City of Isle of Palms
2018 Beach Restoration Project

2018
FINAL REPORT

Prepared for

The City of Isle of Palms
Charleston County, South Carolina

COASTAL SCIENCE & ENGINEERING

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FINAL REPORT

2018 Beach Restoration Project

City of Isle of Palms

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[CSE–2453FR]

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ACKNOWLEDGMENTS

CSE thanks the Isle of Palms City Council (Mayor Jimmy Carroll) and staff (Desirée Fragoso – Interim City Administrator), as well as former council and staff members for their support of CSE and the project. A special thank you is due to Linda Tucker and her efforts to support the beach and CSE since our work started for the City in 2007. The entire IOP staff proved motivated, competent, and a pleasure to work with, and their efforts to secure additional funding through FEMA are commended. CSE also wishes to acknowledge the support of the City Fire and Police departments, who provided safety and security during the project and have supported CSE through our many beach monitoring efforts over the past decade. We also thank the Wild Dunes Community Association (Dave Kynoski), the Wild Dunes Resort (Frank Fredericks), and many individual regimes and owners in Wild Dunes for their financial and logistical contributions to the project. Finally, we appreciate the work and support of SC-DHEC OCRM, the USACE, SCPRT, environmental resource agencies, and FEMA for coordinating the permitting and implementation of the project.

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1.0 INTRODUCTION

This report is prepared following successful completion of the 2018 beach restoration project at Isle of Palms, SC. It provides a summary of the project planning and implementation as well as documents the environmental protection measures incorporated into the project. The data contained here will serve as the baseline condition for future post-project monitoring efforts and will archive the engineering, permitting, and execution of the project for future planning purposes.

This report includes:

- Summary of the project setting, erosion history, and project purpose
- Description of the project specifications and design
- Summary of project requirements
- Summary of borrow area and beach fill sediment analysis
- Summary of Endangered Species protection measures
- Summary of beach profile and volume changes
- Photographic documentation
- Monitoring and maintenance recommendations

1.1 Project At-a-Glance

Nourishment

Sponsor: The beach restoration project was funded by the City of Isle of Palms, the State of South Carolina, Wild Dunes Community Association (including individual property owners and regimes), and Wild Dunes Resort. The City of Isle of Palms served as project owner and administrator.

Engineer: Coastal Science & Engineering (CSE, Columbia, SC)

Contractor: Great Lakes Dredge & Dock Co. (Oak Brook, IL)

Permit: SC048C–OCRM USACE P/N 2016–00803

Scope: Placement of 1,676,518 cubic yards (cy) of sand in the following areas.

Reach 1 (4,400 lf)	Sta 236+00–280+00	942,320 cy	214 cy/ft
Reach 2 (4,400 lf)	Sta 280+00–324+00	734,198 cy	167 cy/ft

Construction Cost: $13,545,585.70

Nourishment Schedule

- 13 December 2017 – Mobilization of equipment and pipe
- 16 January 2018 – First pumping near Beach Club Villas
- 24 February 2018 – Completion of Reach 1
- 23 March 2018 – Completion of Reach 2
- 1 April 2018 – All equipment removed from beach and offshore zone – Project Complete

2.0 PROJECT PLANNING AND BACKGROUND

2.1 Project Setting

The Isle of Palms is a ~7-mile-long barrier island located north of Charleston Harbor. It has a southeast facing shoreline bounded by Breach Inlet and Sullivans Island to the south, Dewees Inlet, and Dewees Island to the north (Figure 2.1). The northern end of the island is wider due to periodic sand additions though shoal bypass events (Kana 2002, Traynum and Kaczkowski 2015). These events result in a net accumulation of sand over several decades, which builds the updrift end of the island. The downcoast end of the island is narrower and terminates in a recurve spit at Breach Inlet. These characteristic morphologies are typical of "drumstick" barrier islands (Hayes 1979) and are present along mixed energy coasts where both tides and waves are dominant influences on the shoreline (Figure 2.1).

FIGURE 2.1. Schematic of the Isle of Palms showing the wider northeast end characteristic of a "drumstick" barrier island.

The eastern end of the island is a dynamic shoreline, influenced by the shoal bypassing of the Dewees Inlet ebb-tidal delta. Figure 2.2 shows aerial images of the east end of the island from the period of 1944–1963. The photos document a large-scale shoal bypass event that impacted the shoreline encompassing the area that is now known as Wild Dunes. The shoal stretched for approximately 2 miles along the eastern end of the island and was so large that a new, ephemeral, barrier beach was established over 1,000 ft seaward of the previous shoreline. This new beach ridge trapped a water-filled lagoon that was flushed by a small channel and the shoal attached to the beach sometime between 1944 and 1949. From 1949 to 1957, the shoal slowly merged with the beach and by 1963, had completely attached to the upland beach, eliminating the lagoon. The emergence of this large shoal appears to be a result of merging of several shoals in the delta partially visible in the 1944 image, including two visible shoals at the northeastern tip of the island. It is likely these shoals were at one point a trailing ebb spit, and the sand from this spit merged with a shoal further west to create the large sand body that formed the lagoon. The shoal ultimately added well over 1,000,000 cy of sand to the beach.

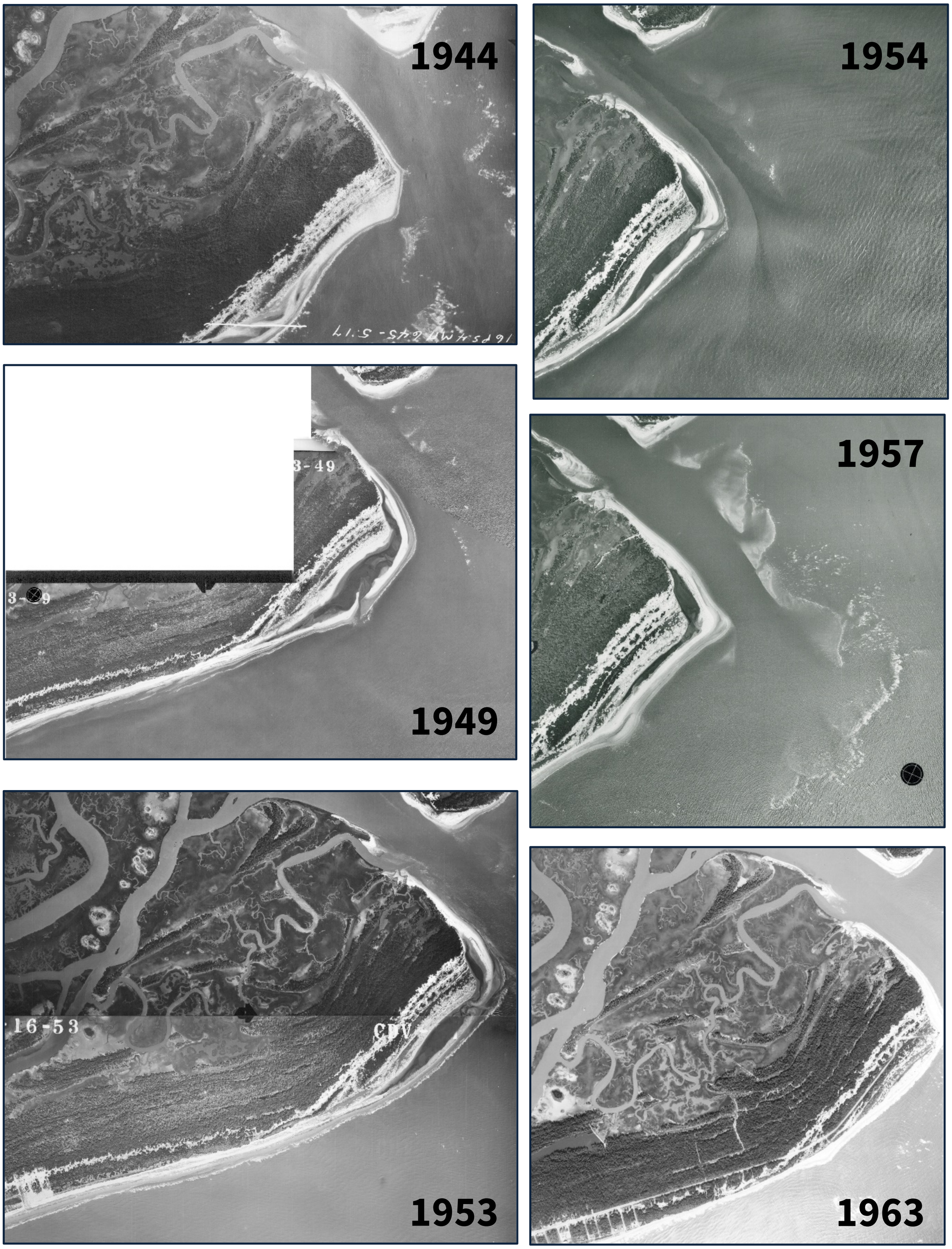

FIGURE 2.2. Historical aerials from CSE 2010 report page 56 (Figure 3.35).

Photo sequence begins (left column from top) in 1944, 1949, and 1953, then continues (right column from top) through 1954, 1957, and 1963. [Note that images are not at the same scale.]

The shoal had the effect of building the shoreline at the northeast end of the island seaward ~500 ft between 1944 and 1963; however, much of the accretion would be subject to future erosion as the shoal sand spread to downcoast areas. In short, the eastern end of the island (east of the present-day Beach Club Villas) was developed on sand that recently accreted to the beach, and not on stable upland area that had existed for decades like the majority of the remainder of the island. Much of the development built in the late 1970's and early 1980's was on areas that were likely wet-sand beach in the 1930's–1940's.

Following the large-scale event mentioned previously, the eastern end of the island continued to experience shoal-bypass events, though all were of substantially smaller magnitude than the 1940's–1960's event. These events generally attached along the central Wild Dunes area and are more characteristic of shoal-bypass events characterized by Kana (2002), with distinct stages of 1) emergence, 2) migration and attachment, and 3) spreading (Fig 2.3). These events have been responsible for focused erosion along various portions of the Wild Dunes area, including two events in the 1980's, another in the late 1990's, and a large event in the mid-2000's that led to the 2008 beach nourishment project.

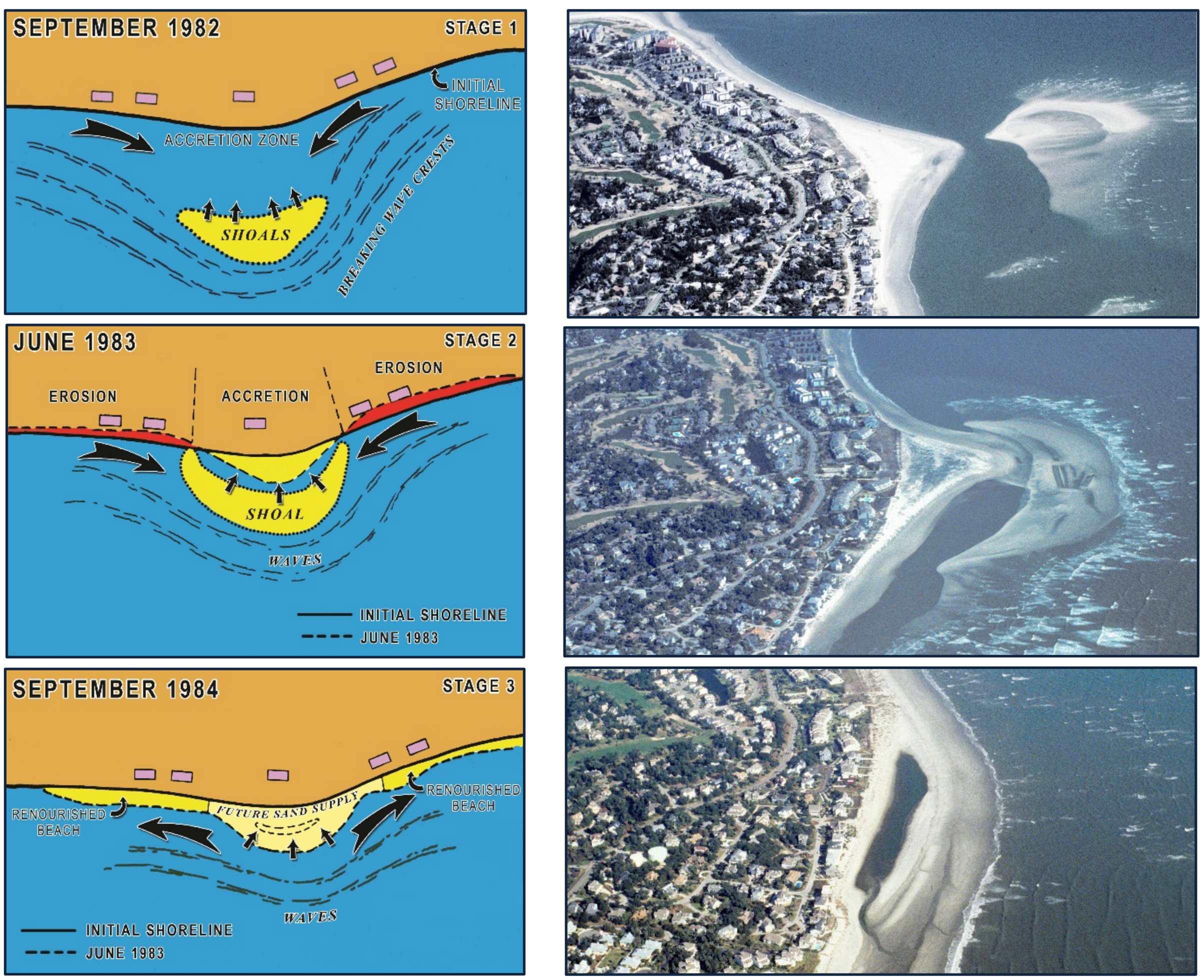

FIGURE 2.3. **[LEFT]** Schematic of the shoal-bypass cycle originally modeled from a bypass event at Isle of Palms. **[RIGHT]** A shoal-bypass event at northeastern Isle of Palms corresponding to the schematic. The upper photo shows a shoal in Stage 1 (1996). The middle image illustrates Stage 2 (1997). The bottom photo shows Stage 3 (1998).

The addition of sand from shoal bypassing at the east end of the island has contributed to relatively steady accretion along the central and western ends, resulting in a wide setback for most properties west of 58th Avenue. In the 1970s, properties along 46th Ave to 53rd Ave had few dunes and had constructed a seawall, and several groins were built by 1984, as shown in Figure 2.4. Since 1984, the beach has accreted rapidly, and all evidence of groins or seawalls have been buried.

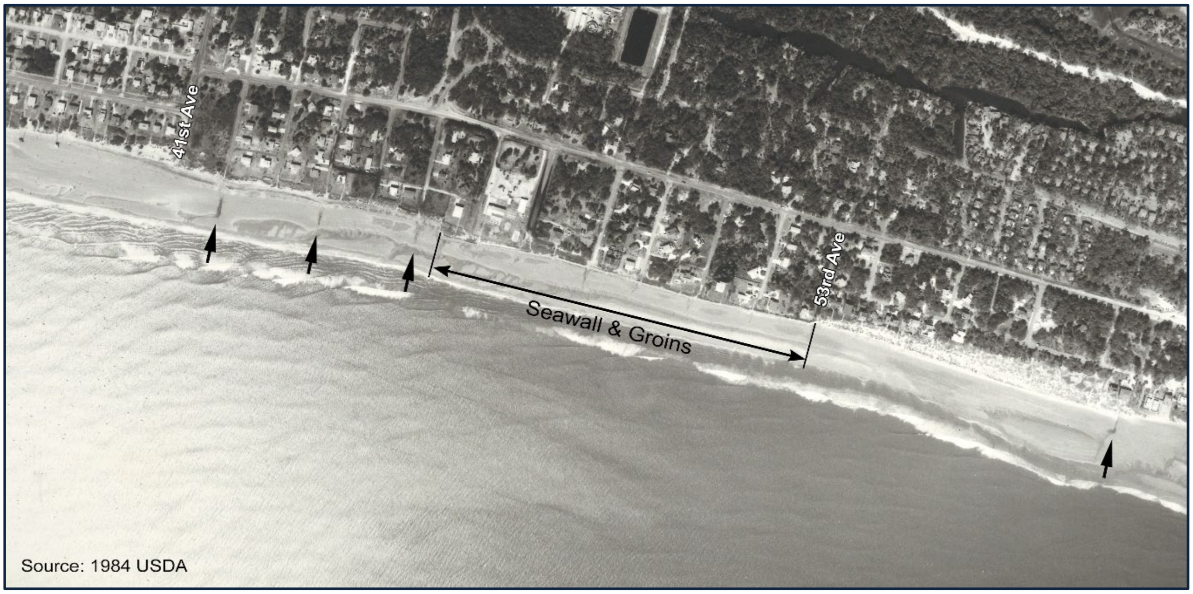

FIGURE 2.4. A seawall and groins were in place in 1984 between 46th Ave to 53rd Ave. Today, due to rapid accretion, these groins and seawalls have been buried.

2.2 Previous Projects

As mentioned in the previous section, erosion mitigation measures at Isle of Palms began by the 1970's with the construction of seawalls and groins in the area between 41st Ave and 53rd Ave. Another groin was visible in 1973 near present-day 58th Avenue. In 1981, a concrete-filled geotextile bag groin was built near the tee of the 17th hole of the Links Course to reduce the erosion threat along the Dewees Inlet shoreline. In 1983, in response to a shoal attachment event, homeowners along Seagrove and Beach Club Villas constructed a rubble mound seawall (Kana, Williams, and Stevens 1985). Sand scraping was also attempted but proved insufficient to preserve a beach under the extreme erosion pressure. In late 1983, the first nourishment project was completed using sand dredged from the new marina. Approximately 350,000 cy of sand was added to the erosional zones adjacent to the shoal as the shoal was beginning stage three of the bypass cycle. This resulted in a dramatic increase in beach width as the nourishment sand added to the accretional shoal sand.

From 1984 to 2007, sand scraping from accretional areas was the only mitigation attempted to combat shoal-induced erosion. CSE is aware of scraping efforts circa 1983, 1987, 1998 (Figure 2.3) which all attempted to move sand to the erosional arcs. From 2004–2007, sandbags were installed along several structures from Shipwatch to Ocean Club in an attempt to prevent additional erosion (Figure 2.5).

FIGURE 2.5. To prevent additional erosion, sandbags were installed along several structures from Shipwatch to Ocean Club from 2004 to 2007.

Erosion reached such a severe condition in 2007 that there was little to no beach along portions of the east end of the island, even at low tide (Figure 2.6). The Wild Dunes Community Association contracted with CSE to evaluate the causes of erosion and prepare a feasibility study outlining alternatives for restoration (CSE 2007). CSE recommended nourishing the beach using sand from an offshore borrow area and began the steps to obtain a permit for the work. The City of Isle of Palms then took ownership of the project and served as the applicant for the permits. Permits were obtained (P/N 2007–02631–2IG), and the City contracted with Weeks Marine for a project including nourishment of 847,000 cy of sand over 10,200 lf (linear feet) of beach. The project extended from 200 ft north of 53rd Avenue to the 17th green of the Links Course.

FIGURE 2.6. Isle of Palms in 2007 prior to beach nourishment.

The 2008 project was completed between 15 May and 15 July 2008 (Figure 2.7). As part of the project, Weeks Marine removed all sandbags from the project area, which totaled ~9,400 bags. Homeowners removed an additional 4,680 bags from under buildings. Averaging ~25,000 cy of sand per day, the dredge RS Weeks pumped sand from three borrow areas 2–3 miles from the beach. The nourishment was placed in three reaches and included ~270,000 cy between 53rd Ave and Dune Crest Ln (Reach A), 552,400 cy from Mariners Walk to the 18th Fairway (Reach B), and 25,000 cy from the 18th tee to the 17th fairway (Reach C). Figure 2.8 shows the layout of the 2008 project. Figure 2.9 shows a post-project aerial photo (2008) which compares to the project area before renourishment (2007).

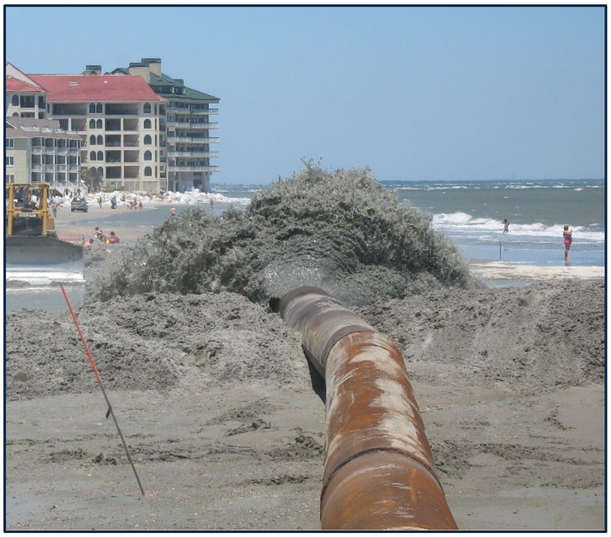

FIGURE 2.7. **[ABOVE]** 2008 beach nourishment project (completed on 15 July 2008).

FIGURE 2.8. **[RIGHT]** 2008 nourishment project map.

FIGURE 2.9. **[LEFT]** Isle of Palms in 2008 following beach nourishment. **[RIGHT]** The project area in 2007 prior to nourishment.

Following the 2008 project, CSE monitored the beach at least annually to document beach volume changes and performance of the project. Two shoal-bypass events occurred in 2009 and 2010, and another, larger event was beginning to emerge offshore in 2010. In anticipation of the need for potential remediation (and after observation of an erosional hotspot forming near the Ocean Club/Seascape area), the City sought a permit for manipulation of the accretional shoal area to expedite attachment and move sand to the erosional hotspots. A project was completed in 2012 that transferred ~80,000 cy of sand from the central portion of Wild Dunes to the east end near Ocean Club. A larger project was completed in late 2014 through early 2015 which moved ~280,000 cy from two accretional areas (an attaching shoal centered near Beach Club Villas and from 53rd to 56th Avenue) to the beach fronting Beachwood East (~70,000 cy) and the area fronting Seascape/Ocean Club/18th hole (~210,000 cy). The project sought to transfer as much sand as possible from the shoal to the beach (Figure 2.10).

FIGURE 2.10. January 2015 aerial image of the 2014–2015 shoal management project showing equipment transferring sand from an attaching shoal to the eroded beach.

2.3 2018 Project Planning and Permitting

CSE has monitored the entire shoreline of Isle of Palms at least every year since the 2008 project. The monitoring data provides information on beach volumes, dune location, and shoal migration. Figure 2.11 shows the baseline stationing used by CSE for monitoring the project area. CSE collects beach profiles at 200 ft spacing, including all even stations from station 200+00 to 370+00. The area of interest for the 2018 project is from 53rd Ave (Station 222+00) to the 18th hole of the Links Course (Station 328+00). The fundamental property measured during the monitoring effort is the volume of sand on the beach at a given time. Volumes are measured by determining the cross-sectional area of the beach from a given point at the landward end of the profile (generally in a location that does not change over time) to a distance offshore at which point the majority of sand movement ceases. At Isle of Palms, this depth is (~) -13 ft NAVD except in the seaward limits of the Dewees Inlet delta. For purposes of monitoring the beach condition, volume calculations for some profiles in the vicinity of inlets are cut short of the -13 ft contour to exclude sand associated with offshore shoals and channels of the inlet.

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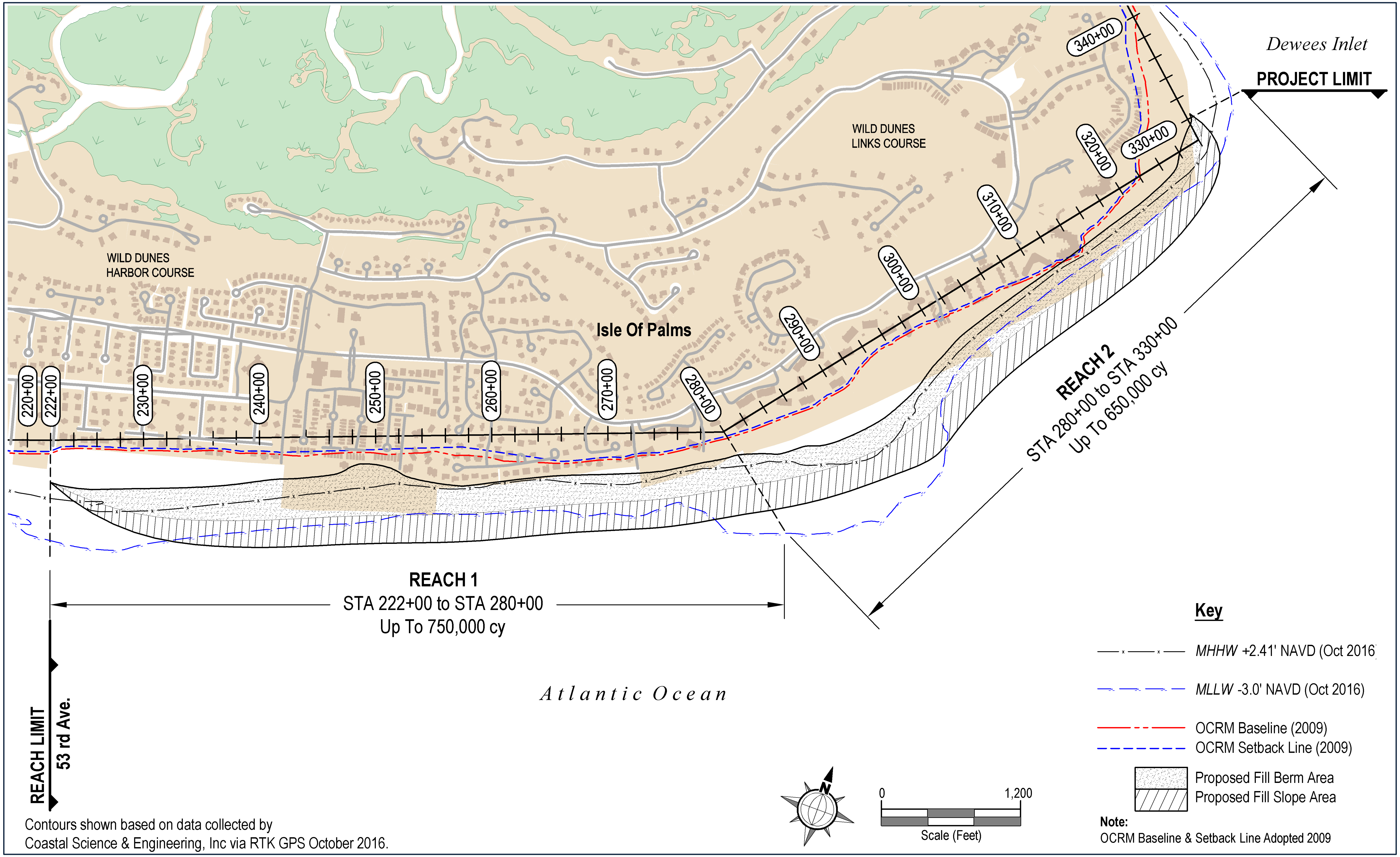


FIGURE 2.11. Project permit plan which shows the baseline stationing used by CSE for monitoring the project area.

Figure 2.12 shows the cumulative beach volume for Reach 5 (53rd Ave to the Wild Dunes Property Owners Beach House — WDPOBH) and Reach 6 (WDPOBH to the 18th Fairway) from July 2007 to April 2018. The interval from July 2008 to January 2018 represents the post-2008 project volume change and is colored orange in the figure. The effects of the 2008 project on beach volume are visible in the 933,000 cy volume increase from Jan–July 2008. From 2008 to January 2018, the beach lost an average of 110,000 cy per year (or 10.1 cy/ft per year), with a maximum annual loss rate of ~194,000 cy observed from 2011–2012. Two time intervals indicated net accretion in reaches 5 and 6; 2007–March 2008, and Sep 2014 – Aug 2015. Both of these time periods coincide with stage three of shoal bypass cycles, where attached sand was spreading along the beach. The period from 2009 to 2013 was highly erosional, with annualized losses greater than 130,000 cy/ft per year between each monitoring event. The majority of the sand losses during this timeframe were losses from spreading of the shoal that attached in 2007 near the center of the project and losses associated with an erosional hotspot centered near the Ocean Club condominium unit. Overall, Reaches 5–6 lost a total of ~1,160,000 cy between July 2008 and January 2018.

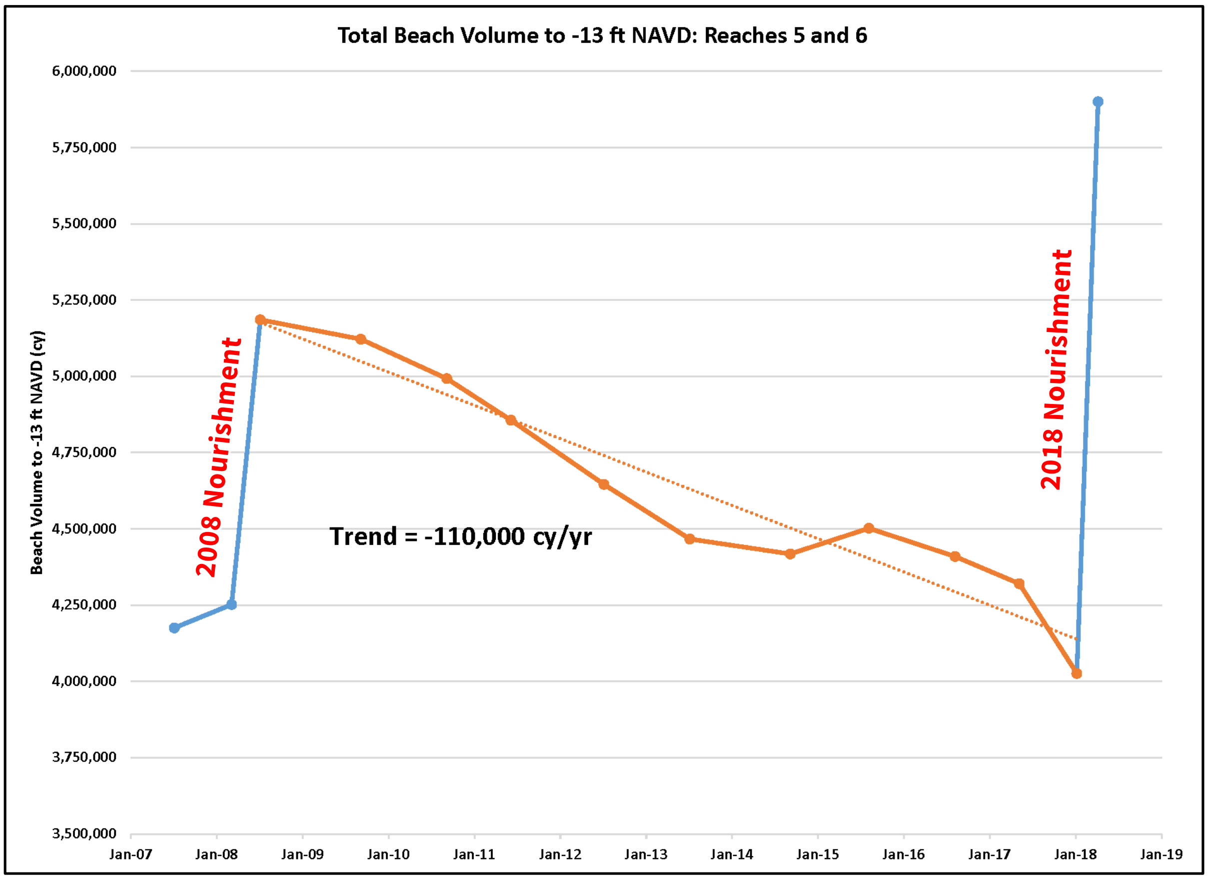


FIGURE 2.12. The Total Volumes Chart illustrates the cumulative beach volume for Reach 5 (53rd Ave to the Wild Dunes Property Owners Beach House - WDPOBH) and Reach 6 (WDPOBH to the 18th Fairway) from July 2007 to April 2018.

Figure 2.13 shows the profile volume for each station in Reaches 5 and 6, with the pre and post project values bolded. The 2008 project impacts are visible in the volume increase between the bold blue and orange lines, and erosion of the 2008 project is tracked in the thin weight lines over time. Details of volume change for individual years and portions of the beach were discussed in monitoring reports provided to the City (CSE 2009/2010/2011a–b/2012/2013/2015/2016a). Generally, along Reach 5, erosion increased from west to east between 2008 and 2014. At the eastern end of the reach (center of the project area), the beach eroded following shoal attachments and accreted during the attachments of 2007 and 2014. By 2014, the beach along Beachwood East was severely eroded, and the erosional signature migrated west through 2018, leaving the area between the Grand Pavilion and Beachwood critically eroded up until the 2018 project. Just before the 2018 project, there was some evidence of recovery along the eastern portion of Beachwood East and Dunecrest Ln; however, there was insufficient sand volume to indicate that a substantial beach would develop along the remainder of the reach.

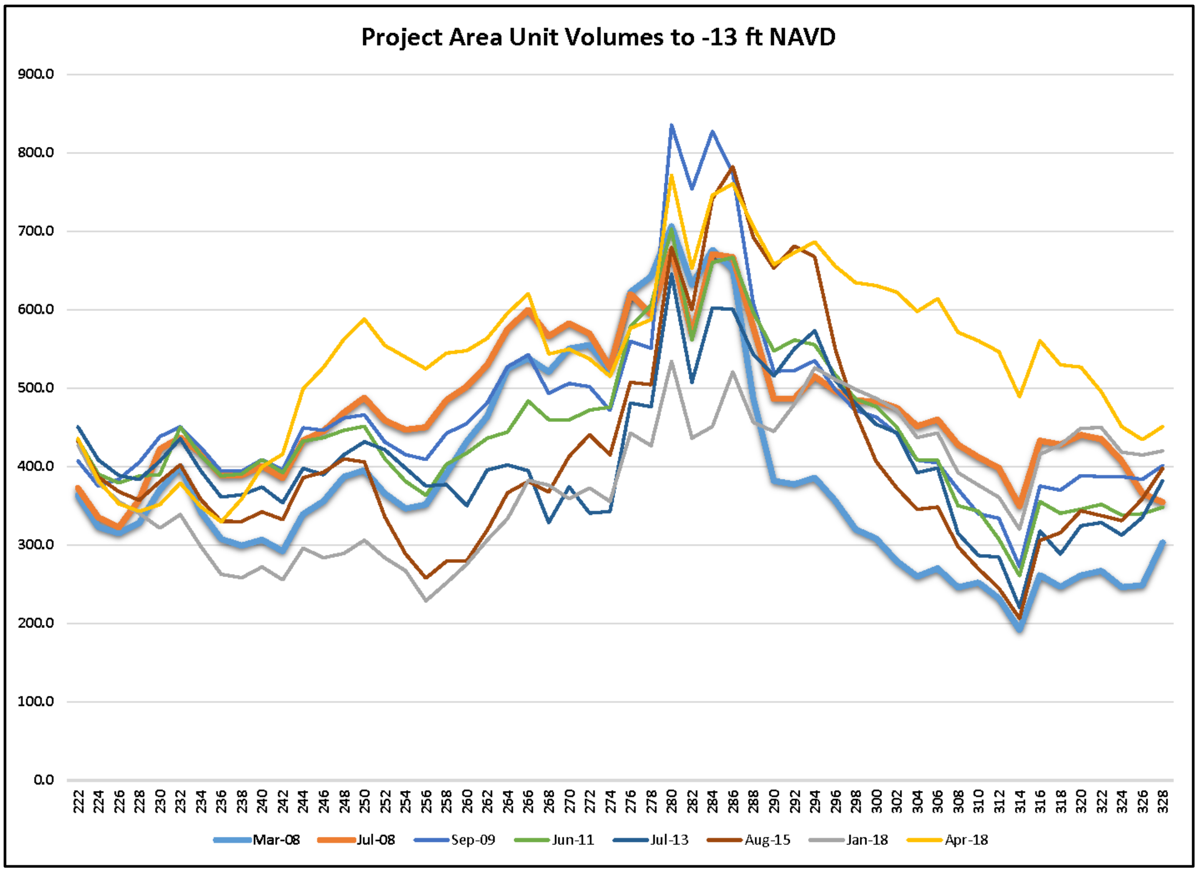


FIGURE 2.13. Profile volume for each station in Reaches 5 and 6, with the pre and post project values bold. The 2008 project impacts are visible in the volume increase between the bold blue and orange lines, and erosion of the 2008 project is tracked in the thin weight lines over time.

Along Reach 6, the general trend was stability/accretion of the western end of the reach (Beach Club Villas and Mariners Walk), and rapid erosion along the eastern end of the reach focused at Seascape and Ocean Club. This latter area appeared to have lost sand to Dewees Inlet, which then likely contributed to the buildup of a “trailing-ebb-spit,” which is a linear sandbar feature that extends from the northeast end of the island on the landward side of the Dewees Inlet channel (Figure 2.14). The eastern half of Reach 6 was erosional through 2016; however, from 2016 through 2017, the beach recovered substantially as sand from the previous shoal attachment spread to the north.

FIGURE 2.14. Trailing-ebb-spit extending from the northeast end of the island on the landward side of the Dewees Inlet channel. Rapid erosion along the eastern end of Reach 6 likely contributed to this event.

Figure 2.15 shows the annualized beach volume change between each survey for the profiles in the project area. The lines represent the magnitude of profile volume gains or losses and are scaled to a yearly rate to eliminate variations in the time between surveys impacting the data (note that pre-post nourishment surveys are excluded). The data show the variation in erosion and accretion rates for each profile, which is a measure of the dynamic nature of the beach near the inlet. West of the 2008 project (stations 202–222), most of the data is in the positive range, meaning the beach has generally accreted. Moving further east, the width of the envelope increases, showing the magnitude of erosion and accretion increased in the area near the shoal attachment zone between stations 274 and 298. Of note is the maximum accretion outside of the shoal attachment zone is along the northern end of the project area (stations 300–320). This suggests (and is confirmed by photos) that a majority of shoal sand attaching in 2014–2015 spread to the north in 2016–2017. The principle message in the data presenting in Figure 2.15 is that the beach in this area is highly dynamic, and the same beach profile can be greatly accreting one year, and highly erosional the following year. The variation in volume change at one location from year to year complicates management practices due to the unpredictable magnitude and duration of volume change trends. Photos of the project area are shown in Figure 2.16 and document the performance of the 2008 project over time.

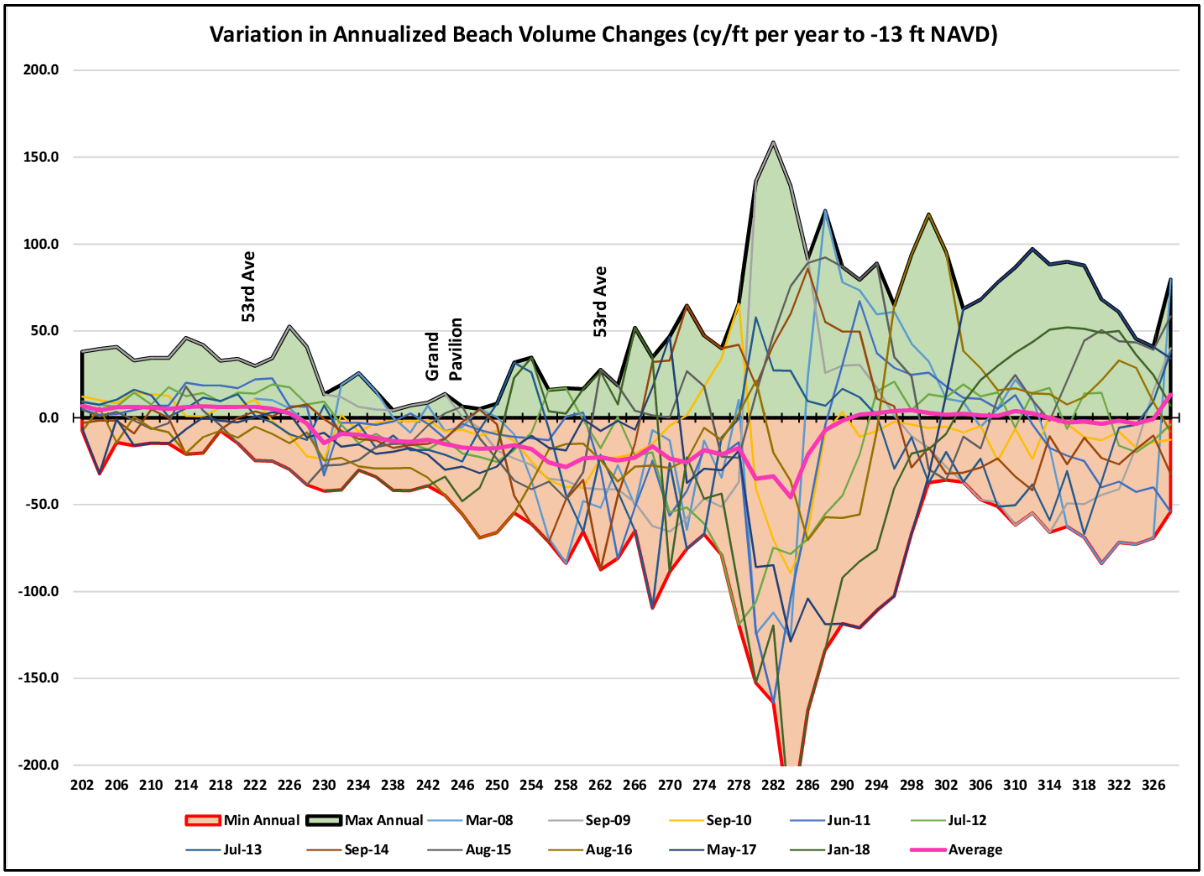


FIGURE 2.15. Annualized beach volume changes between each survey for the profiles in the project area. The lines represent the magnitude of profile volume gains or losses, and are scaled to a yearly rate to eliminate variations in time between surveys impacting the data. West of the 2008 project (stations 202-222), most of the data is in the positive range, meaning the beach has generally accreted.

FIGURE 2.16.

Photos 1–5:
Aerial images of the northeast end of Isle of Palms (Reaches 5–6) from 2008–2016.

Photos 6–7:
View of the northeast end of the island with the Ocean Club condo and the 18th hole of the Links Course in 2012 and 2016.

2.3.1 Engineering

Engineering for the project began with volume analysis to determine the volume of sand required to restore the beach to a desired condition. CSE initially prepared a fill plan based on the beach condition as it existed in 2015, when a recent shoal attachment created a bulge in the shoreline in the center of the project area. CSE updated the fill plan in 2017 following a survey in May of that year. Table 2.1 shows the initial fill plan, which sought to place the majority of the fill in the most severely eroded areas, creating a shoreline with relatively equal unit volumes at the end of the project. Following hurricane impacts in 2015, 2016, and 2017, as well as erosion of the attached shoal, CSE modified the fill template to account for erosion occurring in the center of the project area, as well as substantial accretion at the eastern end. The final fill plan is shown in Table 2.2 and graphically in Figure 2.17. The data reflected show the final design prior to a change order issued during the project that added additional sand to the center of the project area. The fill density averaged 161.5 cy/ft over the length of the project area, with the maximum fill volume of ~325 cy/ft. The nourishment volume decreased along the center of the project area, with a minimum of 50 cy/ft being added.

The design fill profile included a dune, storm berm, fill berm, and sloping section (Fig 2.18). The dune was included in all sections that lacked an existing dune and vegetated area, which included the areas fronting the Grand Pavilion, Seagrove, Beachwood East, and Port of Call to the Links Course. The dune height was set at +10 ft NAVD, which is ~4 ft higher than the typical dry beach elevation. The crest width was 15 ft. In these areas, a ~50 ft wide storm berm was also included in the design to prevent overwash during moderate storm events and extreme tide events from reaching the dune. The elevation of the storm berm was +7.5 ft NAVD, which is high enough to prevent swash from moderate storms and extreme tides from overtopping the berm.

The berm elevation was designed to be +5.5 ft NAVD, which was 0.5 ft lower than the 2008 project berm height. The berm width ranged in distance based on the fill volume design, reaching as much as 600 ft in the highest density areas. The berm width decreased along the central portion of the project area, as the pre-project beach was wider than adjacent areas. The berm width at either end of the project tapered to the existing dune line. The slightly lower berm elevation was designed to reduce the likelihood of persistent escarpments forming in the future. The lower elevation does allow for washover events to overtop the berm occasionally during extreme tides or storm events. This occurs on natural beaches as well; however, the large width of the nourishment berm magnifies the visibility of these events and allows for water to temporarily pond on the flat surface.

The seaward slope of the berm was designed with a slope of 1 on 20; however, the contractor was allowed to adjust the slope of the fill to facilitate efficient placement. The fill slope is useful in planning the design berm width; however, it is quickly adjusted to the natural beach slope by wave action, often within a few weeks of placement. The slope of the intertidal beach is a constantly changing physical feature of the beach that depends on the tide level, wave energy, and sediment grain size.

TABLE 2.1. The initial 2018 fill plan, which sought to place the majority of the fill in the most severely eroded areas, creating a shoreline with relatively equal unit volumes at the end of the project.

Reach	Station	May 2017 Unit Volume (cy/ft)	Nourishment Unit Volume (cy/ft)	Total Nourishment Volume (cy)	Cumulative Nourishment Volume (cy)	Post-Fill Unit Volume (cy/ft)	Location
Reach 1	222	544.1	0			544.1	53rd Ave
	224	566.9	0			566.9	
	226	584.7	0			584.7	
	228	547.4	0			547.4	
	230	556.0	0			556.0	55th Ave
	232	526.3	0			526.3	
	234	505.9	0			505.9	
	236	447.2	0	5,000	5,000	447.2	
	238	430.1	50	15,000	20,000	480.1	
	240	400.7	100	27,500	47,500	500.7	57th Ave
	242	369.6	175	37,500	85,000	544.6	
	244	338.5	200	45,000	130,000	538.5	
	246	319.5	250	55,000	185,000	569.5	
	248	289.9	300	62,500	247,500	589.9	Grand Pavilion
	250	262.4	325	65,000	312,500	587.4	
	252	247.3	325	65,000	377,500	572.3	
	254	235.2	325	67,500	445,000	560.2	Seagrove
	256	231.8	350	67,500	512,500	581.8	
	258	247.8	325	62,500	575,000	572.8	
	260	267.6	300	57,500	632,500	567.6	
	262	329.3	275	50,000	682,500	604.3	Center Beachwood East
	264	386.3	225	40,000	722,500	611.3	
	266	413.5	175	35,000	757,500	588.5	
	268	391.4	175	32,500	790,000	566.4	Dunecrest
	270	450.0	150	27,500	817,500	600.0	
	272	441.1	125	20,000	837,500	566.1	
	274	418.8	75	10,000	847,500	493.8	Beach Club Villas
	276	529.5	25	2,500	850,000	554.5	
	278	535.4	0	0	850,000	535.4	
Reach 2	280	710.9	0		850,000	710.9	Property Owners Beach House
	282	729.8	0		850,000	729.8	
	284	691.4	0		850,000	691.4	
	286	718.0	0		850,000	718.0	
	288	576.0	0	3,000	853,000	576.0	
	290	512.9	30	7,000	860,000	542.9	Mariners Walk
	292	511.9	40	10,000	870,000	551.9	
	294	458.8	60	13,500	883,500	518.8	
	296	416.3	75	17,500	901,000	491.3	
	298	430.6	100	27,500	928,500	530.6	
	300	394.6	175	37,500	966,000	569.6	
	302	384.5	200	42,000	1,008,000	584.5	Summer Dunes Ln
	304	403.2	220	44,500	1,052,500	623.2	
	306	466.5	225	45,000	1,097,500	691.5	
	308	424.3	225	47,500	1,145,000	649.3	
	310	364.8	250	55,000	1,200,000	614.8	Seascape
	312	294.7	300	62,500	1,262,500	594.7	
	314	272.2	325	55,000	1,317,500	597.2	Ocean Club
	316	369.6	225	37,500	1,355,000	594.6	
	318	443.0	150	25,000	1,380,000	593.0	
	320	519.2	100	15,000	1,395,000	619.2	
	322	697.2	50	5,000	1,400,000	747.2	
	324	790.5	0	0		790.5	18th Green (par 3)
	326	518.7				518.7	
	328	481.1				481.1	
Reach 1					850,000		
Reach 2					550,000		
Total					**1,400,000**		

TABLE 2.2. The modified final 2018 fill template designed to account for erosion occurring in the center of the project area, as well as substantial accretion at the eastern end of the island.

Station	Pre-Project Unit Volume (cy/ft)	Fill Vol (cy/ft)	Design Fill Vol (cy/ft)	Post-Project Unit Volume (cy/ft)
230	321.6	**0.0**	321.6	351.6
232	338.9	**0.0**	338.9	379.0
234	298.4	**0.0**	298.4	349.0
236	262.7	**0.0**	262.7	329.7
238	258.3	**26.4**	284.8	358.5
240	272.2	**59.0**	331.2	399.6
242	255.7	**73.9**	329.6	415.9
244	295.9	**170.8**	466.7	499.0
246	283.7	**233.3**	517.0	526.5
248	289.5	**277.7**	567.2	562.6
250	306.2	**296.6**	602.8	587.9
252	283.8	**307.5**	591.2	554.5
254	267.2	**315.2**	582.4	539.7
256	228.9	**320.6**	549.6	524.7
258	251.7	**325.8**	577.6	544.6
260	275.5	**314.6**	590.2	547.9
262	306.5	**298.2**	604.7	563.4
264	333.8	**260.0**	593.8	595.7
266	382.5	**240.0**	622.5	620.5
268	376.4	**210.0**	586.4	543.5
270	359.2	**150.0**	509.2	549.8
272	372.9	**120.0**	492.9	537.1
274	355.6	**90.0**	445.6	515.2
276	442.8	**75.0**	517.8	576.2
278	426.6	**60.0**	486.6	587.3
280	534.3	**60.0**	594.3	771.4
282	436.3	**60.0**	496.3	652.7
284	450.9	**50.0**	500.9	746.0
286	520.6	**50.0**	570.6	760.5
288	456.4	**50.0**	506.4	705.7
290	444.9	**60.0**	504.9	657.8
292	479.3	**60.0**	539.3	672.8
294	526.0	**80.0**	606.0	686.2
296	511.1	**110.0**	621.1	655.5
298	498.4	**130.0**	628.4	634.5
300	487.0	**160.0**	647.0	630.9
302	472.4	**190.0**	662.4	622.6
304	436.9	**225.0**	661.9	597.7
306	442.7	**250.0**	692.7	614.1
308	392.2	**250.0**	642.2	571.3
310	376.4	**250.0**	626.4	560.2
312	361.0	**225.0**	586.0	546.5
314	320.2	**180.0**	500.2	488.9
316	415.6	**140.0**	555.6	560.5
318	427.6	**90.0**	517.6	529.7
320	449.0	**30.0**	479.0	526.7
322	449.8	**20.0**	469.8	495.5
324	418.4	**0.0**	418.4	450.9
326	415.0	**0.0**	415.0	434.3
328	420.0	**0.0**	420.0	451.0

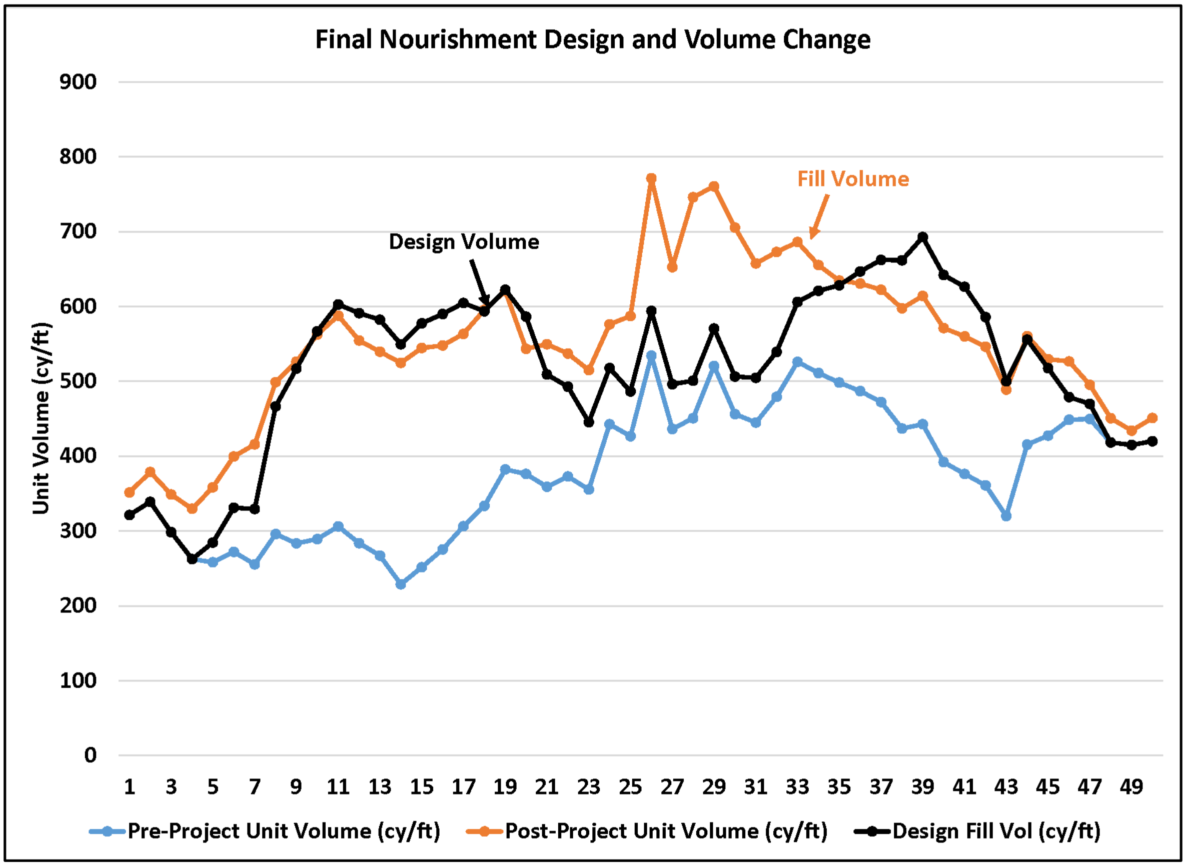


FIGURE 2.17. A graphic representation of the 2018 final fill template (shown in TABLE 2.2).

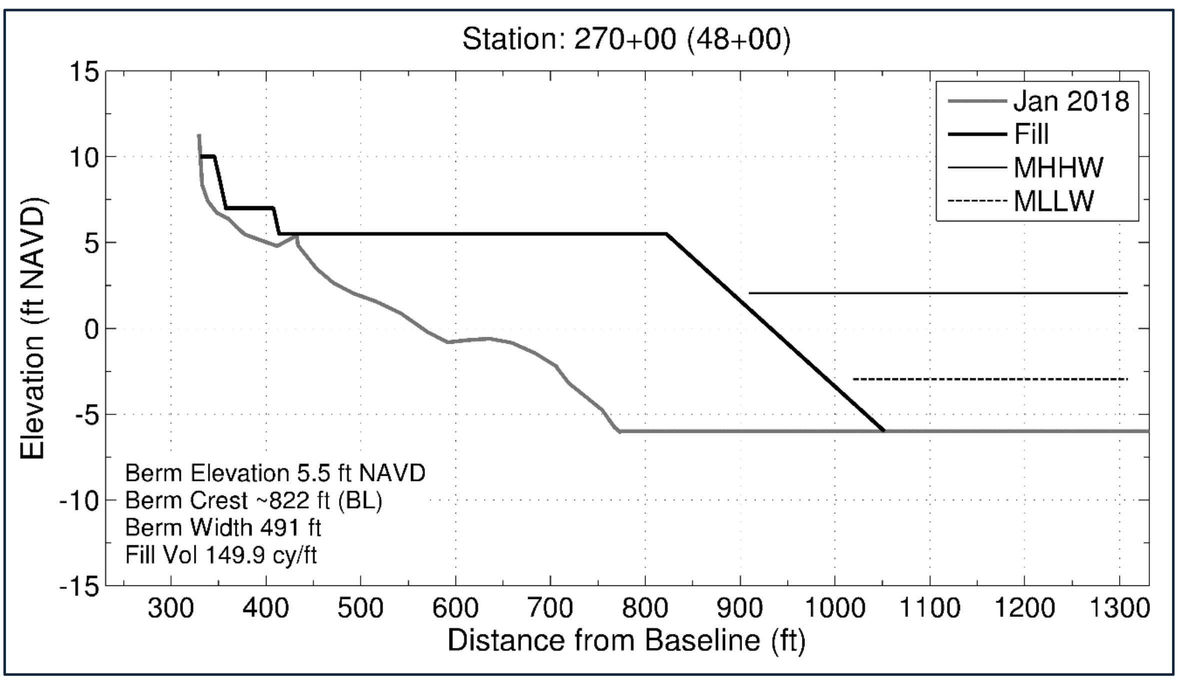


FIGURE 2.18. The design 2018 fill profile which plans for a dune, storm berm, fill berm, and sloping section.

2.3.2 Borrow Areas and Sediment Quality

A critical component of any beach restoration project is the character of the sediment used as fill material, and how it compares to the native beach. To evaluate the native sediment characteristics, CSE obtained sediment samples at 1,000 ft intervals along the project area. At each station, CSE obtained four samples, with one at the toe of the dune, one at the mid berm, one along the sloping face of the beach, and one at the low-tide terrace (shallow low-tide area). For each sample, CSE analyzed the grain size distribution and shell content of the sediment. Results of the analysis are shown in section three of this report. Table 2.3 shows the comparison between before and after project for the various locations along the profile. The average grain size for all samples was 0.199 mm. The dune and low tide area had coarser sand while the berm and beach face had finer sediment. The native beach showed an average shell content ($CaCO_3$) of 6.2 %, with a maximum sample value of 20.7 %.

TABLE 2.3. Comparison of pre- and post-project sediment samples for various stations along the project area.

Station	Befor Project Grain Size (mm)				After Project Grain Size (mm)			
	Dune	Berm	Beach Face	LTT	Dune	Berm	Beach Face	LTT
230	0.213	0.177	0.203	0.297	ND	ND	ND	ND
240	0.171	0.168	0.184	0.212	0.179	0.274	0.383	0.277
250	ND	ND	ND	ND	0.229	0.360	0.713	0.459
260	0.162	0.156	0.177	0.205	0.225	0.439	0.460	0.239
270	0.142	0.152	0.175	0.182	0.237	0.308	0.678	0.407
280	0.182	0.173	0.187	0.337	0.203	0.869	0.456	0.499
290	0.294	0.183	0.177	0.245	0.298	0.468	0.337	0.576
300	0.279	0.168	0.172	0.186	0.181	0.500	0.468	0.356
310	0.182	0.156	0.176	0.323	0.183	0.536	0.385	1.318
320	0.180	0.190	0.199	ND	0.198	0.513	0.643	0.204
Average Grain Size (mm)	0.201	0.169	0.183	0.248	0.215	0.474	0.503	0.482

The sediment character of the post-project beach is dependent on the sediment quality of the borrow area. In the offshore zone of central South Carolina, there are varying sediment types, including deposits of sand, mud, and shelly material. Often, layers exist in the sediments where sand may lie over or under deposits containing mud or silt. In determining a suitable borrow area for beach nourishment, an area must be located that contains sufficient quantity of sand with minimal fine material, and with a thickness and orientation that allows for efficient dredging. For the 2018 project, CSE initially obtained borings near the borrow areas used for the 2008 project (Fig 2.19). This was done due to the likelihood of similar sediment quality, and the desire to place the borrow area along bathymetric highs (ridges) to reduce the likelihood of creating abnormally deep areas in the vicinity.

Following analysis of the first borings, CSE identified a preliminary borrow area situated west of the 2008 Borrow Area A. As part of the coordination with FEMA for post-disaster recovery funds, CSE was required to provide the SC State Historic Preservation Office (SHPO) with the preliminary borrow area spatial configuration. SHPO informed CSE that since the 2008 project, they received funding to study Civil War-era shipwrecks in the vicinity of Charleston Harbor, and located up to 13 wrecks associated with a blockade of the harbor. Referred to as the 2nd Stone Fleet, the wrecks were comprised of old whaling vessels filled with large stone and sunk around the shoals of the harbor. SHPO indicated that they were seeking to designate a four square mile area offshore of Isle of Palms as a historic district and that no dredging would be allowed within the district (Fig 2.20). The area included the proposed borrow area identified by CSE, resulting in the need for additional geotechnical investigations to find an alternate borrow site(s).

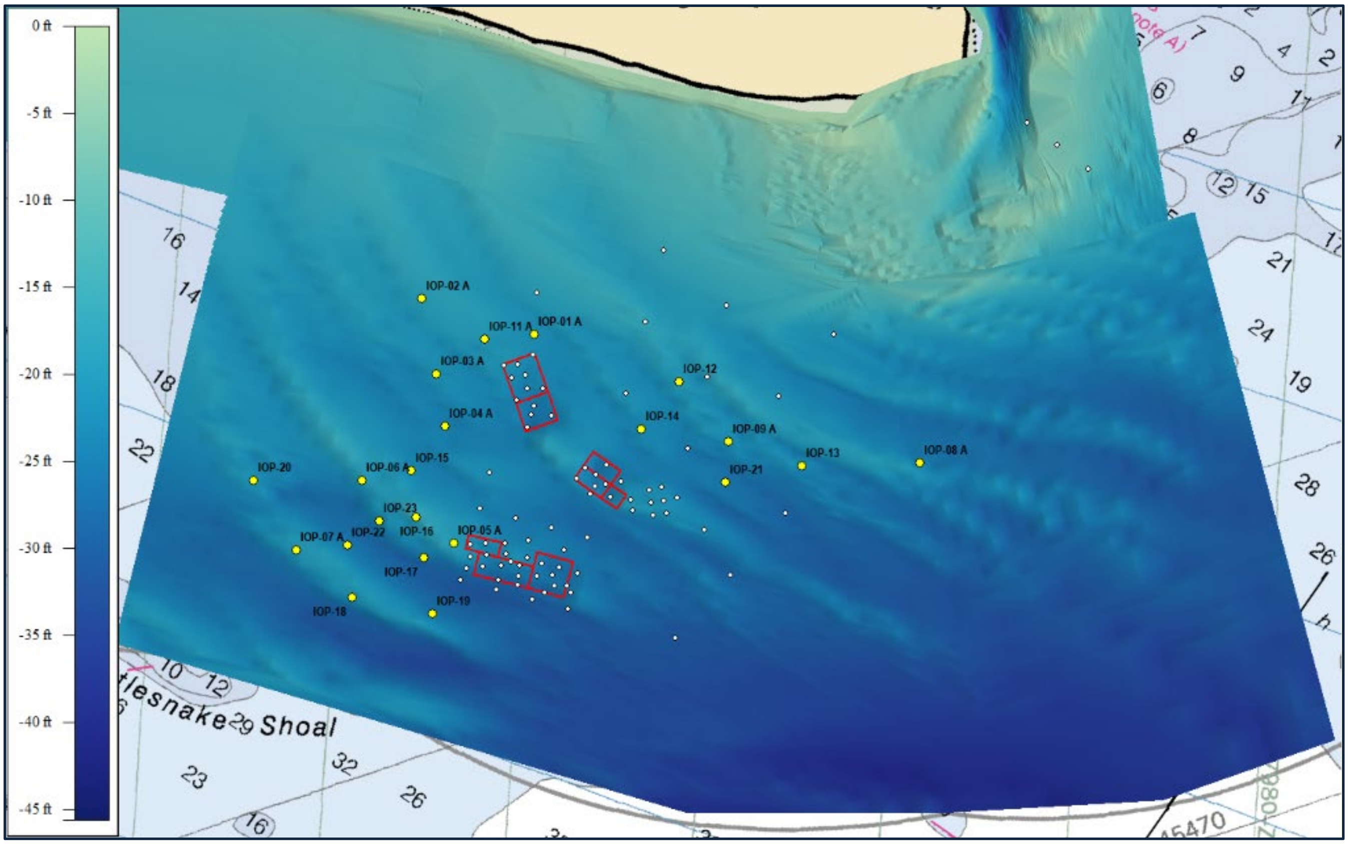


FIGURE 2.19. Borrow areas used for the 2008 renourishment project (red boxes). Initial testing locations for the 2018 project are shown in the bold yellow dots. Borings for the 2008 project are shown as the small dots.

CSE attempted to identify the highest quality sediment sources for borrow material; however, borings revealed areas containing higher than acceptable mud content, or areas with large shells. Additional borings were obtained offshore of Isle of Palms, for a total of 92 borings covering a 3,000 acre (4.7 sq mi) area offshore (Figure 2.20). Each sampling effort sought to refine potential borrow area footprints based on findings of the previous efforts. Each boring was subdivided according to the sediment layering within the boring, and each subsample was analyzed for grain size distribution and shell content. A total of 271 samples were analyzed (Appendix F).

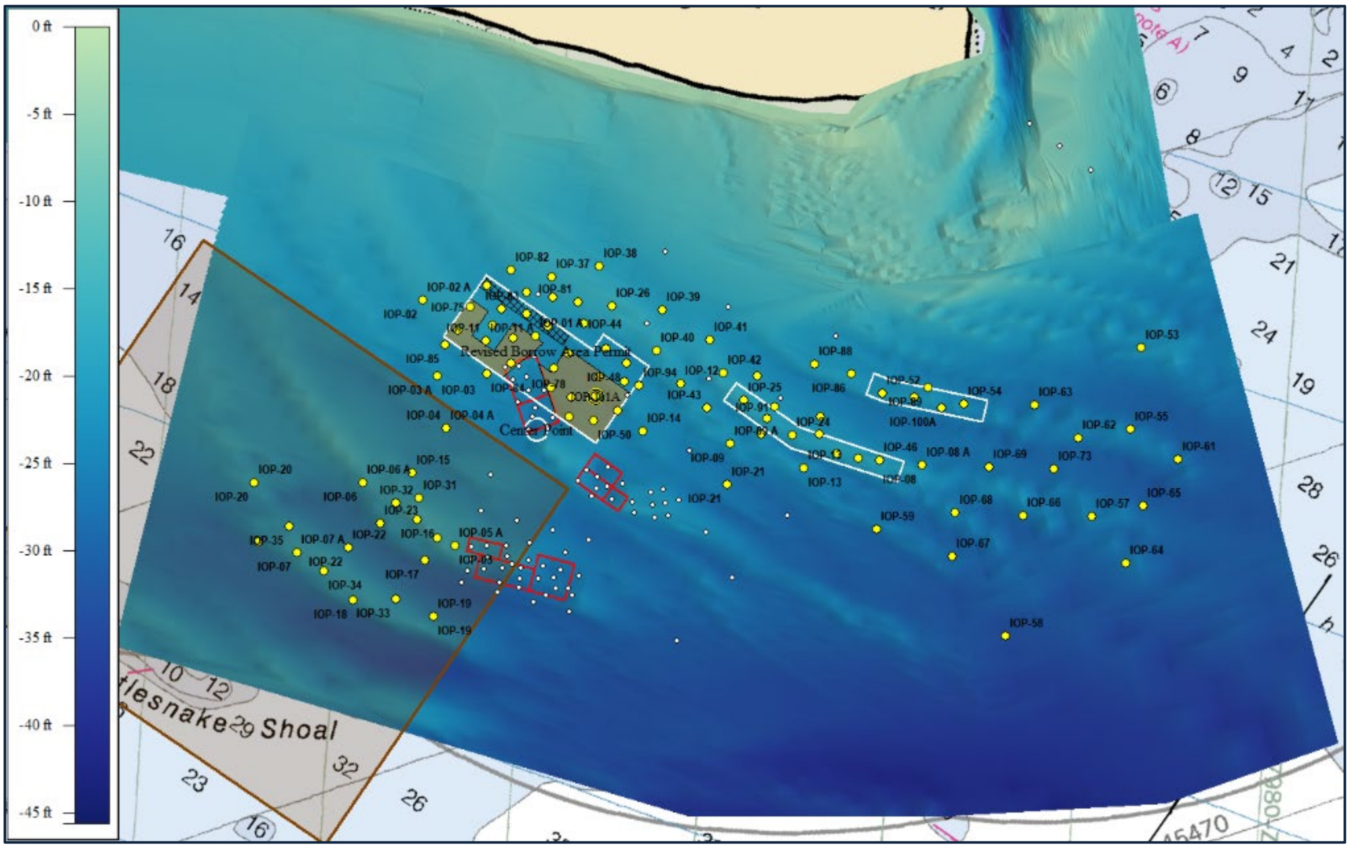


FIGURE 2.20. Boring sample locations indicating a total of 92 borings covering a 3,000 acre (4.7 sq mi) area offshore. The square shape in the left of the image is the SHPO historic district.

Figure 2.21 shows an example of a boring log and photo. Composite values were generated to varying depths below the seafloor to summarize the total sediment quality of the borrow areas. Based on these values, CSE outlined two priority borrow areas (named E and F) that contained sufficient sediment to implement the project (Fig 2.22 and Fig 2.23). Table 2.4 shows the sediment characteristics of the borings within each borrow area.

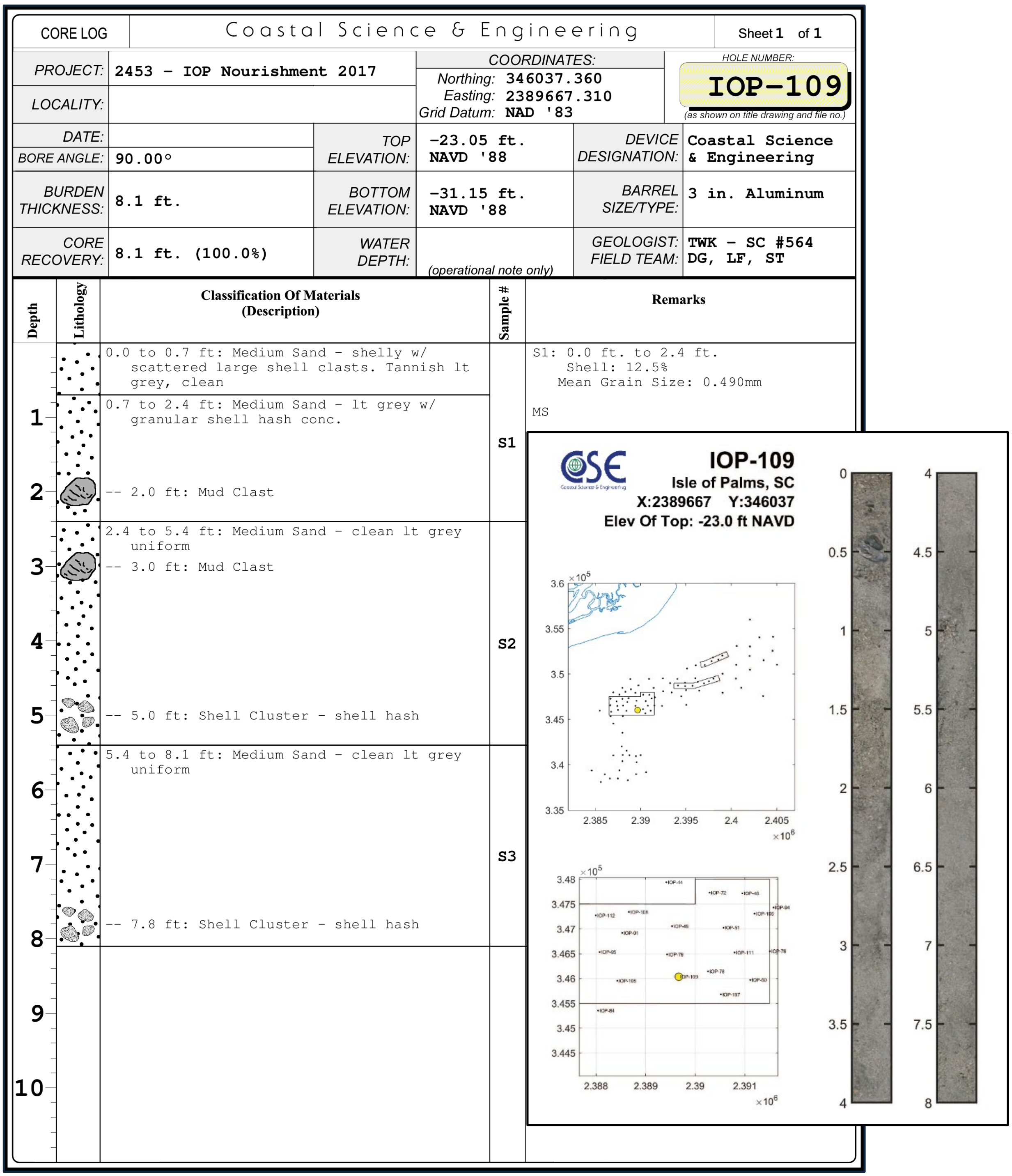
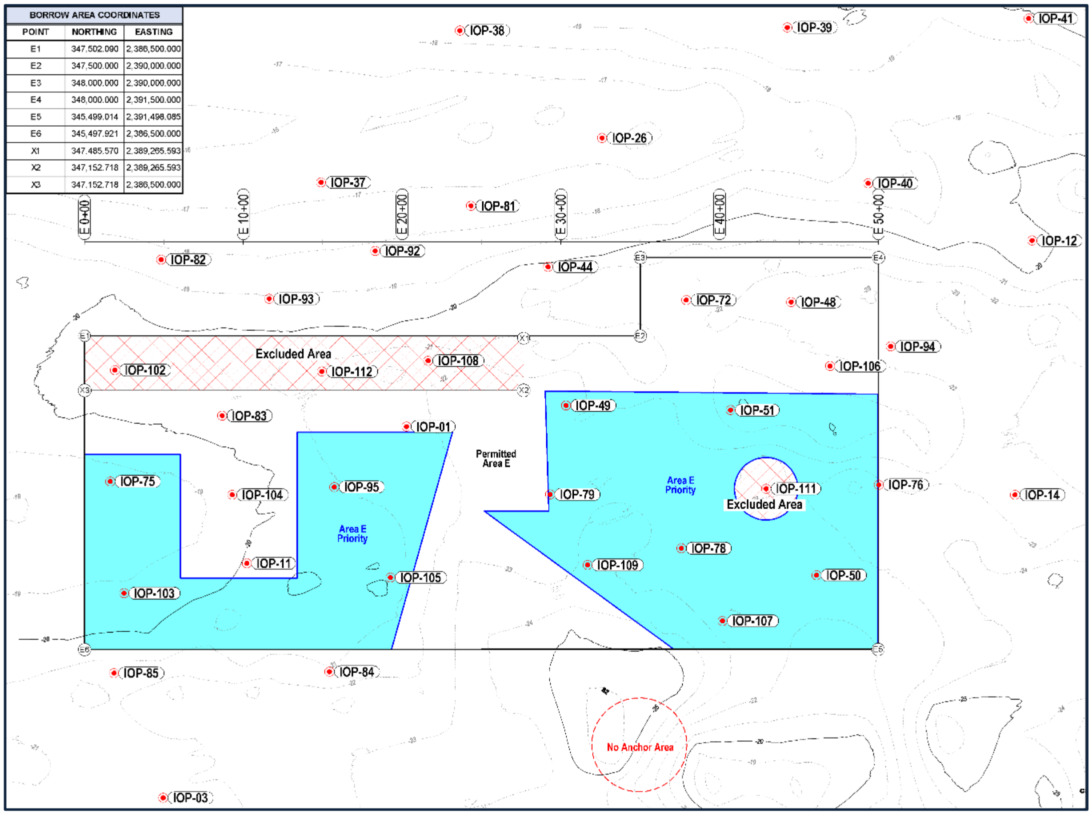
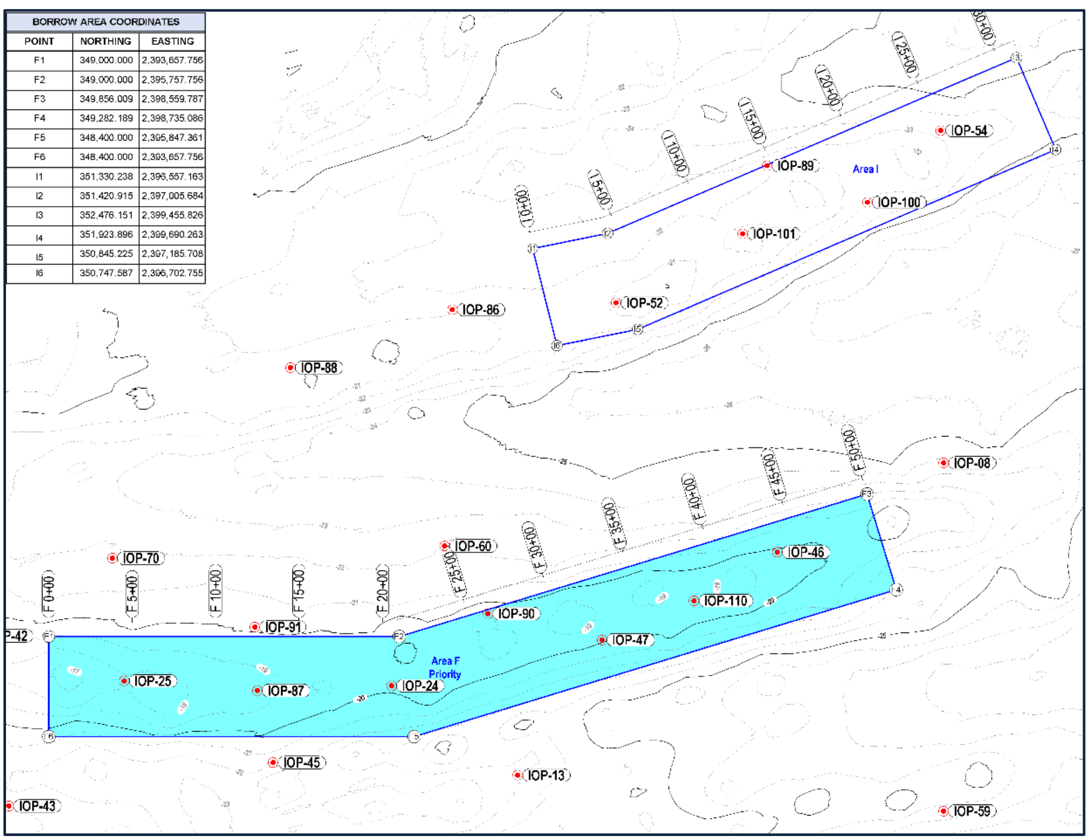


FIGURE 2.21. Example of a boring log and photo. Composite values were generated to varying depths below the seafloor to determine two borrow areas (known as Borrow Area E and Borrow Area F).



BORROW AREA COORDINATES		
POINT	NORTHING	EASTING
E1	347,502.090	2,386,500.000
E2	347,500.000	2,390,000.000
E3	348,000.000	2,390,000.000
E4	348,000.000	2,391,500.000
E5	345,499.014	2,391,498.085
E6	345,497.921	2,386,500.000
X1	347,485.570	2,389,265.593
X2	347,152.718	2,389,265.593
X3	347,152.718	2,386,500.000

FIGURE 2.22. Borrow Area E determined by boring logs taken offshore. "Priority" dredging areas are highlighted in blue.



BORROW AREA COORDINATES		
POINT	NORTHING	EASTING
F1	349,000.000	2,393,657.756
F2	349,000.000	2,395,757.756
F3	349,856.009	2,398,559.787
F4	349,282.189	2,398,735.086
F5	348,400.000	2,395,847.361
F6	348,400.000	2,393,657.756
I1	351,330.238	2,396,557.163
I2	351,420.915	2,397,005.684
I3	352,476.151	2,399,455.826
I4	351,923.896	2,399,690.263
I5	350,845.225	2,397,185.708
I6	350,747.587	2,396,702.755

FIGURE 2.23. Borrow Area F. Area I to the north was permitted but not included in the scope of work.

TABLE 2.4. Sediment characteristics for borings inside of Borrow Areas E and F.

	Core	Mean	STD	>2mm	% Shell
AREA E Priority	49	0.436	0.381	9.2	31.7
	50	0.378	0.357	9.1	21.6
	51	0.419	0.330	13.1	30.3
	75	0.262	0.378	5.2	18.4
	76	0.250	0.393	6.2	22.1
	78	0.341	0.381	8.5	25.5
	79	0.635	0.278	22.6	46.5
	95	0.198	0.576	1.8	5.0
	103	0.258	0.349	6.9	28.7
	105	0.203	0.521	1.6	12.8
	107	0.588	0.296	18.6	40.6
	109	0.364	0.454	5.5	21.6
	Average	**0.361**	**0.391**	**9.0**	**25.4**
AREA E Non-Priority	1	0.344	0.406	5.0	19.0
	11	0.209	0.477	3.6	16.4
	48	0.523	0.293	19.7	33.1
	50	0.378	0.357	9.1	21.6
	72	0.896	0.360	22.0	54.5
	83	0.358	0.369	9.1	26.4
	104	0.227	0.411	3.7	21.3
	106	0.458	0.319	13.6	29.5
	Average	**0.424**	**0.374**	**10.7**	**27.7**
AREA F	24	0.333	0.421	6.4	22.8
	25	0.384	0.320	13.2	31.4
	46	0.404	0.282	16.9	31.2
	47	0.410	0.329	11.0	24.5
	87	0.399	0.321	12.0	35.6
	90	0.268	0.431	4.2	26.9
	110	0.372	0.335	11.5	29.2
	Average	**0.367**	**0.348**	**10.8**	**28.8**
AREA I	52	0.342	0.392	6.5	24.3
	54	0.367	0.410	6.6	22.1
	89	0.401	0.344	9.1	29.7
	100	0.238	0.524	2.3	16.5
	101	0.405	0.337	7.6	23.1
	Average	**0.351**	**0.402**	**6.4**	**23.1**

Borrow Area E was subdivided into priority and non-priority areas in an attempt to place the most beach compatible sand for the project. All of Borrow Area F was considered a priority area, while Area I was considered to be a reserve to be used only if needed. The sediment in Borrow Areas E (priority) and F showed an average mean grain size of 0.361 mm and 0.367 mm, respectively. Shell percentage averaged 25.4% and 28.8%, respectively; however, the majority of the shell was fine shell has less than 2.0 mm in diameter. While the sediment within the identified borrow areas was beach compatible, it did contain small fractions of silty or muddy material, and areas between the borings may have contained higher percentages of fine material. CSE considered the area within the SHPO historic district to contain better material; however, it was agreed that for the present project, the City would use the areas outside of the district. CSE informed the City that during the project, there might be occasions when muddy material or mud rollers may be visible on the beach; however, CSE would work with the dredging company to relocate the dredge if unsuitable material was observed.

2.3.3 Permitting

Permitting for the project required preparation and submission of an application to SCDHEC-OCRM and the USACE. The application included drawings showing the project scope and footprint. It also included a text description of the work, including justification for the project and brief analysis of potential environmental impacts (Appendix A). CSE submitted the permit application in November 2016, and the USACE issued a public notice on 16 December 2016. As part of the permitting process, the permitting agencies are required to solicit comments from resource agencies (SHPO, USFWS, SCDNR, NOAA NMFS) and the public. USFWS required a formal Biological Assessment (BA) to complete Section 7 consultation for the Endangered Species Act (ESA), and NOAA NMFS required an Essential Fish Habitat (EFH) assessment. CSE prepared a comprehensive BA and EFH report documenting the existing environmental conditions and potential impacts of the project (CSE 2016b). USFWS used this report to issue a Biological Opinion (BO) in April 2017 (USFWS 2017), which fulfills the requirements of the ESA.

CSE requested a modification to the permit application to revise the borrow areas based on additional information gained by borings obtained in 2017. A portion of Borrow Area E was eliminated and the provisional Borrow area I was added. SCDHEC OCRM issued the state permit in June 2017 with the USACE issuing the federal permit in August 2017 (P/N 2016–00803). Each permit contained special conditions requiring environmental protection measures and monitoring.

Additionally, impacts of Hurricanes *Matthew* and *Irma* required the project scope to be modified to account for sand volume loss and adjustment of the beach contours. CSE requested another modification to increase the project volume by 285,000 cy. OCRM and USACE issued this modification to the permit in January 2018.

3.0 CONSTRUCTION

The City of Isle of Palms released a Request for Bids in July 2017. The RFB (City RFB 2017–05) included a scope of work of up to 1,400,000 cy of sand placed over 8,800 linear feet of beach. Work would be completed between 1 October 2017 and 30 March 2018 (Bid A) or 1 October 2018 and 30 March 2019 (Bid B). A mandatory pre-bid meeting was scheduled for 1 August 2017, with the bid opening 15 August 2017. Bids were received from three contractors and ranged from $11,875,000 to $15,846,000, with the lowest bid by Great Lakes Dredge & Dock Co for the 2017–2018 construction window (Bid A). Table 3.1 shows the bid tabulation for the project.

TABLE 3.1. Bid tabulation for the project.

	Great Lakes Dredge & Dock Co.	Marinex Construction	Weeks Marine
Bid A (October 2017)			
Mobilization & Demobilization	$ 3,415,000	No bid	$ 2,575,000
Base Bid – Dredging 1M CY	$ 6,000,000	No bid	$ 7,150,000
Unit Price of 400,000 CY	$ 6.15	No bid	$6
Total Price Bid A	**$ 11,875,000**	**No bid**	**$ 12,125,000**
Bid B (October 2018)			
Mobilization & Demobilization	$ 3,465,000	$ 4,800,000	$ 4,575,000
Base Bid – Dredging 1M CY	$ 6,000,000	$ 7,890,000	$ 8,000,000
Unit Price of 400,000 CY	$ 6.15	$ 7.89	$ 6.75
Total Price Bid B	**$ 11,925,000**	**$ 15,846,00**	**$ 15,275,000**
Suspension Cost (per day)	$121,000	$ 50,000	$ 150,000

The City entered into an agreement for the project with GLDD on 7 September 2017 and began mobilizing equipment to IOP in December 2017. GLDD mobilized shore pipe, bulldozers, loaders, and accessory equipment including the "dump shack" to the beach via 53rd Avenue. Initial staging area was positioned near Beach Club Villas, in the center of the project area (Fig 3.1). GLDD placed the subline on the ocean bottom between the borrow area and the beach, completing the last portion on 9 January. The Dredge *Illinois* arrived in the borrow site on 15 January.

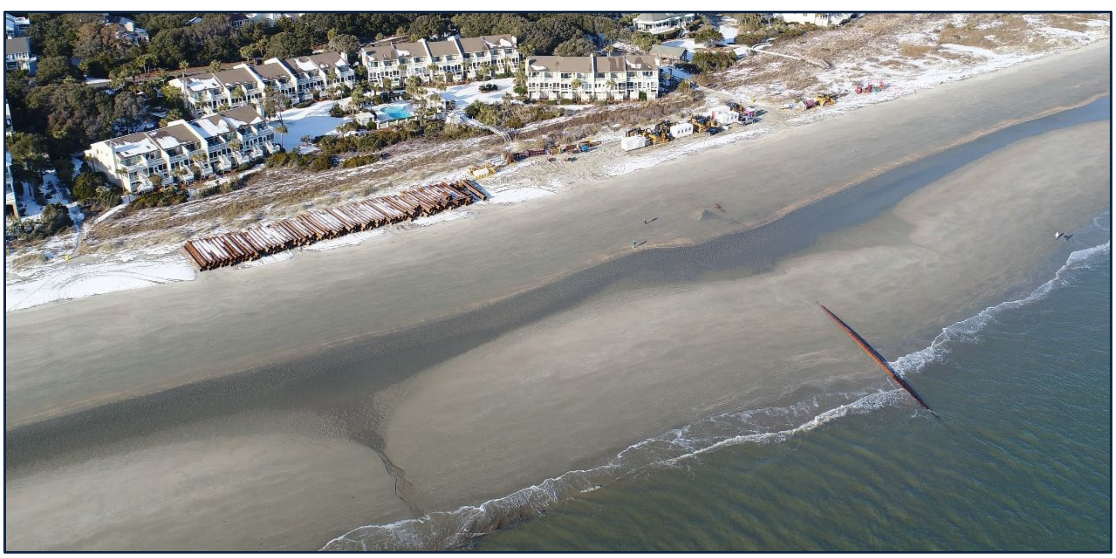


FIGURE 3.1. Initial project staging area located near Beach Club Villas. Note the rare snow event captured in the photo (date 5 January 2018).

First pumping occurred on 16 January, with the pipe located seaward of Beach Club Villas 1 (station 276+00). GLDD established a "pad," which is the initial portion of the fill that established the berm at the design grade. Once the pad was established, GLDD attached the first sections of steel shore pipe, extending in the south/west direction. GLDD quickly worked to widen the fill berm by adding Y-valves so that sand could be added to multiple portions of the berm to create the design profile. Beach fill progressed to the west, with GLDD adding up to 65,000 cy of sand per day. Figure 3.2 shows the fill progress mapped according to engineering stations along the beach. As part of the fill template, GLDD constructed a dune along the majority of the reach. GLDD completed the western section of the fill area on 24 February 2018, adding a total of ~958,000 cy of sand to the beach between stations 236+00 and 278+00 (4,200 lf).

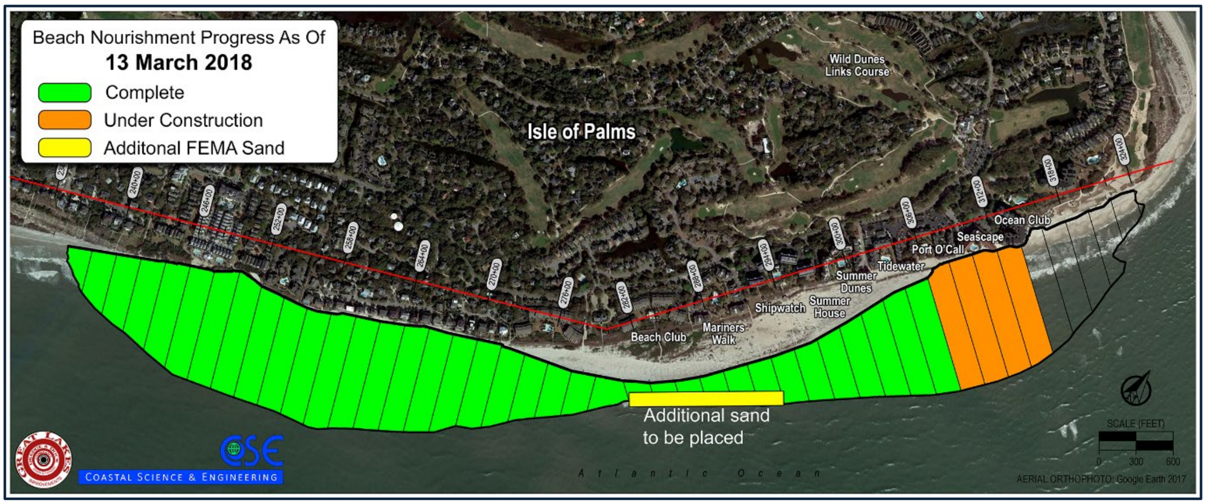


FIGURE 3.2. Fill progress map illustrating all engineering stations along the project area.

After completion of the western end of the fill area, GLDD reversed the elbow at the subline and began pumping sand to the northeast, beginning near the Wild Dunes Property Owners Beach House (POBH). Work continued toward Dewees Inlet until 17 March 2018, when the fill reached the northern boundary of the project design. After completing the northern reach, GLDD repositioned the outflow pipe to station 280+00 (near the POBH) to add additional sand to the project following approval of a change order dated 8 March 2018. The change order approved placement of an additional 276,518 cy of sand, which was the quantity approved for FEMA reimbursement following Hurricane *Irma*. GLDD placed the additional sand between 17 March and 23 March 2018, completing all fill placement for the project on the 23rd of March. GLDD removed all pipe and equipment from the beach on 1 April 2018.

The *Illinois* is a 30-inch suction-cutterhead dredge with 11,350 hp. The dredge operates by placing the cutterhead into the sediment where the cutterhead rotates to loosen the sediment and mix with the surrounding ocean water. The slurry is then pumped through a series of pumps from the cutterhead, through the dredge, and finally through the subline to the beach. The dredge plant is a barge, and maneuvers within the borrow area via a network of anchors and cables. The dredge pulls itself forward and side to side using cables attached to the anchors, creating arcing cuts approximately 200 ft in width. Figure 3.3 shows the dredge cut paths for the project in Borrow Areas E and F. The individual colors represent different days the dredge was operating. The dredge initially started along the eastern part of Borrow Area E, with the dredge moving from the seaward side and moving towards the landward side of the borrow area (moving north). The dredge would move north within a cut until it reached the end of the borrow area and then would shift back south and west to the next cut.

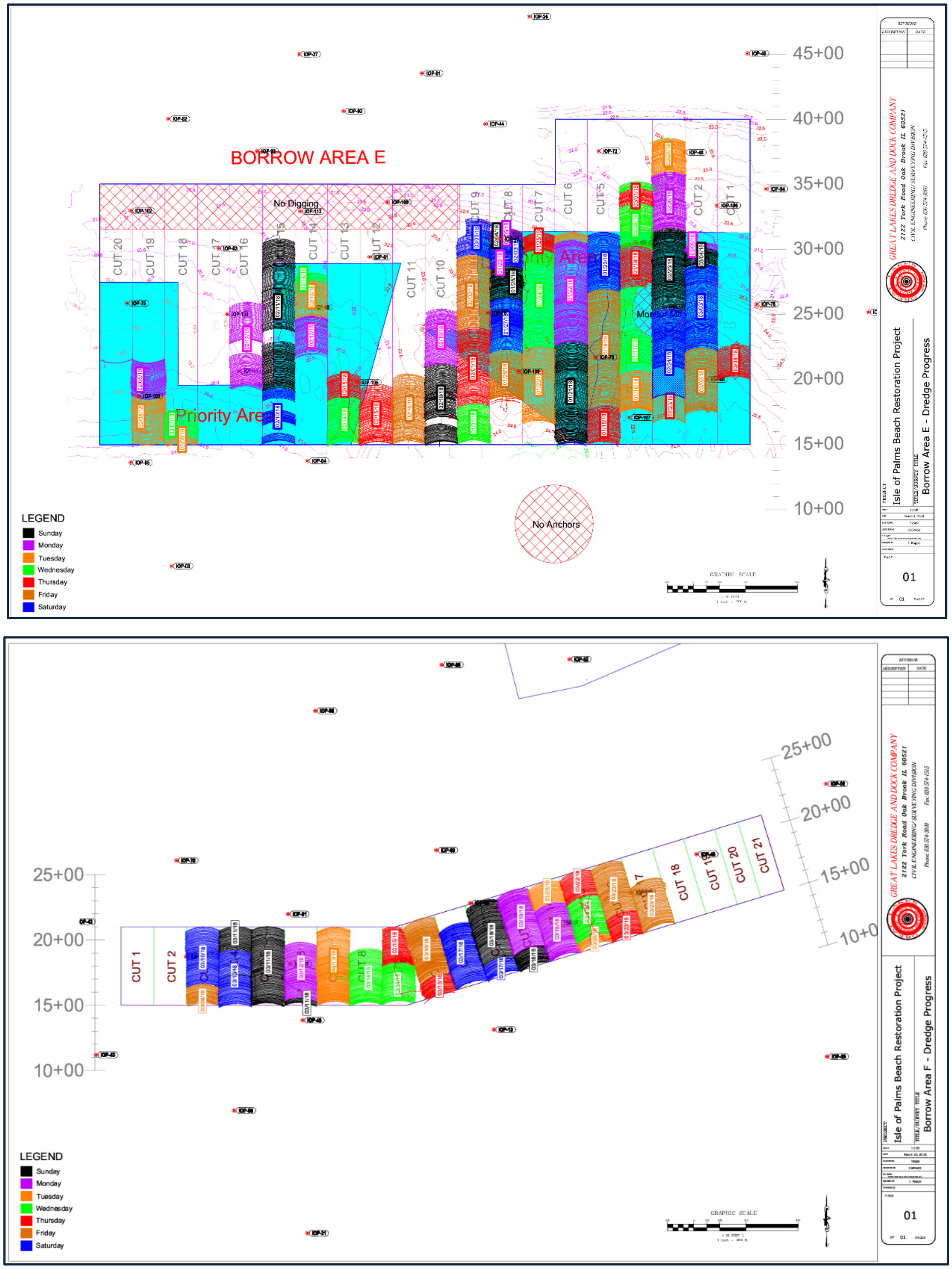


FIGURE 3.3. Dredge cut paths for Borrow Areas E & F. The colors represent the days the dredge was operating.

As the dredge approached the center portion of the borrow area, GLDD encountered pockets of material containing mud at a high enough concentration to leave "mud rollers" or thin layers of mud deposits on the beach. CSE and GLDD worked to alter the dredge plan to reduce the potential for lasting impacts through rigorous monitoring of the outflowing material and relocating the dredge to other portions of the borrow area. Note small gaps in the dredge track data in Figure 3.3 that show where the dredge moved forward along a cut in an attempt to find suitable material. After multiple attempts to find consistent sediment within the western portion of Area E, GLDD elected to focus on the remaining portion of Area E (eastern side) and Area F. The *Illinois* moved from Area E to Area F on 8 March 2018.

3.1 Surveys and Final Fill Profiles

Per the contract requirements, GLDD was required to have a 3rd party surveyor complete before-and-after dredging surveys of the fill area. These surveys are used to determine the volume of sand added to the beach for payment purposes and to ensure that the constructed fill plan matches the design. Survey data were collected at 100 ft spacing along the project area and extended from the landward limit of disturbance to a distance offshore that encompassed all measurable placed material. TI Coastal served as the 3rd party surveyor and provided signed and sealed survey drawings and volume calculations of the BD and AD surveys. Figure 3.4 shows a typical survey section for a completed area of the beach. In the figure, the blue line represents the before-dredge (BD) condition, and the red line shows the after-dredge (AD) condition. The black lines show the design template and the +0.5 ft vertical tolerance allowed for payment calculations. Per the contract, GLDD is paid for any sand placed above the BD condition and within 0.5 vertical feet of the design. Any sand outside of this template is not a pay quantity. CSE evaluated the volumes and supporting data, including maps and raw survey data before making any recommendation for payment.

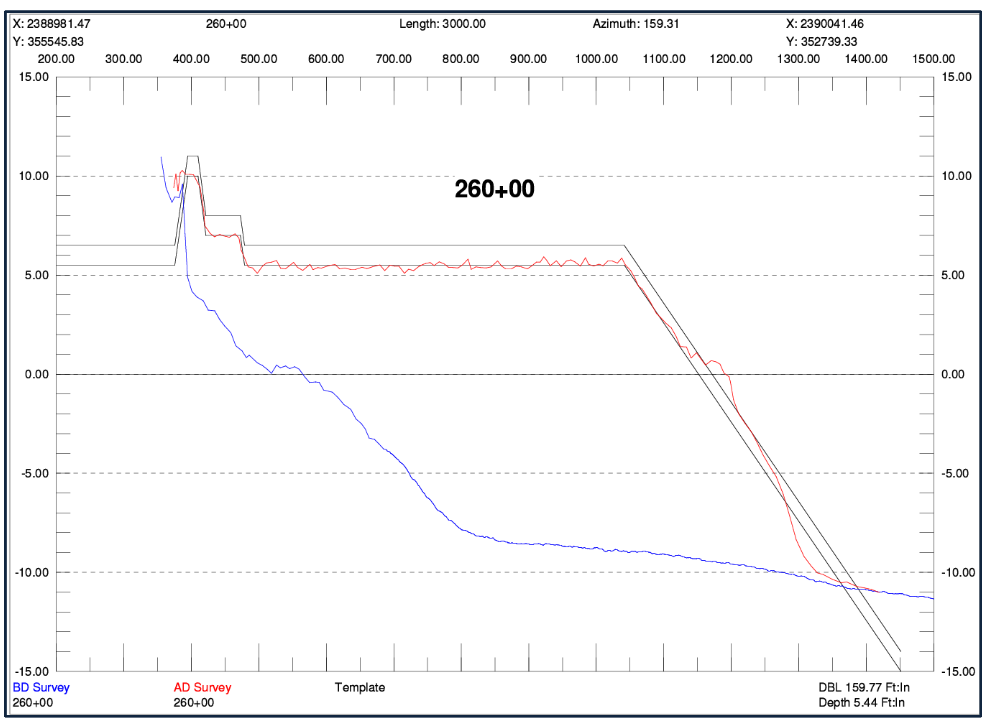


FIGURE 3.4. Example of a typical survey section for a completed area of beach renourishment.

Table 3.2 shows the design and actual fill volumes determined by TI Coastal. The “Design Volume” column represents the volume of sand above the BD condition and below the design template. Note that this volume is less than the final contract amount due to accretion occurring between the pre-project design surveys and TI Coastal’s BD survey. The “Fill Volume” column represents the total amount of sand placed on the beach. The rows highlighted yellow represent the area repumped following the Hurricane *Irma* change order. In total, 1,725,942 cy of sand were added to the project area during the project. Of that total, 974,374 were pumped west of station 280+00 (Property Owners Beach House), and 751,568 cy were placed east of station 280+00. The 49,424 cy of sand placed above the the pay quantity of 1,676,518 cy was not a pay quantity.

In addition to the 3rd party surveys outlined above, CSE completed comprehensive surveys of the project area using monitoring stations previously surveyed for the City since 2007. These profiles are spaced at 200 ft intervals, and data extend to encompass the shoals of Dewees Inlet (Figure 3.5). For the analysis, CSE calculated volumes between the dune line and -13 ft NAVD, which includes all nourishment placement areas. CSE’s volume calculations show good agreement with those of TI Coastal, with CSE’s total volume measured in-place at 1,705,821 cy. Fill volumes averaged ~170 cy/ft. Maximum fill volumes for any station were 295 cy/ft, which added over 500 ft of beach width.

Figure 3.6 shows the beach unit volumes in the project area for the 2008 project, the 2018 project, and for select surveys between the two projects. The figure shows the volume increase due to the project, as well as how the overall beach volume compares to earlier years. As of April 2018, the volume along most of the project area was significantly higher than at any other time measured since 2007. The only exception is near the center of the project area, where shoal attachments have led to a temporary excess sand volume near stations 280-288. Compared to the post-2008 project condition, the area near the Grand Pavilion has nearly 100 cy/ft more sand following the 2018 project. Along the eastern half of the project area, the post-2018 condition is over 150 cy/ft more sand than the 2008 condition. The additional sand volume beyond the 2008 post-project condition should prolong the life expectancy of the project. Additionally, sand volume in the landward portion of the Dewees Inlet delta (in the trailing ebb spit at the north end of the island) also contributes to the overall sand budget along the project area, as this area has built substantially since the last project.

Figure 3.7 shows the total beach volume for the project area since 2007. The impacts of the 2008 and 2018 beach nourishment projects are visible in the sudden increase in volume, while the overall erosional trend occurring between the projects is highlighted in orange. The 2008 project added ~933,000 cy of sand to the beach. The beach lost an average of 110,000 cy of sand from 2008 to 2018, for a total net loss of 1,160,000 cy. The 2018 project added 1,875,000 cy to reaches 5 and 6 (which includes slightly more beach than the 2018 project area), leaving a net increase of 1,725,000 cy more sand than the July 2007 condition.

TABLE 3.2. Design and actual fill volumes determined by TI Coastal.

Station	Design Volume (cy)	Fill Volume (cy)	Station	Design Volume (cy)	Fill Volume (cy)
236+00	0		289+00	11,105	11,132
237+00	804	884	290+00	11,049	11,207
238+00	2,205	3,896	291+00	11,063	11,254
239+00	3,170	5,926	292+00	11,125	11,402
240+00	4,061	8,310	293+00	11,333	11,170
241+00	6,061	11,356	294+00	11,347	10,909
242+00	9,107	13,518	295+00	11,327	11,444
243+00	12,503	15,683	296+00	11,308	11,948
244+00	16,387	18,628	297+00	11,631	11,995
245+00	19,920	21,625	298+00	12,201	12,333
246+00	22,899	24,474	299+00	12,236	12,523
247+00	25,585	27,183	300+00	12,241	13,075
248+00	27,455	28,754	301+00	12,913	13,281
249+00	28,789	28,239	302+00	13,948	14,104
250+00	30,167	31,479	303+00	15,069	15,477
251+00	31,181	32,451	304+00	16,027	16,373
252+00	31,470	33,976	305+00	16,586	16,906
253+00	31,426	32,359	306+00	17,129	17,478
254+00	32,042	32,369	307+00	17,448	18,473
255+00	32,443	30,318	308+00	17,536	18,527
256+00	33,719	34,416	309+00	17,610	18,244
257+00	34,963	35,931	310+00	17,555	18,307
258+00	33,841	34,875	311+00	17,757	18,698
259+00	32,952	33,558	312+00	17,687	18,582
260+00	32,567	32,868	313+00	17,120	17,922
261+00	31,827	32,428	314+00	16,452	16,991
262+00	30,985	32,027	315+00	15,600	16,329
263+00	29,682	30,800	316+00	13,887	14,910
264+00	27,782	28,388	317+00	11,634	12,404
265+00	26,261	26,810	318+00	9,514	10,179
266+00	25,145	25,880	319+00	7,189	8,952
267+00	23,634	24,314	320+00	5,076	8,638
268+00	22,321	22,946	321+00	3,256	7,093
269+00	21,015	22,001	322+00	1,831	4,643
270+00	18,789	19,955	323+00	1,030	2,780
271+00	16,199	17,330	324+00	631	1,609
272+00	13,753	14,883	279+00	0	0
273+00	11,886	12,419	279+80	1,782	1,812
274+00	10,815	11,146	279+90.404	12,904	14,394
275+00	10,220	10,461	280+00	14,782	16,133
276+00	10,142	10,235	281+00	12,116	12,366
277+00	10,368	10,381	282+00	12,265	12,707
278+00	10,533	10,394	283+00	12,658	13,602
279+00	10,860	10,903	284+00	12,539	13,338
279+80	8,977	9,312	285+00	12,243	12,875
279+90.404	8,459	9,138	286+00	12,229	12,552
280+00	8,460	9,147	287+00	12,153	12,283
281+00	11,040	11,720	288+00	11,948	12,239
282+00	11,006	11,551	289+00	12,056	12,328
283+00	11,091	11,565	290+00	12,171	12,270
284+00	11,120	11,190	291+00	11,992	11,919
285+00	10,931	10,094	292+00	10,418	10,852
286+00	10,903	10,901	293+00	6,838	8,118
287+00	11,171	11,319	294+00	3,503	4,813
288+00	11,218	11,336	**Total**	**1,635,358**	**1,725,942**

FIGURE 3.5. Project area map illustrating monitoring stations previously surveyed for the City since 2007. These profiles are spaced at 200 ft intervals encompassing the shoals of Dewees Inlet.

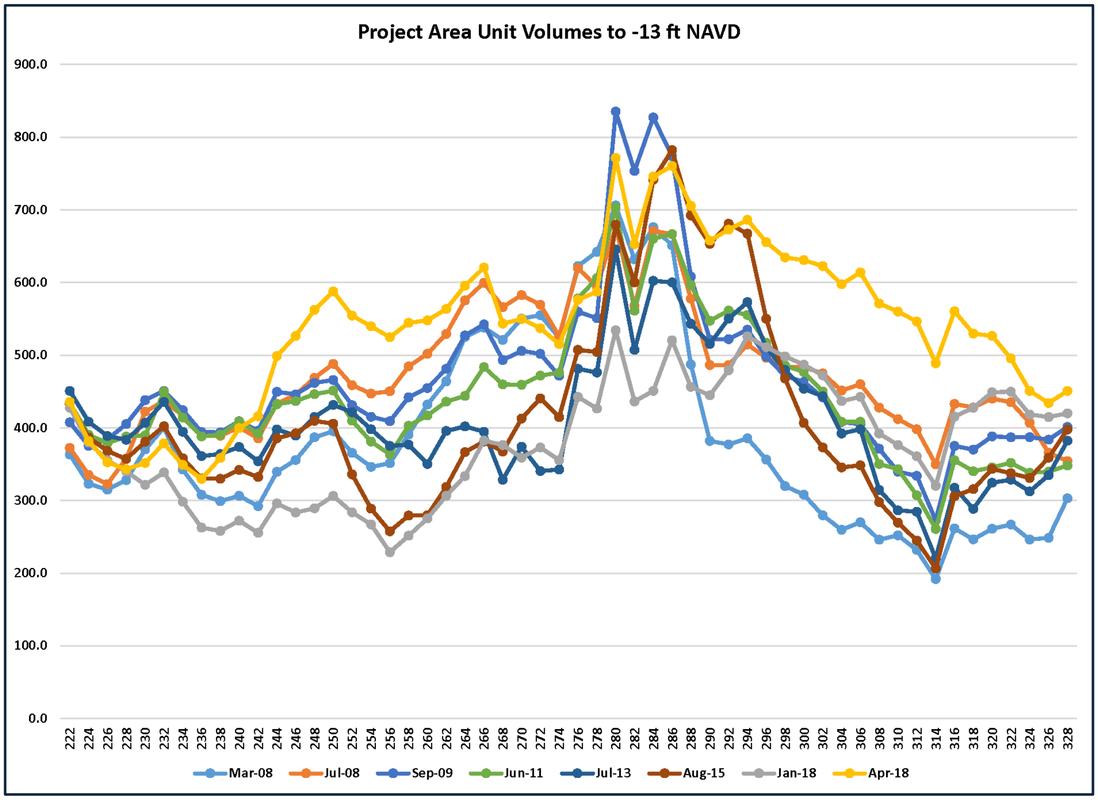


FIGURE 3.6. Beach unit volumes in the project area for the 2008 project, the 2018 project, and for select surveys between the two projects. The figure shows the volume increase due to the project, as well as how the overall beach volume compares to earlier years.

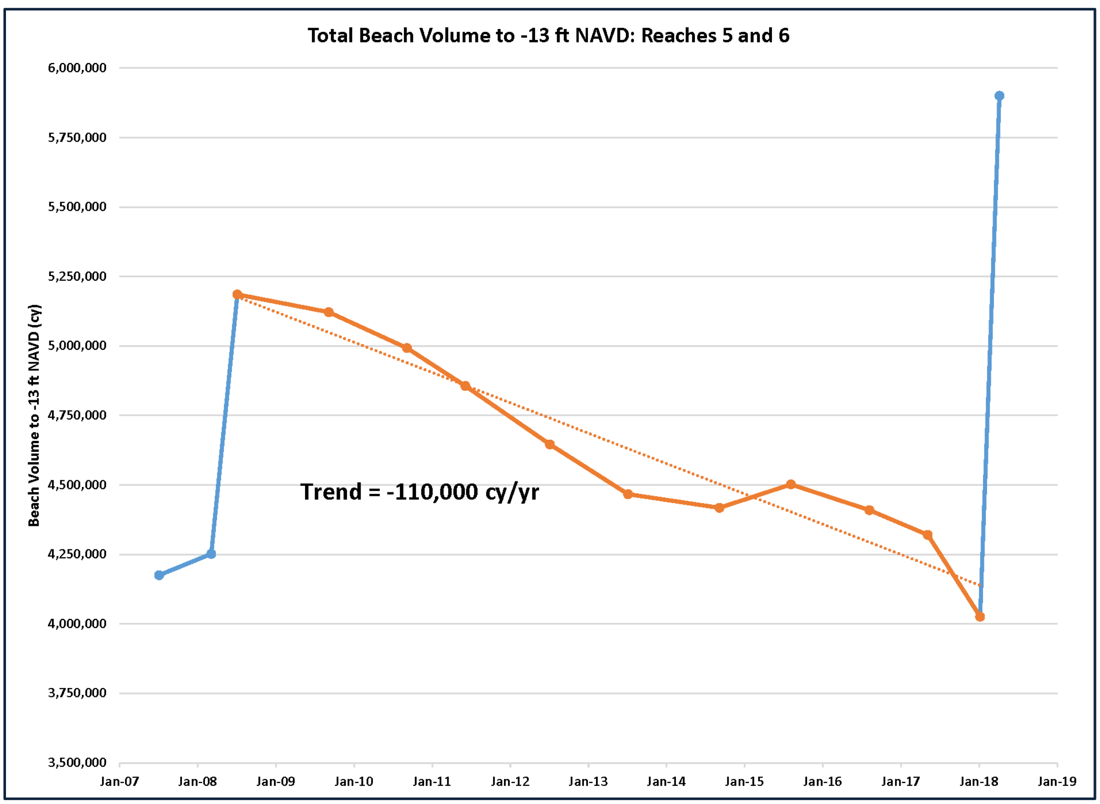


FIGURE 3.7. Total beach volume for the project area since 2007. The impacts of the 2008 and 2018 beach nourishment projects are visible in the sudden increase in volume, while the overall erosional trend occurring between the projects is highlighted in orange.

3.1.1 Borrow Area Surveys

Per conditions of the project permit, post-nourishment borrow area surveys were completed. These surveys will serve as a baseline for future monitoring efforts which will determine infilling rates. Borrow area sediment characteristics are also being evaluated as part of the post-project monitoring and will be discussed later. CSE obtained bathymetric data encompassing all of the dredged portions of Borrow Areas E and F in April 2018. Figure 3.8 shows the colored contour map of the area, with the deeper blues representing the dredged areas. The figure corresponds to the dredge tracks shown in Figure 3.3, with a few segmented cuts along the western end of Area E visible resulting from the dredge relocating to avoid muddy deposits. Figure 3.9 shows an elevation change map which quantifies the vertical elevation change (digging depth) during the project. The contours show that the maximum dredge depth was 8 ft below existing grade, and the majority of the areas were excavated to a shallower depth. Future surveys will track how quickly sediment infills the excavated areas, and whether the infilling is evenly distributed throughout the areas, or focused in specific regions.

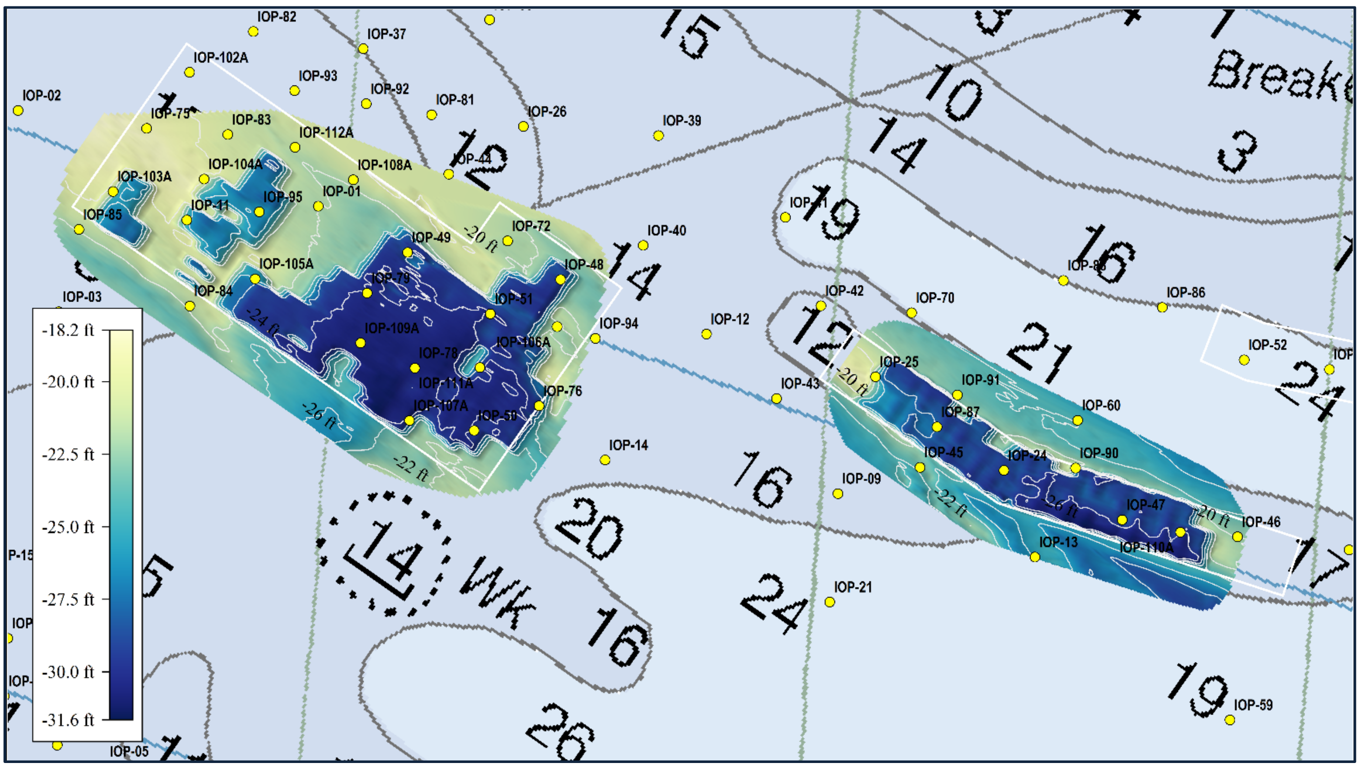


FIGURE 3.8. Colored contoured map of the borrow area. Deeper blues represent dredged areas.

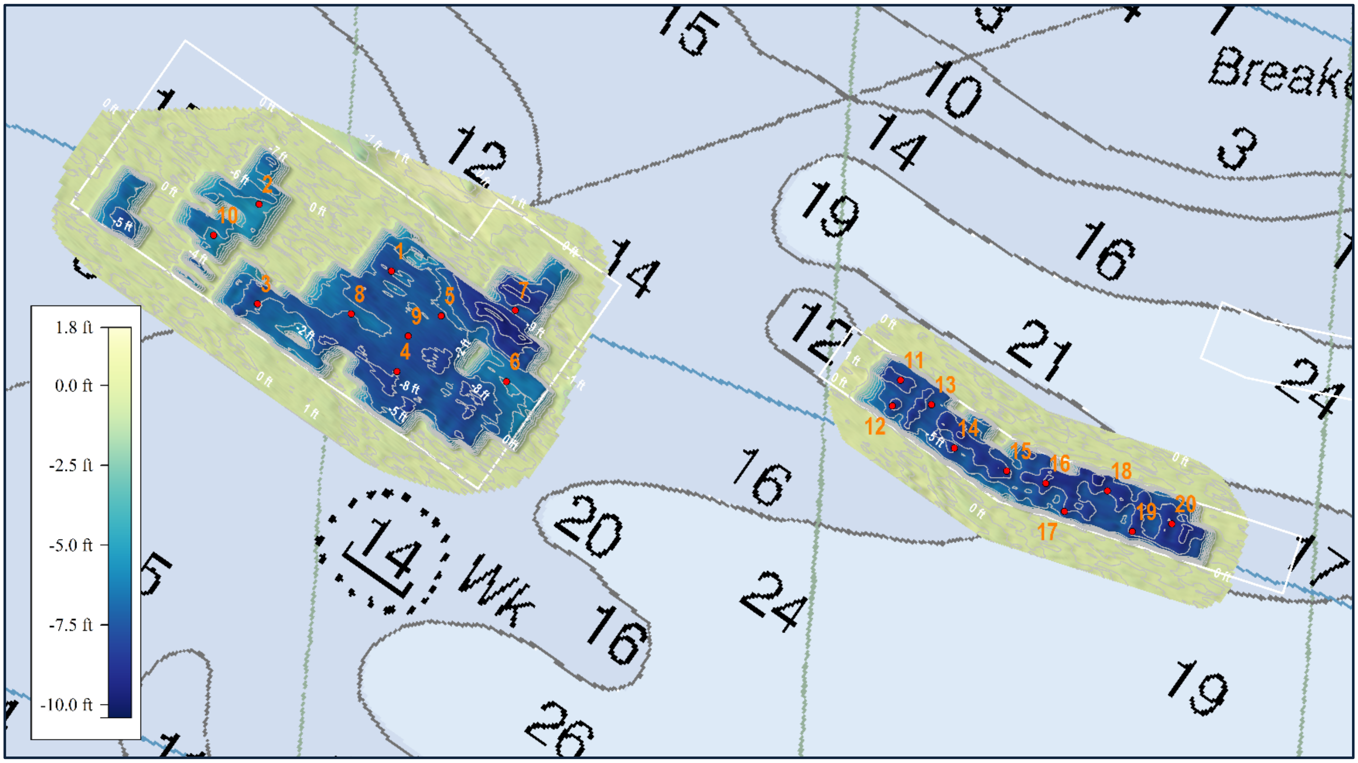


FIGURE 3.9. Elevation change map quantifying the digging depth during the project. Contours show the maximum dredge depth was 8 ft below existing grade while the majority of the areas were excavated at a shallower depth. Red dots show locations of sediment grab samples discussed in section 3.1.2.

3.1.2 Geotechnical Surveys

CSE completed pre and post project geotechnical analysis of the beach and borrow area per requirements of the project permits. Sediment characteristics including grain size distribution and shell content were analyzed. Along the beach, sediment samples were collected along transects at 1,000 ft spacing between stations 230+00 and 320+00. At each station, four samples were collected and processed. Samples were located at the toe of the dune, in the center of the berm, at the center of the sloping beach face, and in the shallow low-tide area (called the low-tide terrace or LTT). Table 3.3 shows the BD and AD sediment statistics for the beach samples.

The average grain size and shell content increased for the post-project samples. This is a result of the coarser sediment present in the borrow area coupled with a higher percentage of shell fragments. While the shell content increased, the majority of the shell was very fine fragments (sand-sized). Figure 3.10 shows the beach sediment statistics for before and after the project, with the AD samples in the dashed lines. Of note is the dune area remained a similar sediment size as the BD samples. This is due to the quick accumulation of wind-blown sand along the dune line. CSE anticipates that the sediment grain size will decrease over time as more wind-blown sand accumulates along the berm, and sediment on the beach face and LTT sorts itself through wave reworking. It can take several months for wave action to sort the sediment into a typical configuration where coarser sand is present in the energetic wave breaking zone, and finer sediment is present along the dune and seaward of the breaker zone.

In the borrow area, CSE compared surface samples from pre-project borings with surface grab samples collected in the excavated portions of the borrow area. Table 3.4 shows the borrow area sediment data, while Figure 3.11 graphs the results for grain size and shell content. In general, the post-project surface sediment was finer than the pre-project, with the mean grain size decreasing from 0.486 mm pre-project to 0.251 mm post project. Shell content also decreased from 32.8 % to 18.0 %. CSE noted that at a few locations, very fine sediment similar to pluff mud was present on the ocean bottom. At these locations (6, 7, 8, 9, and 16), CSE noted between 7 and 25 % of the sample was classified as mud (< 0.0625 mm). This deposit may be a result of localized exposure and settlement of silty and muddy sediment occurring during dredging as the cutterhead worked through the substrate. It is most likely not a result of the settlement of fine material from the surrounding waters, though there is the potential for that to occur over the next few years.

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TABLE 3.3. A comparison of the fill material to the native beach. (Pre-construction data shown in the left table and post-construction in the right table.) Native sediment samples were taken at 1,000 ft intervals along the project area. At each station, CSE obtained 4 samples, with one at the toe of the dune, one at the mid berm, one along the sloping face of the beach, and one at the low-tide terrace (shallow low-tide area). For each sample, CSE analyzed the grain size distribution and shell content of the sediment.

Pre Construction Beach Sediment Characteristics		Method of Moments								
		Mean	STD	Skew	Kurt	Mean	Std	Shell	Gravel	Fines
Sample	Interval	φ				mm		%	%	%
IOP230	**DUNE TOE**	2.23	0.72	-1.27	6.43	**0.213**	**0.607**	6.9	0.1	0.0
IOP230	**BERM**	2.49	0.48	-0.88	8.83	**0.177**	**0.715**	3.5	0.1	0.1
IOP230	**BEACH FACE**	2.30	0.73	-1.79	8.04	**0.203**	**0.605**	9.1	0.6	0.0
IOP230	**LTT**	1.75	0.99	-1.04	3.56	**0.297**	**0.504**	16.2	1.7	0.0
IOP240	**DUNE TOE**	2.55	0.45	-1.10	13.06	**0.171**	**0.733**	6.2	0.2	0.1
IOP240	**BERM**	2.57	0.36	-0.68	11.60	**0.168**	**0.777**	2.6	0.0	0.0
IOP240	**BEACH FACE**	2.44	0.59	-2.01	10.80	**0.184**	**0.664**	7.1	0.4	0.0
IOP240	**LTT**	2.24	0.65	-2.02	10.20	**0.212**	**0.639**	6.8	0.6	0.0
IOP260	**DUNE TOE**	2.62	0.36	-1.79	16.29	**0.162**	**0.779**	3.1	0.0	0.0
IOP260	**BERM**	2.68	0.42	-1.84	13.54	**0.156**	**0.745**	5.6	0.0	0.0
IOP260	**BEACH FACE**	2.50	0.53	-2.04	13.22	**0.177**	**0.692**	5.4	0.3	0.0
IOP260	**LTT**	2.29	0.61	-2.53	12.45	**0.205**	**0.657**	4.6	0.4	0.0
IOP270	**DUNE TOE**	2.82	0.40	-1.33	13.18	**0.142**	**0.759**	3.0	0.0	0.2
IOP270	**BERM**	2.72	0.37	-1.31	18.26	**0.152**	**0.776**	4.2	0.1	0.0
IOP270	**BEACH FACE**	2.52	0.47	-1.60	11.13	**0.175**	**0.723**	3.4	0.1	0.0
IOP270	**LTT**	2.46	0.47	-2.36	17.39	**0.182**	**0.722**	3.3	0.3	0.0
IOP280	**DUNE TOE**	2.46	0.48	-1.68	9.78	**0.182**	**0.717**	4.1	0.1	0.0
IOP280	**BERM**	2.53	0.40	-0.83	10.17	**0.173**	**0.759**	3.3	0.0	0.0
IOP280	**BEACH FACE**	2.42	0.48	-2.85	17.67	**0.187**	**0.716**	4.5	0.1	0.0
IOP280	**LTT**	1.57	1.17	-1.16	4.20	**0.337**	**0.445**	18.4	3.3	0.0
IOP290	**DUNE TOE**	1.77	1.44	-1.43	4.53	**0.294**	**0.369**	20.7	7.3	0.1
IOP290	**BERM**	2.45	0.44	-1.54	11.47	**0.183**	**0.737**	4.2	0.0	0.0
IOP290	**BEACH FACE**	2.50	0.46	-1.56	10.21	**0.177**	**0.727**	5.9	0.0	0.0
IOP290	**LTT**	2.03	0.63	-1.25	5.68	**0.245**	**0.647**	5.9	0.2	0.0
IOP300	**DUNE TOE**	1.84	0.73	-0.89	4.25	**0.279**	**0.601**	9.9	0.4	0.0
IOP300	**BERM**	2.57	0.42	-0.31	9.28	**0.168**	**0.749**	4.8	0.1	0.1
IOP300	**BEACH FACE**	2.54	0.38	-1.10	8.99	**0.172**	**0.766**	3.9	0.0	0.0
IOP300	**LTT**	2.42	0.42	-0.17	5.77	**0.186**	**0.746**	4.6	0.0	0.0
IOP310	**DUNE TOE**	2.46	0.42	-1.07	7.01	**0.182**	**0.747**	2.9	0.0	0.0
IOP310	**BERM**	2.68	0.31	-0.16	6.93	**0.156**	**0.809**	3.5	0.0	0.0
IOP310	**BEACH FACE**	2.50	0.44	-1.97	15.22	**0.176**	**0.735**	3.5	0.1	0.0
IOP310	**LTT**	1.63	0.98	-0.89	3.12	**0.323**	**0.508**	15.5	1.3	0.0
IOP320	**DUNE TOE**	2.48	0.34	-0.56	8.86	**0.180**	**0.789**	2.2	0.0	0.0
IOP320	**BERM**	2.40	0.34	-0.48	7.69	**0.190**	**0.787**	3.1	0.0	0.0
IOP320	**BEACH FACE**	2.33	0.62	-1.96	8.96	**0.199**	**0.651**	5.5	0.1	0.0
	MIN	1.57	0.31	-2.85	3.12	0.142	0.369	2.2	0.0	0.0
	AVG	**2.36**	**0.56**	**-1.36**	**9.94**	**0.199**	**0.689**	**6.2**	**0.5**	**0.0**
	MAX	2.82	1.44	-0.16	18.26	0.337	0.809	20.7	7.3	0.2

Post Construction Beach Sediment Characteristics		Method of Moments								
		Mean	STD	Skew	Kurt	Mean	Std	Shell	Gravel	Fines
Sample	Interval	φ				mm			%	
IOP240	**DUNE TOE**	2.48	0.46	-0.69	8.58	**0.179**	**0.725**	7.7	0.1	0.0
IOP240	**BERM**	1.87	1.07	-1.79	6.41	**0.274**	**0.476**	15.0	2.8	0.1
IOP240	**BEACH FACE**	1.39	0.87	-0.35	2.59	**0.383**	**0.547**	15.6	0.4	0.0
IOP240	**LTT**	1.85	0.91	-1.14	3.92	**0.277**	**0.533**	12.4	0.5	0.0
IOP250	**DUNE TOE**	2.13	1.19	-2.63	11.88	**0.229**	**0.437**	13.1	3.1	0.9
IOP250	**BERM**	1.47	1.35	-1.05	3.62	**0.360**	**0.393**	24.9	6.3	0.4
IOP250	**BEACH FACE**	0.49	1.40	-0.53	2.71	**0.713**	**0.379**	28.2	14.6	0.0
IOP250	**LTT**	1.12	1.29	-0.73	2.86	**0.459**	**0.409**	24.9	6.8	0.0
IOP260	**DUNE TOE**	2.15	0.83	-2.47	11.36	**0.225**	**0.562**	10.9	1.3	0.1
IOP260	**BERM**	1.19	1.41	-1.14	3.99	**0.439**	**0.377**	25.9	8.3	0.2
IOP260	**BEACH FACE**	1.12	1.48	-1.15	3.94	**0.460**	**0.359**	30.4	8.6	0.0
IOP260	**LTT**	2.07	0.65	-1.43	6.26	**0.239**	**0.636**	8.7	0.1	0.0
IOP270	**DUNE TOE**	2.08	0.77	-1.73	8.36	**0.237**	**0.585**	9.3	0.8	0.1
IOP270	**BERM**	1.70	1.27	-1.65	5.26	**0.308**	**0.413**	18.8	5.6	0.2
IOP270	**BEACH FACE**	0.56	1.78	-0.59	2.32	**0.678**	**0.292**	43.7	20.2	0.0
IOP270	**LTT**	1.30	1.65	-1.01	2.66	**0.407**	**0.318**	26.9	14.3	0.0
IOP280	**DUNE TOE**	2.30	0.63	-0.99	6.04	**0.203**	**0.644**	9.7	0.0	0.0
IOP280	**BERM**	0.20	1.95	-0.51	2.14	**0.869**	**0.259**	38.1	25.8	0.2
IOP280	**BEACH FACE**	1.13	1.40	-1.02	3.26	**0.456**	**0.379**	34.7	9.8	0.0
IOP280	**LTT**	1.00	1.49	-0.71	3.00	**0.499**	**0.355**	48.2	10.3	0.2
IOP290	**DUNE TOE**	1.75	0.79	-0.60	3.73	**0.298**	**0.579**	17.2	0.3	0.0
IOP290	**BERM**	1.09	1.38	-0.92	3.24	**0.468**	**0.383**	21.5	9.2	0.1
IOP290	**BEACH FACE**	1.57	1.08	-1.60	6.42	**0.337**	**0.472**	23.6	3.2	0.0
IOP290	**LTT**	0.80	1.71	-0.68	2.32	**0.576**	**0.305**	38.5	18.1	0.0
IOP300	**DUNE TOE**	2.47	0.54	-1.61	11.47	**0.181**	**0.689**	3.7	0.2	0.0
IOP300	**BERM**	1.00	1.58	-0.88	3.28	**0.500**	**0.334**	39.8	11.4	0.2
IOP300	**BEACH FACE**	1.09	1.38	-1.18	4.45	**0.468**	**0.383**	19.8	6.7	0.0
IOP300	**LTT**	1.49	1.73	-1.64	4.63	**0.356**	**0.301**	27.8	12.1	0.0
IOP310	**DUNE TOE**	2.45	0.40	-0.63	8.11	**0.183**	**0.760**	2.3	0.0	0.0
IOP310	**BERM**	0.90	1.71	-0.78	2.94	**0.536**	**0.306**	39.1	13.8	0.3
IOP310	**BEACH FACE**	1.38	1.00	-0.46	2.46	**0.385**	**0.501**	16.9	1.3	0.0
IOP310	**LTT**	-0.40	2.02	0.28	1.92	**1.318**	**0.247**	65.9	41.5	0.0
IOP320	**DUNE TOE**	2.33	0.42	-1.06	10.19	**0.198**	**0.749**	17.0	0.1	0.0
IOP320	**BERM**	0.96	1.66	-0.71	2.73	**0.513**	**0.316**	39.4	13.6	0.3
IOP320	**BEACH FACE**	0.64	1.52	-0.29	2.12	**0.643**	**0.349**	37.6	14.3	0.0
IOP320	**LTT**	2.29	0.67	-1.63	9.12	**0.204**	**0.630**	8.6	0.5	0.2
	MIN	-0.40	0.40	-2.47	1.92	0.181	0.247	2.3	0.0	0.0
	AVG	**1.34**	**1.25**	**-1.00**	**4.78**	**0.445**	**0.442**	**25.9**	**9.1**	**0.1**
	MAX	2.47	2.02	0.28	11.47	1.318	0.760	65.9	41.5	0.3

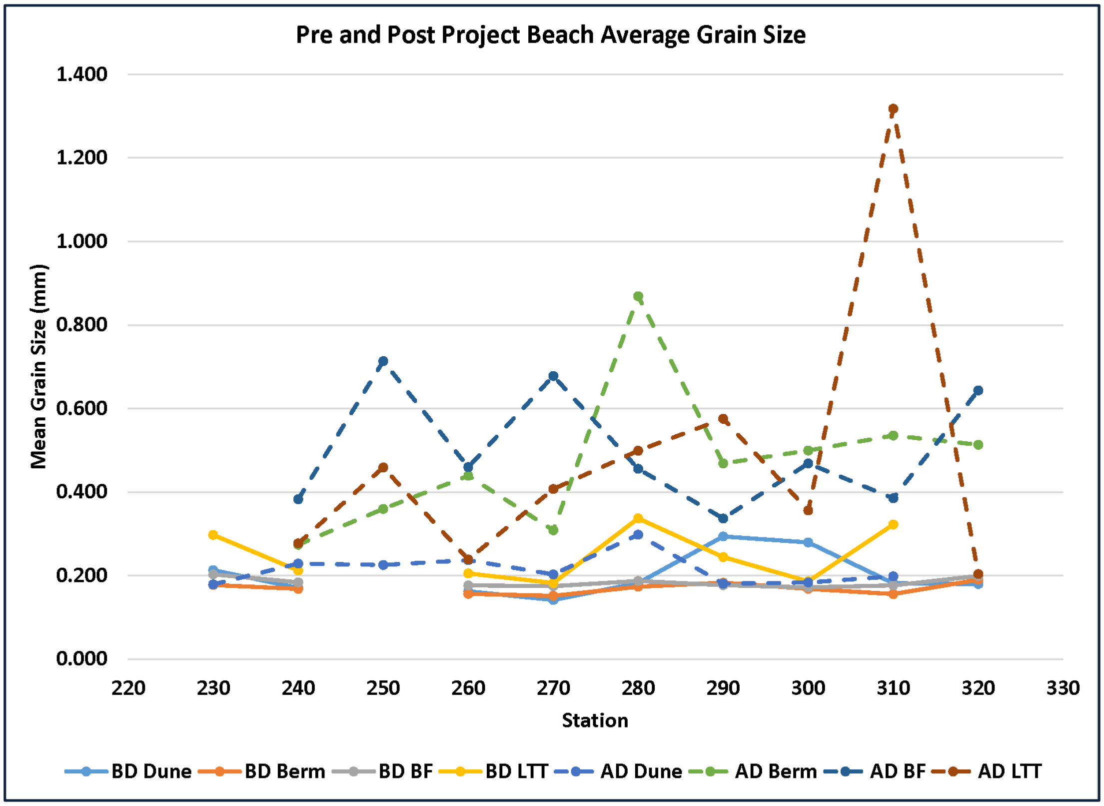

FIGURE 3.10. Beach sediment statistics for before and after the project. After dredge samples are indicated in dashed lines. Note the dune area remained a similar sediment size as the before dredge samples.

TABLE 3.4. Borrow area sediment data gathered by samples collected in the excavated portions of the borrow area.

		Method of Moments								
		Mean	STD	Skew	Kurt	Mean	Std	Shell	Gravel	Fines
Sample	Interval	ϕ				mm		%		
1	Borrow Area E	2.50	0.49	-2.10	19.08	0.177	0.712	4.2	0.5	0.1
2	Borrow Area E	2.75	0.50	-1.07	9.31	0.148	0.707	4.5	0.1	0.4
3	Borrow Area E	0.22	1.27	-0.06	2.79	0.857	0.413	71.3	16.1	0.0
4	Borrow Area E	0.39	1.36	-0.14	2.78	0.765	0.389	77.7	14.8	0.1
5	Borrow Area E	1.99	1.37	-1.20	4.64	0.251	0.386	21.5	4.5	3.2
6	Borrow Area E	2.68	1.32	-0.59	2.61	0.156	0.400	32.3	0.4	25.5
7	Borrow Area E	2.46	1.36	-0.54	2.66	0.181	0.391	25.9	0.9	19.0
8	Borrow Area E	2.77	1.09	-0.86	3.61	0.146	0.469	20.2	0.2	14.6
9	Borrow Area E	1.83	1.48	0.12	2.04	0.281	0.357	3.8	1.0	13.6
10	Borrow Area E	2.76	0.62	-2.29	14.01	0.147	0.652	7.0	0.3	0.7
11	Borrow Area F	2.20	0.71	-0.78	6.22	0.217	0.613	10.1	0.5	0.2
12	Borrow Area F	2.59	0.77	-1.14	5.60	0.166	0.587	9.8	0.3	0.4
13	Borrow Area F	3.05	0.49	-3.15	25.53	0.121	0.712	4.7	0.3	0.7
14	Borrow Area F	2.63	0.65	-0.35	3.57	0.162	0.639	6.9	0.0	0.6
15	Borrow Area F	3.07	0.51	-2.72	18.42	0.119	0.701	6.3	0.0	1.2
16	Borrow Area F	2.80	0.89	-1.04	4.96	0.143	0.541	5.5	0.2	7.5
17	Borrow Area F	1.80	1.06	-2.23	10.68	0.287	0.480	15.3	3.0	0.4
18	Borrow Area F	1.57	1.07	-2.46	10.02	0.337	0.477	20.1	4.5	0.0
19	Borrow Area F	2.48	0.55	-2.14	15.86	0.179	0.681	6.2	0.5	0.2
20	Borrow Area F	2.51	0.43	-0.53	9.49	0.176	0.743	5.8	0.1	0.1

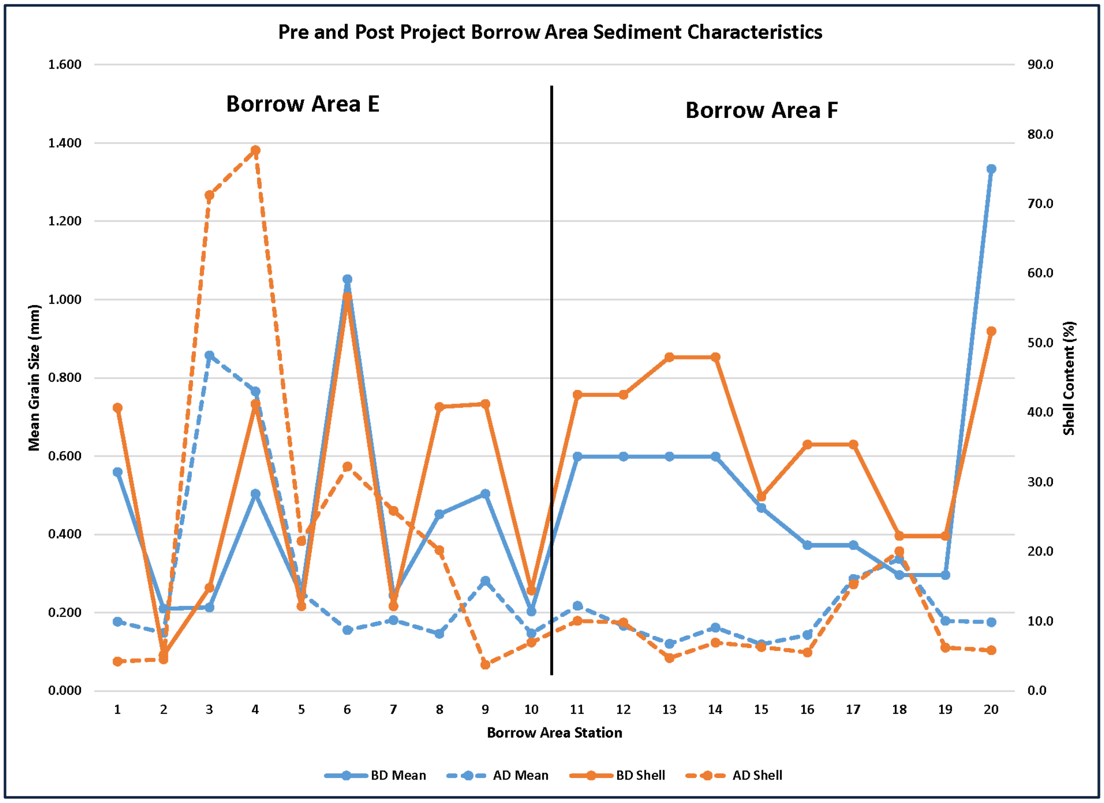

FIGURE 3.11. Graphed results for grain size and shell content for pre- and post-project. Overall, the post-project surface sediment was finer and had less shell content than pre project conditions.

4.0 MAINTENANCE AND RECOMMENDATIONS

As part of the special conditions of the permits for the beach restoration project, the City is required to completed certain post-project monitoring of the beach and borrow areas. Specific requirements are:

- Topographic and bathymetric surveys of the beach profile in the sand placement area for three years following the project
- Sediment analysis along the beach in the sand placement areas
- Bathymetric surveys of the borrow areas in Years 1, 3, and 5 after the project
- Sediment analysis of the surficial sediment in the borrow areas in Years 1, 3, and 5 after the project
- Compaction and escarpment monitoring for the first three years after the project
- Annual reports documenting the above efforts

As of this writing, CSE is under contract with the City for the monitoring services outlined above. CSE will complete each requirement and summarize the results into a summary report suitable to OCRM and the USACE. Reports will be submitted electronically to the City and to the agencies.

In addition to the permit required conditions, CSE recommends that the City regularly inspect the beach and dune area to monitor the evolution of the post-project condition. Special attention should be given to the planting installed in the fall of 2018. During periods of drought, plants should be watered for the first 1–2 years to promote the growth of young plants, and periodic additions of fertilizer should also be implemented. The City should monitor the evolution of dune growth so that public access is maintained in a manner that does not negatively impact the growing dune features.

In addition to the permit required surveys, CSE recommends the City continue supporting additional surveys of the Dewees Inlet delta and remainder of the island. Monitoring the evolution of the shoals of the inlet has proven useful in predicting shoreline trends affecting the east end, and is the only way to accurately measure the total volume of sand within the littoral system of Isle of Palms (for instance, CSE accounted for over 500,000 cy of sand lost from the 2008 project area in the shoal features of Dewees Inlet). Monitoring the remainder of the island (south of the project area) will continue the efforts the City has made over the past 10 years to make informed decisions about the beach, including post-hurricane response and potential large-scale restoration efforts (ie – near Breach Inlet).

Following the 2008 project, the City began the permitting process in 2010 for a permit that would allow for management of attaching shoals, should the need arise. Two shoal management projects were completed to temporarily provide relief to threatened properties. Another project was planned, but not implemented due to the reluctance of private owners to remove experimental wave dissipation systems. CSE expects the 2018 project to last longer than the 2008 project due to the larger sand volume added, as well as the more favorable morphology of the inlet in 2018 (specifically the presence of the large trailing ebb spit attached to the north end of the beach at the 18th hole of the Links Course). However, the City should proactively plan for future projects based on updated monitoring results, noting that the permit process for these projects may take up to two years.

One potential scenario CSE recommends the City pursue is to evaluate the feasibility of a joint project with the USACE to beneficially use dredged material from the Intracoastal Waterway for nourishment. CSE has had initial conversations with the USACE about using material from Breach Inlet to place on the beach, and they are supportive of the idea; however, additional studies would need to be conducted to determine the suitability of the material and any additional cost or environmental impacts of the work. There may also be the potential to do a similar project at the east end using sand from Dewees Inlet. These projects would have to be conducted in concert with federal funding for waterway dredging but may provide a mutually beneficial project for both the USACE and City.

5.0 SELECTED OBLIQUE AERIAL AND GROUND PHOTOS

PHOTO 1. Shore pipe and equipment staged and ready to start construction.

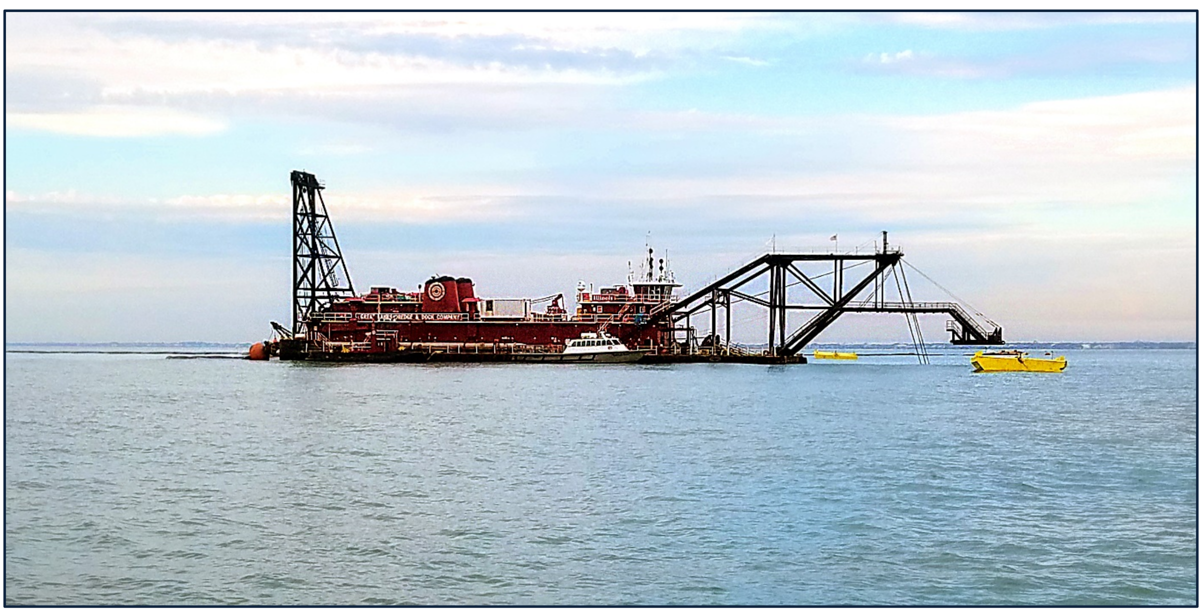

PHOTO 2. Great Lakes Dredge and Dock Company's cutter suction dredge the *Illinois* digging on borrow area F.

PHOTO 3. Removal of Wave Dissipation System in front of the Ocean Club Villas on 2 January 2019 prior to pumping.

PHOTO 4. Water and Sand slurry being pumped on the beach in front of the Property Owner's Association Beach House

PHOTO 5. Construction progressing south in Reach 1 near Beachwood East 21 January 2019.

PHOTO 6. Three discharge points were used in some sections of the beach to accommodate for the large berm specifications of the design.

PHOTO 7. Pumping and beach grading operations underway on 22 January 2018 in front of Beachwood East.

PHOTO 8. Aerial photograph taken from CSE's drone overlooking beach building operations in front of Beachwood East on 21 January 2018.

PHOTO 9. Steven Traynum hosting an onsite visit with local law students as part of a coastal policy program on 31 January 2018.

PHOTO 10. Dune pushed up in front of Wild Dunes Pavilion 15 February 2018.

PHOTO 11. Bulldozers on standby ready to grade near the south end of Reach 1. [Image taken 23 February 2018]

PHOTO 12. Pumping operations in front of the Beach Club Villas on 19 March 2018.

PHOTO 13. Condition of beach in front of Port O' Call, Seascape, and Ocean Club Villas almost 5 months after the project on 17 August 2018.

PHOTO 14. The completed section of dune just south of the Pavilion in Wild Dunes.

PHOTO 15. Pre-project aerial view from the north end of the island with the Ocean Club Villas and Wave Dissipation System in the forefront.

PHOTO 16. Aerial view of the north end just before project completion.

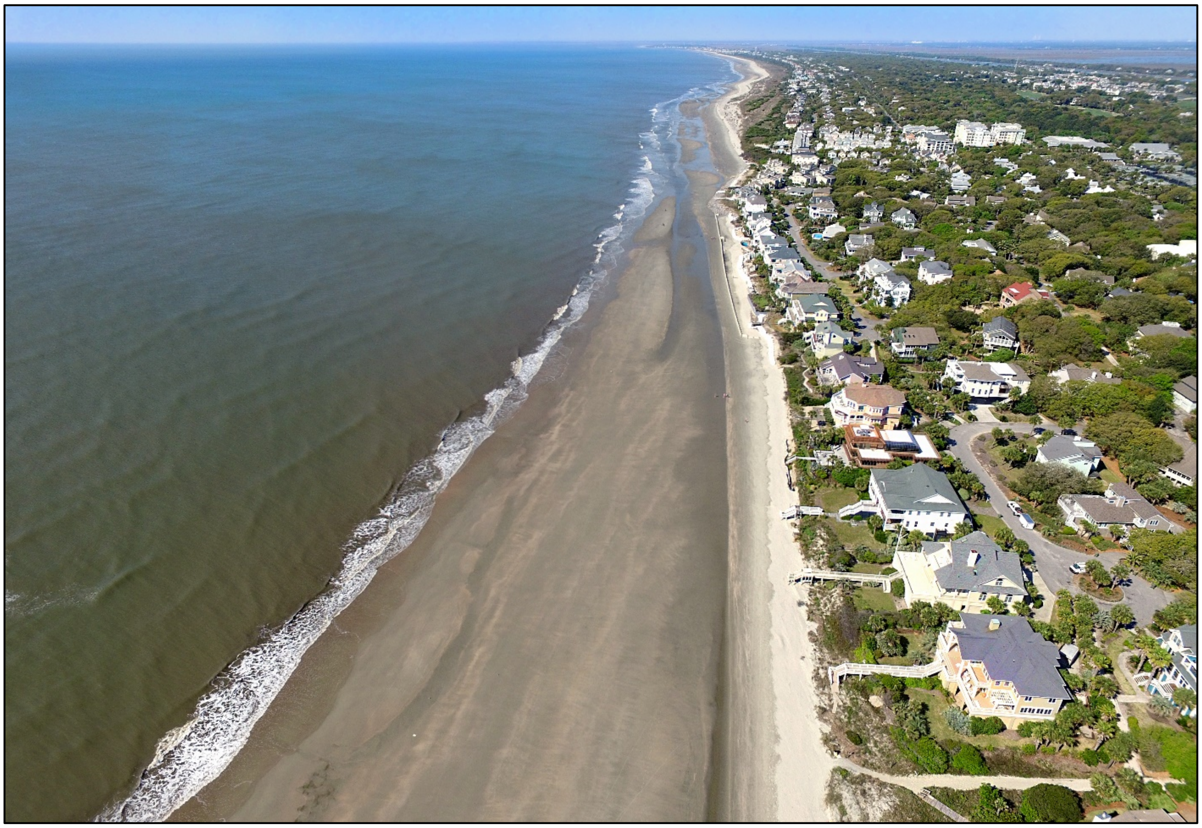

PHOTO 17. Pre project look at Reach 1 (Stations 236+00 through 280+00) with Wave Dissipation System in front of houses at Beachwood East.

PHOTO 18. Reach 1 (Stations 236+00 through 280+00) on 19 March 2018, 4 days before project completion.

PHOTO 19. Looking south at Beachwood East back in 2014 during sandbag installation.

PHOTO 20. Beachwood East in March 2018 after construction.

PHOTO 21. Looking south at the Ocean Club Villas in September 2014 during sandbag installation.

PHOTO 22. Beachfront at Ocean Club Villas in March 2018 after construction.

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