis under NEPA is required for implementation.

Relevant stakeholders must agree on the objectives of the nourishment project and then define metrics to measure whether each objective is achieved. Metrics will inform monitoring and evaluation activities, as well as adaptive management, which is the process of refining management actions as new information is acquired and developed.

For the design and permitting step, data collection should be thorough and quantify the site's resources (e.g., habitat conditions, species), processes (e.g., hydrodynamics, geomorphology), and constraints. Obtaining this information is critical to drafting an effective nourishment design and anticipating environmental impacts. Other important considerations at this stage are the identification of source sediment and coordination with state and federal permitting agencies.

Project implementation proceeds similarly to many other types of construction projects. The schedule will be restricted by seasonal life histories of local species (e.g., bird and sea turtle nesting) and may

require extended coordination among project managers and contractors to establish iterative applications over months or years.

Monitoring is essential for determining whether the project objectives are being met as planned and if there are any ongoing or unanticipated environmental impacts that would trigger adaptive management. Given the potential for climate change impacts in the coastal zone, adaptive management is particularly relevant to beach nourishment objectives.

Basis of Design

The basis of design (BOD) supports the proposed nourishment project with detailed justifications for design choices. It describes how features of the nourished beach (e.g., beach profile, depth of closure, grain size) are expected to respond to coastal processes, such as currents, waves, tides, storms, and seasonal variations in these processes, and identifies thresholds for maintenance and adaptive management. The BOD evaluates the long-term viability of the nourishment project based on ongoing erosive forces and projected sea level rise and provides short-term monitoring and maintenance plans. The BOD also includes other critical considerations for long-term viability of nourishment, such as the continued availability of compatible borrow sediment, environmental changes to adjacent coastal and upland ecosystems, the cost-effectiveness of nourishment (and maintenance) relative to other coastal resilience alternatives, and identifying a threshold for maintenance or adaptive management.

NPS Policy and Guidance

NPS Management Policies 2006 provides important considerations for evaluating when management actions, including beach nourishment, should or should not take place in a park unit. Projects that involve sediment restoration in the intertidal zone are subject to NPS wetland protection policies and procedures because estuarine or marine intertidal zones are defined as wetlands. Other relevant NPS policies relate to modification of natural resources in the floodplain, reuse of surplus soils or sediments, identification of borrow sources, management of biological resources, and adaptation to climate change.

Sediment Properties for Beach Nourishment

Sediment used for beach nourishment should ideally be indistinguishable from native site sediment. If characteristics of the borrow material deviate from native sediment, major physical, biological, and aesthetic consequences could result. Factors used to assess sediment compatibility include grain size, overfill factor, color, mineralogy, organic content, sediment contamination, and foreign matter. Other factors that should be considered when sourcing borrow sediment are distance from the source to the site and dredging impacts on resources.

Nearshore Sediment Placement

A variety of challenges, such as prohibitive cost or presence of shorebird nesting sites, may lead to the decision that placement of borrow material on a beach is not viable. Despite these challenges, the addition of sediment to the coastal system may still be feasible via nearshore placement. The location of the nearshore placement (e.g., the distance from the shoreline, position relative to dredged shipping channels) is a critical consideration, while the shape of the placed sediment is less of a

concern because currents, tides, and waves will quickly adjust the profile. Potential impacts on nearshore and intertidal habitats are a key concern and must be considered.

Offshore Borrow Areas

Using sediment from offshore borrow areas is an attractive option for beach nourishment projects. These deep, distant borrow areas are outside of NPS jurisdiction; therefore, close coordination with partners such as the US Army Corps of Engineers and the Bureau of Ocean Energy Management is required. Sediment compatibility and the effects of dredging on wave transformation and sediment transport must be confirmed prior to any dredging activities. Ecological degradation may be minimized by siting offshore borrow areas away from important biological habitats. A dredge plan should be created that safeguards sediment homogeneity and preserves benthic refugia.

Project Design Considerations to Reduce Environmental Impacts

Beach nourishment is likely to cause localized, short-term environmental impacts; however, it is possible to avoid or mitigate adverse impacts on NPS resources using best management practices. Elements of placement design and construction practices that influence a project's environmental impact include the design profile, volume of sediment placed, location and pattern of placement coverage, beach material compaction, intensity of construction-related traffic, footprints of the equipment selected, and scheduling around biologically productive seasons. Although nourishment can improve habitat (especially for sea turtles, shorebirds, and waterbirds) by widening severely eroded beaches, pre-project planning should consider and address potential environmental impacts.

Monitoring Program

Beach nourishment projects should include scientifically rigorous physical and biological monitoring before, during, and after construction. Monitoring of project performance and environmental impacts provides critical information for adaptive management efforts at the project scale and the improvement of beach nourishment outcomes wherever projects are implemented. Depending on the physical or biological metrics prioritized, monitoring activities may include topographic surveys, visual beach inspections, beach sediment sampling, turbidity monitoring, aerial photography of shoreline position, bathymetric surveys, continuous wave and water-level measurements, and the biological monitoring of birds, sea turtles, fish, seagrasses, corals, macroinvertebrates, and other biological resources. Scientific evidence supporting the use of beach nourishment practices is growing but still limited; further collection and dissemination of data on the physical and biological responses to beach nourishment are needed.

Laws, Policies and Regulations

Numerous federal laws, policies and regulations are applicable to beach nourishment in the national park system. Those pertinent to beach nourishment are discussed in the body of this document, with more detailed information provided in Appendices A and B. *Sediment Placement Regulations of U.S. Coastal States and Territories: Towards Regional Sediment Management Implementation*, provides a very recent overview of permitting requirements by state (ASBPA and CSO 2023).

Project proponents must prepare and consider reasonable alternatives, characterize anticipated impacts to wetlands and floodplains, and demonstrate that beach nourishment would not impair NPS

resources, among other regulatory requirements. State and local regulations relevant to beach nourishment can vary and should be included in planning. Many states have specific requirements for beach nourishment or the beneficial reuse of dredged material. Further information on state and territory requirements for beach nourishment and beneficial reuse is available in Appendices A and B, respectively. Early communication and coordination with regulatory agencies at all levels, for example through regional sediment management planning processes, is a critical component of effective beach nourishment implementation.

Case Studies

Appendix B presents an overview of a recently published report, *Sediment Placement Regulations of U.S. Coastal States and Territories: Towards Regional Sediment Management Implementation* (ASBPA and CSO 2023). The report reviews policies and regulations that cover a range of coastal sediment placement options, including beach nourishment, shoreline stabilization, wetland habitat restoration or creation (sometimes referred to as thin layer placement), and island creation. The report also highlights regional sediment management (RSM) as a preferred strategy to advance beneficial reuse. The report includes a catalogue of detailed state and territory profiles with current policies regarding beneficial use of dredged sediment, natural solutions versus hardened structures, and implementing RSM. Fourteen case studies are presented across a diversity of geographies, conditions, and project objectives. These case studies provide details on recently completed and in-progress projects, including project objectives, outcomes, partners, and lessons learned. Several of these projects were focused on habitat restoration/construction and improving habitat for birds and other wildlife species through marsh restoration, beach nourishment, island creation, in-water shoal creation, and floodplain restoration.

Appendices C, D and E provide case studies at three national seashores to illustrate real-world application of the principles and guidance presented in this document. As part of a sediment management framework at Cape Hatteras National Seashore, North Carolina (Appendix C), the Seashore has parkwide guidelines for the special use permit (SP) applications submitted by entities who wish to conduct transportation maintenance and other sediment management activities. By developing a framework, the Seashore can consider the impacts of multiple sediment management actions (including beach nourishment, dune or habitat restoration, and filling island breaches) over many years in a comprehensive context and cumulative manner, helping to bolster resilience to the impacts of climate change. The north end restoration project at Assateague Island National Seashore, Maryland (Appendix D), is a comprehensive plan to address sediment starvation attributed to the jetty system at the Ocean City Inlet. Beach nourishment, dune restoration, and nearshore placement of dredged materials have been conducted since 2002, and monitoring of project success is ongoing, with many helpful lessons already documented. At Perdido Key in Gulf Islands National Seashore, Florida (Appendix E), largescale beach nourishment (4.1 million m³ [5.4 million yd³] of material along 7.6 km [4.7 mi] of shoreline) and offshore placement (3.0 million m³ [3.9 million yd³] of material) was conducted more than 30 years ago. Lessons from the monitoring program include insights into appropriate design width of the beach, monitoring approach, depth of offshore placement, seasonal timing, and beach configuration. Other beach nourishment projects at Perdido Key are also described.

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Acronyms and Abbreviations

°F	Degrees Fahrenheit
ATV	All-Terrain Vehicle
BACI	Before-After Control-Impact
BMP	Best Management Practice
BO	Biological Opinion
BOEM	Bureau of Ocean Energy Management
CEM	Coastal Engineering Manual
CFR	Code of Federal Regulations
CMP	Coastal Zone Management Plans
COAST	Coastal and Ocean Advisory & Support Team
CZMA	Coastal Zone Management Act
D50	Median Grain Size Diameter
DO	Director's Order
DOC	Depth of Closure
FEMA	Federal Emergency Management Agency
GLRI	Great Lakes Restoration Initiative
GPS	Global Positioning System
I&M	Inventory and Monitoring
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light-detection and Ranging
NCBN	Northeast Coastal and Barrier Network
NCCOS	National Centers for Coastal Ocean Science
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NNBF	Natural and Nature-based Features
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OCS	Outer Continental Shelf
PM	Procedural Manual
RAD	Resist-Accept-Direct
RSLR	Regional Sea Level Rise

RTK	Real-time Kinematic
SLR	Sea Level Rise
USACE	US Army Corps of Engineers
USC	US Code
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service

Introduction

Beaches and dunes are highly dynamic coastal landforms. These natural systems are valuable assets for flood risk management because they dissipate wave energy, can store sediments, and have the potential to adapt to rising sea levels. However, a key limiting factor in the ability of beaches and dunes to provide these and other critical ecosystem services is the delivery of adequate volumes of sediment to the system, especially when nearby anthropogenic perturbations exist. Therefore, the artificial introduction of sediment, also known as beach nourishment, is a management strategy to enhance beach and dune services. Depending on management objectives and conditions at a particular location, beach nourishment may involve placement of sediment (often sand) on the nearshore (seaward of the low-tide water line), the beach (containing the intertidal zone and the “dry” backshore), and/or among the dunes.

The National Park System incorporates 88 coastal units, including national parks, seashores, lakeshores, recreation areas, monuments, preserves, historic sites, and memorials. These areas contain more than 22,500 km (14,000 mi) of shoreline, iconic American features, and a wide variety of geological, biological, and cultural resources. A clear approach to beach nourishment based on sound coastal science and engineering is needed to protect and preserve the beach and associated resources (e.g., dunes, nearshore environments) of the National Park System.

Purpose

This manual is intended to be used as guidance by National Park Service (NPS) staff to plan and manage beach nourishment projects when beach nourishment has been determined to be consistent with NPS *Management Policies 2006*. Applicable portions of this manual may likewise be used when beach nourishment projects within NPS boundaries are initiated by other federal, state, county, or local entities as permitted by the National Park Service. This manual provides tools for resource managers to interface with partners that are completing technical designs and outlines best management practices (BMPs) that can be used to avoid or minimize potential adverse impacts. These tools and practices provide a consistent approach to proposed beach nourishment projects but also contain the flexibility for different outcomes, as appropriate, based on specific park conditions and mandates. An informed, unified approach is necessary to protect beach and associated resources and adaptively manage these resources for future generations, especially in the face of weather variability and climate change. This guidance highlights important considerations and recommends best practices for nourishment projects but does not provide detailed information on technical design for projects. Project design should be tailored to individual project goals and site conditions and requires the expertise of a professional specializing in this type of work.

Regardless of the nature of the action, the National Park Service should consider a broad range of alternatives before selecting a proposed action. This manual assumes that the NPS team considering beach nourishment has already engaged in a high-level planning process that resulted in the determination that beach nourishment was the correct action for the issues identified. Therefore, this manual does not address the need to consider other methods. Instead, this manual assumes that the NPS team is now planning the details of selecting the best way to achieve and implement beach

nourishment. When discussing goals and objectives of beach nourishment, this manual is referring to more focused goals and objectives specific to options for implementing beach nourishment.

This manual does not provide guidance for the development of coastal structures (e.g., seawalls, groins, breakwaters, jetties), projects on shoreline types other than beaches, or dredging projects. However, many of the BMPs presented can be applied to these activities. Coastal structures, management of non-beach shoreline features, and dredging can have potentially significant consequences for beach and associated resources and require professional consultation.

The information in this manual was compiled from federal and state regulations, peer-reviewed and other publications, BMPs, other agency requirements, and experience with past projects. Because of the diversity of coastal units, the topics addressed in the manual will not always apply to a site-specific project. These topics present a starting point for discussion related to beach nourishment within the National Park Service and with other agencies and partners.

Topics Covered

This document covers a wide range of topics to be considered during beach nourishment project planning and implementation. The first section, “Beach Nourishment Project Steps,” outlines a sequence of steps taken as part of a typical beach nourishment project. It is recommended to begin a review of this document by consulting this section. The subsequent sections provide more detailed information on the following select topics relevant to beach nourishment:

- Beach Nourishment Project Steps
- Basis of Design
- NPS Policy and Guidance
- Sediment Properties for Beach Nourishment
- Nearshore Sediment Placement
- Offshore Borrow Areas
- Project Design Considerations to Reduce Environmental Impacts
- Monitoring Program
- State and Territory Beach Nourishment Policies (Appendix A)
- Summary of Sediment Placement Regulations (Appendix B)
- Beach Nourishment Case Studies (Appendix C, Cape Hatteras National Seashore; Appendix D, Assateague Island National Seashore; Appendix E, Gulf Islands National Seashore)

Disclaimer

The information contained within this document is intended only to improve the internal management of the National Park Service. It does not replace or supplant applicable laws, regulations, or other authorities. This document does not create new NPS policy. Instead, it provides guidance for implementing existing NPS policy. It is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or equity by a party against the United

States, its departments, agencies, instrumentalities or entities, its officers or employees, or any other person.

Beach Nourishment Project Steps

Effective beach nourishment is the product of an iterative process that involves information gathering, goal setting, design planning and permitting, implementation, and monitoring and adaptive management. This process may include the consideration of alternative or complementary solutions to beach nourishment (e.g., sediment control structures, managed retreat); however, the focus of this section is to broadly describe the sequence of steps taken to execute a beach nourishment project. Typical project steps are described in detail below. Further detailed guidance may be obtained from the external sources cited or in subsequent sections of this document.

- Step 1: Characterize the Physical System
- Step 2: Define Objectives and Metrics
- Step 3: Design and Permitting
- Step 4: Project Implementation
- Step 5: Monitoring and Adaptive Management

Step 1: Characterize the Physical System

A site may be identified as a candidate for beach nourishment based on any number of factors, such as extreme weather events, long-term observations, changes in visitor use, and planning. Regardless of a site's management history, an essential preliminary step is to assess the feasibility and maintenance requirements of a potential beach nourishment project (Lodder et al. 2021). This assessment should entail (a) developing a conceptual model of the physical system, (b) performing a sediment budget analysis, and (c) assessing existing nearshore, beach, and dune habitats. The conceptual model of physical processes will identify key morphological elements of the site, sediment pathways, sediment sources and sinks, engineered features and other human interventions, and relevant coastal processes and their drivers. This qualitative system model provides the foundation for the quantitative sediment budget analysis, which is a critical framework for determining whether the elements of a beach system are accreting, eroding, or stable. To make this determination, a sediment budget analysis covers not only present conditions but also short-term fluctuations (over months, years) and longer-term trends (over years, decades, centuries), including the observed and projected impacts of climate change on sediment dynamics. Lodder et al. (2021) identifies several resources that provide practical guidance for conceptual physical system modeling and sediment budget analysis, along with multiple case studies from data-rich and data-poor systems. Production of a comprehensive sediment budget is potentially resource-intensive, ideally requiring extensive, high-quality data and the expertise of a modeler. Key considerations for sediment budget analysis include cost, data availability or obtainability, and the selection of an appropriate modeling approach by a qualified analyst. Given these considerations, in many cases a sediment budget analysis is not conducted and can, therefore, be considered a “best case scenario” that parks should work towards if multiple cycles of repetitive beach nourishment are foreseen. Finally, the broad identification of ecosystems and ecological functions and services that were present historically or are currently present indicates what habitats may be expected to exist at the site in the future if beach

nourishment is implemented. This habitat assessment is key in determining whether the proposed beach nourishment is ecologically feasible.

Consideration of socioeconomic and governance factors should not be ignored at this early stage. NPS actions to nourish and enhance beaches are subject to compliance with the National Environmental Policy Act of 1969 (NEPA). The Council on Environmental Quality NEPA regulations state that agencies should apply NEPA early in the planning and decision-making process (40 CFR 1501.2) and that the NEPA process should begin when the entity pursuing the project “has established a goal on which it is actively preparing to make a decision and has developed a proposal to the point where its environmental impacts can be meaningfully analyzed” (40 CFR 1508.1(x); 46.100(b)). Compliance with NEPA may have been completed during the initial, high-level planning process that identified beach nourishment as the correct approach. If so, the project team should review and determine if additional analysis under NEPA is required for implementation, or if the analysis completed is sufficient for implementation.

Prior to initiating the formal NEPA process, the National Park Service typically undergoes a pre-NEPA process first. This allows the National Park Service to fully explore proposed actions and determine if the National Park Service has the data and information needed to complete the NEPA process within the required time limits (40 Code of Federal Regulations [CFR] 1501.10(b)). During the pre-NEPA process, the NPS team will:

- Define project goals and objectives
- Review existing relevant park and NPS management plans to understand their applicability to the specific project
- Develop a preliminary proposed action and alternatives
- Identify data gaps, assess and determine if additional data are needed, and develop stakeholder outreach strategies
- Determine if NEPA is needed, and if so, the appropriate NEPA pathway (categorical exclusion, environmental assessment, or environmental impact statement)

The time required to complete pre-NEPA will vary depending on the need for additional data, and the time required to complete any studies needed. If data gaps are identified, data collection efforts will drive the schedule. Pre-NEPA typically takes nine to 15 months to complete, not including time required for data collection. The NEPA process is typically 12 months for an environmental assessment and two years for an environmental impact statement (40 CFR 1501.10(b)).

Step 2: Define Objectives and Metrics

Beach and associated resources provide multiple ecosystem and societal services and are threatened by various known (i.e., present) and uncertain (i.e., future or unidentified) stressors. It is therefore essential to identify strategic and operational objectives for beach nourishment projects such that nourishment activities target desired outcomes, and project implementation (especially renourishment) is responsive to the results of ongoing monitoring and changing conditions. A strategic objective relates to the broad vision for the site and its services, for example maintaining

flood risk within acceptable limits, conserving breeding and nesting habitats for special-status species, or increasing recreational values. Operational objectives are tied into project monitoring and evaluation, and therefore must be specific, measurable, achievable, relevant, and time-bound. Examples of operational objectives include preserving dune strength as conferred by a particular dune profile, improving nesting success among target species, or maintaining a specific area of a recreational beach.

Strategic and operational objectives will differ among regions, coastal units, and individual projects. For a given project, objectives may even change over time. Once objectives are agreed on, an overall management strategy should also be defined. Taking into account climate change and widespread coastal development, management strategies for beach nourishment will generally fall into one of three types: advancing the shoreline seaward, maintaining existing shoreline conditions, or managed retreat of the shoreline landward. Application of the NPS Resist-Accept-Direct (RAD) framework (see Schuurman et al. 2020) can assist in the decision process toward management strategies for beach and associated resources facing rapid and/or irreversible change. Like the strategic and operational objectives, the selected management strategy may need to be adjusted over time as objectives are achieved or as conditions exceed predetermined thresholds. Lodder et al. (2021) provides examples of goal setting and adaptive management approaches for several real-world nourishment projects.

Step 3: Design and Permitting

As the physical system is conceptualized and modeled and the objectives for the site management are defined, beach nourishment may emerge as the preferred alternative. However, additional information gathering and analysis are required as part of the design process. The project team should identify data gaps and set up procedures to accumulate the necessary information to produce an effective design for nourishment. This typically includes gathering data related to shoreline change and current hydrodynamic and bathymetric information for use in modeling reviews. The NPS team should develop qualitative and quantitative descriptions of critical resources that might be affected, positively or negatively, by the proposed project. Possible sources of borrow sediment are also identified in this step. Other considerations, such as time-of-year restrictions, may be necessary to minimize impacts to fauna and flora that depend on this coastal environment, particularly during spawning and migrating seasons for wildlife and growing season for plants. An important consideration at this stage is the incorporation of impacts under projected climate scenarios.

Once all applicable information is accumulated, the project team should formulate a basis of design. A basis of design specifies the design parameters and methods for project execution, including engineering drawings and contract specifications, as described in detail in the “Basis of Design” section.

Within this step, the project team should interact with state and federal regulatory agencies to acquire the permits necessary to execute the project. This interaction should be initiated as soon as practicable in the design process to reduce the potential for project delays associated with permit acquisition. This can begin during the initial stages of design once the basis of design is established.

Step 4: Project Execution

During this step, the project is fully implemented from tendering through to construction. The first stage of implementation is to procure a construction contractor. Depending on the project objectives and funding source(s), this can be completed through various contracting mechanisms, including bidding of the work or using a design-build strategy in which the design team engages a contractor to perform the work. Once the contracting team is engaged, there should be a mobilization portion of the project in which the construction team prepares for the work and moves equipment to the site. Next, the project work is executed. The final task is restoration of the site and demobilization by the contractor. In some cases, there are warranty items that may require the return of the contracting team to restore or modify certain elements at the site for months or years after the project is completed. Also, in some instances where a beach nourishment operation is scheduled for multiple applications over multiple years, there could be several mobilizations and nourishment operations by the same contracting team.

During construction, it is advisable for a construction management and inspection team to perform oversight of the work. This can be completed by internal NPS staff, the design team, or another third-party contractor. Construction observation can range in frequency from daily at a variable number of hours per day to round-the-clock observation. The frequency should be based on various project needs and the relative complexity.

Step 5: Monitoring and Adaptive Management

Post-construction monitoring is essential for determining whether the project objectives are being met as planned and if there are any ongoing or unanticipated environmental impacts. Post-construction monitoring and sediment sampling can provide information on nourishment volume, beach geometry, and sediment transport patterns. Beach nourishment projects have the potential to impact water quality, alter bathymetry, change sediment characteristics, and impact living organisms, among others. To determine the full effects of beach nourishment on the environment, areas that should be monitored for short- and long-term impacts include the borrow site or upland source, the target beach and subtidal area, and adjacent areas. The monitoring and sampling procedures during post-construction are dependent on the project design and goals. Depending on the objectives, post-construction monitoring can be performed by NPS personnel, the design team, the construction contractor, or other entities. Timing for monitoring can be short or long term, again depending on project objectives, including verification of the efficacy of the project strategies. Recording and disseminating the results of monitoring efforts can contribute substantively to the growing literature on best practices and efficacy of beach nourishment. Beyond this benefit, however, project monitoring is an integral component of adaptive management.

Adaptive management is the process of refining management actions as new information is acquired and developed. It is an iterative process of learning by doing and is particularly applicable to climate-informed planning as it applies the principle of “manage for change, not just persistence” (NPS 2021a). A framework for adaptive management is presented in *Adaptive Management: The U.S. Department of the Interior Technical Guide* (Williams et al. 2009). *Adaptive Management: The U.S. Department of the Interior Applications Guide* (Williams and Brown 2012) builds on the Technical

Guide and can aid in the planning and design of beach nourishment projects. The Applications Guide uses natural resource examples to demonstrate how adaptive management can be implemented and provides potential and actual applications in four thematic areas of climate change, water resources, energy resources, and the interface of human and natural systems. The key steps in adaptive management as referenced in the Applications Guide include:

- 1) Identifying stakeholders
- 2) Developing objectives from guidance where “objectives should be specific and unambiguous, measurable with the appropriate field data, achievable but challenging, results-oriented, and applicable over the timeframe of the enterprise”
- 3) Identifying a set of potential management actions for decision making
- 4) Identifying models that characterize different ideas (hypotheses) about how the system works
- 5) Designing and implementing a monitoring plan to track resource status and other key resource attributes
- 6) The iterative phase (i.e., using the foundation created with the preceding steps), tracking monitoring data, and as indicated by data, consulting with stakeholders, reviewing and adjusting modeling and actions, and continuing monitoring

Application of adaptive management policies to beach nourishment projects allows for useful predictions of changing conditions from factors, such as sea level rise (SLR) and/or erosion issues and can aid in the planning of future beach nourishment actions.

Basis of Design

Regardless of the site-specific design details unique to any particular beach nourishment project, a common set of general considerations support the production of a “basis of design.” The basis of design is a document or set of documents that establishes the amount, layout, and distribution of the sediment to be placed at the site to meet design goals. The basis of design also provides justification for the nourishment design by identifying the criteria, principles and considerations used for calculations and decision-making. It is a product of several beach nourishment project steps, including information gathering, goal setting, design and permitting, and choice of the project timeline. Information such as beach profile cross-section, dune height, existing erosion control structures (e.g., seawalls, jetties), sediment characteristics, and borrow sources are important considerations for the basis of design. Several design alternatives should be objectively analyzed and evaluated before the final design is selected. Due to the complexity of beach and associated resource processes, sound judgment is required to evaluate design elements of each alternative and can be conducted during design review using the knowledge and judgment of a team of experienced personnel. Short- and long-term viability of the design should be considered, along with the anticipated resilience of the design to extreme weather events and the projected impacts of climate change. The prevailing natural coastal processes and the influence of these on the nourishment design should also be considered. Finally, estimated costs and potential alternative solutions must be considered at an early stage.

Short- and Long-Term Viability

To assess the appropriate design, consideration must be given to long-term erosional patterns and SLR impacts, as well as shorter-term thresholds that define when maintenance is needed. Beach nourishment may be viewed as a long-term solution to maintain a shoreline position or volume; however, monitoring and maintenance are required in the short-term to achieve this.

Climate Change and Resilience

The basis of design must consider both present and projected future economic and environmental constraints. This includes impacts of climate change, such as SLR and changes in the frequency and intensity of storms. These impacts of climate change are expected to alter coastal conditions beyond the range historically experienced in many parts of the United States.

Local and Regional Projections for Sea Level Rise

Beach nourishment is a localized activity; therefore, projections for SLR must be as specific as possible to the project location. This requires consideration of local projections for SLR along with projections for vertical land movement, upstream flood control, erosion, and regional ocean current variations. Of these, vertical land movement can be the most significant. Subsidence is the sudden sinking or gradual downward settling of the land surface due to processes such as groundwater extraction, erosion, or glacial isostatic adjustment. Where land subsidence is occurring, relative SLR will be greater than the absolute change in sea level. Conversely, land emergence can occur due to post-glacial isostatic rebound. If the land is rising at a rate greater than absolute SLR, then relative SLR is less than the absolute sea-level change.

Global mean sea level has historically increased by approximately 17 cm (6.7 in) over the last 100 years with noted acceleration since about 1970 (Sweet et al. 2022). Projections of five SLR scenarios for the future global mean sea level are provided by NOAA based on climate scenarios defined by the Intergovernmental Panel on Climate Change (IPCC). These projections of the future global mean sea level vary significantly depending on the selected climate scenario. The five scenarios cover low, intermediate-low, intermediate, intermediate-high, and high projections for global SLR. By 2100, global mean sea level is projected to rise by 0.30 m (0.98 ft) under NOAA's *low* SLR scenario. Over the same time horizon and under NOAA's *high* SLR scenario, global mean sea level is projected to rise by 2.00 m (6.55 ft) (Sweet et al. 2022). A variety of local factors will also modify the relative SLR for each specific location, such as vertical land movement (land subsidence/uplift) and changes in regional ocean currents. Beyond 2100, sea level is projected to rise for centuries under all IPCC scenarios due to continuing deep-ocean heat uptake and mass loss of ice sheets in Greenland and the Antarctic (IPCC 2019).

Boon et al. (2018) analyzed National Oceanic and Atmospheric Administration (NOAA) tide gauge data to detect selected gauge-specific and regional trends in relative SLR and acceleration from 1969 through 2017. Except for some areas in the far northern sections of the US Northeast Coast and Alaska, every other coastal location in the continental United States has experienced an upturn in relative SLR rate since 2013/2014 despite wide differences in the magnitude and trending direction of relative sea-level acceleration. Although the historical record provides key context, future scenarios should be modeled using additional information, rather than simply extrapolating current trends. SLR inundation web-based tools exist for calculating projected rates of sea-level change for many locations along the US coast, such as the US Army Corps of Engineers (USACE) NOAA Sea Level Change Curve Calculator (USACE 2022a). This tool enables the selection of a variety of time scales and severity of projections for project planning needs.

Peek et al. (2015) assessed the long-term exposure (the extent to which an asset experiences a specific climate impact) of more than 10,000 assets within 40 coastal NPS units to 1.0-m (3.3-ft) SLR and associated storm activity. Assets are defined as NPS-owned resources, such as roads, buildings, and parking lots. This study found that 39% of assets had high exposure. Low-lying barrier island park assets in the Southeast Region and many historically and culturally significant assets in the Northeast Region together comprise most high-exposure assets. Further discussion regarding guidance for SLR and climate change can be found in the "NPS Policy and Guidance" section.

Defining Management Thresholds for Sea Level Rise

Beach nourishment projects may have a variety of goals, including preserving wildlife habitat or buffering coastal infrastructure from inland flooding and wave propagation. When considering projections for relative SLR, it may be useful to define thresholds at elevations where SLR would trigger a management response. Threshold elevations may include features, such as an existing dune, the design dune, a known nesting site for target shorebirds, a visitor parking lot, or the first floor of a park building. By referencing these resources and assets to the same vertical datum as relative SLR, managers can compare the projected impacts of various scenarios, set timelines for project

monitoring and evaluation, and make informed decisions about adaptation options. Further discussion regarding guidance for SLR can be found in the “NPS Policy and Guidelines” section.

Holistic Adaptation Planning

In addition to beaches and dunes, other related elements of the coast are vulnerable to climate change, such as freshwater wetland ecosystems, backbay hydrodynamics, and access roads. Risks to these elements should be understood and considered in the design process to help ensure desired outcomes are achieved. Investment of considerable resources into the preservation of beach dynamics via nourishment should be conducted as part of a climate change adaptation planning process that accounts for anticipated changes to the entire coast. Impacts on other geomorphic elements of the coastline may negate positive gains made via beach nourishment. For example, as sea levels rise, backbay hydrology or freshwater wetland ecosystems may transform to such a degree that biota targeted by nourishment activities no longer inhabit the area. Many beach-nesting birds use estuarine marshes on the backside for foraging. As sand moves onto the beachside, onto the dune, and over the backside onto the saltmarsh, this landward beach migration results in landward saltmarsh migration until the system cannot migrate further and the barrier complex and its associated foraging habitats are lost. Rising sea level could also inundate low-lying roads under future SLR scenarios, making it infeasible to access a particular nourishment site.

Nourishment as a Long-Term Adaptation Strategy

Several studies have been conducted to assess the viability of nourishment as a strategy to mitigate the impacts of climate change on beach and associated resources (Parkinson and Ogurcak 2018). There is ongoing debate as to whether this strategy will be economically viable over the long term, given possible limitations on the availability of recoverable borrow sediment and uncertainty in future market conditions affecting project construction costs. Beach nourishment projects that aim to address the projected impacts of climate change over the long term must therefore consider economic, ecologic, and technical details together.

The availability and compatibility of borrow sediment are two determinants of project success that should be considered in the pre-planning stages and at regular intervals as part of adaptive management (see also the “Sediment Properties for Beach Nourishment” section). For long-term planning horizons through 2100, the availability of sediment should not be taken for granted. For example, the volumes of annually placed sediment required to maintain the Florida panhandle’s shoreline in its existing location through the year 2100, as calculated by Houston (2017), exceed the volume available within the panhandle’s currently permitted offshore borrow areas (Parkinson and Ogurcak 2018). Future demand may only be met if potential borrow areas in deeper, more distant waters are permitted in the future. If marine sand reserves are available and projected to remain so on a long-term basis, the compatibility of these borrow areas with the native beach in terms of texture, composition, and color is not guaranteed. Even some of the permitted borrow areas offshore of the Florida panhandle, which are all within 5.0 km (3.1 mi) of the shoreline and in water less than 15.0 m (49.2 ft) deep, have historically contained fine sediment more poorly sorted and slightly darker than the fine-grained, well-to-moderately sorted, white sand native to panhandle beaches (Parkinson and Ogurcak 2018). Beach nourishment projects that are intended to withstand the impacts of future SLR

and coastal storm surge influenced by climate change should undertake an upfront review of long-term sediment volume needs and compatible sediment availability within the design life of the project.

Consideration of Coastal Processes

Coastal processes, such as currents, waves, and winds, continuously affect coastlines, changing them over time in significant ways. These forces should be considered when designing for a beach nourishment project and are discussed in this section.

Longshore Current

Longshore currents, also referred to as drift, flow parallel to the shore and occur when waves break at an angle to the shoreline and part of the wave's energy is directed along the shore. The two mechanisms by which longshore currents act are (1) wave-generated longshore currents within the nearshore region that transport suspended sediment and (2) the saw-tooth mechanism caused by breaking waves and swash, where sediment is transported onto the beach at an oblique angle, followed by a seaward transport of the sediment perpendicular to the shoreline due to gravity-driven return flow (Figure 1) (Astrup and Sørensen 2016). Knowledge of longshore currents at the site is key in designing a successful beach nourishment project. Longshore currents tend to transport sand along the shore and rip currents occur when longshore currents turn seaward. For coastlines composed of mobile, non-cohesive sediments, relatively small gradients in alongshore sediment transport can cause significant changes locally in shoreline positions.

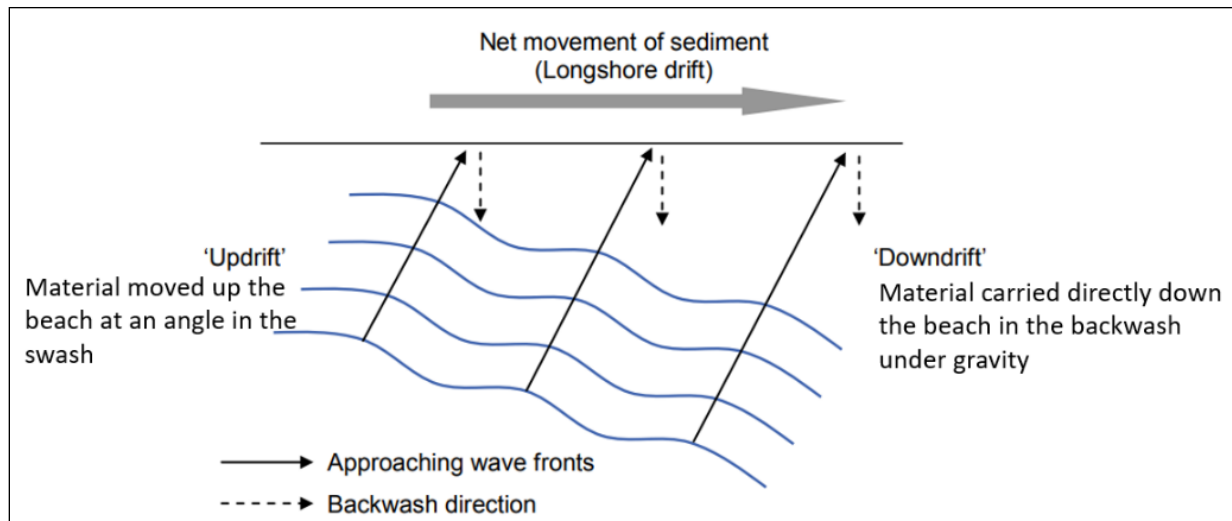


Figure 1. Longshore current mechanisms (adapted from Linham and Nicholls 2010: Figure 4.3).

Hydrodynamic Forcing

Hydrodynamic forcing refers to the forces produced by flowing water and is an important consideration when designing a beach nourishment project. The design of a beach nourishment project should incorporate a comprehensive understanding of how the nourished coast will respond to local hydrodynamic and morphodynamic systems. These responses can be assessed using the concept of depth of closure (DOC). The DOC represents a theoretical depth along a beach profile, where

sediment transport has a de minimis effect and is dependent on factors such as wave height, wave period, and sediment grain size (USACE 2022b). The USACE provides estimates of DOCs for all the coastlines of the United States, including the Great Lakes, using the USACE Wave Information Study wave hindcast data. DOCs are important in estimating nourishment quantities and together with projections for climate change and SLR data, can determine if greater or lower rates of nourishment are required for a particular beach nourishment site over the design life of the proposed project.

Seasonal Forces

The wave and current energy associated with seasonal changes results in natural sediment exchanges that impact the characteristics of the beach and shoreline. In many cases, this will mean sand being transported onto the beach during summer wave conditions and sand being transported away from the beach during winter storm wave conditions, which can involve larger higher-energy waves. Knowledge of seasonal forces at a beach nourishment site can inform the design so that there is an effective placement of sediment during the appropriate season to accomplish project goals.

Significant Storms

Beach nourishment design should incorporate an analysis of predicted impacts of sediment removal and placement under future storm scenarios. Uncommon large storms can result in sediment being transported permanently offshore. Unintended relocation of sediment offshore could have positive or negative effects, depending on the objectives of the beach nourishment project. Offshore sediment could aid in wave attenuation, causing waves to break farther from the shoreline, and thus decreasing their force before they reach the shoreline. Movement offshore could also expose nearshore submerged cultural resources that may have been protected through the beach nourishment effort. Understanding the project objectives will aid in the analysis of potential impacts from future storm events.

Due to the episodic nature of storms, there is uncertainty in predicting exact magnitudes of storm-related sediment transport. For beach nourishment design, Federal Emergency Management Agency (FEMA), USACE, and NOAA databases should be referenced for general storm design criteria and for guidance on selecting design storms. FEMA guidance is used for 100-year storm events as defined by their Flood Insurance Studies and Flood Insurance Rate Maps. In addition, states may have differing requirements regarding flood mapping that should be considered during project design. NOAA is a useful source for hindcast analysis (past storm evaluations), which can be used to identify the frequency of occurrence and relative direction of past storm events. Further discussion regarding guidance for climate change and changes to storm intensity can be found in the “NPS Policy and Guidance” section.

Cost Considerations

The cost of construction has a limiting effect on beach nourishment project feasibility and success. A long-term program to manage beach and associated resources using nourishment requires pragmatic long-term cost estimating. The cost of beach nourishment is highly specific to the site and varies among federal, state, and local projects. USACE maintains and annually updates a list of state-by-state cost adjustment factors developed from a representative breakdown of labor, materials, and

equipment (USACE 2022c) for construction projects. Project managers can use this list to estimate beach nourishment construction budgets in one state based on costs prepared for a project in another state. The cost of beach nourishment is dependent on project-specific characteristics, such as project size, distance to the borrow site, type of borrow site (onshore or offshore), number of trips taken between borrow and nourishment areas, estimated material losses, sediment availability, size of dredges and other equipment, as well as other factors. Beach nourishment cost considerations also include construction costs based on the delivered volume of sediment and the ongoing cost of monitoring. There are a variety of online resources available, including a national database of beach nourishment projects maintained by Western Carolina University, which catalogues the nominal and present-day costs of more than 2,000 projects completed since 1923 (WCU 2021).

In a beach nourishment project, a value analysis should be conducted to evaluate the advantages and costs of proposed alternatives, covering all project phases and components, extending from project start to finish, including post-construction phases. Cost estimates should also include renourishment events that will occur in the future, taking into account inflation and trends in market prices. Also for consideration is that as nearshore borrow areas and other reliable sources of sediment become exhausted and transport more distant, costs are expected to rise more rapidly (Parkinson and Ogurcak 2018).

Potential Alternatives to Beach Nourishment

Beach nourishment is often just one potential solution to the consequences of beach and dune erosion that may be selected after careful consideration of other alternatives. Alternatives specifically targeted at shorelines can include, but are not limited to, the construction of bulkheads, revetments, seawalls, levees (or dikes), living shorelines, and beaches and/or dunes. In-water strategies can include groins, breakwaters, constructed breakwater islands, constructed wetlands, artificial reefs, floating islands, and surge barriers. Natural and nature-based features (NNBF) can also be an alternative to beach nourishment. NNBF include a variety of features that can provide coastal resilience, including wetlands, submerged aquatic vegetation, and mangroves. During the decision-making process, application of the RAD framework (see Schuurman et al. 2020) may assist in the review of these alternatives. The review should be based on the analysis of the project lifecycle, current/future impacted NPS assets (e.g., historic features), potential challenges including construction and maintenance financial costs, as well as indirect costs (e.g., environmental degradation), impacts on community vitality, or the quality of public space and urban design.

Not every alternative to beach nourishment involves structural or physical changes to the shoreline. Managers may respond to the consequences of coastal erosion by selecting a suite of planning and management options that reduce risk through emergency preparedness and changes to visitor use. One option is to develop plans for evacuation, emergency response, and recovery in the aftermath of an extreme event. Visitor awareness of beach and dune erosion and its consequences can be raised through media and park interpretation campaigns. If the risk to NPS assets and resources is found to outpace the mitigating effects of an alternative based solely on planning and management changes, managed retreat may be considered as another alternative. Managed retreat could involve the demolition or relocation of buildings, roads, or trails, the closing of at-risk areas to visitor use, or the

restoration or conversion of habitat. Another alternative to beach nourishment involves adapting infrastructure systems to the impacts of climate change across a range of scales—from a single component of infrastructure to a building or development site to an entire stretch of coastline.

NPS Policy and Guidance

The National Park Service manages its lands and programs in accordance with federal rules and regulations and NPS policies, which are established by the Director of the National Park Service and the Secretary of the Interior. Policies differ from rules and regulations in that they are not legally enforceable but are instead intended to provide a framework with principles and practices for implementing management actions and decision-making. *NPS Management Policies 2006* is the only official service-wide policy document; other relevant NPS documents include various director's orders (DOs), procedural manuals (PMs), reference manuals, guidebooks, and handbooks. *NPS Management Policies 2006* provides important considerations for evaluating when management actions, including beach nourishment, should or should not take place in a park unit. The National Park Service does waive policy requirements when NPS managers determine that will result in the best solution. In some park areas, the resources and processes function naturally. In other areas, human-caused impacts may require some degree of restoration or mitigation. These situations and how the relevant policies apply to proposed beach nourishment projects are explained below.

Preservation of Natural Systems

In parks with shorelines or barrier islands, “natural shoreline processes (such as erosion, deposition, dune formation, overwash, inlet formation, and shoreline migration) will be allowed to continue without interference” (*NPS Management Policies 2006* § 4.8.1.1). However, *NPS Management Policies 2006* § 4.8.1 also directs that intervention in natural geologic processes will be permitted only when:

- Directed by Congress
- Necessary in emergencies that threaten human life and property
- There is no other feasible way to protect natural resources, park facilities, or historic properties
- Intervention is necessary to restore impacted conditions and processes, such as restoring habitat for threatened or endangered species

Beach nourishment is a type of intervention, and any beach nourishment proposed in park areas with natural shoreline processes must meet one or more of the above requirements to be deemed compatible with *NPS Management Policies 2006* § 4.8.1 and § 4.8.1.1. Decisions regarding beach nourishment and other interventions must rely on the results of the best available scientific research and technical information, as required by *NPS Management Policies 2006* § 2.1.2 (also see 16 US Code [USC] § 5936). Additionally, any sediment placement shall be carried out in a way that ensures that park resources and values remain unimpaired to comply with the NPS Organic Act (16 USC § 1) and with *NPS Management Policies 2006* § 1.4.2.

Other policies potentially relevant to beach nourishment proposals (see *NPS Management Policies 2006* § 4.1.5; § 4.4.2.4) require that park landscapes “disturbed by natural phenomena, such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires, will be allowed to recover naturally” unless manipulation (which includes beach nourishment) is necessary to:

- Mitigate for excessive disturbance caused by past human effects
- Preserve cultural and historic resources as appropriate based on park planning documents
- Protect park developments or the safety of people

Restoration of Human-Disturbed Systems

Where human activities or built structures have altered coastal dynamics, ecosystems, tidal regimes, and sediment transport rates (e.g., Figure 2), NPS *Management Policies 2006* directs the National Park Service to investigate, in consultation with appropriate state and federal agencies, alternatives for “mitigating the effects of such activities or structures and for restoring natural conditions” (NPS *Management Policies 2006* § 4.8.1.1). Activities and built structures that alter shoreline processes include structures constructed both parallel (e.g., seawalls, breakwaters, revetments, bulkheads) and perpendicular (e.g., jetties, groins) to the shoreline, shoreline infrastructure, dredged harbors and navigation channels, and dredging or disposal of sediments within and beyond the littoral system. NPS restoration actions in human-disturbed areas seek to return the area to the “natural conditions and processes characteristic of the ecological zone in which the damaged resources are situated” (NPS *Management Policies 2006* § 4.1.5; also see § 4.4.2.4). Beach nourishment to restore shoreline processes, areas disturbed by sediment extraction, and habitat, is an example of this policy (e.g., Figure 3). Throughout the restoration process, the National Park Service should comply with all local, state, and federal laws and regulations.



Figure 2. Beach nourishment was implemented at Assateague Island National Seashore, Maryland to mitigate some of the sediment lost from the beach since the construction of the Ocean City Inlet jetties. 2002 photograph (USACE).



Figure 3. Erosion threatens historic Fort Massachusetts on the north shore of West Ship Island in Gulf Islands National Seashore, Mississippi, pictured here pre-nourishment, April 2002 (BOB WEBSTER). As part of an early phase of barrier island restoration in 2011 to 2012, 459,000 m³ (600,000 yd³) of sand were placed along approximately 3,150 m (10,350 ft) of shorelines to a width of 46 to 168 m (150 to 550 ft) to help protect the shoreline around the fort (USACE 2016a).

Wetland Policy

The National Park Service's wetland protection practices are guided by policy found in NPS *Management Policies 2006* § 4.6.5 and in PM 77-1: *Wetland Protection* (NPS 2016a), which fully incorporates DO 77-1: *Wetland Protection* and establishes procedures for implementing these policies. Projects that involve sediment restoration in the intertidal zone are subject to NPS wetland protection policies and procedures because estuarine or marine intertidal zones (including beach areas between the extreme high and extreme low spring tidal elevations) are defined as wetlands under PM 77-1. The lower limits of marine/estuarine wetlands are classified as the elevation of the extreme low water of spring tide; areas that remain flooded during these conditions are considered subtidal deepwater habitat and are not subject to PM 77-1 (NPS 2016a).

Where wetlands have been degraded due to previous or ongoing human actions (e.g., Figure 4), the National Park Service should, to the extent practicable, restore them to pre-disturbance conditions. For new actions, that are either located in or otherwise could have adverse impacts on wetlands, the National Park Service should employ the following sequence:

1. Avoid short-term (temporary) and long-term (permanent) direct and indirect adverse impacts on wetlands and avoid support of activities that would result in such impacts, wherever practicable

2. Minimize such impacts by designing or modifying the action to reduce wetland degradation or loss and by using the BMPs listed in appendix 2 of PM 77-1
3. Compensate for any remaining unavoidable adverse wetland impacts by restoring natural wetland functions in degraded or former natural wetland habitats on NPS lands



Figure 4. Prisoner's Harbor on Santa Cruz Island, Channel Islands National Park, California where wetlands have been degraded due to previous or ongoing human actions (NPS/KEVIN NOON).

Compensation for wetland impacts or losses requires that at least one acre of wetlands be restored for each acre destroyed or degraded (NPS 2006, 2016a). Compensation at a ratio greater than 1:1 may be required when the wetlands being impacted are of high quality or exceptional value, when it will take several years for the restored site to become fully functional, or when the likelihood of full restoration success is unclear (NPS 2016a). All actions proposed by the National Park Service that have the potential to cause adverse impacts on wetlands are subject to NEPA procedures (DO 12: *Conservation Planning, Environmental Impact Analysis, and Decision-Making*) in addition to the modifications to the NEPA process found in DO 77-1. If the action will result in adverse impacts on wetlands and is not an excepted action under DO 77-1 (see below), a wetland statement of findings must be prepared, circulated for public review and comment, and approved in accordance with NPS wetland protection procedures (PM 77-1 § 5.3.4, 5.3.5 and 5.3.6).

Wetland Excepted Actions

PM 77-1 § 4.2 addresses actions that may qualify as “excepted” from the wetland statement of findings requirements (PM 77-1 § 5.3.4, 5.3.5, and 5.3.6) and wetland compensation requirements

(PM 77-1 § 5.2.3). PM 77-1 § 4.2.1 states that actions designed specifically to restore degraded (or completely lost) natural wetland ecological processes may be excepted. For this exception, “restoration” refers to reestablishing environments in which natural ecological processes can, to the extent practicable, function at the site as they did before disturbance. Beach erosion problems are considered unnatural and occurring more frequently and at greater rates as a result of adverse effects of climate change. Beach nourishment opportunities occur when the above and below high-tide beach is eroded to a point where erosive processes can and will damage shoreline resources. For beach-nourishment actions, sand is placed to extend the beach horizontally and vertically, which will reestablish the location of the intertidal-zone habitat (bounded by the extreme high and low spring tide elevations). Therefore, beach nourishment actions may be considered excepted when they are designed to restore the intertidal habitat in a different location. If the proposed restoration actions will result in a net loss of wetland habitat then they cannot be excepted under PM #77-1 § 4.2.1. The actions will require further compliance with DO#77-1 including developing a Wetland Statement of Findings which may include a wetland compensatory mitigation plan. Exceptions do not imply exemption from the requirements of Section 404 of the Clean Water Act, Section 7(a) of the Wild and Scenic Rivers Act, Section 10 of the Rivers and Harbors Act, the Endangered Species Act, NEPA, the Coastal Zone Management Act (CZMA), or other laws, regulations, or procedures governing NPS activities.

If a project is determined to qualify as an “excepted action,” then no further compliance with DO#77-1 is necessary. However, wetland analyses are addressed in the NEPA compliance document. Examples of analyses include wetland delineations, impacts and benefit of the proposed actions to wetland physical and biological functions, maps, acreages of existing versus restored wetlands (by wetland type), sediment composition, soil type, grain size and color analyses, contaminants analyses, and effects on wetland and wetland-dependent flora and fauna. As noted above, projects that deal with intertidal wetland habitat—the extreme high and extreme low spring tidal elevations—should be used to define the boundaries and acreages of wetlands. The NEPA compliance document is also the place to address compliance with other requirements of PM 77-1, including explanations of avoidance and minimization of wetland impacts to the extent practicable and explanation of why the project was determined to qualify as an “excepted action.”

Floodplain Policy

The National Park Service should manage for the preservation of floodplain values and minimize potentially hazardous conditions associated with flooding. The National Park Service manages the floodplain and proposed actions that fall within the floodplain in accordance with the policies laid out in DO 77-2: *Floodplain Management* and PM 77-2: *Floodplain Management*, as well as NPS *Management Policies 2006*. Specifically, NPS *Management Policies 2006* § 4.6.4 states the National Park Service will:

- Protect, preserve, and restore the natural resources and functions of floodplains
- Avoid the long- and short-term environmental effects associated with the occupancy and modification of floodplains

- Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks

When it is not practicable to locate or relocate development or inappropriate human activities to a site outside and not affecting the floodplain, the National Park Service will:

- Prepare and approve a floodplain statement of findings, in accordance with procedures described in DO 77-2
- Use nonstructural measures as much as practicable to reduce hazards to human life and property while minimizing the impact on the natural resources of floodplains
- Ensure that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program

Revegetation and Landscaping

Any surplus soils or sediments from construction activities within the park may be used for the restoration of other degraded areas in the park if it is determined that the use of the in-park source will not significantly affect cultural or natural resources or ecological processes (*NPS Management Policies 2006* § 9.1.3.2). Soils or sediments imported from inside or outside park boundaries must be:

- Compatible with existing soils or sediments
- Free of undesired seeds and organisms
- Fulfill the horticultural requirements of plants used for restoration

Borrow Pits and Dredge Spoil Areas

Parks should use existing borrow sites or create new sites in the park only after developing and implementing a park-wide borrow management plan that addresses the cumulative effects of borrow site extraction, restoration, and importation. *NPS Management Policies 2006* § 9.1.3.3 requires that materials from borrow pits, quarries, and other clay, stone, gravel, or sand sources on NPS lands, including submerged lands, will be extracted and used only:

- By the National Park Service or its agents or contractors
- For in-park administrative uses
- After compliance with other applicable federal, state, and local requirements
- After compliance with the NEPA and National Historic Preservation Act (NHPA), including written findings that:
 - Extraction and use of in-park borrow materials does not or will not impair park resources or values. Modeling may be needed to assess this item in its entirety, as offshore materials could naturally migrate to shore over time through natural sediment transport processes.
 - It is the park's most reasonable alternative based on economic, environmental, and ecological considerations
 - No outside sources are reasonably available

Sediment dredged within the park may be used for beach nourishment or another resource management activity only if the superintendent first finds that the proposed nourishment or activity will not impair park resources and values and that the proposed activity is consistent with park planning documents (NPS *Management Policies 2006* § 9.1.3.3). The development of new dredge spoil areas or borrow pits or the expansion of existing ones should be analyzed through the NEPA and NHPA processes. In addition, dredging and/or placement activities must meet the requirements of appropriate laws, regulations, executive orders, and related guidance, including but not limited to the Endangered Species Act, PM 77-1, DO 77-2, and sections 401 and 404 of the Clean Water Act.

Biological Resource Management

The National Park Service will maintain all plants and animals native to park ecosystems by (NPS *Management Policies 2006* § 4.4.1):

- Preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur
- Restoring native plant and animal populations in parks when they have been extirpated by past human-caused actions
- Minimizing human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them and being aware of special-status species and consultations that may be needed

Native species are defined as all species that have occurred, now occur, or may occur as a result of natural processes on national park lands (NPS *Management Policies 2006* § 4.4.1.3).

Legal Authority and Jurisdiction

A reference manual has been developed to help NPS coastal park managers understand their legal and regulatory authorities. For jurisdictional guidance on a broad array of ocean and coastal topics see NPS Reference Manual 39-1: *Ocean and Coastal Park Jurisdiction* (NPS 2016b).

Climate Change Guidance

The impacts of climate change have the potential to affect natural and cultural resources, infrastructure, visitor experience, and the health and safety of visitors and staff. Parks must manage these issues while responding and adapting to these changes. To attempt this, parks need to develop forward-looking goals that consider future climatic conditions, and they must evaluate more than one potential scenario when developing management strategies and actions.

Increases in SLR and increases in storm frequency and intensity subsequently increases the cost and scale of beach renourishment episodes. Storm events can fast-track natural migration processes at beaches. A single beach nourishment event does not prevent these natural migration processes and sustained erosion, which leads to necessary subsequent nourishment projects within the same area, usually every few years. Therefore, beach nourishment as a short-term adaptation strategy can be a costly short-term effort (Beavers et al. 2016).

Beach nourishment should be implemented as part of comprehensive climate adaptation planning, ideally at park and landscape scales, as feasible. Furthermore, climate adaptation planning is not an isolated management activity, but a regular practice across comprehensive, strategic, and implementation plans (e.g., general management plans, resource stewardship strategies, long-range transportation plans, visitor use management plans, cultural landscape reports, historic structure reports, and development concept plans).

Executive Order 14008, “Tackling the Climate Crisis at Home and Abroad”, requires that agencies “...make achieving environmental justice part of their missions by developing programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities...”. Below is a brief description of NPS resources intended to provide parks with climate change guidance.

NPS Management Policies 2006 provides comprehensive and flexible guidance that is directly applicable to responding to the challenges of climate change in the management of parks. *NPS Management Policies 2006* requires that decision-making be grounded in the best available science, involve careful and transparent consideration of all pertinent factors, and engage the public in meaningful participation (NPS 2006). Beach nourishment provides a viable management strategy to maintain the “natural conditions” of a shoreline in the face of human activities (e.g., anthropogenic climate change) that “alter the nature or rate of natural shoreline processes” (*NPS Management Policies 2006* § 4.8.1.1).

Guidance for parks on identifying climate adaptation is provided in *Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service* (NPS 2021a). As part of the framework for climate adaptation planning, the guidance encourages that managers assess climate vulnerabilities and risks and assess the implications of these risks on management goals. This guidance also provides a framework for identifying, selecting, and implementing adaptation strategies (NPS 2021a). Additional updated information and guidance for climate change are also available from the NPS climate change website (NPS 2021b).

Climate change is also addressed in *Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager* (Schuurman et al. 2020). This document provides a simple framework of RAD when determining how and when to intervene in ecological change. Land managers can resist the trajectory of climate change by working to maintain ecosystem processes, accept the trajectory of change by allowing ecosystem processes to change without intervention, or direct the trajectory of change by actively shaping ecosystem processes to achieve new conditions. In this context, beach nourishment could fall into this framework depending on the specifics of the project.

There are additional climate change guidance documents developed by the National Park Service not covered here, either because they have been superseded by more recent guidance or are not relevant to this document. Park-specific resources and guidance, including park climate change vulnerability assessments, will also be critical in policy and management decisions for beach nourishment.

Sea Level Rise and Storm Surge Guidance

Fundamentally, adaptation planning (including beach nourishment planning) involves the development of forward-looking goals that consider future climate conditions, under more than one future climate scenario (NPS 2021a). This is important to consider as project life expectancy and planning for renourishment must consider SLR and increased storm impacts to make certain it will deliver effective outcomes once implemented. *Planning for a Changing Climate: Climate-Smart Planning and Management in the National Park Service* (NPS 2021a), *Resource Stewardship Strategy Supplemental Guidance: Integration of Climate Change Scenario Planning into the Resource Stewardship Strategy Process* (NPS 2020), *Resist-Accept-Direct (RAD)—A Framework for the 21st-Century Natural Resource Manager* (NPS Schuurman et al. 2020), and *Coastal Adaptation Strategies Handbook* (Beavers et al. 2016) are guidance documents to assist in this adaptation planning. These documents give guidance for park managers in assessing the risk of SLR and provide resource-specific tools and information on SLR to assist in addressing these impacts and determining appropriate adaptation strategies.

In the context of a changing global climate, historical trends alone are not a reliable predictor of future change; therefore, forward-looking goals must consider modeled climate projections. Given uncertainties in the scope, magnitude, and effects of climate change, park planners are advised to consider multiple scenarios of the future for all but the shortest-term plans (NPS 2021a). Although projections for several climate characteristics are relevant to beach and dune dynamics (e.g., precipitation, storm impacts, wind speed, upland hydrology, ice seasonality), projections for SLR are particularly important when planning a beach nourishment project. The location of the shoreline (as dictated by the coastal landform and its position relative to water levels) is a defining feature of a beach, influencing the nature and rate of sediment transport. Therefore, projections for SLR are particularly important when planning a beach nourishment project. Projections for other climate characteristics are also relevant to beach and dune dynamics (e.g., precipitation, wind speed, upland hydrology, ice seasonality) and should be considered as well.

The NPS publication *Sea Level Rise and Storm Surge Projections for the National Park Service* (Caffrey et al. 2018) provides SLR projections for 118 coastal parks and storm surge projections for 79 of those parks. In addition to including multiple scenarios, the analysis in Caffrey et al. (2018) considers multiple time horizons (the years 2030, 2050, and 2100) based on information from the Intergovernmental Panel on Climate Change (IPCC) and storm surge scenarios from NOAA models. Historical trends in relative sea level are available from NOAA, which maintains the National Water Level Observation Network of tide gauges throughout the country (NOAA 2023a). A new publication by Sweet et al. (2022) provides updated sea level scenarios that consider regional sea level rise (RSLR). This document provides five RSLR scenarios projected to 2150 and present low, intermediate-low, intermediate, intermediate-high, and high projections for RSLR.

Sediment Properties for Beach Nourishment

Sediment used for beach nourishment (Figure 5) should ideally be indistinguishable from native site sediment in terms of color, shape, size, mineralogy, compaction, organic content, and sorting. However, typically, fill material does not exactly match the native sediment, and a compatibility analysis is necessary to consider the similarity. This can also be part of regulatory requirements for certain states. This section presents factors that are typically used to assess sediment compatibility, including grain size, overfill factor, color, mineralogy, organic content, sediment contamination, and foreign matter. Although these factors are important, the team should still evaluate other factors, such as distance from the sand source to the beach nourishment site and dredging impacts to resources. The team should select an alternative that best balances all impacts, adverse and beneficial.



Figure 5. Close-up image of beach sand, Golden Gate National Recreation Area, California (USGS/PATRICK BARNARD).

Grain Size Compatibility

Sediment grain size is the single most important borrow material characteristic (Gravens et al. 2008). The grain size will affect the shape of the nourished beach, the rate at which fill material is eroded from the project, and the biological habitat. Coarse sediments will provide greater resistance to erosion but may reduce the recreational value to users of the beach or impact biological habitat, such as sea turtle nesting ability. The goal for nourishment is to choose sediment that best matches the native material of the beach to help reduce any unintended consequences that could result from modification.

To analyze for grain size, the native beach should be sampled throughout the length and width of the project area and include samples collected along cross-shore transects from the berm crest (or mean high water line) to a water depth corresponding to the position of the typical storm bar (Gravens et al.

2008). The purpose of sampling across the beach and into the nearshore is to capture the zone of active sediment processes. If cross-shore composites exhibit a wide range of median grain size and standard deviation values, an alongshore composite should be calculated for the entire project domain to reduce the variability (Gravens et al. 2008). All sediment samples should be taken from the surface to some predetermined depth and then mixed thoroughly before analysis to ensure representative sediment sampling. Subaqueous borrow areas should be sampled for grain size through physical sampling, such as coring, in a similar manner to that described for the native beach.

Grain size compatibility between borrow and native sediment is determined by comparing the grain size distributions (sand grain frequency, mean and median grain size, and standard deviation). Grain size characteristics are quantified based on sieve analyses of samples, from which particle size distribution curves can be graphed (Figure 6). Table 1 presents information on US standard sieve sizes.

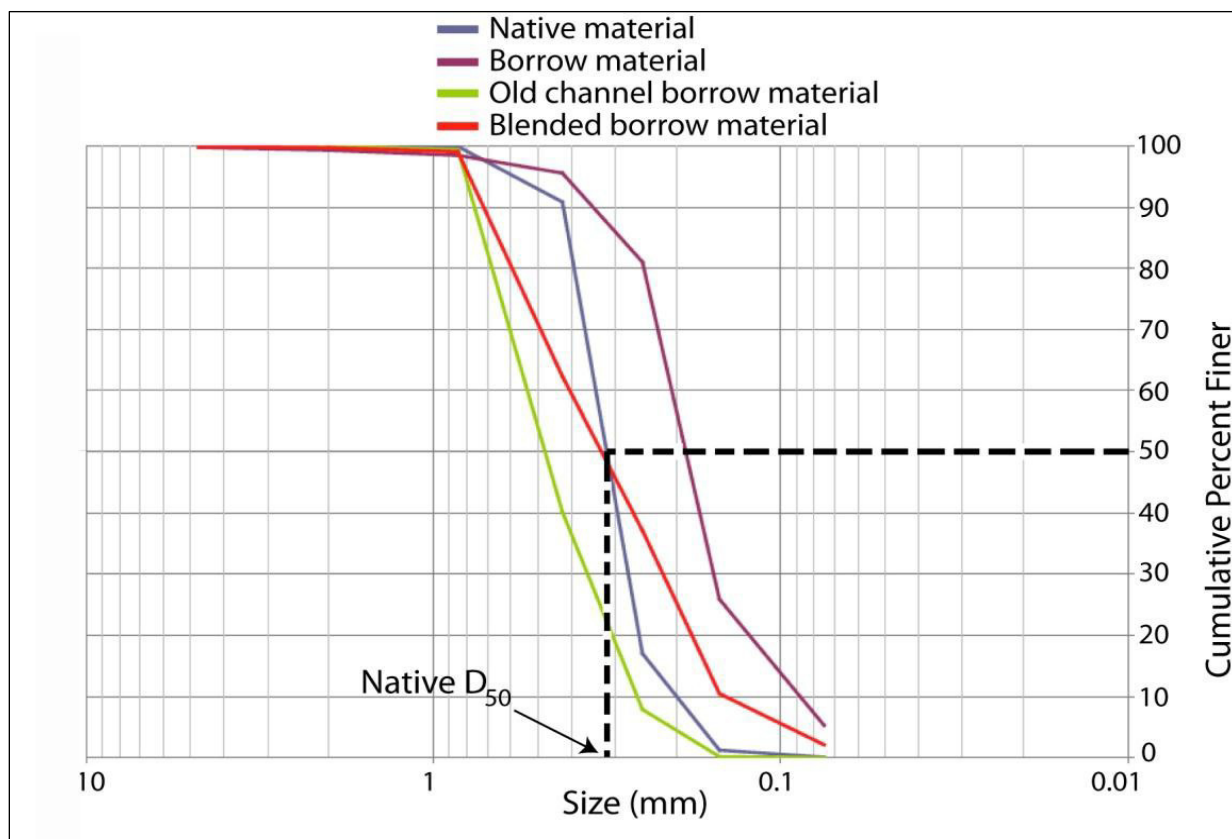


Figure 6. Grain size distribution curves from a restoration project in Gulf Islands National Seashore, Mississippi (adapted from USACE 2010a: Figure 3.c).

Table 1. US standard sieve sizes (King and Galvin 2002).

US Standard Sieve	Opening (inches)	Unified Soil Classification System
Greater than 12 inches	Greater than 11.8	Boulder
3 to 12 inches	3.0 to 11.8	Cobble
0.75 to 3 inches	0.7 to 3.0	Coarse Gravel
#4 to 0.75 inches	0.2 to 0.7	Fine Gravel
#10 to #4	0.08 to 0.2	Coarse Sand
#40 to #10	0.02 to 0.08	Medium Sand
#200 to #40	0.003 to 0.02	Fine Sand
#230 to #200	0.002 to 0.003	Fine-Grained Soil

The mean and median grain sizes are often used to describe the central tendency of the distribution. The median grain size diameter (D50) is the diameter for which 50% of the sediment, by weight, has a smaller diameter. This can be estimated graphically from the particle size distribution curve (Figure 6). The standard deviation is a measure of the spread of the distribution around the mean. The range of grain sizes in the sample is also very important in characterizing the sediment. For example, a sample with a D50 of 0.01 inch and a range of 0.0004 to 0.04 inch will look and act much differently than a sample with a D50 of 0.01 inch and a range of 0.010 to 0.013 inch. King and Galvin (2002) present methods to estimate the mean sediment diameter and standard deviation from statistics of the particle size distribution.

Beach nourishment projects should use fill material with a composite grain size distribution like that of the native beach material. Ideally, the median size of the borrow sediment should not be less than the median of the native material and the spread of sizes in the borrow distribution should not exceed that of the native sediment (King and Galvin 2002). However, this is not always possible due to limitations in available borrow sites or incorporation of beneficial reuse sediment. On severely eroded beaches, the native distribution could be skewed toward the coarse sediments if the fines (silts and clays) have been eroded (King and Galvin 2002). In such cases, the sediment transport analysis is even more important to properly quantify the risks and costs of the proposed beach nourishment project, as compared to alternative shoreline treatment options.

As a general recommendation, suitable material will have grain sizes that range from fine to very coarse sand with limited amounts (less than 10%) of very fine sand, silt, and clay. Sediment with less than 10% fines may help reduce turbidity and biological impacts to beach fauna (see the “Turbidity” section) (Greene 2002). Excessive coarse material and shell hash inclusion should be based on habitat requirements of present and target species because they can alter habitat characteristics and affect aspects such as shorebird feeding (Peterson et al. 2006). The USACE Coastal Engineering Manual (CEM) (Gravens et al. 2008) recommends limits on grain size variation between native and borrow sediments (Table 2).

Table 2. US Army Corps of Engineers' Coastal Engineering Manual recommended grain size compatibility limits (Gravens et al. 2008).

Native Median Grain Diameter	Compatible Borrow Median Grain Diameter
> 0.008 inch	Within ± 0.0008 inch
0.15–0.008 inch	Within ± 0.0004 inch
< 0.006 inch	At least as coarse as native

Some states, such as Florida and North Carolina, have detailed, quantitative requirements regarding sediment compatibility (Table 3). North Carolina also has state regulations regarding sediment compatibility sampling techniques. These requirements can be used as general guidelines for beach nourishment projects in other states. However, it is important to consider the native sediment size carefully when reviewing other state regulations, since these were developed for the native sediment in that specific state. Parks in other states should check with the lead coastal management agency in their state (see Appendix A) for any relevant requirements and adhere to the recommendations outlined in this report for consistency and BMPs. Appendix A provides information related to state beach nourishment requirements and policies.

Table 3. Florida and North Carolina state requirements for beach nourishment sediment. Sources: Florida Administrative Code New 8-23-92, Formerly 16B-41.007 (2017); North Carolina Administrative Code 15A NCAC 07H0312 (readopted effective April 1, 2020).

Beach Nourishment Sediment Requirement	North Carolina	Florida
Particle Size Range (inches)	0.002–0.2	0.002–0.2
Allowable % Silt, Clay, Colloids (Passing #230 Sieve)	Percent by weight of native beach plus additional 5%	5% by weight or less
Allowable % Fine Gravel (Retained on #4 Sieve)	Percent by weight of native beach plus additional 10%	5% by weight or less
Allowable Coarse Material	Percent by weight of native beach plus additional 5%	Percent material retained on 0.75-inch sieve cannot exceed percent on native beach
Dredge Material Allowable % Fines (Passing #230 Sieve)	Up to 10% by weight	Up to 10% by weight (10%–20% for nearshore placement)
Carbonate Content	Percent by weight of native beach plus additional 15%	Must not result in cementation

Overfill Factor Compatibility

Typically, the design of beach fill projects aims to compensate for the grain size differences between borrow sand and native sand by overfilling with borrow sand and assuming that a portion of the fine material will wash out by wave action (King and Galvin 2002). The overfill factor is used to roughly estimate the volume of fill material needed to produce a unit volume of material on the native beach after grain sorting losses (Gravens et al. 2008). For example, an overfill factor of 1.2 indicates that

120 cubic yards of fill sediment must be placed to yield 100 cubic yards of residual fill on the beach. Expressed in another way, this means that 83% of the borrow material is expected to remain as residual beach fill. The overfill calculation provides only an approximate volume estimation and should not be used in the final design process for volume calculations because it does not consider any coastal processes (Gravens et al. 2008). However, this value is critical to consider during the cost estimation for the project to ensure adequate funds are available during construction.

The overfill factor can also be used to assess the general suitability of fill material or to compare the relative merits of different borrow sites. The overfill factor is usually calculated using the Krumbein-James technique (Gravens et al. 2008). Dean (1974) offers another method for computing the overfill factor, which typically yields lower estimates of the overfill factor. The CEM presents a graphical method of calculating the overfill factor from mean and standard deviation values of the native and borrow sediments (Gravens et al. 2008).

The CEM (Gravens et al. 2008) recommends an overfill factor within the range of 1.00 to 1.05 but acknowledges that this is very difficult to achieve. (A value of 1.00 indicates direct compatibility, while values higher than 1.00 indicate greater non-compatibility.) A broader range of 1.0 to 1.5 was identified as satisfactorily compatible in the environmental assessment of the West Ship Island North Shore Restoration project in Mississippi (USACE 2010a). However, post-nourishment monitoring efforts at another project in Morehead City, North Carolina found that sediment with an overfill factor of 1.4 was non-compatible for local beaches (Bodge et al. 2006). In this instance, the non-compatible material contained clay and high fractions of silt and large shells. A similar overfill factor, however, may be acceptable for another project if the grain size distributions (sand grain frequency, mean and median grain size, and standard deviation) of the native and borrow materials are similar. The overfill factor is only one factor used to assess sediment compatibility, and it is important to consider all factors before making a final compatibility decision. These case studies further demonstrate the need for a detailed analysis of shoreline processes to precede the design, as errors in the factor have direct impacts on the viability and cost of the overall project.

Sediment Color Compatibility

Borrow material should be as close as possible in color to the native sediment to limit visual and biological impacts after placement. A change in sediment color can alter the sediment's temperature and affect organisms living in or using the sediment. For example, sand temperature influences the reproductive success of many species, including horseshoe crabs (Avissar 2006) and sea turtles (Crain et al. 1995). A change in beach color can also impact visitor enjoyment.

Sediment color is often described using the Munsell color chart (Munsell Color 2010). In the Munsell system, sediment color is determined visually by comparing the sediment to the Munsell chart and identifying a matching color chip. Colors are measured along three different dimensions: hue, value (lightness or darkness), and chroma (departure from gray), and are recorded in the order of hue followed by value/chroma, such as 10YR 4/6 (Munsell Color 2010). Since moisture affects color, it can be useful to record color twice, once dry and once moist. In some cases, interstitial water contained in the borrow sample can make the material appear darker than the dry sediments, so it is recommended to wash a few samples before making the moist color determination (FDEP 2010).

Florida regulates color compatibility and requires that fill “be similar in color” to native beach sediment (FAC 2017). In Florida, fill material can be expected to lighten one Munsell value once placed on the beach and dried by the sun (FDEP 2010). However, darker- or tanner-colored sands in other states may undergo more drastic lightening when dried. Shell content can also influence the overall color of the sediment and will also likely lighten one Munsell value once dried. Some sediment may not lighten in the sun (e.g., iron-stained sediment), so the source of the color of the sediment should be taken into account when determining color compatibility (FDEP 2010).

Composite Mineralogy

The mineralogy should be very similar between the fill and native material. Mineralogy affects sediment temperature, compaction, and moisture content, all of which can impact biological resources and physical processes. In most places, sand-sized sediment is predominantly composed of quartz particles with lesser amounts of other minerals, such as feldspar (Gravens et al. 2008). Some locations may also have a dominant amount of calcium carbonate that is usually of organic origin. To avoid cementation of the beach, the calcium carbonate content of fill material should be limited. In North Carolina, the composite mineralogy of the borrow material must be “similar to the mineralogy” of the native beach and the carbonate content in the borrow material may not exceed the carbonate content of the native beach by more than 15% (NCAC 2020). In Florida, the carbonate content in the borrow sediment must not result in cementation of the beach (FAC 2017). Projects in other states should consult with the lead coastal state agency on any mineralogy requirements (see Appendix A for a list of state agencies).

Organic Content

Fill material should have similar organic content as the native beach. The organic content in sediment can greatly affect plant and animal populations. For example, the success of incubating turtle eggs can be reduced when the organic content of the fill material is different from the natural beach (Greene 2002). Maintaining the same organic content is also important because organic material supplies nutrients to benthic organisms. In high-energy environments, such as beaches, organic matter consists mainly of decayed macroalgae, feces, and animal remains (Thayer et al. 2003). Measurement of organic content requires the destruction of the organic matter via chemicals or heat. The carbon is then converted to carbon dioxide and measured directly or indirectly. See Schumacher (2002) for more information on the determination of organic content in sediment.

Sediment Contamination

Fill material must be substantially free of harmful chemical contaminants. In general terms, sediment is usually characterized as substantially free of contaminants if it is composed entirely of sand, gravel, or other inert material, and is found in areas of high current or wave energy (Moffatt & Nichol 2006). Chemical contaminants are in many cases associated with silt and clay-sized particles, as well as organic substances. The likelihood for contamination may also be based on previous chemical testing of sediments from the same vicinity and/or proximity of the borrow material to known contaminant sources. Regardless of prior knowledge, all material planned for borrow use should be tested to confirm conformance with the applicable regulatory levels.

The US Environmental Protection Agency (USEPA) has physical and chemical standards for sediments that will be placed in marine environments. Some states have adopted standards that are more rigorous than the USEPA standards. In addition, to preserve and protect park resources, parks may need to develop or adopt more stringent standards. For example, Gateway National Recreation Area in New York has developed draft sediment standards for use in protection, restoration, and maintenance projects. The draft standards exceed USEPA and New York Department of Environmental Quality standards. A higher standard has been deemed necessary by the park to protect and preserve park resources unimpaired.

Although the beneficial use of dredge material from nearby projects is encouraged to both reduce transportation costs and increase the likelihood of compatibility, care must be taken to ensure this material is free of contamination. Dredging within shipping channels and marinas may yield material that has chemical contamination exceeding regulatory standards. Further information on sediment chemical contamination can be found in the *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S.—Testing Manual* (USEPA and USACE 1998).

Foreign Matter

Fill material must be free of trash, debris, and large pieces of organic material because of health and safety hazards and possible odor and visual impacts. For example, Florida (FAC 2017) and North Carolina (NCAC 2020) regulations require that fill material not contain construction debris, toxic material, or other foreign matter.

Selecting Native Material for Compatibility Analysis

If the project site has been impacted and it is difficult to determine what the native sediment consists of, a nearby, undisturbed site can be used when determining native sediment characteristics. The nearby site should have similar coastal processes and similar sediment type and range to be representative of what would originally have been at the impacted project site.

Nearshore Sediment Placement

Nearshore placement (Figure 7) is an alternative to direct beach placement that can be implemented when cost or environmental impacts discourage placement directly on the beach or when the sediment does not meet beach nourishment standards (e.g., for the percentage of silt/clay content). Nearshore placement of sediment dredged from coastal navigation channels (USACE 2010b) and ebb- and flood-tidal deltas (Schupp et al. 2007) that is substantially free of contaminants is of growing interest for coastal managers, scientists, and residents. The common practice of placing dredged sediment far offshore removes sediment from the littoral system and may contribute to long-term shoreline erosion on land adjacent to the channel (Gailani and Smith 2006; Morton 2008). Nearshore placement instead provides beneficial use of the dredged material and, when applied properly, retains sediment within the littoral system.

Generally, the success of nearshore placement in transporting sand to the beach decreases with increasing distance from shore (Smith et al. 2007). Nearshore nourishment should be placed seaward from the outer breaker bar, aiming for a crest height that matches the existing breaker bars (Lodder et al. 2021). No strict requirements are needed for the exact shape of the nourishment because the sea will adjust the profile form quickly. Regional and local sediment transport patterns must therefore be considered in the selection of placement sites for placed sand to benefit the littoral and beach sediment budget. Placement sites should also be chosen to minimize sand movement back into the navigation channel and to limit unwanted impacts to natural wave characteristics (Gailani and Smith 2006). Placement design should consider potential effects on nearshore biological populations and may require sampling and monitoring of biological resources in the nearshore, as well as the intertidal areas. Nearshore placement also has the potential to impact aquatic species spawning and foraging sites and, if not carefully planned, may lead to trapping of large fauna during low tide events (Dean 2005). See the “Project Design Considerations to Reduce Environmental Impacts” and “Monitoring Program” sections for more information.

Sediments removed from and placed into waters of the United States are regulated by the Clean Water Act and Rivers and Harbors Appropriation Act in every state. There are several states, such as Florida, that have state regulations that protect the same waters as the Clean Water Act that are within state boundaries. Florida requires dredge material to have a maximum of 20% by weight of fines (passing a #230 sieve) for nearshore placement (FAC 2017). Projects in other states should consult with the lead coastal management agency in their state (see Appendix A).

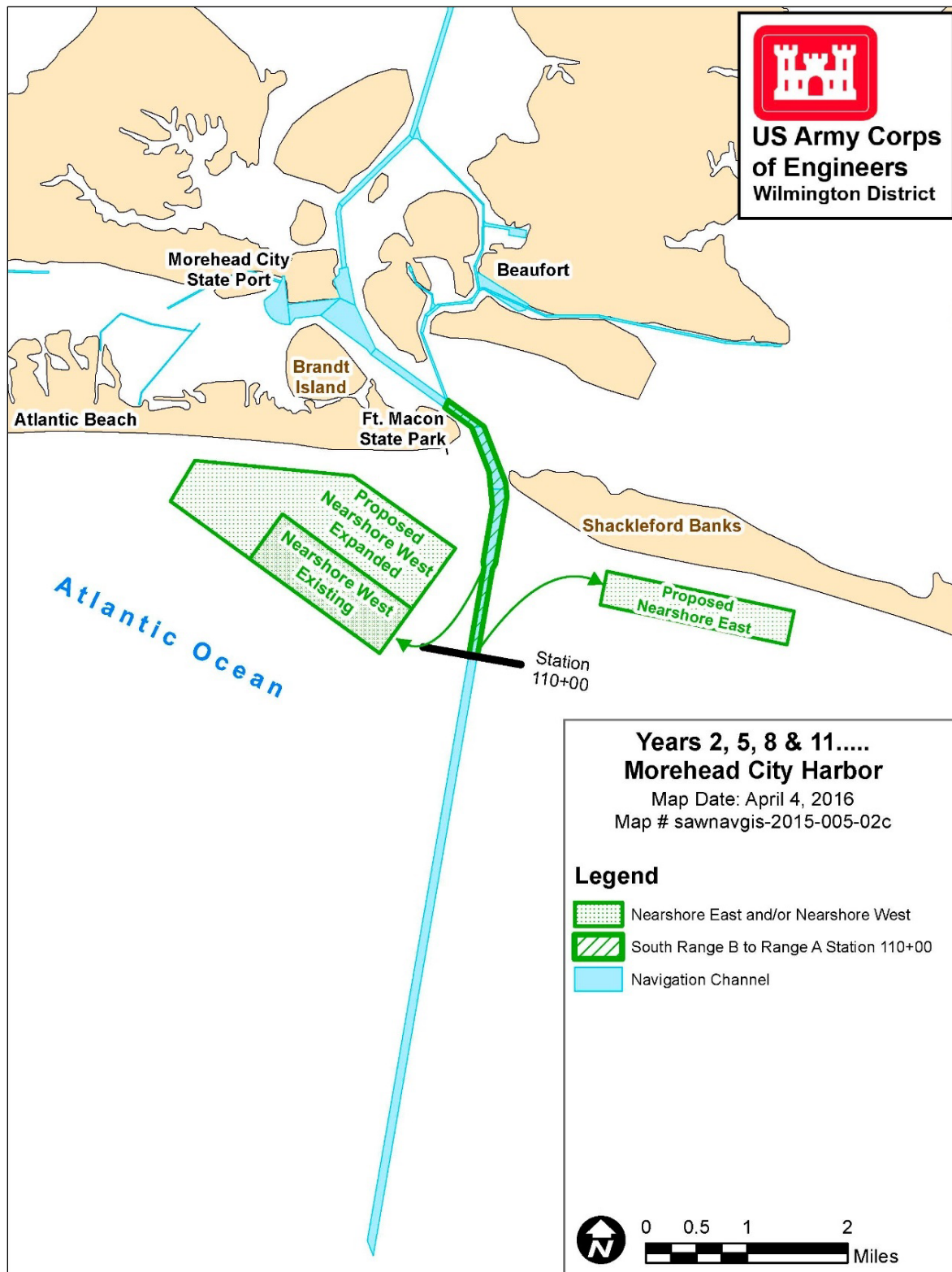


Figure 7. Map of existing and proposed nearshore placement areas at Beaufort Inlet, North Carolina. Shackleford Banks, a barrier island to the east of the inlet, is part of Cape Lookout National Seashore (USACE 2016b: Figure 3).

Offshore Borrow Areas

Offshore areas (i.e., deep waters beyond where waves begin to break) are regularly used as the sediment borrow source for beach nourishment projects. Borrow material may be mined from ebb tidal shoals near inlets or shoals on the continental shelf or reused from the creation or maintenance dredging of harbors, navigation channels, or waterways.

Offshore borrow sources are outside of NPS jurisdiction and use needs to be approved by appropriate agencies, depending on their distance from shore. To determine if they are compatible with existing material, potential borrow sources are generally evaluated through the collection of surface sediment samples, sub-bottom profiling, and/or coring (Dean 2005). Sediment compatibility tests between the borrow and beach sediment and analysis of the available borrow volume are required prior to dredging to ensure the sediment is of suitable quality and volume. The most important factor when considering suitability is grain size (see the “Sediment Properties for Beach Nourishment” section). Suitable borrow sediments are dredged from the seafloor and transported to the beach via dredges, barges, and/or pipelines.

In addition to sediment compatibility, evaluation of borrow sources should also consider the effects of dredging on wave transformation and sediment transport in the area. Pre- and post-dredging bathymetry should be simulated and used to investigate the possible effects of dredging a borrow area on littoral processes in the area (Gravens et al. 2008). The analysis should include a numerical wave model with a focus on wave refraction and diffraction and comparison of breaking wave conditions, longshore transport rates, and transport rate gradients between pre- and post-dredging scenarios. If necessary, the depth or shape of the borrow area may require modification to avoid concentrations of wave energy or altered sediment transport (Gravens et al. 2008). Borrow areas should be in water depths greater than the zone of active sediment transport to avoid any reduction in cross-shore or alongshore sediment transport.

Borrow sites should be located away from important biological habitats, such as significant spawning areas, marine protected areas, or other habitats valuable to local fishery or benthic resources (Rice 2009). Excavation of the borrow site should avoid leaving large depressions or holes if possible, and instead employ a series of shallow, staggered cuts. This method allows the areas in between cuts to act as refugia for repopulation of benthic resources and limits alterations to the seafloor bathymetry (Rice 2009).

Dredging should also leave a sufficient layer of seafloor sediment that matches, as much as possible, the original surface layer to limit changes in habitat. For example, sediments within a borrow area off Folly Beach, South Carolina became increasingly fine (more silt/clay) after dredging and showed little evidence of recovery one year later (Bergquist et al. 2005). It was later determined that the borrow area filled with fine sediments because the area was dredged too deep (3.0 m [9.8 ft] below the seafloor) and was near a harbor full of fine sediment (Bergquist et al. 2005). The biological community also changed after dredging, likely in response to the change in sediment.

Similar to the nourishment site, pre- and post-project monitoring of the borrow site is essential to identify any physical or biological change. Monitoring may include:

- Sediment sampling and analysis
- Wave monitoring and modeling
- Bathymetric and substrate surveys
- Shoreline monitoring and modeling
- Benthic community sampling and their trophic relationships to fishes
- Marine mammal and wildlife monitoring (during operations)

See Greene (2002), Nairn et al. (2004), Dean (2005), Gravens et al. (2008), and Rice (2009) for more information on borrow site evaluation, potential impacts of borrow dredging, and borrow site monitoring. The USACE and the Department of the Interior's Bureau of Ocean Energy Management (BOEM) is a useful resource for sand sources and is responsible for managing the development of the US Outer Continental Shelf (OCS) energy and mineral resources. A BOEM example sand source study is the Atlantic Sand Assessment Project (BOEM 2022), a national offshore sand inventory that helps coastal communities and states plan for the future by having better data on offshore sand resources. BOEM has the authority to negotiate via noncompetitive agreements for the use of OCS sand, gravel, and/or shell resources for shore protection, beach restoration, or coastal wetlands restoration projects by federal, state, or local government agencies and use in construction projects authorized by or funded in whole or in part by the federal government (30 CFR Part 583).

Project Design Considerations to Reduce Environmental Impacts

Every effort should be taken to avoid and/or mitigate impacts to NPS resources, especially habitats of high ecological value, during beach nourishment projects. Projects should have clearly articulated strategic and operational objectives, preferably with quantitative goals that can be measured and monitored. These objectives should be related to and informed by the purpose and significance of the park unit. Careful attention must always be given to any threatened or endangered species. For example, an objective may be to “slow erosion on the seaward side of the fort while protecting native biota” or “restore and maintain 200 feet [ft] of beach habitat perpendicular to the shore for a length of 1 mile, for recreation and habitat protection.” This section includes specific design elements that may help to reduce negative impacts and maximize benefits.

Turbidity

The amount of turbidity in the nearshore environment due to sediment placement should be limited by following these BMPs:

- Use sediment that closely resembles native sediment
- Select sediment with a low percentage of silt and clay
- Limit the rate and total volume of placement
- Use turbidity curtains to contain suspended solids
- Conduct fill placement when tidal elevation and wave energy is low

High turbidity can affect filter feeding invertebrates, block the view of visual feeders, reduce light needed for photosynthesis, coat submerged aquatic vegetation, and be a deterrent to recreational use by the public (Greene 2002; Moffatt & Nichol 2006). Elevated sedimentation levels are also known to negatively influence coral reef communities and have been observed during beach nourishment activities (Jordan et al. 2010). Turbidity will usually disappear within several hours after operations finish, but some studies have shown turbidity to be a long-term problem (Greene 2002). Project managers should check with the lead coastal management agency in their state for any specific requirements (see Appendix A).

Placement Design

Placement Geometry

Placement geometry can have a significant influence on a project’s success and ecological impact. An example of implementation of placement geometry is provided in Figure 8 at Indiana Dunes National Lakeshore in Indiana showing placement operations underway. It is generally accepted that the elevation of the design berm should correspond to the natural berm crest elevation (Dean 2005; Gravens et al. 2008). Construction of a higher berm may produce a steeper beach face slope than natural conditions and prevent turtles from crawling up the beach to nest (Steinitz et al. 1998) or degrade recreational use. Florida regulations, for example, require beach nourishment projects be designed to provide habitat that is suitable for successful marine turtle nesting activity (FAC 2017).



Figure 8. Excavator placing sediment along the Lake Michigan shoreline, Indiana Dunes National Lakeshore, Indiana (NPS).

If the design berm is lower than the natural berm, it may be overtopped and produce flooding and ponding on the berm (Gravens et al. 2008). An alternative design approach is to construct a berm that is slightly lower than the natural elevation and allow storms and overwash processes to build the elevation to the natural level (Dean 2005).

Design berm (beach) width depends on the purpose of the project, project economics, and environmental resources. For federal beach nourishment projects, berm width is calculated through a process of optimization based on storm damage reduction (Gravens et al. 2008). Beach width is optimized by computing the costs and benefits of different design options and choosing the option that maximizes net benefits (Gravens et al. 2008).

A key aspect of defining the design profile is to recognize if the pre-project beach has a healthy, normal profile shape or an unnatural shape. If the natural beach is sediment starved, profiles from nearby, healthy beaches that experience similar wave and tide conditions and have similar grain sizes can be used to determine the design profile. For federal projects, the final design profile is determined through optimization. Storm-induced beach erosion modeling is performed during the optimization process to assess profile response from varied storm conditions. Different profiles are run through the model to find the option that provides maximum net economic benefits (Gravens et al. 2008).

During construction, the berm is built to the desired elevation, but it is often made much wider than the final design profile. The over-building method is used because of the working limitations of the

equipment and the desire to place the material in the most economical way. Waves and current action will then redistribute the sediment to deeper parts of the profile over time (Gravens et al. 2008).

Volume

The total volume of material placed is site-specific and based on the project goals, physical environment, infrastructure, potential downdrift effects, and sensitive biological resources. The volume required is calculated as the difference in cross-sectional area between the pre-project profile and the modified design profile shape (Gravens et al. 2008). The modified design profile shape is different from the design profile because it considers the amount of sediment needed to maintain the design profile before the first renourishment (see Gravens et al. 2008 for more information and examples). Differences in the desired level of protection or potential for increased erosion may lead to alongshore differences in fill volume (Figure 9). It should be noted that this is necessarily a three-dimensional calculation that cannot be accurately estimated by a typical cross-section and a length along the shoreline.

It is important to determine the appropriate amount of material to place at the nourishment site to avoid unintended consequences. Placement of 4.1 million m³ (5.4 million yd³) of sediment on Perdido Key in Gulf Island National Seashore, for example, advanced the shoreline an average of 125 m (410 ft) seaward and caused unanticipated biological impacts (Browder and Dean 2000). If a nourished beach becomes too wide for swash zone nutrients to reach vegetation in the back beach, the success of critical dune-building seaoats (*Uniola paniculata*) seed recruitment may be prevented (NPS 2015a). See the Perdido Key case study in Appendix E for more information.

Coverage

For beach nourishment projects, sediment is generally placed with a rectangular or trapezoidal planform along a continuous section of beach and the platform spreads out over time (Dean 2005). Rice (2009) recommends that sediment should not be placed in one large area, but instead be divided up into smaller sections to leave undisturbed areas of existing biological resources. For this approach, future renourishment efforts should alternate which sections receive fill. Rice (2009) recommends individual sections not exceed 610 m (2,000 ft) in length unless scientific monitoring proves otherwise. If possible, the beach fill should be spread in multiple layers and staggered over time to minimize invertebrate mortality and facilitate benthic invertebrate repopulation. Quite often, however, many nourishment projects deposit thick layers, resulting in high mortality of benthic macrofauna (Speybroeck et al. 2006).

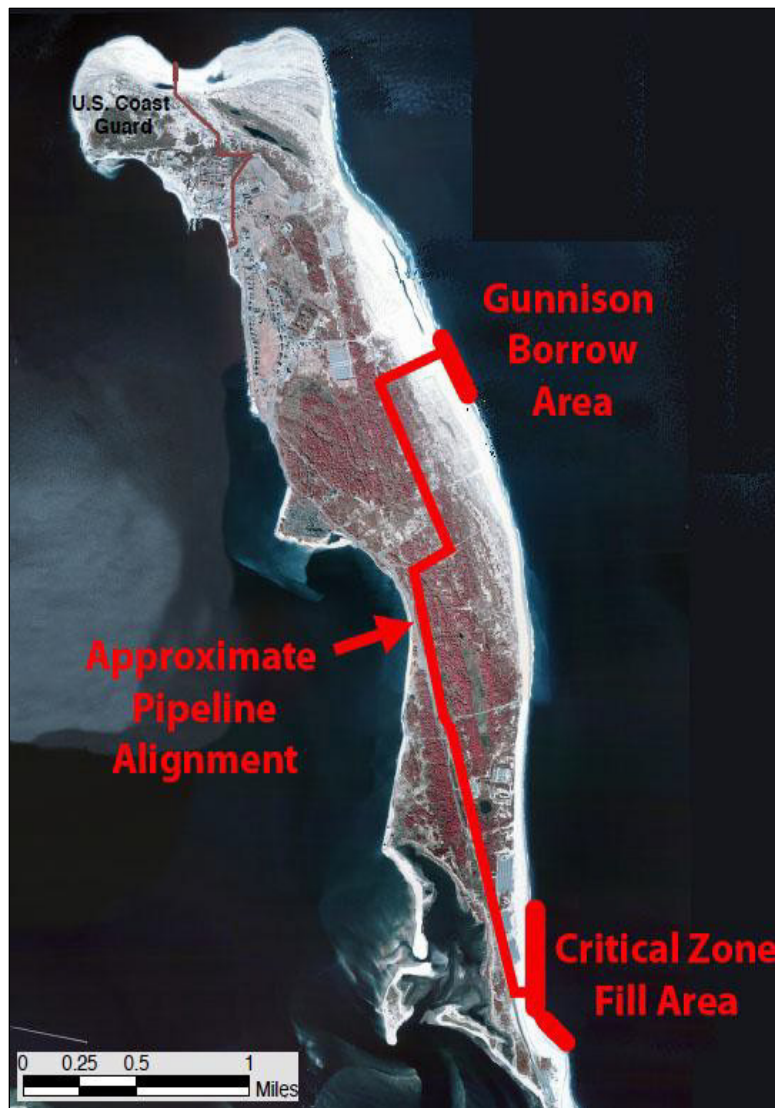


Figure 9. Sand slurry pipeline at Gateway National Recreation Area, New Jersey. The sand was removed from accreting Gunnison Beach and deposited in the eroding critical zone (USFWS 2005: Figure 1).

Nourishment activities should avoid sensitive habitats and areas with high ecological value. Projects should be scheduled to avoid productive biological seasons (see the “Project Timing” section). If sensitive habitats exist within the project area, buffers can be created. Rice (2009) recommends creating buffers of 100 m (328 ft) around wading bird colonies, 200 m (656 ft) around mixed tern/skimmer colonies, and 100 to 200 m (328 to 656 ft) around solitary bird nests; sensitive plants should be given a buffer of at least 10 m (33 ft). If construction activities will occur 24 hours a day, 7 days a week, buffers may need to be greater. Sediment management projects in the nearshore and offshore environments should establish buffers around all reefs, hard bottoms, submerged aquatic vegetation, and other high-value habitats. Rice (2009) suggests buffers be at least 500 m (1,640 ft) around these habitats.

Compaction

Beach nourishment projects should not increase sand compaction. Compaction can be limited by:

- Using compatible fill material with similar grain size, shape, calcium carbonate content, and silt/clay content as is found on the native beach
- Use of construction mats to distribute equipment load
- Staging and storing construction equipment off the beach
- Tilling the fill surface after placement

Compaction affects water retention, permeability, exchange of gases and nutrients, and may decrease turtle nesting success by impeding nest excavation and preventing hatchling emergence (Milton et al. 1997; Steinitz et al. 1998; Defeo et al. 2009). In Florida, beach nourishment permits require measures to reduce sand compaction (FAC 2017). Projects in other states should check with the appropriate state agency for any compaction requirements (see Appendix A for a list of agencies).

Construction

Construction-related traffic should be limited and controlled to minimize adverse impacts to air quality, habitat structure, biological processes (including nesting and foraging), traffic, public safety, and noise. It is not uncommon for such operations to be unsightly and loud, which can affect both wildlife and visitor recreation. All associated vehicles and equipment should be muffled to limit disturbances to the fauna, such as shorebirds abandoning their nests. Project areas should also be clearly marked for safety concerns.

Equipment Considerations

Equipment used in a beach nourishment project includes at a minimum the equipment for recovering sand from the source and the equipment to transport sand from the source area to the project site. This can be from upland or offshore locations. In the case of offshore locations, the choice of dredging equipment is usually determined by the location and character of the borrow area. Pipeline costs increase with length. Nearer borrow areas allow for equipment such as cutter suction dredges to be used, which can then pump the sediment through pipelines to the project site, reducing costs. Distant borrow areas require pumping system booster units in addition to equipment to recover or dredge the sand. Turbidity impacts should be considered in equipment selection, and ecological impacts should be considered when designing access routes for heavy equipment. As distance to borrow site increases, ecological impacts can also increase due to transport length and area affected by dredging and transport. A spill control plan should also be prepared for refueling of equipment.

Project Timing and Time of Year Restrictions

The acquisition of fill material and the construction phase of any project should be timed to avoid the most productive biological seasons, regular storm seasons, and times of high visitor use on beaches. The preferred timing for nourishment depends on the species inhabiting or exploiting the area and the nature and location of the project.

In areas that have nesting seabird and turtle populations, projects should not overlap with nesting seasons. For example, Florida discourages beach nourishment activities during the main portion of

sea turtle nesting season (May 15 to October 31). The state of North Carolina also limits work from May 1 to November 15 to minimize adverse impacts to breeding and migration periods for listed shorebird species and nesting sea turtles. In addition to nesting birds, the timing of construction should also consider resting and foraging birds (Miselis et al. 2021).

Nourishment during the warm season (beginning in April for the Atlantic coast) can affect macrobenthos reproduction, recruitment, and size (Peterson et al. 2000). For the Atlantic and Gulf coasts of the United States, winter (mid-November to February) is the best season for undertaking beach nourishment, partially because it avoids the spawning and recruitment periods for benthic invertebrates (Rice 2009).

If the project may impact essential fish habitat, the NOAA National Marine Fisheries Service (NMFS) and state regulations should be consulted regarding project timing. If any threatened or endangered species habitat may be impacted, consultation with the US Fish and Wildlife Service (USFWS) and NMFS is necessary to determine when (or if) sediment can be extracted and/or placed.

If possible, nourishment projects should avoid storm seasons, such as hurricane season (June to November) in the Gulf States and nor'easter season (October to April) in the Northeastern states. A major storm occurring during the construction phase could potentially transport most of the placed sediment from the project area.

Minimizing Impacts on Biological Resources

Multiple biological resources native to sandy beaches and surrounding ecosystems are protected under NPS *Management Policies 2006* and the Organic Act (16 USC § 1). Although nourishment can lead to improved habitat (especially for sea turtles, shorebirds, and waterbirds) by widening severely eroded beaches, pre-project planning should consider and address potential impacts, both beneficial and adverse to groups such as benthic macroinvertebrates, birds, sea turtles, fish, seagrass, corals, and dune vegetation.

Throughout the years following the Natural Resource Challenge, benthic mapping projects have been conducted intermittently by the National Park Service. From 2008 to 2011, the National Park Service funded benthic mapping pilot projects at ten ocean and coastal units. From 2014 to 2018, the National Park Service funded benthic mapping projects at four coastal units in the northeast in response to Hurricane Sandy. These initiatives resulted in park-specific datasets and reports, as well as guidance documents intended to support future NPS mapping efforts, such as *A Servicewide Benthic Mapping Program for National Parks* (Moses et al. 2010); *Benthic mapping guidance document: Lessons Learned from NPS Benthic Mapping Pilot Projects* (Curdts and Cross 2013); and *Procedures and Criteria for Evaluating Benthic Mapping Data: A Northeast Coastal and Barrier Network Methods Document* (LaFrance Bartley et al. 2019). Currently the Coastal and Ocean Advisory & Support Team (COAST), a national effort established in 2018 and led by the NPS Ocean and Coastal Resources Program, has considered benthic habitat mapping a priority need based on feedback from parks and regions. The COAST benthic mapping team is focusing on the following tasks:

- Ensuring parks have an understanding of and access to existing mapping data and products, tools, and resources
- Producing new geospatial data derived from existing data
- Supporting the collection of new data
- Partnering and collaborating with other federal agencies and entities that collect mapping data and/or develop map products
- Providing technical assistance and guidance for using mapping data and project deliverables to support management needs

The overarching goal of these efforts is to provide parks with benthic mapping information that can support management decisions, including beach nourishment, related to natural and cultural resources, restoration, facilities, infrastructure, and visitor use and safety.

In addition, the National Park Service has received and administered funding from external entities to undertake benthic mapping within parks. For example, mapping has been underway in the Great Lakes since 2010 with funding provided by the EPA-led Great Lakes Restoration Initiative (GLRI) and in partnership with NOAA and academic partners.

Mapping within coastal units has also been conducted by other government agencies. For example, NOAA's National Centers for Coastal Ocean Science (NCCOS) has produced benthic habitat maps and related imagery and publications for areas in the Pacific, Atlantic, and Caribbean (NOAA 2023b). NCCOS and agency partners have also produced a geospatial decision support tool called ShoalMATE, which is used to guide best practices for dredging offshore sand shoals. The development of ShoalMATE is part of a broader initiative to assess essential fish habitat in the Atlantic and Gulf of Mexico in relation to offshore sand features (NOAA 2021).

Benthic Macroinvertebrates

Benthic macroinvertebrates, which may also be referred to as benthic invertebrates, macro-invertebrates, and infaunal organisms in the literature, are often present in beach and nearshore project sites. To limit negative impacts to benthic macroinvertebrates, projects should determine which populations are present and where they occur and use compatible sediment (see the “Sediment Properties for Beach Nourishment” section).

A review of the scientific literature shows variable effects of sediment placement on benthic invertebrate population survival and recovery based on the compatibility of the placed sediment, thickness of sediment, various design factors, and the natural physical processes occurring in the area. Using fill sediment that closely matches the native sediment (e.g., grain size distribution, mineralogy, and organic content) appears to have the greatest influence. Effective project timing, design, and placement rate may also help to prevent negative impacts. As the following sections discussing other biological resources indicate, both sediment compatibility and benthic invertebrate community recovery play key roles in the ecological integrity of nourished beaches.

Although sediment compatibility is widely considered key, impacts to invertebrate survival and recovery may also be reduced by following these recommendations (Peterson et al. 2000, 2006; Smith and Rule 2001; Greene 2002; Bishop et al. 2006; Speybroeck et al. 2006; Defeo et al. 2009; Rice 2009; Vivian et al. 2009; Rosov et al. 2016; Guilfoyle et al. 2019):

Beach Nourishment Site

- Conducting beach nourishment projects outside the most biologically productive seasons, such as seasons of peak larval recruitment (e.g., in the spring/summer for the eastern United States)
- Extending the time between renourishment episodes to permit motile invertebrates to colonize the fill
- Placing fill in several short, non-continuous sections, each no more than 610 m (2,000 ft) long, to leave undisturbed regions for enhanced recovery (Rice 2009)
- Alternating the sections that receive fill during subsequent nourishments so that undisturbed refugia are maintained for benthic organism survival and recolonization
- Generally, limit the thickness of placed sediment to no more than 30.0 cm (11.8 in). This may be refined based on specific species present. This promotes recolonization by native benthic species and is particularly important in the intertidal zones.
- Maintaining the natural beach profile to preserve habitat areas (e.g., tidal, subtidal)

Borrow Area

- Completing sediment removal from borrow areas before the natural seasonal decline in benthic invertebrate populations to allow for recolonization to occur
- If applicable, locating borrow sites in areas that are likely to refill rapidly with beach-compatible sediments while not disrupting cross-shore transport
- If applicable, using a dredging method of shallow cuts interspersed with furrows (i.e., “striped dredging”) to promote recolonization from unimpacted refugia
- If applicable, using a dredging method that avoids creating deep pits with steep side-slopes at borrow areas such that water quality conditions are substantially altered
- If dredging from within an offshore shoal, selectively dredging from the leading edge to allow for net long-term deposition and a faster infilling rate

The rate of longshore transport may also play a role in benthic recovery because high rates of longshore transport can dilute and disperse incompatible sediment and can enhance invertebrate immigration (Van Dolah et al. 1984; Peterson et al. 2006).

Benthic macroinvertebrates, typically crabs (Figure 10), bivalve mollusks, amphipods, and polychaetes, are the prey base for surf fish, shorebirds, and epibenthic invertebrates (Greene 2002). Thus, they are critical to the health of higher trophic levels and can also serve as indicators of habitat for predator species. The effects of sediment placement (beach nourishment or nearshore sediment

placement) on benthic invertebrates vary by project design, location, and species/communities, ranging from few or no detectable effects to widespread, long-lasting impacts.



Figure 10. Ghost crab at Padre Island National Seashore, Texas (NPS).

Peterson et al. (2000) found a decrease of 86 to 99% in macroinvertebrate populations 5 to 10 weeks after nourishment. Although the original organisms will die off, the newly restored beach should become naturally recolonized. Recovery can sometimes be quick (e.g., a few months to less than one year) because of rapid sediment dispersal and/or high natural species tolerance (Gorzelany and Nelson 1987; Nelson 1993; Smith and Rule 2001; Cruz-Motta and Collins 2004). However, when inappropriately selected sediments alter the native habitat characteristics or have high organic or pollutant loads, the effects can be long-lasting. Peterson et al. (2006) documented limited recovery of *Donax* spp. (coquina clam) 7 to 12 months after nourishment in North Carolina and a 70 to 90% decline in feeding shorebirds largely in response to prey depression of *Donax* spp.

Most studies have found a significant decline in benthic invertebrate population at the placement location immediately following sediment placement due to burial and suffocation (Peterson et al. 2000; Cruz-Motta and Collins 2004; Bishop et al. 2006; Manning et al. 2014). However, the duration of the population impact varied by project and by invertebrate group. Studies suggest the most important determinant of impact and rate of recovery of benthic invertebrate populations is the degree to which fill sediment matches the native sediment (Nelson 1993; Peterson et al. 2000). Previous research demonstrates that where fill sediment matches the native sediment (grain size distribution, mineralogy, organic content, and pollution loads), there are limited impacts on benthic invertebrate population abundances and recovery occurs rapidly (between a few months to less than one year) (Gorzelany and Nelson 1987; Nelson 1993; Smith and Rule 2001; Cruz-Motta and Collins

2004). Gorzelany and Nelson (1987) concluded that compatible fill material likely contributed to the lack of negative invertebrate effects at a beach nourishment project in eastern Florida. Similarly, the lack of detectable effects on the invertebrate community structure after nearshore sediment placement in Australia was attributed to compatible sediment and effective placement design (Smith and Rule 2001).

In contrast, other studies have found large depressions of benthic invertebrate populations where incompatible sediment was used (McLachlan 1996; Rakocinski et al. 1996; Peterson et al. 2000, 2006; Harvey et al. 1998; Colosio et al. 2007; Manning et al. 2014). Peterson et al. (2006) reported that unnaturally coarse fill sediment during the Bogue Banks, North Carolina beach nourishment project was associated with limited benthic invertebrate recovery after one year and a 70 to 90% decline in feeding shorebirds, which they attributed to invertebrate prey depression. Rakocinski et al. (1996) also found the delayed recovery of invertebrates in concert with increased silt/clay loading after a large beach and nearshore restoration project (7.1 million m³ [9.3 million yd³] along 6.9 km [4.3 mi] of shoreline) on Perdido Key, Florida in Gulf Islands National Seashore.

Beach nourishment may have variable impacts on benthic macroinvertebrate groups, with some recovering more quickly or completely than others (Leewis et al. 2012; Peterson et al. 2014; Viola et al. 2014; Wooldridge et al. 2016; Danovaro et al. 2018). Wooldridge et al. (2016) determined that the lack of polychaete worm recovery observed following nourishment at eight beaches in San Diego County, California, caused a depression in overall invertebrate species abundance twofold over a monitoring period of 15 months. A review of beach nourishment studies in South Carolina found that beaches are rapidly recolonized after the placement of beach fill but that the composition of that community may be quite different from that present pre-nourishment (Bergquist and Crowe 2009). Mismatched sediments particularly contribute to the incomplete ecological recovery of more vulnerable macroinvertebrate groups, with federal regulatory limits for fines (i.e., 10%) possibly overestimating the threshold value appropriate for polychaetes (Viola et al. 2014). Researchers determined experimentally that polychaetes were the most vulnerable to burrowing inhibition (tolerating up to 4% fines), followed by sand crabs and clams (tolerating up to 20% fines) (Viola et al. 2014). Alternately, nourishment with unnaturally coarse and shelly sediment has been found to have little impact on polychaete populations, instead suppressing densities of haustoriid amphipods and coquina clams for three to four years (Peterson et al. 2014).

Beach invertebrate populations are patchily distributed with densities of hundreds to thousands per square meter often occurring (McLachlan 1996). Intertidal invertebrate populations can also relocate during flood and ebb tides and with the normal deposition-erosion of shore sediments (Barnes and Wenner 1968). Although there is generally limited knowledge of invertebrate ecology, if possible project managers should determine which populations are present and where they occur to protect invertebrate animals during beach nourishment projects. It may be possible to screen mobile invertebrate populations away from sediment discharge areas using block nets. Temporary removal and reseedling are also possible with many beach invertebrate populations.

Birds

The United States coasts support dozens of shorebirds, tern, and skimmer species, many of which are experiencing significant population declines (Guilfoyle et al. 2019). These migratory birds use coasts as breeding and wintering grounds; however, the availability and suitability of stopover areas in the contiguous 48 states are particularly important, as migration is both an essential feature of their life history and a high-mortality period for these birds. Anticipating the impacts of beach nourishment and related coastal engineering projects on shorebird populations can be complicated, depending on the timing of migrations and how populations use the habitat (e.g., breeding, wintering, or stopping over). Generally, deposition of dredged material can be expected to temporarily lower site quality for invertebrate populations on which migratory shorebirds rely for food (Guilfoyle et al. 2019). The placement of unnaturally coarse and shelly sediment has been shown to depress benthic invertebrate populations and their shorebird predator populations for several years following nourishment (Peterson et al. 2014). However, appropriate planning and engineering can enhance shorebird nesting and foraging habitats. To limit negative impacts to birds, projects should determine which species and populations use the site, the timing within the year of that use, how the habitat is used throughout the year, and in which areas. Impacts to invertebrate prey survival and recovery should be reduced following the measures listed previously. Although maintenance of prey species and foraging opportunities are considered key, impacts to shorebird populations may also be reduced by (Rice 2009; Farrell et al. 2016; Guilfoyle et al. 2019):

- Conducting beach nourishment projects outside periods of critical nesting, wintering, or migrating seasons
- Extending the time between renourishment episodes to permit ecological recovery
- Maintaining buffers of 100 m (328 ft) around wading bird colonies, 200 m (656 ft) around mixed tern and skimmer colonies, and 100 to 200 m (328 to 656 ft) around solitary bird nests and larger for species with precocial chicks
- Maintaining buffers of 100 to 200 m (328 to 656 ft) around foraging and roosting sites for shoreline-dependent birds
- Maintaining buffers of 10 m (33 ft) around sensitive plants to maintain shorebird habitat
- Identifying and maintaining buffers (up to 500 m [1,640 ft]) around all reef, hardbottoms, submerged aquatic vegetation, and habitat areas of concern to promote the integrity of seabird and shorebird habitats
- Maintaining the natural beach profile, paying particular attention to the maintenance of tidal pools and flats and opportunities for overwash events to create overwash fans, to preserve habitats and microhabitat diversity
- Regular monitoring during nourishment activities for the presence of protected shorebirds to ensure work avoids disturbance and is paused until birds are out of the work area
- Pausing work in areas surrounding any discovered active shorebird nest until young have fledged and are independent from adults

- Minimizing heavy equipment use and vehicle trips that could flush roosting or foraging shorebirds
- Delineating enclosures clearly to prevent interference by park visitors and their pets
- Avoiding the removal of wrack line material (e.g., stranded kelp, seagrass, shells) from beaches, to ensure continued foraging opportunities for shorebirds
- Ensuring vegetation planting plans are informed by habitat needs, predator discouragement strategies, and preferences of shorebird populations using the site (e.g., for unvegetated zones)

Although the measures listed above apply to shorebirds in general, Maslo et al. (2011) developed target design parameters for piping plover (*Charadrius melodus*) microhabitat on nourished beaches as an example of what could be generated for each impacted species. These recommendations for piping plover include that vegetative cover be kept below 10% on the backshore and below 13% on the primary dune; shells and pebbles constitute 17 to 18% of cover; dunes be constructed no more than 1.1 m (3.6 ft) high; and dune slope does not exceed 13% (Maslo et al. 2011).

Sea Turtles

Sea turtle populations are extant throughout a large portion of NPS coastal parks and can be significantly impacted by nourishment events. However, as an alternative to rapid natural erosion otherwise causing the loss of sea turtle nesting habitat, Wilber et al. (2009) asserts that beach nourishment is generally beneficial to sea turtle populations. Mitigating adverse impacts of beach nourishment on sea turtles may be considered more straightforward than with shorebirds in that sea turtle use of beaches is typically confined to discrete periods of nesting and hatching (Guilfoyle et al. 2019). Nourishment activities can change beach characteristics, such that nest-site selection, digging behavior, clutch viability, and hatchling emergence are adversely affected (Crain et al. 1995).

An important parameter in sea turtle nesting habitat and a determinant of nesting success is sand temperature, which can be influenced by borrow sediment selection (Wilber et al. 2009; Shambloott et al. 2021). Incubation temperatures affect hatchling sex determination in sea turtles with warmer nests producing proportionately more females (Mrosovsky 1988). Across eight beaches in the high-density loggerhead sea turtle nesting region of North Carolina, Shambloott et al. (2021) found that nourishment was a significant predictor of mean monthly sand temperatures in both univariate and multivariate predictive models. Across a season, nourished sections of beach were, on average, 0.44 degrees Celsius (°C) (0.8 degrees Fahrenheit [°F]) (range 0.28 to 0.80°C [0.50 to 1.44°F]) warmer than unnourished sections. This discrepancy was attributed to the reduced albedo of the borrow sediments, which were coarser and darker than the natural beach sand.

Sand compaction on nourished beaches has not been shown to influence metrics of nesting success, such as nesting frequency (Wilber et al. 2009). The impacts of beach nourishment on surrounding subtidal environments inhabited by sea turtles during other periods of their life cycle should also be considered. Impacts to sea turtle populations may be reduced by (Rice 2009; Guilfoyle et al. 2019; Shambloott et al. 2021):

- Conducting beach nourishment projects outside seasons of sea turtle nesting and hatching
- Extending the time between renourishment episodes to permit ecological recovery
- Maintaining or installing sand fencing as needed in intermittent segments that do not obstruct the movement of nesting and hatchling sea turtles between the dune line and other areas of the beach
- Maintaining the natural beach profile, including dune backslope to subtidal bar and trough morphology, to enable movement of nesting and hatchling sea turtles
- Ensuring borrow sediment is compatible with the native sediment, especially color and grain size
- Maintaining buffers of 100 to 200 m (328 to 656 ft) around sea turtle nesting sites
- Maintaining buffers of 10 m (33 ft) around sensitive plants to maintain sea turtle nesting habitat
- Maintaining buffers (up to 500 m [1,640 ft]) around all reef, hardbottoms, submerged aquatic vegetation, and habitat areas of concern to promote the integrity of sea turtle habitats

Beach nourishment can be expected to reduce nesting success within the year following a nourishment event but has been shown in some cases to recover or even improve by the next nesting season (Wilber et al. 2009).

Fish, Seagrass, and Corals

The responses of intertidal and subtidal communities, including protected groups of fish, seagrass, and corals, to beach nourishment has been studied more in recent years (González-Correa et al. 2008, 2009; Wilber et al. 2009; Jordan et al. 2010; Vanden Eede et al. 2014; Munsch et al. 2015; Post et al. 2017; Martin and Adams 2020). The growing base of evidence sheds light on the pathways by which beach nourishment has long been understood, but not necessarily demonstrated, to adversely impact fish and other subtidal or intertidal biological resources (e.g., through sediment burial of nearshore habitats or depression of benthic invertebrate prey populations). Ray et al. (2003) concluded, after studying the response of multiple fish species to large-scale nourishment in New Jersey, that their discovery of negligible adverse impacts can be attributed to the use of compatible borrow sediments. To limit negative impacts to fish, seagrass, and corals, projects should characterize the subtidal nearshore habitats in the vicinity of the project, identify the fish species using these nearshore habitats, and determine whether fish populations use the site during particular points in their life cycle and/or during particular seasons. Impacts to invertebrate prey survival and recovery should be reduced following the measures listed previously. Impacts may be further reduced by (Rice 2009; Guilfoyle et al. 2019; Martin and Adams 2020):

- Selecting compatible sediment to reduce the likelihood of turbidity and other water quality effects impacting local fish, seagrass, and coral populations.
- Refraining from burying marshes, benthic communities, oyster reefs, clam beds, or other valuable benthic and fish habitats

- Maintaining buffers (up to 200 m [656 ft]) around all reef, hardbottoms, submerged aquatic vegetation, and habitat areas of concern to promote the integrity of fish habitats
- Avoiding beach nourishment activities during fish reproductive seasons
- Extending the time between renourishment episodes to permit ecological recovery
- Locating areas mined for sediment away from all sensitive habitats
- Employing shallow and/or staggered dredging methods that do not significantly alter bathymetry, and retain a significant layer of sediment that matches the original surface

Unique and sensitive life histories of native fish should be considered when planning beach nourishment activities, as these species may be particularly vulnerable to changes in beach morphology or other nourishment effects. The California grunion (*Leuresthes tenuis*), for example, is a marine fish endemic to the Pacific coast of North America that has a unique beach-spawning behavior in which it emerges fully from the water during spawning runs under the full or new moon. Eggs are buried 10 to 20 cm (3.9 to 7.9 in) below the sand surface, but above the waterline, and are washed free weeks later by subsequent rising tides (Martin and Adams 2020). The formation of large sand scarps, either naturally or connected to nourishment projects, is a barrier to grunion spawning, and among other factors may be contributing to the decline in this species observed in California (Martin and Adams 2020). Likewise, Post et al. (2017) found that juvenile common sole (*Solea solea*), which use nearshore habitat in the North Atlantic as critical nursery, demonstrated a significant habitat preference for fine-grained sediments. Because juvenile sole have a small home range and are not expected to relocate in response to unfavorable conditions, the impacts of beach nourishment with incompatible sediment on the recruitment of adult sole may be substantial. Flatfish relatives of the common sole that are native to North American coasts are likewise sensitive to grain size, given their demersal lifestyle (Gibson and Robb 2000).

Dune Vegetation

Dune ecosystems are vulnerable to the same “coastal squeeze” threatening many beach ecosystems nationwide, where erosion, SLR, and coastal development are together limiting the available substrate where dunes can flourish. In some cases, beach and dune restoration projects that include activities such as beach nourishment and dune stabilization may alter community assemblages and interfere with the natural geomorphologic evolution of dunes (NPS 2015b; Daneshgar et al. 2017). The introduction of nonnative plant species and rigid stabilizing structures may be particularly deleterious to dune ecosystems. To limit negative impacts to dune vegetation, nourishment projects should establish target plant community assemblages for the foredune, trough, and backdune zones (as appropriate) based on known native species (including protected plant and animal species) and determine the predominant local dune migration patterns. Impacts to dune vegetation may be reduced by (NPS 2015b; MDEQ 2017):

- Minimizing disturbed dune areas and dune soil movement during nourishment activities
- Preventing travel of personnel and vehicles into steeply sloped and other sensitive areas (e.g., containing trees or rare plants)
- Maintaining buffers of 10 m (33 ft) around sensitive plants

- Planting only native dune species
- Monitoring the distribution of and, where appropriate, removing nonnative and invasive plant species such as European beach grass (*Ammophila arenaria*) and ice plant (*Carpobrotus* spp.)
- Integrating vegetation planting and monitoring strategies with plans to restore habitat for other important biological resources, especially birds, sea turtles, and pollinators
- If locating sand fencing, ensuring that it will not direct or collect sand onto sensitive habitats, such as where dune vegetation could become smothered or in nesting shorebird habitat
- If selecting sand fencing, using biodegradable post materials, such as untreated wood

Other Biological Resources

The mechanisms of impact described above apply to additional native biota not yet explicitly mentioned, which may be particularly relevant to the missions of individual coastal units. Beach nourishment can impact critical habitat and/or prey populations of protected pinnipeds, such as the Hawaiian monk seal (*Neomonachus schauinslandi*), whales and dolphins, butterflies and bees, coral reefs, and seagrass bed inhabitants such as queen conch (*Strombus gigas*) and the West Indian manatee (*Trichechus manatus*). Individual coastal units must consider the potential impacts of beach nourishment projects on sensitive, protected, and otherwise important coastal and marine habitats and species.

Managing Invasive Species

The management and control of invasive species in NPS units are mandated and guided by NPS *Management Policies 2006* and Executive Order 13751, “Safeguarding the Nation from the Impacts of Invasive Species” (December 5, 2016). Preventing the introduction of invasive species is considered the preferred, primary strategy for protecting native ecosystems and species, and where introduction cannot be or has not been prevented, secondary strategies include eradication, control, and/or long-term management to ensure the protection of natural resources. Early detection is a powerful tool to limit the spread of exotic and invasive species and is often the least costly intervention. In general, efforts to eradicate, control, and manage established exotic species long-term are progressively costly to coastal units.

Beach nourishment project managers must anticipate and plan to mitigate the potential for projects to create or worsen an invasive species problem. Beach nourishment may contribute to invasive species problems via the direct introduction of invasive species with emplaced sediment, engineered reef structures, or vegetative plantings. Organic contaminants from the borrow site can include eggs, larvae, dormant or sessile crustaceans, pathogens, and seeds, which may be introduced to the nourished beach when sediment is placed (Miselis et al. 2021). Beach nourishment may be conducted in concert with nearshore reef restoration, through which reef-forming organisms (e.g., corals, oysters) may be introduced or reintroduced to the site. Likewise, dune restoration and slope stabilization that accompanies or follows sediment placement can disturb native plant communities if plantings include non-native or invasive species. In addition to facilitating direct introductions of invasive species, beach nourishment may disturb local conditions to such a degree that invasive

species already present in the area have a significant advantage over native species in recolonizing post-disturbance. Planning of beach nourishment must therefore consider environmental conditions in the area that may compound direct disturbances to the beach. Factors such as eutrophication, turbidity, and proximity to major ports or shipping channels may contribute to regional conditions that favor invasive success; however, more studies are needed (Zviely et al. 2021). Although little research has been published demonstrating the consequences of nourishment on the success of invasive species, Daneshgar et al. (2017) found that nourishment of secondary dune communities in New Jersey was linked to conditions promoting Asiatic sand sedge (*Carex kobomugi*) invasion to the detriment of native dune species. Deeper burial (up to 60 cm [23.6 in]) correlated with reduced plant community diversity and reduced native plant biomass, while the native seaside goldenrod (*Solidago sempervirens*) within invaded communities exhibited significantly lower photosynthesis rates than individuals in non-invaded communities.

Best practices to prevent the introduction and/or slow the spread of established invasive species during beach nourishment projects are mentioned throughout the “Minimizing Impacts to Existing Biological Resources” section and summarized here:

- Thoroughly wash equipment prior to entering a park unit to ensure seeds and viable plant material from other areas that may have invasive species is not introduced
- Minimize the introduction of invasive species by selecting sediment based on thorough screenings for non-native and invasive species
- Use only native species for projects that include reef and/or dune vegetation restoration,
- Monitor the presence/absence and distribution of invasive and non-native species at the project site, and where appropriate, remove individuals and assemblages
- Minimize the depth of placed sediment, and alternate nourished areas of beach when renourishing to facilitate rapid recolonization by native species
- Extend the time between renourishment episodes to permit ecological recovery
- Maintain strict buffers around sensitive plants and animal habitats to minimize disturbances to native species

Monitoring Program

Beach nourishment projects should include scientifically rigorous pre-project, during construction, and post-project physical and biological monitoring. Monitoring is necessary to assess project performance, identify any impacts, and ensure project functionality and environmental standards. Monitoring provides critical information for adaptive management efforts at the project scale (Rice 2009) and the improvement of beach nourishment outcomes wherever projects are implemented (Wilber et al. 2009). Scientific evidence supporting the use of beach nourishment practices is growing but still limited; Peterson and Bishop (2005) and Wilber et al. (2009) found that 53% to 87% of monitoring studies reviewed were terminated before recovery was demonstrated. Further collection and dissemination of data on the physical and biological responses to beach nourishment are needed.

Monitoring plans will vary by project due to the project size, budget, species present, and overall project goals. These plans, depending on scope and purpose, may be completed by project partners outside of the National Park Service. However, some high-level monitoring guidelines apply to most projects regardless of scale and scope, and monitoring plans must ensure that permit conditions from various entities are included. For example, if an Endangered Species Act biological opinion (BO) has been produced, monitoring needs to include conditions of the BO. Robust and reliable monitoring of the physical and biological impacts of beach nourishment will (Peterson and Bishop 2005; Bergquist and Crowe 2009; Rice 2009; Wilber et al. 2009):

- Relate directly to the stated objective(s) of the beach nourishment project
- Involve collaboration among experts in various relevant fields, such as engineers, managers, and biologists
- Document basic project characteristics (e.g., sediment volumes placed, project timing, nourishment depth, changes in beach width and slope, and berm elevation), along with monitoring methodologies, data, statistical analyses, and results
- Conduct monitoring during construction and convey data to project managers in a timely manner to facilitate adaptive management
- Focus on potential mechanisms of impact rather than changes to population totals for target biota, which are highly variable in space and time
- Identify monitoring objectives and select methodologies that are supported by scientific evidence, and where possible, that contribute to a better understanding of physical and biological responses to nourishment-related disturbance
- Use Before-After Control-Impact (BACI) monitoring designs with analogous statistical analyses, such that the magnitude and duration of biologically meaningful effects can be detected

Project size and budget are major determinants of whether BACI monitoring will be feasible for a given project. For smaller projects, control areas may not be necessary if the goal is only to show whether project objectives have been achieved within the project area. If control areas are established

and monitored, areas of nourishment and control sites should be interspersed to avoid spatial interdependence. Otherwise, the nourished site should be bracketed by control sites on both sides (Peterson and Bishop 2005). Reviews and meta-analyses of beach nourishment monitoring have revealed that monitoring efforts often suffer from invalid assumptions and improper interpretation of results (Peterson and Bishop 2005; Bergquist and Crowe 2009; Wilber et al. 2009). After a review of 46 beach monitoring studies, Peterson and Bishop (2005) concluded that many monitoring programs have serious flaws because they are conducted by contractors usually associated with the proponents of the project rather than by independent researchers and have no independent peer review. Instead, it is suggested that monitoring programs should be carried out by a neutral third party and include anonymous scientific peer review. The selection of sampling devices and methods and the statistical methods used to determine effect size for target biota can likewise have a substantial sway on the results of monitoring efforts (Wilber et al. 2009). In this context, the effect size is the difference between the change that occurs in the impact group and the change that occurs in the control group. Even if a BACI monitoring design is used, Bergquist and Crowe (2009) found that in South Carolina projects, nourishment monitoring data have rarely been analyzed in such a way as to maximize the statistical power of this design.

The following sections present important considerations regarding specific components of beach nourishment monitoring. Many of the aspects and components presented below are also applicable to the monitoring of the borrow site. The NPS I&M Program has developed various monitoring protocols that can guide parks in developing a monitoring program. All of the protocols are available on the I&M Monitoring Protocol Database (NPS 2023).

Seasonality

Each characteristic or variable of a monitoring plan should have its own seasonal requirement, and therefore timing constraints, that should be identified and addressed in the monitoring plan. For example, because resource aspects (such as migratory bird use, hydrologic patterns, turtle nesting density, fish abundance, invertebrate abundance, and wave energy) change over various time scales, each should be assessed individually (Thayer et al. 2003). Both the project and control areas should be sampled each time sampling is conducted and in the same month at a minimum. Annual monitoring should be done at the same time of year to reduce the effects of seasonality on the detection of long-term trends.

Frequency

Monitoring should occur before, during, and after nourishment activities. Pre-project monitoring is required to obtain baseline data on significant flora and fauna in the area and to document the natural spatial and seasonal variability of the biological and physical systems (Gravens et al. 2008). These data can then be compared with data collected after restoration to assess any project-related impacts. All relevant biological and physical variables should be sampled at the same time (or as close as possible) and sampling techniques must be consistent throughout the project to allow for hypothesis testing (Nelson 1993).

Duration

The duration of monitoring will vary by project size, the variables being monitored, and overall monitoring goals. Pre-project monitoring should include enough time to gather baseline information on the pre-existing systems. A pre-project sampling period of at least a year is highly recommended to observe storm events and seasonal patterns (Thayer et al. 2003). Monitoring during construction is critical to ensure that proper design specifications are met and should include periodic sampling of the fill material to identify any incompatible material (Thayer et al. 2003; Rice 2009). Post-construction monitoring should span a period that permits statistical analysis.

Monitoring Components

To establish a baseline, monitoring plans should contain one or more of the following components measured before the project is started, during construction, and for an appropriate length of time after the project is complete. This information is also very important to provide an adaptive management strategy for the site if this is a goal for the project.

- Topographic surveys
- Visual beach inspections
- Beach sediment sampling
- Turbidity monitoring
- Aerial shoreline configuration (photography)
- Bathymetric surveys
- Continuous wave and water-level measurements
- Biological monitoring of birds, sea turtles, fish, seagrasses, corals, macroinvertebrates, and other biological resources

The physical characteristics, flora, and fauna monitored will vary by project. The project area may have highly sensitive areas, such as sea turtle nesting sites, or might include federally threatened and/or endangered species (Figure 11). Similarly, the physical conditions will differ widely between project sites, requiring different monitoring components. It is not expected that every project will incorporate all the monitoring activities listed below. The components are presented as examples of activities that may be included in a monitoring plan.



Figure 11. A federally listed threatened and endangered species, a piping plover (*Charadrius melodus*) chick, in Cape Cod National Seashore, Massachusetts. Beaches in the seashore serve as critical breeding habitat (NPS).

Topographic Surveys

Topographic surveys provide elevation data and are used to calculate and monitor beach volumes, monitor shoreline position, and document changes in the beach cross-section (Figure 12).

Topographic data can be collected with a real-time kinematic (RTK) Global Positioning System (GPS) during surveys conducted on foot or from all-terrain vehicles (ATV), or light-detection and ranging (LiDAR) surveys (aerial or terrestrial).

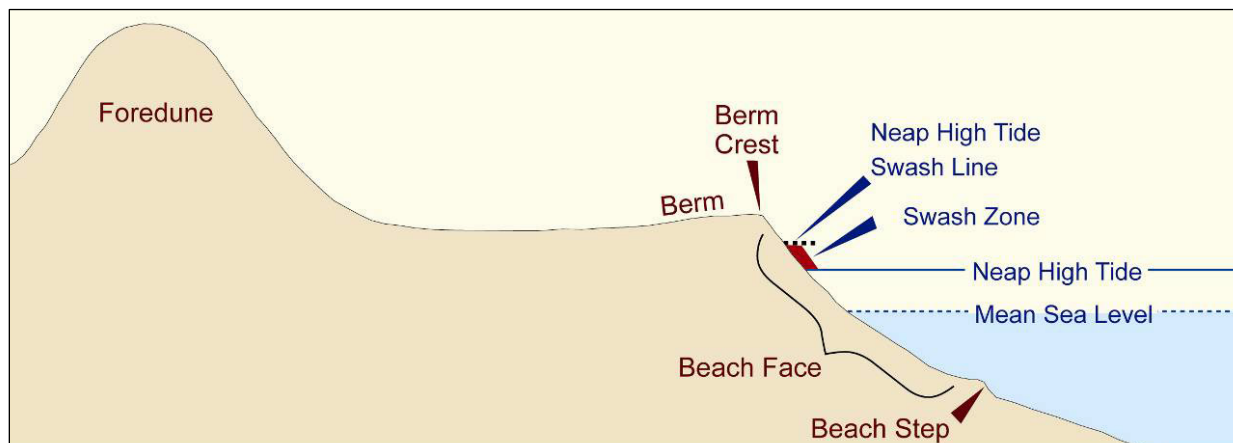


Figure 12. Conceptual dune-beach profile showing the juxtaposition of water level, topographic features, and the identification of the neap high-tide swash line (Psuty et al. 2010: upper part of Figure 3).

Variations in the volume of sand in a beach nourishment project, along with the width of the beach, can be recorded by periodic beach profile surveys. Profile surveys are accomplished by repeating transects at regular intervals perpendicular to the shoreline using traditional surveying techniques. Profile surveys should re-occupy the same transects every time and be referenced to a common

baseline that is set at the beginning of the study (Gravens et al. 2008). Surveys should occur at low tide and cover the entire beach profile from the upper beach out to beyond the depth of closure (seaward limit of profile change). The frequency of the profile surveys varies over the project life with initial surveys at certain sites needing to be conducted with enough frequency to capture seasonal changes. As an example, immediately post-construction, quarterly surveys may be required due to profile adjustments but may decrease to less frequent (annual) surveys over time. Annual surveys should be conducted, ideally, during the time of year when wave energy is lowest. Since the distance between the profiles is usually large, the topographic data derived from profiling is spatially limited and needs to be noted when making inferences about large beach areas; however, the transects do provide detailed data along each line.

Full coverage, high-resolution topographic surveys of the entire beach can be done using an ATV-mounted GPS receiver. The receiver collects position and elevation data at regular intervals (e.g., 1 second). The georeferenced elevations are gridded to produce a three-dimensional surface of the beach. A typical survey of Ocean Beach (a 6.9-km [4.3-mi]-long beach in Golden Gate National Recreation Area, California) consists of roughly 20,000 individual elevations (Hansen and Barnard 2010). The NPS Northeast Coastal and Barrier Network (NCBN) has developed an ATV ocean shoreline position monitoring protocol (Psuty et al. 2010), which the Southeast Coast Network and Gulf Coast Network follow with slight modifications for each network's needs. The NCBN coastal geomorphological program conducts these ATV GPS surveys along the entire shoreline of several parks twice a year (spring and fall) to accurately map the position of the high-tide swash line to determine the long-term trends in the seasonal and annual variability in shoreline position for the ocean shoreline in NCBN parks. The US Geological Survey Digital Shoreline Analysis System tool is then used to transform the surveyed shorelines into a data matrix of distance measurements from which temporal and spatial changes are determined. Note that ATV surveys may not be appropriate for all areas, particularly those with sensitive habitats or threatened species.

Full coverage, high-resolution elevation data can also be collected by airborne (drone or aircraft) or stationary LiDAR (Gares et al. 2006). LiDAR measures distance by sending pulses of light that strike and reflect from the surface. The LiDAR system also measures the time of the pulse return and the GPS position, allowing it to record accurately georeferenced data. LiDAR generates very large and dense point datasets that can be analyzed to provide highly accurate and detailed three-dimensional elevation models (NOAA 2012).

Visual Beach Inspections

Visual inspections should occur concurrently with all baseline and post-project monitoring events. If possible, conduct inspections at low tide to gather observations of the entire beach area. Inspections should note all observations about the condition of the beach (e.g., dune vegetation, storm scarping or overwash, post-storm recovery berms, sand bars, points and cusps, channels, longshore variability in beach features, sediment color, presence of shell hash, compaction, and slope). An observation checklist can be helpful to ensure consistent methods over time.

Sediment Samples

Sediment sampling is needed to determine any change in the grain size distribution over time, which could affect the beach shape and biological habitat. Sediment grab samples should be collected regularly along the profile survey lines and occur concurrently with annual profile surveys. Samples should re-occupy the same locations along the profile (e.g., berm, foreshore, cusp, foredune), include more than the surface layer of sediment, and be mixed well before analysis to ensure representative sampling of the beach.

Turbidity Monitoring

Turbidity monitoring should be conducted regularly during construction. Turbidity levels are often measured using a Secchi disk that is mounted on a pole or line and lowered down in the water. The areal extent of increased turbidity can also be determined using either ground-based or aerial (drone-based) photographs in locations where drone flight is permitted. If monitoring indicates excessive, prolonged turbidity, construction should be halted or modified.

BMPs for limiting turbidity should be employed, including the use of compatible sediment with a low percentage of silt and clay, silt fencing, or silt curtains to confine the suspended solids, and timing of the fill placement when tidal elevation and wave energy are low (see the “Project Design Considerations to Reduce Environmental Impacts” section for more information).

Aerial Photography

Vertical aerial photography is used to monitor long-term fill performance, shoreline position, and beach width (Gravens et al. 2008). Aerial photographs provide a total-project perspective that cannot be obtained with profile surveys alone and are an important resource for communicating with others. Vertical aerial photographs should be acquired at least annually and near midday around low tide to minimize shadows and capture the greatest area of beach (Gravens et al. 2008). Ideally, photographs should be taken just before the winter storm season and as close as possible to the date of the beach profile surveys. It is best to use the largest scale photography available. To perform any analysis of an image, it must first be georeferenced (aligned to a map coordinate system).

Bathymetric Surveys

Bathymetric surveys are used to measure the bathymetry, or elevation, of the seafloor. Bathymetry can be measured using a single or multibeam echosounder system. In addition, in some cases, aerial-based LiDAR equipment can also deliver accurate bathymetry depending on the system and the amount of turbidity present. An echosounder measures depth using sound signals emitted from an instrument mounted on a boat. Shoreface profiles, offshore borrow sites, nearshore placement sites, and dredging sites can all be assessed and monitored through bathymetric surveying. Bathymetric data (Figure 13) can be used to find the depth of borrow sites (and whether the dredger can reach them), the surface area of sediment that is available to be dredged, the recharge rate of the dredged area, the shape of the shoals (which is important for fish habitat and wave attenuation), and bathymetric change over time. Data can also be used to model incoming waves and help to predict how wave energy may change if the bathymetry is modified. Bathymetric surveys are also important for capturing nearshore data to extend beach profiles offshore. Bathymetric profiles should align with the dry beach profiles and extend offshore some distance beyond the expected depth of closure.

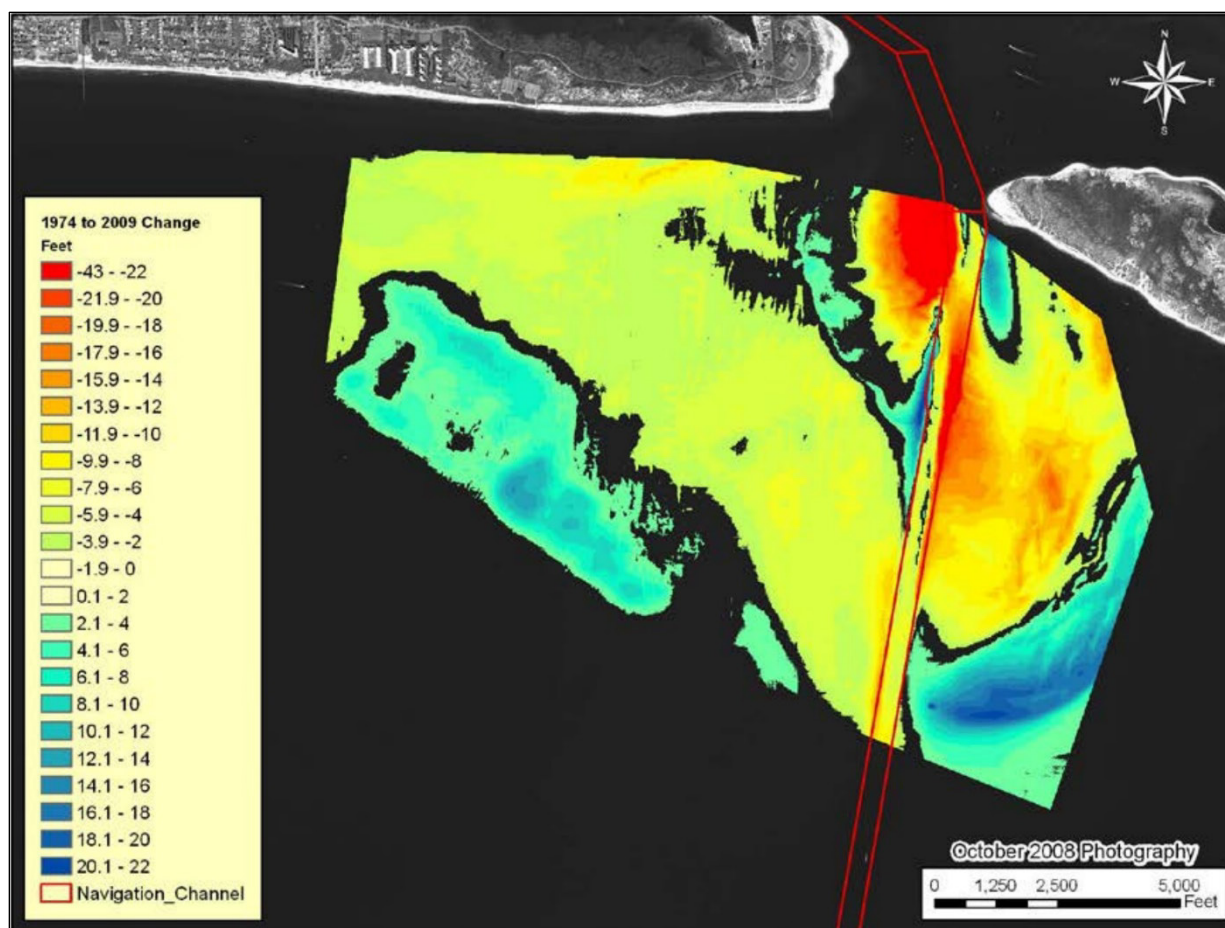


Figure 13. Bathymetric change from 1974 to 2009 at Beaufort Inlet, North Carolina, adjacent to Cape Lookout National Seashore (adapted from USACE 2016b: Figure 3-18).

Waves, Currents, and Water Level Measurements

Waves, currents, and water levels are necessarily measured for all nourishment projects because they are the primary hydrodynamic forces controlling beach evolution (Gravens et al. 2008). Wave, current, and water level measurements should be taken before, during, and after the project. These data can be compared to measured beach response to help understand project behavior. Wave and water level measurements are often collected using a pressure gauge, buoy, or other sensor placed offshore of the project area. This information can also be used in hydrodynamic models, which can be used in the design of projects, as well as prediction of how a nourishment event will perform.

Biological Monitoring

A critical element of monitoring the response of biological resources to beach nourishment is determining the biological characteristics most sensitive to the impact in question. A common approach in impact assessments is to compare the species richness or population densities of target biota between nourished and control beaches and/or between pre- and post-nourishment periods. However, this monitoring approach (i.e., focusing only on diversity and abundance) may not be appropriate for all target biota or all modes of impact. For example, impacts to sea turtles may not be apparent through monitoring nesting frequencies if the mode of impact is temperature forcing the sex

ratios of hatchlings (Wilber et al. 2009). In addition, because the number of individuals in an assemblage can vary greatly across space and time, it can be challenging to capture nourishment response using this approach. Lybolt and Tate (2008) found that assumptions of habitat homogeneity of nearshore hardbottom habitat were ill-suited for nourishment project monitoring in central Palm Beach County, Florida. Nearshore hardbottom was buried and re-exposed with weekly or daily frequency with a strong likelihood that coral and algae could tolerate this episodic burial. Fish distribution in the surf zone likewise has particularly high temporal and spatial variability, for example, so an examination of the suspected mechanisms of impact on fish populations would likely yield clearer results. Alternative monitoring approaches include analysis of stomach contents if the suspected mechanism is prey population suppression and examinations of gill epithelial tissue if the suspected mechanism is increased turbidity from a sediment plume (Wilber et al. 2009).

See the “Minimizing Impact to Existing Biological Resources” section for more information on the effects of sediment placement on native biota and actions to help reduce impacts.

Sea Turtle Monitoring

Most parks with sea turtle habitat have a turtle management program that can provide data necessary to evaluate pre- and post-project adverse or positive effects of a beach nourishment project (Figure 14). The loggerhead sea turtle (*Caretta caretta*) and green sea turtle (*Chelonia mydas*) are federally listed threatened and endangered species, respectively, and are regularly monitored during beach nourishment activities. Many different variables related to sea turtles have been monitored, including nest density, grain size distribution, sand moisture content, incubation period, hatching success, emerging success, hatchling fitness, clutch size, sand compaction, and sand temperature (Milton et al. 1997; Steinitz et al. 1998; Davis et al. 1999; Rumbold et al. 2001; Brock et al. 2009). Nesting density is often measured as part of monitoring programs and is determined by observing crawl tracks. Crawl tracks can also indicate the species and type of crawl (Rumbold et al. 2001).

The duration of post-nourishment monitoring for impacts on sea turtles should extend at least one nesting season beyond the expected date of the design profile equilibration but ideally longer. Davis et al. (1999) and Rumbold et al. (2001) monitored loggerhead sea turtle nesting success for two years following beach nourishment in Florida. Steinitz et al. (1998) found sea turtle nesting decreased in the nesting seasons immediately following beach nourishment, and that it took two years (the third nesting season) for nesting success on the nourished beach to be statistically like a beach without nourishment, although the beach profile had stabilized after only one year.



Figure 14. Kemp's ridley sea turtle (*Lepidochelys kempii*), a federally listed endangered species, Padre Island National Seashore, Texas (NPS).

Monitoring of abiotic features can elucidate mechanisms of impact on sea turtle nesting. Long et al. (2011) compared sea turtle nesting success on a hurricane- and nourishment-impacted Florida beach (pre- and post-alteration) with LiDAR imaging of the beach. Multiple regression models revealed that three parameters—beach slope, volume, and profile—may be the most significant variables determining loggerhead turtle nesting site selection. Changes in beach profile were particularly negatively correlated with loggerhead nesting success. Additional abiotic characteristics of placed sediment should be monitored during nourishment activities and throughout the remainder of the monitoring study. Changes to sand moisture content, grain size distribution, compaction, sand color, and sand temperature may each impact sea turtle nesting success.

Benthic Invertebrate Monitoring

Benthic invertebrate species are often sampled to characterize ecological response following nourishment because their relatively sedentary and short life cycles capture the spatial distribution of perturbations and because they are an important component of the nearshore food web (Peterson et al. 2000). In this way, the results of invertebrate monitoring can be interpreted to represent how suitable a nourishment design has been for its ecological setting and as a mechanism of impact to indicate or quantify how nourishment influences the population of a target predator species.

Sampling device and methods selection depend on the target species identified for the sampling effort. Macroinvertebrates can be sampled concurrently with sediment and beach profile sampling; however, counts of macroinvertebrates with differing ecologies and behaviors will vary depending on the sampling mode (e.g., pitfall trapping vs. quadrat sieving) (Fanini and Lowry 2016). Pitfall traps are effective for sampling macroinvertebrates that spend time on the sand surface, while quadrat

sieving is an appropriate choice for sampling biota that burrow in the substrate. Fanini and Lowry (2016) recommend that both methods be used when possible, to avoid bias in biodiversity estimates and note that quadrat sieving may be more efficient when focusing on talitrid amphipod sampling.

The timing and frequency of invertebrate sampling should be designed to maximize the opportunity to capture representative population samples. A stratified sampling plan perpendicular to the shoreline, day and night sampling, and sampling during different tidal elevations may be appropriate because invertebrates (and other animals) respond to these environmental cues differently (Rudloe 1980; Peterson et al. 2006). In nearshore benthos sampling, Peterson and Bishop (2005) recommend coring over grab sampling because coring extends to the full depth of occupation of the sediment column, captures sedimentary strata, and includes the same amount of sediment per sample.

Where ghost crabs occur, these macroinvertebrates are often monitored as an indicator of beach ecosystem health (Schlacher et al. 2016). Ghost crab monitoring can be cost-effective, as burrows are considered a reliable proxy for crab abundance and size and are easily identified and counted. Ghost crabs can be monitored by counting active ghost crab burrow holes along the upper (mid-intertidal to dune crest) portion of beach profiles (Peterson et al. 2006). Lucrezi et al. (2009) found that several environmental factors significantly influence ghost crab burrow numbers and recommend that counts be limited to within a few hours after sunrise on days with low wind. Because burrow occupation rates vary over time and space, traditional monitoring methods can introduce bias related to crab abundance and size. Pombo and Turra (2019) proposed and analyzed a novel method of ghost crab burrow monitoring that reduces sampling bias by conducting a traditional burrow survey, gently covering the burrows with sand, and surveying again within 12 to 24 hours to confirm burrow occupation.

Beach nourishment has the potential to impact the substrate inhabited by benthic macroinvertebrates, and therefore the behavior of these organisms may be altered if the placed sediment is dissimilar to the native sediment. Changes to beach profile and width have been demonstrated to influence talitrid amphipod behavior (Scapini et al. 2019). Mechanisms of impact related to changes in sediment type and beach profile can be monitored directly by assessing the position, location, and movement of target invertebrates, empirically or in situ. Fanini et al. (2007) use a novel approach to assess habitat suitability and stability by studying macrofaunal behavior (sandhopper orientation) following a nourishment project that substantially altered the beach sediment composition.

Shorebird Monitoring

Because impacts of beach nourishment to shorebird populations may be multipronged (e.g., affecting variably foraging, nesting, predation, loafing, etc.), monitoring efforts should be informed by a solid understanding of how the target bird species use the habitat and what the expected mechanisms of impact are. The assessment of shorebird populations as part of beach nourishment projects and habitat quality monitoring efforts should employ different strategies depending on whether the birds are breeding, wintering, or stopping over. Coastal engineering impacts on birds will need to be assessed by a BACI design where pre- and post-project monitoring of species richness and abundance metrics are undertaken. Quantifying foraging behavior, including the number of prey consumed per unit time, may also convey information on the success of beach nourishment to

successfully create high-quality foraging habitat. Nourishment monitoring efforts in North Carolina have studied mole crabs, coquina clams, and ghost crabs and have documented the effects of prey population changes on shorebird populations (Peterson et al. 2000, 2006). Assessing physiological conditions and application of an Integrated Population Modeling approach can provide information on shorebird survival during the non-breeding season (Gibson et al. 2018). These efforts should focus on documenting the success of beach nourishment to create and enhance coastal habitats for breeding and nonbreeding shoreline-dependent birds.

Successful monitoring efforts can also act to promote adaptive management responses to alter nourishment projects as necessary to meet goals to improve conditions for target populations. Sensitive and protected shorebird species may trigger monitoring during construction phases to mitigate the impacts of sediment placement and related activities on active nests and unfledged young. An observation of adult protected birds alone may require the project to pause, depending on the specific conditions of the permit (Guilfoyle et al. 2019).

Other Biological Resources

Other biological resources may require monitoring depending on the project and species present. Fish, seagrass, dune plants, and corals are just some of the resources that may be monitored. Nearshore nourishment projects may monitor subtidal populations of invertebrates or fish that burrow and lay eggs in subtidal sands (e.g., sand lance and grunion).

Permits and Regulations

In addition to the NPS Organic Act, the key federal laws related to beach nourishment in units of the National Park System are Section 404 of the Clean Water Act of 1972, the Rivers and Harbors Appropriation Act of 1899, and NEPA of 1969. NEPA requires the federal government to consider all reasonable alternatives before beginning any federal action. The analysis of alternatives is completed through an environmental assessment or environmental impact statement, unless an action qualifies for a categorical exclusion. Wetland and/or floodplain statements of findings may need to be attached to NEPA documents, as required by NPS wetland protection and floodplain management procedures and federal acts and executive orders (a representative list follows). State and county laws and permitting requirements may also apply. The NPS decision-maker must issue a written finding that the planned action will not lead to an impairment of park resources and values before proceeding. More information regarding the NEPA process can be found in the NPS DO 12: *Conservation Planning, Environmental Impact Analysis, and Decision-Making* (NPS 2011) and the NPS NEPA Handbook (NPS 2015c). For information related to NPS jurisdiction see the Reference Manual 39-1: *Ocean and Coastal Park Jurisdiction* (NPS 2016b).

Other federal laws and executive orders affecting coastal nourishment projects include, but are not limited to, the Endangered Species Act; CZMA; NHPA; Clean Air Act; Fish and Wildlife Coordination Act; Land and Water Conservation Fund Act; Water Resources Development Act; Shore Protection Act; Coastal Barrier Improvement Act; Outer Continental Shelf Lands Act; Magnuson-Stevens Fishery Conservation and Management Act; Marine Mammal Protection Act; Migratory Bird Treaty Act; Executive Order 13089, “Coral Reef Protection”; Executive Order 13158, “Marine Protected Areas”; Executive Order 11990, “Protection of Wetlands”; Executive Order 11988, “Floodplain Management”; and Department of the Interior’s Secretarial Order 3289: *Climate Change*.

Communication with all affected agencies and stakeholders early and throughout the project is key for a smooth permitting process. For example, if a project will be interacting with the USFWS, it is recommended to contact the USFWS person who will ultimately be writing the response letter and discuss concerns they foresee related to the project. Early coordination with the BOEM is also important if OCS sand or gravel will be mined; *A Citizen’s Guide to the Bureau of Ocean Energy Management’s Marine Minerals Leasing* (BOEM 2020) provides guidelines for obtaining resources from the OCS.

State and local regulations may also play an important role in beach nourishment projects. Many states have specific beach nourishment requirements that must be considered when planning a beach nourishment project. Appendix A lists the lead coastal management agency for states containing a national park unit with ocean, coastal, or Great Lakes shoreline, as identified in Curdts (2011). Appendix A also includes a summary of some of the major regulations related to beach nourishment for each state. Appendix B presents updated information on relevant federal, state, and territorial policies and regulations related to sediment management and beneficial use of dredged material (ASBPA and CSO 2023).

The CZMA of 1972 requires coastal states to develop and implement coastal zone management plans (CMPs). CMPs provide for the management of land and water uses that have a direct and significant impact on coastal resources. CMPs must be submitted to the Department of Commerce's NOAA for approval by the state. The CZMA requires federal agencies to conduct activities in a manner consistent with the state's federally approved coastal management program. If the project's state does have a federally approved program, a statement of consistency must be presented to the lead state agency by the federal project proponent to determine the project's consistency with the state's coastal management program prior to the beginning of the project. State coastal management program managers and federal consistency contacts for each state can be found on NOAA's Office of Coastal Management website (NOAA 2023c).

A synopsis of state policies, laws, and regulations on beach nourishment, nearshore sand mining, dredge and fill operations, sand scraping/dune reshaping, dune creation/restoration, and public access is located in Appendix B of *State, Territory, and Commonwealth Beach Nourishment Program, A National Overview* (NOAA 2000).

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Appendix A: State and Territory Beach Nourishment Policies

Twenty-three US states and four US territories contain a national park unit with ocean, coastal, or Great Lakes shoreline, as identified in Curdts (2011). Agency information sources for beach nourishment policies in these states and territories are presented in Table A-1 and the following paragraphs.

Table A-1. Information sources for state/territory beach nourishment policies. Table adapted from NOAA (2000).

State/Territory	Lead Coastal Management Agency
Alaska	Department of Natural Resources, Alaska Coastal Management Program
American Samoa	Department of Commerce
California	Coastal Commission; San Francisco Bay Conservation and Development Commission; State Coastal Conservancy
Florida	Department of Environmental Protection; Department of Transportation
Georgia	Department of Natural Resources, Coastal Resources Division
Guam	Bureau of Statistics and Plans
Hawaii	Office of Planning; Office of Conservation and Coastal Lands
Indiana	Department of Natural Resources
Louisiana	Office of Coastal Protection and Restoration
Maine	Department of Marine Resources
Maryland	Department of Natural Resources
Massachusetts	Office of Coastal Zone Management
Michigan	Department of Natural Resources and Environment, Office of the Great Lakes
Minnesota	Department of Natural Resources
Mississippi	Department of Marine Resources
New Jersey	Department of Environmental Protection, Division of Coastal Engineering
New York	Department of Environmental Conservation; Department of State
North Carolina	Department of Environmental Quality, Division of Coastal Management
Ohio	Department of Natural Resources, Office of Coastal Management
Oregon	Department of Land Conservation and Development; Oregon Parks and Recreation Department
Puerto Rico	Department of Natural and Environmental Resources
South Carolina	Department of Health and Environmental Control, Ocean and Coastal Resource Management
Texas	General Land Office
Virgin Islands	Department of Planning and Natural Resources, Division of Coastal Zone Management
Virginia	Department of Environmental Quality
Washington	Department of Ecology
Wisconsin	Department of Administration

The following state and territory policies are subject to change and may not be complete. More information was found for some places than others. States and territories with limited information do not necessarily have fewer policies or requirements. States not listed may also have relevant policies. Please confirm all requirements with the appropriate state agency. Additional federal and/or local permits may also be required.

The National Oceanic and Atmospheric Administration (NOAA) has a sea level rise (SLR) viewer for the coastal US states that contains various scenarios and projections (NOAA 2022). Some states on this list do not have a readily available SLR guidance or assessment form, and the NOAA viewer can be used as a supplement to those states.

Alaska

The Alaska Department of Natural Resources (DNR) oversees the Alaska Coastal Management Program. The Alaska Administration Code 112.200 states that placement of structures and the discharge of dredged or fill material into coastal waters must, at a minimum, comply with the standards contained in 33 Code of Federal Regulations (CFR) (Navigation and Navigable Waters) § 320–323. In addition to the statewide policies, some coastal districts also have enforceable policies related to beach nourishment and disposal of dredged material. The Division of Geology and Geophysical Surveys under the Alaska DNR handles much of the coastal resilience and management matters for the state.

Alaska Department of Natural Resources, Geological and Geophysical Surveys. 2023. Alaska Coastal Management Program. Available at: <https://dggs.alaska.gov/pubs/project/767> (accessed February 16, 2023).

Alaska Department of Natural Resources, Office of Project Management and Permitting. 2023. Coastal Impact Assistance Program. Available at: <http://dnr.alaska.gov/commis/CIAP/ciap.htm> (accessed February 16, 2023).

Glick, P., J. Clough, and B. Nunley. 2010. Assessing the Vulnerability of Alaska's Coastal Habitats to Accelerating Sea-level Rise Using the SLAMM Model: A Case Study for Cook Inlet. Prepared for the National Wildlife Federation. Available at: <https://www.nwf.org/~media/PDFs/Regional/Alaska/Alaska%20SLAMM%20Summary%20Report.ashx> (accessed February 16, 2023).

American Samoa

The American Samoa Government Department of Commerce serves as the lead agency for the American Samoa Coastal Management Program (ASCMP). Land use permits are required for placing fill, dredging, or removing sediment from any coastal wetlands. The Department of Commerce keeps its website up to date with public notices for land use permits. American Samoa also has a Meteorology Division that publicizes SLR projections. The projections are based on the Predictive Ocean Atmosphere Model for Australia (POAMA-2) Global Climate Model under Pacific-Australia Climate Change Science Adaptation Planning (PACCSAP).

National Oceanic and Atmospheric Administration Office for Coastal Management. 2022. American Samoa Coastal Management Program. Available at: <https://coast.noaa.gov/states/american-samoa.html> (accessed February 16, 2023).

Samoa Meteorological Services. 2023. Sea Level Prediction for Samoa. Available at: <http://www.samet.gov.ws/index.php/clews-products/sea-level-prediction-for-samoa#MAM> (accessed February 16, 2023).

California

The three California administrators of the National Coastal Zone Management Program authorized by the federal Coastal Zone Management Act (CZMA) of 1972 are the California Coastal Commission (CCC), the San Francisco Bay Conservation and Development Commission, and the State Coastal Conservancy. The CCC is the lead agency responsible for carrying out California's Coastal Management Program by planning for and regulating development in the coastal zone consistent with the policies of the California Coastal Act. The CCC requires permits for any development within the coastal zone, broadly defined as the placement or erection of any solid material or structure; discharge or disposal of any dredged material; grading, removing, dredging, mining, or extraction of any materials; or changing the intensity of use of land. The CCC has a webpage dedicated to SLR guidance measures and guidelines for the projection of SLR. The CCC uses a comprehensive approach to synthesize multiple methods for projecting SLR. The San Francisco Bay Conservation and Development Commission is responsible for the San Francisco Bay-Delta portion of the coastal zone. In areas where there is a certified Local Coastal Program, one must apply to that city or county directly. The State Coastal Conservancy is a non-regulatory state agency and one of ten conservancies within the California Natural Resources Agency. Among other responsibilities, the Coastal Conservancy works with communities throughout California's coast to help them adapt to climate change and mitigate its causes. This work includes assessments of threats from climate change—such as rising seas, extreme weather events, beach and bluff erosion, flooding, and drought—and actions to counter those threats.

California Coastal Commission (CCC). 2023. California Coastal Commission. Available at: <https://www.coastal.ca.gov/index.html> (accessed February 16, 2023).

California Coastal Commission (CCC). 2023. Sea Level Rise Adopted Policy Guidance. Available at: <https://www.coastal.ca.gov/climate/slrguidance.html> (accessed February 16, 2023).

California Ocean Protection Council. 2018. State of California Sea-Level Rise Guidance 2018 Update. Available at: http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf (accessed February 16, 2023).

State of California Coastal Conservancy. 2023. Natural Infrastructure for Coastal Adaptation to Sea Level Rise. Available at: <https://scc.ca.gov/climate-change/climate-ready-program/natural-infrastructure/> (accessed February 16, 2023).

Florida

The Florida Department of Environmental Protection (DEP) serves as the lead agency for the Florida Coastal Program. A Joint Coastal Permit is required to conduct any coastal construction activities. Florida has extensive eligibility criteria for coastal construction permits, including requirements related to marine turtle protection, design, siting, and sediment compatibility. Florida law requires that all sandy sediment excavated from the coastal system be deposited on the adjacent beach or in the nearshore. Monitoring programs are also required for any construction that is determined to have an adverse impact. Multiple models are available for SLR projections in Florida; however, none are advertised by DEP or the Florida Department of Transportation (FDOT), and both are the leaders in coastal resilience for the state. FDOT advertises adaptations and community plans for SLR and the issues that arise because of it. Those pages have further resources leading to other strategies and information regarding SLR in general.

Florida Department of Environmental Protection. 2023. Beaches. Available at:

<https://floridadep.gov/rcp/beaches#JCP> (accessed February 16, 2023).

Florida Department of State. 2023. Florida Administrative Code and Florida Administrative Register: Rules and Procedures for Application for Coastal Construction Permits. Available at:

<https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62B-41> (accessed February 16, 2023).

Florida Department of Transportation. 2023. Resilience. Available at:

<https://www.fdot.gov/planning/policy/resilience/default.shtm> (accessed February 16, 2023).

Georgia

The Georgia DNR, Coastal Resources Division Coastal Management Program serves as the lead agency for the Georgia Coastal Program. A permit is required for all shoreline engineering activities and all land alteration on beaches, sand dunes, and submerged lands. A permit will be issued only if the activity will not impair the values and functions of the natural system of sediment transport including the coastal sand dunes, beaches, sandbars, and shoals and if the activity is not contrary to the public interest. The Georgia Shore Protection Act outlines the permitting process and requirements for beach nourishment activities. The Coastal Resources Division has assembled a document detailing its post-disaster and redevelopment plan in the event of a natural disaster on the coast. Outlined within the document are guidelines on SLR and beach nourishment. Georgia appears to use a variety of outside sources for projections for SLR but is adaptive in its planning for changes to sea level.

Georgia Department of Natural Resources. 2023. Coastal Resources Division. Available at:

<https://coastalgadnr.org/> (accessed February 16, 2023).

Georgia Conservancy. 2023. Changes to the Shore Protection Act. Available at:

<https://www.georgiaconservancy.org/advocacy/shore-protection> (accessed February 16, 2023).

Georgia Department of Natural Resources. 2023. Post Disaster Recovery and Redevelopment Planning, A Guide for Georgia Communities. Available at: <https://coastalgadnr.org/sites/default/files/crd/CZM/Hazards/GARecoveryGuidanceDocument.pdf> (accessed February 16, 2023).

Guam

The Guam Bureau of Statistics and Plans (BSP) oversees the Guam Coastal Management Program (GCMP) and the land use, protection, and development within Guam's coastal zone. Guam BSP issues Coastal Zone Consistency Determinations. The Guam Territorial Seashore Protection Act requires a permit from the Guam Land Use Commission/Guam Seashore Protection Commission for any development (e.g., discharge of any dredged material or dredging, mining, or removal of any material) within the seashore zone (within 10 m of MHW). The GCMP is part of the Application Review Committee, which was established to provide technical review and advice on development activity on Guam to the Guam Land Use Commission and the Guam Seashore Protection Commission. The GCMP's set of functions falls under natural resources projects and planning, geographic information system (GIS), and coastal outreach engagement.

Guam Bureau of Statistics and Plans. 2023. Home. Available at: <https://bsp.guam.gov/> (accessed February 16, 2023).

Guam Bureau of Statistics and Plans. 2023. The Guam Coastal Management Program. Available at: <https://bsp.guam.gov/guam-coastal-management-program/> (accessed February 16, 2023).

National Oceanic and Atmospheric Association. 2023. Trends on Guam SLR. Available at: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=1630000 (accessed February 16, 2023).

Hawaii

The Office of Conservation and Coastal Lands (OCCL), within the Hawaii Department of Land and Natural Resources, is responsible for overseeing beach and marine lands out to the seaward extent of the state's jurisdiction. Permits are required for all beach nourishment activities and are broken into two categories. Category I includes projects less than 382 m³ (500 yd³) and Category II represents projects from 382 to 7,646 m³ (500 to 10,000 yd³). Projects greater than 7,646 m³ (10,000 yd³) require individual consultation with other agencies. All projects require sediment compatibility between the native and proposed fill material. Applications and beach nourishment guidelines are available on the Office of Conservation and Coastal Lands website. The Coastal Lands program supports the Small Scale Beach Nourishment program in which coastal landowners are encouraged to use natural beach restoration rather than hard shoreline armoring through an easy application system. Hawaii has an extensive document on SLR risk and management titled Hawaii SLR Vulnerability and Adaptation report, and supplemental documents that propose action items have been released in the four years since the report was released.

The Office of Planning is the state's lead agency under the federal CZMA. The Office of Planning also leads the coordination of a climate change adaptation policy for the State of Hawaii. Act 286

(2012), Climate Change Adaptation Priority Guidelines, was passed by the legislature and signed into law. Hawaii is one of few states in the nation to adopt a statewide climate adaptation policy for addressing the impacts of climate change. Act 286 is codified as HRS § 226-109. Because the policy is an amendment to the Hawaii State Planning Act, all county and state actions must consider the policy in its land use, capital improvement, and program decisions.

Hawaii Department of Land and Natural Resources. 2023. Department of Conservation and Coastal Lands. Available at: <https://dlnr.hawaii.gov/occl/> (accessed February 16, 2023).

Hawaii Department of Land and Natural Resources. 2023. Office of Conservation and Coastal Lands, Coastal Lands Program. Available at: <https://dlnr.hawaii.gov/occl/coastal-lands-program/> (accessed February 16, 2023).

Hawaii Climate Change Mitigation and Adaptation. 2019. Hawaii Sea Level Rise Vulnerability and Adaptation Report. Available at: https://climateadaptation.hawaii.gov/wp-content/uploads/2017/12/SLR-Report_Dec2017.pdf (accessed February 16, 2023).

Hawaii Department of Land and Natural Resources. 2020. State Climate Change Mitigation and Adaptation Commission Endorses Tools for Sea Level Rise Planning. Available at: <https://dlnr.hawaii.gov/blog/2020/12/16/nr20-197/> (accessed February 16, 2023).

Indiana

The Indiana DNR regulates beach nourishment in Indiana. Beach nourishment activities are encouraged through state statutes to protect and increase sand in Indiana along Lake Michigan. There are four main areas in Indiana where beach nourishment occurs: Hammond, Whiting, Portage, and Burns Harbor. A permit is required to place fill, erect a permanent structure, or remove material from a navigable waterway. Some projects may be eligible for a general permit. A royalty fee for the removal of materials dredged from Lake Michigan may be waived if any suitable material is placed along the Lake Michigan shoreline as beach nourishment for the beneficial use of the general public. Beach nourishment sand must be free of water-borne contaminants but testing for such contaminants is not standardized among agencies that do the testing. The DNR webpage includes a Lake Michigan extension in which various coastline processes, including lake level fluctuation, the Lake Michigan Coastal Program, and beach nourishment can be found. The Lake Michigan Coastal Program considers erosion, pollution control, and technical assistance, among other topics.

Indiana Department of Natural Resources. 2023. Home. Available at: <https://www.in.gov/dnr/> (accessed February 16, 2023).

Indiana Department of Natural Resources. 2023. Water, Lake Michigan. Available at: <https://www.in.gov/dnr/water/lake-michigan/> (accessed February 16, 2023).

Louisiana

The Louisiana DNR, Office of Coastal Management (OCM) works to protect, develop, and restore or enhance the resources of the state's coastal zone. The OCM is governed by the Interagency Affairs and Field Services Division, and the Permits/Mitigation Division of the DNR, and both oversee

regulating development activities and managing resources of the state's coast in compliance with the Louisiana Coastal Resources Program. Additionally, Louisiana has a Coastal Protection and Restoration Authority (CPRA), which is involved in a variety of projects, including storm risk reduction, barrier building, and wetlands planning. The CPRA assisted in adding Louisiana to NOAA's SLR viewer. The primary function of the CPRA is to develop an annual plan with inventories on projects and project schedules for restoring and protecting the state's coast. A coastal use permit is required for projects that may impact coastal waters, including dredging or filling.

Louisiana Department of Natural Resources. 2023. Office of Coastal Management. Available at: <http://www.dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=85> (accessed February 16, 2023).

Louisiana Coastal Protection and Restoration Authority. 2023. Home. Available at: <https://coastal.la.gov/> (accessed February 16, 2023).

Maine

The Maine Coastal Program is a division of the Maine Department of Marine Resources (effective 2017). Any dredging, bulldozing, removing, or displacing of material within the coastal sand dune system or coastal wetlands requires a Natural Resources Protection Act (NRPA) permit. The NRPA requires beach nourishment projects to use material that has texture and color characteristics consistent with the natural beach material. The profile of the newly nourished beach must also be compatible with the natural beach profile, and the timing of the project should minimize impacts on existing wildlife. The Maine Department of Agriculture, Conservation, and Forestry presents information on coastal hazards, including an interactive map with SLR/storm surge scenarios on the coast. In 2021, Maine published a five-year comprehensive document with an outlook on the coastal program. The document will be used to develop strategies for projects to be undertaken by the Coastal Program.

Maine Department of Marine Resources. 2023. Maine Coastal Program. Available at: <https://www.maine.gov/dmr/programs/maine-coastal-program> (accessed February 16, 2023).

Maine Department of Environmental Protection. 2023. Natural Resources Protection Act. Available at: <https://www.maine.gov/dep/land/nrpa/index.html> (accessed February 16, 2023).

Maine Department of Agriculture, Conservation, and Forestry. 2023. Maine Geological Survey, Coastal Hazards. Available at: <https://www.maine.gov/dacf/mgs/hazards/coastal/index.shtml> (accessed February 16, 2023).

Maine Department of Marine Resources. 2023. Maine Coastal Program Strategic Outlook. Available at: https://www.maine.gov/dmr/sites/maine.gov.dmr/files/docs/MCP%20Strategic%20Outlook%202021_2025_CZMA%20309%20Assessment_PUBLIC%20VERSION_NOAA_Approved.pdf (accessed February 16, 2023).

Maryland

The Maryland DNR is the lead agency for Maryland's Chesapeake and Coastal Program. The Coastal Zone Management Program was created to establish a relationship with the federal CZMA. The state is awarded funds based on the length of the tidal shoreline and the size of the coastal population. The Chesapeake and Coastal Program deals with coastal resources and coastal uses. A link to the enforceable policies under the program can be found below. Maryland's coastal policies include the following beach nourishment requirements:

- The fill material grain size shall be equal to or greater in grain size and character to the existing beach material or determined otherwise to be compatible with existing site conditions and acceptable to Maryland DNR
- The fill material shall be relatively free of organic material, floating debris, or other objects
- Silt and clay fills that change the sandy nature of the existing beach materials are not acceptable
- Gravel fill may be acceptable if particle sizes are equal to or greater than the existing beach materials
- Fill material shall be placed above the mean high water line before final grading to achieve the desired beach profile unless site conditions prohibit the placement of fill material above the mean high water line and specific measures are designed to prevent material from washing away from the site

The Maryland Commission on Climate Change Act of 2015 set a condition that requires the University of Maryland Center for Environmental Science (UMCES) to establish a science-based SLR projection for the state at least every 5 years. The most recent projections were released in Sea-Level Rise Projections for Maryland 2018 (University of Maryland Center for Environmental Science 2018).

Maryland Department of Natural Resources. 2023. Coastal Zone Management Act Grant. Available at: <https://dnr.maryland.gov/ccs/Pages/funding/czma.aspx> (accessed February 16, 2023).

Maryland Department of Natural Resources. 2023. Maryland Coastal Zone Management Program Enforceable Policies. Available at: <https://dnr.maryland.gov/ccs/Pages/Enforceable-Policies.aspx> (accessed February 16, 2023).

University of Maryland Center for Environmental Science. 2018. Sea-Level Rise Projections for Maryland 2018. Available at: <https://www.umces.edu/sea-level-rise-projections> (accessed February 16, 2023).

Massachusetts

The Massachusetts Office of Coastal Zone Management (CZM), within the Executive Office of Energy and Environmental Affairs, serves as the lead agency for policy and technical assistance related to coastal management. The CZM oversees a variety of programs that deal with coastal management, including coastal habitat, marine invasive species, and coastal water quality. The

proponents of beach nourishment projects are required to obtain a permit that includes characterizing beach conditions and stability and documenting the physical and chemical properties of the fill and native material. The Massachusetts Department of Environmental Protection (DEP) and CZM published a report detailing best management practices for beach nourishment projects in Massachusetts. By following the guidance, proponents can expedite the permitting process. Massachusetts has an interactive viewer for SLR and coastal flooding based on modeling of coastal flooding. The CZM has also published a comprehensive document on SLR guidance which can be found below. The document provides a written representation of what is available on the interactive viewer.

Massachusetts Department of Environmental Protection. 2007. Beach Nourishment, MassDEP's Guide to Best Management Practices for Projects in Massachusetts. Available at: https://www.mass.gov/doc/beach-nourishment-massdeps-guide-to-best-management-practices-for-projects-in-ma/download?_ga=2.148966646.1527594315.1626190488-644616988.1626190488 (accessed February 16, 2023).

Massachusetts Office of Coastal Zone Management. 2023. Home. Available at: <https://www.mass.gov/orgs/massachusetts-office-of-coastal-zone-management-czm> (accessed February 16, 2023).

Massachusetts Office of Coastal Zone Management. 2023. Massachusetts Sea Level Rise and Coastal Flooding Viewer. Available at: <https://www.mass.gov/service-details/massachusetts-sea-level-rise-and-coastal-flooding-viewer> (accessed February 16, 2023).

Massachusetts Office of Coastal Zone Management. 2013. Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning. Available at: <https://www.mass.gov/files/documents/2016/08/vp/slr-guidance-2013.pdf> (accessed February 16, 2023).

Michigan

The Office of the Great Lakes, within the Michigan Department of Natural Resources and Environment, administrates Michigan's Coastal Management Program. The Coastal Management Program deals heavily with erosion, flooding, and planning. The resilience extension on the coastal program website contains resources on lake water levels, planning, training, and erosion. The Shorelands Protection and Management section of the Natural Resources and Environmental Protection Act is the key state statute regarding coastal erosion and the environmental protection of coastal areas. Permits are required for dredging, filling, grading, or placement of permanent structures in designated environmental areas.

Michigan Department of Environment, Great Lakes, and Energy. 2023. Coastal Management. Available at: <https://www.michigan.gov/egle/about/organization/Water-Resources/coastal-management> (accessed February 16, 2023).

State of Michigan. 2023. Shorelands Protection and Management Permit—High Risk Erosion Area (Part 323). Available at: <https://www.michigan.gov/som/Government/State-License-Search/s/shorelands-protection-and-management-permit-high-risk-erosion-areas-hrea-part-323> (accessed February 16, 2023).

Minnesota

The Minnesota DNR manages Minnesota's Lake Superior Coastal Program (MLSCP). One goal of the DNR is to limit the use of beach sand and other types of fill to prevent damage to fish spawning areas, aquatic habitats, and the water quality of Minnesota's lakes. For most projects constructed below the ordinary high-water level of public waters, an individual public waters work permit is required. MLSCP will work with NOAA's Office for Coastal Management (OCM) to assess areas of high management priority. Minnesota has developed five-year strategies to enhance its coastal management programs with these high-priority areas in mind.

Minnesota Department of Natural Resources. 2023. Minnesota's Lake Superior Coastal Program. Available at: <https://www.dnr.state.mn.us/waters/lakesuperior/index.html> (accessed February 16, 2023).

Minnesota Department of Natural Resources. 2023. Requirements for Projects Involving Public Waters. Available at: https://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/requirements.html (accessed February 16, 2023).

Mississippi

The Mississippi Department of Marine Resources serves as the lead authoritative agency for activities in the coastal zone. The Office of Coastal Resources Management is responsible for implementing the Mississippi Coastal Program. Permits are required for any dredging or filling activities and fill material must be non-toxic and either stabilized or of sufficient size as to not be displaced during typical storm tides. Information on permit necessity and submittal requirements can be found below. Additionally, the Gulf of Mexico Alliance (GOMA) is a Regional Ocean Partnership working to sustain resources in the Gulf based on six priority issues identified by the governors of the five Gulf states. They notably deal with habitat resources and coastal resilience.

Mississippi Department of Marine Resources. 2023. Coastal Resources Management. Available at: <https://dmr.ms.gov/coastal-resources-management-2/> (accessed February 16, 2023).

Mississippi Department of Marine Resources. 2023. Mississippi Coastal Permitting. Available at: <https://dmr.ms.gov/permitting/permit-info/> (accessed February 16, 2023).

Mississippi Coastal Program. 2015. Coastal Zone Management Act& 309 Assessment and Strategy 2016-2020. Available at: <https://dmr.ms.gov/wp-content/uploads/CRM/MS-Final-309-Assessment-and-Strategy-2016-2020.pdf> (accessed February 16, 2023).

Mississippi Department of Marine Resources. 2023. Gulf of Mexico Alliance. Available at: <https://dmr.ms.gov/goma/> (accessed February 16, 2023).

New Jersey

New Jersey's Coastal Management Program (NJCMP) is administered by the New Jersey DEP. The NJCMP addresses sustainability, ocean planning, coastal resilience, and planning for energy facilities. New Jersey promotes the development and use of living shorelines for extra natural protection from erosion and the promotion of ecological habitats. The Division of Coastal Engineering, operating under the DEP, is responsible for administering beach nourishment, shore protection, and coastal dredging projects throughout New Jersey. New Jersey regulates nourishment as a non-structural shoreline protection measure. Uncontaminated dredged sediments with 75% sand or greater are generally encouraged for beach nourishment (New Jersey Administrative Code 7:7E-4.8). Beach nourishment projects, such as non-structural shore protection measures are encouraged (New Jersey Administrative Code 7:7E-7.11), provided that:

- 1) The particle size and type of fill material is compatible with the existing beach material to ensure that the new material will not be removed to a greater extent than the existing material would be by normal tidal fluctuations
- 2) The elevation, width, slope, and form of proposed beach nourishment projects are compatible with the characteristics of the existing beach
- 3) The sediment deposition will not cause unacceptable shoaling in downdrift inlets and navigation channels
- 4) Public access to the nourished beach is provided in cases where public funds are used to complete the project

New Jersey DEP uses SLR projections from the Science and Technical Advisory Panel convened at Rutgers University. The state has assembled documents on SLR guidance and statewide climate change resilience strategies.

New Jersey Department of Environmental Protection. 2023. Division of Coastal Engineering.

Available at: <https://www.nj.gov/dep/shoreprotection/index.html> (accessed February 16, 2023).

New Jersey Department of Environmental Protection. 2023. Coastal Management Program.

Available at: <https://www.state.nj.us/dep/cmp/> (accessed February 16, 2023).

New Jersey Department of Environmental Protection. 2023. Home. Available at:

<https://dep.nj.gov/slr/> (accessed February 16, 2023).

New York

The New York Department of State administers the State Coastal Management Program (CMP). The CMP provides a framework for decision-making affecting New York's coast and provides state coastal policies. A list of the policies and plans can be found on the webpage of the second link below. New York has adopted into law Part 490 for projected SLR. The Department of Environmental Conservation (DEC) is required to adopt regulations for science-based SLR projections as a result of the Community Risk and Resiliency Act. The DEC uses ClimAID SLR projections (more information about ClimAID can be found on the webpage concerning Part 490 below). Part 490 establishes the SLR projections but does not impose any requirements. The DEC

administers a Coastal Erosion Control Permit Program that regulates beach restoration activities. The following standards must be met for permit issuance. The proposed activity:

- Is reasonable and necessary, considering reasonable alternatives to the proposed activity, and the extent to which the proposed activity requires a shoreline location
- Will not be likely to cause a measurable increase in erosion at the proposed site or other locations
- Prevents, if possible, or minimizes adverse effects on:
 - Natural protective features and their functions and protective values
 - Existing erosion protection structures
 - Natural resources including, but not limited to, significant fish and wildlife habitats and shellfish beds

New York State Department of Environmental Conservation. 2023. Coastal Erosion Management Permit Program. Available at: <https://www.dec.ny.gov/permits/6064.html> (accessed February 16, 2023).

New York State Department of State. 2023. State Coastal Management Program. Available at: <https://dos.ny.gov/state-coastal-management-program> (accessed February 16, 2023).

New York Department of Environmental Conservation. 2023. Adopted Part 490, Projected Sea-Level Rise. Available at: <https://www.dec.ny.gov/regulations/119069.html> (accessed February 16, 2023).

North Carolina

The North Carolina Department of Environmental Quality (DEQ), Division of Coastal Management implements and supervises coastal zone management programs. The division is responsible for permitting, land-use planning, beach and waterfront access, grants for marine sewage pump out, and North Carolina Coastal Reserves. North Carolina has extensive regulations regarding beach nourishment and requires a Coastal Area Management Act permit. Beach restoration, sand nourishment, and disposal projects may be allowed when (15A North Carolina Administration Code 07M.0202):

- 1) Erosion threatens to degrade public beaches and damage public and private properties
- 2) Beach restoration, nourishment, or sand disposal projects are determined to be socially and economically feasible and cause no significant adverse environmental impacts
- 3) The project is determined to be consistent with state policies for shoreline erosion response and state use standards for Ocean Hazards, Public Trust Waters, Areas of Environmental Concern, and the relevant rules and guidelines of state and federal review agencies

The code also states that clean beach quality material dredged from navigation channels within the active nearshore, beach, or inlet shoal systems must not be removed permanently from the active nearshore beach or inlet shoal system unless no practical alternative exists. Preferably this dredged

material will be disposed of on the ocean beach or shallow active nearshore area where environmentally acceptable and compatible with other uses of the beach (15A NCAC 07M.1101). North Carolina has detailed, quantitative requirements regarding sediment compatibility and sampling techniques.

North Carolina began writing SLR assessment reports in 2010 and has, and will continue to, update their reports every five years. The Coastal Resources Commission (CRC) Science Panel oversees the reports. The CRC used the most recent report of the Intergovernmental Panel on Climate Change (IPCC) for scenario-based SLR projections. They combined this data with tide gauge records from NOAA to determine accurate SLR projections for North Carolina's coast. The most recent assessment available to the public is from 2015.

North Carolina Department of Environmental Quality. 2023. Division of Coastal Management. Available at: <https://deq.nc.gov/about/divisions/division-coastal-management> (accessed February 16, 2023).

North Carolina Office of Administrative Hearings. 2023. North Carolina Administrative Code. Available at: <http://ncrules.state.nc.us/ncac.asp> (accessed February 16, 2023).

North Carolina Department of Environmental Quality. 2023. Sea Level Rise Study Update. Available at: <https://deq.nc.gov/about/divisions/coastal-management/coastal-resources-commission/sea-level-rise-study-update> (accessed February 16, 2023).

Ohio

The Ohio DNR, Office of Coastal Management implements the Ohio Coastal Management Program. A Shore Structure Permit is required before undertaking the construction of an erosion, wave, or flood control structure along the Lake Erie shoreline in Ohio. Shore structures include beach nourishment, seawalls, groins, breakwaters, and more.

Ohio Department of Natural Resources. 2023. Office of Coastal Management. Available at: <https://ohiodnr.gov/discover-and-learn/safety-conservation/about-odnr/coastal-management> (accessed February 16, 2023).

Ohio Department of Natural Resources. 2023. Shore Structure Permit. Available at: <https://ohiodnr.gov/buy-and-apply/regulatory-permits/lake-erie-land-and-water-permits/shore-structure-permit> (accessed February 16, 2023).

Oregon

The Oregon Department of Land Conservation and Development (DLCD) serves as the lead agency for the Oregon Coastal Management Program. Oregon's ocean shore is managed by the Oregon Parks and Recreation Department, which has an extensive permitting program for shoreline protection. A permit is required for any improvement made within the ocean shore. An improvement is defined as filling, removing material, or constructing on the ocean shore, or the land lying between the extreme low tide of the Pacific Ocean and the statutory vegetation line or the line of established upland shore vegetation, whichever is farther inland. Details on how to apply and what constitutes as

different projects are outlined on the Ocean Shores Permits website. Ocean shore rules can also be found on the same website. Oregon does not appear to have a guideline or assessment specifically for SLR, but the DLCD deals with land use planning and climate change to combat events that may arise from SLR. Oregon has a comprehensive document with plans on how the state will combat climate change-driven events of various types. NOAA's interactive map on SLR contains various scenarios and projections for Oregon.

Oregon Department of Land Conservation and Development, Coastal Management Program. 2023. Home. Available at: <https://www.oregon.gov/lcd/ocmp/Pages/index.aspx> (accessed February 16, 2023).

Oregon Parks and Recreation Department. 2023. Ocean Shores Permits. Available at: <https://www.oregon.gov/oprd/PRP/Pages/PER-ocean-shore.aspx> (accessed February 16, 2023).

Oregon Department of Land Conservation and Development. 2023. Climate Change. Available at: <https://www.oregon.gov/lcd/CL/Pages/index.aspx> (accessed February 16, 2023).

Puerto Rico

The Office of the Coastal Zone and Climate Change Program underneath the Department of Natural and Environmental Resources (DNER) implements Puerto Rico's Coastal Zone Management Program. The Office of Permit Management, Department of Agriculture, Environmental Quality Board, and Institute of Puerto Rican Culture share the responsibilities of coastal management. The DNER is the main point of contact for permit requirements. A comprehensive document on SLR projections and plans for adaptations to SLR is available below.

Puerto Rico Department of Natural and Environmental Resources. 2022. Office of the Coastal Zone Management and Climate Change Program. Available at: <https://www.drna.pr.gov/oficinas/opmzccc/> (accessed February 16, 2023).

Tetra Tech. 2015. Phase I—Sea Level Rise Adaptation Review of Design Criteria for Coastal Infrastructure in Puerto Rico. Prepared for Puerto Rico Department of Natural and Environmental Resources. Available at: https://www.drna.pr.gov/wp-content/uploads/2017/05/SLR_AdaptationReviewForCoastalInfrastructureInPR_20150930.pdf (accessed February 16, 2023).

South Carolina

The South Carolina Department of Health and Environmental Control, Ocean and Coastal Resource Management is mandated with protecting and enhancing South Carolina's coastal resources. A permit is required for any land-disturbing activity in coastal waters, tidelands, beaches, or the beach/dune system. The Beachfront Management Act has established a statewide beachfront management program. The Beachfront Management Act policies severely restrict the use of hard erosion control devices since these methods have proven ineffective in sufficiently protecting the coast and encourage the replacement of hard erosion control devices with soft technologies that will provide for the protection of the shoreline without long-term adverse effects. The main goal of the Beachfront Management Act is to protect, preserve, restore, and enhance the beach system.

Charleston, South Carolina has published an SLR strategy document with ways to make their coastline more resilient to flooding and SLR. SLR projections are based on NOAA data. The state does not appear to have a comprehensive document on SLR, but the coastal hazards section under the Department of Health and Environmental Control has information on coastal management related to all hazards including SLR.

South Carolina Department of Health and Environmental Control. 2019. Ocean and Coastal Resources Management. Available at: <https://scdhec.gov/environment/your-water-coast/ocean-coastal-resource-management-ocrm> (accessed February 16, 2023).

South Carolina Department of Health and Environmental Control. 2019. Special Area Management Plans. Available at: <https://scdhec.gov/environment/your-water-coast/ocean-coastal-resource-management/coastal-planning/special-area> (accessed February 16, 2023).

City of Charleston South Carolina, Mayors Office of Resilience and Sustainability. 2023. Flooding and Sea Level Rise Strategy. Available at: <https://www.charleston-sc.gov/1981/Flooding-Sea-Level-Rise-Strategy> (accessed February 16, 2023).

Texas

The Texas General Land Office (GLO) is the designated lead coastal management agency. A permit is required for any construction within 1,000 feet landward from mean high tide and is issued by local governments in conjunction with the GLO. Living shorelines are also permitted through GLO and may be done on private landowner property. The Texas GLO website contains sparse amounts of information about the coast and coastal resilience, but directs viewers to the page below on SLR. Please see the NOAA viewer above for more desired information on Texas SLR and flooding.

The Texas General Land Office. 2023. Texas Coastal Management Program. Available at: <https://www.glo.texas.gov/coast/grant-projects/cmp/index.html> (accessed February 16, 2023).

The Nature Conservancy. 2012. Sea Level Rise. Available at: <http://slr.stormsmart.org/> (accessed February 16, 2023).

Virgin Islands

The US Virgin Islands Coastal Zone Management Program (VICZMP) is managed and administered by the Division of Coastal Zone Management, located within the Department of Planning and Natural Resources. A Coastal Zone Management permit is required for any development activity along the coast, excluding all federal land, offshore islands, and cays. The permit system is divided into major and minor permits, with the distinction being how much effect the project will have on the coastal environment and community. The Virgin Islands base their SLR on NOAA data and have developed plans on coastal resilience.

United States Virgin Islands Department of Planning and Natural Resources. 2023. Coastal Zone Management. Available at: <https://dpr.vi.gov/coastal-zone-management/> (accessed February 16, 2023).

United States Virgin Islands Department of Planning and Natural Resources. 2023. Coastal Resilience. Available at: <https://dpnr.vi.gov/coastal-zone-management/what-we-do/coastal-resilience/> (accessed February 16, 2023).

Schill, S., J. Brown, A. Justiniano, and A. Hoffman. 2014. US Virgin Islands Climate Change Ecosystem-Based Adaptation, Promoting Resilient Coastal and Marine Communities. Available at: https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/grants/NA09NOS4190173/USVI/USVI_TNC_USVI_EBA_Guidance.pdf (accessed February 16, 2023).

Virginia

The Virginia Coastal Zone Management Program comprises a network of state agencies and local governments with authority in the coastal zone. The Virginia DEQ serves as the lead agency. Any shoreline stabilization project, including riprap, bulkheads, breakwaters, beach nourishment, groins, or jetties require a joint permit. The joint permit application is used to apply for permits from the Local Wetlands Boards, Virginia Marine Resources Commission, Department of Environmental Quality, and the US Army Corps of Engineers. In 2018 Virginia's governor signed an executive order initiative to increase Virginia's resilience to SLR. Virginia will publish the state's first Coastal Resilience Master Plan, which is to be updated every 5 years. The plan will align state efforts with local governments to mitigate flooding and other risks often brought on by SLR.

Virginia Department of Environmental Quality. 2023. Coastal Zone Management. Available at: <https://www.deq.virginia.gov/coasts/coastal-zone-management> (accessed February 16, 2023).

Virginia Department of Conservation and Recreation. 2023. Virginia Coastal Resilience Master Plan. Available at: <https://www.dcr.virginia.gov/crmp/plan#plan> (accessed February 16, 2023).

Virginia Office of the Governor. 2018. Executive Order 24: Increasing Virginia's Resilience to Sea Level Rise and Natural Hazards. <https://www.dcr.virginia.gov/crmp/document/ED-24-Increasing-Virginias-Resilience-To-Sea-Level-Rise-And-Natural-Hazards.pdf> (accessed February 16, 2023).

Washington

The Washington State Department of Ecology is the lead coastal management agency. Washington's Shoreline Management Act (SMA) establishes a local state partnership in administering permits. The SMA requires that all counties develop and implement the Shoreline Master Program. All shoreline permits are processed by the local government and then sent to the Department of Ecology for approval. Permits are required for any development within the shorelines of the state. Development consists of the construction of structures, dredging, filling, dumping, and removal of any sand, gravel, or minerals. Washington encourages the use of soft shoreline stabilization techniques over hard armor techniques. The Department of Ecology has a robust section on SLR and the impacts that arise because of it. A 2018 assessment of SLR projections is available based on a comprehensive approach that synthesized data from multiple sources.

Washington Department of Ecology. 2023. Washington Coastal Zone Management. Available at: <https://ecology.wa.gov/Water-Shorelines/Shoreline-coastal-management/Coastal-zone-management> (accessed February 16, 2023).

Washington Department of Ecology. 2023. Protecting coastal communities. Available at: <https://ecology.wa.gov/Air-Climate/Responding-to-climate-change/Sea-level-rise> (accessed February 16, 2023).

Miller, I. M., H. Morgan, G. Mauger, T. Newton, R. Weldon, D. Schmidt, M. Welch, and E. Grossman. 2018. Projected Sea Level Rise for Washington State—A 2018 Assessment. Prepared for the Washington Coastal Resilience Project. Available at: https://cig.uw.edu/wp-content/uploads/sites/2/2019/07/SLR-Report-Miller-et-al-2018-updated-07_2019.pdf (accessed February 16, 2023).

Wisconsin

The Wisconsin Coastal Management Program is administered by the Department of Administration. Placement of structures, dredging, and any other activity that impacts navigable waters require permits from the Wisconsin DNR. Waterway projects may fall under general permits (project meets specific, size design, and technical requirements), or individual permits (when there is no exemption or general permit required). There are several projects with permit exemptions including biological shore erosion control.

Wisconsin Department of Administration. 2023. Wisconsin Coastal Management Plan. Available at: <https://doa.wi.gov/Pages/LocalGovtsGrants/CoastalManagement.aspx> (accessed February 16, 2023).

Wisconsin Department of Natural Resources. 2023. Waterways Permitting Process. Available at: <https://dnr.wisconsin.gov/topic/Waterways/Permits/PermitProcess.html> (accessed February 16, 2023).

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Curdts, T. 2011. Shoreline length and water area in the ocean, coastal and Great Lakes parks: updated statistics for shoreline miles and water acres (rev1b). NPS/WASO/NRR—2011/464. National Park Service, Natural Resource Stewardship and Science, Fort Collins, Colorado. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2180595> (accessed February 16, 2023).

National Oceanic and Atmospheric Administration (NOAA). 2000. State, territory, and commonwealth beach nourishment programs: a national overview. Office of Ocean & Coastal Resource Management, National Ocean Service, National Oceanic & Atmospheric Administration, Washington, D.C. OCRM Program Policy Series, Technical Document 00-01. Available at: <https://coast.noaa.gov/data/czm/media/finalbeach.pdf> (accessed February 16, 2023).

National Oceanic and Atmospheric Administration (NOAA). 2023. Sea level rise viewer. Available at: <https://coast.noaa.gov/slr/#/layer/slr/0/-13361506.865552677/4967472.737803477/5/satellite/none/0.8/2050/interHigh/midAccretion> (accessed February 16, 2023).

Appendix B: Summary—Sediment Placement Regulations of US Coastal States and Territories

The regulatory context for the beneficial reuse of dredged sediment is explored comprehensively in the report *Sediment Placement Regulations of U.S. Coastal States and Territories: Towards Regional Sediment Management Implementation*, co-written by the American Shore and Beach Preservation Association (ASBPA) and Coastal States Organization (CSO) with funding from the US Army Corps of Engineers' (USACE) Institute for Water Resources (IWR) (ASBPA and CSO 2023). Policies and regulations reviewed to produce the report cover a range of coastal sediment placement options, including beach nourishment, shoreline stabilization, wetland habitat restoration or creation (sometimes referred to as thin layer placement), and island creation. The report highlights regional sediment management (RSM) as a preferred strategy to advance beneficial reuse. RSM uses science, engineering, and planning to keep sediment within the watershed, estuaries, and coastal system while creating economic efficiencies in dredging and coastline placement projects (such as beach nourishment; ASBPA and CSO 2023).

Because sediment placement regulations and related state and federal policies are frequently cited as a significant limitation to implementing RSM, the report's comparative analysis of policies and regulations serves to support state and federal RSM. National and regional trends are reviewed, prominent regulatory barriers are identified, and recommendations are made for policy change and further research. Case studies of successful beach nourishment and other sediment placement projects showcase best practices in managing sediment resources and implementing effective RSM. The contents of this report (e.g., case studies and state profiles) are useful for the planning of individual beach nourishment projects by the National Park Service (NPS) and its partners. In addition, the National Park Service may be able to systemically enhance the effectiveness of its beach nourishment efforts by considering and implementing the report's recommendations for advancing RSM.

With only three exceptions (Alaska, the US Virgin Islands, and the Commonwealth of the Northern Mariana Islands), all US coastal states and territories have adopted policies to encourage, or even require, that suitable dredged sediments are used in a beneficial manner. All US coastal states regulate the percent of fine-grained sediment in general shoreline placement projects through either qualitative (similar to native) or quantitative (measurable) policies. ASBPA and CSO (2023) is an excellent resource for regulatory information specific to a particular state or territory, complementing the compilation of beach nourishment policies for states and territories presented in Appendix A of this document. In ASBPA and CSO (2023), the catalogue of detailed state and territory profiles identifies state and territory policies under three categories: (1) policies encouraging or requiring the beneficial use of dredged sediment; (2) policies encouraging or requiring the use of natural solutions (as defined by the state/territory, to include dunes, wetlands, or other designs enhancing or integrating into the coastal ecosystem) versus hard structures for erosion control and shoreline stabilization projects; and (3) policies implementing RSM principles by encouraging or requiring that projects avoid impacts to sediment supply, erosion, or hydrodynamics. For example, the North

Carolina state profile identifies the Department of Environmental Quality Division of Coastal Management as the state agency that regulates sediment placement and lists the relevant state laws carried out by this agency. Descriptions and authorities for three relevant North Carolina state permits are provided: Joint Coastal Management Permit, Water Quality Certification, and Right of Entry Letter. State policies are listed that include, in the case of North Carolina, requirements for beneficial reuse, encouragement of natural solutions, and requirements to avoid hydrodynamic impacts. Additional policies applicable to sediment placement projects are listed, including requirements for quantitative limitations on physical sediment conditions and the availability of sediment at public disposal sites.

The 14 case studies presented in the report highlight examples of beach nourishment across a diversity of geographies, conditions, and project objectives. These case studies provide details on recently completed and in-progress projects, including project objectives, outcomes, partners, and lessons learned. Several of these projects were focused on habitat restoration/construction and improving habitat for birds and other wildlife species through marsh restoration, beach nourishment, island creation, in-water shoal creation, and floodplain restoration. For example, one case study outlines a thin-layer placement project in a low-elevation California salt marsh to protect habitat for the federally endangered light-footed Ridgway's rail (*Rallus obsoletus levipes*). Several of these case studies also highlight planning or guidance projects that have clarified practice and regulation for beneficial use of material. Nationwide, the USACE developed a database of dredging events and their sediment placement to better understand how federal coastal and inland navigation projects are meeting RSM goals at project and district levels. Another case study outlines the work completed by North Carolina to develop guidance for thin-layer placement in tidal marshes. This guidance was developed by an interagency working group to streamline the process for these new projects, identify suitable sites, and closely monitor project outcomes.

Policy recommendations proposed by the report are directed at state, territory and federal decision makers and agencies, and emphasize collaborative efforts to strengthen beneficial reuse and RSM (Table B-1). In addition, further investment in research is recommended to develop cost-effective, accurate, and efficient methods to determine sediment suitability, and to improve the understanding of changes in physical sediment characteristics during the dredging process to inform a regulatory shift toward science-based requirements.

Table B-1. Summary of policy recommendations. Adapted from ASBPA and CSO (2023).

Issue	States and Territories	Federal
Policy and regulatory	Incentivize beneficial reuse through funding, regulatory, and planning requirements, testing waivers, streamlined permitting, and clear technical guidance.	Support the USACE goal of increased beneficial reuse, including through developing implementation guidance and procedures to better assess economic and environmental benefits and improve stakeholder engagement.
Interagency collaboration	Proactively and frequently host participatory planning and implementation discussions among beneficial reuse champions at a regional scale to discuss pilot projects and permitting efficiency and develop collaborative guidance and plans.	Sustain and increase interagency collaboration to streamline permitting, manage environmental trade-offs, and renew a national commitment to sediment management.
Funding	Collaboratively develop flexible beneficial reuse policies and programs that identify cost-saving opportunities, funding sources, and partners.	Increase opportunities to fund beneficial reuse projects through collaborative valuation and policy determinations and expanded funding mechanisms.
Project development and review	Implement effective and efficient project development and review procedures through collaborative consultations and improved technical guidance.	Collaboratively develop and implement 5-Year Regional Dredged Material Management Plans, increase staff capacity, and explore beneficial reuse opportunities under existing authorities.

Literature Cited

American Shore and Beach Preservation Association (ASBPA) and Coastal States Organization (CSO). 2023. Sediment placement regulations of U.S. coastal states and territories: towards regional sediment management implementation. American Shore and Beach Preservation Association, Fort Myers, Florida, and Coastal States Organization, Washington, D.C. Available at: https://asbpa.org/wp-content/uploads/2023/03/ASBPA_CS0-Sediment-Regulations_reduced-size.pdf (accessed April 10, 2023).

Appendix C: Case Study—Cape Hatteras National Seashore, North Carolina

Cape Hatteras National Seashore (the Seashore) is located along the Outer Banks of North Carolina and is the nation's first national seashore, authorized in 1937, reauthorized as Cape Hatteras National Seashore Recreational Area in 1940, and established in 1953. Consisting of more than 12,100 hectares (30,000 acres) distributed along approximately 108 km (67 mi) of ocean-facing shoreline, the Seashore is part of a dynamic barrier island system (Figure C-1). The Seashore was established to preserve the wild and primitive character of the barrier islands, protect the diverse plant and animal communities sustained by coastal island processes, and provide for recreational use and enjoyment that is compatible with preserving the distinctive natural and cultural resources of the Seashore. The Seashore is a popular destination, drawing more than 2 million visitors a year.

Anthropogenic activities (e.g., dune building, dune vegetation planting, inlet dredging, maintenance of dunes, relative sea level rise [SLR], increased storm frequency and intensity) have impacted natural accretion and erosion processes at the Seashore for decades. As a result, natural migration and the evolution of the barrier island environments are impacted. Erosion rates are as high as 3 m (10 ft) per year in some areas of the Seashore (NCDENR 2012). Areas of frequent erosion have been observed over the past several decades by National Park Service (NPS) staff and state agencies. In some locations (e.g., portions of Ocracoke Island and the end of Hatteras Island), frequent erosion results in the loss of shoreline and upland habitats. Over the next 30 years, SLR is projected to continue impacting Seashore resources, private property, and State Route 12, which links the peninsulas and islands of the northern Outer Banks. The National Oceanic and Atmospheric Administration (NOAA) projects that by 2050, relative SLR rise at Oregon Inlet will be between approximately 0.24 and 1.1 m (0.8 and 3.6 ft) (NOAA 2020). Current sea-level rise rates measured at Oregon Inlet from 1977 to 2019 are +0.5/−0.1 cm/year (+0.2/−0.04 in/year) (NOAA 2020). Numerous actions have been taken to protect and repair areas after high water events.

In March 2021, the National Park Service developed an environmental impact statement (EIS), which includes a sediment management framework for authorizing sediment management actions within its boundaries, including consistent mitigation measures to reduce the impacts on Seashore resources and values (e.g., beach nourishment). This framework provides parkwide guidelines for the special use permit (SUP) applications the National Park Service may receive from entities needing to address transportation maintenance actions and other sediment management requests during the next 20 years.



Figure C-1. Cape Hatteras National Seashore, North Carolina, with areas of likely sediment management indicated (NPS).

The framework for issuing SUPs for sediment management at the Seashore aims to mitigate impacts of human-altered shoreline processes, consistent with applicable NPS management policies and with the missions of the Seashore and the adjacent Pea Island National Wildlife Refuge (NWR). This framework includes the method, locations, and frequency for sediment management actions that may be permitted over the next 20 years. By developing a framework, the Seashore can consider the impacts of multiple sediment management actions over many years in a more comprehensive context and cumulative manner, helping to bolster resilience to the impacts of climate change. The Seashore has received requests and anticipates future requests for sediment management activities to protect critical infrastructure, such as roads, bridges, electrical transmission facilities, and other public transportation facilities; to repair island damages, including breaches that also affect transportation; and to restore habitat through the placement of dredged material along eroded sections of barrier islands. This sediment management framework can assist in addressing these requests in a timely manner while avoiding and minimizing impacts that may be associated with such actions.

The framework describes the various actions, which were reviewed in the EIS, that could be implemented to address sediment management at the Seashore. The preferred alternative from the framework allows the National Park Service to permit agencies, municipalities, and others to conduct, with conditions, sediment management in the form of ocean side and sound side beach nourishment, dune restoration, habitat restoration, and filling island breaches. A SUP application package would be provided to each project proponent that would include a pre-application and a list of conditions that must be adhered to as part of the project.

Sediment Management Actions

The preferred alternative from the framework permits actions, such as beach nourishment, habitat restoration, dune nourishment and sand relocation, and emergency beach repairs along approximately 87 km (54 mi) of Seashore. For the purposes of this case study relevant to beach nourishment, the following sections present the specifics regarding the beach nourishment action.

Beach Nourishment

The sediment management framework guides the development of beach nourishment projects at the Seashore. Beach nourishment consists of placing large volumes of sand (e.g., millions of cubic meters or yards) on the beach and within the surf zone and is one method for temporarily slowing erosion (Dean 2005). The additional volume provided via nourishment places erodible material in between uplands and the ocean, such that the nourishment sand is eroded instead of uplands and dunes. Areas with a greater sand deficit would receive a greater volume of sand via nourishment, ideally, to make up for the deficit and provide excess volume for added protection. The excess volume provides a reservoir to accommodate average annual erosion losses for a number of years before the deficit volume is impacted once more.

Beach nourishment may be proposed by other entities and permitted by the National Park Service to mitigate erosion at various sites along the Seashore. Beach nourishment may include placement of sediment dredged or trucked in from other locations (anticipated to be outside of NPS property boundaries), provided the sediment is a close match or is compatible with the native mean grain size found at the project site. During placement of dredged sediment, a submerged pipeline would cross

the surf zone and connect to elbows and valves at the edge of the beach. Portions of this pipeline may be left in place during sand placement. After an initial platform of sand is pumped into place on the existing beach and shaped by bulldozers, lengths of steel shore pipe would be connected parallel to the beach. A splitter placed at the end of the pipe would spray a slurry of sediment and water along the shoreline. This slurry is pumped continuously for the duration of the project's construction, with work stoppages only occurring for weather, mechanical delays, or potentially due to the detection of sensitive resources (see Figures C-2, C-3, and C-4).

During placement of trucked material, dump trucks would transport sand from an upland borrow pit outside Seashore boundaries to the project area. At this time, most beach nourishment projects along the Seashore (and along the Outer Banks in general) contain millions of cubic meters or yards of sediment within their designs. Because there are limited upland sand resources within an economical distance to the Seashore, nearly all beach nourishment projects would likely be performed via dredge and fill operations.

The nourishment would be expected to spread laterally toward unnourished areas where the profiles have more sand (Dean 2005; Elko et al. 2007; Luijendijk et al. 2017). Nourishment volumes are determined by using survey data to calculate the volume needed to reach some minimum ideal beach size. By identifying local deficits in beach volume, project planners may determine the amount of sand to place across sites within the Seashore. This method allows planners to compensate for the deficit in beach volume at a site and place excess volumes to compensate for future anticipated erosion (Dean 2005).



Figure C-2. Hopper-style dredge (COASTAL SCIENCE & ENGINEERING, INC. [CSE]).



Figure C-3. Aerial of onshore beach nourishment setup depicting elbow pipe (CSE).

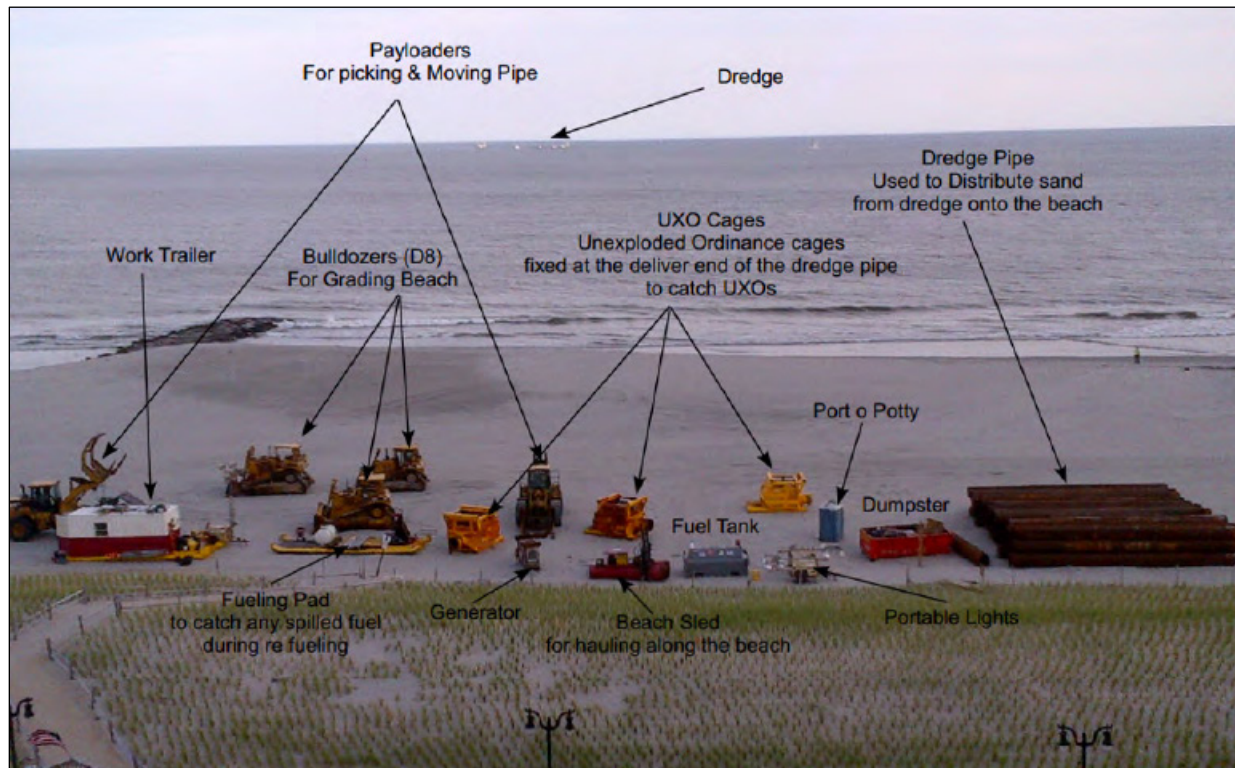


Figure C-4. Ground-based perspective of beach nourishment onshore setup (CSE).

Locations for anticipated beach nourishment along the Seashore oceanfront include, but are not limited to, Bodie Island, north of Mirlo Beach, Avon, Haulover Sound access and areas south towards Buxton, Buxton, the Bypass Road (Cape Hatteras Point Area), Frisco to Hatteras, Hatteras Village, south end of Hatteras Island, north end of Ocracoke (South Dock), and Ocracoke Island. These locations include sites where future beach nourishment project requests are considered likely or known based on North Carolina Department of Transportation feasibility studies, discussions with cooperating agencies, and erosion studies. The National Park Service may also undertake beach nourishment on the sound side of the Seashore. Sound side nourishment may include placement of dredged material or sediment trucked in from other locations, similar to actions described above. Based on discussions with Seashore staff, sound side areas that may be subject to sediment management actions include Haulover Day Use Area, Salvo Day Use Area, Frisco to Hatteras (State Route 12), Sandy Bay “Isabelle Inlet”, and areas near inlets that typically provide valuable nesting habitat for shorebirds.

Special Use Permit Process

Under the preferred alternative, the Seashore would use the NPS SUP process to allow agencies, municipalities, and others to conduct sediment management activities at the Seashore. The following section describes the process the Seashore would follow for reviewing, issuing, and managing SUPs for larger-scale sediment management activities under the preferred alternative, such as beach nourishment. As needed, the Seashore would update this process to comply with any applicable law, regulation, and policy, such as NPS Special Park Uses policies. The Seashore may also update the process, based on a routine review of ecological monitoring data, review of peer-reviewed and gray literature reports on sediment management activities, changing site conditions, and/or information obtained from the public and partner agencies and stakeholder groups.

Step 1: The National Park Service Provides an Information Package for SUP Applicants

If an agency or other organization expresses interest in submitting a SUP application for a sediment management project, the Seashore would develop a package of documents for project proponents/permit applicants with information on what activities may be permitted under the final environmental impact statement (FEIS) and record of decision (ROD) and under what conditions. The Seashore would provide the information package to interested parties on request and may also post it on the Seashore’s website for easy public access. The package may include, but is not limited to:

- Map of areas of likely sediment management and reference areas identified in the FEIS and ROD
- Map of known sea turtle and shorebird nesting habitat
- List of mitigation measures from the National Park Service and consulting agencies and additional measures identified in the FEIS and ROD
- List of approved activities identified in the ROD
- List of monitoring metrics

Step 2: The Applicant Prepares and Submits the SUP Application to the National Park Service

- After reviewing the document package described above and deciding to proceed with a request to the National Park Service for the sediment management activity, the project proponent would submit an SUP application form (OMB Control #1024-0026/NPS 10-930) to the Seashore and include relevant supporting documentation. The types of supporting documentation the Seashore may require could include:
 - Description of the proposed project
 - Description of the coastal processes in the project area, including shoreline change rates (if known)
 - Technical analysis information of identified potential sand sources and suitability for beach placement
 - Pre-nourishment beach and offshore topographic/bathymetric survey data, aerial photography, and sediment-related information
 - An ecological monitoring plan including a proposed reference zone to monitor ecological resources post project
 - Project design and construction parameters (e.g., project length, beach width, berm height, filled volume density, sediment characteristics, date of construction) and regional/site-specific conditions (e.g., background shoreline erosion rates, alongshore sediment transport rates, wave conditions)
 - If the application is for repeat nourishment:
 - Post-nourishment beach and offshore topographic/bathymetric survey data, aerial photography, and sediment-related information related to former project
 - Annual post-construction surveys and aerial photos and performance assessment reports
 - Pre- and post-nourishment benthic invertebrate surveys
- Note: If the SUP applicant needs to collect data at the Seashore to prepare the SUP application, an NPS Scientific Research and Collecting Permit may be required for scientific activities that involve fieldwork, specimen collection, or have the potential to disturb resources or visitors. Information on this process is available on the NPS Research Permit and Reporting System website (NPS 2023).

Step 3: The National Park Service Reviews the SUP Application

- Upon receipt of a complete SUP application, the National Park Service would review supplemental documentation to determine if the proposal is an appropriate action identified in the FEIS and ROD.
 - The National Park Service would:

- Determine if the proposed project type (e.g., beach nourishment, dune nourishment, breach repair, habitat restoration) is included in the FEIS and ROD:
 - Yes—proceed to the next section
 - No—
 - If the proposal is different from actions disclosed in FEIS and ROD, determine if the proposed action would have the same impacts as identified in FEIS or
 - Return the proposal to the applicant to adjust the proposed project to meet the sediment management framework
- Determine if the proposal would occur within Pea Island NWR:
 - Yes—refer the applicant to Pea Island NWR for review
 - No—proceed to next section
- Determine if the proposal is located outside a reference zone identified in the FEIS and ROD:
 - Yes—proceed to the next section
 - No—advise the applicant that the permit may be denied or if new site conditions have been identified that warrant sediment management actions, additional National Environmental Policy Act (NEPA) compliance would be required before the National Park Service would consider the permit application. Also, additional compliance may not be limited to NEPA.
- Determine if the size (volume and length) of the proposal is within the parameters identified within the FEIS and ROD:
 - Yes—proceed to the next section
 - No—
 - If the proposal is different from actions disclosed in FEIS and ROD, determine if the proposed project would have the same impacts as identified in FEIS or
 - Return the proposal to the applicant to adjust the proposed project to meet the sediment management framework
- Determine if the proposal is within the total annual limit for the linear length of impacted shoreline identified in the FEIS and ROD:
 - Yes—proceed to the next section
 - No—

- If the proposal is different from actions disclosed in FEIS and ROD, determine if the proposed project would have the same impacts as identified in FEIS or
 - Return the proposal to the applicant to adjust the proposed project to meet the sediment management framework
- Determine the time of year of the proposal—is the construction window between November 16 and April 1?
 - Yes—proceed to the next section
 - No—work with the applicant to determine if they can conduct the project between November 16 and April 1; however, if not feasible due to safety or other logistical considerations, include additional mitigation measures
- Determine if the applicant provided an appropriate pre-site assessment and surveys:
 - Yes—proceed to the next section
 - No—require the applicant to provide these assessments and surveys
- If the National Park Service has determined the permit applicant has satisfied the above criteria, the National Park Service proceeds to the site resource review.

Step 4: The National Park Service Conducts Site Resource Review Where Sediment Management Activities are Proposed

- Through the Seashore’s internal scoping process with interdisciplinary staff, the National Park Service would:
 - Determine if site conditions are similar to those discussed in the FEIS and ROD (assessment of the current condition of resources)
 - Review NPS policies and reference manuals for the appropriate site resource conditions present in the project area and assess impacts to determine if additional compliance is needed
 - Director’s Order 77-1: Wetland Protection, PM 77-1: Wetland Protection, Director’s Order 28: Cultural Resources
 - Determine if there is potential for the presence of wildlife during proposal timelines by reviewing NPS historical wildlife activity data for appropriate species within the project area
 - Survey for sensitive plant species and delineate no-work buffers if these species are within the project area
 - Determine if known cultural resources are present by reviewing known archeological data and delineating no-work buffer zones if cultural resources are present within the project area

- If cultural resources are unknown, the permit applicant may be required to perform an archeological site survey, which may require an Archeological Resources Protection Act (ARPA) permit
 - The National Park Service would consult with the State Historic Preservation Office (SHPO) before SUP issuance, as appropriate
- Identify monitoring responsibilities for the project
 - NPS point-of-contact (POC)
 - Request Applicant and Contractor POC
 - Determine interagency (e.g., USFWS, US Army Corps of Engineers [USACE], North Carolina Department of Environmental Quality, Department of Water Resources [NCDWR], National Marine Fisheries Service [NMFS]) POC, if applicable
 - Review appropriate reference zone for ecological monitoring
- Incorporate all mitigation measures applicable to the project activities, found in the next section, in SUP general conditions
- If sediment management is proposed for habitat restoration, the following actions may be required and may be expanded to include additional requirements/mitigation measures based on the project's site resources review:
 - Habitat restoration projects proposed by the National Park Service and other agencies or organizations may require an Interagency Agreement (federal) or Memorandum of Understanding (state and county) outlining each agency's role and responsibility for implementing the project
 - The interagency agreement may include the requirement of a maintenance and restoration plan for the project site
 - Applicable mitigation measures detailed below would be included in the interagency agreement, as appropriate
 - The agency permittee and the National Park Service would conduct habitat restoration efficacy monitoring which may include components of the monitoring strategy described below

Step 5: The National Park Service Approves the SUP for Sediment Management Activities

- If the proposal meets and includes all criteria above and mitigations identified in the FEIS and ROD, then the National Park Service would approve and issue an SUP (excluding habitat restoration activities which may require an interagency agreement)
 - The National Park Service may issue an SUP in advance of the permittee acquiring other necessary permits and approvals and would require the permittee to submit proof of those permits before commencing activities under the permit
- The National Park Service identifies visitor use issues at project locations and issues press release(s) notifying the public of closures

Step 6: The Permittee Implements the Sediment Management Project

- After the NPS SUP has been issued and prior to project implementation, the following actions may be required and may be expanded to include additional requirements/mitigation measures based on the project's site resources review
- The permittee provides copies of the following permits, if applicable, to the National Park Service:
 - North Carolina Department of Environmental Quality (NCDEQ) Major Development and Excavation/Filling Permit (i.e., Coastal Area Management Act permit)
 - NCDEQ Individual 401 Water Quality Certification
 - USACE 404 Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899
 - Bureau of Ocean Energy Management Lease agreement for dredging in the Outer Continental Shelf
- The permittee would schedule a pre-construction meeting with the National Park Service and may invite other agencies to review all agency permits with the contractor
- The permittee would submit a project schedule to the National Park Service
- The permittee would be responsible for developing public notices and scheduling public meetings with NPS participation
- The National Park Service or permittee's trained wildlife monitor would conduct daily wildlife surveys and monitoring activities, which may include relocating sea turtle nests found within project areas or adjusting no-work buffers around shorebird and sea turtle nesting areas
- The permittee must conduct at least weekly project meetings with the National Park Service throughout the duration of the project. The National Park Service may require weekly reports of on-site inspections during project implementation.

Step 7: The Permittee Completes the Sediment Management Project

- The National Park Service and permittee notify the USFWS Ecological Services Field Office of any incidental take during the project activities
- The permittee conducts post-project monitoring and surveys for two years unless monitoring indicates that additional years are necessary and submits reports to the National Park Service
- The permittee conducts a post-project review meeting with the National Park Service
 - The permittee would conduct nourishment site monitoring to evaluate sediment grain size, the recovery of benthic organisms, and post-project beach profile surveys within the project area for two years unless monitoring indicates that additional years are necessary
 - The permittee would conduct monitoring on grain size and benthic organisms within the reference area for two years unless monitoring indicates that additional years are necessary

- The National Park Service would continue to conduct routine sea turtle, shorebird, and shoreline monitoring within project sites and reference areas
- For more details on monitoring and surveys

Step 8: The National Park Service Conducts Ongoing Scientific Review after Sediment Management Activities

- Every two years, the National Park Service would convene agency regulatory partners, including cooperating agencies, to review the results of project monitoring of all previously permitted sediment management projects, emerging scientific information, new regulatory requirements, and new erosion and transportation management solutions. A summary of these findings would be posted on the Seashore’s website to provide an opportunity for the public to review and provide input.
- If biological and physical monitoring data indicate that recovery rates are longer than anticipated or impacts are occurring that were not accounted for in the FEIS and ROD, the National Park Service may consider reducing the frequency or modifying the locations or project conditions of future projects.

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Appendix D: Case Study—North End Restoration Project, Assateague Island National Seashore, Maryland

Since its construction in 1935, a jetty system at Ocean City Inlet has caused unnatural sediment deprivation on northern Assateague Island, Maryland (USACE 1998; Figure D-1), thereby lowering island elevation, accelerating the natural shoreline erosion rate, and causing associated habitat degradation. To mitigate the impacts of the loss of natural sand transport processes, the US Army Corps of Engineers (USACE) and the National Park Service worked with other partners to create a comprehensive restoration plan (USACE 1998). The location of the project is shown in Figure D-2.



Figure D-1. Aerial image looking south showing the Ocean City Inlet and eroded Assateague Island at the top of the image (INTEGRATION AND APPLICATION NETWORK/JANE THOMAS; <https://ian.umces.edu/media-library/aerial-view-of-the-ocean-city-inlet-from-isle-of-wight-bay/>, CC BY-SA 4.0).

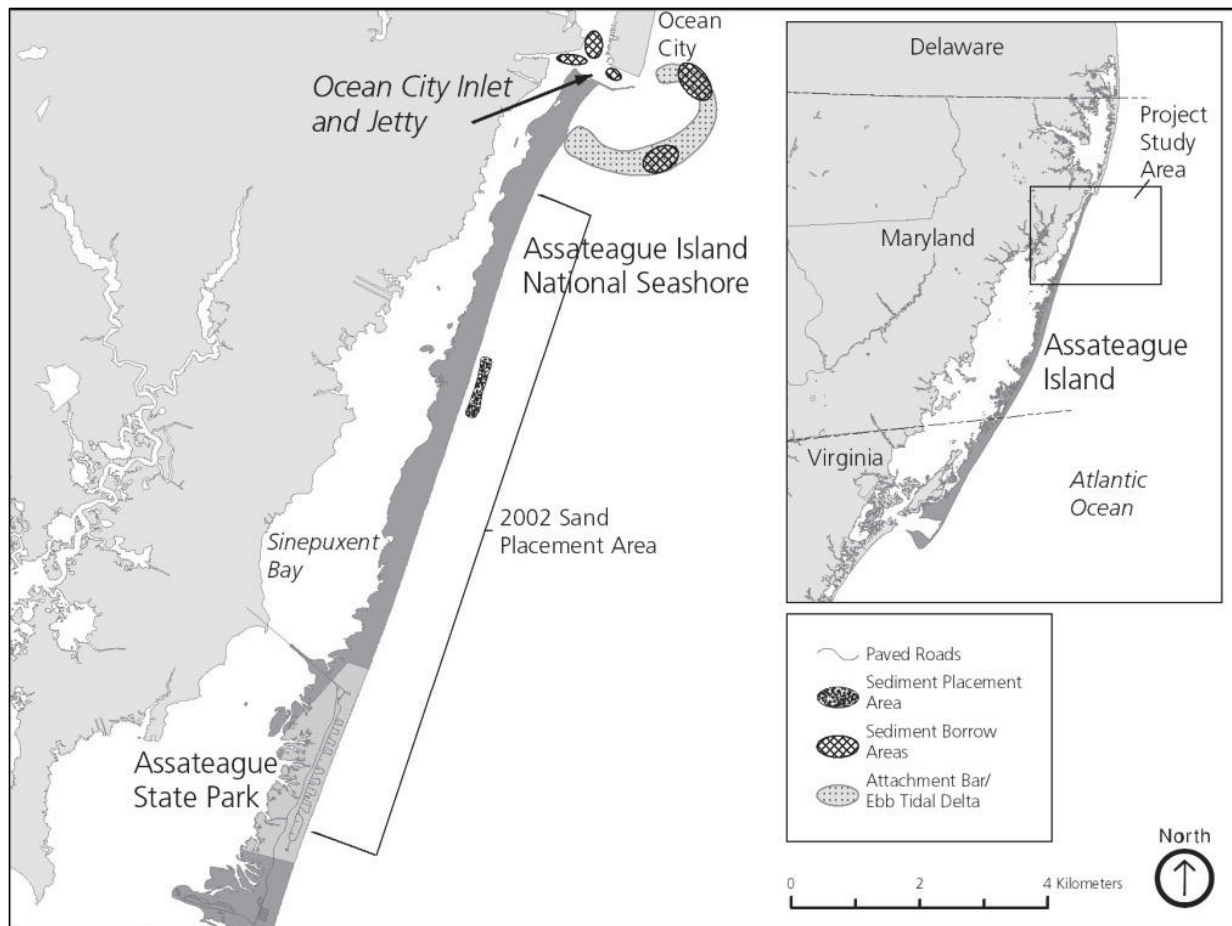


Figure D-2. Location map of the North End Restoration Project, Assateague Island National Seashore, Maryland (Schupp et al. 2007: Figure 1).

The first short-term phase of the comprehensive restoration plan occurred in 2002. This one-time beach nourishment widened the beach by 30 m (98 ft) over a distance of 10.5 km (6.5 mi) by replacing about 15% (1.4 million m³ [1.8 million yd³]) of the sand captured by the inlet since 1934 (USACE 1998). Additionally, a low foredune was constructed along the 2.4-km (1.5-mi) area most vulnerable to overwash as a temporary measure to prevent imminent island breaching and the consequences that a breach would have on the island, the populated mainland, and inlet hydrodynamics.

The second phase, initiated in 2004 to dredge sand (bypass dredging), is the Assateague Island Long-Term Sand Management (LTSM) (USACE 1998). This phase aims to mitigate sediment transport and erosion impacts caused by the inlet and jetties by addressing the source of the problem, sediment starvation. Mobile bypassing uses a shallow-draft hopper dredge to remove sand that has been redirected to a number of locations in the vicinity of the inlet and places this sand within the surf zone along the northern end of Assateague Island. The hopper dredge places most of the sediment about 80 to 250 m (262 to 820 ft) from the high-water shoreline in depths of -1.5 to -4.9 m (-5 to -16 ft) (NAVD88), on the crest and just seaward of the nearshore bar. This biannual effort moves a

sediment volume approximately equal to the natural pre-inlet longshore transport rate (145,000 m³/year [189,000 yd³/year]). This phase is currently planned to continue through 2027.

Since the 1998 USACE study was completed, the National Park Service has prepared the General Management Plan/Environmental Impact Statement (GMP/EIS) for Assateague Island National Seashore (NPS 2016, 2017). The preferred alternative of the GMP/EIS was designed so that “natural processes and the effects of climate change/sea level rise would be the primary forces influencing the condition and evolution of natural resources” and included “a long-term shifting of seashore facilities and assets to adapt to climate change”. Additionally, the USACE prepared an environmental assessment to account for changes in navigation and resource conditions, including changes attributed to climate change and sea level rise (USACE 2022). In the 2022 environmental assessment, USACE evaluated inlet navigation improvements at the Ocean City inlet, including sediment transport through the inlet. USACE proposes to realign approximately 1,024 m (3,360 ft) of the Ocean City Inlet navigation channel to immediately south of its current position. This alternative requires dredging of the inlet bottom sand locally to realign the channel (Figure D-3). To reduce shoaling in the federal channel, two 91-m (300-ft) gaps in the existing breakwaters at the north end of Assateague Island (182 m [600 ft] total) would be connected and an additional 46-m (150-ft) jetty constructed, which extends to the northwest out into Sinepuxent Bay. Modeling of the proposed action by USACE (Figure D-4) demonstrates likely changes in sediment transport and deposition with the proposed inlet changes. As this plan is finalized and implemented, the following sections will be updated.

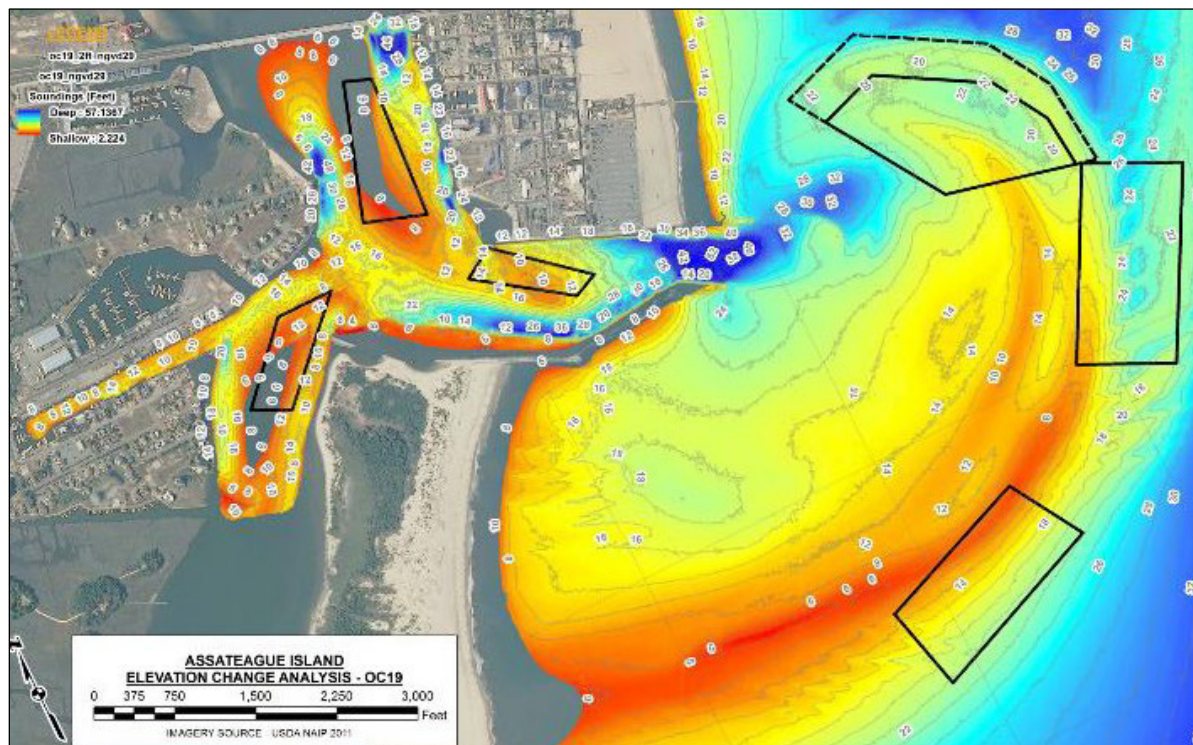


Figure D-3. Proposed dredging at the Ocean City inlet. Borrow locations for Assateague long-term sand management project are shown as black polygons (USACE 2022: Figure 3-1 [misabeled 2-1]).



Figure D-4. 2D sediment transport modeling shows shoaling in blue shaded areas and scouring in red shaded areas for the proposed action. 2D modeling aids in determining short-term sediment trends and assessment of various alternatives (USACE 2022: Figure 2.4).

Measures of Project Success

Quantitative metrics were identified and used to evaluate the overall performance of the project (USACE 1998) and identify if, and when, established threshold conditions for project modification were met:

- Volume of sand mechanically bypassed (to show that the volume was equal to a natural pre-inlet rate of sediment transport)
- Shoreline change rate (to determine whether the management intervention achieved the desired goal of shoreline erosion slowing to a natural pre-inlet rate of change)
- Success and population size of the piping plover (*Charadrius melodus*), a federally listed threatened and endangered bird species (one indicator of a healthy early-succession beach habitat)
- Percent area of sparse vegetation (a second indicator of healthy early-succession beach habitat)
- Changes in the elevation of the constructed foredune (significant growth or decline would indicate the need for further intervention)

- Frequency and extent of overwash events across the foredune (less than three events per year would indicate that the foredune was acting as an unnatural barrier) with consideration given to wave and wind conditions and the behavior of the surrounding areas of the North End

Additionally, although it was not established as a project metric, the nearshore volumetric change is regularly calculated to determine how much of the bypassed sand is reaching the shoreline. When the 2022 environmental assessment is implemented, this section will be updated to reflect that plan.

Monitoring Program

Pre-construction and post-construction monitoring surveys of the project area measured these characteristics (USACE 1998):

- Topographic and volumetric change: light-detection and ranging (LiDAR) data (as available) and cross-island topographic profiles spaced at 0.5-km (0.3-mi) intervals (twice yearly)
- Shoreline response: high water shoreline position (quarterly)
- Occurrence of plant communities (associations): observation of stratified random sampling points to calculate the area of sparse vegetation (annually)
- Piping plover reproductive success: number of breeding pairs, nest attempts, chicks hatched, chicks fledged (annually)
- Nearshore bathymetry: bathymetric profiles extending from the upper beachface to the depth of closure (annually) and swath bathymetry of the tidal deltas and within the depth of closure (as available)
- Meteorological conditions: Remote automated weather stations on Assateague Island National Seashore (hourly wind speed and direction, precipitation, temperature), USACE nearshore wave gauge (hourly significant wave height, period, and direction), and National Oceanic and Atmospheric Administration tidal station (water level)

When the 2022 environmental assessment is implemented, this section will be updated to reflect that plan.

Lessons Learned Since the 1998 USACE Study: Potential Pitfalls

Several unexpected and undesirable outcomes resulted from decisions made in the planning and implementation phases:

Placement Location

Although the project was intended to slow the shoreline erosion rate to approximately 1.5 m/yr (4.9 ft/year) (± 1.7 m/yr [± 5.6 ft/yr]), analysis of the shoreline position data indicated that directly onshore of the target placement site, the shoreline had begun accreting at a rate of up to 10 m/yr (33 ft/year) over the first three years of mechanical bypassing (Figure D-5). This shoreline change rate was unnaturally high and therefore undesirable. The bypassed sand had been expected to move alongshore due to wave action, but the calm weather conditions (measured by the nearshore wave gauge and on-island weather station) likely led to its relative immobility. To correct this condition,

the target placement area was extended to the north and south of the initial target area to distribute the sand more widely until stronger weather conditions prevailed.

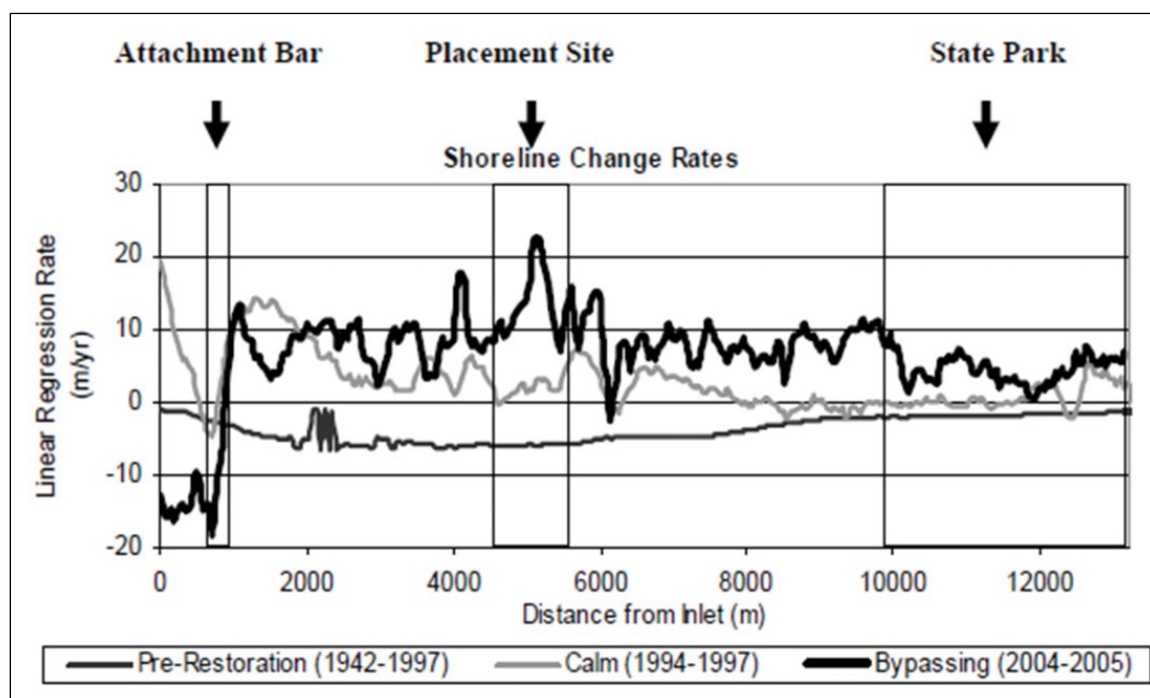


Figure D-5. Monitoring data illustrated that the shoreline section directly onshore of the sediment placement site became highly and unnaturally accretional, signaling the need for a change in placement site at Assateague Island National Seashore (Schupp et al. 2007: Figure 3).

Sediment Size Distribution

Although the dredge material targeted for foredune construction had a sediment size distribution similar to the native beach material, the sediment that was eventually placed on the island had a larger proportion of coarse-grained materials, including gravel, than the native sediment. The wind carried away the smaller particles and left the coarser (gravel) sediments as a lag surface, which limits the ability of the underlying sediment to be moved during wind and storm events and also influences nest site selection of piping plover.

Model Parameters

The dimensions of the nourished beach and the temporary foredune, which was built to prevent breaching in the short period before the long-term mechanical bypassing phase could begin, were modeled with the assumption that the recent erosion rates and storm frequency were representative of the years to come. Instead, weather conditions were much calmer after the foredune was built, and Assateague Island National Seashore did not experience major storm impacts for 10 years following construction. As a result, the beach in front of the foredune did not erode as quickly as expected, and the design height and setback of the constructed foredune prevented overwash along the project's entire length (2.4 km [1.5 mi]), while the surrounding portions of the North End experienced overwash. The foredune also grew in volume, maintained its height, and sheltered the island interior

from wind and waves. This fostered succession from sparsely vegetated habitat to an increasing area of herbaceous vegetation, shrub communities, and the associated growth of embryo dunes due to the sand-trapping effects of the increased vegetation (Figure D-6).



Figure D-6. Unexpected conditions led to a loss of overwash processes and a sheltered island interior at Assateague Island National Seashore, fostering vegetation succession and dune growth (NPS).

The monitoring program enabled Assateague Island National Seashore to identify and quantify these undesirable changes in ecosystem function and to clearly and convincingly communicate to cautious partners that there was a pressing need for action. The National Park Service and project partners are now mitigating these conditions by notching the foredune to allow overwash, discussing appropriate placement sites before every mechanical bypassing cycle, and continuing to analyze monitoring data to identify any other undesirable conditions that may arise.

Lessons Learned Since the 1998 USACE Study: Success Stories

Many methods selected for this project appear to have been the correct choice for minimizing undesirable impacts to visitors and the ecosystem.

Placement Timing

Mechanical bypassing is scheduled for early spring (February to March) and late fall (October) to minimize potential conflicts with high recreational use (June to August), piping plover breeding season (April to August), and northeaster storms (November to February).

Mechanical Bypassing Method

To minimize impacts to the beach ecosystem, it was preferable to place sand in the shallow nearshore area instead of directly onto the beach. The dredge vessel (Figure D-7) carries about 350 m³ (460 yd³) and varies the specific dump location, so the total volume bypassed is dispersed in time and distance. Therefore, any one load is unlikely to impact benthic communities through heavy burial. This method is significantly different from traditional beach nourishment projects that place large volumes of sand directly onto the beach and then often redistribute the sand with heavy equipment. Those methods create significant change in short periods of time and can bury and crush invertebrate communities.

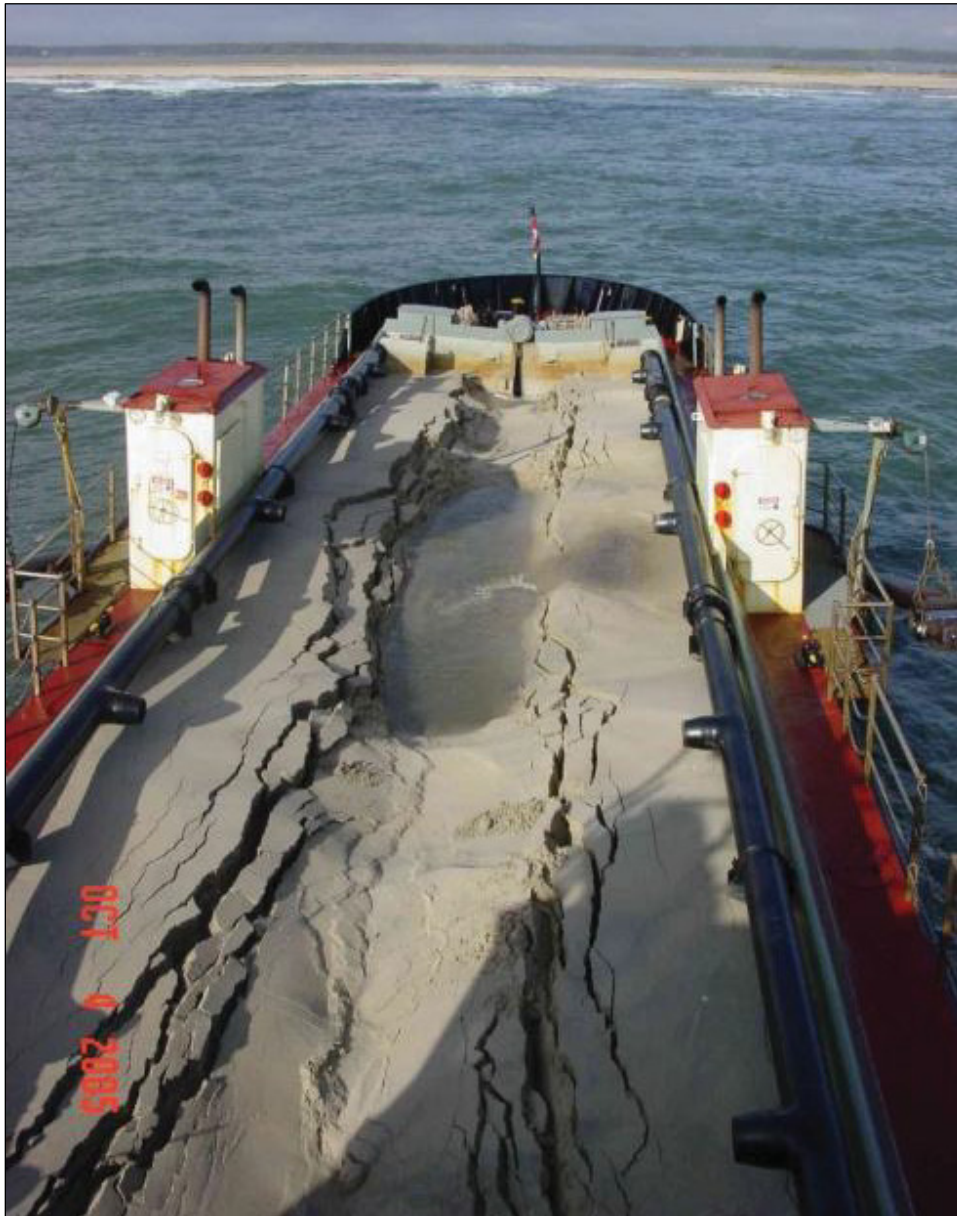


Figure D-7. A hopper dredge placing sediment on and just seaward of the nearshore bar at Assateague Island National Seashore. Waves and currents move the sediment onto the shoreline (NPS).

Importance of Long-Term Monitoring

By evaluating the monitoring data regularly, undesirable conditions and trends have been detected. Management actions to rectify these undesirable results have included notching the foredune to allow overwash, changing the sediment placement site, changing the amount of sediment dredged, rescheduling surveys to capture appropriate data, and identifying new needs for data and modeling.

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Appendix E: Case Study—Perdido Key, Gulf Islands National Seashore, Florida

Project Description

The eastern end of Perdido Key, a barrier island in Gulf Islands National Seashore, Florida (Figure E-1), has experienced long-term erosion (Dean 1988), primarily due to the interruption of littoral drift caused by maintenance dredging of Pensacola Pass. To dispose of dredged material from a deepening project at Pensacola Pass and counteract shoreline erosion, the US Army Corps of Engineers (USACE) initiated a large, two-phase beach and profile nourishment project at Perdido Key from 1989 to 1991. The amount of acceptable quality material available for beach placement was determined from vibracores. Grain size, visual evidence, and color information were compiled for each core to assess sediment quality.

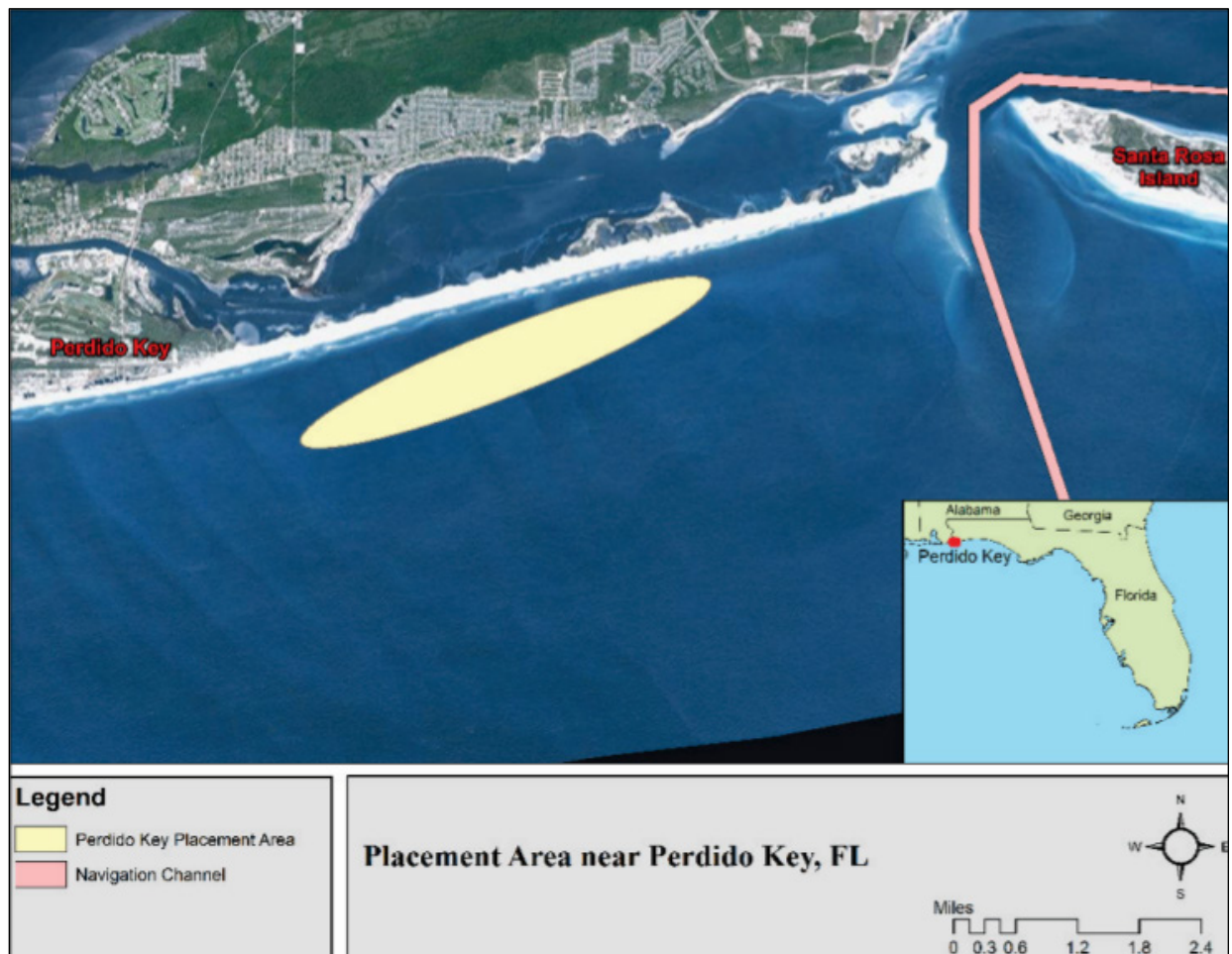


Figure E-1. Location of Perdido Key, Gulf Islands National Seashore, and 2011 sediment placement area near Perdido Key, Florida (Gailani et al. 2019: Figure 7).

The first phase of restoration included onshore placement of roughly 4.1 million m³ (5.4 million yd³) of material along 7.6 km (4.7 mi) of shoreline from November 1989 to September 1990. The second

phase included offshore placement of an additional 3.0 million m³ (3.9 million yd³) of material in water depths of roughly 6 m (20 ft) from November 1990 to September 1991 (Rakocinski et al. 1996).

Monitoring Program

The monitoring program began in 1989 with a pre-construction survey of the project area and adjacent shorelines. After the nourishment project, surveys were conducted on an annual or biennial basis.

Physical monitoring included beach profile surveys (Figure E-2), bathymetric surveys of the offshore portion of the profiles and the offshore placement area, wave, tide, and current measurements, and meteorological data collection (Browder and Dean 2000). As part of the project, the US Navy agreed to a 5-year monitoring plan that included:

- Geophysical studies to determine the behavior of the placed material and develop a predictive model
- Vegetation monitoring to determine patterns of revegetation
- Effects of the new sand on undisturbed habitats
- The similarity of the new beach to the old in terms of vegetation composition
- Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*) ecology monitoring to examine mouse population biology and response to habitat alteration
- Benthic community studies to determine the composition of benthic communities, short-term effects of placed material, and rates of recovery
- Ecosystem synthesis to integrate and interpret the above studies into a whole-system framework for management

Lesson Learned from Monitoring: Beach Width

The nourishment project advanced the shoreline an average of 125 m (410 ft) seaward (Browder and Dean 2000). Post-construction monitoring determined that this was too wide to allow sufficient nutrients from the swash zone to reach the vegetation resulting in a production failure of sea oat seeds (R. Hoggard, pers. comm., 2010). These seeds are vital to the survival of the endangered beach mouse on Perdido Key. A reduction in the beach mouse population was documented in the nourishment area; however, a study conducted by Sankaran (1993) concluded that this was a result of the initial population size being below the critical level required and not necessarily related to the beach nourishment (Dean 2005).

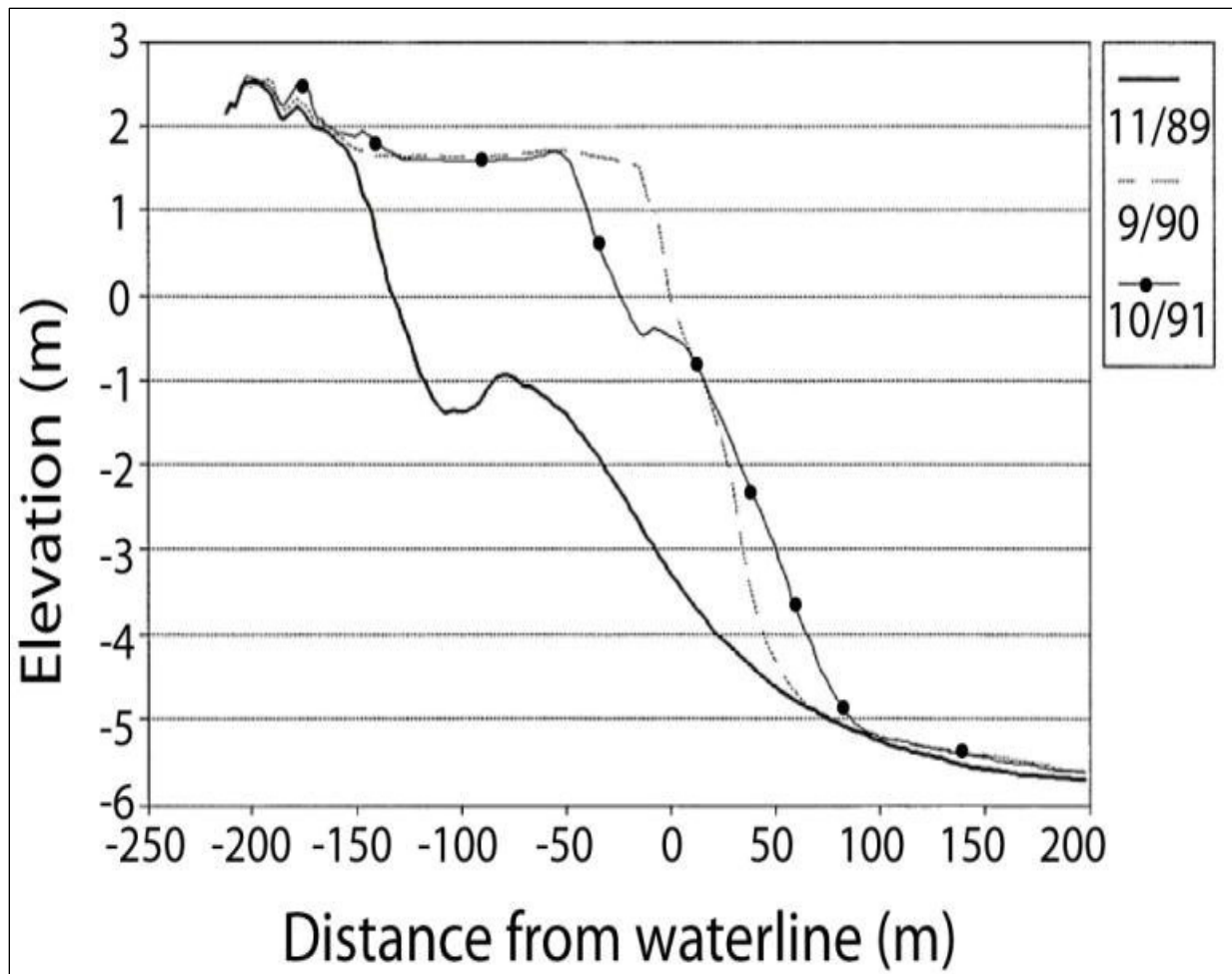


Figure E-2. Average profiles (based on seven profiles) within the nourishment area, Gulf Islands National Seashore, Florida (after Work and Dean 1992: Figure 10).

Monitoring for Future Nourishment Projects

Recommendations for future monitoring efforts at Perdido Key include the following studies:

- Sea turtle nesting/hatching surveys and nest relocation
- Visual escarpment surveys (before turtle season and routinely during the season) and follow-up inspections
- Piping plover surveys of bayside and Gulf beaches (bi-monthly from July 15 through May 15 every year for 10 years)
- Perdido Key beach mouse tracking surveys
- Sediment dynamics and island morphology (fate of sediments)
- Effects on sea oat production and other island vegetation
- Benthic recruitment following placement
- The success of littoral zone placement

Design Considerations for Future Projects at Perdido Key

Littoral Zone Placement

Post-nourishment studies by Dean et al. (1995) concluded that sediment placed deeper than 3.7 m (12 ft) will not move back onto the shore if it is outside the outer bar. It is therefore recommended to place sediment on the beach or in the nearshore zone inside the outer sand bar to keep sediment in the littoral zone.

Mid-Island Placement

The National Park Service's intent of receiving dredged material is to restore sediment to the littoral system, not to just anchor the island in place. Previously, material was only placed along the eroding eastern shoreline. Future placement at Perdido Key should consider mid-island and north beach placement as well.

Seasonal Timing

Dredging and sediment placement have a significant potential to impact the animal communities on and around the island if the placement activities are not timed correctly to avoid periods of high animal activity. To avoid substantial biological disturbances, as well as to the visiting public, placement activities should be limited to the months of November through February.

Federally listed threatened and/or endangered species present in the project area include:

- Loggerhead sea turtle (*Caretta caretta*)
- Green sea turtle (*Chelonia mydas*)
- Leatherback sea turtle (*Dermochelys coriacea*)
- Kemp's ridley sea turtle (*Lepidochelys kempii*)
- Piping plover (*Charadrius melodus*)
- Least tern (*Sterna antillarum*)
- Gulf sturgeon (*Acipenser oxyrinchus desotoi*)
- Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*)
- Florida manatee (*Trichechus manatus latirostris*)

Beach Configuration

The final beach configuration after nourishment has a significant influence on the recovery and function of the barrier island. Future beach nourishment at Perdido Key should follow the recommendations outlined by Dean et al. (1995), including:

- Placement of sediments over a short beach length with tapered ends
- Shoreline length to be based on a placement density from 54 to 65 m³ per 0.3 m (70 to 85 yd³ per 1 ft) of beach
- Limit placement volumes to 382,000 m³ (500,000 yd³) or less
- Limit shoreline advance to no more than 61 m (200 ft)

Future beach configuration at Perdido Key should also include compatible slopes for nesting sea turtles, beach widths conducive to beach mouse productivity and success, varying berm elevation to allow overwash to penetrate the back beach, placements to be in alternate segments to support benthic repopulation, and reduced renourishment volumes to reduce impacts.

Additional Beach Nourishment Projects at Perdido Key, Florida

Additional beach nourishment activities at Perdido Key since the two-phase beach and profile nourishment project from 1989 to 1991 include:

- Nearshore berm development with the aim of rapidly mobilizing sediment and transport to downdrift shoreline and beaches
- The Perdido Key Beach Restoration Project (east and west segments) to address the 4.8-km (3.0-mi) segment of critically eroded beach on Perdido Key through beach and/or dune restoration
- The Perdido Key Sediment Placement to partially supplement the natural sediment budget for the Perdido Key Unit of Gulf Islands National Seashore

These beach nourishment activities are summarized in the following sections.

Perdido Key, Florida Nearshore Berm

In 2011, sediment dredged from the Pensacola Pass navigation channel was placed in the form of a nearshore berm, along the eastern portion of the island in the intertidal zone of Perdido Key, located in the panhandle of Florida (Figure E-1). The overall objective was to place a swash-zone berm so that sediment would rapidly mobilize and transport to downdrift shorelines and beaches. The period of dredging and placement was November 2011 to January 2012 with a total of 400,000 m³ (520,000 yd³) being placed. The swash zone berm was monitored using 44 beach profile transects (R45-R68) that were established using real-time kinematic (RTK) Global Positioning System (GPS). The berm eroded approximately 23 m (75 ft) during the first 5 months following placement and continued to retreat over the next 14 months. An active berm crest was formed by eroded sediment from the foreshore being deposited as overwash on the dry beach. This natural equilibrium process restored the beach to the natural beach contour by July 2013 and by 2019, on average, a total of 2.1 m (7 ft) of the berm remained in terms of beach width. Some sediment from the berm was deposited in the nearshore of the control area to the west of the project (Gailani et al. 2019).

Perdido Key, Florida Beach Restoration Project—Gulf Beach

Tropical storm impacts—most notably Hurricane Ivan in September 2004—destroyed the primary dune system, substantially lowered the elevation of the dry beach berm, and transported a significant quantity of sand offshore of the primary bar at Perdido Key. The need to significantly increase the level of storm protection provided by the Perdido Key beaches to upland infrastructure and environmental habitat prompted the 2006 *Perdido Key, Florida Feasibility Study for Beach Restoration* (Olsen Associates, Inc. 2006), which recommended that Escambia County, Florida and the Florida Park Service consider a comprehensive beach nourishment project along the westernmost 10 km (6 mi) of the Gulf of Mexico shoreline of Perdido Key. This recommendation put into action the Perdido Key Beach Restoration Project, which is divided into east and west segments and is

funded through USACE, Escambia County, and the Florida Park Service (Taylor Engineering, Inc. 2020). The Perdido Key East and West projects lie adjacent to one another and span a total of 23 km (14 mi) with the Perdido Key East project receiving nearshore placement material from Pensacola Pass maintenance since 2012, totaling more than 920,000 m³ (1,200,000 yd³). Strategic sediment placement has shown support of a healthy flood shoal complex and sustainable beach for recreation and environmental habitat for sea turtles and nesting shorebirds (USACE 2020). The Perdido Key West project is a future project, requiring an estimated 1,450,000 m³ (1,900,000 yd³) of material over the next 50 years.

Perdido Key Sediment Placement—Future Project

The Perdido Key Sediment Placement project (NOAA 2020) aims to partially supplement the natural sediment budget by reintroducing sand back into the barrier island system for the Perdido Key Unit of Gulf Islands National Seashore and partially restore injuries to the barrier island habitat caused by the Deepwater Horizon oil spill. The placement goal is at least 306,000 m³ (400,000 yd³) of sediment dredged from Pensacola Pass to be placed onto the easternmost 3 km (2 mi) of Perdido Key by Spring of 2026 (NOAA 2020; FDEP 2021). This project involves collaboration between the National Park Service and the USACE with the sediment dredge and placement events currently targeted from May 2022 to October 2024.

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