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Inventory of Coastal Engineering Projects in Coastal National Parks

Natural Resource Technical Report NPS/NRPC/GRD/NRTR—2010/373

ON THE COVER
A wooden bulkhead and rock revetment at Cape Lookout National Seashore Park Headquarters, Harker's Island, NC
Photograph by: Andy Coburn, Western Carolina University

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Abstract or Executive Summary

A reconnaissance-level investigation, analysis and inventory of coastal engineering projects in ten coastal national parks was completed by the Program for the Study of Developed Shorelines (PSDS) at Western Carolina University (WCU) with funding provided by the National Park Service (NPS) Recreation Fee Program. The coastal national parks inventoried for this project include:

1. Apostle Islands National Lakeshore (APIS)
2. Boston Harbor Islands National Recreation Area (BOHA)
3. Cape Lookout National Seashore (CALO)
4. Channel Islands National Park (CHIS)
5. Fire Island National Seashore (FIIS)
6. Fort Pulaski National Monument (FOPU)
7. Indiana Dunes National Lakeshore (INDU)
8. Jean Lafitte National Historical Park and Preserve (JELA)
9. Lewis & Clark National Park (LEWI)
10. Timucuan Ecological and Historic Preserve (TIMU)

This document provides a summary of findings in each park and includes information on identified coastal engineering projects including historic data, imagery, cost and a discussion of impacts (where available and appropriate). This summary report serves as a supplement to a Geographic Information Systems (GIS) database of coastal engineering projects.

Acknowledgments

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Introduction

Purpose of the Inventory

The purpose of the NPS Coastal Engineering Inventory is to help the NPS define the extent of human-altered coastal areas in the National Park System. This, in turn, will help the NPS understand its resources, establish baselines, develop desired future conditions, balance the protection of historic resources and infrastructure with the preservation of natural systems, and improve post-storm response. All of these actions will improve the ability of the NPS to manage coastal park units in accordance with NPS policies. These policies are summarized as follows:

Maintenance of Natural Processes

Generally, NPS policy requires that natural coastal processes in parks, such as erosion, shoreline migration, deposition, overwash, and inlet formation be allowed to continue without interference (NPS Management Policies § 4.8.1.1). The NPS may intervene in these processes only in limited circumstances, such as when there is no other feasible way to protect natural resources, park facilities, or historic properties (NPS Management Policies § 4.8.1).

Restoration of Natural Processes

In parks where pre-existing or new activities or structures have altered and/or are currently altering coastal dynamics, ecosystems, tidal regimes, and sediment transport rates, the NPS policy is to investigate, in consultation with appropriate state and federal agencies, alternatives for mitigating the effects of such projects and for restoring natural conditions (NPS Management Policies § 4.8.1.1). 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, as called for by park management plans (NPS Management Policies § 4.1.5 and § 4.4.2.4). An example would be the restoration of shoreline processes.

Park landscapes disturbed by natural events, such as hurricanes, are allowed to recover naturally unless manipulation is necessary to 1) mitigate for excessive disturbance caused by past human effects, 2) preserve cultural and historic resources as appropriate based on park planning documents, or 3) protect park developments or the safety of people. (NPS Management Policies § 4.1.5 and § 4.4.2.4).

Construction of Facilities

Generally, the NPS must avoid the construction of buildings, roads, and other development that will cause unacceptable impacts on park resources and values (NPS Management Policies § 9.1). Development will not compete with or dominate park features or interfere with natural processes (NPS Management Policies § 9.1.1.2). In shoreline areas, this means that new developments will not be placed in areas subject to wave erosion or active shoreline processes unless 1) the development is required by law; or 2) the development is essential to meet the park's purposes, as defined by its establishing act or proclamation, and

- no practicable alternative locations are available;
- the development will be reasonably assured of surviving during its planned life span without the need for shoreline control measures; and

- steps will be taken to minimize safety hazards and harm to property and natural resources (NPS Management Policies § 4.8.1.1).

Replacement of Facilities

Park development that is damaged or destroyed by a hazardous or catastrophic natural event will be thoroughly evaluated for relocation or replacement by new construction at a different location. If a decision is made to relocate or replace a severely damaged or destroyed facility, it will be placed, if practicable, in an area that is believed to be free from natural hazards (NPS Management Policies § 9.1.1.5 and § 4.1.5).

Cooperative Conservation

Under NPS policy, park superintendents are required to monitor state government programs for managing state-owned submerged lands and resources within NPS units. When there is potential for such programs to adversely impact park resources or values, superintendents will make their concerns known to appropriate state government officials and encourage compatible land uses that avoid or mitigate potential adverse impacts. When federal acquisition of state-owned submerged lands and resources within NPS units is not feasible, NPS will seek to enter into cooperative agreements with state governments to ensure the adequate protection of park resources and values (NPS Management Policies §3.4).

Methods

"Coastal engineering" can be defined as any anthropogenic activity that impacted, currently impacts or has the potential to impact littoral sediment transport. The WCU PSDS and NPS Geologic Resources Division identified several common coastal engineering projects, and selected ten coastal national parks in which coastal engineering projects (attributes) were identified, inventoried and mapped. Additional information (attribute data) on each identified coastal engineering project including type, cost, material, year of construction, and maintenance history was also obtained, where possible, through literature searches, correspondence with park personnel, and site visits. Data were collected in 2008 and 2009.

PSDS obtained a digital shapefile containing all NPS park boundaries from the NPS Data Store < http://science.nature.nps.gov/nrdata/> and removed park boundaries not included in this study using ArcMap Version 9.3. A GIS layer containing only the boundaries of the ten coastal parks of interest was created and stored in a File Geodatabase created using ArcCatalog Version 9.3.

Georeferenced digital orthophoto imagery in. jpg, .tiff and MrSID file format was obtained for each park through an array of federal, state, university and NGO sources including the USGS National Map Seamless Server < http://seamless.usgs.gov/index.php>, NOS Data Explorer < http://nosdataexplorer.noaa.gov/nosdataexplorer/>, GOS-Geospatial One Stop < http://gos2.geodata.gov/wps/portal/gos>, NPS Data Store < http://science.nature.nps.gov/nrdata/> and ESRI ArcGIS Online <. http://www.esri.com/software/arcgis/arcgisonline/world_imagery.html>. Digital imagery for each park was downloaded (in the file format available) and combined with the park boundary GIS layer in ArcMap to create a basemap. Folders were created for all parks using ArcCatalog, and digital imagery for each park was stored in that park's respective folder.

A visual inspection of digital orthophoto imagery for each park was completed by PSDS. Locations of all discernible coastal engineering projects were digitized using ArcMap, and a comprehensive online and hardcopy literature search was undertaken to obtain attribute data associated with each identified coastal engineering project.

When a literature search resulted in the discovery of a previously unidentified coastal engineering project, additional research was undertaken to confirm the existence of the newly discovered project, and to locate associated attribute data. Once a project's existence was confirmed, additional orthophoto imagery with greater resolution was obtained, when possible, and the location of the coastal engineering project was digitized using ArcMap. Although hundreds of online and hardcopy sources were queried, only those providing relevant data were cataloged.

Site visits to Fire Island National Seashore, Jean Lafitte National Historical Park and Preserve and Cape Lookout National Seashore, along with staff correspondence from each park, were used to complement, supplement and revise the methodology used, as well as to confirm initial findings based on an examination of aerial imagery.

A comprehensive GIS File Geodatabase comprising all ten coastal national parks was compiled using ArcMap with identified coastal engineering projects placed into one of three groups: 1) erosion control structures 2) dredge and fill projects and 3) beach/dune construction projects based on a similarity among each group's attributes.

The resulting comprehensive GIS File Geodatabase was converted into a .csv spreadsheet and imported into an online database that can be searched, and is sortable, by various project attributes.

Individual park summaries and a comprehensive summary that combines findings across all ten parks have also been developed.

Results

This project identified a total of 402 discrete coastal engineering projects in, and adjacent to, the ten parks inventoried. A breakdown of projects by type and park is provided in Table 1.

Table 1. Coastal engineering projects by type and park.

Coastal Engineering Project Type*	Number of Projects Identified
Revetment	96
Bulkhead	103
Seawall	33
SHORELINE STABILIZATION STRUCTURES	**232**
Groin	62
Jetty	20
SEDIMENT TRAPPING STRUCTURES	**82**
DREDGE AND FILL PROJECTS	**52**
BEACH NOURISHMENT / DUNE CONSTRUCTION	**17**
Breakwater	8
Dike	7
Levee & Floodwall	4
OTHER STRUCTURES	**19**
TOTAL	**402**

Coastal National Park	Number of Projects Identified
Apostle Islands National Lakeshore	8
Boston Harbor Islands National Recreation Area	51
Cape Lookout National Seashore	15
Channel Islands National Park	9
Fire Island National Seashore	93
Fort Pulaski National Monument	14
Indiana Dunes National Lakeshore	43
Jean Lafitte National Historical Park and Preserve	52
Lewis & Clark National Historical Park	12
Timucuan Ecological and Historic Preserve	105

*See glossary at the end of the document for coastal engineering project definitions

Across all ten parks, approximately 132,000 linear feet of shoreline wass identified as being stabilized by a bulkhead, 141,000 linear feet of shoreline is stabilized by a revetment, 50,000 linear feet of shoreline is stabilized by a seawall and 242,790 feet of shoreline has been impacted by beach nourishment/dune construction (NOTE: this figure includes lengths of shoreline that have been repeatedly impacted). The cumulative volume of sand emplaced on beaches within all ten coastal parks through beach nourishment and dune construction is approximately 20,784,691 cubic yards. In addition, dredging and filling activities have displaced over 78,000,000 cubic yards of sediment and impacted approximately 11,000 acres of subaerial and submerged land in, and adjacent to, the ten parks.

The classification of coastal engineering projects was based on a visual assessment of digital aerial orthophoto imagery, a comprehensive literature review, site visits and factors such as:

1) Position/placement along a shoreline,
2) Shoreline type (open ocean vs. estuarine),
3) Alignment relative to the shoreline (parallel vs. perpendicular),
4) Intent (as surmised by a visual assessment/site visit) and
5) Observed impacts (if any).

This inventory considered a coastal engineering project to be distinct - or discrete – if there is no discernable, physical separation between it and an adjacent coastal engineering project. A series of bulkheads constructed along an estuarine shoreline by individual interests, for example, would be classified as one structure as long as no identifiable gaps were observed between them.

It should be noted that some projects - such as erosion control structures with compound functions (such as a structure that acts as a breakwater and jetty) and navigation maintenance projects that place dredge spoil on a beach – serve multiple purposes. In such cases, the primary function or reason for the project was ascertained, and the project was classified accordingly.

Finally, some coastal engineering projects - such as the creation of dune notches and beach scraping - have been identified, but not included in this summary due to the limited and ephemeral nature of their existence and impacts.

Discussion

While the availability of attribute data on coastal engineering projects is incomplete and difficult to obtain, especially for projects completed before 1990, this study identified a surprisingly large number (402) of coastal engineering projects, indicating a greater extent of human-altered coastal areas in the National Park System than previously recognized.

This study identified 232 shoreline stabilization structures (revetments, bulkheads and seawalls), 82 sediment trapping structures (groins and jetties), 52 dredge and fill projects, seventeen beach/dune construction projects and nineteen other projects.

Although not evaluated in this report, impacts associated with coastal engineering projects are widely recognized, and the extent of coastal engineering identified in this study indicates impacts to littoral sediment transport, as well as subaerial and submerged habitats, are highly likely – and possibly pervasive - within the National Park System.

The type, extent and degree of impacts caused by coastal engineering, however, are typically dictated by a complex array of factors including the type, size, location and age of coastal engineering projects as well as local and regional littoral, physical, geological, and biological processes.

It should be pointed out that the number of coastal engineering projects in a park is not an accurate indicator of the extent of coastal engineering within that park since a project, such as a bulkhead, revetment or beach construction, can encompass significant lengths (hundreds-to-thousands of feet) of shoreline.

The widespread existence of coastal engineering projects in coastal national parks also seems to violate NPS Management Policies § 4.8.1.1 which require that natural coastal processes such as erosion, shoreline migration, deposition, overwash and inlet formation be allowed to continue in parks without interference (although the NPS may intervene in limited circumstances, such as when there is no other feasible way to protect natural resources, park facilities, or historic properties).

Additional Findings

Different types of coastal engineering projects often have unique, and disparate, attributes, making it difficult to group and/or compare projects.

The quality (resolution) and relevance of available digital orthophoto imagery varies by park, with the highest resolution imagery often difficult to manipulate due to its large file size.

Erosion control structures were digitized using line segments, rather than polygons, due to the resolution and clarity of available digital orthophoto imagery.

Site visits confirmed the value of digital aerial orthophoto imagery in identifying erosion control structures, and proved beneficial in terms of confirming data obtained through a visual inspection of aerial orthophoto imagery.

Recommendations

NPS should commence a study to evaluate the direct, secondary and long-term cumulative impacts of coastal engineering projects on coastal processes and coastal habitats within one or more coastal national parks.

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Appendix A. Apostle Islands National Lakeshore.

Figure 1. Raspberry Island Lighthouse, Raspberry Island, WI (Source: National Park Service).

Summary of Findings

Located in Lake Superior and the State of Wisconsin, Apostle Islands National Lakeshore (APIS) was established by Public Law 91-424 on September 26, 1970 to "…conserve and develop for the benefit, inspiration, education, recreational use and enjoyment of the public…" 20 of the 22 islands in the archipelago as well as a 13-mile-long strip of shoreline on the mainland (Figures 1 and 2). In 1986, Long Island was added to the lakeshore.[1]

Eight coastal engineering projects were identified in/adjacent to APIS. One involves bank and slope stabilization on Raspberry Island, the second involves construction of three stone

[1] Lowey, J. 2000. Statement of Jacqueline Lowey, Deputy Director, National Park Service, Department of the Interior, before the Subcommittee on National Parks, Historic Preservation and Recreation of the Committee on Energy and Natural Resources, U.S. Senate, concerning S.134, a bill to direct the Secretary of the Interior to study whether the Apostle Islands National Lakeshore should be protected as a wilderness area. Online. (http://www.nps.gov/legal/testimony/106th/aposliln.htm).

revetments and slope stabilization on Outer Island, and the third involves construction of revetments associated with Little Sand Bay Harbor on the Bayfield Peninsula.

Over the final decades of the twentieth century, the rate of bluff erosion along portions of Raspberry and Outer Islands increased dramatically, placing the bluff much closer to each island's light station. Between 1987 and 1991, Outer Island suffered its highest rate of erosion and averaged approximately one foot of bank loss per year. Erosion at the Raspberry Island Light Station has been more sporadic, with heavy spring rains in 1991 resulting in some mass wasting of the slope directly in front of the light station structures.[2]

Fearing that, if left unchecked, these historically significant structures would topple into the lake, legislation (S. 134, also known as the Gaylord Nelson Apostle Islands Stewardship Act of 2000) was introduced to address stabilization of Raspberry Island Lighthouse and Outer Island Lighthouse. The bill passed the Senate in October 2000 and was referred to the House Subcommittee on National Parks and Public Lands where it was never acted upon.

Nevertheless, the Fiscal Year 2001 Interior Appropriations Conference Report signed by President Clinton included allocations of $1.36 million for repair of erosion at the Raspberry Island Lighthouse and $600,000 at the Outer Island Lighthouse. The legislation was promoted by U.S. Sen. Russ Feingold, a Democrat from Wisconsin.[3]

Raspberry Island

Of the two stations, the erosion situation at Raspberry Island was deemed most critical (Figure 3).[4] In 2001, a large-scale shoreline stabilization project was initiated at Raspberry Island Light Station that included a combination of a rip-rap revetment to stabilize the toe of the slope and bio-engineering on the remaining portion of the slope (Figures 4 and 5). Bioengineering included the use of brush layers and fascines and covering the slope with coconut fiber. In addition, plant materials were gathered from the site and propagated at NRCS's Rose Lake Plant Materials Center. In 2003, these plants were placed in-between the rows of brush layers and fascines to increase the stabilization and enhance the aesthetics of the slope. A total of 675 shrubs and forbs were planted including 54 speckled alder, 178 willows, 53 red-osier dogwoods, 349 red elderberry, 13 wild strawberry, 19 staghorn sumac, eight bristly rose, and one clump of eight wild roses.

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[2] Lowey, J. 2000. Statement of Jacqueline Lowey, Deputy Director, National Park Service, Department of the Interior, before the Subcommittee on National Parks, Historic Preservation and Recreation of the Committee on Energy and Natural Resources, U.S. Senate, concerning S.134, a bill to direct the Secretary of the Interior to study whether the Apostle Islands National Lakeshore should be protected as a wilderness area. Online. (http://www.nps.gov/legal/testimony/106th/aposliln.htm).

[3] Merkel, J. 2001. Erosion control projects set for two Apostle Islands' lighthouses. (http://www.lighthousedepot.com/lite_digest.asp?action=get_article&sk=930&bhcd2=1236115044).

[4] Pepper, T. 2007. Seeing the light. Online. (http://www.terrypepper.com/lights/superior/raspberry/index.htm).

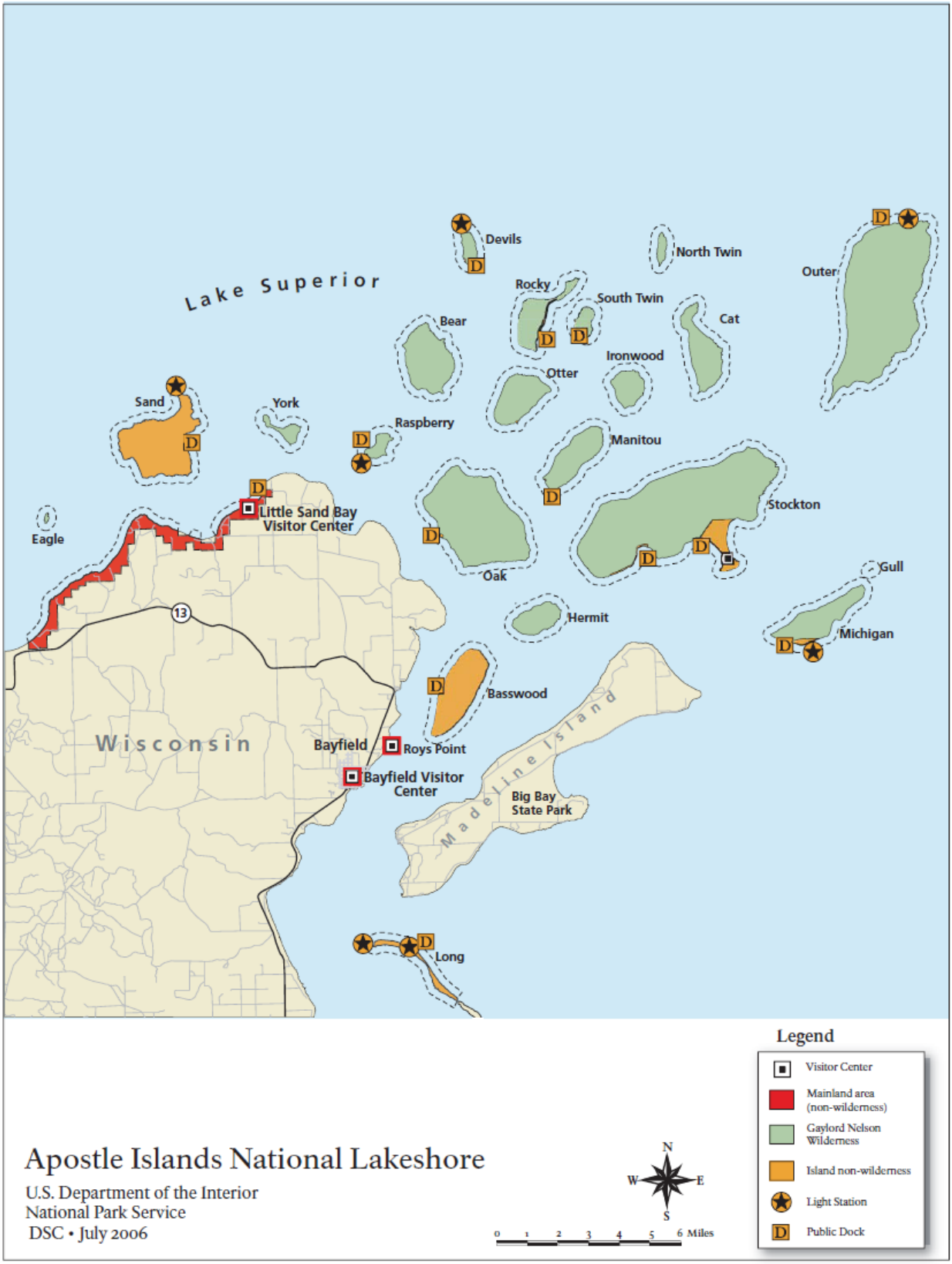

Figure 2. Apostle Islands National Lakeshore.

Figure 3. Raspberry Island Lighthouse before construction.

Slope regrading and drainage improvements were additional components of the bank stabilization. A drainage system at the top of the bluff was installed to intercept runoff. Groundwater is also being intercepted and diverted away from the reconfigured slope through a perforated pipe buried in a trench installed parallel to the top of the bluff.

A rock revetment was built to stabilize the foot of the slope. This structure extends approximately 210 feet northwest, and 130 feet east, of the existing dock. The top of the armorstone is approximately five feet above the dock surface.[5] The base of the reconfigured slope now extends approximately 45 feet further into the lake than before construction (Figure 6).[6] The total cost of the project was $985,004.[7]

[5] Pepper, T. 2007. Seeing the light. Online. (http://www.terrypepper.com/lights/superior/rasperry/index.htm).
[6] National Park Service. 2002. Raspberry Island lighthouse bank stabilization project. Online. (http://eparka.org/news/43/S1/9U/143S19UM9/1027864302782.html).
[7] Randy Ross, Chief of Facility Management, Apostle Islands National Lakeshore, Personal communication, July 2008.

Figure 4. Raspberry Island Bank Stabilization Project.

Figure 5. Raspberry Island Bank Stabilization Project during construction.

Figure 6. Completed Raspberry Island Bank Stabilization Project.

Outer Island

Bank Stabilization at Outer Island Light Station was completed in September 2006 at a cost of $1,989,497 (in 2008 dollars).[8] This project involved the construction of a stone revetment along approximately 1,500 linear feet of shoreline on both sides of the existing concrete dock with a trench on top to redirect water flow. At the bottom of the slope is a protective wall with a stone breakwater below the surface of the lake (Figure 7).[9] The revetment was built in 2004 and crib walls and vertical slope grids created out of lumber and rocks were constructed on-site in 2005. In addition, approximately 300 willow live stakes and approximately 3,900 propagated shrubs and plants were planted.

Little Sand Bay Harbor

Little Sand Bay Harbor, located on the Bayfield Peninsula of Wisconsin, is operated by the NPS (Figure 8).[10] Shoaling due to the accumulation of sediment is a concern, and can be accentuated by drops in Lake Superior water level.

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[8]Randy Ross, Chief of Facility Management, Apostle Islands National Lakeshore, Personal communication, July 2008.

[9]Merkel, J. 2001. Erosion control projects set for two Apostle Islands' lighthouses. (http://www.lighthousedepot.com/lite_digest.asp?action=get_article&sk=930&bhcd2=1236115044).

[10]Wu, C. 2008. Sediment traps in Little Sand Bay Harbor. Online. (http://homepages.cae.wisc.edu/~chinwu/CEE618_Impacts_of_Changing_Climate/Adam/Sediment%20Trap%20Home.html).

Figure 9 shows average monthly water levels for Lake Superior since the middle of the 19th century. Extremely high water levels occurred in the 1870s, early 1950s, early 1970s, mid-1980s, and mid-1990s, while low water levels were experienced in the late 1920s, mid-1930s, mid-1960s, and in the late 1990s leading up to today. As the hydrograph illustrates, water levels tend to follow a cyclical pattern.[11]

Figure 7. Outer Island Bank Stabilization.

[11] Great Lakes Information Network. 2009. Online. (http://www.great-lakes.net/teach/envt/levels/lev_3.html).

Figure 8. Little Sand Bay Harbor.

Lake Superior is being affected by a drought, and lack of normal snow and rainfall accumulations the past four years which has caused the lake to reach low water levels not seen in recent decades.[12] As a result, the NPS must regularly dredge the harbor to maintain water depths to accommodate its own boats, as well as those of the public. According to a UW-Madison study, sedimentation is greatest near the north wall of the harbor. [13]

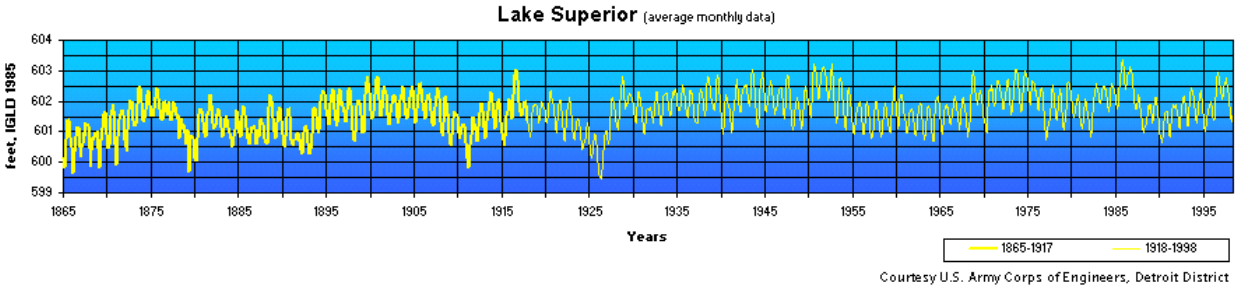

Figure 9. Lake Superior water levels.

[12] Minnesota North Shore Visitor Guide. 2009. Online. (http://www.northshoreguide.com/lakesuperior/index.htm).
[13] UW-Madison Civil and Environmental Engineering, Madison, Wisconsin.

Appendix B. Boston Harbor Islands National Recreation Area.

Figure 10. Boston Lighthouse, Little Brewster Island (Photo by Carol Sampson, United States Lighthouse Society, http://www.uslhs.org/Photo_Album_2006_Massachusetts.php).

Summary of Findings

One of the newest national parks -- legislation was signed November 12, 1996 -- the Boston Harbor Islands National Recreation Area (BOHA) includes 34 islands ranging in size from less than one to over 200 acres (Figure 10). The islands are situated within the large "C" shape of the Greater Boston shoreline. Most are within two to four miles of points on the mainland (Figure 11).

Boston Harbor is part of the Boston Basin, a geologic feature created by a shift in the Earth's crust millions of years before the glaciers. In the past 100,000 years, two separate periods of glaciations contributed to the development of the topography seen in the Boston Basin today and also created the local drainage system consisting of the Charles, Mystic, and Neponset watersheds.

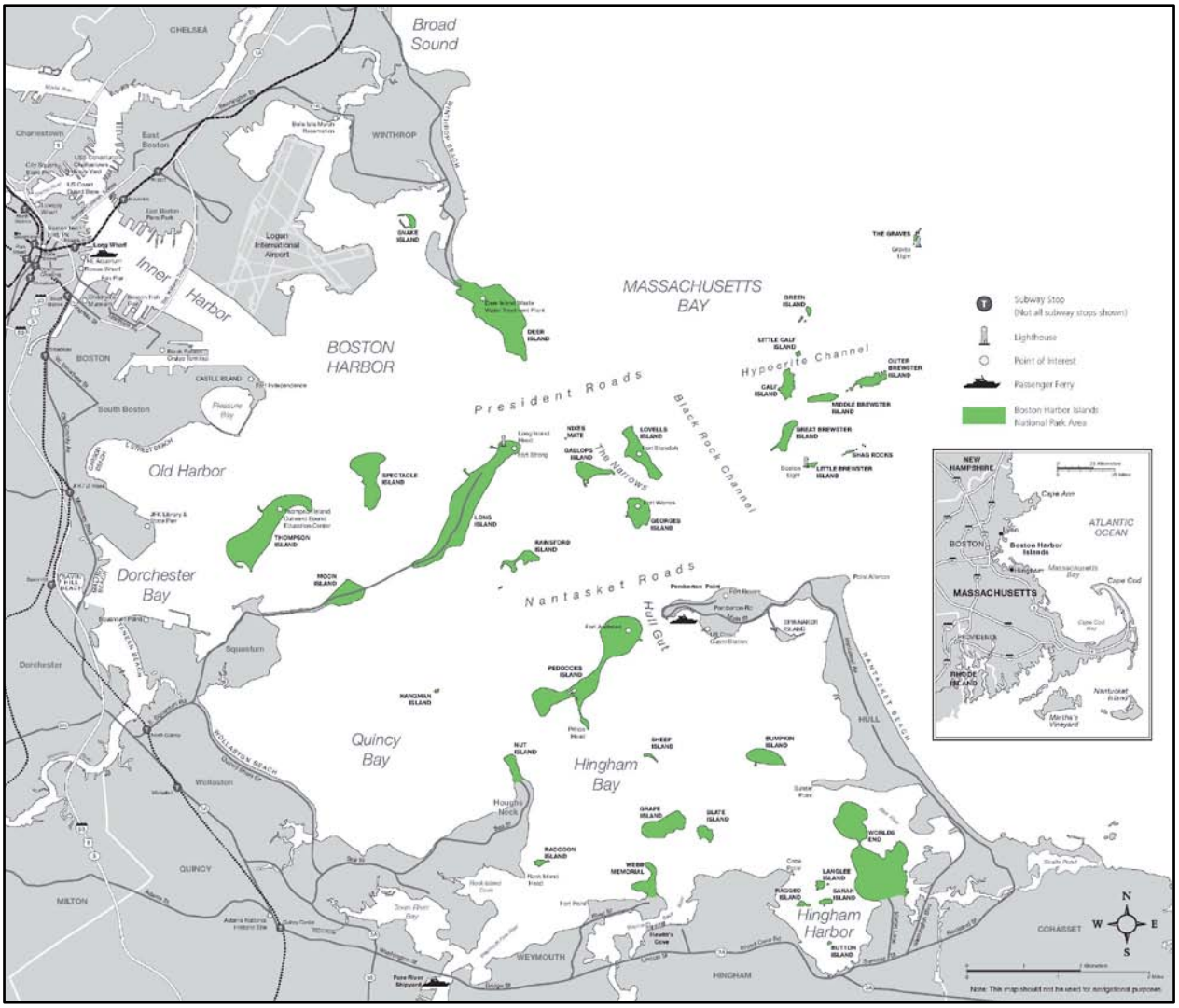

Figure 11. Islands of Boston Harbor Islands National Recreation Area.

The cores of many harbor islands are drumlins—glacier-formed, asymmetrical, elongate masses of till formed into smooth-sloped hills on the Boston Basin lowlands. In profile, they look like upside-down teaspoons. As the climate warmed and glaciers receded from the Boston area some 15,000 years ago, the melting of glacial ice raised the level of the ocean, eventually creating this section of the basin and isolating the islands. Although most of the islands have one or more drumlins, about a dozen are outcrops of bedrock that have been molded by glacial processes.

Geologists believe the islands illustrate two separate periods of glacial action. Most of the harbor islands are composed of two layers of glacial till, their bases laid down by glacial expansion during the early Pleistocene Era (from 1.8 million to ~10,000 years ago) when sea level was 20 meters lower than it is today, and their upper parts deposited when the ice retreated many thousands of years later, some 15,000 years ago.

Natural coastal processes, especially northeast storms, continue to reshape island landforms. As a result, rates of erosion on the islands can be dramatic. In general, the highest rates of erosion

occur along beaches facing north and east, which are the dominant directions for winds and seas in these storms. Human use of the islands also affects shoreline processes. Removal or damaging vegetative cover can promote erosion, whereas structures have been built to prevent erosion.

NPS policy is to let shoreline processes take place unimpeded. 1998 NPS Management Policy states, *Natural shoreline processes...that are not influenced by human actions will be allowed to continue without abatement except where control measures are required by law. In instances where human activities or structures have altered the nature or rate of shoreline processes, the National Park Service will, in consultation with appropriate state and federal agencies, investigate alternatives for mitigating the effects of such activities or structures. The National Park Service will comply with provisions of state coastal zone management plans prepared under the Coastal Zone Management Act (16 USC 1451 et seq.) when such provisions are more environmentally restrictive than National Park Service management zoning.*

Boston Harbor and its improved tributaries have been the subject of numerous reports by the U.S. Army Corps of Engineers (USACE) since 1825, from which time to 1866, the projects studied and adopted were focused primarily on works of preservation: projects designed and built to preserve navigable depths in the harbor by protecting the surrounding headlands and islands from erosion by constructing seawalls, jetties and aprons.[14]

A total of 51 coastal engineering projects have been identified in BOHA including one beach nourishment episode, five dredging episodes, eleven groins, two jetties, fourteen revetments and eighteen seawalls.

Erosion Control Structures

In general, the geomorphic history of the islands can be summarized as: 1) glacial shaping of landforms with a northwest–southeast orientation; 2) sea level rise after glacial retreat, which partly surrounded the glacial hills to form islands, with erosion and deposition reorienting the islands to a northeast–to–southwest bearing; and 3) human intervention, leading to greater local erosion control needs.

In 1978, Massachusetts adopted policies concerning the protection, development and revitalization of coastal resources within the state. All lands on the islands, except federal lands, are subject to Massachusetts coastal zone management policies; all federal activities related to marine resources must be consistent with these policies.

There are many erosion control structures within the Boston Harbor Islands NRA that can affect, and have affected, the rate of erosion and the movement and transport of sediments in the harbor and on the islands.

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[14] United States and Massachusetts Port Authority. 2008. Boston Harbor Navigation Improvement Project: Draft feasibility report and supplemental environmental impact statement. U.S. Army Corps of Engineers, Concord, Massachusetts.

The first seawall in BOHA was started in 1825 to preserve Georges Island. Seawalls have also been constructed on other islands including Calf Island, Deer Island, Gallops Island, Great Brewster Island, Long Island, Lovells Island, Rainsford Island and Point Allerton. All these walls have been built by the Federal Government under the direction of the USACE.

An 1840 survey disclosed that the preservation of these islands from the wash of the sea was indispensable as covers of the anchorages and roadsteads, and also to the maintenance of requisite depths in the channels. The aggregate length of these walls is about 3 miles, and the total amount expended in their construction and maintenance is about $1,500,000.[15]

Deer Island

Deer Island, which houses a large waste water plant, was once separated from Winthrop, but has been connected to the mainland since Shirley Gut was filled in by a hurricane in 1938. The three prominent sides of this island have been protected by granite seawalls, originally built about 1828. Between 1865 and 1869 these walls were partly rebuilt, and backed with concrete in some areas. All the walls were originally built dry, and have required some level of repair.[16]

Repairs were again made in 1894 to the south and middle walls. In addition, nearly all the backfill and shell-stone paving behind the wall was replaced. These repairs were made at a cost of $3,451.25 ($84,819.12 in 2008 dollars). [17]

In 1864, two split-stone jetties, 25 and 128 feet long, were placed at about the middle of the main face of the north wall and middle wall.[18] Today, two stone groins are located at the southern tip of the island.[19]

Gallops Island

A 2,385-foot long granite block seawall, originally constructed in 1868 by the USACE and extended in 1869, 1870, 1890 and 1892 at a total cost of $15,000, bounds the north, west and east sides of the island. A 3,050-foot long rubble mound revetment, completed in 1884, covers part of the foundation of the seawall.[20] The USACE also constructed nine jetties on the island in 1873-1874 (only two exist today).[21]

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[15] American Society of Civil Engineers. 1873. Proceedings. The Society. New York, New York.
[16] United States. 1894. Annual report. Washington: Government Printing Office, Washington, D.C.
[17] Ibid.
[18] United States. 1879. Annual report. Washington: Government Printing Office, Washington, D.C.
[19] National Park Service. 2009a. Boston Harbor Islands National Recreation Area, island facts: Deer Island. Online. (http://home.nps.gov/boha/historyculture/facts-deer.htm).
[20] United States. 1894.
[21] United States, McClure, J. and C.W. Raymond. 1903. Analytical and topical index to the reports of the chief of engineers and officers of the Corps of Engineers, United States Army, 1866-1900. Government Printing Office, Washington, D.C.

Georges Island

By 1825, heavy erosion and the sale of sand and gravel to passing ships in need of ballast had diminished Georges Island to half of its original size. The first act taken by the federal government after it purchased the island was to build a massive 2,150-foot long seawall, completed in 1835, to protect it from further erosion.[22] The seawall on the northern and eastern shores was constructed in 1835. Riprap along the western shoreline of Georges Island was constructed in 1884-85.[23] Three groins are visible at low tide on the north shore of the island.

Great Brewster Island

Observations made at Great Brewster showed that from 1820 to 1868 an annual average of five feet horizontally was washed away into the channel from the big bluff on the North Head. This island, on the north side of the entrance to the main ship-channel, is protected by a granite seawall 2,840 feet in length, originally built in 1850, and extended in 1854, 1865, 1866 and 1867. The wall, which now extends three-quarters of the way around the island, consists of coursed granite 18 feet high on a concrete foundation and backed with concrete.[24] In 1851, a 50-foot long stone jetty was built at the South Head wall.[25]

Long Island

The North Head of Long Island is protected by a 2,081-foot long granite seawall completed in 1874 at an estimated cost of $72,000.[26] The foundation of the seawall and its southern and western ends are protected by aprons of rabble-stone aggregate (1,375 feet in length) built in 1874 and extended in 1884.[27] Around 1874, ten triangular stone jetties projecting between twelve and twenty feet were constructed.[28]

Lovell's Island

Lovell's Island, on the north side of the Main Ship Channel, lies about a mile northward of Georges Island and is approximately 30 or 40 feet high. The northern shore is covered by a 750-foot long granite seawall, built in 1843 at a cost of $15,000, and repaired in 1878.[29] The western shore is protected by a 975-foot long rubble-stone apron, built in 1873, repaired and extended in 1884. The eastern shore is protected by an 800-foot long granite seawall that was completed in

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[22] Klein, C. 2008. Discovering the Boston Harbor Islands: A guide to the city's hidden shores. Union Park Press, Boston, Massachusetts.
[23] United States. 1894. Annual report. Government Printing Office, Washington, D.C.
[24] Ibid.
[25] United States and Massachusetts Port Authority. 2008. Boston Harbor Navigation Improvement Project: Draft feasibility report and supplemental environmental impact statement. U.S. Army Corps of Engineers, Concord, Massachusetts.
[26] United States. 1872. Annual report of the Secretary of War. U.S. Government Printing Office, Washington, D.C.
[27] Ibid.
[28] Shurtleff, N. B. 1871. A topographical and historical description of Boston. Printed by request of the City Council, Boston, Massachusetts.
[29] Ibid.

1869, a 1,440-foot long rubble-stone apron (between the northern and eastern sea wall), and a 1,330-foot long apron south of the east seawall.[30]

A jetty was constructed on Lovell's Island in 1873.[31] In addition, the northwest shoreline contains what appear to be three groins and a breakwater, although no record of their construction could be located.

Moon Island

Moon Island contains a 1,700-foot long stone revetment along the northwest shore, and two stone seawalls, one along the northeast head, and the other along the southeast head.

Rainsford Island

The north head of this island is protected by a 1,500-foot long granite seawall originally built around 1840 and extensively repaired in 1884-85.[32]

Spectacle Island

The island was initially composed of two small drumlins connected by a spit. Beginning in the 1920s, deposition of the city's garbage expanded the size of the island by 36 acres. The island is now two earth mounds, terraced with retaining walls, roads and vegetation. A granite seawall, crumbling in many places and fronted by an extensive rock revetment, is located along the northern and eastern shores.[33] A shorter, concrete seawall was constructed on the west side of the island in 1996.[34]

Thompson Island

A 1,000-foot long stone revetment of unknown origin or cost is located on the north shore of Thompson Island.[35]

Worlds End

A 300-foot long stone revetment is located along the northwest shoreline. In addition, three groins of unknown origin are located along the southeast shoreline.

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[30] United States. 1887. Annual reports of the War Department. Government Printing Office, Washington, D.C.

[31] United States, Robert, H. M., Raymond, C. W., Schermerhorn, L. Y., Potter, S. O. L. and H.B. Schermerhorn. 1881. Analytical and topical index to the reports of the chief of engineers and the officers of the Corps of Engineers, United States Army, upon works and surveys for river and harbor improvement, 1866-[1892]. Government Printing Office, Washington, D.C.

[32] United States. 1907. Annual reports of the War Department. Government Printing Office, Washington, D.C.

[33] National Park Service. 2009b. Boston Harbor Islands National Recreation Area, island facts: Spectacle Island. Online. (http://www.nps.gov/boha/historyculture/facts-spec.htm).

[34] Cashman, J. 2005. Environmental portfolio. Online. (http://www.jaycashman.com/environmental/portfolio_spectacle.html).

[35] United States. 1887.

Beach Nourishment (Sand Placement)

Approximately 16,000 cubic yards of accumulated coarse sand were mechanically removed from the marina on Spectacle Island and placed on Spectacle Island South Beach in 2006. Sand was placed in the intertidal zone along the South Beach in an area that has experienced erosion from storm events. It is anticipated that a sacrificial dune will provide sand during storm events that will replenish the beach area. The project temporarily altered 390,000 square feet of shoreline.[36]

Dredging

Boston Harbor and its navigable tributaries have been extensively modified by the Federal government (the USACE) and State and local agencies and interest groups since the first USACE navigation project in the harbor was authorized in 1822 (Table 2).

Deep water access to the harbor is provided by three entrance channels; the Broad Sound North Channel at 40 feet, the Broad Sound South Channel at 30 feet, and the Narrows Channel at 27 feet.[37]

In 2008, the USACE completed a Feasibility Report and Supplemental Environmental Impact Statement (EIS) for the Boston Harbor Deep Draft Navigation Improvement Feasibility Study that proposes to alter several shipping channels including:

1. Deepening the North Entrance Channel to 50 feet, widened at Finns Ledge Bend,
2. Deepening the Main Ship Channel from Outer Confluence to Reserved Channel to 48 feet, widened to 900 feet below Castle Island and 800 feet above. Widened further in the bends,
3. Deepen President Roads Anchorage Area to 48 feet, and
4. Widen Reserved Channel Turning Area to about 1600 feet and deepen to 48 feet.

According to the EIS, approximately 12,000 cubic yards of material will be dredged from these channels, and 1,100 acres of subtidal lands will be impacted. All dredged material has been deemed suitable for unconfined ocean disposal by U.S. EPA, and will be deposited in the Massachusetts Bay disposal site located about 20 miles east of Boston Harbor. This site has been used since at least the 1940s. Construction is projected to begin in 2011.[38]

[36] Massachusetts Department of Conservation and Recreation. 2006. Certificate of the Secretary of Environmental Affairs on the Notice of Project Change.

[37] United States and Massachusetts Port Authority. 2008. Boston Harbor Navigation Improvement Project: Draft feasibility report and supplemental environmental impact statement. U.S. Army Corps of Engineers, Concord, Massachusetts.

[38] Ibid.

Table 2. Project construction and maintenance history for Boston Harbor, Deep Draft & Main Shipping Channels[39].

Work Dates	Work Accomplished	Quantities
July 1867 – Fall 1869	Improvement Dredging of the 23-Foot Narrows Channel at Reduced Width of 625 Feet and Reduced Depth of –21.5 Feet	159,809 cy
July 1867 – Sept 1867	Removal of Tower Rock from Narrows Channel Approach off Hull to –23 Feet MLW	150 Tons Ledge
Oct 1867 – Dec 1968 and June 1869	Removal of Corwins Rock from Narrows to –23 Feet MLW	1,356 Tons Ledge (609 cy)
FY 1869	Improvement Dredging with Experimental Plant of the 23-Foot Channel at Middle Ground	450 cy Hardpan
July 1869 – Aug 1869	Removal of Barrel Rock from the Approach to the Broad Sound South Channel to –22.5 Feet	225 Tons Rock
Aug 1869 – Dec 1870	Removal of Kelly's Ledge from Narrows Approach	509 Tons Ledge
July 1870 - June 1871	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	26,120 cy Yellow Hard Pan
Dec 1871 – June 1872	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	20,305 cy
November 1872	Removal of a Large Boulder from Upper Middle Shoal	6 cy Boulder
May 1873 – June 1873	Removal of Wreck of Schooner Delos from Nantasket Roads	Wreck Removal
June 1873 – July 1873	Continue Removal of Kelly's Rock from the Narrows Channel	118 Tons Ledge
April 1874 – July 1876	Continue Improvement Dredging of the 23-Foot Harbor Channel at Upper Middle Ground	90,860 cy
Aug 1874 – Sept 1874	Removal of the Ledge Southwest of Bug Light from the Narrows Approach	16 cy Ledge
Sept 1874 – June 1875	Removal of State Rock and Palmyra Rock from the Lower Middle Ground Bar to –23 Feet	62 cy Rock
Oct 1874 – Sept 1875	Continue Improvement Dredging of the 23-Foot Narrows Channel at Lovells Island and Great Brewster Spit	60,284 cy
Oct 1874 – Dec 1875	Continue Improvement Dredging of the 23-Foot Harbor Channel at the Upper Middle Ground	42,844 cy
May 1875 – Sept 1875	Continue Removal of Kelly's Rock from the 23-Foot Narrows Channel	80 cy Ledge
September 1875	Removal of another Ledge from the Narrows East of Georges Island	16 cy Ledge
May 1876 – Nov 1876	Continue Improvement Dredging of the 23-Foot Harbor Channel at the Upper Middle Ground	88,150 cy
FY 1876 – Sept 1876	Removal of Nash's Rock from the Narrows Channel to –21 Feet	200 cy Ledge Estimated
June 1876 – Nov 1876	Removal of Ledge from Dredged Area in Narrows at Great Brewster Spit	96 cy Ledge
July 1876 – August 1876	Removal of Ledge from Dredged Area in 23-Foot Upper Middle Bar Channel	37 cy Ledge
June 1877 – Sept 1877	Continue Improvement Dredging of the 23-Foot Narrows Channel at Lovells Island	29,134 cy

[39] United States and Massachusetts Port Authority. 2008. Boston Harbor Navigation Improvement Project: Draft feasibility report and supplemental environmental impact statement. U.S. Army Corps of Engineers, Concord, Massachusetts..

June 1877 – Dec 1877	Partial Removal of Additional Ledges from the Narrows Channel near Kelly's Rock	76 cy Ledge
April 1878 – Aug 1878	Removal of Ledges from the Upper Middle Shoal to –23 Feet	82 cy Ledge
Sept 1877 – Nov 1877	Continue Removal of Nash's Rock from the Narrows Channel	320 Tons Boulders
Aug 1878 – March 1880	Improvement Dredging to Remove the Man-of-War Shoal at the Mystic-Charles Confluence to –23 Feet	85,917 cy
Aug 1878 – June 1879	Partial Removal of Additional Ledges from the Narrows Channel near Kelly's Rock	132 cy Ledge
August 1878	Complete the Removal of Nash's Rock from the Narrows Channel to –21 Feet	45 Tons Ledge and Boulders
July 1879 – Nov 1879	Complete Removal of Kelly's Rock from the Narrows to –23 Feet MLW	146 cy Ledge
Sept 1879 – June 1880	Improvement Dredging of Anchorage Shoal to Widen the 23-Foot Upper Harbor to 1,100 Feet	21,054 cy
June 1880 – Aug 1880	Improvement Dredging to Widen the 23-Foot Lower Middle Channel to 600 Feet	5,007 cy Hardpan
Oct 1879 – March 1880	Begin Improvement Dredging to Remove the Shoal at the Mouth of the Mystic River Opposite the Navy Yard to -23 Feet MLW	47,953 cy
Nov 1880 – June 1881	Continue Improvement Dredging of the Shoal at the Mouth of the Mystic River -23 Feet	48,343 cy
Aug 1880 – April 1883	Continue Improvement Dredging of Anchorage Shoal to Widen the 23-Foot Upper Harbor	155,243 cy
Dec 1881 – June 1883	Continue Improvement Dredging of the Shoal at the Mouth of the Mystic River -23 Feet	82,020 cy
Sept 1883 – Oct 1883	Improvement Dredging of the 12-Foot Nixes Mate Channel	19,900 cy
Sept 1883 – Nov 1883	Improvement Dredging to Remove a Spur Shoal off Castle Island to Widen the 23-Foot Channel	31,950 cy Plus 20 Tons Ledge
Oct 1887 – June 1888	Continue Improvement Dredging of the 23-Foot Channel at the Lower Middle Shoal	65,576 cy
Oct 1887 – June 1888	Continue Improvement Dredging of the 23-Foot Channel at the Narrows	3,430 cy
July 1888 – May 1889	Removal of Ledge from the 23-Foot Channel at the Lower Middle Shoal to Complete the 1,000 Foot Width	375 cy Rock
Dec 1888 – May 1889	Continue Improvement Dredging of the 23-Foot Channel at the Upper and Lower Middle Shoal	146,556 cy
August 1889	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	5,942 cy
April 1890 – June 1890	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	111 cy Ledge
June 1891 – July 1891	Continue Improvement Dredging to Widen the 23-Foot Channel in the Narrows at Great Brewster Spit to 625 Feet	28,510 cy
Sept 1891 – Jan 1892	Improvement Dredging of the 15-Foot Nubble (Nixes Mate) Channel	7,674 cy
FY 1892	Improvement Dredging of the 18-Foot and 15-Foot Jeffries Point Channel	139,962 cy
April 1892 – Nov 1892	Continue Improvement Dredging of the 23-Foot Channel at the Upper Middle Shoal	211,992 cy
Dec 1892 – April 1895	Begin Improvement Dredging of the 27-Foot Narrows Channel along Lovells Island	580,048 cy Plus 31 cy Boulders & 9,000 cy Ledge
April 1895 – Sept 1895	Continue Improvement Dredging of the 27-Foot Narrows Channel along Lovells Island to a Minimum Width of 550 Feet	149,479 cy
May 1895 – Nov 1897	Begin Improvement of the 27-Foot Channel at the Lower Middle Ground and Elsewhere in the Main Channel by Removal of	6,721 cy Ledge

	Ledge	
Oct 1897 – June 1899	Continue Improvement Dredging to Widen the 27-Foot Narrows Channel to 1,000 Feet	1,150,703 cy
July 1899 – Dec 1902	Improvement Dredging of the 27-Foot Channel from President Roads to Boston through the Upper and Lower Middles and Shoals	1,830,653 cy Plus 159 cy Boulders & 3,505 cy Rock
July 1900 – May 1904	Begin Improvement Dredging of the 30-Foot	888,957 cy Plus
Oct 1902 – May 1906	Continue Ledge Removal from the 27-Foot Narrows Channel	19,008 cy Ledge (in-place)
December 1902	Removal of a Ledge from President Roads Channel to –30 Feet MLW	21 cy Ledge
April 1903 – Jan 1912	Begin Improvement Dredging of the 35-Foot Main Ship Channel at 600 Feet Wide	7,478,102 cy Plus 19 cy Boulders
Sept 1903 – Nov 1903	Maintenance Dredging of the 27-Foot Narrows Channel	23,147 cy
Sept 1903 – Nov 1910	Improvement Dredging of the 35-Foot Broad Sound North Entrance Channel at 600 Feet	2,101,912 cy Plus 116 cy Boulders
Nov 1903 – Fall 1904	Continue Ledge Removal from the 27-Foot Narrows Channel	223 cy Ledge (in-place)
FY 1904 – March 1906	Continue Ledge Removal from the 27-Foot Lower Main Harbor Channel	2,066 cy Ledge (in-place)
Aug 1904 – Oct 1905	Continue and Complete Improvement Dredging and Ledge Removal from the 30-Foot Broad Sound South Entrance Channel	76,427 cy Plus 156 cy Ledge and 15 cy Boulders
August 1904 – Dec 1904	Maintenance Dredging of the 27-Foot Narrows Channel by Contract	26,600 cy
Jan 1905 – April 1905	Maintenance Dredging of the 27-Foot Narrows Channel by US Hydraulic Dredge Gillespie	46,841 cy
July 1905 – Aug 1908	Removal of Ledge from the 35-Foot Channel off Governors Island (also Completes the 27-Foot Upper Main Ship Channel)	1,338 cy Ledge above –27 Feet & 15,217 cy below 27 Feet (in-place)
Nov 1906 – Jan 1907	Complete Ledge Removal from the 27-Foot Lower Main Ship (Narrows) Channel	25 cy Ledge
Aug 1907 – Aug 1909	Removal of Ledge from the 35-Foot Main Ship Channel in the Lower Harbor	15,200 cy Ledge (in-place)
Annual Report for 1907, Appendix B-9, Page 907	The Lower Reaches of the Mystic River below the Chelsea Bridge were Incorporated into the Project for the Main Ship Channel of Boston Harbor as Authorized by the River & Harbor Act of 2 March 1907	Modification – No Further Mystic River Work below Chelsea Bridge
Nov 1907 – June 1908	Continued Improvement Dredging of the 25-Foot Channel in the Mystic River Mouth below the Chelsea Bridge. Further Work in the Reach Accomplished under the 35-Foot Project	38,732 cy
Oct 1907 – Jan 1912	Improvement Dredging to Widen the 35-Foot Channel to its 1,500 and 1,200 Foot Widths (Divisions 5, 6, 7 & 8 - MSC, and 5a, 6a, 7a & 8a - BSNC)	MSC: 9,169,600 cy Plus 5 cy Boulders BSNEC: 2,625,190 cy Plus 234 cy Boulders
FY 1911	Removal of 20 Small Ledge Pinnacles from the Upper 35-Foot Main Ship Channel	Unknown
July 1911 - Aug 1911	Shoal in the Old Dump Ground in Broad Sound was Removed to a Depth of -45 Feet MLW	140,000 cy
July 1911 – March 1915	Continue Removal of Ledge from the 35-Foot Main Ship Channel in the Lower Harbor and Inner End of the 35-Foot Broad Sound North Entrance Channel	110,601 cy Ledge
April 1913 – June 1913	Maintenance Dredging of the 35-Foot Broad Sound North	189,744 cy

	Entrance Channel by U.S. Hopper Dredge Atlantic	
July 1913 – Dec 1913	Maintenance Dredging of the 30-Foot Broad Sound South Entrance Channel and 35-Foot Broad Sound North Entrance Channel by U.S. Hopper Dredge Atlantic	358,839 cy
March 1915	Removal of Ledge from the 35-Foot Inner Confluence	800 cy Ledge
May 1915 – July 1917	Maintenance Dredging of the 35-Foot Main Ship Channel	901,353 cy
May 1915 – July 1917	Maintenance Dredging of the 35-Foot Broad Sound North Entrance Channel	141,162 cy
May 1916 – June 1916	Maintenance Dredging of the 15-Foot Nubble or Nixes Mate Channel	19,494 cy
June 1926 – Oct 1929	Begin Improvement Dredging of the 40-Foot Broad Sound North Entrance Channel Lane	826,773 cy
July 1930 – Aug 1930	Continue and Complete Improvement Dredging of the 40-Foot Broad Sound North Entrance Channel Lane	21,832 cy Plus 39 cy Boulders
March 1933 – Jan 1934	Maintenance Dredging of the 35-Foot Main Ship Channel	714,546 cy
Oct 1933 – April 1935	Improvement Dredging of the 40-Foot President Roads Anchorage	2,853,342 cy Plus 5 cy Boulders
March 1936 – Jan 1937	Begin Improvement Dredging of the 40-Foot Main Ship Channel as Far as South Boston Pier #6 (Commonwealth Pier)	1,714,698 cy
Oct 1936 – March 1937	Improvement Dredging of the Northwest Corner of the 40-Foot President Roads Anchorage	249,529 cy
Feb 1938 – Aug 1939	Improvement - Removal of Ledge from the Lower 40-Foot Main Ship Channel up to South Boston	61,778 cy Plus 44,171 cy Ledge
Dec 1939 – Jan 1940	Maintenance Dredging of the 40-Foot Main Ship Channel by U.S. Hopper Dredge Marshall	52,533 cy
May 1946 – June 1946	Improvement Dredging of the 30-Foot Channel over the Sewer Siphon below Chelsea Street Br.	7,359 cy
March 1951 – Oct 1951	Improvement Dredging of the 40-Foot Main Ship Channel Extension up to Mystic Pier #1 in Charlestown	913,073 cy
July 1951 – Oct 1951	Maintenance Dredging of the 35-Foot Sections of the Main Ship Channel	153,020 cy
Nov 1956 – Oct 1958	Improvement Dredging to Extend the 40-Foot President Roads Anchorage North and West and Dredging the 35-Foot Middle Ground Anchorage to the West	4,382,016 cy
Oct 1959 – May 1960	Continue Improvement Dredging to Extend the 40-Foot President Roads Anchorage North and West and Dredging the 35-Foot Middle Ground Anchorage	682,400 cy
Feb 1963 – Aug 1963	Maintenance Dredging of the 40-Foot President Roads Anchorage	750,051 cy
May 1965 – Nov 1965	Maintenance Dredging of the 40-Foot Main Ship Channel Lanes	867,000 cy
March 1967 – Sept 1967	Maintenance Dredging of the 35-Foot Main Ship Channel Lanes	801,850 cy
June 1968 – FY 1969	Maintenance Dredging of the 40-Foot Broad Sound North Entrance Channel and the 40-Foot Main Ship Channel	300,043 cy Plus 7,250 cy Hard Material
August 1973	Removal of an Isolated Rock Pinnacle from the 40-Foot Main Ship Channel	Unknown (“Several Hundred cy”)
June 1982 – March 1983	Maintenance Dredging of the 40-Foot President Roads Anchorage	441,000 cy
Oct 1998 – Jan 1999 Maintenance May 1999 – Feb 2000 Improvement	Maintenance and Improvement Dredging and Ledge Removal for the 40-Foot Reserved Channel and Turning Basin Deepening with Maintenance Dredging to Overlying 35-Foot Depth and Limited Maintenance Dredging of Adjacent Areas of the Main Ship Channel	Maintenance: 213,680 cy Improvement: 237,978 cy Rock: 15,670 cy

June 2001 – Sept 2001	Ledge Removal for 38-Foot Chelsea Creek Deepening at 3 Areas in the Upper Channel and Turning Basin	6,700 cy Plus 6,000 cy Rock
August 2004 – June 2005	Maintenance Dredging of the 40-Foot President Roads Anchorage Area to –41 Feet	989,000 cy 1,166,447 cy Pay
September 2004	Removal of Three Large Boulders from the Broad Sound North Entrance Channel	Quantity Unknown
May 2005	Removal of a Sunken Steel Barge from the Broad Sound North Entrance Channel	Wreck Removal
Oct 2007 – Dec 2007	Removal of Ledge Pinnacles from Three Areas: Main Ship Channel at the 35/40-Foot Lanes Slope Transition between Castle and Spectacle Islands, Broad Sound North Entrance Channel 40-Foot Lane, and Western Side of the 40-Foot President Roads Anchorage	MSC: 200 cy PRA: 2,400 cy BSNEC: Not yet completed

Appendix C. Cape Lookout National Seashore.

Figure 12. Cape Lookout Lighthouse and Keeper's Quarters, Core Banks, NC (Photo by Andy Coburn, Western Carolina University).

Summary of Findings

Fifteen coastal engineering projects in or adjacent to and potentially impacting Cape Lookout National Seashore (CALO) were identified and mapped (Figures 12 and 13). Of these, eight are erosion control structures, five are navigation dredging projects and two are beach nourishment projects.

Erosion Control Structures

A total of eight erosion control structures were identified in, or adjacent to, Cape Lookout National Seashore. Only five, however, are currently having an impact on sediment transport. These include: 1) Jetty at Cape Lookout Bight, 2) Two groins on Shackleford Banks, 3) Jetty at Fort Macon State Park and 4) Bulkhead at the CALO park headquarters on Harkers Island (Table 3). This section provides an overview of these structures, as well as a summary of impacts.

Figure 13. Location of Coastal Engineering Projects in/adjacent to CALO.

Table 3. Summary of erosion control structures (numbers indicate location on Figure 13).

Type		Location	Material
1	Bulkhead	Harkers Island	Wood
2	Groin	Shackleford Banks	Rock
3	Groin	Shackleford Banks	Rock
4	Jetty	Fort Macon State Park	Rock
5	Jetty	Cape Lookout Bight	Rock
6	Breakwater	Shackleford Banks	Rock
7	Groin	Fort Macon State Park	Rock
8	Groin	Fort Macon State Park	Concrete/rock

Jetty at Cape Lookout Bight (5)

South Core Banks was initially connected to Shackleford Banks. Core Banks extended southwest beyond Shackelford Banks to form Cape Lookout. A major sand spit extended northwest to form a protected embayment called the Cape Lookout Bight. Beginning in 1912, there was an effort to turn this into a harbor of refuge for ocean-going ships in time of storms and, at the same time, to connect Cape Lookout with the railroad at Beaufort.[40]

Sand fencing was constructed in 1913 and construction of a 7,050-ft long rock breakwater to protect the harbor began in 1914. The landward 4,800 feet of the rubble-mound breakwater, authorized by Congress in 1912, was completed in 1917 before construction was terminated and the project discontinued due to the start of World War I (Figure 14).[41]

The jetty caused a major accretion of sand that elongated the spit towards Shackleford Banks and significantly increased the areal extent of Cape Lookout Bight.[42]

Specifications for the breakwater called for quarry-run stone graded so that at least 10% was greater than 10 tons, at least 40% was greater than 7 tons, and at least 70% greater than 2 tons. The breakwater was constructed on a 2-foot-thick stone mattress.

[40] Stick, D., 1958. The Outer Banks of North Carolina, 1584–1958. University of North Carolina Press, Chapel Hill, North Carolina.
[41] Riggs, S. R., and D.v.d.P. Ames. 2007. Effect of storms on barrier island dynamics, Core Banks, Cape Lookout National Seashore, North Carolina, 1960-2001. Scientific Investigations Report, 2006-5309. U.S. Geological Survey, Reston, Virginia.
[42] Ibid.

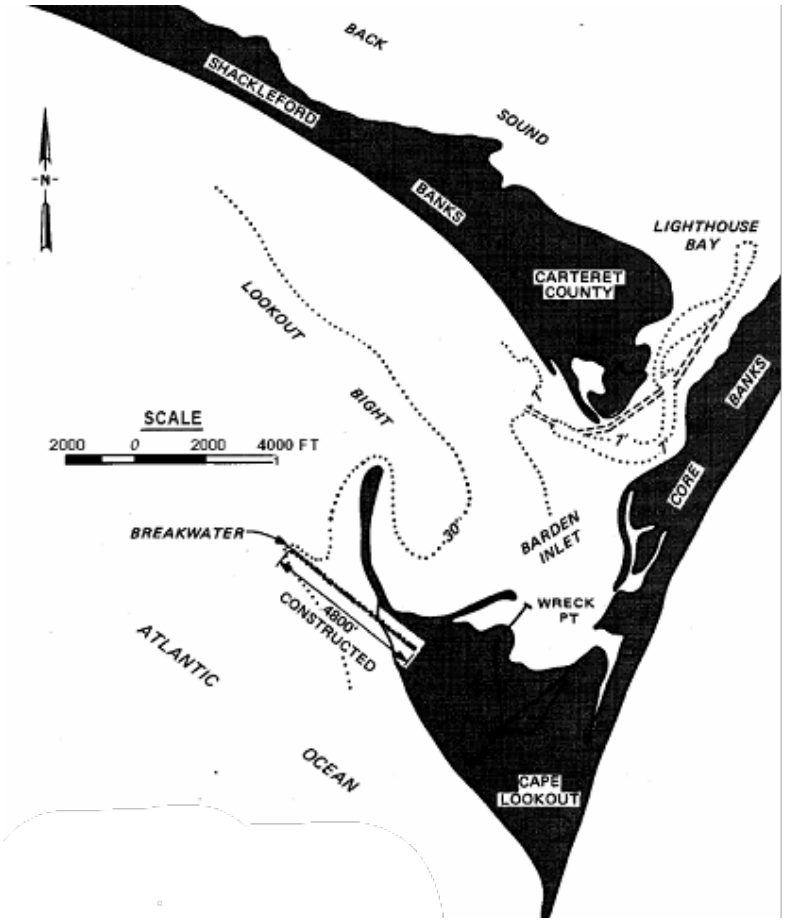

Figure 14. Jetty at Cape Lookout Bight (U.S. Army Corps of Engineers, Case Histories of Corps Breakwater and Jetty Structures, 1988).

The design section had a 20-foot crest width at +6.5 feet mlw with 1V:1H side slopes. About 651,400 tons of stone were placed at a total cost of $1,363,800 ($28,274,967 in 2007 dollars). Since its completion, no maintenance or repairs have been made, and no plans exist to restore the breakwater to its original condition. The breakwater was deauthorized by Congress on November 1, 1981 and no additional funds may be obligated without congressional reauthorization.[43]

Shackleford Banks (2, 3, 6)

Three erosion control structures were identified on Shackleford Banks: a now-landlocked jetty (originally called a breakwater) built at Shackleford Point in 1882 (labeled 1 in Figure 15) and two groins (labeled 2 and 3 in Figures 15 and 16) located on the sound side of the island built prior to 1882.

[43] Sargent, F. E. 1988. Case histories of Corps breakwater and jetty structures report 2, South Atlantic Division, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

The breakwater and groin 3 were built by the USACE in an effort to stabilize Shackleford Point and improve navigation through Beaufort Inlet. The history of groin 2 is unknown. [44]

Based on aerial imagery and field observations, the two groins continue to interrupt the net westerly longshore transport of sediment along the backside of the island. The result is a small fillet on the eastern, or updrift, side of each groin, and a sediment deficit of unknown quantity on the western, or downdrift, side.

When originally constructed in 1882, the breakwater/jetty extended several hundred feet into Beaufort Inlet. Over time, as the western end of Shackleford Banks accreted, the breakwater eventually became landlocked (Figure 17).

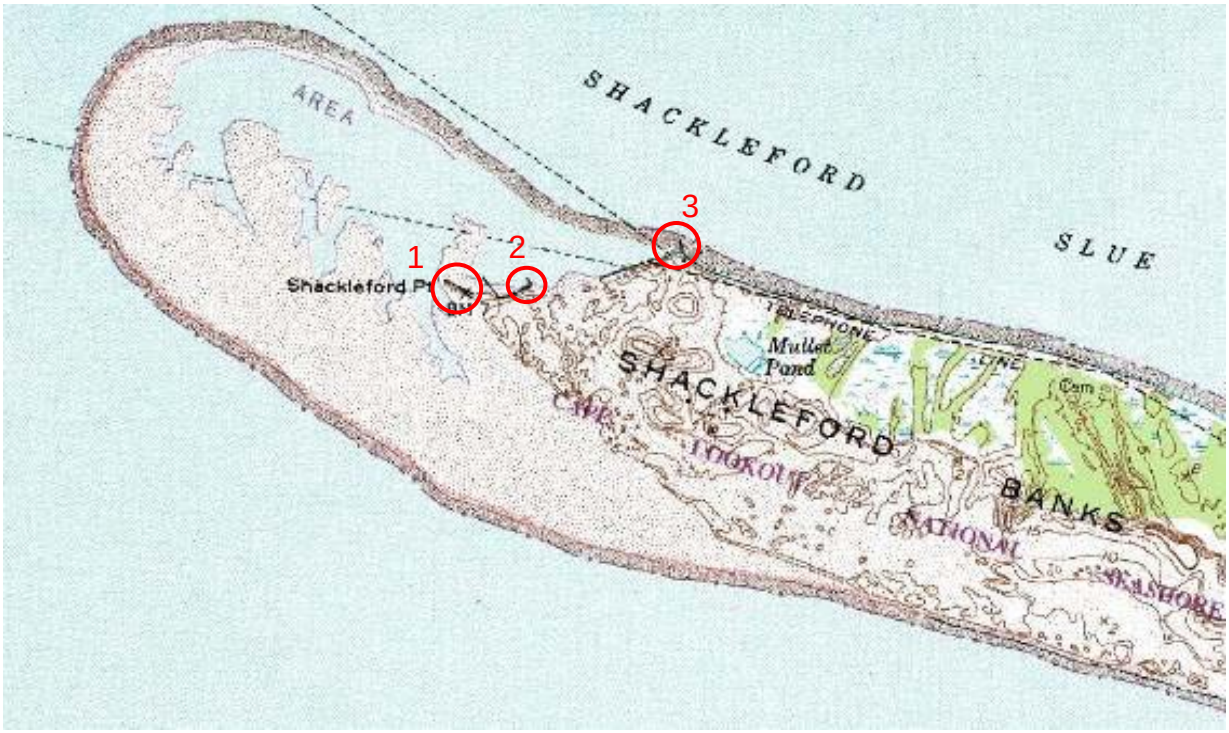

Figure 15. Erosion control structures on Shackleford Banks.

Although this structure is not currently impacting sediment transport in Cape Lookout National Seashore, it has the potential to do so if exposed.

[44] U.S. Army Corps of Engineers. 1883. Beaufort Harbor: Improvement of Shackleford Point. Map.

Figure 16. Shackleford Banks Groins (June 2008).

Figure 17. Landlocked breakwater.

Fort Macon State Park/Bogue Banks (4, 7, 8)

Two erosion control structures are located at the eastern terminus of Bogue Banks at Fort Macon State Park: 1) A 330-foot long groin, originally constructed in 1889/90, that is now entirely landlocked and 2) a jetty, constructed in 1962 and last repaired in 1972, which extends into the Atlantic Ocean at Beaufort Inlet (Figure 18).

The jetty provides some impoundment of the easterly-directed sediment transport; however, significant transport occurs over, through, and around the structure, resulting in pervasive deposition of sand along the west bank of the navigation channel. The groin is having no discernable impact on sediment transport.[45]

Figure 18. Jetty at Fort Macon State Park (image taken June 2008).

Harkers Island (1)

The NPS Cape Lookout National Seashore Park Headquarters is located at the southeastern end of Harkers Island, Carteret County, North Carolina at an area identified as Shell Point. The shoreline of the Park Headquarters property has been experiencing erosion for many years,

[45] Olsen Associates. 2006. Regional sand transport study: Morehead City Harbor Federal Navigation Project, Jacksonville, Florida.

primarily due to the effects of wave action with occasional inundation at high tide and, to a lesser extent, wake from boat traffic. As a result, the shoreline has been reinforced extensively with bulkheads (Figure 19).

The southeastern shoreline of the NPS/CALO Park Headquarters, including the boat basin and adjacent areas, is currently protected with timber bulkheads, typically four to six feet above mean sea level. The northern 330 feet of bulkhead is in fair condition, with washouts behind the bulkhead where material has washed through holes in the backup sheeting at tie-rod locations. A 680-foot portion of the bulkhead along the north side of the boat basin entrance, as well as the portion surrounding the boat basin itself, is also in poor condition.

The rest of the bulkhead, approximately 410 feet, along the south side of the basin entrance and along the shoreline to the south end of bulkhead construction, as well as the boat ramp, is in poor condition and showing signs of deterioration and failure.

Extensive renovations are currently underway that include repair and replacement of existing bulkheads. Repair includes excavation behind portions of the existing bulkhead to inspect and repair any holes, placement of a stone filter layer and filter fabric and construction of concrete splash protection along the top of the wall. This also involves replacement of portions of existing bulkheads which are failing, as well as other selected portions not failing, but where the new

Figure 19. Cape Lookout National Seashore Park Headquarters

system is desired. The replacement structure is a vinyl sheet pile system placed just outside the existing bulkheads.

The existing boat ramp, which is in disrepair, is also being replaced with a new concrete ramp about 20 feet wide. The adjacent bulkheads are being extended since the new ramp would be narrower than the existing one.

Construction of a new stone breakwater extension at the outer opening of the basin entrance will allow the entrance channel to be widened by removing the high-ground peninsula adjacent to the channel. The breakwater extension begins at the south corner of the boat basin entrance, and extends 50 feet across open water toward the opposite corner of the entrance. It will extend to a height of 3 feet above ordinary high water, and have a footprint that covers approximately 1,800 square feet of bottom in open waters.[46]

In addition to repair/replacement of the existing bulkhead, construction of an offshore stone sill of trapezoidal cross-section will also take place along the shoreline on either end of the bulkhead (Reaches 1 and 3 in Figure 20).[47]

Beach Nourishment

Two beach nourishment projects comprising a total of ten beach nourishment episodes were identified in, or within 2 miles of, Cape Lookout National Seashore (Table 4). One project (consisting of nine beach nourishment episodes) is located on Fort Macon State Park on Bogue Banks (outside the park boundary). The other project, consisting of a single nourishment episode, is located on Core Banks.

Table 4. Summary of beach nourishment projects
(Reference indicates location on Figure 13 on Page 39).

Reference	Location	Status	Episodes
9	Cape Lookout	Completed	1
10	Fort Macon	Ongoing	9

Fort Macon/Bogue Banks (10)

The USACE Dredge Disposal to Eastern Bogue Banks is part of the maintenance program implemented for the Morehead City Federal Navigation Project (Figure 21).

[46] National Park Service. 2004. Environmental assessment for National Park Service, Cape Lookout National Seashore, Harkers Island Shore Protection Project, Carteret County, North Carolina.
[47] Ibid.

Figure 20. NPS Reaches, Harkers Island.

The aerial scope of dredging operations at the harbor is divided into five regions known as Range A, the Cutoff, Range B, Range C, and the turning basin. Historically, the Cutoff and Range A (collectively known as the ***outer harbor***) have been maintained by hopper dredging that collects sediment from the base of the channel and travels to one of two offshore areas located one to approximately two and a half miles offshore to dispose of the dredged material (this is more fully discussed in the next section on Dredging).

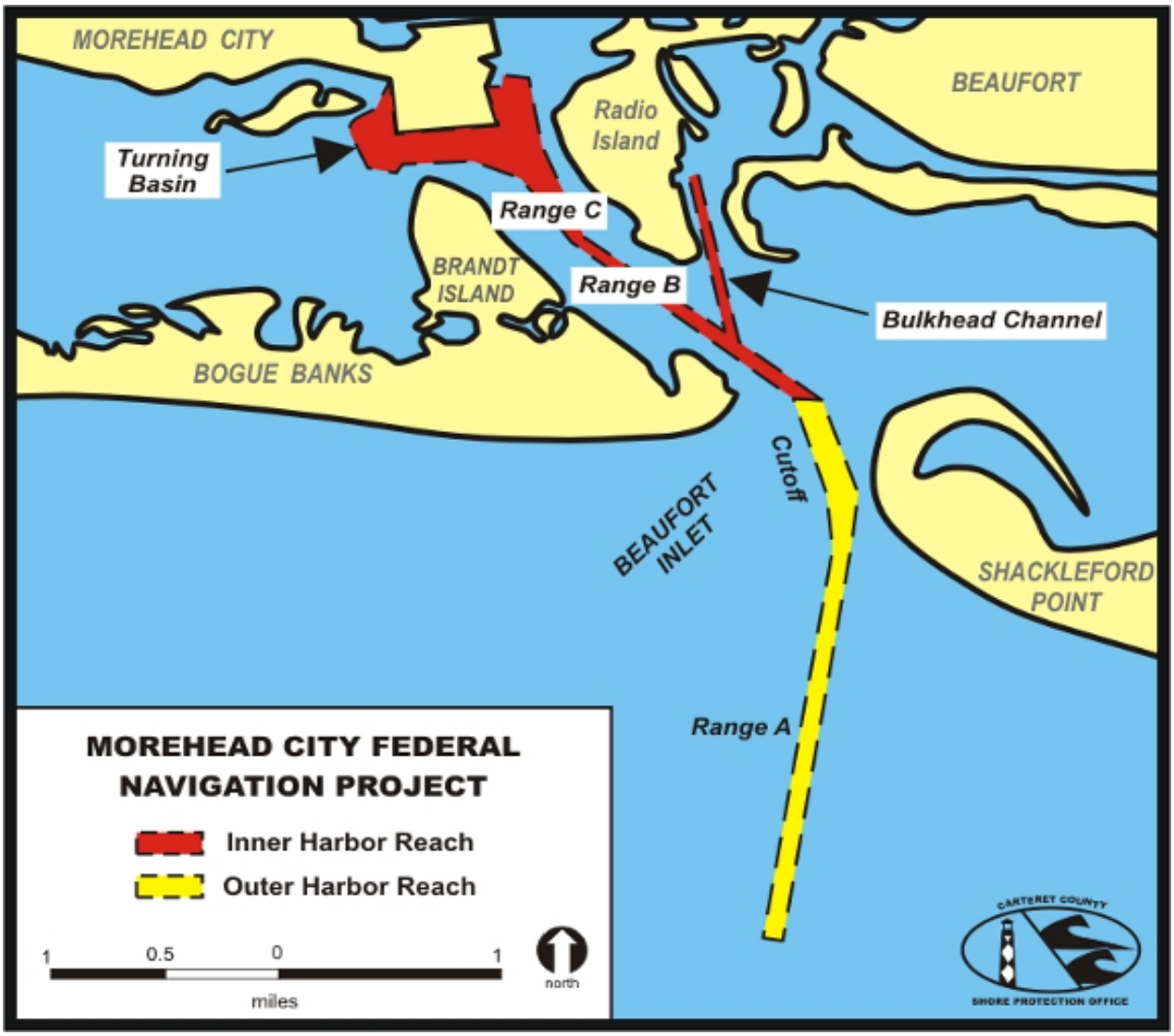

Figure 21. Morehead City Federal Navigation Project.

Cape Lookout (9)

In spring 2006, the NPS completed a beach nourishment project on Cape Lookout at a cost of $925,498 ($975,197 in 2007 dollars). The project included the placement of 60,000 cubic yards of sand along 2,600 linear feet of estuarine shoreline subdivided into two zones: a northern and southern fill area (Figure 22).[48]

[48] United States. 2005. Environmental assessment: Cape Lookout National Seashore protection of lighthouse and associated historic structures. National Park Service, Harkers Island, North Carolina.

Figure 22. Location of CALO beach nourishment project.

The northern fill area was approximately 1,000 linear feet long with an estimated fill width of 50 feet, contoured at a grade of +3.5 feet relative to sea level (beach elevation). The southern fill area was approximately 1,600 linear feet long with an estimated fill width of 100 feet, also contoured at the +3.5-foot elevation. The southern fill area also included a berm (or quasi-dune feature) that extended 1,250 linear feet, at a +7.5-foot elevation, with a top width of 15 feet. The break between the northern and southern fill areas was the pier commonly used by ferry services and National Park vessels.

Based on past erosion rates, the project was designed to provide seven-to-ten years of protection to the lighthouse and associated structures. Although the USACE estimate of seven-to-ten years protection is based on historic erosion rates, the actual life of this project - and all beach nourishment projects - cannot be predicted with any degree of accuracy due to the unpredictable nature of future storm activity.[49]

An aerial reconnaissance completed in June 2007 (approximately one year post-project) indicates that a significant amount of emplaced sediment remains within the project boundary (no quantitative analysis was attempted).

Dredging

Maintenance dredging for navigation has had, and continues to have, a significant impact on sediment transport to/from/along Cape Lookout National Seashore. Five dredging projects encompassing at least 184 episodes have been identified within two miles of the park boundary (Table 5).

Table 5. Summary of dredging projects (reference indicates location on Figure 13 on Page 39).

Reference	Location	Status	Episodes
11	Beaufort Inlet	Ongoing	96
12	Barden Inlet	Ongoing	69
13	Ocracoke Inlet	Ongoing	5
14	New Drum Inlet	Complete	10
17	Drum Inlet	Complete	4

Beaufort Inlet/Morehead City Harbor Federal Navigation Project (11)

The 97-year-old Morehead City Harbor Federal Navigation Project, which includes construction and maintenance of a channel and basins for navigation through Beaufort Inlet, has impacted sediment transport to/from Cape Lookout National Seashore (Figure 18).

This inlet represents the downdrift end of the park, and is included here as a first approximation (low-end estimate) of how much sand moves through CALO. Although the inlet technically is not within the park boundary, manipulation of Beaufort Inlet lends insight into the volumes of material moving through the area.

[49] United States. 2005. Environmental assessment: Cape Lookout National Seashore protection of lighthouse and associated historic structures. National Park Service, Harkers Island, North Carolina.

It has been concluded that there was net average annual sand bypassing of about 94,000 cubic yards/yr from east to west across Beaufort Inlet between 1900 and 1933.[50] During this period, the interior flood tidal delta system was mostly stable to slightly accretional, the ebb tidal delta accumulated sand at a net rate of about +208,000 cubic yards/yr and the *overall* inlet complex exhibited a net average annual gain of about +206,000 cubic yards/yr.

The sediment budget concludes a minor net residual gain of +24,000 cy/yr along central/west Atlantic Beach (between 14,000 and 24,000 ft west of the inlet). This volume resulted in modest accretion along this area and/or ultimately supplemented accelerating westerly drift rates further to the west, which contributed to the easterly growth of Bogue Banks into the inlet.

From 1933 through 2004, however, the overall inlet complex was erosional at an average-annual rate of -303,000 cubic yards/yr. No bypassing occurred, and the rate of littoral supply from the tidal deltas to the shorelines did not meet (balance) the potential littoral requirement.[51]

Since the commencement of dredging in 1911, approximately 72.1 million cubic yards of sediment have been dredged from the Morehead City Harbor Project. Of this total, at least 55.8 million cubic yards were dredged from the outer channel (Range A and Cut-Off), and 16.3 million cubic yards were dredged from the inner channel (Range B, Range C and Turning Basin). As discussed in the previous section, material removed from the inner channel is periodically deposited along the beaches of Bogue Banks.

Over a 93-year period since navigation improvements began (1911-2004), the average annual maintenance dredging volume has been about 590,000 cubic yards/yr. Prior to 1936, maintenance dredging totaled less than 91,000 cubic yards/yr. After the channel location was maintained in a fixed position in 1936 and design depth increased from 30 ft to 35 ft in 1961, total maintenance requirements increased from about 631,000 cubic yards/yr (1936-1961) to 770,000 cubic yards/yr (1962-1978). After the channel was deepened to 40 ft in 1978, maintenance requirements remained mostly unchanged due to a realignment of the channel to the east. After the channel was deepened to its current 45 ft in 1994, the rate of maintenance dredging has remained about 1,170,000 cubic yards/yr (1995-2004).[52]

Until 1997, all material dredged from the outer channel was disposed of offshore. In the early years, disposal likely also included ebb tidal delta areas nearer shore. Comparison of early (1900) and recent (1998-2004) bathymetric surveys suggests that between 26.6 million cubic yards and 33.5 million cubic yards of the outer-channel dredging can be accounted for as offshore disposal beyond the ebb tidal delta.[53]

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[50] Olsen Associates, Inc. 2006. Regional sand transport study: Morehead City Harbor Federal Navigation Project, Jacksonville, Florida.
[51] Ibid.
[52] Ibid.
[53] Ibid.

Since 1997, the USACE has required that all sediment dredged from the outer channel be placed in a nearshore disposal area, subject to allowable sea conditions and contractor discretion.

Impacts

A USACE Section 111 study states that between the commencement of the navigation project's principal improvements in 1936 and the present, the ebb tidal delta volume has decreased in volume, deepened, increased in area and elongated seaward. The USACE describes the seaward movement of the ebb tidal delta as a result of the channel deepening and "yearly repetition of maintenance dredging along a fixed alignment." The USACE describes the latter as having "greatly reduced the ability of Beaufort Inlet to naturally bypass littoral sediment from Bogue Banks to Shackleford Banks and vice versa" and to likewise allow Shackleford Point to "store a large volume of littoral sediment that would have otherwise remained in the active littoral zone."[54]

Prior to principal navigation improvements, from 1876-1933, Bogue Banks was advancing eastward *toward* the inlet, and Shackleford Banks was retreating eastward *away* from the inlet. After 1936, the shoreline processes reversed. Bogue Banks retreated rapidly back toward its 1876 location, and Shackleford Banks advanced westward, approaching its current location by 1974. Over the next 30 years, from 1974 to 2004, Shackleford Banks consolidated its westerly growth and advanced into the eastern bank of the channel at the inlet throat.[55]

The effects of navigation dredging projects upon the waves and sediment transport patterns, from about 1900 to the present, have mostly been limited to within about four miles west of Beaufort Inlet (central Atlantic Beach) and to within about the first three miles of Shackleford Banks.

Barden Inlet (12)

Barden Inlet opened in 1933 as a small and ephemeral inlet and was originally called "Cape Inlet" and "The Drain".[56] Barden Inlet separated Cape Lookout from Shackleford Banks.

In 1937, the inlet was authorized by Congress to be dredged to a depth of 7 ft, and has been dredged ever since by the USACE using a sidecast dredge that deposits sediment alongside of the existing channel. The federal channel in Barden Inlet is not fixed, like the channel in Beaufort Inlet, but maintained wherever it is at the time of dredging.

The last major channel realignment in Barden Inlet occurred in 1979 when the USACE used a sidecast and hopper dredge to move the channel several hundred feet west, adjacent to the

[54] Olsen Associates, Inc. 2006. Regional sand transport study: Morehead City Harbor Federal Navigation Project, Jacksonville, Florida.
[55] Ibid.
[56] Stick, D., 1958. The Outer Banks of North Carolina, 1584–1958. University of North Carolina Press, Chapel Hill, North Carolina.

shoreline of Shackleford Banks.[57] This move, along with subsequent yearly maintenance dredging of the channel, has had a minimal impact on sediment transport along the eastern terminus of Shackleford Banks.[58]

Barden Inlet also served as a source of sediment for the 2006 beach nourishment project on Cape Lookout.

Drum Inlet(s) (14, 17)

Drum Inlet initially opened in about 1899, separating North Core Banks from South Core Banks, and closed naturally in 1910. Drum Inlet was re-opened by a major hurricane that came ashore at Cape Lookout on September 16, 1933 and traveled just west of Core Banks into Pamlico Sound. As the storm passed, the northwest to southeast winds reversed the storm surge, which swept eastward and overwashed Core Banks, opening Drum Inlet in the process.[59]

The inlet was relatively constant in width and fixed in place from the time it opened until 1955. By 1956, the inlet had narrowed and shallowed, and by 1957 had begun a rapid southwestward migration. Prior to 1957, the channel thalweg depth (measured along a line drawn along the axis of the adjacent islands) averaged 14.5 ft below mlw (based on nine data points) and ranged from 10.5 to 22.4 ft below mlw. By 1957, the minimum depth was listed as less than 1.5 ft. Thus, the cross-sectional area of Drum Inlet was more than an order of magnitude smaller than Ocracoke Inlet with about one-third the channel depth.[60]

In 1938, Congress authorized the USACE to dredge and maintain Drum Inlet with a 200-foot wide and 12-foot deep channel.[61] The Inlet was dredged at least four times on an irregular basis from 1939 to 1952 in order to help keep it open.

The inlet closed naturally in January 1971. In response, the USACE artificially opened New Drum Inlet in December 1971 about 2.5 mi to the southwest of the Drum Inlet site. Between 1971 and 1998, New Drum Inlet was dredged at least ten times.[62] Although not quantified, the creation of New Drum Inlet likely had an impact on sediment transport similar to that of Drum Inlet.

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[57] National Park Service. 1983. Cape Lookout National Seashore resources management plan and environmental assessment. National Park Service, Harkers Island, North Carolina.
[58] Orrin H. Pilkey, Personal Correspondence, 2008.
[59] Barnes, J., 2001. North Carolina's hurricane history, 3rd ed. University of North Carolina Press, Chapel Hill, North Carolina.
[60] Riggs, S.R., and D.v.d.P. Ames. 2007. Effect of storms on barrier island dynamics, Core Banks, Cape Lookout National Seashore, North Carolina, 1960-2001. Scientific Investigations Report, 2006-5309. U.S. Geological Survey, Reston, Virginia.
[61] Stick, D., 1958. The Outer Banks of North Carolina, 1584–1958. University of North Carolina Press, Chapel Hill, North Carolina.
[62] U.S. Army Corps of Engineers, Greg Williams, Personal Correspondence, 2008.

In September 1999, Hurricane Dennis reopened Drum Inlet, which is now called Old Drum or New-Old Drum Inlet.[63] In 2005, Hurricane Ophelia opened a third inlet in the vicinity of the other two inlets. Now located approximately a quarter mile south of New Drum Inlet, this inlet - referred to as Ophelia Inlet - is the largest of the three inlets that currently exist on Core Banks.[64]

Considering the ephemeral nature of inlets in this area, the absence of any maintenance dredging since 1998 and the fact that the area has been directly and indirectly impacted by several hurricanes during this time, historic dredging of Drum and New Drum Inlets no longer has any discernable impact on sediment transport along CALO.

Ocracoke Inlet (13)

Efforts to improve the navigation of Ocracoke Inlet date back to the 1820s when the USACE began an extensive dredging project in 1826.[65] This effort was abandoned in 1835 due to rapid shoaling. The channel was re-opened in 1895, but not maintained as a result of economic constraints brought about by the creation of Hatteras Inlet in 1846. A third dredging effort was authorized by Congress in 1954.[66]

Today, the USACE periodically maintains a channel in Ocracoke Inlet using a sidecast dredge. Impacts to CALO resulting from continued maintenance of the Ocracoke Inlet navigation channel are influenced by the frequency and scope of dredging, as well as the distance of the channel from the northern terminus of Portsmouth Island.

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[63] Riggs, S.R., and D.v.d.P. Ames. 2007. Effect of storms on barrier island dynamics, Core Banks, Cape Lookout National Seashore, North Carolina, 1960-2001. Scientific Investigations Report, 2006-5309. U.S. Geological Survey, Reston, Virginia.

[64] Michael Rikard, National Park Service, Personal Communication, 2008.

[65] Stick, D., 1958. The Outer Banks of North Carolina, 1584–1958. University of North Carolina Press, Chapel Hill, North Carolina.

[66] United States, McClure, J. and C.W. Raymond. 1903. Analytical and topical index to the reports of the chief of engineers and officers of the Corps of Engineers, United States Army, 1866-1900. Government Printing Office, Washington, D.C.

Appendix D. Channel Islands National Park.

Figure 23. Water Canyon Beach and Torrey Pines, Santa Rosa Island (Photo by Derek Lohuis, National Park Service).

Summary of Findings

The eight Channel Islands span 160 miles off the coast of southern California, and lie in a region between the mainland coast and the deep ocean called the "Continental Shelf" (Figures 23 and 24). The sea floor here is comprised of canyons, banks (underwater plateaus), escarpments, sea mounts and deep basins (Santa Cruz Basin is deeper than Arizona's Grand Canyon). This topography—shallow and deep, smooth and rugged, sunlit and dark— creates habitats for a diversity of species.

The islands rose from the ocean millions of years ago and were born of plate tectonics, volcanic activity and fluctuating sea levels. These islands on the edge of the continent have never been connected to the mainland. During the ice ages ocean levels dropped as the polar caps expanded.

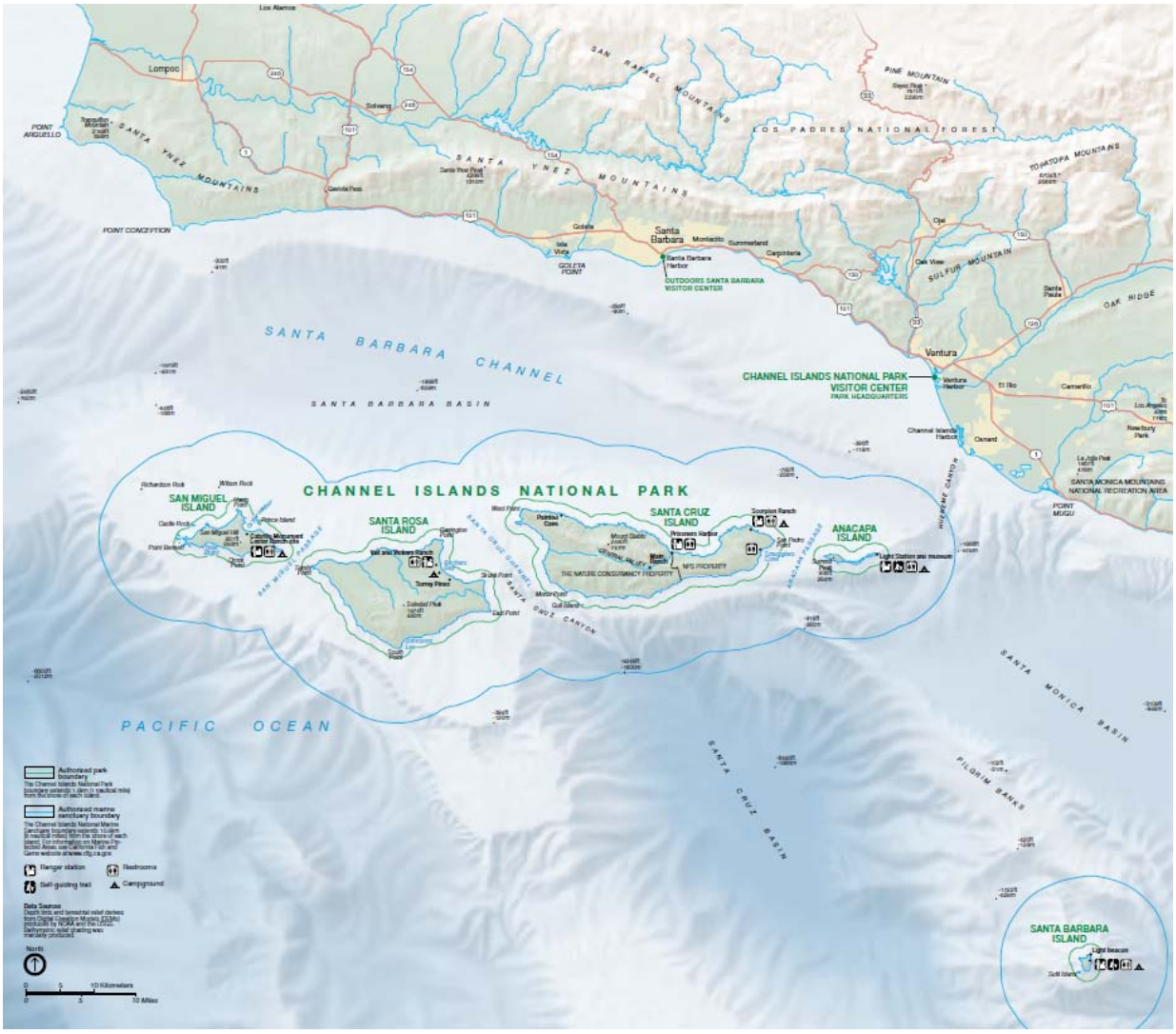

Figure 24. Channel Islands National Park.

What are now San Miguel, Santa Rosa, Santa Cruz, and Anacapa islands were once joined as a single island called “Santarosae”. When the sea level rose again it created the four islands we see today.

San Miguel Island

This westernmost island receives the brunt of the northwesterly winds, fog, and severe weather from the open ocean. The cold, nutrient-rich water surrounding the 9,491-acre, eight-mile-long and four-mile-wide island is home to a diversity of sea life. Submerged rocks surround the 28-mile coastline.

Santa Rosa Island

The second-largest island, with 53,051 acres—15 miles long and 10 miles wide— has rolling hills, deep canyons, a coastal lagoon, and beaches adorned with sand dunes and driftwood.

Santa Cruz Island
Santa Cruz Island resembles what southern California looked like more than 100 years ago. The largest island in the national park, with 61,972 acres, Santa Cruz is 22 miles long and from two to six miles wide. A central valley splits the island along the Santa Cruz Island fault, with volcanic rock on the north and older sedimentary rock on the south. Today, the Nature Conservancy and NPS preserve and protect the island.

Anacapa Island
A five-mile-long spine of rock emerges from the ocean twelve miles from the mainland, breaks into three islets, and provides habitat to a large variety of species of plants and seabirds. On charts, this island of 737 acres appears as “East”, “Middle” and “West Anacapa”.

Santa Barbara Island
Steep cliffs of this smallest island—644 acres (or about one square mile)—rise above rocky shores to a grassy mesa flanked with twin peaks.

The Robert J. Lagomarsino Visitor Center at Channel Islands National Park
The visitor center is located in the Ventura Harbor in Ventura, California, 70 miles north of Los Angeles and 30 miles south of Santa Barbara. Although no coastal engineering projects were identified within the boundaries of Channel Islands National Park, the shoreline in the vicinity of the Visitor Center is stabilized with nine structures including three groins, four revetments, a jetty and a breakwater (Figure 25).

Figure 25. Shoreline Stabilization in the vicinity of the Visitor Center in Ventura, CA.

Appendix E. Fire Island National Seashore.

Figure 26. Fire Island Lighthouse, Fire Island, NY (Photo by http://en.wikipedia.org/wiki/Fire_Island_Light).

Summary of Findings

A total of 93 coastal engineering projects were identified in, and immediately adjacent to, Fire Island National Seashore (FIIS, Figure 26). This total includes 40 groins, 29 bulkheads, eleven beach nourishment/dune construction projects, five dredging projects, three revetments, three jetties and two geotube seawall structures (Figure 27).

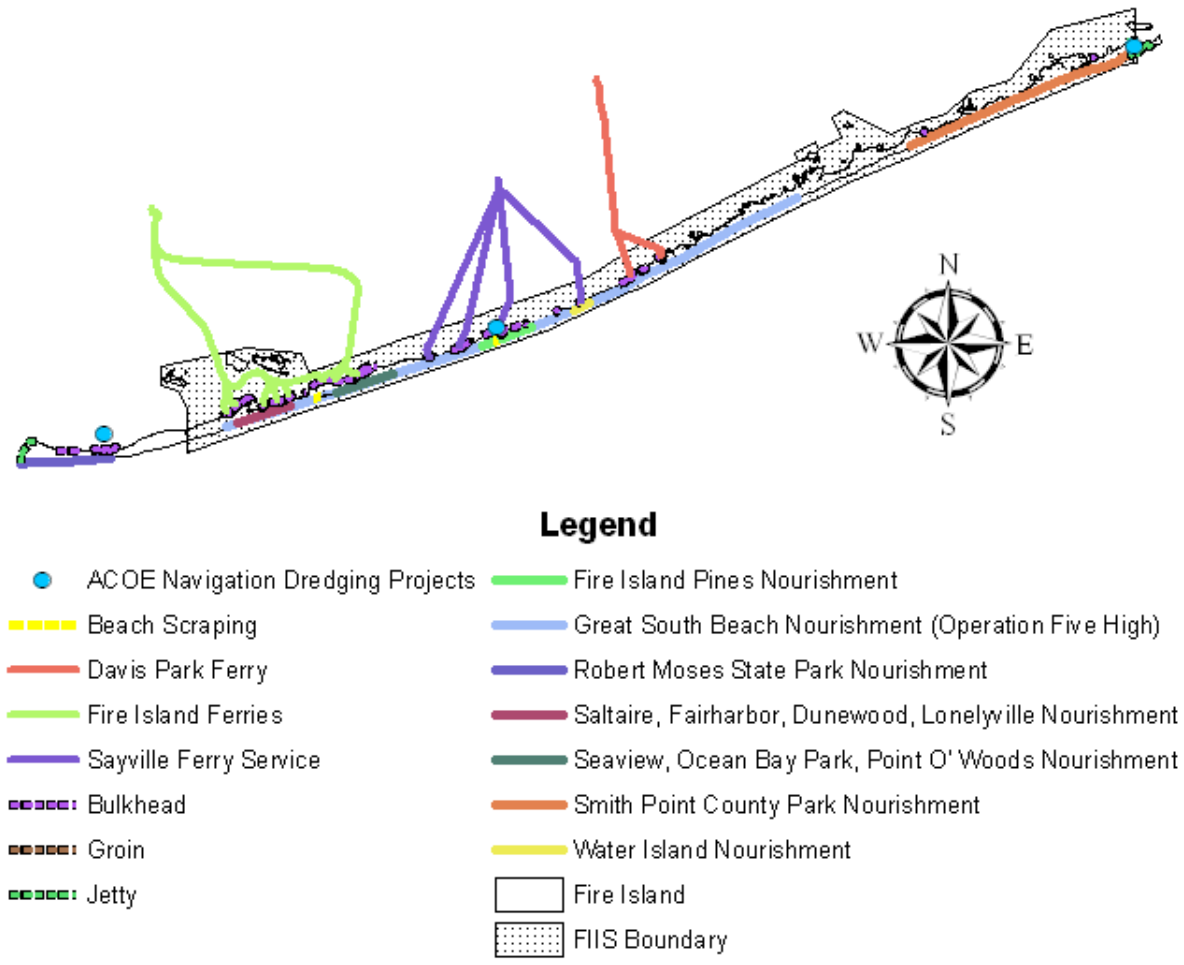

Figure 27. Coastal engineering at Fire Island National Seashore.

Bayside Stabilization Structures

Seventeen communities, encompassing about 4,100 private structures exist within the boundaries of FIIS (Figure 28). With very little developable land remaining, however, new construction on Fire Island has been steadily decreasing since the 1960's and 1970's, and has slowed to less than two units per year since 1991.[67]

[67] United States, Land Use Ecological Services, Inc, and Coastal Planning & Engineering, Inc. 2008. Environmental assessment: Fire Island community short-term storm protection: Fire Island, Suffolk County, New York. Prepared by Land Use Ecological Services.

Figure 28. Fire Island & Fire Island National Seashore.

Bulkheads

On the bayside of Fire Island, approximately 77,000 linear feet of bulkhead has been identified (Figure 29). A "bulkhead" is a vertical structure or partition, usually running parallel to the estuarine shoreline, constructed to retain upland soils while providing protection from wave action and erosion (Figure 30). Bulkheads are typically cantilevered or anchored sheet piles or gravity structures such as rock-filled timber cribs and gabions, concrete blocks, armorstone units or wood.

Many of the bulkheads along the Fire Island bayside shoreline were installed prior to the creation of FIIS. Some have been constructed subsequently, without permission of the FIIS management, while others have been constructed under the issuance of special use permits.

Bulkheads, such as that located at Sailors Haven in Figure 30, negatively impact both natural ecosystem processes and private property that is not bulkheaded. Bulkheads replace natural formations and prevent upland sand sources from entering the littoral drift system, causing sediment starvation downdrift and shifting negative effects to neighboring land. The interaction of waves with a structure increases wave reflection and turbulence, nearshore current velocities and sediment transport at the base of the structure which can lead to undermining.[68]

On December 5, 2005, in recognition of the erosion concerns of individual property owners, park management adopted the following policy regarding special use permits for bulkheads on properties within the boundaries of the park:

1. Permit applications for new bulkheads, where no bulkhead previously existed, will be denied.
2. Permit applications will be approved when they propose:
   a. replacement in kind of minor structures with little or no change in location, capacity or appearance; or
   b. routine maintenance and repairs to non-historic structures; and

[68] Kraus, N. C. and W.G. McDougal. 1996. The effects of seawalls on the beach: Part I, an updated literature review. *Journal of Coastal Research* 12(3): 691-701.

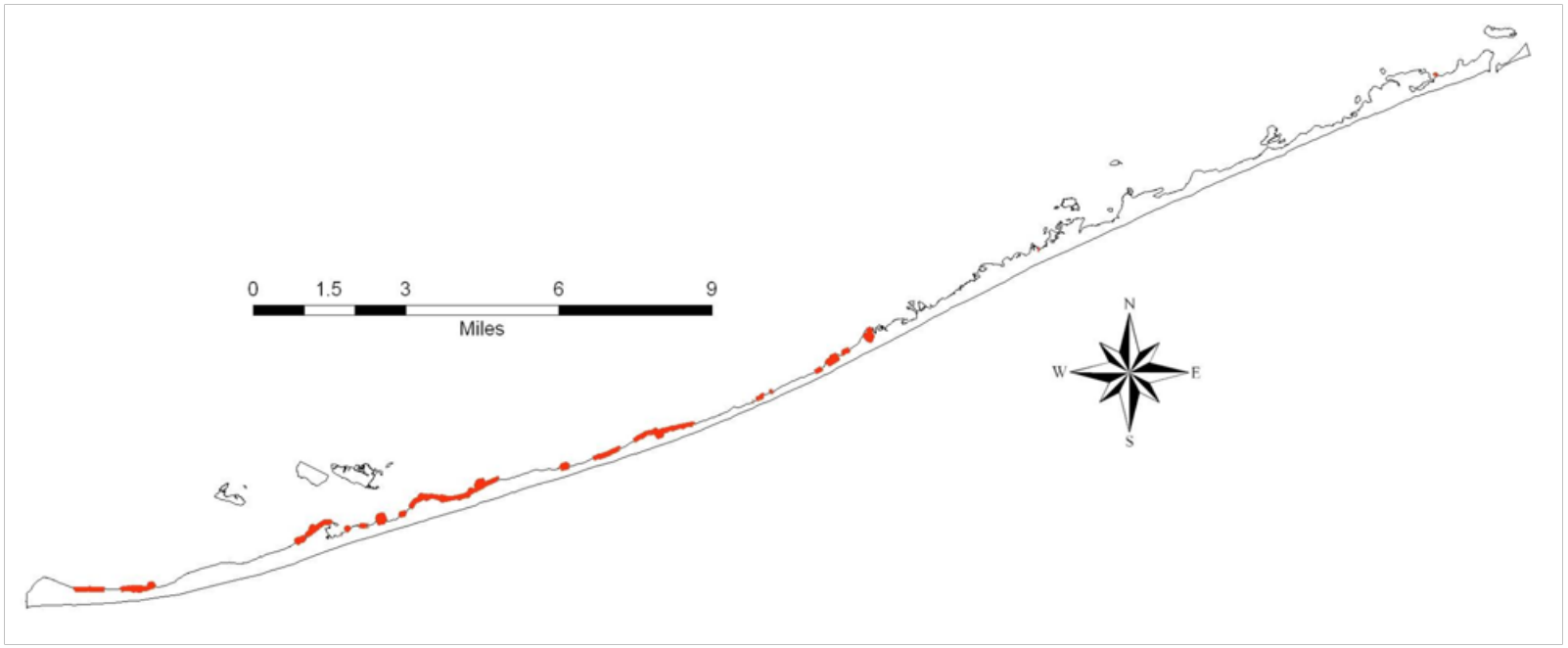

Figure 29. Extent of bayside bulkheading along Fire Island.

c. in both a) and b) above, applicants agree that approved structures will be removed at such time that FIIS management recognizes a comprehensive and ecologically sound approach to bayside sediment transfer that may include existing bulkheads being replaced by a more sustainable shoreline protection method.
d. Bulkhead permits of this type will be processed under a categorical exclusion consistent with Director's Order 12, Chapter 3.4.

3. Permit applications to remove traditional and install new non-traditional bulkheads, may be approved when an applicant(s) submits an innovative and environmentally sensitive design, not involving shore hardening, which has been demonstrably successful in similar bay-shore environments with analogous ecosystem dynamics. Such systems should not introduce non-native flora or fauna, result in changes in predation, have high potential for negatively affecting adjacent property, or otherwise negatively impact the shore. Multiple property owners along a variably bulkheaded contiguous stretch of shoreline, proposing a unified or comprehensive approach of an innovative nature, are highly encouraged to submit a joint application. Proposals of this type will require a higher level of environmental review, such as an Environmental Assessment (EA) or an Environmental Impact Statement (EIS).[69]

Figure 30. Bayside bulkhead at West Sailors Haven Picnic Area.

[69] National Park Service, 2009c. Bulkheads and shoreline erosion control. Online. (http://www.nps.gov/fiis/planyourvisit/bulkheads-and-shoreline-erosion-control.htm).

Groins

In addition to bulkheads, the bayside of Fire Island also contains a number of old groins. A groin is an erosion control structure that extends perpendicularly, or at nearly right angles, from the shore and is relatively short when compared to navigation jetties at tidal inlets. Often constructed in groups called groin fields, a groin's primary purpose is to trap and retain sand. Groins can be constructed from a wide range of materials including armorstone, pre-cast concrete units or blocks, rock-filled timber cribs and gabions, steel sheet pile, timber sheet pile, grout filled bags and tubes and assorted debris including ballast rocks.

An old groin field containing 28 short, shore-perpendicular structures consisting of rocks of unknown origin and concrete debris have been identified along the bayside shoreline, just east of Bay Walk, in Fair Harbor (Figures 31 and 32). In addition, seven wooden groins have been identified along the bayside shoreline just east of Talisman/Barrett Beach (Figures 33 and 34).

The negative impact of groins on downdrift shorelines is well understood - when they work as intended, sand moving along the beach in the so-called downdrift direction is trapped on the updrift side of the groin, causing a sand deficit and increasing erosion rates on the downdrift side. This well-documented impact is widely cited in engineering and geologic literature.

Figure 31. Old bayside groin field in Fair Harbor.

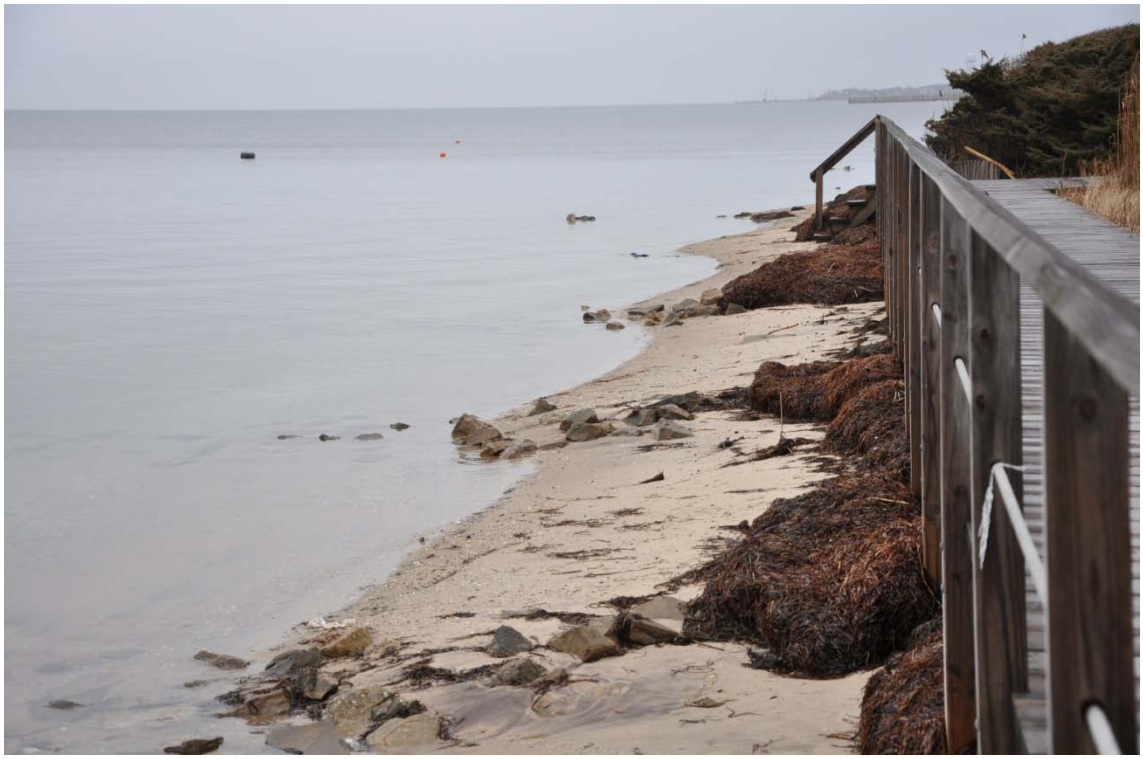

Figure 32. Fair Harbor Groins.

Figure 33. Timber groins east of Talisman/Barrett Beach.

Figure 34. Timber groins at Water Island (east of Talisman/Barrett Beach).

Ocean/Inlet Stabilization Structures

Jetty construction at Moriches Inlet took place from 1952 to 1953 (Figure 35). Between 1982 and 1986, the USACE rehabilitated the outer end of the west jetty, placed a scour blanket fronting the west jetty, repaired both jetties, and placed a stone revetment along the bayside of the beach directly east of the east jetty.

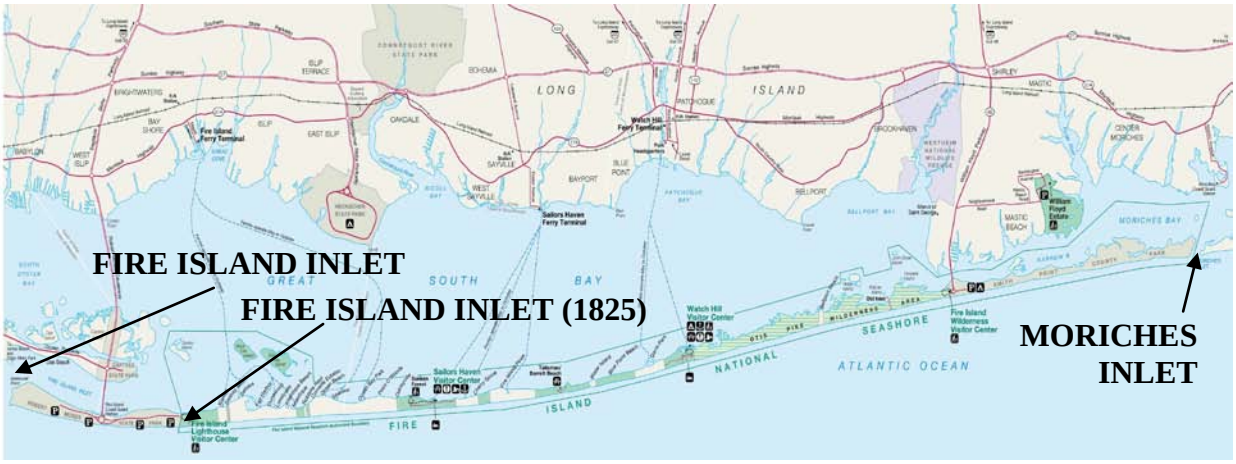

Figure 35. Location of Tidal Inlets.

After placement of the jetty, the inlet created an offshore sand buildup, which normally would have been transported to Fire Island. Over the past decade, shoreline change previously caused by the Moriches Inlet project has been reversed by the naturally occurring bypass process at the inlet. This action suggests that substantial natural bypassing of the inlet is now taking place.[70]

Since 1825, Fire Island Inlet at the western boundary of Fire Island has migrated approximately 26,246 feet to the west. The inlet's migration, and that of Fire Island, was halted in 1941 by the construction of the Federal jetty on the eastern shoulder of the inlet at Democrat Point.[71] The jetty, approximately 5,000 feet in length, was successful in arresting inlet movement for more than a decade, but it did not provide a stable navigation channel. The Fire Island jetty is likely the cause of the very large positive displacement of the shoreline at the western extremity of the island.[72]

Two tetrapod-type groins (230 feet in length) were constructed in Ocean Beach in 1976 by the village and state to protect a water tower in Ocean Beach (Figure 36).[73] After construction, the beach updrift of the structures experienced sediment accumulation and improved stability, while the downdrift beach experienced considerable cutback and displacement of the former foredune ridge.

In 1999, also in Ocean Beach, a 600-foot long geotextile (geotube) structure was installed at a cost of $95,000 to protect a water tower (Figure 37). Another geotube, constructed in the mid 1990s, is located along the ocean beach in Fire Island Pines.[74]

[70] Allen, J.R., C. LaBash, P. August, and N. Psuty. 2002. Historical and recent shoreline changes, impacts of Moriches Inlet, and relevance to Long Island Breaching at Fire Island National Seashore, NY. Technical Report NPS/BSO-RNR/NRTR/2002-7. U.S. Department of the Interior, National Park Service.

[71] Koppelman, L. and S. Forman. 2008. The Fire Island National Seashore: A history. State University of New York Press, Albany, New York.

[72] U.S. Army Corps of Engineers. 2002. Fire Island to Montauk Point reformulation study, Draft Interim Report. U.S. Army Corps of Engineers, New York District, New York.

[73] Ibid.

[74] Fire Island Ecology Coalition. 2002. Online. (http://www.firei.org/site/bd_beach.shtml).

Figure 36. Ocean Beach groin.

Figure 37. Geotextile structure at Ocean Beach.

Beach Nourishment (Sand Placement)

A significant amount of sand has been placed mechanically on Fire Island since the 1940s, although accounts of overall amounts deposited differ widely (Figure 38). Psuty, et al (2005), states that the beaches of Fire Island have been nourished with almost 7,062,933 cubic yards of sand since the 1940s[75]. A 1999 USACE report puts the amount of sand deposited on Fire Island between 1955 and 1994 at 6,415,333 cubic yards[76]. A 2008 Environmental Assessment entitled *Fire Island Community Short-Term Storm Protection*, prepared by Land Use Ecological Services, Inc, states that 11,474,519 cubic yards of sand have been deposited on Fire Island between 1933 and 2007[77]. This section utilizes data contained in the 2008 Environmental Assessment (EA).

Sand placement within the developed communities (Kismet through Davis Park) began in the late 1940s, and approximately 11 million cubic yards of sand has been placed on Fire Island since. Between 1945 and 1979, 5 million cubic yards of sand were placed in the developed communities - most after Hurricane Donna in 1960 and the Ash Wednesday Storm of 1962, and prior to the formation of Fire Island National Seashore.

During the period between 1980 and 1997, approximately 1.9 million cubic yards was placed in the developed communities, most of it associated with the aftermath of major storms in 1992-93.

Following the 1992-93 storms, a number of communities were nourished as emergency repair. Western Fire Island was nourished with 465,000 cubic yards, and Fire Island Pines received approximately 133,800 cubic yards. Seaview, Ocean Bay Park, and Point O'Woods were nourished with approximately 382,600 cubic yards total.

In 1997, Fire Island Pines completed its project by placing 650,000 cubic yards. Some taper section(s) on federal property were allowed on these earlier projects.

In 2003-04, five communities were nourished with sand from two new offshore borrow areas (NPS Special Use Permit #COMM 1750 6000 1011). Communities were grouped into two reaches: 1) Western Fire Island (Saltaire, Fair Harbor, Dunewood, and Lonelyville) and 2) Fire Island Pines. Construction volumes for Western Fire Island and Fire Island Pines were 717,728 and 560,840 cubic yards, respectively, measured within the project limits in February 2004.

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[75] Psuty, N. P., M. Grace and J.P. Pace. 2005. The coastal geomorphology of Fire Island: A portrait of continuity and change. Sandy Hook Cooperative Programs, Institute of Marine and Coastal Sciences, Rutgers, The State University of New Jersey, New Brunswick, New Jersey.

[76] United States. 1999. Fire Island Inlet to Montauk Point, Long Island, New York: Reach 2, west of Shinnecock Inlet: draft decision document: an evaluation of an interim plan for storm damage reduction: volume 1 - main report and environmental assessment. U.S. Army Corps of Engineers, New York District, New York, New York.

[77] United States, Land Use Ecological Services, Inc, and Coastal Planning & Engineering, Inc. 2008. Environmental assessment: Fire Island community short-term storm protection: Fire Island, Suffolk County, New York. Prepared by Land Use Ecological Services.

Following an April 2007 nor'easter, the community of Davis Park applied for and received Federal funding from the Federal Emergency Management Agency (FEMA) to nourish its beaches with approximately 25,460 cubic yards of sand from an upland source (NPS Special Use Permit #NER-1750-5700-054). Sand was barged to Davis Park from the south shore of Long Island, placed with a payloader, and graded with a bobcat.[78]

Two ongoing beach nourishment projects on Fire Island, one being undertaken by Suffolk County and the other by eleven Fire Island communities, ended in March 2009. Partial funding for the projects came from the Federal Emergency Management Agency (FEMA) who worked with the New York State Emergency Management Office (SEMO), with remaining funds coming from Fire Island community erosion control tax district funds, and from Suffolk County. The 11-community project encompassed 29,000 linear feet of shoreline, included an estimated volume of 1.9 million cubic yards and is expected to have cost $23-24 million.[79] The Smith Point County Park project included the emplacement of up to 350,000 cubic yards of dredged material from Moriches Inlet along 13,000 linear feet of beach.[80]

Beach Scraping and Dune Construction

Beach scraping, the mechanical relocation of sand from the beach to reconstruct foredunes that have eroded during storms, is the most common beach maintenance and storm protection effort that has been undertaken in the developed communities of Fire Island. Since 1993, approximately 150,000 cubic yards of sand has been excavated from the beach to augment dunes in the developed communities (Table 6).

The New York State Department of Environmental Conservation (NYSDEC) issues permits for beach scraping for a maximum duration of 10 years. NYSDEC permits are currently valid and in full effect for the following communities: Kismet Beach Erosion Control District (BECD), Village of Saltaire, Fair Harbor BECD, Dunewood BECD, Lonelyville BECD, Atlantique BECD, Fire Island Summer Club BECD, Corneille Estates BECD, Village of Ocean Beach, Seaview BECD, Ocean Bay Park BECD, Point O'Woods BECD, Fire Island Pines BECD, Davis Park BECD and Water Island BECD. Most of these permits expire in July 2010 or 2011.

NYSDEC permits require that a community or "reach" must be at least 100 feet wide from the toe of the dune to the beach scarp and be over elevation 7 feet (NGVD) in order for scraping to occur. Some communities, such as Kismet, use scraping as their primary protection measure. However, narrow, severely eroded, or low elevation beach/dune systems are not candidates for scraping programs.

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[78] United States, Land Use Ecological Services, Inc, and Coastal Planning & Engineering, Inc. 2008. Environmental assessment: Fire Island community short-term storm protection: Fire Island, Suffolk County, New York. Prepared by Land Use Ecological Services.

[79] Smith, J. 2008. New York Newsday, Melville, New York.

[80] Suffolk County (N.Y.) and Greenman-Pedersen. 2008. Draft environmental assessment for beach nourishment and maintenance dredging at Smith Point County Park and Cupsogue County Park July 30, 2008. Greenman-Pedersen, Babylon, New York.

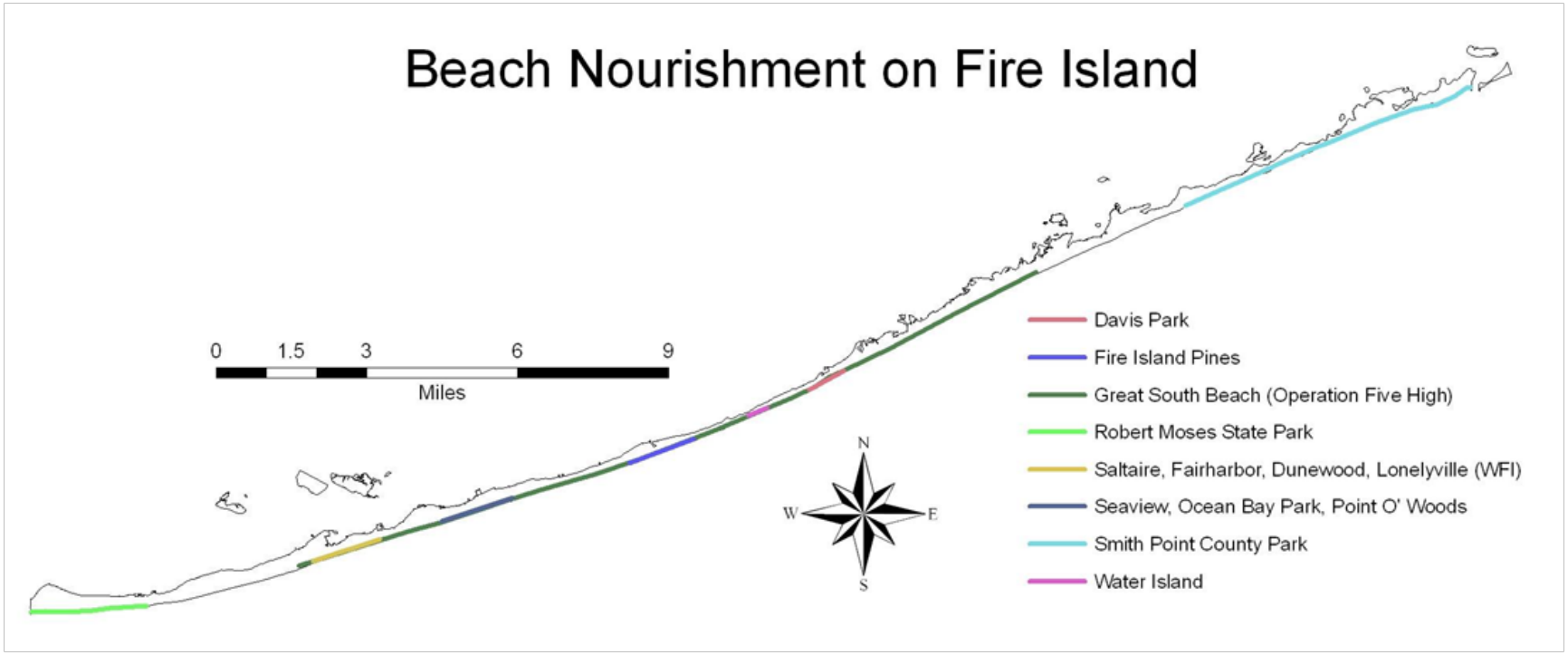

Figure 38. Beach Nourishment on Fire Island.

Beach scraping permits allow for the relocation of a maximum 2.2 cubic yards per linear foot of shoreline in all areas with a beach width of 100 feet and beach elevation of +7 feet NGVD/+9 feet NGVD at the toe of the dune. Scraping occurs in a 60-foot wide area that extends from 40 to 100-foot seaward of the dune toe. To scrape, a bulldozer pushes sand into stockpiles on the beach. Sand is stockpiled at a rate of 2.2 cubic yards per linear foot, which equates to a cut depth of approximately one foot. A payloader then transports scraped sand for placement on the dune. Since scraping simply redistributes sand within the existing sand budget, impacts are typically localized and minor.[81]

Dredging

Moriches Inlet opened in 1931 and is dredged only when major issues of navigation become apparent. From 1953 to the present, dredging quantities for the inlet total approximately 3,269,877 cubic yards, an annual average of 58,391 cubic yards. The dredged material is typically placed along the beaches adjacent to the inlet, or within the nearshore on both sides of the inlet. Historically, most of the known placement of dredge spoil was east of the inlet. However, in an effort to restore the east-west alongshore transport, dredged material is now distributed both east and west of the Moriches Inlet.[82]

Since 1971, the maintenance of Fire Island Inlet has consisted of periodic dredging of the navigation channel, sporadic dredging of the littoral reservoir immediately adjacent to the jetty, land reclamation and feeder beach nourishment[83]. Dredging of the inlet has been performed almost annually since 1954 at an average annual cost of about $5 million. These dredging operations have totaled to nearly 20,927,210 cubic yards from 1954 to 1994 (about 523,000 cubic yards per year)[84]. Most of the dredged material has been placed west of the inlet, between Fire Island and Jones Inlet.[85]

Periodic maintenance dredging to facilitate passenger ferry service to and from Fire Island has occurred over the years. Although the amount of sediment dredged and removed from the bayside littoral system has not been quantified, most was placed along either the bayside shoreline, ocean beach, or stockpiled for later disposal.

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[81] United States, Land Use Ecological Services, Inc, and Coastal Planning & Engineering, Inc. 2008. Environmental assessment: Fire Island community short-term storm protection: Fire Island, Suffolk County, New York. Prepared by Land Use Ecological Services.

[82] Smith, W.G., K. Watson, D. Rahoy, C. Rasmussen, and J.R. Headland. 1999. Historic geomorphology and dynamics of Fire Island, Moriches and Shinnecock Inlets, New York. Proceedings of Coastal Sediments '99 Conference, American Society of Civil Engineers. 1597-1612.

[83] Ibid

[84] U.S. Army Corps of Engineers. 2002. Fire Island to Montauk Point reformulation study. Draft Interim Report. U.S. Army Corps of Engineers, New York District, New York.

[85] Ibid

Table 6. Beach scraping projects on Fire Island (1993-2007).

Year	Community	Excavation Length (lf)	Excavation Location
1993	Corneille Estates/FI Summer Club	900	length of community
1994	Atlantique	900	length of community
	Corneille Estates/FI Summer Club	900	length of community
	Davis Park/Ocean Ridge	3450	length of community
	Kismet	950	length of community
	Lonelyville	1000	length of community
	Robbins Rest	350	length of community
1995	Water Island	1050	Charach Walk to East Walk
1996	Kismet	950	length of community
	Ocean Bay Park	2300	length of community
	Point O' Woods	4200	length of community
	Robbins Rest	350	length of community
	Seaview	1500	eastern 1500' of community
	Water Island	1050	Charach Walk to East Walk
1997	Davis Park/Ocean Ridge	3450	length of community
	Ocean Bay Park	2300	length of community
	Seaview	1500	eastern 1500' of community
1998	Davis Park/Ocean Ridge	3450	length of community
	Ocean Beach	1800	length of community
	Saltaire	3350	length of community
	Seaview	1500	eastern 1500' of community
1999	Davis Park/Ocean Ridge	3450	length of community
	Ocean Beach	630	between jetties only
	Saltaire	3350	length of community
	Seaview	2750	length of community
2000	Ocean Ridge (Davis Park)	1730	Ocean Ridge only
2001	Ocean Bay Park	2300	length of community
	Ocean Beach	1800	length of community
	Seaview	2750	length of community
2005	Ocean Ridge (Davis Park)	1730	Ocean Ridge only
	Kismet	950	length of community
	Ocean Bay Park	1300	western 1300' of community to Ontario Walk
	Point O' Woods	975	3rd St. to 6th St. (+/-)
2006	Kismet	950	length of community
	Ocean Bay Park	1300	western 1300' of community to Ontario Walk
	Seaview	850	Brookhaven only
2007	Kismet	950	length of community
	Ocean Bay Park	1300	western 1300' of community to Ontario Walk
	Seaview	850	Brookhaven only
	Corneille Estates/FI Summer Club	900	length of community

Appendix F. Fort Pulaski National Monument.

Figure 39. Fort Pulaski (Photo by National Park Service).

Summary of Findings

Fort Pulaski National Monument (FOPU) is composed of a series of small islands surrounded by tidally-influenced rivers and channels that extend from the mouth of the Savannah River to about seven miles upstream. The Park comprises a total of 5,623 acres[86], 608 of which are located on Cockspur Island, with the rest distributed among Daymark Island, Cockspur Island Lighthouse Reservation, and McQueens Island (Figures 39 and 40).[87]

Almost 5,000 acres of the park exist as tidal salt marsh, but the upland areas, which occur primarily on Cockspur Island, support a maritime forest. In 1998, Fort Pulaski NM contained 4,372 acres of salt marsh, 859 acres of open water, 35 acres of cypress-gum swamp, 12 acres of shrub wetland, and four acres of evergreen forested wetland.[88]

[86] Meader, J.F. 2003. Fort Pulaski National Monument: Administrative history. C. Brinkley, Southeast Region NPS, Cultural Resources Division. Online. (http://www.nps.gov/fopu/pdf/fopu_ah.pdf).

[87] Johnstone, S. 2004. Echoes from the past: The archeology of Fort Pulaski. National Park Service, Southeast Archeological Center. Online. (http://www.cr.nps.gov/seac/pulaski/).

[88] McFarlin, C. and M. Alber. 2005. Assessment of coastal water resources and watershed conditions at Fort Pulaski National Monument, Georgia. Technical Report NPS/NRWRD/NRTR 2005/345. Department of Marine Sciences, University of Georgia, Athens, Georgia.

Figure 40. Boundary of Fort Pulaski National Monument.

A total of fourteen coastal engineeering projects were identified in and adjacent to FOPU includng six dikes, four revetments, two jetties and two fill projects.

Historically, Cockspur Island was a series of small marsh hammocks (small patches of upland surrounded by salt marsh), but its strategic military position at the mouth of the Savannah River prompted its fortification, which resulted in the island and habitats that now exist. Dredge spoil

was also used as fill on McQueens Island in order to connect Savannah to the resort area of Tybee Island. [89]

Following transfer of the Park to the NPS in 1933, the Civil Works Administration (CWA), Civilian Conservation Corps (CCC) and Public Works Administration (PWA) worked on a number of projects including construction of a landing walk along the South Channel for ferry service, vegetation removal, restoring dikes and the moat (which required dirt addition and removal, respectively), mosquito control (which required ditching), maintaining ferry service for visitors and filling in marshes in preparation for - and construction of - the bridge across the South Channel to FOPU.

Savannah River Shoreline Stabilization

Two rock revetments are located along the north shore of Cockspur Island which are intended to protect the island against shoreline erosion (Figure 41). The first was constructed during the 1890s to reduce channel shoaling, and extends from the northeast corner of Cockspur Island to a jetty along the southern edge of the Savannah River Channel. The second revetment was built by the USACE in the early 1970s along the central portion of the north shore to protect the Savannah Bar Pilots facility.[90]

Two small riprap revetments are also located at the base of the bridge connecting McQueens Island to Cockspur Island over the Savannah River.

Ditches and Dikes

Several dikes (channels, ditches and embankments) were constructed on the northern shoreline of Cockspur Island around 1828 to help control flooding and facilitate drainage (Figure 41).[91] Repairs to FOPU began in 1956 under the NPS *Mission 66* initiative. Major activities funded under this initiative included repairing the drainage system, which involved digging over 7,000 feet of ditches and installing tide-gates. Subsequently, the historic dike system was restored to a height of 12 feet.[92]

Ocean/Inlet Stabilization

Congress authorized construction of the Federal navigation project at Savannah Harbor, which began in 1874 with river channel dredging. Construction of two jetties at the mouth of the Savannah River entrances was completed in 1896, and an offshore breakwater was completed in 1897 at the south end of Barrett Shoals (Figures 41 & 42). Although these structures have had a

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[89] Meader, J.F. 2003. Fort Pulaski National Monument: Administrative history. C. Brinkley, National Park Service, Southeast Region, Cultural Resources Division. Online. (http://www.nps.gov/fopu/pdf/fopu_ah.pdf).
[90] Alexander, C. 2008. Rates and processes of shoreline change at Ft. Pulaski National Monument. Skidaway Institute of Oceanography, Savannah, Georgia.
[91] Groh, L. 2000. Fort Pulaski National Monument: Archeological overview and assessment. National Park Service, Southeast Archeological Center, Tallahassee, Florida.
[92] Meader, J.F (2003).

significant historic impact on Cockspur Island and continue to impact Tybee Island (southeast of FOPU), they do not appear to have any appreciable influence on FOPU.[93]

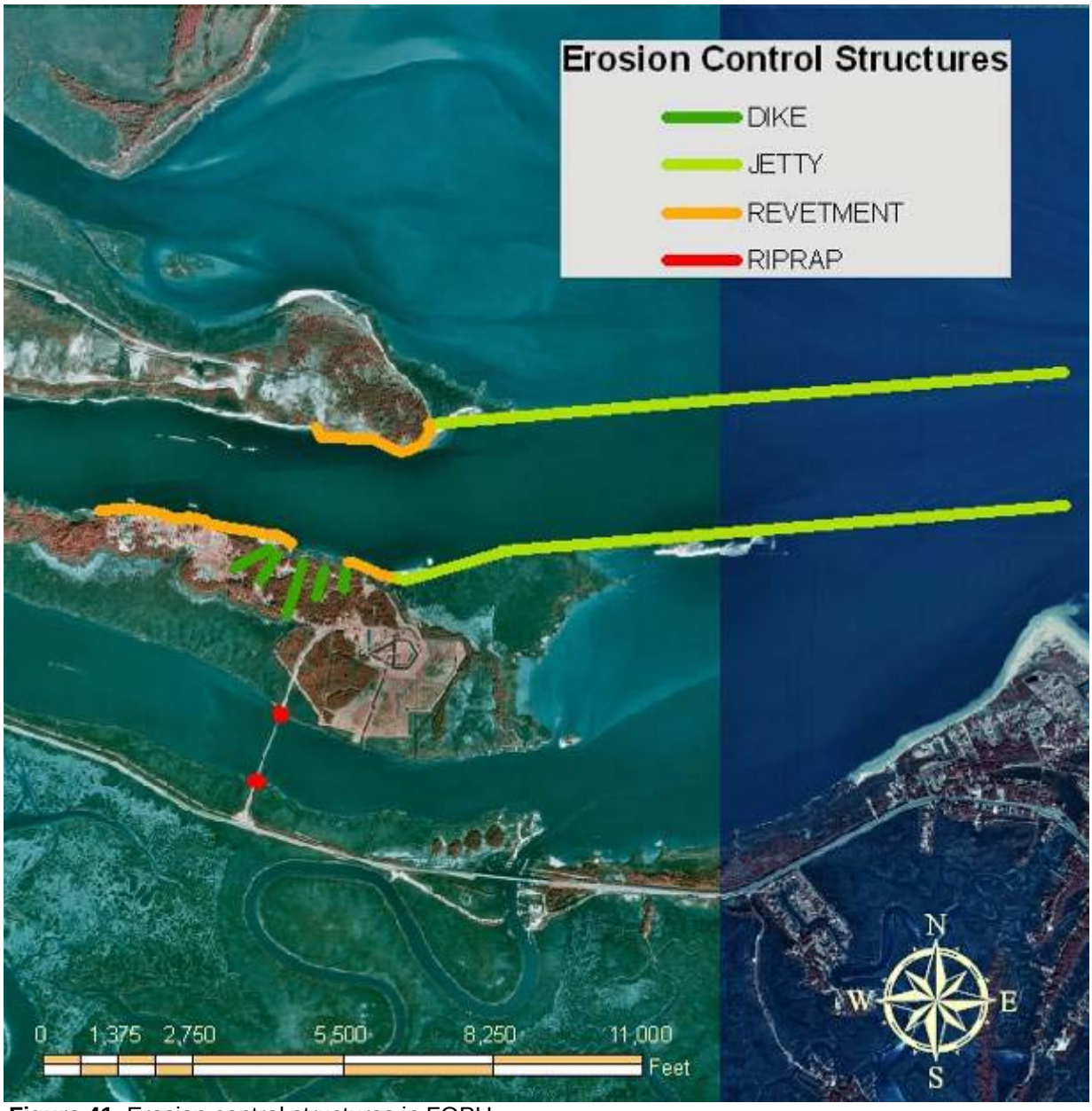

Figure 41. Erosion control structures in FOPU.

[93] Smith, J. M., and D.K. Stauble. 2008. Impact of Savannah Harbor Deep Draft Navigation Project on Tybee Island shelf and shoreline. U.S. Army Corps of Engineers, Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg, Mississippi.

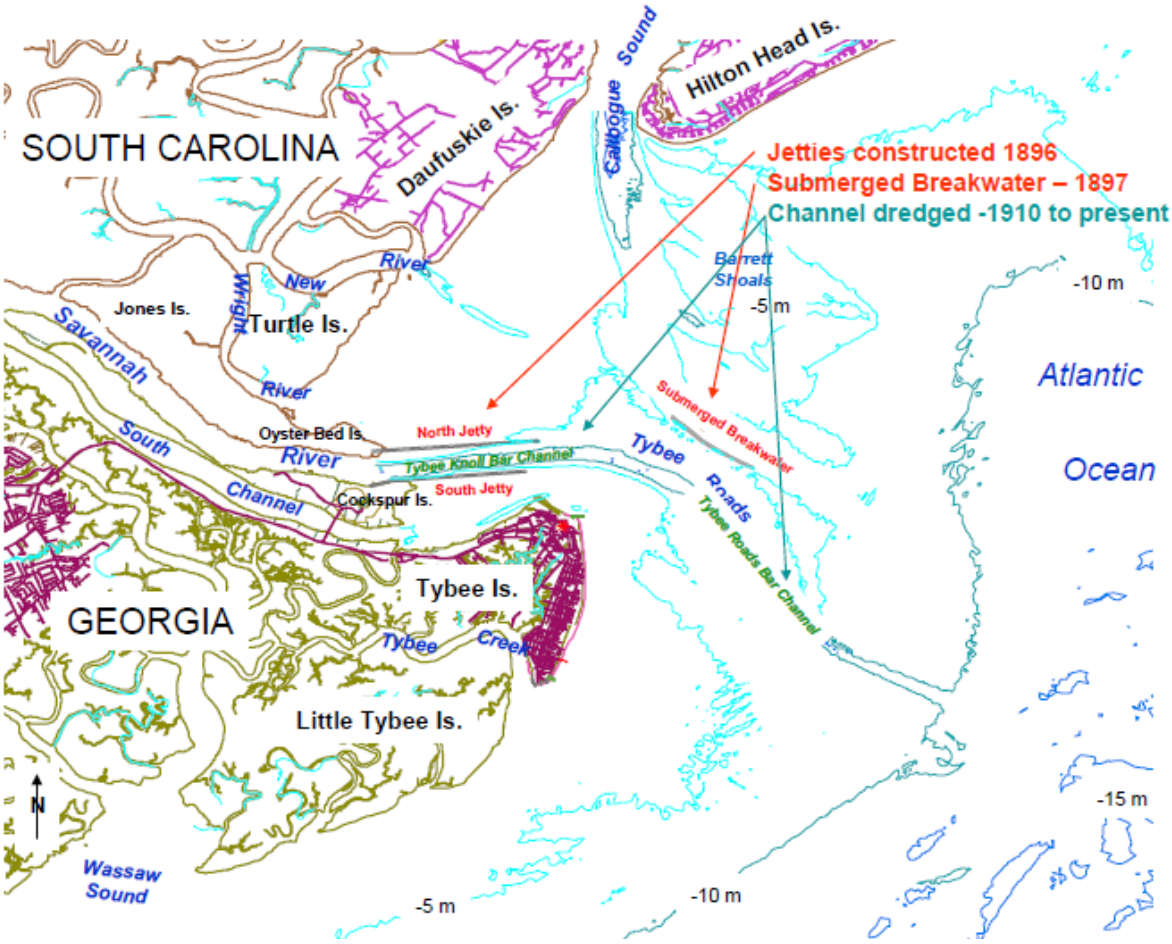

Figure 42. Coastal engineering in the vicinity of Fort Pulaski.

Dredging/Dredge Spoil Deposition

Dramatic changes to the landscape of Cockspur Island began as early as 1867, when dredge-spoil material from the deepening of Savannah Harbor was placed on the north end of the island. Much of the land mass along the north and west shores of Cockspur Island were built up with dredge spoil during the 1880s (Figure 43).

Multiple requests for additional dredge material followed due to the low elevation of the area. Eventually, the jetties and dredge-spoil deposition caused Cockspur Island to merge with Long ("Bird") Island as the marsh that separated the two was filled in. Hydraulic fill was also placed between Jones and Oyster Bed Island between 1929 and 1930.[94]

[94] McFarlin, C. and M. Alber. 2005. Assessment of coastal water resources and watershed conditions at Fort Pulaski National Monument, Georgia. Technical Report NPS/NRWRD/NRTR 2005/345. Department of Marine Sciences, University of Georgia, Athens, Georgia.

The main navigation channel of the Savannah River is located south of Oyster Bed Island (Figure 42). Cockspur Island separates the main navigation channel from the South Channel of the Savannah River. Construction and maintenance of the Federal navigation channel at Savannah Harbor has resulted in disruption of sediment transport pathways across Tybee Roads. Sediment shoaling in the navigation channel has necessitated annual dredging in order to maintain navigability.

Maintenance harbor dredging around Fort Pulaski is first noted in 1867 and continued to occur as the harbor and port developed. The navigation channel of the Savannah River was deepened from 21.5 ft mean low water (mlw) to a depth of 26 ft mlw in 1912 to accommodate larger ships. Depth increases were later made in 1936 to 30 ft mlw and 1945 to 36 ft mlw. The channel was widened and deepened in 1972 to a depth of 40 ft mlw. In 1994, the authorized depth of the channel was increased to 44 ft mlw. At present, approximately 31 miles of navigation channel exist, extending from Savannah Harbor across Tybee Roads into the Atlantic Ocean.[95]

[95] McFarlin, C. and M. Alber. 2005. Assessment of coastal water resources and watershed conditions at Fort Pulaski National Monument, Georgia. Technical Report NPS/NRWRD/NRTR 2005/345. Department of Marine Sciences, University of Georgia, Athens, Georgia.

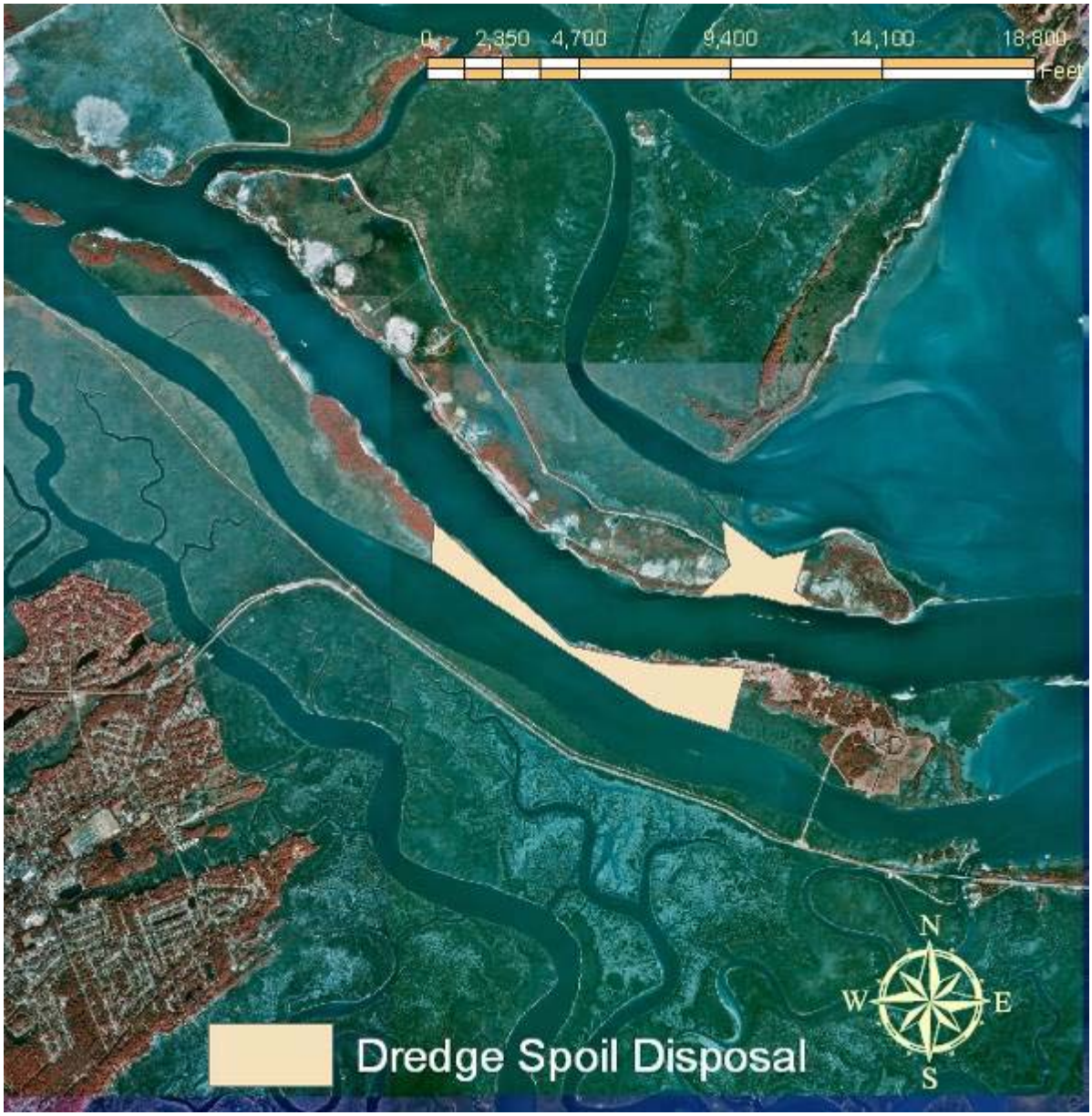

Figure 43. Dredge spoil disposal locations.

In 1936, shortly after acquisition of Fort Pulaski by the NPS, Congress passed a "special-use permit" (49 Stat. 1979) that allowed unlimited use of a "strip of land extending shoreward 200 feet from the present high water line" by the USACE for the deposit of dredge-spoil material. By

1939, the USACE had dredged land northwest of Cockspur Island, deposited the spoil to construct a new shoreline, and then stabilized the new shoreline with riprap.[96]

In 1942, the NPS granted the USACE a second special use permit to construct "Elba Island Cut" (running through northwest McQueen's Island) to shorten the intracoastal waterway), and spoil material was deposited on either side of the cut on McQueen's Island. In 1943, spoil was again deposited along the north shore of Cockspur Island, connecting it to Long ("Bird") Island.[97].

Dredging activity and the placement of spoil deposits along the north shore of Cockspur Island continued through the 1970s and 1980s, although various state and federal acts served to restrict these activities. In 1996, the "special-use permit" was overturned, officially removing the USACE right to deposit dredge-spoil along the north shore of Cockspur Island.[98]

Potential direct effects of channel deepening include increased erosion of banks due to channel widening (which can increase channel current velocities and tidal ranges), channel widening, flank over steepening and collapse, and increased wave energy at the shore from increased ship traffic.[99]

Although concern about impacts from increased shipping on erosion exists, relatively few studies have specifically addressed the impacts of ship-generated waves. Of those that have, most contain conflicting conclusions. A recent study found no supporting evidence that waves from ship –generated wakes influence adjoining estuaries.[100]

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[96] National Park Service. 1995. Resource management plan: Fort Pulaski National Monument. U.S. Department of the Interior, National Park Service, Washington, D.C.

[97] National Park Service. 1995.

[98] Meader, J.F. 2003. Fort Pulaski National Monument: Administrative history. C. Brinkley, National Park Service, Southeast Region, Cultural Resources Division. Online. (http://www.nps.gov/fopu/pdf/fopu_ah.pdf).

[99] Barbe, D.E., K. Fagot, and J.A. McCorquodale. 2000. Effects on dredging due to diversions from the lower Mississippi River. *Journal of Waterway, Port, Coastal, and Ocean Engineering* 126:121-129.

[100] Cox, R., R.A. Wadsworth, and A.G. Thomson. 2003. Long-term changes in salt marsh extent affected by channel deepening in a modified estuary. *Continental Shelf Research* 23:1833-1846.

Appendix G. Indiana Dunes National Lakeshore.

Figure 44. Burns Ditch Breakwall, west of the mouth of Burns Ditch (Photo by NPS Staff).

Summary of Findings

A total of 43 coastal engineering projects have been identified in, and immediately adjacent to, INDU (Figures 44 and 45). These 43 coastal engineering projects include fifteen revetments, thirteen seawalls, five breakwaters, three jetties, one bulkhead, three dredging projects and three beach/dune construction (beach nourishment) projects.

Figure 45. Indiana Dunes National Lakeshore and location reference map.

1. Michigan City Harbor
2. Mt. Baldy
3. Beverly Shores
4. NIPSCO Bailly Generating Station
5. ArcelorMittal
6. Port of Indiana – Burns International Harbor
7. US Steel
8. Burns Waterway Small Boat Harbor and Portage Burns Waterway
9. Ogden Dunes
10. US Steel

A natural pattern of erosion and deposition moves sand in a westward direction along the beaches of INDU. In several areas, jetties, breakwaters and other erosion control structures have been built along the Lake Michigan shoreline. These structures have interrupted the movement of sand, altering the natural patterns of erosion and deposition in many places. The net result has been increased erosion of the national lakeshore's beaches and dunes.[101]

According to the Indiana Lake Michigan Coastal Program, Indiana's 45 miles of shoreline can be divided into six distinct segments – or reaches - separated, in most cases, by the presence of a coastal structure (Figure 46 and Glossary).[102] These reaches, moving from east to west along the coast, are:

- Reach 6: Indiana-Michigan border to the Michigan City Harbor.
- Reach 1: Michigan City Harbor to boundary between the Town of Beverly Shores and the Indiana Dunes State Park at Kemil Road.
- Reach 2: Kemil Road to the east side of the Burns International Harbor complex.
- Reach 3: Burns International Harbor to the USX- Gary Harbor complex.
- Reach 4: Buffington Harbor to the Indiana Harbor and Ship Canal complex.
- Reach 5: Indiana Harbor and Ship Canal to the Calumet Harbor in Illinois.

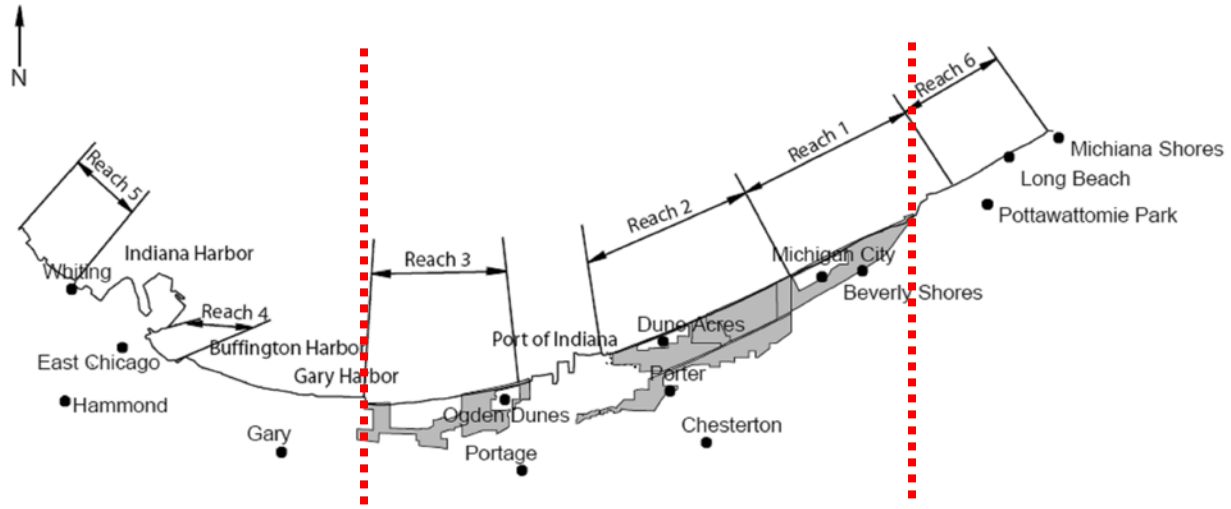

Figure 46. Six reaches of the Indiana shoreline (Red lines indicate the approximate boundaries of Indiana Dunes National Lakeshore).

Because only Reaches 1, 2, and 3 include INDU shoreline, only they and the Burns International Harbor Complex (Burns International Harbor, ArcelorMittal and U.S. Steel) - a heavily

[101] National Park Service. 2009d. Indiana Dunes National Lakeshore environmental factors. Online. (http://www.nps.gov/indu/naturescience/environmentalfactors.htm).
[102] Ibid.

constructed length of shoreline that provides no source of sediment and constitutes a total littoral barrier - are included in this report.

Erosion Control/Shoreline Protection Structures

Residential and industrial development along Indiana's coastline has resulted in efforts to stabilize dynamic beaches, and a total of 40 erosion control/shore protection structures have been identified in, and immediately adjacent to, INDU. These structures - which consist of five breakwaters (locally referred to as breakwalls), three jetties, fifteen rock revetments, sixteen seawalls and one bulkhead - impact approximately 37,000 linear feet of lakeshore (Figure 47).

According to the Combined Coastal Program Document and Draft Environmental Impact Statement for the State of Indiana, coastal structures along INDU are classified based on criteria set forth by Wood and Davis (1986) using a scheme that assesses the degree of impact a structure imposes on the process/response system of the beach and nearshore zone. This classification scheme has three principal groups of structures referred to as primary, secondary and tertiary.[103]

Primary Structures

Primary structures are large coastal constructions that form total or near total barriers to sediment transport parallel to the beach in the nearshore zone. This type of structure is represented by the Michigan City Harbor jetties, Port of Indiana/ArcelorMittal Industrial Complex breakwaters, U.S. Steel breakwaters.

Each of these structures extends lakeward across the littoral zone to a distance offshore where sediment transport becomes negligible. Their impact on the downdrift shoreline is to increase erosion and subsequent dune-bluff recession by blocking sediment coming from the updrift direction that would normally supply the downdrift transport. Coastal engineers refer to these structures as "total sediment barriers."[104]

Secondary Structures

Secondary structures are moderately sized structures that have significant impact on sediment transport, but do not form total sediment barriers. These structures generally affect between 25 and 75 percent of the net sediment transport in the nearshore zone. There are three types of secondary structures: shore-crossing, shore-parallel and combined.[105]

Shore-perpendicular secondary structures protrude out into the nearshore zone to a distance greater than the inner-bar and less than or equal to the outer-bar positions. An example of this

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[103] United States and Indiana. 2001. Combined coastal program document and draft environmental impact statement for the state of Indiana. The Office of Ocean and Coastal Resource Management, Silver Spring, Maryland.
[104] Wood, W. L., J.H. Hoover, M.T. Stockberger and Y. Zhang. 1988. Coastal situation report for the state of Indiana. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[105] Ibid.

type of structure is the breakwater at the mouth of the Portage/Burns Waterway. Shore-parallel secondary structures are relatively long (100's to 1000's of feet/ 10's to 100's of meters) engineering constructions that significantly influence net sediment transport. These structures can be located onshore (such as revetments and seawalls) or offshore (such as detached or reef breakwaters). Examples of shore-parallel structures include the 13,000-foot long Beverly Shores rock revetment, steel sheet pile seawall and rock revetment in Dune Acres and seawall in Ogden Dunes (A, B and C in Figure 47).

Combined secondary structures are those constructed with both shore-perpendicular and shore-parallel structures. The most common example of this type of structure is a series of shore-crossing groins protruding lakeward from a long rock revetment or conventional seawall system. Structures of this type are not presently exposed on the Indiana shoreline, although such a system was constructed in 1967 in front of the Northern Indiana Public Service Company (NIPSCO) Bailly Power Plant at the west end of Reach 2. This system is presently buried by sediment trapped by the Port of Indiana/ArcelorMittal Industrial Complex breakwaters.[106]

Tertiary Structures

Tertiary structures are defined as small-sized structures that have a localized impact on sediment transport. These structures generally affect less than 10 percent of the net sediment transport in the littoral zone. Tertiary structures are typically breakwaters, short groins, sand bags and debris piles built or placed on the shore to protect a small number of coastal residences.[107]

Since tertiary structures can be shore-perpendicular, shore-parallel, or a combination of the two, their effect on the adjacent shoreline is similar to that of secondary structures. The main difference between secondary and tertiary structures is the distance downdrift, and lakeward, to which their effect is felt.

Tertiary structures have the greatest impact on the beach and upland immediately downdrift of the structure. The sequential building of tertiary structures over linear shoreline distances of 100's to 1000's of feet (10's to 100's of meters) typically results in the emplacement of a secondary structure.[108]

The scheme used by the State of Indiana to define erosion control structures along the INDU shoreline is presented here as a reference. This report does not attempt to utilize this methodology to classify identified coastal engineering structures.

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[106] Wood, W. L., J.H. Hoover, M.T. Stockberger and Y. Zhang. 1988. Coastal situation report for the state of Indiana. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[107] Ibid.
[108] United States and Indiana. 2001. Combined coastal program document and draft environmental impact statement for the state of Indiana. The Office of Ocean and Coastal Resource Management, Silver Spring, Maryland.

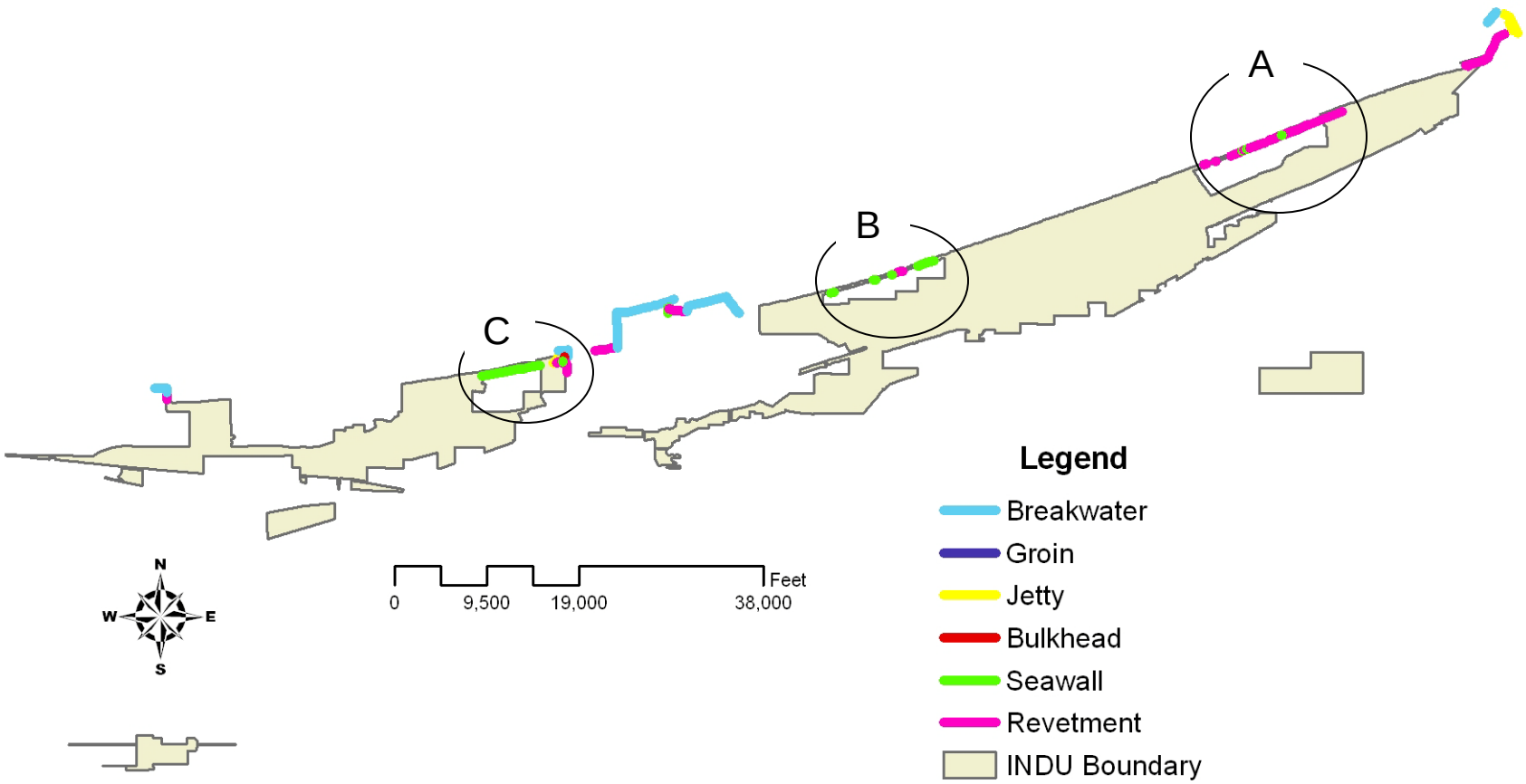

Figure 47. Erosion control structures in and adjacent to INDU.

Beverly Shores: A
Dune Acres: B
Ogden Dunes: C

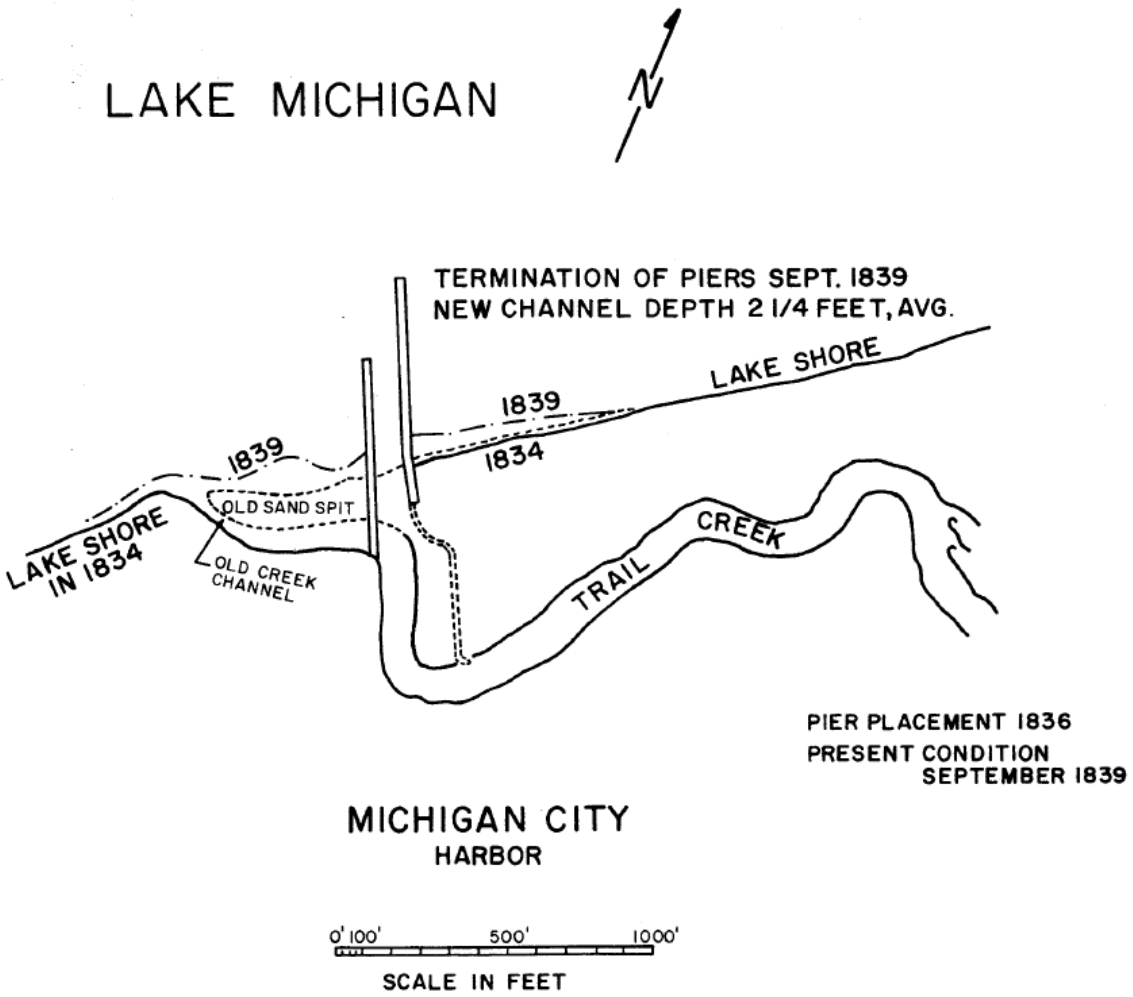

Figure 48. Original Michigan City Harbor structure.

Michigan City Harbor

The shoreline at Michigan City remained unaltered by man until 1836 when the outlet to Trail Creek was modified by a jetty system constructed on its eastern and western sides (Figure 48). These jetties were extended periodically from 1836 through 1869. In 1884 the east breakwater was constructed, followed by a new east jetty in 1902, the offshore breakwater in 1903 and west jetty in 1909.[109]

Once an active commercial harbor, Michigan City is now almost entirely recreational. Harbor infrastructure currently includes a 1,304-foot long outer detached breakwater, a 2,276-foot long east jetty and a 835-foot long west jetty (Figure 50).[110]

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[109] U.S. Army Corps of Engineers. 2008b. Indiana shoreline monitoring: Burns International Harbor to Michigan City Harbor 2008. U.S. Army Corps of Engineers, Buffalo, New York.

To the west of the harbor, along 4,500 feet of shoreline, is a sheet pile seawall protected by a rock revetment (Figure 49). These structures protect a recreational boat marina, U.S. Coast Guard Station and a NIPSCO coal-fired power plant. The Michigan City Harbor jetties and breakwater complex act as a total sediment barrier.[111]

Figure 49. Rock revetment west of Michigan City Harbor.

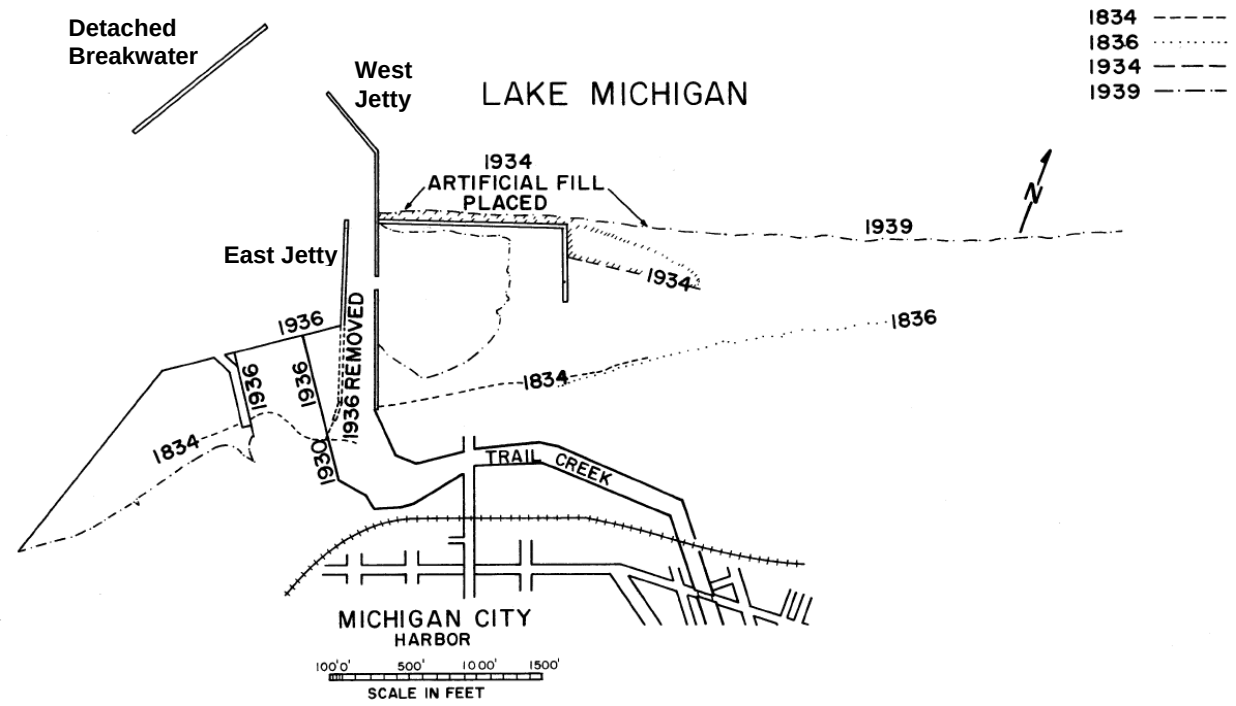

Figure 50. Michigan City Harbor today.

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[110] U.S. Army Corps of Engineers. 2009a. Navigation information. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois. Online. (http://www.lrc.usace.army.mil/co-o/Mich_City.htm).

[111] Wood, W. L. and S.E. Davis. 1986. Indiana Dunes National Lakeshore shoreline situation report. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.

Beverly Shores

In 1974, a rock revetment was constructed along the coast to protect Lake Front Drive from erosion. The 13,000-foot long revetment, which terminates at Derby Avenue, lies along the shoreline just north of the Town of Beverly Shores (Figure 51). The National Lakeshore property is unprotected from Derby Avenue to the east boundary of the Indiana Dunes State Park at Kemil Road, except for an isolated area that was protected by a rock revetment near the west end of Beverly Shores.[112]

Figure 51. Rock Revetment along Lake Front Drive, Beverly Shores.

Port of Indiana-Burns International Harbor/NIPSCO Bailly Generating Station

These 2.6 miles of coastline includes the NIPSCO Bailly Generating Station, ArcelorMittal, Burns International Harbor (authorized by the River and Harbor Act of 1965) and U.S. Steel Midwest Division. This industrial complex serves as a total barrier to sediment moving southwestward (Figure 52).[113]

The accretion of sand around the intake structure of the Bailly Generating Station, constructed in the early 1960s, has been attributed to the prevailing littoral drift that generally transports sand from the east toward the west in this nearshore region of Lake Michigan, and the construction of a breakwater for a steel plant in 1968 (Figure 52). This accumulation of sand necessitated several subsequent dredging episodes that are discussed later in this document.

The ArcelorMittal breakwaters include an eastern breakwater, oriented perpendicular to the shore and extending 2,000 feet out into the waters of Lake Michigan (Figure 53). A northern breakwater that encloses Lake Michigan waters previously served as ArcelorMittal's permitted

[112] U.S. Army Corps of Engineers. 2008a. Chicago District.

[113] Wood, W. L., J.H. Hoover, M.T. Stockberger and Y. Zhang. 1988. Coastal situation report for the state of Indiana. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.

lakefill disposal site for slag. West of this breakwater is 1,500 feet of stabilized shoreline forming the south side of the entrance channel to Burns International Harbor.

In 1966, construction began on the lakeward extension of the Burns Waterway Harbor complex (Figure 54). By spring 1967, a jetty, approximately 1,000 feet in length, existed at the far eastern end of the present complex. The entire outer breakwater structures of the Burns Waterway Harbor complex were completed in their present configuration by spring 1969.[114]

Figure 52. Port of Indiana-Burns International Harbor Complex including ArcelorMittal, U.S. Steel and NIPSCO Bailly Generating Station.

[114] Wood, W. L., J.H. Hoover, M.T. Stockberger and Y. Zhang. 1988. Coastal situation report for the state of Indiana. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.

Figure 53. ArcelorMittal Breakwater.

Figure 54. Port of Indiana-Burns International Harbor.

A series of submerged breakwaters were completed in 1998 lakeward of this breakwater to reduce the size of storm waves impacting the structure.[115] The northern 1,200 feet of the shore-perpendicular western breakwater is federally owned and constructed of the same rubble mound as the 5,830-foot long northern, shore-parallel breakwater (A in Figure 54).[116] South of, and connected to, the federal breakwater is a 2,400-foot rubble mound and steel sheet piling breakwater owned by U.S. Steel Midwest Division (B in Figure 54).

The shoreline immediately west of the U.S. Steel breakwater has a rock revetment in place to control erosion on the eastern most portion of U.S. Steel's shoreline (Figure 55).

[115] Wood, W. L., J.H. Hoover, M.T. Stockberger and Y. Zhang. 1988. Coastal situation report for the state of Indiana. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[116] U.S. Army Corps of Engineers. 2009c. Navigation information. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois. Online. (http://www.lrc.usace.army.mil/co-o/Burns_Hbr.htm).

Figure 55. U.S. Steel.

Burns Waterway Small Boat Harbor

At the western end of U.S. Steel's shore is the east jetty wall of the Burns Waterway Small Boat Harbor, also known as the "Portage Burns Waterway" (Figure 56). This stretch of shoreline is within a closed littoral system bounded by Burns International Harbor to the east and U.S. Steel breakwater to the west.[117] This stretch of lakeshore is accretional in the western third near Gary, and recessional in the eastern third near Ogden Dunes due to the trapping of sand by the Burns International Harbor complex.[118]

Construction and improvement of Burns Waterway Small Boat Harbor was authorized in 1960, and a rock jetty along the eastern side was already trapping dredged material by 1969. The jetty system at Burns Waterway Small Boat Harbor was expanded in 1985 to provide a safer entrance configuration for small boats.[119]

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[117] Wood, W.L. and S.E. Davis. 1986. Indiana Dunes National Lakeshore shoreline situation report. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[118] Ibid.
[119] Ibid.

Figure 56. Burns Waterway Small Boat Harbor and Portage Burns Waterway.

Today, the harbor is protected by a 1,043-foot long rubble mound breakwater to the west and a 678-foot long rubble mound breakwater to the north. Maintenance repairs of both breakwaters were completed in FY 2003 and remain in satisfactory condition (Figure 56).[120]

Ogden Dunes

West of Burns Waterway Small Boat Harbor and east of the boundary of the Town of Ogden Dunes is open erodible beach owned by the National Lakeshore. The eastern most properties in Ogden Dunes are armored with vertical steel sheet piling walls (Figure 57). In 1997, a second steel seawall was constructed 19 feet north of the existing walls by the state of Indiana because of a threat to the old wall.[121] The concern was that the old wall might be undermined due to high lake levels, the presence of waves and excessive toe scour of the lake bottom in front of the wall. All the homes in Ogden Dunes are now protected by some form of erosion protection.[122]

[120] U.S. Army Corps of Engineers. 2009b. Navigation information. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois. Online. (http://www.lrc.usace.army.mil/co-o/burnsnallboat.pdf).
[121] Indiana Department of Natural Resources. 2009a. A synthesis of major topics in the Lake Michigan coastal area. Online. (http://www.state.in.us/nrc_dnr/lakemichigan/coadyn/coadyna.html).
[122] Indiana Department of Natural Resources, March 5, 1998.

Figure 57. Two Generations of Steel Sheet Pile in Ogden Dunes, IN.

U.S. Steel

Farther to the west is the City of Gary and a small stretch of National Lakeshore property that abuts the U.S. Steel-Gary Harbor complex (Figure 58). This area is characterized by wide beaches due to the U.S. Steel breakwater complex, built in 1966, that traps the westward moving sand.[123] This same effect can be seen at the NIPSCO Bailly power plant and east of the Michigan City Harbor jetty. [124]

Dredge/Fill Projects

Large tributaries to Lake Michigan used for passage by recreational and commercial vessels suffer from increasing sediment loads, making passage difficult, if not impossible. Dredging is a common mechanism used to alleviate this condition; however, dredging often raises environmental concerns involving reduced clarity of the water and resuspension of harmful agents during dredging, and disposal locations.[125]

NIPSCO

Dredging occurs in the vicinity of the Bailly Generating Station water intake structure, which is owned and operated by NIPSCO. Sand that accumulates near the intake structure must be periodically dredged to prevent sand and debris from clogging the screens and cooling tubes and to reduce the amount of sand entering the generating station (Figure 59).[126]

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[123] Indiana Department of Natural Resources, March 5, 1998.

[124] Indiana Department of Natural Resources. 2009b. A synthesis of major topics in the Lake Michigan coastal area. Online. (http://www.in.gov/nrc_dnr/lakemichigan/coadyn/coadynb.html).

[125] Indiana Department of Natural Resources. 2009c. A synthesis of major topics in the Lake Michigan coastal area. Online. (http://www.state.in.us/nrc_dnr/lakemichigan/watqual/watqual2c.html).

[126] U.S. Army Corps of Engineers. 2005. Application For Five-Year Navigable Waterways Act permit from the Indiana Department of Natural Resources for maintenance dredging in the vicinity of the Northern Indiana Public

Figure 58. U.S. Steel Breakwater.

When this structure was originally installed, it extended approximately 1,500 feet into Lake Michigan.[127] A substantial amount of sand began to accumulate lakeward of the Bailly Generating Station and around the intake structure during the mid to late 1970s and, today, the structure is approximately 700 feet from the beach line due to sand build up following the 1968 installation of a breakwater that prevents sand from flowing farther east to fill in washed out areas of the beach. As a result, sand in the areas around the intake structure must continually be dredged to prevent accretion into the intake, and a total of more than 1.5 million cubic yards of sand was removed in 1980, 1982, 1986, 1989, 1992, 1995, 1997, 2000, and 2007.[128]

In 2006, the USACE proposed to dredge this location annually through 2010, removing between 100,000 and 400,000 cubic yards of sediment each time. Dredge spoil disposal is proposed for the Ogden Dunes lakeshore.

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ervice Company (NIPSCO) Bailly Generating Station Water Intake Structure, U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois.

[127] Lugar, R. 2009. Lugar, Bayh secure funding to study shoaling near the Burns Waterway Harbor. Online. (http://lugar.senate.gov/press/record.cfm?id=274529).

[128] U.S. Army Corps of Engineers. 2008a. Chicago District

Figure 59. Bailly Generating Station water intake structure.

Burns International Harbor

The Port of Indiana Burns International Harbor (Figure 54) includes a 30-foot deep by 400-foot wide approach channel, a 28-foot deep outer harbor basin and two 27-foot deep by 620-foot wide harbor arms to the east and west.

The Chicago District of the USACE routinely undertakes maintenance dredging in the harbor. In 2007, 131,500 cubic yards of sediment was removed and deposited in an open lake disposal area one mile north of the harbor. Approximately 135,000 cubic yards of sediment were dredged in 2008. [129]

Burns Waterway Small Boat Harbor

The Burns Waterway Small Boat Harbor (Figure 56) contains 5,200 ft of Federal channel leading to the public marina. The width of the channel varies from 100 feet at the outer harbor basin to 65 feet beginning at the first private bridge located about 3,500 feet south of the outer harbor basin.

[129] U.S. Army Corps of Engineers. 2008c. FY08 Burns Harbor Channel Dredging NIPSCO. Online. (http://www.lrc.usace.army.mil/ct/bidabs-w912p6-08-b-0008.pdf).

The harbor is primarily a harbor of refuge providing access to several recreational docks and a small commercial charter fishing industry. This project was last dredged during the summer of 2000. Dredged material was placed just west of the harbor.[130] Depths are the authorized navigation depths for the project and are referenced to Low Water Datum for Lake Michigan.[131]

Michigan City Harbor

Dredging has been required in the harbor entrance channel to maintain an 18-foot depth required for navigation. From 1920 through 1978, a total of 1.6 million cubic yards of sand have been removed from this area.[132] The project includes a 425 to 150-foot wide by 14-foot deep navigation channel from Lake Michigan to the entrance of the Washington Park Marina, a 150-foot wide by 12-foot deep channel from the marina to Franklin Street, a 50-foot wide by 10-foot deep channel in Trail Creek from Franklin Street to Turning Basin #2, and a 50-foot wide by 6-foot deep channel from Turning Basin #2 to Miller Street. The harbor supports the U.S. Coast Guard, commercial fishing, and several recreational marinas. The above depths are the authorized navigation depths for the project and are referenced to Low Water Datum for Lake Michigan.[133]

Beach/Dune Construction (Nourishment)

Beach/dune construction, also known as "beach nourishment" or "beach replenishment", involves the introduction of sediment along a shoreline to increase or protect the size of the recreational beach (includes dune and berm construction and nearshore disposal of sediment for the purpose of shoreline stabilization). Three beach/dune construction nourishment projects, encompassing multiple construction episodes, were identified within INDU: 1) In the Vicinity of Mt. Baldy, 2) At Ogden Dunes/Beverly Shores, and 3) At Burns Waterway Small Boat Harbor.

Michigan City Harbor/Mount Baldy

Michigan City Harbor presents a physical barrier to littoral movement, contributing to beach and dune erosion along INDU. As a result, the USACE Chicago District has placed periodic sand nourishment immediately downdrift of the harbor since 1974. Beach/dune construction in the vicinity of Michigan City Harbor, however, dates back to 1930 when fill extended the beach far enough to reach the lakeward side of the present harbor basin (Table 7).[134]

In 1974, 227,00 cubic yards of sand was placed in front of Mount Baldy, and an additional 80,000 cubic yards was placed in the same location in 1981 (Figure 60). In 1996, the Michigan

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[130] U.S. Army Corps of Engineers. 2009b. Navigation information. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois. Online. (http://www.lrc.usace.army.mil/co-o/burnsnallboat.pdf).
[131] Ibid.
[132] Wood, W.L. and S.E. Davis. 1986. Indiana Dunes National Lakeshore shoreline situation report. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.
[133] U.S. Army Corps of Engineers. 2009a. Navigation information. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois. Online. (http://www.lrc.usace.army.mil/co-o/Mich_City.htm).
[134] Davis, S. E., W. L. Wood and L. Weishar. 1981. La Porte County, Indiana shoreline situation report. Great Lakes Coastal Research Laboratory, School of Civil Engineering, Purdue University, West Lafayette, Indiana.

City Harbor channel was again dredged, and 10,000 cubic yards of material was deposited offshore in a previously used lake-bottom disposal site for contaminated dredge material approximately 1.25 miles north-northwest of the Michigan City Lighthouse. Forty-five thousand cubic yards of material dredged from Trail Creek was pumped to the Mount Baldy beach area west of Michigan City.[135]

Also in 1996, the Crescent Dune area east of Mount Baldy received about 57,000 cubic yards of sand as mitigation for the littoral drift losses associated with the Michigan City Harbor structures. The USACE approved a local quarry as the source of sand to be used by the contractor, and additional sand has been trucked to the site almost annually since 1997.

A long-term plan resulting in the emplacement of up to 230,000 cubic yards of sand will continue at five to six year intervals for the next 50 years.[136]

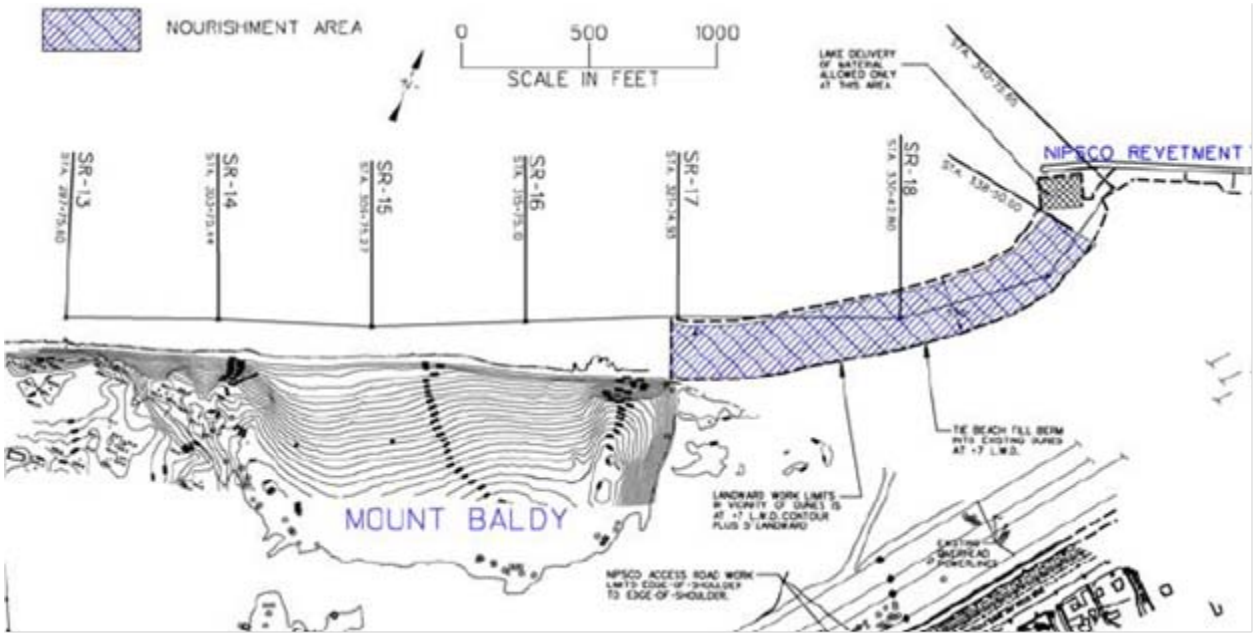

Figure 60. Beach/dune construction in the vicinity of Mt. Baldy/Michigan City Harbor.

[135] U.S. Army Corps of Engineers. 1996b. Fact sheet, Michigan City Harbor maintenance dredging. U.S. Army Corps of Engineers, Chicago, Illinois.
[136] U.S. Army Corps of Engineers. 1996a. Fact sheet, beach nourishment at Indiana Dunes National Lakeshore. U.S. Army Corps of Engineers, Chicago, Illinois.

Table 7. History of beach/dune construction in Indiana Dunes National Lakeshore. [137]

YEAR	Beach/Dune Construction by Project and Sediment Source (sediment volumes below in cubic yards)	
	Inland Source (Truck transport)	Michigan City Harbor (hydraulic dredge)
1930		N/A
1974	227,000	
1981	80,000	
1987		68,039
1988-1991		
1992		74,642
1993-1995		
1996	57,000	48,201
1997	73,000	
1998	107,000	
1999	36,000	
2000		60,000
2001	42,750	
2002		
2003	47,523	51,119
2004	17,5002[1]	
2005	9,500[2]	13,962
2006		41,298
2007	17,273[3]	
2008	17,273[4]	
TOTAL	**697,273**	**357,261**

1 23,700 tons placed in July 2004 equates to approximately 17,500 cubic yards (USACE)
2 11,443 tons placed in October 2005 equates to approximately 9,500 cubic yards (USACE)
3 19,000 tons from American Aggregate, Inc. Nimes MI placed in December 2007 equates to approximately 17,273 cubic yards (USACE)
4 19,000 tons from American Aggregate, Inc. Nimes MI placed in May 2008 equates to approximately 17,273 cubic yards (USACE)

NIPSCO/Ogden Dunes/Beverly Shores

Beach sand is regularly provided by the dredging efforts of NIPSCO, adjacent to the Burns International Harbor Complex, which must keep its water intake at the Bailly Plant from being clogged by sand trapped by the ArcelorMittal breakwater. Seventy-five percent of the dredged

[137] Indiana Dunes National Lakeshore. 2008. Indiana Dunes National Lakeshore History of Beach Nourishment.

sand is "by-passed" to Ogden Dunes to the west and deposited on the outer sand bar. The other 25% is "back-passed" to Beverly Shores (Figure 61).[138]

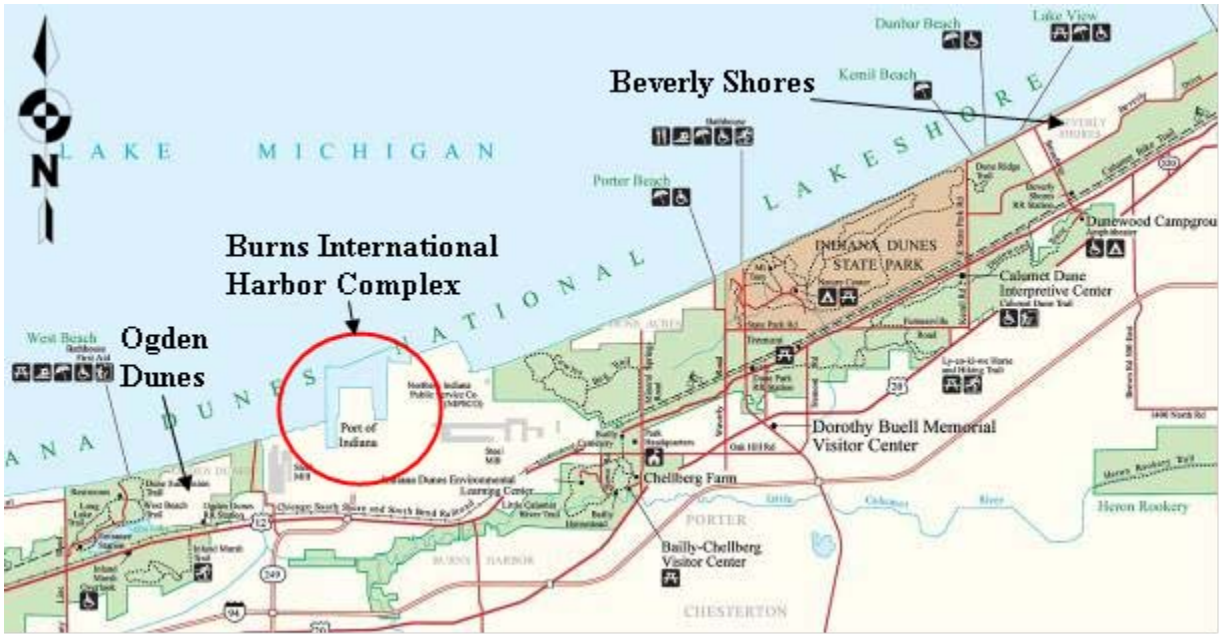

Figure 61. Ogden Dunes, Beverly Shores and Burns Harbor.

[138] Indiana Department of Natural Resources. 2009d. A synthesis of major topics in the Lake Michigan coastal area. Online. (http://www.in.gov/nrc_dnr/lakemichigan/coadyn/coadynf.html).

Appendix H. Jean Lafitte National Historical Park and Preserve.

Figure 62. Barataria Preserve, Jean Lafitte National Historical Park and Preserve (Photo by NPS Staff).

Summary of Findings

Jean Lafitte National Historical Park and Preserve (JELA) was established by Congress in 1978, and an additional 8,900 acres were added through the Omnibus Public Lands Management Act of 2009. The purpose of the park is to preserve natural and historical resources of the Mississippi River delta region, and to interpret them in such manner as to portray the development of the region's diverse culture.

JELA has six sites scattered throughout south Louisiana although only two - Barataria Preserve and Chalmette Battlefield – were evaluated (Figures 62 and 63). Three cultural centers and a visitor center were excluded.

A total of 52 coastal engineering projects were identified in and immediately adjacent to JELA including 26 bulkheads, one floodwall, three levees, six revetments and sixteen dredge/fill projects.

Figure 63. Jean Lafitte National Historical Park and Preserve.

Barataria Preserve

The Barataria Preserve unit (Preserve) in Jefferson Parish was established to preserve and interpret representative examples of the delta's ecosystem and its cultural overlay. The Preserve provides habitat for the characteristic flora and fauna of the delta, stop-over habitat for migratory birds and important nursery habitat for estuarine organisms. It contains many of the complex terrestrial and aquatic plant and animal communities that characterize the northern Gulf Coast.

The Preserve flanks the West Bank of the New Orleans metropolitan area, and separates the communities of Crown Point, Isle Bonne, Lafitte and Barataria from the metropolitan area. The northern and eastern boundaries of the Preserve are the levees that comprise the current West Bank Hurricane Protection system.

The NPS's vision for the Preserve focuses on preserving or restoring its ecosystem and providing an opportunity for recreation in a natural setting free from resource impairment. In addition, the NPS vision encourages those actions that sustain the region's nationally significant culture which contributes to the nation's diversity.

Prior to canal building in the Barataria basin, the area of the Preserve in the upper basin was connected to the Gulf of Mexico through two natural waterways. The first was through Bayou Barataria and the second through Bayou Perot. In addition, uninterrupted sheet flow was possible over the marsh surface between the upper and lower basins.

Dredging

Almost 48 miles of dredged canals have been identified within the boundaries of the Preserve. Canal building began concurrent with the first French colonial settlement and forest clearing of the natural levees for agriculture in the early eighteenth century. The earliest canals were drains for newly cleared agricultural fields, built to carry rainwater from the higher natural levees into adjacent swamps. Some of these drainage canals were extended as small craft navigation routes in the late eighteenth and early nineteenth centuries, linking plantation backlands with bayous and lakes. Examples include Millaudon Canal and Woods Place Canal. Other canals were dredged as meander cut-offs in natural waterways such as Bayou Segnette. With the advent of industrial logging in the late nineteenth century, canals were dredged by steam shovel to provide access to baldcypress timber. The most prominent such feature in the Preserve is Kenta Canal. Several finger canals were dredged at angles to Kenta and into the swamp to facilitate log removal. Traces of linear excavations, the drag marks left by huge logs being dragged, radiate out from the canal heads. These historic canals make up almost 15 miles of the canal network within the Preserve. Some historic canals, such as Delery Canal, have been naturally reclaimed and overtaken by floating marsh.

The twentieth century, and the discovery of oil and gas, brought a new era of canal building, and wider, deeper canals. There are about 13.5 miles of oil and gas exploration canals in the Preserve, of which about one mile has been restored to marsh and shallow open water habitat. These oil and gas drill hole access canals are straight, wide, deep and flanked by spoil banks. They end in a distinctive wide rectangular section, known as a "key-hole", where the well drilling operation took place. Linked to the oil and gas industry are pipeline canals, which account for just under six miles of open canal in the Preserve, and are narrow linear canals. "Pipeline Canal" contains a twenty inch natural gas line and bisects the Preserve from southwest to northeast. More than half of the pipeline is laid in the bed of historic Kenta Canal. Later pipelines laid through the Preserve used a less intrusive technique—they were laid in temporary excavations which were backfilled, allowing at least partial wetland vegetative recovery of the right-of-way.

Twentieth century navigational "needs" led to both canal building and to the dredging and widening of natural waterways. Both Bayou Segnette and Bayou Barataria (which forms part of the Preserve boundary) were widened and deepened by dredging. About 7.3 miles of Bayou Barataria along the Preserve boundary was channelized by the USACE in the 1930s to serve as a reach of the Gulf Intracoastal Waterway (GIWW). Erosion caused by boat wakes has more than tripled the width of the GIWW/Bayou Barataria, from averaging about 100 feet to over 400 feet. Dozens of prehistoric and historic archeological sites have been lost in the process. In the 1950s

the USACE dredged lower Bayou Barataria to become part of the Barataria Waterway, providing a link between the GIWW and the Gulf of Mexico. In 1958 the Bayou Segnette Waterway was dredged to link the GIWW and the Barataria Waterway with the community of Westwego and Company Canal. The Bayou Segnette Waterway includes 6.3 miles of a straight, deep navigation canal through the Preserve, and about 3.6 miles of channelized Bayou Segnette within the Preserve.

The GIWW, situated between the Preserve and the gulf, fundamentally changed the area's hydrology. First, it created an east-west conduit for water perpendicular to the line of flow. Second, the spoil excavated to create the channel was piled in an almost continuous fashion on both banks through the swamps and marshes southwest of the Preserve, creating a barrier to sheet flow, and storm surge.

Sections of the GIWW immediately adjacent to the Preserve below Bayou des Familles, created by channelizing Bayou Barataria where it was flanked by its own natural levees, caused little modification to sheet flow. East of Bayou des Familles, Bayou Barataria was a marsh drain, lacking substantial natural levees. In that reach little spoil was excavated, and some surface sheet flow still takes place, but bank-side erosion has been more severe.

Subsequent to the construction of the GIWW, oil and gas exploration led to the excavation of a series of canals, and petroleum product pipeline canals, which penetrated the GIWW's spoil banks, creating tidal connections of various volumetric prisms with water bodies to the south. In addition, the narrow meandering Bayou Barataria below the GIWW reach was channelized, deepened and straightened, and a deepwater navigation channel (the Barataria Bay Waterway) was dredged that linked it directly to the Gulf of Mexico.

Smaller bayous have also been dredged at unknown dates, as evidenced by spoil piles along the banks of Bayou des Familles and Bayou Bouef. However, with the exception of about 2000 feet of Bayou des Familles at its confluence with Bayou Barataria, these appear to have been small scale projects that did not fundamentally alter the depth and width of the bayous.

One major canal network extending six miles through the Preserve including "Twin Canals", "Parallel Canal" and "Horseshoe Canal", was dredged in the early 1970s, just before establishment of the park, to provide borrow for a levee system. The levees, built by a developer, were meant to facilitate drainage of wetlands for a planned subdivision. Finally, about one mile of modern canals dredged in the Bayou aux Carpes area were apparently dredged for local commercial purposes, linking the bayou to the highway and other canals.

Levees

Much of the upper estuary has been deprived of natural sheet flow from the higher areas of natural levee along the river and its distributary courses. These areas have been deforested and developed, and ringed by drainage or hurricane protection levee systems. This has required the

construction of pumping stations to lift rainwater over the levees and speed the discharge of pumped stormwater through outfall canals. Run-off that previously arrived in the Preserve through gradual down-slope sheet-flow now arrives at pumping station outfalls, highly concentrated point sources, dispensing water in high volume pulses of contaminated urban or agricultural runoff. [139]

Over time, these levees, originally constructed to surround forced drainage basins, have been improved and linked to form hurricane protection levees to protect development inside the drainage basins. Much of the boundary of the Preserve is now formed by hurricane protection levees built by the USACE and maintained by the Southeast Louisiana Flood Protection Authority, West Jefferson Levee District. Many of these levees were constructed in part from adjacent borrow pits or borrow canals. Most of the levees are earthen, but sections include floodwalls, constructed from steel sheet piles and concrete. About 35 miles of hurricane protection levee now separates the Preserve from adjacent drained and developed areas in Jefferson Parish.

Sections of dikes and levees constructed by landowner's to facilitate drainage and development are now within the Preserve boundary on Federal land. Included in about 64,000 linear feet (lf) are almost 16,000 lf of low dike on the so-called CIT tracts in the northeast corner, about 29,000 lf of higher earthen levees surrounding the so-called Bayou des Familles tract, and some 19,000 lf of levee surrounding the Bayou aux Carpes area. None of these levee systems are continuous enough at this point to form a complete hydrologic barrier. They were all prevented from being completed by legal and regulatory action. However, the CIT levees were functional long enough to allow drainage and subsidence of about 700 acres of baldcypress swamp, though forest remains intact.

Shoreline Stabilization

Approximately 15,600 feet of Lake Salvador shoreline in the Barataria Preserve is stabilized. This includes about eleven thousand feet of shoreline stabilized with a rock revetment. The rest is a geo-crib structure. The rock is either paced upon geotextile to form a "beach" along the immediate peaty marsh shoreline, or is placed upon geotextile on the lake bottom a distance offshore. At Cheniere Grand Coquille, an archeologic site, the rock is well offshore (beyond the zone of *in situ* archeologic material), and is backed by islands constructed from bottom sediment excavated to access the site for rock placement. Included in the shoreline stabilization along the lake is a 4675-foot geo-crib (two parallel rows of wooden pilings with a geotextile tube full of native sediments within). The geo-crib encloses an area of former marsh that experienced severe erosion. The USACE will place approximately 500,000 cubic yards of dredged sediment behind the geo-crib to re-create marsh through beneficial use. The geo-crib will be enhanced with a rock revetment facing to provide protection to the new marsh. On the other side of this reclamation

[139] National Park Service. 2006b. The Louisiana Coastal Protection and Restoration Plan and Jean Lafitte National Historic Park and Preserve Park position statement. Online. (http://www.nps.gov/jela/parkmgmt/upload/LACPR-Park%20Position%20Statement%20Feb%202008.pdf).

area, where it fronts the Bayou Segnette Waterway, there is approximately 6,700 feet of rock revetment, and about 150 feet of pile enforced wooden fencing to close off a canal.

The Gulf Intracoastal Waterway bisects the park at Jones Point. About one thousand feet of rock revetment lines the north bank of the waterway at that point.

There are bulkheads and other features related to the fishing camps, which have been a feature of the landscape along shorelines in the Barataria Preserve since prehistoric times. "Modern" camps are generally cabins that are accessed by water only, used for recreational purposes, and have limited, or no, utilities. Out of a total of approximately 200 modern camps within the preserve boundary, there were about 20 on federal land, of which 3 active leases remain. Most of the remainder, around 150, are on lands administered by the City of New Orleans as part of a bequest from the Edward Wisner Foundation.

Reclamation

The goal of NPS management at Barataria is to restore hydrologic function and natural habitat through reclamation of non-historic man-made features, including canals, adjacent spoilbanks, and dikes. To date, two oil and gas exploration have been restored to marsh and shallow open water habitat by degrading the spoil banks and using the material as backfill, for a combined total of about 5,600 feet of canal. Restoration will continue in 2010. Where these two canals meet the navigable Bayou Segnette Waterway, parallel earthen dikes were constructed to partially restrict tidal interchange. The combined distance of the four offset segments is about 900 feet.

Chalmette Battlefield

The Chalmette Battlefield unit (Battlefield) in St. Bernard Parish protects the site of the 1815 Battle of New Orleans, in addition to an ante-bellum house and the Chalmette National Cemetery, where over 15,000 veterans are interred.

Approximately 437 feet of Chalmette Battlefield shoreline along the Mississippi River is stabilized by a rectangular concrete bulkhead, which was originally constructed to protect a railhead. The remainder of the river bank, about 1,940 feet, is stabilized by concrete and a stone riprap revetment. The unit also includes approximately 2,570 feet of earthen (faced with concrete) mainline Mississippi River levee which occupies a wide corridor topped by a low concrete floodwall. The floodwall was installed in the early 1980s so as to minimize the width and impact of the levee footprint on the historic landscape. This compromise achieved that goal, but added a non-historic visual element. A gate through the floodwall allows riverboat visitors to gain access to the battlefield from a dock. [140]

[140] National Park Service. 2006b. The Louisiana Coastal Protection and Restoration Plan and Jean Lafitte National Historic Park and Preserve Park position statement. Online. (http://www.nps.gov/jela/parkmgmt/upload/LACPR-Park%20Position%20Statement%20Feb%202008.pdf).

Appendix I. Lewis & Clark National Historical Park.

Figure 64. Cape Disappointment Lighthouse: Cape Disappointment, Ilwaco, WA (Photo by Andrew Cier).

Summary of Findings

The Lewis and Clark National Historical Park (LEWI) encompasses 12 sites along 40 miles of Pacific coast in Oregon and Washington (Figures 64 and 65). Twelve coastal engineering projects were identified in and immediately adjacent to LEWI including four revetments, three jetties, two groins, one bulkhead, and two dredge/fill projects.

The most prominent coastal engineering effort in LEWI is the jetties constructed at the Mouth of the Columbia River (MCR) between Cape Disappointment in Washington and Fort Stevens in Oregon. The jetties, comprised of over twelve million tons of stone, were built and maintained at a total cost of $1 billion. More than 600 million cubic yards of sediment has been discharged to the ocean as a result of MCR jetty construction. In addition, 190 million cubic yards of sediment has been dredged from the MCR channel between 1904 and today. Present annual average MCR channel dredging is 3.5 million cubic yards of sand.

Shoreline Stabilization

Dismal Nitch (WA)

A small narrow-gauge railroad had been developed between Ilwaco and the northern villages of the Long Beach Peninsula with service that began in 1889. Later in 1906 under the ownership of the Oregon Railroad and Navigation Company the line was extended from Ilwaco to Megler, with a new deep water port developed at Megler at the same time. Its terminus was at the east end of the present day Dismal Nitch site.

Construction of this rail extension to Megler changed that part of the shoreline forever, and obscured the wooded shore and cliffs known to native peoples, fishermen and the members of the Lewis & Clark expedition. Immense boulders were carved from the cliffs and poured into the river to create an embankment in order to protect the rail construction from erosion. The construction of the rail terminal and ferry landing put the name "Megler" on the map, and when the four-mile long bridge was built across the Columbia in 1963-66, it was named the "Astoria-Megler Bridge".[141]

The existing Safety Rest Area (SRA), now designated the "Dismal Nitch Safety Rest Area", was built in 1968-69 over filled land that served the ferryboat landing. Ferry terminal structures were dismantled and pilings at the boat landing area at the east end of the site were removed.

A larger area of rock fill topped by one foot of topsoil was built to accommodate the SRA. At the west end of the current site, additional rock and topsoil fill had been placed at the site from 1956 to 1961 to create this unpaved and undeveloped portion of the site which exists today.

When the SRA was constructed on the site of the old ferry landing in 1968-1969, the existing embankment was extended to the south with additional imported fill. Two thousand tons of heavy, loose rip-rap was laid along the bank to protect it from erosion topped by one foot of topsoil for landscaping (Figure 66). The landfill was obtained by demolition of adjacent cliffs and by importation.[142]

[141] National Park Service. 2006a. Dismal Nitch master plan. Online. (http://home.nps.gov/lewi/planyourvisit/upload/DismalNitchMasterPlan12_4_06-sec1.pdf).
[142] Ibid

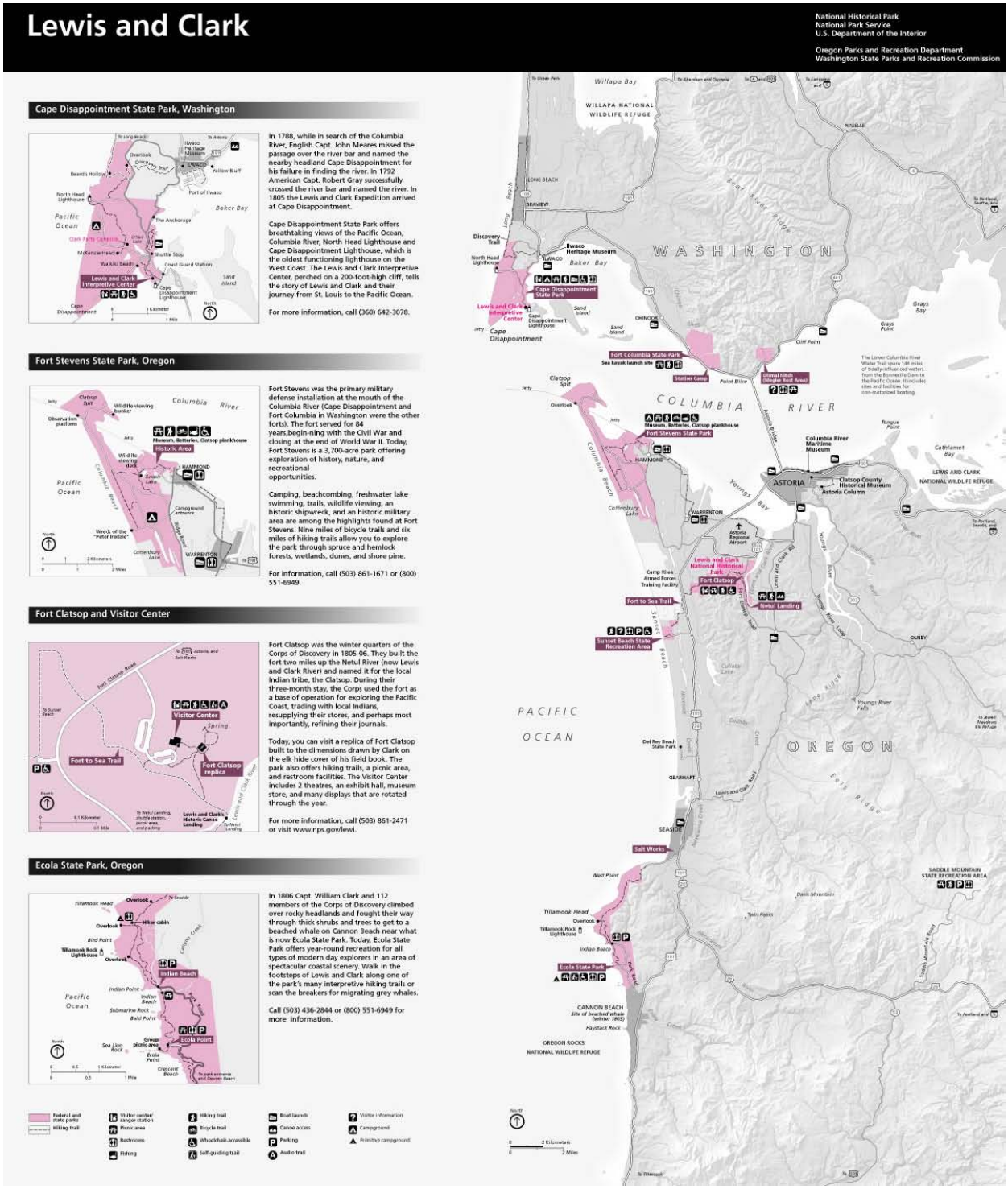

Figure 65. Lewis & Clark National Historical Park.

Figure 66. Rock revetment at Dismal Nitch.

Station Camp (WA)

The entire length of the Station Camp unit in Washington (approximately 6,500 feet of shoreline) is stabilized with a rock revetment (Figure 67) to protect State Highway 101.

Fort Columbia (WA)

Significant lengths (over 2,000 feet) of the Columbia River shoreline on either side of Fort Columbia are stabilized with a riprap revetment. Sections of road and revetment that were damaged by wave action during winter storms in 2007 were repaired in 2008 by the Washington State Department of Transportation at a cost of $300,000.[143]

Fort Clatsop & Netul Landing (OR)

Fort Clatsop is located on the Lewis and Clark River, approximately two miles upstream from the confluence of the Lewis and Clark and Columbia Rivers. Approximately 200 yards further upstream of Fort Clatsop is a 5-acre site now called "Netul Landing", which includes a

[143] Washington State Department of Transportation. 2008. Express Lane – January 12 – 18, 2008: Weekly summary of WSDOT news and activities. Online. (http://198.238.212.10/Communications/ExpressLane/2008/01_18.htm).

canoe/kayak launch along with other visitor use infrastructure. The Netul Landing site has a concrete bulkhead along 60 feet of Lewis and Clark River shoreline at the bus entrance, numerous pilings and a small rock revetment located north of the bulkhead on the shoreline (Figure 68).

Jetties

The USACE has been involved in improving navigation at the MCR since the 1870s. Early work at the mouth included detailed surveys of the Columbia River bar and the construction of jetties (Figure 69). Eventually the work included dredging a navigation channel from the ocean to the estuary.

According to the Portland District of the USACE, abnormal numbers and sizes of storms

Figure 67. Station Camp Rock Revetment.

between 2000 and 2005 have accelerated degradation of the jetties caused by wave impact. In addition, the sand spits, upon which the jetties are founded, have been receding, thus undermining the outer portions of the jetties. Beaches on the ocean sides of the jetties, formed initially as a direct result of jetty construction, have also been receding gradually over the years, thus exposing previously protected sections of the jetties to storm waves.[144]

Due to the need for more immediate repairs to avoid a potential jetty breach at critical locations, the USACE is initiating design for shorter-term interim repair at those locations. Interim jetty repair construction commenced with the North Jetty repair in 2005. The South Jetty Interim Repair began in April 2006 and was completed in 2007.[145]

South Jetty: Clatsop Spit, OR

In July 1884, Congress authorized construction of a jetty at Fort Stevens with an initial appropriation of $100,000. The improvement called for a 4.5-mile-long low-tide jetty, extending from near Fort Stevens on the south cape by a slightly convex curve northward to a point about three miles south of Cape Disappointment. Completion of the South Jetty at the MCR required 10 years and cost just under $2 million. After 1889, construction began to have noticeable effects on the bar and in 1893, a Board of Engineers convened to assess the results attained and to recommend any necessary changes to the original project. In its report, the Board described the jetty as "a long thin, narrow backbone of solid material resting upon a very doubtful foundation, against which the forces in action at the locality have accumulated large quantities of the shifting sands."

The Board believed that the durability of the jetty depended upon the continued accumulation of this sand, for it served to reduce the wave energy impacting the structure. In order to control the tidal flow across the jetty, which removed the protective sand deposited along the base of the structure and to cut the damage to the jetty tramway from floating debris, the Board urged for the construction of four rock groins - short segments perpendicular to the jetty's north side - to prevent the tide from displacing sand surrounding the jetty.[146]

When completed in 1895, the jetty measured 30 feet wide at its crest and from 80 to 90 feet across its base. It maintained a height of ten to twelve feet above the mean level of lower low water except at the outer end where the height sloped sharply down to four feet. Measurements in the channel over the bar showed that a minimum of 30 feet had been obtained by the improvement, and in many places 31 feet of safe water could be relied upon. Benefits to navigation were substantial and, within two years of completion, the value of tonnage passing over the bar more than doubled from the previous decade.

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[144] U.S. Army Corps of Engineers. 2009e. Top issues: Columbia River Jetties. Online. (https://www.nwp.usace.army.mil/issues/jetty/history.asp).

[145] Ibid

[146] Paulson, S. 2007. Improvement of mouth of the Columbia River. Online. (http://www.ohs.org/education/oregonhistory/historical_records/dspDocument.cfm?doc_ID=DFB3AD7C-A955-583F-530036194C6C3E2D).

Figure 68. Pilings and Rip Rap Revetment at Netul Landing.

Despite the benefits provided by the completion of the South Jetty, substantial new work was necessary by 1902 in order to support navigation on the lower Columbia River. Annual surveys made at the mouth since 1897 showed that "marked shoaling" each year diminished the project depth. Nor was the channel stabilized, as was essential for the ever larger ships desiring entrance into the Columbia River.

Thus, in 1902, the Board of Engineers submitted to the Secretary of War a project designed to eliminate the shoaling and re-establish a deep and dependable channel. The plan called for major repairs to the existing four-mile jetty, a 2.5-mile extension, and channel dredging. The project

depth was to be 40 feet. The cost, estimated at $2,510,000, included $250,000 to re-outfit the old Army transport Grant as a dredge. The authorization for work on the South Jetty also provided for a jetty on the north side of the mouth of the Columbia from Cape Disappointment, if that were necessary to obtain project depth.

The ocean soon began to take its toll on the jetty, and it was rebuilt starting in 1906. By 1913, the district completed the new work on the South Jetty at a cost of nearly $8 million. As reconstructed, the average top width of the jetty was 25 feet and the height above sea level varied from 10 feet at the shore end to 24 feet at the outer end.

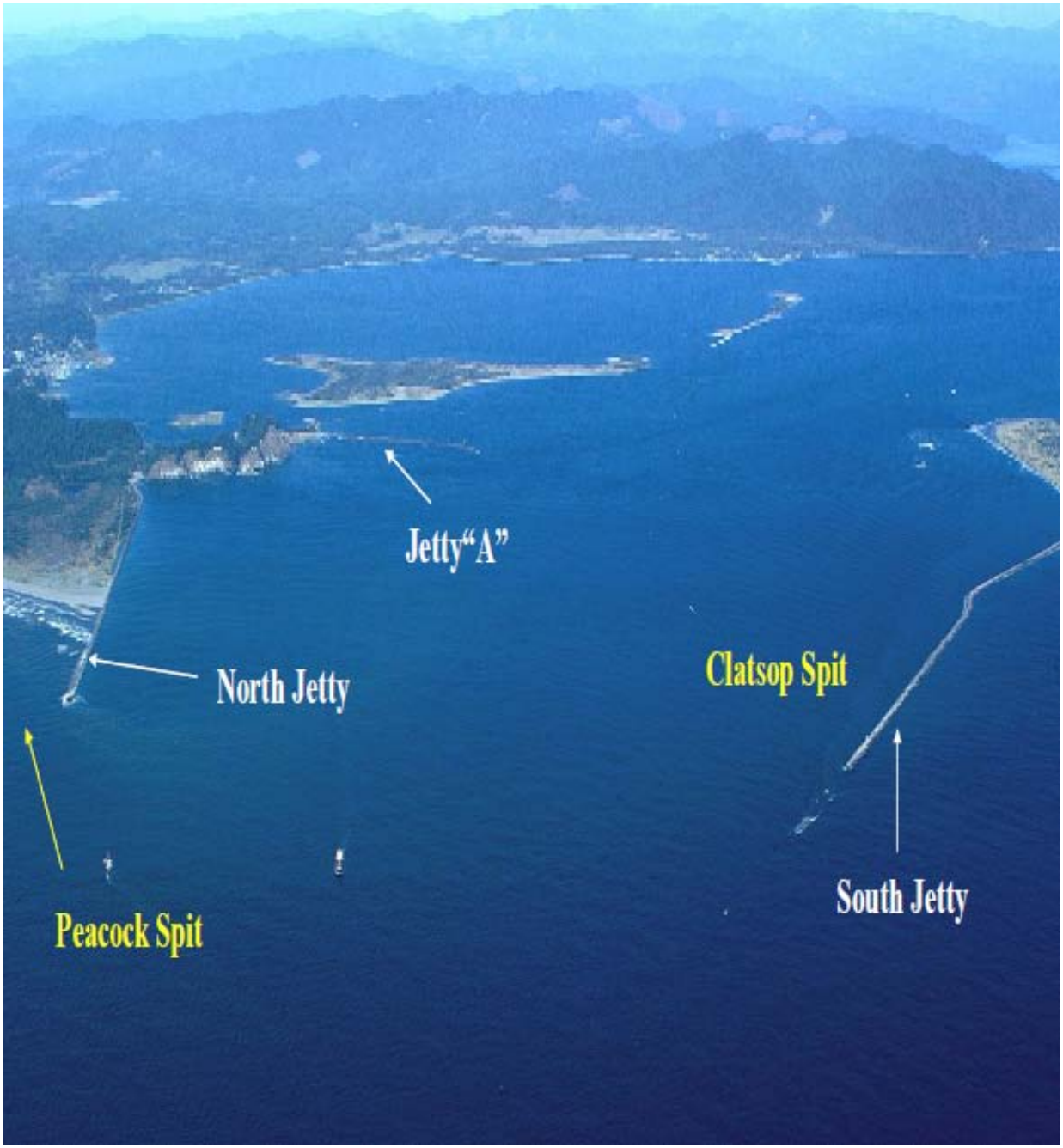

Figure 69. Jetties at the mouth of the Columbia River.

According to the USACE, the last repairs on the inland portion of the jetty were made in 1982, and work was done farther out in the mid-1960s. Fearing that a five-year storm could breach deteriorated sections of the jetty and flood the shipping channel with sand, the USACE embarked on a program in 2005 to complete interim repairs that would prevent a jetty breach for the next 10 to 15 years. Plans are under way for a more durable long-term rehabilitation of the jetties in the future.

On February 16, 2005 the USACE awarded a contract for the MCR South Jetty Interim Repair to Kiewit Pacific, of Vancouver, Washington. The base contract was awarded for $11.4 million to repair the inland reach of the jetty with options of about $7.7 million that could be exercised for repairs to the seaward reach.

The interim repair contract for the south jetty occurred in two phases with the inland phase completed in 2006 and the seaward reach completed in 2007. The job involved placing upwards of 145,000 tons of jetty stone in two areas over a 5,300-foot-section of the jetty.

The project restored the jetty to 30 feet wide at the top, which will be 25 feet over the mean lower low water level. Kiewit Pacific acquired rock for the project from a single source, Martin Marietta's Beaver Lake Quarry in Skagit County, Washington.

Rocks, ranging in size from 11 tons to about 20 tons, were barged from the Port of Anacortes through Puget Sound and the Strait of Juan de Fuca to the Pacific Ocean, down the Washington Coast and through the mouth of the Columbia to the Nygard Logging dock at nearby Warrenton, Oregon. They were stockpiled at Nygard and trucked several miles through Fort Stevens State Park to the job site. [147]

The rocks placed along a 2,100-foot long stretch of Reach A weighed an average of 11 tons while the rocks placed along 2,200 feet of Reach B averaged 16 tons due to more severe wave action at the end of the jetty. The contractor used a Manitowoc 4600 Vicon crane, specially built to handle the increased side loads of jetty work, to place the rocks. [148]

North Jetty: Peacock Spit, Cape Disappointment, WA

Construction of the South Jetty resulted in a depth of only 36 to 37 feet of safe water over the channel entrance. Therefore, the USACE decided to go ahead with construction of the North Jetty so that the desired project depth of 40 feet could be accomplished.

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[147] Paulson, S. 2007. Improvement of mouth of the Columbia River. Online. (http://www.ohs.org/education/oregonhistory/historical_records/dspDocument.cfm?doc_ID=DFB3AD7C-A955-583F-530036194C6C3E2D).

[148] Noll, P. 2009. Online. (http://www.paulnoll.com/Oregon/Tourism/Coast-Astoria-Lincoln/Columbia-Jetty-west.html).

Construction began in the spring of 1914 and was completed by May 1917. As finished, the North Jetty had a top width of 25 feet and an elevation varying from 28 to 32 feet above mean lower low water. Surveys made the following spring showed that the depth across the entrance at all locations measured at least 40 feet. When completed, the jetties at the mouth of the Columbia River contained 9,000,000 tons of stone and were the largest in the world.

The cost of the 2.5-mile North Jetty was roughly $5,000,000. Engineers used the same methods of operation on the North Jetty as they had employed on the south structure. Because of its more sheltered location, however, work proceeded more rapidly on the northern jetty than on the southern one. The workers found it possible to construct trestle and place rock throughout the entire year, whereas work had to be suspended each winter on the South Jetty.

With the rubble stone jetty exposed to incessant wave action, normal repair operations by barge were impossible. Maintenance had to be carried out by constructing expensive trestles, and deferred until the benefits justified the cost.

By 1931, the sea had flattened the South Jetty to the low-water level and had spread out the stone so that the width of the outer 2.75 miles was 200 feet at low-water level. From 1931 to 1936, the USACE Portland District oversaw the retopping of the South Jetty to 25 feet above low water to within approximately 3,300 feet of the outer end of the jetty. The reconstruction project added 2,200,000 tons of stone to the structure, with the average rock weighing up to 25 tons each.

To halt the disintegration at the sea end, two methods were employed. First, the outer end was injected with 12,787 tons of hot asphaltic mastic to bind the stones into an impregnable mass, but it failed to prevent the continued breakdown of the end. Finally, a solid concrete terminal was constructed above the low-water level. This proved effective. As completed, the South Jetty top width varied from 45 to 70 feet, with an elevation of 26 feet above mean lower low water. The base width of the outer portion measured approximately 350 feet, and the total height from the bottom reached up to 76 feet.[149]

Jetty "A": Cape Disappointment, WA

Jetty A is a 0.3-mile long spur jetty constructed by the USACE in 1939 approximately 3 miles upriver from the tips of the North and South Jetties. It extends into the river from the Washington side and is designed as a training structure to direct flow away from the base of the North Jetty.[150, 151]

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[149] U.S. Army Corps of Engineers. 2009e. Top issues: Columbia River Jetties. Online. (https://www.nwp.usace.army.mil/issues/jetty/history.asp).

[150] U.S. Army Corps of Engineers. 2009f. Top issues: Columbia River Jetties. Online. (https://www.nwp.usace.army.mil/issues/jetty/faq.asp).

[151] Demirbilek, Z., L. Lin and O.G. Nwogu. 2008. Wave modeling for jetty rehabilitation at the mouth of the Columbia River, Washington/Oregon, USA. Defense Technical Information Center, Ft. Belvoir, Virginia.

Dredging

The MCR deep-draft navigation project consists of a 1/2-mile wide navigation channel extending for about six miles through a jettied entrance (three miles seaward and shoreward of the tip of the North Jetty) between the Columbia River and the Pacific Ocean (Figure 70). The northerly 2,000 feet of the channel is maintained at 55 feet and the southerly 640 feet is maintained at 48 feet, with an additional five feet of depth allowed for advanced maintenance. The channel was deepened to its present depths in 1984 and has been maintained at those depths to date. [152]

The USACE has been dredging the MCR entrance since 1904. Long-term net removal of littoral sediment from the Columbia River system by dredging amounts to 3.3 million cubic yards per year for the period 1939 to 1999.[153] At present the USACE Portland District dredges 4-5 million

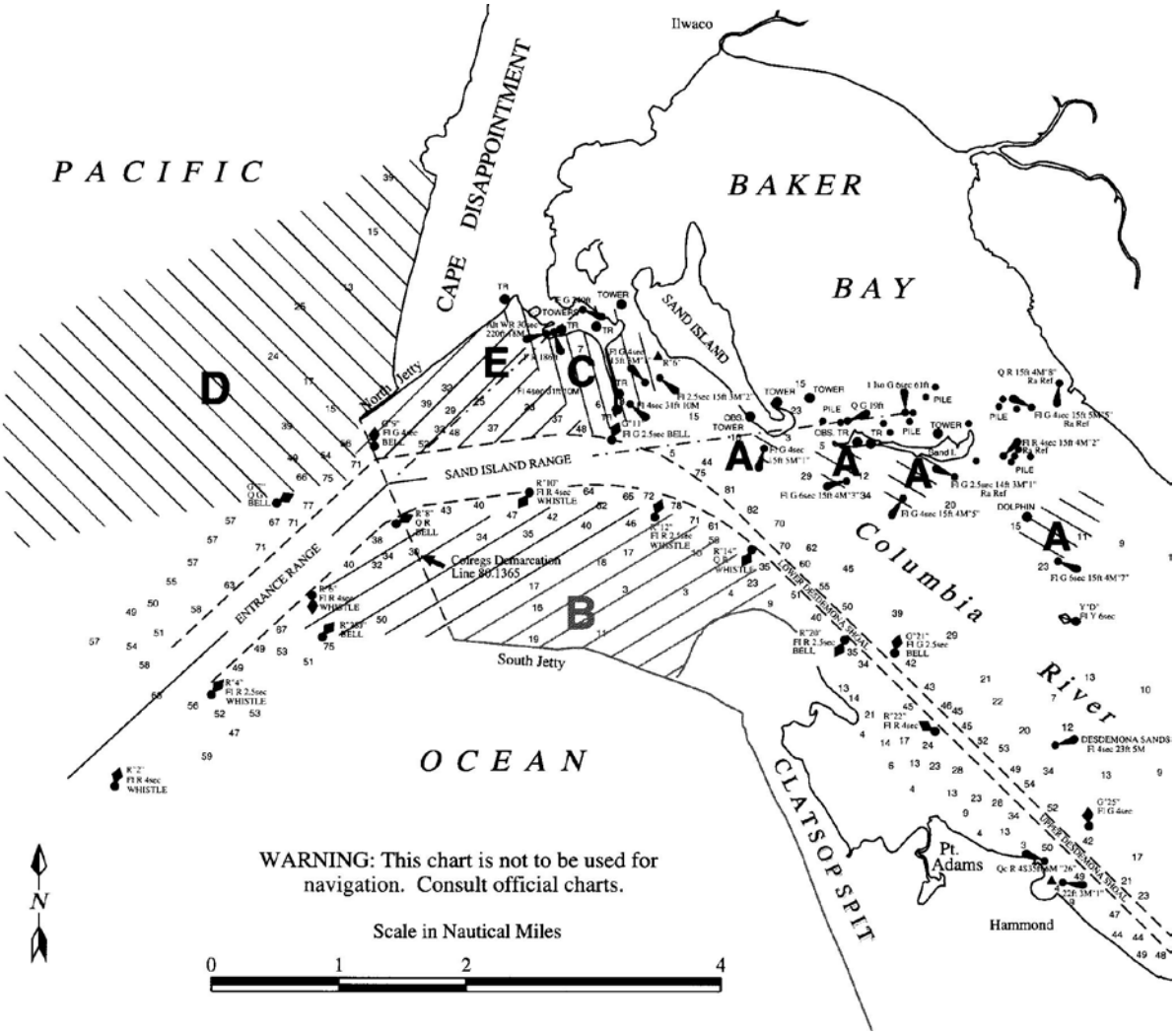

Figure 70. MCR Channel.

[152] U.S. Army Corps of Engineers. 2007. Final environmental assessment repair of North and South Jetties mouth of the Columbia River, Clatsop County, Oregon and Pacific County, Washington. Online. (http://www.nmfs.noaa.gov/pr/pdfs/permits/acoe_ea.pdf).

[153] Ibid.

cubic yards per year of sand and places the material in open water disposal sites.[154] Anthropogenic changes to the Columbia River and MCR have contributed to a reduction in sand supply to the Pacific Northwest's coastal system by a factor of three from 5.6 million cubic yards per year between 1878 and 1935 to 1.4 million cubic yards per year for the period 1958 to 1997.[155] Ongoing erosion of the mid-continental shelf and nearshore at the MCR, including Peacock Spit to the north and Clatsop Spit to the south, are resulting in increasing nearshore wave energy, increased shoreline erosion, and increased risk of jetty undermining and breaching.[156]

Hopper dredging was started in 1904, with the dredged material placed offshore or in estuarine disposal sites. Starting in 1945, ocean disposal sites were specified and used for the disposal of dredged material. In addition, regular annual maintenance dredging was commenced in 1945. In 1956, the navigation channel was deepened to 48 feet, and deepened again in 1984 to a depth of 55 feet on the northern side of the channel. The deeper channel required an increase in the amount of dredged material placed offshore.

Between 1958 and 2003, it appears that dredged material placed at Ocean Dredged Material Disposal Site (ODMDS) E has been transported primarily north-northwest (and then east-southeast). Dredged material placed within the eastern half of ODMDS E is believed to be transported north-northwestward onto the crest of Peacock Spit, and ultimately toward Benson Beach.

Dredged material placed within the western half of ODMDS E is believed to be transported west-northwestward onto the crest and ocean-facing slope of Peacock Spit. Dredged material that is transported onto the crest and ocean-facing slope of Peacock spit appears to be carried along the flank of the spit in a clockwise path, and ultimately carried back toward shore. Dredged material placed in the eastern half of ODMDS E appears to be subjected to a higher transport potential than dredged material placed in the western half of the site.

The USACE speculates that if dredged material had not been placed at ODMDS E (65 million cubic yards (MCY) during 1973-2003), erosion would have occurred over a much larger area of Peacock Spit than what is indicated at present. Consequently, Benson Beach (Ft. Canby State Park) would have experienced significantly higher erosion (landward recession). Dredged

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[154] Osborne, P. and N. Sultan. 2005. Dredging operations and sand placement alternatives Southwest Washington Littoral Drift Restoration Project, Mouth of Columbia River, North Jetty. Online. (http://www.washington-coastal.com/downloads/2005%20BB%20Alternatives%20report%20v5_drFINAL.pdf).

[155] Gelfenbaum, G., C.R. Sherwood, C.D. Peterson, G.M. Kaminsky, M. Buijsman, D.C. Twitchell, P. Ruggiero, A.E. Gibbs, and C. Reed. 1999. The Columbia River Littoral Cell: A sediment budget overview. Proceedings of the Coastal Sediments '99 Conference. American Society of Civil Engineers. 1660-1675.

[156] Allan, L.C. 2002. Columbia River Littoral Cell technical implications of channel deepening and dredge disposal. Open File Report O-02-02. Oregon Department of Geology and Mineral Industries, Portland, Oregon.

material placed at ODMDS E does not appear to be moving south toward the navigation channel (at least in any appreciable quantity).[157]

Proposed Dredging

Under a proposed channel deepening and maintenance project, the USACE would continue to dredge approximately 4.5 to 5.7 million cubic yards per year. The following dredged material placement areas will be used to accomplish this work (Figure 71).[158]

North Jetty Site

This site is near the MCR North Jetty and closely matches a historical placement site. The USACE reoccupied this site starting in 1999 to protect the jetty from potential undermining. Approximately 100,000 to 500,000 cubic yards of sand will be placed in this site each year.

Shallow Water Site

This ODMDS is designated by U.S. EPA under Section 102 of the Marine Protection, Research and Sanctuaries Act (MPRSA). This site is located off the end of the North Jetty and is highly dispersive. Of the 27 million cubic yards that has been placed in the Shallow Water Site between 1997 and 2007, less than 10% remained within the site at the start of the dredging season in 2008. Most of the material dispersing from this site moves onto the ebb tidal shoal and to the north and northwest into the Southwest Washington littoral cell. The USACE and U.S. EPA actively manage this site to feed material to the Peacock Spit area, feed the littoral drift to the north, shore up the shoal that the jetty rests upon, and minimize adverse wave amplifications.

Deep Water Site

This ODMDS is designated by U.S. EPA under Section 102 of the MPRSA and is located approximately six miles from RM 0 off the coast of Oregon. Use of the site will be managed to allow maximum use of the other disposal sites to the maximum extent practicable or when weather or sea conditions preclude the safe use of the other disposal sites.

Prospective New Disposal Site (404 site) south of the MCR South Jetty

The USACE, in collaboration with the State of Oregon and the Lower Columbia Solutions Group is currently considering the use of a new dredged material beneficial use site south of the MCR South Jetty in the state of Oregon.

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[157] U.S. Army Corps of Engineers. 2003. Utilization and recommendation report MCR ocean dredged material disposal sites. U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Online. (https://www.nwp.usace.army.mil/op/n/projects/mcr/docs/URMCRApr04.pdf).

[158] U.S. Army Corps of Engineers. 2009d. Public notice reference number: PM-E-09-05 channel maintenance dredging at the mouth of the Columbia River. U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Online. (https://www.nwp.usace.army.mil/op/n/docs/2009/MCRDredgingDisposalPublicNotice2009.pdf).

Based on previous bathymetric and vibracore studies, this area is losing between 88,000 and 270,000 cubic yards per year and pre-historic clay layers are being exposed. Use of this site is intended to reverse this trend, and as the material gradually builds up at the new site, it would also serve to break waves at a distance from the South Jetty with the intent of decreasing wave damage to the jetty itself.

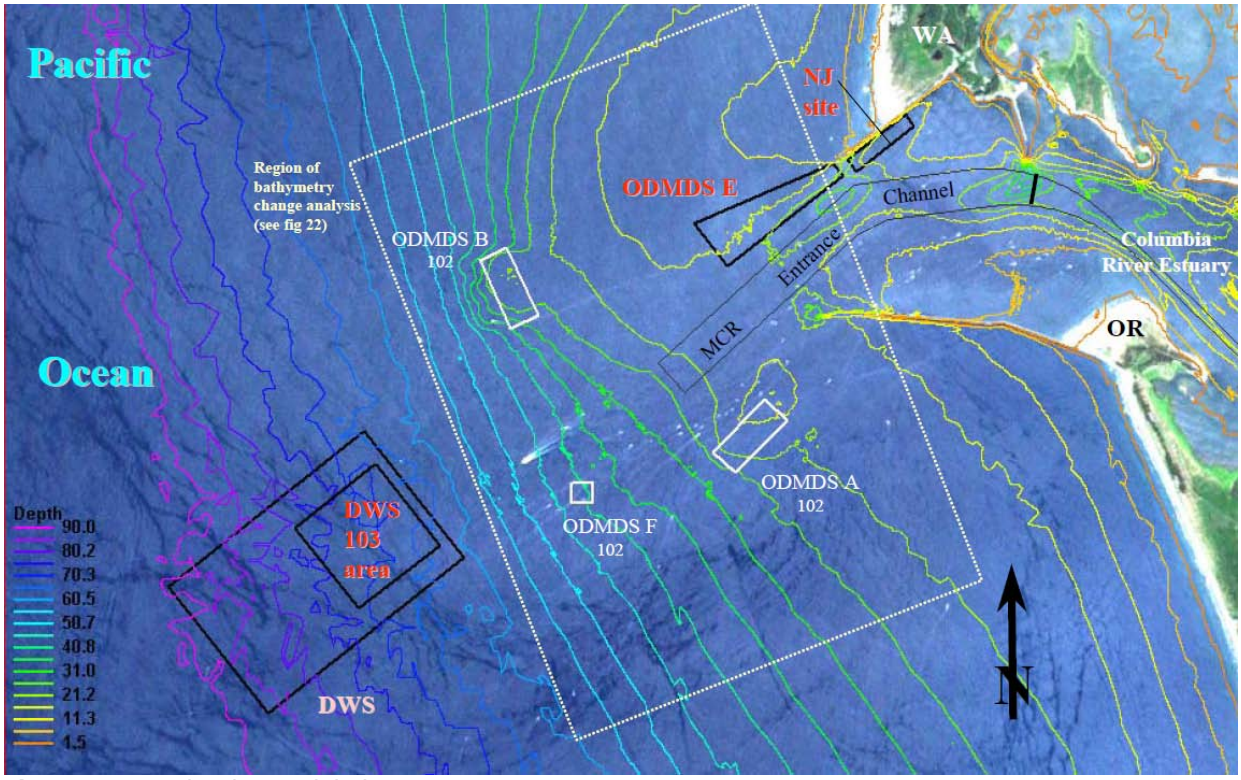

Figure 71. Dredged material placement areas.

Beach Nourishment

Cape Disappointment State Park (Benson Beach, WA)

In 2002, approximately 43,000 cubic yards of dredged sediment from the MCR project was placed directly on Benson Beach as a test program to determine the feasibility of placing sediment through direct pump-off from a hopper dredge (Figure 72).

In 2008, beneficial placement of 125,000 cubic yards of material occurred in the intertidal and uplands adjacent to the MCR North Jetty at Cape Disappointment State Park. The sand berm area

Figure 72. Benson Beach, north of the North Jetty.

was damaged during the storms that occurred in December 2007 and was needed to lessen the probability of damage to the North Jetty from future storms.[159]

A joint WA Department of Ecology and USACE public notice (CENWP-PM-E-08-07) was issued on May 28, 2008. This notice included both the MCR North Jetty Berm Repair and Southwest Washington Littoral Drift Restoration (Benson Beach) Regional Sediment Management (discussed below). The Water Quality Certification was issued on July 2, 2008 by the State of Washington and is valid until 2012. A Finding of No Significant Impact was signed July 3, 2008, completing compliance requirements of the National Environmental Policy Act.

Nearshore Placement South of the South Jetty, OR

A Nearshore Placement, South of the South Jetty, Collaborative Group, convened under the auspices of the Lower Columbia Solutions Group, is working to develop a potential nearshore beneficial use site on the ocean side of the South Jetty to assist long-term stability of that jetty.

[159] Moritz, H. 2008. Challenges in maintaining large coastal navigation structures and sediment-nourished shoals. Online. (http://chl.erdc.usace.army.mil/dirs/events/275/21%20Hans%20Moritz%2085th%20CERB.pdf).

The beneficial purpose of this placement would be to restore sand in an area that would protect the South Jetty from adverse wave conditions. During September 2005, a research disposal of 34,254 cubic yards of material was placed in this location by the Federal Dredge Essayons under an MPRSA Section 102 research permit issued by U.S. EPA to the Port of Astoria/Lower Columbia River Solutions Group.[160]

SW Washington Littoral Drift Restoration

Under Regional Sediment Management, the USACE is continuing to work with the State of Washington, Pacific County, the Southwest Washington Coastal Communities and the Lower Columbia Solutions Group on another proposed use of dredged material which will supply sand to the littoral drift system (ocean currents running along the shoreline) which moves sand northward along the Long Beach peninsula as a beneficial use of sediment.

The USACE evaluated potential impacts associated with this project in an Environmental Assessment issued for public review on June 5, 2006 under Public Notice Number CENWP-PM-E-06-02. If authority and funding are provided, up to 1,000,000 cubic yards of sand could be placed in the intertidal zone on Benson Beach. A Finding of No Significant Impact was signed July 3, 2008, completing compliance requirements of the National Environmental Policy Act. The Water Quality Certification is valid until 2012.

[160] U.S. Army Corps of Engineers. 2006. Public notice reference number: NWPOD-CRA-F-06-001, Channel maintenance at the mouth of the Columbia River. Online. (https://www.nwp.usace.army.mil/op/n/projects/mcr/docs/PNMCRCMJul06.pdf). U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Appendix J. Timucuan Ecological and Historic Preserve.

Figure 73. Entrance to Fort Caroline,Timucuan Ecological and Historic Preserve, FL (photo courtesy of InsideFlorida.com).

Summary of Findings

The Timucuan Ecological and Historic Preserve, created by Public Law 100-249 in 1988, is 46,000 acres of salt marsh grasses, waterways and wooded islands (Figures 73 and 74). Approximately 75 percent of the Timucuan Ecological and Historic Preserve (TIMU) is comprised of wetlands and waterways that form an extensive estuarine system between the Nassau and St. Johns Rivers. Less than 30 percent of TIMU is under NPS direct management; the remainder falls under the auspices of more than 300 different landowners.

A total of 105 coastal engineering projects were identified in and immediately adjacent to TIMU including 45 bulkheads, 40 revetments, four jetties, two groins, one dike, one breakwater, and twelve dredge/fill projects.

Figure 74. Timucuan Ecological and Historic Preserve (TIMU).

Inlet Stabilization

Shortly after the beginning of the Civil War, Union troops occupied Fort Steele, a fort built by Confederate troops on the beach near Mayport and St. Johns Lighthouse. After the Civil War, Mayport resumed its role as a fishing village and tourist attraction until 1867, when the lumber industry revived the St. Johns River economy as northern investors opened sawmills and retail stores throughout Jacksonville.[161]

In 1880 the government modified the St. Johns' bar by constructing jetties from large stones, lime rock, and oyster shell on the south and north sides of the river (Figure 75). At completion in 1895, the south jetty reached 2.5 miles into the Atlantic while the northern jetty extended for three miles into the ocean.[162]

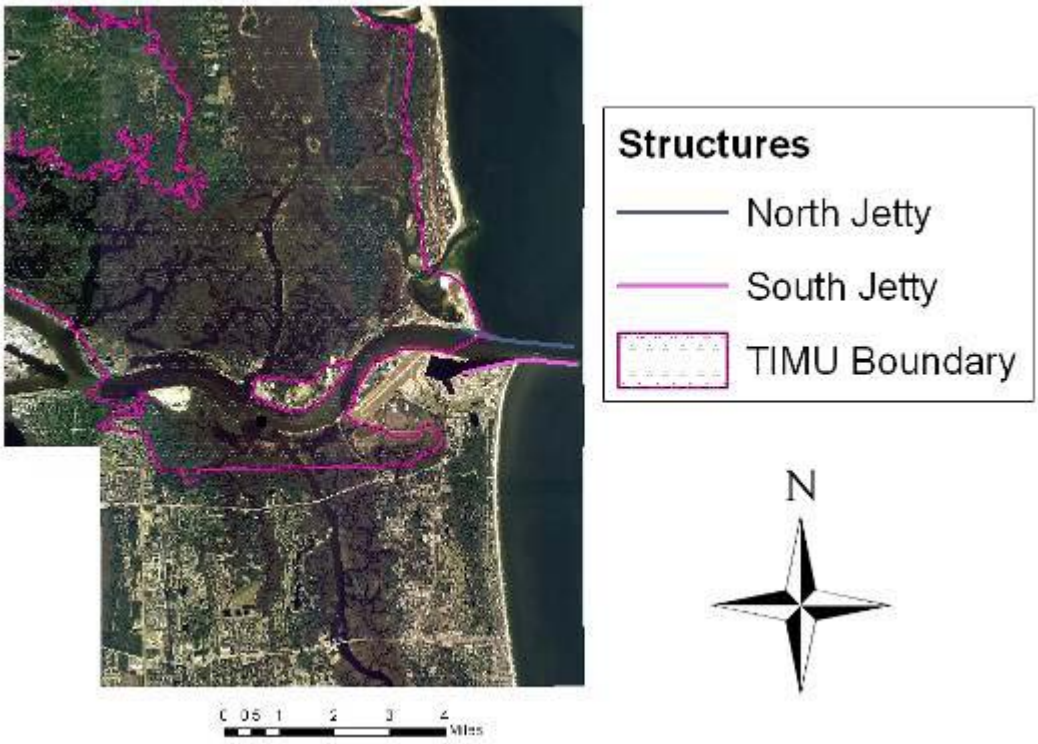

Figure 75. St. Johns River Jetties.

The north jetty, which is within the TIMU boundary currently, extends into the Atlantic Ocean about 7,500 ft from the southern tip of Wards Band. The south jetty, outside of the TIMU boundary, extends about 4,700 ft from the shoreline at the northeastern tip of Naval Station (NAVSTA) Mayport. The jetties extend into 20 ft of water (relative to mean lower low water

[161] Moore, D. W. 2001. Integrated cultural resource management plan, and Cold War update Naval Station Mayport, Duval County, Florida. Hardy Heck Moore & Myers, Austin, Texas.
[162] Ibid.

(MLLW)) and are thought to allow little or no sediment transport beyond the St. Johns River inlet.[163]

Stabilization of the St. Johns River entrance has had a significant impact on beaches to both sides of the inlet, although impacts to the remainder of TIMU are of lesser significance. Long-term accumulation of sediment updrift of the St. Johns River entrance jetties has resulted in the northward migration of Ft. George Inlet and reorientation of Little Talbot Island. South of the St. Johns River entrance jetties, a progressively southward spreading erosion pattern has essentially been held in check by numerous beach nourishments since 1963.[164]

Shoreline Stabilization

Approximately 75,000 feet of shoreline within TIMU is artificially stabilized. Approximately 40,912 feet is stabilized by wood, steel, and concrete bulkheads, while 28,139 feet is stabilized by rock revetments and training walls (walls built along the bank of a river or estuary, parallel to the direction of flow, to direct and confine the flow). The majority of stabilized shorelines are found along the St. Johns River (Figure 76).

In addition to stabilized shorelines, one breakwater (on Amelia Island, north of the TIMU boundary), two groins (one on Amelia Island, north of the TIMU boundary, and the other within the TIMU boundary on the St. Johns River) and an earthen dike have also been identified.

Dredging

A total of twelve dredge/spoil disposal sites – all related to navigation – impacting 36,86,193 square meters of land were identified in, and adjacent to, the TIMU boundary.

St. Johns River

The St. Johns River has a long history of dredging and channel realignment. The USACE became involved with the St. Johns River entrance in the 1850s when it was decided that dredging would allow ships greater access. These attempts at dredging were unsuccessful as the channel filled up with sediment until it was decided that jetty construction would stabilize the entrance channel. The Rivers and Harbors Act of 1910 authorized excavation of a channel 30 ft deep from Jacksonville to the mouth of the river and a turning basin near Mayport.

[163] Naval Facilities Engineering Command Jacksonville FL Southeast Division. 2008. Final environmental impact statement for the proposed homeporting of additional surface ships at Naval Station Mayport, FL. Volume 1, Final Environmental Impact Statement. Defense Technical Information Center, Ft. Belvoir, Maryland. Online. (http://handle.dtic.mil/100.2/ADA491893).

[164] Florida Division of Recreation and Parks. 2009. Additional information for Little Talbot Island State Park. Online. (http://www.floridastateparks.org/littletalbotisland/info.cfm).

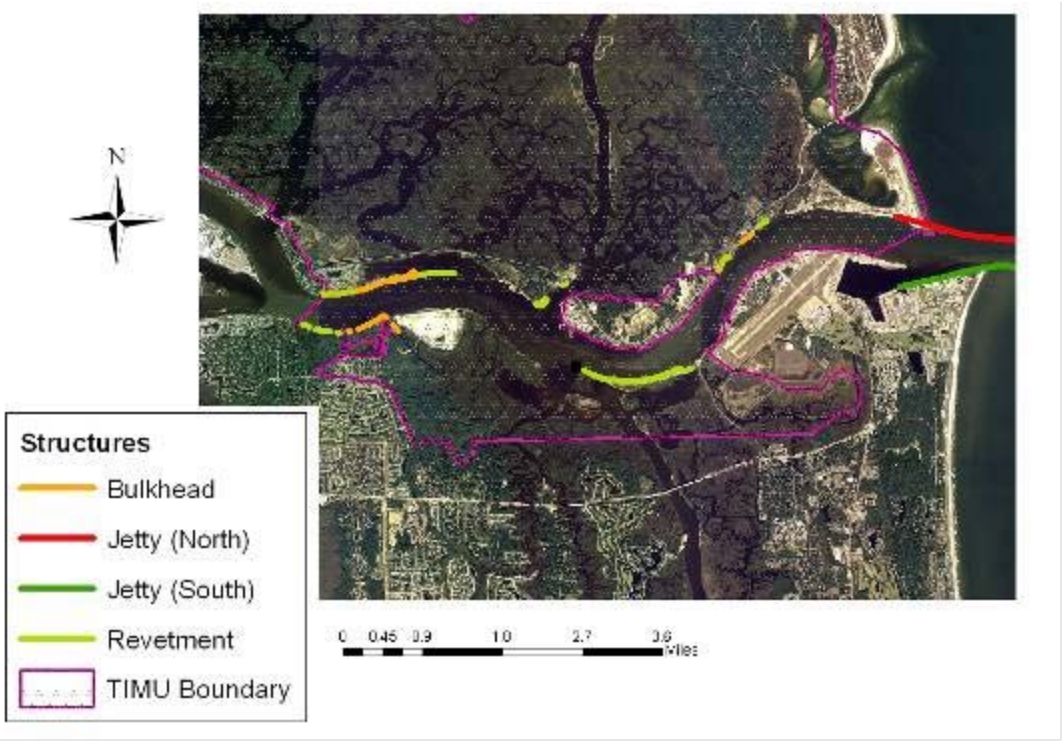

Figure 76. Shoreline stabilization in TIMU.

The current water depths of the Naval Station (NAVSTA) Mayport turning basin, entrance/approach channel, and Jacksonville Harbor Bar Cut 3 federal navigation channel are maintained at approximately -42 ft MLLW (Figure 77). The turning basin is approximately 123 acres in size. The NAVSTA Mayport entrance/approach channel is approximately 500 ft wide extending approximately 5,000 ft until it joins with the federal navigation channel.

The federal navigation channel is 800 ft wide and extends eastward from the NAVSTA Mayport entrance channel approximately 19,600 ft into the Atlantic Ocean, naturally increasing in depth from the maintained depth of -42 ft to greater than -55 ft MLLW. The inner portion of the Jacksonville Harbor Bar Cut 3 federal navigation channel is within the St. Johns River and extends approximately 3,000 ft from NAVSTA Mayport entrance channel to the eastern end of the jetties. [165]

The Navy currently removes approximately 900,000 cy from the NAVSTA Mayport turning basin and entrance channel every two years for maintenance dredging. The USACE currently removes approximately 300,000 cy from the outer portion of the federal navigation channel

[165] Naval Facilities Engineering Command Jacksonville FL Southeast Division. 2008. Final environmental impact statement for the proposed homeporting of additional surface ships at Naval Station Mayport, FL. Volume 1, Final Environmental Impact Statement. Defense Technical Information Center, Ft. Belvoir, Maryland. Online. (http://handle.dtic.mil/100.2/ADA491893).

every three years for maintenance dredging (amounting to a total annual average of 550,000 cy).[166]

Maintenance dredge spoil is taken to the Jacksonville ODMDS, located 5.5 nautical miles southeast of the NAVSTA Mayport turning basin. The Jacksonville ODMDS has been in use since 1952. NAVSTA Mayport has used the ODMDS regularly since 1954 and has been taking all of its maintenance dredged material to the Jacksonville ODMDS since two upland dredged material placement sites on NAVSTA Mayport reached capacity in 1993.[167]

During the 13 year period from 1996 to 2008, the Federal Navigation Project was permitted to dispose of approximately 1.1 million cy of maintenance dredged material and the Navy was permitted to dispose of approximately 4.9 million cy of maintenance dredged material in the Jacksonville ODMDS, equating to an overall annual average disposal of 460,000 cy over that period of time.[168]

In addition to the removal of sediment from the St. Johns River entrance and inlet, nine upland dredge spoil disposal sites that receive dredge spoil from maintenance dredging of the St. Johns River are located close to TIMU. Of these, only three (Dayson Dredge Material Site, NAVTA Mayport Dredge Disposal Site and JPA Buck Island Dredge Material Site) are located within the TIMU (Figure 78 and Table 8).

[166] Naval Facilities Engineering Command Jacksonville FL Southeast Division. 2008. Final environmental impact statement for the proposed homeporting of additional surface ships at Naval Station Mayport, FL. Volume 1, Final Environmental Impact Statement. Defense Technical Information Center, Ft. Belvoir, Maryland. Online. (http://handle.dtic.mil/100.2/ADA491893).
[167] Ibid.
[168] Ibid.

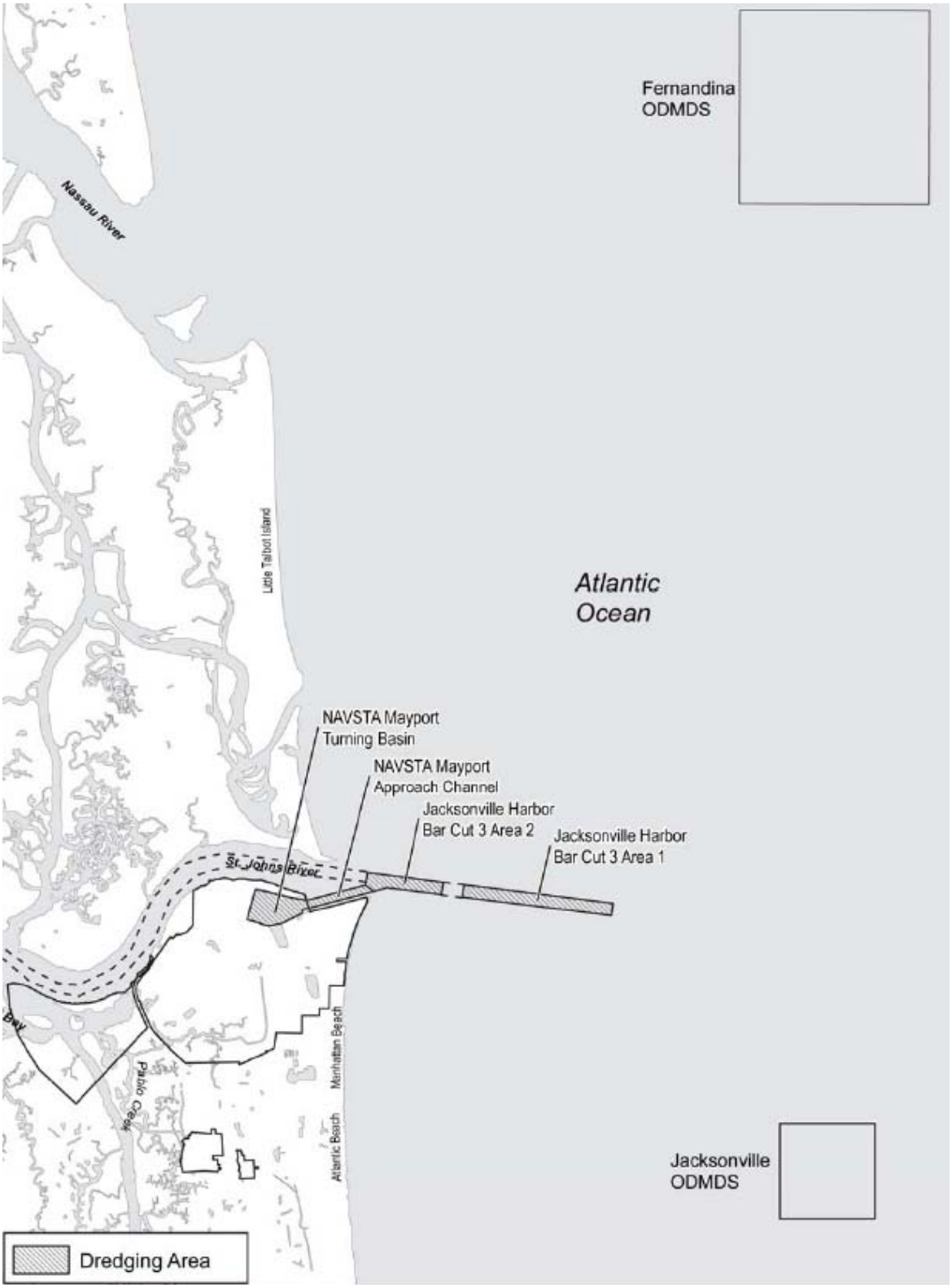

Figure 77. Dredging in St. Johns River Inlet.

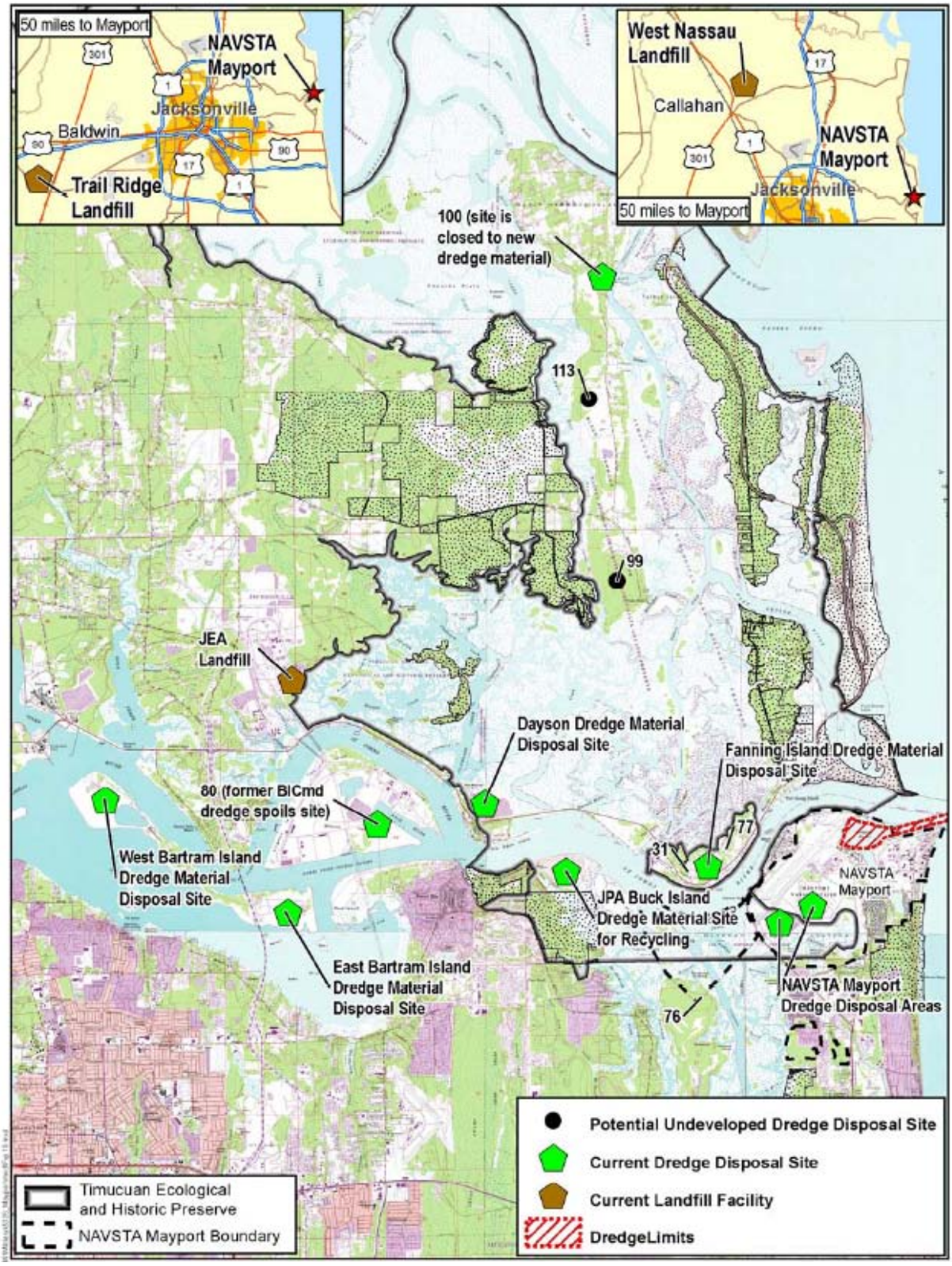

Figure 78. Upland dredge disposal sites.

Table 8. Information related to upland dredge disposal sites.

Site	Current Capacity	Availability	Dewatering Required	Mode of Transport
NAVSTA Mayport Dredge Disposal Sites	At capacity, but work underway to evaluate feasibility of reuse options	Not available, at capacity	At disposal site	Hydraulic pump
East Bartram Island	1,648,000 cy	Not available for full 5.2 million cy volume, supports federal maintenance requirements, Navy use requires coordination and approval	At disposal site	Hydraulic pump/barge
West Bartram Island	3,282,000 cy	Not available for full 5.2 million cy volume, supports federal maintenance requirements, Navy use requires coordination and approval	At disposal site	Hydraulic pump/barge
Jacksonville Port Authority Buck Island	1,622,800 cy, but fluctuates as material is used for construction fill	Not available for full 5.2 million cy volume, supports federal maintenance requirements, Navy use requires coordination and approval	At disposal site	Hydraulic pump/barge
Marine Corps Dayson Site	Supports dredging of the slipway in support of Maritime Prepositioning Force Program	Not available, capacity committed to slipway maintenance	At disposal site	Barge
Fanning Island	730,000 cy/day	Temporary only, not available for full 5.2 million cy volume, Navy use requires coordination and approval	No	Hydraulic pump
Jacksonville Electric Authority Site	Not applicable	Used for mixing dredged material with bed ash (energy by product) for stabilization prior to upland disposal elsewhere	Yes	Hydraulic pump/barge
West Nassau Landfill	3,000 cy/day for 12 years	Requires approval by landfill director, City of Jacksonville and Florida Dept. of Environmental Protection	Yes	Truck
Trail Ridge Landfill	3,000 cy/day for 14 years	Requires approval by landfill director, City of Jacksonville and Florida Dept. of Environmental Protection	Yes	Truck

Appendix K. Glossary.

Beach Nourishment: The introduction of sediment along a shoreline to increase or protect the size of the recreational beach (includes dune and berm construction and nearshore disposal of sediment for the purpose of shoreline stabilization).

Dredging: The mechanical removal and/or deposition of sediment to increase or maintain the depth of a navigable waterway.

Seawall: Vertical structures used to protect backshore areas from heavy wave action, and in lower wave energy environments, to separate land from water. They can be constructed using a range of materials including poured concrete, steel sheet pile, concrete blocks, gabions, sandbags, and timber cribs.

Bulkhead: Vertical structures or partitions, usually running parallel to the estuarine shoreline, for the purpose of retaining upland soils while providing protection from wave action and erosion. Bulkheads are either cantilevered or anchored sheet piles or gravity structures such as rock-filled timber cribs and gabions, concrete blocks or armorstone units.

Revetment: A cover or facing of material placed directly on an existing slope, embankment or dike to protect the area from waves and strong currents. They are usually built to preserve the existing uses of the shoreline and to protect the slope. Like seawalls, revetments armor and protect the land behind them. Revetments are commonly constructed using armorstone (high wave energy environments) or rip-rap stone (lower wave energy environments) in combination with smaller stone and geotextile fabrics. Other construction materials include gabions, poured concrete (usually in stepped fashion), pre-cast concrete blocks, and grout filled bags.

Jetty: Structures that extend perpendicularly or at nearly right angles from the shore commonly used to limit the volume of sediment deposited in inlet channels and prevent inlet migration.

Groin: Structures that extend perpendicularly or at nearly right angles from the shore and are relatively short when compared to navigation jetties at tidal inlets. Often constructed in groups called groin fields, their primary purpose is to trap and retain sand. Groins can be constructed from a wide range of materials including armorstone, pre-cast concrete units or blocks, rock-filled timber cribs and gabions, steel sheet pile, timber sheet pile, and grout filled bags and tubes.

Breakwater: Shore-parallel structures that reduce the amount of wave energy reaching a protected area. They are similar to natural bars, reefs or nearshore islands and are designed to dissipate wave energy. The reduction in wave energy slows the littoral drift, produces sediment deposition and a shoreline bulge or "salient" feature in the sheltered area behind the breakwater. Some longshore sediment transport may continue along the coast behind the nearshore breakwater.

Dike: Earthen structures (dams) that keep elevated water levels from flooding interior lowlands. In open coast areas, dikes that separate low lying areas from open water are often constructed

with a revetment or similar armor layer on the open water side to protect the dike from wave action and erosion.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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