2006 EAST END BEACH RESTORATION PROJECT
KIAWAH ISLAND SOUTH CAROLINA

Survey Report No 11

March 2018

Prepared for:

Town of Kiawah Island

South Carolina

COASTAL SCIENCE & ENGINEERING

2006 EAST END BEACH RESTORATION PROJECT

Kiawah Island – South Carolina

BEACH MONITORING PROGRAM

SURVEY REPORT NO 11

Annual Beach and Inshore Surveys

Prepared for:

Town of Kiawah Island, South Carolina

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[CSE 2446 YR3]
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COVER PHOTO: Aerial images of the 2015 project area in February 2017 (upper) and October 2017 (lower).

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Synopsis

This report is the 11th in a series of annual monitoring reports initiated following the 2006 East End beach restoration project. It presents results of detailed surveys encompassing the oceanfront of Kiawah Island (SC) with particular focus on the area around the Ocean Course and Stono Inlet, where shoals from the Stono Inlet delta add sand to the beach but create episodic erosional issues as sand and channels migrate.

The Town of Kiawah Island has completed two projects at the East End to manage a lagoon flushing channel, which has migrated into upland areas threatening the Ocean Course. The 2006 project moved about 550,000 cubic yards (cy) of sand and restored a wide, dry-sand beach in front of the Ocean Course. By 2014, the flushing channel was again beginning to migrate toward the Ocean Course, and another channel relocation event was completed in the late spring of 2015, moving a total of 100,000 cy. Each of these projects occurred in designated critical habitat for piping plovers and incorporated methods to reduce impacts and prolong habitat formation suitable for these birds.

Kiawah Island has now suffered from three substantial storms over the past three years, including Hurricane *Joaquin* (2015), Hurricane *Matthew* (2016), and Hurricane *Irma* (September 2017). Each storm contributed higher-than-normal erosion across the island. Hurricane *Matthew* caused severe dune loss ranging from ~15 feet (ft) to 40 ft along most of the residential area, and even higher rates of loss were observed west of Beachwalker Park. The storm resulted in damaged walkovers, but there was no significant property damage.

By February 2017, the entire island showed significant recovery of the dry-sand berm and some dune growth; however, Hurricane *Irma* caused additional damage to the dune field. *Irma* resulted in another 10–20 ft of dune loss beyond what was lost with Hurricane *Matthew*; however, overall sand volume loss was lower (Fig A). With the additional dune loss, some areas along the golf courses were within OCRM's definition of an emergency condition, and other areas had insufficient setbacks from the high-tide line. The Town conducted a dune restoration project along these areas after securing state and federal authorization. Figure B shows the dune position change since 2012 over the island. Figure C shows an example of the dune position change from Eugenia Avenue.

FIGURE A. September 2017 post-storm photo of the area near Beach Access 32 showing the eroded dune following Hurricane *Irma*.

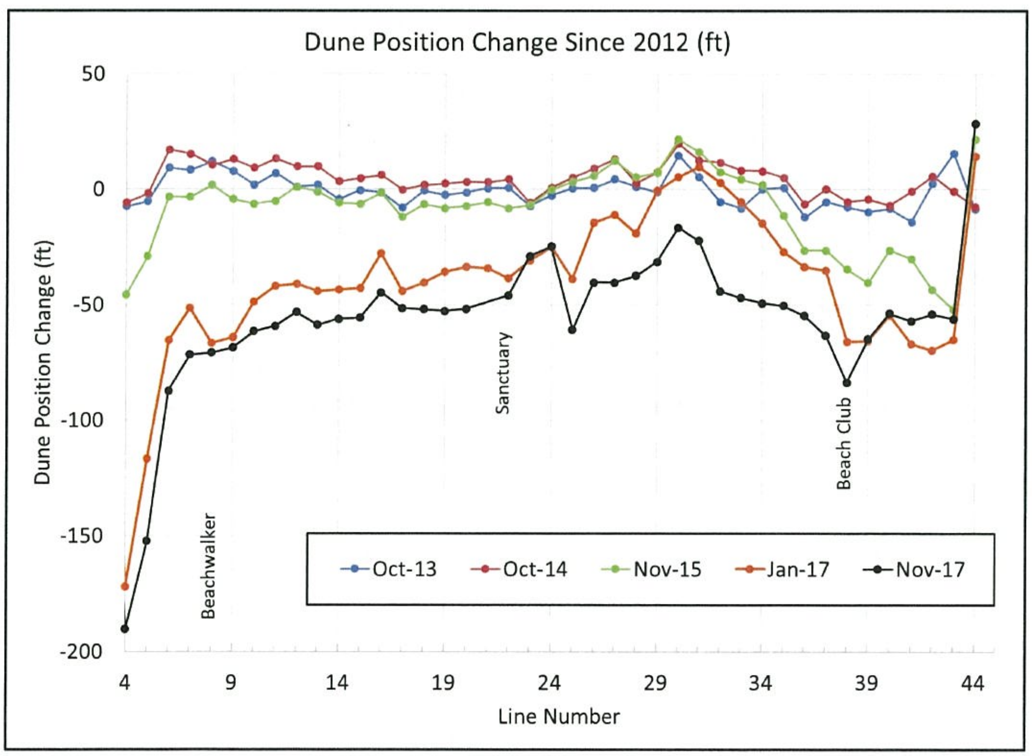

FIGURE B. Yearly dune position change since 2012. Negative values indicate erosion of the dune. Hurricanes *Joaquin* (2015), *Matthew* (2016), and *Irma* (2017) have resulted in loss of the foredune at Kiawah Island in recent years.

FIGURE C. Example of dune position change since October 2016 along Eugenia Avenue.

Overall, the island lost 210,800 cy of sand from January 2017 to November 2017 (Table A). This compares to a loss of ~756,000 cy from November 2015 to January 2017. Any sustained erosion at Kiawah Island is counter to the historical trend and is likely a direct result of the storm events. For comparison, from 2007 to 2014, the island gained an average of 242,200 cubic yards per year (cy/yr) of sand. From January 2017 to November 2017, the Kiawah Spit Reach was accretional due to the elongation of the spit toward Seabrook Island, gaining 166,000 cy. The central reaches of West Beach, Turtle Point, and Ocean Course were fairly stable, losing a total of 21,000 cy (0.6 cy/ft). The Lagoon Reach was the most erosional area, losing an average of 33.7 cy/ft for a total of 270,000 cy. The eastern end of the island adjacent to Stono Inlet also eroded, losing 85,900 cy or 14.3 cy/ft. Volume change for each reach is provided in Table A.

CSE recommends the Town regularly assess the recovery of the dune area through photographs or dune-line GPS surveys. CSE does not believe additional emergency-type action is required; however, if the Town or other parties desire to restore the dune system beyond what was accomplished by the Town's restoration efforts, upland sand can be used for minor nourishment. CSE does not believe sand fencing is warranted; however, if sand fencing is installed, it should be installed as close to the primary dune as possible. The next monitoring event will occur in fall/winter 2018–2019.

TABLE A. Beach volumes and unit volumes for each reach and the entire island between 1999 and 2017. Volumes are to −10 ft NAVD. Reach boundaries are described in the text.

					Reach Volume Change Since Previous (cy)										
Reach	**Name**	**Length**			**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**	**Nov-15**	**Jan-17**	**Nov-17**
1	Kiawah Spit	8,820				-1,258	52,266	122,097	-79,109	-18,370	2,719	-32,006	-929,746	-4,793	166,319
2	West Beach	11,798				-45,703	29,573	13,884	6,665	120,120	56,926	47,462	-1,426	-136,481	13,818
3	Turtle Point	13,614				-56,689	80,539	-11,176	3,068	189,784	129,833	139,419	85,843	-195,550	-49,869
4	Ocean Course	9,000			126,733	-62,036	101,144	24,202	110,622	119,828	101,070	132,427	64,299	-37,239	14,695
5	Lagoon	8,000			-59,912	263,729	327,273	295,006	-209,689	-18,890	-100,438	33,388	-270,196	-185,717	-269,902
6	Stono Inlet	6,000			-4,620	-12,857	-40,673	16,174	4,577	21,459	-40,119	-79,644	-80,624	-196,292	-85,861
1-6	**All**	**57,232**				**85,187**	**550,121**	**460,187**	**-163,865**	**413,932**	**149,991**	**241,047**	**-1,131,850**	**-756,072**	**-210,800**

					Reach Unit Volume Change Since Previous (cy/ft)										
Reach	**Name**	**Length**			**Aug-07**	**Oct-08**	**Aug-09**	**Oct-10**	**Oct-11**	**Oct-12**	**Oct-13**	**Oct-14**	**Nov-15**	**Jan-17**	**Nov-17**
1	Kiawah Spit	8,820				-0.1	5.9	13.8	-9.0	-2.1	0.3	-3.6	-105.4	-0.5	18.9
2	West Beach	11,798				-3.9	2.5	1.2	0.6	10.2	4.8	4.0	-0.1	-11.6	1.2
3	Turtle Point	13,614				-4.2	5.9	-0.8	0.2	13.9	9.5	10.2	6.3	-14.4	-3.7
4	Ocean Course	9,000			14.1	-6.9	11.2	2.7	12.3	13.3	11.2	14.7	7.1	-4.1	1.6
5	Lagoon	8,000			-7.5	33.0	40.9	36.9	-26.2	-2.4	-12.6	4.2	-33.8	-23.2	-33.7
6	Stono Inlet	6,000			-0.8	-2.1	-6.8	2.7	0.8	3.6	-6.7	-13.3	-13.4	-32.7	-14.3
1-6	**All**	**57,232**				**1.5**	**9.6**	**8.0**	**-2.9**	**7.2**	**2.6**	**4.2**	**-19.8**	**-13.2**	**-3.7**

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1.0 INTRODUCTION

This report is prepared as part of a series of annual beach monitoring reports initiated following the 2006 East End restoration project (CSE 2005, 2007). The Town of Kiawah Island (SC) is sponsoring annual surveys of the sandy shoreline for purposes of determining the rates of sand movement, accretion, and erosion within the project area and along the remainder of the beach. This eleventh report of the series follows over a dozen shoreline erosion reports prepared by Research Planning Institute (RPI) and Coastal Science & Engineering (CSE) for Kiawah Island since the 1980s (eg – Kana et al 1983, CSE 1999). Annual post-project surveys have been conducted in the fall of every year between 2007 and 2017. The present survey was completed in November 2017 to provide a beach condition assessment close to the passage of Hurricane Irma in September 2017 while remaining close to the season of the previous survey.

The purpose of this report is to describe the current health of Kiawah Island as compared to past conditions. This involves documenting sand volume changes along the entire island (Captain Sams Inlet to Penny's Creek) to identify areas where the beach and dunes may be eroding or accreting. Annual monitoring provides a quantitative account of sand volume changes, which can then be used to infer sediment transport rates along the shoreline and predict future areas of concern before critical situations arise. It also identifies areas of concern and provides recommendations for any remedial action, which may be warranted.

The scope of work for the annual monitoring effort includes:

- Ground surveys of the dunes, beach, and inshore zone.
- Oblique aerial photography.
- Data analysis and production of a technical report describing beach volume changes.

The next section presents a brief description of Kiawah Island and its historical shoreline changes. A summary of the methods used during surveying and data analyses follows in Section 3. Section 4 includes the results of the survey. Section 5 presents a discussion of CSE's present findings and recommendations.

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2.0 SETTING AND HISTORY

Kiawah Island is one of the healthiest barrier islands in South Carolina. The addition of sand generated from Stono Inlet has led to stable dunes spanning the beachfront with only minor localized erosion in specific hotspots as sand migrates downcoast from Stono Inlet. The addition of sand through the process of inlet bypassing and the foresight of the island's developers to properly study the processes controlling the morphology of the island (Hayes et al 1975, Hayes 1977) make Kiawah Island an excellent example of beachfront development and a premier community along the South Carolina coast (Fig 2.1).

FIGURE 2.1. Kiawah Island in October 2017. Sand from Stono Inlet attaches to the island at the eastern end then migrates west, nourishing the beach.

2.1 Geologic History of Kiawah Island

Kiawah Island has been studied in detail since 1974 when Professor Miles O. Hayes and colleagues at the University of South Carolina initiated field measurements and review of the geologic history of the island. Using Kiawah Island as a model, Hayes coined the term "drumstick" barrier island, which today commonly describes barrier islands of the South Carolina coast and other "mixed-energy settings" (Fig 2.2) (Hayes 1977, 1994; Hayes & Michel 2008). The oldest part of the island, adjacent to the Kiawah River, was found to be about 4,000 years old. The island's eastern end has prograded several thousand feet seaward since the mid 1800s, leading to the creation of parallel dune ridges, each representing the shoreline at the time it was created.

The island is roughly 10 miles long, bounded by Stono Inlet to the east and Captain Sams Inlet to the west (Fig 2.3). The eastern end episodically gains sand by way of shoal-bypassing events (Williams & Kana 1986, Gaudiano 1998), and the sand eventually spreads to downcoast parts of the island until reaching Captain Sams Inlet, where it accumulates and forms Kiawah spit. These shoal-bypassing cycles are responsible for the continued growth of Kiawah Island, but can also cause temporary erosion, which will be discussed later. The geologic history of Kiawah and the processes controlling sand movement along the island are discussed in more detail in CSE (1999).

2.2 Previous Shoreline Studies

The first shoreline assessment of Kiawah Island was performed by Hayes and his students in the early 1970s (Hayes et al 1975). Based on the geomorphology of the island, Hayes identified five zones along the beach and recommended two middle zones (West Beach and Turtle Point) as being suitable for development landward of the second dune ridge (Fig 2.4). Early development of the island was based on the findings of these studies, and it became one of the first localities in the state to implement rigorous setback lines.

From 1981 to 1987, regular monitoring efforts were conducted by RPI and CSE (cf – Sexton et al 1981, Williams & Kana 1987). In July 1988, the Beach Management Act (BMA) of South Carolina was enacted, and by 1989, management of the State's beach monitoring programs was taken over by the State, ending CSE's involvement. In 1994, CSE was again contracted by the Town of Kiawah Island and conducted monitoring through 1999.

From 1981 through 1999, Kiawah Island either gained sand or remained stable. Specific areas showed sporadic erosion; however, the magnitude of sand loss was generally small. The West Beach area (encompassing Windswept Villas, Mariners Watch Villas, Eugenia Avenue, West Beach Village, and Kiawah Inn) remained stable, losing only 0.21 cubic yards per foot per year (cy/ft/yr) from 1983 until 1999 (with episodic accretion and erosion events). All other areas showed gains in sand volume between 1983 and 1999. Details of volume changes from 1983 to 1999 are given in CSE (1999).

FIGURE 2.2. Barrier-island drumstick model (after Hayes 1977) using Isle of Palms as an example. The upcoast end is wider due to additions of sand from shoal-bypass events in the inlet. Net transport to the south builds a spit at the downcoast end of the island.

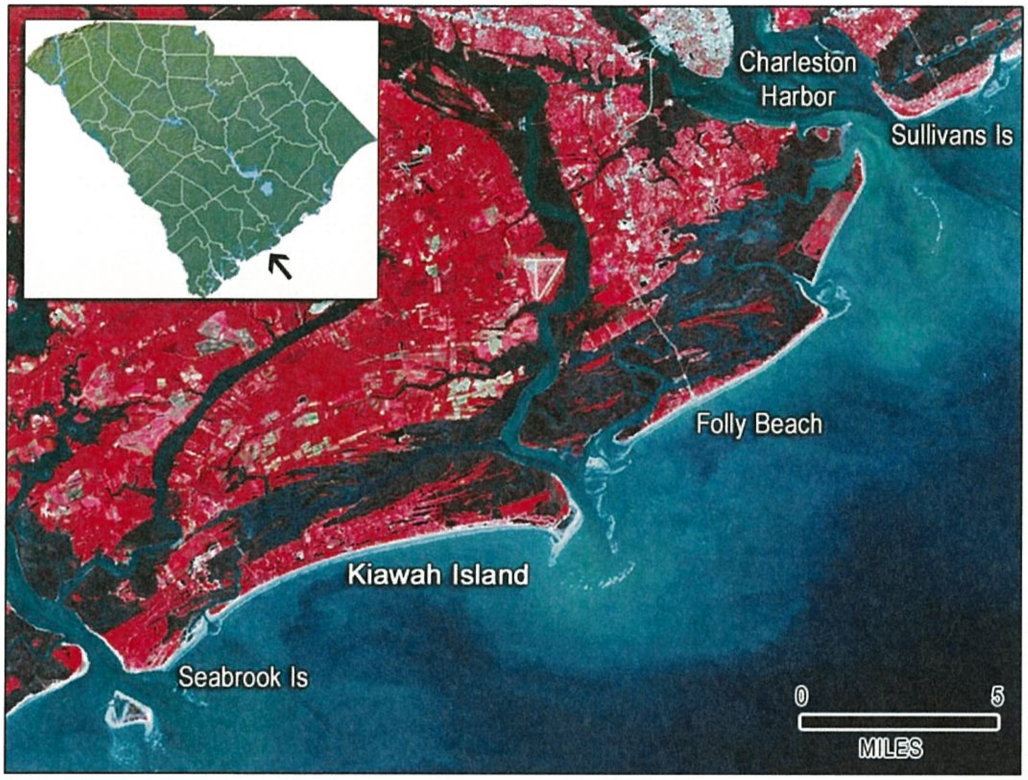


FIGURE 2.3. South Carolina coastline from Seabrook Island to Charleston Harbor. [Image courtesy Research Planning Inc and SCDNR].

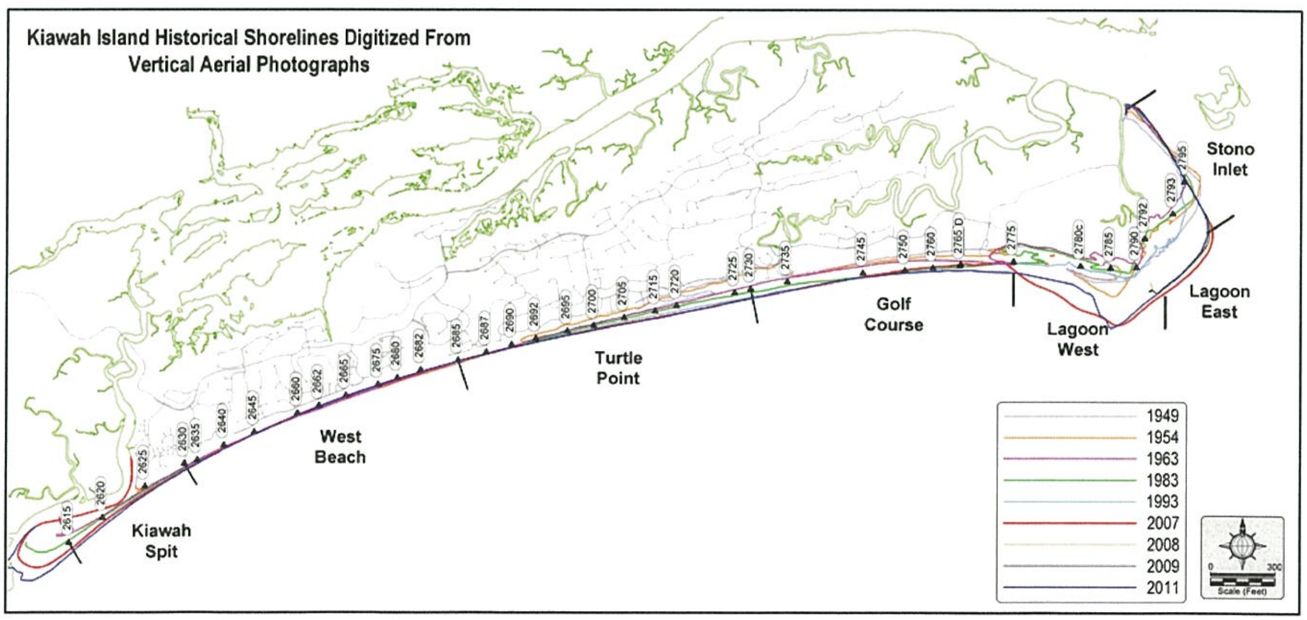


FIGURE 2.4. Historical shorelines (seaward vegetation lines). West Beach has been slightly erosional whereas all other reaches have been accretional since 1949. [Updated from CSE 1995]

2.2.1 Stono Inlet

Sand from Stono Inlet is the major littoral source for Kiawah Island (Kana et al 1981). Inlet ebb-tidal deltas often contain as much or more sand than the adjacent barrier islands along the southern two-thirds of the South Carolina coast (Sexton & Hayes 1996). In this mixed-energy environment (Hayes 1994), waves and tidal currents both have a significant impact on shaping the morphology of the inshore zone (Fig 2.5). Sand is moved seaward by strong ebb-tidal currents at the inlets. Waves then push deposited sand landward in the form of shoals. This produces characteristic features common to much of the central and southern South Carolina coast—such as lobate deltas extending miles offshore, marginal flood channels (small channels near the beach flanking the main channel and dominated by flood currents), and migrating shoals (cf – Fig 2.2 and Fig 2.3).

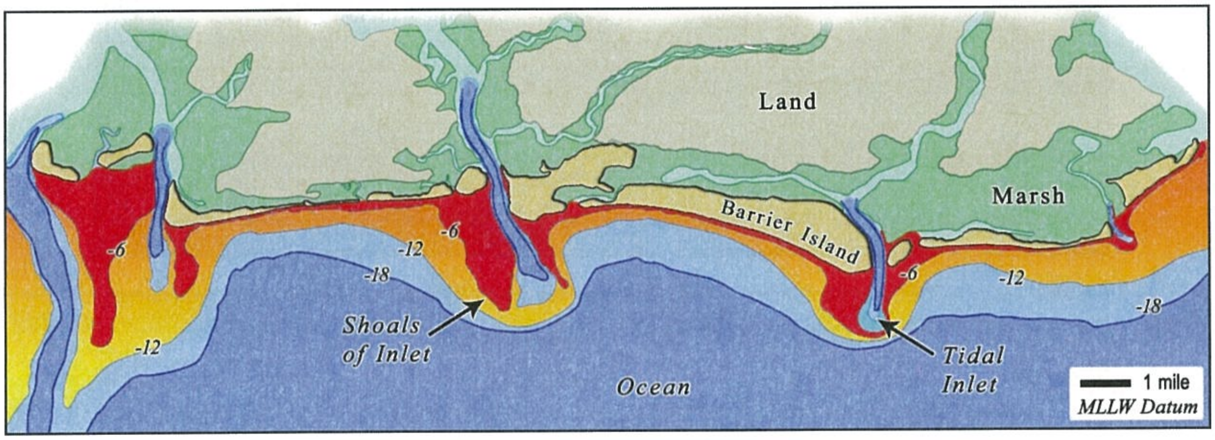
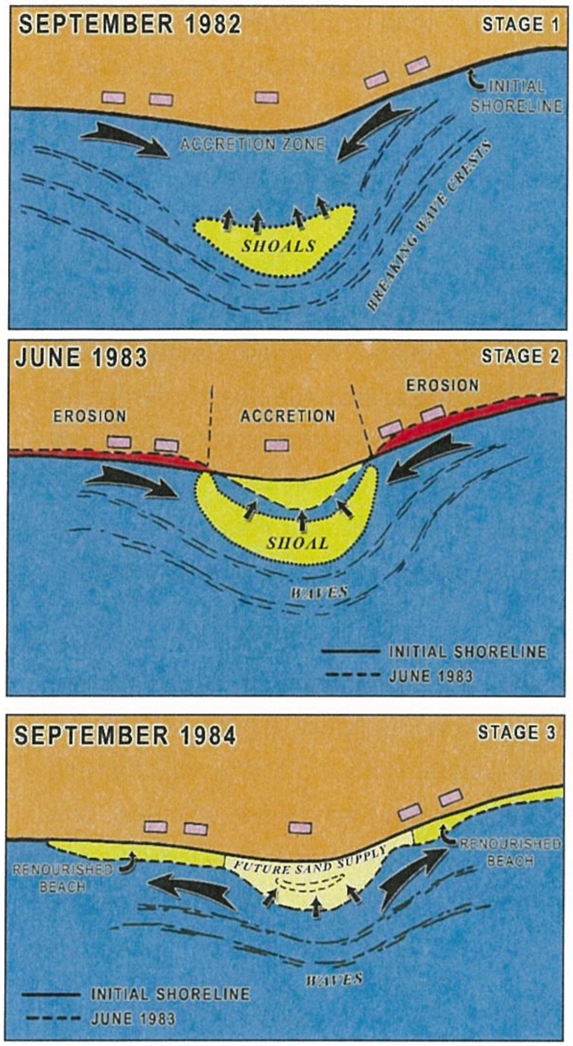


FIGURE 2.5. Nearshore bathymetry for a typical section of the central and southern South Carolina coast. Ebb-tidal deltas contain large amounts of sand, which alter the local bathymetry. This in turn directs wave energy and sediment transport patterns along the adjacent beaches. [From *Coastal Erosion and Solutions — A Primer* (Kana 2011) — CSE]

Periodically, sand stored in the ebb-tidal delta of Stono Inlet is released when the inlet channel shifts position. Shoals on the downcoast (west) side of the channel are freed from the delta and are pushed shoreward by wave action. During this process, the beach in the lee of the shoal builds because of decreased wave energy (Fig 2.6). Adjacent to the areas of accretion, erosional arcs are formed by changes in the wave patterns due to refraction around the offshore shoal. This process continues until waves have pushed the shoal to the point of attachment along the beach.

Once attached, the shoal is considered to be in Stage 3 of the shoal-bypass cycle (Kana et al 1985, Williams & Kana 1986). Waves continue to push the shoal landward and upward while spreading sand laterally along the beach. Shoal spreading (Stage 3) provides natural nourishment with sand moving downcoast via longshore currents.

THE THREE STAGES OF SHOAL BYPASSING



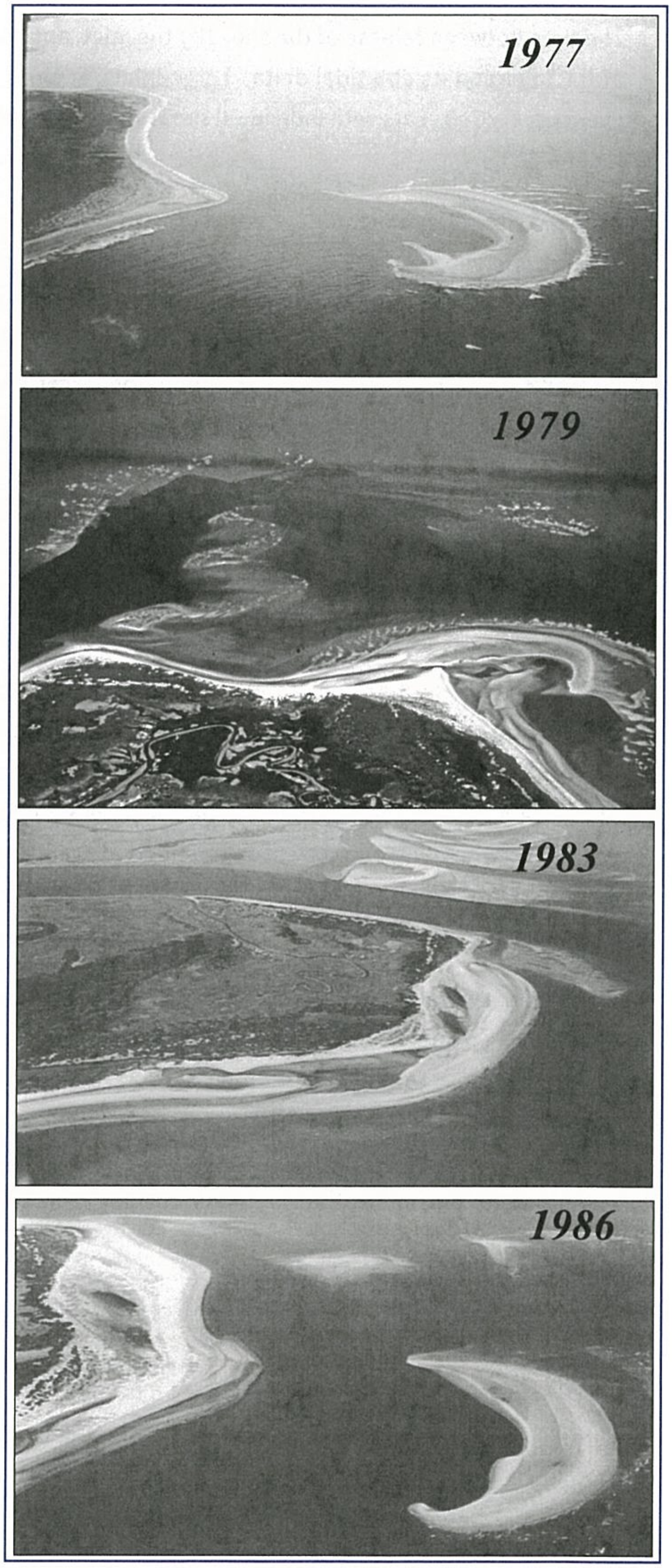


FIGURE 2.6.

[LEFT]
Schematic of the shoal-bypass cycle originally modeled from a bypass event at Isle of Palms (SC). During Stages 1 and 2 of the cycle, accretion in the lee of the shoal is accompanied by erosion on either side of the attachment site. (After Kana et al 1985)

[RIGHT]
Shoal bypassing at the eastern end of Kiawah Island.

Stage 1 in 1977 (upper). Stage 2 in January 1979 (upper middle) (courtesy of Research Planning Institute Inc). Stage 3 in 1983 (lower middle). Stage 1 in 1986 (lower). Note the similarity between the 1977 shoal and the 1986 shoal, but the additional sand accumulated on Kiawah in 1986. [After Kana et al 1999]

The time between release of the shoal by the inlet, and attachment and spreading depends on the size of the inlet and its ebb tidal delta. Large inlets, such as Stono Inlet, tend to initiate shoal-bypassing events every 7–8 years with individual shoal volumes often exceeding 0.5 million cubic yards (Gaudiano & Kana 2001).

Kiawah Island has recently experienced two impressively large shoal-bypassing events. The first formed offshore in 1994 and had completely attached to the eastern end of Kiawah by 1997. The second began attaching to Kiawah along its eastern flank in 1998. The western flank of the second shoal overlapped the eastern Kiawah shoreline as it built and migrated west and north between 1998 and 2004 (Fig 2.7). These two events were the largest ever documented on the South Carolina coast (CSE 2005). They contained such a large quantity of sand that wave action was not able to completely push the shoal against the original shoreline, and a new beach line and dune system were formed more than 2,000 ft seaward of the original shoreline. This created a lagoon between the new and old shorelines along with a roughly 2-mile-long barrier beach (Fig 2.7). The recent shoal-bypass events showed how rapidly barrier islands can form, even in the presence of sea-level rise and other erosional forcing (Kana 2002).

By 2004, the shoals had completely attached at the eastern end but remained offshore at the western end as sand migrated westward, reaching near the (old) Ocean Course Clubhouse (Fig 2.7). The shoals had not completely attached at the western end due to a natural channel maintained by tidal flushing of the lagoon. CSE (2005) estimated the two shoals added ~5 million cubic yards to Kiawah Island. Due to the overwhelming quantity of sand added at the eastern end, the shoreline near the Ocean Course jumped seaward and changed orientation. This protrusion altered the direction of approaching waves and caused focused erosion along the Ocean Course.

As longshore transport moved the shoal westward, the flushing channel migrated with the shoal, encroaching on the Ocean Course, specifically the 16th and 18th holes. The beach at the original Ocean Course Clubhouse (near OCRM monument 2775) retreated over 500 ft between 2000 and 2005. The magnitude of the bypassing event was so great, it was apparent that severe erosion would continue for several years before the cycle would be complete (Gaudiano & Kana 2001). The Ocean Course remained vulnerable to erosion as the shoal and flushing channel migrated westward. This led to the plan for beach restoration by CSE (2005).

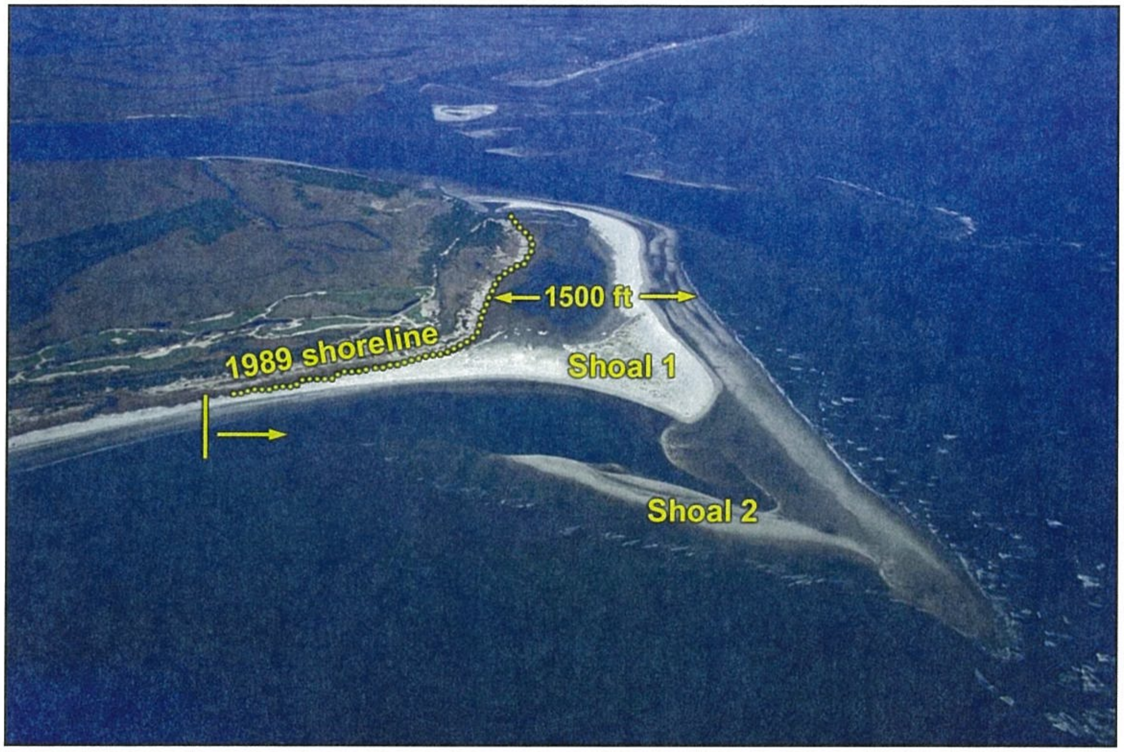


FIGURE 2.7. The eastern end of Kiawah Island in December 1998 (upper) and February 2005 (lower). Note the 1989 shoreline situated well inland from the outer beach. Shoals 1 and 2 added upward of 5 million cubic yards to Kiawah in the 1990s. As waves pushed the new sand shoreward, an incipient barrier island/lagoon/marsh formed. The new lagoon was flushed via a channel at the western end of the accreted beach. [From CSE 2007]

2.3 2006 East End Beach Restoration Project

In June and July of 2006, the East End beach restoration project (SCDHEC–OCRM permit No P/N 2005-1W-310-P, USACE permit No 2005-1W-310) was completed by L. Dean Weaver Company Inc. This project sought to artificially create Stage 3 of the shoal-bypassing cycle and avoid further erosion of the Ocean Course. The details of the project are given in the final report "2006 East End Erosion and Beach Restoration Project: Kiawah Island" (CSE 2007). The objectives of the project were to:

- Accelerate the shoal-bypassing cycle so as to restore westerly sand transport along Kiawah Island.
- Eliminate rapid erosion along the Ocean Course, particularly around the 16th, 17th, and 18th fairways and the driving range.
- Maintain viable, piping plover beach habitat along the newly accreted barrier spit east of the Ocean Course, including areas of frequent washovers and the adjacent incipient dune habitat.
- Preserve the environmental, cultural, and aquatic resources of the Town.
- Provide protection to oceanfront recreational facilities and community infrastructure as a resource of tax revenue and income.
- Maintain the economic viability of tourism, the Town's largest industry.
- Make a new source of sand from the accreting shoal more readily available for natural nourishment along downcoast areas.

The project consisted of closure of the existing flushing channel, creation of a new channel to maintain the tidal environment of the lagoon, and excavation and transfer of nourishment sand from the new inlet and accreted shoal areas to eroded downcoast areas. These actions were designed to provide a smoother transition between Kiawah's main beach and the accreted shoal. The contracted volume for the project was 550,000 cubic yards (cy), the majority of which was placed between the new clubhouse and just west of the old flushing channel. The new flushing channel was positioned at the apex of the attached shoal (Fig 2.8).

FIGURE 2.8. Before (February 2006) and after (July 2006) aerial photos of the 2006 East End beach restoration project.

2.4 2015 East End Channel Realignment Project

The 2006 beach restoration project proved effective in restoring a dry sand beach along the Ocean Course. The new flushing channel relocated naturally in 2007 to a point in the middle of the open lagoon area. Between 2007 and 2013, the channel meandered across the intertidal beach; however, the throat of the channel remained east of the 2006 closure dike. In early 2014, the channel began to encroach on the closure dike, and the Town began planning for another channel relocation in the event the channel continued to migrate west. The plan called for periodic relocation of the flushing channel, using the minimal amount of sand necessary, if the channel migrated west beyond its position in February 2014. A permit application was submitted with the intended construction window of September–October; however, by the fall of 2014, the migration of the channel expedited and quickly eroded much of the dune area fronting the Ocean Course driving range. The Town applied for a one-time modification to the construction window to allow for construction during the spring–summer time frame, which was granted by regulatory agencies.

The 2015 project was constructed between May and June 2015 by Lake Moultrie Construction Company Inc DBA Lake Moultrie Water Company and Ashridge Inc, A Joint Venture (St. Stephen SC) at a cost of $538,000. A total of 100,000 cy of sand was transferred, and the new inlet was opened ~3,000 ft to the east. A closure dike was built across the original channel, connecting to the remaining portion of the 2006 closure dike (Fig 2.9). Excess sand was placed along the seaward edge of the driving range to facilitate recovery of the eroded areas and protect the range. The completed project accomplished the goal of eliminating the cause of erosion along the Ocean Course while minimizing the construction impacts through lower volumes and limited manipulation of the beach area (Fig 2.10).

FIGURE 2.9. Closure of the pre-project channel on 22 May 2015.

FIGURE 2.10. Aerial image of the completed 2015 channel relocation project in July 2015. The new inlet was opened ~3,000 ft east of the old channel.

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3.0 METHODOLOGY

This section describes the methodologies of the topographic survey and habitat mapping used by CSE to monitor changes at Kiawah Island.

3.1 Survey

The present survey was conducted by RTK-GPS* (Trimble™ R8 GNSS system) in November 2017. The survey was scheduled to obtain data following Hurricane Irma, while still occurring near the season of previous monitoring effots. Profiles along Kiawah Island were surveyed perpendicular to the local shoreline (CSE baseline) azimuth from the control points to a minimum of −12 ft NAVD (the depth equal to the normal limit of sand movement in this setting) or at least 3,000 ft from the dune. Surveys were conducted by combining a land-based survey and a bathymetric survey (Fig 3.1). Land surveys were accomplished using an RTK-GPS between the foredune and low-tide wading depth [(~)−6 ft NAVD], whereas overwater work was accomplished via RTK-GPS combined with a precision echo-sounder mounted on CSE's shallow-draft boat, the RV Southern Echo.

*[*Real-time kinematic global positioning system]*

FIGURE 3.1.

CSE's monitoring methods include land-based data collection via RTK-GPS (upper left) and hydrographic data collection via RTK-GPS linked to a precision echo-sounder. CSE's shallow-draft vessel, the *R/V Southern Echo,* is shown in the lower image.

Working around the tidal cycle, data collected on land were extended into shallow depths in the surf zone at low tide. Then data were collected from the boat at high tide such that overlap of the two surveys occurred close to shore (Fig 3.2). Appendix A includes profiles for the most recent survey compared to earlier surveys. CSE has updated profile sheets to include profile volumes and aerial images showing profile locations.

Surveys conducted from 2007 to 2011 involved 23 stations west of the East End project area (using existing OCRM monuments spaced ~1,000–2,500 ft apart) and 64 stations in the project area spaced 400 ft apart. The present baseline reduces the maximum spacing in the downcoast profiles to ~1,000 ft. CSE also reduced the total number of lines in the project area from 64 to 24 by increasing the spacing from 400 ft to 1,000–1,200 ft. The baseline was also modified at the East End to reduce the number of turns in the baseline and to simplify volume calculations.

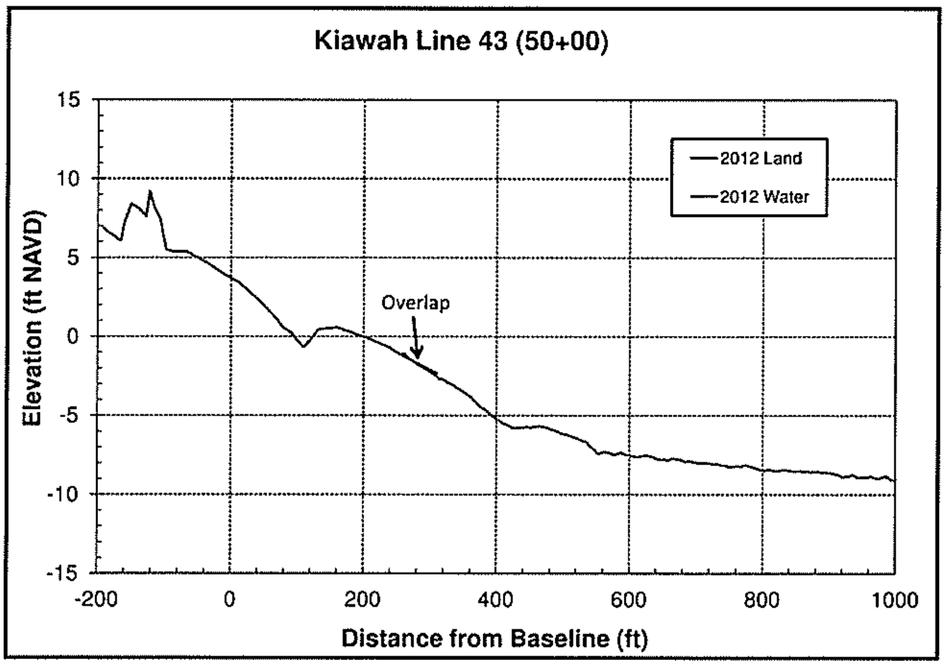

FIGURE 3.2. CSE combines land-based and hydrographic data collection to produce continuous profiles of the beach. Land-based work is accomplished at low tide, while hydrographic work is performed at high tide. This allows for overlap of the two data collection methods and ensures quality data and a complete profile.

The present baseline is comprised of 61 profiles with Lines 1–37 representing the shoreline west of the 2006 project area and Lines 38–61 representing the project area and eastern end of the island (Table 3.1). The baseline is shown in Figure 3.3. Line numbering increases from west to east—Line 1 is near Captain Sams Inlet ~1.2 miles southwest of the Beachwalker Park vehicle access. Line 61 is at the tip of the sand spit at the junction of the Stono River and Penny's Creek. OCRM monument names and CSE project stationing are indicated where the new profile lines coincide with previous stations (ie - Line 35 is OCRM station 2725). The current reaches (Fig 3.3) are defined in Table 3.2.

Volume calculations for the lagoon were obtained via digital terrain models (DTMs) produced from CSE survey data. This eliminates the need for volume adjustments due to differing baseline and beach configurations. Profiles are still used for inferring changes to the beach shape, the position of shoals and channels, and elevations of berms.

3.2 Volume Calculations

To estimate changes in the sand volume along Kiawah Island, survey data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which calculates volumes based on 2-D profile data (in x–y format) and distances between subsequent lines. The resulting volumes provide a more quantitative and objective way of determining beach condition, including the ideal minimum beach profile and how sand quantities at a site (volume per unit length of shoreline) compare with the desired condition (Kana 1993). Volume results calculated via this method integrate all the small-scale perturbations across the beach and yield a simple measure of its condition which is less susceptible to seasonal fluctuations in the profile, a problem with shoreline change studies that are based on movement of a single contour.

Unit-volume calculations allow for distinguishing the quantity of sediment in the dunes, on the dry beach, in the intertidal zone to wading depth, and in the remaining area offshore to the approximate limit of profile change. Figure 3.4 depicts the profile volume concept. The reference boundaries are site-specific but ideally encompass the entire zone over which sand moves each year—dune to the depth of closure (DOC*), which is the depth of water where little sand movement to or from the beach occurs. [**DOC is the depth beyond which there is negligible change in bottom elevation.*]

TABLE 3.1. Kiawah Island beach monitoring stations referenced in the present report. Order is generally west to east. Offset and cutoff refer to distances from the benchmark/baseline for the start and end of beach volume calculations.

Reach	Line	Name	Offset	Cutoff	Distance to Next	Easting	Northing
1	1		-200	2,500	1,000	2262721.7	271034.2
	2		0	2,500	997	2263451.4	271718.0
	3		250	2,500	1,153	2264178.6	272399.3
	4	OCRM 2615	140	1,500	844	2265064.0	273138.6
	5		93	2,500	845	2265739.8	273644.8
	6	OCRM 2620	86	1,500	1,157	2266414.9	274152.4
	7		95	2,500	978	2267397.7	274763.4
	8	OCRM 2625	189	1,500	1,040	2268125.0	275417.0
	9		100	1,500	806	2269055.6	275882.0
2	10	OCRM 2630	152	1,500	547	2269723.8	276332.8
	11	OCRM 2635	41	1,500	1,232	2270247.2	276490.7
	12	OCRM 2640	94	1,500	665	2271326.8	277083.3
	13		67	1,400	665	2271935.3	277351.5
	14	OCRM 2645	47	1,200	945	2272543.9	277619.7
	15		27	1,400	946	2273408.4	278001.2
	16	OCRM 2660	28	1,100	1,025	2274273.9	278383.2
	17		15	1,400	1,026	2275234.5	278740.9
	18	OCRM 2665	5	1,000	691	2276196.1	279099.0
	19		0	1,400	692	2276850.6	279320.6
	20	OCRM 2675	0	1,100	831	2277505.6	279542.3
	21	OCRM 2680	46	1,300	1,266	2278288.1	279822.4
	22		0	1,400	1,267	2279502.6	280179.9
3	23	OCRM 2685	10	1,200	1,033	2280718.1	280537.6
	24	OCRM 2687	40	1,500	1,215	2281707.1	280837.2
	25	OCRM 2690	80	1,300	1,145	2282876.3	281167.0
	26	OCRM 2692	279	1,500	1,205	2283935.3	281602.5
	27	OCRM 2695	119	1,400	1,080	2285131.1	281719.2
	28	OCRM 2700	100	1,400	1,269	2286187.8	281943.8
	29	OCRM 2705	130	1,500	635	2287413.8	282268.9
	30		143	1,500	643	2288034.7	282401.8
	31	OCRM 2715	145	1,500	889	2288663.4	282536.4
3	32	OCRM 2720	208	1,500	645	2289526.0	282752.7
	33		309	1,700	646	2290143.9	282937.6
	34	OCRM 2722	390	1,600	1,125	2290763.1	283122.9
	35	OCRM 2725	322	1,600	666	2291875.6	283288.9
	36	OCRM 2730	316	1,600	666	2292526.8	283430.6
	37		300	1,700	752	2293263.8	283580.0
4	38	0+00	300	1,600	1,000	2294001.1	283729.5
	39	10+00	165	1,700	1,000	2294999.2	283790.2
	40	20+00	30	1,500	1,000	2295997.4	283850.9
	41	30+00	-55	1,500	1,000	2296995.5	283911.6
	42	40+00	-140	1,500	1,000	2297993.6	283972.3
	43	50+00	-219	1,500	1,000	2298991.7	284033.0
	44	60+00	-295	1,500	1,000	2299989.8	284093.8
	45	70+00	-370	1,500	1,000	2300988.0	284154.5
	46	80+00	-300	1,500	1,000	2301986.1	284215.2
5	47	90+00	-374	1,800	1,000	2302984.2	284275.9
	48	100+00	-250	2,000	1,000	2303982.3	284336.6
	49	110+00	0	2,500	1,000	2304980.4	284397.3
	50	120+00	350	3,200	1,000	2305978.6	284458.0
	51	130+00	780	3,500	1,000	2306976.7	284518.8
	52	140+00	1100	3,500	1,000	2307974.8	284579.5
	53	150+00	500	2,800	1,000	2308972.9	284640.2
	54	160+00	65	1,500	1,000	2309971.0	284700.9
	55	170+00	-775	1,000	0	2310969.2	284761.6
6	56	Inlet 0+00	300	1,300	1,200	2310528.3	285452.3
	57	Inlet 12+00	700	1,420	1,200	2309882.6	286463.7
	58	Inlet 24+00	900	1,420	1,200	2309237.0	287475.2
	59	Inlet 36+00	920	1,420	1,200	2308591.3	288486.6
	60	Inlet 48+00	912	1,720	1,200	2307945.7	289498.1
	61	Inlet 60+00	640	1,520	0	2307300.1	290509.5

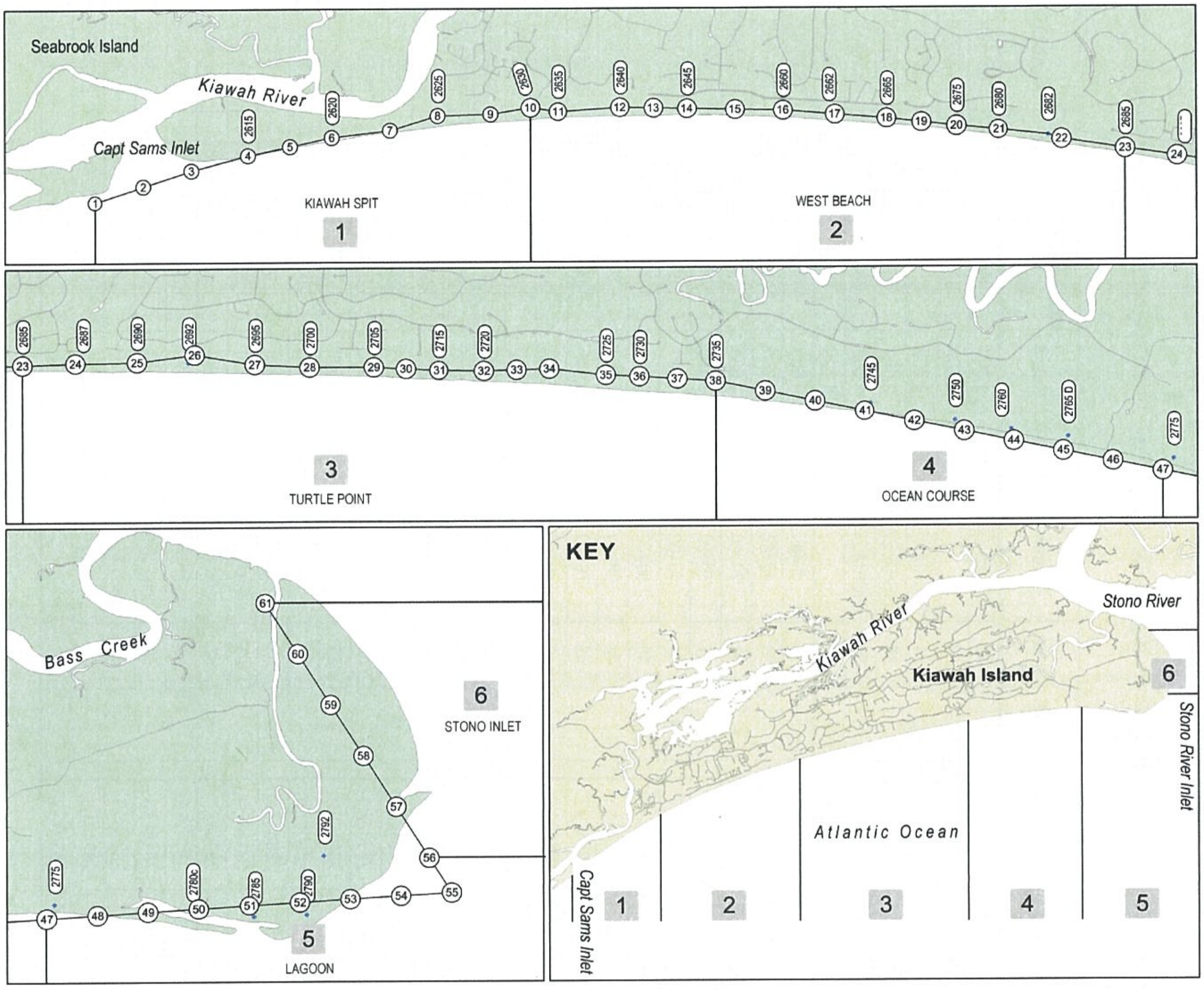

FIGURE 3.3. General location of beach stations and reaches monitored for the present report. Line numbers are shown in circles.

TABLE 3.2. Kiawah Island reaches referenced in the present report.

Reach	Approximate Geographic Boundaries	Line Numbers	Reach Length (ft)
Kiawah Spit	West end of Kiawah Island to Beachwalker Park	1–10	8,820
West Beach	Beachwalker Park to Turtle Point	10–23	11,798
Turtle Point	Turtle Point Area	23–38	13,614
Ocean	Ocean Course Area	38–47	9,000
Lagoon	Lagoon Area	47–55	8,000
Stono Inlet	Stono Inlet Shoreline	56–61	6,000

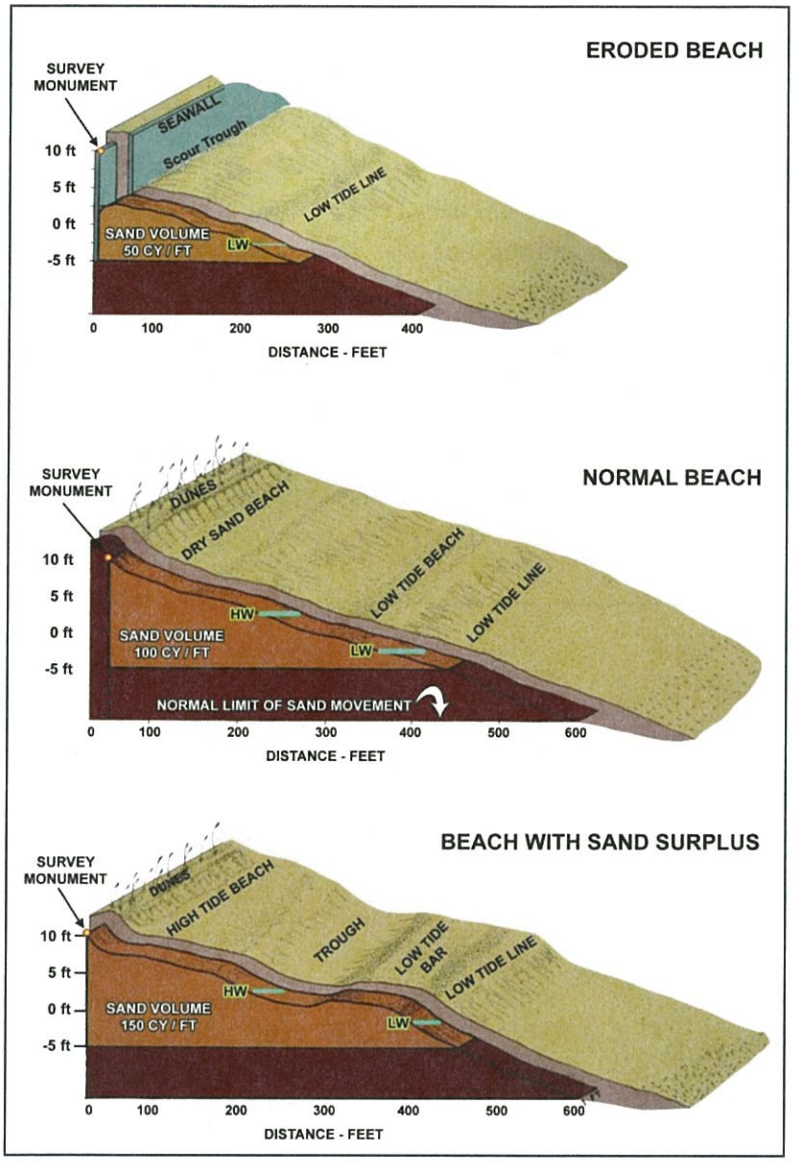

FIGURE 3.4. The concept of profile volumes - the volume of sand between defined contours over a 1-ft (unit) length of beach. [After Kana 1990]

For the present survey (November 2017), sand volume was calculated between the primary dune and −10 ft NAVD. The −6 ft NAVD contour has been used in past reports for consistency with earlier studies and limitations of pre-2007 data. While most sand movement occurs above −6 ft NAVD, some profile changes do occur between −6 ft and −10 ft NAVD. Significant changes can occur within this lens when underwater bars form or change and as shoals move onshore and alter morphology. Especially at the northeastern end, volume calculations were cut off at a set distance (profile specific) due to data coverage or morphological considerations (ie – the profile flattens over the ebb-tidal delta before reaching −10 ft NAVD). Profiles and calculation limits are shown in Appendix A.

Figure 3.5 shows a representative profile from Kiawah Island over an approximate 11-year period. The lower portion of the graph tracks the standard deviation in elevation based on the mean profile elevation of the set of profiles at the station. A standard deviation of <0.25 ft over several hundred feet at the outer end of a profile is evidence of little change in bottom elevation over the period encompassed by the data. This analysis confirms that nearly all measurable volume change along Kiawah's beach occurs above −10 ft NAVD and that a realistic value for DOC at decadal scales is ~10 ft.

Comparative volumes and volume changes were computed using standard procedures. [CSE incorporates the average-end-area method in which the average of the area under the profiles computed at the ends of each cell is multiplied by the length of the cell to determine the cell's sand volume.] Volume results at each profile line were extrapolated to the next line. Net volumes were calculated for each profile as well as for project reaches (see Tables 3.1 and 3.2).

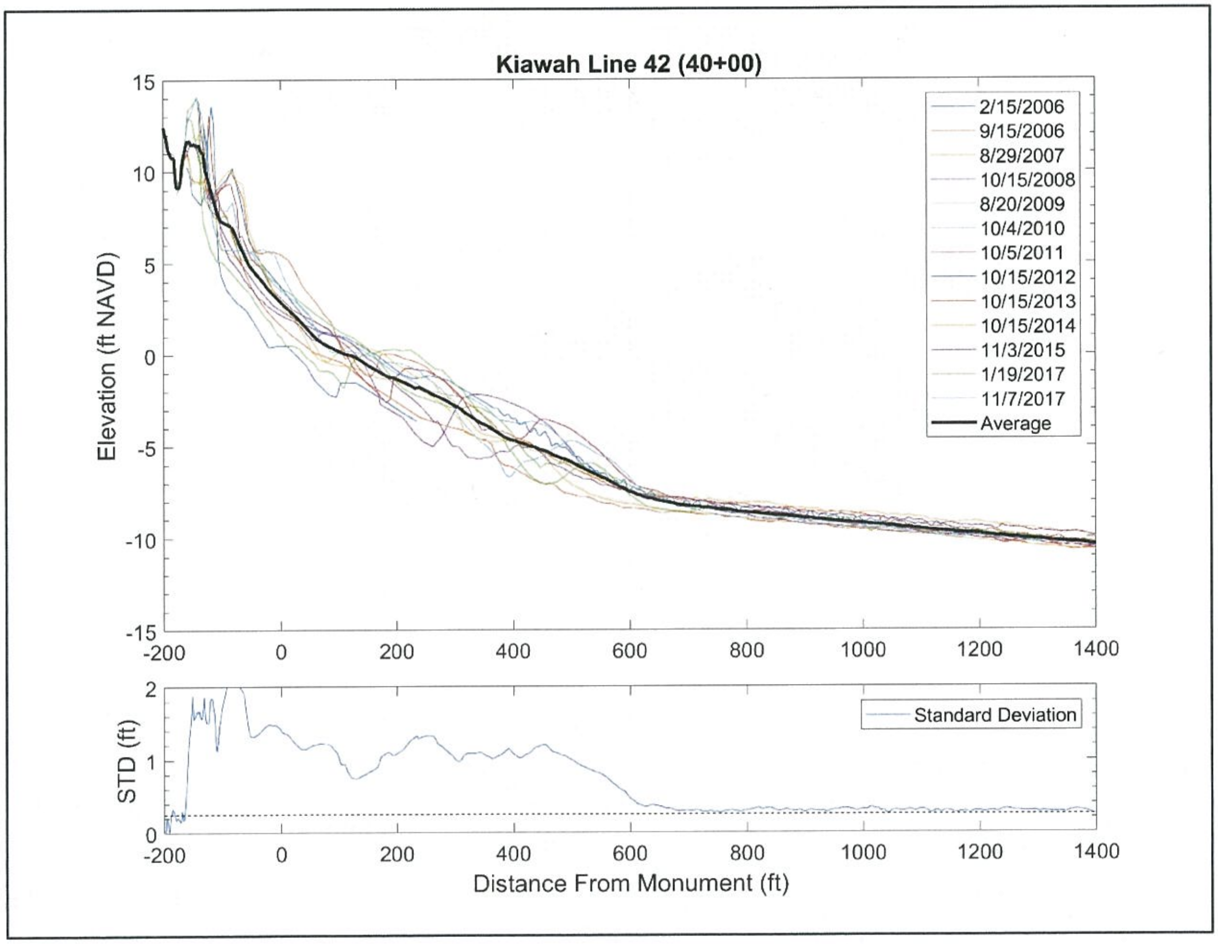

FIGURE 3.5. Comparison of repetitive profiles at a monitoring station along Kiawah Island and computation of standard deviation. Where the profiles converge, the standard deviation is low and is an indicator of little sediment exchange (approximate closure depth).

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4.0 RESULTS

Results of the November 2017 monitoring survey are presented in the following sections. Attention is given to the areas affected by the 2015 inlet and channel relocation projects as well as areas impacted by recent storms. Section 4.1 discusses each project and the impacts they had on the morphology and sediment transport pathways. Section 4.2 provides detailed sand volume changes for reaches along the eastern end of Kiawah Island, comparing present volumes with selected conditions from previous years. Section 4.3 provides results of the downcoast reaches.

4.1 2015 Inlet Realignment Projects

4.1.1 Kiawah Island East End Channel Realignment Project

A general description of the 2015 Kiawah Island East End channel realignment project was provided in Section 2. Additional details of the construction and post-project condition were provided in the 2015 monitoring report (CSE 2016). This monitoring report focuses on changes occurring over the past year and CSE's opinion on likely changes to occur over the next few years. Figure 4.1 shows the project area in February 2017 and October 2017 (post-Hurricane *Irma*).

The most significant change occurring in the project area in recent years is opening of a new flushing channel during Hurricane *Matthew*. The channel is located at the approximate location of the 2006 constructed channel and has persisted since its creation in 2016. The channel constructed in 2015 appears to be slowly infilling, although it has continued to migrate to the west.* Over the past year, it migrated ~700 ft, although over half of that occurred during Hurricane *Irma*. A majority of the measured "migration" is likely a shifting of the vegetated area of the overwash berm due to the storm rather than actual movement of the channel bottom. CSE expects the migration to slow as the channel continues to infill.

*[*As this report was being finalized (April 2018), CSE conducted an overflight and noted the constructed channel was closed as of 12 April.*]

The constructed dike performed well during Hurricane *Matthew*; however, it nearly breached during Hurricane *Irma*. Most of the width of the dike overwashed during the storm, but the higher dune at the landward side remained. The outer berm of the small ponded area seaward of the driving range overwashed, which resulted in continued infilling of the pond in front of the clubhouse (Line 45) and landward migration of the berm in front of the driving range (Line 46).

Following Hurricane *Irma*, the Town sponsored a dune restoration project, and sand was scraped from the outer intertidal beach to construct a dune seaward of the driving range. This will help prevent future overwash into the driving range and will also serve as a buffer between the range and the lagoon habitat. CSE continues to expect the ponded area to slowly infill as overwash and wind-blown sand accumulate in the pond. The small flushing channel draining the pond has fluctuated in position and has also decreased in size as the pond has infilled. There is presently more sand in the upper beach profile seaward of the practice green (near the small channel), although there is a lower overall beach volume when considering the entire profile.

FIGURE 4.1. Aerial images of the 2015 project area in February 2017 (upper) and October 2017 (lower).

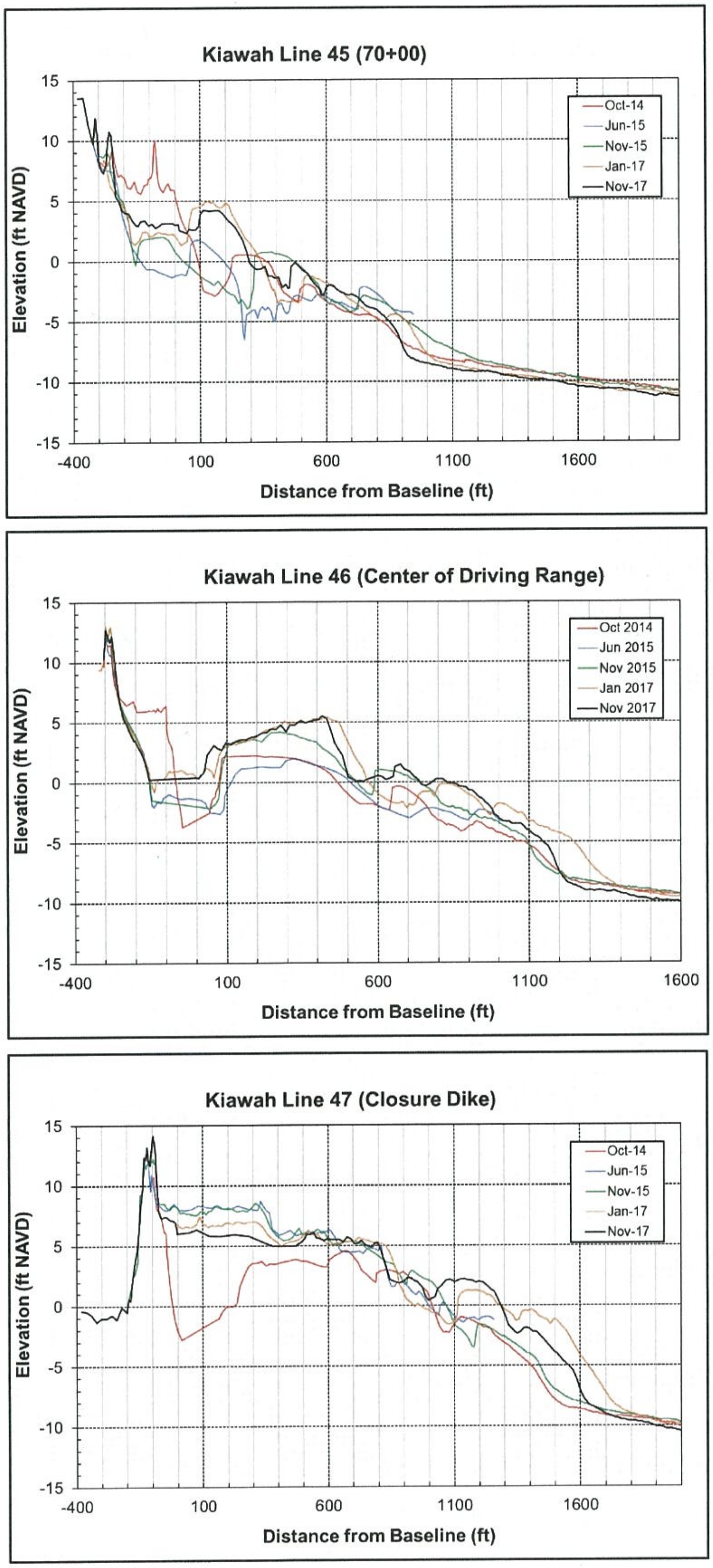


FIGURE 4.2.

Profiles from the 2015 East End project area.

Line 45 is at the Ocean Course beach access.

The ponded area has infilled over 3 ft since 2015, as shown in Line 46.

A high berm has built seaward of the pond, stretching from west of the clubhouse to the constructed inlet.

The Town has been collecting quarterly dune-line surveys since project completion. Figure 4.3 shows the position of the dune line (or line of stable dry sand not regularly wetted by spring tides) from June 2015 to September 2017 (post-*Irma*). Since June 2015, the dune line, which represents the boundary of the inlet, has moved ~1,900 ft to the west. The western boundary of the inlet is also migrating landward, which is similar to evolution of the previous inlet from 2010 to 2014. The westward growth and extension of the outer berm from 2015 to December 2017 is also evident in the dune-line surveys; however, in 2017, the dune line on the outer bar shifted landward and retreated further east. Again, this survey defines the limit of vegetation, and much of this was lost during Hurricane *Irma*. It is likely to extend again to the west under normal weather conditions.

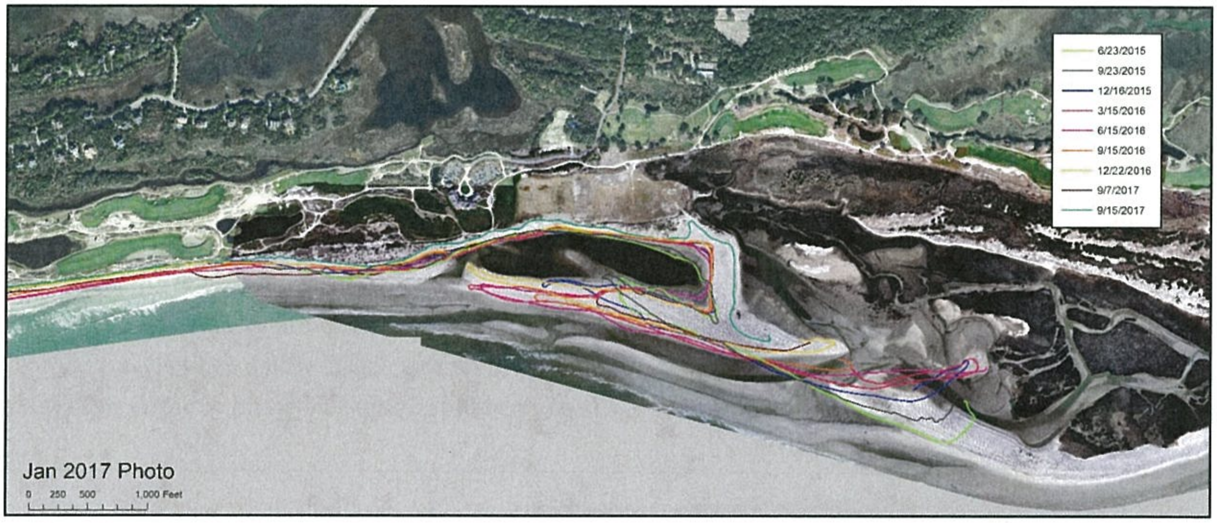


FIGURE 4.3. Position of the dune line or line of stable dry beach from June 2015 to September 2017. Data were collected by Town staff. The inlet has migrated over 1,400 ft to the west.

Overall, the 2015 channel realignment project is performing nearly as expected, and has withstood well the impacts of two major hurricanes. The area should continue to be monitored periodically by Town staff and if significant changes are observed, CSE should be consulted.

4.1.2 2015 Captain Sams Inlet Relocation

The Seabrook Island Property Owners Association (SIPOA) sponsored and implemented the third relocation of Captain Sams Inlet along the western boundary of Kiawah Island in the spring of 2015. Similar projects were completed in 1983 and 1996 in an effort to maintain a sand supply to Seabrook Island. The general design of the project was to relocate the inlet (using land-based equipment) to its 1960 position by opening a new channel through Captain Sams spit and closing the old channel with a sand dike. The project is similar to the channel relocation project at the eastern end of Kiawah, only larger in scale. The inlet historically migrates toward Seabrook Island at a rate of 200–300 ft/yr. When it reaches a certain point, it begins to rapidly erode Seabrook Island's North Beach, and sediment transport is reduced to other portions of Seabrook. SIPOA had an agreement with the Town of Kiawah Island and owners of the spit property to relocate the channel in 2015 back to the 1963 position.

The 2015 relocation was conducted under permits obtained by SIPOA with an allowable construction window of 15 May to 15 August. The new channel was opened on 2 June 2015. Additional sand was stockpiled on both sides of the old channel, and the old channel was closed on the night of 11–12 June. A total of ~140,000 cy of sand was excavated and transferred from the basin and intertidal area during the project.

The project resulted in the western 2,800 ft of Kiawah Island being shifted to Seabrook. This reduced the sand-volume along the spit by ~750,000 cy. Figure 4.4 shows the post-construction photo and locations of monitoring stations. Profile Line 1 is now on the Seabrook side of Captain Sams Inlet; Line 2 is essentially in the inlet channel. For volume analysis, any volume associated with these profiles is excluded from computations. As the inlet migrates over time, the lines will be reincorporated into the volume measures as applicable. CSE anticipates the spit will return to its pre-project location within the next 12–15 years.

Over the past year, sand has accumulated along the Kiawah side of Captain Sams Inlet, resulting in elongation of the spit and volume gains in the growing inlet delta on the Kiawah side of the inlet. For example, Line 3 (just north of the inlet) gained 45.5 cy/ft of sand, mostly in the intertidal beach zone. The remainder of the spit eroded between January and November 2017, which is likely a result of Hurricane *Irma*. CSE expects continued growth of the spit towards Seabrook Island over the next year.

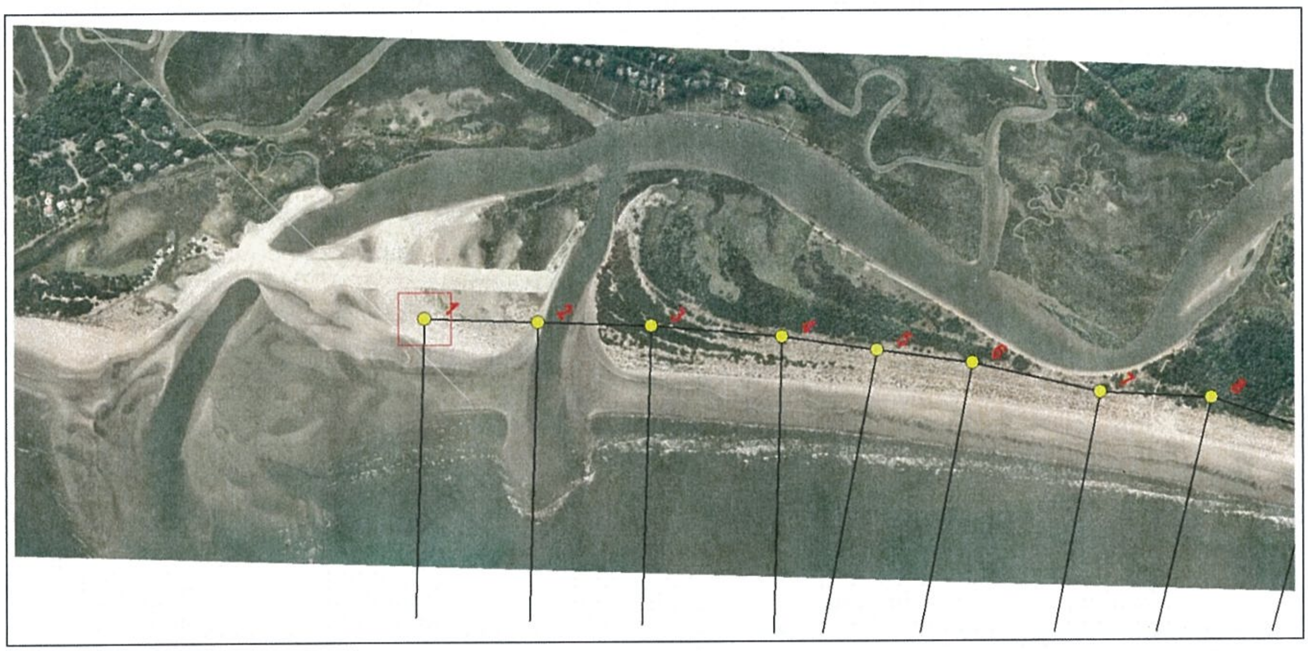


FIGURE 4.4. Post-project map of the west end of Kiawah Island and Town beach monitoring stations. Lines 1 and 2 are now located on the Seabrook side of the new inlet.

FIGURE 4.5. October 2016 (upper – post-*Matthew*) and June 2017 (lower) aerial images of Captain Sams Inlet, which was relocated ~3,000 ft to the east by SIPOA in May–June 2015.

4.2 Beach Volume Changes (January 2017 – November 2017)

Reach volume changes are reported from the eastern end of the island (Reach 6 – Stono Inlet) to the western end (Reach 1 – Captain Sams spit). Methods for volume calculations are given in Section 3. Unit volumes for each station are provided in Table 4.1. Volumes for each reach are provided in Table 4.2. Overall, the entire island was erosional over the past year due to Hurricane *Irma* in September 2017. Over the past year, the Captain Sams Inlet, West Beach, and Ocean Course reaches showed a net gain in sand, while the remaining reaches eroded. Most of the gains in Captain Sams were due to elongation of the spit toward Seabrook Island and not due to seaward growth of the front beach profiles.

4.2.1 Reach 6 – Stono Inlet

Stono Inlet Reach spans ~6,000 ft from Line 56 to Line 61 (see Fig 3.3). Beach profiles in this reach are steeper than the front-beach reaches due to the presence of Stono Inlet and reduced wave energy along the inlet. Unit volumes from Stono Inlet are shown in Figure 4.6. The reach was fairly stable from 2006 to 2012, but has eroded at a higher rate since 2012. Erosion has been most severe along the seaward end of the reach as the beach has transitioned into an overwash bar. Line 56 has lost over 25 cy/ft of sand each year since 2014 and has lost over 260 cy/ft since 2007. The magnitude of erosion decreases moving inland with the net volume loss decreasing from 93 cy/ft at station 57 to a gain of 72 cy/ft at station 61.

Over the past year, profiles in the reach showed a volume change from -46.0 cy/ft to +18.4 cy/ft. Accretion was observed at the three most inland lines (59–61). Overall, the reach lost 85,860 cy (14.3 cy/ft). This is less than half of the loss measured over the previous year; however, is still the second highest loss rate observed since 2007.

Erosion of the Stono Inlet Reach is a result of a lack of sediment supply from the Lagoon Reach to the southwest. The Stono Inlet Reach is fed by sand moving from the Lagoon Reach, and over the past two years, the majority of sediment eroding from the lagoon is washing over the berm rather than being transported to the inlet shoreline. Without an addition of sand from another shoal-bypass event, the Lagoon Reach and Stono Inlet Reach are expected to continue to erode over the next several years.

TABLE 4.1. Unit volumes for monitoring profiles at Kiawah Island (to −10 ft NAVD).

Kiawah Island 2017 (Nov 2017) Monitoring Survey			Unit Volume (cy/ft)												
Reach	Line	Distance to Next (ft)	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17
1 - Kiawah Spit	1	1,000								601.9	577.7	576.6	694.4	667.9	592.4
	2	997								489.3	494.0	477.6	362.0	406.0	435.3
	3	1,153								339.7	346.1	337.0	252.8	256.5	302.0
	4	844	300.2		392.4	392.4	391.9	406.7	392.1	388.2	384.7	387.0	360.9	330.5	325.6
	5	845								384.3	384.5	386.4	372.2	351.2	341.0
	6	1,157	252.5		361.9	361.1	375.2	384.1	380.9	384.5	384.0	386.0	378.2	357.1	349.6
	7	978								316.7	315.3	312.7	310.8	300.4	293.9
	8	1,040	240.1		309.0	309.9	321.6	334.7	331.0	347.6	353.8	346.8	340.1	334.3	337.0
	9	806								334.9	335.6	334.6	329.3	320.7	321.5
2 - West Beach	10	547	268.3		300.9	299.1	303.6	318.7	317.3	335.8	339.8	339.1	333.3	323.1	328.4
	11	1,232	255.0		289.3	290.4	300.2	307.1	312.3	323.8	324.3	325.1	320.0	314.6	317.4
	12	665	232.5		261.1	257.9	273.1	273.1	275.4	284.8	293.0	294.6	292.5	278.8	285.4
	13	665								277.8	281.6	287.8	287.3	276.7	274.0
	14	945	251.9		252.3	248.5	257.7	258.2	259.3	270.8	278.3	280.9	276.1	272.5	269.5
	15	946								268.1	273.7	279.5	273.5	269.0	264.9
	16	1,025	235.6		254.5	252.6	258.3	260.3	253.0	265.4	269.6	278.3	277.4	268.6	270.2
	17	1,026								251.7	256.6	261.8	257.4	251.9	251.3
	18	691	242.2		251.2	243.9	245.2	246.7	242.8	252.0	262.1	267.4	259.9	252.8	249.7
	19	692								252.1	254.6	257.9	261.7	233.2	245.0
	20	831	272.6		243.8	239.0	239.3	238.1	239.8	248.2	253.0	260.3	261.7	240.6	240.5
	21	1,266					222.0	220.0	226.8	234.0	238.9	235.1	243.8	231.8	231.4
	22	1,627								258.2	257.5	267.0	271.9	252.0	257.4
3 - Turtle Point	23	1,033	234.3		253.9	249.0	252.2	253.0	257.3	261.3	271.3	270.5	285.4	272.7	271.5
	24	1,215					257.1	255.4	259.3	265.6	274.8	285.7	291.6	273.7	273.4
	25	1,145	229.2		260.3	254.0	258.4	254.0	257.9	271.9	280.7	291.7	299.0	274.0	278.7
	26	1,205					259.9	251.5	258.0	265.2	278.2	294.2	291.0	276.1	279.9
	27	1,080	266.2		262.7	274.3	279.7	270.2	277.2	287.6	304.5	314.5	324.5	307.8	306.5
	28	1,269	299.2		278.2	291.8	295.2	292.3	300.8	307.4	323.9	336.5	343.9	333.2	323.5
	29	635	268.3		321.9	313.4	325.8	323.1	322.1	344.5	360.4	370.5	381.7	368.2	365.6
	30	643								345.7	354.7	369.1	384.0	364.4	360.7
	31	889	265.3		322.6	325.1	326.1	331.3	326.6	346.8	353.7	373.8	382.8	372.2	360.9
	32	645	286.4		306.2	302.0	306.9	309.3	305.3	323.3	330.2	351.9	354.5	349.2	335.1
	33	646								282.4	299.6	310.3	318.6	299.1	297.4
	34	1,125					254.9	260.5	256.0	272.8	280.6	287.1	296.6	281.3	272.9
	35	666	217.0		252.1	250.3	253.3	254.3	245.3	269.3	267.0	273.8	277.2	273.3	264.2
	36	666	252.2		257.4	204.3	259.9	263.7	258.2	275.8	275.7	276.7	279.8	275.0	265.2
	37	752								283.9	288.2	285.3	288.7	267.7	269.4
4 - Ocean Course	38	1,000		255.8	260.4	261.1	264.7	269.7	264.0	280.1	279.4	282.8	273.3	260.4	260.7
	39	1,000								277.5	276.9	271.5	270.5	256.5	258.4
	40	1,000		253.1	251.6	257.3	276.6	279.3	277.3	288.9	291.4	286.3	279.5	255.7	266.1
	41	1,000								285.1	274.2	289.1	264.9	235.5	263.2
	42	1,000		231.3	247.4	262.8	273.9	287.0	288.0	297.0	297.7	291.4	262.4	255.0	269.6
	43	1,000								326.2	311.1	325.0	299.5	310.0	312.8
	44	1,000		294.9	355.1	346.9	351.5	362.9	356.3	371.2	364.1	424.1	514.2	429.6	419.1
	45	1,000								454.2	527.4	531.0	524.0	547.2	547.7
	46	1,000		505.6	500.1	453.5	465.3	441.4	486.7	537.7	572.5	551.5	581.0	651.8	633.4
5 - Lagoon	47	1,000								647.9	696.4	848.6	934.2	982.2	953.1
	48	1,000		617.4	578.8	541.8	561.5	562.6	689.5	758.3	839.2	879.5	903.6	898.4	904.3
	49	1,000								980.1	978.1	959.2	921.1	959.7	932.6
	50	1,000								1012.4	1005.7	1025.4	1025.9	957.2	896.5
	51	1,000								929.1	838.9	799.5	779.4	733.9	734.8
	52	1,000								708.2	622.4	561.9	541.3	480.5	472.6
	53	1,000								761.9	711.5	636.9	529.2	472.9	455.8
	54	1,000								574.6	563.2	519.3	414.7	357.1	342.5
	55	0								588.4	621.0	602.3	579.0	560.6	537.3
6 - Stono Inlet	56	1,200		465.8	456.2	413.3	363.2	331.0	366.5	385.7	378.6	350.4	324.7	224.3	195.3
	57	1,200		222.1	221.9	241.5	240.8	231.6	209.8	218.6	220.9	223.5	205.4	175.3	129.3
	58	1,200		158.9	156.1	153.2	149.7	169.2	176.4	182.1	171.1	154.6	122.6	101.9	94.0
	59	1,200		167.6	166.9	164.9	168.1	180.7	178.6	173.7	161.1	145.3	140.6	137.7	140.6
	60	1,200		150.0	156.8	154.5	157.1	173.5	172.5	160.8	146.9	131.3	137.2	130.8	141.2
	61	1,200		108.9	111.3	123.7	137.5	146.2	144.4	146.2	159.6	163.2	182.3	165.1	183.5

TABLE 4.2. Volumes and Unit Volumes for each monitoring reach. Volumes are calculated to -10 ft NAVD. Note 2014–2015 volumes for Reach 1 were influenced by relocation of Captain Sams Inlet, which resulted in the western ~2,800 ft of the reach being lost to Sea brook Island.

			Reach Total Volume (cy)												
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17
1	Kiawah Spit	8,820	2,527,990		3,309,434	3,308,176	3,360,442	3,482,539	3,403,430	3,385,060	3,387,780	3,355,774	2,426,028	2,421,235	2,587,554
2	West Beach	11,798	2,925,119		3,018,972	2,973,269	3,002,842	3,016,726	3,023,391	3,143,512	3,200,438	3,247,900	3,246,474	3,109,992	3,123,811
3	Turtle Point	13,614	3,119,193		3,768,036	3,711,347	3,791,886	3,780,710	3,783,778	3,973,563	4,103,395	4,242,815	4,328,658	4,133,108	4,083,240
4	Ocean Course	9,000		2,881,490	3,008,223	2,946,188	3,047,332	3,071,534	3,182,156	3,301,984	3,403,054	3,535,481	3,599,780	3,562,542	3,577,236
5	Lagoon	8,000		6,559,380	6,499,468	6,763,197	7,090,470	7,385,476	7,175,787	7,156,897	7,056,459	7,089,847	6,819,651	6,633,934	6,364,032
6	Stono Inlet	6,000		1,464,695	1,460,076	1,447,219	1,406,546	1,422,719	1,427,296	1,448,756	1,408,636	1,328,992	1,248,369	1,052,076	966,215
1-6	**All**	**57,232**			**21,064,209**	**21,149,396**	**21,699,517**	**22,159,704**	**21,995,839**	**22,409,771**	**22,559,762**	**22,800,809**	**21,668,959**	**20,912,887**	**20,702,088**

			Reach Unit Volume (cy/ft)												
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17
1	Kiawah Spit	8,820	286.6		375.2	375.1	381.0	394.8	385.9	383.8	384.1	380.5	275.1	274.5	293.4
2	West Beach	11,798	247.9		255.9	252.0	254.5	255.7	256.3	266.4	271.3	275.3	275.2	263.6	264.8
3	Turtle Point	13,614	229.1		276.8	272.6	278.5	277.7	277.9	291.9	301.4	311.7	318.0	303.6	299.9
4	Ocean Course	9,000		320.2	334.2	327.4	338.6	341.3	353.6	366.9	378.1	392.8	400.0	395.8	397.5
5	Lagoon	8,000		819.9	812.4	845.4	886.3	923.2	897.0	894.6	882.1	886.2	852.5	829.2	795.5
6	Stono Inlet	6,000		244.1	243.3	241.2	234.4	237.1	237.9	241.5	234.8	221.5	208.1	175.3	161.0
1-6	**All**	**57,232**			**368.0**	**369.5**	**379.2**	**387.2**	**384.3**	**391.6**	**394.2**	**398.4**	**378.6**	**365.4**	**361.7**

			Reach Volume Change Since Previous (cy)												
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17
1	Kiawah Spit	8,820				-1,258	52,266	122,097	-79,109	-18,370	2,719	-32,006	-929,746	-4,793	166,319
2	West Beach	11,798				-45,703	29,573	13,884	6,665	120,120	56,926	47,462	-1,426	-136,481	13,818
3	Turtle Point	13,614				-56,689	80,539	-11,176	3,068	189,784	129,833	139,419	85,843	-195,550	-49,869
4	Ocean Course	9,000			126,733	-62,036	101,144	24,202	110,622	119,828	101,070	132,427	64,299	-37,239	14,695
5	Lagoon	8,000			-59,912	263,729	327,273	295,006	-209,689	-18,890	-100,438	33,388	-270,196	-185,717	-269,902
6	Stono Inlet	6,000			-4,620	-12,857	-40,673	16,174	4,577	21,459	-40,119	-79,644	-80,624	-196,292	-85,861
1-6	**All**	**57,232**				**85,187**	**550,121**	**460,187**	**-163,865**	**413,932**	**149,991**	**241,047**	**-1,131,850**	**-756,072**	**-210,800**

			Reach Unit Volume Change Since Previous (cy/ft)												
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17
1	Kiawah Spit	8,820				-0.1	5.9	13.8	-9.0	-2.1	0.3	-3.6	-105.4	-0.5	18.9
2	West Beach	11,798				-3.9	2.5	1.2	0.6	10.2	4.8	4.0	-0.1	-11.6	1.2
3	Turtle Point	13,614				-4.2	5.9	-0.8	0.2	13.9	9.5	10.2	6.3	-14.4	-3.7
4	Ocean Course	9,000			14.1	-6.9	11.2	2.7	12.3	13.3	11.2	14.7	7.1	-4.1	1.6
5	Lagoon	8,000			-7.5	33.0	40.9	36.9	-26.2	-2.4	-12.6	4.2	-33.8	-23.2	-33.7
6	Stono Inlet	6,000			-0.8	-2.1	-6.8	2.7	0.8	3.6	-6.7	-13.3	-13.4	-32.7	-14.3
1-6	**All**	**57,232**				**1.5**	**9.6**	**8.0**	**-2.9**	**7.2**	**2.6**	**4.2**	**-19.8**	**-13.2**	**-3.7**

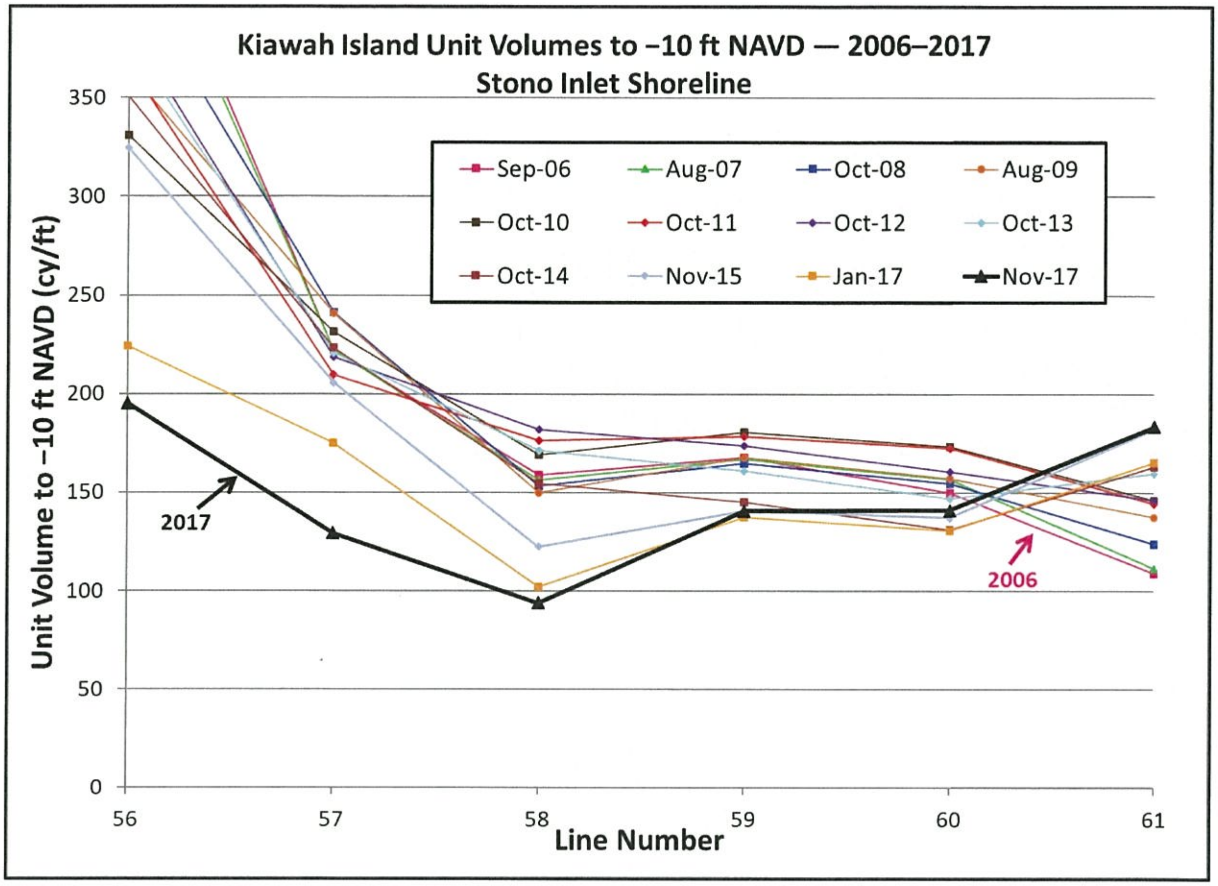


FIGURE 4.6. Unit volumes for stations along the Stono Inlet Reach. Line numbers run east (oceanward) to west.

Hurricane *Matthew* resulted in the washout of a significant dune area between Lines 56 and 58. This area was eroded further by Hurricane *Irma*, and multiple connections between the lagoon and ocean were present including one along the Stono Inlet Reach near Lines 56 and 57. Profiles for the reach show over 70 ft of beach recession from November 2015 to January 2017 (following Hurricane *Matthew*) and another loss of over 100 ft of beach for January to November 2017 (after Hurricane *Irma*). Ground photos (Fig 4.7) show the eroded beach condition and washover condition at Stations 56 and 57 (Fig 4.8). Further inland, the beach is still eroded; however, no marsh exists landward of the dunes, and the beach is migrating into upland area rather than overwashing. Since 2007, the reach has lost a total of 494,000 cy, which is an average annual erosion rate of 8.0 cy/ft/yr.

FIGURE 4.7.

November 2017 ground images of the Stono Inlet Reach.

Upper) Line 56

Middle) Line 58

Lower) Line 60

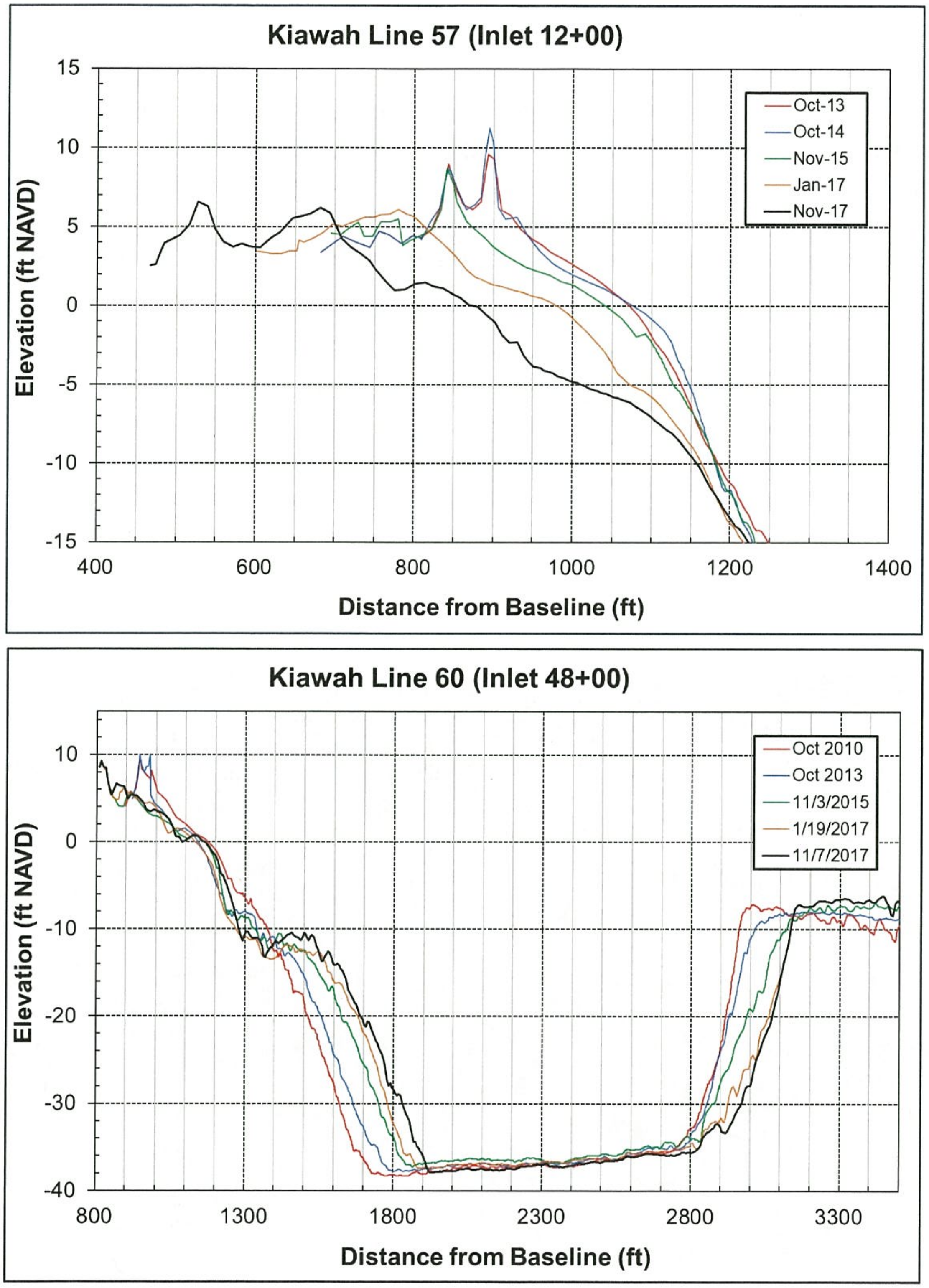


FIGURE 4.8. Profiles from Line 57 (upper) and Line 60 (lower) along the Stono Inlet shoreline. Hurricane *Matthew* eroded all of the remaining dunes in 2016. The berm shifted over 100 ft landward over the past year (due largely to impacts of Hurricane *Irma*). Of note is that the eastern slope of the channel has moved ~200 ft away from Kiawah Island over the past seven years.

4.2.2 Lagoon Reach

The Lagoon Reach spans 8,000 ft from the 2006 closure dike (Line 47 along the 2015 closure dike) to Line 55 at the eastern point of the island (Fig 4.9). Monitoring reports for the 2007–2011 surveys subdivided this reach into the eastern and western lagoons. The 2012 report combined these reaches and adjusted the baseline to simplify data collection and reporting, and the present report continues this method. This reach encompasses the area of the island most influenced by shoal-bypass events (see Section 1 and Fig 4.10).

Due to the rapid shoreline fluctuations and varying shoreline directions in this reach, CSE has elected to compute beach volumes using digital terrain models (DTMs) created from survey data. These volumes represent the volume of sand within the established boundaries and to a set depth. The analogy of a sandbox is often used, where the volume of sand is measured within the same sandbox each year. DTMs are also used to create contours at specified elevations for each survey, which can then be compared to provide a visual representation of the linear shoreline change.

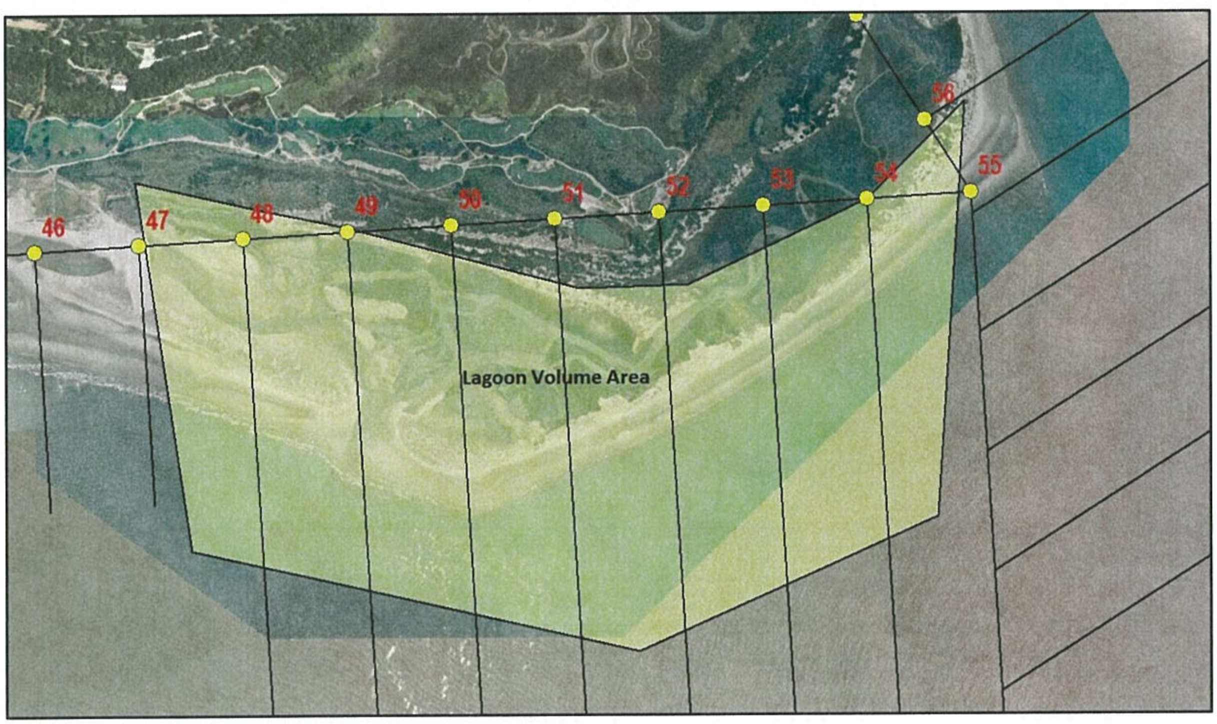


FIGURE 4.9. The Lagoon Reach extends from Line 47 to Line 55. Due to the dynamic nature of the area, the total volume for this reach is calculated from DTMs within the boundaries shown here.

Figure 4.10. June 2017 aerial images of the Lagoon Reach. The 2015 constructed channel is visible in the foreground of the upper image, while the channel created during Hurricane *Matthew* is visible in the lower image.

A shoal-bypass event occurred in the Lagoon Reach between 2007 and 2009, attaching in late 2009 at the southern apex of the lagoon. During the attachment process, the beach in the lee of the shoal accreted, gaining sand from nearby adjacent areas and creating a large protrusion in the shoreline. Once attached, sand spread rapidly from the attachment site, contributing to gains along the western lagoon and Stono Inlet shoreline between 2009 and 2012. Beginning in 2012, another shoal-bypass event became visible in a similar location as the previous event.

In 2012, the incoming shoal was positioned ~1,700 ft from the beach and was still far enough offshore to have only limited impacts to the beach. Between 2012 and 2014, the shoal migrated ~1,200 ft landward (Fig 4.11). More information and photos of the evolution of these shoal events were provided in previous monitoring reports to the Town (ie – CSE 2015). Between October and November 2015, the shoal continued to migrate landward, attaching to the beach at the −7 ft contour (low-tide wading depth). Interestingly, the shoal decreased in elevation, which may indicate that the sand is presently moving in a more alongshore direction rather than directly toward the beach. As of January 2017, the shoal had completely merged with the beach.

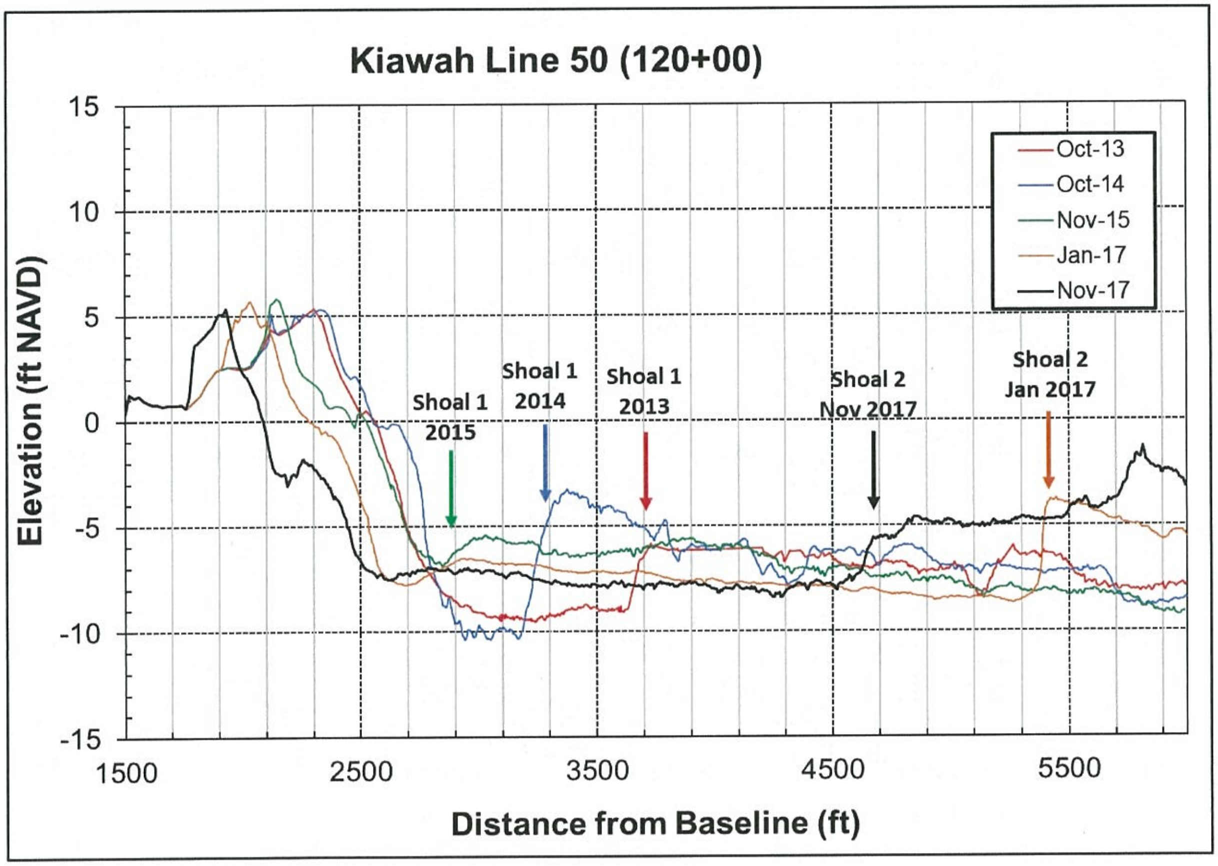


FIGURE 4.11. Profiles from Line 50 showing recent and ongoing shoal attachment events. Landward migration of the two shoals is visualized by the colored arrows on the plot.

Another shoal emerged in the observable data in January 2017, positioned ~2,800 ft from the shoreline. Between January and November 2017, the leading edge of the shoal migrated ~800 ft landward. The leading edge of the shoal decreased in elevation; however, in November 2017, the seaward portion of the shoal near the limit of CSE data increased to a point where it is likely subaerial at low tide. This shoal appears larger than the previous shoal event, and CSE expects it to continue to approach the beach and eventually merge with the shoreline. This process will take a few years and will ultimately add sand to the lagoon area.

In typical shoal attachment events, the beach builds out in the lee (directly behind the incoming shoal) of the shoal and erodes on either side of the attachment point until it fully merges. Since this entire area is in an overwash state, CSE expects fairly significant landward retreat in the areas adjacent to the shoal attachment site.

The erosional trend observed in the Lagoon Reach in recent years continued in 2017 due to a lack of new sand attaching via shoal events coupled with overwash of the outer berm. As of November 2017, the entire outer berm of the Lagoon Reach showed maximum elevations less than 6 ft NAVD (Figs 4.12–4.13). This elevation is too low to prevent overtopping during modest spring tides or small storm events. Overwash results in more rapid landward migration of the beach compared to typical alongshore sand losses.

The most significant change in the lagoon area is the continued development of the channel created by Hurricane *Matthew* and the gradual infilling of the 2015 constructed channel. CSE observed the 2015 channel completely closed to flow in March 2018; however, it may reopen during any higher-than-normal tide event. Figure 4.14 shows an aerial image from October 2017 (post-*Irma*) in which the 2015 channel is visible. These channels should be monitored throughout the upcoming year to document migration and potential changes to the tidal prism through either channel.

Overall, the Lagoon Reach lost 270,000 cy (33.7 cy/ft) of sand over the past year. This continues an erosion trend observed over the past three years, each of which saw losses greater than 23 cy/ft. CSE expects continued erosion of the lagoon area over the next year as no shoals are presently attaching to the beach. Presently, the reach holds ~135,000 cy **<u>less</u>** sand than the 2007 condition. It is important to note that the entire lagoon system is an ephemeral feature, created from two large shoal-bypass events beginning in the 1990s. The sand from those events continues to attempt to merge with the earlier shoreline through washovers and spreading to downcoast areas. Additional sand continues to periodically attach to the eastern end, which may temporarily halt the landward retreat of the outer berm and extend the life of the lagoon further into the future.

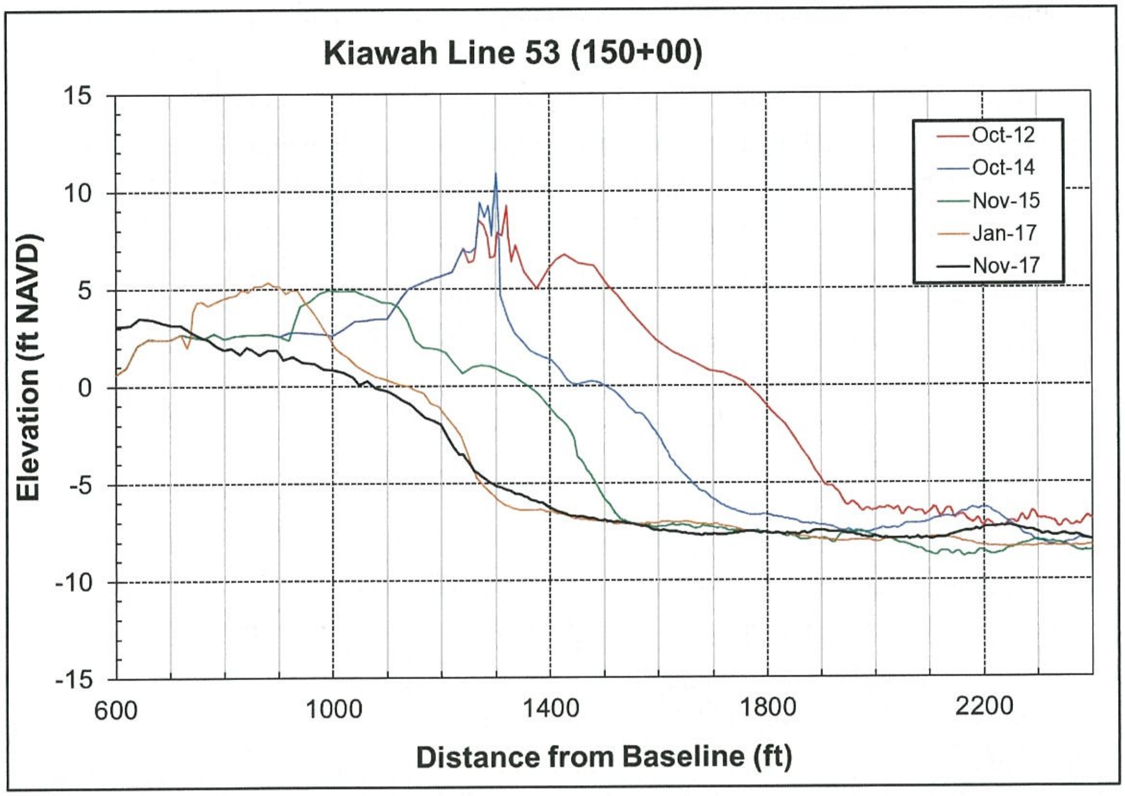


FIGURE 4.12. Profiles from Line 53 showing rapid shoreline recession and loss of dunes over the past five years. Peak elevations of 4–5 ft are insufficient to prevent overwash during storms and spring tides.

FIGURE 4.13. November 2017 ground photo of Line 49 showing the low berm and evidence of recent washover.

FIGURE 4.14. October 2017 aerial of the Lagoon Reach showing the mostly infilled 2015 channel.

4.2.3 Reach 4 – Ocean Course

Ocean Course Reach is the transition zone between the developed shoreline with a typical strand beach and the dynamic lagoon area (Fig 4.15). It spans ~9,000 ft between Line 38 (Kiawah Beach Club) and Line 47 (closure dike). West of the Ocean Course Clubhouse, the beach profile is much more consistent from year to year, allowing for more applicable volume measures using individual profiles and the average-end-area method. This reach was the recipient of the majority of nourishment fill in the 2006 and 2015 projects; however, in the 2015 project, sand was shifted from the intertidal beach within the reach to higher in the profile, so the net volume gain was limited to only the sand quantity hauled from the new inlet area.

Ocean Course Reach gained sand every year between 2008 and 2015, totaling 653,000 cy (72.6 cy/ft). The reach lost 37,200 cy (4.1 cy/ft) of sand from November 2015 to January 2017; however, over the past year, the reach gained 14,700 cy (1.6 cy/ft). Unit volumes for each profile in the reach are shown in Figure 4.16. Counter to the previous year, the western end of the reach was accretional with Lines 38 through 43 gaining an average of 9.6 cy/ft (Fig 4.17, upper). Lines 44 and 46 lost 10.5 and 18.4 cy/ft, while line 45 at the clubhouse beach access shown no volume change (Fig 4.17, lower). October 2017 aerial images are provided in Figure 4.18.

FIGURE 4.15. September 2017 aerial image of the Ocean Course Reach following Hurricane *Irma*. The storm eroded dunes along the course and, in one location, reached the cart path.

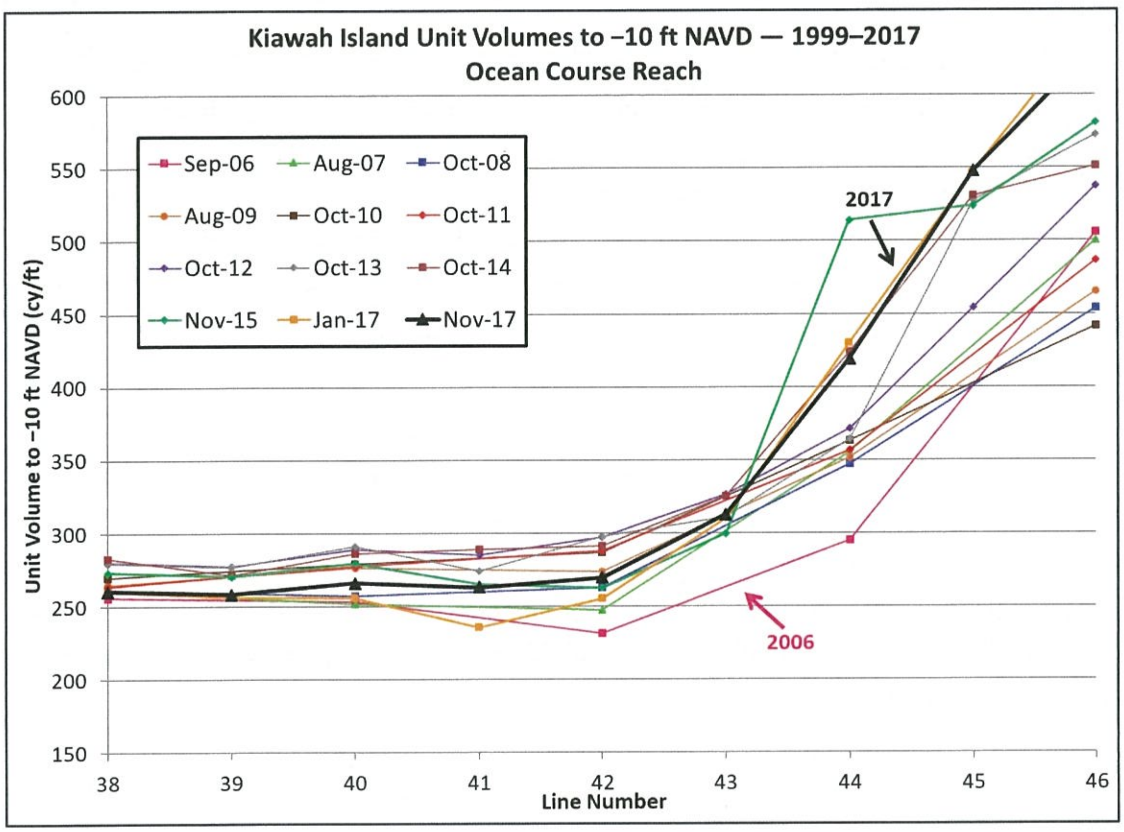
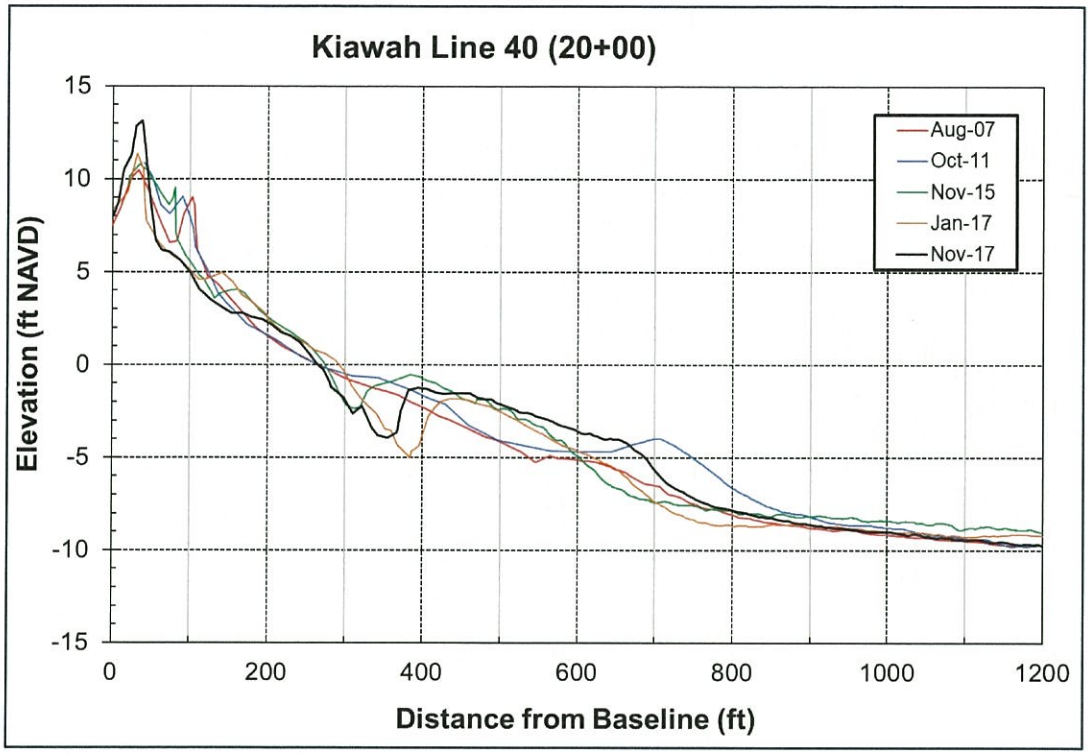


FIGURE 4.16. Unit volumes for the profiles of the Ocean Course Reach.



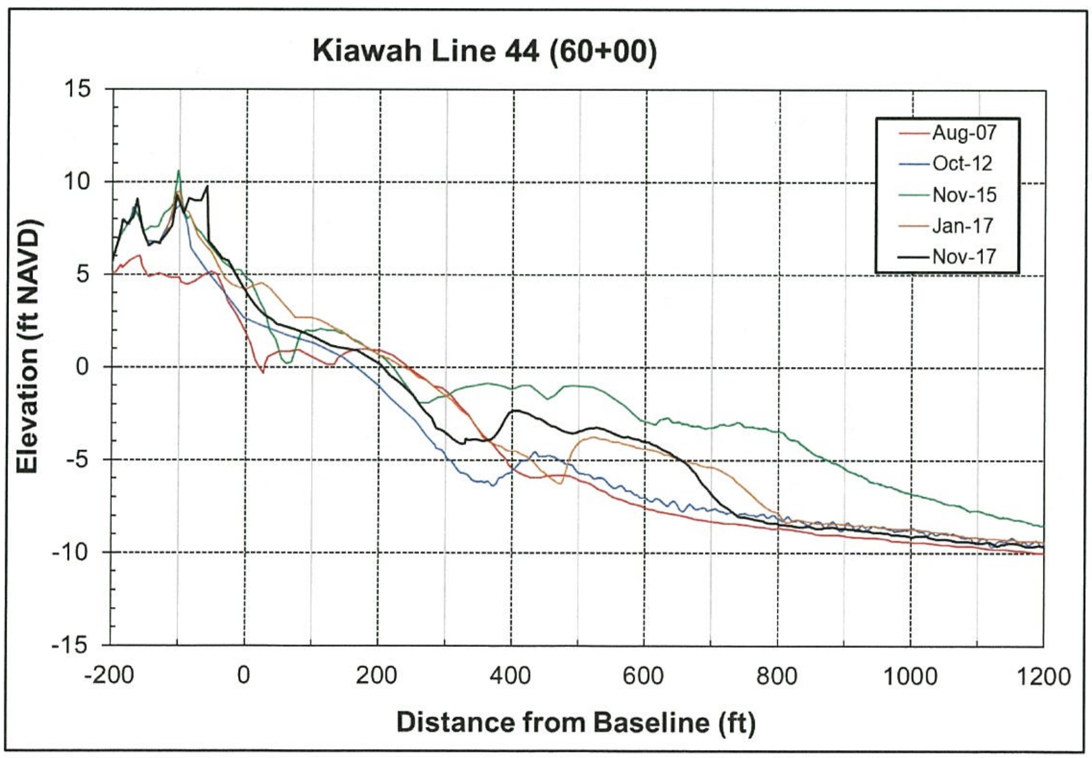


FIGURE 4.17. Profiles from Lines 40 (upper) and 44 (lower). At both lines, the November 2017 dune is healthier than the January 2017 condition, despite no dune restoration occurring at Line 44.

FIGURE 4.18. October 2017 aerial images of the Ocean Course Reach.

The November 2017 monitoring survey was conducted after the post-Hurricane *Irma* beach scraping effort was completed along the Ocean Course Reach. *Irma* resulted in significant dune loss along the majority of the reach west of Hole 18. This area was scraped to construct a 6-ft-high, 20-ft-wide dune. The dune restoration is reflected in the beach profiles, which generally show that the post-scraping dune was overall healthier than the January 2017 (post-Hurricane *Matthew*) condition (Fig 4.19). The reach has gained 569,000 cy of sand since 2007, all via natural accretion. This translates into an average gain of 6.2 cy/ft/yr. CSE expects continued accretion in the Ocean Course Reach as the Lagoon Reach continues to lose sand; however, localized variability is likely due to washover of the ponded area seaward of the driving range, and movement of intertidal bars impacts beach volume.

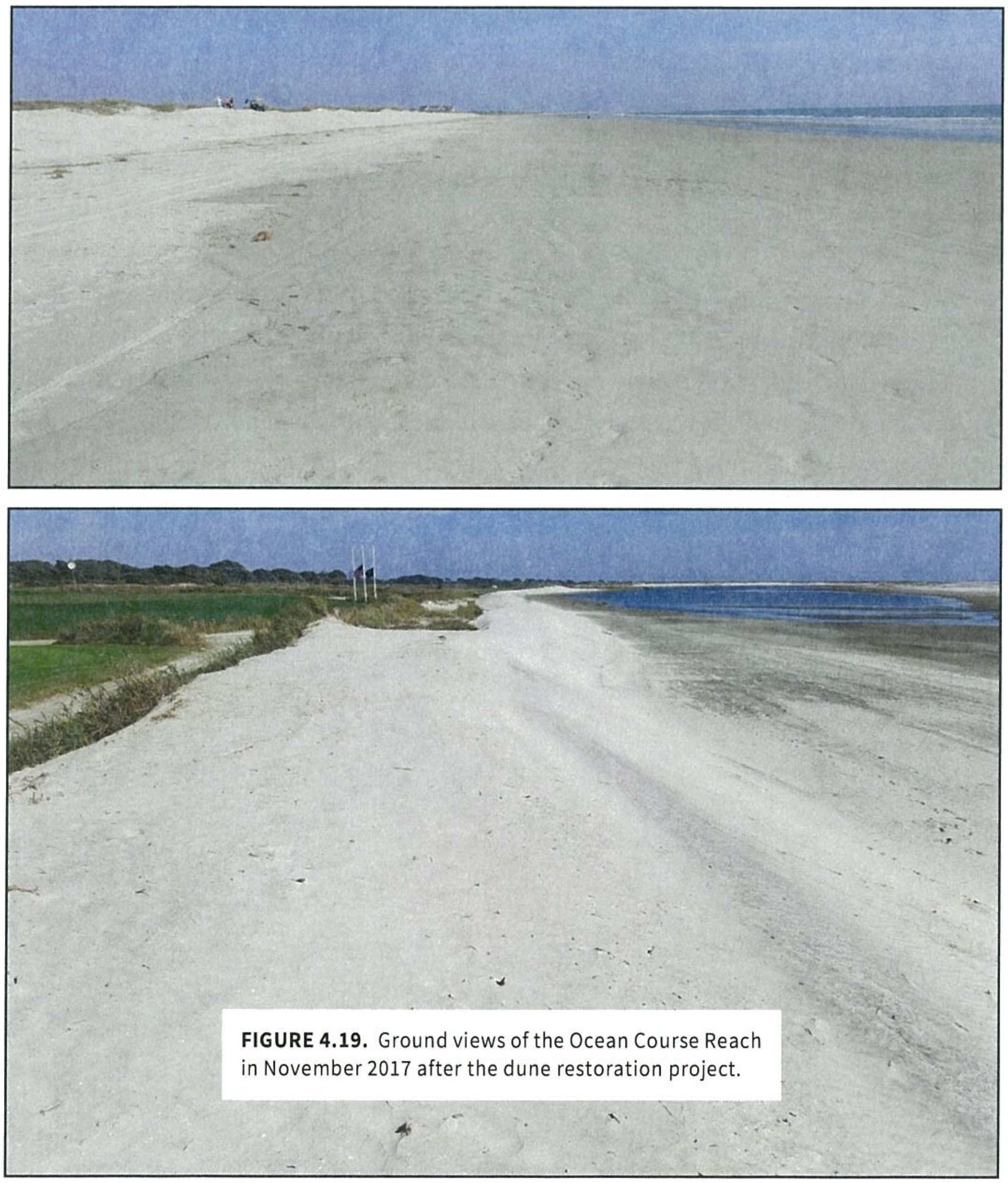


FIGURE 4.19. Ground views of the Ocean Course Reach in November 2017 after the dune restoration project.

4.3 Downcoast Reaches

The November 2017 monitoring data for reaches downcoast (west) of the East End project area were compared to 1999 and 2006–2017 data. Profiles in these areas use OCRM monuments and newly (2012) created profiles so that profile spacing does not exceed 1,267 ft. CSE added these new lines to better monitor local beach changes along the "populated" beach. CSE has collected data at certain downcoast stations since the early 1980s. Historically, West Beach Reach has been stable, while the Turtle Point Reach and Kiawah Spit Reach have been accretional. Profiles are given in Appendix A.

At several of the downcoast stations, the 1999 profile lines terminate before reaching −10 ft NAVD. At these stations, volumes were computed to −6 ft NAVD and then adjusted by a factor of 1.95 to produce a representative volume to −10 ft. This scale factor was computed from volume analysis of the 1999 profiles which did extend to −10 ft NAVD.

Figure 4.20 shows unit volumes for each station in the downcoast reaches. While the typical trend along this area is accretion, yearly changes can vary in magnitude of volume change, and periods of erosion in some areas are common. Last year (November 2015 to January 2017), losses in the downcoast reaches averaged 9.8 cy/ft and were as high as 30.4 cy/ft. This resulted in a total loss of 337,000 cy of sand. Hurricane *Irma* resulted in up to 20 ft of additional dune erosion in addition to what was lost with Hurricane *Matthew*. Despite the erosion of the dune during the storm, the reaches gained 130,000 cy (3.8 cy/ft) of sand from January to November 2017, most of which was due to the elongation of Kiawah Spit. Post storm emergency scraping was performed along the Turtle Point Golf Course prior to the November survey, and additional scraping occurred along Eugenia Ave after the survey.

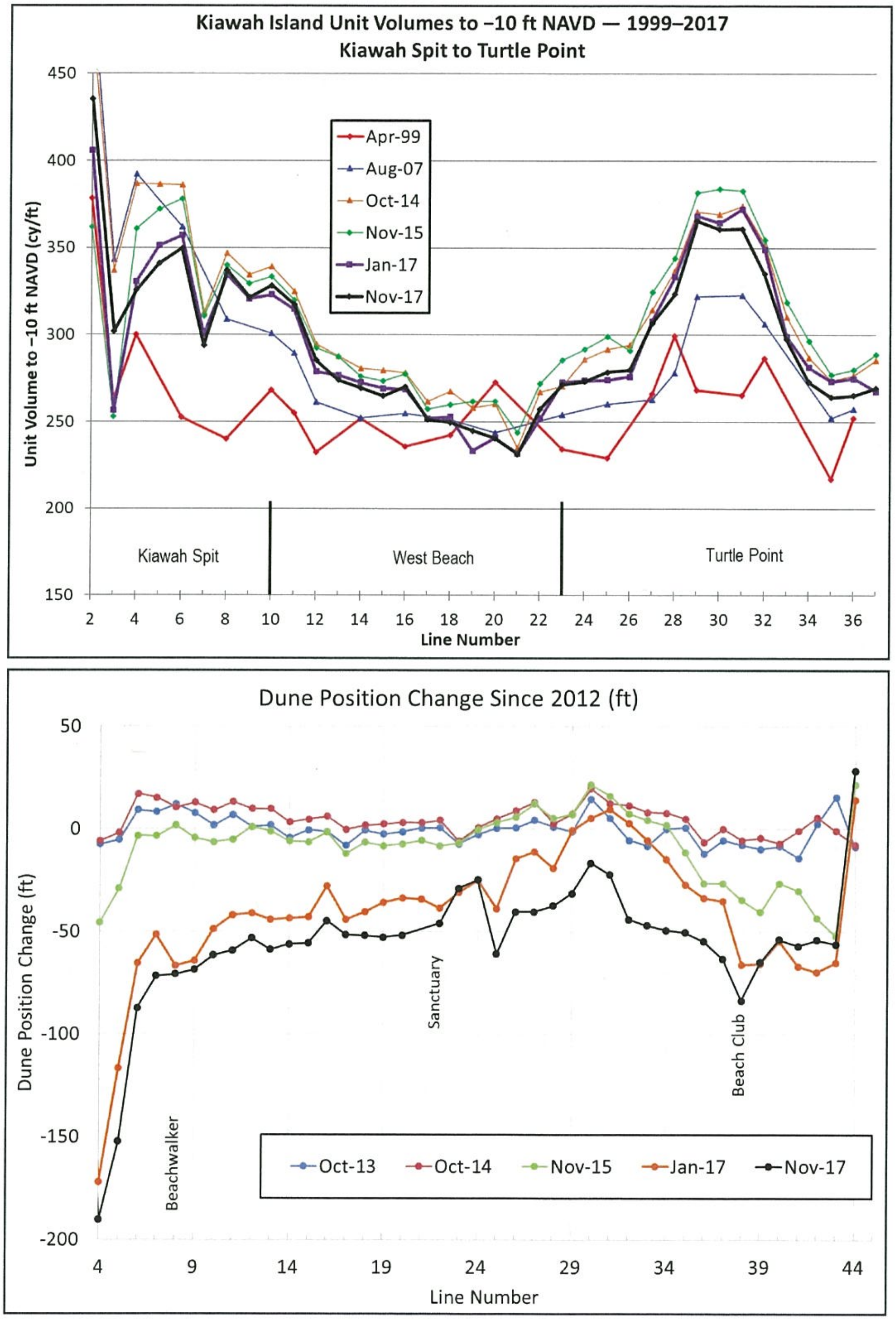


FIGURE 4.20. Unit volumes in the downcoast reaches between 1999 and 2017 (upper) and dune-line linear change (measured at the +7-ft NAVD contour) (lower). Lines 1 and 2 are on the Seabrook side of Captain Sams Inlet following the 2015 relocation project.

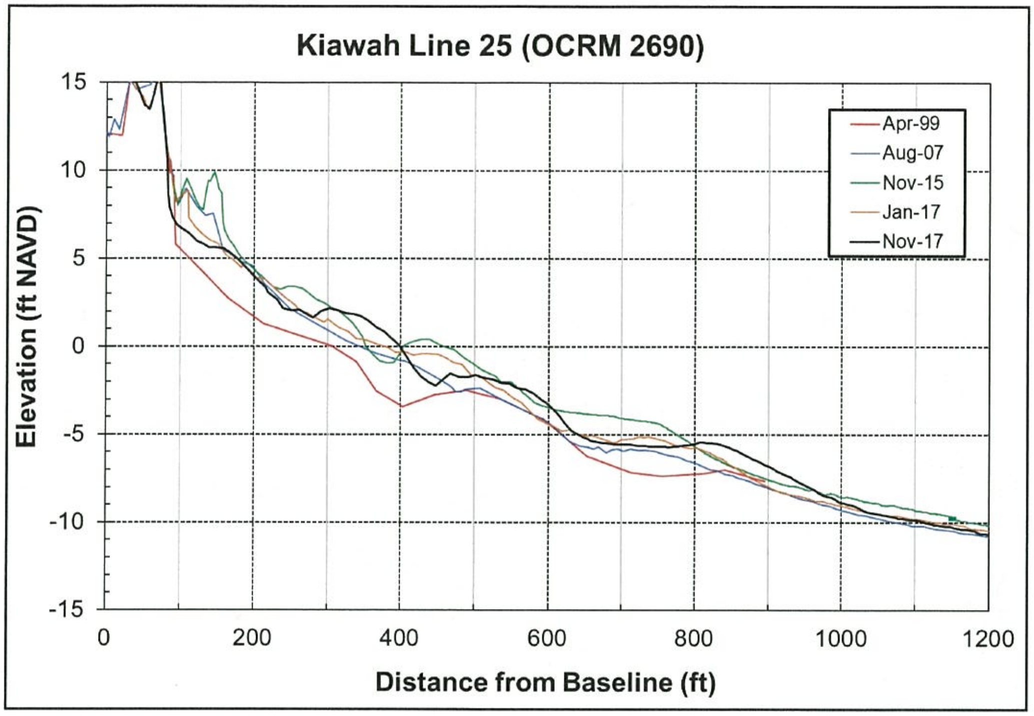
4.3.1 *Turtle Point Reach*

Turtle Point Reach extends 13,614 ft from Line 23 (16th Hole of Turtle Point Golf Course) to Line 38 (Kiawah Beach Club). The reach was fairly stable from 2007 to 2011, showing yearly unit volume changes ranging from −4.2 cy/ft to +4.0 cy/ft. The reach was much more accretional from 2011 to 2015, gaining an average of 10.0 cy/ft. From 2010 to 2015, the reach gained 528,000 cy; it had gained a total of 591,000 (41.2 cy/ft) since 2007. The reach lost 195,500 cy from November 2015 to January 2017 due to Hurricane *Matthew*. The reach showed much less erosion over the past year, despite Hurricane *Irma*, showing a net loss of ~50,000 cy (3.7 cy/ft). The reach has averaged 2.3 cy/ft/yr accretion since 2007.

Unit volume change within the reach ranged from −14.0 cy/ft to +4.6 cy/ft. Erosion was generally higher along the eastern portion of the reach, which is counter to the historical trend. Profiles show dune loss from Hurricane *Irma* coupled with accretion in the lower beach profile. A more pronounced bar developed in the November 2017 profiles, again due to the storm. The bar is positioned further offshore and reflects a shifting of sand from the upper beach to the underwater zone. For example, at Line 27, the beach lost 5.6 cy/ft above the −6 ft contour, while the profile below the −6 ft contour gained 4.3 cy/ft.

In some locations, the dune eroded nearly 50 ft during Hurricane *Irma* (ie – Line 32 in Fig 4.21). Ground photos (Fig 4.22) show an escarpment present along most of the reach following Hurricane *Irma* with some recovery by November 2017. In areas where the dune breached, ponding may be present in areas during extreme tides. As the beach recovers and a new dune line forms, the frequency of any ponding is expected to decrease. A dune was reconstructed along the Turtle Point Golf Course prior to the November survey, because this area was within the state's definition of an emergency condition following *Irma*.

The significant setbacks of properties and the historical accretion trend of the Turtle Point Reach suggests that the reach will recover without any additional action from the Town. Repeated storms over the past three years have eroded the primary dune along most of the reach; however, overall sand losses were relatively low, especially with *Irma*. Every profile still shows a higher sand volume than the 1999 condition. The only area of present concern is the beach in front of Turtle Point Golf Course. Post-*Irma* scraping restored the dune to the pre-storm condition (Fig 4.23); however, there remains a narrow setback between the ocean and the golf course.



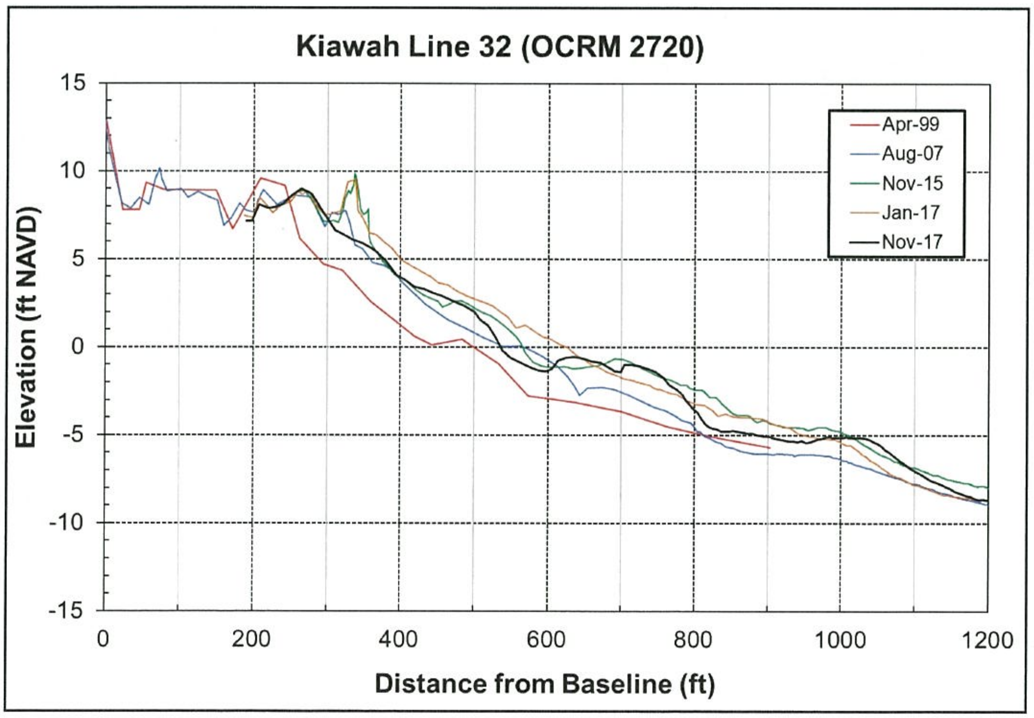


FIGURE 4.21. Profiles from the Turtle Point Reach. Over the past year, most of the profiles lost sand along the upper beach, but gained sand in the lower profile. This is typical of winter or storm profiles. Despite volume losses due to hurricanes in the past few years, the present beach remains much further seaward than the 1999 condition.

FIGURE 4.22. Ground photos from Line 28 post-*Irma* September 2017 (upper) and November 2017 (lower).

FIGURE 4.23. Post-scraping photo of the area seaward of the Turtle Point Golf Course in November 2017.

4.3.2 West Beach Reach

West Beach Reach encompasses the beach between Lines 10 and 23 (Sand Alley to the 16th Tee of Turtle Point Golf Course). Historically, this reach has been fairly stable compared to remaining reaches. Although the reach has experienced periods of erosion, properties within the reach are sufficiently set back to allow for a substantial vegetated buffer between the ocean and the structures. The reach lost 3.8 cy/ft of sand from 2007 to 2008, but accreted during every monitoring interval between 2008 and 2014. From 2014 to 2015, the reach as a whole was stable, although within the reach, the western half eroded and the eastern half accreted. The reach was highly erosional from 2015 to January 2017 (Hurricane *Matthew*), losing over 136,000 cy.

During the past year, the reach gained sand, adding 13,800 cy (1.2 cy/ft). Volume change varied along the reach with stations showing changes from −4.1 cy/ft to +11.8 cy/ft. While no significant volume loss was observed, there was significant loss of sand along the dune following Hurricane *Irma*. As previously mentioned, sand from the dune shifted lower in the beach profile during the storm. It will migrate back to the upper beach with calmer weather conditions. The reach now contains 104,800 cy (8.9.0 cy/ft) more sand than the 2007 condition, which is an average annual accretion rate of 0.9 cy/ft/yr. Since 1999, the reach has gained 198,700 cy (1.2 cy/ft/yr).

Profiles from the reach (Fig 4.24) show a consistent pattern of erosion of the primary dune, leaving a significant escarpment. As shown in Figure 4.20, the dune receded ~20 ft along the reach. With the combined effects of Hurricane *Joaquin*, Hurricane *Matthew*, and Hurricane *Irma*, and the pre-existing narrower setbacks of structures in the reach, several of the properties were left vulnerable to damage. The Town obtained a permit for beach scraping to rebuild the dunes along Eugenia Avenue and seaward of the Sanctuary. This effort restored the storm protection offered by the primary dune and also improved recreational access along the shoreline. CSE generally recommends sand scraping only after significant storm events, because these efforts do not add sand to the system; rather, they simply restore sand that was lost from the upper profile and accelerate natural recovery.

Photos in Figure 4.25 show the post-storm (September), November 2017, and post-restoration condition along the West Beach Reach. The oceanfront homes along Eugenia Avenue have the narrowest setback of any area on Kiawah. CSE believes that the scraping project completed in the winter of 2017–2018 restored a sufficient dune for moderate storm events such as Hurricane *Irma*. CSE expects additional recovery to occur this spring and summer due to the relatively low erosion rate observed over this past year.

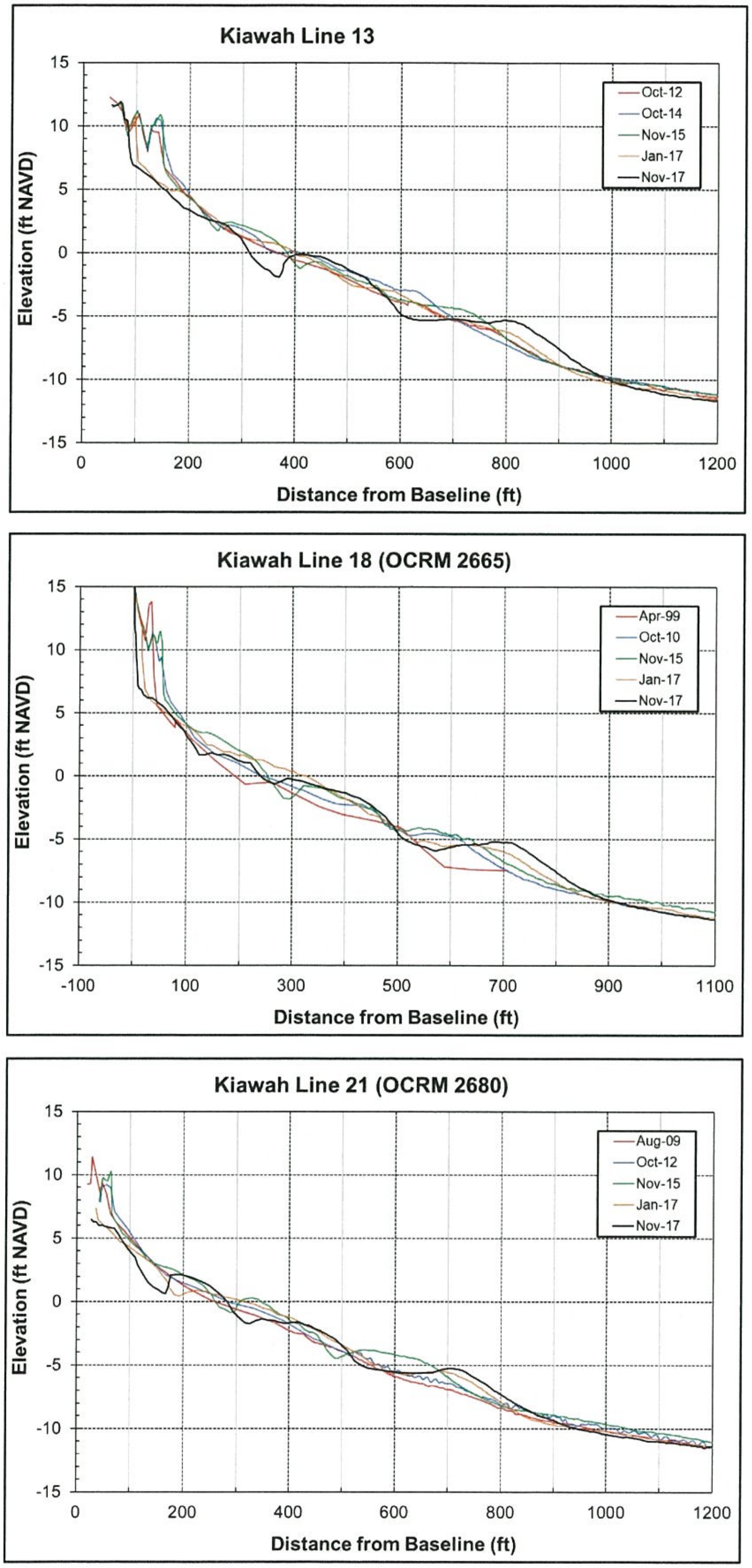


FIGURE 4.24.

Representative profiles from West Beach Reach. The eastern end of the reach (Lines 18–21) have been the least accretional areas of Kiawah over the past two decades. Line 20 is the only line showing less volume than the 1999 condition.

FIGURE 4.25. **[UPPER]** Post-Hurricane *Irma* photo from the Sanctuary. **[MIDDLE]** November 2017 image (left) and December 2017 (right) from near Line 18 at the eastern end of Eugenia Avenue. **[LOWER]** November 2017 photo from Line 12 near the Sandcastle.

4.3.3 Kiawah Spit Reach

Kiawah Spit Reach encompasses the downdrift end of the island (Fig 4.26). It acts as a collection site for sand transported by longshore currents from upcoast areas. As wave action transports sand to the west, it feeds the spit, causing growth into Captain Sams Inlet and forcing the inlet to migrate toward Seabrook Island.

FIGURE 4.26. June 2017 aerial images of the Kiawah Spit Reach.

Previous shoreline monitoring reports by CSE referenced three OCRM monuments in this reach. CSE has added six additional lines to better account for beach changes along the spit with the most westward line located near the 2012 position of Captain Sams Inlet. To compare equivalent shoreline segments, CSE extrapolated volume to the western end of the spit for the lines without 1999–2011 data. This was accomplished by applying the percent of volume change at the most westward line with data (Line 4) to the lines without data, beginning at the 2011–2012 change and working back in time.

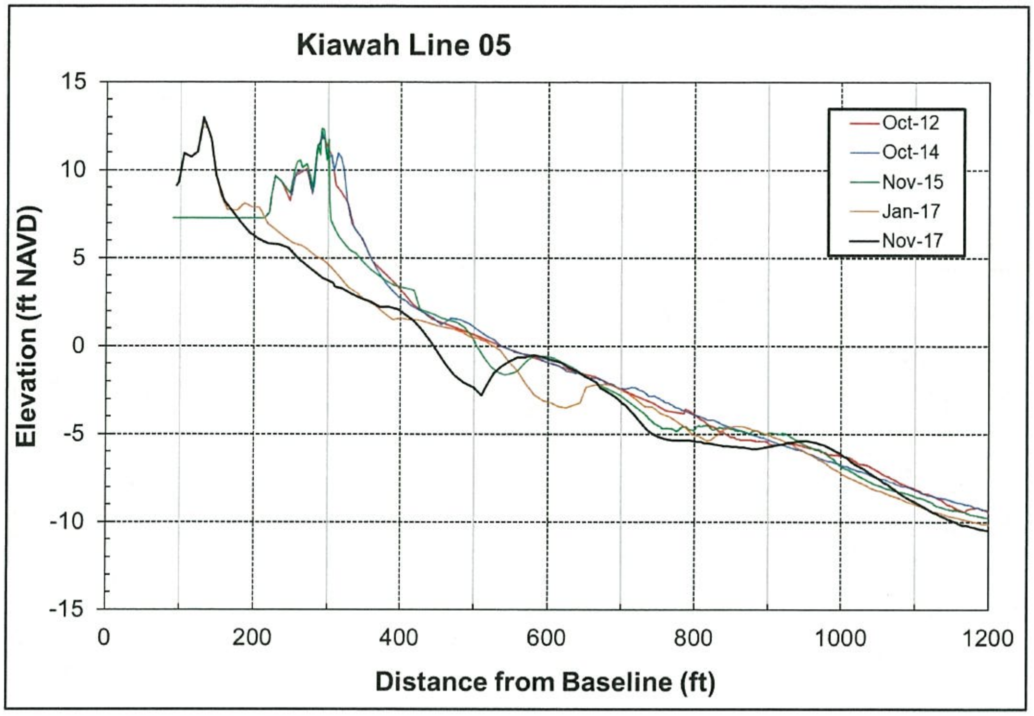
For example, the 2011–2012 volume change at Line 4 was −3.9 cy, which is ~1 percent of the 2011 volume. This percentage was applied to the 2012 volume at Lines 1–3 to obtain 2011 volumes for each of those lines. The 2010–2011 volume change at Line 4 was then applied to these new 2011 volumes for Lines 1–3 to provide new 2010 volumes, and so on. While the method is obviously limited in accuracy, it does provide a rough volume estimate of the lines west of Line 4 for comparison with more recent results.

As mentioned in Section 4.1.2—in June 2015, Captain Sams Inlet was relocated ~3,000 ft to the east by heavy equipment. This placed the eastern margin of the inlet ~450 ft west of Line 3. Any sand volume previously associated with Kiawah Island between Line 1 and this point is now considered to be part of Seabrook Island. This resulted in a dramatic loss in sand volume in the reach between the 2014 and 2015 surveys.

Between October 2014 and November 2015, the reach lost a total of 929,700 cy (105.4 cy/ft) of sand, mostly due to the inlet relocation (Fig 4.27). While the historical trend along the spit is accretion, an erosional pattern was observed between 2010 and 2014 with the reach losing 79,100 cy during that time. Over the past year, the reach gained sand, although most of the gain was a result of elongation of the spit rather than buildup of the beach profile. The section of beach between Lines 3 and 10 showed relatively little net volume change, gaining 4,000 cy.

The center of the reach showed higher volume loss than the eastern and western ends. Most profiles showed similar dune recession as the other reaches (~20 ft) due to Hurricane *Irma*. Since 2012, the reach has lost ~100 ft of dunes, mostly due to the recent storms. CSE believes the historical trend of accretion will eventually restore most of the lost dune area along the spit; however, it is likely to take several years for this to occur.

The end of Kiawah spit is growing to the west as Captain Sams Inlet continues the natural migration toward Seabrook Island (see Fig 4.5). Immediately after the relocation project, the inlet channel was steeply sloped on the Kiawah side and little sand flats were present. Since then, the intertidal flats along the inlet margin and extending seaward on the Kiawah side of the channel have grown significantly (Fig 4.28). The Seabrook Island Property Owners Association is monitoring the migration of the inlet in detail.



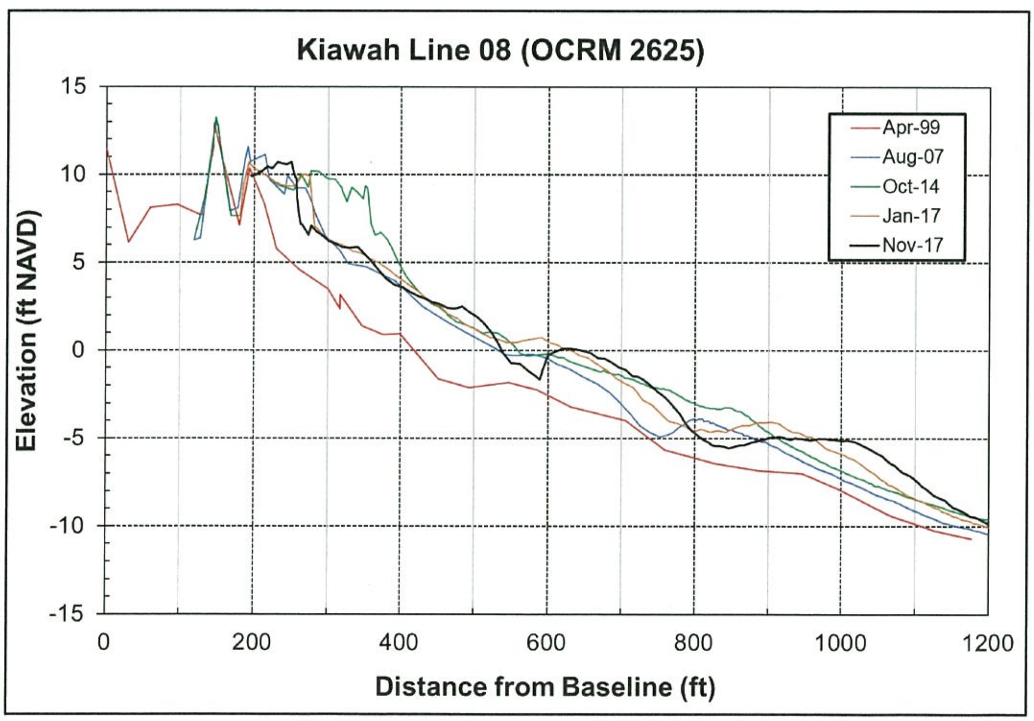


FIGURE 4.27. Profiles from Kiawah Spit Reach.

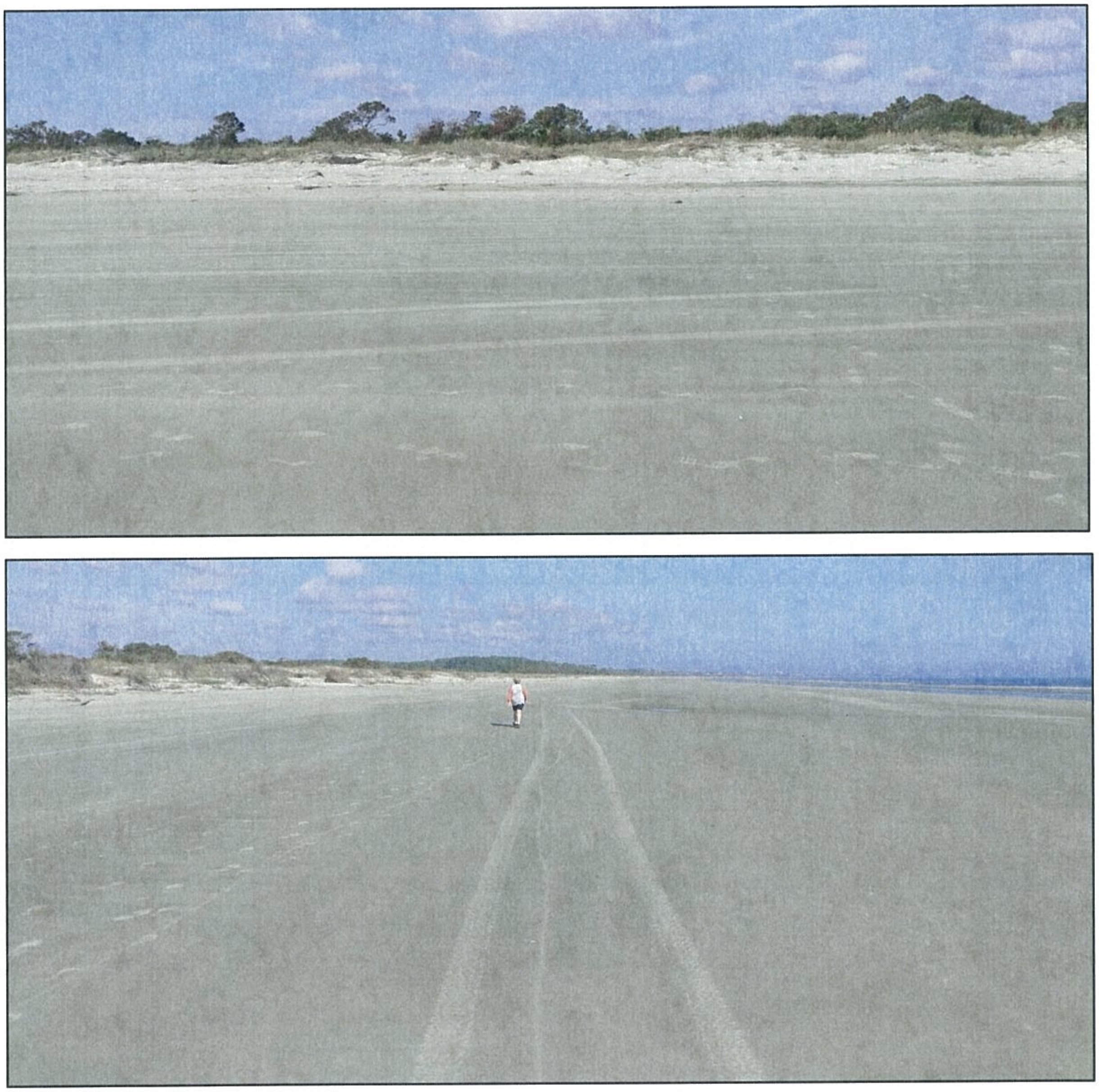


FIGURE 4.28. Ground photos of the Kiawah Spit Reach (November 2017), approximately two months after Hurricane *Irma*.

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5.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The 2017 monitoring survey, conducted in November 2017, is the 11th annual monitoring event since completion of the 2006 beach restoration project and the third following the 2015 channel realignment project. It is also the third survey since Captain Sams Inlet was relocated by the Seabrook Island Property Owners in June 2015. The survey was completed in November 2017, approximately two months after passage of Hurricane *Irma*.

Hurricane *Irma* impacted the area in early September 2017. Like Hurricane *Matthew* in 2016, the storm resulted in significant dune recession along the entire island and damage to walkovers. It also washed over almost all of the lagoon at the eastern end of the island. The recent string of storms have occurred at a frequency that has not allowed the dune to recover before the next storm hit. This has resulted in the dune line shifting further landward during each storm event. While storm impacts occur over the period of a few days, it can take several months or even years of sustained normal weather and accretion to allow sufficient wind-blown sand to accumulate, vegetation to regrow, and dune heights to increase before the beach returns to its pre-storm condition.

Overall, the island lost a total of 210,800 cy (3.7 cy/ft) of sand between January and November 2017. This compares to a loss of over 750,000 cy of sand the previous year, when the beach was impacted by Hurricane *Matthew*. The eastern end of the island eroded because the lagoon area is presently in an erosional phase. The Turtle Point Reach also lost a modest amount of sand over the past year. The West Beach and Ocean Course reaches were mostly stable, each gaining about 1.5 cy/ft.

The lagoon at the eastern end continues to evolve in response to changes in the shoals of Stono Inlet. Presently, the lagoon is in an erosional phase, where no new sand is attaching to the beach. This, coupled with the storm events, has left much of the lagoon area east of the 2015 dike in a state of washover. The outer berm is overtopped by extreme tides and minor storm events, which results in a rapid landward migration of the berm. The eastern end of the lagoon continues to be highly erosional, and the new inlet opened following Hurricane *Matthew* now appears to contain the majority of tidal exchange. This *Matthew* inlet is now the only inlet with flow at low tide, and the 2015 constructed inlet is often completely closed to flushing, even during neap high tides.

CSE expects the lagoon to continue to erode over the next few years, especially at the eastern end. A new shoal has emerged offshore and is migrating toward the beach. This will be a new source of sand to the lagoon area, but may also cause additional erosion as it approaches. The Town should monitor the 2015 channel location and closure dike, and if a new channel develops or the dike begins to erode, another relocation project may be required.

The closure dike was nearly breached by Hurricane *Irma*; however, the small dune on the lagoon side withstood the storm. The ponded area between the dike and the clubhouse is slowly infilling with sand,

and the flushing channel to the ponded area continues to decrease in size, meaning there is very little exchange of water and few currents in the channel except for high-surf and spring-tide conditions.

Post-storm beach scraping was completed in the areas of Eugenia Avenue, the Sanctuary, Turtle Point, the Beach Club, and the Ocean Course. This effort restored the dune that was lost during *Irma* and offered immediate protection for these properties. Work was completed under emergency authorization from OCRM and the USACE, as well as a permit modification to the East End project permit. CSE generally recommends that sand scraping only be considered immediately after storm events, such as was accomplished by the Town. Under normal circumstances, CSE generally recommends any sand for dune restoration be brought in from an outside source since this adds sand to the beach profile rather than redistribution of existing sand.

CSE is aware that some owners along Eugenia Avenue are considering additional dune restoration via minor nourishment using upland sand. If such a project is conducted, CSE recommends that the owners coordinate so that all sand is added during one effort, and that efforts be made to make a continuous dune line rather than sporadic mounds at individual properties. This will create a dune with more integrity during storm events and will produce a more aesthetic vista.

Since a dune presently exists along all of Kiawah, CSE recommends allowing the beach and dune to recovery naturally rather than installing sand fencing. Placing sand fencing in these areas may promote dune growth in a location where it does not want to form naturally, or it may restrict sand from building the more landward dune features. One larger, wide dune offers more protection than a small series of low foredunes. If sand fencing is installed, it should be set as close to the primary dune as possible. This will reduce the chance that the fencing could be eroded in the future and increases the recreational area of the beach.

CSE recommends the Town conduct regular visual assessments of the dune recovery throughout the next year. It may be worthwhile for the Town to sponsor a reduced-scope survey of the dune field in the near future to provide an updated condition assessment. A few stations (boardwalks or easily repeatable locations) should be photographed to document beach and dune changes, looking alongshore and toward the dune. This will provide a visual record of whether the dune is recovering and will assist in determining if additional efforts are required (ie – sand fencing or minor nourishment). Alongshore photos should be taken near the vegetation line or at a fixed point near the dune.

The lack of structural damage resulting from Hurricanes *Matthew* and *Irma* is a testament to the proper planning and accretional nature of Kiawah Island. While many communities along South Carolina's coast experienced significant property damage, sand overwash onto public roads, and required emergency sand scraping, Kiawah was able to withstand significant dune recession with only damage to walkovers. The long-term accretion trend is expected to continue and contribute to recovery from Hurricane *Matthew*. CSE is scheduled for another monitoring event in fall of 2018.

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7.0 ACKNOWLEDGMENTS

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