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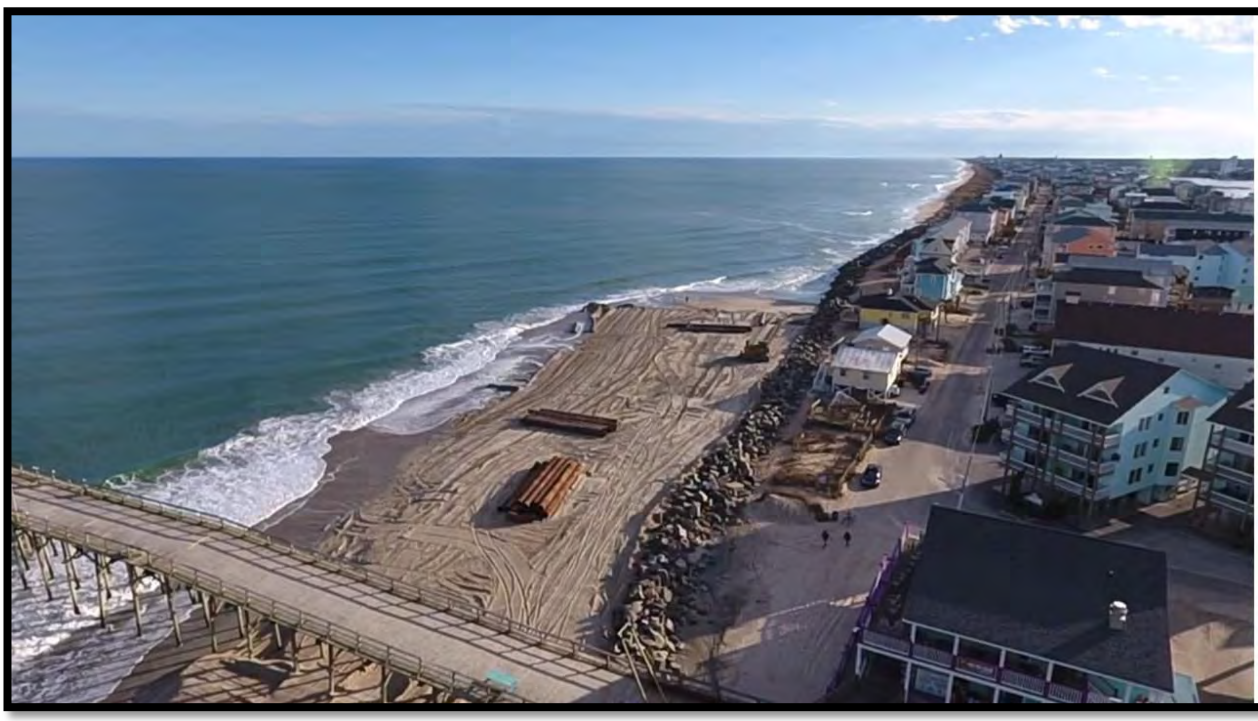
US Army Corps of Engineers
Wilmington District

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

APPENDICES



June 2019

Wilmington District – U.S. Army Corps of Engineers

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GEOTECHNICAL APPENDIX A

GEOTECHNICAL

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

CAROLINA BEACH INLET, NC

AND

BORROW AREA B

JUNE 2019

Prepared by:

Geotechnical and Dam Safety Section

U.S. Army Corps of Engineers, Wilmington District

Executive Summary

The Carolina Beach and Vicinity, NC coastal storm risk management (CSRM) project was authorized by the Flood Control Act of 1962 (FCA) which includes both the Carolina Beach and Area South (southern Carolina Beach and Kure Beach) projects. Construction of the Carolina Beach CSRM project was initiated in 1964. Federal participation in periodic renourishment for this project was extended to a full 50 years, or FY 2014, under the authority of Section 934 of the Water Resources Development Act of 1986. Federal participation was further extended under the Water Resources Reform and Development Act (WRRDA) of 2014, as amended, an additional 6 years or FY 2020. Carolina Beach Inlet has been used as the primary sand borrow site to support triennial beach renourishment activities on Carolina Beach since 1982. Although long-term beach renourishment under the current authority will end after FY 2020, the project remains eligible for a 15-year extension under Section 1037 of WRRDA 2014, as amended, subject to authorization of a beach renourishment evaluation study, which is the key purpose of this report. Federal participation in periodic renourishment would begin at initiation of construction of the first cycle of nourishment in the proposed 15-year extension. As a result, this study investigates the viability of Carolina Beach Inlet as a borrow area to support future beach renourishment activities.

USACE reviewed historical data for borrow areas within a dredging limit boundary established by the *Section 934 Reevaluation Report and Environmental Assessment* (1993). Additionally, the research summarized in this appendix also focused on a subpart of the Section 934 boundary referred to as the "Inshore Dredge Material Management Site" (IDMMS). Although not formally named until June 2017, the area within the present-day "IDMMS" has consistently supported triennial dredging and renourishment activities.

Historical vibracore logs from 1997 through 2014, and respective grain size data indicate that suitable sand has been consistently present within the IDMMS and that this material has been well-distributed within the borrow area. Additionally, prior bathymetric surveys and measured volumes of previously dredged sand, show that the Section 934 area, and especially the IDMMS, have consistently accumulated enough material to support beach renourishment once every three years. Although the IDMMS is a dredging site for obtaining beach renourishment material, the area is recharged by sand through natural sediment deposition, as well as disposal of dredged material from the main inlet channel. These recharge processes will help the IDMMS, as well as the overall Section 934 borrow area, recover from triennial dredging so that new sand can accumulate and be available for future dredging and renourishment projects.

Based on analysis of data as presented in this Appendix, the majority of the USACE Section 934 area, and the IDMMS specifically, is recommended as a suitable borrow area for future triennial renourishment. However, historical data from the small portions of the Section 934 area lying in the northern and southeastern-most extents of the IDMMS are limited. As a result, if these specific portions of the Section 934 zone were to be targeted for future renourishment dredging, respective vibracore sampling should be conducted to confirm the existence of suitable material.

This study also investigates using offshore "Borrow Area B" as an alternative borrow source to Carolina Beach Inlet, due to potential inlet use restrictions in the future. Borrow Area B has been used as a sand borrow site to support triennial renourishment activities on the Area South CSRM project since 2013. Vibracore logs from 2012 and 2018 show that suitable sand exists and is well-distributed inside the borrow area, with the most voluminous sand resources occurring in the northwestern portion of the site. Additionally, estimates of Borrow Area B sand volume indicate that the site is capable of supporting renourishment activities for both the Carolina Beach and Area South projects. As a result, Borrow Area B is recommended as a suitable borrow area for future renourishments.

This report is arranged such that similarities between Carolina Beach Inlet and Borrow Area B are addressed together, under the same headings and sub-headings. Examples include text about sand resource requirements, as well as the geologic setting of each location. Conversely, borrow area-specific matters, such as the compatibility analyses are addressed in separate sub-sections.

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1.0 GENERAL

1.1 PURPOSE

The purpose of this geotechnical appendix is to provide information and recommendations regarding the continued use of Carolina Beach Inlet to support beach renourishment at the Carolina Beach CSRM project, subject to authorization of a beach renourishment evaluation study developed under the authority of Section 1037 of the Water Resources Reform and Development Act of 2014, as amended. This Act authorized studies on qualifying coastal storm risk management projects to investigate the Federal interest in extending periodic renourishment starting at initiation of construction of the first cycle of renourishment in the proposed 15-year extension. However, continued use of Carolian Beach Inlet as the primary borrow source could be restricted in the future. As a result, this appendix also provides information and recommendations regarding an alternative offshore borrow site to support respective triennial renourishment activities.

1.2 INITIAL BEACH NOURISHMENT

Carolina Beach erosion control mitigation activities were authorized by Congress as part of the 1962 Flood Control Act (USACE, 1987). As originally authorized, beach nourishment construction required suitable fill material to conform with and extend the shoreline of Carolina Beach in a seaward direction. Initial construction and subsequent maintenance occurred during the mid to late 1960s using material excavated from the "Carolina Beach Harbor" area (Figure 1). Although the harbor area served as a resource for initial nourishment material, Carolina Beach Inlet was eventually selected for this purpose during the early 1980s. Long term use of the inlet is advantageous when compared with using material from the harbor area. For instance, sand which is excavated from Carolina Beach Inlet is generally recharged by natural shoreline processes, while harbor area material is in finite supply. Additionally, material can be excavated from the inlet and transported to nearby beach renourishment construction sites without interfering with municipal infrastructure, local traffic, or privately owned real estate. Conversely, material removed from the harbor area would have to be transported through piping systems which would overlie local roads and traverse individually-owned lots.

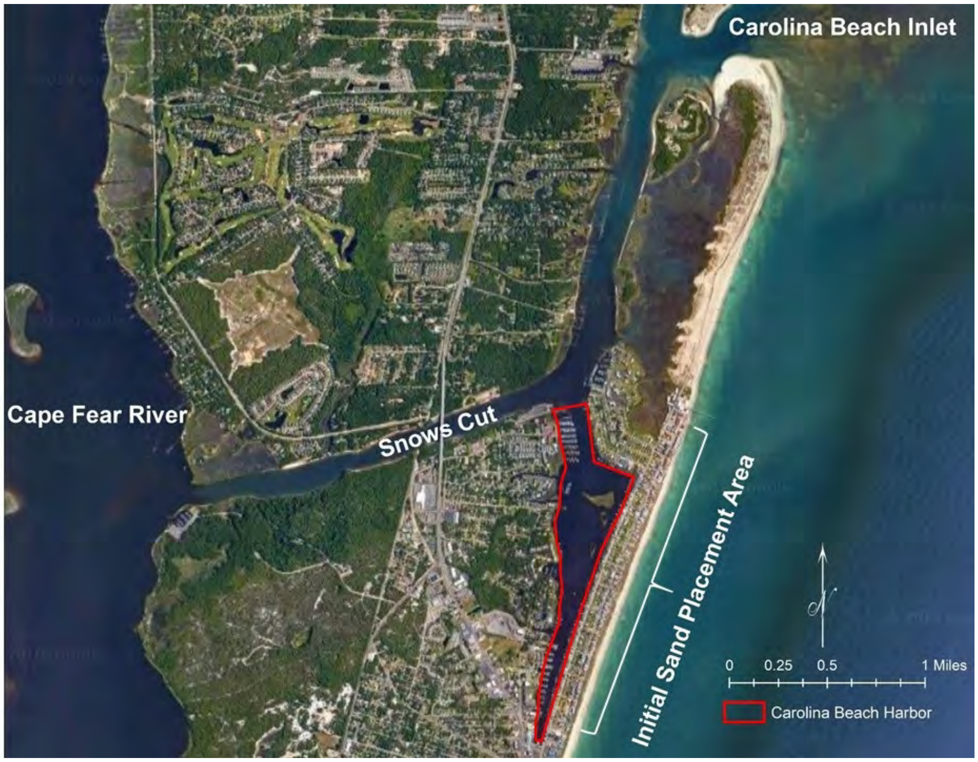

Figure 1. Carolina Beach Initial Sand Placement.

1.3 CAROLINA BEACH INLET

Carolina Beach Inlet was constructed via local interests and efforts in 1952 and separates Masonboro Island from the northeastern sand spit of Carolina Beach, NC. The inlet also connects Myrtle Grove Sound and the Atlantic Intracoastal Waterway (AIWW) to the Atlantic Ocean (Figure 2). Although the 1962 Flood Control Act authorized federal nourishment activities for Carolina Beach, the inlet is not known to have been used as a source until 1982. USACE formally established borrow area limits within Carolina Beach Inlet as part of its implementation of Section 934 of the Water Resources Development Act of 1986 (Figure 3) to occur on a cyclic, triennial basis through 2014. Federal participation was further extended under Section 1037 of the Water Resources Reform and Development Act (WRRDA) of 2014, as amended, an additional 6 years or FY 2020.

This study investigates the suitability of using Carolina Beach Inlet as a long-term, on-going sand source for future beach renourishment activities along the Carolina Beach shoreline.

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Figure 2. Carolina Beach Inlet Location.

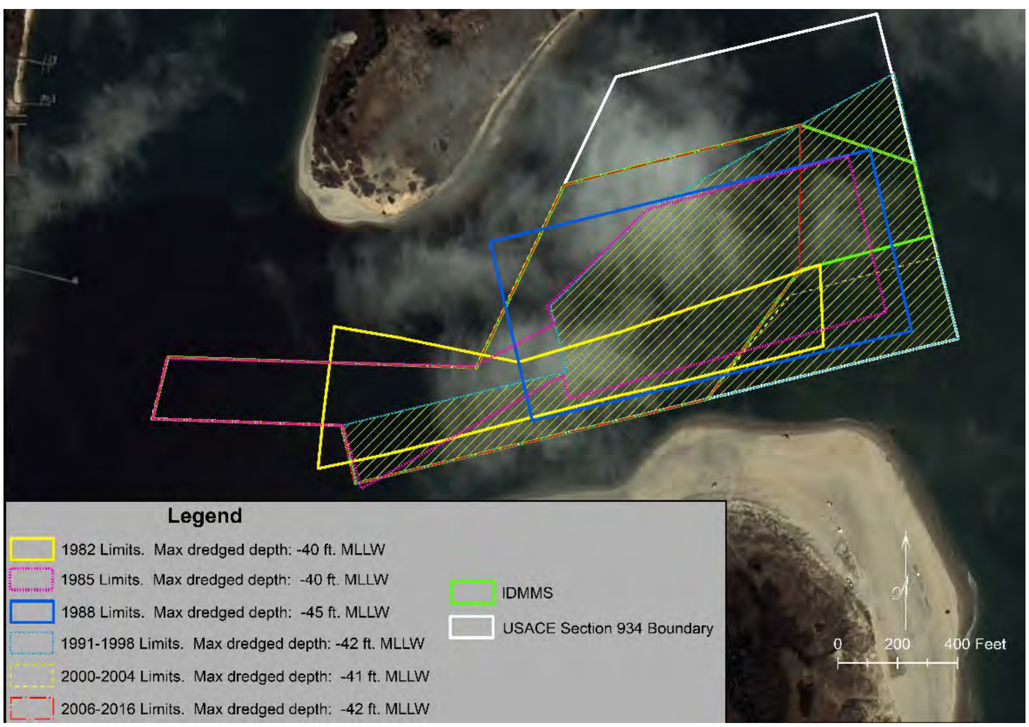

Figure 3. Carolina Beach Inlet Historical Dredging Limits. Dredging projects have occurred within the Section 934 limits, since the 1990s. Additionally, major portions of the area now termed the "IDMMS" are included within other historical boundaries. For instance, the IDMMS comprises 96 percent of the 2000 – 2004 dredged areas and includes all of the 2006 – 2016 areas.

1.4 BORROW AREA B

Another sand resource area known as “Borrow Area B” is being considered as an alternative to Carolina Beach Inlet. Borrow Area B is located about 0.5 to 2.5 miles east of the town of Carolina Beach, NC. The site ranges in width from 0.5 to 1.0 miles and is around 2.0 miles in length, with a surface area of approximately 1040 ac (Figure 4). This document describes the quality of sand within Carolina Beach Inlet and Borrow Area B, and addresses the availability of suitable beach fill for future renourishment projects.

Figure 4. Borrow Area B Location Map.

1.5 BORROW AREA SOURCES AND BEACH PLACEMENT HISTORY

Carolina Beach Inlet has been used as a sand source for beach nourishment for Carolina Beach since 1982 and has supported triennial renourishment since 1988 (Table 1). As part of these efforts, USACE's *Section 934 Reevaluation Report and Environmental Assessment* (1993) established a formal boundary within which inlet dredging for renourishment projects were to occur. Since then, dredging has generally conformed to formal borrow area boundaries inside the Section 934 limits. In June 2017, New Hanover County established a new boundary called the "Inshore Dredge Material Management Site (IDMMS)," which overlaps large portions of previously established borrow areas (Figure 3). As a result, the area within the IDMMS, which lies within USACE's 934 Boundary, has consistently and reliably supported historical dredging and renourishment. Today, the IDMMS serves as both a resource area, as well as a disposal area for sand which has been dredged from the Carolina Beach Inlet navigation channel.

Table 1. Carolina Beach Renourishment History

Year of Renourishment	Sand Volume (yd^3)	Borrow Source Used	Dredge Depth Range (Elevation (ft.) MLLW)[1]
1965	2,632,000	Carolina Beach Harbor	N/A
1981-1982	3,662,000	Carolina Beach Inlet	-17 to -40
1985	764,162	Carolina Beach Inlet	-17 to -40
1988	950,913	Carolina Beach Inlet	-21 to -45
1991	1,008,763	Carolina Beach Inlet	-19 to -40
1995	1,157,742	Carolina Beach Inlet	-15 to -43
1998	1,204,646	Carolina Beach Inlet	-20 to -42
2001	567,345	Carolina Beach Inlet	-22 to -41
2004	800,387	Carolina Beach Inlet	-20 to -40
2007	632,143	Carolina Beach Inlet	-23 to -42
2010	689,600	Carolina Beach Inlet	-23 to -40
2013	989,200	Carolina Beach Inlet	-22 to -39
2016	881,470	Carolina Beach Inlet	-25 to -37

[1] Designed maximum dredging depth is generally around -40 ft., MLLW.

Unlike Carolina Beach Inlet, Borrow Area B does not have an extensive use history. For instance, prior to the exploitation of Borrow Area B, another site called, "Borrow Area A" had been used as a source of beach renourishment material for Carolina Beach and Kure Beach. This former borrow area lies about 3.0 to 5.3 miles south of Borrow Area B. Over the years, Borrow Area A supported various beach renourishment cycles and was eventually depleted of suitable sand resources. As a result, Borrow Area

B was identified as a new potential sand resource, based on limited vibracoring activities which had occurred in 1991. A more thorough geotechnical investigation occurred during the summer of 2012, involving the collection of 53 vibracores. Since that time, this site has been used to support beach renourishment activities at Carolina Beach and Kure Beach during 2013, 2016 and 2019.

2.0 EVALUATION OF EXISTING DATA

2.1 GEOLOGIC SETTING

Carolina Beach Inlet separates Masonboro Island and Carolina Beach. These barrier islands flank the western edge of the Onslow Bay, which is bound by Cape Lookout to the north and Cape Fear to the south (NCGS, 1985). The islands consist of unlithified sediment and unconformably overlie lithified and semi-indurated Oligocene (Snyder et al., 1991) and Eocene (Harris and Zullo, 1991) sandy, molluscan-mold and bryozoan-echinoid limestone. Thus, Onslow Bay is limited in naturally-occurring offshore sand supply and subsequent sand recharge onto barrier beaches (Riggs et al., 1995).

Carolina Beach Inlet receives and retains sand-sized quartz grains via longshore current, similar to that described by Ritter (1989). Although the direction of littoral sediment transport is generally in a north-to-south direction (Duke, 2001), seasonal variations exist which temporarily reverse this trend (USACE, 1962). Tidal currents have resulted in a well-formed ebb tidal delta just seaward of the inlet, but flood tidal delta development, which is common in other barrier island inlets (i.e. Ritter, 1999, Haven, 2013) is curtailed due to frequent channel dredging. Ultimately, sand that would naturally recharge the Carolina Beach shoreline is deposited into and retained within Carolina Beach Inlet (Cleary, 2008). As a result, the inlet has historically served as a reliable sand resource, holding material comparable to sand remaining on and eroding from Carolina Beach.

Similar to Carolina Beach Inlet, Borrow Area B is near the western edge of Onslow Bay. Site material consists of unlithified sediment, which also overlies Oilgocene (Snyder et al., 1991) and Eocene (Harris and Zullo, 1991) sandy, molluscan-mold and bryozoan-echinoid limestone. Unconsolidated sediment within Borrow Area B lies in water depths which are generally below the typical wave base. As a result, with the exception of sediment entrainment via unusual storm-driven waves and currents, clastic sedimentary deposition into or erosion from within the borrow site is not expected to routinely occur.

2.2 SAND RESOURCE REQUIREMENTS

Sand resource sampling via vibracoring generally precedes sand borrowing and beach nourishment. Vibracore logs and respective laboratory data are assessed after collection to determine the suitability of a given sand resource. Typical USACE contract specifications for renourishment projects generally recognize suitable beach material as Poorly Graded Sand (SP), or Poorly Graded Sand with Silt (SP-SM) per the Unified Soil Classification System (USCS), as long as the portion of material meets these criteria:

- Less than 10 percent, by weight, material passes #200 sieve over weighted average.
- Less than 10 percent, by weight, material retained on the #4 sieve over weighted average.
- Material retained on the 3/4 inch sieve does not exceed, by percentage or size that found on the native beach.
- Contains no construction debris, toxic material, or other foreign matter.
- Contains no clasts of lithified rock.

2.3 SAND SUITABILITY – CAROLINA BEACH INLET

New vibracoring was not performed as part of the Carolina Beach Inlet study. However, prior vibracore records and laboratory data from 1997 through 2014 were reviewed to assess the historical consistency of sand resources within the IDMMS, as well as other parts of the Section 934 limits. Historical vibracore locations are shown in Figure 5, while sand suitability information from each core is provided in Table 2. Due to historical dredging, as well as naturally occurring erosional and depositional changes, the material into which some of the shorter-length historical cores were drilled no longer exists (Figure 6). However, information from these cores, when compared with deeper cores still shows a consistent occurrence of suitable sand within most of the Section 934 limits, and especially within the IDMMS.

Analysis of historical vibracores shows that material within the IDMMS generally ranges from SP to SW (Well Graded Sand), with a mean fine-grained content of 1.8 percent and a mean shell content of 5.8 percent. Although a few cores yielded sand with a classification ranging from SP-SC (Clayey Sand and Sand-Clay Mixtures) or SP-SM (Silty Sands and Sand-Silt Mixtures) overall, composite fine-grained content within these samples was still below the 10 percent threshold for beach nourishment. Additionally, core log notations of clay or silt “lenses” sometimes reflect fines which occur as individual clasts and are not indicative of a wide-ranging fine-grained sedimentary layer. Two other cores within the IDMMS, CBI-V-09-07 and CBI00-12 yielded inorganic silts or limestone particles at depth. However, these lithologies were encountered below the base of recoverable, suitable sand layers.

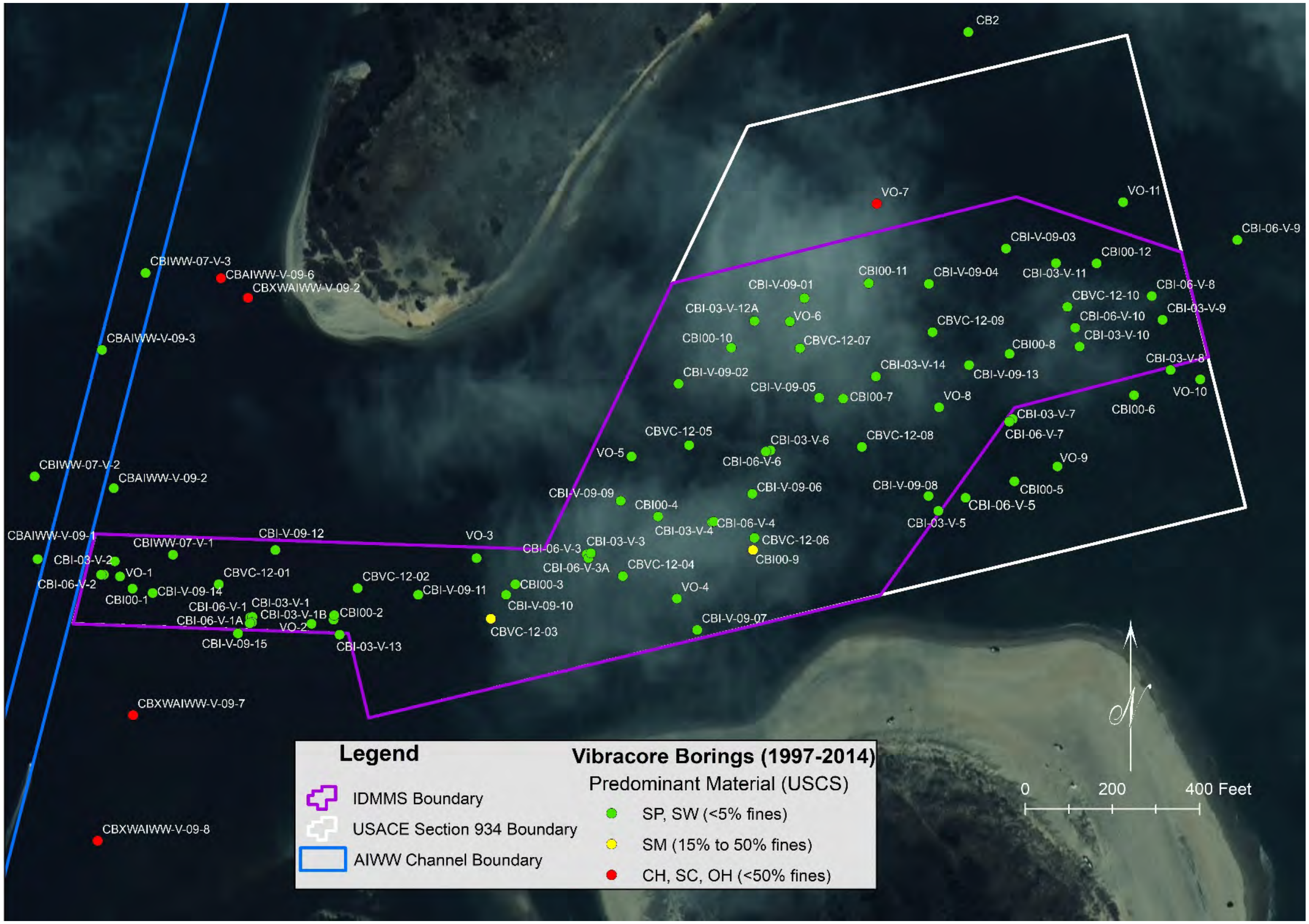

Figure 5. Carolina Beach Inlet Historical Vibracores (1997-2014). Green indicates beach suitable material, while yellow indicates material that may be used, if mixed with nearby suitable sediment. Red indicates unsuitable material. The beach compatibility color code is based on the material from which a core was taken at the time of collection. Regardless, historical vibracore records indicate the presence of consistent, suitable material within the IDMMS and within much of the overall 934 boundary, over time.

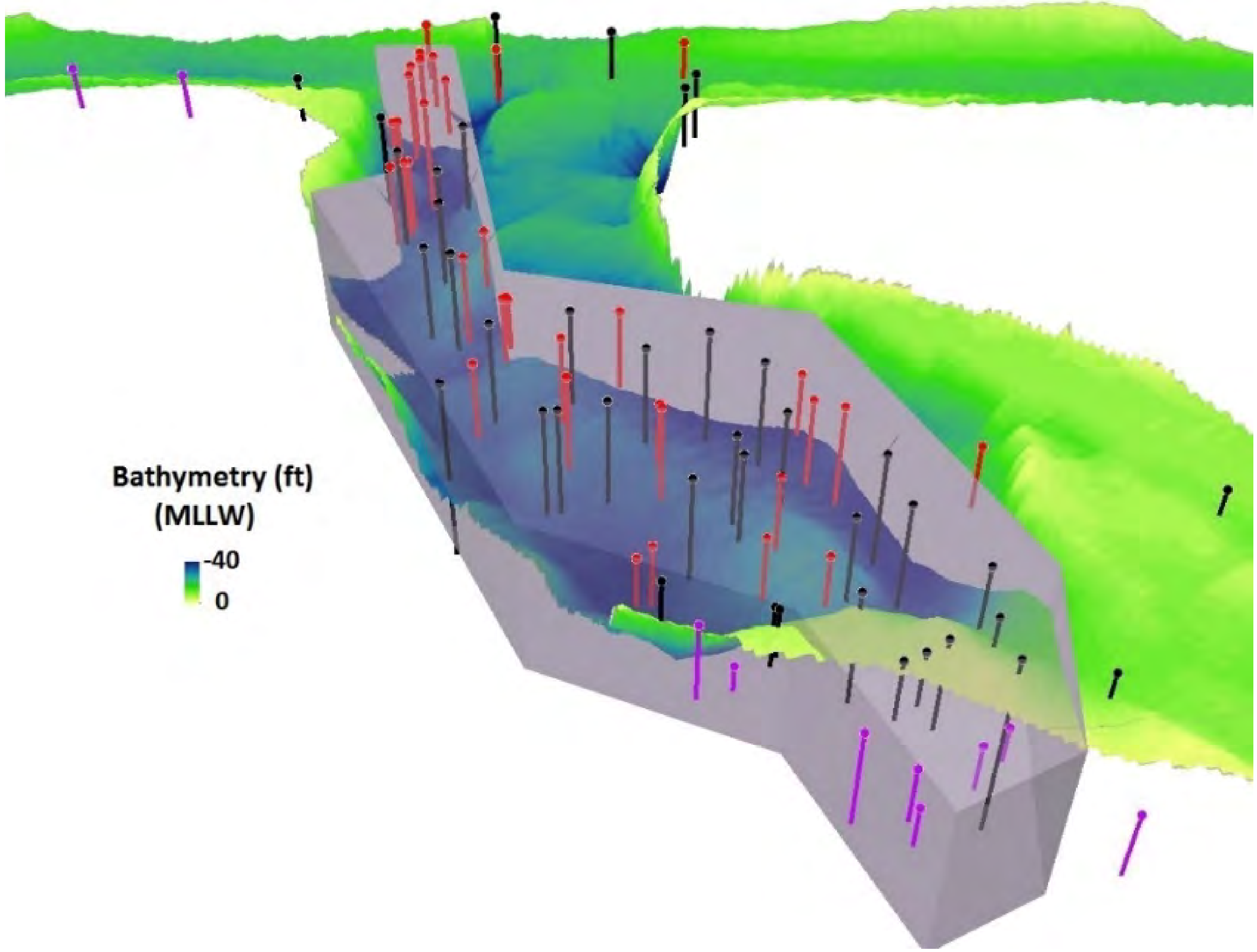

Figure 6. Carolina Beach Inlet Vibracore Locations 3D Rendering (Vertical Exaggeration is 10:1). The image is not rendered to scale, but is oriented such that the viewer is looking down the inlet and toward the southwest. Bathymetry was surveyed in June 2017. Red cores are “suspended” and do not intersect the bathymetric surface. Black cores penetrate the surface, while purple cores penetrate the seafloor, but were outside of the bathymetric survey. The gray polygon represents the IDMMS.

Table 2. Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
1997	VO-1	SP	-9.9 to -15.2	2.0	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-1	SP-SM	-15.2 to -17.4	9.0	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-2	SP	-19.8 to -30.75	2.0	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-3	SP	-10.8 to -15.0	2.0	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-4	SP	-8.8 to -19.4	2.5	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-5	SP	-14.8 to -20.4	1.5	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-6	SP	-18.8 to- 22.4	2.0	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-7	SC	-3.8 to -5.8	35.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-7	SM	-5.8 to -9.8	18.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-7	CH	-9.8 to -13.3	80.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-7	SM	-13.3 to -15.8	18.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-8	SP	-3.8 to -15.8	2.5	ND	Inside IDMMS	Inside 934 Boundary
1997	VO-9	SP	-1.8 to -6.0	2.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-10	SP	-0.8 to -9.3	2.0	ND	Outside IDMMS	Inside 934 Boundary
1997	VO-11	SP	-11.0 to -17.6	2.0	ND	Outside IDMMS	Inside 934 Boundary
2000	CBI00-1	SP	-14.3 to -24.3	1.6	0.2	Inside IDMMS	Inside 934 Boundary
2000	CBI00-2	SP	-13.3 to -19.4	2.2	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-3	SP	-11.8 to -23.5	1.9	0.3	Inside IDMMS	Inside 934 Boundary
2000	CBI00-4	SP	-12.7 to -23.2	1.4	0.1	Inside IDMMS	Inside 934 Boundary
2000	CBI00-5	SP	-8.2 to -19.8	1.8	8.3	Outside IDMMS	Inside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2000	CBI00-6	SW	-8.4 to -14.2	1.4	14.7	Outside IDMMS	Inside 934 Boundary
2000	CBI100-6	SP	-14.2 to -24.3	0.9	15.6	Outside IDMMS	Inside 934 Boundary
2000	CBI00-7	SP	-12.1 to -23.6	1.9	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-8	SP	-19.7 to -30.2	1.3	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-9	SP	-25.8 to -28.5	0.8	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-9	SM	-28.5 to -33.0	21.2	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-9	SP	-33.0 to -36.8	8.2	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-10	SW	-26.2 to -32.0	1.4	4.9	Inside IDMMS	Inside 934 Boundary
2000	CBI00-10	SP	-32.0 to -32.8	2.0	2.2	Inside IDMMS	Inside 934 Boundary
2000	CBI00-10	SW	-32.8 to -37.3	4.9	1.3	Inside IDMMS	Inside 934 Boundary
2000	CBI00-11	SW	-25.5 to -33.5	1.4	20.1	Inside IDMMS	Inside 934 Boundary
2000	CBI00-11	SP-SM	-33.5 to -33.9	11.0	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-12	SP	-32.5 to -35.8	1.6	30.4	Inside IDMMS	Inside 934 Boundary
2000	CBI00-12	SW	-35.8 to -37.7	2.4	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-12	SP-SM	-37.7 to -40.8	7.4	ND	Inside IDMMS	Inside 934 Boundary
2000	CBI00-12	SM-LS[4]	-40.8 to -47.5	32.9	9.9	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-1	SP	-8.0 to -8.5	1.0	4.0	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-1B	SP	-8.4 to -12.7	1.5	5.0	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-2	SP	-10.7 to -11.2	0.8	4.0	Inside IDMMS	Inside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4] The designation "LS" refers to limestone. The core log indicates that trace limestone gravel was encountered below -42.0 ft., as part of the SM material.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2003	CBI-03-V-2A	SP	-10.8 to -14.3	3.0	ND	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-3	SP	-10.4 to -13.4	0.5	6.5	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-4	SP	-8.1 to -3.3	1.3	3.0	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-5	SP	-7.1 to -12.6	1.1	6.7	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-6	SP	-8.5 to -15.5	0.5	2.5	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-7	SP	-9.6 to -15.6	1.4	19.0	Outside IDMMS	Inside 934 Boundary
2003	CBI-03-V-8	SP	-3.4 to -13.7	1.1	24.7	Outside IDMMS	Inside 934 Boundary
2003	CBI-03-V-9	SP	-7.6 to -11.7	1.3	31.0	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-10	SP	-11.2 to -15.6	1.3	23.3	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-11	SP	-15.9 to -20.9	0.7	32.0	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-12A	SP	-15.2 to -16.4	1.0	ND	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-13	SP	-15.9 to -22.4	2.3	ND	Inside IDMMS	Inside 934 Boundary
2003	CBI-03-V-14	SP	-13.4 to -19.3	0.7	4.5	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-1A	SP	-7.9 to -15.9	0.4	0.7	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-2	SP	-11.3 to -19.4	1.4	1.2	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-3A	SP	-12.7 to -16.9	1.2	9.3	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-3A	SP-SM	-16.9 to -17.4	6.2	ND	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-4	SP	-19.5 to -25.4	1.2	0.3	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-5	SP	-3.4 to -13.6	1.2	3.8	Outside IDMMS	Inside 934 Boundary
2006	CBI-06-V-6	SP	-18.7 to -24.7	1.4	0.2	Inside IDMMS	Inside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2006	CBI-06-V-7	SP	-3.7 to -12.2	1.8	12.0	Outside IDMMS	Inside 934 Boundary
2006	CBI-06-V-8	SP	-4.2 to -8.8	2.2	22.1	Inside IDMMS	Inside 934 Boundary
2006	CBI-06-V-9	SP	-3.6 to -16.1	1.3	19.4	Outside IDMMS	Outside 934 Boundary
2006	CBI-06-V-10	SP	-5.4 to -14.0	0.8	14.7	Inside IDMMS	Inside 934 Boundary
2007	CBIWW-07-V-1	SP	-8.2 to -15.4	0.9	1.2	Inside IDMMS	Inside 934 Boundary
2007	CBIWW-07-V-2	SP	-13.8 to -21.8	1.0	1.3	Outside IDMMS	Outside 934 Boundary
2007	CBIWW-07-V-3	SP	-5.6 to -11.1	0.8	0.4	Outside IDMMS	Outside 934 Boundary
2009	CBI-V-09-01	SP	-15.0 to -26.3	1.2	2.0	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-02	SP	-23.6 to -49.8	1.8	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-03	SP	-8.7 to -19.7	1.4	5.6	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-04	SP	-14.3 to -29.3	0.9	0.5	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-05	SP	-15.2 to -29.7	2.0	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-06	SP	-23.4 to -25.3	0.6	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-06	SM	-25.3 to -29.9	19.7	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-06	SP-SM	-29.9 to -32.9	8.3	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-06	SP	-32.9 to -38.4	2.3	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-07	SP-SM	-31.9 to -34.2	6.9	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-07	SM	-34.2 to -36.7	31.8	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-07	SP-SM	-36.7 to -37.9	9.9	ND	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-07	SP	-37.9 to -42.9	2.4	ND	Inside IDMMS	Inside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2009	CBI-V-09-07	ML*	-42.9 to -49.6	NR	NR	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-08	SP	-2.7 to -15.8	0.4	6.3	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-09	SP	-13.6 to -29.3	1.5	0.4	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-10	SP	-10.7 to -27.4	1.6	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-11	SP	-7.9 to -25.1	1.8	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-12	SP	-13.0 to -29.2	1.9	2.0	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-13	SP	-3.6 to -12.9	1.0	24.5	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-14	SP	-8.9 to -25.4	1.5	1.9	Inside IDMMS	Inside 934 Boundary
2009	CBI-V-09-15	SP	-7.5 to -25.5	1.7	0.1	Outside IDMMS	Outside 934 Boundary
2009	CBI-V-09-16	SP	-5.7 to -21.6	1.7	0.1	Inside IDMMS	Inside 934 Boundary
2009	CBAIWW-V-09-1	SP	-9.0 to -16.3	1.0	6.7	Outside IDMMS	Outside 934 Boundary
2009	CBAIWW-V-09-2	SP	-8.1 to -15.5	1.0	6.3	Outside IDMMS	Outside 934 Boundary
2009	CBAIWW-V-09-3	SP	-8.4 to -16.4	1.2	18.3	Outside IDMMS	Outside 934 Boundary
2009	CBAIWW-V-09-6	CH	-10.0 to -12.5	63.0	ND	Outside IDMMS	Outside 934 Boundary
2009	CBAIWW-V-09-6	SM	-12.5 to -14.3	27.0	ND	Outside IDMMS	Outside 934 Boundary
2009	CBAIWW-V-09-6	OH*	-14.3 to -18.7	NR	NR	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-1	SP	-8.5 to -15.8	ND	<5.00	Inside IDMMS	Inside 934 Boundary
2009	CBXWAIWW-V-09-2	CH	-8.3 to -10.8	73.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-2	SC	-10.8 to -13.3	35.0	ND	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-2	CH	-13.3 to -14.3	75.0	<5.00	Outside IDMMS	Outside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2009	CBXWAIWW-V-09-2	OH*	-14.3 to -15.6	NR	NR	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-2	SP*	-15.6 to -16.1	NR	NR	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-2	OH*	-16.1 to -17.3	NR	NR	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-7	SC	-7.1 to -12.4	31.0	1.25	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-8	SC	-3.9 to -5.3	42.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-8	CH	-5.3 to -6.9	56.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-8	CH	-6.9 to -8.9	58.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-8	SP-SM	-8.9 to -12.2	5.0	ND	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-9	CH	-3.6 to -5.6	59.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-9	SM	-5.6 to -8.1	35.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-9	SM	-8.1 to -10.4	18.0	<5.00	Outside IDMMS	Outside 934 Boundary
2009	CBXWAIWW-V-09-9	SP	-10.4 to -11.6	3.0	ND	Outside IDMMS	Outside 934 Boundary
2012	CBVC-12-01	SP	-11.8 to -17.2	1.0	3.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-01	SW	-17.2 to -18.1	1.0	11.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-01	SP	-18.1 to -29.8	1.2	4.3	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-02	SP	-17.2 to -37.2	1.3	3.8	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-03	SP	-22.1 to -36.8	1.2	3.3	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-03	SC*	-36.8 to 38.4	NR	NR	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-03	SM-SC*	-38.4 to -40.2	NR	NR	Inside IDMMS	Inside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Table 2 (continued). Carolina Beach Inlet Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location (IDMMS)	Location (934 Boundary)
2012	CBVC-12-04	SP	-24.0 to -28.4	1.3	3.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-04	SP-SM	-28.4 to -30.7	5.1	5.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-04	SP-SC	-30.7 to -32.7	8.3	6.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-04	SP-SM*	-32.7 to -40.0	NR	NR	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-04	SP-SC*	-40.0 to -45.0	NR	NR	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-05	SP	-22.9 to -42.0	1.3	3.5	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-06	SP	-21.6 to -26.6	2.0	3.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-06	SP-SC	-26.6 to -27.6	5.8	4.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-06	SP	-27.6 to -33.1	3.8	4.5	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-06	SC	-33.1 to -37.6	15.5	5.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-06	SP	-37.6 to -19.5	2.2	3.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-07	SP	-20.2 to -38.2	1.3	3.5	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-08	SP	-14.0 to -32.3	1.7	4.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-08	SC*	-32.3 to -34	NR	NR	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-09	SW	-11.6 to -17.0	1.1	17.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-09	SP	-17.0 to -28.6	1.2	3.0	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-10	SW	-4.4 to -13.4	0.8	23.6	Inside IDMMS	Inside 934 Boundary
2012	CBVC-12-10	SP	-13.4 to -21.6	0.8	9.0	Inside IDMMS	Inside 934 Boundary
2014	CB2	SP	-6.8 to -8.5	2.2	ND	Outside IDMMS	Outside 934 Boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]All classifications are based on laboratory analysis, except where indicated by a *. The * refers to a visual classification only.

[3]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Additionally, laboratory results for the CBVC cores reported “carbonate percentages,” not shell percentages. “Carbonate” can include both shells, as well as calcitic or aragonitic matrix. However, the low percentages reported and lack of carbonate-lithified clasts within the cores indicated that reported “carbonate” likely represented shells. As a result, these “carbonate” percentages were included in the average shell content calculation of 5.8 percent. Finally, quantitative shell percentages were not available within lab data for cores CB2 or VO-1 through VO-11. As a result, these cores were not calculated as part of average shell content. However, some of the VO core logs note a qualitative remark of “trace shell” content, which is generally considered to be less than five percent.

Vibracores from outside the IDMMS were grouped together into a single dataset for analysis, which included cores both outside the Section 934 boundary, as well as cores between the 934 and IDMMS limits (Table 2). Overall, these cores showed increased fine-grained and shell content which averaged to 11.5 percent and 8.9 percent, respectively. These increased averages for fine-grained, non-sandy material were influenced by cores collected in the AIWW, which constitutes a lower energy depositional environment, compared to the IDMMS area. Due to entrainment and settling velocities of clastic material (Komar, 1976 and Bjorlykke, 2010), the presence of fine-grained particles in low-energy AIWW areas is not unexpected.

After comparing data from within the IDMMS with grouped core data from outside the IDMMS, a final analysis of the nine cores which were outside of the IDMMS, but within the Section 934 boundary was conducted (Table 3). These cores reveal an average fine-grained and shell content of 4.96 percent and 9.73 percent, respectively. Sediment classifications mostly range from SW to SP, even though increased shell content is noted within six of these cores. Additionally, the data from these cores reveal an average increase in fine-grained material, compared to sediment within the IDMMS. However, the respective data set is skewed due to core VO-7, which is located north of the northern IDMMS boundary and south of the Section 934 northern boundary (Figure 5). Material from this core was classified as CH to SM, with a fine-grained content ranging from 18 to 80 percent. Additionally, VO-7 is the only non-AIWW vibracore which revealed CH material above the typical -40 ft. MLLW design dredge cut depth. (The -40 ft. MLLW depth was established by SAW’s ECP-ED as the design depth for the last several renourishment cycles.) However, as a result of either dredging or erosion, the sedimentary material into which this core was bored in 1997 no longer exists at the respective location. As a result, present-day lithology of material in the vicinity of the VO-7 location is unknown. Regardless, the other eight cores within this data set are comparable to the IDMMS cores, with respect to clastic content.

Table 3. Vibracores from within the USACE Section 934 area, but outside the IDMMS[1]

Yr. Drilled	Boring No.	USCS Classification	Material Range (Elevation, ft. MLLW)	Avg. % Fines[2]	Avg. % Shell	Location
2006	CBI-06-V-5	SP	-3.4 to -13.6	1.2	3.8	NE area of 934 boundary
2006	CBI-06-V-7	SP	-3.7 to -12.2	1.8	12.0	NW area of 934 boundary
2003	CBI-03-V-7	SP	-9.6 to -15.6	1.4	19.0	SE area of 934 boundary
2003	CBI-03-V-8	SP	-3.4 to -13.7	1.1	24.7	SE area of 934 boundary
2000	CBI00-5	SP	-8.2 to -19.8	1.8	8.3	SE area of 934 boundary
2000	CBI00-5	SW	-17.0 to -19.8	1.8	21.8	SE area of 934 boundary
2000	CBI00-6	SW	-8.4 to -14.2	1.4	14.7	SE area of 934 boundary
2000	CBI00-6	SP	-14.2 to -24.3	0.9	15.6	SE area of 934 boundary
1997	VO-7	SC	-3.8 to -5.8	35.0	ND	SE area of 934 boundary
1997	VO-7	SM	-5.8 to -9.8	18.0	ND	SE area of 934 boundary
1997	VO-7	CH	-9.8 to -13.3	80.0	ND	SE area of 934 boundary
1997	VO-7	SM	-13.3 to -15.8	18.0	ND	SE area of 934 boundary
1997	VO-9	SP	-1.8 to -6.0	2.0	ND	SE area of 934 boundary
1997	VO-10	SP	-0.8 to -9.3	2.0	ND	SE area of 934 boundary
1997	VO-11	SP	-11.0 to -17.6	2.0	ND	SE area of 934 boundary

[1]Data are from USACE core and lab records, as well as from CP&E (2012) and O'Brien & Gere (2015).

[2]The column "Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

Based on data availability, a subset of the most recent vibracore data ranging from years 2009 – 2012 was assessed for median grain size. Median grain size determination is essential for data input and shoreline modeling by USACE. The selected vibracore locations are spatially well distributed within the IDMMS (Figure 7) and therefore provide a reliable assessment of grain size with the overall area of interest. Recent vibracore data from areas outside the IDMMS, but inside the other portions of the Section 934 boundary were not available. Additionally, older vibracores (pre-2009) were typically taken within material that has since been dredged or eroded from the borrow area. As a result, median grain size data from these older samples were not incorporated into the median size calculations, which are indicative of present-day site conditions. Regardless, based on the most recent vibracoring data, the overall IDMMS median grain size is 0.19 mm, while the mean grain size is 0.23 mm, with a standard deviation of 0.16 mm, based on $n = 142$ samples. These grain size values are smaller than those suggested by USACE's (1993), *Section 934 Reevaluation Report and Environmental Assessment, Carolina*

Beach & Vicinity document. USACE (1993) shows limited results from a 1970 survey of native beach sands, from which samples were collected prior to federal renourishment activities. Resultant data revealed a mean grain size of 0.31 mm, along with a standard deviation of 0.53 mm. However, neither the median, nor the number of samples (n) were reported, which likely affected this high standard deviation value. Regardless, the 1970 mean of 0.31 mm is not much larger than the mean derived from the 2009 and 2012 core data. Additionally, the 1970 mean is still within one standard deviation ($s =$ 0.16 mm) of the 0.23 mm mean from the recent vibracore information. This data comparison, along with the extensive, on-going history of renourishment from Carolina Beach Inlet (Table 1), indicates continued occurrence of suitable sand within the IDMMS.

Core data from 2009 and 2012 were used to develop fence diagrams through the IDMMS portion of the USACE 934 boundary (Figures 8 and 9). Review of these images shows that dredging and subsequent beach renourishment, prior to the December 2017 bathymetric survey has removed much of the strata into which vibracores CBI-V-09-05, 08, 10, 16, and CBVC-12-06 were drilled.

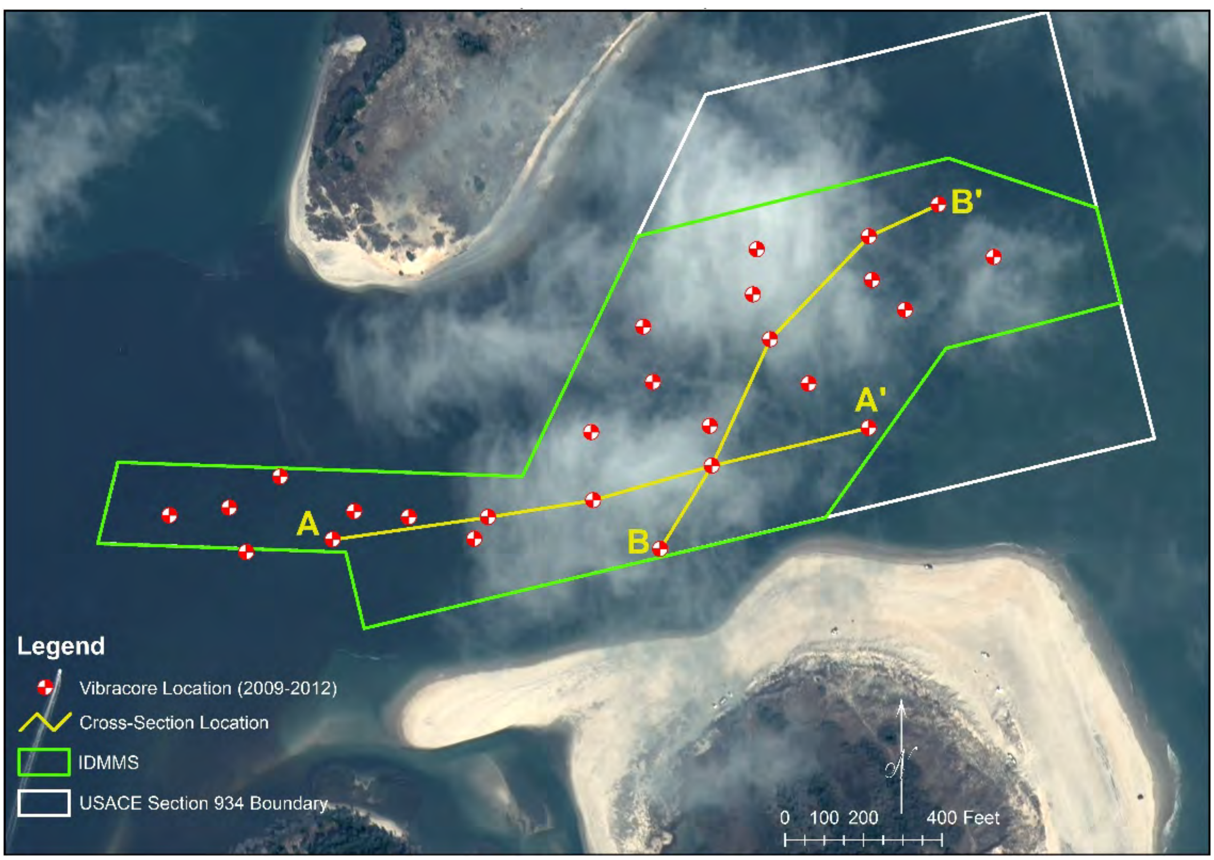

Figure 7. Carolina Beach Inlet Vibracores Assessed for Grain Size. Lines A-A' and B-B' denote fence diagram locations, as shown in Figures 8 and 9.

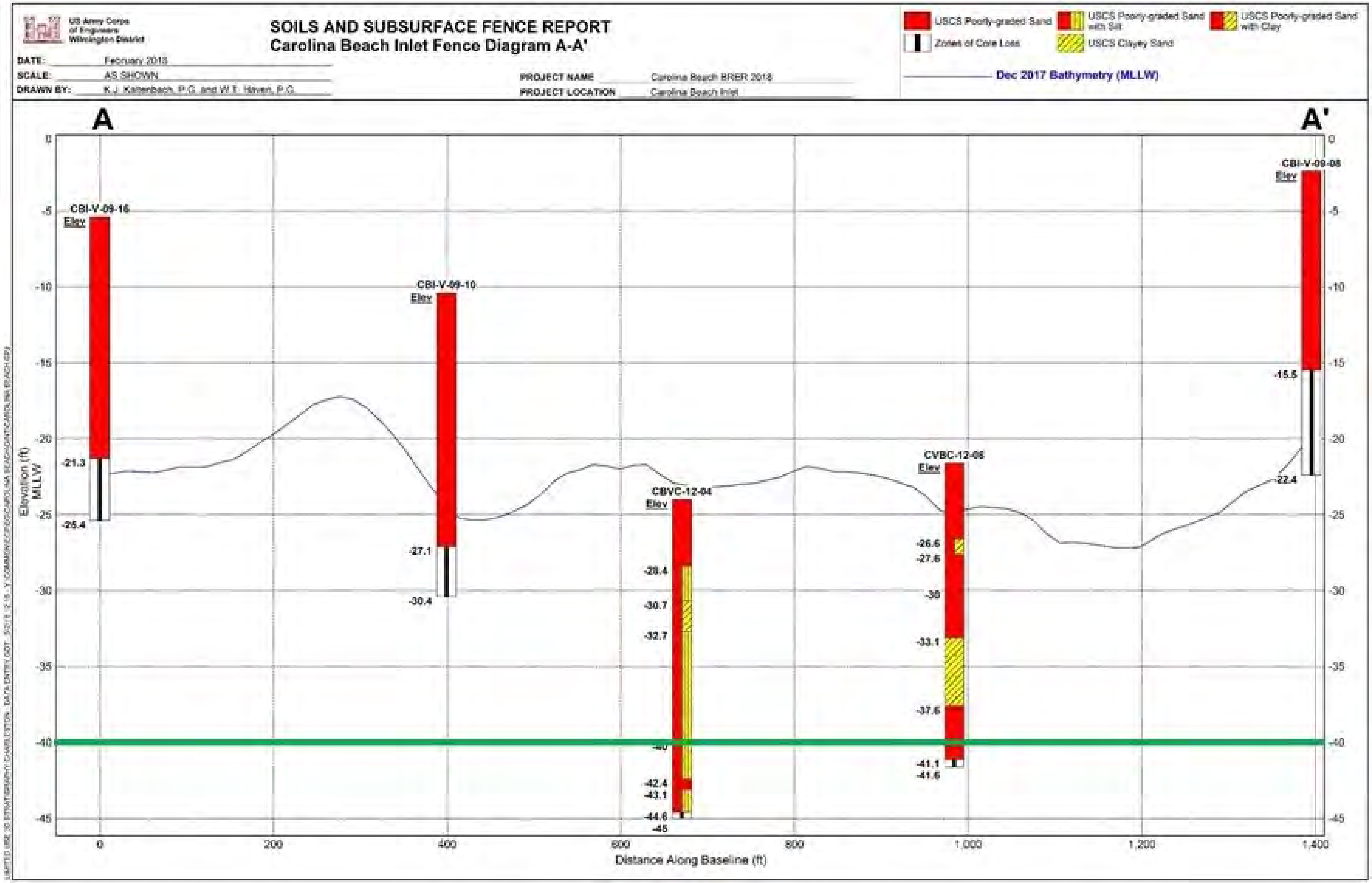

Figure 8. Carolina Beach Inlet Fence Diagram A-A'. See Figure 7 for profile location. The green line denotes the typical design dredging depth, while the smooth black line represents the inlet bottom from a December 2017 bathymetric survey.

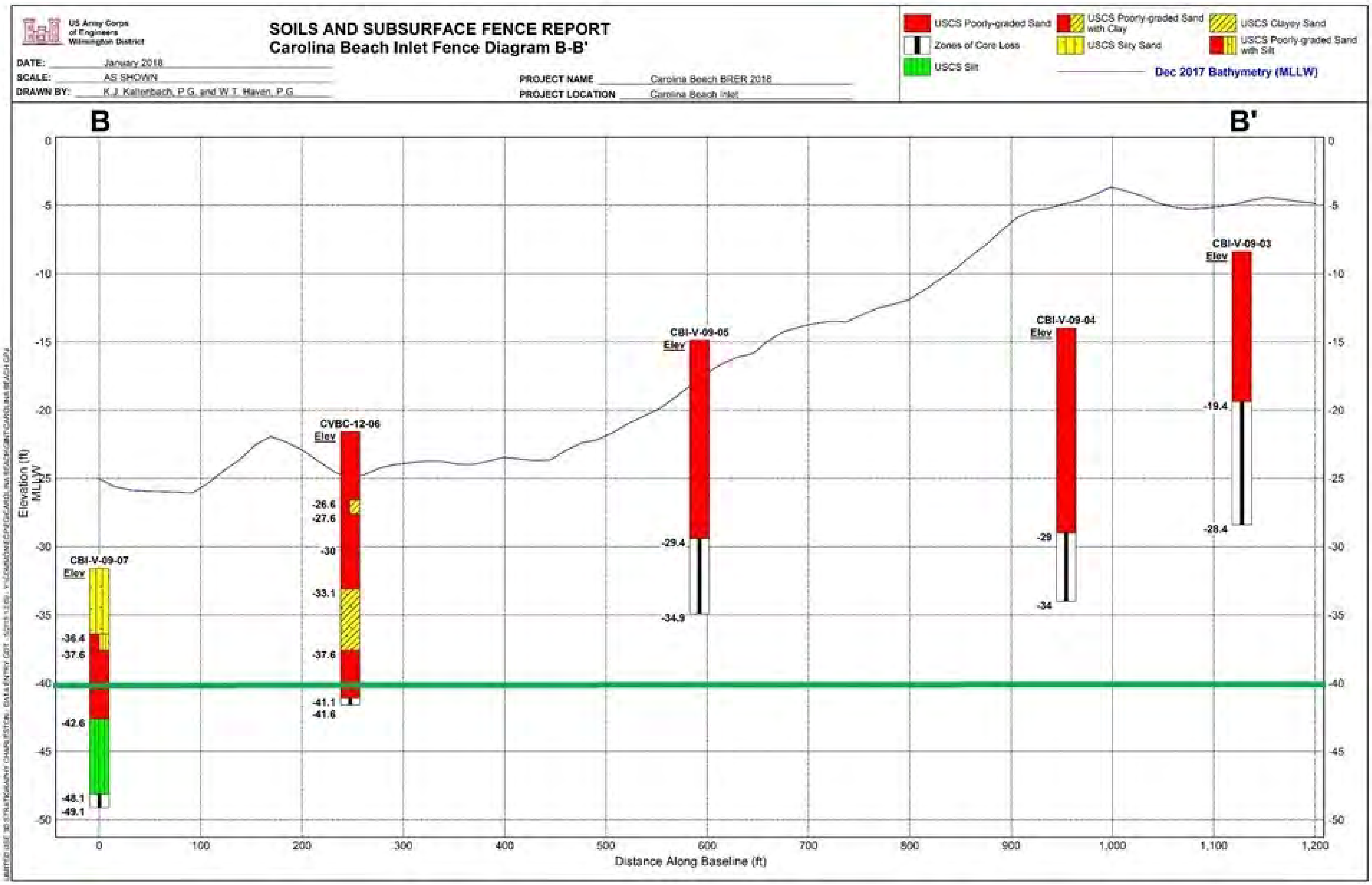

Figure 9. Carolina Beach Inlet Fence Diagram B-B'. See Figure 7 for profile location. The green line denotes the typical design dredging depth, while the smooth black line represents the inlet bottom from a December 2017 bathymetric survey.

Conversely, clastic sediment in the vicinity of vibracores CBI-V-09-03, 04, 07, and CBVC-12-04 has accumulated to bathymetric elevations higher than at the time these cores were collected. Regardless, respective core records, combined with data from Table 2 show a historical trend indicating that suitable sand has accumulated and has generally been well distributed throughout the borrow area over time. Additionally, while vibracores CBI-V-09-03, 04, 05, and 08 show “Zones of Core Loss,” respective, missing sediment likely represents areas of suitable renourishment material (Figures 8 and 9). This conclusion is based on (1) the fieldwork difficulties of retaining sandy particles in core tubes at depth and (2) the lithology of nearby cores at similar depths. Finally, core CBI-V-09-07 was bored near the southern edge of USACE’s Section 934 boundary and has unsuitable material below 42.6 ft. However, respective core lithology indicates the presence of suitable sediment above this depth. Additionally, based on review of available dredging project specifications which had been developed for the last several renourishment cycles, future dredging projects are not likely to have design depths below -40 ft. (MLLW).

2.4 CAROLINA BEACH INLET SAND REPLENISHMENT

Renourishment material removed from the Section 934 boundary is naturally replaced by sand from littoral transport. Additionally, during June 2017, the IDMMS portion of the 934 area was established as a sand repository to store material that had been dredged for nearby inlet channel maintenance. For instance, anthropogenic discharges of material into the IDMMS occurred during August 30 – September 02, and December 07 – 16, 2017, wherein 7,740 yd^3 and 11,795 yd^3 were deposited, respectively.

Inlet sand recharge, specifically into the IDMMS, is evident when analyzing bathymetric survey data from pre- and post- dredging conditions. Some examples of comparative bathymetric surveys are provided for illustrative purposes. For instance, Figures 10 and 11, respectively, show bathymetric conditions prior to and after dredging for the 2001 Carolina Beach renourishment project. Figures 12 and 13 delineate pre- and post-dredging bathymetry for the 2007 renourishment cycle and Figures 14 and 15 show conditions related to the 2010 renourishment. Finally, Figures 16 and 17 provide comparative information for the 2013 cycle, while Figures 18 and 19 provide images for the 2016 cycle.

Each of the pre-dredging examples (Figures 10, 12, 14, 16, and 18) show a borrow area which had already “recovered” from a previous triennial dredging and renourishment project. Respective post-dredging examples (Figures 11, 13, 15, 17, and 19), along with information from Table 1, show that Carolina Beach Inlet, and specifically the IDMMS, has served as a consistent and reliable source area for beach renourishment sand. Additionally, comparison of these pre- and post-dredging images indicate that dredging activities are spread throughout various parts of the borrow area. As a result, areas within the IDMMS where vibracoring and follow-on lab analysis did not occur have consistently been dredged, recharged with suitable sand, and dredged again. Finally, Figure 20, reflects IDMMS bathymetry from a December 2017 USACE survey. The shallower bathymetry in this image, as compared to that in Figure 19, reflects IDMMS material accumulation since the 2016 beach renourishment dredging cycle.

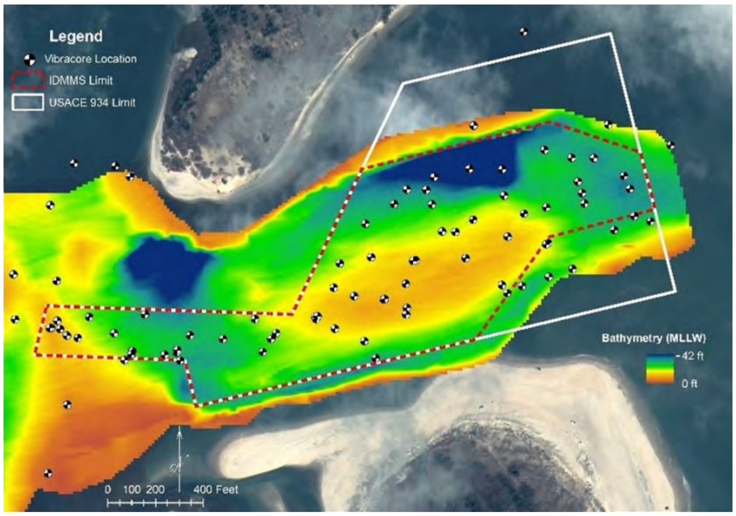

Figure 10. IDMMS Pre-Dredging Bathymetry, January 2001.

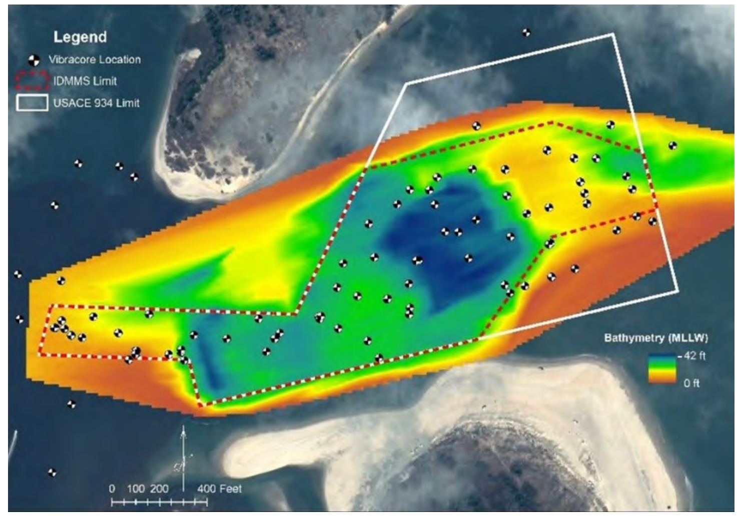

Figure 11. IDMMS Post-Dredging Bathymetry, March 2001.

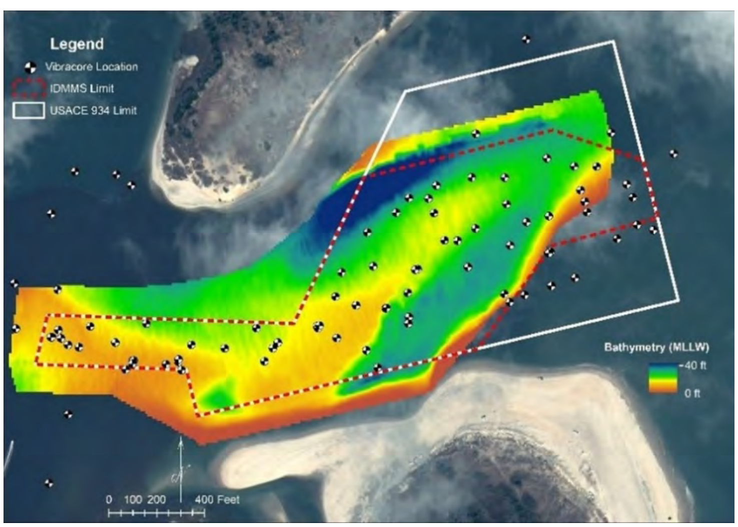

Figure 12. IDMMS Pre-Dredging Bathymetry, January 2007.

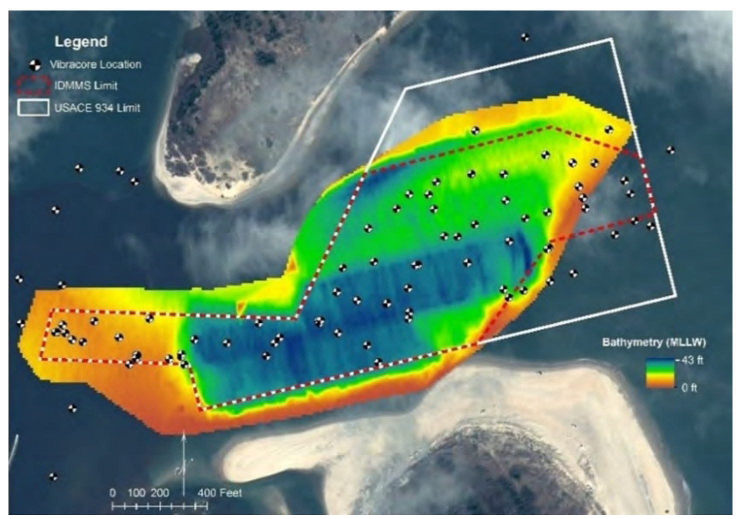

Figure 13. IDMMS Post-Dredging Bathymetry, February 2007.

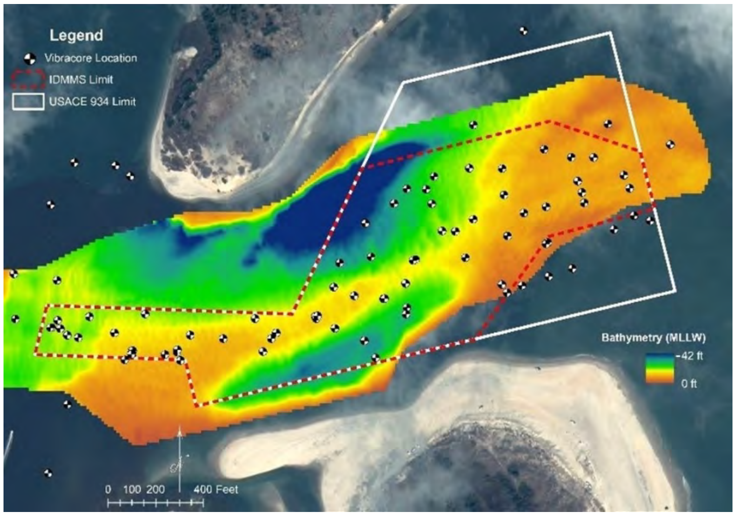

Figure 14. IDMMS Pre-Dredging Bathymetry, April 2010.

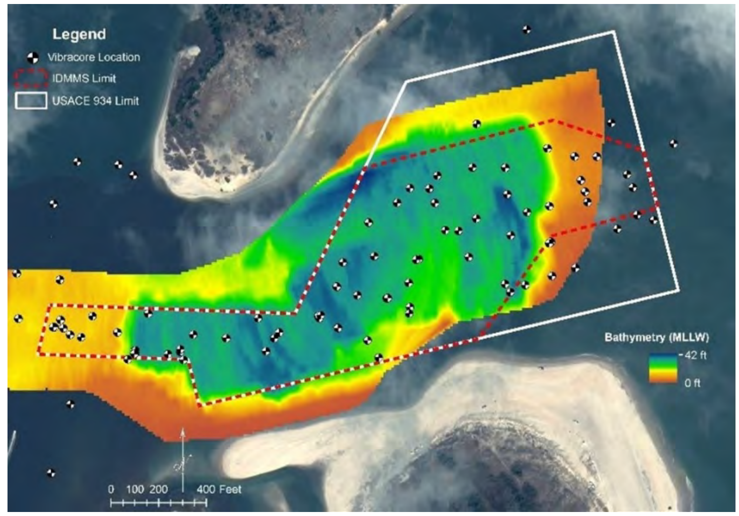

Figure 15. IDMMS Post-Dredging Bathymetry, May 2010.

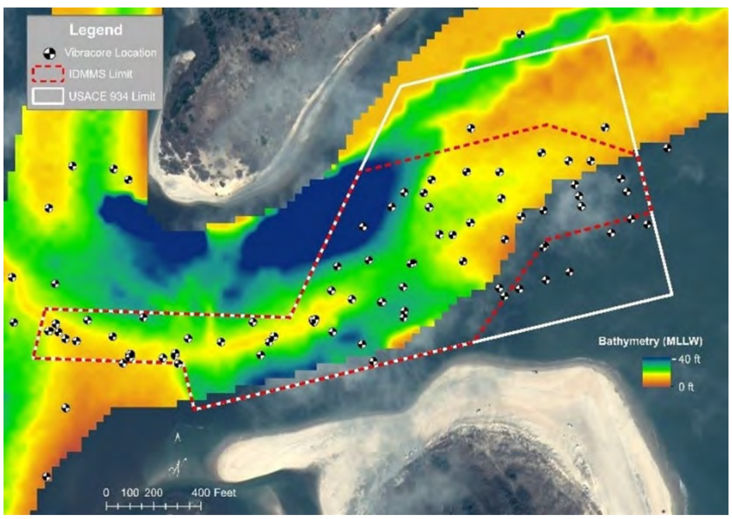

Figure 16. IDMMS Pre-Dredging Bathymetry, October 2012.

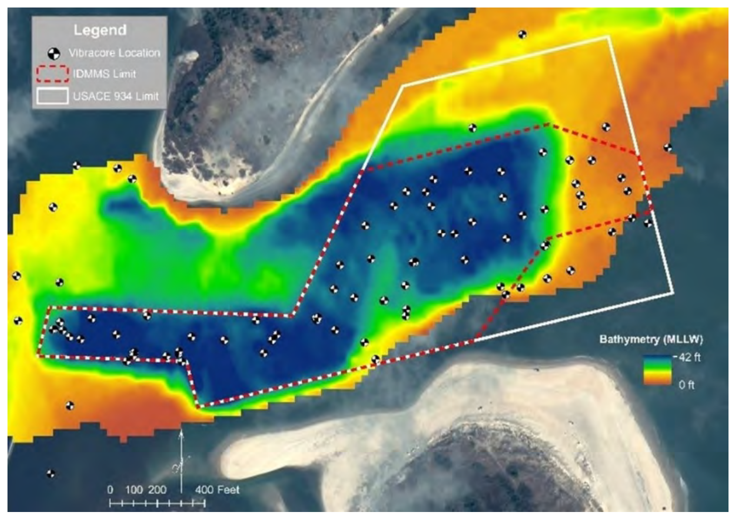

Figure 17. IDMMS Post-Dredging Bathymetry, March 2013.

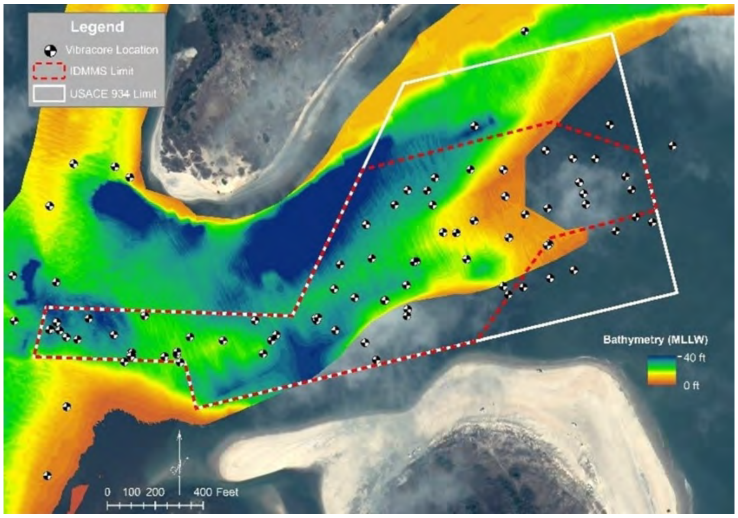

Figure 18. IDMMS Pre-Dredging Bathymetry, January 2016.

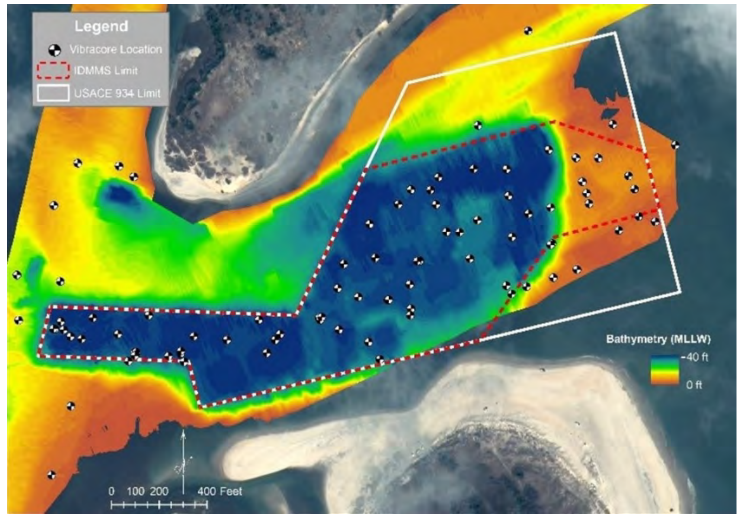

Figure 19. IDMMS Post-Dredging Bathymetry, April 2016.

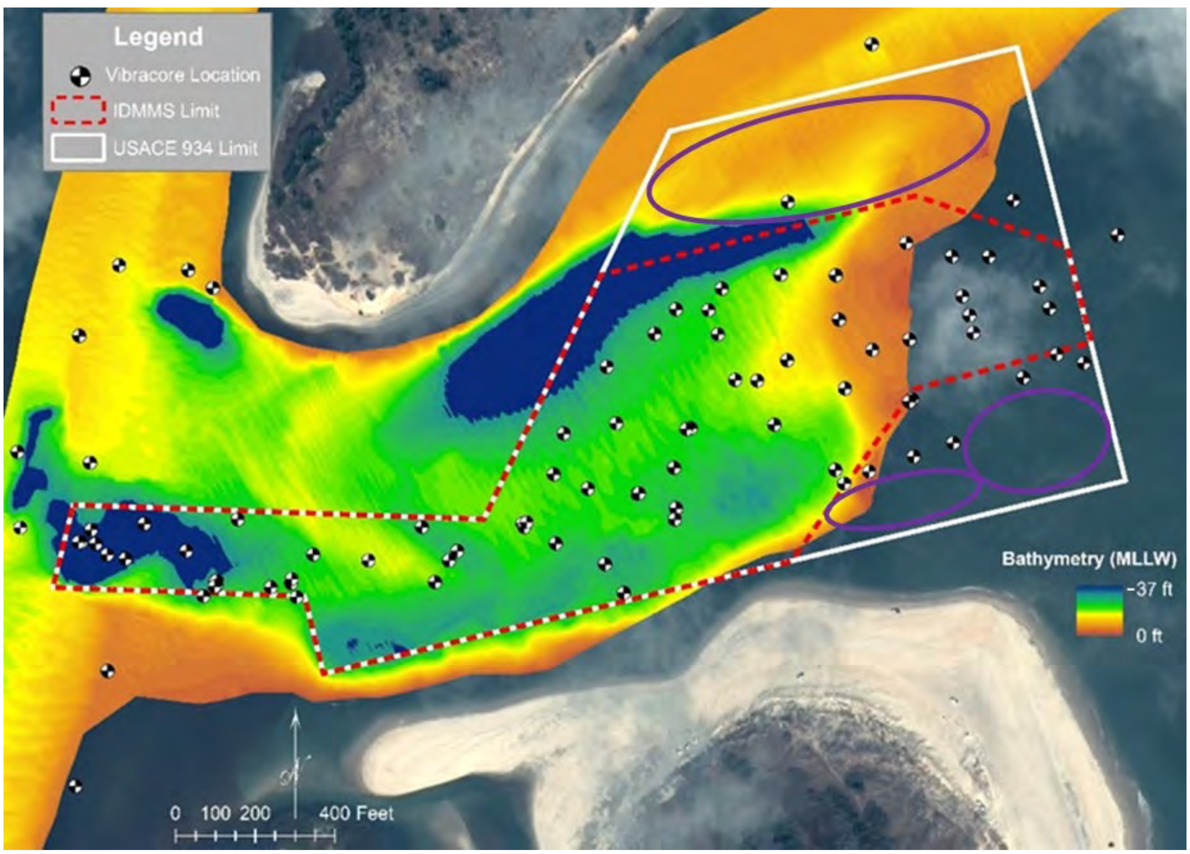

Figure 20. IDMMS Bathymetry from December 2017 Condition Survey. Purple ovals delineate general areas where future vibracoring is recommended.

2.5 SAND SUITABILITY – BORROW AREA B

Prior vibracore records and laboratory data from 1991 and 2012 were initially reviewed to assess the historical consistency of sand resources within Borrow Area B. Additionally, new vibracores and respective laboratory information were obtained during the summer and fall of 2018, which were incorporated into this study. Several of the 1991 vibracores sampled material from outside Borrow Area B, while others were located in roughly the same location as the 2012 vibracores. Additionally, since coring operations were completed in 1991, several hurricanes have passed through this area, allowing for the possibility that unusually large wave heights and strong water currents might have resulted in lithologic redistribution of surficial, unconsolidated sediment. As a result, this study largely focused information obtained from the 2012 and 2018 cores, which provided the most recent and spatially well-distributed data available. These vibracore locations are shown in Figure 21, while sand compatibility information for each core is provided in Table 4.

USCS classification of sediment within the borrow area ranges widely from CH to SW. Based on the 2012 and 2018 vibracores, the mean fines content within Borrow Area B is 11.7 percent, which is slightly above the desired fines percentage of 10 or less. However, this respective sample population was taken from all vibracores, at varying depths. As a result, this mean value considers both suitable and unsuitable material, the latter of which is not included within the suitable material isopach map (Figure 22) and generally occurs at depth, beneath the suitable material. Thus, the average fines content for the suitable material within Borrow Area B is 3.6 percent. Average shell content for all sampled material within the borrow area is 2.2 percent, while average shell content within the suitable material is 3.0 percent. Additionally, suitable renourishment sediment occurs throughout the entire borrow area. However, recoverable volumes are greatest in the northwestern half of the borrow site, which is closer to the beach than other portions of the borrow site. As a result, future dredging could be focused within this area, to maximize sand recovery, and to take advantage of dredging operations proximity, with respect to beach placement work. Refer to Figure 21, as well as Figures 23 through 26 for related fence diagram locations and profiles.

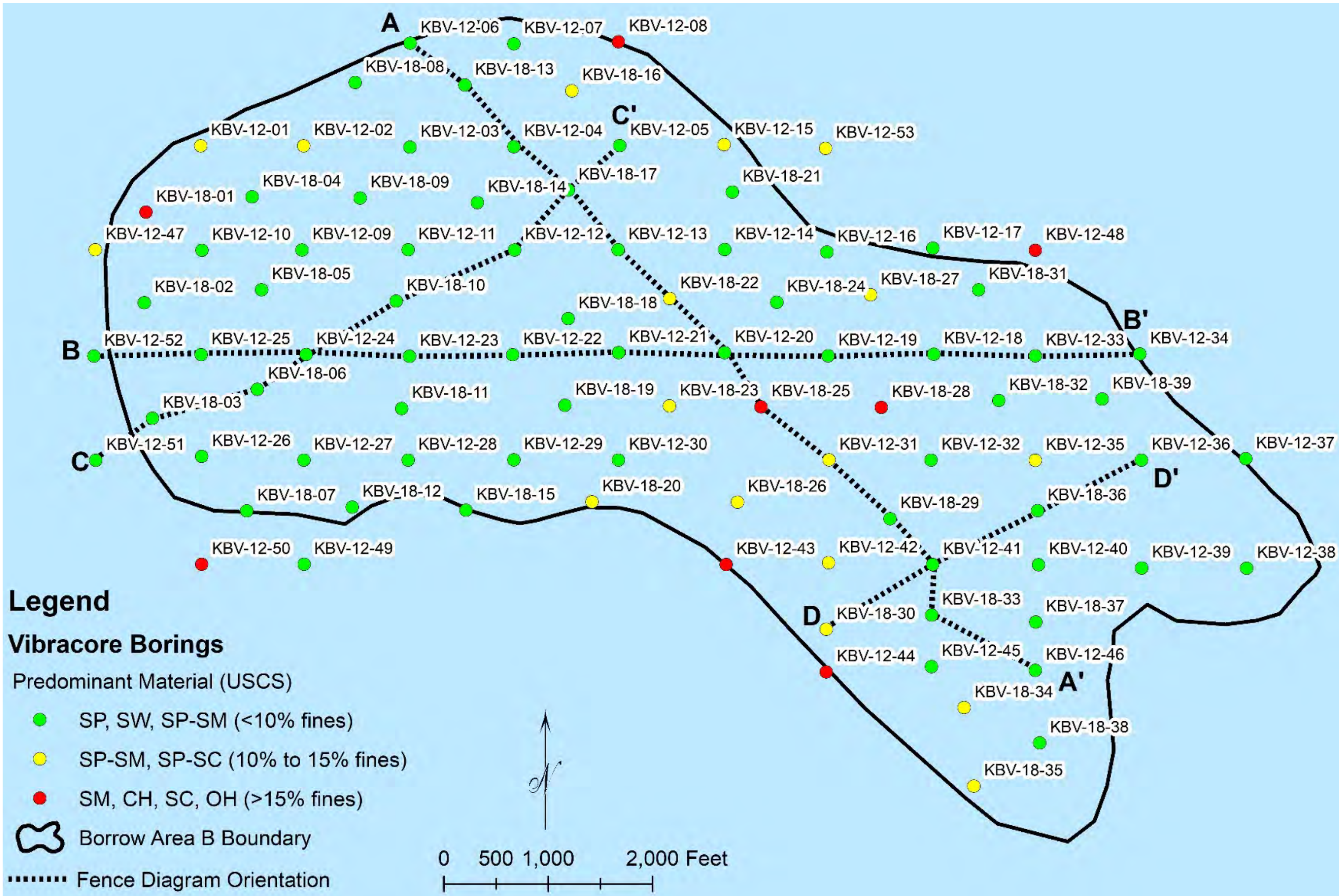

Figure 21. Borrow Area B Vibracore Location Map (2012 and 2018). The color green indicates beach suitable material, while yellow indicates material that may be used, if mixed with nearby suitable sediment. Red indicates unsuitable material. The beach compatibility color code is based on the material from which a core was taken at the time of collection. Fence diagrams are shown as Figures 23 through 26.

Table 4. Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-01	CL	-30.5 to -34.5	74.18	10.23	Inside Borrow Area B
2018	KBV-18-01	CL	-34.5 to -38.5	95.52	ND	Inside Borrow Area B
2018	KBV-18-01	CL	-38.5 to -43.5	96.01	ND	Inside Borrow Area B
2018	KBV-18-01	CL	-43.5 to -45.5	96.82	ND	Inside Borrow Area B
2018	KBV-18-01	SP*	-45.5 to -46	NR	NR	Inside Borrow Area B
2018	KBV-18-02	SP	-31.7 to -35.7	1.49	4.04	Inside Borrow Area B
2018	KBV-18-02	SW-SC	-35.7 to -37.5	8.44	13	Inside Borrow Area B
2018	KBV-18-02	SP-SC	-37.5 to -39.7	9.43	4.6	Inside Borrow Area B
2018	KBV-18-02	CL	-39.7 to -41.7	77.59	ND	Inside Borrow Area B
2018	KBV-18-02	SP*	-41.7 to -46.1	NR	NR	Inside Borrow Area B
2018	KBV-18-03	SP*	-31.7 to -32.5	NR	NR	Inside Borrow Area B
2018	KBV-18-03	CL*	-32.5 to -32.6	NR	NR	Inside Borrow Area B
2018	KBV-18-03	SW-SC	-32.6 to -38.5	2.04	18.01	Inside Borrow Area B
2018	KBV-18-03	SP-SC	-38.5 to -39.3	8.21	2.3	Inside Borrow Area B
2018	KBV-18-03	SP	-39.3 to -45.3	3.92	ND	Inside Borrow Area B
2018	KBV-18-03	SP-SC	-45.3 to -45.7	5	ND	Inside Borrow Area B
2018	KBV-18-03	SP*	-45.7 to -47.1	NR	NR	Inside Borrow Area B
2018	KBV-18-04	SP	-28.7 to -34.5	2.04	7.52	Inside Borrow Area B
2018	KBV-18-04	SP-SM	-34.5 to -36.3	6.72	8.37	Inside Borrow Area B
2018	KBV-18-04	SP-SM	-36.3 to -34.1	5.09	0.8	Inside Borrow Area B
2018	KBV-18-04	SP	-43.1 to -46.9	1.94	0.6	Inside Borrow Area B
2018	KBV-18-05	SP	-29.9 to -36.5	1.66	2.4	Inside Borrow Area B
2018	KBV-18-05	SP-SC	-36.5 to -38.2	6.69	5.1	Inside Borrow Area B
2018	KBV-18-05	SP-SC	-38.2 to -42.9	6.44	19.37	Inside Borrow Area B
2018	KBV-18-05	SP	-42.9 to -46.1	4.8	0.4	Inside Borrow Area B
2018	KBV-18-06	SP	-35.5 to -39.8	2.23	3.1	Outside Borrow Area B
2018	KBV-18-06	SP	-39.8 to -42.3	2.42	6.14	Outside Borrow Area B
2018	KBV-18-06	SP-SC	-42.3 to -47.0	6.68	2.7	Outside Borrow Area B
2018	KBV-18-06	SP*	-47.0 to -48.0	NR	NR	Outside Borrow Area B
2018	KBV-18-06	SM Ƭ[4]	-48.0 to -50.5	12.31	ND	Outside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ƭ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-07	SP	-29.8 to -34.9	1.15	2	Inside Borrow Area B
2018	KBV-18-07	SP	-34.9 to -40.8	2.74	ND	Inside Borrow Area B
2018	KBV-18-07	SP	-40.8 to -45.0	3.61	6.5	Inside Borrow Area B
2018	KBV-18-07	GP-GC[Ŧ]	-45.0 to -48.1	7.32	ND	Inside Borrow Area B
2018	KBV-18-07	SP*	-48.1 to -49.8	NR	NR	Inside Borrow Area B
2018	KBV-18-08	SP	-37.3 to -42.5	3.51	ND	Outside Borrow Area B
2018	KBV-18-08	SP	-42.5 to -50.2	1.56	2.2	Outside Borrow Area B
2018	KBV-18-08	SP-SC	-50.2 to -51.5	6.45	0.8	Outside Borrow Area B
2018	KBV-18-08	SM	-51.5 to -55.8	29.74	ND	Outside Borrow Area B
2018	KBV-18-09	SP	-25.1 to -28.2	3.14	4.6	Inside Borrow Area B
2018	KBV-18-09	SP	-28.2 to -32.1	2.79	0.9	Inside Borrow Area B
2018	KBV-18-09	SP	-32.1 to -35.6	3.59	11.2	Inside Borrow Area B
2018	KBV-18-09	SW	-35.6 to -41.9	4.29	21.91	Inside Borrow Area B
2018	KBV-18-10	SP	-32.2 to -39.1	2.05	8.9	Inside Borrow Area B
2018	KBV-18-10	SM	-39.1 to -42.4	13.36	0.3	Inside Borrow Area B
2018	KBV-18-10	SP-SM	-42.2 to -43.7	6.58	5.1	Inside Borrow Area B
2018	KBV-18-10	SP*	-43.7 to -45.3	NR	NR	Inside Borrow Area B
2018	KBV-18-10	SP-SM*	-45.3 to -45.6	NR	NR	Inside Borrow Area B
2018	KBV-18-10	SM*	-45.6 to -47.2	NR	NR	Inside Borrow Area B
2018	KBV-18-11	SP	-35.1 to -38.6	4.73	2.9	Inside Borrow Area B
2018	KBV-18-11	SP	-38.6 to -45.1	1.84	2.8	Inside Borrow Area B
2018	KBV-18-11	SM	-45.1 to -47.1	13.63	5.5	Inside Borrow Area B
2018	KBV-18-11	SM	-47.1 to -53.0	18.87	5.8	Inside Borrow Area B
2018	KBV-18-12	SP	-34.0 to -35.9	2.64	0.6	Inside Borrow Area B
2018	KBV-18-12	SP	-35.9 to -45.0	2.63	1.4	Inside Borrow Area B
2018	KBV-18-12	SM	-45.0 to -45.7	19.33	ND	Inside Borrow Area B
2018	KBV-18-12	SP-SM[Ŧ]	-45.7 to -52.7	10.29	ND	Inside Borrow Area B
2018	KBV-18-13	SP	-36.0 to -42.5	2.98	3.9	Inside Borrow Area B
2018	KBV-18-13	SP	-42.5 to -45.0	3.04	3.14	Inside Borrow Area B
2018	KBV-18-13	SP	-45.0 to -49.1	4.41	1.2	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

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Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-13	SP	-49.1 to -52.9	1.33	6.5	Inside Borrow Area B
2018	KBV-18-14	SP	-25.6 to -28.2	1.61	1.7	Inside Borrow Area B
2018	KBV-18-14	SP	-28.2 to -32.1	1.24	2.1	Inside Borrow Area B
2018	KBV-18-14	SP	-32.1 to -36.4	3.28	0.5	Inside Borrow Area B
2018	KBV-18-14	SW	-36.4 to -43.3	2.91	8.1	Inside Borrow Area B
2018	KBV-18-15	SP	-36.6 to -43.8	0.39	3.9	Outside Borrow Area B
2018	KBV-18-15	SP-SM	-43.8 to -46.2	5.95	ND	Outside Borrow Area B
2018	KBV-18-15	SM Ͳ	-46.2 to -48.6	13.02	ND	Outside Borrow Area B
2018	KBV-18-15	SP* Ͳ	-48.6 to -49.9	NR	NR	Outside Borrow Area B
2018	KBV-18-15	SM* Ͳ	-49.9 to -53.3	NR	NR	Outside Borrow Area B
2018	KBV-18-16	SP-SC	-36.5 to -37.9	11.07	0.5	Inside Borrow Area B
2018	KBV-18-16	SP	-36.5 to -42.5	2.15	0.7	Inside Borrow Area B
2018	KBV-18-16	SP	-42.5 to -47.6	3.42	2.8	Inside Borrow Area B
2018	KBV-18-16	CL	-47.6 to -56.5	35.52	ND	Inside Borrow Area B
2018	KBV-18-17	SP*	-24.6 to -26.0	NR	NR	Outside Borrow Area B
2018	KBV-18-17	SP-SM	-26.0 to -28.1	9.51	2.6	Outside Borrow Area B
2018	KBV-18-17	SP	-28.1 to -34.5	2.92	0.2	Outside Borrow Area B
2018	KBV-18-17	CL	-34.5 to -37.6	87.14	ND	Outside Borrow Area B
2018	KBV-18-17	SM	-37.6 to -40.6	37.06	0.2	Outside Borrow Area B
2018	KBV-18-18	SP	-37.8 to -45.0	3.12	ND	Inside Borrow Area B
2018	KBV-18-18	SM	-45.0 to -49.3	42.28	0.1	Inside Borrow Area B
2018	KBV-18-18	SM	-49.3 to -55.3	33.97	ND	Inside Borrow Area B
2018	KBV-18-18	SM	-55.3 to -57.2	24.43	ND	Inside Borrow Area B
2018	KBV-18-19	SP	-37.6 to -38.7	1.72	6.05	Inside Borrow Area B
2018	KBV-18-19	SP	-38.7 to -47.0	2.32	0.7	Inside Borrow Area B
2018	KBV-18-19	SW	-47.0 to -47.9	2.11	12.38	Inside Borrow Area B
2018	KBV-18-19	SP	-47.9 to -50.4	3.62	0.5	Inside Borrow Area B
2018	KBV-18-20	SP*	-39.8 to -40.8	NR	NR	Inside Borrow Area B
2018	KBV-18-20	SM	-40.8 to -45.0	17.69	ND	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ͳ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-20	SM	-45.0 to -47.0	14.04	ND	Inside Borrow Area B
2018	KBV-18-20	SM	-47.0 to -48.3	12.59	3.3	Inside Borrow Area B
2018	KBV-18-20	SP-SM	-48.3 to -56.1	9.85	0.5	Inside Borrow Area B
2018	KBV-18-21	SP	-27.5 to -33.9	1.19	1.5	Inside Borrow Area B
2018	KBV-18-21	SP-SM	-33.9 to -36.8	9.39	9.91	Inside Borrow Area B
2018	KBV-18-21	SP	-36.8 to -41.5	2.53	0.1	Inside Borrow Area B
2018	KBV-18-21	SP-SM	-41.5 to -43.0	7.25	1.9	Inside Borrow Area B
2018	KBV-18-22	SP*	-31.7 to -34.0	NR	NR	Inside Borrow Area B
2018	KBV-18-22	SP-SM	-34 to -37.5	6.17	ND	Inside Borrow Area B
2018	KBV-18-22	SM	-37.5 to -41.7	37.65	ND	Inside Borrow Area B
2018	KBV-18-22	SM	-41.7 to -47.7	24.68	0.1	Inside Borrow Area B
2018	KBV-18-22	SM	-47.7 to -51.1	34.51	ND	Inside Borrow Area B
2018	KBV-18-23	SP-SM	-40.0 to -41.4	8.75	3.5	Inside Borrow Area B
2018	KBV-18-23	SM	-41.4 to -49.7	31.59	1.2	Inside Borrow Area B
2018	KBV-18-23	SM	-49.7 to -52.5	35.58	1	Inside Borrow Area B
2018	KBV-18-23	SM	-52.5 to -59.7	34.8	ND	Inside Borrow Area B
2018	KBV-18-24	SP	-35.5 to -38.7	3.17	0.6	Inside Borrow Area B
2018	KBV-18-24	SP-SM	-38.7 to -43.0	6.34	0.9	Inside Borrow Area B
2018	KBV-18-24	SM	-43 to -46.0	31.3	ND	Inside Borrow Area B
2018	KBV-18-24	SM	-46.0 to -54.9	34.5	ND	Inside Borrow Area B
2018	KBV-18-25	SM	-36.2 to -37.6	47.37	3.3	Inside Borrow Area B
2018	KBV-18-25	SM	-37.6 to -43.2	41.34	0.7	Inside Borrow Area B
2018	KBV-18-25	SM	-43.2 to -49.2	33.3	ND	Inside Borrow Area B
2018	KBV-18-25	SM	-49.2 to -56.1	34.35	0.4	Inside Borrow Area B
2018	KBV-18-26	SP*	-44.5 to -45.3	NR	NR	Outside Borrow Area B
2018	KBV-18-26	SP-SM	-45.3 to -50.0	8.57	1.6	Outside Borrow Area B
2018	KBV-18-26	SM	-50.0 to -51.0	17.92	ND	Outside Borrow Area B
2018	KBV-18-26	SP-SM	-51.0 to -55.5	7.54	ND	Outside Borrow Area B
2018	KBV-18-26	SM	-55.5 to -60.5	24.34	ND	Outside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-27	SP	-35.0 to -38.6	2.84	3.1	Inside Borrow Area B
2018	KBV-18-27	SM	-38.6 to -39.9	14.59	0.9	Inside Borrow Area B
2018	KBV-18-27	SP-SM	-39.9 to -42.6	5.47	1.6	Inside Borrow Area B
2018	KBV-18-27	SM	-42.6 to -55.0	36.92	ND	Inside Borrow Area B
2018	KBV-18-28	CL*	-43.0 to -44.3	NR	NR	Inside Borrow Area B
2018	KBV-18-28	SM	-44.3 to -45.5	23.14	0.3	Inside Borrow Area B
2018	KBV-18-28	SP	-45.5 to -47.9	1.48	0.1	Inside Borrow Area B
2018	KBV-18-28	SM	-47.9 to -52.5	44.55	0.2	Inside Borrow Area B
2018	KBV-18-28	SM	-52.5 to -63.0	28	ND	Inside Borrow Area B
2018	KBV-18-29	SP	-40.8 to -44.4	1.54	0.5	Inside Borrow Area B
2018	KBV-18-29	SM	-44.4 to -45.9	12.15	0.43	Inside Borrow Area B
2018	KBV-18-29	SM	-45.9 to -48.3	38.87	0.5	Inside Borrow Area B
2018	KBV-18-29	SM	-48.3 to -54.8	35.69	ND	Inside Borrow Area B
2018	KBV-18-30	SP-SM	-37.1 to -39.6	11.81	ND	Outside Borrow Area B
2018	KBV-18-30	SW-SM[Ŧ]	-39.6 to -45.1	7.85	12.4	Outside Borrow Area B
2018	KBV-18-30	SM[Ŧ]	-45.1 to -47.6	12.02	0.7	Outside Borrow Area B
2018	KBV-18-30	SP-SM[Ŧ]	-47.6 to -55.0	9.35	3	Outside Borrow Area B
2018	KBV-18-31	SP	-34.5 to -38.5	1.53	1.5	Inside Borrow Area B
2018	KBV-18-31	SP	-38.5 to -44.4	2.03	6.7	Inside Borrow Area B
2018	KBV-18-31	SM	-44.4 to -45.5	26.09	ND	Inside Borrow Area B
2018	KBV-18-31	SM	-45.5 to -54.5	39.3	ND	Inside Borrow Area B
2018	KBV-18-32	SP	-42.6 to -44.2	2.43	0.6	Inside Borrow Area B
2018	KBV-18-32	SP-SM	-44.2 to -49.6	6.52	2.4	Inside Borrow Area B
2018	KBV-18-32	SM	-49.6 to -52.1	25.64	0.03	Inside Borrow Area B
2018	KBV-18-32	SM	-52.1 to -62.6	22.41	ND	Inside Borrow Area B
2018	KBV-18-33	SP	-33.0 to -39.8	3.35	0.9	Inside Borrow Area B
2018	KBV-18-33	SP	-39.8 to -44.3	1.94	0.2	Inside Borrow Area B
2018	KBV-18-33	GP-GM[Ŧ]	-44.3 to -46.0	7.24	ND	Inside Borrow Area B
2018	KBV-18-33	SP-SM	-46.0 to -49.9	7.29	7.48	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2018	KBV-18-34	SP	-36.3 to -39.9	4.14	0.2	Inside Borrow Area B
2018	KBV-18-34	SM	-39.9 to -42.3	14.25	ND	Inside Borrow Area B
2018	KBV-18-34	SW-SM Ŧ	-42.3 to -47.3	11.62	ND	Inside Borrow Area B
2018	KBV-18-34	SW-SM Ŧ	-47.3 to -54.6	7.81	ND	Inside Borrow Area B
2018	KBV-18-35	SP	-37.8 to -42.2	3.22	0.3	Inside Borrow Area B
2018	KBV-18-35	SM	-42.2 to -42.8	12.32	4.2	Inside Borrow Area B
2018	KBV-18-35	SP-SM Ŧ	-42.8 to -46.8	10.82	ND	Inside Borrow Area B
2018	KBV-18-35	SM	-46.8 to -52.9	14.19	1.1	Inside Borrow Area B
2018	KBV-18-36	SP	-45.2 to -46.7	1.94	0.8	Inside Borrow Area B
2018	KBV-18-36	SP	-46.7 to -47.4	0.85	2.7	Inside Borrow Area B
2018	KBV-18-36	SM	-47.4 to -50.2	31.6	ND	Inside Borrow Area B
2018	KBV-18-36	SM	-50.2 to -51.9	38.69	0.2	Inside Borrow Area B
2018	KBV-18-37	SP	-37.8 to -40.9	2.74	0.3	Inside Borrow Area B
2018	KBV-18-37	SM	-40.9 to -42.1	46.36	ND	Inside Borrow Area B
2018	KBV-18-37	SM	-42.1 to -45.3	43.89	ND	Inside Borrow Area B
2018	KBV-18-37	SP-SM	-45.3 to -57.8	7.48	0.08	Inside Borrow Area B
2018	KBV-18-38	SP	-36.6 to -44.5	1.74	0.2	Inside Borrow Area B
2018	KBV-18-38	SP-SM	-44.5 to -47.8	10.67	0.5	Inside Borrow Area B
2018	KBV-18-38	SP-SM	-47.8 to -51.6	7.78	2	Inside Borrow Area B
2018	KBV-18-38	SP-SM Ŧ	-51.6 to -52.6	9.39	2	Inside Borrow Area B
2018	KBV-18-39	SP-SM	-44.4 to -49.5	7.93	0.6	Inside Borrow Area B
2018	KBV-18-39	SM	-49.5 to -51.4	45.78	ND	Inside Borrow Area B
2018	KBV-18-39	SM	-51.4 to -55.9	32.83	ND	Inside Borrow Area B
2018	KBV-18-39	SM	-55.9 to -64.4	32	ND	Inside Borrow Area B
2012	KBV-12-01	SP	-32.64 to -34.94	1.57	NR	Inside Borrow Area B
2012	KBV-12-01	CH*	-34.94 to -35.44	NR	NR	Inside Borrow Area B
2012	KBV-12-01	SP	-35.44 to -40.04	2.61	NR	Inside Borrow Area B
2012	KBV-12-01	SC*	-40.04 to -40.54	NR	NR	Inside Borrow Area B
2012	KBV-12-01	SP	-40.54 to -46.54	1.19	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-01	SM	-46.54 to -50.64	30.37	NR	Inside Borrow Area B
2012	KBV-12-02	SP	-30.94 to -33.74	0.88	NR	Inside Borrow Area B
2012	KBV-12-02	SP-SM	-33.74 to -36.24	10.45	NR	Inside Borrow Area B
2012	KBV-12-02	SP	-36.24 to -44.24	1.7	NR	Inside Borrow Area B
2012	KBV-12-02	SP-SM*	-44.24 to -44.94	NR	NR	Inside Borrow Area B
2012	KBV-12-02	SM	-44.94 to -48.74	30.2	NR	Inside Borrow Area B
2012	KBV-12-03	SP	-29.74 to -33.44	1.25	NR	Inside Borrow Area B
2012	KBV-12-03	SP-SM	-33.44 to -35.44	5.77	NR	Inside Borrow Area B
2012	KBV-12-03	GW*	-35.44 to -35.94	NR	NR	Inside Borrow Area B
2012	KBV-12-03	SP	-35.94 to -38.74	1.55	NR	Inside Borrow Area B
2012	KBV-12-03	SP	-38.74 to -43.14	1.86	NR	Inside Borrow Area B
2012	KBV-12-03	SM*	-43.14 to -43.44	NR	NR	Inside Borrow Area B
2012	KBV-12-04	SP	-29.14 to -35.14	1.15	NR	Inside Borrow Area B
2012	KBV-12-04	SW*	-35.14 to -36.04	NR	NR	Inside Borrow Area B
2012	KBV-12-04	SP	-36.04 to -37.44	2.87	NR	Inside Borrow Area B
2012	KBV-12-04	SP	-37.44 to -44.14	4.46	NR	Inside Borrow Area B
2012	KBV-12-05	SP	-31.24 to -38.04	1.48	NR	Inside Borrow Area B
2012	KBV-12-05	SM	-38.04 to -39.64	16.07	NR	Inside Borrow Area B
2012	KBV-12-05	CH	-39.64 to -43.44	71.47	NR	Inside Borrow Area B
2012	KBV-12-05	SM	-43.44 to -45.74	14.11	NR	Inside Borrow Area B
2012	KBV-12-05	SP-SM*	-45.74 to -48.04	NR	NR	Inside Borrow Area B
2012	KBV-12-05	SP*	-48.04 to -50.94	NR	NR	Inside Borrow Area B
2012	KBV-12-05	SM*	-50.94 to -51.34	NR	NR	Inside Borrow Area B
2012	KBV-12-06	SP	-34.34 to -37.84	1.65	NR	Inside Borrow Area B
2012	KBV-12-06	SP	-37.84 to -42.84	1.57	NR	Inside Borrow Area B
2012	KBV-12-06	SP	-42.84 to -47.54	1.96	NR	Inside Borrow Area B
2012	KBV-12-06	SW*	-47.54 to -48.34	NR	NR	Inside Borrow Area B
2012	KBV-12-06	SM*	-48.34 to -52.14	NR	NR	Inside Borrow Area B
2012	KBV-12-07	SP	-34.04 to -37.34	1.85	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ƭ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-07	SP	-37.34 to -40.04	1.13	NR	Inside Borrow Area B
2012	KBV-12-07	SP	-40.04 to -45.04	1.03	NR	Inside Borrow Area B
2012	KBV-12-07	SP	-45.04 to -47.04	1.11	NR	Inside Borrow Area B
2012	KBV-12-07	SM*	-47.04 to -47.54	NR	NR	Inside Borrow Area B
2012	KBV-12-08	SM	-35.04 to -36.54	41.19	NR	Inside Borrow Area B
2012	KBV-12-08	SP*	-36.54 to -37.14	NR	NR	Inside Borrow Area B
2012	KBV-12-08	SW	-37.14 to -39.24	4.56	NR	Inside Borrow Area B
2012	KBV-12-08	CH*	-39.24 to -40.54	NR	NR	Inside Borrow Area B
2012	KBV-12-08	SP	-40.54 to -46.64	3.88	NR	Inside Borrow Area B
2012	KBV-12-08	SM	-46.64 to -57.04	32.9	NR	Inside Borrow Area B
2012	KBV-12-09	SP	-25.04 to -30.04	1.06	NR	Inside Borrow Area B
2012	KBV-12-09	SP	-30.04 to -31.84	1.4	NR	Inside Borrow Area B
2012	KBV-12-09	SP	-31.84 to -35.64	4.58	NR	Inside Borrow Area B
2012	KBV-12-09	SW	-35.64 to -38.44	3.55	NR	Inside Borrow Area B
2012	KBV-12-09	SP*	-38.44 to -43.44	NR	NR	Inside Borrow Area B
2012	KBV-12-10	SP	-27.34 to -28.74	0.91	NR	Inside Borrow Area B
2012	KBV-12-10	SP	-28.74 to -33.34	0.71	NR	Inside Borrow Area B
2012	KBV-12-10	SP	-33.34 to -40.14	3.03	NR	Inside Borrow Area B
2012	KBV-12-10	SP	-40.14 to -44.34	1.01	NR	Inside Borrow Area B
2012	KBV-12-11	SP	-25.94 to -29.94	0.62	NR	Inside Borrow Area B
2012	KBV-12-11	SP	-29.94 to -34.54	1.21	NR	Inside Borrow Area B
2012	KBV-12-11	SM	-34.54 to -35.04	43.63	NR	Inside Borrow Area B
2012	KBV-12-11	SW*	-35.04 to -36.04	NR	NR	Inside Borrow Area B
2012	KBV-12-11	SM*	-36.04 to -36.54	NR	NR	Inside Borrow Area B
2012	KBV-12-11	SP	-36.54 to -41.44	2.55	NR	Inside Borrow Area B
2012	KBV-12-12	SP	-27.64 to -31.34	0.85	NR	Inside Borrow Area B
2012	KBV-12-12	SP	-31.34 to -35.34	0.98	NR	Inside Borrow Area B
2012	KBV-12-12	SW*	-35.34 to -35.84	NR	NR	Inside Borrow Area B
2012	KBV-12-12	SP	-35.84 to -40.94	1.17	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

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Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-12	SP	-40.94 to -44.64	1.23	NR	Inside Borrow Area B
2012	KBV-12-12	SM*	-44.64 to -45.94	NR	NR	Inside Borrow Area B
2012	KBV-12-13	SP	-32.14 to -35.14	0.94	NR	Inside Borrow Area B
2012	KBV-12-13	SP	-35.14 to -37.24	1.14	NR	Inside Borrow Area B
2012	KBV-12-13	SM	-37.24 to -38.14	18.5	NR	Inside Borrow Area B
2012	KBV-12-13	SW-SM*	-38.14 to -40.74	NR	NR	Inside Borrow Area B
2012	KBV-12-13	SP	-40.74 to -46.64	5.01	NR	Inside Borrow Area B
2012	KBV-12-13	SC*	-46.64 to -50.74	NR	NR	Inside Borrow Area B
2012	KBV-12-14	SP	-37.44 to -40.64	0.98	NR	Inside Borrow Area B
2012	KBV-12-14	SP	-40.64 to -43.04	4.75	NR	Inside Borrow Area B
2012	KBV-12-14	SP-SM	-43.04 to -47.24	7.51	NR	Inside Borrow Area B
2012	KBV-12-14	SW*	-47.24 to -47.74	NR	NR	Inside Borrow Area B
2012	KBV-12-14	SM	-47.74 to -58.44	28.56	NR	Inside Borrow Area B
2012	KBV-12-15	SP	-34.14 to -37.74	1.73	NR	Inside Borrow Area B
2012	KBV-12-15	SM	-37.74 to -38.84	36.32	NR	Inside Borrow Area B
2012	KBV-12-15	SP*	-38.84 to -39.64	NR	NR	Inside Borrow Area B
2012	KBV-12-15	SM	-39.64 to -41.54	16.91	NR	Inside Borrow Area B
2012	KBV-12-15	SP-SM	-41.54 to -50.84	5.24	NR	Inside Borrow Area B
2012	KBV-12-15	SM*	-50.84 to -54.94	NR	NR	Inside Borrow Area B
2012	KBV-12-16	SP	-39.04 to -41.94	0.92	NR	Inside Borrow Area B
2012	KBV-12-16	SP-SM	-41.94 to -47.94	5.34	NR	Inside Borrow Area B
2012	KBV-12-16	SM	-47.94 to -56.04	30.8	NR	Inside Borrow Area B
2012	KBV-12-16	SM	-56.04 to -60.34	30.91	NR	Inside Borrow Area B
2012	KBV-12-17	SP	-39.74 to -42.84	0.88	NR	Outside Borrow Area B
2012	KBV-12-17	SP-SM	-42.84 to -46.24	6.05	NR	Outside Borrow Area B
2012	KBV-12-17	GW*	-46.24 to -47.74	NR	NR	Outside Borrow Area B
2012	KBV-12-17	SP-SM	-47.74 to -51.84	9.54	NR	Outside Borrow Area B
2012	KBV-12-17	SM	-51.84 to -56.74	32.17	NR	Outside Borrow Area B
2012	KBV-12-18	SP	-37.04 to -38.64	0.71	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-18	SP	-38.64 to -43.84	1.36	NR	Inside Borrow Area B
2012	KBV-12-18	SM	-43.84 to -46.34	13.03	NR	Inside Borrow Area B
2012	KBV-12-18	SP-SM	-46.34 to -50.84	8.7	NR	Inside Borrow Area B
2012	KBV-12-18	SM*	-50.84 to -57.54	NR	NR	Inside Borrow Area B
2012	KBV-12-19	SP	-38.24 to -41.84	1.12	NR	Inside Borrow Area B
2012	KBV-12-19	SP	-41.84 to -45.54	4.34	NR	Inside Borrow Area B
2012	KBV-12-19	SP	-45.54 to -47.84	4.59	NR	Inside Borrow Area B
2012	KBV-12-19	SM	-47.84 to -56.04	28.38	NR	Inside Borrow Area B
2012	KBV-12-20	SP	-37.94 to -41.24	0.87	NR	Inside Borrow Area B
2012	KBV-12-20	SP	-41.24 to -44.14	1.19	NR	Inside Borrow Area B
2012	KBV-12-20	SP-SM	-44.14 to -47.34	8.26	NR	Inside Borrow Area B
2012	KBV-12-20	SM	-47.34 to -58.64	30.54	NR	Inside Borrow Area B
2012	KBV-12-21	SP	-37.84 to -39.84	1.62	NR	Inside Borrow Area B
2012	KBV-12-21	SW	-39.84 to -44.34	1.52	NR	Inside Borrow Area B
2012	KBV-12-21	GW	-44.34 to -45.44	1.29	NR	Inside Borrow Area B
2012	KBV-12-21	SP-SM*	-45.44 to -46.34	NR	NR	Inside Borrow Area B
2012	KBV-12-21	SP	-46.34 to -49.44	4.6	NR	Inside Borrow Area B
2012	KBV-12-21	SM*	-49.44 to -58.34	NR	NR	Inside Borrow Area B
2012	KBV-12-22	SP	-35.44 to -39.94	1.58	NR	Inside Borrow Area B
2012	KBV-12-22	SP	-39.94 to -43.94	2.49	NR	Inside Borrow Area B
2012	KBV-12-22	SW-SM	-43.94 to -45.44	5.77	NR	Inside Borrow Area B
2012	KBV-12-22	SM	-45.44 to -52.14	25.36	NR	Inside Borrow Area B
2012	KBV-12-23	SW	-33.54 to -35.04	0.79	NR	Inside Borrow Area B
2012	KBV-12-23	SP	-35.04 to -38.34	2.75	NR	Inside Borrow Area B
2012	KBV-12-23	GW*	-38.34 to -39.64	NR	NR	Inside Borrow Area B
2012	KBV-12-23	SW	-39.64 to -43.24	2.58	NR	Inside Borrow Area B
2012	KBV-12-23	SP	-43.24 to -46.34	1.14	NR	Inside Borrow Area B
2012	KBV-12-23	OH*	-46.34 to -51.74	NR	NR	Inside Borrow Area B
2012	KBV-12-23	SM*	-51.74 to -52.74	NR	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ƭ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-24	SP	-32.34 to -36.34	1.88	NR	Inside Borrow Area B
2012	KBV-12-24	GW*	-36.34 to -36.94	NR	NR	Inside Borrow Area B
2012	KBV-12-24	SP	-36.94 to -41.84	2.38	NR	Inside Borrow Area B
2012	KBV-12-24	SP	-41.84 to -45.14	1.83	NR	Inside Borrow Area B
2012	KBV-12-24	SW-SM	-45.14 to -50.14	7.18	NR	Inside Borrow Area B
2012	KBV-12-25	SP	-28.34 to -32.74	0.94	NR	Inside Borrow Area B
2012	KBV-12-25	SP	-28.34 to -36.44	3.66	NR	Inside Borrow Area B
2012	KBV-12-25	SP	-36.44 to -42.54	1.3	NR	Inside Borrow Area B
2012	KBV-12-25	SP	-42.54 to -43.64	1.61	NR	Inside Borrow Area B
2012	KBV-12-25	CH*	-43.64 to -44.94	NR	NR	Inside Borrow Area B
2012	KBV-12-25	SW*	-44.94 to -45.34	NR	NR	Inside Borrow Area B
2012	KBV-12-26	SP	-27.54 to -29.34	0.8	NR	Inside Borrow Area B
2012	KBV-12-26	SP	-29.34 to -33.04	2.18	NR	Inside Borrow Area B
2012	KBV-12-26	SW*	-33.04 to -34.04	NR	NR	Inside Borrow Area B
2012	KBV-12-26	SP	-34.04 to -37.14	4.54	NR	Inside Borrow Area B
2012	KBV-12-26	SC*	-37.14 to -37.64	NR	NR	Inside Borrow Area B
2012	KBV-12-26	SP	-37.64 to -43.24	1.36	NR	Inside Borrow Area B
2012	KBV-12-26	SM*	-43.24 to -43.34	NR	NR	Inside Borrow Area B
2012	KBV-12-27	SW	-29.74 to -33.74	0.87	NR	Inside Borrow Area B
2012	KBV-12-27	SW	-33.74 to -35.14	3.43	NR	Inside Borrow Area B
2012	KBV-12-27	SP	-35.14 to -39.74	1.93	NR	Inside Borrow Area B
2012	KBV-12-27	SP	-39.74 to -47.34	1.66	NR	Inside Borrow Area B
2012	KBV-12-28	SW	-34.54 to -35.74	2.38	NR	Inside Borrow Area B
2012	KBV-12-28	SP	-35.74 to -41.84	1.25	NR	Inside Borrow Area B
2012	KBV-12-28	SP	-41.84 to -44.04	1.53	NR	Inside Borrow Area B
2012	KBV-12-28	SP	-44.04 to -49.04	3.03	NR	Inside Borrow Area B
2012	KBV-12-29	SP-SM	-38.54 to -43.14	5.2	NR	Inside Borrow Area B
2012	KBV-12-29	SP	-43.14 to -45.04	1.5	NR	Inside Borrow Area B
2012	KBV-12-29	SP	-45.04 to -50.04	0.99	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ƭ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-29	SP	-50.04 to -54.74	2.96	NR	Inside Borrow Area B
2012	KBV-12-30	SP	-38.54 to -44.64	2.15	NR	Inside Borrow Area B
2012	KBV-12-30	SP-SM	-44.64 to -46.04	7.03	NR	Inside Borrow Area B
2012	KBV-12-30	SP	-46.04 to -50.04	2.76	NR	Inside Borrow Area B
2012	KBV-12-30	SP	-50.04 to -57.24	0.92	NR	Inside Borrow Area B
2012	KBV-12-31	SP-SM	-42.24 to -44.44	7.28	NR	Inside Borrow Area B
2012	KBV-12-31	SP	-44.44 to -47.04	3.9	NR	Inside Borrow Area B
2012	KBV-12-31	SM	-47.04 to -53.04	33.53	NR	Inside Borrow Area B
2012	KBV-12-31	SM	-53.04 to -60.44	36.94	NR	Inside Borrow Area B
2012	KBV-12-32	SP	-37.34 to -41.34	1.66	NR	Inside Borrow Area B
2012	KBV-12-32	SP-SM	-41.34 to -44.44	5.97	NR	Inside Borrow Area B
2012	KBV-12-32	SW	-44.44 to -47.14	3.6	NR	Inside Borrow Area B
2012	KBV-12-32	SP-SM	-47.14 to -47.84	NR	NR	Inside Borrow Area B
2012	KBV-12-32	SM	-47.84 to -58.14	31.13	NR	Inside Borrow Area B
2012	KBV-12-33	SP	-37.14 to -43.94	1.6	NR	Inside Borrow Area B
2012	KBV-12-33	GW*	-43.94 to -44.44	NR	NR	Inside Borrow Area B
2012	KBV-12-33	SP-SM	-44.44 to -49.94	10.74	NR	Inside Borrow Area B
2012	KBV-12-33	SM	-49.94 to -56.84	25.56	NR	Inside Borrow Area B
2012	KBV-12-34	SP	-40.64 to -45.14	1.63	NR	Inside Borrow Area B
2012	KBV-12-34	SW	-45.14 to -46.14	3.23	NR	Inside Borrow Area B
2012	KBV-12-34	SM	-46.14 to -51.14	12.22	NR	Inside Borrow Area B
2012	KBV-12-34	SM	-51.14 to -59.94	28.08	NR	Inside Borrow Area B
2012	KBV-12-35	SP	-37.64 to -40.54	0.78	NR	Inside Borrow Area B
2012	KBV-12-35	SP	-40.54 to -45.94	0.95	NR	Inside Borrow Area B
2012	KBV-12-35	SM*	-45.94 to -46.94	NR	NR	Inside Borrow Area B
2012	KBV-12-35	SP-SM	-46.94 to -49.04	8.27	NR	Inside Borrow Area B
2012	KBV-12-35	SP-SC*	-49.04 to -50.74	NR	NR	Inside Borrow Area B
2012	KBV-12-35	SM	-50.74 to -57.64	32.48	NR	Inside Borrow Area B
2012	KBV-12-36	SP	-39.04 to -41.34	0.71	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ͳ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-36	SP	-41.34 to -48.64	1.62	NR	Inside Borrow Area B
2012	KBV-12-36	SP-SM	-48.64 to -51.04	9.18	NR	Inside Borrow Area B
2012	KBV-12-36	SM	-51.04 to -60.24	29.64	NR	Inside Borrow Area B
2012	KBV-12-37	SP	-39.84 to -41.94	1.57	NR	Inside Borrow Area B
2012	KBV-12-37	SW	-41.94 to -42.84	NR	NR	Inside Borrow Area B
2012	KBV-12-37	SP	-42.84 to -47.64	1.56	NR	Inside Borrow Area B
2012	KBV-12-37	GW-GM*	-47.64 to -48.34	NR	NR	Inside Borrow Area B
2012	KBV-12-37	SM	-48.34 to -50.34	34.32	NR	Inside Borrow Area B
2012	KBV-12-37	SM	-50.34 to -57.84	28.05	NR	Inside Borrow Area B
2012	KBV-12-38	SP	-42.74 to -45.54	3.06	NR	Inside Borrow Area B
2012	KBV-12-38	SP	-45.54 to -51.04	1.53	NR	Inside Borrow Area B
2012	KBV-12-38	SM	-51.04 to -54.74	31.7	NR	Inside Borrow Area B
2012	KBV-12-39	SP	-38.74 to -44.24	0.69	NR	Inside Borrow Area B
2012	KBV-12-39	SP	-44.24 to -47.04	4.25	NR	Inside Borrow Area B
2012	KBV-12-39	SM	-47.04 to -54.74	39.94	NR	Inside Borrow Area B
2012	KBV-12-39	SM	-54.74 to -58.24	33.08	NR	Inside Borrow Area B
2012	KBV-12-40	SP	-38.14 to -43.54	0.7	NR	Inside Borrow Area B
2012	KBV-12-40	SW	-43.54 to -44.64	1.44	NR	Inside Borrow Area B
2012	KBV-12-40	SP	-44.64 to -46.74	2.02	NR	Inside Borrow Area B
2012	KBV-12-40	SM	-46.74 to -56.94	35.33	NR	Inside Borrow Area B
2012	KBV-12-41	SP	-37.64 to -40.44	0.76	NR	Inside Borrow Area B
2012	KBV-12-41	SP	-40.44 to -44.44	1.26	NR	Inside Borrow Area B
2012	KBV-12-41	SP-SM	-44.44 to -46.44	5.12	NR	Inside Borrow Area B
2012	KBV-12-41	SM	-46.44 to -49.74	50.17	NR	Inside Borrow Area B
2012	KBV-12-41	SP-SM*	-49.74 to -51.74	NR	NR	Inside Borrow Area B
2012	KBV-12-41	SM*	-51.74 to -53.44	NR	NR	Inside Borrow Area B
2012	KBV-12-41	SP-SM*	-53.44 to -54.34	NR	NR	Inside Borrow Area B
2012	KBV-12-41	SM*	-54.34 to -60.84	NR	NR	Inside Borrow Area B
2012	KBV-12-42	SP	-39.84 to -42.84	1.22	NR	Inside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ŧ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-42	SM	-42.84 to -44.44	23.71	NR	Inside Borrow Area B
2012	KBV-12-42	SM	-44.44 to -50.84	14.63	NR	Inside Borrow Area B
2012	KBV-12-42	SP-SM	-50.84 to -54.14	11.94	NR	Inside Borrow Area B
2012	KBV-12-42	SP*	-54.14 to -55.14	NR	NR	Inside Borrow Area B
2012	KBV-12-42	CH*	-55.14 to -55.44	NR	NR	Inside Borrow Area B
2012	KBV-12-42	SP*	-55.44 to -59.04	NR	NR	Inside Borrow Area B
2012	KBV-12-42	SM*	-59.04 to -59.14	NR	NR	Inside Borrow Area B
2012	KBV-12-43	SP	-39.54 to -40.94	2.19	NR	Outside Borrow Area B
2012	KBV-12-43	GW-GM	-40.94 to -44.04	7.81	NR	Outside Borrow Area B
2012	KBV-12-43	SW-SM	-44.04 to -49.04	6.75	NR	Outside Borrow Area B
2012	KBV-12-43	SW-SM	-49.04 to -59.04	7	NR	Outside Borrow Area B
2012	KBV-12-44	SP	-40.24 to -41.34	1.96	NR	Outside Borrow Area B
2012	KBV-12-44	GW-GM	-41.34 to -44.74	9.08	NR	Outside Borrow Area B
2012	KBV-12-44	GM	-44.74 to -49.24	12.76	NR	Outside Borrow Area B
2012	KBV-12-44	GW-GM	-49.24 to -60.54	6.26	NR	Outside Borrow Area B
2012	KBV-12-45	SP	-39.04 to -45.04	1.15	NR	Inside Borrow Area B
2012	KBV-12-45	SP	-45.04 to -45.94	1.87	NR	Inside Borrow Area B
2012	KBV-12-45	SP	-45.94 to -53.24	2.8	NR	Inside Borrow Area B
2012	KBV-12-45	SM	-53.24 to -55.04	24.24	NR	Inside Borrow Area B
2012	KBV-12-45	SP*	-55.04 to -58.24	NR	NR	Inside Borrow Area B
2012	KBV-12-45	SP-SM*	-58.24 to -60.44	NR	NR	Inside Borrow Area B
2012	KBV-12-46	SP	-40.54 to -42.04	0.53	NR	Inside Borrow Area B
2012	KBV-12-46	SP	-42.04 to -46.54	1.51	NR	Inside Borrow Area B
2012	KBV-12-46	SP-SM	-46.54 to -49.04	7.06	NR	Inside Borrow Area B
2012	KBV-12-46	SW-SM	-49.04 to -61.04	8.28	NR	Inside Borrow Area B
2012	KBV-12-47	SP	-32.94 to -33.84	2.69	NR	Outside Borrow Area B
2012	KBV-12-47	SW-SC*	-33.84 to -34.24	NR	NR	Outside Borrow Area B
2012	KBV-12-47	SM	-34.24 to -37.74	13.66	NR	Outside Borrow Area B
2012	KBV-12-47	SP-SM	-37.74 to -44.04	7.2	NR	Outside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ҭ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-47	SP	-44.04 to -51.04	3.19	NR	Outside Borrow Area B
2012	KBV-12-48	SP	-36.14 to -39.94	1.92	NR	Outside Borrow Area B
2012	KBV-12-48	SP-SM	-39.94 to -41.14	9.39	NR	Outside Borrow Area B
2012	KBV-12-48	SP-SM	-41.14 to -46.04	10.47	NR	Outside Borrow Area B
2012	KBV-12-48	SP-SM	-46.04 to -49.34	13.22	NR	Outside Borrow Area B
2012	KBV-12-48	SM*	-49.34 to -56.94	NR	NR	Outside Borrow Area B
2012	KBV-12-49	SP	-34.54 to -38.54	1.02	NR	Outside Borrow Area B
2012	KBV-12-49	SP	-38.54 to -39.44	3.01	NR	Outside Borrow Area B
2012	KBV-12-49	SW*	-39.44 to -42.44	NR	NR	Outside Borrow Area B
2012	KBV-12-49	SP*	-42.44 to -43.54	NR	NR	Outside Borrow Area B
2012	KBV-12-49	SP	-43.54 to -46.54	1.3	NR	Outside Borrow Area B
2012	KBV-12-49	GW	-46.54 to -50.84	4.25	NR	Outside Borrow Area B
2012	KBV-12-49	SW-SM*	-50.84 to -54.54	NR	NR	Outside Borrow Area B
2012	KBV-12-50	CH*	-34.44 to -35.24	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SM	-35.24 to -36.54	17.22	NR	Outside Borrow Area B
2012	KBV-12-50	SW	-36.54 to -38.34	1.39	NR	Outside Borrow Area B
2012	KBV-12-50	SC*	-38.34 to -38.94	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SP*	-38.94 to -39.24	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SW*	-39.24 to -41.24	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SP	-41.24 to -45.44	3.58	NR	Outside Borrow Area B
2012	KBV-12-50	SM	-45.44 to -46.44	14.14	NR	Outside Borrow Area B
2012	KBV-12-50	SP*	-46.44 to -47.74	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SP-SM*	-47.74 to -49.44	NR	NR	Outside Borrow Area B
2012	KBV-12-50	GM*	-49.44 to -53.44	NR	NR	Outside Borrow Area B
2012	KBV-12-50	SM*	-53.44 to -55.94	NR	NR	Outside Borrow Area B
2012	KBV-12-51	SP	-23.94 to -30.24	0.75	NR	Outside Borrow Area B
2012	KBV-12-51	SP	-30.24 to -32.44	0.81	NR	Outside Borrow Area B
2012	KBV-12-51	SW-SM*	-32.44 to -33.44	NR	NR	Outside Borrow Area B
2012	KBV-12-51	SP*	-33.44 to 41.36	NR	NR	Outside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ͳ.

Table 4 (continued). Borrow Area B Vibracore Data[1]

Year Drilled	Boring Number	USCS Classification[2]	Material Range (Elevation, ft. MLLW)	Avg. % Fines[3]	Avg. % Shell	Location
2012	KBV-12-51	SM	-35.44 to -36.94	18.63	NR	Outside Borrow Area B
2012	KBV-12-51	SP	-36.94 to -41.14	2.74	NR	Outside Borrow Area B
2012	KBV-12-52	SP	-30.54 to -36.24	1	NR	Outside Borrow Area B
2012	KBV-12-52	SP	-36.24 to -38.84	2.71	NR	Outside Borrow Area B
2012	KBV-12-52	SP	-38.84 to -44.14	1.45	NR	Outside Borrow Area B
2012	KBV-12-52	SP-SM	-44.14 to -49.04	11.29	NR	Outside Borrow Area B
2012	KBV-12-53	SP	-37.64 to -39.94	1.29	NR	Outside Borrow Area B
2012	KBV-12-53	SW-SM	-39.94 to -42.54	9.41	NR	Outside Borrow Area B
2012	KBV-12-53	SW-SC*	-42.54 to -44.34	NR	NR	Outside Borrow Area B
2012	KBV-12-53	SM	-44.34 to -49.44	33.72	NR	Outside Borrow Area B
2012	KBV-12-53	SM	-49.44 to -58.14	33.45	NR	Outside Borrow Area B

[1]"NR" and "ND" refer to "Not Reported" and "Not Detected," respectively.

[2]Classifications are based on laboratory analysis, except where indicated by *, which denotes a visual classification.

[3]"Avg. % Fines" refers to the percentage of granular material which passes through the No. 200 sieve.

[4]Sample results showing minor clasts of coquina or $CaCO_3$-cemented sand grains are denoted with a Ꚍ.

Median and mean grain sizes for the suitable material within Borrow Area B are 0.36 mm and 0.51 mm, respectively, with a standard deviation of 0.30 mm, based on $n = 224$ samples. The mean grain size from this data set matches well with the mean value of 0.31 mm, as determined from a 1970 pre-nourishment beach sampling event, even though the 1970 sampling revealed a large standard deviation of 0.53 mm. Additionally, this study estimated the volume of suitable material to be 12.6 million yd^3, which is comparable to the 12.7 million yd^3, which was determined by the Design and General Engineering Section using INROADS. Both of these estimates considered the post-2016 dredging conditions of the borrow source, since it has been used support renourishment activities at Carolina Beach and Kure Beach during 2013 and 2016. Most recently, approximately 1.0 million yd^3 of material was removed during the 2019 dredging event for Kure Beach placement. This puts the current volume estimate for Borrow Area B at approximately 11.6 million yd^3. As part of dredging and beach placement, bathymetric surveys were performed before and after respective operations to assess the impact of dredging activities on the overall borrow site (Figures 27 through 30).

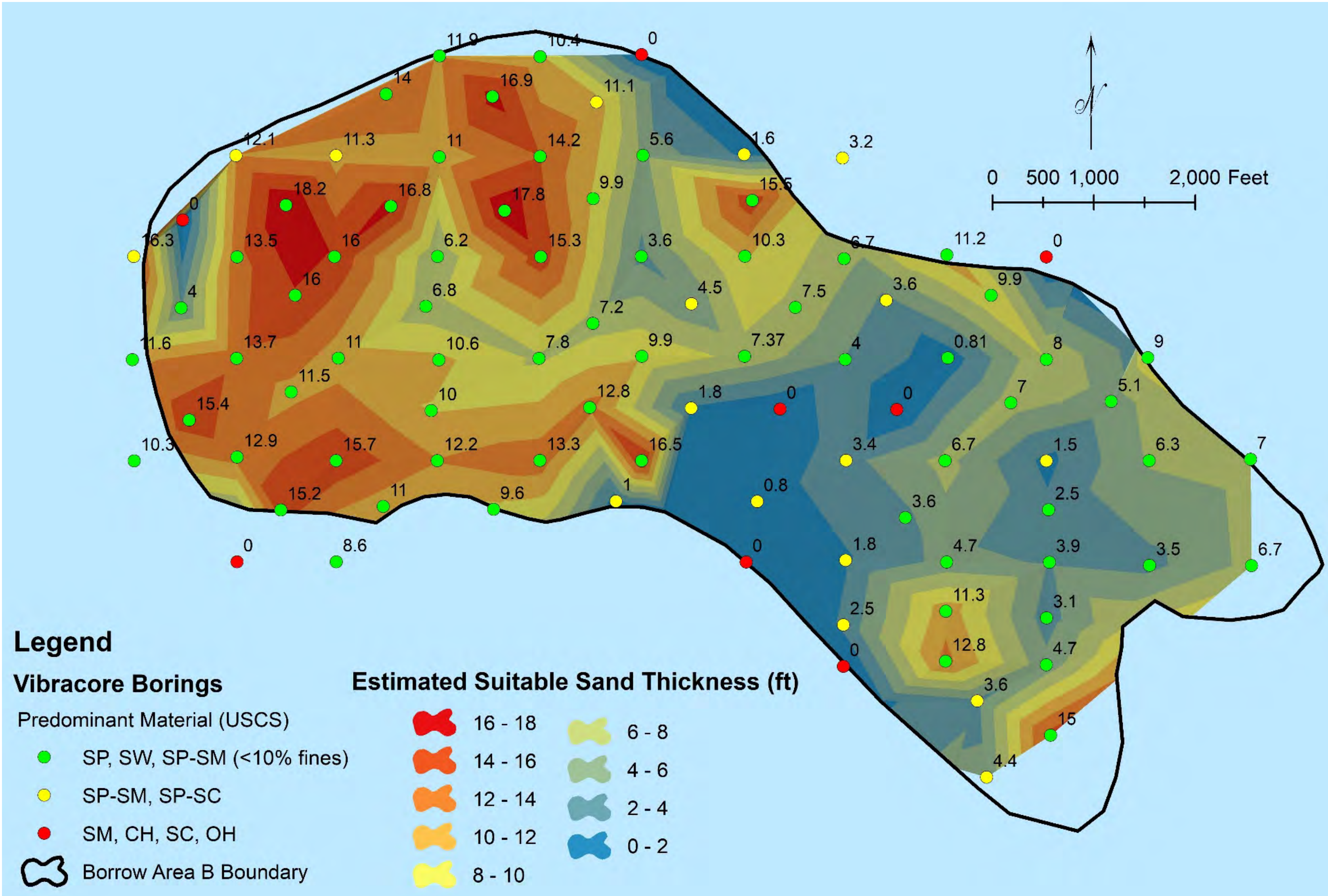


Figure 22. Borrow Area B Isopach Map of Suitable Renourishment Material. The thickest and most voluminous zones of suitable material occur in the northwestern portion of the borrow area.

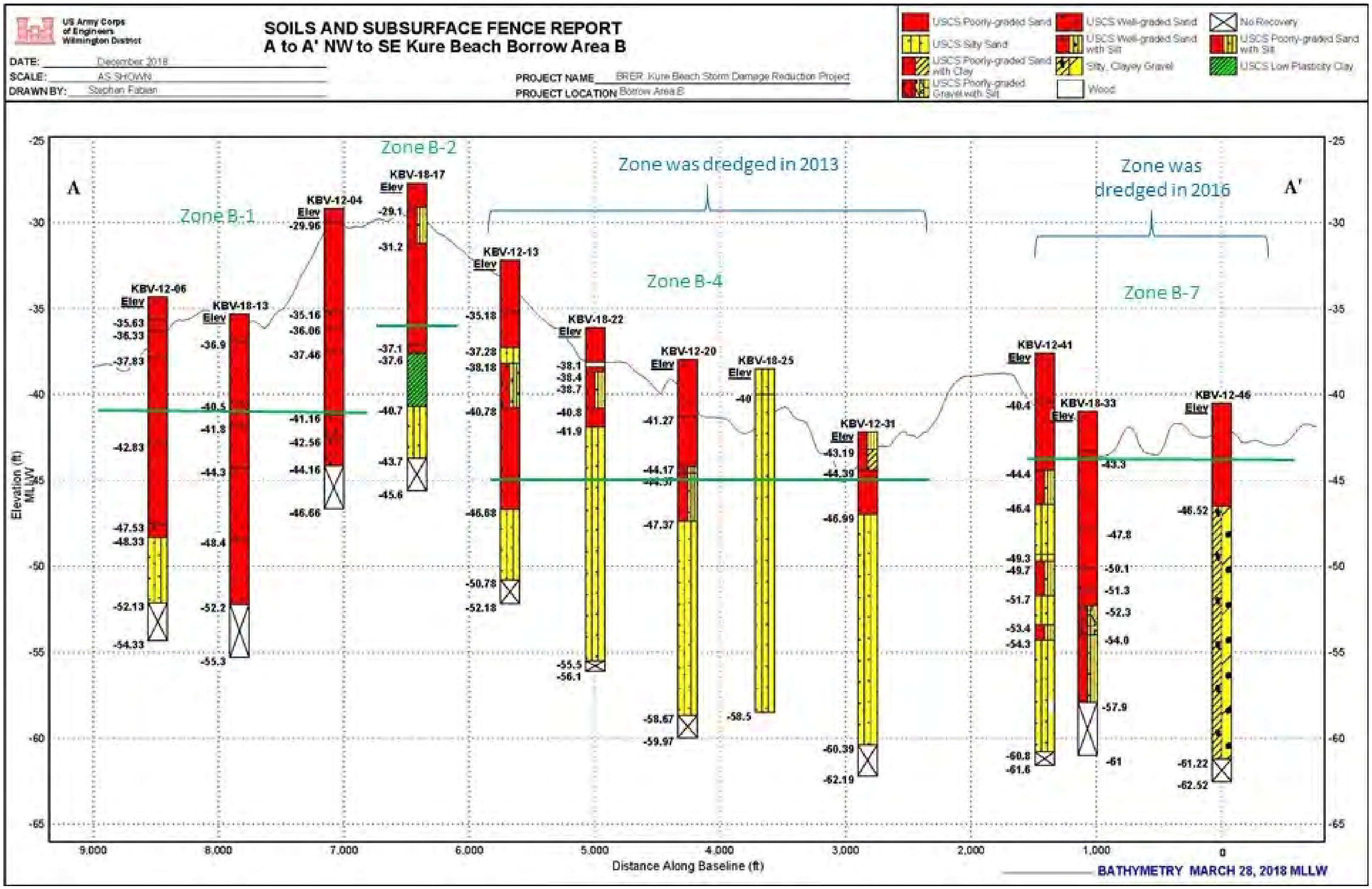


Figure 23. Borrow Area B Fence Diagram A-A'. See Figure 21 for profile location. Horizontal green lines show the proposed maximum dredging depth for future operations, as shown in Figure 31 and Table 5. The smooth, black line represents the ocean bottom from a March 2018 bathymetric survey. Areas where significant differences occur between the 2012 core elevations and the 2018 bathymetry are the result of dredging which occurred after the 2012 vibracores were taken.

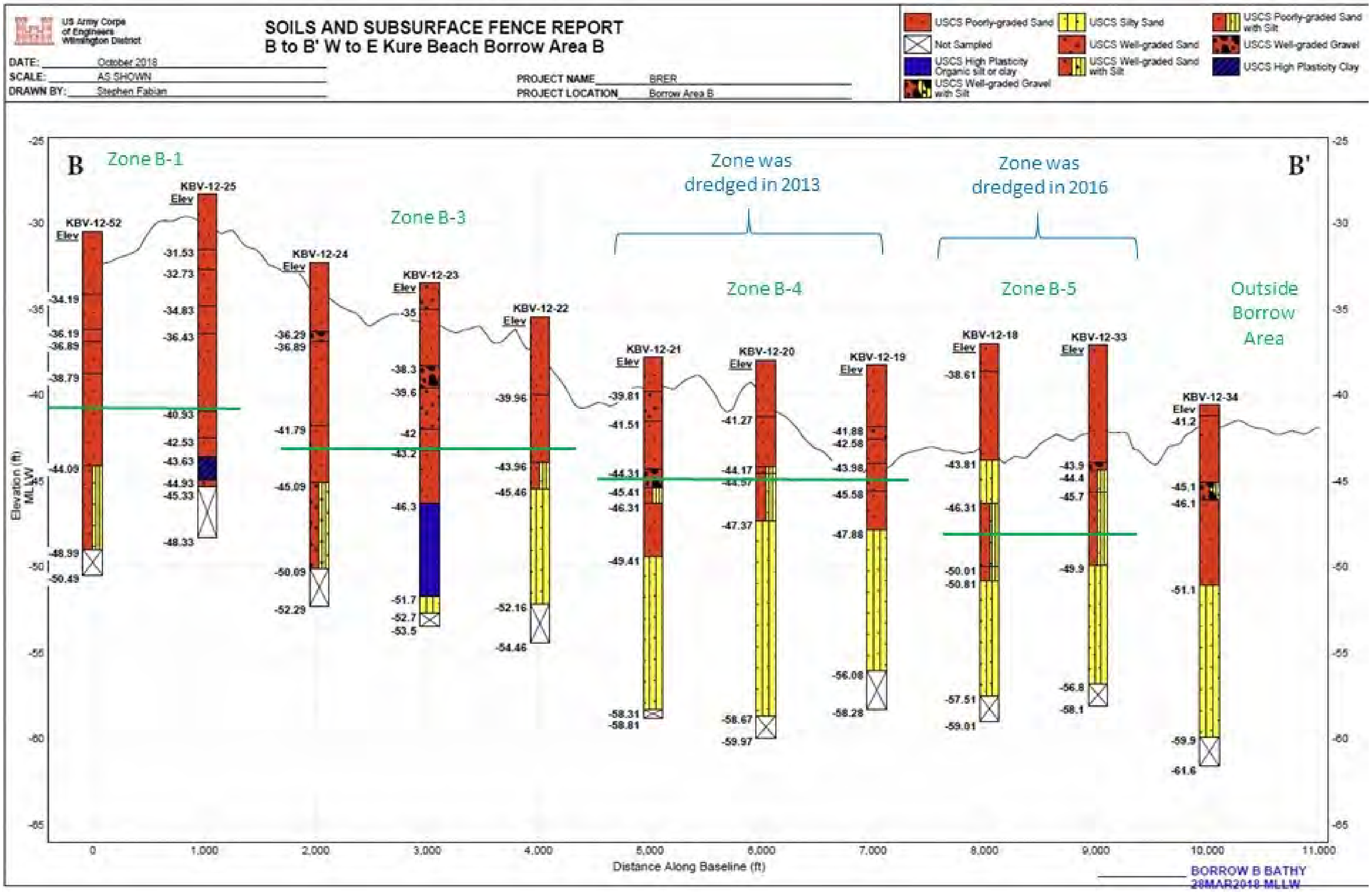


Figure 24. Borrow Area B Fence Diagram B-B'. See Figure 21 for profile location. Horizontal green lines show the proposed maximum dredging depth for future operations, as shown in Figure 31 and Table 5. The smooth, black line represents the ocean bottom from a March 2018 bathymetric survey. Areas where significant differences occur between the 2012 core elevations and the 2018 bathymetry are the result of dredging which occurred after the 2012 vibracores were taken.

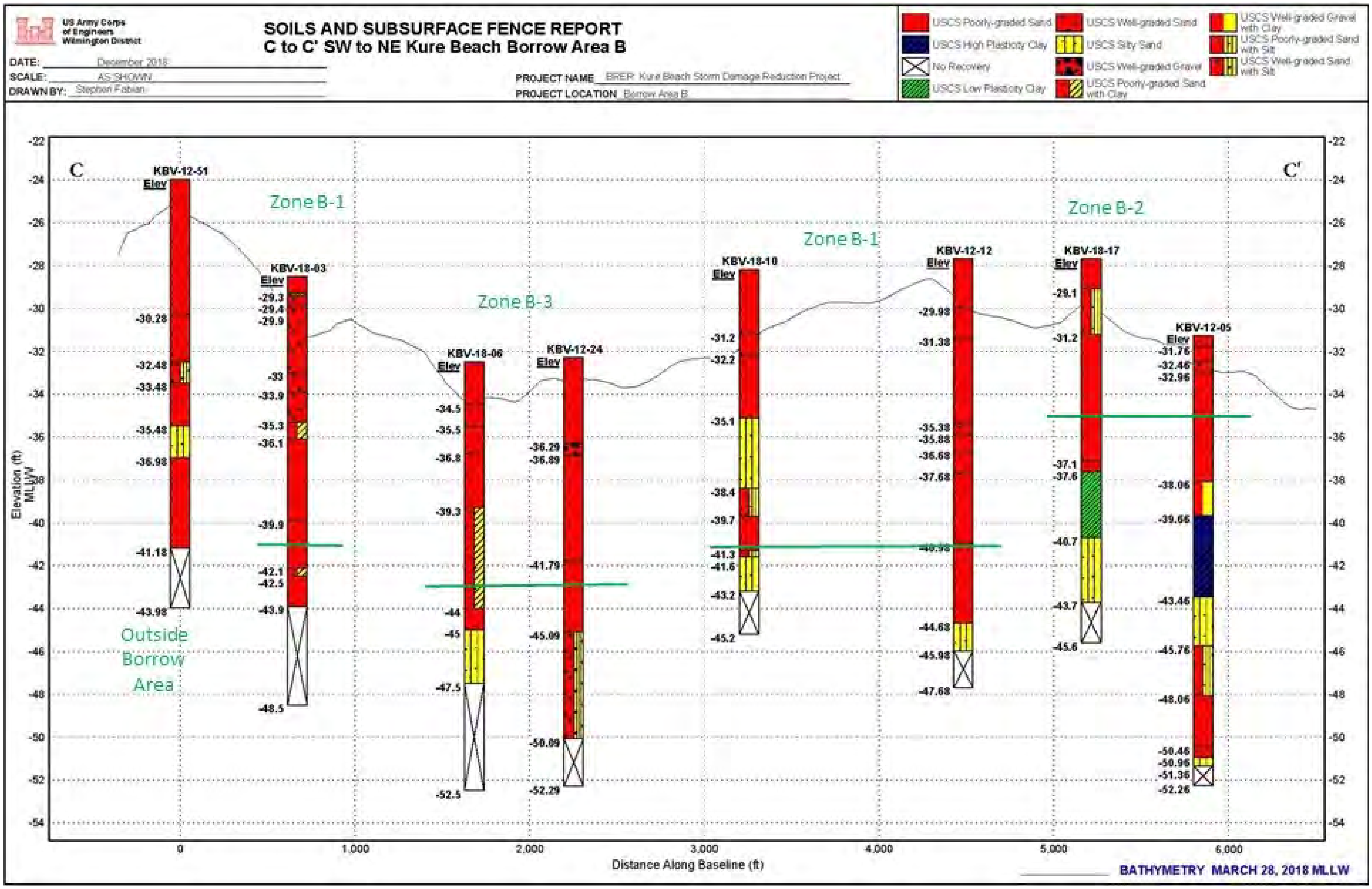


Figure 25. Borrow Area B Fence Diagram C-C’. See Figure 21 for profile location. Horizontal green lines show the proposed maximum dredging depth for future operations, as shown in Figure 31 and Table 5. The smooth, black line represents the ocean bottom from a March 2018 bathymetric survey.

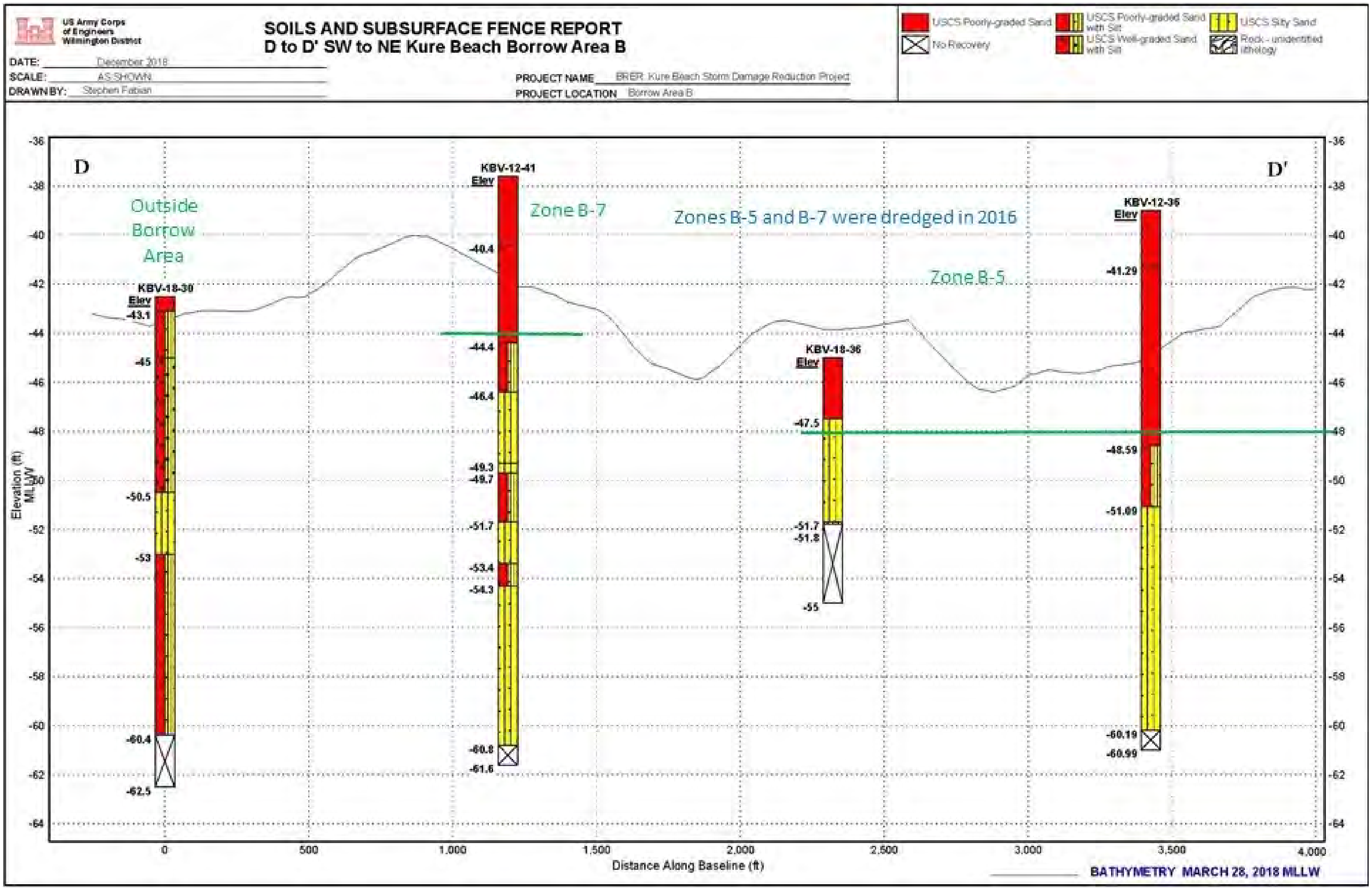


Figure 26. Borrow Area B Fence Diagram D-D'. See Figure 21 for profile location. Horizontal green lines show the proposed maximum dredging depth for future operations, as shown in Figure 31 and Table 5. The smooth, black line represents the ocean bottom from a March 2018 bathymetric survey. Areas where significant differences occur between the 2012 core elevations and the 2018 bathymetry are the result of dredging which occurred after the 2012 vibracores were taken.

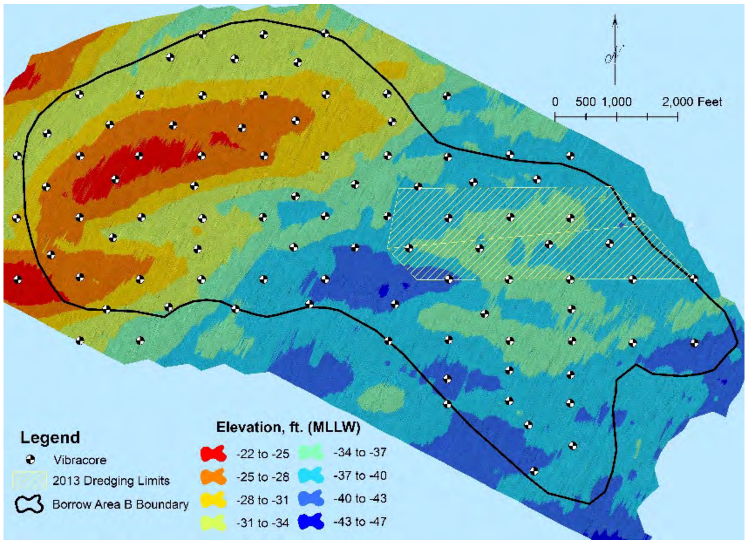


Figure 27. Borrow Area B Pre-Dredging Bathymetry, February 2013.

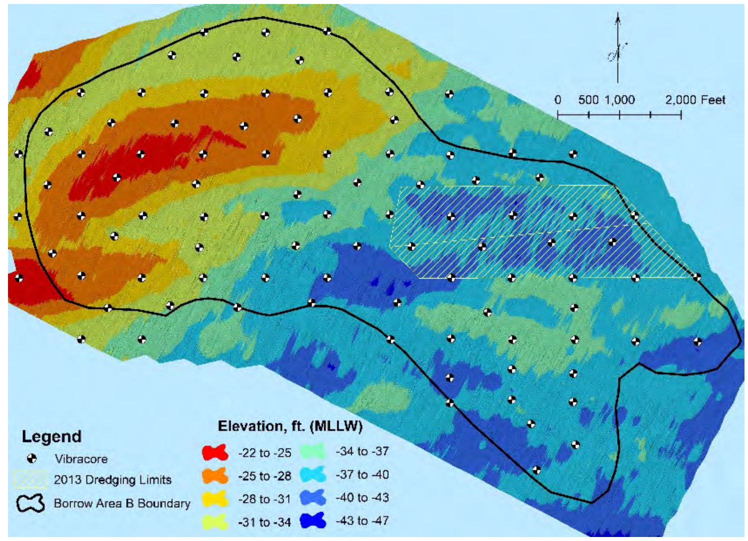


Figure 28. Borrow Area B Post-Dredging Bathymetry, April 2013.

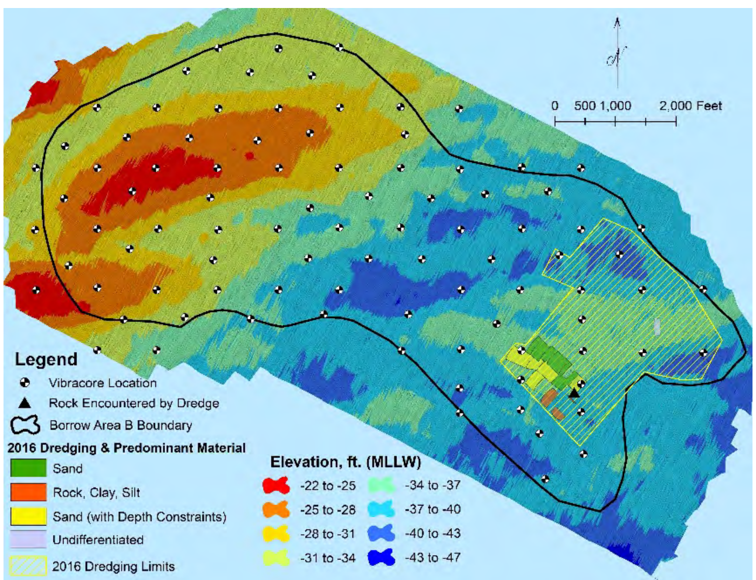


Figure 29. Borrow Area B Pre-Dredging Bathymetry, November 2015.

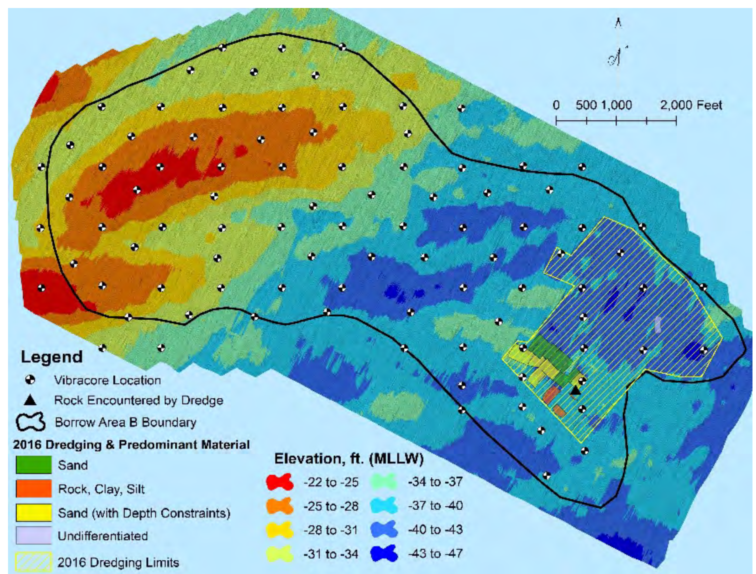


Figure 30. Borrow Area B Post-Dredging Bathymetry, May 2016.

Although sediment from Borrow Area B has been successfully used for renourishment operations, 2016 dredging from the southeastern portion of the site resulted in the entrainment and deposition of lithoclasts onto the beach. This rocky material was apparently entrained from beneath the overlying unconsolidated sediment and occurred when the dredge cutter head was accidently lowered beneath suitable material. The location of lithoclast entrainment is shown in Figures 29 and 30 and noted as

"Rock Encountered by Dredge." As a result, new dredge cut elevation limits have been established for future renourishment contracts to reduce the likelihood that new dredging will entrain lithified material (Figure 31 and Table 5).

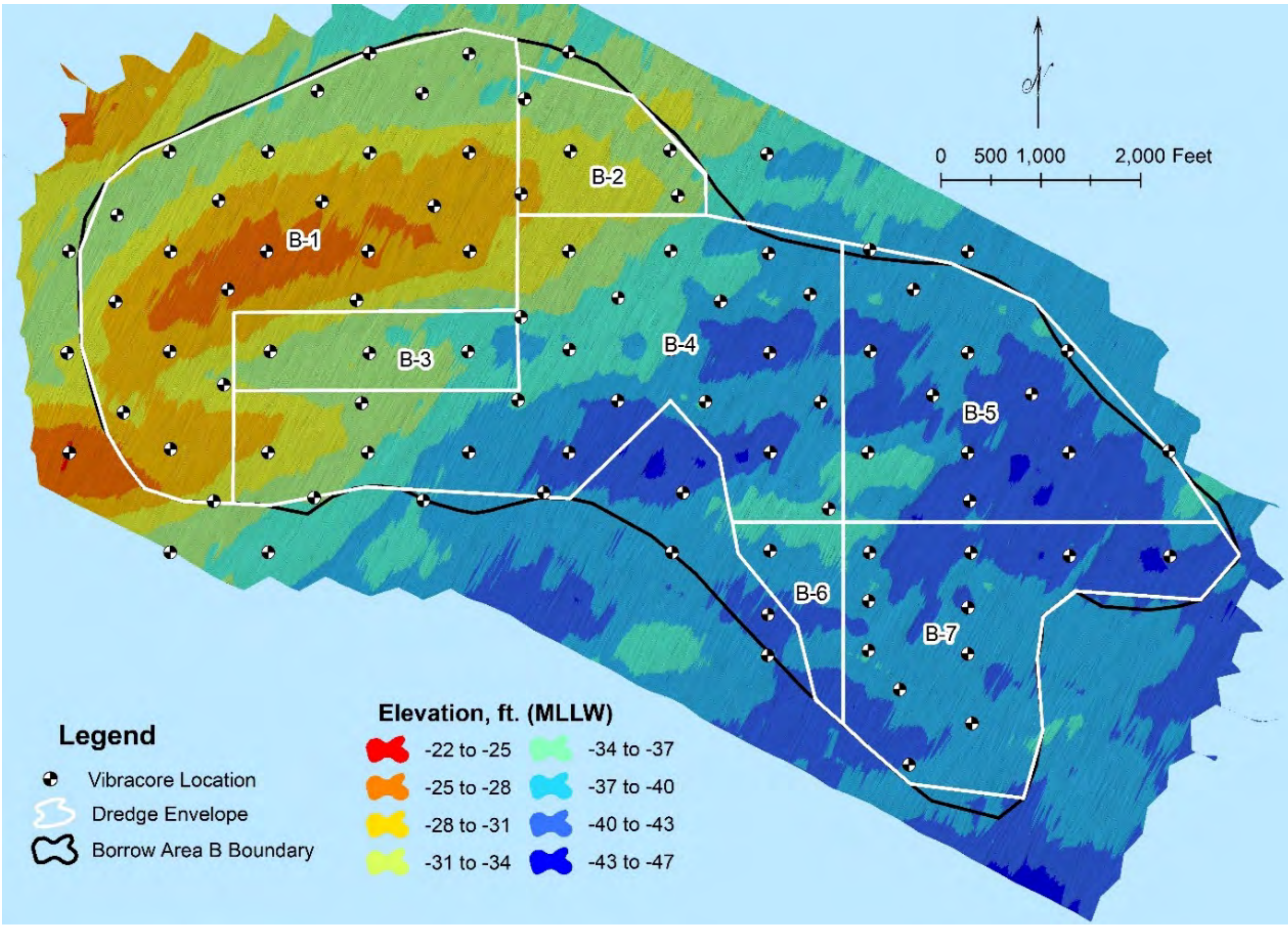
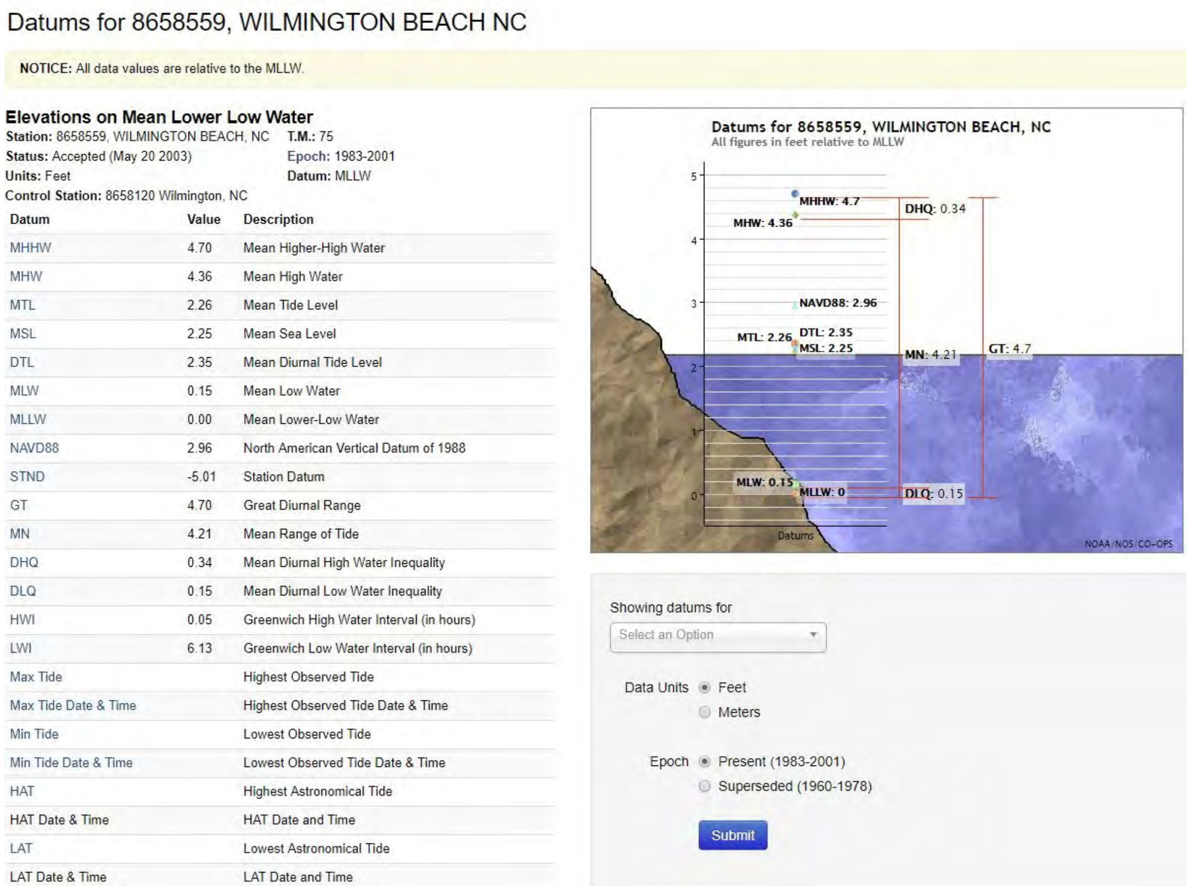


Figure 31. Borrow Area B – March 2018 Bathymetric Survey, with Dredge Cut Zones. See Table 5 for proposed maximum dredging depths for each zone.

Table 5. Borrow Area B Proposed Dredging Zones[1]

Zone Name	Maximum Dredging Depth (Elevation, ft. NAVD88)	Maximum Dredging Depth (Elevation, ft. MLLW)
B-1	-44	-41
B-2	-38	-35
B-3	-46	-43
B-4	-48	-45
B-5	-51	-48
B-6	-45	-42
B-7	-47	-44

[1] Elevation conversion is based on NOAA's Wilmington Beach Datum. See Figure 32 for details.



Datums for 8658559, WILMINGTON BEACH NC

NOTICE: All data values are relative to the MLLW.

Elevations on Mean Lower Low Water

Station: 8658559, WILMINGTON BEACH, NC **T.M.:** 75
Status: Accepted (May 20 2003) **Epoch:** 1983-2001
Units: Feet **Datum:** MLLW
Control Station: 8658120 Wilmington, NC

Datum	Value	Description
MHHW	4.70	Mean Higher-High Water
MHW	4.36	Mean High Water
MTL	2.26	Mean Tide Level
MSL	2.25	Mean Sea Level
DTL	2.35	Mean Diurnal Tide Level
MLW	0.15	Mean Low Water
MLLW	0.00	Mean Lower-Low Water
NAVD88	2.96	North American Vertical Datum of 1988
STND	-5.01	Station Datum
GT	4.70	Great Diurnal Range
MN	4.21	Mean Range of Tide
DHQ	0.34	Mean Diurnal High Water Inequality
DLQ	0.15	Mean Diurnal Low Water Inequality
HWI	0.05	Greenwich High Water Interval (in hours)
LWI	6.13	Greenwich Low Water Interval (in hours)
Max Tide		Highest Observed Tide
Max Tide Date & Time		Highest Observed Tide Date & Time
Min Tide		Lowest Observed Tide
Min Tide Date & Time		Lowest Observed Tide Date & Time
HAT		Highest Astronomical Tide
HAT Date & Time		HAT Date and Time
LAT		Lowest Astronomical Tide
LAT Date & Time		LAT Date and Time

Figure 32. Wilmington Beach Tidal Datum. This datum was used to convert elevations relative to MLLW to NAVD88 and vice-versa. See https://tidesandcurrents.noaa.gov/datums.html?id=8658559 for image reference. Additionally, NOAA's V-Datum software was used to confirm values in Table X. This software may be accessed here: https://vdatum.noaa.gov/vdatumweb/.

Determination of a maximum dredging depth for the proposed dredged zones was based on the 2012 vibracores and considered strata of both suitable and unacceptable material. Additionally, a vertical two-foot "buffer" was added to the tops of unacceptable zones, as indicated by vibracore lithologic logs. The 2018 vibracores were combined with the 2012 information, along with bathymetric data from 2017 and 2018 to reassess the maximum dredging depths. Initially, some of the 2018 vibracores that had been collected in the southeastern portion of the borrow area suggested that respective dredge cut depths should be raised. However, comparing the 2012 and 2018 cores with 2017 and 2018 bathymetric data showed that overall, the 2012 cores mostly matched present-day bathymetry, except in areas where dredging had occurred in 2013 and 2016, well after the 2012 cores were collected (Figures 23 and 24). This vertical mismatch between the 2012 vibracore surfaces and the 2018 bathymetry would be expected within areas that were dredged after core collection, due to the lack of regularly-occurring sediment recharge into the borrow area. Conversely, based on initial contractor data submission, some of the 2018 vibracores matched with 2018 bathymetry, but other others plotted several feet above the 2018 bathymetry. An inquiry was made to the vibracoring contractor regarding this matter, who stated that elevation reference errors had occurred due to a time zone error in calculating the local tidal correction. The contractor has since taken steps to correct this error and has resubmitted respective core data, which have been incorporated into Figures 23, 25, and 26, which show only a few minor mismatches between the 2018 vibracore elevations and the 2018 bathymetry. Regardless, present evidence does not suggest that modifying the proposed maximum dredge cut depths, as shown in Table 5, is appropriate. Additionally, renourishment contracts generally require that operations cease in the event that unsuitable material is entrained from a borrow area and deposited onto a beach. This contractual practice should continue, while proposed maximum dredge cut depths will be modified as new, relevant information is received.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Historical vibracore logs and respective laboratory data indicate that well-distributed, suitable sand has consistently occurred within the Section 934 boundary and, more specifically within the IDMMS. Additionally, the presence of suitable sand, as suggested by vibracore data, has been confirmed by triennial dredging in areas where coring did and did not occur.

Historical bathymetric surveys, as well as measured volumes of dredged sand, show that the Section 934 area, and especially the IDMMS, have consistently accumulated enough material to support beach renourishment once every three years. While the IDMMS is naturally recharged by sand through littoral transport, the area is also being used as a repository for material which has been dredged from the nearby Carolina Beach Inlet channel. This combination of natural and anthropogenic deposition will continue to recharge sand into the borrow area between renourishment cycles.

The majority of the Section 934 area, and more specifically the IDMMS, is recommended as a suitable sand resource location for future triennial renourishment. Vibracore data also suggest that much of the area lying between the IDMMS southerly boundaries and the Section 934 southeast corner also contains suitable material. However, supplementary vibracore data from the most southerly portion of the 934 corner area would help to better identify the potential for additional beach-suitable material. Additionally, historical geotechnical data from the small portion of the Section 934 area lying north of the IDMMS is limited to one vibracore collected in 1997, which revealed fine-grained material. Moreover, according to bathymetric surveys from 2017, the material into which that core was bored is no longer present at that location. As a result, if either the northeasterly or southeasterly portion of the Section 934 zone were to be targeted for future renourishment dredging, respective vibracore sampling should be conducted to confirm the existence of suitable material (Figure 20).

Similarly, Borrow Area B vibracore logs, laboratory data, and recent renourishment projects from 2013 and 2016 indicate the occurrence of well-distributed, suitable material. Based on the information provided in this report, the majority of Borrow Area B, and more specifically, the northwestern portion of the site, is recommended as a suitable sand resource for future renourishment. However, this borrow site does not receive the regularly-occurring sedimentary recharge as observed in the Section 934 area, and therefore, constitutes a finite resource. On the other hand, when compared with the Section 934 material, sand from Borrow Area B is more coarse-grained and thus, more resistant to erosion if placed on the beach. As a result, Borrow Area B could serve as a suitable alternative, if needed, in the future.

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ADDITIONAL REFERENCE NOTES – BORROW AREA DATA

The 1982 Carolina Beach Inlet dredge limit boundaries were manually geo-referenced and digitized from USACE, 1981, "Final Environmental Impact Statement, Beach Erosion Control and Hurricane Wave Protection, Carolina Beach and Vicinity New Hanover County, North Carolina."

The 1985 Carolina Beach Inlet dredge limit boundaries were manually geo-referenced and digitized from USACE, 1987, "Carolina Beach Hurricane Wave and Shoreline Protection Project."

The 1988 Carolina Beach Inlet dredge limit boundaries were manually geo-referenced and digitized from USACE's "Carolina Beach Inlet Borrow Area" after dredge survey, dated 29 APR 1988.

The Section 934 boundary was manually geo-referenced and digitized from USACE, 1993, "Section 934 Reevaluation Report and Environmental Assessment, Carolina Beach & Vicinity."

The 1991 – 1998 and the 2000 – 2004 Carolina Beach Inlet dredge limit boundaries were provided via conversion of USACE CAD files into ArcGIS format.

The 2006 – 2015 Carolina Beach Inlet dredge limit boundaries are delineated in various USACE reports, such as USACE, 2009, "Beach Renourishment: Carolina Beach, Kure Beach, and Ocean Isle Beach, New Hanover and Brunswick Counties, North Carolina." IFB No. W912HN-09-B-0004.

Bathymetric data for Carolina Beach Inlet and Borrow Area B were provided by USACE's Wilmington District Navigation Branch.

Data for Table 1, "Carolina Beach Renourishment History" were provided by J.E. Bingham and J.M. Medlock, USACE.

Information for anthropogenic sand discharges into the IDMMS was provided by D.A. Sinclair, USACE (personal communication, 2017).

DRAFT

APPENDIX B

COASTAL

CAROLINA BEACH, NC
BEACH RENOURISHMENT EVALUATION REPORT

JUNE 2019

Prepared by:
Water Resources Section
U.S. Army Corps of Engineers, Wilmington District

DRAFT

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1 Introduction

The U.S. Army Corps of Engineers (USACE) Wilmington District is conducting a Level II Economic Update of the coastal storm damage reduction project along a portion of Carolina Beach, NC (New Hanover County). The study area includes approximately 14,000 feet of Carolina Beach as shown in **Figure 1**. The southernmost 11,950 feet of the project consists of a 50 foot berm and 25 foot wide dune while the northern 2,050 feet is protected by a rock revetment in addition to a 130 foot berm. The ultimate goal of the study is to calculate the benefits for the currently authorized project template for use in calculating the project benefit to cost ratio for a proposed 15 year extension to the authorization.

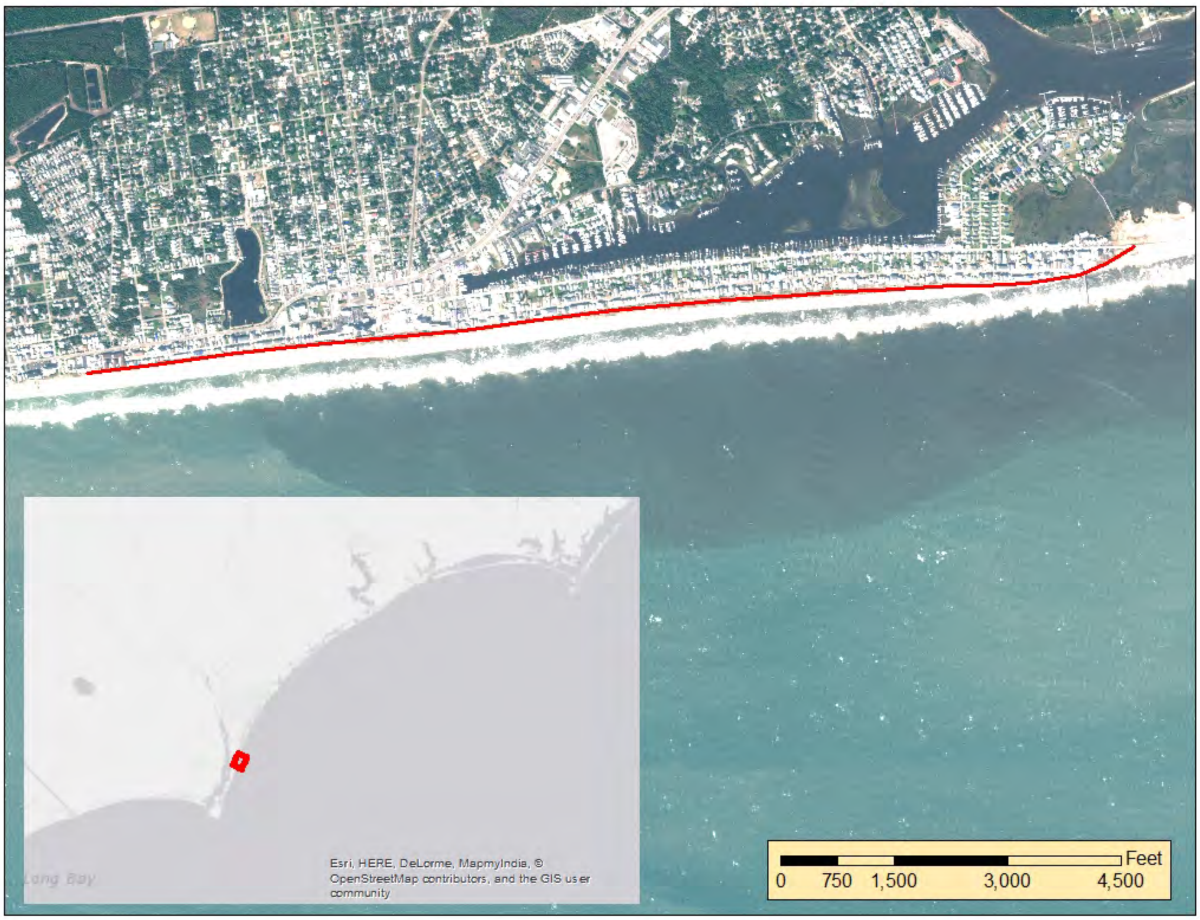

Figure 1. Carolina Beach Project Area

The Beach-fx software was utilized to analyze the physical performance of the authorized template for the storm damage reduction project in the Carolina Beach study area as well as the economic benefits and costs. Beach-fx is an event-based, Monte Carlo life cycle simulation tool capable of estimating storm damage along coastal zones caused by erosion, flooding, and wave impact. The software also calculates the economic benefits and costs associated with alternatives.

The purpose of this appendix is to describe, in detail, the Coastal Engineering input driving the Beach-fx software for the Carolina Beach study area. This includes developing the representative reaches for the study area, a historical storm suite, historic shoreline change conditions, and profile response to the array of storm events using SBEACH.

2 Natural Forces

2.1 Winds

Local winds are the primary means of generating the small-amplitude, short period waves that are an important mechanism of sand transport along the North Carolina shoreline. Winds in the project vicinity vary seasonally with prevailing winds ranging from the north though the southwest (in clockwise direction). The greatest velocities originate from the north-northeast quadrant in fall and winter months and from the southwest quadrant in the spring and summer.

Wind data offshore of the project area is available from the USACE Wave Information Study (WIS) Program. WIS hindcast data are generated using the numerical hindcast model WISWAVE (Hubertz, 1992). WISWAVE is driven by wind fields overlaying a bathymetric grid. Model output includes significant wave height, peak and mean wave period, peak and mean wave direction, wind speed, and wind direction. In the Atlantic, the WIS hindcast database covers a 33-year period of record extending from 1980 to 2012.

There are 565 WIS stations along the Atlantic Coast. WIS Station 63298 is representative of offshore deep water wind and wave conditions for the project area. **Table 1** provides a summary of wind data from WIS Station 63298, located at latitude 34.08° N, longitude -77.67° W (about 11 miles east-northeast of Carolina Beach; **Figure 2**). This table contains a summary of average wind speeds and frequency of occurrence broken down into eight 45 degree angle-bands. This table indicates that winds are predominantly from the southwest. The wind rose presented in Figure 3 provides a further breakdown of winds in the project area.

Table 1. Average Wind Conditions

Wind Direction (from)	WIS Station #63298 (1980 – 2012)	
	Percentage Occurrence (%)	Average Wind Speed (mph)
North	12.9	17.5
Northeast	16.1	16.6
East	9.1	12.6
Southeast	7.1	11.7
South	13.3	13.1
Southwest	20.5	14.3
West	11.0	15.2
Northwest	10.0	16.9

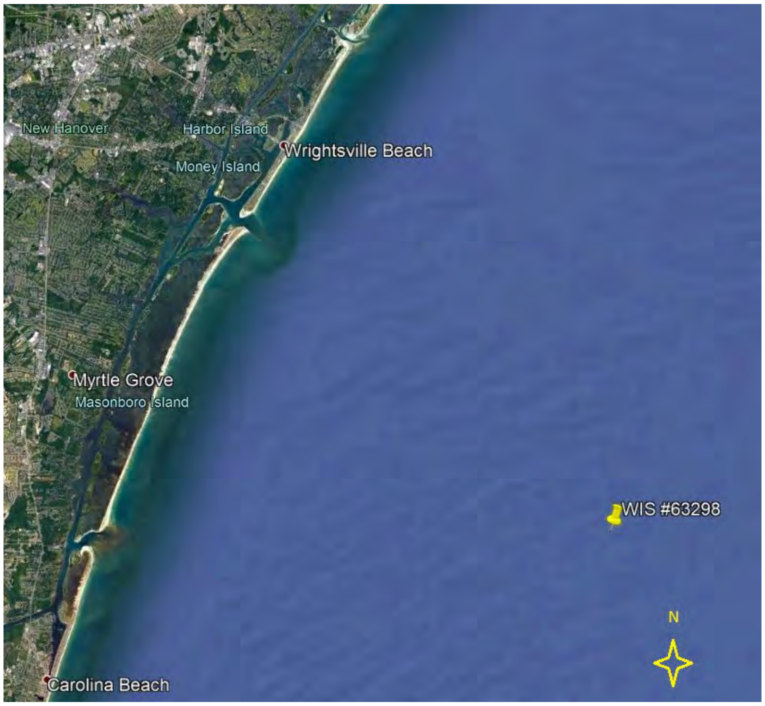

Figure 2. Location of WIS Station #63298 Relative to Project (Not to Scale)

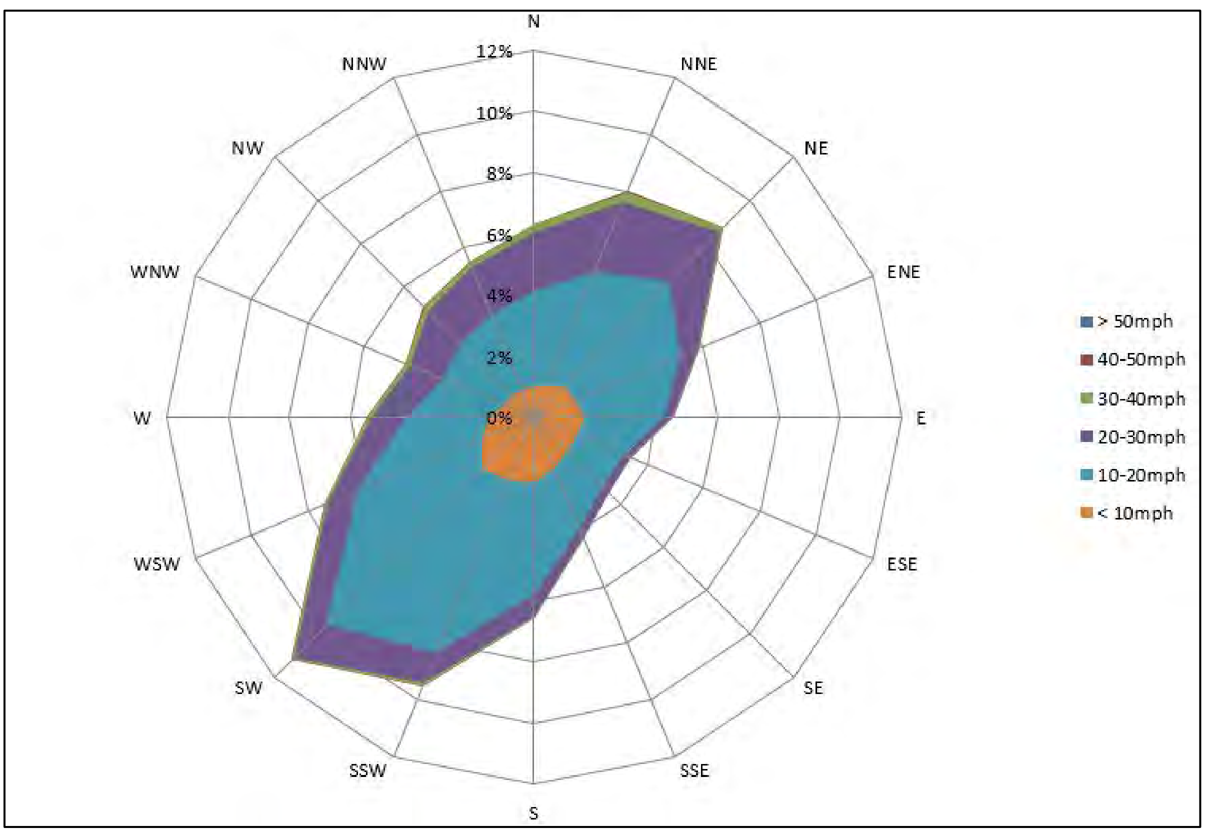

Figure 3. Wind Rose – WIS Station 63298

Wind conditions in Coastal North Carolina are seasonal. A further breakdown of the wind data provides a summary of the seasonal conditions (**Table 2**).

Between October and February, frontal weather patterns driven by cold Arctic air masses can extend to North Carolina and further south. These fronts typically generate northeast winds before the frontal passage and northwest winds behind the front. Along much of the Atlantic coast "Northeaster" behavior is responsible for the increased intensity of wind speed in the northeast sector during the fall and winter months. However, due to its position at the southern end of the state, shielded by the geography of the northern coast and barrier islands which extend northeast to Hatteras before curving back to a northern orientation, winds from the northeast during the fall and winter are only slightly more intense than the average.

The summer months (June through August) are characterized by southwest winds and tropical weather systems traveling west to northwest in the lower latitudes. Additionally, daily breezes onshore and offshore result from differential heating of land and water masses.

During the summer and fall months, tropical waves may develop into tropical storms and hurricanes, which can generate devastating winds, waves, and storm surge when they impact the project area. These storms contribute greatly to the overall longshore and cross-shore sediment transport at the site. These intense seasonal events will be discussed in greater detail under Section 2.4: Storm Effects.

Table 2. Seasonal Wind Conditions

Month	WIS Station #63298 (1980 – 2012)	
	Average Wind Speed (mph)	Predominant Direction (from)
January	17.7	N
February	17.4	N
March	17.1	SW
April	15.3	SW
May	13.2	SW
June	12.4	SW
July	12.1	SW
August	11.7	SW
September	13.7	NE
October	15.3	NE
November	16.6	N
December	17.0	N

2.2 Waves

The energy dissipation that occurs as waves enter the nearshore zone and break is an important component of sediment transport in the project area. Incident waves, in combination with tides and storm surge, are important factors influencing the behavior of the shoreline. The Carolina Beach study area is exposed to both short period wind-waves and longer period open-ocean swells originating predominantly from the east and southeast.

Damage to the Carolina Beach shoreline and upland development is attributable to large storm waves produced primarily by tropical disturbances, including hurricanes, during the summer months, and by Northeasters during the late fall and winter months.

Wave data for this report were obtained from the long-term USACE WIS hindcast database for the Atlantic coast of the U.S. This 33-year record extends from 1980 through 2012 and consists of a time-series of wave events at 3-hour intervals for stations located along the east and west coasts of the US as well as the Gulf of Mexico and Great Lakes. The WIS station closest to the project area is #63298, located approximately 11 miles offshore. The location of WIS station #63298 relative to the study area is shown previously in **Figure 2**.

Table 3 summarizes the percentage of occurrence and average wave height of the WIS waves by direction. It can be seen that the dominant wave direction is from the southeast with contributions from the east. This can be seen in greater detail in the wave rose presented in Figure 4. The total wave climate reflects both the open-ocean swell and more locally generated wind-waves.

Similar to wind conditions, wave conditions in Coastal North Carolina experience seasonal variability. The seasonal breakdown of wave heights is shown in **Table 4**. The intensity of fall and winter wave conditions is only slightly greater than waves in the spring and summer. This again reflects the shielding effect that the northern portions of the North Carolina have on the project vicinity. Waves originating from the east to southeast dominate year round.

Wave periods show the same relative seasonal uniformity as wave heights. **Table 5** provides a seasonal breakdown of percent occurrence by wave period. From this table, it can be seen that wave with periods of greater than 9 seconds dominate throughout the year. Shaded values show the dominant wave period for each month.

Table 3. Average Wave Heights (1980 to 2012)

Wave Direction (from)	WIS Station #63298 (1980-2012)	
	Percentage Occurrence (%)	Average Significant Wave Height (ft)
North	1.2	3.1
Northeast	4.4	3.9
East	31.6	4.0
Southeast	46.1	3.4
South	14.1	3.9
Southwest	1.6	3.6
West	0.5	3.2
Northwest	0.6	3.2

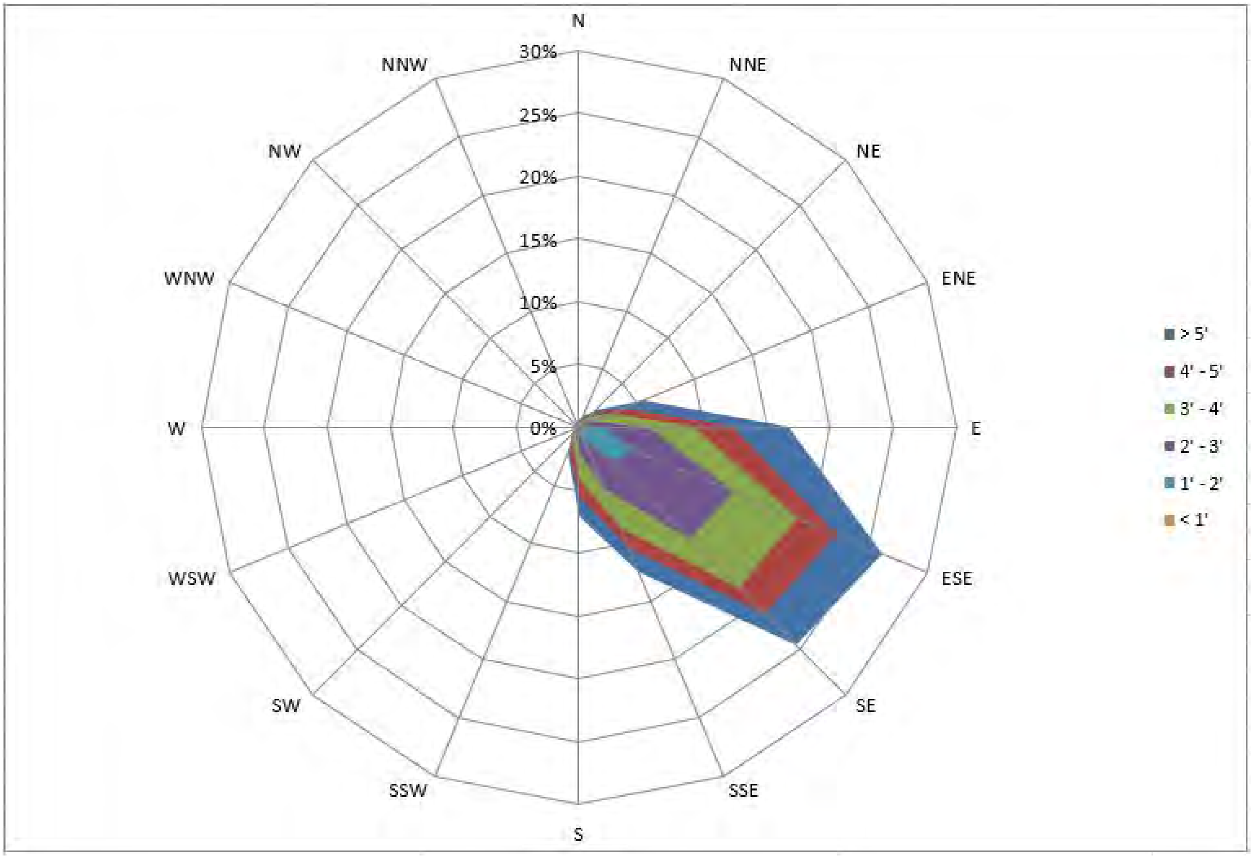

Figure 4. Wave Rose – WIS Station 63298

Table 4. Seasonal Wave Conditions

Month	WIS Station #63298 (1980-2012)	
	Average Wave Height (ft)	Predominant Direction (from)
January	4.0	SE
February	4.1	SE
March	4.1	E
April	3.6	SE
May	3.3	SE
June	3.0	SE
July	3.0	SE
August	3.0	SE
September	4.0	SE
October	3.9	E
November	4.1	E
December	3.9	E

Table 5. Peak Wave Period – Percent Occurrence

Wave Period (Sec)	Percent Occurrence by Wave Period Band Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
< 4.0	4.7	4.0	4.1	2.6	0.7	1.3	0.3	0.8	0.6	2.5	2.5	3.2
4.0 - 4.9	5.2	5.3	4.4	4.0	4.1	3.9	3.8	3.7	2.5	3.5	4.3	4.7
5.0 - 5.9	6.9	6.6	8.4	9.8	10.2	10.1	11.8	8.7	6.6	6.1	5.4	7.2
6.0 - 6.9	10.7	11.0	11.8	14.5	12.1	12.9	14.9	12.4	10.4	10.7	7.4	9.6
7.0 - 7.9	4.4	6.1	6.9	9.3	9.8	10.4	13.0	13.3	12.6	10.1	6.7	5.5
8.0 - 8.9	4.9	6.8	8.6	10.1	12.9	12.4	11.8	18.2	14.5	13.6	10.8	6.4
9.0 - 9.9	8.3	8.0	10.7	13.5	19.3	19.3	18.7	18.6	14.1	17.2	15.8	9.5
10.0 - 10.9	14.9	13.1	15.2	15.0	17.8	22.1	19.0	12.7	11.9	13.1	17.4	17.8
11.0 - 11.9	21.7	18.9	12.6	12.2	9.1	6.9	5.7	4.8	9.2	10.9	13.8	15.6
> 12.0	18.4	20.1	17.3	8.9	4.1	0.7	1.2	6.8	17.7	12.3	15.9	20.6

2.3 Tides

Astronomical tides are created by the gravitational pull of the moon and sun and are entirely predictable in magnitude and timing. The National Oceanic and Atmospheric Administration (NOAA) regularly publishes tide tables for selected locations along the coastlines of the Unites States and selected locations around the world. These tables provide times of high and low tides, as well as predicted tidal amplitudes.

Tidal datums for the Carolina Beach project site were obtained from NOAA tide station 8658559 Wilmigton Beach, NC. Tidal datums are summarized in **Table 6**. The tide range (difference between Mean High Water and Mean Low Water) is 4.21 feet in the project area.

Table 6. Tidal Datums

Tidal Datum	Elevation Relative to NAVD88 (feet)
Mean Higher High Water (MHHW)	1.74
Mean High Water (MHW)	1.40
North American Vertical Datum (NAVD88)	0.00
Mean Tide Level (MSL)	-0.70
Mean Low Water (MLW)	-2.81
Mean Lower Low Water (MLLW)	-2.96

2.4 Storm Effects

The shoreline of Carolina Beach is influenced predominantly by tropical systems which occur during the summer and fall. Northeasters during the late fall, winter, and spring do have an effect, but to a lesser degree due to shielding effects of the coastal geography north of the project site. Although hurricanes typically generate larger waves and storm surge, Northeasters also impact the shoreline because of their longer duration and higher frequency of occurrence.

During intense storm activity, the shoreline is expected to naturally modify its beach profile. Storms erode and transport sediment from the beach into the active zone of storm waves. Once caught in the waves, this sediment is carried along the shore and re-deposited farther down the beach or is carried offshore and stored temporarily in submerged sand bars. Periodic and unpredictable hurricanes and coastal storms, with high energy breaking waves and elevated water levels, can change the width and elevation of beaches and accelerate erosion. After storms pass, lower energy waves usually return sediment from the sand bars to the beach, which is restored gradually to its natural shape. While the beach profile typically recovers from storm energy as described, extreme storm events may cause sediment to leave the beach system entirely, sweeping it into inlets or far offshore into deep water where waves cannot return it to the beach. Therefore, a portion of shoreline recession due to intense storms may never fully recover.

Carolina Beach is located in an area of significant hurricane activity. **Figure 5** shows historic tracks of hurricanes and tropical storms from 1852 to 2016, as recorded by the National Hurricane Center (NHC) and is available from the National Oceanic and Atmospheric Administration (http://csc.noaa.gov/hurricanes/#). Note that the NOAA hurricane mapping tool had not been updated to include the 2018 at the time of this report. The shaded circle in the center of this figure indicates a 50-nautical mile radius drawn from the center of the study. Based on NHC records 86 hurricanes tropical storms have passed within this 50-mile radius over the 164-year period of record. The 50-mile radius (centered on the project) was chosen for display purposes in **Figure 5** because any tropical disturbance passing within this distance, even a weak tropical storm, would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.

In recent years, a number of named storms, passing within the 50 mile radius have significantly impacted the project area, including Florence (2018), Colin (2016), Hermine (2016), Matthew (2016), Arthur (2014), and Beryl (2012). Damages from these storms, as well as from more distant storms causing indirect impacts, included substantial erosion and damage from winds, waves, and elevated water levels.

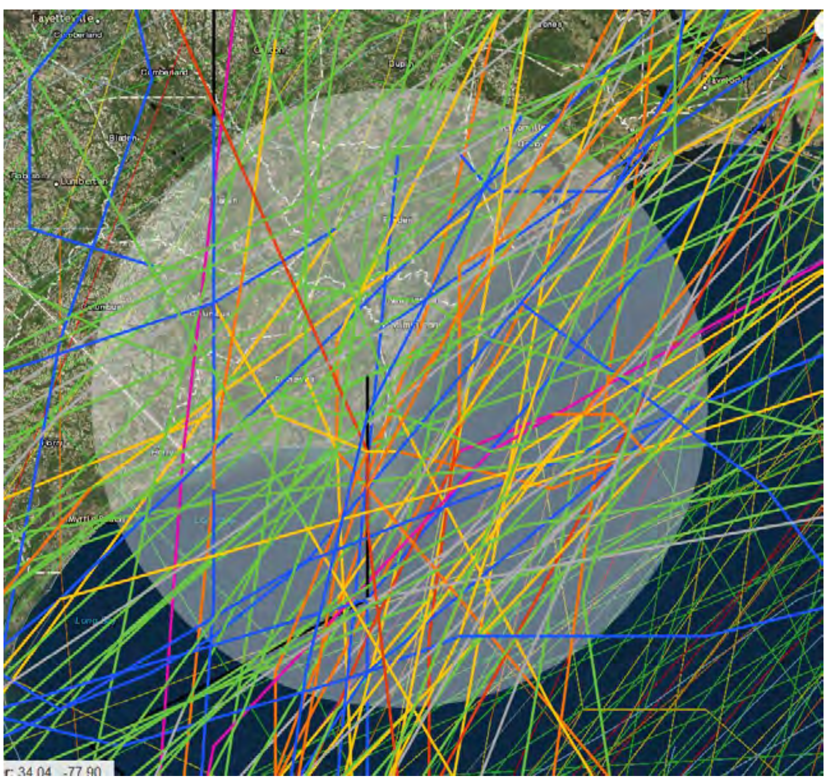

Figure 5. Historic storm tracks – Hurricanes and Tropical Storms (1852 – 2016, 50 NM radius)

2.5 Storm Surge

Storm surge is defined as the rise of the ocean surface above its astronomical tide level due to storm forces. Surges occur primarily as a result of atmospheric pressure gradients and surface stresses created by wind blowing over a water surface. Strong onshore winds pile up water near the shoreline, resulting in super-elevated water levels along the coastal region and inland waterways. In addition, the lower atmospheric pressure which accompanies storms also contributes to a rise in water surface elevation. Extremely high wind velocities coupled with low barometric pressures (such as those experienced in tropical storms, hurricanes, and very strong Northeasters) can produce very high, damaging water levels. In addition to wind speed, direction and duration, storm surge is also influenced by water depth, length of fetch (distance over water), and frictional characteristics of the nearshore sea bottom. An estimate of storm surge is required for the design of dune crest elevations. An increase in water depth may increase the potential for coastal flooding and allow larger storm waves to attack the shore.

Due to sand management over the life of the project within the dune (sand fencing and planting) the existing condition dune system along the Carolina Beach study area varies between 8 and 19 feet NAVD88 (authorized template is 12.5 feet NAVD88 where authorized) and is susceptible to overtopping from extreme storm surges. This can be seen from **Table 7** which provides surge levels vs storm frequency taken from the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) conducted in 2006 (FEMA, 2006) and updated in 2018 (FEMA, 2018). The storm surge elevations presented include the effects of astronomical high tide and wave setup.

Table 7. Storm Tide Elevations (FEMA, 2006 & 2018)

Return Period (Years)	Total Storm Tide Level (Feet, NAVD88)
25	6.4
50	8.4
100*	10.0
500*	15.0
* Updated as part of the 2018 FIS	

2.6 Sea Level Change

Relative Sea Level Change (RSLC) was calculated using the USACE Sea Level Change Curve Calculator which is available at: http://www.corpsclimate.us/ccaceslcurves.cfm. This Calculator uses the methodology described in Engineer Regulation (ER) 1100-2-8162, *Incorporating Sea Level Changes in Civil Works Programs* (USACE 2013).

Extreme water levels (EWL) incorporated into the calculator are based on statistical probabilities using recorded historic monthly extreme water level values. EWL analysis is described below. *NOAA Technical Report NOS CO-OPS 067 - Extreme Water Levels of the United States 1893-2010* describes the methods and data used in the calculation of the exceedance probability levels using a generalized extreme value (GEV) statistical function (NOAA 2013). The USACE method uses the same NOAA recorded monthly extreme values in a percentile statistical function. Both methods use data recorded and validated by NOAA at the long-term, established tide gauges. The extreme values at the gauge can be significantly different than what may occur at the project site due to differences in site characteristics and complex interactions of physical forces that vary between the locations. The level of confidence in the exceedance probability decreases with longer return periods. Additional information is available at the CO-OPS website at: http://tidesandcurrents.noaa.gov/est/.

Relative sea level (RSL) refers to local elevation of the sea with respect to land, including the lowering or rising of land through geologic processes such as subsidence and glacial rebound. It is anticipated that sea level will rise within the next 100 years. To incorporate the direct and indirect physical effects of projected future sea-level change on design, construction, operation, and maintenance of coastal projects, the USACE has provided guidance in EC 1165-2-212 (USACE, 2012) which has been superseded by ER 1100-2-8162 and Engineer Technical Letter (ETL) 1100-2-1 (USACE 2013, 2014).

ER 1100-2-8162 provides both a methodology and a procedure for determining a range of sea level change estimates based on global sea level change rates, the local historic sea level change rate, the construction (base) year of the project, and the design life of the project. Three estimates are required by the guidance, a Low (Baseline) estimate representing the minimum expected sea level change, an Intermediate estimate, and a High estimate representing the maximum expected sea level change. These estimates are referenced to the midpoint of the latest National Tidal Datum epoch, 1992. The reader is referred to ER 1100-2-8162 for a detailed explanation of the procedure, equations employed and variables included to account for the eustatic change as well as site specific uplift or subsidence to develop corrected rates.

Based on historical sea level measurements taken from NOS gage 8659084 at Southport, North Carolina, the historic sea level change rate *(e+M)* was determined using the *updated published* SLC fetched from *http://www.corpsclimate.us/ccaceslcurves.cfm*. The economic analysis period for this study begins with a Beach-fx model start date of 2021 (economic base year of 2022) and extends to the end of the project life in 2037. At Gauge 8659084, the mean sea level trend is 2.01 mm/year (0.00659 feet/year) with a 95% confidence interval of +/- 0.41 mm/year (0.00134 feet/year) based on monthly mean sea level data over a 74 year record (**Figure 6**) which is equivalent to a change of 0.11 feet over the remaining life of the project (2037). The Intermediate rate was determined to be 3.91 mm/year (0.0128 feet/year). The High rate was determined to be 9.92mm/year (0.0325 feet/year). This results in an Intermediate and High change in sea level between the start year (2021) and the end of the project life (2037) of 0.21 feet and 0.54 feet, respectively. RSLC between 2021 and 2037 is shown graphically in **Figure 7**. **Figure 7** shows the relative change in the water level between the start and end dates for the USACE scenarios, which is calculated using Eq. 3 of ER 1100-2-8162. This accounts for the difference in start date (2021) and 1992, the origin of the estimates. Note that the graph starts at zero in the project start year. Associating change in sea level with a particular datum is not possible unless an assumed rate/curve is used to transfer the datums developed for the current National Tidal Datum Epoch (NTDE) to the project start year. The Sea Level Change Curve Calculator tool simply shows the change in height during the project's life.

The FEMA Base Flood Elevation (BFE), defined as the 1% Annual Exceedance Probability (AEP) Flood, is the regulatory requirement for the elevation or floodproofing of structures and are referenced to FEMA panels (**Figure 8**). BFE at Carolina Beach is 10 feet (Section 2.5: Storm Surge). Using the SLR calculator, the BFE was plotted relative to relative sea level change (**Figure 9**). Tidal datums and extreme water levels (including the BFE) for Gauge 8659084 are shown in **Figure 10**.

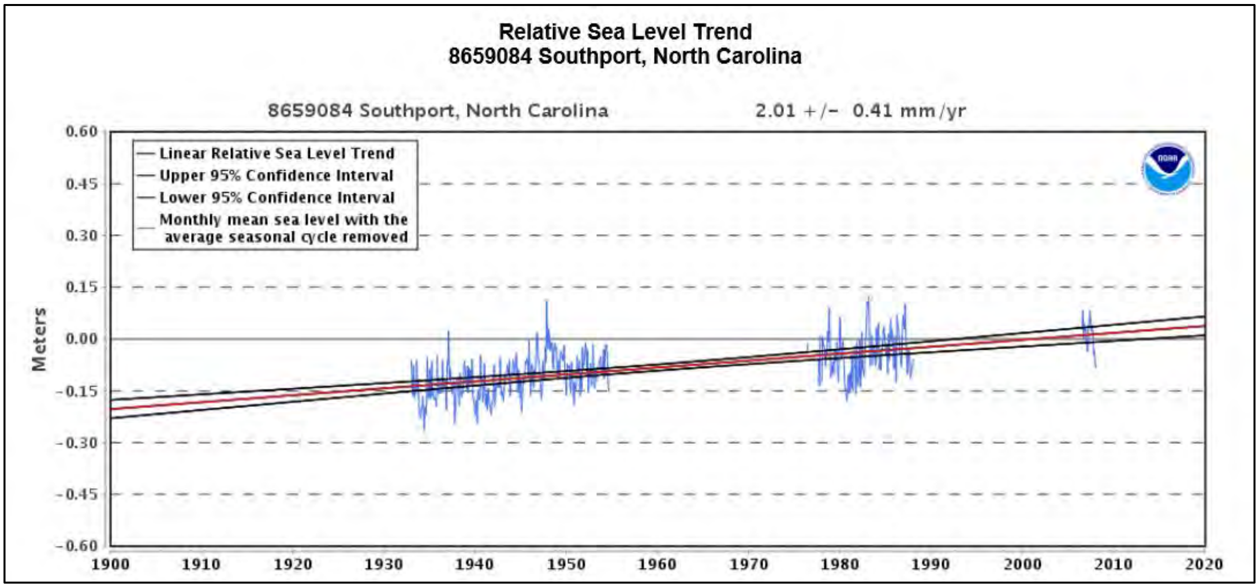

Figure 6. Relative Sea Level Trend, NOAA Gauge 8659084

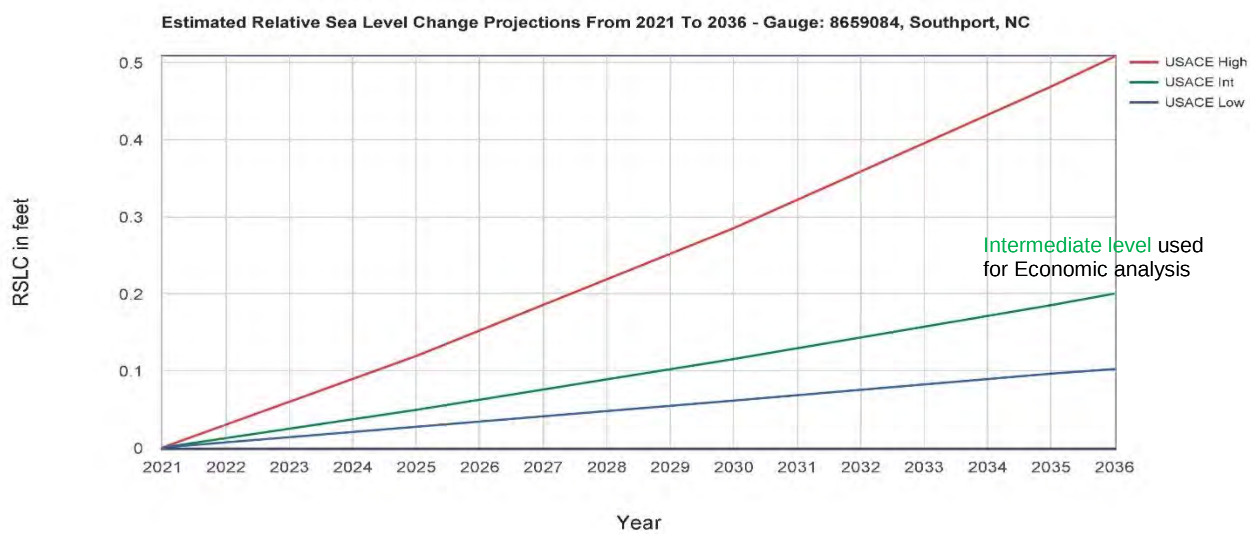

Figure 7. Project Sea Level Change, Start Year (2021) to End of Project Life (2036)

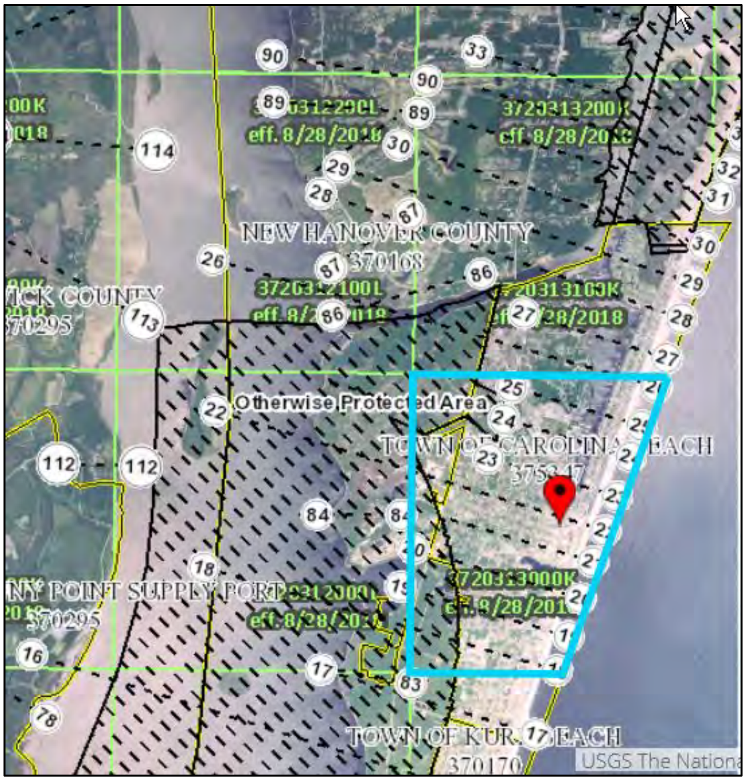

Figure 8. FEMA Flood Map Panels for Carolina Beach

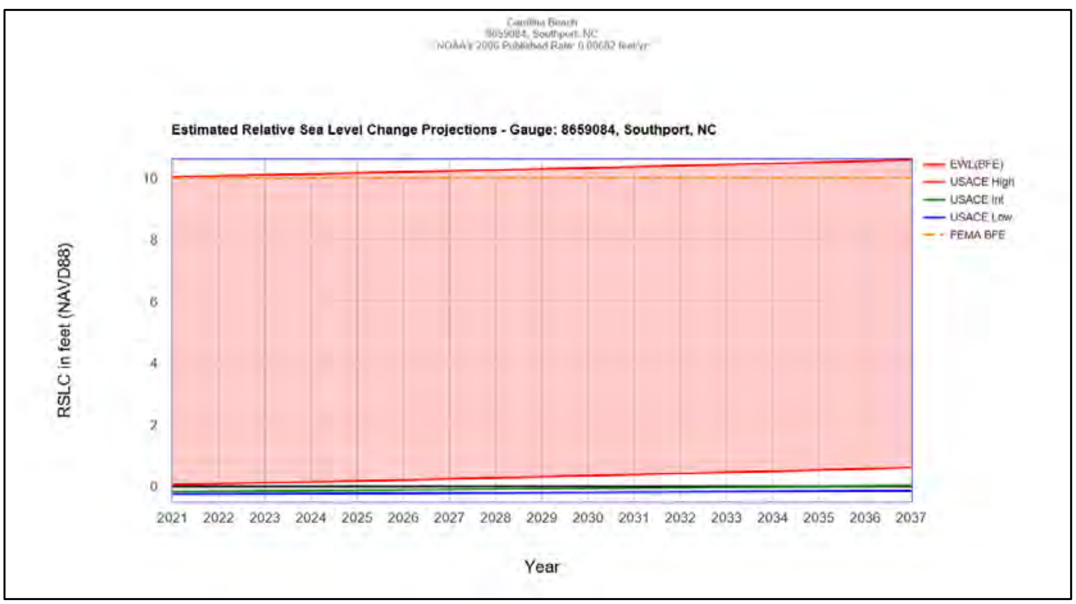

Figure 9. Estimated Relative Sea Level Change with BFE

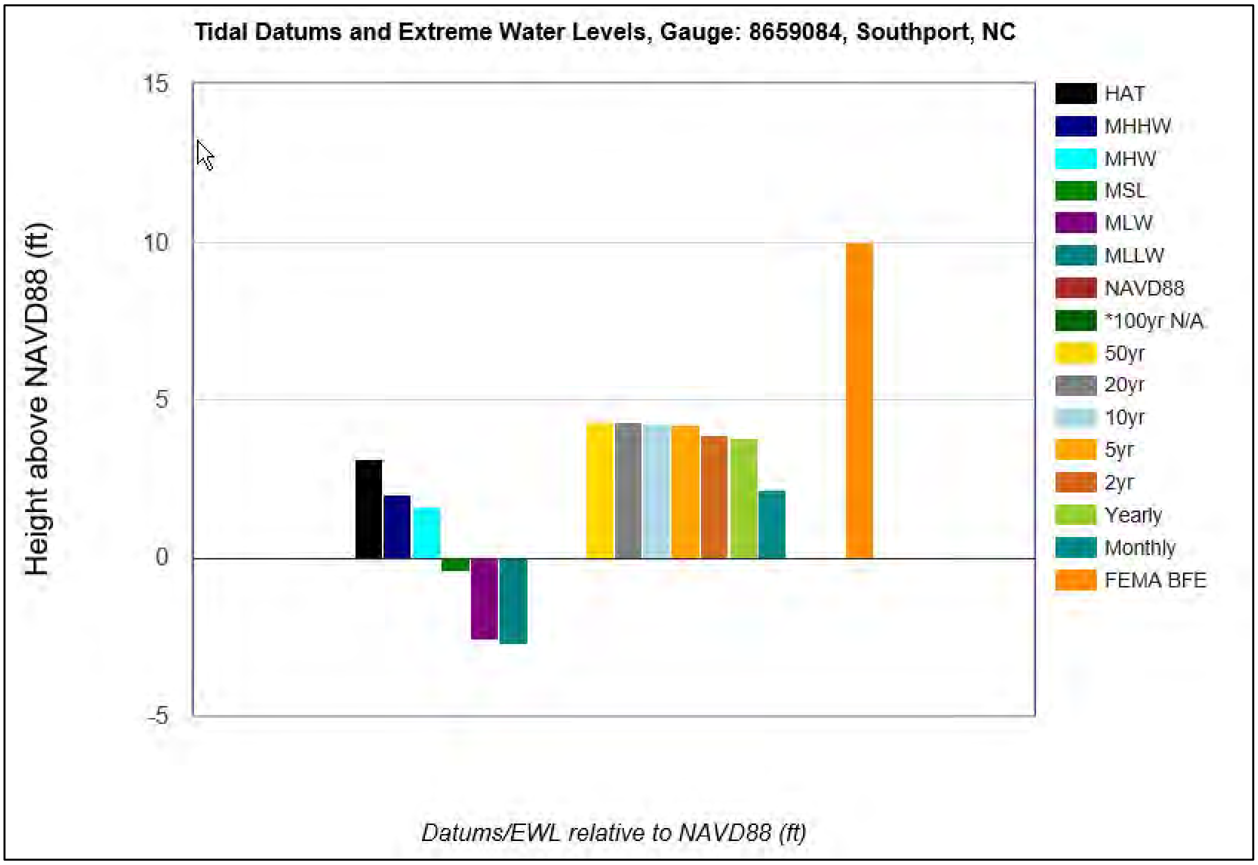

Figure 10. Tidal Datums and Extreme Water Levels

Potential impacts of rising sea level on total water levels experienced at the site include overtopping of waterside structures, increased shoreline erosion, and flooding of low lying areas. Three cross-sections were drawn along the Carolina Beach project site to determine elevations across the barrier island (**Figure 11**). Elevations at each transect are plotted with the BFE as well as the 4%, 2%, and 0.2% AEP water elevations for the High seal level change scenario at the end of the project life (**Figure 12** to **Figure 14**). These figures indicate that the existing conditions at Carolina Beach are less susceptible to widespread flooding in the southern end of the project and extremely susceptible along the northern end. Flooding and dune over-wash will occur along the northern end of the project during storm events greater than the 4% AEP.

In general, RSLC (Baseline, Intermediate, and High) will not affect the overall function of the project. Relative vulnerability to flooding during extreme events is consistent between both with and without project conditions. However, adaptation in the form of additional sand volume will be required to maintain project performance.

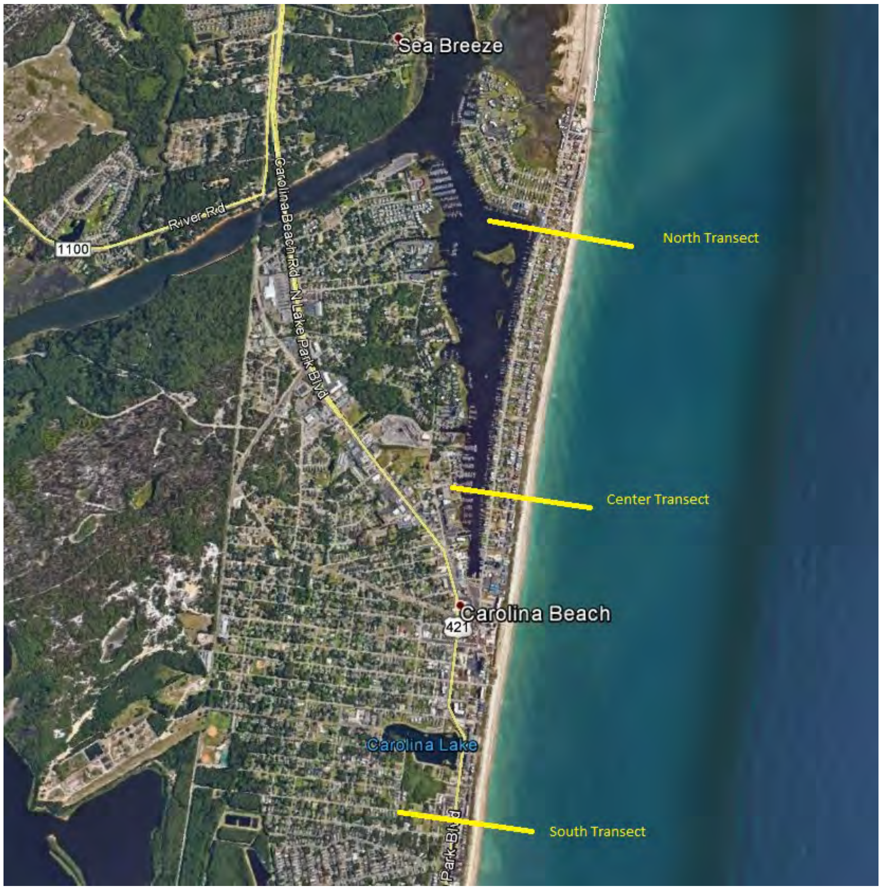

Figure 11. Carolina Beach Elevation Transects

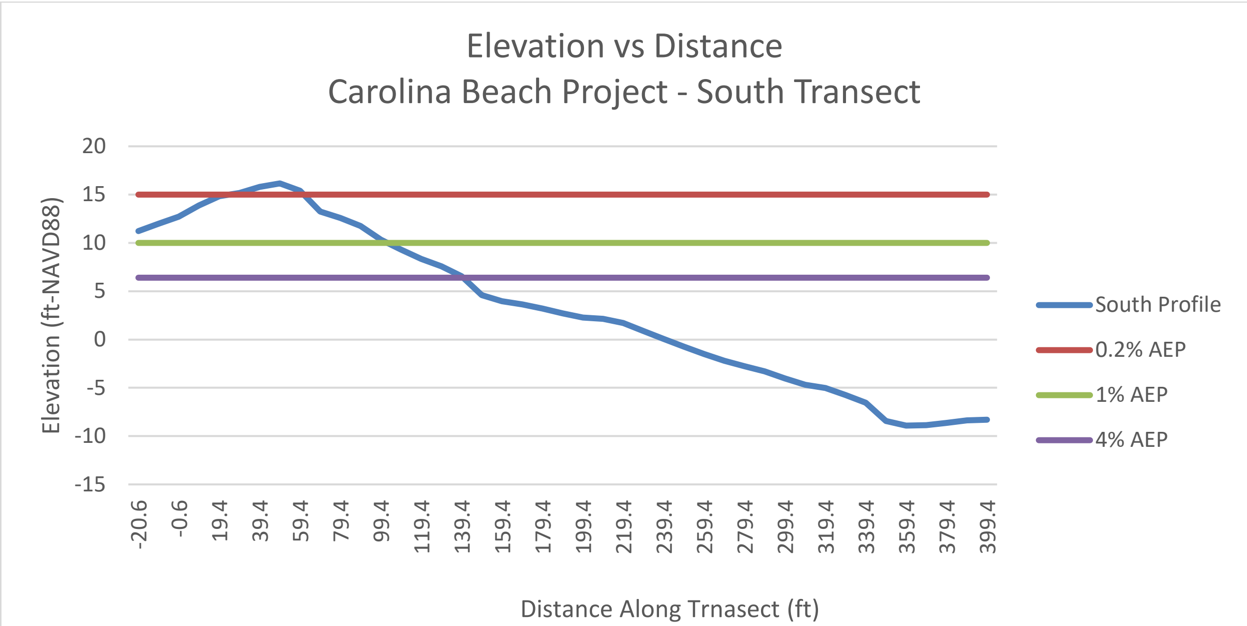

Figure 12. Land and AEP Elevations – South Transect

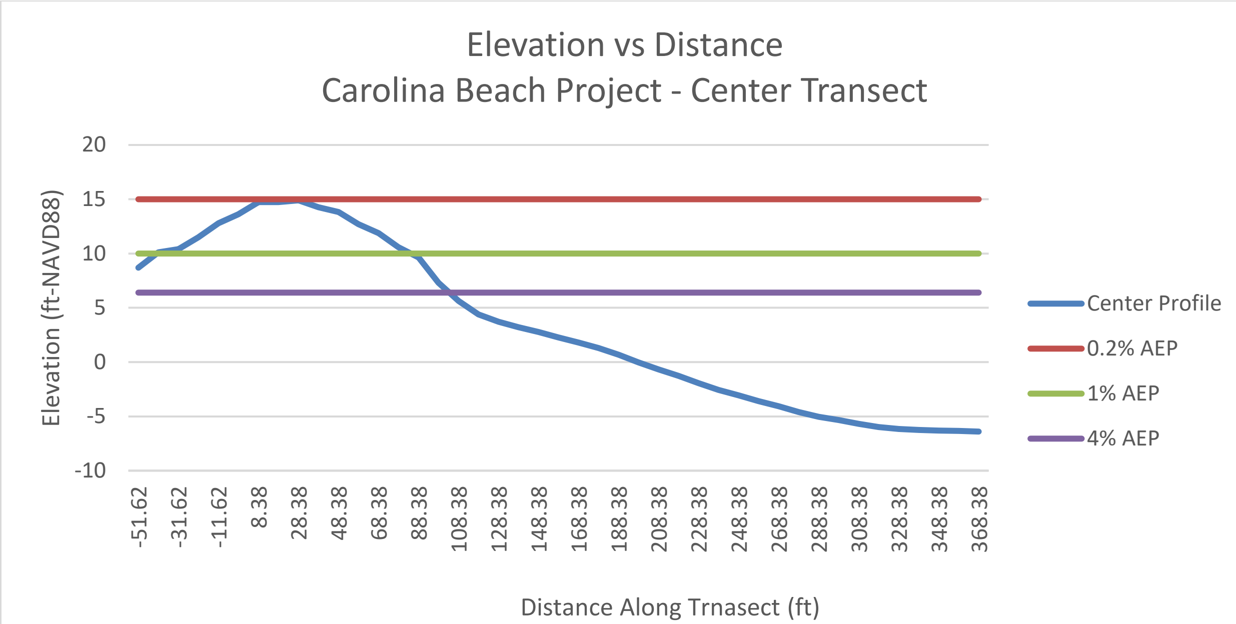

Figure 13. Land and AEP Elevations – Center Transect

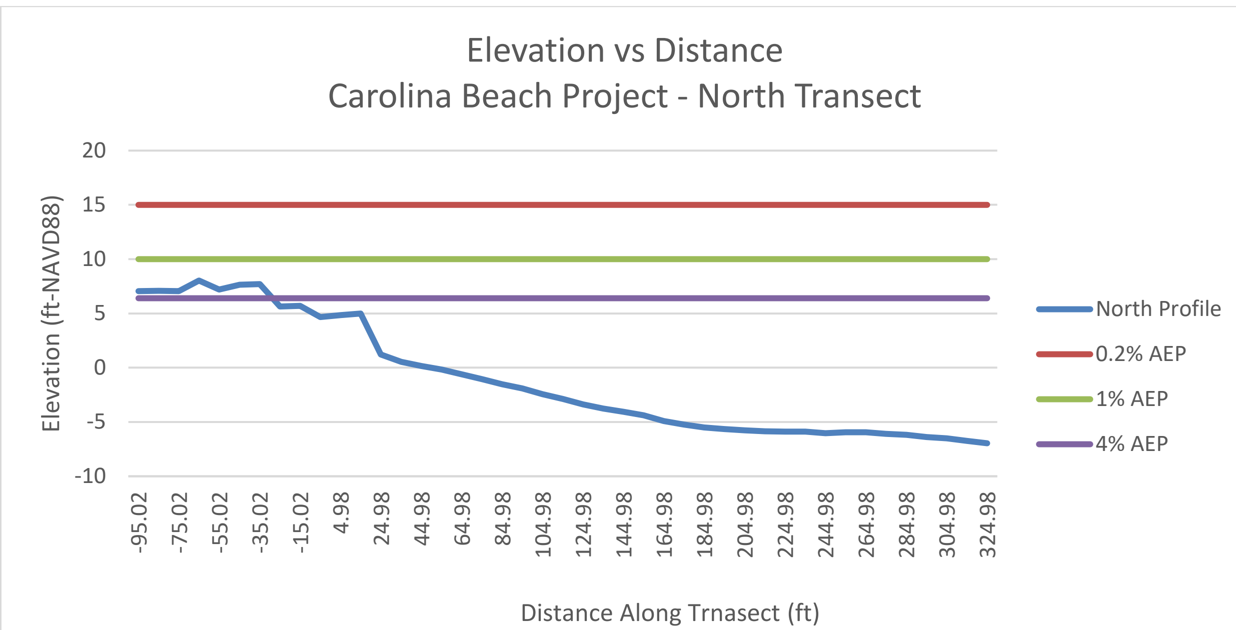

Figure 14. Land and AEP Elevations – North Transect

3 Beach-*fx* Life-Cycle Shore Protection Project Evolution Model

Federal participation in projects is based on a favorable economic justification in which the benefits of the project outweigh the costs. Determining the Benefit to Cost Ratio (BCR) requires both engineering analysis (project cost, performance, and evolution) and economic analyses (plan formulation, plan selection, and quantification of project benefits). The interdependence of these functions has led to the development of the life-cycle simulation model Beach-*fx*. Beach-*fx* combines the evaluation of physical performance and economic benefits and costs of shore protection projects (Gravens et. al., 2007), particularly beach nourishment, to form the basis for determining the justification for Federal participation.

3.1 Background & Theory

Beach-*fx* is an event-driven life-cycle model. USACE guidance (USACE, 2006) requires that flood damage reduction studies include risk and uncertainty. The Beach-*fx* model satisfies this requirement by fully incorporating risk and uncertainty throughout the modeling process (input, methodologies, and output). Over the project life-cycle, typically 50 years for new studies and the remaining project life for existing projects, the model estimates shoreline response to a series of historically based storm events applied for each of three USACE sea level change scenarios as required by Engineering Regulation, ER 110-2-8162 (USACE, 2013). These plausible storms, the driving events, are randomly generated using a Monte Carlo simulation. The corresponding shoreline evolution includes not only erosion due to the storms, but also allows for storm recovery, post-storm emergency dune and/or shore construction, and planned nourishment events throughout the life of the project. Risk based damages to structures are estimated based on the shoreline response in combination with pre-determined damage functions for all structure types within the project area. Uncertainty is incorporated not only within the input data (storm occurrence and intensity, structural parameters, structure and contents valuations, and damage functions), but also in the applied methodologies (probabilistic seasonal storm generation and multiple iteration, life cycle analysis). Results from the multiple iterations of the life cycle are averaged over a range of possible values.

The project site itself is represented by divisions of the shoreline referred to as “Reaches”. Because this term may also be used to describe segments of the shoreline to which project alternatives are applied (Sbeach reaches), Beach-*fx* reaches will be referred to in this appendix as “economic reaches”. Economic reaches are contiguous, morphologically homogenous areas that contain groupings of structures (residences, businesses, walkovers, roads, etc…), all of which are represented by Damage Elements (DEs). DEs are grouped within divisions referred to as Lots. **Figure 15** shows a conceptual representation of the model setup. Note that a single Sbeach Reach may be composed of several economic reaches. Economic reaches capture the diversity of shoreline dimension and erosion potential that can occur over a single economic reach.

Within the model, each economic reach is associated with a representative beach profile that approximates the cross-shore profile and beach composition of the reach. Multiple econoomic reaches may share the same representative beach profile while groupings of economic reaches may represent a single design reach. For Carolina Beach, the project area can be separated into five Sbeach reaches which are represented by thirteen model reaches. **Table 8** provides Carolina Beach Sbeach and economic reaches (shown in **Figure 16**).

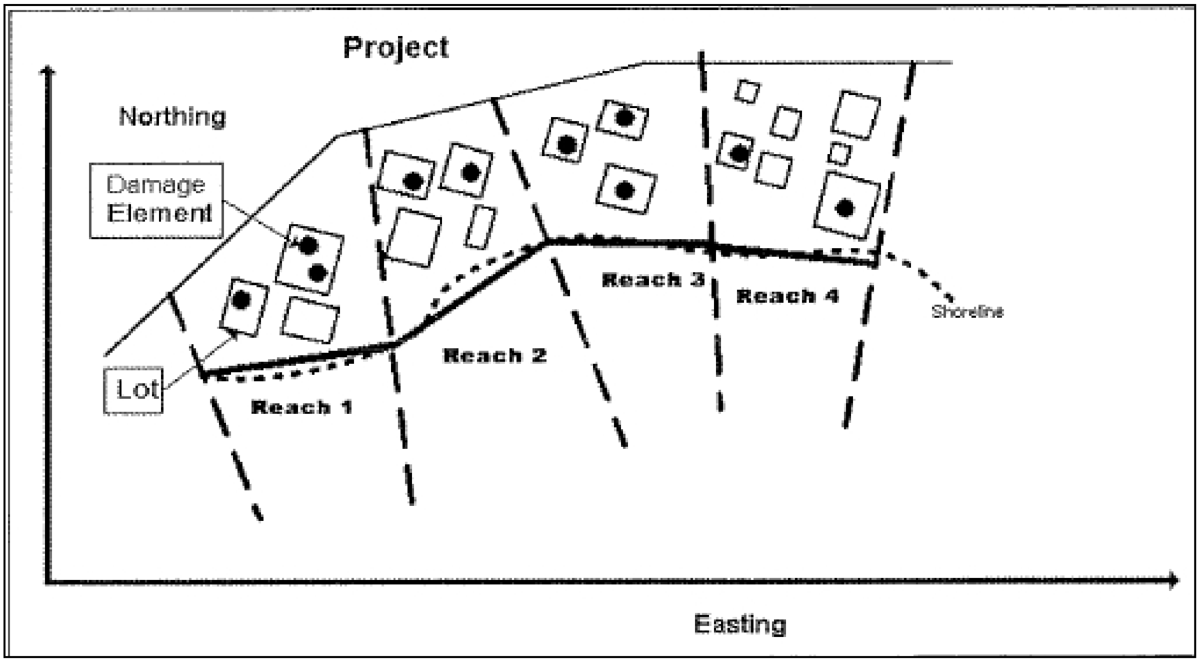

Figure 15. Beach-fx Model Setup Representation

Table 8. Carolina Beach Economic and Sbeach Reaches

Sbeach Reach	Economic Reach
CB 01	R14 – R16
CB 02	R11 – R13
CB 03	R04 – R10
CB 04	R3
CB 05	R01 – R02

Implementation of the Beach-*fx* model relies on a combination of meteorology, coastal engineering, and economic analyses and is comprised of four basic elements:

- Meteorologic driving forces
- Coastal morphology
- Economic evaluation

- Management measures

The subsequent discussion in this section addresses the basic aspects of implementing the Beach-*fx* model. For a more detailed description of theory, assumptions, data input/output, and model implementation, refer to Gravens et al. 2007; Males et al., 2007, and USACE 2009.

This following sections describe the engineering aspects and parameters of the Beach-*fx* model followed by a discussion of the economic parameters and analysis.

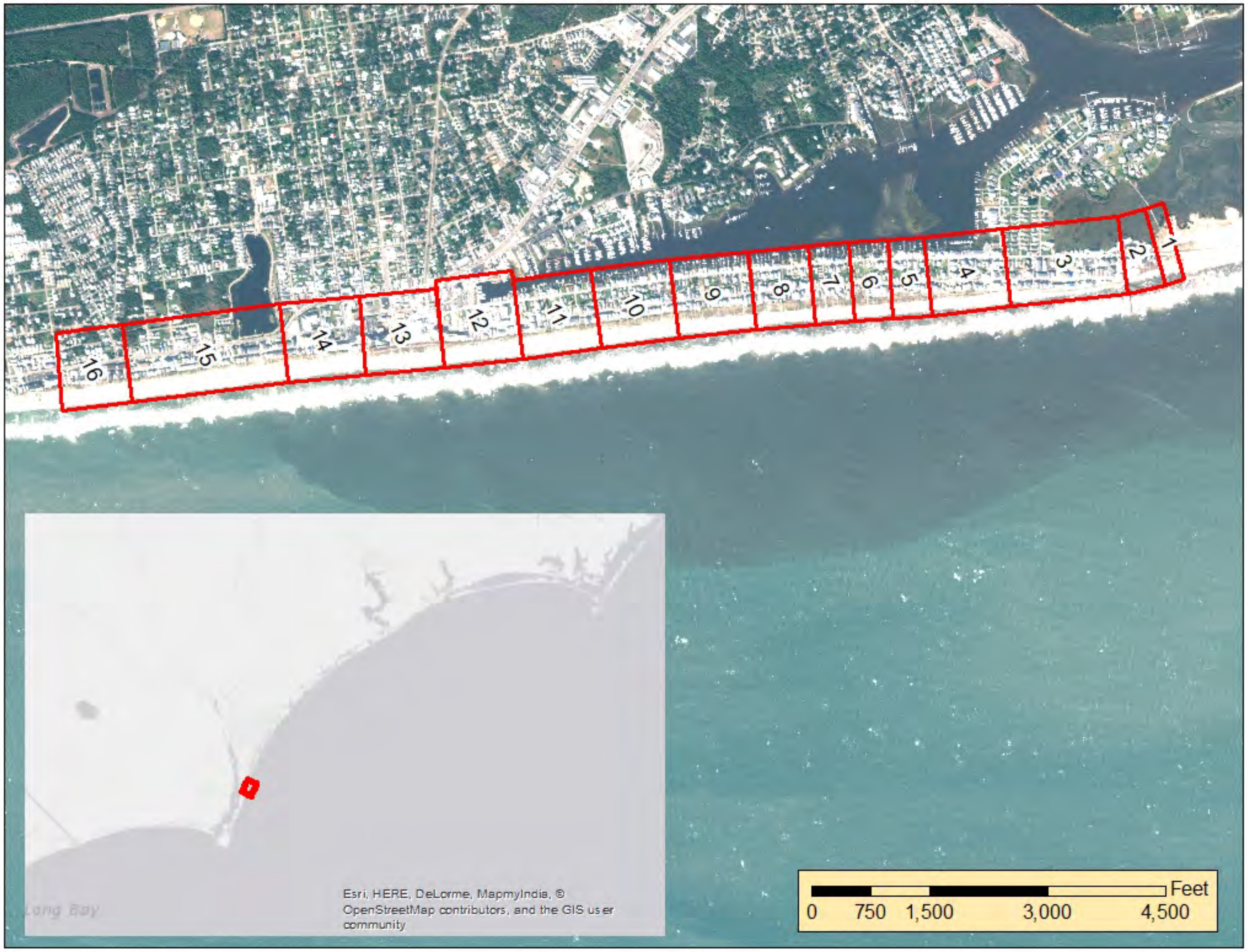

Figure 16 Carolina Beach Economic Reaches

3.2 Engineering Parameters

3.2.1 Meteorologic Driving Forces

The predominant driving force for coastal morphology and associated damages within the Beach-*fx* model is the historically based set of storms that is applied to the life-cycle simulation. Because the eastern coast of North Carolina is subject to seasonal storms, tropical storms (hurricanes) in the summer months and extra-tropical storms (Northeasters) in the winter and fall months, the "plausible storms" dataset for Carolina Beach is made up of both types. These storms were derived from hindcast data obtained from Oceanweather Incorporated (see Sub-appendix A: Development of Storm Suite). The Carolina Beach plausible storm set contains 21 tropical storms and 9 extra-tropical storms.

Because storm events may to be of limited duration, passing over a given site within a single portion of the tide cycle, it is assumed that any of the historical storms could have occurred during any combination of tidal phase and tidal range. Therefore, each of the plausible storm surge hydrographs was combined with possible variations in the astronomical tide. This was achieved by combining the peak of each storm surge hydrograph with the astronomical tide at high tide, mean tide falling, low tide, and mean tide rising for each of three tidal ranges corresponding to the lower quartile, mean, and upper quartile tidal ranges. This resulted in 12 distinct combinations for each historically based storm and a total of 252 tropical storm conditions and 108 extra-tropical storms in the plausible storm dataset.

In addition to the plausible storm dataset, the seasonality of the storms must be specified. Storm seasons are based on the season in which the original historical storm occurred. Storm probability is defined through the Probability Parameter which is determined for each season and storm type by dividing the number of storms by the total number of years in the storm record (extra-tropical or tropical). Four storm seasons were specified for Carolina Beach (**Table 9**).

The combination of the plausible storm dataset and the specified storm season allows the Beach-*fx* model to randomly select from storms of the type that fall within the season currently being processed. For each storm selected, a random time within the season is chosen and assigned as the storm date. The timing of the entire sequence of storms is governed by a pre-specified minimum storm arrival time. To allow for the possible frequency of Northeaster events in this area, a minimum arrival time of 7 days was specified for Carolina Beach. Based on this interval, the model attempts to place subsequent storm events outside of a 14 day window surrounding the date of the previous storm (i.e. a minimum of 7 days prior to the storm event and a minimum of 7 days following the storm event). However, due to the probabilistic nature of the model the minimum arrival time may be overridden as warranted during the course of the life cycle analysis.

Table 9. Carolina Beach Beach-*fx* Storm Seasons

Storm Season	Start Date	End Date	Probability Parameter Extra-Tropical Storm	Probability Parameter Tropical Storm
Extratrop Winter	Dec 1	Apr 30	0.54	0.00
Tropical Early	May 1	Jul 31	0.02	0.09
Tropical Peak	Aug 1	Sep 30	0.00	0.72
Extratrop/Tropical	Oct 1	Nov 30	0.11	0.20

3.2.2 Coastal Morphology

The Beach-*fx* model estimates changes in coastal morphology through four primary mechanisms:

- Shoreline storm response
- Applied shoreline change
- Project-induced shoreline change
- Post-storm berm recovery

Combined, these mechanisms allow for the prediction of shoreline morphology for both with and without project conditions.

3.2.3 Shoreline Storm Response

Shoreline storm response is determined by applying the plausible storm set to simplified beach profiles that represent the shoreline features of the project site. For this study, application of the storm set to the idealized profiles was accomplished with the SBEACH coastal processes response model (Larson and Kraus 1989). SBEACH is a numerical model which simulates storm-induced beach change based on storm conditions, initial profiles, and shoreline characteristics such as beach slope and grain size. Output consists of post-storm beach profiles, maximum wave height and wave period information, and total water elevation including wave setup. Pre- and post-storm profiles, wave data, and water levels can be extracted from SBEACH and imported into the Beach-*fx* Shore Response Database (SRD). The SRD is a relational database used by the Beach-*fx* model to pre-store results of SBEACH simulations of all plausible storms impacting a pre-defined range of anticipated beach profile configurations.

3.2.4 Representative Profiles

In order to develop the idealized SBEACH profiles from which the SRD was derived, it was necessary to first develop representative profiles for the project shoreline. The number of representative profiles developed for any give project depends on the natural variability of the shoreline itself. Typically, profiles taken along the project shoreline are compared, aligned, and averaged into composite profiles representative of dimensionally consistent segments of the shoreline. These segments are the basis of the model reaches discussed previously. A representative profile may define one or more model reaches. For Carolina Beach 29 representative profiles define 16 economic reaches. This is necessary as each of the 16 economic reaches have either a unique background erosion rate or upland width. Representative profiles are developed according to the similarity between the following seven dimensions:

- Upland elevation
- Dune slope
- Dune height
- Dune width
- Berm height
- Berm width
- Foreshore slope

The start year of the current Beach-fx analysis is 2021. The last scheduled re-nourishment prior to the start year will occur in Spring 2019. Therefore the 2021 shoreline would represent 2 years of erosion applied to the construction template. In order to estimate a 2021 shoreline, representative profile dimensions for the initial shoreline condition were derived from the March 2015 Carolina Beach survey taken nearly 3 years after the 2013 re-nourishment. Because the 2015 survey did not capture the full upland extent of the dune system, additional upland information was obtained from a North Carolina Floodplain Mapping Program (NCFMP) topographic Lidar survey.

Idealized profiles were calculated from the 2015 shoreline survey, supplemented by the 2014 NCFMP Lidar survey, using the Composite Dune Methodology. **Table 10** provides the dimensions of the idealized future without project representative profiles and the economic reaches they define.

3.2.5 SBEACH

SBEACH simulates beach profile changes that result from varying storm waves and water levels. These beach profile changes include the formation and movement of major morphological features such as longshore bars, troughs, and berms. SBEACH is a two-dimensional model that considers only cross-shore sediment transport; that is, the model assumes that simulated profile changes are produced only by cross-shore processes. Longshore wave, current, and sediment transport processes are not included in SBEACH and are computed externally when required.

SBEACH is an empirically based numerical model, which was formulated using both field data and the results of large-scale physical model tests. Input data required by SBEACH describes the storm being simulated and the beach of interest. Basic requirements include time histories of wave height, wave period, water elevation, beach profile surveys, and median sediment grain size.

It should be noted that SBEACH is the USACE recommended model for shoreline response. The Beach-*fx* model, also developed by USACE, is specifically designed to import and process output files exported directly from the SBEACH model.

SBEACH simulations are based on six basic assumptions:

Table 10. Dimensions of Idealized Without Project Representative Profiles

Sbeach Reach	Economic Reach	Upland Elevation (ft-NAVD88)	Dune Height (ft-NAVD88)	Dune Width (ft)	Dune Slope (H:1V)	Berm Elevation (ft-NAVD88)	Berm Width* (ft)	Foreshore Slope (H:1V)
CB05	R1, R2	7	11	0	0.1	9.5	10	0.1
CB04	R3	7	11	0	0.1	9.5	0	0.1
CB03	R4 – R10	7	17.5	10	0.1	9.5	10	0.1
CB02	R11 – R13	7	17.5	10	0.1	9.5	0	0.1
CB01	R14 – R16	7	17.5	10	0.1	9.5	0	0.1

- Waves and water levels are the major causes of sand transport and profile change
- Cross-shore sand transport takes place primarily in the surf zone
- The amount of material eroded must equal the amount deposited (conservation of mass)
- Relatively uniform sediment grain size throughout the profile,
- The shoreline is straight and longshore effects are negligible
- Linear wave theory is applicable everywhere along the profile without shallow-water wave approximations

Once applied, SBEACH allows for variable cross shore grid spacing, wave refraction, randomization of input waves conditions, and water level setup due to wind. Output data consists of a final calculated profile at the end of the simulation, maximum wave heights, maximum total water elevations plus setup, maximum water depth, volume change, and a record of various coastal processes that may occur at any time-step during the simulation (accretion, erosion, over-wash, boundary-limited run-up, and/or inundation).

3.2.5.1 SBEACH Calibration and Verification

Traditionally, calibration and verification of the SBEACH model is performed as part of the study being undertaken. However, data was not available for calibration of the Carolina Beach model. Calibration factors from the Wrightsville Beach, NC project were considered representative of the island and were used within the model.

3.2.5.2 SBEACH Simulations

Carolina Beach SBEACH simulations were completed for each of the without project profiles and an array of incremental profiles covering a range of potential with-project conditions in combination with each of the tropical and extra-tropical storms in the plausible storm database. From these profiles, changes in the key profile dimensions were extracted and stored in the Carolina Beach-*fx* SRD.

3.2.6 Applied Shoreline Change

The applied shoreline change rate (in feet per year) is a Beach-*fx* morphology parameter specified at each of the model reaches. It is a calibrated parameter that, combined with the storm-induced change generated internally by the Beach-*fx* model, returns the historical shoreline change rate for that location. Calibration is essential to insure that the morphology behavior is appropriate and representative of the study area.

The target shoreline change rate is an erosion or accretion rate equivalent to the historical background shoreline change rates for the project area. Traditionally, background erosion rates are determined from surveys, aerials, or other records of pre-project shoreline behavior. For Carolina Beach, background erosion rates were obtained from the 1993 Section 934 Re-evaluation study. However, these shoreline change rates did not reflect the addition of the revetment at the north end of the project after initial project construction. To account for the presence of the armor, erosion loss rates were reduced in model reaches R1 and R2 were revised from -27 feet/year and -19 feet/year, respectively, to -10 feet/year. This value is consistent behavior in the adjacent reach (R3) and is considered more representative of shoreline response in the presence of the revetment.

During Beach-*fx* calibration, applied erosion rates were adjusted for each model reach and the Beach-*fx* model was run for repeatedly for 300 iterations over the 50-year project life cycle. Calibration is achieved when the rate of shoreline change, averaged over hundreds of life cycle simulations, is equal to the background (target) shoreline change rate. **Table 11** provides the historical background erosion rates and the calibrated Beach-fx applied erosion rates.

Table 11. Historical Background Charge Rates and Calibrated Beach-fx Applied Erosion Rates

Model Reach	Historical Background Change Rate (feet/year)	Calibrated Beach-fx Applied Erosion Rates (feet/year)
R1	-10	-9.721
R2	-10	-9.721
R3	-9.5	-3.768
R4	-6.5	-4.867
R5	-4.5	-3.527
R6	-3.3	-2.931
R7	-3.3	-2.931
R8	-3.3	-2.931
R9	-3.3	-2.931
R10	-3.3	-2.931
R11	-3.3	-2.850
R12	-3.3	-2.850
R13	-3.3	-2.850
R14	-3.3	-2.860
R15	-3.3	-2.860
R16	-3.3	-2.860

3.2.7 Project Induced Shoreline Change

The project induced shoreline change rate accounts for the alongshore dispersion of placed beach nourishment material. Beach-*fx* requires the use of shoreline change rates in order to represent the planform diffusion of the beach fill alternatives after placement. Traditionally the one-dimensional shoreline change model GENESIS (Hanson and Kraus, 1989), a PC-based program capable of simulating long term spatial changes in longshore transport, has been employed for USACE feasibility studies. However, model setup, calibration, verification, and application to an array of beach renourishment alternatives can be complex and time consuming.

In order to bring the analysis more in line with the accelerated schedules required under SMART Planning guidelines, an alternative methodology was employed. Engineering Manual EM 1110-2-3301 Design of Beach Fills (USACE, 1995) provides guidance on the selection of shoreline change models. Four acceptable alternatives are discussed:

- GENESIS – One-dimensional model (PC based)
- Dean and Yoo (1992) – One line analytical model (spreadsheet/calculator based)
- Multi-contour 3D – Three dimensional model with variable profile and longshore capabilities (PC based)

- Fully 3D Model – Three dimensional model that calculate waves and currents in addition to sediment transport (PC based)

Of the alternatives, the one line analytical model is simplest to apply and produces valid planform diffusion estimates for variable fill widths and lengths. It should be noted that the governing equation within the GENESIS and GenCade models is a one line analytical solution.

3.2.7.1 One Line Analytical Model

While Dean and Yoo provides the basic governing formulations for assessing shoreline change rates, it does not specify a discrete analytical solution. These governing formulations, based on the conservation of sand combined with sediment transport, have existed for several decades. In that time, many analytical solutions have been developed to solve them. Because the analytical solution presented by Larson et al. (1987) is the closest in formulation to the GENESIS model traditionally used in more complex USACE applications, it was selected as the one-line model for use with the Carolina Beach project.

3.2.7.2 One Line Analytical Solution

The analytical solution for shoreline evolution derived by Larson et al. can be described by:

$$y(x,t) = \frac{1}{2} y_o \left[erf\left(\frac{a-x}{2\sqrt{\varepsilon t}}\right) + erf\left(\frac{a+x}{2\sqrt{\varepsilon t}}\right)\right]$$

Where

a = one half of the length of the fill
y_o = original cross-shore width of the fill
x = long-shore distance (where x = 0 is the center point of the fill)
t = time (where t = 0 is initial placement)
ε = diffusion coefficient

The diffusion coefficient is defined as:

$$\varepsilon = \frac{2Q}{(h_* + B)}$$

Where Q can be computed using the CERC equation, given as:

$$Q = \frac{K H_b^{\frac{5}{2}} \sqrt{\frac{g}{\lambda}} \sin(2\theta)}{16(s-1)(1-p)}$$

Where

K = non-dimensional sediment transport proportionality factory (see Section 3.2.7.3.3)
H_b = breaker height
g = acceleration due to gravity

λ = breaking wave height proportionality factor
θ = angle of wave approach
s = specific gravity of sediment
p = porosity of sediment

3.2.7.3 Input Parameters

3.2.7.3.1 Breaker Wave Height

The breaker wave height is an estimate of the height of waves as they arrive and break on a given beach. This parameter is typically calculated analytically based on deep-water wave characteristics (USACE, 1984). However, for the Carolina Beach project, only an estimated value for this parameter was required. This is due to the fact that measured shoreline change rates were available to calibrate the analytical solution. The value of H_b becomes independent of the analytical results during the calibration process.

3.2.7.3.2 Wave Angle

Wave angle like the breaker wave height is normally a value determined from measured data. This parameter also becomes independent of analytical results during the calibration process. Therefore, the wave angle was set to 45deg, which results in maximum dispersion.

3.2.7.3.3 Non-dimensional Sediment Transport Coefficient, K

The sediment transport coefficient *K* can be highly variable. It is dependent on sediment characteristics, properties of the suspension medium, and local wave climate. Small changes in any of the environmental or sediment factors can have a significant impact on the value of *K*. Given its variability, *K* can be set initially based on known or generally accepted parameter values, and then fine-tuned using measured or historical data for the project site. The one line model is calibrated in just this manner, where *K* is adjusted to maximize replication of measured shoreline change rates.

3.2.7.4 Calibration

In order to apply a one-line model it is necessary to calibrate the model using the available data. For Carolina Beach, best available data are the historical erosion rates. Past application of the one line model have shown that as a fill equilibrates, the dispersion rate decreases until till it approximates the background erosion rate when the project berm width reaches approximately 20 feet in width. Using the background shoreline changes rates and a project fill (berm) width of the 20 feet, the one line model was calibrated with a resultant K value of 1.9.

3.2.7.5 Shoreline Change Rates

Using the calibrated one line model, the project induced shoreline change rates for the existing project were calculated. The existing project is composed of two design berm templates, a 130 foot berm in the north of the project (model reaches R1 through R3) and a 50 foot berm over the remainder of the project. **Table 112** provides the calculated project induced shoreline change rates representative of the existing project.

Table 12. Project Induced Shoreline Change Rates

Model Reach	Design Berm Width (feet)	Shoreline Change Rate (feet/year)
R1	130	-39.9
R2	130	-38.0
R3	130	-32.9
R4	50	-10.5
R5	50	-9.3
R6	50	-8.7
R7	50	-8.1
R8	50	-7.5
R9	50	-6.9
R10	50	-6.6
R11	50	-6.7
R12	50	-7.3
R13	50	-8.2
R14	50	-9.5
R15	50	-11.9
R16	50	-14.6

3.2.8 Post Storm Berm Recovery

Post storm recovery of eroded berm width after passage of a major storm is a recognized process. Although present coastal engineering practice has not yet developed a predictive method for estimating this process, it is an important element of post-storm beach morphology. Within Beach-*fx*, post-storm recovery of the berm is represented in a procedure in which the user specifies the percentage of the estimated berm width loss during the storm that will be recovered over a given recovery interval. It is important to note that the percentage itself is not a “stand alone” parameter that is simply applied during the post storm morphology computations. The percentage of berm recovery is estimated prior to model calibration and becomes a tunable calibration parameter to ensure model convergence (when the model reproduces the target erosion rates as discussed in Section 3.2.6: Applied Shoreline Change). For Carolina Beach calibration required a varying berm recovery factor ranging between 95 and 99%.

3.2.9 Management Measures

Shoreline management measures that are provided for in the Beach-*fx* model are emergency nourishment and planned nourishment.

3.2.9.1 Emergency Nourishment

Emergency nourishments are generally limited beach fill projects conducted by local governments in response to storm damage. The Beach-*fx* model assumes emergency fill events have a single profile template, a consistent length of coverage, and occur when specific post-storm shoreline conditions are met. Carolina Beach does not have a history of consistent emergency nourishment in response to storm related erosion. The lack of a history of consistent locally sponsored post-storm emergency events, makes assigning realistic emergency fill triggers and specifications within Beach-*fx* impossible. Therefore, this management measure was not included in the Willoughby Spit Beach-*fx* analysis.

3.2.9.2 Planned Nourishment

Planned nourishments are handled by the Beach-*fx* model as periodic events based on nourishment templates, triggers, and nourishment cycles. Nourishment templates are specified at the model reach level and include all relevant information such as order of fill, dimensions, placement rates, unit costs, and borrow-to-placement ratios. Planned nourishments occur when user defined nourishment triggers are exceeded and a mobilization threshold volume is met. At a pre-set interval, all model reaches which have been identified for planned nourishment are examined. In reaches where one of the nourishment threshold triggers is exceeded, the required volume to restore the design template is computed. If the summation of individual model reach level volumes over the extent of the project exceeds the mobilization threshold volume established by the user, then nourishment is triggered and all model reaches identified for planned nourishment are restored to the design template.

3.2.9.2.1 Nourishment Templates

Beach-*fx* planned nourishment templates are defined by three dimensions, the template dune height, template dune width, and template berm width. Berm elevations and dune and foreshore slopes remain constant based on the existing profiles.

3.2.9.2.2 Nourishment Distance Triggers and Mobilization Threshold

Beach-*fx* planned nourishment templates have three nourishment distance triggers (1) berm width, (2) dune width, and (3) dune height. Each distance trigger is a fractional amount of the corresponding nourishment template dimension. When the template dimensions fall below the fraction specified by the trigger, a need for re-nourishment is indicated. For Carolina Beach the dune width trigger was set to .99, dune height triggers were set to 0.90 and the berm width trigger was set to 0.90.

The mobilization threshold (minimum nourishment volume required to trigger a nourishment cycle) can be set in coordination with the berm trigger to control the nourishment cycles. The berm trigger can be used to maintain an “allowable” minimum berm width if desired. For Carolina Beach, rather than a specific minimum berm width, the trigger and threshold were used to ensure an “allowable” minimum volume of material. The berm trigger was set at 0.90, which allows Beach-fx to begin assessing volume deficiencies almost immediately. The mobilization threshold was then set to a volume reflecting expected volume losses between placement events (3 year authorized re-nourishment interval). The mobilization threshold that best replicated the existing project performance was 675,000 cubic yards.

3.3 Project Volumes and Renourishment Interval

Shoreline response modeling and economic analyses for this study focused on validation of the existing authorized template. It was estimated that initial construction in the base year (2022) would require approximately 800,000 cubic yards, followed by an additional 800,000 cubic yards of re-nourishment at 3 year intervals.

As part of the validation study, shoreline response modeling and economic analyses was updated to current practices, including the application of the Beach-*fx*. While the dimensions of the authorized design template remained constant as required for Section 1037 compliance, project volumes and re-nourishment requirements estimated using current risk based methodologies differed from original estimates. **Tables 13 and 14** provide Beach-*fx* project volumes and re-nourishment intervals for the authorized project for each of the three sea level change scenarios.

Table 13. Beach-*fx* Project Volumes and Renourishment Interval: Authorized Project

Project Volumes (Over Remaining Project Life – 15 Years)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	769,307 – 854,219	3 - 4	621,770 – 1,033,492
	Average	781,521	4	758,827
Intermediate	Min - Max	779,764 – 882,125	4 - 5	828,666 – 1,243,146
	Average	838,496	4	946,396
High	Min - Max	789,309 – 874,432	2 – 4	621,518 – 895,263
	Average	801,946	3	720,136

Table 14. Beach-*fx* Project Volumes and Renourishment Interval: Authorized Project, 50 Year Project

Project Volumes (Over Remaining Project Life – 50 Years)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	769,307 – 822,784	1 - 12	605,231 – 906,733
	Average	778,866	4	713,279
Intermediate	Min - Max	774,069 – 827,826	2 - 11	607,010 – 906,682
	Average	783,721	4	700,426
High	Min - Max	789,309 – 843,872	2 - 8	609,872 – 965,642
	Average	799,168	4	720,116

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Sub-Appendix B:

Development of Storm Suite

5 Development of Storm Suite

The storm suite used in this analysis was developed based on the storm field characteristics identified a location offshore of the project location at an approximate depth of 54 feet. The study is part of the GROW-FINE EC28km hindcast study conducted by Oceanweather Incorporated (OWI). The GROW-FINE EC28km was developed to specifically address the intense tropical cyclones and winter storms that affect the U.S. East Coast to include storm surge data from the ADCIRC model using the standard Western North Atlantic mesh. In addition to a continuous period of 1980-2005, the significant tropical cyclones (landfall Category 2 or greater) from the period 1924-2005 and significant winter storms from 1957-2003 have been hindcast (OWI, 2008). Storm data were obtained at station 2240 which is located at 34.00 N and 77.75 W in water depth of 54 feet. **Table 1** lists the 111 OWI Tropical storms covering the period 8/21/1924 00:00 to 10/26/2005 18:00. **Table 2** lists the 34 OWI Extratropical storms covering the period 12/3/1957 00:00 to 2/19/2003 00:00.

A MATLAB program was used to read and define the OWI storms time series for each storm event. **Table 3 and 4** state the storm number and the start and end date for the Tropical and Extratropical storms respectively. Also, the program predicts the tide at ADCIRC station 409 (34.0534 N and 77.8618 W) using the 10 major tidal constituents (ZO,K1,O1,Q1,M2,S2,N2,K2,M4,M6) estimated at the station using the East Coast Tidal Constituents Database. The storm surge for each storm event is extracted by subtracting the predicted tide from the storm water level time series.

SBEACH (Storm Induced BEAch CHange) is used to calculate dune, berm, and subaqueous profile changes (both erosion and accretion) produced by a specific storm event. Graven (2005) and USACE (2010) used a minimum storm surge threshold of 1.0 ft to identify significant storms for SBEACH simulations. The MATLAB code was used to estimate the peak surge and peak wave height for each storm event.

For the 111 Tropical storm events, 29 storms with storm surge less than 1 ft were eliminated. The remaining storm events were clustered within ranges of storm surge and wave height values as shown in **Table 5**. Time series of storm surge and wave height within each cluster were examined and one storm was selected as representative for the set of storms. The representative storms were selected such as to be stable and have complete simultaneous time series of storm surge and wave height with reasonably long storm duration. The 111 Tropical storm events were reduced to 21 events listed in **Table 6**. **Figure 1** shows the peak storm surge and wave height for the representative Tropical storm events.

For the 34 Extratropical storm events, 3 storms with storm surge less than 1 ft were eliminated (1, 9 and 14). The remaining storm events were clustered within ranges of storm surge and wave height values as shown in **Table 7**. Time series of storm surge and wave height within each cluster were examined and one storm was selected as representative for the set of storms. The representative storms were selected such as to be stable and have complete simultaneous time series of storm surge and wave height with reasonably long storm duration. Unfortunately, storm 25 with the maximum storm surge of 3.87 ft could not be salvaged from the available surge hydrograph data due to severe numerical instability. As a result, the 34 Extratropical storm events were reduced to 9 events listed in **Table 8**. **Figure 2** shows the peak storm surge and wave height for the representative Extratropical storm events.

Excel files were created with the surge hydrograph, wave height and period for each of the selected storms. Visual quality assessment was conducted on each storm by looking at the storm duration and the numerical stability of the data. The portion of storm that was judged to be important in the context of beach profile response modeling was clipped and smoothed in some cases. For some storms, the wave data was shifted in time due to incompatibility between the timing of the surge and wave data. In such cases the wave data was shifted in time such that the wave height peak coincides with the surge peak (Gravens, 2005).

Each storm surge hydrograph was combined with a cosine representation of the astronomical tide to generate a plausible total water level elevation. Each storm surge was combined with three representative tidal ranges (spring, mean and neap) and the peak surge elevation was aligned with four tidal phases (high tide, mid-tide falling, low tide and mid-tide rising) to create suite of 12 storms of each historical storm surge hydrograph. The spring, mean and neap tidal ranges (4.74, 3.55 and 2.75 ft) were obtained from 20-year-long equilibrium tide at station 409. Combining N storm events with three tidal ranges at four phases will result in a total of NX3X4 storm events.

Tropical Storm Year_Number (Name)	Date Range (GMT)
1924_02 (NOT NAMED)	1924082100-1924082806
1924_03 (NOT NAMED)	1924090200-1924090512
1924_07 (NOT NAMED)	1924102100-1924102418
1925_02 (NOT NAMED)	1925113006-1925120600
1926_01 (NOT NAMED)	1926072512-1926080212
1926_02 (NOT NAMED)	1926080518-1926080900
1926_04 (NOT NAMED)	1926091100-1926091715
1926_06 (NOT NAMED)	1926091718-1926091918
1926_10 (NOT NAMED)	1926102012-1926102318
1927_01 (NOT NAMED)	1927082212-1927082600
1928_01 (NOT NAMED)	1928080700-1928081212
1928_04 (NOT NAMED)	1928091612-1928092018
1929_02 (NOT NAMED)	1929092300-1929100506
1930_02 (NOT NAMED)	1930090918-1930091506
1932_04 (NOT NAMED)	1932090512-1932091018
1933_05 (NOT NAMED)	1933072900-1933073115
1933_08 (NOT NAMED)	1933082109-1933082700
1933_12 (NOT NAMED)	1933090309-1933090415
1933_13 (NOT NAMED)	1933091221-1933091906
1933_18 (NOT NAMED)	1933100412-1933100900
1934_06 (NOT NAMED)	1934090512-1934091018
1935_02 (NOT NAMED)	1935090200-1935090800
1935_04 (NOT NAMED)	1935092800-1935100200
1935_06 (NOT NAMED)	1935103112-1935110503
1936_13 (NOT NAMED)	1936091512-1936092018
1936_15 (NOT NAMED)	1936092100-1936092606
1937_04 (NOT NAMED)	1937091400-1937091600
1938_04 (NOT NAMED)	1938092000-1938092306
1939_02 (NOT NAMED)	1939081100-1939082118
1940_03 (NOT NAMED)	1940080800-1940081518
1940_04 (NOT NAMED)	1940083006-1940090400
1940_05 (NOT NAMED)	1940091400-1940091806
1941_03 (NOT NAMED)	1941091706-1941092618
1941_05 (NOT NAMED)	1941100506-1941101206
1943_09 (NOT NAMED)	1943101600-1943101818
1944_01 (NOT NAMED)	1944071418-1944072000
1944_03 (NOT NAMED)	1944073109-1944080418
1944_07 (NOT NAMED)	1944091203-1944091618
1944_11 (NOT NAMED)	1944101900-1944102306
1945_01 (NOT NAMED)	1945062415-1945062900
1945_09 (NOT NAMED)	1945091500-1945092018
1946_02 (NOT NAMED)	1946070506-1946070918
1946_04 (NOT NAMED)	1946091200-1946091612
1947_04 (NOT NAMED)	1947091506-1947091906

Table 1- Tropical storms names and dates (OWI, 2008)

1947_08 (NOT NAMED)	1947101200-1947101618
1948_03 (NOT NAMED)	1948082715-1948090206
1948_07 (NOT NAMED)	1948092118-1948092512
1948_08 (NOT NAMED)	1948100500-1948100818
1949_01 (NOT NAMED)	1949082209-1949082612
1949_02 (NOT NAMED)	1949082612-1949083100
1950_01 (ABLE)	1950081509-1950082212
1950_04 (DOG)	1950090515-1950091318
1950_11 (KING)	1950101700-1950101900
1951_01 (ABLE)	1951051509-1951052412
1951_08 (HOW)	1951100112-1951100712
1952_02 (ABLE)	1952082815-1952090318
1953_02 (BARBARA)	1953081118-1953081618
1953_04 (CAROL)	1953090500-1953090900
1954_03 (CAROL)	1954082518-1954090200
1954_05 (EDNA)	1954090806-1954091300
1954_09 (HAZEL)	1954101412-1954101706
1955_02 (CONNIE)	1955080906-1955081412
1955_03 (DIANE)	1955081412-1955082112
1955_09 (IONE)	1955091600-1955092206
1956_03 (BETSY)	1956081306-1956081906
1958_04 (DAISY)	1958082412-1958083100
1958_08 (HELENE)	1958092403-1958093000
1958_10 (JANICE)	1958100600-1958101112
1959_08 (GRACIE)	1959092315-1959100312
1960_05 (DONNA)	1960090912-1960091406
1961_05 (ESTHER)	1961091700-1961092718
1961_07 (FRANCES)	1961100400-1961100918
1962_04 (DAISY)	1962100421-1962100900
1963_08 (GINNY)	1963101721-1963110100
1964_05 (CLEO)	1964082600-1964090406
1964_06 (DORA)	1964090612-1964091600
1964_09 (GLADYS)	1964091718-1964092512
1964_11 (ISBELL)	1964101318-1964101800
1965_03 (BETSY)	1965090206-1965090918
1966_01 (ALMA)	1966061012-1966061512
1967_04 (DORIA)	1967090800-1967092112
1968_08 (GLADYS)	1968101806-1968102306
1969_07 (GERDA)	1969090606-1969091100
1971_08 (GINGER)	1971090600-1971100506
1976_03 (BELLE)	1976080606-1976081112
1979_04 (DAVID)	1979090206-1979090800
1984_05 (DIANA)	1984090712-1984091618
1985_07 (GLORIA)	1985092506-1985092900
1989_08 (HUGO)	1989092006-1989092406
1990_02 (BERTHA)	1990072412-1990080218

Table 1- Tropical storms names and dates (OWI, 2008) (Continued)

1991_02 (BOB)	1991081600-1991082106
1992_02 (ANDREW)	1992082100-1992082506
1993_05 (EMILY)	1993082718-1993090312
1995_06 (FELIX)	1995081500-1995082212
1996_02 (BERTHA)	1996071003-1996071512
1996_05 (EDOUARD)	1996082921-1996090312
1996_06 (FRAN)	1996090312-1996090918
1996_08 (HORTENSE)	1996091218-1996091518
1998_02 (BONNIE)	1998082312-1998083018
1999_04 (DENNIS)	1999082612-1999090818
1999_06 (FLOYD)	1999091315-1999091912
1999_09 (IRENE)	1999101418-1999101918
2002_08 (GUSTAV)	2002090812-2002091218
2003_09 (ISABEL)	2003091421-2003092018
2004_01 (ALEX)	2004073018-2004080600
2004_03 (CHARLEY)	2004081300-2004081612
2004_06 (FRANCES)	2004090306-2004091100
2004_10 (JEANNE)	2004091918-2004093012
2005_12 (KATRINA)	2005082418-2005082712
2005_16 (OPHELIA)	2005090512-2005091900
2005_24 (WILMA)	2005102312-2005102618

Table 1- Tropical storms names and dates (OWI, 2008) (Continued)

Winter Storm Reference Name	Date Range (GMT)
19571203	1957120300-1957120700
19580319	1958031900-1958032300
19610202	1961020200-1961020600
19620303	1962030300-1962031100
19690208	1969020800-1969021200
19720619	1972061900-1972062500
19730201	1973020100-1973020500
19730209	1973020900-1973021300
19730321	1973032100-1973032500
19741130	1974113000-1974120500
19780106	1978010600-1978011300
19780205	1978020500-1978020900
19800114	1980011400-1980011800
19800206	1980020600-1980021000
19801023	1980102300-1980102700
19810131	1981013100-1981020400
19810210	1981021000-1981021400
19830209	1983020900-1983021300
19840327	1984032700-1984033100
19850210	1985021000-1985021400
19920102	1992010200-1992010600
19921209	1992120900-1992121300
19930210	1993021000-1993021400
19930302	1993030200-1993030600
19930312	1993031200-1993031600
19940301	1994030100-1994030500
19941222	1994122200-1994122600
19951110	1995111000-1995111600
19960106	1996010600-1996011000
19980126	1998012600-1998013000
19980203	1998020300-1998020700
19990101	1999010100-1999010500
20010320	2001032000-2001032400
20030215	2003021500-2003021900

Table 2- Extratropical storms names and dates (OWI, 2008)

Storm Event No.	Start Date		End Date	
1	21-Aug-24	0:00:00	28-Aug-24	6:00:00
2	2-Sep-24	0:00:00	5-Sep-24	12:00:00
3	21-Oct-24	0:00:00	24-Oct-24	18:00:00
4	30-Nov-25	6:00:00	6-Dec-25	0:00:00
5	25-Jul-26	12:00:00	2-Aug-26	12:00:00
6	5-Aug-26	18:00:00	9-Aug-26	0:00:00
7	11-Sep-26	0:00:00	17-Sep-26	15:00:00
8	17-Sep-26	18:00:00	19-Sep-26	18:00:00
9	20-Oct-26	12:00:00	23-Oct-26	18:00:00
10	22-Aug-27	12:00:00	26-Aug-27	0:00:00
11	7-Aug-28	0:00:00	12-Aug-28	12:00:00
12	16-Sep-28	12:00:00	20-Sep-28	18:00:00
13	23-Sep-29	0:00:00	5-Oct-29	6:00:00
14	9-Sep-30	18:00:00	15-Sep-30	6:00:00
15	5-Sep-32	12:00:00	10-Sep-32	18:00:00
16	29-Jul-33	0:00:00	31-Jul-33	15:00:00
17	21-Aug-33	9:00:00	27-Aug-33	0:00:00
18	3-Sep-33	9:00:00	4-Sep-33	15:00:00
19	12-Sep-33	21:00:00	19-Sep-33	6:00:00
20	4-Oct-33	12:00:00	9-Oct-33	0:00:00
21	5-Sep-34	12:00:00	10-Sep-34	18:00:00
22	2-Sep-35	0:00:00	8-Sep-35	0:00:00
23	28-Sep-35	0:00:00	2-Oct-35	0:00:00
24	31-Oct-35	12:00:00	5-Nov-35	3:00:00
25	15-Sep-36	12:00:00	20-Sep-36	18:00:00
26	21-Sep-36	0:00:00	26-Sep-36	6:00:00
27	14-Sep-37	0:00:00	16-Sep-37	0:00:00
28	20-Sep-38	0:00:00	23-Sep-38	6:00:00
29	11-Aug-39	0:00:00	21-Aug-39	18:00:00
30	8-Aug-40	0:00:00	15-Aug-40	18:00:00
31	30-Aug-40	6:00:00	4-Sep-40	0:00:00
32	14-Sep-40	0:00:00	18-Sep-40	6:00:00
33	17-Sep-41	6:00:00	26-Sep-41	18:00:00
34	5-Oct-41	6:00:00	12-Oct-41	6:00:00
35	16-Oct-43	0:00:00	18-Oct-43	18:00:00

Table 3- Dates of extracted Tropical storm events from OWI storms time series

36	14-Jul-44	18:00:00	20-Jul-44	0:00:00
37	31-Jul-44	9:00:00	4-Aug-44	18:00:00
38	12-Sep-44	3:00:00	16-Sep-44	18:00:00
39	19-Oct-44	0:00:00	23-Oct-44	6:00:00
40	24-Jun-45	15:00:00	29-Jun-45	0:00:00
41	15-Sep-45	0:00:00	20-Sep-45	18:00:00
42	5-Jul-46	6:00:00	9-Jul-46	18:00:00
43	12-Sep-46	0:00:00	16-Sep-46	12:00:00
44	15-Sep-47	6:00:00	19-Sep-47	6:00:00
45	12-Oct-47	0:00:00	16-Oct-47	18:00:00
46	27-Aug-48	15:00:00	2-Sep-48	6:00:00
47	21-Sep-48	18:00:00	25-Sep-48	12:00:00
48	5-Oct-48	0:00:00	8-Oct-48	18:00:00
49	22-Aug-49	9:00:00	26-Aug-49	12:00:00
50	26-Aug-49	12:00:00	31-Aug-49	0:00:00
51	15-Aug-50	9:00:00	22-Aug-50	12:00:00
52	5-Sep-50	15:00:00	13-Sep-50	18:00:00
53	17-Oct-50	0:00:00	19-Oct-50	0:00:00
54	15-May-51	9:00:00	24-May-51	12:00:00
55	1-Oct-51	12:00:00	7-Oct-51	12:00:00
56	28-Aug-52	15:00:00	3-Sep-52	18:00:00
57	11-Aug-53	18:00:00	16-Aug-53	18:00:00
58	5-Sep-53	0:00:00	9-Sep-53	0:00:00
59	25-Aug-54	18:00:00	2-Sep-54	0:00:00
60	8-Sep-54	6:00:00	13-Sep-54	0:00:00
61	14-Oct-54	12:00:00	17-Oct-54	6:00:00
62	9-Aug-55	6:00:00	14-Aug-55	12:00:00
63	14-Aug-55	12:00:00	21-Aug-55	12:00:00
64	16-Sep-55	0:00:00	22-Sep-55	6:00:00
65	13-Aug-56	6:00:00	19-Aug-56	6:00:00
66	24-Aug-58	12:00:00	31-Aug-58	0:00:00
67	24-Sep-58	3:00:00	30-Sep-58	0:00:00
68	6-Oct-58	0:00:00	11-Oct-58	12:00:00
69	23-Sep-59	15:00:00	3-Oct-59	12:00:00
70	9-Sep-60	12:00:00	14-Sep-60	6:00:00
71	17-Sep-61	0:00:00	27-Sep-61	18:00:00
72	4-Oct-61	0:00:00	9-Oct-61	18:00:00

Table 3- Dates of extracted Tropical storm events from OWI storms time series (Continued)

73	4-Oct-62	21:00:00	9-Oct-62	0:00:00
74	17-Oct-63	21:00:00	1-Nov-63	0:00:00
75	26-Aug-64	0:00:00	4-Sep-64	6:00:00
76	6-Sep-64	12:00:00	16-Sep-64	0:00:00
77	17-Sep-64	18:00:00	25-Sep-64	12:00:00
78	13-Oct-64	18:00:00	18-Oct-64	0:00:00
79	2-Sep-65	6:00:00	9-Sep-65	18:00:00
80	10-Jun-66	12:00:00	15-Jun-66	12:00:00
81	8-Sep-67	0:00:00	21-Sep-67	12:00:00
82	18-Oct-68	6:00:00	23-Oct-68	6:00:00
83	6-Sep-69	6:00:00	11-Sep-69	0:00:00
84	6-Sep-71	0:00:00	5-Oct-71	6:00:00
85	6-Aug-76	6:00:00	11-Aug-76	12:00:00
86	2-Sep-79	6:00:00	8-Sep-79	0:00:00
87	7-Sep-84	12:00:00	16-Sep-84	18:00:00
88	25-Sep-85	6:00:00	29-Sep-85	0:00:00
89	20-Sep-89	6:00:00	24-Sep-89	6:00:00
90	24-Jul-90	12:00:00	2-Aug-90	18:00:00
91	16-Aug-91	0:00:00	21-Aug-91	6:00:00
92	21-Aug-92	0:00:00	25-Aug-92	6:00:00
93	27-Aug-93	18:00:00	3-Sep-93	12:00:00
94	15-Aug-95	0:00:00	22-Aug-95	12:00:00
95	10-Jul-96	3:00:00	15-Jul-96	12:00:00
96	29-Aug-96	21:00:00	3-Sep-96	12:00:00
97	3-Sep-96	12:00:00	9-Sep-96	18:00:00
98	12-Sep-96	18:00:00	15-Sep-96	18:00:00
99	23-Aug-98	12:00:00	30-Aug-98	18:00:00
100	26-Aug-99	12:00:00	8-Sep-99	18:00:00
101	13-Sep-99	15:00:00	19-Sep-99	12:00:00
102	14-Oct-99	18:00:00	19-Oct-99	18:00:00
103	8-Sep-02	12:00:00	12-Sep-02	18:00:00
104	14-Sep-03	21:00:00	20-Sep-03	18:00:00
105	30-Jul-04	18:00:00	6-Aug-04	0:00:00
106	13-Aug-04	0:00:00	16-Aug-04	12:00:00
107	3-Sep-04	6:00:00	11-Sep-04	0:00:00
108	19-Sep-04	18:00:00	30-Sep-04	12:00:00
109	24-Aug-05	18:00:00	27-Aug-05	12:00:00
110	5-Sep-05	12:00:00	19-Sep-05	0:00:00
111	23-Oct-05	12:00:00	26-Oct-05	18:00:00

Table 3- Dates of extracted Tropical storm events from OWI storms time series (Continued)

Storm Event No.	Start Date		End Date	
1	3-Dec-57	0:00:00	7-Dec-57	0:00:00
2	19-Mar-58	0:00:00	23-Mar-58	0:00:00
3	2-Feb-61	0:00:00	6-Feb-61	0:00:00
4	3-Mar-62	0:00:00	11-Mar-62	0:00:00
5	8-Feb-69	0:00:00	12-Feb-69	0:00:00
6	19-Jun-72	0:00:00	25-Jun-72	0:00:00
7	1-Feb-73	0:00:00	5-Feb-73	0:00:00
8	9-Feb-73	0:00:00	13-Feb-73	0:00:00
9	21-Mar-73	0:00:00	25-Mar-73	0:00:00
10	30-Nov-74	0:00:00	5-Dec-74	0:00:00
11	6-Jan-78	0:00:00	13-Jan-78	0:00:00
12	5-Feb-78	0:00:00	9-Feb-78	0:00:00
13	14-Jan-80	0:00:00	18-Jan-80	0:00:00
14	6-Feb-80	0:00:00	10-Feb-80	0:00:00
15	23-Oct-80	0:00:00	27-Oct-80	0:00:00
16	31-Jan-81	0:00:00	4-Feb-81	0:00:00
17	10-Feb-81	0:00:00	14-Feb-81	0:00:00
18	9-Feb-83	0:00:00	13-Feb-83	0:00:00
19	27-Mar-84	0:00:00	31-Mar-84	0:00:00
20	10-Feb-85	0:00:00	14-Feb-85	0:00:00
21	2-Jan-92	0:00:00	6-Jan-92	0:00:00
22	9-Dec-92	0:00:00	13-Dec-92	0:00:00
23	10-Feb-93	0:00:00	14-Feb-93	0:00:00
24	2-Mar-93	0:00:00	6-Mar-93	0:00:00
25	12-Mar-93	0:00:00	16-Mar-93	0:00:00
26	1-Mar-94	0:00:00	5-Mar-94	0:00:00
27	22-Dec-94	0:00:00	26-Dec-94	0:00:00
28	10-Nov-95	0:00:00	16-Nov-95	0:00:00
29	6-Jan-96	0:00:00	10-Jan-96	0:00:00
30	26-Jan-98	0:00:00	30-Jan-98	0:00:00
31	3-Feb-98	0:00:00	7-Feb-98	0:00:00
32	1-Jan-99	0:00:00	5-Jan-99	0:00:00
33	20-Mar-01	0:00:00	24-Mar-01	0:00:00
34	15-Feb-03	0:00:00	19-Feb-03	0:00:00

Table 4- Dates of extracted Extratropical storm events from OWI storms time series

DRAFT

Storm Surge (ft)	Wave Height ,Hs (ft)	Storms	Selected Storm ID
>8.5		97,101	97
7-8		70,99	99
7-Jun		61,67,95	95
5-Apr		62,63,100,110	62
3.5-4		37,87,102	102
3-3.5		82,89	89
2.5-3		19,59,64,74	59
2-2.5	Hs>12	4,38,40,88	88
	12>Hs>10	28,57	57
1.5-2	>12	69,76,80,106	69
	12>Hs>10	45,55,60,84,104,105	60
	10>Hs>8	24,51,68,78,108	68
	8>Hs	81,103	103
1-1.5	Hs>15	12	12
	15>Hs>14	86	86
	11>Hs>10	1,39,56	1
	10>Hs>9	21,22,30,49,71,77,83	83
	9>Hs>8	14,17,41,79,85,93,96,111	85
	8>Hs>7	13,18,25,44,46,54,66,94,107	25
	7>Hs>6	8,31,34,50,53	31
	6>Hs	3,58,72,90,109	90

Table 5- Clustered Tropical storm events

Representative Storm ID	Start Date	End Date	Peak Surge (ft)	Peak Wave Height (ft)
1	21-Aug-24	28-Aug-24	1.44	10.44
12	16-Sep-28	20-Sep-28	1.46	16.25
25	15-Sep-36	20-Sep-36	1.26	7.82
31	30-Aug-40	4-Sep-40	1.04	6.19
57	11-Aug-53	16-Aug-53	2.07	10.85
59	25-Aug-54	2-Sep-54	2.62	14.63
60	8-Sep-54	13-Sep-54	1.52	11.52
62	9-Aug-55	14-Aug-55	4.49	17.89
68	6-Oct-58	11-Oct-58	1.65	9.47
69	23-Sep-59	3-Oct-59	1.6	12.46
83	6-Sep-69	11-Sep-69	1.36	9.22
85	6-Aug-76	11-Aug-76	1.18	8.59
86	2-Sep-79	8-Sep-79	1.25	14.25
88	25-Sep-85	29-Sep-85	2.24	13.85
89	20-Sep-89	24-Sep-89	3.17	21.01
90	24-Jul-90	2-Aug-90	1.07	5.68
95	10-Jul-96	15-Jul-96	6.23	27.66
97	3-Sep-96	9-Sep-96	8.63	29.53
99	23-Aug-98	30-Aug-98	7.33	27.47
102	14-Oct-99	19-Oct-99	3.76	17.48
103	8-Sep-02	12-Sep-02	1.82	7.74

Table 6- Representative Tropical storm events

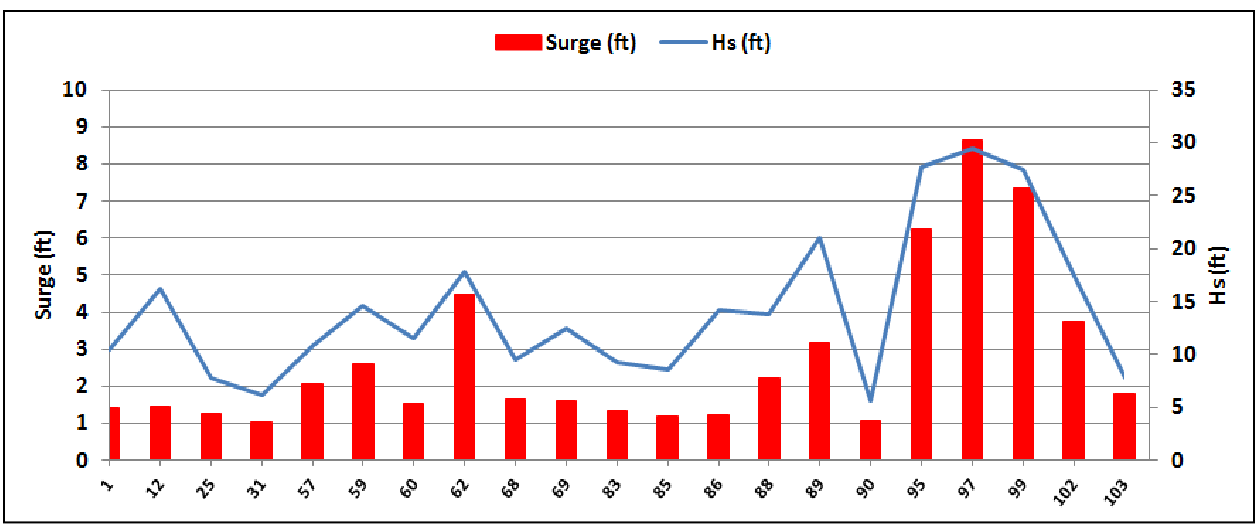

Figure 1- Peak storm surge and wave height for the representative Tropical storm events

Storm Surge (ft)	Wave Height ,Hs (ft)	Storms	Selected Storm ID
>3		25	25
2.5-3	Hs>14	33	33
	10>Hs>8	27	27
2-2.5		15,8,21	15
1.5-2	>10	6,11,20,22,32	32
	10>Hs>8	3,10,13,17,30	10
	8>Hs	12,23,31	31
1-1.5	>10	7,16,19,24,26,28	26
	10>Hs>8	4,18	18
	8>Hs	2,5,29,34	34

Table 7- Clustered Extratropical storm events

Representative Storm ID	Start Date	End Date	Peak Surge (ft)	Peak Wave Height (ft)
10	30-Nov-74	5-Dec-74	1.73	9.45
15	23-Oct-80	27-Oct-80	2.3	13.01
18	9-Feb-83	13-Feb-83	1.42	8.02
26	1-Mar-94	5-Mar-94	1.33	14.92
27	22-Dec-94	26-Dec-94	2.69	9.93
31	3-Feb-98	7-Feb-98	1.85	7.49
32	1-Jan-99	5-Jan-99	1.61	10.16
33	20-Mar-01	24-Mar-01	2.82	14.97
34	15-Feb-03	19-Feb-03	1.42	4.39

Table 8- Representative Extratropical storm events

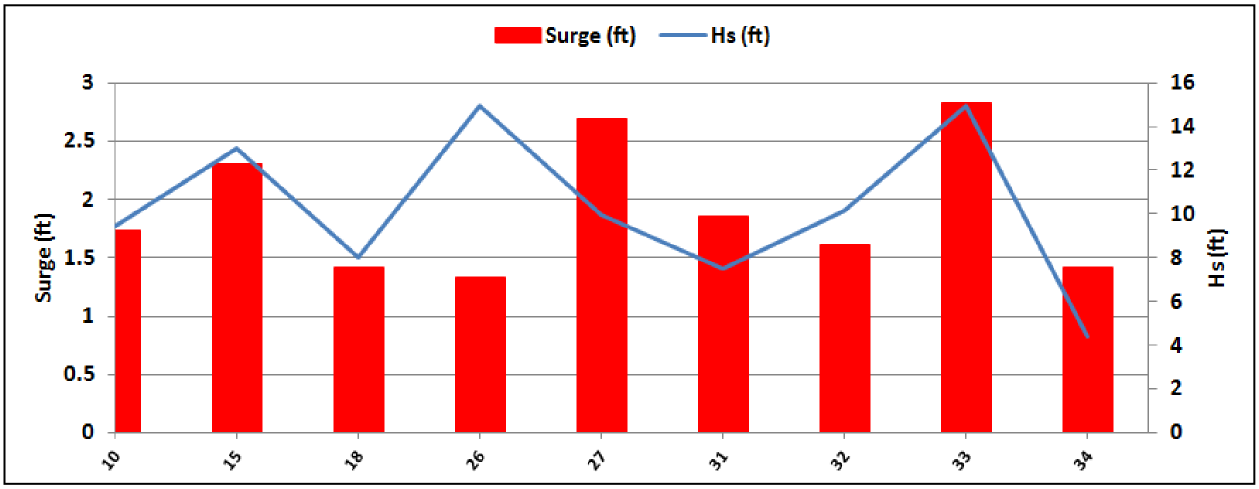

Figure 2- Peak storm surge and wave height for the representative Extraropical storm events

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APPENDIX C

PARKING AND ACCESS

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

APRIL 2019

Prepared by:

Plan Formulation and Economics Section
U.S. Army Corps of Engineers, Wilmington District

DRAFT

Public Access and Parking

The important function of this analysis is to address the adequacy of public access at Carolina Beach and determine whether the spirit and intent of the Project Cooperation Agreement (PCA) is being met. According to Article II, Paragraph *i*, "The town shall provide and maintain necessary access roads, parking areas and other public use facilities open and available to all on equal terms." With regards to the term "necessary," the project must continue to conform with USACE regulations to be eligible for expenditure of Federal funds. The regulations regarding public access and parking are ER 1165-2-130, dated 15 June 1989, and ER 1105-2-100, dated 22 April 2000. These regulations stipulate that the beaches receiving the material must be open to the public and provide reasonable access. The Corps' regulations require that in order to be deemed "public" beaches, the sponsor must provide public access points every one-half mile with sufficient public parking within one -quarter mile. The regulations also refer to sufficient parking in terms of accommodating "projected use demands," and are further defined as sufficient to accommodate the lesser of the peak hour demand or the beach capacity. Finally, in computing parking requirements, the number of beach users not requiring parking is to be deducted from the design figure.

In addition to these requirements, handicap access and parking must be considered and implemented as required by State and Federal regulations. Section 504 of the Rehabilitation Act and the Architectural and Transportation Barriers Act ensure reasonable accommodation and accessibility for all individuals with disabilities to properties and programs that receive or benefit from Federal financial assistance. Our recent inspection of the walkover ramps and designated handicap parking spaces at Carolina Beach find that they meet the intent of these regulations, although there are abundant opportunities for improvement in these features.

There are 44 public access points on Carolina Beach that range from simple walkovers to handicap accessible dune walkover structures. Each of these access points are clearly marked with signs. Figure 2 shows the location of each access point. Four of the access sites include public parking and shower and changing facilities. The following estimates of public parking spaces were provided by the Town of Carolina Beach Planning and Inspections Department. The number of marked parking spaces has increased slightly from 2002, reversing a downward trend over the previous ten years.

The following, produced by Wilmington District GIS personnel demonstrates that the Carolina Beach project is maintaining adequate parking for the 44 CAMA access points, translating into a total of 763 parking spots on Carolina Beach.


US Army Corps of Engineers®
Wilmington District
Carolina Beach
Parking and Access
Map Book
Sunny Point Army Terminal
Carolina Beach State Park
Snows Cut
Telfairs Creek
Carolina Beach Yacht Basin
Carolina Beach
1
2
3
4
5
Wilmington
0
0.25
0.5
1
Miles
U.S. Army Corps of Engineers
Wilmington District
Wilmington, North Carolina

Notes:

1. Horizontal Datum: North American Datum 1983. NC State Plane (ft.) East 3200

2. Map Book Scale 1:3600
   1 inch = 300 ft.

Data Sources:

1. Imagery © NC CGIA. Dates: 2016

2. Beach Accesses: CAMA - NC Division of Coastal Management

3. Parcel Data: NC OneMap

4. Project Extents: USACE-SAW

5. Quarter Mile Buffer Distance: USACE-SAW

6. Existing Parking: New Hanover County / USACE-SAW

Methodology:
Parking spaces were verified and geolocated visually by the analyst. Heads-up digitizing of parking space locations was performed using 2016 NC CGIA Aerial Orthophotography imagery as well as Google Earth Imagery (various dates). Point locations were compiled and attributed according to their spatial locations, and cross-referenced against data provided by New Hanover County. These data were then spatially intersected with a quarter mile buffer from each CAMA beach access as per USACE CSDR Parking and Access Planning policy guidance. Lastly, the quantity of spaces within each quarter mile buffer was aggregated. All accesses meeting the requirement of 10 spaces per access are symbolized in green. All spots that do not meet this minimum requirement are symbolized in red.

There were three identified accesses that do not have sufficient parking per USACE planning guidance: Spartanburg Ave (5 spaces), Clam Shell Ln. (7 spaces), and Sand Dollar Ln. (9

Legend

- Parking Space
- Parking Area
- Parcels
- Town Parcel
- CSDR Project Area

Beach Access

- <10 Parking Spaces
- ≥ 10 Parking Spaces
- <10 Parking Spaces
- ≥ 10 Parking Spaces

US Army Corps of Engineers ®
Wilmington District

Carolina Beach Parking/Access Assessment Notes Page

U.S. Army Corps of Engineers
Wilmington District
Wilmington, North Carolina

U.S. Army Corps of Engineers
Wilmington District

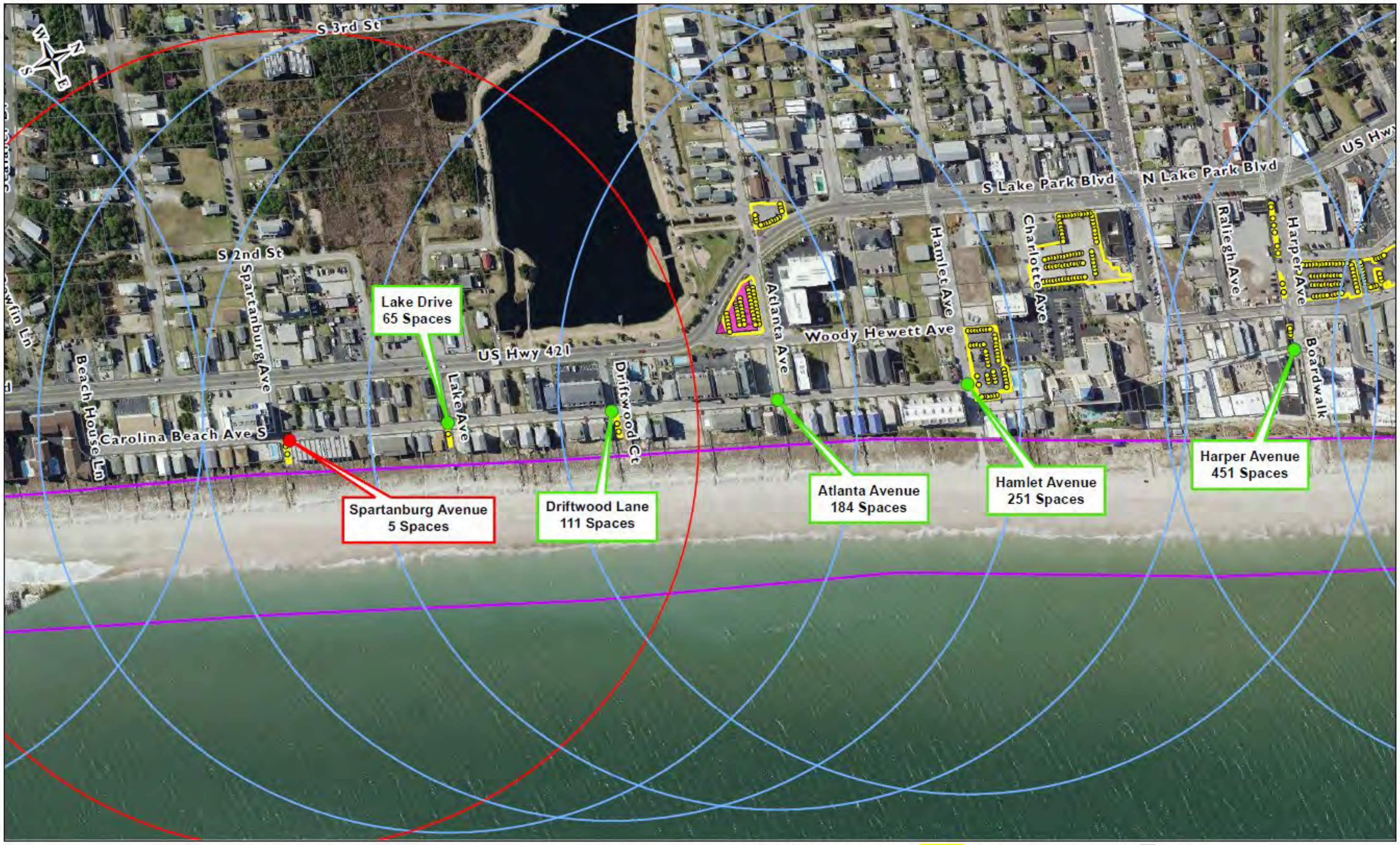
Carolina Beach BRER
Parking and Access
MapBook

Imagery
© NC CGIA 2016

Scale 1:3,600
1 inch equals 300 feet
0 150 300 600 Feet

Beach Access
<10 Parking Spaces
≥ 10 Parking Spaces
Parking Space
Parking Area
.25 Mile Buffer <10 Parking Spaces
.25 Mile Buffer ≥ 10 Parking Spaces
Parcels
Town Parcel
CSDR Project Area

Sheet 1 of 5



U.S. Army Corps of Engineers
Wilmington District

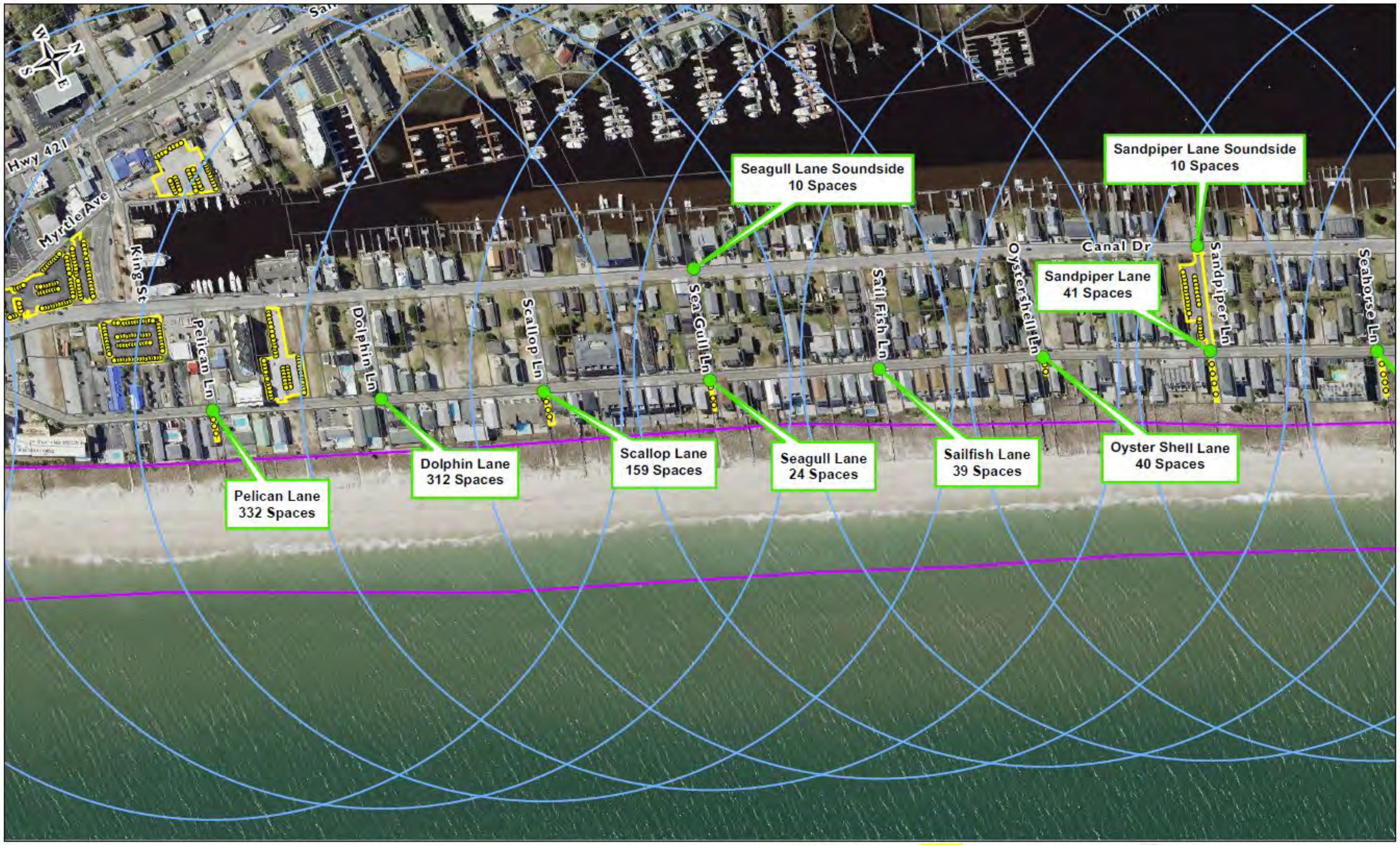
Carolina Beach BRER
Parking and Access
MapBook

Imagery
© NC CGIA 2016

Scale 1:3,600
1 inch equals 300 feet
0 150 300 600 Feet

Beach Access
<10 Parking Spaces
≥ 10 Parking Spaces
Parking Space
Parking Area
.25 Mile Buffer <10 Parking Spaces
.25 Mile Buffer ≥ 10 Parking Spaces
Parcels
Town Parcel
CSDR Project Area

Sheet 2 of 5



U.S. Army Corps of Engineers
Wilmington District

Carolina Beach BRER
Parking and Access
MapBook

Imagery
© NC CGIA 2016

Scale 1:3,600
1 inch equals 300 feet
0 150 300 600 Feet

Beach Access
- <10 Parking Spaces
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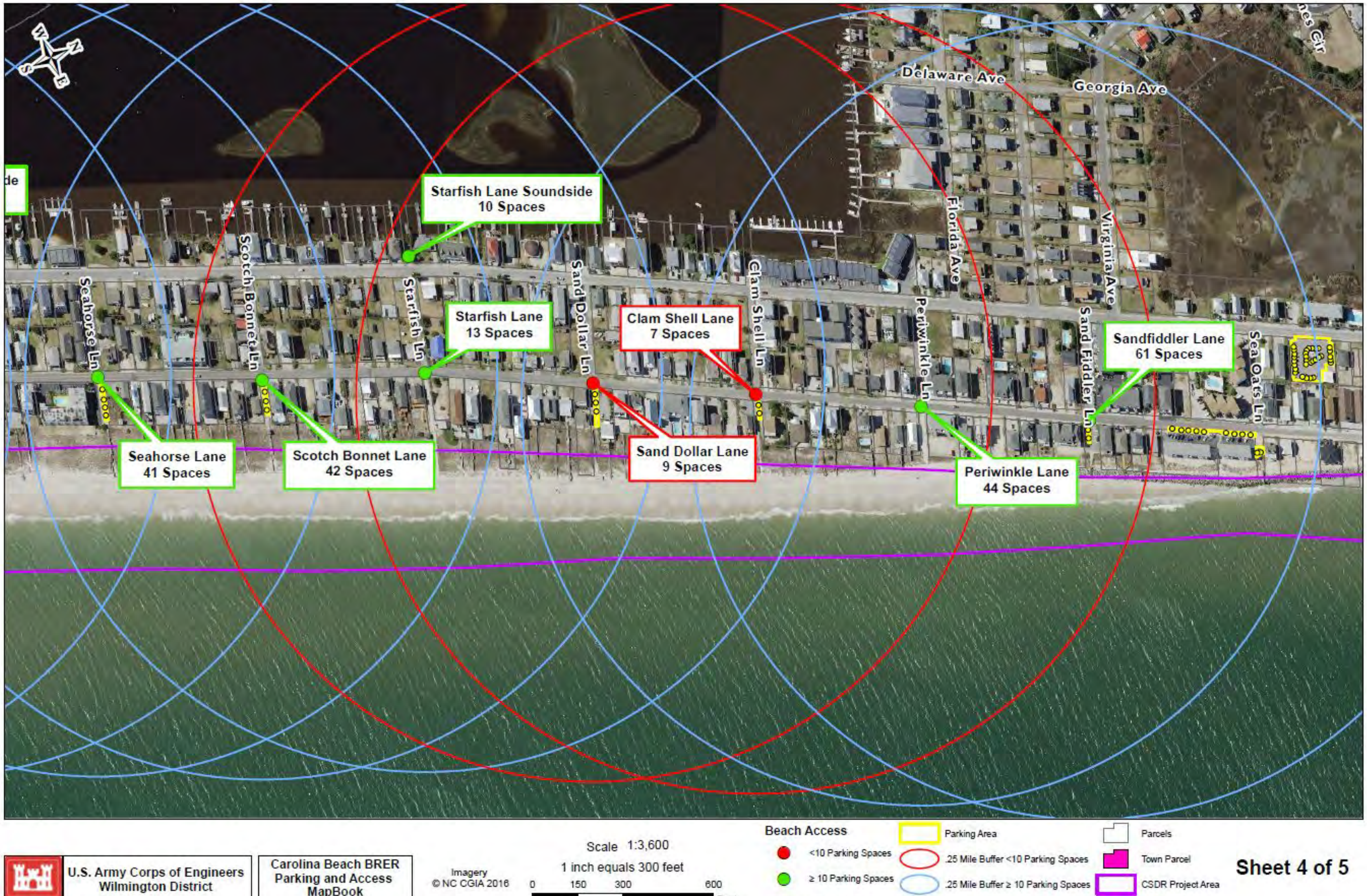
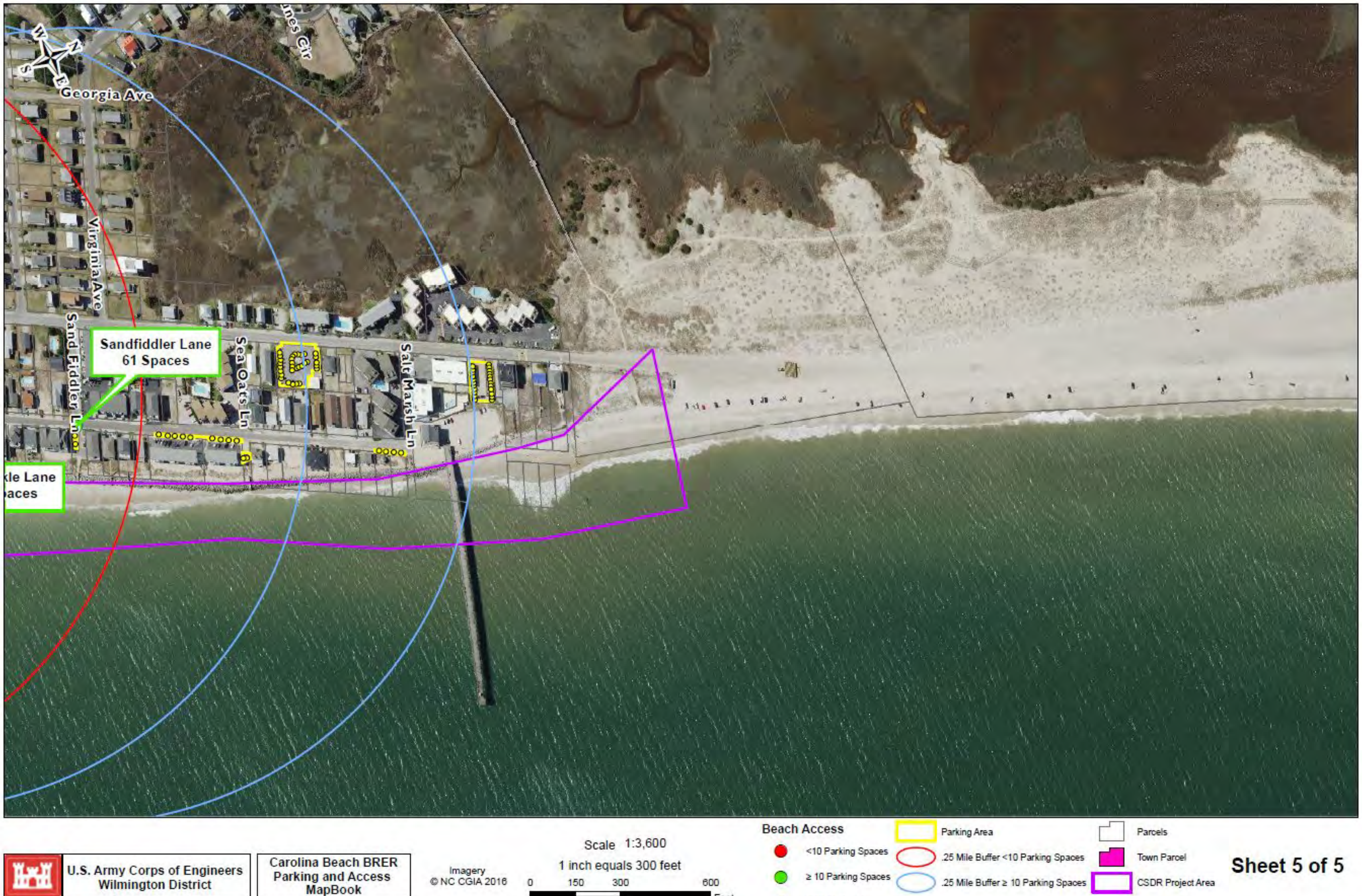
- Parking Space
- Parking Area
- .25 Mile Buffer <10 Parking Spaces
- .25 Mile Buffer ≥ 10 Parking Spaces
- Parcels
- Town Parcel
- CSDR Project Area

Sheet 3 of 5



Delaware Ave
Georgia Ave
Starfish Lane Soundside
10 Spaces
Starfish Lane
13 Spaces
Clam Shell Lane
7 Spaces
Sandfiddler Lane
61 Spaces
Seahorse Lane
41 Spaces
Scotch Bonnet Lane
42 Spaces
Sand Dollar Lane
9 Spaces
Periwinkle Lane
44 Spaces
Seahorse Ln
Scotch Bonnet Ln
Starfish Ln
Sand Dollar Ln
Clam Shell Ln
Periwinkle Ln
Florida Ave
Virginia Ave
Sand Fiddler Ln
Sea Oats Ln
U.S. Army Corps of Engineers
Wilmington District
Carolina Beach BRER
Parking and Access
MapBook
Imagery
© NC CGIA 2016
Scale 1:3,600
1 inch equals 300 feet
0 150 300 600
Feet
Beach Access
<10 Parking Spaces
≥ 10 Parking Spaces
Parking Space
Parking Area
.25 Mile Buffer <10 Parking Spaces
.25 Mile Buffer ≥ 10 Parking Spaces
Parcels
Town Parcel
CSDR Project Area
Sheet 4 of 5



Georgia Ave
Virginia Ave
Sand Fiddler Ln
Sea Oats Ln
Salt Marsh Ln
Sandfiddler Lane
61 Spaces
kle Lane
aces
Beach Access
<10 Parking Spaces
≥ 10 Parking Spaces
Parking Space
Parking Area
.25 Mile Buffer <10 Parking Spaces
.25 Mile Buffer ≥ 10 Parking Spaces
Parcels
Town Parcel
CSDR Project Area
U.S. Army Corps of Engineers
Wilmington District
Carolina Beach BRER
Parking and Access
MapBook
Imagery
© NC CGIA 2016
Scale 1:3,600
1 inch equals 300 feet
0 150 300 600
Feet
Sheet 5 of 5

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APPENDIX D

REAL ESTATE

CAROLINA BEACH, NC
BEACH RENOURISHMENT EVALUATION REPORT

JUNE 2019

Prepared by:
Acquisition Branch

U.S. Army Corps of Engineers, Savannah District

REAL ESTATE SUMMARY

Table of Contents

SECTION 1. THE REAL ESTATE REPORT

1.1 Purpose and Need for Action

The purpose of the Carolina Beach and Vicinity, NC Coastal Storm Risk Management (CSRM) Project – Carolina Beach Portion – Beach Renourishment Evaluation Report (BRER); hereafter referred to as the *Carolina Beach BRER*, is to determine Federal interest for continued coastal storm risk management (CSRM) through periodic nourishment in the Carolina Beach project area from 2022 through 2036. Current Federal participation will end after 2020 with the last renourishment interval of the current authorization occurring in 2019.

1.2 Study Authority and Scope

The Carolina Beach BRER will determine the feasibility of extending the period of nourishment for a period not to exceed 15 additional years, beginning on the date of initiation of construction of Congressionally-authorized nourishment. The 50-year project at Carolina Beach, which was authorized in the Flood Control Act of 1962, completed the period of Federal participation in cost-sharing in December 2014. Two three-year extensions were authorized that extend Federal nourishment through the 2019 cycle; therefore, the project is eligible for continued construction of periodic nourishments from the 2022 construction cycle through 2036. This timeline is illustrated below in Figure 1.

This study was authorized in the Water Resources Reform and Development Act (WRRDA) of 2014 under Section 1037(a) -- Hurricane and Storm Damage Reduction, with amendments in WRDA of 2018 under Section 1158. Under current guidance, a BRER will be prepared and cost shared 50% Federal and 50% non-Federal. Funding to complete the Carolina Beach BRER was provided in January 2017, and included a Federal funding limit of $375,000 for all BRER activities. After completion and approval of the Carolina Beach BRER, Congressional authorization will be needed to extend Federal participation in periodic nourishments through FY 2036.

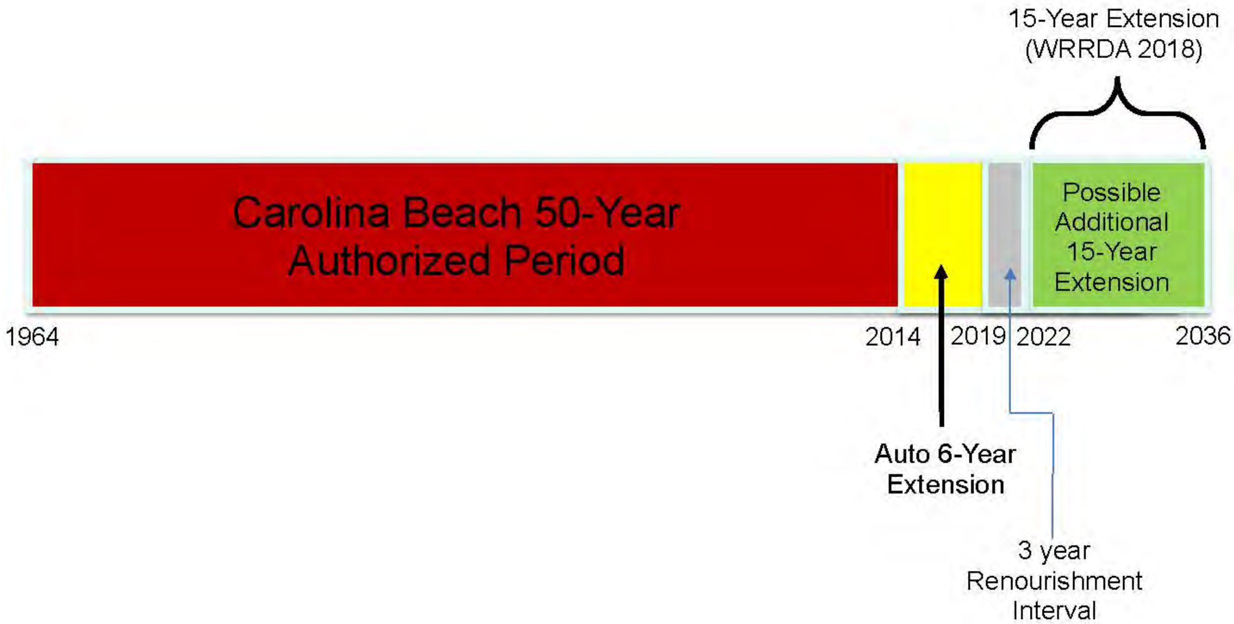


Figure 1. Carolina Beach CSRM Authorization History

1.3 Study Area

The Carolina Beach CSRM project is located in the Town of Carolina Beach, in southeastern North Carolina. The area is comprised of a peninsula which separates the lower Cape Fear River from the Atlantic Ocean. Running just west of the Town is the Atlantic Intracoastal Water Way (AIWW) which connects to the Cape Fear River via the U.S. Army Corps of Engineers (USACE) constructed Snow's Cut canal. The shoreline in the study area is a continuous strip of beach composed of medium-sized sand with a north-northeast to south-southwest alignment. The area along the shoreline within the project footprint is fully developed with cottages, duplexes, condominiums, motels, hotels and various commercial establishments. The study area also includes the historical borrow area of Carolina Beach Inlet which is located north of the terminus of the constructed project. Additionally, an alternative Borrow Area B is located offshore of the northern reach of the project. Borrow Area B is currently being utilized for the Area South portion of the Carolina Beach and Vicinity CSRM project. A map of the study area is provided as Figure 2.

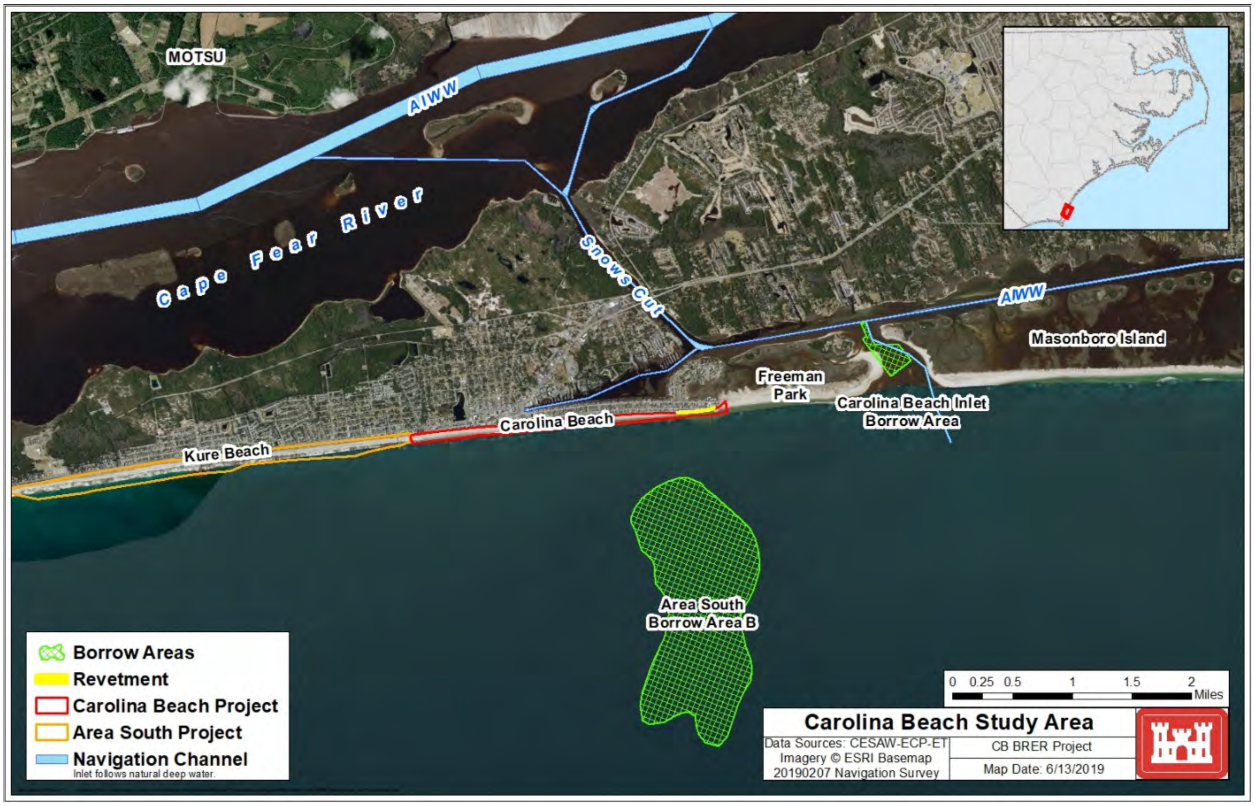


Figure 2. Map of the Study Area

1.4 History of the Project

Carolina Beach, located in New Hanover County in southeastern North Carolina, experienced 21 hurricanes and 29 tropical storms within a 50-mile radius prior to 1964, including the devastating Hurricane Hazel in 1954, a Category Four event. The significant damage resulting from Hurricane Hazel was a key factor in the authorization and construction of the Federal project. In recognition of the need to manage storm risk to Carolina Beach, a partnership was undertaken between the Town of Carolina Beach and USACE to construct a berm and dune project, and to provide periodic nourishment. Initial construction of the Federal project started in 1964. Remedial work included partial restoration in 1967 and 1971. Emergency work was required in 1967, 1970, 1973, and 1980 following severe storms. Emergency work included construction of a 1,100-foot stone seawall in 1970 and extensions there to 500 feet north and 450 feet south in 1973, totaling 2,050 feet.

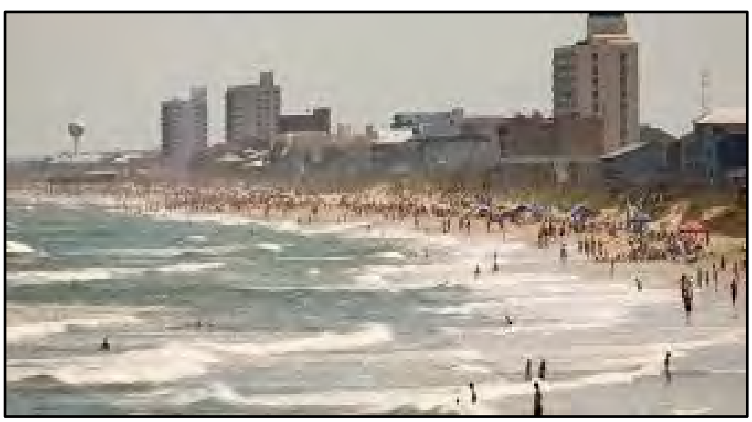
Since initiation of construction of the project in 1964, there have been 10 hurricanes and 14 tropical storms whose centers have passed within 50 miles of Carolina Beach, averaging a storm every 2.4 years (source: NOAA). Since 1993, renourishment cycles have been on a regular 3-year interval. Key authorization changes which have affected this project are as follows:

- 1993 – Completion of 934 Report (extended project life through 2014)
- 2014 – End of Carolina Beach 50 Year Project (3-year extension authorized to 2017 in WRRDA-14)
- 2016 – 3-year extension expanded to a total of 6 years to 2020 (WRRDA-16)

Figure 3 Carolina Beach pre-1964 construction

Figure 4 Carolina Beach post construction

Figure 5 Carolina Beach present day



1.5 Project Description

The authorized project is located in New Hanover County, in southeastern North Carolina. The study area starts a few hundred feet south of Carolina Sands Drive and runs northward approximately 14,000 feet to the end of First Avenue near Carolina Beach Inlet. The project area consists of a continuous strip of beach with a north-northeast to south-southwest alignment. The average width of the project area, from the dune line inland, is 700 feet, and consists of a sacrificial berm and dune. The dune crown has a width of 25 feet at an elevation of 12.5 feet north Atlantic Vertical Datum 88 (NAVD88) and is integrated with a shoreline berm that has a crown width of 50 feet at elevation 9.5 feet NAVD88 and beach fill extending approximately 14,000 feet from the northern to the southern limits of Carolina Beach. Included with this project is a 2,050-foot long rock revetment located on the far northeast segment of the project. The historical borrow area associated with the project is located within Carolina Beach Inlet, located 1.4 miles north of the northern terminus of the project. The renourishment cycle has been performed on a 3-year interval since 1993. Historic volumes placed for each renourishment cycle have averaged 880,000 cubic yards (cy) over the life of the project. Typical renourishments focus on reconstruction of the berm portion of the template. While the dune system has not been overtopped since initial construction, some dune reconstruction has been required to repair erosion damage to the toe of the dune. A map of the project area is located at Figure 6.

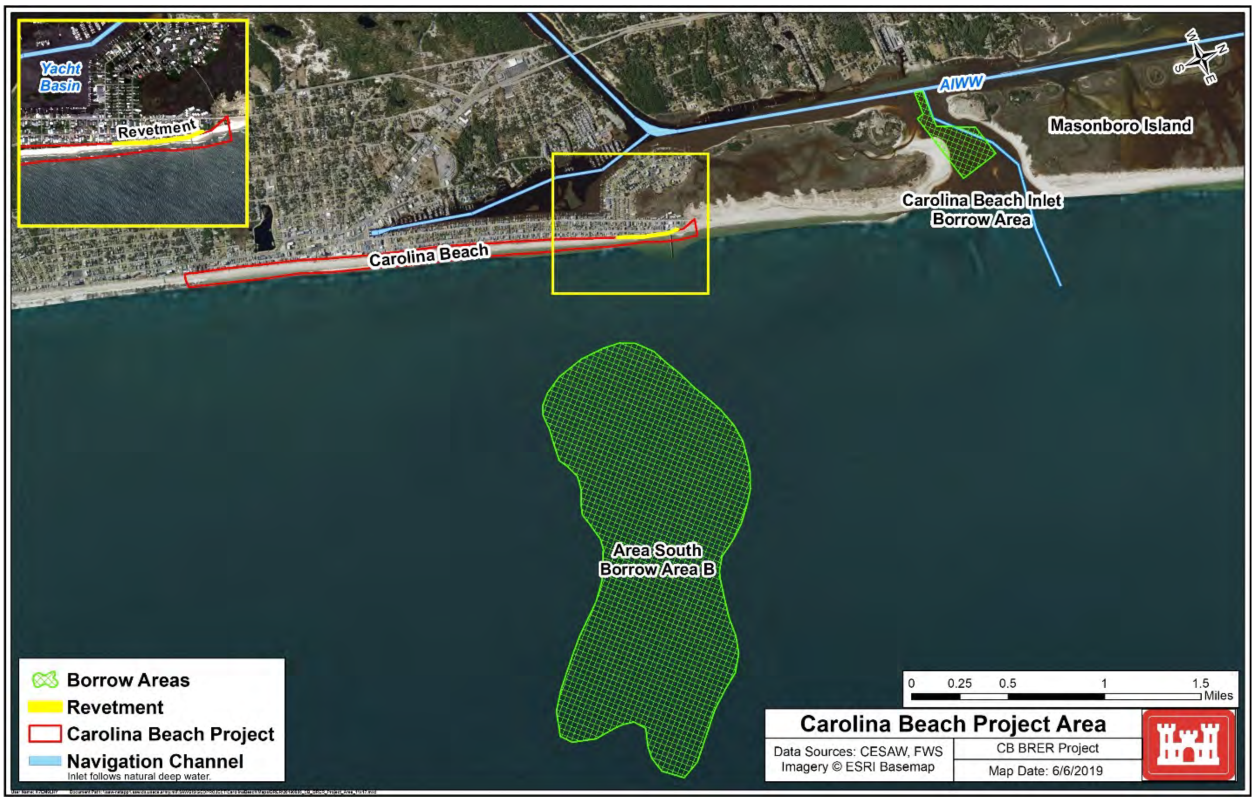


Figure 6 Map of the Project Area

1.6 Real Estate Requirements

All of the lands required for the Carolina Beach and Vicinity, NC CSRM project were in place prior to the 1964 initial construction for the project. A town building line, located along the ocean shoreline, was established in 1963. All land seaward of this building line is public property. The Water Resources Reform and Development Act of 2016 (WRRDA-16) extended the project life to a total of 56 years through 2020. The Town of Carolina Beach is the project sponsor for the project, signing amendments to the Project Cooperation Agreement on 6 July 2015 and 27 December 2017.

All construction will be within the non-Federal sponsor's owned lands provided by the Town of Carolina Beach for the original project. The proposed borrow site for the project is located at Carolina Beach Inlet. If Carolina Beach Inlet is utilized as the sand borrow source, then it is recommended that the sponsor secure perpetual easements for running the pipeline across nine privately owned parcels at the northern limits of the Carolina Beach Project area.

A. Pipeline Routes:

a. The AIWW Route:

Section 934 Reevaluation Report and Environmental Assessment (February 1993) identified the AIWW Pipeline route that runs from the **Borrow Area A (hereafter referred to as *Carolina Beach Inlet)*** southward along the east edge of the AIWW to a land cut known as Snows Cut. The Sponsor has acquired two easements which cross the island, linking the AIWW route with the Carolina Beach Project area. This AIWW route was sufficient to allow placement of the pipelines cross island. However, due to environmentally sensitive areas (i.e. marsh land and sand dunes) this route was not the preferred route.

b. The Ocean Route:

Section 934 Report also noted the Ocean route that runs from **Carolina Beach Inlet** southward along the ocean's edge to the northern limits of the Carolina Beach Project area. The centerline of the Ocean route is intended to fall on the seaward toe of the dune line providing a fifty foot wide easement which crosses nine privately owned parcels. Approximately 6,700 feet in length this Ocean route links **Carolina Beach Inlet** with the Staging Area located at the northern limits of the Carolina Beach Project area. The Ocean route is preferred because it has much less potential for damaging problems associated with transporting borrow material over environmental sensitive areas. Should the Ocean Route be used we recommend that perpetual pipeline easements be required from the Sponsor for the nine private parcels. See Sec. 1.20 Estates for Proposed Project for a standard perpetual pipeline easement. See Figure 6 above.

c. Offshore Route:

Additionally, an alternative **Borrow Area B** (Kure Beach) is located off shore of the northern reach of the project. Borrow Area B is included in the Carolina Beach BRER study in the event the traditional Borrow Area A in the Carolina Beach Inlet is not available. Use of a vertical pipeline to Carolina Beach and no private easements would be required. See Figures 6 and 7.

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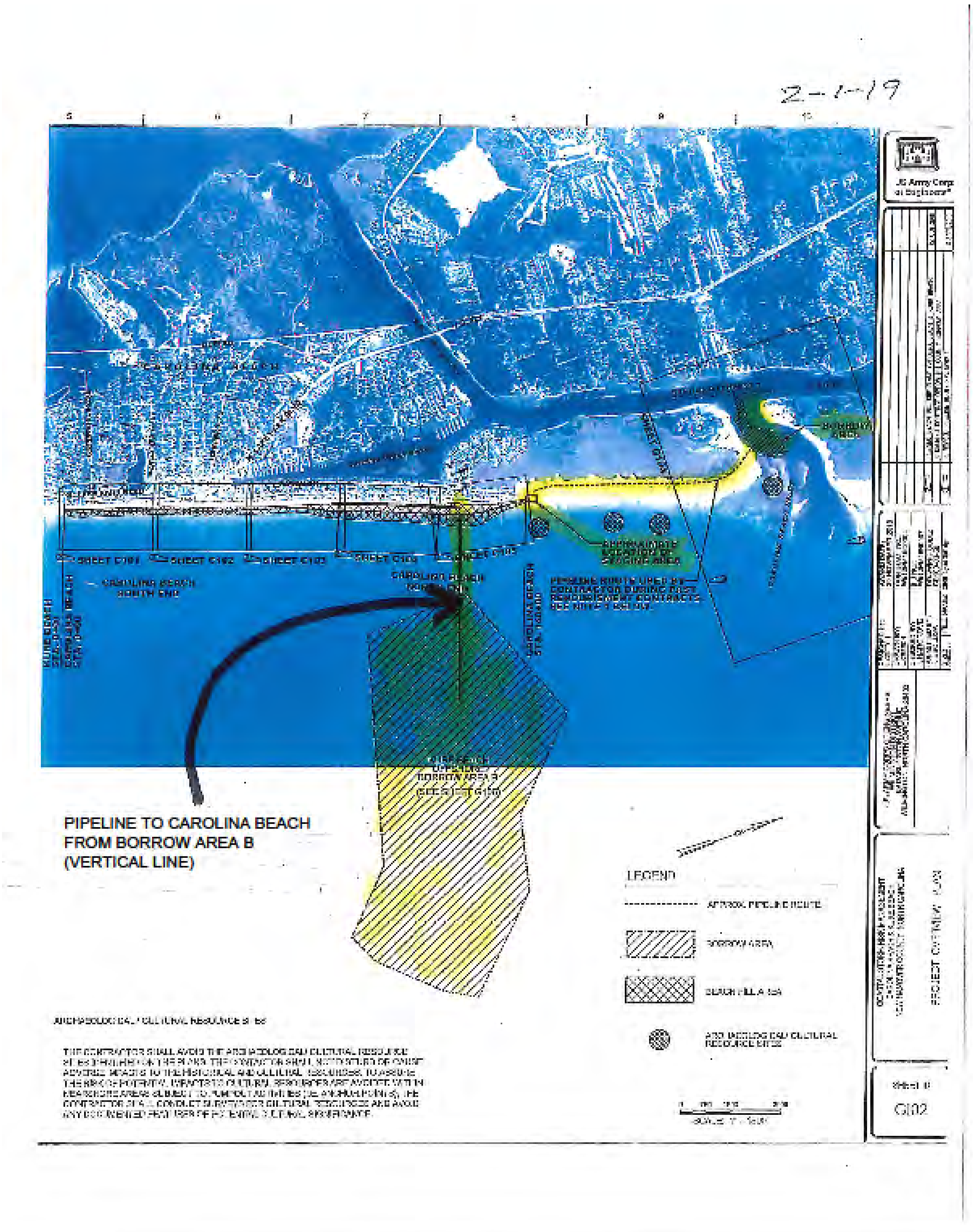

Figure 7 Proposed Pipeline Routes

1.7 Utility/Facility Relocation

There are no utility/facility relocations with this project

1.8 Existing Projects

In addition to Carolina Beach itself, there are multiple existing federal coastal storm risk management projects in or near the study area. The Kure Beach (Area South) portion of the Carolina Beach and Vicinity CSRM is immediately adjacent on the south side of the Carolina Beach portion of the project. Kure Beach portion was authorized along with the entirety of the Carolina Beach and Vicinity CSRM by the Flood Control Act of 1962. The Kure Beach (Area South) portion called for protecting 18,000 feet of shoreline within the town limits of Kure Beach and a very small portion of Carolina Beach. Initial construction was completed in 1998. Since initial construction, Kure Beach has shared the same 3 year renourishment interval with Carolina Beach.

See Section 2.3 of the Main Report for a complete listing of existing projects.

1.9 Environmental Impacts

All environmental impacts are addressed in the Environmental Appendix F to the Main Report.

1.10 Project Sponsor Responsibilities and Capabilities

The Town of Carolina Beach will be the non-Federal Project Sponsor (NFS). The NFS has the responsibility to acquire all real estate interests required for the Project. The NFS shall accomplish all alterations and relocations of facilities, structures and improvements determined by the government to be necessary for construction of the Project. The sponsor will have operation and maintenance responsibility for the project after construction is completed. The state of South Carolina claims ownership of all lands seaward of the last line of stable vegetation or all lands below the ordinary mean high water line. Access to the project along with all staging areas will be on Sponsor Owned lands located throughout the project area. There are 44 existing public access points within the study area.

Title to any acquired real estate will be retained by the NFS and will not be conveyed to the United States Government. Prior to advertisement of any construction contract, the NFS shall furnish to the government an Authorization for Entry for Construction (Exhibit “A” to the Real Estate Appendix) to all lands, easements and rights-of-way, as necessary. The NFS will also furnish to the government evidence supporting their legal authority to grant rights-of-way to such lands. The NFS shall comply with applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, approved 2 January 1971, and amended by Title IV of the Surface Transportation Uniform Relocation Assistance Act of 1987, Public Law 100-17, effective 2 April 1989, in acquiring real estate interests for the Project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act(s). An Assessment of the Non-Federal Sponsor’s Capability to Acquire Real Estate is at Exhibit “B” to the Real Estate Appendix

The non-Federal sponsor is entitled to receive credit against its share of project costs for the value of lands it provides and the value of the relocations that are required for the project. Generally, for the purpose of determining the amount of credit to be afforded, the value of the LER is the fair market value of the real property interest, plus certain incidental costs of acquiring those interests, that the non-federal sponsor provided for the project as required by the Government.

The NFS should not acquire lands required for the project prior to execution of the Project Partnership Agreement (PPA). Should the NFS proceed with acquisition of lands prior to execution of the PPA, it is at the risk of not receiving credit or reimbursement for any costs incurred in the connection with the acquisition process should the PPA not be signed. There is also risk in acquiring lands either not needed for the project or not acquired in compliance with requirements for crediting purposes in accordance with 49 CFR Part 24, dated March 2, 1989.

1.11 Government Owned Property

The Town of Carolina Beach is owner of the land proposed for staging area for the project. There is no Federally owned land within the areas proposed for construction of the project.

1.11 Historical Significance

All historical significance are addressed in the Environmental Appendix F to the Main Report.

1.12 Mineral Rights

There are no known mineral activities within the scope of the proposed project.

1.13 Hazardous, Toxic, and Radioactive Waste (HTRW)

There are no known hazardous, toxic, or radioactive waste located within the project area.

1.14 Navigation Servitude

Navigation Servitude is not applicable to this project.

1.15 Zoning Ordinances

Zoning ordinances are not of issue with this project. Application or enactment of zoning ordinances is not to be used in lieu of acquisition.

1.16 Induced Flooding

There will be no flooding induced by the construction or the operation and maintenance of the project.

1.17 Public Law 91-646, Relocation Assistance Benefits

There are no relocations of individuals, businesses or farms for this project.

1.18 Attitude of Property Owners

The project is fully supported. There are no known objections to the project from landowners within the project area.

1.19 Acquisition Schedule

The project sponsor is responsible for acquiring real estate interests required for the project. The NFS owns the parcel proposed for staging area. Should the Carolina Beach Inlet borrow area be used for the project a perpetual pipeline easement will be required. A map of the proposed pipeline route is shown on the Figure 7. It is projected that 3-6 months will be required for the acquisition and can begin when final plans and specs have been completed and the PPA has been executed. The Project Sponsor, Project Manager and Real Estate Technical Manager will formulate the milestone schedule upon project approval to meet dates for advertisement and award of a construction contract.

1.20 Estates for Proposed Project

The following standard perpetual pipeline easement will be used should the Ocean route pipeline from Borrow area A be required for the project.

A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____,_____ and _____), for the location, construction, operation, maintenance, alteration; repair and patrol of (overhead) (underground) (specifically name type of utility or pipeline); together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the land owners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

1.21 Real Estate Estimate

The real estate requirements are minimal for this project.

Non Federal	$2,500
Federal	$1,000

Exhibits

Exhibit A - Authorization For Entry For Construction and Attorney's Certificate of Authority

Exhibit B – Assessment of Non-Federal Sponsor's Real Estate Acquisition Capability

AUTHORIZATION FOR ENTRY FOR CONSTRUCTION

I ________________________________, _________________________ for the
(Name of accountable official) (Title)

(Sponsor Name) _______, do hereby certify that the ____(Sponsor Name) has acquired the real property interest required by the Department of the Army, and otherwise is vested with sufficient title and interest in lands to support construction for (Project Name, Specifically identified project features, etc.). Further, I hereby authorize the Department of the Army, its agents, employees and contractors, to enter upon _____________________
(identify tracts)

to construct (Project Name, Specifically identified project features, etc.) as set forth in the plans and specifications held in the U. S. Army Corps of Engineers' (district, city, state)

WITNESS my signature as ________________________________ for the
(Title)

(Sponsor Name) this ___ day of ______________, 20__________.

BY: ________________________
(Name)

____
(Title)

ATTORNEY'S CERTIFICATE OF AUTHORITY

I, _________________________ , ________________________________ for the
(Name) (Title of legal officer)

(Sponsor Name), certify that _____________________________ has
(Name of accountable official)

authority to grant Authorization for Entry; that said Authorization for Entry is executed by the proper duly authorized officer; and that the Authorization for Entry is in sufficient form to grant the authorization therein stated.

WITNESS my signature as _________________________ for the
(Title)

(Sponsor Name), this__________day of______________, 20_____.

BY: ________________________
(Name)

____
(Title)

Exhibit A

Assessment of Non-Federal Sponsor's
Real Estate Acquisition Capability
Carolina Beach, NC

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? **YES**

b. Does the sponsor have the power to eminent domain for this project? **YES**

c. Does the sponsor have "quick-take" authority for this project? **YES**

d. Are any of the land/interests in the land required for this project located outside the sponsor's political boundary? **NO**

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? **NO**

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P. L. 91-646, as amended? **NO**

b. If the answer to II.a. is "yes", has a reasonable plan been developed to provide such training? (yes/no)

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? **YES**

d. Is the sponsor's projected in-house staffing level sufficient considering its other work load, if any, and the project schedule? **YES**

e. Can the sponsor obtain contractor support, if required in a timely fashion? **YES**

f. Will the sponsor likely request USACE assistance in acquiring real estate? **YES - only in advisory capacity**

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? **YES**

b. Has the sponsor approved the project/real estate schedule/milestones? **NO – Project Milestone will be developed during PED; will be joint effort between RE, PM and NFS**

Exhibit B
1st page

IV. Overall Assessment:

a. Has the sponsor performed satisfactory on other USACE projects?
YES

b. With regard to the project, the sponsor is anticipated to be: **Highly capable**

V. Coordination:

a. Has this assessment been coordinated with the sponsor? **YES**

b. Does the sponsor concur with this assessment? **YES**

Prepared by:

____
Dorothy Steinbeiser
Senior Realty Specialist

Reviewed and approved by:

____
John S. HInely
Chief, Acquisition Branch

Exhibit B
2nd page

DRAFT

APPENDIX E

COST ENGINEERING

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

JUNE 2019

Prepared by:

Technical Support Section
U.S. Army Corps of Engineers, Wilmington District

SECTION 1 COST ENGINEERING

The Cost Engineering Appendix documents the results of cost development and contingency analyses prepared to evaluate dredging and borrow source alternatives for the Carolina Beach BRER located at Carolina Beach, North Carolina.

The goal of the cost development and contingency analyses is to provide a basis for a reasonable price and contingency for comparing alternatives.

The result of alternative comparisons have been used for the purpose of determining the Recommended Plan.

The costs developed for alternative comparisons have been developed at a Class 3 estimate level. The class of estimates are explained in detail in ER1110-2-1302 and ASTM E2516. A risk analysis has been developed, using Oracle Crystal Ball, for each alternative to develop proper contingencies for comparison in selecting the Recommended Plan.

The cost estimates for each alternative have been entered into a Total Project Cost Summary (TPCS) through midpoint of construction over the life of the project. Although these costs have not undergone Agency Technical Review (ATR), the basis and cost development have been prepared and will be reviewed during ATR.

The TPCS for both action alternatives, one being designated as the Recommended Plan, will be refined, and submitted for ATR prior to approval, budgeting, and funds authorization. The TPCS will undergo technical review and the resulting Cost Certification will be documented in the final Carolina Beach BRER.

1.1 Format & Basis

Costs were developed in accordance with the requirements of Engineering Regulation (ER) 1110-2-1302 with the support of the Project Delivery Team (PDT) as provided per ER 5-1-11. A formal Oracle Crystal Ball Risk Analysis, rather than an Abbreviated Risk Analysis, has been performed for both alternatives prior to selection of the Recommended Plan. Both TPCS, one being designated the Recommended Plan, will receive a cost certification after ATR as the study progresses.

1.1.1 Civil Works Work Breakdown Structure (CWWBS)

USACE Civil Works cost estimates are summarized by feature code levels. The CWWBS feature codes can be found in ER 1110-2-1302 and are shown below.

- 03-20 Construction Elements
- 30 Planning, Engineering, and Design
- 31 Construction Management

1.1.2 Cost Engineering Dredge Estimating Program (CEDEP)

CEDEP is a proprietary software program used throughout USACE for the preparation of dredging costs, including costs associated with mobilization and demobilization of equipment. All measures were developed using CEDEP with input from the PDT. The dredging costs developed from CEDEP are included in the cost summaries for alternatives. Additionally, cost summaries include Planning/Engineering/Design (PED), and Supervision/Administration (S&A).

There were two (2) alternatives evaluated for beach replenishment. (1) Pipeline cutter suction dredge from Carolina Beach Inlet with placement to the beach, and (2) pipeline cutter suction dredge from pre-existing Offshore Borrow Source B which is currently used for beach replenishment at Kure Beach, North Carolina under the Carolina Beach – Area South project authorization. Hopper dredging from the offshore borrow source will be allowed, and was considered. However, the project schedule would be impacted, and the cost analysis is not conclusive that it would be more economical if corrections were made to mitigate the schedule impact.

The Carolina Beach Inlet has been used for all beach replenishments since original project authorization in 1962. However, a different borrow source was used for initial construction of the project in 1964.

Beach template quantities of 800,000 cubic yards (CY) per cycle every three (3) years were determined through modeling by the PDT, and given to the cost engineer for analysis. If authorized, this project extension would include five (5) additional replenishment cycles beginning in fiscal year (FY) 2022, and continuing in FY 2025, 2028, 2031, and 2034.

1.1.3 Microcomputer Aided Cost Engineering System (MCACES)

MCACES is the USACE approved estimating software for the preparation of the cost estimate for the Recommended Plan. MCACES was used to document cost estimates for all alternatives and is included as an attachment to this Cost Engineering Appendix.

1.1.4 Risk Analysis

A Cost and Schedule Risk Analysis (CSRA), using Oracle Crystal Ball, was performed as a joint effort between the cost engineer, Cost Mandatory Center of Expertise (MCX), and the PDT for all alternatives. The risk analysis evaluated the project alternatives for risk elements which may cause a variance to cost, schedule, or both.

The contingencies developed for the alternatives range from 26% for pipeline suction cutter head from Carolina Beach Inlet to 27% for pipeline suction cutter head from Offshore Borrow Source B.

1.1.4.1 Identified Risks

There are both schedule and cost risks which can impact dredging and beach nourishment projects. Major cost drivers for both alternatives are market availability, type of dredges to perform the work, fuel volatility, quantity variations, and mobilization/demobilization pricing.

1.1.5 Total Project Cost Summary (TPCS)

During the evaluation of alternatives, a TPCS was completed for each alternative for economic comparison between alternatives. As the study continues, both TPCS, one being for the Recommended Plan, will be refined and submitted to ATR for Cost Certification.

Alternative 1: No action.

Alternative 2: Carolina Beach Inlet Borrow Source with pipeline suction cutter head dredge – The attached TPCS shows the five (5) additional nourishments at October 1, 2018 (FY19) price level of $35.935 million, and $45.278 million with 26% contingency. Fully-funded with contingency, this alternative is $59.830 million.

Alternative 3: Offshore Borrow Source B with pipeline suction cutter head dredge – The attached TPCS shows the five (5) additional nourishments at October 1, 2018 (FY19) price level of $40.535 million, and $51.479 million with 27% contingency. Fully-funded with contingency, this alternative is $68.008 million.

1.1.6 Value Engineering (VE) Study

Value Engineering is required during the Planning-Engineering-Design (PED) Phase under 41 U.S.C. 1711 and OMB Cir. A-131, and will be applied per ER 11-1-321 on a per nourishment basis. A regional Programmatic Value Study was conducted in June 2018 at the U.S. Army Corps of Engineers - Jacksonville District Office for the South Atlantic Division dredging program. The resulting report will be referenced in bridging documents to address each nourishment project through FY 2036. If another programmatic value study is conducted, it will be referenced for future projects.

1.1.7 District Quality Control Review

The District Quality Control (DQC) review, which is a technical review of the cost products by a senior cost engineer at the USACE district level, will be performed for Recommended Plan developed cost prior to submission for Cost Certification in accordance with ER 1110-2-1150.

1.1.8 Cost Mandatory Center of Expertise (MCX) TPCS Certification

The cost certification is the determination by the Civil Works Cost Engineering - Agency Technical Review by the Mandatory Center of Expertise (MCX) that the cost products meet current cost regulations and standards. The certification will include both TPCS, one being the Recommended Plan. Per ER 1110-2-1302, the review for obtaining the cost certification will be conducted for both TPCS, one being the Recommended Plan, and documented in the final report.

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **Carolina Beach Renourishment**
PROJECT NO: P2 113752
LOCATION: New Hanover County, North Carolina

DISTRICT: Wilmington District **PREPARED: 2/21/2019**
POC: CHIEF, COST ENGINEERING, Stephen Roman

This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC): 2022 Effective Price Level Date: 1 OCT 21									
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-18** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
17	BEACH REPLENISHMENT	$34,810	$9,051	26.0%	$43,861	8.7%	$37,854	$9,842	$47,696	$56,074	$103,770	21.3%	$45,901	$11,934	$113,909
	CONSTRUCTION ESTIMATE TOTALS:	$34,810	$9,051		$43,861	8.7%	$37,854	$9,842	$47,696	$56,074	$103,770	21.3%	$45,901	$11,934	$113,909
30	PLANNING, ENGINEERING & DESIGN	$750	$195	26.0%	$945	11.8%	$839	$218	$1,057	$0	$1,057	24.7%	$1,046	$272	$1,318
31	CONSTRUCTION MANAGEMENT	$375	$98	26.0%	$473	11.8%	$419	$109	$528	$0	$528	28.0%	$537	$140	$676
	PROJECT COST TOTALS:	$35,935	$9,343	26.0%	$45,278		$39,112	$10,169	**$49,281**	$56,074	**$105,355**	21.4%	$47,484	$12,346	$115,904

ESTIMATED TOTAL PROJECT COST: $115,904

______________________ **CHIEF, COST ENGINEERING, Stephen Roman**

______________________ **PROJECT MANAGER, Jim Medlock**

______________________ **CHIEF, REAL ESTATE, Michael Hins**

______________________ **CHIEF, PLANNING, Elden Gatwood**

______________________ **CHIEF, ENGINEERING, Greg Williams**

______________________ **CHIEF, OPERATIONS, Roger Bullock**

______________________ **CHIEF, CONSTRUCTION, Dennis Lynch**

______________________ **CHIEF, CONTRACTING, John Mayo**

______________________ **CHIEF, PM-PB, Robert Keistler**

______________________ **CHIEF, DPM, Christine Brayman**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			21-Feb-19	Program Year (Budget EC):			2022					
		Effective Price Level:			1-Oct-18	Effective Price Level Date:			1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
17	BEACH REPLENISHMENT	$6,962	$1,810	26.0%	$8,772	8.7%	$7,571	$1,968	$9,539	2022Q2	0.8%	$7,628	$1,983	$9,611
	CONSTRUCTION ESTIMATE TOTALS:	$6,962	$1,810	26.0%	**$8,772**		$7,571	$1,968	$9,539			$7,628	$1,983	$9,611
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	26.0%	$25	11.8%	$22	$6	$28	2021Q3	-1.8%	$22	$6	$28
1.0%	Planning & Environmental Compliance	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2021Q3	-1.8%	$13	$3	$17
15.0%	Engineering & Design	$50	$13	26.0%	$63	11.8%	$56	$15	$70	2021Q3	-1.8%	$55	$14	$69
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2021Q3	-1.8%	$13	$3	$17
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$9	26.0%	$45	11.8%	$40	$10	$51	2021Q3	-1.8%	$40	$10	$50
1.0%	Contracting & Reprographics	$8	$2	26.0%	$10	11.8%	$9	$2	$11	2021Q3	-1.8%	$9	$2	$11
3.0%	Engineering During Construction	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2022Q2	0.9%	$14	$4	$17
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	26.0%	$67	11.8%	$59	$15	$75	2022Q2	0.9%	$60	$16	$75
2.0%	Project Operation:	$10	$3	26.0%	$13	11.8%	$11	$3	$14	2022Q2	0.9%	$11	$3	$14
2.5%	Project Management	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2022Q2	0.9%	$14	$4	$17
	CONTRACT COST TOTALS:	$7,187	$1,869		$9,056		$7,822	$2,034	**$9,856**			$7,878	$2,048	**$9,926**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: Effective Price Level:			21-Feb-19 1-Oct-18	Program Year (Budget EC): Effective Price Level Date:			2022 1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 2 or CONTRACT 2													
17	BEACH REPLENISHMENT	$6,962	$1,810	26.0%	$8,772	8.7%	$7,571	$1,968	$9,539	2025Q2	10.1%	$8,335	$2,167	$10,503
	CONSTRUCTION ESTIMATE TOTALS:	$6,962	$1,810	26.0%	**$8,772**		$7,571	$1,968	$9,539			$8,335	$2,167	$10,503
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	26.0%	$25	11.8%	$22	$6	$28	2024Q3	9.6%	$25	$6	$31
1.0%	Planning & Environmental Compliance	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2024Q3	9.6%	$15	$4	$19
15.0%	Engineering & Design	$50	$13	26.0%	$63	11.8%	$56	$15	$70	2024Q3	9.6%	$61	$16	$77
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2024Q3	9.6%	$15	$4	$19
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$9	26.0%	$45	11.8%	$40	$10	$51	2024Q3	9.6%	$44	$11	$56
1.0%	Contracting & Reprographics	$8	$2	26.0%	$10	11.8%	$9	$2	$11	2024Q3	9.6%	$10	$3	$12
3.0%	Engineering During Construction	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2025Q2	12.6%	$15	$4	$19
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	26.0%	$67	11.8%	$59	$15	$75	2025Q2	12.6%	$67	$17	$84
2.0%	Project Operation:	$10	$3	26.0%	$13	11.8%	$11	$3	$14	2025Q2	12.6%	$13	$3	$16
2.5%	Project Management	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2025Q2	12.6%	$15	$4	$19
	CONTRACT COST TOTALS:	$7,187	$1,869		$9,056		$7,822	$2,034	**$9,856**			$8,614	$2,240	**$10,854**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District PREPARED: 2/21/2019
POC: CHIEF, COST ENGINEERING, Stephen Roman

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: / Effective Price Level:			21-Feb-19 / 1-Oct-18	Program Year (Budget EC): / Effective Price Level Date:			2022 / 1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 3 or CONTRACT 3													
17	BEACH REPLENISHMENT	$6,962	$1,810	26.0%	$8,772	8.7%	$7,571	$1,968	$9,539	2028Q2	20.3%	$9,108	$2,368	$11,477
	CONSTRUCTION ESTIMATE TOTALS:	$6,962	$1,810	26.0%	**$8,772**		$7,571	$1,968	$9,539			$9,108	$2,368	$11,477
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	26.0%	$25	11.8%	$22	$6	$28	2027Q3	22.5%	$27	$7	$35
1.0%	Planning & Environmental Compliance	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2027Q3	22.5%	$16	$4	$21
15.0%	Engineering & Design	$50	$13	26.0%	$63	11.8%	$56	$15	$70	2027Q3	22.5%	$69	$18	$86
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2027Q3	22.5%	$16	$4	$21
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$9	26.0%	$45	11.8%	$40	$10	$51	2027Q3	22.5%	$49	$13	$62
1.0%	Contracting & Reprographics	$8	$2	26.0%	$10	11.8%	$9	$2	$11	2027Q3	22.5%	$11	$3	$14
3.0%	Engineering During Construction	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2028Q2	26.1%	$17	$4	$21
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	26.0%	$67	11.8%	$59	$15	$75	2028Q2	26.1%	$75	$19	$94
2.0%	Project Operation:	$10	$3	26.0%	$13	11.8%	$11	$3	$14	2028Q2	26.1%	$14	$4	$18
2.5%	Project Management	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2028Q2	26.1%	$17	$4	$21
	CONTRACT COST TOTALS:	$7,187	$1,869		**$9,056**		$7,822	$2,034	**$9,856**			$9,420	$2,449	**$11,869**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared:			**21-Feb-19**	Program Year (Budget EC):			2022	FULLY FUNDED PROJECT ESTIMATE				
		Effective Price Level:			1-Oct-18	Effective Price Level Date:			1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	PHASE 4 or CONTRACT 4													
17	BEACH REPLENISHMENT	$6,962	$1,810	26.0%	$8,772	8.7%	$7,571	$1,968	$9,539	2031Q2	31.5%	$9,953	$2,588	$12,541
	CONSTRUCTION ESTIMATE TOTALS:	$6,962	$1,810	26.0%	**$8,772**		$7,571	$1,968	$9,539			$9,953	$2,588	$12,541
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	26.0%	$25	11.8%	$22	$6	$28	2030Q3	37.4%	$31	$8	$39
1.0%	Planning & Environmental Compliance	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2030Q3	37.4%	$18	$5	$23
15.0%	Engineering & Design	$50	$13	26.0%	$63	11.8%	$56	$15	$70	2030Q3	37.4%	$77	$20	$97
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2030Q3	37.4%	$18	$5	$23
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$9	26.0%	$45	11.8%	$40	$10	$51	2030Q3	37.4%	$55	$14	$70
1.0%	Contracting & Reprographics	$8	$2	26.0%	$10	11.8%	$9	$2	$11	2030Q3	37.4%	$12	$3	$15
3.0%	Engineering During Construction	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2031Q2	41.4%	$19	$5	$24
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	26.0%	$67	11.8%	$59	$15	$75	2031Q2	41.4%	$84	$22	$106
2.0%	Project Operation:	$10	$3	26.0%	$13	11.8%	$11	$3	$14	2031Q2	41.4%	$16	$4	$20
2.5%	Project Management	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2031Q2	41.4%	$19	$5	$24
	CONTRACT COST TOTALS:	$7,187	$1,869		**$9,056**		$7,822	$2,034	**$9,856**			$10,303	$2,679	**$12,981**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			**21-Feb-19**	Program Year (Budget EC):			2022	FULLY FUNDED PROJECT ESTIMATE				
		Effective Price Level:			1-Oct-18	Effective Price Level Date:			1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 5 or CONTRACT 5													
17	BEACH REPLENISHMENT	$6,962	$1,810	26.0%	$8,772	8.7%	$7,571	$1,968	$9,539	2034Q2	43.7%	$10,876	$2,828	$13,704
	CONSTRUCTION ESTIMATE TOTALS:	$6,962	$1,810	26.0%	**$8,772**		$7,571	$1,968	$9,539			$10,876	$2,828	$13,704
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	26.0%	$25	11.8%	$22	$6	$28	2033Q3	54.5%	$35	$9	$44
1.0%	Planning & Environmental Compliance	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2033Q3	54.5%	$21	$5	$26
15.0%	Engineering & Design	$50	$13	26.0%	$63	11.8%	$56	$15	$70	2033Q3	54.5%	$86	$22	$109
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2033Q3	54.5%	$21	$5	$26
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$9	26.0%	$45	11.8%	$40	$10	$51	2033Q3	54.5%	$62	$16	$78
1.0%	Contracting & Reprographics	$8	$2	26.0%	$10	11.8%	$9	$2	$11	2033Q3	54.5%	$14	$4	$17
3.0%	Engineering During Construction	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2034Q2	59.1%	$21	$6	$27
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	26.0%	$67	11.8%	$59	$15	$75	2034Q2	59.1%	$94	$25	$119
2.0%	Project Operation:	$10	$3	26.0%	$13	11.8%	$11	$3	$14	2034Q2	59.1%	$18	$5	$22
2.5%	Project Management	$12	$3	26.0%	$15	11.8%	$13	$3	$17	2034Q2	59.1%	$21	$6	$27
	CONTRACT COST TOTALS:	$7,187	$1,869		**$9,056**		$7,822	$2,034	**$9,856**			$11,269	$2,930	**$14,199**

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: **Carolina Beach Renourishment**
PROJECT NO: P2 113752
LOCATION: New Hanover County, North Carolina

DISTRICT: Wilmington District **PREPARED: 2/21/2019**
POC: CHIEF, COST ENGINEERING, Stephen Roman

This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC): 2022	Effective Price Level Date: 1 OCT 21								
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-18** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
17	BEACH REPLENISHMENT	$39,410	$10,641	27.0%	$50,051	8.7%	$42,856	$11,571	$54,427	$56,074	$110,501	21.3%	$51,967	$14,031	$122,072
	CONSTRUCTION ESTIMATE TOTALS:	$39,410	$10,641		$50,051	8.7%	$42,856	$11,571	$54,427	$56,074	$110,501	21.3%	$51,967	$14,031	$122,072
01	LANDS AND DAMAGES	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$750	$203	27.0%	$953	11.8%	$839	$226	$1,065	$0	$1,065	24.7%	$1,046	$282	$1,329
31	CONSTRUCTION MANAGEMENT	$375	$101	27.0%	$476	11.8%	$419	$113	$533	$0	$533	28.0%	$537	$145	$682
	PROJECT COST TOTALS:	$40,535	$10,944	27.0%	$51,479		$44,114	$11,911	**$56,025**	$56,074	**$112,099**	21.4%	$53,550	$14,458	$124,082

ESTIMATED TOTAL PROJECT COST: $124,082

_____________________________ **CHIEF, COST ENGINEERING, Stephen Roman**

_____________________________ **PROJECT MANAGER, Jim Medlock**

_____________________________ **CHIEF, REAL ESTATE, Michael Hins**

_____________________________ **CHIEF, PLANNING, Elden Gatwood**

_____________________________ **CHIEF, ENGINEERING, Greg Williams**

_____________________________ **CHIEF, OPERATIONS, Roger Bullock**

_____________________________ **CHIEF, CONSTRUCTION, Dennis Lynch**

_____________________________ **CHIEF, CONTRACTING, John Mayo**

_____________________________ **CHIEF, PM-PB, Robert Keistler**

_____________________________ **CHIEF, DPM, Christine Brayman**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			21-Feb-19	Program Year (Budget EC):			2022					
		Effective Price Level:			1-Oct-18	Effective Price Level Date:			1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 1 or CONTRACT 1													
17	BEACH REPLENISHMENT	$7,882	$2,128	27.0%	$10,010	8.7%	$8,571	$2,314	$10,885	2022Q2	0.8%	$8,636	$2,332	$10,968
	CONSTRUCTION ESTIMATE TOTALS:	$7,882	$2,128	27.0%	**$10,010**		$8,571	$2,314	$10,885			$8,636	$2,332	$10,968
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	27.0%	$25	11.8%	$22	$6	$28	2021Q3	-1.8%	$22	$6	$28
1.0%	Planning & Environmental Compliance	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2021Q3	-1.8%	$13	$4	$17
15.0%	Engineering & Design	$50	$14	27.0%	$64	11.8%	$56	$15	$71	2021Q3	-1.8%	$55	$15	$70
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2021Q3	-1.8%	$13	$4	$17
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$10	27.0%	$46	11.8%	$40	$11	$51	2021Q3	-1.8%	$40	$11	$50
1.0%	Contracting & Reprographics	$8	$2	27.0%	$10	11.8%	$9	$2	$11	2021Q3	-1.8%	$9	$2	$11
3.0%	Engineering During Construction	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2022Q2	0.9%	$14	$4	$17
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	27.0%	$67	11.8%	$59	$16	$75	2022Q2	0.9%	$60	$16	$76
2.0%	Project Operation:	$10	$3	27.0%	$13	11.8%	$11	$3	$14	2022Q2	0.9%	$11	$3	$14
2.5%	Project Management	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2022Q2	0.9%	$14	$4	$17
	CONTRACT COST TOTALS:	$8,107	$2,189		$10,296		$8,823	$2,382	**$11,205**			$8,886	$2,399	**$11,285**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**				**TOTAL PROJECT COST (FULLY FUNDED)**				
		Estimate Prepared: Effective Price Level:			**21-Feb-19** 1-Oct-18	Program Year (Budget EC): Effective Price Level Date:			2022 1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***P***	***L***	***M***	***N***	***O***
	PHASE 2 or CONTRACT 2													
17	BEACH REPLENISHMENT	$7,882	$2,128	27.0%	$10,010	8.7%	$8,571	$2,314	$10,885	2025Q2	10.1%	$9,437	$2,548	$11,985
	CONSTRUCTION ESTIMATE TOTALS:	$7,882	$2,128	27.0%	**$10,010**		$8,571	$2,314	$10,885			$9,437	$2,548	$11,985
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	27.0%	$25	11.8%	$22	$6	$28	2024Q3	9.6%	$25	$7	$31
1.0%	Planning & Environmental Compliance	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2024Q3	9.6%	$15	$4	$19
15.0%	Engineering & Design	$50	$14	27.0%	$64	11.8%	$56	$15	$71	2024Q3	9.6%	$61	$17	$78
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2024Q3	9.6%	$15	$4	$19
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$10	27.0%	$46	11.8%	$40	$11	$51	2024Q3	9.6%	$44	$12	$56
1.0%	Contracting & Reprographics	$8	$2	27.0%	$10	11.8%	$9	$2	$11	2024Q3	9.6%	$10	$3	$12
3.0%	Engineering During Construction	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2025Q2	12.6%	$15	$4	$19
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	27.0%	$67	11.8%	$59	$16	$75	2025Q2	12.6%	$67	$18	$85
2.0%	Project Operation:	$10	$3	27.0%	$13	11.8%	$11	$3	$14	2025Q2	12.6%	$13	$3	$16
2.5%	Project Management	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2025Q2	12.6%	$15	$4	$19
	CONTRACT COST TOTALS:	$8,107	$2,189		$10,296		$8,823	$2,382	**$11,205**			$9,716	$2,623	**$12,339**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: / Effective Price Level:			21-Feb-19 / 1-Oct-18	Program Year (Budget EC): / Effective Price Level Date:			2022 / 1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 3 or CONTRACT 3													
17	BEACH REPLENISHMENT	$7,882	$2,128	27.0%	$10,010	8.7%	$8,571	$2,314	$10,885	2028Q2	20.3%	$10,312	$2,784	$13,096
	CONSTRUCTION ESTIMATE TOTALS:	$7,882	$2,128	27.0%	**$10,010**		$8,571	$2,314	$10,885			$10,312	$2,784	$13,096
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	27.0%	$25	11.8%	$22	$6	$28	2027Q3	22.5%	$27	$7	$35
1.0%	Planning & Environmental Compliance	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2027Q3	22.5%	$16	$4	$21
15.0%	Engineering & Design	$50	$14	27.0%	$64	11.8%	$56	$15	$71	2027Q3	22.5%	$69	$18	$87
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2027Q3	22.5%	$16	$4	$21
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$10	27.0%	$46	11.8%	$40	$11	$51	2027Q3	22.5%	$49	$13	$63
1.0%	Contracting & Reprographics	$8	$2	27.0%	$10	11.8%	$9	$2	$11	2027Q3	22.5%	$11	$3	$14
3.0%	Engineering During Construction	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2028Q2	26.1%	$17	$5	$21
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	27.0%	$67	11.8%	$59	$16	$75	2028Q2	26.1%	$75	$20	$95
2.0%	Project Operation:	$10	$3	27.0%	$13	11.8%	$11	$3	$14	2028Q2	26.1%	$14	$4	$18
2.5%	Project Management	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2028Q2	26.1%	$17	$5	$21
	CONTRACT COST TOTALS:	$8,107	$2,189		**$10,296**		$8,823	$2,382	**$11,205**			$10,624	$2,868	**$13,492**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			21-Feb-19	Program Year (Budget EC):			2022	FULLY FUNDED PROJECT ESTIMATE				
		Effective Price Level:			1-Oct-18	Effective Price Level Date:			1 OCT 21					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 4 or CONTRACT 4													
17	BEACH REPLENISHMENT	$7,882	$2,128	27.0%	$10,010	8.7%	$8,571	$2,314	$10,885	2031Q2	31.5%	$11,268	$3,042	$14,311
	CONSTRUCTION ESTIMATE TOTALS:	$7,882	$2,128	27.0%	**$10,010**		$8,571	$2,314	$10,885			$11,268	$3,042	$14,311
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	27.0%	$25	11.8%	$22	$6	$28	2030Q3	37.4%	$31	$8	$39
1.0%	Planning & Environmental Compliance	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2030Q3	37.4%	$18	$5	$23
15.0%	Engineering & Design	$50	$14	27.0%	$64	11.8%	$56	$15	$71	2030Q3	37.4%	$77	$21	$98
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2030Q3	37.4%	$18	$5	$23
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$10	27.0%	$46	11.8%	$40	$11	$51	2030Q3	37.4%	$55	$15	$70
1.0%	Contracting & Reprographics	$8	$2	27.0%	$10	11.8%	$9	$2	$11	2030Q3	37.4%	$12	$3	$16
3.0%	Engineering During Construction	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2031Q2	41.4%	$19	$5	$24
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	27.0%	$67	11.8%	$59	$16	$75	2031Q2	41.4%	$84	$23	$106
2.0%	Project Operation:	$10	$3	27.0%	$13	11.8%	$11	$3	$14	2031Q2	41.4%	$16	$4	$20
2.5%	Project Management	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2031Q2	41.4%	$19	$5	$24
	CONTRACT COST TOTALS:	$8,107	$2,189		**$10,296**		$8,823	$2,382	**$11,205**			$11,618	$3,137	**$14,755**

**** TOTAL PROJECT COST SUMMARY ****

**** CONTRACT COST SUMMARY ****

PROJECT: Carolina Beach Renourishment
LOCATION: New Hanover County, North Carolina
This Estimate reflects the scope and schedule in report; Beach Renourishment Evaluation Report

DISTRICT: Wilmington District
POC: CHIEF, COST ENGINEERING, Stephen Roman
PREPARED: 2/21/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: Effective Price Level:			21-Feb-19 1-Oct-18	Program Year (Budget EC): Effective Price Level Date:			2022 1 OCT 21	FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Mid-Point Date P	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
	PHASE 5 or CONTRACT 5													
17	BEACH REPLENISHMENT	$7,882	$2,128	27.0%	$10,010	8.7%	$8,571	$2,314	$10,885	2034Q2	43.7%	$12,313	$3,325	$15,638
	CONSTRUCTION ESTIMATE TOTALS:	$7,882	$2,128	27.0%	**$10,010**		$8,571	$2,314	$10,885			$12,313	$3,325	$15,638
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$20	$5	27.0%	$25	11.8%	$22	$6	$28	2033Q3	54.5%	$35	$9	$44
1.0%	Planning & Environmental Compliance	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2033Q3	54.5%	$21	$6	$26
15.0%	Engineering & Design	$50	$14	27.0%	$64	11.8%	$56	$15	$71	2033Q3	54.5%	$86	$23	$110
1.0%	Reviews, ATRs, IEPRs, VE	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2033Q3	54.5%	$21	$6	$26
1.0%	Life Cycle Updates (cost, schedule, risks)	$36	$10	27.0%	$46	11.8%	$40	$11	$51	2033Q3	54.5%	$62	$17	$79
1.0%	Contracting & Reprographics	$8	$2	27.0%	$10	11.8%	$9	$2	$11	2033Q3	54.5%	$14	$4	$18
3.0%	Engineering During Construction	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2034Q2	59.1%	$21	$6	$27
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$53	$14	27.0%	$67	11.8%	$59	$16	$75	2034Q2	59.1%	$94	$25	$120
2.0%	Project Operation:	$10	$3	27.0%	$13	11.8%	$11	$3	$14	2034Q2	59.1%	$18	$5	$23
2.5%	Project Management	$12	$3	27.0%	$15	11.8%	$13	$4	$17	2034Q2	59.1%	$21	$6	$27
	CONTRACT COST TOTALS:	$8,107	$2,189		**$10,296**		$8,823	$2,382	**$11,205**			$12,706	$3,431	**$16,137**

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APPENDIX F

ECONOMICS

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

CAROLINA BEACH INLET, NC

AND

BORROW AREA B

JUNE 2019

Prepared by:

Plan Formulation and Economics Section
U.S. Army Corps of Engineers, Wilmington District

DRAFT

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1. INTRODUCTION

The purpose of this economics appendix is to tell the story of the economics investigation, and provide greater detail on the results of the analysis. The sections that follow will cover the following topics:

-Existing Conditions: Items discussed include an assessment of socio-economic conditions, spatial organization of the study area, and an inventory of the coastal infrastructure within the study area.

- Hurricane & Storm Damage Reduction Benefits: This section will cover the methods used to estimate the future without, and future with project condition using Beach-fx, accounting for risk and uncertainty. The future without project condition will cover the distribution of the damages in the following dimensions:

- Spatial (Where)
- Categorization of structures (What)
- Damage driving parameter (How)
- Temporal (When)
- The future with project condition discussion will address the alternatives evaluated, and the analysis results. In addition, an analysis of alternative performance under the intermediate and high sea level change scenarios is provided.

- NED & TSP Plan Selection and Performance: This section addresses the rationale for NED and TSP selection. A detailed description of the performance of the NED Plan is provided with the same 4 dimensions given in the Hurricane & Storm Damage Reduction section. A discussion on the project's incidental recreation benefits is also provided.

1.1 **Existing Socio-Economic Conditions**

Carolina Beach is located on the southeast coast of North Carolina in New Hanover County, which has more than 25 miles of coastline along the Atlantic Ocean. The largest towns in New Hanover County are Wilmington, Carolina Beach, Kure Beach, and Wrightsville Beach. The entirety of the study area in the Feasibility study is located within the town limits of Carolina Beach.

1.1.1 Demographic Characteristics

According to the US Census Bureau, the 2010 population of Carolina Beach was 5,706, and 202,607 for New Hanover County, making it the 9th most populous county in North Carolina. In the past several years, the county has seen strong population growth. In fact, between 200 and 2010, the county grew by over 26%. According to reports by the North Carolina State office of Budget and Management, New Hanover County is expected to increase in size to over 270,000 persons by 2029. The ethnic makeup of New Hanover County is 79.9 % white, 16.9% African American, less than 1% Native American, less than 1% Asian, less than 1% Pacific Islander, and less than 1% from other races. 2.1% of the population were Hispanic or Latino of any race. Carolina Beach's racial makeup was 98.1% white, with less than 1% of each additional race represented. The Hispanic population in Carolina Beach represents less than 1% of the total population.

1.1.2 Economic Characteristics

New Hanover County has a service based economy that has benefited from an influx of permanent residents, and a thriving tourism industry. The service sector includes banking/finance, real estate, insurance, healthcare, and related commercial businesses. The percentage of the workforce employed in social services (defined as educational services, healthcare, or social assistance) is 13%, with the highest percentage of individuals working in the Finance-Insurance-Real Estate industry (24%), followed by Construction (15%).

With numerous notable attractions located in its borders and nearby, tourism is a critical component of the New Hanover County and Carolina Beach economy. In addition to miles of beaches, the county possess numerous access points to the Intercostal Waterway, which is popular for recreational fishing and boating related activities.

Income

On average, the socioeconomic composition of New Hanover County and Carolina Beach is lower than the remainder of North Carolina. The median household income are $51,232 and $37,662 respectively for the county and town, and a State average of $48,256. The per capita income in New Hanover County and Carolina Beach are $31,708 and $24,128 respectively, with the State average of $25,774.

1.2 Description of Study Area

Carolina Beach is located in New Hanover County in southeastern North Carolina adjacent to the Atlantic Ocean. The project consists of a dune with a base generally bordering at or near the building line with a crown width of 25 feet at an elevation of 15 feet national geodetic vertical datum (NGVD), together with an integral shoreline berm with a crown width of 50 feet and a top elevation of 12 feet NGVD for a total distance of 14,000 feet.

1.3 Data Collection

Economists and real estate specialists have collected and compiled detailed structure information for The Carolina Beach coastline, which includes: over 640 single family homes; 42 different multi-family structures; 18 commercial buildings; 9.6 miles of road; and over 40 other structures that are vulnerable to future hurricane and storm damages. In addition, data was collected on nearly 3.8 miles of any coastal armoring or walkover structures on Carolina Beach. In total, over 742 damageable structures were collected for economic modeling using Beach-*fx*. The structure inventory includes all structures that are within 500 feet of the mean high water line.

GIS and Planning professionals from the USACE Wilmington District (SAW) using geo-spatial parcel data from New Hanover County provided detailed data on each structure including: geographic location, structure type, foundation type, construction type, width, length, number of floors, depreciated replacement value, and year built. The elevations of paved surfaces such as roads, and parking lots were acquired from USACE SAW LIDAR data.

2. COASTAL STORM RISK MANAGEMENT BENEFITS

This section of the appendix covers the approach used to estimate the economic benefits of reducing hurricane and storm related damages in Carolina Beach using Beach-fx. The topics covered include:

- Benefit Estimation Approach Using Beach-fx
- FWOP Condition[1]
- The Future-With Project Condition (FWP)

2.1 Benefit Estimation Approach Using Beach-fx

Beach-fx was developed by the USACE Engineering Research and Development Center in Vicksburg, Mississippi. On April 1, 2009 the Model Certification Headquarters Panel certified the Beach-fx CSRM model based on recommendations from the Planning Center of Expertise (PCX) and in accordance with EC 1105-2-412 (Assuring Quality of Planning Models). The model was reviewed by the PCX for Coastal and Storm Damage and found to be appropriate for use in CSRM studies and is therefore the optimum model for use in the Carolina Beach CSRM Validation Study. The model links the predictive capability of coastal evolution modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the costs and total damages under various shore protection alternatives. The output generated from the model is then used to determine the benefits of each alternative. As an event-based Monte Carlo life-cycle simulation, Beach-fx fully incorporates risk

[1] Beach-fx was run for several scenarios, however, the FWOP/FWP condition for which damages will be characterized throughout the appendix is the Total Project Analysis which consists of a 50-year period of analysis and base year of 2022.

and uncertainty. It is used to simulate future hurricane and storm damages at existing and future years and to compute accumulated present-worth damages and costs. Storm damage is defined as the ongoing monetary loss to contents and structures incurred as a direct result of waves, erosion, and inundation caused by a storm of a given magnitude and probability. The model also computes permanent shoreline reductions so that land-loss benefits can be derived exogenously. These damages and associated costs are calculated over a 50-year[2] period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Beach-fx also provides the capability to estimate the costs of certain future measures undertaken by state and local organizations to protect coastal assets. Based on these attributes, Beach-fx is an ideal modeling tool for use in the Carolina Beach CSRM Validation study.

Of course, the above mentioned computations require inputs from USACE personnel in order to function accurately. Data on historic storms, beach survey profiles, and private, commercial and public structures within the project area are used as these inputs.

The future structure inventory and values are the same as the existing condition. This conservative approach neglects any increase in value accrued from future development. Though North Carolina has historically experienced increases in density and value in real-dollar terms, using the existing inventory is considered preferable due to the uncertainty involved in projections of future development.

The FWOP damages are used as the base condition and potential project alternatives, in this case the previously authorized beach nourishment alternative, are measured against this base. The difference between FWOP and FWP damages will be used to determine primary CSRM benefits.

Once benefits for the authorized project are calculated, they will be compared to the costs of implementing the project. For this validation report there will be two distinct comparisons of costs and benefits with several sensitivities under each of the two main comparisons. First, the total project benefits as estimated over a 50-year period of analysis will be compared to the total costs of the project, including those already expended. Additionally, the remaining benefits of the project as estimated by Beach-fx using the remaining period of federal participation (15-years) will be compared to the remaining costs of the authorized project (i.e. the cost of the remaining nourishments).

2.2 Assumptions

Beach-fx accuracy is not only dependent upon inputs but also requires a meticulous level of thought be given to the parameters (i.e. assumptions) under which the model is bound. This section describes some key assumptions specific to the Carolina Beach CSRM study and the resulting consequences.

3.2.1 Timeframe and Discount Rate

- **Start Year:** For the Total Project Analysis the start year is 2021, the year prior to the base year from the authorizing document and represents the starting shoreline prior to initial construction. For the remaining-benefit remaining-cost analysis (i.e. Remaining Project Analysis) the year in which the simulation begins is 2022. This year determines the starting shoreline position which will be impacted by standard erosion and storm forces throughout the remaining period of analysis.

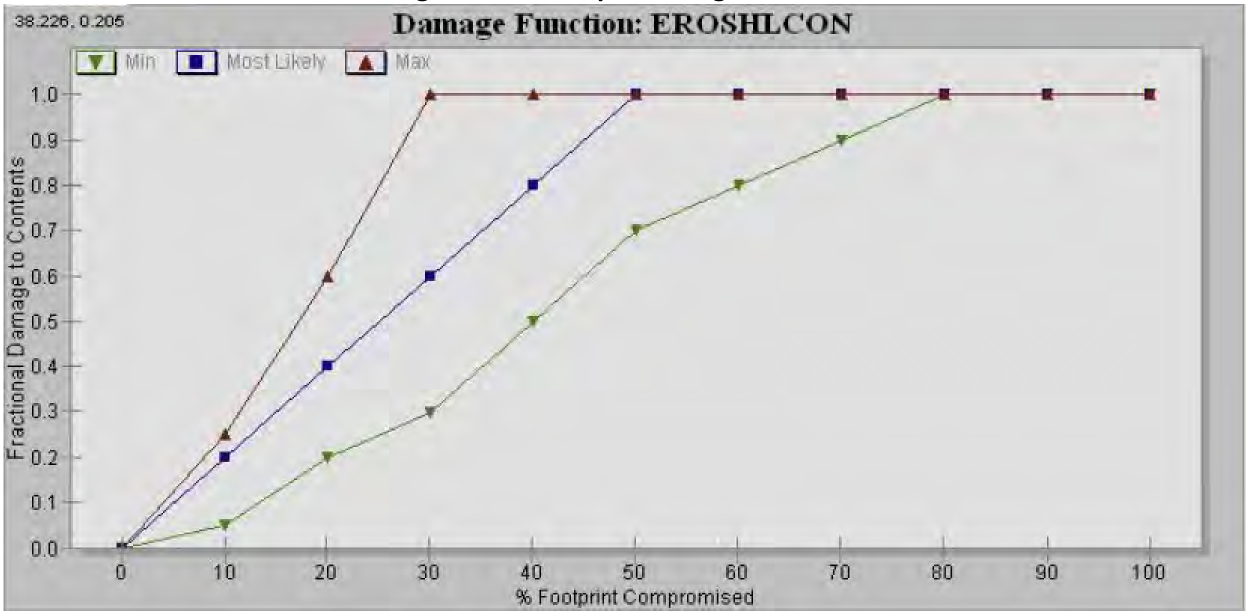
[2] The 50-year period of analysis is used for all references of Total Project BCR. For any Remaining Benefit Remaining Cost Ratios (RBRCR's), the period of analysis used in the Beach-fx model is equal to the remaining period of federal participation for Carolina Beach (15-years).

- **Base Year:** For the total project analysis run in Beach-fx the base year is 2022. For the remaining benefit remaining cost analysis the year in which the benefits of the next periodic nourishment would be expected to begin accruing is 2022 and is thus the base year.
- **Period of Analysis:** There are two distinct periods of analyses that will be discussed in this validation report. The 50-year period of analysis will be used to validate the authorized project by capturing the full life-cycle benefits and will be used to calculate a Total Project BCR. The intention of estimating benefits from a full 50 years is not to make any statement on continuing authorization of the Carolina Beach project beyond its current period of federal participation but rather to economically validate continued periodic nourishment based on a holistic view of the project, from past to present and future. A 15-year period of analysis will be used to compare the remaining benefits that will accrue from the next four periodic nourishments authorized and scheduled for Carolina Beach and will be used to calculate a Remaining Benefit Remaining Cost Ratio (RBRCR).
- **Discount Rates:** Several discount rates will be used in the Total Project analysis: 2.875% (FY2019), 7.875% (applicable rate, FY1982), 7% (OMB Rate). For the remaining project analysis only the FY2019 Federal Water Resources Discount Rate of 2.875% will be used.
- **Iterations:** Beach-fx was run using 300 iterations as is recommended by ERDC. The moving average of FWOP damages stabilized by this point and was thus determined an adequate number of iterations.
- **Sea-Level Rise Scenarios –** For the Total Project analysis the base sea-level rise scenario is utilized as this is the rate experienced in the project historically and is thus the most accurate way to characterize what the entire project has experienced since initial construction. For the Remaining Project analysis all three sea-level rise scenarios will be examined and damages under each will be reported.

2.2.2 Damage Functions

Damage functions are used within the model to determine the extent of storm-induced damages attributable to any specific combination of damage element type, foundation type, and construction type. There are a total of six types of damage function which include erosion damages, inundation damages, and wave damages for both contents and structure. The functions are completely user-definable within the model and transfer damages to the individual damage elements. Damage is determined as a percentage of overall structure or content value using a triangular distribution (minimum, most likely, maximum). The range of percentage points used for the damage is determined by parameters dependent upon which function is being triggered. For erosion it is dependent upon the extent to which the structure's footprint has been compromised and inundation and wave-attack are dependent upon storm-surge heights in excess of first-floor elevation. An example diagram of how these damage functions operate is provided by **Figure 2-1**.

Figure 2-1: Example Damage Function



For the vast majority of aforementioned combinations within this study the damage functions used were those developed under the Institute for Water Resources (IWR), within the Coastal Storm Damage Workshop (CSDW), Coastal Storm Damage Relationships Based on Expert Opinion Elicitation in 2002 or the damage functions established in the North Atlantic Coast Comprehensive Study (NACCS). However, the wave damage functions needed to be adjusted for certain damage elements based on their relative position in the upland. In order to account for the fact that property and structures in the first row would attenuate wave energy, properties in the second and third rows were assigned altered wave damage functions. Properties located in the second row had a downward revision to the fractional damage at every wave height whereas the properties in the third row had the null wave damage function assigned since it is assumed that properties set that far back would not incur damages from wave attack due to the aforementioned attenuation.

2.2.3 Coastal Armoring

Beach-fx allows for assumptions surrounding coastal armoring (e.g. sandbags, breakwaters, seawalls) as well. A user can define the different types of armoring applied to individual damage elements as well as a distance trigger, applied at the lot level, which will prompt construction of said armor. However, there is no evidence of historical armoring in the Carolina Beach area and is therefore omitted from the model.

(sections 2.3 to section 3 will be populated after SAJ economist guidance and model statistical review)

2.3 Future without Project Condition (FWOP)

Damages throughout this section are based on the estimated FWOP damages resulting from the Beach-fx model runs assuming base sea levels, a 50-year period of analysis, and the current FY2019 Federal Water Resources Discount Rate of 2.875% (i.e. the Total Project analysis).

Descriptive statistics on the damages per the FWOP model results are as follows:

- Mean: $6,257,462 (AAEQ)
- Standard deviation: $3,049,671 (AAEQ)
- Coefficient of Variance: 0.49
- Median: $5,967,323 (AAEQ)

The coefficient of variance is neither relatively high nor relatively low for the FWOP damage estimation in Carolina Beach. This is due to the fact that damages are occurring from both the consistent and relatively moderate erosion throughout the study area as well as the relatively high frequency of storm impacts. The former impact tends to lower the coefficient of variance since the erosion impacts are consistent in all iterations while the latter tends to increase it since storm impacts will be greater in some iterations than others. Thus, with an area like Carolina Beach where neither effect is significantly greater than the other the FWOP damage estimation will be relatively consistent throughout the 300 iterations. Pursuant to estimating FWOP damages and associated costs for the study area in Carolina Beach, Beach-fx was used to estimate damages and costs in the following categories:

- <u>Damages:</u>
    - <u>Structure Damage:</u> Economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Structure damages account for 69% of the damages for the FWOP.
    - <u>Contents Damage:</u> The material items housed within the structures (usually air-conditioned and enclosed) that are potentially subject to damage. Content damages are 31% of the total damages.

2.3.1 Damage Distribution by Structure Category and Type

This section addresses what is being damaged in the FWOP by structure category and type. The coastal inventory was categorized as ‘Commercial’, ‘Public Access & Recreation’, and ‘Residential’. **Table 2-1** provides greater detail on the type of structures within each category as well as the composition of the FWOP damages within those categories. The distribution of the damages by category is as follows:

- Commercial: 12.7%
- Public Access & Recreation Structures: 0.8%
- Residential: 86.6%

Table 2-1: Distribution of FWOP Damages by Damage Category ($AAEQ)

Category	Structure	Contents	Total	% of Total
Commercial	$443,989.91	$240,751.05	$684,741	10.95%
Residential	$3,706,950.39	$1,649,353.62	$5,356,304	85.62%
Public	$192,537.37	$22,546.30	$215,084	3.44%
Total	$4,343,477.67	$1,912,650.97	$6,256,129	

2.3.1.1 **Commercial**

The Carolina Beach shoreline is dotted with various commercial real estate subject to damage. There are several hotels, various restaurants, and a few retail shops which are at risk of damage in the FWOP. The average total damage estimated for this category is $687,741 (AAEQ) which represents roughly 11% of all damages.

2.3.1.2 **Residential**

The two primary categories of residential found in the study area are multifamily (RES3-) and single-family (SF-) structures and are further delineated based on the size of the structure. The entire category is estimated to experience around $5.4M (AAEQ) in the FWOP which is almost 86% of all damages.

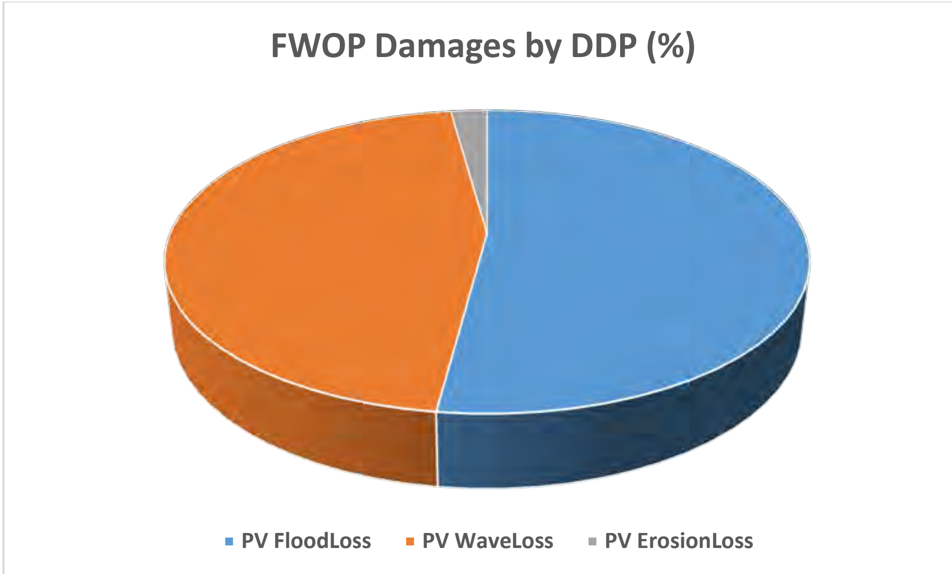
2.3.1.3 **Public and Recreation Structures**

Carolina Beach has a limited number of public buildings at risk in the study area and that fact is reflected in the relatively low average damages (3.4%) estimated in the FWOP. Recreation structures refer to those that provide the general public with safe access and facilities to enjoy the beaches and shorelines throughout Carolina Beach which can include, but are not limited to dune walks, public shower and bathroom facilities, and life-guard stations. Though these items represent limited dollar damages they are important to the overall recreation capacity and experience of Carolina Beach.

2.3.2 **FWOP Damage Distribution by Damage Driving Parameter**

It is very typical for coastlines in the South Atlantic Region to experience most damages due to erosion. Carolina Beach is no exception; however, flooding still remains a major risk factor in the area. The distribution of damage is as follows:

- Erosion: 2%
- Inundation: 52%
- Wave Attack: 46%



A major contributor to the lower risk presented by erosion in the study area, as compared to other areas in the South Atlantic, is attributable to newer construction in the area and increased building code standards as they relate to building homes on foundations with pile supports. Almost all of the first-row structures in the Carolina Beach study area are single-family homes and are required by code to be built on pile foundations. A piled foundation assists, if properly constructed, in reducing the risk of damages caused by erosion and scour in a coastal area.

2.4 FWOP Condition Conclusion

- Damages are driven both by gradual and consistent background erosion as well as from impacts of the relatively high frequency storm events that occur in the study area.
- The overwhelming majority of the damage is structural in nature. Residential structures, specifically single-family homes, account for nearly all damages.
- Inundation is the highest contributing factor to damages followed very closely by wave attack. Together those two parameters account for 98% of damages.

2.5 Future with (Authorized) Project Condition

This section of the appendix details the effectiveness of the authorized project in reducing coastal storm risk in the study area. More information on the specifics of the authorized project profile, volumes, and modeling details can be found in the Engineering Appendix of this Validation Report. Again, the residual damage estimates provided in this section of the report apply only to the Beach-fx model runs for the 50-year life-cycle using the current FY2019 Water Resources Discount Rate of 2.875% and the base sea-level rise scenario. The FWP damages will be broken down similarly to the FWOP so that a better understanding of how (what is damaged and what causes the damage) and where (spatial extent of damages) residual damages occur in the FWP.

2.5.1 Beach-fx Conceptualization of the Authorized Project

Beach-fx planned nourishment templates of a 100-foot berm extension and 55-foot wide dunes were configured in a manner such that periodic nourishments would attempt to match the authorized plan both in historic quantity placed and authorized nourishment interval. Across the 300 iterations and 50-

year cycle this was accomplished since Beach-fx estimated an average placement of 700,000 cubic-yards (CY) and an interval of four years.

2.5.2 Performance of Authorized Project – Coastal Storm Risk Management

The following section will characterize the residual damages in the future-with project (FWP). Beach-fx estimates that average annual damages in the FWP will be $1,033,354. This estimate represents an 85% reduction in FWOP damages and indicates a robust reduction in coastal storm risk throughout Carolina Beach. Descriptive statistics on the damages per the FWP model results are as follows:

- Mean: $1,650,608 (AAEQ)
- Standard deviation: $1,558,967 (AAEQ)
- Coefficient of Variance: .94
- Median: $1,105,598 (AAEQ)

2.5.2.1 FWP Damage Distribution by Structure Category and Type

Damages in the FWP by structure type and category are demonstrated in Table 2-2.

Table 2-2: Distribution of FWP Damages by Type ($AAEQ)

Category	Structure	Contents	Total	% of Total
Commercial	$54,704.93	$24,496.77	$79,202	4.80%
Residential	$1,047,671.11	$434,679.42	$1,482,351	89.83%
Public	$67,283.67	$21,420.38	$88,704	5.38%
Total	$1,169,659.71	$480,596.57	$1,650,256	

The distribution of damages in the FWP is similar to the FWOP. This is to be expected due mainly to the heavy concentration of single-family residences throughout the study area and especially the location of those residences in the first-row. The above table also shows that generally the different varieties of structure types receive equal protection from the presence of a project.

2.5.2.2 FWP Damages by Damage Driving Parameter

Again the FWP damages take a departure from the FWOP damage pattern with respect to the damage driving parameter. The composition is as follows:

- Erosion: 1%
- Inundation: 35%
- Wave Attack: 64%

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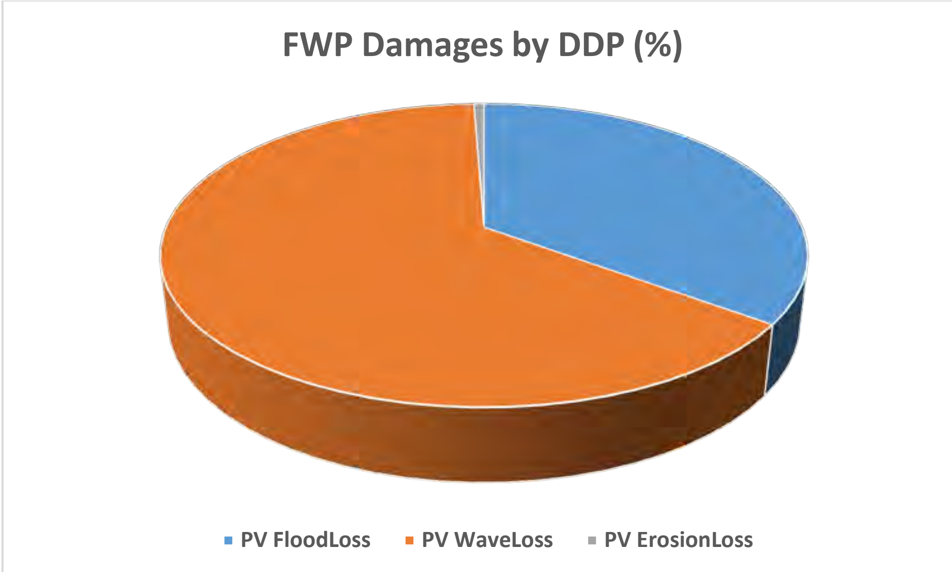


This damage distribution may seem counterintuitive but it is actually to be expected based on the nature of the project and based on why the damages occur the way they do in the FWOP. Remembering back to the discussion in section **2.3** Carolina Beach damages were characterized both by gradual and consistent background erosion that is amplified over time (i.e. damages from consistent erosion increase throughout the period of analysis) and also by impacts from probabilistic storm occurrences that accelerate erosion damages but also greatly increase the risk of damages from inundation and wave attack due to increased surge impacts. It is expected that residual damages will be largely from storm impacts and will be inundation and wave attack related if the majority of structures in the first row are on pile foundations, as they are in Carolina Beach.

2.5.3 Future-With Project Summary

The following are key takeaways from the FWP condition:

- 74% of all damages are avoided, leaving residual damages of $1,650,256(AAEQ)
- Majority of residual damages come from storm-induced wave attack
- The types of structures damaged in the FWP are very similar to those damaged in the FWOP

3. The Authorized Plan Benefits and Costs

3.1 Primary Coastal Storm Risk Management Benefits

Primary CSRM benefits are calculated from the reductions in damages to structures and contents as well as the land loss avoided in the FWP condition. The above sections described the damages in the FWOP and FWP given the Beach-fx model runs for the Total Project analysis utilizing the 50-year POA and the FY2019 Water Resources Discount Rate of 2.875%. The following sections will detail the benefits derived from the reduction in damage to the abovementioned scenario as well as listing out the average annual benefits under the various discount rates described in Section **2.2**. Additionally, the benefits under the Remaining Project analysis (i.e. 15-year POA) will be introduced.

3.1.1 Total Project Analysis Primary Benefits – Structure and Content Damage Reduction

The following table lists the damage reduction to the Carolina Beach structure and content inventory and, thus, the resulting benefits under the various discount rates for the Total Project Analysis.

Table 3-1: CSRM Structure & Content Damage Reduction Benefits for Total Project (50-Year POA)

Validation Report Discount Rates	**Structure and Content Damages**		**Damage Reduction Benefits**
	Future-Without Project	Future-With Project	
FY19 Discount Rate (2.875%)	$ 6,257,000	$ 1,651,000	**$ 4,606,000**
OMB Discount Rate (7%)	$ 4,383,000	$ 1,430,000	**$ 2,953,000**

3.1.2 Primary Benefits – Land Loss

In outlining the process and procedures to be used in the evaluation of CSRM projects, ER-1105-2-100 details the inclusion of land loss due to erosion, stating that such damages should be computed as the market value of the average annual area expected to be lost. Prevention of land loss is a component of primary benefits and is computed based on output data from Beach-fx. Land loss benefits must be added to the structure and content benefits as computed by Beach-fx to obtain the total primary CSRM benefits of the project.

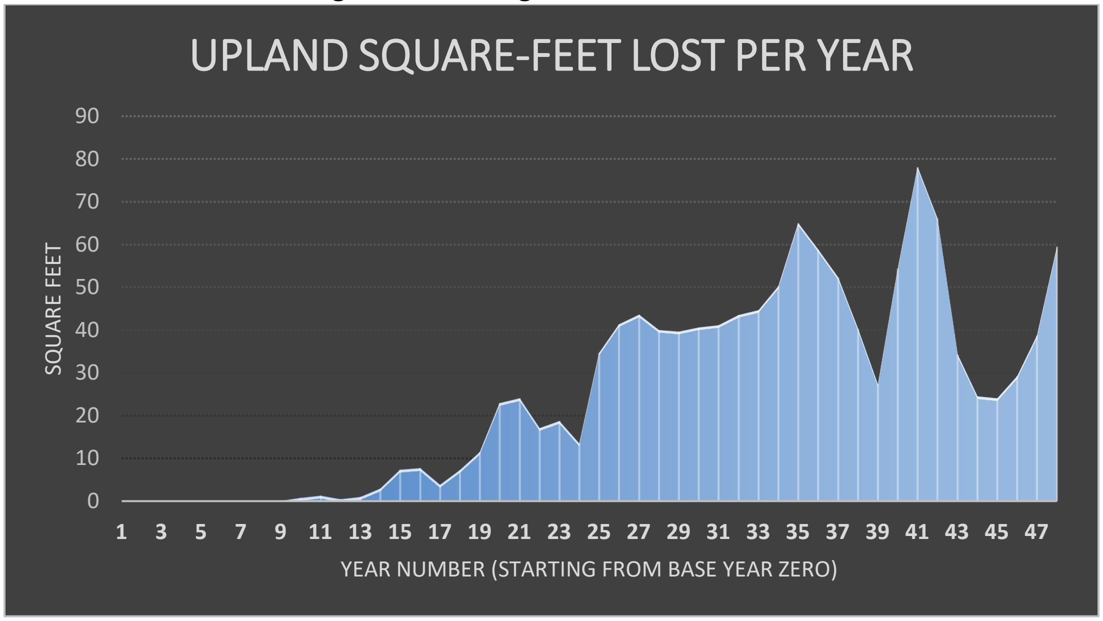
Following the guidance provided, two key pieces of information are needed to calculate land loss benefits of a CSRM project: (1) the square-footage of the land lost each year and (2) the market value of land in the project footprint.

In the case of Carolina Beach, annual reduction in upland width across all Beach-fx model reaches was obtained from the Beach-fx *LandLoss.csv* FWOP and FWP output files based on modeled changes to the shoreline. ER 1165-2-130 does not allow land loss benefits be claimed for beach areas subject to temporary shoreline recessions. Thus, changes in upland width, rather than changes in berm and dune width, are used as the appropriate measure of land loss. Beach-fx measures upland width from the landward toe of the dune back to the landward-most edge of the profile.

For Beach-fx reaches located within the project area, the basis of the annual changes in upland width calculation is the width in each reach in the model start year, compared to the average upland berm width maintained throughout the period of analysis in the FWP. The difference between the constant with-project width and the without-project width in a given year results in the *cumulative* loss of upland width given the profile of that specific reach. However, for the purpose of calculating land loss benefits, the *annual* loss of width is needed. This is obtained by taking the cumulative change in width in a given year and subtracting from it from the cumulative change in width from the previous year. This calculation results in the yearly incremental change in dune and upland width for a given reach.

Using the annual decrease in width for a specific reach and the corresponding length of shoreline eligible for land-loss benefits, the total annual square-footage of land lost is obtained on a reach-by-reach basis and then summed across all study reaches for a given project year. **Figure 3-1** graphically displays the square-feet lost in Carolina Beach each year.

Figure 3-1: Average Land Lost Each Year



As the second component of the land-loss benefits calculation, ER 1105-2-100 instructs that nearshore land values be used to estimate the value of land lost. SAW Planning, with the assistance of SAS Real Estate personnel determined that the land value at Carolina Beach is $52/SF.

Using the analysis technique described, the total average annual value of land-loss benefits over the 50 year period of analysis is estimated in Table 4-5 below at the various discount rates.

Table 3-2: Total Project Average Annual Land Loss Benefits (Various Discount Rates)

	FY19 Discount Rate (2.875%)	OMB Discount Rate (7%)
Average Annual Land Loss Benefits (50-Year POA)	$ 1,309,000	$ 690,000

3.1.3 Total Primary Benefits for Total Project

The following table is a summary table for the two primary benefit categories estimated in the Carolina Beach Validation Report via Beach-fx.

Table 3-3: Total Primary CSRM Benefits for Total Project

Primary CSRM Benefits (AAEQ)	FY19 Discount Rate (2.875%)	OMB Discount Rate (7%)
Land Loss Benefits	$ 1,309,000	$ 690,000
Damage Reduction Benefits	$ 4,606,000	$ 2,953,000
Total Primary Benefits	***$ 5,915,000***	***$ 3,643,000***

3.1.4 Total Benefit Computation

The methodology and assumptions outlined above were also conducted over a 15-year period of analysis in Beach-fx in order to isolate and gauge only the impact of the remaining four periodic nourishments. Additionally, a sea-level rise sensitivity was conducted across the 15 years in order to understand how sea-level rise may impact damages, and thus benefits, in the remaining years of the project. The base year for the remaining benefit computation is 2022 since that is when the next periodic nourishment is scheduled to be constructed and the corresponding potential benefits accrued. The only discount rate utilized in the model runs was the current FY2019 rate of 2.875%. The following table summarizes the remaining benefits across the three sea-level rise scenarios.

Table 3-4: Total Benefit Computation with Sea-Level Rise ($AAEQ)

Sea-Level Rise Assumptions	Damage Reduction Benefits	Land Loss Benefits	Total Primary Benefits
Base Sea-Level Rise	$ 4,183,000	$ 1,309,000	$ 5,492,000
Intermediate Sea-Level Rise	$ 4,606,000	$ 1,309,000	$ 5,915,000
High Sea-Level Rise	$ 7,173,000	$ 1,309,000	$ 8,482,000

3.2 Incidental Recreation Benefits

Carolina Beach is one of several beaches in New Hanover, Brunswick, and Pender Counties. Beach oriented recreation is a popular activity with area residents and visitors. Beach Access is accomplished staying at a beach front facility, using an access point close to a condominium, cottage, or hotel/motel, and parking at a or near an access point. There are 22 public Access points along the length of Carolina Beach, and 734 parking spaces. Figure X in the main report shows the location of the access points. The without versus the With project comparison of experience quality is measured by the unit day value method. This method measures the quality in terms of a set of criteria to which points are assigned to reflect the without versus the With project beach conditions. The points are converted to dollar values which are applied to visitation to ultimately arrive at recreation benefits. Table 3-5 displays the criteria, judgment factor points (with and without project), explanations, and general recreation values ($).

Table 3-5: Beach Recreation Analysis

Beach Recreation Analysis **Without Versus With Project**				
Criteria	Project Points Without	Project Points With	Change	Explanation
Recreation Experience	7	8	1	Wider Beach with Project, increased area equates to added user utility
Availability of Opportunity	2	2	0	Other beaches within an hour travel time
Carrying Capacity	3	7	4	With project conditions increase the number of visitation participants
Accessibility	11	13	2	With project conditions marginally subjected to storm damage by erosion
Environmental	5	8	3	With project conditions stabilize dune and improve vegetation growth, decrease beach slope
Total Points	28	38	10	
Points To Dollar Totals	**$6.05**	**7.61**	**$1.56**	

Existing visitations were established using average occupancy rates and average number of occupants of cottages, condominiums, duplexes, and hotels/motels for holidays, weekend days, and week days during the beach season. This information was obtained from the Town of Carolina Beach and New Hanover County. Public parking availability was determined from New Hanover County Estimates and confirmed by Wilmington District GIS personnel. The calculation of maximum daily beach use is contained in Table 3-6.

Table 3-6: Daily Beach Use Carolina Beach

Daily Beach Use Carolina Beach			
Rental Properties	Units	Avg persons/Unit	Maximum Seasonal Use
Cottages/Duplexes	524	8	4192
Condominiums	1134	5	5670
Hotel Rooms*	875	2	1750
Total	2533	NA	**11612**
Parking Based Day Users: (733 Parking Spaces) (turnover rate of 2)(2.5 persons per car)=max seasonal day use visitations Total Max Daily Recreation Visitations: 15,277			

The primary beach season is from Memorial Day to Labor Day, with limited use during late March, April, and Early October for a total of about 124 days. Beach visitation is determined by time of year (seasonal factor), time of week (visitation factor), and weather. The seasonal factor is an adjustment to the maximum daily beach visits to account for season differences in beach popularity. Previous studies of use at nearby comparable beaches (similar access) indicate that average week day use is approximately 36 percent of beach capacity, and that average weekend day use is 64 percent of capacity. Holiday use consists of July 4^{th} at capacity, Memorial Day at 50% of capacity, and Labor Day at 44% of capacity. The weather is favorable for beach use an estimated 80 percent (99 days) of the total beach days based on a 30-year climatological summary of Wilmington, NC. Table 3-7 shows the expected annual recreation visitation by month and type of day of the week for the 124 days of the beach season considering seasonal variation from the average, average visitation, and weather applied to a maximum daily beach use of 15,277 visitations.

Table 3-7: Total Maximum Annual Recreation Visitations

Total Maximum Annual Recreation Visitations With Project Carolina Beach					
Month	Type	# of Days	Seasonal factor	Visitation Factor	Weighted Visitation
March	Weekend	1	0.1	0.64	956
April	Weekend	4	0.4	0.64	15,301
May	Weekend	5	0.5	0.64	23,907
	Weekday	8	0.5	0.36	21,516
	Holiday	1	1	0.5	7,471
June	Weekend	9	0.76	0.64	65,410
	Weekday	21	0.76	0.36	85,851
July	Weekend	9	1	0.64	86,066
	Weekday	21	1	0.36	112,962
	Holiday	1	1	1	14,942
August	Weekend	8	0.9	0.64	68,853
	Weekday	23	0.9	0.36	111,348
September	Weekend	10	0.44	0.64	42,077
	Holiday	1	1	0.44	6,574
October	Weekend	2	0.27	0.64	5,164
					668,397
Weather Factor					0.8
Total Expected Annual Beach Recreation Visitation					**534,718**
Updated Recreation Benefit WOP vs WP				$1.56	$834,160.08

Recreation Benefits Summary- Expected annual beach recreation visitation of 534,718 combined with an increase in the quality of visitation of $1.56/visit yields total expected annual beach recreation benefits of $834,000 (rounded). Recreation benefits are to be the same for any beach nourishment placement method.

3.3 Authorized Plan Costs

For the total project analysis all costs are considered, In order to compare to the Beach-fx benefits, which were computed based on FY21 price-levels, any sunk costs must be inflated to FY21 levels using the most recent Civil Works Construction Cost Index (feature code 17 for Beach Replenishment). Remaining costs for the four planned nourishments will also be computed. For the total project analysis all costs will be discounted back to the base year of 1986 and amortized over the 50-year period of analysis.

It is necessary to discount the costs back to the base year and then amortize them over the 50-year period of analysis. As discussed above in detailing the discount rate assumptions and maintaining consistency with how benefits were computed, the total project analysis will include analyses at various discount rates.

3.3.1 Authorized Plan Cost

The cost for Carolina Beach depends on what borrow area will be utilized. Currently, there is uncertainty as to whether or not the Carolina Beach Inlet, which is the existing borrow source utilized for each of the past nourishment activities, will be available for use in the future. Therefore two cost estimates will be established, one based on Carolina Beach Inlet and one based on utilizing an offshore borrow source.

3.3.1.1 Carolina Beach Inlet Cost

Future costs utilizing the Carolina Inlet are based on the assumed unit cost ($8.50/CY) and the mobilization cost ($5,000,000) provided by cost engineering and are used in conjunction with the estimated nourishment volume and nourishment interval from Beach-fx to establish the FY2019 cost for each future nourishment. The following table details the remaining cost for Carolina Beach utilizing the Carolina Beach Inlet at FY2019 price levels.

Table 3-8: Carolina Beach Cost Estimate (FY19) – Carolina Beach Inlet Borrow Site

Year	PED	Construction Management	Mobilization Cost	Placement Cost[3]	Total Cost (FY19)
2022	$ 189,000	$ 95,000	$ 5,000,000	$ 3,772,000	$ 9,056,000
2025	$ 189,000	$ 95,000	$ 5,000,000	$ 3,772,000	$ 9,056,000
2028	$ 189,000	$ 95,000	$ 5,000,000	$ 3,772,000	$ 9,056,000
2031	$ 189,000	$ 95,000	$ 5,000,000	$ 3,772,000	$ 9,056,000
2034	$ 189,000	$ 95,000	$ 5,000,000	$ 3,772,000	$ 9,056,000
Total Remaining Cost (FY2019 Price Level)					**$ 45,280,000**

[3] Based on the Beach-fx estimated average quantity needed for the final nourishment activities in the 50-year total project model runs (700,000 CY)

The costs need to be discounted and amortized at the current discount rate (2.875%) and at the 7% OMB rate, as seen in the below tables.

Table 3-9: Average Annual Cost for Total Project Analysis – Carolina Beach Inlet

	Current FY19 Rate - 2.875%	OMB Rate - 7%
Average Annual Cost (POA 50 Years)	$ 1,718,289	$ 3,280,982

Table 3-10: Average Annual Costs Utilizing Sea Level Rise Analysis – Carolina Beach Inlet

	Base Sea Level	Intermediate Sea Level	High Sea Level
Average Annual Cost (2.875%,)	$ 2,209,000	$ 2,246,000	2,434,000

3.3.1.2 Offshore Borrow Cost Estimate

Future costs utilizing an offshore borrow area are based on the assumed unit cost ($95/CY) and the mobilization cost ($5,000,000) provided by cost engineering and are used in conjunction with the estimated nourishment volume and nourishment interval from Beach-fx to establish the FY2019 cost for each future nourishment. The following table details the remaining cost for Carolina Beach utilizing the offshore borrow area at FY2019 price levels.

Table 3-11: Carolina Beach Cost Estimate – Offshore Borrow Site

Year	PED	Construction Management	Mobilization Cost	Placement Cost[4]	Total Cost (FY19)
2022	$ 191,000	$ 95,000	$ 5,000,000	$ 5,010,000	$ 10,296,000
2025	$ 191,000	$ 95,000	$ 5,000,000	$ 5,010,000	$ 10,296,000
2028	$ 191,000	$ 95,000	$ 5,000,000	$ 5,010,000	$ 10,296,000
2031	$ 191,000	$ 95,000	$ 5,000,000	$ 5,010,000	$ 10,296,000
2034	$ 191,000	$ 95,000	$ 5,000,000	$ 5,010,000	$ 10,296,000
Total Remaining Cost (FY2019 Price Level)					**$ 51,480,000**

Costs have then been annualized in the exact same fashion outlined above for Carolina Beach Inlet and have been summarized in the following two tables.

[4] Based on the Beach-fx estimated average quantity needed for the final nourishment activities in the 50-year total project model runs (700,000 CY)

Table 3-12: Average Annual Cost for Total Project – Offshore Borrow Area

	Current FY19 Rate - 2.875%	OMB Rate - 7%
Average Annual Cost (POA 50 Years)	$ 1,953,567	$ 3,730,233

Table 3-13: Average Annual Costs Utilizing Sea Level Rise Analysis – Offshore Borrow Area

	Base Sea Level	Intermediate Sea Level	High Sea Level
Average Annual Cost (2.875%, 15 Years)	$2,496,000	$2,535,000	$2,749,000

3.3.2 <u>Summary of Authorized Project – Total Project Analysis</u>

The following tables summarize the average annual cost for Carolina Beach for the Total Project analysis and demonstrate the difference based on the borrow area utilized for the remaining four periodic nourishments.

Table 3-14: Complete Cost Summary for Total Project Analysis

	Current FY19 Rate - 2.875%	OMB Rate - 7%
Total Average Annual Cost – Carolina Beach Inlet	$ 1,718,213	$ 3,280,982
Total Average Annual Cost - Offshore Borrow Source	$ 1,953,530	$ 3,730,233

3.4 Benefit Cost Ratios of the Authorized Plan

The following table summarize the various benefit-cost ratios for the Carolina Beach Authorized

Table 3-15: Carolina Beach Authorized Project Total Project Benefit-Cost Ratio

Plan	AAEQ Cost	AAEQ Benefit	Net Benefit	Benefit Cost Ratio
Carolina Beach Inlet, 2.875 %	$1,718,213	$6,758,000	$5,039,787	3.9
Carolina Beach Inlet, 7.0%	$3,280,982	$4,486,000	$1,205,018	1.4
Offshore Borrow Area, 2.875%	$1,953,530	$6,758,000	$4,804,470	3.5
Offshore Borrow Area, 7.0%	$3,730,233	$4,486,000	$755,767	1.2

DRAFT

APPENDIX G

SECTION 404(b)(1) GUIDELINES ANALYSIS

CAROLINA BEACH, NC

BEACH RENOURISHMENT EVALUATION REPORT

JUNE 2019

Prepared by:

Environmental Resources Section
U.S. Army Corps of Engineers, Wilmington District

DRAFT

CAROLINA BEACH

BEACH RENOURISHMENT EVALUATION REPORT

NEW HANOVER COUNTY, NORTH CAROLINA

Preliminary Evaluation of Section 404 (b) (1) Guidelines 40 CFR 230

This evaluation covers the placement of all fill material into waters and wetlands of the United States required for the maintenance of the Wilmington Beach, New Hanover County, North Carolina. The proposed project plans to place inlet sediment on the ocean beaches of Carolina Beach. Please note, prior to any construction the required Section 401 Water Quality Certificates from the NC Division of Water Quality will be obtained for the project and all conditions/restrictions will be complied with.

Section 404 Public Notice No. CESAW-TS-PE-

	Preliminary 1/	Final 2/
1. <u>Review of Compliance (230.10(a)-(d))</u> A review of the NEPA Document indicates that:		
a. The discharge represents the least environmentally damaging practicable alternative and if in a special aquatic site, the activity associated with the discharge must have direct access or proximity to, or be located in the aquatic ecosystem to fulfill its basic purpose (if no, see section 2 and NEPA document);	YES ☒ NO☐	YES ☐ NO☐
b. The activity does not: 1) violate applicable State water quality standards or effluent standards prohibited under Section 307 of the CWA; 2) jeopardize the existence of federally listed endangered or threatened species or their habitat; and 3) violate requirements of any federally designated marine sanctuary (if no, see section 2b and check responses from resource and water quality certifying agencies);	YES☒ NO☐*	YES☐ NO☐
c. The activity will not cause or contribute to significant degradation of waters of the U.S. including adverse effects on human health, life stages of organisms dependent on the aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values (if no, see section 2);	YES☒ NO☐	YES☐ NO☐
d Appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem (if no, see section 5).	YES☒ NO☐*	YES☐ NO☐

<u>Proceed to Section 2</u>

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2.Technical Evaluation Factors (Subparts C-F) **N/A** **Not Significant** **Significant**

a. Physical and Chemical Characteristics of the Aquatic Ecosystem (Subpart C)

	N/A	Not Significant	Significant
(1) Substrate impacts.		X	
(2) Suspended particulates/turbidity impacts		X	
(3) Water column impacts.		X	
(4) Alteration of current patterns and water circulation.		X	
(5) Alteration of normal water fluctuations/hydroperiod.		X	
(6) Alteration of salinity gradients.		X	

b. Biological Characteristics of the Aquatic Ecosystem (Subpart D)

	N/A	Not Significant	Significant
(1) Effect on threatened/endangered species and their habitat.		X	
(2) Effect on the aquatic food web.		X	
(3) Effect on other wildlife (mammals birds, reptiles, and amphibians).		X	

c Special Aquatic Sites (Subpart E)

	N/A	Not Significant	Significant
(1) Sanctuaries and refuges.	NA		
(2) Wetlands.	NA		
(3) Mud flats.	NA		
(4) Vegetated shallows.	NA		
(5) Coral reefs.	NA		
(6) Riffle and pool complexes.	NA		

d. Human Use Characteristics (Subpart F)

	N/A	Not Significant	Significant
(1) Effects on municipal and private water supplies.	NA		
(2) Recreational and commercial fisheries impacts		X	
(3) Effects on water-related recreation.		X	
(4) Aesthetic impacts.		X	
(5) Effects on parks, national and historical monuments, national seashores, wilderness areas, research sites, and similar preserves.		X	

Proceed to Section 3

3. Evaluation of Dredged or Fill Material (Subpart G) 3/

a. The following information has been considered in evaluating the biological availability of possible contaminants in dredged or fill material. (Check only those appropriate.)

(1) Physical characteristics ☒

(2) Hydrography in relation to known or anticipated sources of contaminants ☒

(3) Results from previous testing of the material or similar material in the vicinity of the project ☒

(4) Known, significant sources of persistent pesticides from land runoff or percolation ☐

(5) Spill records for petroleum products or designated (Section 311 of CWA) hazardous substances ☐

(6) Other public records of significant introduction of contaminants from industries, municipalities, or other sources ☒

(7) Known existence of substantial material deposits of substances which could be released in harmful quantities to the aquatic environment by man-induced discharge activities ☐

(8) Other sources (specify). ☐

List appropriate references.

b. An evaluation of the appropriate information in 3a above indicates that there is reason to believe the proposed dredge or fill material is not a carrier of contaminants, or that levels of contaminants are substantively similar at extraction and disposal sites and not likely to result in degradation of the disposal site.** YES ☒ NO ☐*

Proceed to Section 4

4. Disposal Site Determinations (230.11(f)).

a. The following factors as appropriate, have been considered in evaluating the disposal site.

(1) Depth of water at disposal site. ☒

(2) Current velocity, direction, and variability at disposal site ☒

(3) Degree of turbulence. ☒

(4) Water column stratification ☒

(5) Discharge vessel speed and direction ☒

(6) Rate of discharge ☒

(7) Dredged material characteristics (constituents, amount and type of material, settling velocities). ☒

(8) Number of discharges per unit of time. ☒

(9) Other factors affecting rates and patterns of mixing (specify)

List appropriate references.

b. An evaluation of the appropriate factors in 4a above indicates that the disposal site and/or size of mixing zone are acceptable. YES ☒ NO ☐*

5. Actions to Minimize Adverse Effects (Subpart H).

All appropriate and practicable steps have been taken, through application of recommendations of 230.70-230.77, to ensure minimal adverse effects of the proposed discharge. List actions taken. YES ☒ NO ☐*

Return to section 1 for final stage of compliance review.

6. Factual Determinations (230.11).

A review of appropriate information as identified in items 2-5 above indicates that there is minimal potential for short- or long-term environmental effects of the proposed discharge as related to:

a. Physical substrate at the disposal site (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

b. Water circulation, fluctuation, and salinity (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

c. Suspended particulates/turbidity (review sections 2a, 3, 4, and 5). YES ☒ NO ☐*

d Contaminant availability (review sections 2a, 3, and 4). YES ☒ NO ☐*

e. Aquatic ecosystem structure and function (review sections 2b and c, 3, and 5). YES ☒ NO ☐*

f. Disposal site (review sections 2, 4, and 5). YES ☒ NO ☐*

g. Cumulative impact on the aquatic ecosystem. YES ☒ NO ☐*

h. Secondary impacts on the aquatic ecosystem. YES ☒ NO ☐*

7. Findings.

a. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines. . . . . ☒

b. The proposed disposal site for discharge of dredged or fill material complies with the Section 404(b)(1) guidelines with the inclusion of the following conditions:. . . . . ☐

c. The proposed disposal site for discharge of dredged or fill material does not comply with the Section 404(b)(1) guidelines for the following reasons(s):

(1) There is a less damaging practicable alternative . . . . ☐

(2) The proposed discharge will result in significant degradation of the aquatic ecosystem . . . . ☐

(3) The proposed discharge does not include all practicable and appropriate measures to minimize potential harm to the aquatic ecosystem. ☐

___________________________ Date: _____________________

Kevin P. Landers Sr.
Colonel, U.S. Army
District Engineer

*A negative, significant, or unknown response indicates that the permit application may not be in compliance with the Section 404(b)(1) Guidelines.

1/ Negative responses to three or more of the compliance criteria at this stage indicate that the proposed projects may not be evaluated using this "short form procedure." Care should be used in assessing pertinent portions of the technical information of items 2 a-d, before completing the final review of compliance.

2/ Negative response to one of the compliance criteria at this stage indicates that the proposed project does not comply with the guidelines. If the economics of navigation and anchorage of Section 404(b)(2) are to be evaluated in the decision-making process, the "short form evaluation process is inappropriate."

3/ If the dredged or fill material cannot be excluded from individual testing, the "short-form" evaluation process is inappropriate.

EXECUTIVE SUMMARY

The Flood Control Act of 1962 and the Water Resources Development Act of 1986 granted the Carolina Beach (CB) Coastal Storm Damage Reduction (CSDR) project a 50-year authorization from the initial construction commencement date. The project design strives to provide hurricane and wave protection to the Town of Carolina Beach (Town) through periodic beach nourishment events. The three-year cycled maintenance events can place material acquired from the engineered Inshore Dredge Material Management Site in Carolina Beach Inlet south along approximately 14,000 feet (ft.) of shoreline from the Town's northern municipal limits. The CSDR template contains a 25-ft. wide dune at elevation +13.5 ft. National Geodetic Vertical Datum (NGVD) [+15.4 ft. mean low water (MLW)] adjoining a 50-ft. wide berm at elevation +10.5 ft. NGVD (+12.4 ft. MLW). The authorized template also allows a varying construction berm width at elevation +5.5-ft NAVD (+6.5 NGVD; +8.4-ft MLW) as advance nourishment to offset the anticipated long-term erosional forces. As authorized in 1962, the project would protect against a 100-year storm surge. [United States Army Corps of Engineers (USACE), 1992]. The benefit cost ratio (BCR) for the project equals 3.5 based on analysis of the fiscal year (FY) 2016 CSDR maintenance event. The USACE found the project provided an average annual benefit of $10.6 million (M) with an average annual cost of approximately $3.0 M. The USACE calculated the BCR based on a 7% interest rate (New Hanover County, 2015).

The CB CSDR project commenced in 1964 and would have exceeded its federal authorization timeline in 2014. The authorization has received a 6-year extension through the Water Resources Reform and Development Act (WRRDA) of 2014 and 2016 allowing the project to successfully compete for its 3-year maintenance cycles in FY2016 and FY2019. WRRDA 2014 also provided a potential project extension, through a Beach Renourishment Evaluation Report (BRER), if continuing the project for an additional 15 years would be in the federal government's continued financial interest. As part of the BRER analysis, WRRDA 2014 required the local sponsor of the CSDR project to provide a plan for reducing the risk to property and life (Public Law (PL) 113-121, 2014). This report details the actions taken by the County, the Town and elements of the State of North Carolina (the non-Federal stakeholders) to facilitate the risk reduction for residents, guests and infrastructure of Pleasure Island, as well as efforts taken to insure the CSDR project's ongoing viability. The following items represent local risk reduction efforts in support of the CSDR project.

- Project performance monitoring and analysis;
- Dune management initiatives;
- Management of Carolina Beach Inlet;
- Development of floodplain management plans;
- Adopting state and local construction regulations;
- Proactively monitoring sea level change policy and adaptation measures and
- Establishment of action plans for natural disasters.

Project Performance Monitoring & Analysis

The County and Town initiated a shoreline monitoring program in 2014 to analyze the CSDR project performance. The monitoring includes physical and analytical procedures focused on describing the shoreline migration and volumetric change experienced within the project area and adjacent shoreline. The monitoring provides an initial step for evaluating the CSDR project's reduction in storm damage risk afforded to Carolina Beach's upland infrastructure. Annual surveys of the beach face along Pleasure Island (Carolina Beach, Kure Beach, Ft. Fisher and Carolina Beach Inlet) help identify the shoreline migration and volumetric change trends. The Town and County use this information as a guide for improving management strategies involving the CSDR project and Carolina Beach Inlet.

The surveys and monitoring efforts provide the foundation for an analytical and numeric modeling analysis used to estimate the erosion and storm damage risk associated with discontinuing the CB CSDR project. The analyses use the previously monitored shoreline trends to estimate the potential damage anticipated if the federal government discontinues the CSDR project. Based on a numeric modeling study, the CB CSDR project helps alleviate an infrastructure property risk totaling approximately $187,867,033.00. Additional losses would also be applicable for structure relocation costs and small business investments. This estimated financial loss would likely result from the shoreline recession expected over the next 15-year period without the CB CSDR project. Appendix A shows the analytical analysis results.

Dune Management Initiatives

The Town and County understand the importance of maintaining a primary dune feature to help reduce the storm risk to upland infrastructure. On an annual basis, the Town plans and implements several initiatives for managing and enhancing the dune system. These initiatives include the following:

- Inspections and educational programs;
- Nuisance vegetation management and removal;
- Restoration and enhancement of dune vegetation;
- Access management within concentrated areas of pedestrian foot traffic;
- Establishment of public parking locations within walking distance of managed beach access points and
- Continued maintenance of the federally constructed northern rock revetment.

The Town strives to enhance or repair the dune system in the dormant winter months rather than the more active summer months. The Town also conducts final inspections of the dunes in the spring and makes any necessary repairs prior to May of each year. The Town maintains this schedule to avoid working on the beach during turtle nesting season. Possible repair work may include replacing nuisance vegetation found in the dune system with native plants. Nuisance vegetation may spread throughout the dune system and hinder the growth and subsequent dune stabilization afforded by the native plants. Invasive vegetation may create negative effects for the wildlife utilizing the dune complex and makes the area more susceptible to aeolian erosion and storm damage.

In efforts to protect the dunes, the Town also maintains access paths with educational signage for beach goers. The access paths may include foot trails or dune walkover structures depending on the expected pedestrian traffic volume. The Town designs the foot trails to traverse over as opposed to through a dune. This helps reduce the risk of creating a weak or low point in the dune system accessible by storm or flood waters. The Town places walkover structures where heavier pedestrian traffic may be expected. The walkover structures go above the dune to minimize any obstructions to the dune or vegetation establishment/growth. The Town also constructed a boardwalk along the area's most active central business district, which helps protect the dunes and established vegetation by encouraging pedestrian traffic through managed paths.

The public signage provided by the Town advises beachgoers on safe practices in an effort to enhance their visits. These may include tips for avoiding rip currents, explanations of the lifeguards' flag signals, seasonal pet accessibility as well as handicap access. The signs also include instructions or rules applicable to help protect the dune system.

Establishment of the public parking facilities helps to protect the dune system by providing convenient parking for beach goers. The Town sites the parking facilities adjacent or approximate to beach access-points well behind the dune system and in association with public infrastructure. Planned parking locations facilitate controlled access to the beach.

The Town also helps protect the dune system through engineered or alternative means such as donated Christmas trees. The Town accepts Christmas tree donations each year and works with volunteers to identify beneficial sand trapping areas for tree placement. The Town also holds the sole responsibility for maintaining the engineered rock revetment located along CB's north end. The USACE built the rock revetment supplementing the CSDR project. However, the Town must maintain the revetment as an obligation of the project's local sponsorship. The Town has reset approximately 80% of the exposed rock within the revetment since 2013 and continually monitors the structure's condition.

Carolina Beach Inlet Management

The County and the Town work proactively to maintain the function of Carolina Beach Inlet in regards to reducing the storm damage risk to infrastructure, property and life. A significant improvement was the County obtaining state and federal maintenance dredging permits including the inlet and the Atlantic Intracoastal Waterway (AIWW) crossing. Historically, only the USACE held the proper authorizations to dredge the inlet and adjoining AIWW crossing. However, concerns with federal funding and equipment availability prompted the County to partner with the State of North Carolina to obtain the locally held permits. The County was issued the permits in May 2016 and now holds the authority to maintain the inlet and AIWW crossing in the absence of federal funds and plant accessibility. The NC Division of Coastal Management (NCDCM) Permit 50-16 and USACE General Permit (GP) 198000291 provide the authorizations directly to New Hanover County.

The County's inlet maintenance dredging authorization helps provide reasonable navigable passage through the inlet. This helps reduce the risk for nearby boaters in the Atlantic Ocean seeking a safe harbor. The authorization also allows placement of the dredge material as beneficial re-use along and adjacent to reaches of Freeman Park. Such beneficial reuse may help reduce the storm damage risk by allowing the maintenance sand to remain in the in-situ shoreline transport system. Under the federal authorization, the USACE maintained full control over placement of the dredge material. However, the County permit provides a local option for placing the material in any of the County's authorized CB locations. County options include side casting the material adjacent to the inlet cut, placing the material as beneficial re-use along Freeman Park or within the CSDR template via a hydraulic pipeline dredge, placed in the nearshore area via a hopper dredge or the inshore dredge material management site (IDMMS).

The sustainability of the CSDR's IDMMS depends on the passive recharge of the borrow area and the ability for sand to migrate along the inlet shoulders. The USACE estimates approximately 250,000 cubic yards/year (cy/yr) passively move into the engineered borrow site. The County's authorization provides for maintaining the Carolina Beach Inlet's authorized template of an 8-ft. depth and 150-ft. bottom width. The County's inlet management options enhance the probability that sediment will continue to passively migrate or be actively placed in the IDMMS.

Floodplain Management

The stakeholders understand new development may be at a significant risk if proper floodplain management is not implemented. New development can increase stormwater runoff by clearing vegetated pervious habitat and replacing with impervious surfaces. The County and the Town continue to analyze and review new possibilities for improving management strategies. Current floodplain management initiatives conducted by the County and Town include the following:

- Adoption of a Flood Damage Prevention Ordinance;
- Participation in the National Flood Insurance Program (NFIP) and
- Modifying existing development, structures and utilities.

The Flood Damage Prevention Ordinance provides standards to supplement the North Carolina Department of Environmental Quality (NCDEQ) coastal stormwater rules. These guidelines regulate uncontrolled stormwater runoff from new development. The ordinance addresses construction in multiple types of floodplain areas and focuses on a proactive development approach. The NFIP offers insurance to properties within flood prone areas but also provides recommendations to help protect against flood damage. The Federal Emergency Management Agency (FEMA) manages the program and offers a reduction in insurance premiums for communities that implement NFIP recommendations. FEMA uses a Community Rating System (CRS) to evaluate premium reductions available to a community. A community receives an improved CRS value based on the number and type of flood prevention activities implemented.

The Town also works to improve existing structures and utilities reducing their storm and flood damage risk. The Town pursues grant opportunities to raise existing structures above the current base flood elevation (BFE) as well as to relocate utilities below grade or improve their lifecycle and maintenance conditions. Since 2009, the Town has received funding to raise 14 structures and has identified at least 10 additional structures. The Town also plans street and drainage projects based on available funding to help alleviate flooding issues including potential sound side effects.

State & Local Construction Regulations

The Town further attempts to reduce the storm damage risk generated from new construction by regulating state and locally adopted codes and requirements. The Town follows requirements established by the NCDCM for citing new construction along the oceanfront as well as within areas of environmental concern (AEC). This includes requiring applicable setback distances to help protect against normal erosion. NCDCM establishes minimum distances from the seaward most line of stable vegetation for new construction. These setback distances are generated from the proposed structure's size and the local erosion rate. The Town has also adopted a 'development line' to provide additional safeguards for reasonable development for areas landward of the CSDR project. Furthermore, NCDCM also prohibits citing new construction on top of the oceanfront or primary dune system.

The Town subscribes to the International Code Council (ICC) of current safe building practices. Town staff will inspect all new construction to document compliance with the current ICC practices. The Town also protects against the storm damage risk generated from derelict or damaged structures left unrepaired through the establishment of minimum housing standards. Town staff monitors and inspects any damaged structures appearing to fall below the established minimum standards. The Town will work with the legal owner but may also seek legal action to accomplish any necessary repair/removal actions.

Sea Level Change and Natural Disaster Action Plans

The Town recognizes sea level change may increase a coastal communities storm damage risk. The risk would be further increased in the event of a natural disaster such as a major hurricane or tsunami. Although the ultimate effects of sea level change remain unclear; the Town continues to monitor, review and consider adaptation policies and resiliency recommendations from the state and federal government. The Town has taken steps to help reduce the risk to property and life presented by a natural disaster. The Town has adopted emergency action plans that are implemented during a major event. This includes major hurricanes or tsunamis as well as a nuclear event at the Brunswick County Nuclear Power Plant. The plans provide emergency protocols for notifying residents and guests of a potential threat as well as follow-up information to help track the situational status. The plans include evacuation and re-entry procedures with combined efforts from the Town, Kure Beach and the County. Implementation of the plans will help reduce confusion and aid in distributing critical information for the residents and guests of Pleasure Island.

The items discussed above provide an avenue followed by the County and the Town for implementing risk reduction measures for the residents and guests of Pleasure Island. Combined with the continued achievements established by the USACE and County CSDR project and in coordination with the County and the State, these elements form a solid foundation to help protect and recover from a storm event or natural disaster.

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AEC	Area of Environmental Concern
BCR	Benefit Cost Ratio
BFE	Base Flood Elevation
BRER	Beach Renourishment Evaluation Report
CB	Town of Carolina Beach
County	New Hanover County
CRC	Coastal Resource Commission
CRS	Community Rating System
CSDR	Coastal Storm Damage Reduction
CSP	Critical Service Personnel
EOC	Emergency Operations Center
ESP	Essential Service Personnel
FEMA	Federal Emergency Management Agency
GP	General Permit
HMA	Hazard Mitigation Assistance
IDMMS	Inshore Dredge Material Management Site
M	Million
MHWL	Mean High Water Line
MLW	Mean Low Water
NCAC	North Carolina Administrative Code
NCDCM	North Carolina Division of Coastal Management
NCDEQ	North Carolina Department of Environmental Quality
NCDWR	North Carolina Division of Water Resources
NCGS	North Carolina General Statute
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
PCA	Project Cooperation Agreement
PGL	Policy Guidance Letter
PL	Public Law
SRL	Sever Repetitive Loss
USACE	United States Army Corps of Engineers
WRDA	Water Resource Development Act
WRRDA	Water Resource Reform & Development Act

INTRODUCTION

The Carolina Beach (CB) & Vicinity Coastal Storm Damage Reduction (CSDR) Project obtained federal authorization under the Flood Control Act of 1962 in Public Law (PL) 87-874 [U.S. Army Corps of Engineers (USACE), 2010]. The project falls within the southern extents of New Hanover County, NC (County), along the shoreline of Pleasure Island. The project includes two (2) shoreline segments referenced as the Carolina Beach (CB) and Area South portions (Kure Beach). The CB portion covers approximately 14,000 lineal feet (ft.) of shoreline extending from the northern municipal limits abutting Freeman Park, located on the northern end of Pleasure Island, into the jurisdictional limits of CB (USACE, 1992). Figure 1 shows the limits of the CB CSDR project. The Area South project extends from the southern terminus of the CB Project and covers approximately 18,000 ft. of shoreline including a 1500-ft southern transition incorporating most of the Town of Kure Beach (USACE, 2010).

The project design strives to provide hurricane and wave protection through 3-year cycled CSDR maintenance events. The USACE's design basis aims to protect against a 100-year storm surge. The CB placement template contains a 25-ft. wide dune at elevation +13.5 National Geodetic Vertical Datum (NGVD) [+15.4 ft. mean low water (MLW)] adjoining a 50-ft. wide storm berm at elevation +10.5 NGVD (+12.4 MLW). The authorized template also allows a varying construction berm width at elevation +5.5-ft NAVD (+6.5 NGVD; +8.4-ft MLW) as advance nourishment to offset the anticipated long-term erosional forces.The benefit cost ratio (BCR) for the project equals 3.5 based on analysis of the fiscal year (FY) 2016 CSDR maintenance event. The USACE found the project provided an average annual benefit of $10.6 million (M) with an average annual cost of approximately $3.0 M. The USACE calculated the BCR based on a 7% interest rate (New Hanover County, 2016).

Both the Carolina Beach and the Area South (Kure Beach) projects received federal authorization for a 50-year period from their initial construction. For CB, the initial construction occurred in 1964 and federal participation was expected to conclude in 2014 (USACE, 2010). However, the Water Resources Reform and Development Act (WRRDA) of 2014 authorized a 3-year extension and the USACE to investigate through a Beach Renourishment Evaluation Report (BRER) if continuing the project another 15 years falls within the federal government's continued interest. As part of the BRER, WRRDA 2014 requires the non-federal sponsor to provide a plan for reducing risk to people and property throughout the project duration (PL 113-21, 2014). The following report details the actions taken by the County, the Town and elements of the State of North Carolina (the non-Federal stakeholders) to facilitate the risk reduction for residents and guests of Pleasure Island as well as efforts taken to insure the CSDR project's ongoing viability. The tasks or actions presented include the following:

- Project performance monitoring;
- Dune management initiatives;
- Management of Carolina Beach Inlet;
- Development of floodplain management plans;
- Adopting state and local construction regulations;
- Proactively monitoring sea level change policy and adaptation measures;
- Establishment of emergency procedures for major storm events and
- Addressing special circumstances unique to the community.

The CB CSDR project is the first example of such a project reaching its federal authorization lifecycle. As such, WRRDA 2014 granted a three (3) year extension to the federal authorization to allow time for the USACE to evaluate extending the project (PL 113-21, 2014) as well as allowing for an FY16 maintenance event. WRDA 2016 granted an additional 3-year extension allowing the CB project to compete for FY2019 maintenance funds. The BRER must be completed and considered before extending the federal authorization an additional 15 years. The Area South project (Kure Beach) did not initiate construction until 1997 and should maintain federal authorization through 2047.

PROJECT RELATED INITIATIVES

The County and the Town maintain an active involvement in reviewing the performance of the CSDR project to stay abreast of future expectations and potential issues. Apart from reviewing performance monitoring documentation generated by the USACE, the County and the Town conduct independent studies to gauge performance measures and protection levels afforded by the CSDR project. This includes annual shoreline monitoring data with additional analytical analyses to help ascertain the protection expected by continuing the project.

Annual Shoreline Monitoring

The County implemented an annual shoreline monitoring program in 2014 to help evaluate the CSDR's project performance. The work falls within a larger scope to evaluate the performance of all three (3) federal CSDR initiatives located within New Hanover County. This includes the CB and Area South (Kure Beach) segments as well as the Wrightsville Beach CSDR project.

As part of the monitoring, the County uses annual surveys to identify shoreline and volumetric trends occurring across the project area. The monitoring for CB includes the project area and adjacent shorelines along Freeman Park and Carolina Beach Inlet. Figure 1 shows the limits of the CB physical monitoring attributed to the CSDR project. The monitoring extends beyond the sand placement template to gauge how the adjacent shoreline responds to the overall project effects. This includes the sand transport within Carolina Beach Inlet and the engineered borrow site. The monitoring helps to show how the material diffuses from the project area and supplements protection levels on the adjacent shorelines. The monitoring also helps to quantify the sediment volume remaining within the project area and to identify erosional 'hotspots' where accelerated levels of sediment transport exist. This information assists decision makers in planning future nourishment events reducing the storm damage risk to infrastructure, property and life.

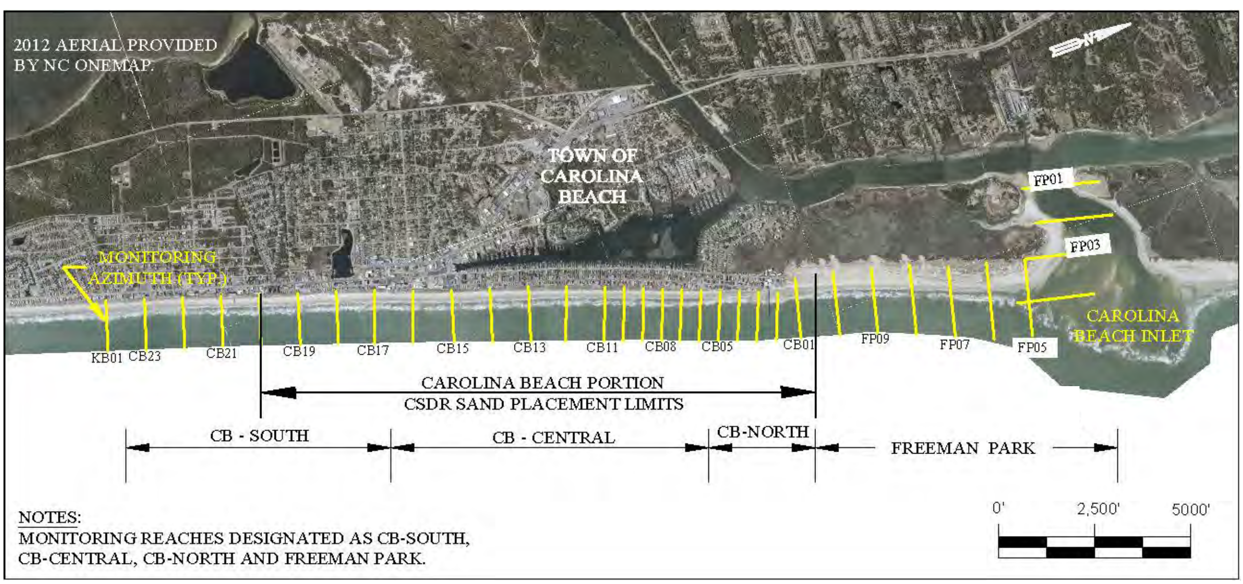

Figure 1. Carolina Beach CSDR Sand Placement & Physical Monitoring Limits

Risk Reduction Analysis

In an effort to evaluate the risk reduction afforded by the CB CSDR project, the County conducted an analysis using the monitoring data collected since 2014. The County supplemented this data with historical monitoring data collected by the USACE for 2006, 2007, 2009 and 2012 as well as shoreline data available from NCDCM. The additional data aids to establish a background or historical pattern anticipated for future shoreline trends with and without continuing the CB CSDR project.

Based on the data collected through 2016 from the annual surveys conducted by New Hanover County and the historical data provided by the USACE, the CB CSDR project limits experience an annual volumetric loss of approximately -230,000 cubic yards per year (cy/yr). This equates to an average annual loss of approximately -16.4 cubic yards per year for every linear foot of shoreline (cy/yr/lf) across the project area. Equating this volumetric loss into a shoreline loss yields an annual average shoreline recession of approximately -10.5 feet per year (ft/yr), or 0.6 ft for every cubic yard lost. Appendix A provides additional information on the process used to determine these values.

Based on these calculations, the CB CSDR provides a property and infrastructure value financial risk reduction for erosional losses totaling approximately $187.9M.00 over a 15 year period. Additional losses may also be applicable for structure relocation ($26.5M), lost tax base value ($150.4M) and annual tax revenues ($1.2M) and small business investments. These are the losses anticipated if the federal government fails to extend and fund the CB CSDR. Appendix A provides the analytical analysis and supplemental numeric modeling conducted to estimate the average annual shoreline recession and associated financial risk of discontinuing the CB CSDR. Table 1 shows the summary of the estimated financial risk reduction associated with extending the CB CSDR authorization for a 15 year period.

Table 1. Results of the Estimated Risk Reduction Associated with the CB CSDR

Category		Units	Financial Risk
Structures		147 ea.	$187,779,317.00
	Residential	127	$153,737,417.00
	Commercial	19	$33,706,900.00
	Government	1	$335,000.00
Waterline		65 lf.	$5,798.00
Roadway		185 lf.	$81,918.00
TOTAL			**$187,867,033.00**

Both the analytical and modeling efforts advance the understanding of the property and infrastructure value at risk associated with discontinuing the CSDR project. The modeling tasks utilize the GenCade and SBEACH platforms to evaluate the financial value of the infrastructure protected by the CB CSDR over the next 15 years. GenCade combines the theory and computational power of GENESIS (Hanson and Kraus, 1989) and Cascade into a single module. Hanson and Kraus developed GENESIS in 1989 as part of work conducted for the Coastal & Hydraulics Laboratory (CHL) of the USACE. GENESIS calculates the shoreline change (1-D) anticipated in response to management initiatives such as coastal structures or sand placement projects (USACE, 2016a). GENESIS provides project level results generally accepted for detailed design estimates (Frey et al, 2012). The Cascade model provides regional scale estimates for sediment transport and shoreline evolution and addresses the more complex coastal processes of transferring sediment through inlets or tidal-shoal complexes (Larson et al., 2002). GenCade combines the resources of GENESIS and Cascade to provide design level estimates on the response to nourished shorelines adjacent to inlets or other transport gradients. The USACE developed GenCade through the CHL, with assistance from the Coastal Inlets Research Program [(CIRP) Frey et al, 2012]. SBEACH provides answers concerning cross-shore transport of sediment during storms. For this risk reduction study, it was deemed important to capture both expected shoreline and potential storm-induced change to accurately quantify potential risk to adjacent infrastructure.

DUNE MANAGEMENT

Dune management satisfies a significant role in helping to reduce the storm damage risk to infrastructure, property and life along the coast. The County and the Town have implemented a proactive strategy to help stabilize and enhance the CB dune system. These efforts aid in reducing the risk of storm and flood damage occurring during major weather events, including the potential loss of life property and infrastructure. The implemented strategy includes monitoring and inspection programs as well as enhancement and stabilization initiatives. The Town also provides and maintains specific public infrastructure supporting and sustaining the dune system.

Inspection & Educational Programs

The Town conducts numerous inspections of the dune system each year. The inspections cover the primary dune feature including the vegetation cover and beach access walkways/paths. The Town also posts educational signs to help inform the general public on local practices to sustain the dunes.

During early spring prior to the tourist season, the Town schedules an annual inspection while routinely assessing the dune status throughout the summer and fall. The inspections document any access locations showing significant damage or refurbishment needs. The Town implements corrective actions or improvements prior to the sea turtle nesting season. In accordance with the North Carolina Administrative Code (NCAC) 15A 07H 1805(f), this generally requires completion of all work in the dune system by May 1st of each year; however, under extenuating circumstances this timeline may be extended. The Town addresses any outstanding issues after turtle nesting season begins on a prioritization and budgetary demand basis while also maintaining compliance with the NCAC.

The Town also works with North Carolina Sea Grant (Sea Grant) to identify potential improvements for the dune system. Sea Grant offers outreach programs for research and education concentrating on coastal issues and maintains an office within the County. Sea Grant works through publically funded grants and fellowships to universities, government agencies and coastal businesses (Sea Grant, 2016). Sea Grant conducted a dune inspection during the summer of 2015 in partnership with the County and the Town. Future inspections will occur on a periodic basis based on the Town's concerns and condition of the dune system.

As referenced, the Town maintains educational signs approximate to the dune access paths to inform beach-goers on the importance of the coastal dunes and shoreline systems. The signs help instruct readers how to help preserve the dune system as well as informs them of safety precautions while recreating. The safety precautions include explanations on how to interpret the lifeguard stations' flags and how to escape rip currents. Figure 2 provides an example of the educational signs provided by the Town.

Figure 2. Oceanfront Educational Signage

Invasive Vegetation Management and Removal

The Town also helps protect the dune and beach system by removing non-native invasive vegetation [e.g. Beach Vitex (*Vitex rotundifolia*)] that may out-compete the native plants considered necessary for dune stabilization. Invasive plants may create a negative environment for other local/typical flora and fauna. Non-indigenous and/or invasive vegetation can negatively affect endangered or threatened species as well as dune sustainability.

Native grasses within the dune and beach system can provide habitat in addition to helping stabilize the area. The root system of a dune planting offers an anchor for shifting sands during an erosional event. The root system and to a lesser degree the blades also trap/capture windblown sand to help enhance the dune system. The grassy blades may also offer food or protection to species within the dune system. Established vegetation may help to slow or prevent wave uprush. These actions help reduce the flood risk to local infrastructure landward of the dune features while sustaining important natural habitats.

The Town regulates the access paths' locations and removal of nuisance vegetation through ordinances. Appendix B provides the following ordinances addressing access across the dune system and removal of nuisance vegetation.

- Section 10-13: Public Access to and from the Beachfront of the Atlantic Ocean;
- Section 10-74: Beach Vitex Prohibited and
- Section 11-55: Sand Dunes.

The Town will continue to work with public and private entities to protect and preserve the beach and dune system. New ordinances will be added as needed to address any necessary changes or additions to the existing regulations.

Restoration and Enhancement of Dune Vegetation

The Town works with volunteer groups to help enhance the dune features. The volunteer groups assist the Town to monitor and install new plantings where needed along the dune complex. The Town monitors the dune vegetation periodically throughout the year and notes where improvements may be warranted. Generally, in the winter months, the Town will coordinate with the volunteers to install new vegetation within identified areas. Town staff works to prioritize sites with the available funding by ranking the planting areas based on need and location. The areas requiring the greatest amount of plantings receive first priority to concentrate construction efforts. Utilizing volunteer staff also helps to improve the project by maximizing the funding benefits. Figure 3 shows a representative picture of the dune vegetation established along Carolina Beach.

Town staff also works with local residents to place donated Christmas trees along the dune front as a means for entrapping sand. The Town adheres to the standards published by the State of North Carolina through the Coastal Area Management Act (CAMA) for placement of the Christmas trees. The trees provide an additional buffer to dissipate wind and trap moving sand on the dune system during storm events or normal weather patterns. The Town partners with the Surfrider Foundation to place donated Christmas trees along project reaches and within Freeman Park.

Figure 3. Typical Vegetation Maintained within the Primary Dune System (post FY16 CSDR maintenance event)

Access Management

The Town continually works to maintain access paths to aid in protecting the beach and dune system. The Town permits private access paths partners for ocean front property owners. The Town also works with federal, state and county officials to designate appropriate paths for the general public's use. The access paths take the least destructive path over the dune system and avoid cutting through the dunes. When available, the paths include walkover structures, including boardwalks, to avoid interference with the dune system. These actions help in minimizing the potential impacts of access paths and allow the dune system to thrive. Preserving the dune height eliminates a potential throughway for flood waters and waves generated from offshore storm events. This reduces the risk of flooding and helps protect the public infrastructure. Figure 4 shows an example of the dune access paths and walkover structures maintained by the Town.

Figure 4. Typical Dune Access (Walkover Structure & Foot Path)

The Town maintains a public boardwalk in areas receiving the greatest amounts of pedestrian traffic as an additional measure to protect the dune system. The boardwalk remains landward of the dune system to allow continued sand accumulation. Figure 5 shows a typical view of the boardwalk position landward of the primary dune along the CB oceanfront. Without the boardwalk, the high volume of pedestrian traffic would most likely trample the dune and lower the feature's established elevation. This would increase the risk of flood damage to the infrastructure along the central business district behind the boardwalk feature. The Town inspects the boardwalk annually during the spring and prior to the tourist season to identify any necessary repair work. During the summer months, when activity on the boardwalk peaks, the Town inspects the structure weekly.

The Town has initiated a Boardwalk Improvement Project in partnership with the County, the NC Division of Water Resources (NCDWR) and the NC Division of Coastal Management (NCDCM). The central business district improvements will help the Town provide a continued safe and attractive facility for beach access. These improved and managed accesses will help reduce the Town's risk of potential storm damage through continued dune management (Town of Carolina Beach, 2016b).

Figure 5. Carolina Beach Boardwalk & Primary Dune

Public Parking

The establishment of public parking also assists to minimize potential impacts to the dune system. Parking locations positioned within ¼ mile from a public access point help to direct beach goers toward designated dune crossings. Maintaining an adequate volume of public parking locations within a ¼ mile radius from any beach access point also satisfies a requirement for federal participation in the CSDR project. In order for the federal government to continue cost-sharing, adequate public parking and access must be maintained (USACE, 2010). The Town has provided an adequate quantity of parking locations in accordance with the federal cost share agreement since the initiation of the project cooperation agreement (PCA). The Town intends to continue this management practice of maintaining public parking locations in accordance with the PCA throughout the life of the project. Appendix C shows approximately 261 public parking spaces currently reside within ¼ of mile from public accesses. The Town and NCDCM place signage to identify the public parking and access locations for beach goers. This helps improve the potential for the general public to utilize the sites. Figure 6 shows examples of the public parking/access signage.

Figure 6. Typical Public Parking & Access Signage

Northern Rock Revetment

The northern rock revetment comprises another prominent feature along the CB oceanfront completed by the USACE in 1973 to further reduce erosional effects and the potential risk of storm damage. The Town partnered with the USACE for the construction of the revetment within the northern extent of the CSDR footprint when inlet influenced erosion rates required additional management actions. The USACE constructed the revetment supplementing the CSDR; however, the Town now holds full responsibility for maintaining the structure. The maintenance work on the structure remains exempt from state permitting requirements in accordance with NCGS 113A-103(5) (b) (5). In addition, federal permit requirements do not apply since the work does not extend seaward of the MHWL (USACE, 2016b). As part of their purview to maintain the structure, the Town repositioned approximately 80% of the exposed stone within the structure in 2013 at a cost of approximately $12,000 (Hardison, 2016). The Town conducted additional maintenance in 2015 to further rehabilitate the structure. Figure 7 below shows the current condition of the revetment following the 2016 periodic maintenance of Carolina Beach.

Figure 7. Northern Rock Revetment after the 2016 CSDR Maintenance Event

MANAGEMENT OF CAROLINA BEACH INLET

Carolina Beach Inlet provides a substantial contribution towards helping reduce the risk to infrastructure, property and life for citizens and visitors of Pleasure Island; the County and NC. The inlet provides an accessible connection between the Atlantic Ocean and the AIWW for small recreational, fishing and commercial vessels. The inlet connection provides a route to safe harbor for boaters nearby in the Atlantic Ocean. In addition, an engineered borrow site within the inlet throat serves as a designed sediment trap for the CSDR project (USACE, 1992). The County, the Town and the State take an active role in managing Carolina Beach Inlet through support of maintenance dredging and beneficial re-use alternatives. The County and Town continuously investigate strategies that may help enhance the performance or management of Carolina Beach Inlet as discussed below.

Inlet Management Strategies

An important inlet maintenance strategy pursued by the County, the Town and the NCDWR involved obtaining held permits to maintain Carolina Beach Inlet. Historically, the USACE has completed maintenance work under federal authorizations. However, the USACE's dependency on federal funding and a limited shallow draft dredge fleet has proven problematic. By acquiring state and federal permits, the County and the Town can continue the maintenance operations independent of federal participation. This establishes a secondary means for maintaining the inlet's access when federal funding or dredge plant access is unavailable.

In partnership with the Town and the NCDWR, the County obtained the state and federal permits to conduct the maintenance operations in May 2016. The County's authority to maintain the inlet will allow continued maintenance dredging reducing the risk of lost access to a protective harbor. The next navigable inlet in proximity to Carolina Beach Inlet is Masonboro Inlet to the north and the Cape Fear River entrance to the south. Masonboro Inlet lies approximately 8 miles to the north of Carolina Beach Inlet and the Cape Fear River entrance falls approximately 21 miles to the south. Therefore, the use of Carolina Beach Inlet significantly reduces the travel distance for small recreational boaters and commercial interests.

The beneficial re-use of dredge material from the maintenance activities also provides a secondary benefit to the inlet management strategies. The placement of beneficial re-use material along Freeman Park's oceanfront can help to provide protection from storm wave impacts on public infrastructure. During inlet maintenance events conducted by the USACE, the local stakeholders do not have the authority to manage the material placement without consent of the USACE. However, the newly obtained local authorizations provide the County the ability to place the dredge material within any of the approved locations. This may include side-casting the material adjacent to the inlet cut or placing the material as beneficial re-use within the approved locations along Freeman Park. Beneficial re-use material may be placed in the nearshore or along the beach front. Figure 8 shows the typical inlet footprint requiring maintenance dredging and the beneficial re-use material placement sites.

CSDR Benefit

The management of Carolina Beach Inlet also plays a vital role in the long term performance of the federal and County CSDR project, as the engineered borrow site resides adjacent the inlet throat. Figure 9 shows the plan view location of the engineered borrow site within the inlet. The USACE estimates 250,000 cubic yards (CY) passively migrates into the engineered borrow site on an annual basis (USACE, 1992). This material migration provides a substantial quantity of the beach quality sand required for the CSDR project's periodic maintenance. Failure to properly manage Carolina Beach Inlet could disrupt the sediment recharge occurring in the engineered borrow site and alter the effectiveness of the CSDR project. The mismanagement of Carolina Beach Inlet maintenance material could increase the risk to infrastructure, property and life. The inlet and engineered borrow site must be properly managed ensuring an adequate volume and quality of sand to maintain the CSDR project.

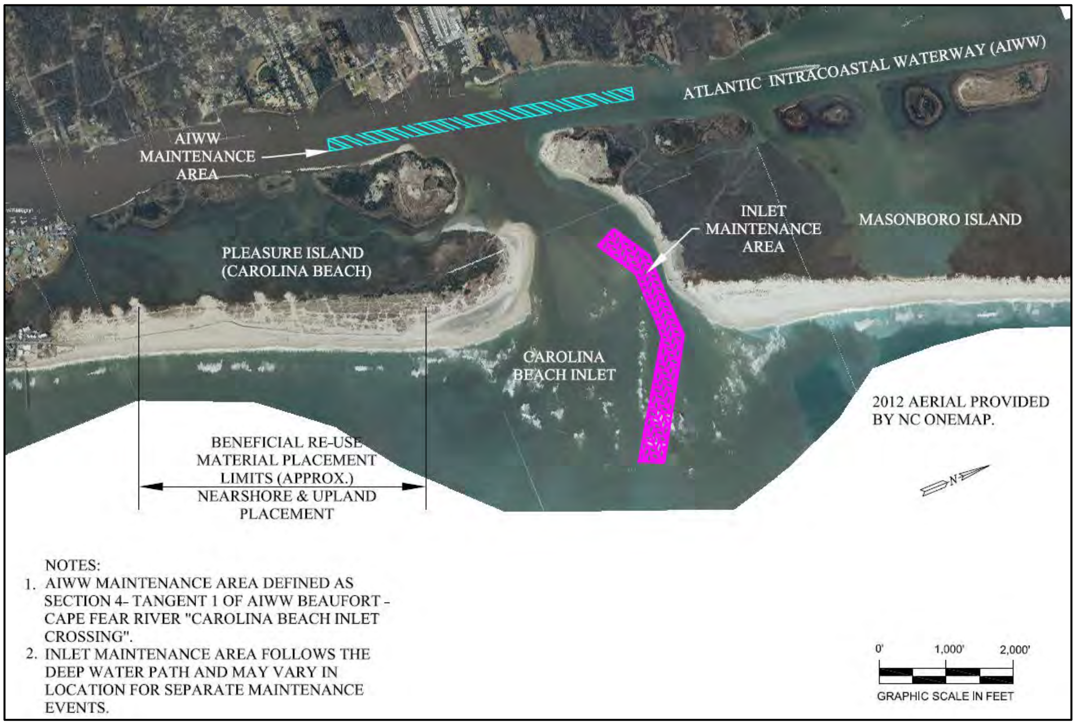

Figure 8. Carolina Beach Inlet Maintenance Areas & Beneficial Re-Use Material Placement Limits

Figure 9. Carolina Beach Inlet CSDR Borrow Site

The County's efforts to secure state and federal permits to maintenance dredge Carolina Beach Inlet provides additional protection for the CSDR project. In the event the federal government becomes unable to fund or implement the maintenance operations, the County may conduct them. This will help provide a

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continued passive sand recharge of the CSDR borrow site and maintain the historic level of project performance.

The County has recently (2017) secured authorization to place maintenance material from Carolina Beach Inlet within the CSDR borrow site for staging until the next periodic maintenance event (three year cycles). This management alternative, an inshore dredge material management site (IDMMS) creates a direct link between the maintenance dredging activities and the CSDR project by pre-staging inlet maintenance sand for future nourishment events. Potentially, this allows improved material management within the inlet and along the Town's oceanfront during CSDR maintenance intervals. Theoretically; the practice should, at a minimum, improve the efficiency of the combined projects by reducing the travel distance required to move the material during an inlet maintenance event. Additionally, during a CSDR periodic nourishment pre-staged inlet maintenance material should be available supporting the CSDR maintenance event.

FLOODPLAIN MANAGEMENT

The County, the Town and the State conduct and regulate actions related to floodplain management to help reduce flood condition risks. New construction and population growth pose the most likely risks to floodplain management. With a population growth of approximately 6% between 2010 and 2014 (US Census, 2016), the Town must remain prepared for new challenges in floodplain management. To help control the flood risk generated by new development or population growth, the Town has established flood damage prevention ordinances and also participates in the National Flood Insurance Program (NFIP).

The Town also pursues opportunities to renovate existing buildings and infrastructure to help reduce the flood damage risk to life and property. Examples of the actions taken to improve the current Town infrastructure include raising existing structures with first floor elevations below the current base flood elevation (BFE) as defined by the Federal Emergency Management Agency (FEMA). In addition, the Town pursues opportunities to relocate or improve utilities in efforts to reduce the storm damage risk to residents and guests.

Flood Damage Prevention Ordinance

The Town established a flood prevention ordinance aimed at preserving the public health, safety and general welfare of residents and guests. Appendix D provides the Town's flood prevention ordinance. The ordinance provides regulations and compliance measures to minimize potential damages resulting from flood conditions. The ordinance complies with federal guidance delivered in Policy Guidance Letter (PGL) 52 for Floodplain Management Plans and section 202 (c) of the 1996 Water Resource Development Act (WRDA), shown in Appendix E.

The ordinance addresses construction activities for houses and facilities located in several types of floodplain designations including the following:

- Standard floodplain areas where data identifies the base flood elevation;
- Special floodplain areas where no base flood elevation has been provided;
- Riverine floodplains without designated floodways or non-encroachment areas;
- Designated floodways and non-encroachment areas and
- Coastal high hazard areas.

The ordinance includes specific goals and objectives with regulations designed to help minimize or prevent future flood damages. The regulations establish protocols for development occurring within a floodplain or area susceptible to water inundation. The protocols help to limit or prevent the increase of flood waters to volumes greater than the capacity of the receiving lands. The ordinance also requires improvements to drainage structures (natural or constructed) to compensate for increased flows generated by new development or renovations. The improvements provide a means for development to meet compliance with the ordinance intent and gain approvals for construction. Furthermore, the ordinance details corrective actions to obtain compliance with development codes and procedures for requesting a variance under applicable provisions.

The flood damage prevention ordinance also stipulates penalties such as fines or imprisonment for violations or non-compliance. This action allows the Town a means to enforce the ordinance on a fair and equal basis. Additionally, the Town may also seek any other lawful action necessary to discourage or mitigate violations under the ordinance.

National Flood Insurance Program (NFIP)

FEMA administers the NFIP in efforts to help local communities take appropriate steps to reduce the risk to life and property from potential flood damage. The NFIP provides recommendations to assist local communities in regulating construction of new and improved structures. The NFIP also provides reduced premiums for flood insurance coverage based on the actions taken by the governing community to help reduce the potential flood risk. FEMA provides the reduced premiums through a Community Rating System (CRS). A local community improves their rating through implementation of recommended practices designed to lower the flood risk potential. However, only recommended practices that exceed the NFIP minimum standards help the communities to garner improved ratings (FEMA, 2016a).

The Town currently holds a Class 7 CRS rating, which entitles NFIP policy holders to a 15% premium discount (PBS&J, 2010). The Town evaluates additional or new standards as applicable to help improve the CRS rating on a continuous basis. Any changes in the flood damage prevention protocols would be documented in a revised flood prevention ordinance.

Raising Existing Structures

The Town has participated in the Unified Hazard Mitigation Assistance (HMA) and the Sever Repetitive Loss (SRL) grant programs since 2009 to raise existing structures above the BFE. (The HMA program superseded the SRL grant process in 2013.) These programs provide federal grants to improve structures currently insured under the NIFP that may experience repetitive flood damage. The Town has utilized the grants to raise existing structures above the minimum BFE to help reduce the flood risk. The Town has successfully received funding to raise 14 structures since 2009 with federal grants totaling approximately $2.2 million. The Town provides up to a 25% funding match with the grant program. The FY 2016 grant process concluded in May 2016 and the Town anticipated funding to renovate 10 additional structures. The estimated budget for the work requested under the FY 2016 grants equaled approximately $1.7 million. FEMA announced approximately $199 million would be available in FY 2016 for grant assistance (FEMA, 2016b). Appendix F provides the FY 2016 letter of interest from the Town for the grant program.

Relocating/Improving Utilities

The Town routinely evaluates the opportunity to replace or relocate utilities in efforts to improve the landscape of the Town and reduce the flood damage risk to life and property. One area where the Town works to improve conditions entails placing overhead utilities below ground to protect them from storm damage. Utilities such as phone and electric cables are placed below grade within right-of-way areas maintained by the Town. The Town requests grants to help with the construction costs for the utility relocations and coordinates with the utility owners to complete the work when funding becomes available.

Similarly, the Town works to improve storm drainage features unable to carry current demand loads. This includes the periodic maintenance dredging of Carolina Beach Lake, which provides retention time for stormwater outflows. The Town also plans street and drainage projects based on available funding to help alleviate flooding issues along locally traveled side streets.

STATE & LOCAL CONSTRUCTION REGULATIONS

The Town understands the importance of ensuring all new construction or building modifications comply with current practices and regulations. This helps to safeguard the public health, safety and welfare of the area residents and guests. The Town works with state and other local agencies to identify the best practices for construction and implements compliance through a permitting and inspection program.

Setbacks & Developmental Areas

One method to help regulate construction includes the Town mandating policies established by the NCDCM to help appropriately site oceanfront development. Although this practice does not guarantee safety from storm damage or erosion, the practice does reduce the risk of damage to people and property. NCDCM has established setback factors for oceanfront development based on erosion trends measured over the past 50 years. The setback distances establish the seaward most position for a structure. The setback graduations generally start from the first line of stable vegetation (static line) and extend landward. However, the Town approved a 'development line' in July, 2016 to supplement the static line.

A development line is applicable when a community maintains a long-term commitment to a CSDR project to allow vegetation to establish seaward of any documented static line. When this occurs, the community may apply for the establishment of a development line in accordance NCDCM policy. The development line designates the seaward most line where development may occur. In accordance with 15A NCAC 07J .1300, applicable setback distances would still apply, however they would be measured from the most seaward line of vegetation at the time of the development as opposed to the 'static line'. This option helps communities with structures that otherwise would be designated as non-conforming when the community has taken action to manage the coastal system.

Applicable setback distances vary based on the proposed structure size and relate to an annualized 50-year shoreline recession rate (setback factor). NCAC Rule 15A 7H.0304 (1) a. establishes the value of two (2) as the minimum acceptable setback factor. Table 2 provides the current setback distances utilized by the Town (NCDCM, 2016b). The setback regulations help maintain NCDCM's goal for preserving the primary dune system and providing coastal infrastructure storm and flood protection.

The NCDCM works through the North Carolina Coastal Resource Commission (CRC) to determine and adopt setback requirements. The CRC utilizes a program initiated in 1979 to record the shoreline position along the North Carolina coast. Approximately every five (5) years, aerial photography records the wet/dry line along the sandy beach. The CRC then interprets the wet/dry line as the mean high water line and uses it as a reference for the shoreline location. (NCDEQ, 2016b). After the data collection process, a computer simulation compares the change in shoreline position to determine an appropriate setback factor. The CRC strives to average or combine blocks of independent shoreline lengths where the setback factor remains relatively consistent (NCDEQ, 2016b). This helps to unify construction location standards by providing a consistent setback factors across longer distances.

Table 2. NCDCM Setback Distances

Proposed Structure Size	Setback Distance (ft.)
$X < 5{,}000\ ft^2$	60 feet or 30 times the setback factor
$5{,}000\ ft^2 \leq X < 10{,}000\ ft^2$	120 feet or 60 times the setback factor
$10{,}000\ ft^2 \leq X < 20{,}000\ ft^2$	130 feet or 65 times the setback factor
$20{,}000\ ft^2 \leq X < 40{,}000\ ft^2$	140 feet or 70 times the setback factor
$40{,}000\ ft^2 \leq X < 60{,}000\ ft^2$	150 feet or 75 times the setback factor
$60{,}000\ ft^2 \leq X < 80{,}000\ ft^2$	160 feet or 80 times the setback factor
$80{,}000\ ft^2 \leq X < 100{,}000\ ft^2$	170 feet or 85 times the setback factor
$100{,}000\ ft^2 \leq X$	180 feet or 90 times the setback factor

Notes: (1) Setback distances extend from the seaward most line of vegetation (static line).
(2) Setback factors are shoreline specific erosion rates
(2) "X" indicates proposed structure size.

The Town established the 'development line' to help protect approximately 64 structures previously considered non-conforming with setback distances measured from the static line. Under this designation, repairing or rebuilding the homes would be prohibited if they were damaged beyond 50% of their value. This interpretation could severely impact the home owners in the event of a major storm or disaster event. The structures were constructed prior to the establishment of the static line and were in compliance with the applicable building codes at the time of construction. By establishing the development line supplementing the static line, the Town helped to change the structures status to conforming so repair work could occur in the event of major damage. Appendix G shows the original 'static line' and the newly designated 'development line' along the Town oceanfront.

The Town also requires NCDCM approval for siting development in areas of environmental concern (AEC) designated by the CRC. The areas of concern generally include locations that experience increased erosion or shoreline migration trends such as an Inlet Hazard AEC. The areas of concern also cover lands subject to strong current velocities due to flood and waves during storm events. The NFIP designates these areas as "V" zones but they also qualify as High Hazard Flood AEC's (Lopazanski, 2014).

Building Construction/Renovation

The Town mandates that new construction and building renovations must meet compliance with the North Carolina building code in efforts to safeguard the public health, safety and welfare. The Town subscribes to the International Code Council (ICC) to provide the most applicable codes. The Town maintains an inspections department responsible for reviewing new construction and offers advice regarding practices and techniques. The governing codes for construction may be viewed from the Town's building inspections department internet page linked through the Town's website (www.carolinabeach.org) or directly from ICC (http://codes.iccsafe.org). In addition, Town staff remains available to address questions from residents and builders to educate and assist them with complying with the regulations. (Town of Carolina Beach, 2016a).

The Town documents new construction activity and any compliance certifications through a permitting process. The permits provide long-standing records of the construction process that may be reviewed by future residents and interested parties. This process helps protect the safety and well-being of the general public by providing an independent professional opinion of the applicable building standards and practices.

Derelict Building Removal

The Town has also adopted minimum housing standards to help lower the risk to life and property from unsafe, derelict or abandoned structures. Left unattended, the structures could become a fire hazard or produce debris capable of damaging adjacent properties or harming persons during a major storm event.

The Town follows established ordinances to monitor and document any structures that may be considered unsafe. Municode (2016) provides the ordinances for the Town through a subscription service.

Structures damaged by storm events may be abandoned along the oceanfront when they become uninhabitable. Property owners may choose to 'walk away' from the buildings over repairing or relocating them. As wave damage continues, the structures may break apart and become hazards to beach goers. The Town works to prevent the abandoned structures from injuring visitors and residents by monitoring and inspecting any applicable structure within the Town's municipal boundary. The Town coordinates with the legal owner of any potential structure to promote and/or assess if the repairs will be completed. However, if the repairs do not occur within a timely manner, the Town maintains the authority to make the necessary repairs to the structure or to remove it all together. The cost of any actions taken by the Town may be passed on to the referenced property owner through liens or assessments. The liens may be applied on any property under the same ownership within one (1) mile of the Town's municipal limits, with the exception of a primary residence. In addition, the Town may sell portions or all of the abandoned property to recover the cost incurred repairing or removing the referenced structure (Municode, 2016).

SEA LEVEL CHANGE

The ultimate effect that sea level change may have on the CSDR project remains unknown. However, the Town monitors current policy changes and guidance that incorporates best management practices associated with sea level change. Applicable guidance and policy will most likely come from the NCDCM. The CRC directed the NCDCM to investigate the potential effects of sea level change on coastal North Carolina. The NCDCM published a draft report on the potential effects of sea level change in March 2015 (NCDCM, 2016a). Expectations suggest the CRC will incorporate the findings of NCDCM's sea level change report in future policy decisions (NCDEQ, 2011).

The NFIP will most likely also modify regulations as sea level change effects coastal communities. The Town and County will continue to monitor data and publications released by the scientific community to stay abreast of the changing situation.

Similar USACE CSDR projects within the region have analyzed sea level rise effects with and without project conditions. When assessed against historical rates as well as intermediate/high rates predicted by the National Research Council or the Intergovernmental Panel on Climate Change; the results showed minimal increases to project costs. Such results may support the position of CSDR projects systematically adapting to sea level rise oscillations (USACE 2014).

TROPICAL EVENT EVACUATION & RE-ENTRY PLAN

The Town has established an Emergency Evacuation Plan and Re-Entry Plan to document emergency procedures in the event of a natural disaster. The documented policies and processes contained in the respective plans promote a systematic and controlled protocol for evacuating Pleasure Island and the surrounding area. Although the plans may apply to any type of disaster, they specifically relate to occasions that may be forecasted such as a major storm or hurricane.

Appendices H and I provide the Evacuation Plan and Re-Entry Plan respectively. The plans describe collaborative efforts for providing the safe evacuation and re-entry of the Town and nearby Kure Beach in the event of a qualifying emergency. The Town of Kure Beach, also part of New Hanover County, lies adjacent and south of Carolina Beach on Pleasure Island. Therefore, the plans incorporate actions anticipated by Kure Beach and the County by assuming consistency with information provided from each governmental entity.

The evacuation plan outlines responsible parties for issuing and implementing evacuation orders and for allowing returning citizens island access. To help facilitate the evacuation or re-entry process, the plans partition the Town into sectors. The evacuation procedures are mandated based on a specific sector of the town as opposed to the entire population at once. This helps maintain a sustainable volume along the roadways by limiting traffic flow for egress or ingress.

The re-entry plan requires a joint decision from the towns of Carolina Beach, Kure Beach and the County prior to re-entry being allowed. The re-entry plan delegates the County's Emergency Operations Center (EOC) as the overall authority for issuing consent for re-entry. Once the EOC offers consent, re-entry may occur on a tiered basis with emergency personnel and law enforcement gaining first access. The tiers advance through critical service personnel (CSP), pass holders and essential services personnel (ESP) to the general public as the Town's and EOC determine appropriate.

The re-entry plan also establishes an off-island Emergency Service Center where displaced residents can obtain information or updates regarding the disaster event and re-entry passes when available. This provides a central location for residents to receive aid and critical services to help reduce the disaster risk.

SPECIAL CIRCUMSTANCES

Apart from the items already discussed, the County and the Town have compiled a manual of planning and response procedures for circumstances not generally considered along a coastal town. The manual documents the appropriate actions and responsibilities for emergency personnel to notify and assist residents with evacuating Pleasure Island if a disaster event occurs. Although the potential disaster events do not necessarily relate directly to a major storm event, a major storm event could contribute to their occurrence. The list below details the referenced events.

- A nuclear event at the Brunswick Nuclear Power Plant;
- Military Ocean Terminal Sunny Point (MOTSU); and,
- A tsunami.

Brunswick Nuclear Power Plant

Appendix J provides a nuclear response plan for the Town. The plan details response initiatives proposed to reduce the risk to life and property resulting from an event at the Brunswick County Nuclear Power Plant. Figure 10 shows the respective facility falls within approximately 8.5 miles of the Town. As a result, the Town must maintain a response plan acceptable to the U.S. Nuclear Regulatory Commission (NRC) for a plume and pathway emergency planning zone (EPZ) (NRC, 2016). The plume and pathway EPZ plan covers a 10-mile radius from the nuclear facility.

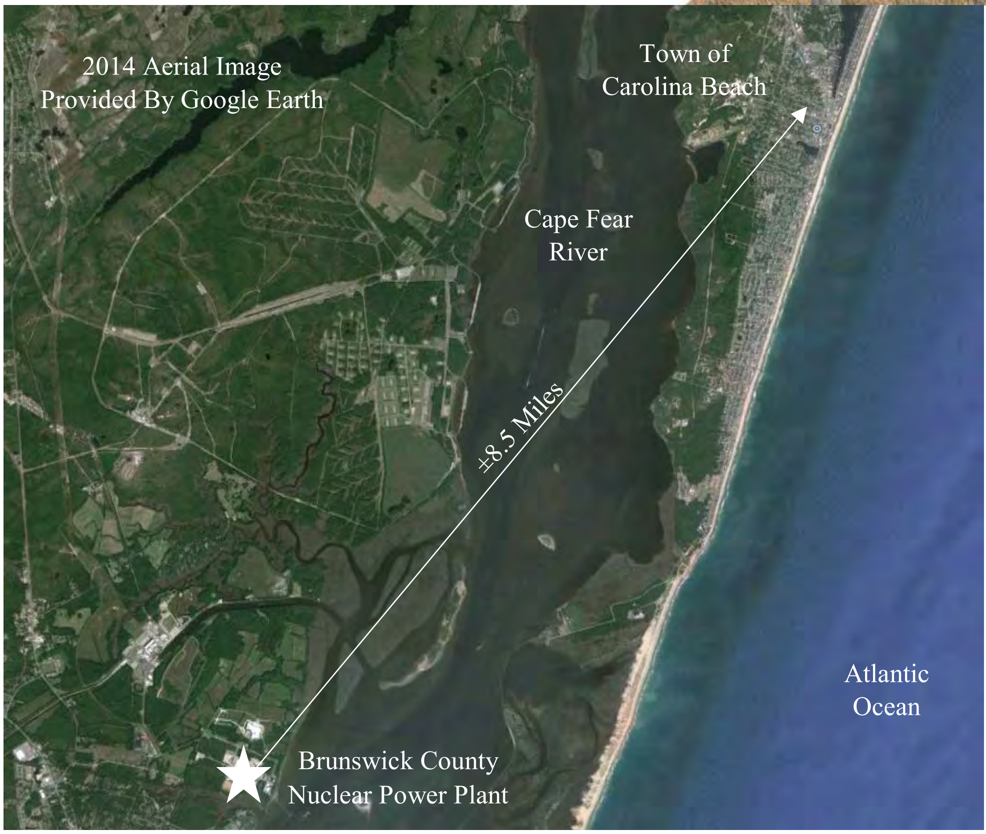

Figure 10. Brunswick County Nuclear Power Plant Location

The plan details the primary emergency agency responsible for notifying residents that a nuclear event has occurred and the precautionary procedures to follow. The plan discusses required planning and recovery tasks to help maintain an effective communication strategy for a prompt response and expedited recovery. The Town also maintains an evacuation and re-entry plan to reduce the risk to property and life if a nuclear event occurs. Appendices H & I contain the evacuation and re-entry plan, which is combined with the Tropical Event Evacuation and Re-entry Plan.

MOTSU

The Military Ocean Terminal at Sunny Point (MOTSU) also resides in proximity to the Town and New Hanover County. The Department of Emergency Management for New Hanover County coordinates regularly with MOTSU to stay informed of operations and on-going activities. In the event of an emergency situation, the County would respond in accordance with the evacuation and re-entry plans shown in Appendix G & H, or as directed by MOTSU (S. Still, personal communication, October 31, 2016). Meeting regularly with MOTSU personnel provides an additional confidence level for the County's intent to reduce the risk to residents and guests of New Hanover County and the Town of Carolina Beach.

Tsunami

Appendix K includes a Tsunami Plan for reducing the risk to life and property during a possible tsunami. The plan defines coordination and operational procedures to follow if the NOAA National Tsunami Warning Center, located in Palmer Alaska, issues a tsunami warning. The plan discusses primary evacuation zones such as the beach front and identifies minimum safe boundaries such as 300 ft. inland and 15 ft. above sea level. The plan also identifies the managing agencies responsible for providing public notifications and emergency information.

The risk of a tsunami remains low for the County and Pleasure Island. However, as the plan describes, an undersea earthquake; submarine landside; volcanic activity or an extreme meteorological event could propel a tsunami towards Pleasure Island. The plan lists an earthquake along the Puerto Rico Trench as the most probable genesis for creating a tsunami event. As stated in the plan, the earthquake would need to reach a Richter scale magnitude of 9.0 to create a potential event.

The Tsunami Plan also provides warning and watch notifications anticipated in response to a tsunami event along with corresponding safety protocols. The plan encourages early notifications by emergency management officials to provide sufficient warning to residents and guests located in risk areas. Adjustments to the notifications or supplemental advisories may occur as necessary to provide the most relevant safety and response information available.

SUMMARY

The CB federal CSDR authorization is the first in the nation to exceed its original 50-year life cycle. The federal authorization for the CB CSDR project will lapse at the end of 2020 if Congress does not extend the project. As a condition of the BRER re-authorization process, the local sponsor must provide a plan for reducing the storm damage risk to infrastructure (CSDR project), property and life. The Town, the County and the State of NC share stakeholder responsibilities and maintain an active pursuit to reduce the potential storm damage risk for residents, guests and infrastructure. Examples of actions and policies implemented to help reduce the potential risk include the following:

- Studies to maintain/enhance the CSDR project performance;
- Implementation of policies to protect the primary dunes;
- Activities to maintain Carolina Beach Inlet;
- Floodplain management initiatives;
- Regulating new building construction and minimum housing standards;
- Monitoring sea level change and adaptation/resiliency recommendations and
- Adoption/implementation of natural disaster action plans.

Project Performance Enhancements

The County and Town have initiated a long term effort to review the CSDR project performance and analyze potential enhancements. An annual monitoring program consisting of beach profile surveys provides the foundation for comparing performance measures. The monitoring program compares the annual surveys to document shoreline migration and volumetric change within the project boundary and adjacent oceanfront.

The monitoring data also provides the nucleus for estimating the risk reduction associated with continuing the CSDR project. New Hanover County and the Town of Carolina Beach conducted a risk assessment utilizing the monitoring data collected since 2014 and additional data requested from the USACE covering 2006 to 2012 as well as historical shoreline data from NCDCM. The risk assessment involved a numeric modeling analysis utilizing the GenCade and SBEACH software packages to estimate the recession and storm risk anticipated over the next 15-year period if the CB CSDR is discontinued. The analysis provides a property and infrastructure value financial risk of approximately \$187.9M, excluding potential structure relocation costs (\$26.5M), lost tax base value (\$150.4M), lost annual tax revenues (\$1.2M) and small business investments over the next 15 years potentially resulting from erosion and storm losses.

Dune Protection Policies

The Town proactively strengthens and protects the primary dune system along the Town's oceanfront. The Town understands the important role a primary dune system provides in buffering wave energy and flood waters during storm events. The dune system can be the last line of defense between public infrastructure and the ocean forces during weather episodes. The Town continues to invest in the following strategies to help maintain/manage CB and help reduce the risk of storm damage to infrastructure, property and life:

- Inspections and educational programs;
- Nuisance vegetation management and removal;
- Restoration and enhancement of dune vegetation;
- Access management within concentrated areas of pedestrian foot traffic;
- Establishment of public parking locations within walking distance of beach access points and
- Continued maintenance of the 1973 federally constructed northern rock revetment.

Dune Inspections and Educational Signage

The Town conducts inspections of the dune system throughout the year to identify areas that warrant improvements. The improvements generally consist of restoring dune vegetation or improving/repairing dune accesses. Town staff implements/completes the inspection work; however, NC Sea Grant periodically participates in the inspection activities. A recent inspection that included NC Sea Grant occurred during the summer of 2015 in partnership with the County. The Town implements any improvements of the dune system in compliance with the North Carolina Administrative Code.

The Town also uses signage to help educate beachgoers on general safe practices while enjoying the beach and coastal environment. The practices include techniques for avoiding rip currents and explanations of the lifeguards' flag signals used on the beach. The signage also provides general rules and regulations to help preserve/protect the dune and beach system.

Nuisance Vegetation Management and Removal

Removing nuisance vegetation helps maintain the dunes by protecting the native vegetation and habitat. Nuisance vegetation can out-compete the native plants and weaken the dune substrate. Native vegetation provides the best means for anchoring the dune sand through a root and leaf system while also providing habitat for coastal species.

Dune walkovers allow sand accumulation and the establishment of vegetation to continue along the dune complex without interruption from pedestrian foot traffic. Establishing foot paths over as opposed to through the dunes preserves the integrity of the dune feature and does not create a passage for floodwaters.

Restoration and Enhancement of Dune Vegetation

As opportunities allow, the Town helps to restore the native dune vegetation with supplemental plantings. These plantings help prolong the life of the dunes by providing additional root and stem systems to help capture wind-driven sand and reduce wave energy. Donated Christmas trees placed in partnership between the Town and volunteer staff provide further efforts for trapping wind-blown sand. The Town generally conducts at least one (1) vegetation enhancement project each year and also organizes the placement of donated Christmas trees annually.

Public Access and Parking

A key practice to maintain the dune system entails establishing public access points. The Town endeavors to establish public access points in a least destructive manner to preserve the dune system. This includes constructing dune walkover structures where pedestrian traffic warrants or designing foot paths to traverse over the dunes. These actions help to preserve and maintain the protective features of the dune system. The public boardwalk constructed by the Town helps direct pedestrian traffic along appropriate routes across the dune system. The Town erected the boardwalk along the most heavily accessed portion of the Town's central business district. The boardwalk location remains landward of the primary dune and directs pedestrians to established beach access points. This limits the potential for pedestrian traffic to impede upon the dune system. Public parking spaces located in proximity to beach access points also help to route pedestrian traffic through the appropriate access points. Together, the parking spaces and nearby access points creates a path of least resistance for beach goers arriving by car while helping to sustain the dune system.

Maintenance of the Northern Rock Revetment

The continued maintenance of the northern rock revetment provides another example of the Town's commitment to manage the increased risk of storm damage potential. The USACE completed the revetment (1973) when erosion rates and inlet influences threatened the northern shoreline of the CSDR project. However, the structure's maintenance remains the Town's responsibility. The Town has repositioned greater than 80% of the stone encompassing the structure since 2013. This work has restored the structure's integrity and ability to protect the shoreline and the landward coastal infrastructure.

Management Practices for Carolina Beach Inlet

As stakeholders, the County and Town partner to manage Carolina Beach Inlet in the best interest of the inlet and the CSDR project. The management practices help maintain reasonable access for mariners and improve the CSDR projects ability to provide storm protection. These efforts help reduce the storm damage risk to infrastructure, property and life.

The management practices that support the ocean access include securing state and federal permits to dredge the inlet. Historically, the USACE has maintained the inlet for navigation but the work has always been subject to available funding and dredge plant accessibility. The County and Town may now conduct the inlet maintenance dredging, if necessary. This increases the likelihood that ocean access for mariners will be available through the inlet. This also provides the County with the authority to beneficial re-use the material within the permitted placement areas, either in the nearshore, along the beachfront or next to the cut within the IDMMS.

Maintaining the inlet also helps sustain the CSDR project by providing passive sediment flow to recharge the IDMMS. The USACE estimates approximately 250,000 CY of sand migrates through the inlet into the borrow site annually. If maintenance activities no longer occur, shoaling material within the inlet may impede migrating sediment and prevent the engineered borrow site from recharging. If the engineered borrow site cannot provide the necessary CSDR project volume, this may limit the effectiveness of the CSDR maintenance events. Conversely, the County and the Town may manage the available volume in the engineered borrow site by placing the inlet maintenance material within the IDMMS. This action required additional permits above the previous authorizations; however, the County received the additional authorizations in 2017.

Floodplain Management Initiatives

The floodplain management initiatives undertaken by the Town addresses stormwater runoff generated by new construction and building renovations. The Town also participates in the NFIP which provides potential flood prone properties the ability to obtain flood insurance. Additionally, the Town works to protect and improve existing infrastructure and utilities through grant programs. With recent population growths measured at approximately 6% between 2010 and 2014, the Town must remain proactive in floodplain management to curtail future floodplain challenges.

Flood Damage Prevention Ordinance

The Town has established a flood damage prevention ordinance to review development plans for adequate storm drainage facilities on new site development projects. The ordinance satisfies the federal guidance recommended in Policy Guidance Letter (PGL) 52 for Floodplain Management Plans and section 202 (c) of the 1996 Water Resource Development Act (WRDA). The ordinance also helps to protect properties down stream of new or redevelopment by reducing the risk of increased flood waters as a result of the construction project. The ordinance includes specific goals for site development projects in order to obtain the Town's construction authorization. The ordinance also provides corrective actions and penalties for non-compliant projects and information required for requesting an ordinance variance.

National Flood Insurance Program

The NFIP provides flood insurance to homeowners within participating communities and also provides recommendations for regulating new development. A participating community may be eligible for discounted insurance premiums through the Community Rating System (CRS) if the community implements the recommended development practices. The community must require homeowners to achieve above the minimum NFIP requirements to receive the discounted premium. FEMA administers the NFIP and evaluates each community's eligible CRS rating. The Town currently holds a Class 7 CRS rating, which entitles NFIP policy holders to a 15% premium discount.

Infrastructure Improvements

Retrofitting existing structures and improving utilities also provide the Town a means to reduce the storm damage risk to residents and guests. The Town works through the Unified Hazard Mitigation Assistance (HMA) federal grant program to identify and raise structures with existing first floors below the minimum BFE. With grant funding totaling approximately $2.2 million, the Town has raised approximately 14 structures since 2009. An additional $1.7 million in grants were requested for FY 2016 to raise approximately 10 additional structures.

The Town also requests applicable grants to relocate or improve utilities to reduce the storm or flood damage risk to property and life. This includes relocating overhead utilities to underground locations as well as conducting stormwater system improvements.

Regulations for New Building Construction & Minimum Housing Standards

The Town coordinates with the State and other local agencies to specify the best construction practices for renovations or new construction. This includes properly citing oceanfront development landward of state required setback distances within AECs. The Town also implements the most current building codes approved by the State and works to ensure owner's remove or repair dilapidated or damaged homes.

Setback Distances

The Town works with the NCDCM to designate the proper setback distance for oceanfront development. The setback distance is the minimum distance from the most seaward line of stable vegetation that a structure may be cited. The Town has also established a 'development line' as an additional means of evaluating new development.

The NCDCM develops setback distances from the local 50-year annualized erosion rate and scales their application based on the proposed structure's size. The NCDCM uses aerial photography to determine the shoreline position and calculates the annualized erosion rate on approximate five-year intervals. The NCDCM has established the value of two (2) as the minimum setback factor. Otherwise, the 50-year annualized erosion rate provides the applicable setback factor. The Town also verifies NCDCM's acceptance for any development or significant renovations within an AEC. Owners must provide a permit from the NCDCM approving the development before the Town will review the proposed structure location.

Building Codes for New Construction or Redevelopment

The Town subscribes to the ICC to provide the most current North Carolina building codes. The codes are available from the Town's website (www.carolinabeach.org) or directly from ICC (http://codes.iccsafe.org). Town staff will review the code with interested parties in efforts to help construction projects meet compliance with the standards. Staff will also conduct inspections at construction milestones to monitor compliance with the codes.

Minimum Housing Standards

The Town has established minimum housing standards within their adopted code of ordinances. The minimum housing standards provide guidance on when a structure may be considered unsafe or abandoned. The Town will coordinate with the owner of any structure believed to be abandoned so repairs can be made in a timely fashion. However, the Town may also seek other legal resolutions, such as liens or assessments, to complete the work if owners continue to delay.

Sea Level Change

Currently, the effects sea level change will bring to the CSDR project performance remain uncertain. However, The Town and County actively monitor policy changes and guidance recommendations to provide resiliency to the Pleasure Island shoreline. The Town will most likely evaluate any guidance provided by the NCDEQ and the NFIP to assess what strategies may be implemented for a sustainable project future. Other regional USACE assessments may support the position of CSDR projects systematically adapting to sea level rise fluctuations.

Natural Disaster Action Plans

Action plans have been established to document policies and procedures for assisting the residents and guests of Pleasure Island in the event of a natural disaster. The plans establish evacuation and re-entry procedures in addition to emergency procedures to implement during a tsunami or nuclear event. Although the most likely natural disaster remains a hurricane or tropical storm, a tsunami could be generated from some type large seismic activity along the Puerto Rico Trench. Also, a nuclear event could occur at the Brunswick County Nuclear Power plant located less than 10 miles from the Town.

The action plans describe collaborative efforts that must be conducted between the Town, the County and the adjacent Town of Kure Beach. The plans include all three (3) governmental entities because they each would be using the same evacuation and re-entry route through the Town. CB borders the only vehicular access off of Pleasure Island.

The plans establish checkpoints and Emergency Service Centers to aid displaced residents or provide important information concerning the respective disaster. The plans also provide safety protocols such as early warning systems and minimum safe boundaries for large wave events. The plans designate levels or tiers for operational personnel's re-entry onto Pleasure Island. The plans also divide the Town into sectors for evacuation and re-entry purposes. This would help minimize traffic congestion during evacuation or re-entry by concentrating on specific Town sectors.

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