2008 BEACH RESTORATION PROJECT
ISLE OF PALMS SOUTH CAROLINA

Monitoring Report No 1
December 2009

Prepared for:

City of Isle of Palms

2008 Isle of Palms Beach Restoration Project

YEAR 1 MONITORING REPORT

Prepared for:

City of Isle of Palms

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[2300YR1]

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COVER PHOTO – Oblique aerial images of the northeastern end of the Isle of Palms (looking southwest).

[UPPER] Before the project (5 December 2007). **[LOWER]** After the project (26 June 2008).

(Photos by TW Kana)

EXECUTIVE SUMMARY

This report presents results of Year 1 beach and inlet monitoring following the 2008 beach restoration project at the Isle of Palms which was accomplished in May-June 2007 under permit P/N 2007-02631-2IG. As part of the Operations, Monitoring, and Contingency Plan (CSE 2008c) for the project, annual surveys are being conducted to track the performance of the project, measure sand volumes remaining, and provide a condition survey of the beach, inlets, and shoals from Dewees Inlet to Breach Inlet. Year 1 monitoring involved condition surveys in March and September 2009, as well as collection of sediment samples in July 2009. These data are compared with pre-project and post-project conditions in the project area (north of 53rd Avenue). Data for remaining areas of the Isle of Palms and Breach Inlet are compared with earlier surveys by SCDHEC Office of Ocean and Coastal Resource Management (OCRM). The report includes:

- Shoreline history and summary of the 2008 beach restoration project.
- Description of the data collection and analysis methods.
- Monitoring results by section of shoreline using seven (7) reaches along the island.
- Nourishment volume remaining within the project limits.
- Identification of local erosion "hot spots."
- Findings and recommendations.

The 2008 beach restoration project borrowed sand from deposits ~2.5 miles offshore and placed 933,895 cubic yards (cy) in three reaches between 53rd Avenue and Dewees Inlet. As of September 2009 (1.3 years after project completion), Reach A (53rd Avenue to Beach Club Villas) retained ~71.1 percent of the nourishment volume; Reach B (Mariners Walk Villas to the 18th fairway of Wild Dunes Links Course) retained ~85.5 percent of the nourishment volume; and Reach C (a 1,000-foot length of Dewees Inlet shoreline adjacent to the 17th hole and 18th tee of the Wild Dunes Links Course) retained ~95.0 percent of the nourishment volume. While ~96,500 cy were lost in Reach A between July 2008 (post-project) and September 2009, ~30,000 cy accreted along the approximate half-mile section downcoast of the project area (ie – between 53rd Avenue and the Citadel beach house). This downcoast accretion confirms the spreading of nourishment sand to unnourished areas of the Isle of Palms. Losses along Reach B (Ocean Club area) partly account for the low rate of loss along Dewees Inlet.

The 2009 surveys confirm that sand is continuing to enter the Isle of Palms littoral zone in the vicinity of the Wild Dunes Property Owners Beach House (situated between Beach Club Villas I and II) via a process called "shoal bypassing" (described in the report). A broad, triangular, underwater platform containing ~4.3 million cubic yards accounts for some new sand added to the beach in 2009. The presence of this deposit close to shore continues to cause rapid changes in the lee of an attaching shoal (erosion trend). This is the same underlying beach and shoal condition which led to the 2008 project. The "2008" shoal-bypassing event accounts for rapid nourishment losses in the vicinity of Seascape Villas and Ocean Club (Reach B) as well as a localized area fronting the Wild Dunes Grand Pavilion (Reach A). No properties are imminently threatened along these erosion hot spots; however, the rate of nourishment loss has been very noticeable in these areas and bears close monitoring in the coming year. Despite focused erosion along certain limited sections of shoreline, 95 percent of the project area remains in much better condition than pre-project.

The present surveys (2009) indicate that downcoast sections of the Isle of Palms from 53rd Avenue to 6th Avenue lost ~34,000 cy between March and September 2009. This equates to an average beach recession rate of ~3 feet (ft) over this 3.4-mile segment. The 2009 trend of erosion is counter to a long term, averaging over 3 cubic yards per foot per year (cy/ft/yr) (~4-5 ft/yr). CSE believes the 2009 erosion trend is due to the ongoing process of shoal attachment off the Wild Dunes Property Owners Beach Hosue, which is inhibiting downcoast transport of nourishment sand. No properties between 6th Avenue and 53rd Avenue are imminently threatened.

CSE obtained detailed bathymetry in Breach Inlet as part of the present monitoring and noted localized rapid erosion along a 400-ft section at the end of the Isle of Palms spit. This erosion hot spot is caused by encroachment of the "marginal flood channel" of Breach Inlet. The marginal flood channel is a secondary channel of the inlet which hugs the Isle of Palms spit. Shoals on the seaward side of the channel migrated shoreward and forced the channel against the low-tide teach; this led to the erosion and scarping along the high-tide beach. No properties are imminently threatened, and it appears that a new marginal flood channel is beginning to form seaward of the existing channel. This type of process is common along spits on the updrift sides of inlets.

Based on the results of the present monitoring, CSE recommends the following.

The City should begin looking into alternatives to combat short-term, localized erosion through one or more methods. There are multiple alternatives for addressing localized erosion, each with a varying degree of environmental, economic, and political influences. To properly evaluate which alternative(s) may best accomplish the goals of a certain project, a feasibility study should be conducted to determine the scientific, environmental, economic, and political aspects of each alternative. Alternatives include:

- Do nothing
- Sand scraping from attached shoals or accreting areas of the beach
- Nourishment from upland sources
- Nourishment from offshore, delta shoals, or inland waterways

CSE believes scraping from attaching shoals will provide the most economical alternative; however, cost analysis of each alternative should be performed. The scale of any project will likely impact which alternative is in the community's best interest. CSE also recommends the City evaluate additional monitoring of the northeast end to provide semi-annual condition surveys of erosion hotspots and Dewees Inlet shoals. Morphological changes in the attaching and offshore shoals are currently impacting the shoreline and additional monitoring is advisable due to the rapidity of changes.

CSE expects the permitting process for any alternative to take at least two years to complete, and recommends the City evaluate the alternatives and establish a plan for remedial nourishment so that action may be taken before a crisis situation arises.

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1.0 INTRODUCTION

This monitoring report is provided to the City of Isle of Palms by Coastal Science & Engineering (CSE) as part of a three-year contract for beach monitoring following the 2008 Isle of Palms Beach Restoration Project (P/N 2007-02631-2IG, CSE 2008a). This report details the first two data collections under the current contract. Discussions presented in the report are based on comparisons of pre- and post-project surveys with surveys performed in March/April and September 2009. Additional data collections are planned for summer 2010 and 2011.

The analyses presented in this report provide an updated condition of the beach ~9 months and ~15 months after the completion of the restoration project. There are several objectives of post-project beach monitoring, some of which are required by the conditions of the permits. This report provides beach profile volumes along the length of the Isle of Palms (IOP), including detailed volume changes in the project areas. It also addresses the current physical and environmental condition of the beach and offshore borrow areas impacted by the project, including sand grain size, beach slope, beach compaction, and borrow area infilling rates. Ground and aerial photography are included to identify features such as dunes, escarpments, sand texture and color, and to give a visual representation of the beach width to compare with previous and future surveys.

Setting

Isle of Palms is an ~7-mile long, southeast-facing, barrier island located ~8 miles east of Charleston, South Carolina. It is bounded by Dewees Inlet and Dewees Island to the northeast and Breach Inlet and Sullivan's Island to the southwest. The center of the Atlantic Intracoastal Waterway represents the landward boundary of the island north of the Isle of Palms connector, while the center of Hamlin Creek serves as the landward boundary south of the connector. The total area of the island is ~4.5 square miles and includes salt marsh, tidal creeks, an active beach and dune system, and historical maritime forest; however, most of the island has been developed into residential and commercial areas, and only very limited stands of maritime forest currently exist (IOP 2008). The island is relatively flat with average elevations of 8 to 10 feet (ft) above mean sea level. Elevations may be higher on recent and ancient dune ridges. An extensive system of salt marsh, tidal creeks and mud flats exists between the island and the mainland of Mt Pleasant (Fig. 1.1).

Hayes (1979) stated “the most important control of the geomorphology of depositional coasts is the type and amount of hydrologic energy expended within an area.” Specifically, the energy Hayes refers to is wave energy and tidal current energy (related to tidal range). Most of the South Carolina coast is strongly influenced by both wave and tidal energy, and is thus considered a mixed-energy coast. Mixed-energy environments generally have moderate wave heights (2-5 ft) and are mesotidal (tidal ranges of ~3-11 ft). Mean tide range measured at the IOP pier is 4.84 ft (NOAA water level station 8665530). Wave conditions at the island are moderate with a mean significant wave height of 2.4 ft (Jensen 1983). Typical mixed-energy environments often possess relatively short barrier islands and numerous tidal inlets. The tidal inlets most often contain large ebb-tidal deltas, and the inlet channels follow a course which is skewed to the downdrift side (typically to the south in South Carolina).

Another feature typical of the central South Carolina barrier islands is the “drumstick” shape produced by the interaction of waves and tides, and formation of prominent ebb-tidal deltas at the inlets. Seaward shoals of each delta produce wave refraction and variable longshore transport rates. This leads to a wider upcoast (northern) end and a relatively thin downcoast end (Breach Inlet end, Fig. 1.2). The wider end of the island is influenced by shoal bypassing, a process whereby sand is periodically released from the inlet delta and moved onshore through wave action. This process occurs at somewhat regular intervals (average interval between events from 1941 to 1997 is 6.6 years, Gaudiano 1998) and contributes to the overall health of the island. However, it also can cause focused erosion in areas adjacent to the shoal attachment zone (Kana et al 1985). Longshore sediment transport is also modified by inlet shoals, contributing to accumulation of sand and growth of the island near the southern terminus of the ebb tidal delta. This produces a characteristic bulge in the shoreline some distance downcoast from Dewees Inlet (marked “A” in Fig 1.1).

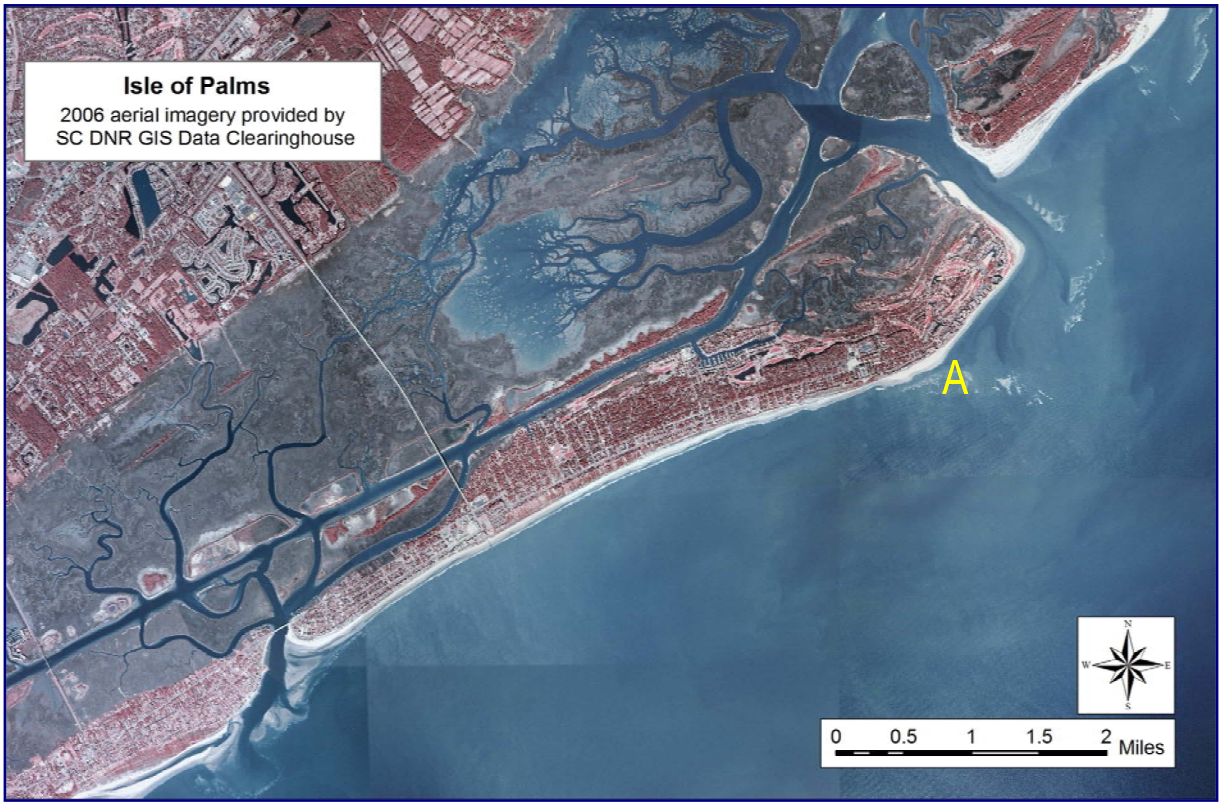

FIGURE 1.1.

[UPPER]
2006 vertical aerial image of IOP, bounded by Dewees Inlet on the northeast and Breach Inlet on the southwest.
[Source – SCDNR]

[LOWER]
Oblique aerial image looking northwest from Breach Inlet at low tide on 22 May 2009.
[Photo courtesy of C Jones]

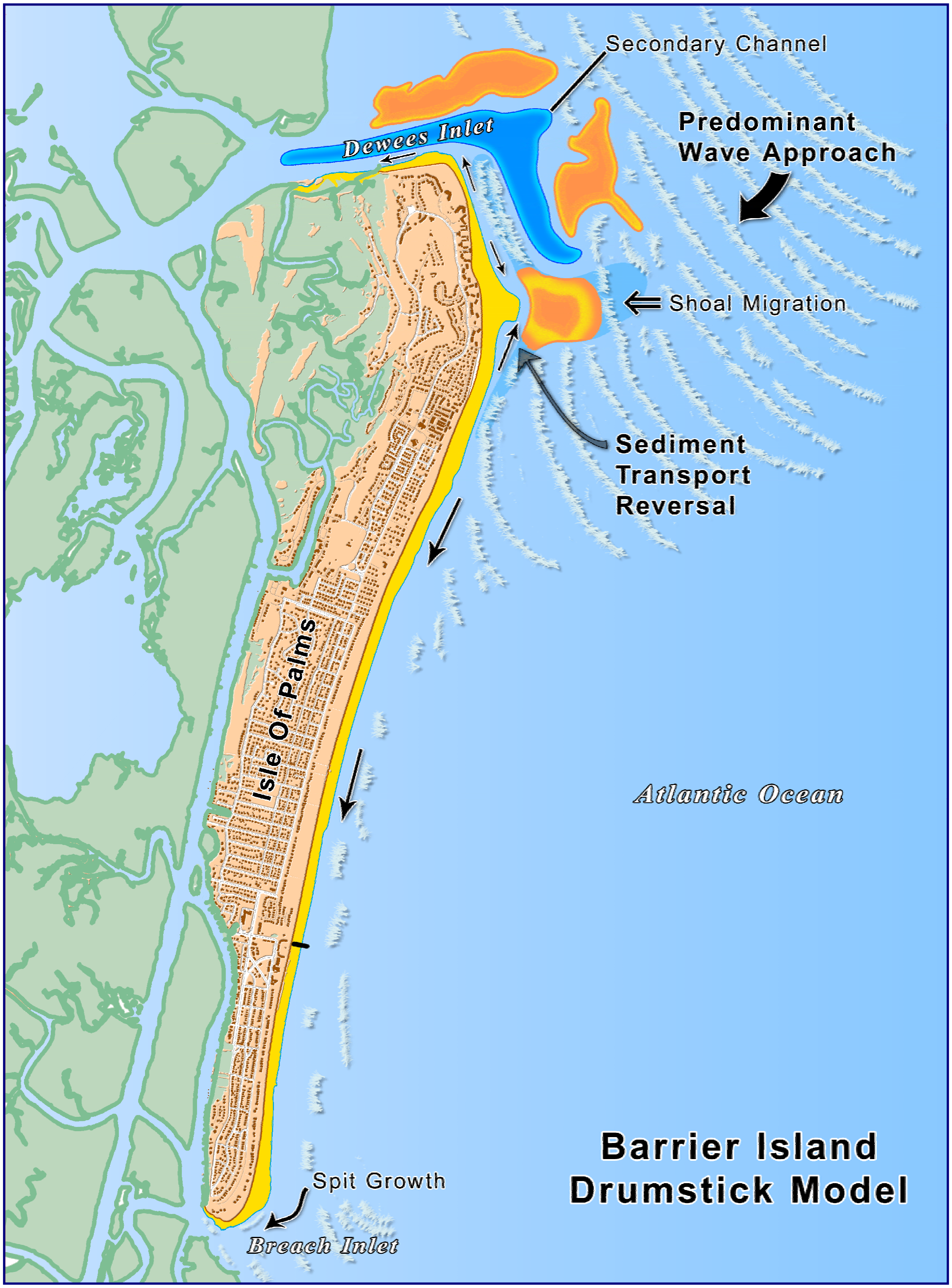

FIGURE 1.2. Isle of Palms is a typical "drumstick" barrier island (after Hayes 1979), where the upcoast end is wider due to sediment accumulation through shoal-bypass events, and the downcoast end usually forms a growing recurve spit. Other examples of drumstick barrier islands along South Carolina are Bull Island, Kiawah Island, and Fripp Island. Zones of sediment transport reversal generally occur in the lee of delta shoals which are situated offshore. Upon shoal attachment to the beach, transport directions in the vicinity of the shoal switch, spreading sand away from the attachment point (cf — Fig 1.4).

Historical Shoreline Change

Previous studies of shoreline change along IOP show that the island is one of the few along the South Carolina coast which has gained sand over the past ~75 years. In a study of shoreline changes of the central South Carolina coast, it was estimated that IOP gained 6.6 cubic meters per meter per year (m^3/m/yr) [2.6 cubic yards per foot per year (cy/ft/yr)] between 1934 and 1994 (SCSGC 2001, Fig. 1.3). During this time period, only the northeast end was erosional, losing 4.3 m^3/m/y (1.7 cy/ft/yr). The rest of the island gained sand, with the central portion gaining 3.1 m^3/m/yr, the southern portion gaining 14.3 m^3/m/yr and southern spit in the vicinity of Breach Inlet gaining 19.7 m^3/m/yr. The shoreline around Dewees Inlet gained 4.4 m^3/m/yr. This is equivalent to an average annual gain of ~83,000 cy/yr between 1934 and 1994 over the length of the island.

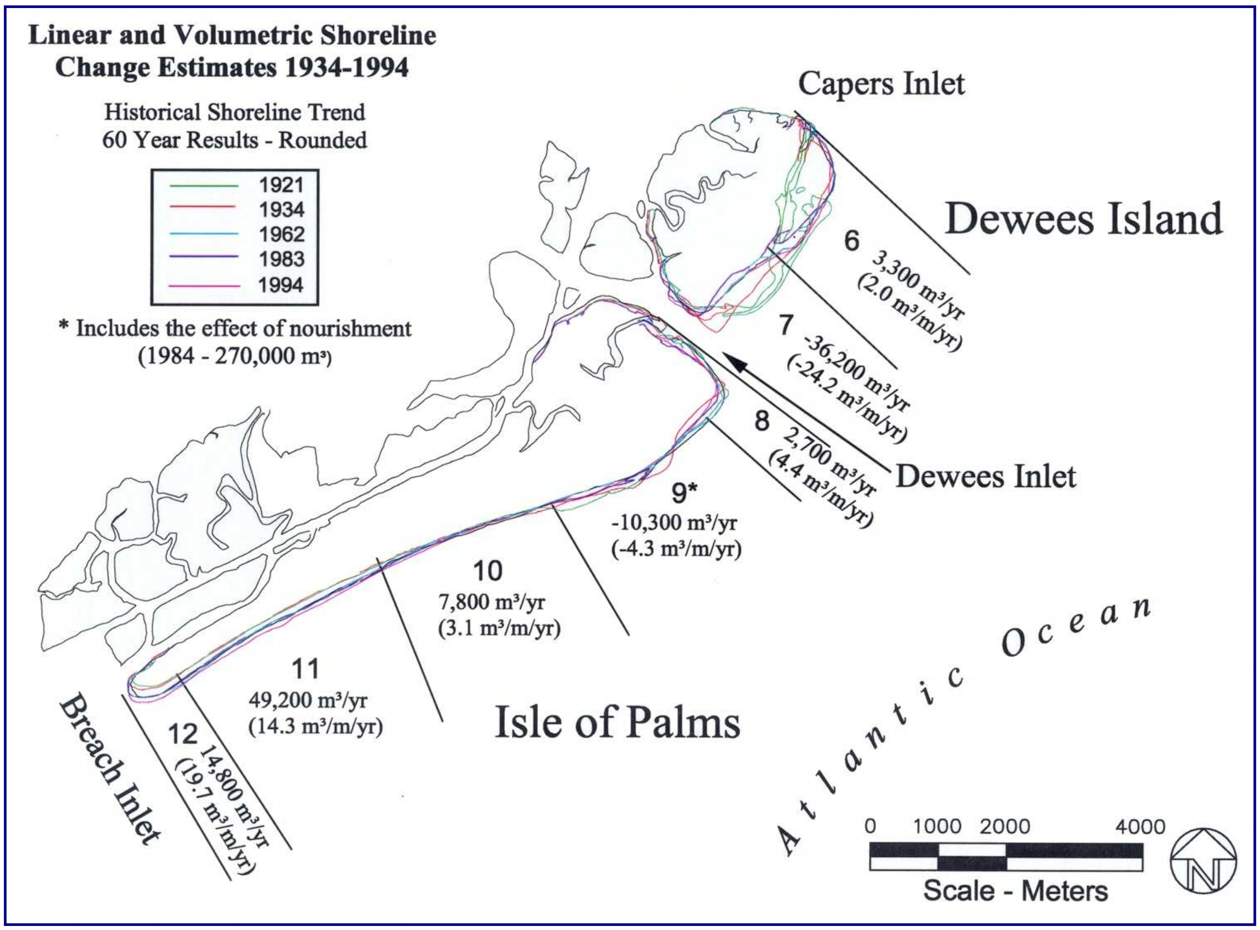

FIGURE 1.3. Historical shorelines and erosion rates at Isle of Palms (from SCSGC 2001).

The long-term accretion trend at the Isle of Palms is a direct result of shoal bypassing at Dewees Inlet. Numerous episodic events have deposited sand on the northeastern end of the island (Gaudiano 1998). In each event, a portion of the deposited sand is shifted back to Dewees Inlet while the balance moves downcoast, leading to accretion along the central area and southeastern end of the island. Shoal-bypass events have added to the sand supply, but surveys indicate more sand shifts downcoast (or into Dewees Inlet) than has remained at the bulbous updrift end of the island during the past century. The annual average sand gain from shoal-bypass events at the northeastern end of the island is ~100,000 cubic yards per year (cy/yr); however, ~120,000–130,000 cy/yr are typically lost to downcoast areas each year, leaving a net sand deficit of ~20,000–30,000 cy/yr at the northeastern end (CSE 2007a).

Shoal bypassing at Dewees Inlet has been the underlying source of sand for IOP, but it has led to significant erosion events at the northeast end. CSE has studied several shoal-bypass cycles at IOP, using the area as a model for the process (Kana et al 1985). A shoal-bypass event, which impacted the Wild Dunes community in the early 1980s, was used as a case study for these events and is shown schematically in Figure 1.4. Three stages of the event were defined from this study. Stage 1 is formation and emergence offshore of the bypassing shoal. Its onshore migration rate, scale, and proximity to the shoreline control the extent of changes along the beach in its lee. The shoal's effect as a breakwater is greatest as it nears attachment to the shoreline (Stage 2). The beach directly behind the shoal accretes rapidly while the adjacent segments of beach erode. Once fully attached to the beach (often creating a small lagoon or isolated pond between the former shoreline and the new outer beach), sand begins to spread laterally in either direction (Stage 3). In some events where the bypassing shoal is asymmetric or alongshore wave energy is variable, Stage 3 conditions may occur at one end of the bar while Stage 2 continues at the other end.

The shoal-bypass event in front of the Wild Dunes community in the early 1980s demonstrated that onshore migration and welding of the bar to the shoreline required about three years to process from Stage 1 to Stage 3. That particular event was estimated to involve ~0.5 million cubic yards of sand. During the event, erosion along the flanks of the shoal forced considerable remedial action ranging from frequent sand scraping to construction of rock revetments (RPI 1982-1984). As Stage 3 began in early 1984, the developer of the resort implemented an ~350,000 cy nourishment project using sand from the 41st Street marina basin. Sand was pumped immediately north and south of the shoal-attachment points to restore the eroded areas just as shoal sand was starting to renourish these sections. The net result was a dramatic widening of this section of the beach by upward of 500 ft.

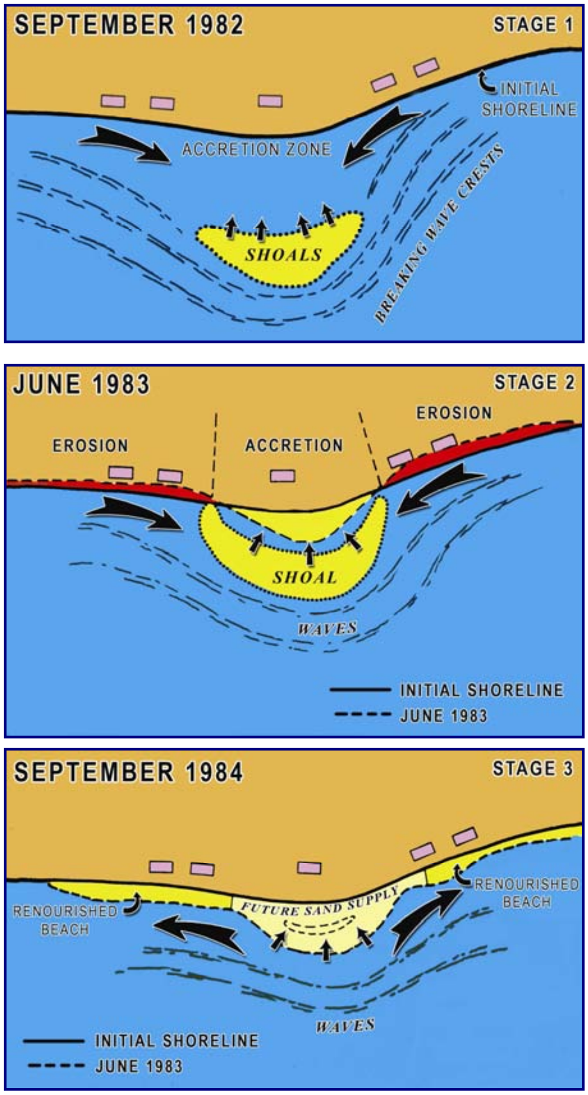

FIGURE 1.4.

[LEFT]
Schematic of the shoal-bypass cycle originally modeled from a bypass event at IOP. 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-bypass event at the northeastern end of IOP. The upper photo shows a shoal in Stage 1 of the bypass cycle in March 1996. The middle image, taken in 1997, shows that the shoal is beginning to attach to the beach and is in Stage 2 of the bypass cycle. The lower image (from December 1998) shows the shoal completely attached (Stage 3), and sand has spread to previously eroded areas.

Another bypassing event impacted the northeastern end in 1987. Erosion associated with this event, coupled with erosion caused by several large winter storms, led the Wild Dunes community to import ~50,000 cy of sand from upland sources. Some existing revetments were also lengthened during this time (Williams and Kana 1987).

The shoreline at the northeastern end of IOP remained relatively healthy until 1995, when major dune erosion in the vicinity of Beach Club Villas, Beachwood East, and Dune Crest Lane forced remedial measures. Sand was scraped from the shoal accretion zone and transferred to the adjacent erosion zones. Another bypassing event attached in 1998 (shown in Fig 1.4) and between 1999 and 2002, the beach remained in Stage 3 of the cycle. During this period, the shoreline was relatively straight, which allowed for uninterrupted sand transport to downcoast areas as well as storm protection for all structures.

The shoal-bypassing event which led to the 2008 project appears to have begun around 2003. By 2004, some areas (eg – Port O'Call) experienced 150 ft of beach recession in one year (ATM 2006). In February 2007, exposed bars extended nearly one-half mile offshore around Beach Club Villas and the WDCA beach house (Fig 1.5). The southern part of the attaching shoal was already in Stage 3 with some sand moving south to nourish other parts of IOP; the northern side remained in Stage 2. As Figure 1.5 shows, all properties north of Beach Club Villas had lost their dry-sand beach by then. To protect buildings, property owners placed ~5 gallon-sized sand bags along the scarped dune. These bags quickly were destroyed or washed away, and large (1 cy) sand bags were placed in front of buildings for protection. Erosion continued into 2008, eventually claiming half of the signature 18th hole of the Wild Dunes Links Course and leaving no dry beach (even at low tide) in front of several properties.

FIGURE 1.5.

[UPPER]

February 2007 oblique aerial image of the northeastern end of IOP showing the approaching shoal in Stage 2 of the bypass cycle.

Note loss of dry beach and various shore-protection measures from Mariners Walk Villas to the 18th fairway.

[LOWER]

Small, 5-gallon-sized sand bags (left) and large 1 cy-sized sandbags (right) installed to temporarily offer protection to buildings.

Prior to the 2008 project, little to no beach was present at low tide near the Ocean Club condominiums.

Left image courtesy of Coastal Carolina University Beach Erosion Research and Monitoring Program.

The 2008 Isle of Palms Beach Restoration Project

The Wild Dunes Community Association retained CSE in May 2007 to develop an analysis of erosion and prepare a plan for long-term restoration of the beach. CSE (2007) determined the northeastern end of IOP was losing ~30,000 cy/yr and had a deficit upward of 400,000 cy as a result of net losses since the 1980s. Despite periodic additions of sand by way of shoal-bypassing events, more sand was eroding from the northeastern end of IOP each year (on average). While some of the sand was lost to Dewees inlet, much of it shifted south to other portions of IOP. Studies by Stephen et al (1975), Kana and Gaudiano (2001), and others demonstrated that the sand supply from the northeastern end of the island accounts for the stability and growth of downcoast areas of the Isle of Palms.

CSE (2007) determined that upward of 900,000 cy should be added along the northeastern end of IOP to restore the sand deficit and provide reserves that will accommodate future erosion events over an approximate ten-year period. A recommended offshore borrow source, meeting necessary criteria for economics and environmental impacts, was identified and confirmed through geotechnical studies (CSE 2007a, 2008b).

Following a number of community meetings and discussions with City and State officials, the City of Isle of Palms elected to proceed with the final design and planning for the project. The City was the appropriate government entity to coordinate various property regimes and individual homeowners impacted by erosion. Drawing on the studies by CSE for Wild Dunes Community Association, the City contracted with CSE to prepare the permit application, the final design, and manage construction of the project. The City's contract coastal engineer, Christopher Jones (PE), provided coordination and review of CSE's work.

The specific objectives of the 2008 beach restoration project were to:

- Restore the recreational beach along the northeastern erosion zone of IOP from 53rd Avenue to the terminal groin along Dewees Inlet, excluding areas with a sand surplus in the active sand-bypassing zone or which were likely to receive sand as a result of natural spreading to downcoast areas.
- Restore a protective beach seaward of buildings such that dune enhancement may be initiated by the applicant and individual property owners.
- Remove emergency sandbags, all of which were in violation of OCRM permits after approximately November 2007.

- Place nourishment volumes of variable section quantities to reduce the variability of beach width caused by inlet sand-bypassing processes.
- Provide a protective buffer between existing infrastructure and the ocean.
- Improve the overall aesthetics of the beach and enhance its recreational value.
- Restore habitat for nesting sea turtles.

Permits Obtained

To implement the project objectives, it was necessary to obtain permits from the South Carolina Department of Health and Environmental Control – Office of Ocean and Coastal Resources Management (SCDHEC-OCRM) and the US Army Corps of Engineers (USACE). The following permits were obtained by the City of Isle of Palms.

- SCDHEC-OCRM Permit 2007-02631-2IG-P issued 18 March 2008.
- USACE, Department of the Army Permit 2007-02631-2IG issued 07 May 2008.

The federal (US Army Corps of Engineers) permit required the submission and approval of an Operations, Monitoring, and Contingency Plan (OMCP) (CSE 2008c) to ensure compliance with all conditions of the permits. An important part of the OMCP was documentation of sandbag removal and sediment quality of both the sand contained in the sandbags and sand pumped from offshore.

Construction Contract

The City of Isle of Palms entered into a contract with Weeks Marine of Covington (LA) for placement of 780,000 cy of sand along 9,200 liner feet of beach. Two change orders increased the total volume to 847,400 cy over 10,200 ft of beach and added a fill section to the Dewees Inlet shoreline. The original bid was for $7,914,100, and the total cost after the change orders was $8,402,090. Weeks Marine selected Dirt Cheap Inc (Charleston SC) as subcontractor for the sandbag removal portion of the project. Weeks Marine was required to have U.S. Coast Guard certifications and licenses, a contractor's license to work in the state of South Carolina, and a business license in the City of Isle of Palms.

Project Construction

The restoration project was designed to add ~850,000 cy of sand to ~10,200 linear feet of beach (Fig. 1.6). The fill was to be placed in three reaches. Reaches A and B were located along the oceanfront spanning from ~53rd Avenue to the 18th hole of the Wild Dunes Links Course, separated by an accretion zone associated with the shoal-bypassing event. Reach C represented a portion of the Dewees Inlet shoreline. Roughly 2,600 linear feet of Reach A bordered publically accessible areas of the City. The remaining fill bordered the Wild Dunes community. Design fill volumes for full sections (excluding tapers) were 75 cy/ft in Reach A, 140-180 cy/ft for Reach B, and 27 cy/ft in Reach C.

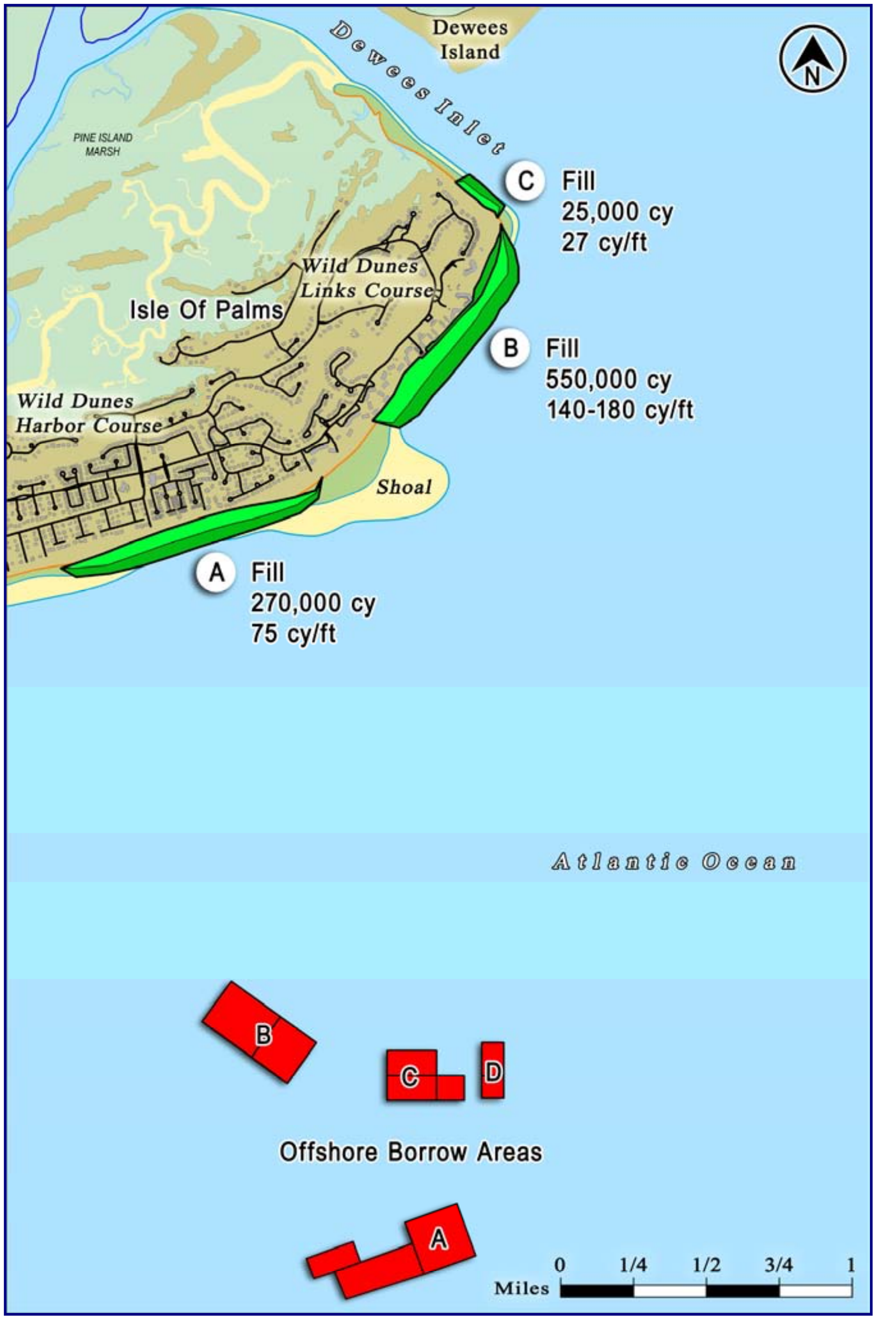

FIGURE 1.6. Project map of the 2008 IOP restoration project. The project was designed to nourish sections of the beach and provide sufficient sand to offset losses associated with long-term erosion as well as an ongoing shoal-bypass event. Borrow areas were located 2-3 miles offshore. Area D was not dredged.

An important aspect of the project was the removal of sandbags which had been placed in front of buildings. Bid documents estimated ~13,125 large (~1 cy) sandbags and ~5,400 cy of small sandbags existed in front of, between, and underneath buildings in Reach B. Dirt Cheap began removing accessible sandbags prior to dredging, starting at the southwestern limit of the sandbags and moving toward Dewees Inlet. They used a combination of excavators, a bobcat, and a long-reach forklift to lift or dig the sandbags; then cut the bags to remove the sand (Fig. 1.7). On-site personnel would visually determine whether the sediment within the bags was beach quality. Unacceptable material was removed from the beach by truck. Sandbag removal took 16 working days to complete between 19 May and 5 June 2008. A total of 9,401 large bags were removed.

FIGURE 1.7. Contractor, Dirt Cheap Inc, removing sandbags prior to nourishment. In the left image, a track hoe digs to remove buried small and large bags. In the right image, a long-reach forklift removes accessible bags. Material was dumped from the bags and inspected for compatibility. Unacceptable material was removed from the beach by truck. [Photos by S. Traynum]

Weeks Marine began placing sand on the beach on 24 May 2008. It quickly became apparent that the sandbag removal operation was not going to progress quickly enough to stay ahead of the nourishment operation. The lack of high-tide dry beach in front of Seascape Villas and the Ocean Club provided an additional obstacle. Weeks Marine determined that the best solution was to construct a small berm (~100 ft wide) in front of the buildings (Fig 1.8). This provided a protected area for Dirt Cheap to work continuously throughout the day and allowed the nourishment operation to continue uninterrupted. Once all bags were removed, Weeks Marine doubled back and pumped the remaining fill into these sections.

FIGURE 1.8. A temporary berm was built by Weeks Marine to protect buildings and the work area while Dirt Cheap Inc. removed remaining sandbags. Once all bags were removed, the area was re-pumped to fill in the remaining berm. [Photo by S. Traynum]

The cutterhead-suction dredge (*RS Weeks*) arrived in the borrow area on 24 May 2008 (Fig 1.9). The dredge used a 30-inch pipe and up to 12,000 horsepower to pump the slurry to the beach. Three borrow areas situated between 2 and 3 miles offshore of the Isle of Palms were used for the project (see Fig 1.6). At the guidance of state regulatory and resource agencies, the borrow areas were placed around bathymetric ridges to minimize creation of deep holes. The selected borrow areas were identified as deposits having sediment which both matched the native beach and provided a stable fill. Project permit conditions restricted the depth of cut to 7 ft below existing grade. Detailed geotechnical data for the borrow areas is given in CSE (2008b).

FIGURE 1.9.

[UPPER]
The 12,000 hp cutterhead suction dredge (*RS Weeks*) used in the 2008 beach restoration project.

[LOWER]
The nine-foot-diameter cutterhead aboard *RS Weeks*. The dredge was not pumping when this image was taken due to a break in the swing wire, which controls the position of the dredge in the borrow area.

[Photos by S. Traynum]

Nourishment activities continued 24 hours per day, with the only down time due to mechanical repairs to the dredge or stoppage to relocate pipe. On the beach, bulldozers shaped the fill to the design template. Temporary dikes were used to channel the slurry and control the fill placement (Fig 1.10, upper). Pumping began in Reach B, along the most severely eroded area of Wild Dunes. Once Reach B was complete, Reach C along Dewees Inlet was filled, followed by Reach A between 53rd Avenue and Beach Club Villas. Borrow area A was used to fill the majority of Reach B. Borrow area C was used to fill the northern end of Reach B and all of Reach C. Borrow area B was the sediment source for Reach A. The design berm was set at an elevation of +6 ft NAVD, with the beach face sloping at 1 on 20 (1 on 12 in Reach C due to the naturally steeper shoreline along inlets). A storm berm (set at +8 ft NAVD) was incorporated in the design along the most severely eroded areas of Wild Dunes.

Final pumping was 25 June 2008 near 53rd Avenue. Weeks Marine was issued substantial completion and began demobilizing equipment. The beach was tilled to a depth of 36 inches overnight on 30 June (Fig 1.10, lower). Pre- and post-nourishment surveys were performed by Weeks Marine and CSE to verify each section was filled to design. The final volume added to the beach calculated from Weeks Marine's surveys was 933,895 cy, which was ~10 percent greater than the design volume of 847,400 cy. The overage of 86,495 cy was not a pay quantity as stated in the contract; therefore, the City was only required to pay for the contract volume of 847,400.

The result of the project was a wide beach which offered recreational area, habitat for nesting turtles, and storm protection for structures. The beach was initially widened up to 350 ft in the most severely eroded areas near Ocean Club and the 18th hole of the Wild Dunes Links Course (Fig 1.11). Other areas received a volume of sand which offset the deficit that had developed in recent years. Normally, the initial beach width after construction is wider than design because of the nature of fill placement. Nourishment profiles require upward of a year to adjust and take on a natural shape. Much of the adjustment is a shift of material into deeper water to build up the toe of the beach. Pumping during construction generally cannot control the run-out into the surf. Therefore, wave action at the site has to work the nourished berm into the final configuration (Dean 2002). Following the project, the Wild Dunes Links Course reclaimed a substantial portion of the berm for re-construction of the 18th hole which had been lost to erosion prior to the project.

FIGURE 1.10.

[UPPER]
First pumping on 24 May 2008 in project reach B.

[MIDDLE]
Pumping in reach B. Note the grade stake in the foreground (to the left of the pipe) marking the design elevation. Flags were attached to the stake at the design elevations, and bulldozers shaped the pumped material to these flags to produce the designed beach profile.

[LOWER]
Tilling the beach after completion of the project. Tilling reduces the compaction of the sand. The entire project area was tilled to a depth of 36 inches.

[Photos by S. Traynum]

FIGURE 1.11. Before (5 December 2007) and after (26 June 2008) oblique aerial images of the northeastern end of Isle of Palms (looking southwest). [Images by TW Kana]

Post-Project Monitoring Requirements

Several monitoring requirements were outlined in the conditions of the permit and in the OMCP (CSE 2008c). Many of the requirements involved aspects of project construction and have already been completed. Monitoring efforts which extend beyond project construction will be addressed through work performed in the present monitoring contract (CSE Project 2300), as well as work included in the project contract (CSE Project 2277). Specific monitoring requirements which are ongoing are as follows:

- Borrow area bathymetric surveys including production of digital terrain models (DTMs) and calculation of infilling rates.
- Beach compaction measurements and escarpment monitoring prior to turtle nesting season.
- Sediment quality analysis of the fill with comparison to pre- and post-project conditions.
- Monitoring of beach slopes (profiles).
- Borrow area (offshore) and fill area (beach) benthic macrofauna surveys comparing pre- and post-project densities. (CSE Project 2277 data have been provided in separate reports.)

The current compliance status regarding the above-listed requirements is outlined in later sections of this report.

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2.0 METHODS

Monitoring efforts for the 2009 report took place during several deployments to the Isle of Palms. CSE collected topographic and bathymetric data in March and September 2009. Sediment compaction measurements were also collected in March 2009. Beach sediment samples were collected in July 2009.

Changes in the volume of sand in the active beach zone were evaluated by obtaining topographic and bathymetric data along shore-perpendicular transects at established locations along the beach (herein referred to as the baseline, Fig 2.1). The baseline for the present report is modified from earlier reports to encompass the entire island. Modifications were also made around turns in the baseline, which provide better detail and greater consistency in comparing beach volume changes. The present baseline spans from the center of the Breach Inlet bridge (Station 0+00) and continues to Cedar Creek spit at the northeastern end of the island (Station 376+00). The new baseline overlaps the baseline used in the project beginning at 53rd Avenue, which was the location of project station 0+00. That station is now station 222+00. Stationing relates to distance along the shore with the number before the "+" symbol representing 100 ft. Therefore, station 36+00 is 3,600 ft from station 0+00. The baseline is generally set landward of the present active beach to allow for future erosion/accretion.

Topographic data were collected via RTK-GPS (Trimble™ R8 GNSS), which provides position and elevation measurements at sub-centimeter accuracy. Beach profiles were obtained by collecting data at low tide along the dunes, berm, and active beach to low-tide wading depth. Over-water work was then performed at high tide to overlap the land-based work (Fig 2.2). Over-water work was collected with RTK-GPS coupled with an Odom HydroTrak™ precision echo sounder mounted on CSE's shallow-draft vessel, the *RV Congaree River*. Profiles were collected from the most landward accessible point in the dune system to a minimum of 1,500 ft from the baseline. Profiles in the project area extended up to 15,000 ft offshore to encompass the shoals associated with Dewees Inlet and to monitor changes in bathymetry in the vicinity of the nourishment borrow areas. Alongshore spacing of the profiles ranged from 200 ft to 1,000 ft with the more closely spaced profiles in the project area and along Breach Inlet. Comparative profiles from CSE's monitoring efforts are shown in Appendix A. The complexity of areas impacted by inlets requires more detailed analysis (closer profile spacing) to fully incorporate volume changes associated with shoal-bypassing events and inlet migration. Bathymetric data were collected in the borrow areas at 100 ft spacing for comparison to pre- and post-dredging DTMs.

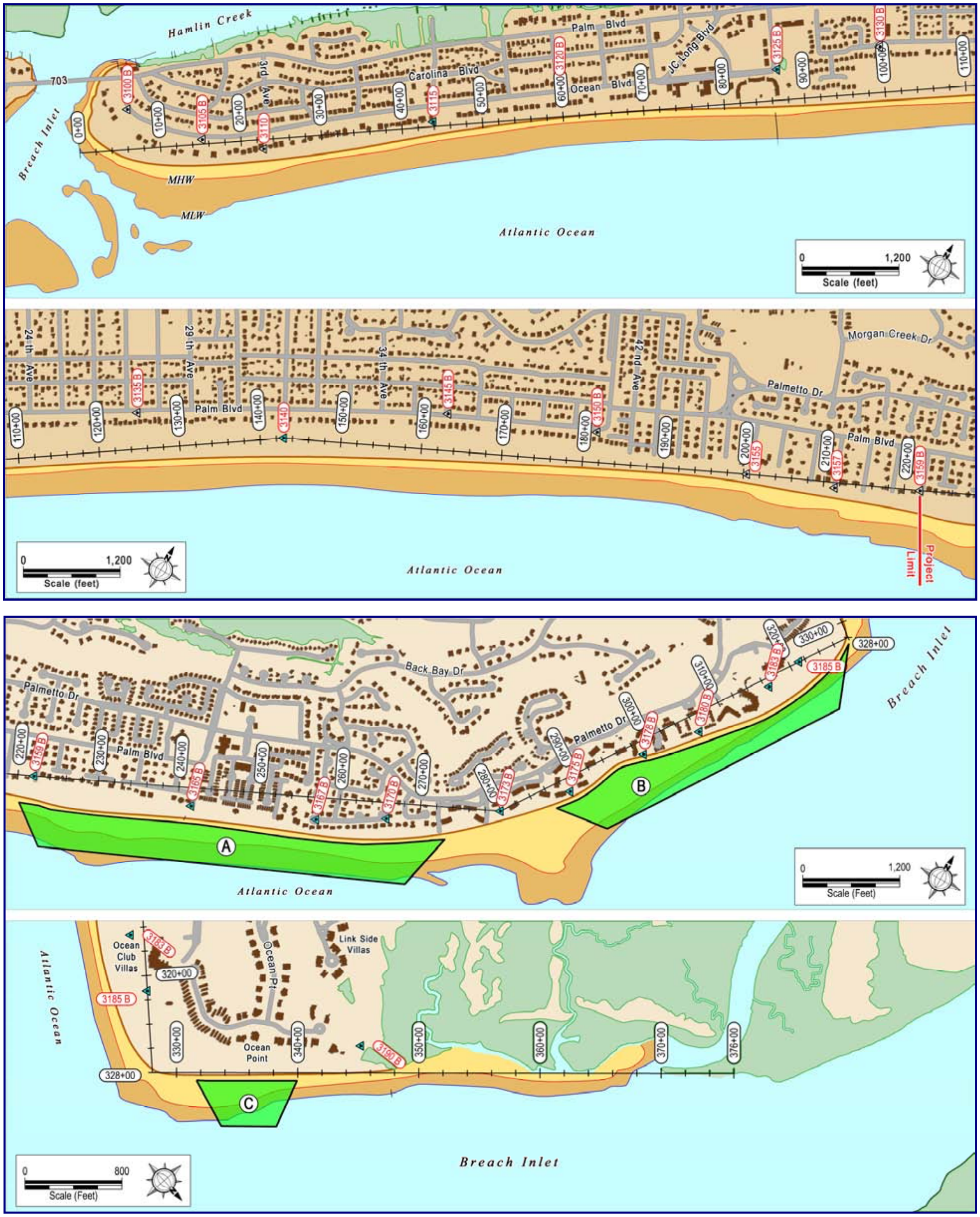


FIGURE 2.1 CSE established a monitoring baseline to encompass the length of IOP. The baseline between stations 222+00 and 376+00 corresponds to the baseline used in the 2008 project (project stations 0+00 through 174+00). Red labels indicate locations of OCRM survey monuments. CSE profile sections are oriented perpendicular to the baseline while OCRM profiles are perpendicular to the local beach azimuth. [CSE and OCRM azimuths are only significantly different at Breach Inlet.]

FIGURE 2.2. CSE beach monitoring methods include land-based data collection using Trimble™ RTK GPS from the backshore to low-tide wading depth and over-water work using RTK GPS linked to a precision echosounder aboard CSE's shallow draft boat (RV *Congaree River).*

To better understand regional sand volume changes, seven reaches were defined along IOP. By combining several profiles into a reach, it is easier to identify overall sediment gains and losses over large portions of the beach. In the project area, the reaches differ from reaches used during construction so as to encompass areas where no work was performed. [Some sections of this report may refer to volume changes within constructed project reaches and will be clearly indicated.] The reaches used for monitoring purposes are shown in Figure 2.3 and are defined as follows:

(1) Breach Inlet	0+00 – OCRM 3115	Breach Inlet – 6th Ave
(2) South IOP	OCRM 3115 – OCRM 3125	6th Ave - Pier
(3) Central IOP	OCRM 3125 – OCRM 3140	Pier – 31st Ave
(4) North IOP	OCRM 3140 – 222+00	31st Ave – 53rd Ave
(5) South Wild Dunes	222+00 – 280+00	53rd Ave – Property Owners Beach House
(6) North Wild Dunes	280+00 – 328+00	Prop. Owners Beach House – Dewees Inlet
(7) Dewees Inlet	330+00 – 370+00	Dewees Inlet Shoreline

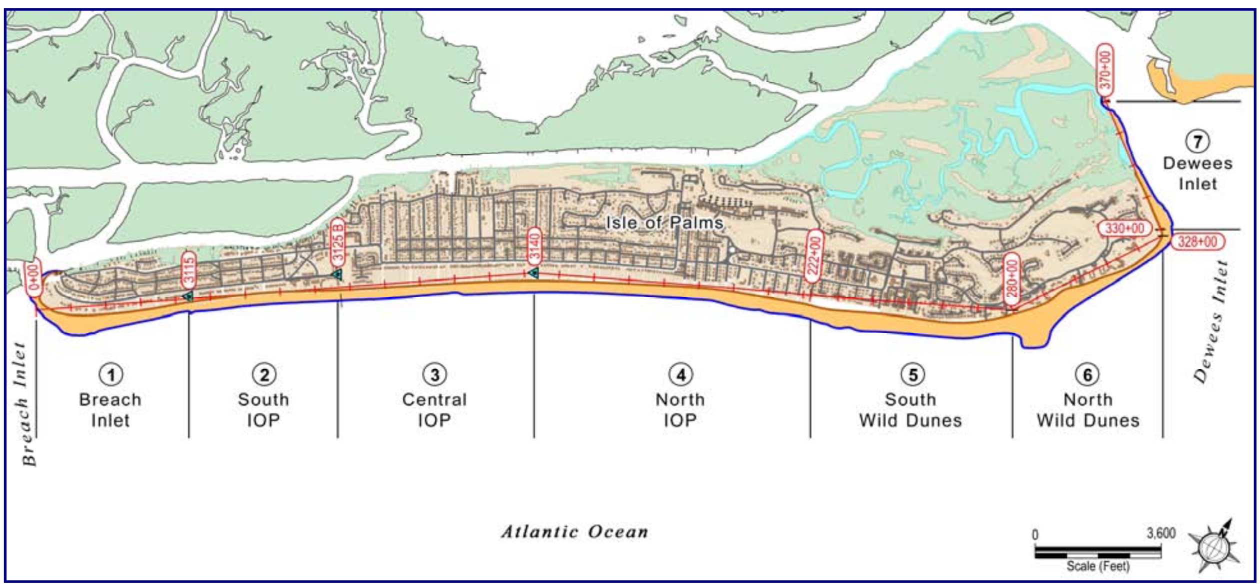


FIGURE 2.3. Location map of the reaches used in post-project monitoring at IOP. The 2008 beach restoration project occurred in subareas within the *North Wild Dunes* and *South Wild Dunes* reaches, as well as the *Dewees Inlet* reach.

To determine changes in beach volume along IOP, survey data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which converts 2-D profile data in x-y format to 3-D volumes. The software provides a quantitative and objective way of determining ideal minimum beach profiles and how the sand volume per unit length of shoreline compares with the desired condition. It also provides an accurate method of comparing historical profiles—as the volume method measures sand volumes in the active beach zone rather than extrapolating volumes based on single-contour shoreline position (ie – from aerial photography). Unit-volume calculations can distinguish 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 2.4 depicts the profile volume concept. The reference boundaries are site-specific, but ideally encompass the entire zone over which sand moves each year.

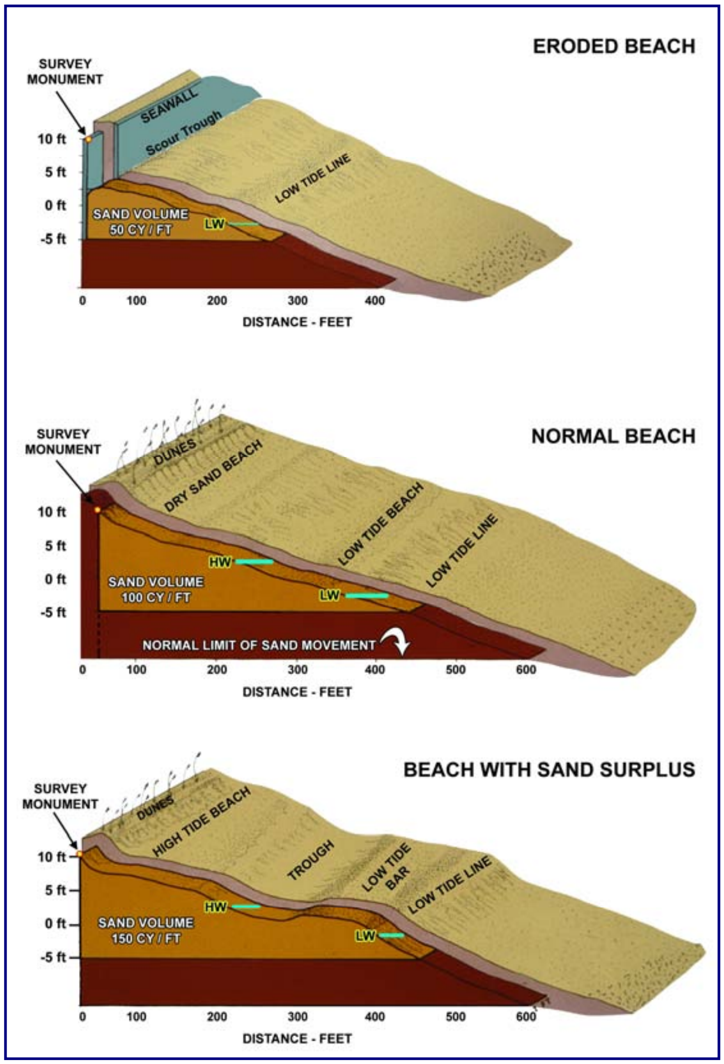


FIGURE 2.4. Calculation of unit-width profile volumes is a means of comparing the condition of one section of beach with another. Profile volumes are the amount of sand contained in a one-foot length of beach between specified elevations. [After Kana 1990]

For the present survey, sand volume was calculated between the primary dune and between −9 ft and −18 ft NAVD. The lower calculation limit was site-specific, as profiles in the center of the island and along Dewees Inlet generally have deeper closure depths than areas in the unstable inlet/shoal zones. Comparative volumes and volume changes were computed using standard procedures (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). Certain adjustments were made to account for changes in the baseline direction and for volumes at the turn in the baseline at Dewees Inlet.

Sand volumes for offshore areas were calculated from digital terrain models (DTMs) produced from MATLAB and AutoCAD® Civil 3D®. DTMs are digital 3D representations of the topography and bathymetry of an area and are useful for calculating changes in contour positions and calculating sediment volumes. Position data were entered into software as x-y-z coordinates and were processed to provide cross-section profiles and volumes. DTMs from the 2009 data collections were compared with earlier collections (pre- and post-project) to determine changes in shoal positions and volumes as well as infilling rates of the offshore borrow areas. Colored contour maps were also produced from the DTMs.

Beach compaction measurements were performed in accordance with conditions of the permit. Triplicate measurements were made at depths of 6 inches, 12 inches, and 18 inches at the toe of the dune and middle of the berm every 500 ft in the project area. Several stations outside of the project area were sampled to provide a "native" compaction value. Results of the compaction measurements and subsequent communication with USFWS indicated that the project area **DID NOT** need to be tilled. Results of the compaction measurements and the accompanying letter were submitted to USFWS (Appendix B).

Sediment samples from the nourished beach were collected on 6 July 2009. These samples were analyzed as outlined in the OMCP (CSE 2008c), using 0.25-phi intervals for grain-size analysis. Percent by weight of calcium carbonate was analyzed through dissolution with dilute HCl. At each sampling site, five samples (minimally) were collected—one each from the toe of dune, middle of berm, berm crest, mid beach face, and low-tide terrace. Sample transects were collected at 2,000-ft spacing throughout the project area, and additional samples were collected in adjacent unnourished areas for comparison. To provide island-wide sediment characteristics, four transects were added outside of the project area at ~1-mile intervals between Breach Inlet and 53rd Avenue.

3.0 RESULTS

Results of the March and September 2009 data collections are presented in this section. Where applicable, profiles from these dates are compared to previous CSE profiles. Volume changes are discussed in detail beginning at the upcoast end of the island, along the Dewees Inlet shoreline, then progressing south toward Breach Inlet. Unit volumes for each station and reach are given in Figure 3.1, Table 3.1, and Table 3.2. Following the volume changes, sediment quality and compaction results are given.

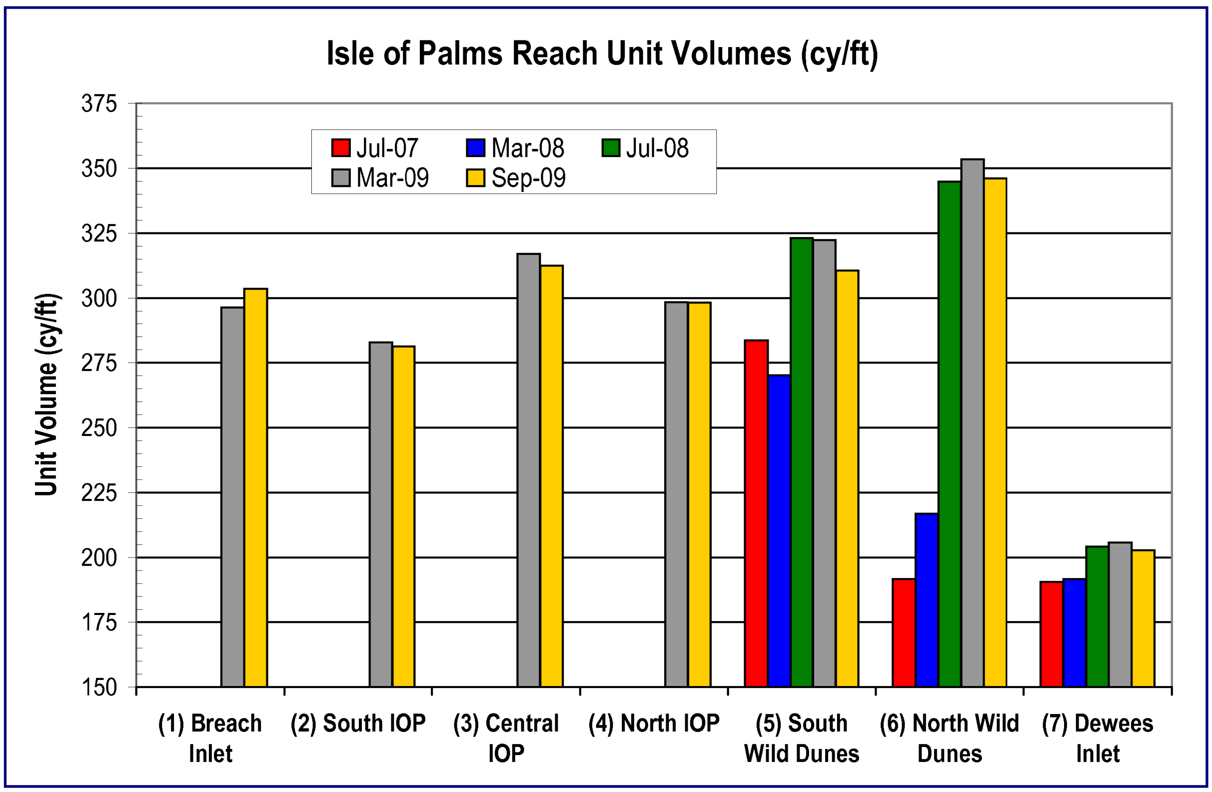


FIGURE 3.1. Average unit-width volumes for each monitoring reach at Isle of Palms. Unit volumes were calculated from the primary dune to a profile specific depth, generally between −9 ft and −13 ft NAVD for the beachfront. Nourishment occurred prior to the July 2008 data collection in Reaches 5, 6, and 7. Design fill unit volumes for full sections were ~75 cy/ft in the South Wild Dunes reach, ~140-180 cy/ft in the North Wild Dunes reach, and ~27 cy/ft in the Dewees Inlet reach.

TABLE 3.1. Profile unit-width volumes for each monitoring station at Isle of Palms. Nourishment occurred between stations 224 to 274 and stations 286 to 340 prior to the July 2008 data collection. Volumes are calculated between the approximate crest of the primary dune and the indicated "elevation lens" depth. Nourishment areas are highlighted in blue (project reach A), green, (project reach B), and yellow (project reach C).

Reach	Line	Elevation Lens (ft NAVD)	Distance to Next (ft)	Unit Volume (cy/ft)				
				Jul-07	Mar-08	Jul-08	Mar-09	Sep-09
Breach Inlet	3100	-13	0				548.8	347.2
	3105	-11	0				406.3	523.4
	0	-10	400				351.5	272.5
	4	-10	400				275.8	244.5
	8	-10	400				271.8	289.1
	12	-10	400				387.8	424.3
	16	-10	400				350.0	389.4
	20	-10	270				271.7	317.3
	3110	-11	730				295.4	311.6
	30	-12	1000				275.9	276.9
	40	-12	390				261.2	261.3
South IOP	3115	-12	610				294.4	288.1
	50	-12	1000				293.2	296.7
	60	-12	1000				265.6	269.5
	70	-12	1000				284.1	282.7
	80	-12	670				276.3	265.7
Central IOP	3125	-12	330				312.4	308.1
	90	-13	1000				300.9	292.5
	100	-13	1000				311.1	304.4
	110	-13	1000				307.2	306.8
	120	-13	500				330.4	323.6
	3135	-12	500				315.4	314.3
	130	-13	1000				298.9	294.1
	140	-13	290				371.1	367.3
North IOP	3140	-12	710				296.0	292.4
	150	-13	1000				311.5	299.5
	160	-13	290				297.8	284.6
	3145	-12	710				268.2	263.7
	170	-13	1000				292.5	291.8
	180	-12	150				277.7	275.7
	3150	-12	850				289.6	295.3
	190	-12	1000				280.6	275.9
	200	-12	200				360.3	349.3
	202	-12	200			280.5	317.7	325.0
	204	-12	200			286.8	315.9	333.0
	206	-12	200			288.7	314.3	336.4
	208	-11	200			278.8	304.5	317.0
	210	-11	200			287.8	306.7	328.2
	212	-11	200			258.0	274.0	298.1
	214	-11	200			251.7	281.8	305.3
	216	-11	200			253.4	286.8	302.3
	218	-11	200			274.5	309.6	312.9
	220	-11	200			269.5	305.9	309.1
South Wild Dunes	222	-10	200	243.8	252.0	261.0	292.6	295.7
	224	-10	200	214.0	221.5	233.5	269.0	273.0
	226	-10	200	214.0	217.6	225.3	274.0	286.8
	228	-10	200	224.6	222.6	252.1	292.2	299.8
	230	-12	200	343.6	323.3	375.3	389.5	391.1
	232	-12	200	307.1	320.1	357.5	377.5	371.0
	234	-10	200	228.7	245.9	320.5	335.1	327.9
	236	-10	200	204.0	214.2	295.1	317.1	300.6
	238	-10	200	204.7	204.8	294.6	318.1	299.6
	240	-10	200	189.0	184.4	277.6	307.6	285.8
	242	-10	200	175.6	182.6	273.6	304.3	283.8
	244	-10	200	193.6	189.8	283.1	313.0	297.7
	246	-10	200	185.1	181.8	271.0	286.4	271.4
	248	-10	200	182.0	188.7	272.2	280.5	267.2
	250	-10	200	186.2	188.5	282.2	278.3	261.2
	252	-10	200	200.6	197.9	291.9	275.9	265.5

Reach	Line	Elevation Lens (ft NAVD)	Distance to Next (ft)	Unit Volume (cy/ft)				
				Jul-07	Mar-08	Jul-08	Mar-09	Sep-09
South Wild Dunes (continued)	254	-10	200	217.5	197.5	298.1	270.3	267.1
	256	-10	200	249.2	212.3	313.2	276.2	273.8
	258	-10	200	242.6	201.7	297.6	256.8	252.6
	260	-10	200	250.9	229.1	305.9	270.5	256.9
	262	-10	200	323.8	283.5	346.2	340.9	297.5
	264	-10	200	324.6	289.4	349.3	340.9	300.6
	266	-10	200	348.5	303.7	374.3	328.9	303.3
	268	-10	200	298.1	292.7	338.1	272.0	266.2
	270	-10	200	368.7	365.0	394.5	314.9	312.5
	272	-10	200	403.7	363.2	377.0	326.0	307.7
	274	-10	200	350.9	341.5	344.6	300.7	289.8
	276	-10	200	484.9	461.8	459.1	427.9	399.1
	278	-10	400	456.2	463.2	415.2	384.9	371.7
North Wild Dunes	280	-10	200	585.8	461.0	436.6	602.3	603.9
	282	-10	200	599.2	488.4	423.6	594.3	616.9
	284	-10	200	629.5	515.3	522.2	627.9	679.5
	286	-10	200	460.8	445.3	471.8	553.2	587.5
	288	-10	200	253.3	333.0	423.8	433.6	453.8
	290	-10	200	200.1	255.4	357.3	387.9	390.9
	292	-10	200	196.1	246.8	355.6	382.7	389.3
	294	-10	200	189.1	235.7	363.0	378.1	380.7
	296	-10	200	168.9	213.5	354.7	359.8	353.7
	298	-10	200	159.3	191.1	354.1	349.5	339.4
	300	-10	200	147.9	173.6	347.5	336.8	323.6
	302	-10	200	132.1	149.8	339.3	329.5	306.7
	304	-10	200	134.2	141.5	333.2	307.5	289.8
	306	-10	200	191.5	171.7	372.6	359.8	312.2
	308	-10	200	160.4	155.4	341.0	301.7	287.0
	310	-10	200	140.4	152.6	312.9	284.6	241.6
	312	-9	200	78.9	84.3	254.1	207.7	188.3
	314	-10	200	93.1	86.9	246.1	198.9	168.7
	316	-9	200	152.4	109.7	282.6	241.9	226.0
	318	-9	200	145.1	103.6	287.3	248.1	232.2
	320	-9	200	169.2	114.9	298.5	258.2	245.8
	322	-10	200		205.4	368.5	336.5	318.2
	324	-9	200		167.5	317.0	298.1	286.9
	326	-9	200		141.1	258.2	281.4	276.9
	328	-9	100		200.3	244.5	300.7	280.8
Dewees Inlet	330	-18	200	242.9	228.2	262.4	281.7	297.0
	332	-18	200	263.5	286.9	333.6	340.5	344.8
	334	-18	200	240.9	252.6	295.8	324.2	328.5
	336	-18	200	230.1	232.8	284.0	281.2	291.3
	338	-18	200	212.8	214.7	261.2	247.8	240.3
	340	-18	200	204.3	204.6	244.6	223.2	216.1
	342	-18	200	231.0	227.6	246.4	239.2	232.7
	344	-18	200	201.5	201.1	209.5	208.3	205.0
	346	-18	200	199.3	198.4	198.1	201.8	197.7
	348	-15	200	142.7	150.9	147.2	150.7	149.0
	350	-15	200	171.6	170.1	169.7	170.7	167.5
	352	-15	200	164.0	159.8	160.4	155.2	153.3
	354	-15	200	177.0	170.1	171.1	168.1	165.0
	356	-15	200	193.1	186.5	185.6	183.1	177.9
	358	-15	200	181.3	175.3	171.9	173.1	163.8
	360	-15	200	180.7	177.2	172.0	174.4	164.2
	362	-15	200	178.0	173.3	167.4	173.1	164.5
	364	-15	200	145.9	146.2	141.2	137.5	139.7
	366	-13	200	136.2	137.4	131.6	146.1	138.9
	368	-13	200	157.1	168.9	174.2	183.7	178.5
	370	-13	0					176.0

TABLE 3.2. Isle of Palms reach volume analysis from July 2007 through September 2009. Nourishment occurred May-June 2008, prior to the July 2008 data collection. Volumes are calculated for each profile to a profile-specific depth, and then extrapolated to the next profile using the average-end-area method. The March 2008 data collection represents the prenourishment condition.

			Total Volume (cy)					Average Unit Volume (cy/ft)				
Reach	Limits	Length	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09
(1) Breach Inlet	0-3115	4390	-	-	-	1,300,813	1,332,791	-	-	-	296.3	303.6
(2) South IOP	3115-3125	4280	-	-	-	1,210,927	1,204,056	-	-	-	282.9	281.3
(3) Central IOP	3125-3140	5620	-	-	-	1,781,858	1,756,250	-	-	-	317.1	312.5
(4) North IOP	3140-222	7910	-	-	-	2,360,592	2,358,731	-	-	-	298.4	298.2
(5) South Wild Dunes	222-280	6000	1,701,596	1,621,342	1,938,618	1,934,086	1,863,730	283.6	270.2	323.1	322.3	310.6
(6) North Wild Dunes	280-328	4900	938,888	1,062,649	1,689,466	1,731,929	1,695,633	191.6	216.9	344.8	353.5	346.0
(7) Dewees Inlet	330-370	4000	762,175	766,568	816,758	822,893	810,992	190.5	191.6	204.2	205.7	202.7

			Net Change Since Previous (cy)					Unit Change Since Previous (cy/ft)				
Reach	Limits	Length	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09
(1) Breach Inlet	0-3115	4390	-	-	-	-	31,978	-	-	-	-	7.3
(2) South IOP	3115-3125	4280	-	-	-	-	-6,870	-	-	-	-	-1.6
(3) Central IOP	3125-3140	5620	-	-	-	-	-25,608	-	-	-	-	-4.6
(4) North IOP	3140-222	7910	-	-	-	-	-1,861	-	-	-	-	-0.2
(5) South Wild Dunes	222-280	6000	-	-80,255	317,276	-4,532	-70,355	-	-13.4	52.9	-0.8	-11.7
(6) North Wild Dunes	280-328	4900	-	123,761	626,818	42,463	-36,296	-	25.3	127.9	8.7	-7.4
(7) Dewees Inlet	330-370	4000	-	4,393	50,190	6,135	-11,901	-	1.1	12.5	1.5	-3.0

			Net Change Since Prenourishment (cy)					Unit Change Since Prenourishment (cy/ft)				
Reach	Limits	Length	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09	Jul-07	Mar-08	Jul-08	Mar-09	Sep-09
(1) Breach Inlet	0-3115	4390	-	-	-	-	-	-	-	-	-	-
(2) South IOP	3115-3125	4280	-	-	-	-	-	-	-	-	-	-
(3) Central IOP	3125-3140	5620	-	-	-	-	-	-	-	-	-	-
(4) North IOP	3140-222	7910	-	-	-	-	-	-	-	-	-	-
(5) South Wild Dunes	222-280	6000	-	-	317,276	312,744	242,389	-	-	52.9	52.1	40.4
(6) North Wild Dunes	280-328	4900	-	-	626,818	669,280	632,985	-	-	127.9	136.6	129.2
(7) Dewees Inlet	330-370	4000	-	-	50,190	56,325	44,424	-	-	12.5	14.1	11.1

Dewees Inlet Volume Changes

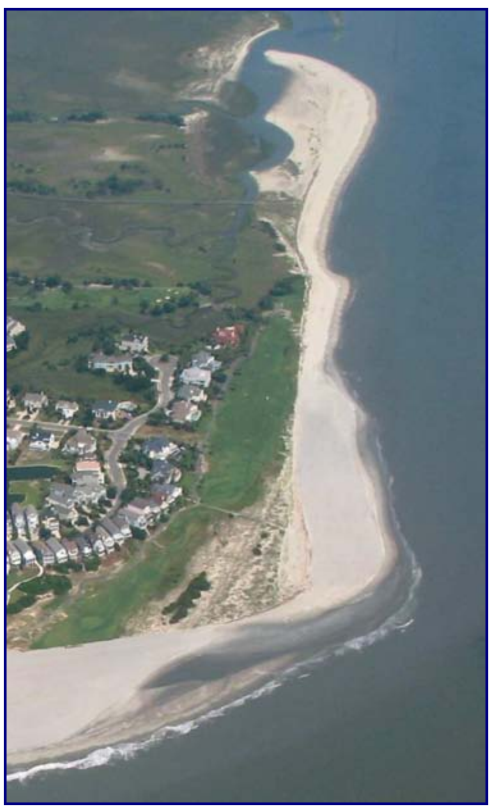
FIGURE 3.2

[UPPER LEFT]
The Dewees Inlet reach in December 2007.

[LOWER LEFT]
June 2008 near the end of the project.

[LOWER RIGHT]
September 2009.

Left images by TW Kana.
Right image by C Jones.



Dewees Inlet (Fig 3.2, previous page) generally receives less wave energy than the rest of the Isle of Palms, due to the sheltering effects of the ebb-tidal delta associated with the inlet. Shorelines along stable inlets usually show less dynamic volume changes than ocean-facing beaches; however, over time, they can experience severe erosion due to several factors. One factor thought to contribute to localized erosion along the Dewees Inlet shoreline is wave focusing through breaks in the inlet delta (Kana and Dinnel 1980). Breaks between the outer shoals allow larger waves or destabilizing diffracted waves to reach the shoreline and cause localized erosion. A low profile groin was built in 1981 near the 17th tee of the Wild Dunes Links Course to trap sand moving into Dewees Inlet and slow erosion (Kana et al 1985). The monitoring reach extends from the turn in the shoreline near the 18th tee to the end of Cedar Creek Spit.

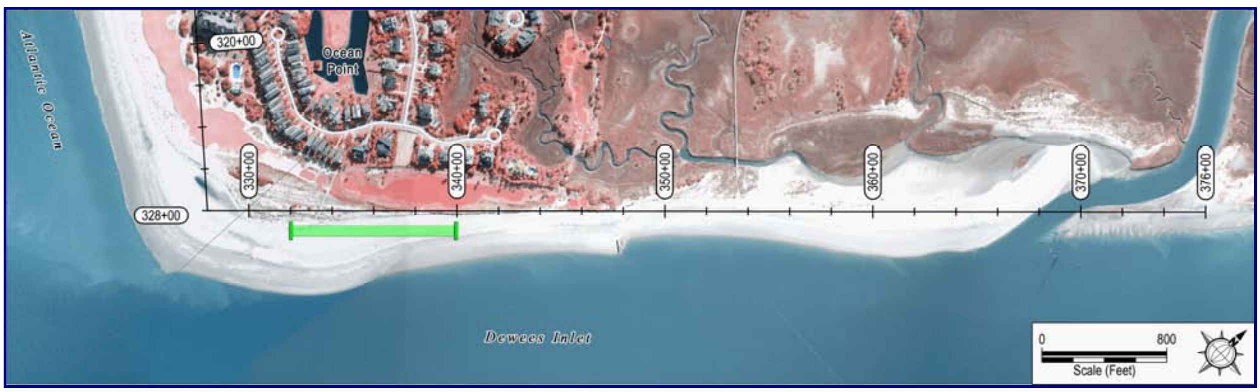


FIGURE 3.3. Station map of the Dewees Inlet area. The *Dewees Inlet* monitoring reach spans from station 330+00 near the 18th tee to station 368+00 near Cedar Creek spit. The approximate limits of nourishment Reach C are identified by the green bar. The 1981 low profile groin is positioned near station 348+00. March 2009 aerial image by Independent Mapping Consultants Inc.

Volume calculations from the 2009 monitoring efforts show that the seaward portion of project Reach C is gaining sand, while the rest of the reach has eroded following the nourishment (Fig 3.4). Between July 2008 and September 2009, stations 330 through 336 (near the 17th green to the turn in the shoreline around the 18th fairway) gained between 7.3 cy/ft and 34.7 cy/ft (Fig 3.5), whereas stations 338 through 342 (17th fairway) lost between −13.7 cy/ft and −28.6 cy/ft (cf – Table 3.1). The remainder of the reach to Cedar Creek showed continued erosion with stations west of the groin losing up to 8.1 cy/ft since July 2008. The area around the sandbag groin remained stable, and the terminus of Cedar Creek spit accreted by up to 7.3 cy/ft.

Stations 346 through 364 (17th tee to Cedar Creek spit) currently show less volume than the pre-nourishment (March 2008) condition. The total volume loss of the *Dewees Inlet* reach between July 2008 and March 2009 was 12,200 cy (3.1 cy/ft); however, between March and September 2009, the reach gained 6,500 cy (1.6 cy/ft). [Note: These results are based on profile volumes between the foredune and −13 ft to −18 ft NAVD. They do not include changes along the Dewees Inlet channel margin between −18 ft and −38 ft, the approximate inlet depth along the reach.]

Within the fill limits of the *Dewees Inlet* project area (nourishment Reach C), the beach lost 1.8 cy/ft between July 2008 and March 2009, but remained stable between March and September 2009, losing only 0.3 cy/ft (Fig 3.6). Losses in the landward portion of the project fill were offset by gains in the seaward end. The project area currently retains 95 percent of the nourishment volume placed in 2008 (Fig 3.7). Accretion between stations 330 and 336 (area of the 18th tee and fairway) is likely due to losses in other areas of the reach as well as sand buildup around the turn in the shoreline adjacent to the 18th fairway, which is building from losses in the *North Wild Dunes* reach. The volume change trends along the 18th fairway of the Wild Dunes Links Course, which wraps around the northeastern point of the island, provide an indicator of net sand transport from the oceanfront to the inlet shoreline in this area, consistent with the findings of Kana and Dinnel (1980).

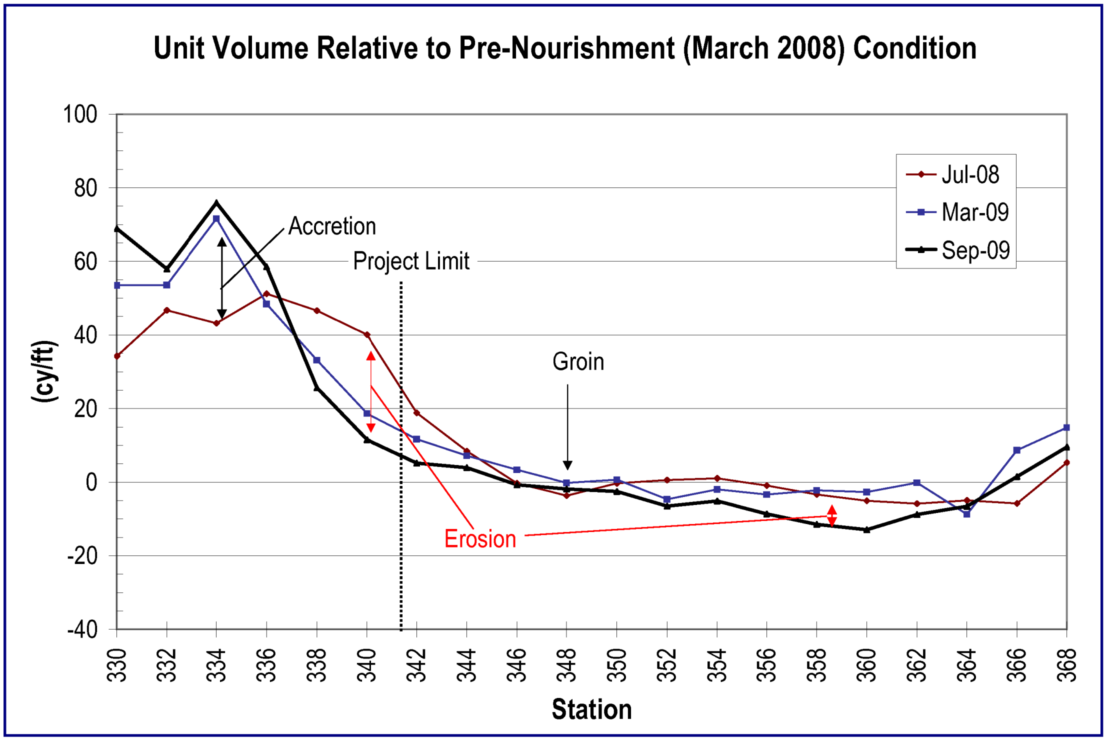


FIGURE 3.4. Unit volumes for stations in Dewees Inlet relative to the pre-nourishment condition of March 2008. Profiles in the southeastern portion of the reach (17th green – 18th tee) have accreted following the project, while the remaining stations have remained stable or eroded. Values greater than 0 cy/ft indicate the station retains more sand than the pre-nourishment condition, regardless of the trend from July 2008 to September 2009.

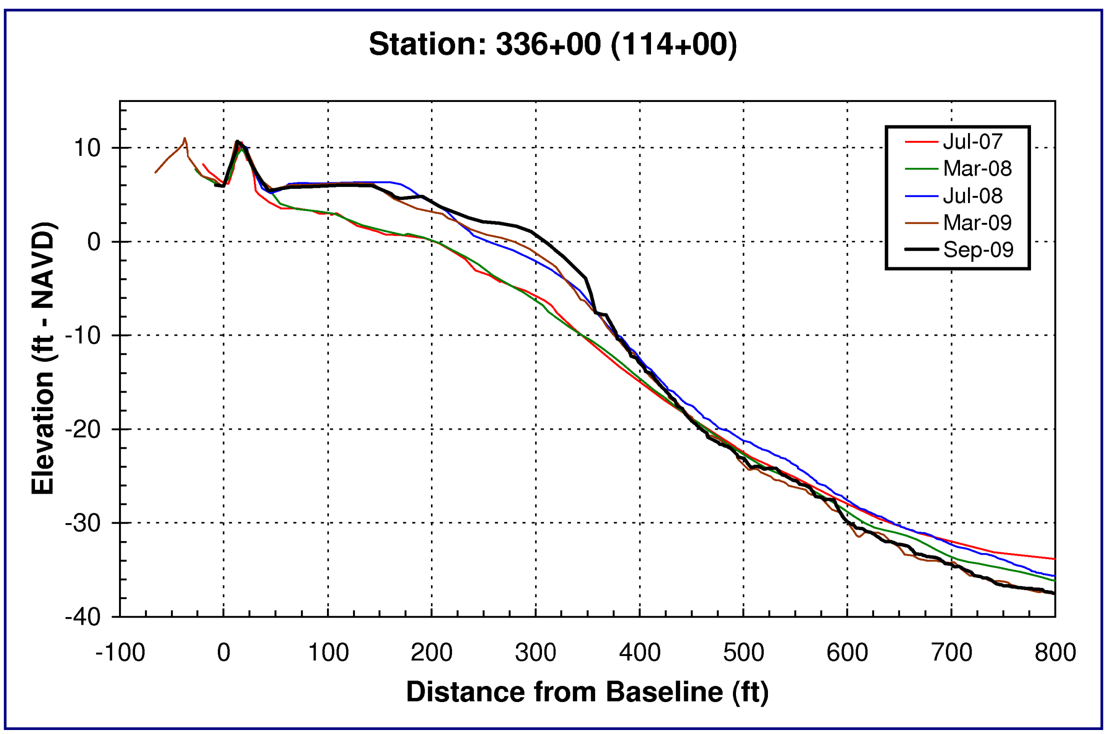
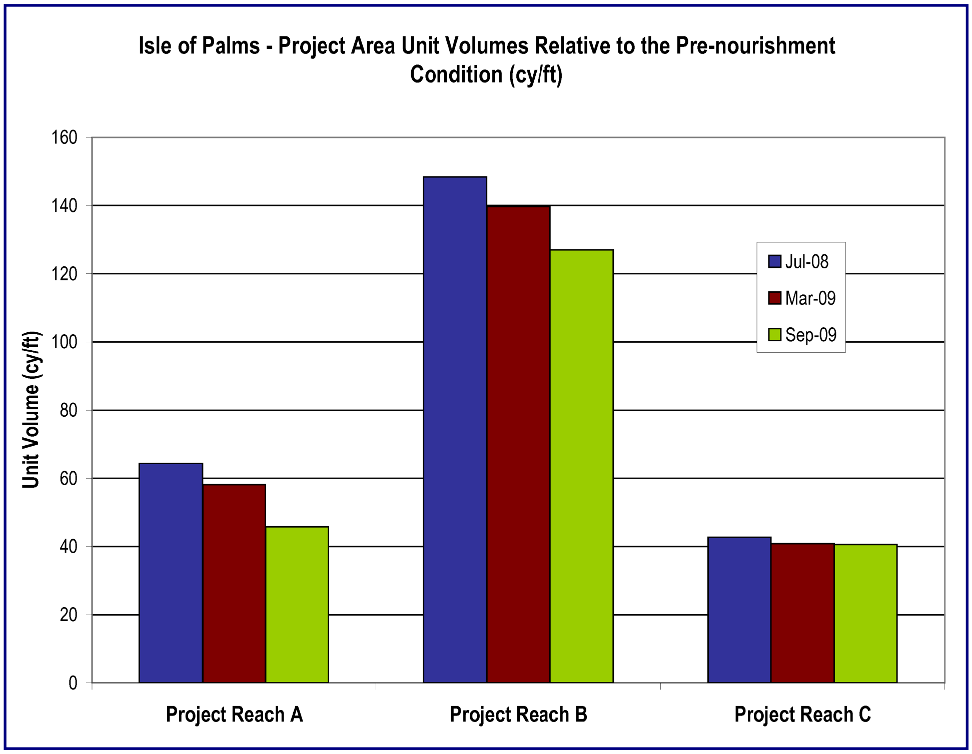


FIGURE 3.5. Profiles from station 336+00 (near the 17th green) in the Dewees Inlet project area. This profile currently contains 7.3 cy/ft more sand than immediately after the project. The new sand migrated from the oceanfront in the opposite direction to the normal play of golfers along the 18th fairway.

FIGURE 3.6. View looking northwest in the *Dewees Inlet* reach in the vicinity of the 17th green of the Wild Dunes Links Course in October 2007 (upper) and September 2009 (lower).



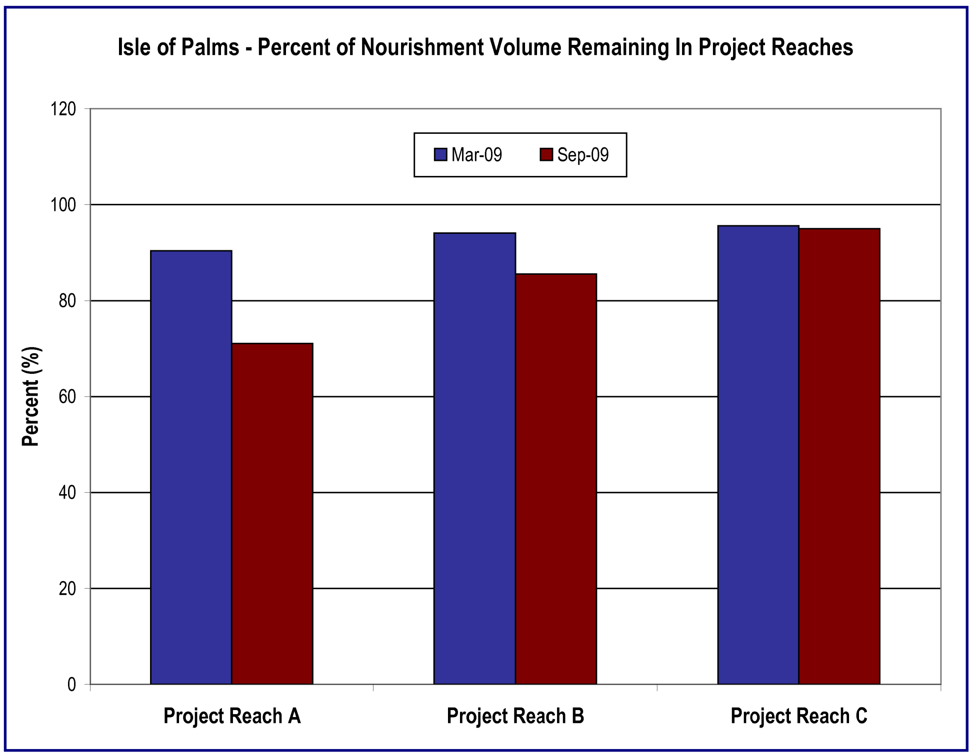


FIGURE 3.7. [UPPER] Project area unit volumes relative to the pre-nourishment (March 2008) condition, which is zero on these graphs. [Note that the project area limits differ from monitoring reach limits.] **[LOWER]** Percent of nourishment volume remaining in each project area.

Wild Dunes Volume Changes

North Wild Dunes

FIGURE 3.8. The *North Wild Dunes* reach in December 2007 (upper left), June 2008 near the end of the project (upper right), and September 2009 (lower). [Upper images by TW Kana; lower image by C Jones]

The *North Wild Dunes* reach (Fig 3.8, previous page) extends from the Wild Dunes Property Owners Beach House northeast ~4,900 ft to the 18th fairway, where the beach turns into Dewees Inlet (stations 280+00 to 328+00, Fig 3.9). This area has been highly impacted by shoal-bypassing events since the island's development. Depending on the location and timing of bypass events, the shoreline can change hundreds of feet over a period of several months (Kana et al 1985, Gaudiano 1998). As was the case in 2007-2008, the shoreline may encroach on development in this reach when shoal-bypass events are prolonged. Previous studies have suggested that the background, long-term erosion for the northeastern end of IOP is between 15,000 cy/yr and 30,000 cy/yr, even though the estimated average volume of sand added by each shoal-bypass event is ~500,000 cy (CSE 2007a). This means that, while large fluctuations in the shoreline and severe local erosion may occur, the long-term erosion rate for the area is relatively low. Sand simply migrates from one area of the beach to another and is either transported back to Dewees Inlet or downcoast to IOP, eventually being replaced by offshore sand through another shoal-bypassing event.

FIGURE 3.9. The *North Wild Dunes* reach spans from the Wild Dunes Property Owners Beach House (station 280+00) to the 18th fairway of the Wild Dunes Links Course (station 328+00). The approximate limits of nourishment Reach B are identified by the green bar. March 2009 aerial image by Independent Mapping Consultants Inc.

Prior to nourishment in June 2008, most of the *North Wild Dunes* reach was severely eroded with profile volumes seaward of development well below an ideal condition. Sandbags were piled against buildings, and little or no dry beach was present (see Fig 1.5). The condition was beginning to improve just before the nourishment as the shoal attaching at the western end of the reach was in Stage 3 of the bypass cycle. Sand was moving from the shoal toward Dewees Inlet, but not quickly enough to restore the beach along most properties north of the Wild Dunes Property Owners Beach House.

Additional sand was needed to supplement the natural sand transport condition. Between March and July 2008, ~638,000 cy of sand were added to the reach through nourishment and natural spreading of sand from the shoal (the design volume for this reach was 550,000 cy). Average profile unit volumes increased from 185 cy/ft to 331 cy/ft (calculated to −9 ft and −10 ft NAVD).

Since July 2008, the reach has shown accretion in the western portion and erosion in the central and eastern portions (Fig 3.10). Accretion in the western area of the reach is a result of the emergence and attachment of a new shoal off the Wild Dunes Property Owners Beach House. The shoal formed shortly after completion of the project, originating on the same "swash platform" which produced the "2006" shoal. Wave action moved sand from the seaward end of the shoal toward the beach, where it built on itself to produce the visible sandbar in the vicinity of the Wild Dunes Property Owners Beach House. [The new shoal attached a few hundred feet to the north of the previous shoal.]

At the attachment location, sand volumes on the beach have increased over 150 cy/ft since July 2008 and currently show unit volumes equal to or greater than those in the nourished areas. Sediment transport away from this shoal (indicated by increasing profile volumes) has reached ~1,000 ft north to station 296 (Shipwatch Villas), leaving stations 280 to 296 much healthier than pre-project conditions (Fig 3.10). North of station 296, the trend has been rapid erosion since July 2008 with maximum losses (50-70 cy/ft) occurring between stations 306 and 322 (Port O'Call to Ocean Club, Fig 3.11).

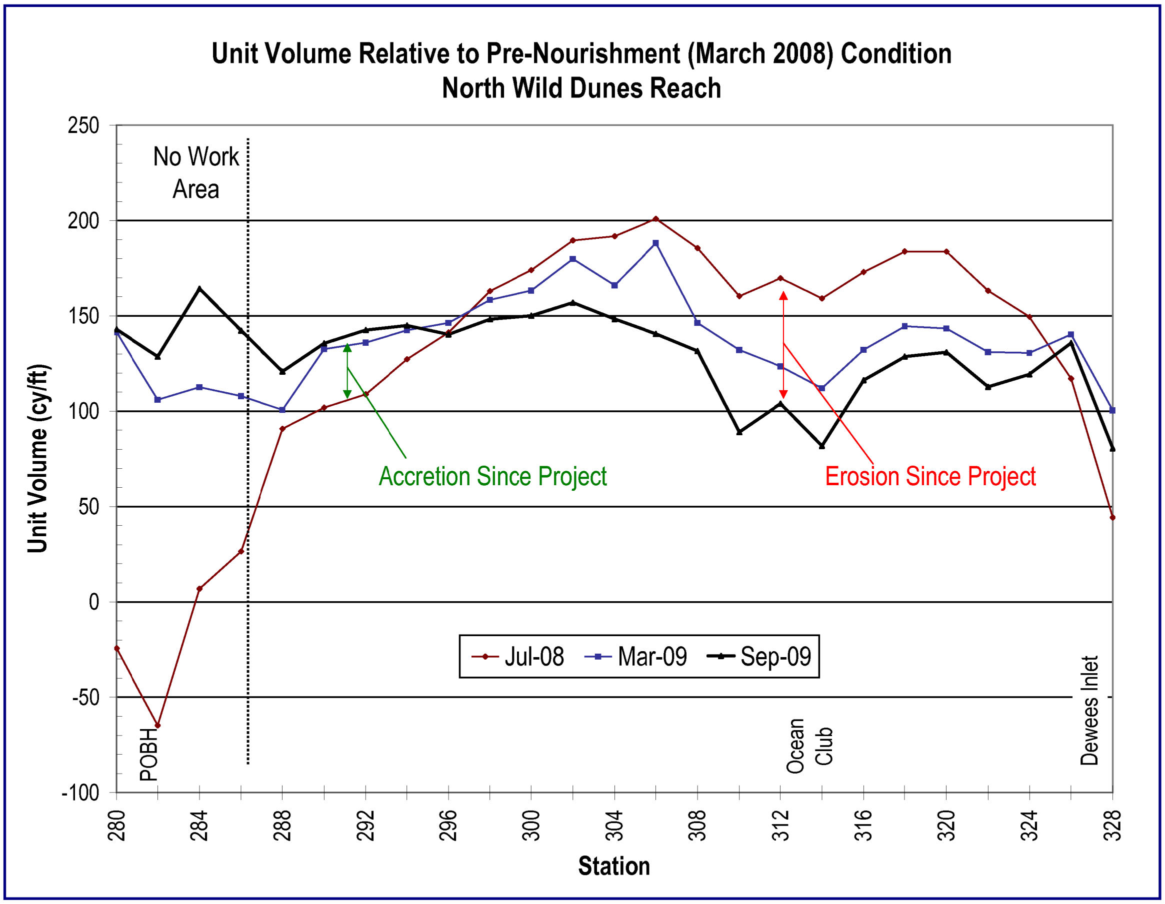
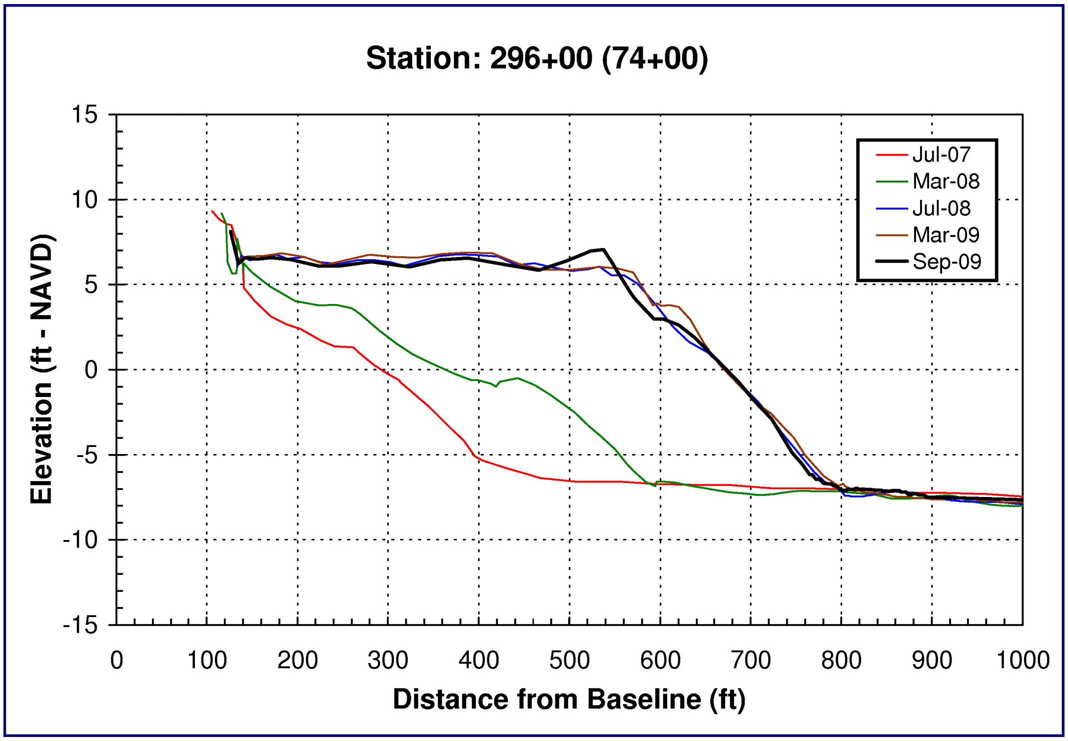


FIGURE 3.10. Profile unit-width volumes for stations in the *North Wild Dunes* reach, compared to the pre-nourishment condition. Erosion has dominated the northeastern portion of the reach, while accretion has occurred in the southwestern portion of the reach. Both the erosion and accretion are due to the attachment of another (2009) shoal near the Wild Dunes POBH.



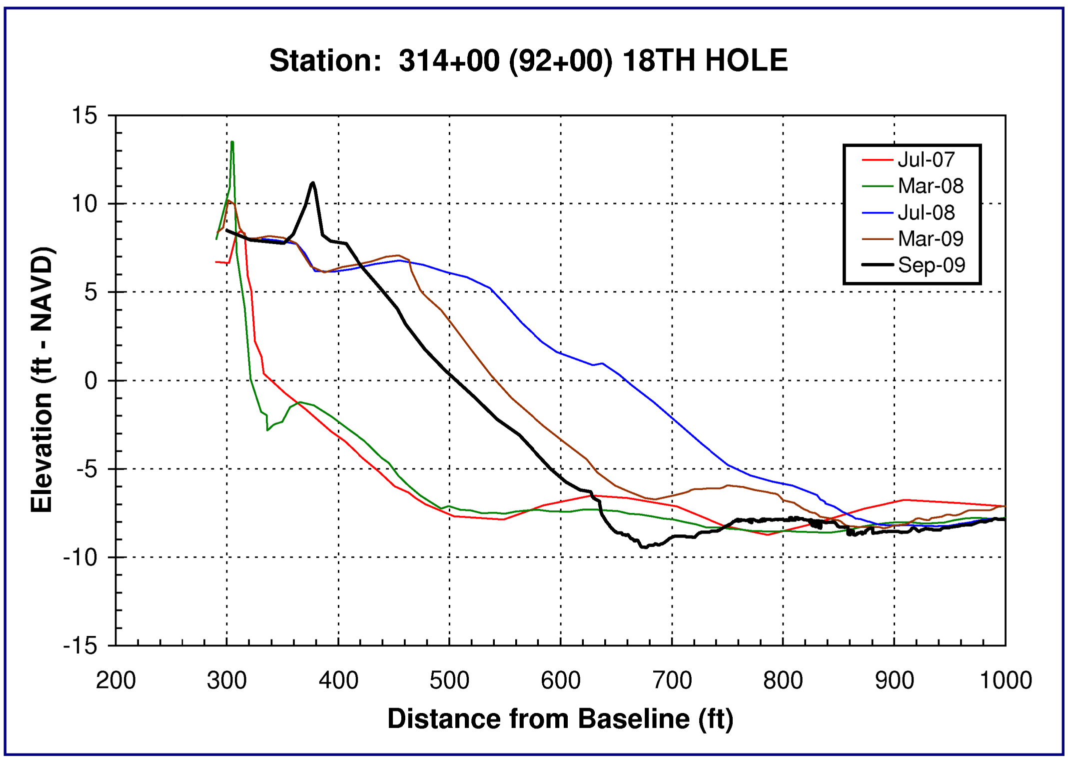


FIGURE 3.11. Profiles from stations in the *North Wild Dunes* reach. Station 296+00 has remained stable since July 2008, while station 314+00 has experienced significant erosion. CSE expects sand from the ongoing shoal-bypass event (now in Stage 3) to migrate into eroded areas in the next year, reducing the erosion rate and potentially rebuilding some of the area between Port O'Call and Ocean Club.

The central and northern portions of the reach have eroded since July 2008 with the worst erosion occurring between stations 310 and 314 (near the Ocean Club building and the 18th green). Profiles 310 through 314 have lost up to 77 cy/ft of sand since July 2008, representing one half of the nourishment volume (Fig 3.11, lower). Erosion was initially rapid in this area between July 2008 and March 2009, but diminished between March and September 2009. While the erosion rate is expected to continue to decline in front of Ocean Club as sand from the "2008" shoal-bypass event moves north, this area should be closely monitored. As in previous bypassing events, the rate of change in shoreline position occurs rapidly over a short segment of beach, complicating management of the erosion.

Overall, the *North Wild Dunes* reach contains ~633,000 cy more sand than the pre-nourishment (March 2008) condition, and ~6,000 cy more sand than the post-nourishment (July 2008) condition (Fig 3.12). The reach gained 8.7 cy/ft between July 2008 and March 2009. Most of the gain occurred at the shoal attachment site (southwestern portion of the reach), with minor accretion at the northeastern end of the reach near the turn in the shoreline. The central portion of the reach eroded. Overall, the reach lost 7.4 cy/ft between March and September 2009, but continued to accrete in the shoal attachment area.

The length of beach within the project boundary (project Reach B, between Shipwatch and the 18th fairway) presently retains 127.0 cy/ft more sand than the pre-nourishment condition (compared to 148.4 cy/ft immediately following nourishment). As of March 2009, 94 percent of the fill remained, while 85.5 percent remained as of September 2009. Individual stations retain between 51.4 percent and 133.1 percent of the nourishment volume. [Calculation excludes the taper sections, which would bias the results.]

FIGURE 3.12.

[UPPER] View south in December 2007 near Summer Dunes Lane prior to the project.

[MIDDLE LEFT] View north in December 2007 near Summer Dunes Lane prior to the project

[MIDDLE RIGHT] View north of the same area in June 2008 immediately following the project.

[LOWER] The same area in September 2009 looking south (left image) and north (right image).

[Photos by S. Traynum and Weeks Marine]

South Wild Dunes

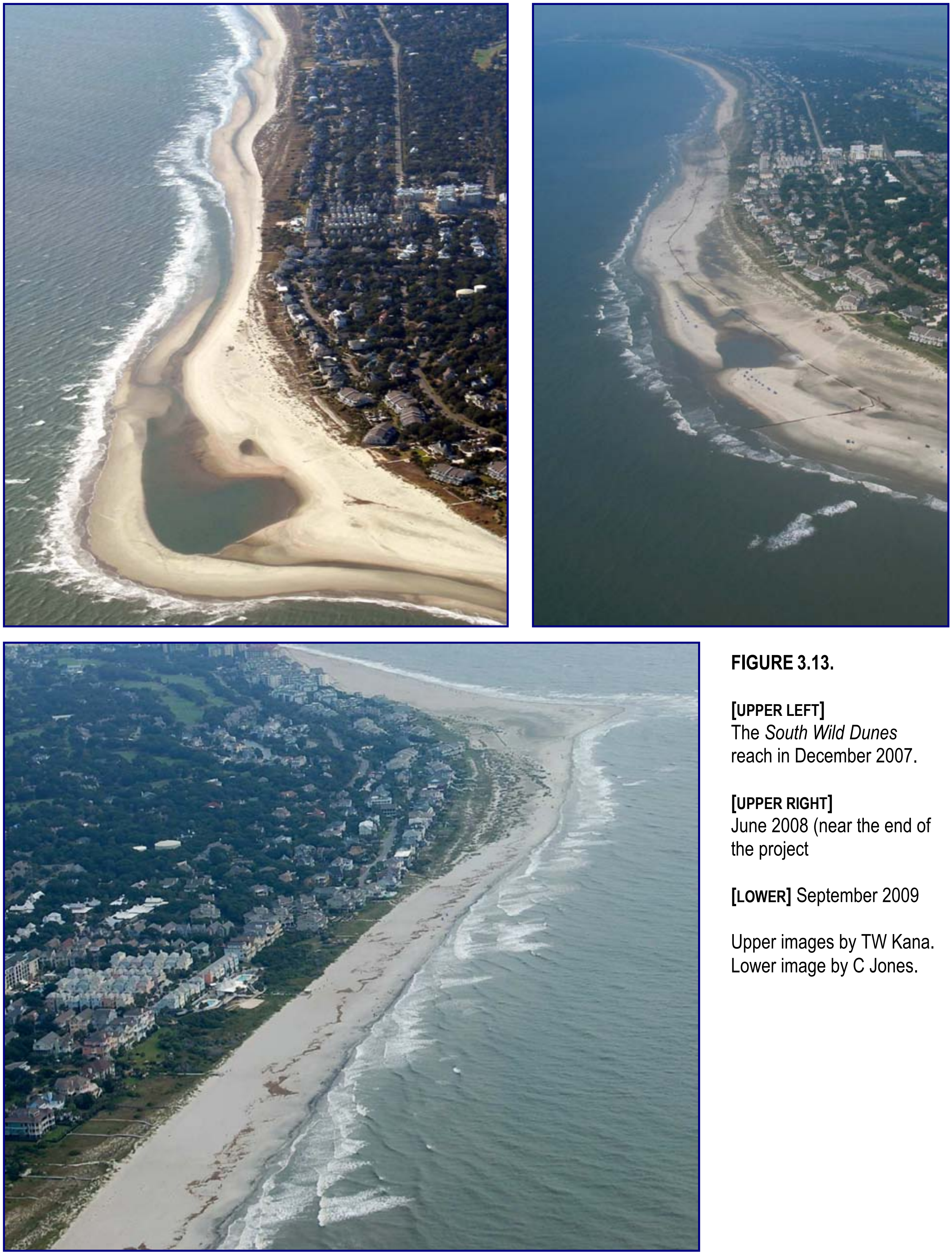


FIGURE 3.13.

[UPPER LEFT]
The *South Wild Dunes* reach in December 2007.

[UPPER RIGHT]
June 2008 (near the end of the project

[LOWER] September 2009

Upper images by TW Kana.
Lower image by C Jones.

The *South Wild Dunes* reach (Fig 3.13, previous page) spans ~6,000 ft between 53rd Avenue and the Wild Dunes Property Owners Beach House (Fig 3.14, stations 222+00 thru 280+00) and encompasses project Reach A. Like the *North Wild Dunes* reach, this area is greatly influenced by shoal-bypass events, especially at the northern end of the reach where the majority of shoals attach to the beach. Prior to the 2008 nourishment, an erosional arc had formed in the area of the Wild Dunes Grand Pavilion (Fig 3.15, station ~248+00). Erosional arcs are typical in areas adjacent to shoal attachment sites because of wave refraction and sediment transport reversals, which drive sand from these areas into the lee of the shoal during Stages 1 and 2 of the shoal-bypass cycle. Immediately prior to nourishment, the "2006" shoal had completely attached (Stage 3) at the northern end of the reach, and sand was beginning to spread into the eroded areas.

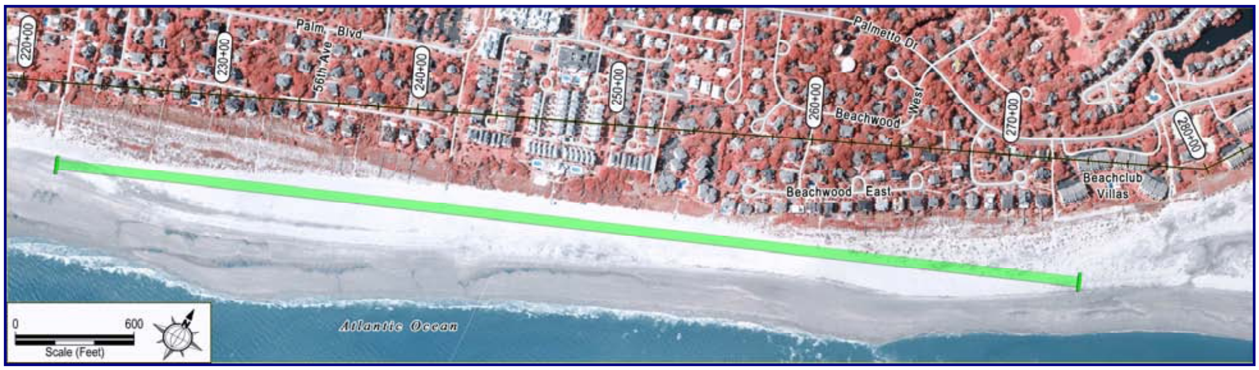


FIGURE 3.14. The *South Wild Dunes* reach spans from 53rd Avenue (station 222+00) to the Wild Dunes POBH (station 280+00). The approximate limits of nourishment Reach A are identified by the green bar. March 2009 aerial image by Independent Mapping Consultants Inc.

The *South Wild Dunes* reach gained ~627,000 cy of sand between March and July 2008, which includes nourishment and natural accretion from the shoal attachment (cf – Table 3.2). The design volume was 270,000 cy, and CSE estimates ~341,000 cy of sand were added to the project area between March and July 2008. [Note the project reach limits differ from the monitoring reach, producing the difference in accretion numbers.] Design fill unit volumes were ~75 cy/ft throughout area A, decreasing in the taper sections. Dry beach width increased up to ~225 ft in this reach.

The northern portion of the *South Wild Dunes* reach was highly erosional prior to the nourishment project, losing up to 45 cy/ft between July 2007 and March 2008 (Fig 3.16). The rest of the reach was more stable, gaining sand at most stations. Erosion prior to the project was due to spreading of the "2006" shoal, which was attached to the beach in 2007 at the northern end of the reach. The bulge of sand created an unnatural shape in the shoreline until wave action worked this area into a straighter shoreline between 2007 and 2008.

Since the project in June 2008, emergence of a new shoal off the Wild Dunes Property Owners Beach House has caused the northern two-thirds of the reach to erode further as sand from this area was deposited in the area directly behind the attaching shoal (in the *North Wild Dunes* reach). As of September 2009, stations 248-278 (eastern end of Grand Pavilion to Wild Dunes Property Owners Beach House) retain less volume than the post-nourishment condition. The majority of erosion occurred between July 2008 and March 2009. An example profile showing the decrease in erosion rates is station 256, which eroded at a rate of 54.0 cy/ft/yr between July 2008 and March 2009, and then only eroded at 5.8 cy/ft/yr between March and September 2009 (Fig 3.17). Stations 266-278 (Dunecrest Lane to Wild Dunes Property Owners Beach House) currently contain lower sand volumes compared to the pre-nourishment condition.

FIGURE 3.15. The *South Wild Dunes* reach in September 2007 (upper) and March 2009 (lower). Note the erosional arc in the 2007 image adjacent to the Wild Dunes Grand Pavilion (center of image). Wave refraction around shoals causes sand to erode from areas adjacent to the attachment site (right edge of image), producing the erosional arcs. Following nourishment in 2008, another shoal attachment event caused erosion along portions of the project area. The project was designed to provide sufficient sand to withstand erosion associated with small-scale bypass events in the next decade. The uncertainty about project performance centers mainly on the scales of change associated with large-scale shoal-bypassing events.

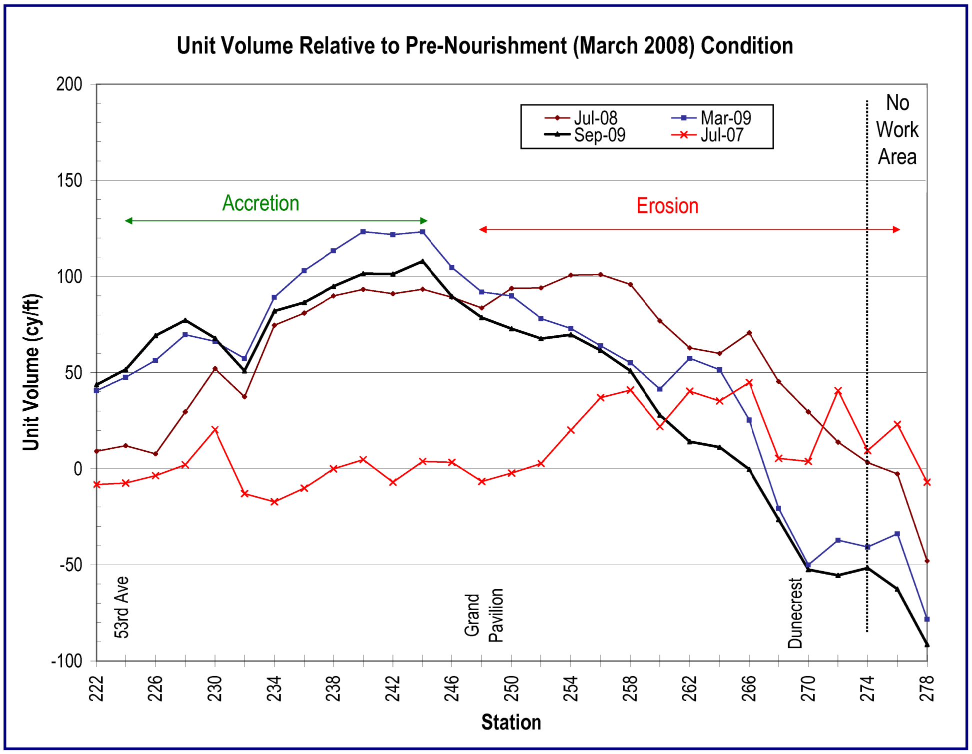


FIGURE 3.16. Profile unit-width volumes in the *South Wild Dunes* reach, compared to the pre-nourishment condition of March 2008. Erosion in the northern part of the reach (stations 250-278) is associated with the attachment of the current shoal-bypass event and should lessen or reverse to accretion now that the shoal is in Stage 3 of the bypass cycle.

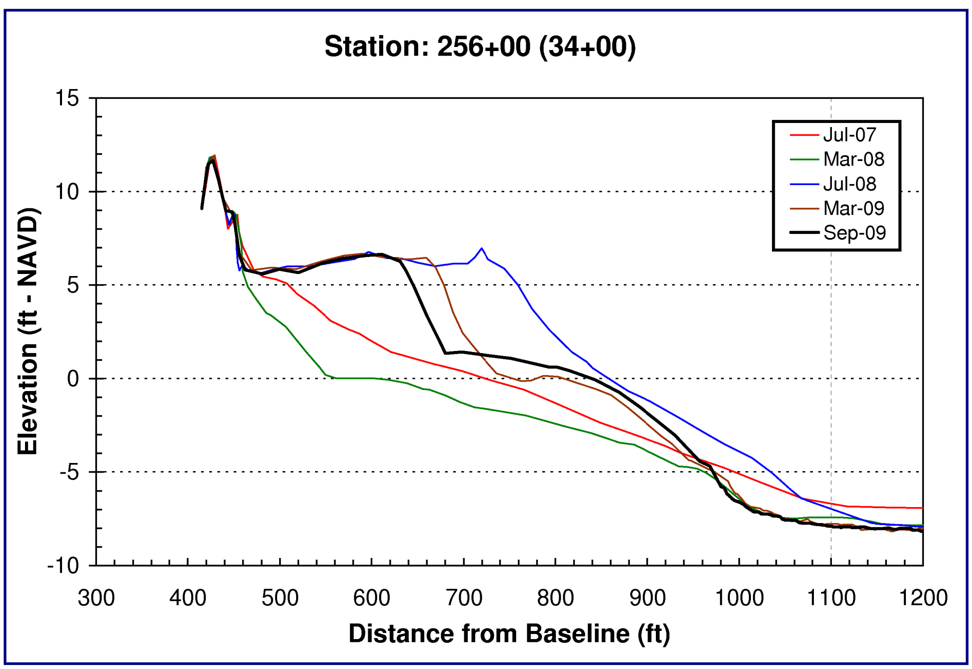


FIGURE 3.17. Profiles from station 256+00 in the *South Wild Dunes* reach. This area initially eroded rapidly while the current shoal-bypass event was in Stage 2. Now that the shoal is attached (Stage 3), the erosion trend should slow or reverse to accretion.

Despite recent erosion along the northern half of the reach, a wide dry beach area and growing dunes still exist because of the influx of sand associated with the first (2006 attachment) shoal. At least 300 ft of beach/dunes exist between the high tide line and structures in the reach. The new ("2008") shoal was completely attached by September 2009, and sand had begun to spread from the shoal as evident in the reduced erosion rates. CSE expects reduced erosion followed by accretion in areas adjacent to the attached shoal as waves continue to work the area over the next year.

Overall, the *South Wild Dunes* reach has lost ~75,000 cy of sand since July 2008 with ~70,000 cy of that lost between March and September 2009. Even though the time period between March and September 2009 showed a high net loss, volume changes were more consistent than the previous period. Between July 2008 and March 2009, stations 222-248 (53rd Avenue thru the Grand Pavilion) gained an average of 26.0 cy/ft, while stations 250-278 (eastern end of Grand Pavilion to Wild Dunes Property Owners Beach House) lost an average of 34.8 cy/ft. By comparison, the respective stations lost an average of 7.5 cy/ft and 16.0 cy/ft between March and September 2009. Large fluctuations in volumes are expected immediately following nourishment as the beach fill equilibrates with the surrounding shoreline. In the case of the Wild Dunes' reaches, the changes are further impacted by the "2008" shoal-bypass event.

Within the 2008 project Reach A, ~96,500 cy of sand were lost between July 2008 and September 2009 (cf – Fig 3.7). The project area currently retains an average of 45.8 cy/ft more sand than the pre-nourishment condition, compared to 64.4 cy/ft more sand immediately post-nourishment. In March 2009, 90.4 percent of the nourishment volume remained in the project area. This reduced to 71.1 percent in September 2009 (Fig 3.18). Again, CSE expects sand to migrate from the shoal attachment site to areas which eroded over the past year. The volume may not fully restore all sections to post-nourishment conditions, but should significantly widen some portions of the beach.

FIGURE 3.18. View northeast from station 254+00 (adjacent to Seagrove Villas) prior to the project in October 2007 (upper) and views northeast (lower left) and southwest (lower right) in September 2009. An erosional arc associated with the 2006 shoal-bypass event had formed in this area prior to the project (see Fig 3.15).

Isle of Palms Volume Changes

The Isle of Palms (IOP) monitoring reaches represent the central portion of the island and have historically been stable to accretional over the past several decades. The reaches are considered to be outside of the influence of Dewees and Breach Inlets and are classified as "S" for standard erosion zones by SCDHEC-OCRM. Erosion/accretion signatures along "S" zones tend to be predictable in the long term. Short-term changes in sand volume are generally smaller in magnitude than in areas close to inlets.

For the present report, CSE defined three reaches along the central Isle of Palms shoreline, designated as "*IOP North*," "*IOP Central*," and "*IOP South*." Together, they represent 17,810 ft of shoreline between 6th and 53rd Avenues (Fig 3.19). CSE established new profile stations at 1,000-ft spacing as well as reoccupied monuments established by SCDHEC-OCRM, which have been surveyed generally every year since the early 1990s. CSE profiles were obtained in March and September 2009 as part of the present monitoring agreement between the City and CSE.

From March 2009 to September 2009, the three reaches lost ~34,000 cy of sand over the ~18,000-ft of shoreline represented. This translates to a unit volume change of 1.93 cy/ft (erosion) which is opposite the historical trend (cf – Fig 1.3). Unit volume changes from March to September 2009 are shown for each profile in Figure 3.20. The likely cause of the erosion is the interruption of longshore transport of sand from the northeastern end in recent years as the two bypassing events have trapped sand during the attachment process. Now that the shoals have attached, new sand from the shoal (as well as nourishment sand) is available to feed downcoast areas. Detailed volume changes for each of the three reaches follows.

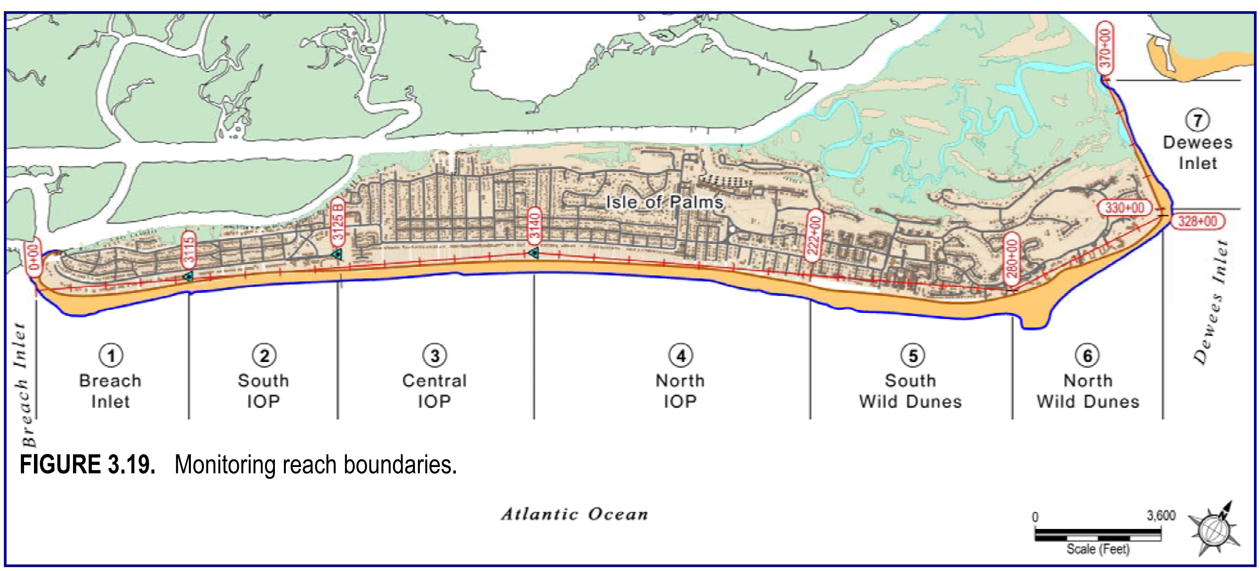


FIGURE 3.19. Monitoring reach boundaries.

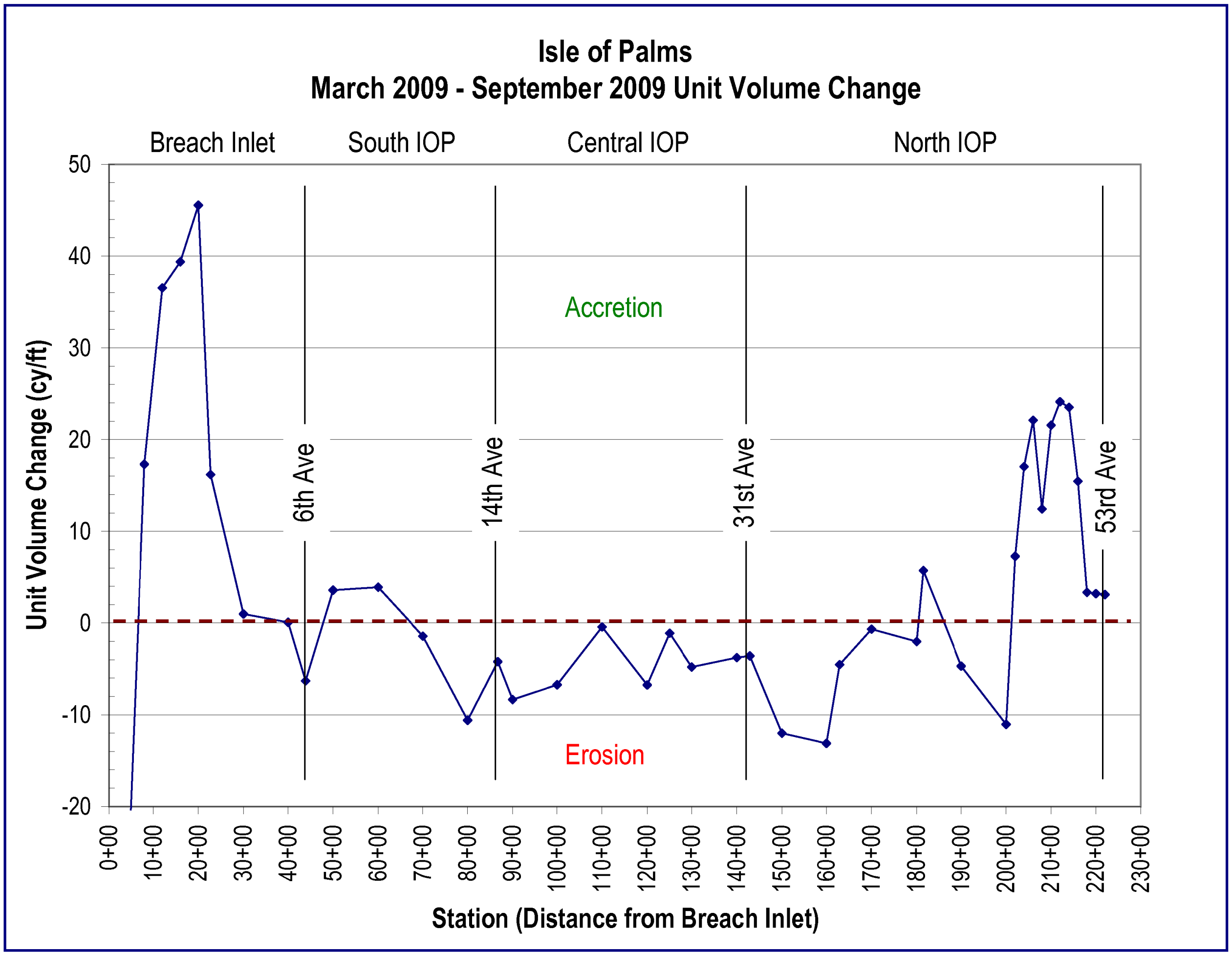


FIGURE 3.20. Profile unit-width volume change (cy/ft) between March and September 2009 for the *Isle of Palms* and *Breach Inlet* reaches. CSE established and surveyed profiles spaced 1,000 ft apart in the Isle of Palms reaches and reoccupied monuments surveyed annually by SCDHEC-OCRM. Historically, these reaches have been accretional; however, between March and September 2009, most stations outside of the influence of the inlet or project were erosional. Change is relative to the March 2009 condition.

North Isle of Palms

The *IOP North* reach encompasses the beach between 31st Avenue and 53rd Avenue (stations OCRM 3140 to CSE 222+00, Fig 3.21). It showed the lowest erosion rate of the three IOP reaches, even though three of the profiles in the reach eroded at over 10 cy/ft. The 7,910 ft reach lost only ~1,800 cy (0.2 cy/ft) as a whole, but volume change was not consistent over its length. Erosion dominated the beach between OCRM station 3140 and CSE 200+00 (31st Avenue to the Citadel beach house), a length of ~5900 ft (Fig 3.22). Accretion from station 202 to station 222 (between the Citadel beach house and 53rdAve) offset the losses in the southern portion of the reach. Stations 202-222 gained 29,569 cy (14.8 cy/ft), while the rest of the reach lost 31,431 cy (5.3 cy/ft). The accretion at the northern end of the reach is an indicator of sand spreading downcoast from the nourishment area. As of September 2009, profiles suggest that sand from the project area has moved ~2,000 ft downcoast. CSE will continue to track the quantity and rate of sediment transport to downcoast areas of the Isle of Palms.

CSE conducted the September 2009 survey during an extreme high tide. Photos (Fig 3.23) suggest that little dry beach is present; however, under normal tide conditions, there is a dry beach 20-30 ft wide at most stations in the reach. Wider berms are present near the project area where sand is moving into the reach from upcoast. Historical accretion in all of this reach (combined with sufficient setbacks for development) has led to a substantial dune system between most structures and the beach. As long as there is slow, steady accretion, the foredune will continue to build wider and higher, offering more storm protection to property behind the dunes. In future monitoring reports, CSE will provide estimates of the level of protection afforded by the dune system by determining the volume of sand above potential storm-surge levels.

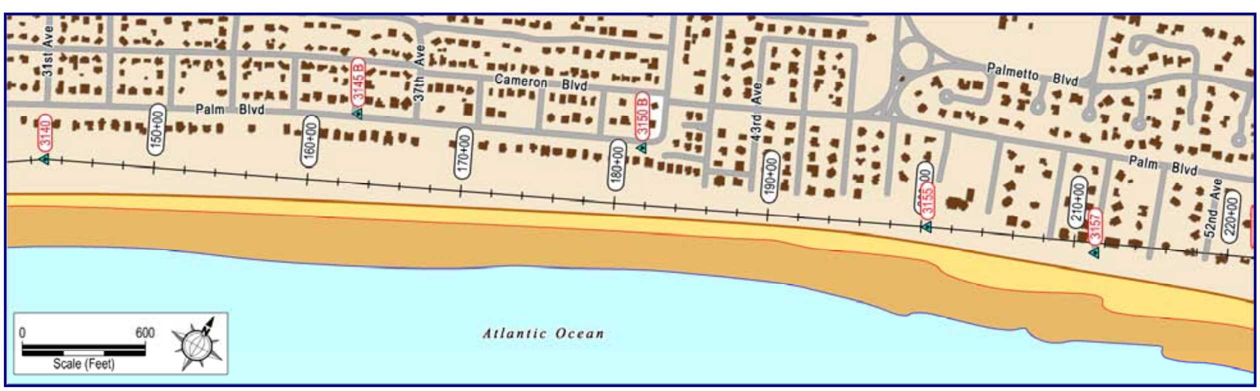


FIGURE 3.21. The *IOP North* reach spans from stations OCRM 3140 (31st Avenue) to CSE 222+00 (53rd Avenue).

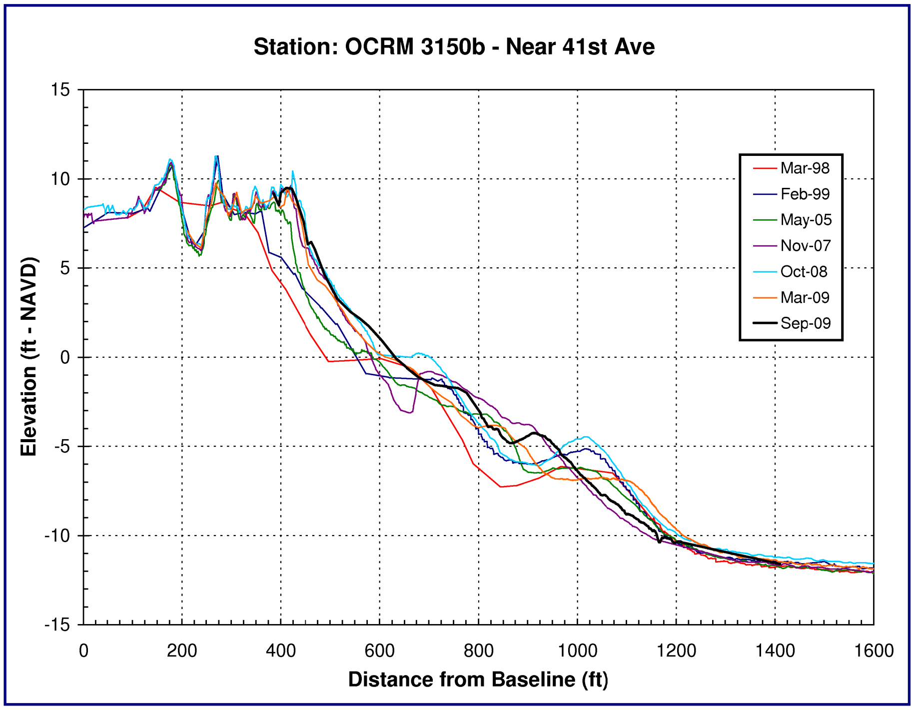


FIGURE 3.22. Profiles from OCRM station 3150b in the *IOP North* reach showing an accretional trend over the last ten years. [Profiles prior to March 2009 courtesy OCRM.]

FIGURE 3.23.

[UPPER]
View southwest from 53rd Avenue in March 2009. Sand is moving from the project area downcoast, building the beach at this location.

[LOWER]
Views from station 170+00 (~38th Avenue) in September 2009. Extreme spring tides cause the beach to look eroded; however, this station remained stable between March and September 2009.

Central Isle of Palms

The *IOP Central* reach spans the oceanfront between the pier and 31st Avenue (OCRM monuments 3125 – 3140, Fig 3.24). As previously mentioned, the long-term trend in this area is stable to accretional. Profiles from OCRM station 3135 (near 27th Avenue) show the beach in this area has gained ~40 ft in width at the +5 ft NAVD contour (Fig 3.25) over the past ten years. A similar trend is evident at OCRM station 3125 (14th Avenue) with dune growth and beach widening over the past ten years.

Opposite from the historical trend, the *IOP Central* reach was the most erosional of the IOP reaches between March and September 2009. As a whole, the reach lost ~25,600 cy (4.6 cy/ft). Profile volume change ranged from −0.43 cy/ft to −8.35 cy/ft for the stations in this reach. Erosion in this area (as well as in all the IOP reaches) is likely due to the recent shoal attachment events at the north-eastern end of the island. The process interrupts the natural, longshore-sediment transport pattern, which generally moves sand from northeast to southwest. CSE expects downcoast areas to slowly transition from erosional to accretional over the next few years as sand spreads from the present shoal-bypass zone. Figure 3.26 shows the beach condition in September 2009.

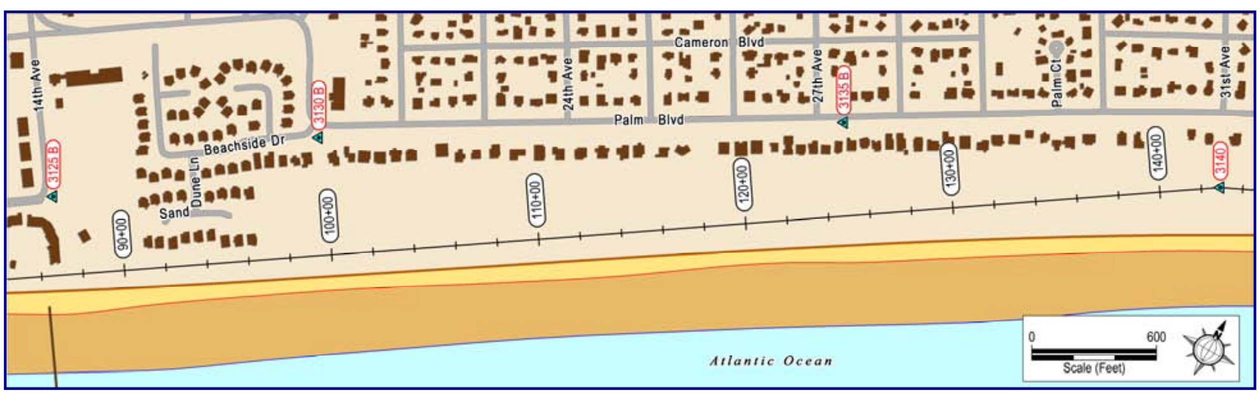
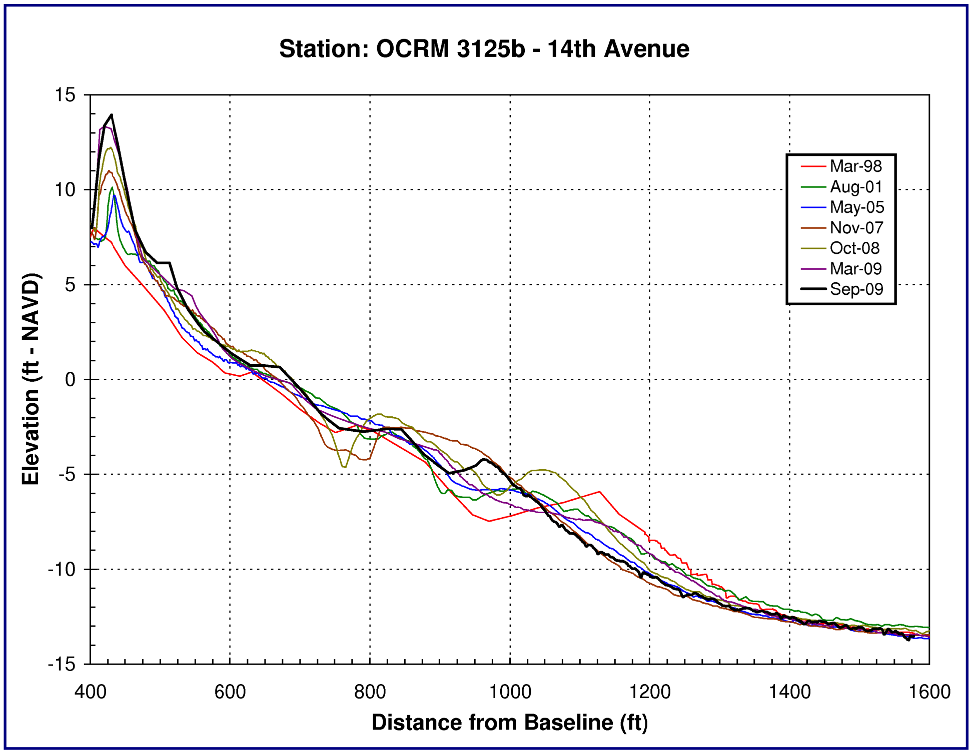


FIGURE 3.24. The *IOP Central* reach spans from stations OCRM 3125 (pier) to OCRM 3140 (31st Avenue).



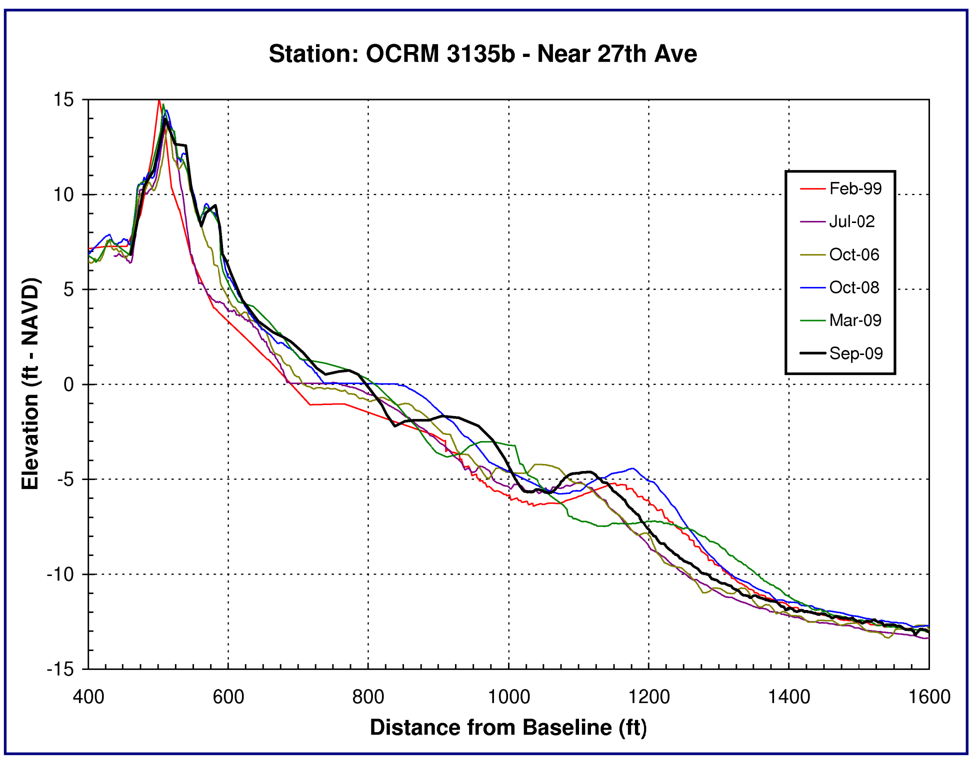


FIGURE 3.25. Profiles from OCRM station 3125 (upper) and OCRM station 3135 (lower), showing long-term accretion despite erosion in 2009. Protective dunes reach to +15 ft NAVD in this area and have been building since 1998. [Profiles prior to March 2009 courtesy SCDHEC-OCRM.]

FIGURE 3.26. Views northeast (upper) and southwest (lower) of station 110+00 in the *IOP Central* reach (vicinity of 24th Ave). No scarping is present in the dunes, even under spring tide conditions, indicating a healthy supply of sand in the area.

South Isle of Palms

The *IOP South* reach spans 4,280 ft between 6th Avenue and the pier (OCRM monuments 3115 – 3125, Fig 3.27). The two southernmost stations (7th and 8th Avenues) gained an average of 3.74 cy/ft, while the other stations in this area eroded an average of 6.12 cy/ft between March and September 2009. Total volume loss was 6,870 cy (1.6 cy/ft) over the reach. OCRM station 3115 (6th Avenue) has been fairly stable since 2002 (Fig 3.28) as evident in the growth of the dunes. As of September 2009, station 3115 contained ~1.5 cy/ft more sand than the July 2002 condition; however, the March 2009 condition showed 8.2 cy/ft more sand than the 2002 condition. A small scarp was present in September 2009 near station 60+00 (8th Avenue). It was ~6 inches high and was likely caused by the high spring tide around the time of CSE's data collection (Fig 3.29).

Long-Term Trends in the IOP Reaches

CSE used profile data collected by the state of South Carolina to determine long-term volume change along the central portion of the Isle of Palms (between 6th Avenue and 41st Avenue). The State has collected profiles since the 1980s; however, only since 1998 have the profiles encompassed the entire beach profile to closure depth (the depth at which measurable change in the bottom approaches zero). CSE reoccupied OCRM monuments in March and September 2009, and combined those data with the State profiles to produce an ~11-year record of sand volume.

Profile volumes from 1998 to 2009 are shown in Figure 3.30 for the OCRM stations in the IOP reaches (away from the influence of tidal inlets). The plot shows generally increasing unit volumes at each station with the 2009 condition always showing greater volume than the 1998 condition. Two instances where erosion was present at the majority of stations were between 2001 and 2002, and between 2008 and 2009. Between August 2001 and July 2002, the stations lost an average of ~20 cy/ft; however, it should be noted that the offshore data from August 2001 is anomalously higher than other dates, suggesting that the data may contain an error. True volumes are likely less than those calculated for August 2001, which would reduce the erosion measured from these profiles between 2001 and 2002. CSE calculated the long term accretion rate with and without the August 2001 data. **The 11-year trend for average unit volume change in the IOP reaches is 2.9 cy/ft/yr (2.7 cy/ft/yr including the Aug 2001 data) accretion.** The average unit volume decreased by ~15 cy/ft between October 2008 and September 2009.

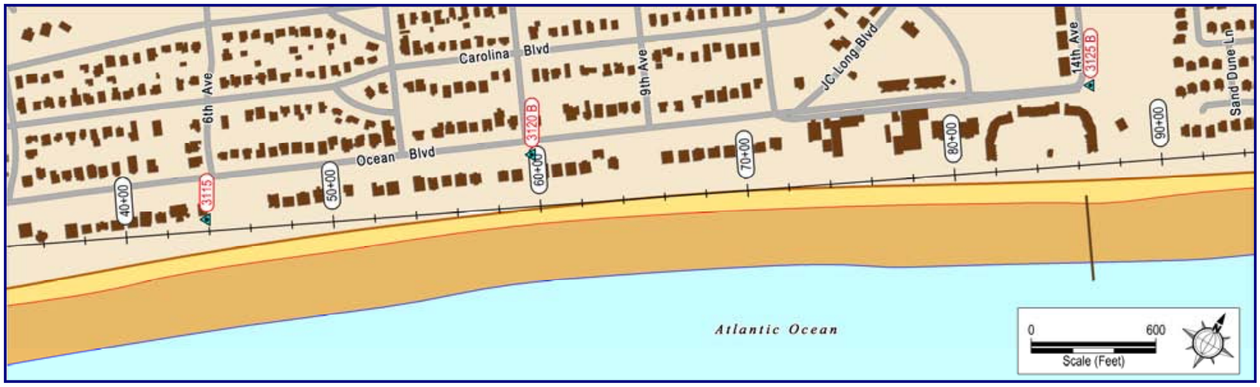


FIGURE 3.27. The *IOP South* reach spans from OCRM 3115 (6th Avenue) to OCRM 3125 (pier).

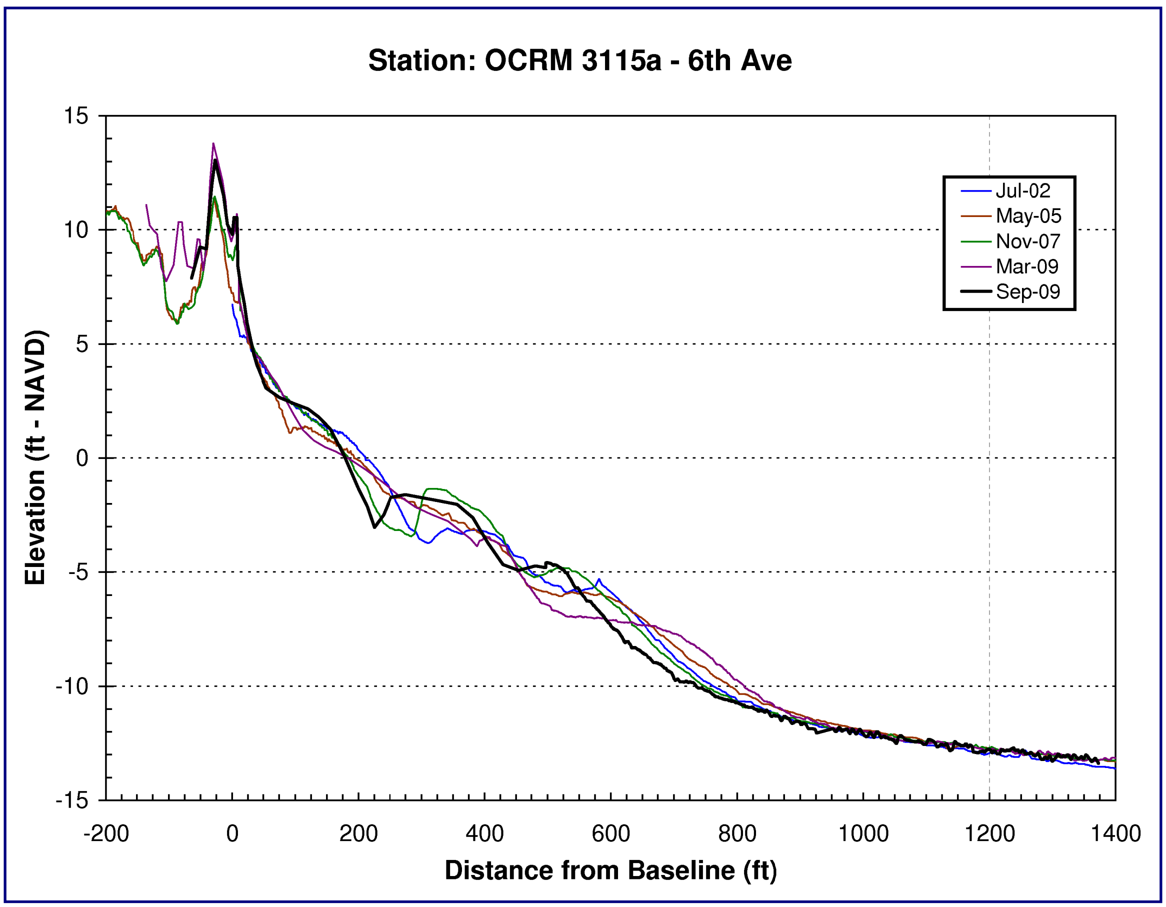


FIGURE 3.28. Profiles from OCRM station 3115 (6th Avenue) in the *IOP South* reach.

FIGURE 3.29. Photos from station 60+00 (8th Ave) in September 2009. Note a small scarp visible seaward of the vegetation line. The scarp is likely the result of high spring tides around the time of the photo. CSE expects this area to rebuild under normal wave and tide conditions.

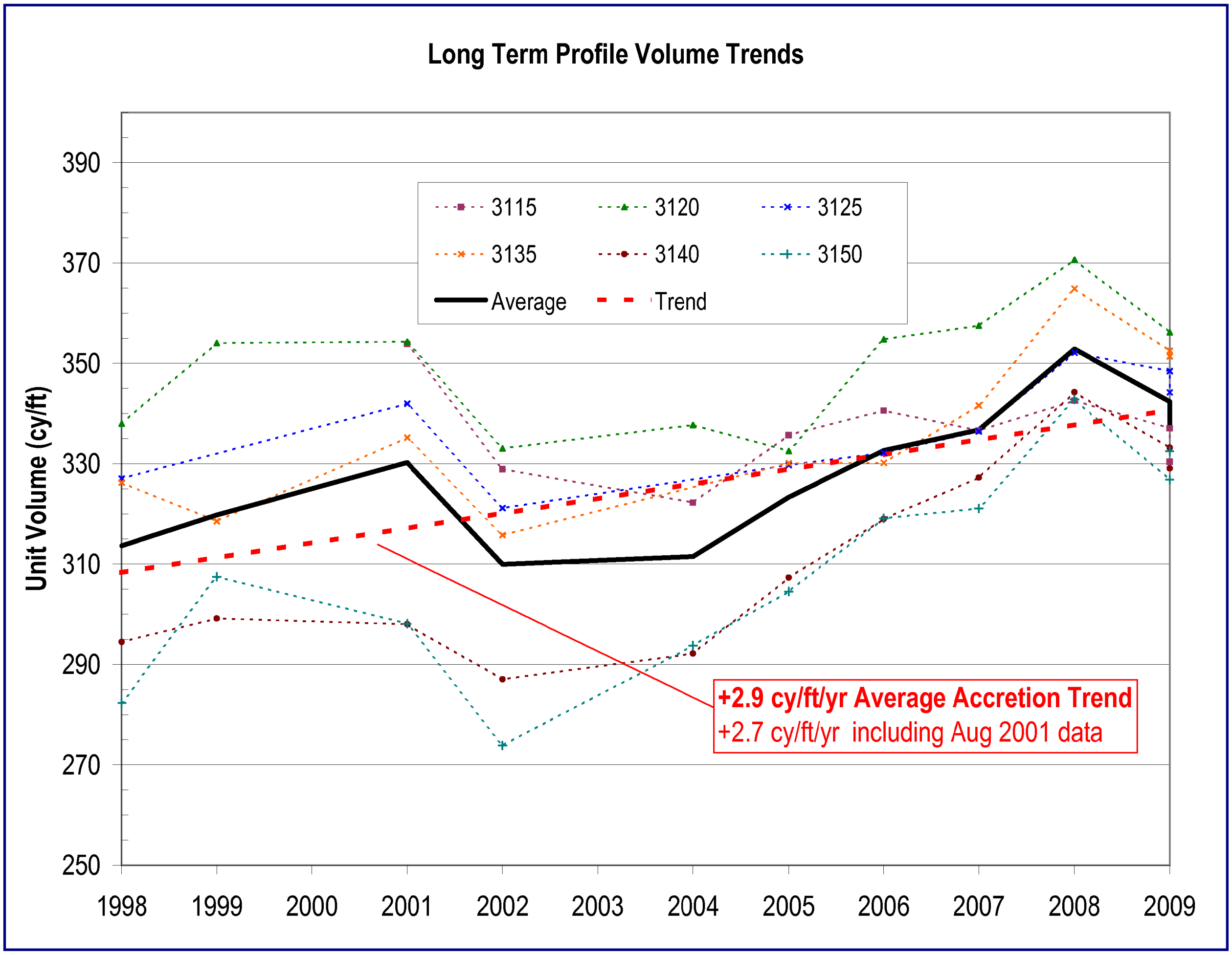


FIGURE 3.20. Long-term volume change in the IOP reaches. Data obtained by the State were used to compute an ~11-year trend showing an average annual accretion of ~2.7 cy/ft/yr between OCRM stations 3115 and 3150.

Breach Inlet

The *Breach Inlet* reach, between Breach Inlet and 6th Avenue (Fig 3.31), is classified as an unstabilized inlet erosion zone due to the dynamic nature of the shoals associated with the inlet delta. While labeled as unstable, the long-term trend for this reach is accretional with an estimated growth of ~8.9 ft/yr (linear beach width). The historical accretion trend in this reach is due to a plentiful sand supply from upcoast and sand trapping by the Breach Inlet ebb-tidal delta. Sand supply originates from shoal-bypass events at Dewees Inlet and longshore sand transport from north to south over the length of the Isle of Palms. Excess sand is deposited along the southern spit of the island (the *Breach Inlet* reach) and in the Breach Inlet ebb-tidal delta. Shoals of Breach Inlet from a protuberance in the shoreline, which backs sand up along the oceanfront much like a terminal groin traps sand. Changes in this area are related to bars from the inlet delta migrating onto the beach or marginal flood channels moving landward or seaward. Such natural processes lead to rapid changes in the beach volume compared to the central IOP reaches.

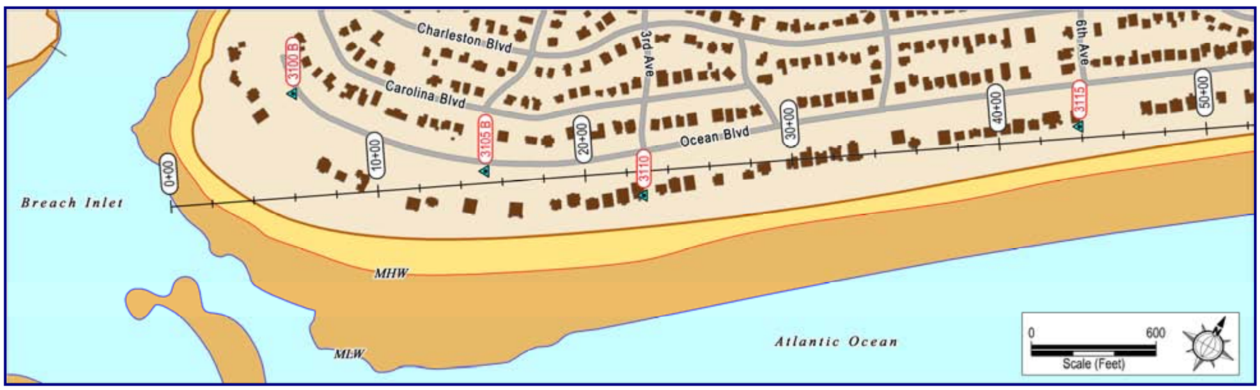


FIGURE 3.31. The *Breach Inlet* reach spans ~4,200 ft from Breach Inlet to OCRM station 3115 (6th Avenue).

Between March and September 2009, the two stations closest to Breach Inlet (0+00 and 4+00) were highly erosional, while the remaining stations in the reach showed accretion. Stations 8+00 through OCRM 3110 (3rd Ave) each gained over 15 cy/ft, including gains over 35 cy/ft for stations 12+00 through 20+00. Stations 30+00 and 40+00 were more stable, only gaining 1.0 and 0.1 cy/ft (respectively). It is difficult to determine the source of sand causing the accretion, but profiles suggest that some of the sand gained is a result of the onshore migration of a bar on the updrift side of the inlet.

The marginal flood channel running north along the beach from Breach Inlet has moved landward at stations 0+00 and 4+00, causing significant reductions in beach volume at those locations. At station 4+00, the landward edge of the channel moved ~200 ft landward between March and September 2009 (Fig 3.32). Channel encroachment reduces the platform which supports the upper beach, causing sand losses in the upper profile. Erosion is visible in the form of an escarpment along the dunes. **This problem is localized and should be temporary given the historical trend of accretion in this area.**

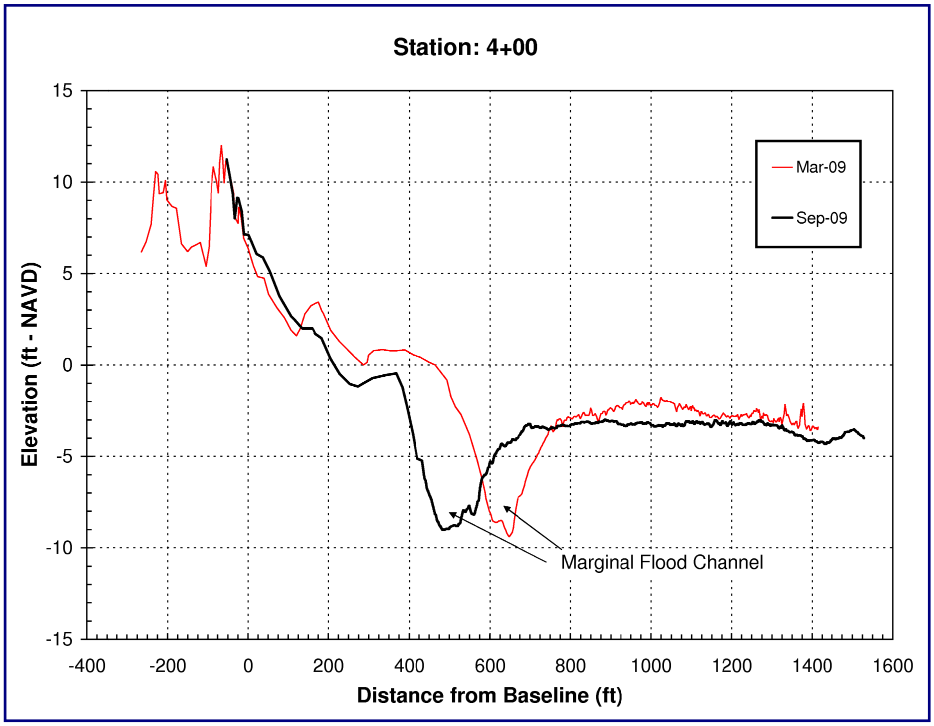


FIGURE 3.21. March and September 2009 profiles from station 4+00 near Breach Inlet. While the upper beach built out between March and September, the lower beach lost a significant volume of sand as the marginal flood channel of Breach Inlet migrated closer to the shore.

Figure 3.33 shows colored digital terrain models (DTMs) of the northeastern shoal of Breach Inlet. It is apparent from the models that the marginal flood channel has migrated landward, causing erosion of the end of the spit (stations 0+00 and 4+00). There appears to be a secondary channel forming further offshore in the September 2009 model. The main (ebb) inlet channel runs to the southwest in front of Sullivan's Island (not visible in the models) while a secondary ebb channel (E on Fig 3.33) is visible in the lower left of the model. The terminus of the secondary channel appears to have migrated to the west. The shoal immediately east of the secondary ebb channel has migrated to the west, causing the ebb channel to narrow and deepen. Future monitoring efforts will track changes in the shoals on the updrift side of Breach Inlet and will attempt to identify the underlying causes of shoreline movement along the *Breach Inlet* reach.

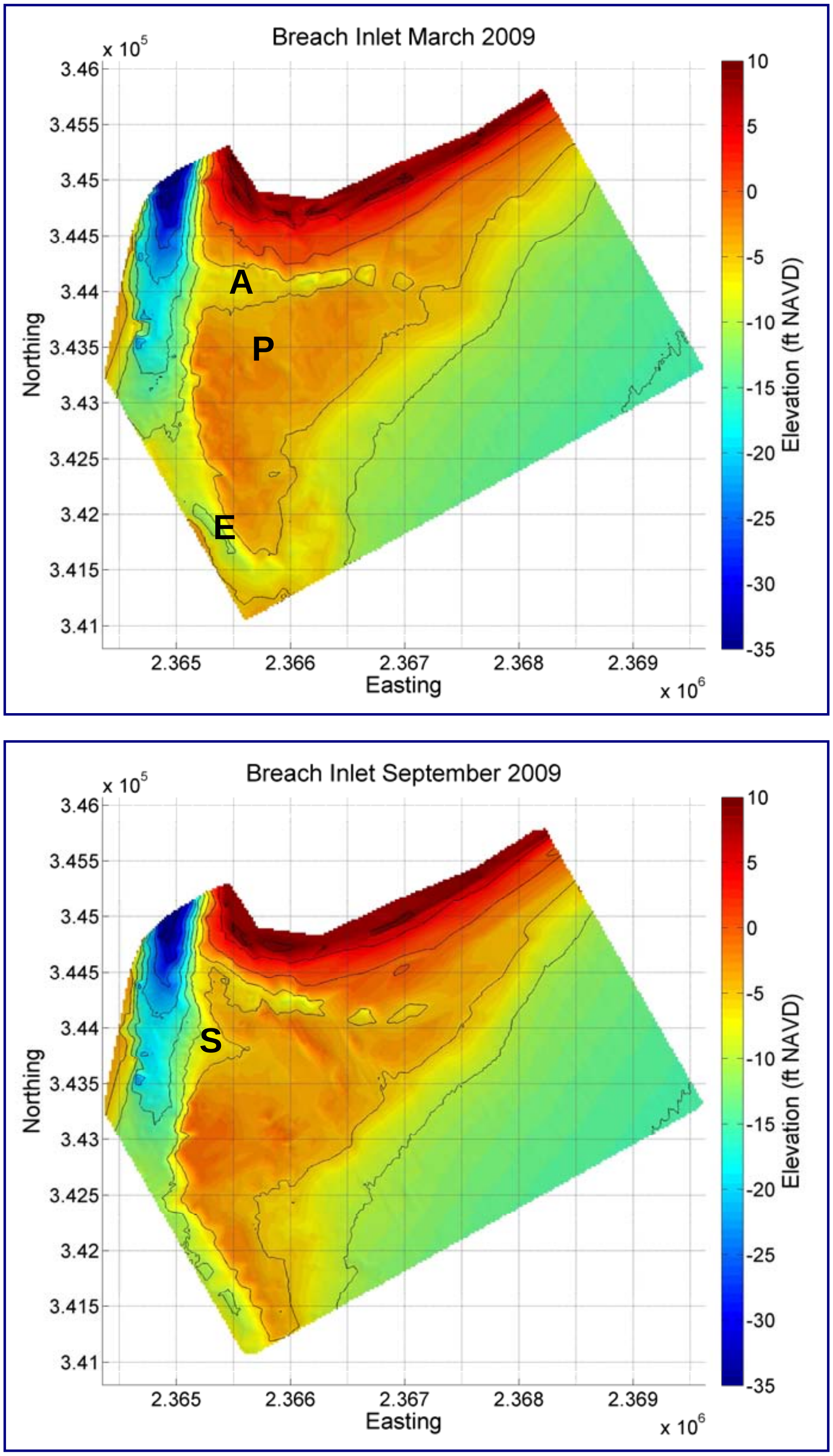


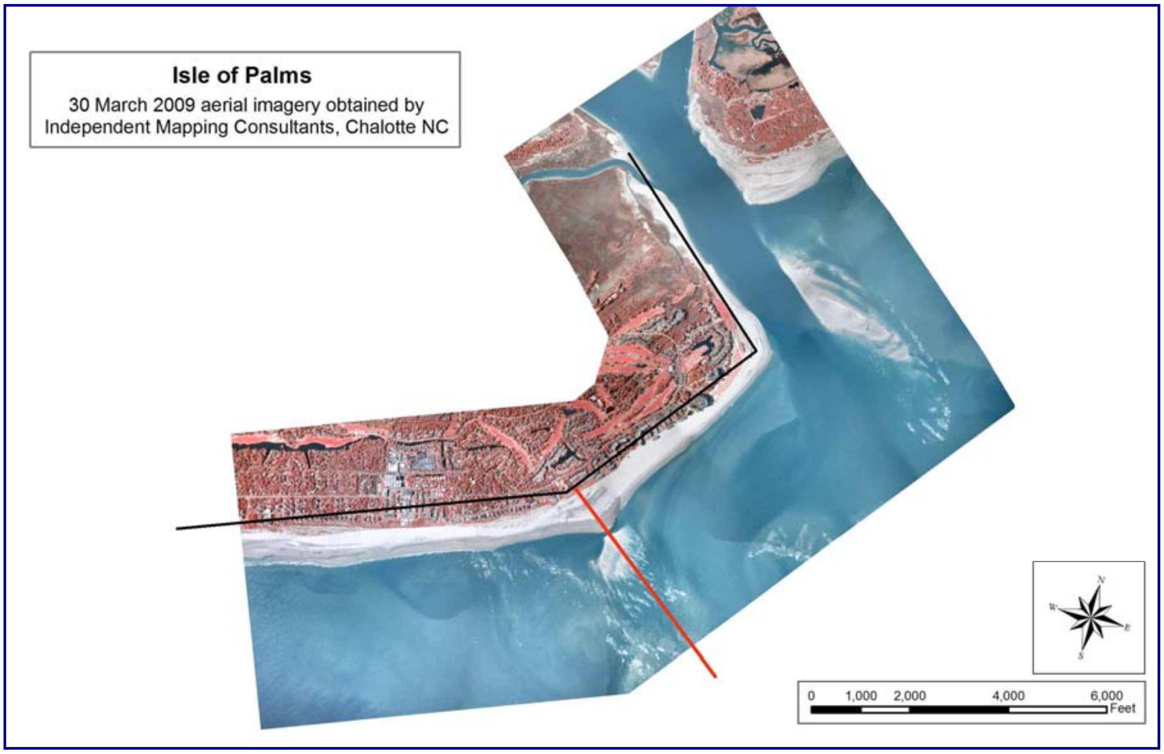
FIGURE 3.33. Colored DTMs of Breach Inlet and neighboring IOP shoreline. Note the marginal flood channel (A) has migrated closer to the beach between March and September 2009. A "spillover lobe" (S) in the lower map is an indicator of an incipient marginal channel across the swash platform (P) of the ebb-tidal delta. The secondary ebb channel (E) of the inlet is at the lower left edge of each image.

Attaching Shoal

Between March and September 2009, a bypassing shoal ("2008" shoal) fully attached to the beach just north of the Wild Dunes Property Owners Beach House. It originated from the same platform of sand as the previous shoal-bypass event, which ultimately led to the need for the nourishment project. In March 2009, the "2008" shoal was separated from the beach by a narrow and relatively deep channel as seen in the 2009 aerial image and profile from station 282+00 (Fig 3.34). Using a digital terrain model (DTM) from the March 2009 monitoring data, CSE estimates that ~330,000 cy of sand came ashore in the "2008" shoal.

The evolution of the "2008" shoal is shown in profiles from station 282+00. In 2007, the "2006" shoal had attached to the beach, leaving an ephemeral lagoon offshore of the Wild Dunes Property Owners Beach House (evident as the sharp dip in red line at ~750 ft). The "2008" shoal was formed at the seaward end of the platform, ~3,500 ft from the baseline. By March 2008, the leading edge of the "2008" shoal was ~2,500 ft from the baseline (data did not extend past 2,500 ft for this date), and the maximum elevation reached −5.0 ft NAVD. The leading edge had migrated ~400 ft by July 2008 and built 1 ft higher. In March 2009, the leading edge was ~1,200 ft from the baseline and only 100 ft from the shoreline. Elevation had increased to −2.0 ft NAVD. The shoal was attached in September 2009, widening the beach by ~200 ft at +5 ft NAVD compared to the July 2008 condition.

The "2008" shoal built from a large platform of sand on the southern side of the Dewees Inlet delta. The platform, which slopes offshore in the vicinity of the Wild Dunes Property Owners Beach House, is estimated to contain over 4.3 million cubic yards of sand. This value only includes the portion of the delta downcoast of the inlet and excludes the offshore shoals to the east and north of the inlet channel. It is likely that this platform will continue to be a source of sand for shoal-bypass events. Shoals are built as sand from the outer portions of the platform is transported landward by wave action. As more sand is added, the shoals build higher which, in turn, causes them to experience more wave energy (breaking waves). Once the shoals become exposed, they are more easily moved shoreward by breaking waves than sand in deeper water. This leads to discrete shoal-bypassing events every few years.



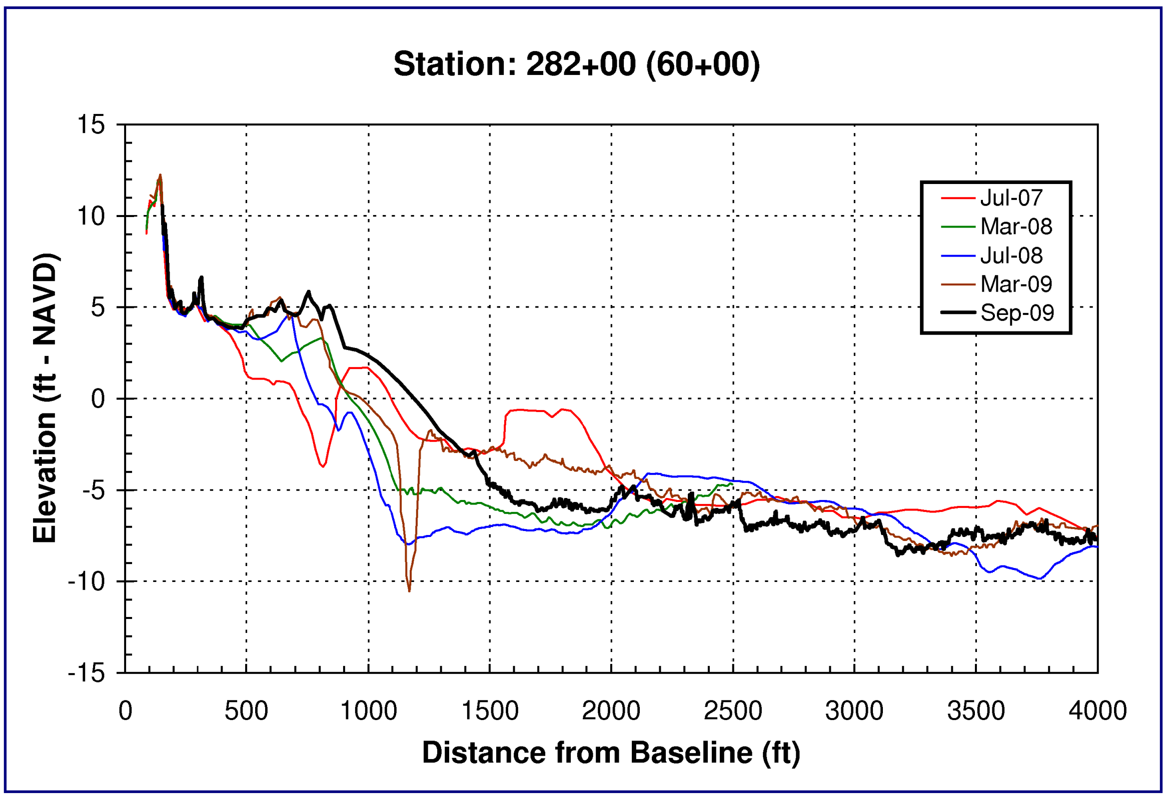


FIGURE 3.34. **[UPPER]** March 2009 aerial image of the northeast end of Isle of Palms. The shoal off the Wild Dunes POBH (red line at station 282+00) was ~100 ft from the shoreline at this time and was completely attached by September 2009. **[LOWER]** Profiles from station 282+00 near the Wild Dunes POBH show the landward migration of the 2009 shoal. Note the "2006" shoal (red line) attached to the shoreline with an ephemeral lagoon in July 2007 and completely welded to the beach in March 2008 (green line).

As of September 2009, the “2008” shoal had completely attached to the shoreline and was beginning to spread sand to adjacent areas. Erosion associated with the present bypass event should lessen and eventually produce accretion. Ideally, the ~330,000 cy would spread into the areas eroded prior to attachment, including the northern portion of the *South Wild Dunes* reach near Dunecrest Lane and Beach Club Villas as well as eroded portions of the *North Wild Dunes* reach near Seascape and Ocean Club. As of September 2009, there was no obvious shoal offshore, but the swash platform off the Wild Dunes Property Owners Beach House remains large and continues to modify incoming waves. There appears to be significant changes in the size and location of the main channel of Dewees Inlet, which leaves the potential for shoal-bypass events of large magnitude in the near future. This will be discussed in the following section.

Dewees Inlet and Delta

Dewees Inlet’s ebb-tidal delta is the sand source responsible for the historical accretion along the Isle of Palms. The seaward end of the main channel is deflected to the south due to dominant wave forcing from the northeast driving sand to the southwest. The southerly deflection results in the large platform of sand in the nearshore of the northeastern end of the island (discussed in the previous section). The channel is bounded by a large sand shoal on the northeast and southeast, separated by a secondary channel which runs parallel to the inlet (between Isle of Palms and Dewees Island). The cross-sectional area of the inlet (measured at station 362+00) is ~35,000 square feet (ft^2) (3,250 m^2) and shows long term stability.

Monitoring efforts by CSE reveal that the delta of Dewees Inlet is changing in several important ways. Figures 3.35 and 3.36 show DTMs of the inlet in July 2007, July 2008, March 2009, and September 2009 with features of interest labeled:

A) Dewees Inlet main channel.

B) The shoal platform and site of recent bypass events.

C) Offshore shoal on the seaward limit of the Dewees Inlet main channel.

D) Secondary (incipient) Dewees Inlet channel and its associated spillover lobe.

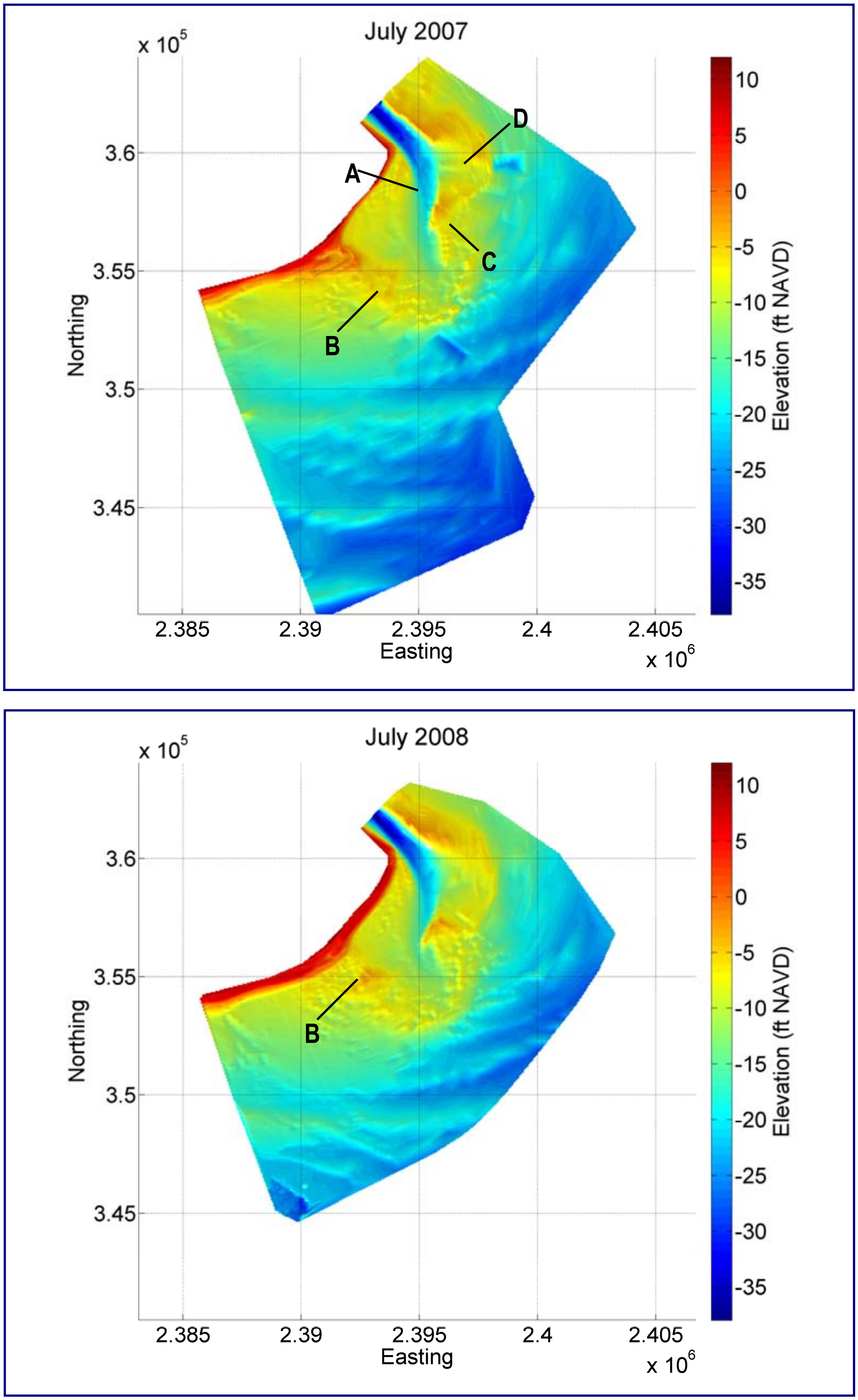


FIGURE 3.35. DTMs from July 2007 (upper) and July 2008 (lower) showing changes in the shoals of the Dewees Inlet ebb-tidal delta. Labels are described in the text.

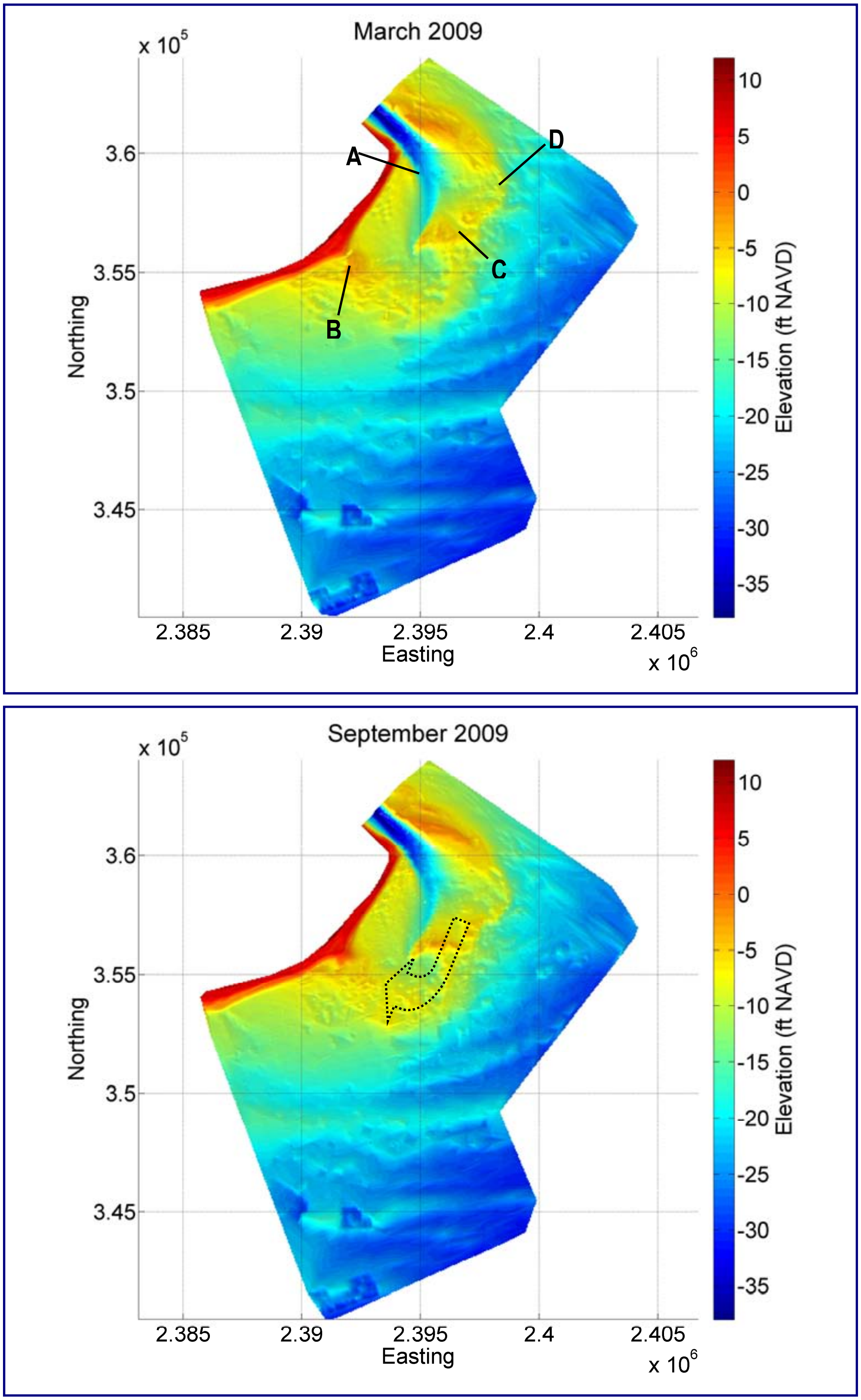


FIGURE 3.36. DTMs from March (upper) and September (lower) 2009 showing changes in the shoals of the Dewees Inlet ebb-tidal delta. Labels are described in the text. The general sand transport pathway is highlighted by the arrow. Borrow areas for the project are the small deep-blue patches at the lower corners of the DTMs.

Changes in the morphology are evident in the series of DTMs from 2007 to 2009. Of note is that there currently is no pronounced shoal directly offshore of the Wild Dunes Property Owners Beach House. However, the sand platform remains extensive and is likely to produce an emergent shoal in the next few years. The “2008” shoal attachment cycle is evident in the series of DTMs, beginning with a low, flat area trailing the “2006” shoal event. In July 2008, the shoal (B) is more organized, though still submerged at low tide (cf – Fig 3.35, lower). By March 2009, the shoal is subaerial (ie – exposed at low tide), and is only separated from the beach by a narrow but deep channel. The downcoast edge of the shoal spreads more laterally than the upcoast side and remains detached for longer. The shoal is attached by September 2009, though the downcoast side is still offshore in the form of a sandbar. The sheltered area on the downcoast side of an attachment is typical and is caused by southerly longshore sediment transport.

The main channel of Dewees Inlet (A) is deflected to the south, running more parallel to the island’s coastline before turning offshore. It is apparent from the DTMs that the shoal on the eastern boundary of the channel (C) is migrating to the southwest and infilling the outer portion of the main channel. The leading edge of the shoal moved ~1,400 ft to the southwest between July 2007 and September 2008. The seaward boundary of the channel has also moved closer to the beach, as shown in the profile from station 308+00 (Fig 3.37). At that locality, the channel has migrated ~1,200 ft toward the beach since July 2007. CSE estimates that as of September 2009, ~500,000 cy of sand have shifted into the area occupied by the July 2007 channel. The actual width of the channel has decreased from ~2,000 ft wide to only ~800 ft wide at station 308+00 (Fig 3.37). Widths near the outer limits of the channel have decreased even more.

Figure 3.38 shows a profile beginning at the beach near the Wild Dunes Property Owners Beach House and running east through the mouth of the main inlet channel. This profile offers a better understanding of how the outer end of the channel appears to be closing. In July 2007, the mouth of the channel was roughly 1,200 ft wide and reached to −17 ft NAVD in elevation. The width decreased to ~700 ft by July 2008, and the elevation reached only to −15 ft NAVD. As of September 2009, the channel width was further reduced to ~500 ft, though the elevation remained similar to the 2008 condition. The seaward boundary of the channel migrated ~1,000 ft closer to the shore (note the profile is not perpendicular to the shoreline) between July 2007 and September 2009.

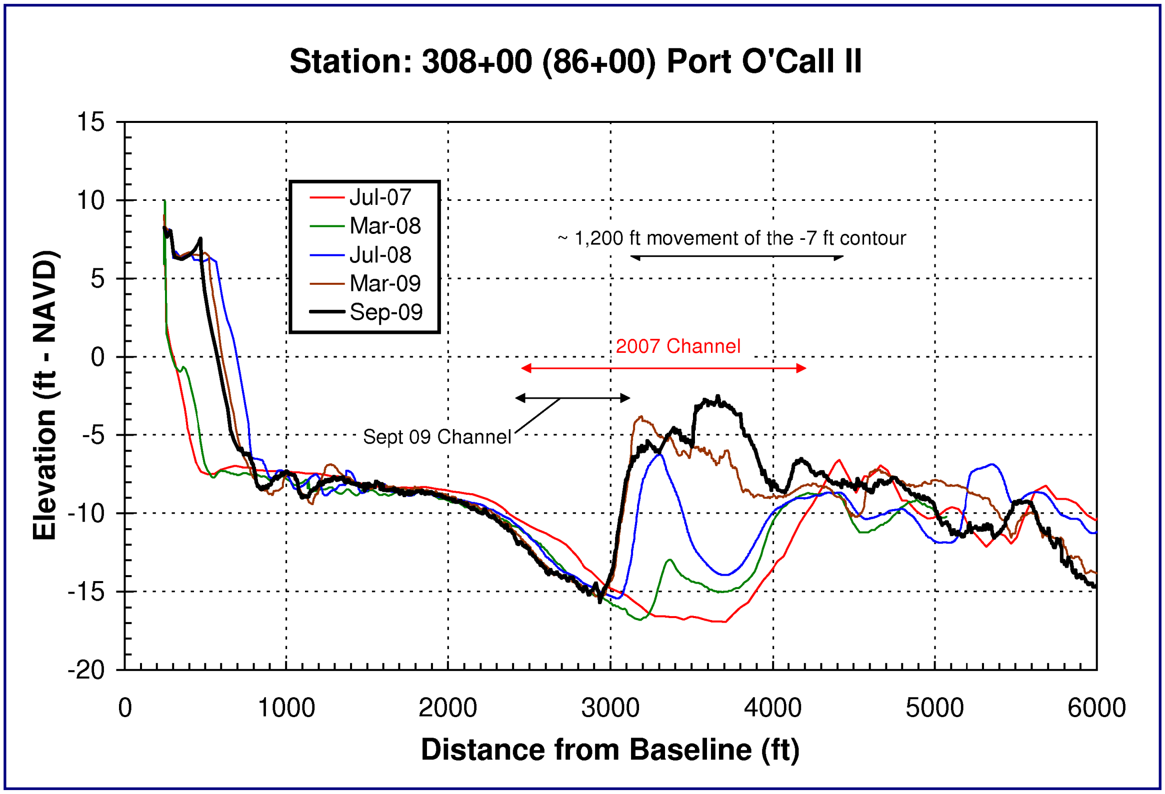


FIGURE 3.37. Profile from station 308+00 showing landward movement of the outer lobe of the ebb-tidal delta on the seaward side of the Dewees Inlet main channel. The shoal moved ~1,200 ft closer to the beach between July 2007 and March 2009, but migrated little between March and September 2009.

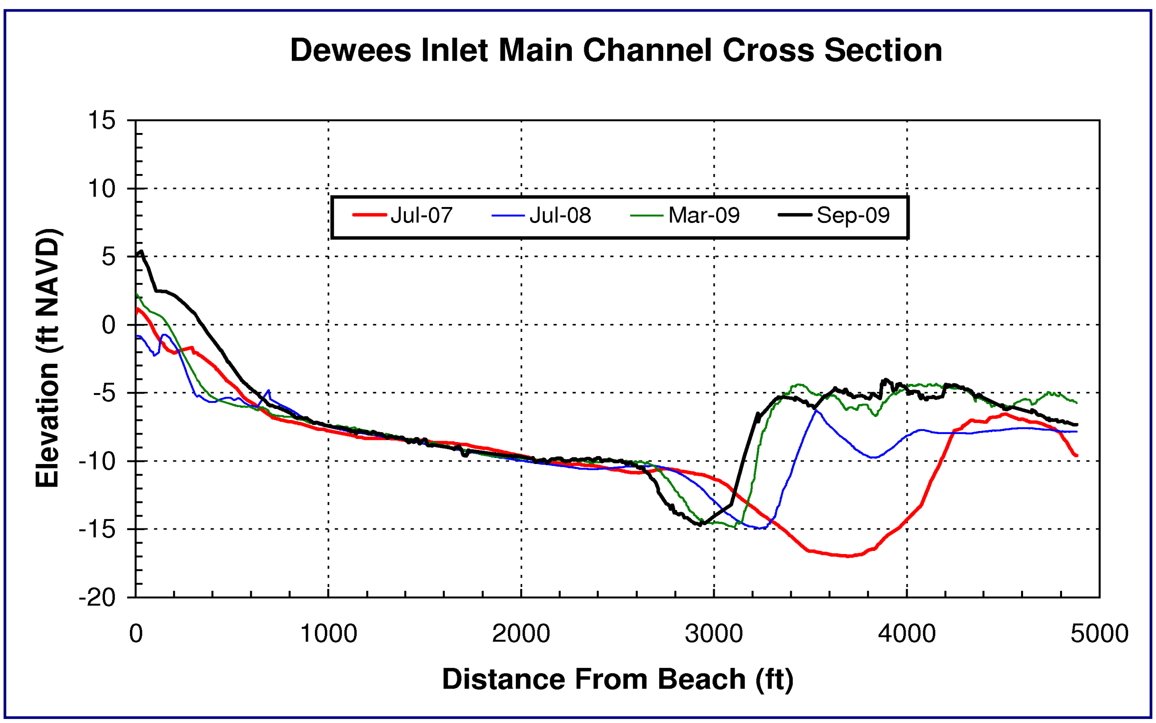


FIGURE 3.38. Cross section through the outer portion the Dewees Inlet main channel. The section runs from the Wild Dunes POBH to the shoal on the seaward side of the Dewees Inlet channel. The mouth of the channel shoaled by ~2 ft and narrowed by ~1,000 ft between July 2007 and September 2009.

As the outer lobe of the ebb-tidal delta migrates into the main ebb channel, it reduces the cross-sectional area through which tidal currents can flow. This means that for the same tidal volume entering and leaving the inlet over a given time, current speed must increase, or there must be another path for water to flow. DTMs produced by CSE show that in response to the narrowing of the main channel, a secondary channel of Dewees Inlet is widening and deepening to accommodate tidal flow. The secondary channel (D) is aligned with the inner portion of the inlet (between Isle of Palms and Dewees Island). In July 2007, the secondary channel was much shallower and less well defined than the main channel (−9 ft compared to −20 ft NAVD). Cross sections running perpendicular to the secondary channel show that it has become wider and deeper since 2007 (sections shown in Appendix C).

The DTMs also show that a new terminal lobe (outer crest of the ebb tidal delta) is beginning to form seaward of the secondary channel. This is an indication that ebb-tidal currents have increased through the secondary channel as the main channel has shoaled. Increased velocity is responsible for widening and deepening the secondary channel, and sand removed by this process is being deposited further offshore, forming the new terminal lobe. The lobe grew ~900 ft seaward between July 2007 and September 2009.

The changes noted in the positions and cross-sectional areas of the main and secondary channels have potentially significant consequences. There exists the possibility that the seaward end of the main channel could be abandoned and the secondary channel could become the dominant channel. This would release a large volume of sand currently on the seaward side of the main channel and make it available for future shoal-bypass events. This process is termed channel abandonment and occurs at many inlets, though it has not been documented at the Isle of Palms in recent years. The movement of the offshore shoal into the main channel and the expansion and deepening of the secondary channel suggest that this process is beginning. Due to the lack of historical bathymetric data, it is unclear whether the changes in morphology are only temporary and the main channel will remain dominant, or whether the channel is in the process of abandonment. Future surveys of the area will continue to track changes in the positions of the shoals and channels, and will confirm whether the channel is being abandoned or whether it will redevelop in its current configuration. Regardless, a large volume of sand is moving closer to the beach and will likely affect beach volumes in the future.

If the present channel is abandoned, several million cubic yards of sand may be released to the Isle of Palms over the next decade or longer. It would likely be several years before significant changes are seen in the active beach. Changes to the beach associated with such a large release of sand are uncertain, but may include significant areas of localized accretion and erosion, much like what was present prior to the nourishment project. It is unclear whether sand would come ashore as a single large shoal (similar to recent shoal-bypassing events at Kiawah Island—CSE 2005, 2007b, 2009), or whether there would be an increase in scale and frequency of more typical shoal-bypass events which have impacted IOP in recent history. The uncertainty of rates and the rapidity of changes in the ebb-tidal delta, inlet channels, and shoal platform show the necessity for continued monitoring of the inlet. Given the importance of these changes to the future of the Isle of Palms, consideration should be given to increasing the frequency of surveys around Dewees Inlet.

Borrow Areas

Three separate borrow areas were used in the 2008 nourishment project and are shown in Figure 3.39 (a fourth area–D–was available but was not used). The borrow areas were situated on offshore ridges and were limited to excavation depths of ~7 ft at the request of permitting agencies to avoid creation of deep holes. Elevation contours of the pre-nourishment condition are shown on Figure 3.39. Special conditions of the permit required topographic monitoring of the borrow areas for three years. Data were collected at 100-ft spacing throughout each of the borrow areas, extending beyond the limit of each area to account for changes near the boundaries.

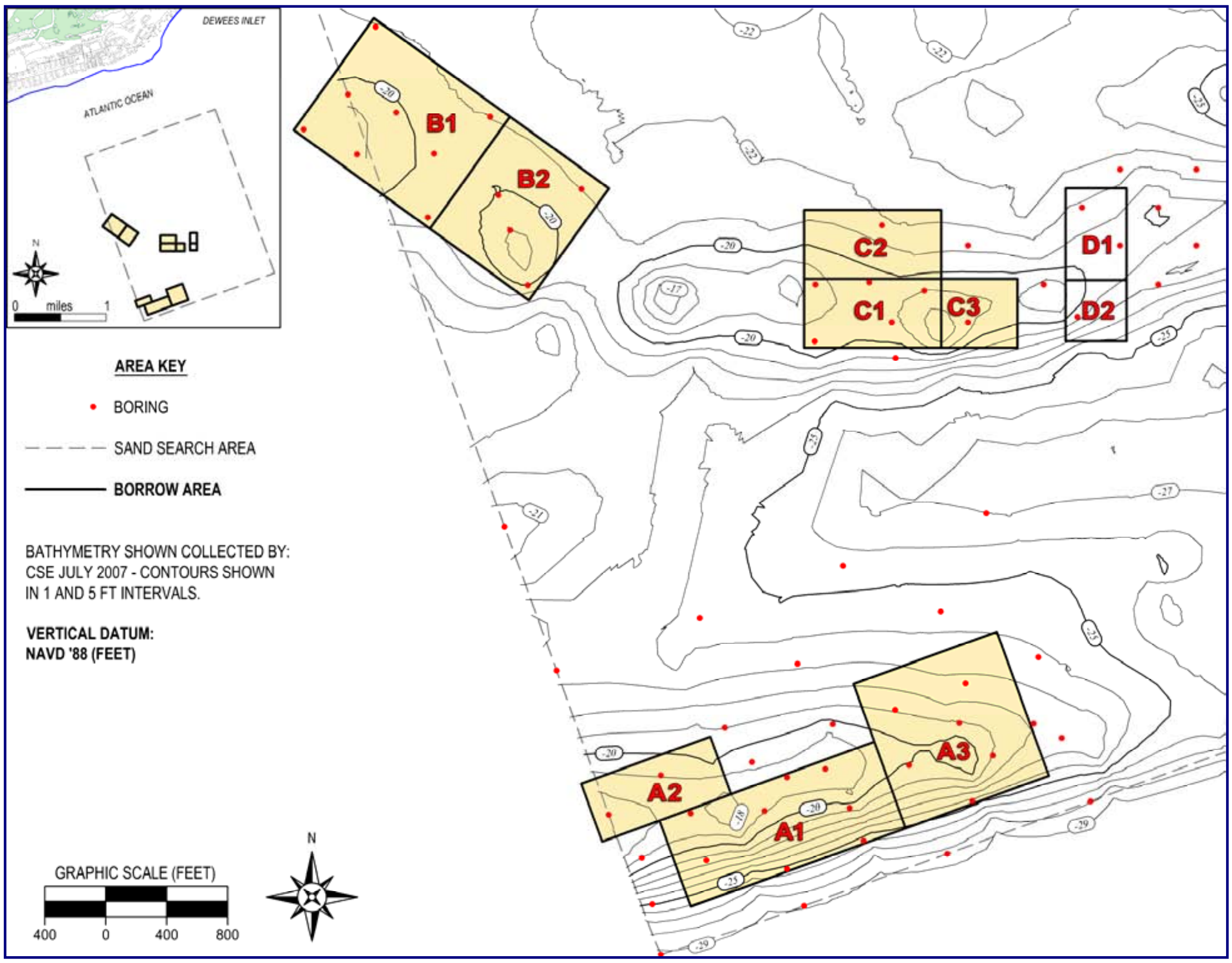


FIGURE 3.39. Locations of the borrow areas used in the 2008 nourishment project. ("D" areas were not used.) Contours show bathymetry in July 2007, prior to the project. The borrow areas were situated on topographic highs as recommended by resource agencies.

DTMs from May 2008 (before dredging) and September 2009, and the elevation change between the post-dredge condition and September 2009 are shown in Figures 3.40-3.42. Profile sections for each borrow area are shown in Figure 3.43. Generally, deeper portions of each borrow area have filled in, while higher areas have eroded. Infilling is also occurring at the boundaries of the borrow areas where material from undredged areas is falling into the dredged area. Borrow area A shows a net change of 53,954 cy infill since dredging (Table 3.3). This represents 10.6 percent of the volume dredged in 2008. Borrow area B gained 83,590 cy between the post-dredge and September 2009 conditions, equaling 20.7 percent of the dredge volume. Borrow area C infilled by 38,750 cy, representing 15 percent of the dredge volume. Note that dredge volumes were calculated from before and after surveys of the borrow areas and not by volumes placed on the beach. In-place volumes are smaller than dredge volumes due to losses of fine material at the beach during pumping. Sediment quality in the borrow areas is beyond the scope of the present report; however, it is addressed in biological monitoring reports prepared by CSA South Inc (CSA 2009). Generally, some fine material (mud) is accumulating in the borrow areas, likely inhibiting future use of each area for nourishment purposes. Sediment quality and topography will continue to change in the borrow areas, and future geotechnical studies would be needed prior to determining the potential suitability for re-use of any area.

TABLE 3.3. Borrow area infilling volumes. Volume changes between the before (BD) and after dredge (AD) conditions represent the amount of material removed from each area during the project (red values). Positive values show sediment accumulation in the borrow areas.

IOP Borrow Area A		
Base Model	**Comparison Model (date)**	**Volume Diff (cy)**
Weeks BD	Weeks AD	-508,524
Weeks AD	CSE March 2009	36,232
CSE March 2009	CSE Sept 2009	17,722
Weeks AD	**CSE Sept 2009**	**53,954**

IOP Borrow Area B		
Base Model	**Comparison Model (date)**	**Volume Diff (cy)**
Weeks BD	Weeks AD	-403,891
Weeks AD	CSE March 2009	52,660
CSE March 2009	CSE Sept 2009	30,930
Weeks AD	**CSE Sept 2009**	**83,590**

IOP Borrow Area C		
Base Model	**Comparison Model (date)**	**Volume Diff (cy)**
Weeks BD	Weeks AD	-258,243
Weeks AD	CSE March 2009	10,290
CSE March 2009	CSE Sept 2009	28,460
Weeks AD	**CSE Sept 2009**	**38,750**

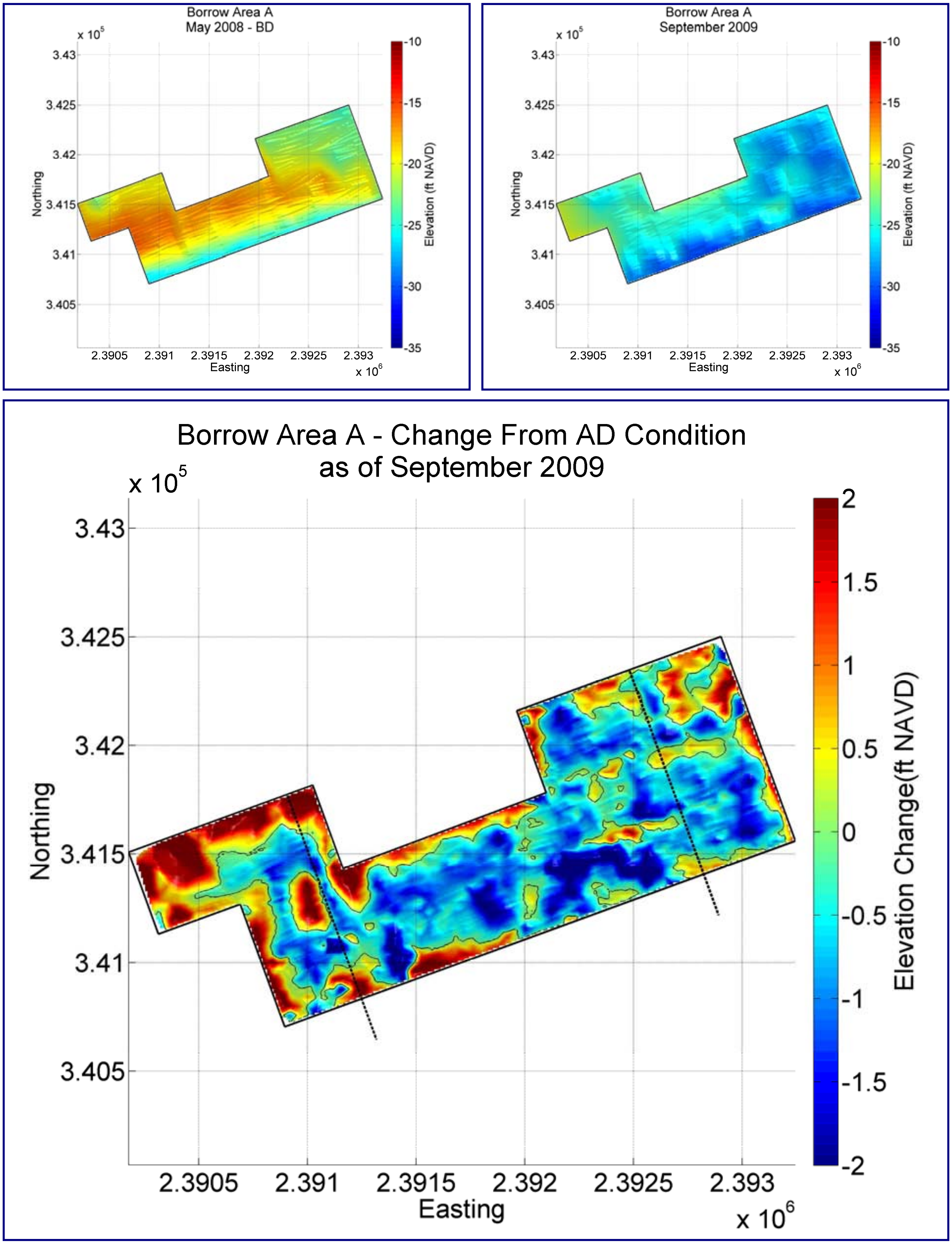


FIGURE 3.40. DTM models of borrow area A before nourishment (upper left), in September 2009 (upper right), and the elevation change between the post-dredge and September 2009 conditions showing infilling/erosion following the project (lower). Generally, areas left higher (where the dredge ladder was raised to avoid muddy sediments) eroded and shifted to deeper sections. Boundary areas also gained elevation as material from undredged areas sloughed into the dredged areas. [Dashed lines are the locations of sections in Figure 3.43. BD = before dredging. AD = after dredging.]

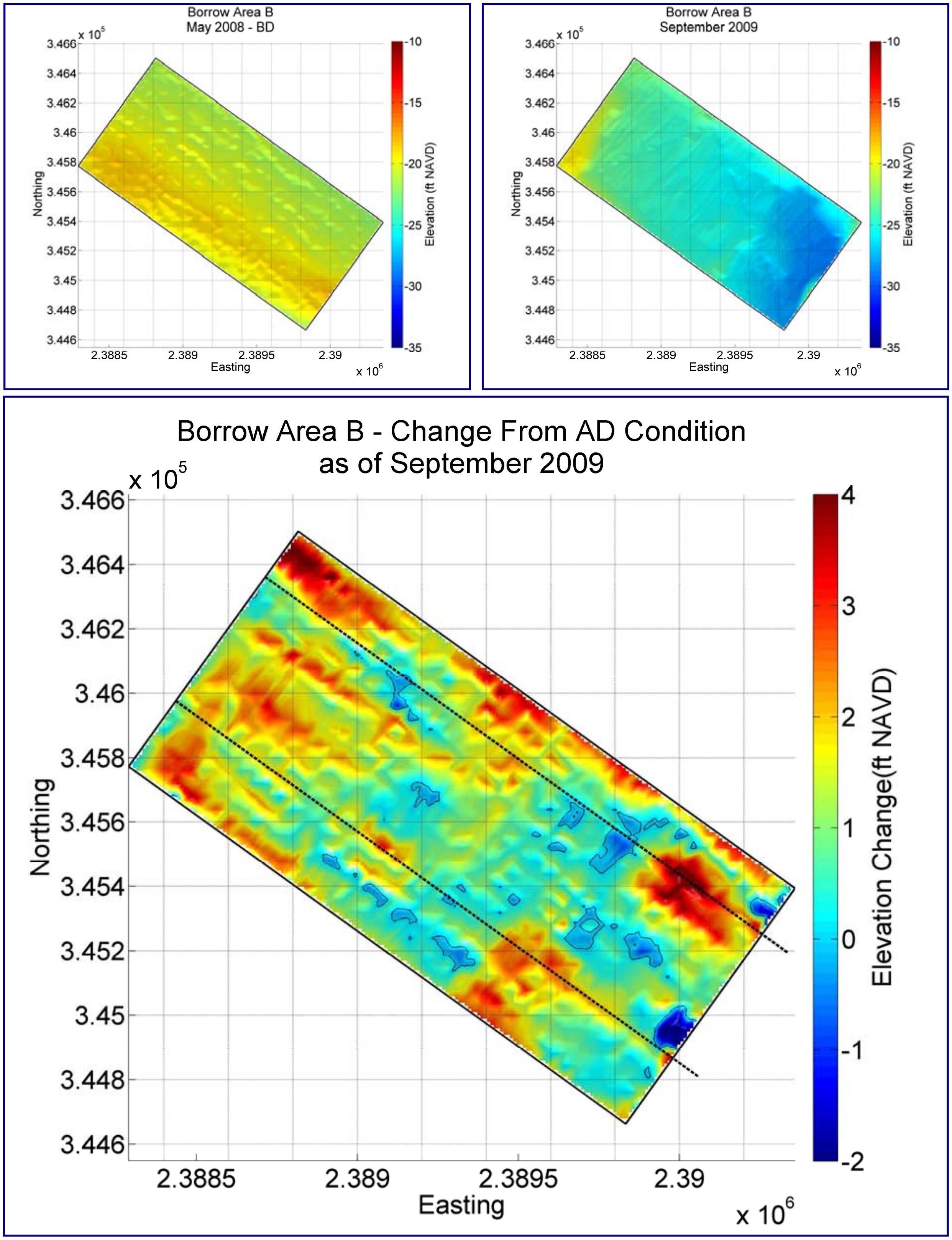


FIGURE 3.41. DTM models of borrow area B before nourishment (upper left), in September 2009 (upper right), and the elevation change between the post-dredge and September 2009 conditions showing infilling/erosion following the project (lower). Generally, areas left higher (where the dredge ladder was raised to avoid muddy sediments) eroded and shifted to deeper sections. Boundary areas also gained elevation as material from undredged areas sloughed into the dredged areas. [Dashed lines are the locations of sections in Figure 3.43. BD = before dredging. AD = after dredging.]

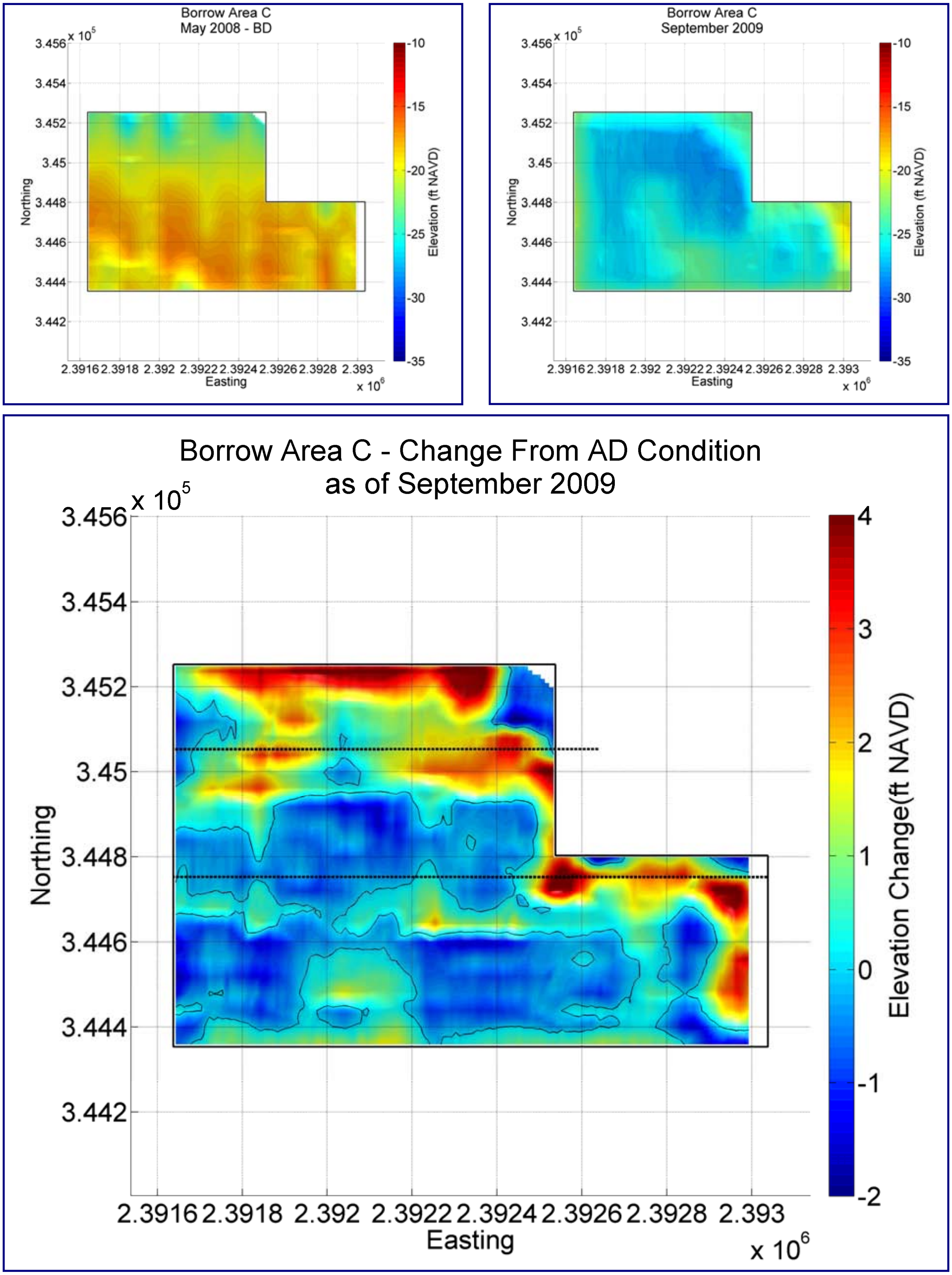


FIGURE 3.42. DTM models of borrow area C before nourishment (upper left), in September 2009 (upper right), and the elevation change between the post-dredge and September 2009 conditions showing infilling/erosion following the project (lower). Generally, areas left higher (where the dredge ladder was raised to avoid muddy sediments) eroded and shifted to deeper sections. Boundary areas also gained elevation as material from undredged areas sloughed into the dredged areas. [Dashed lines are the locations of sections in Figure 3.43. BD = before dredging. AD = after dredging.]

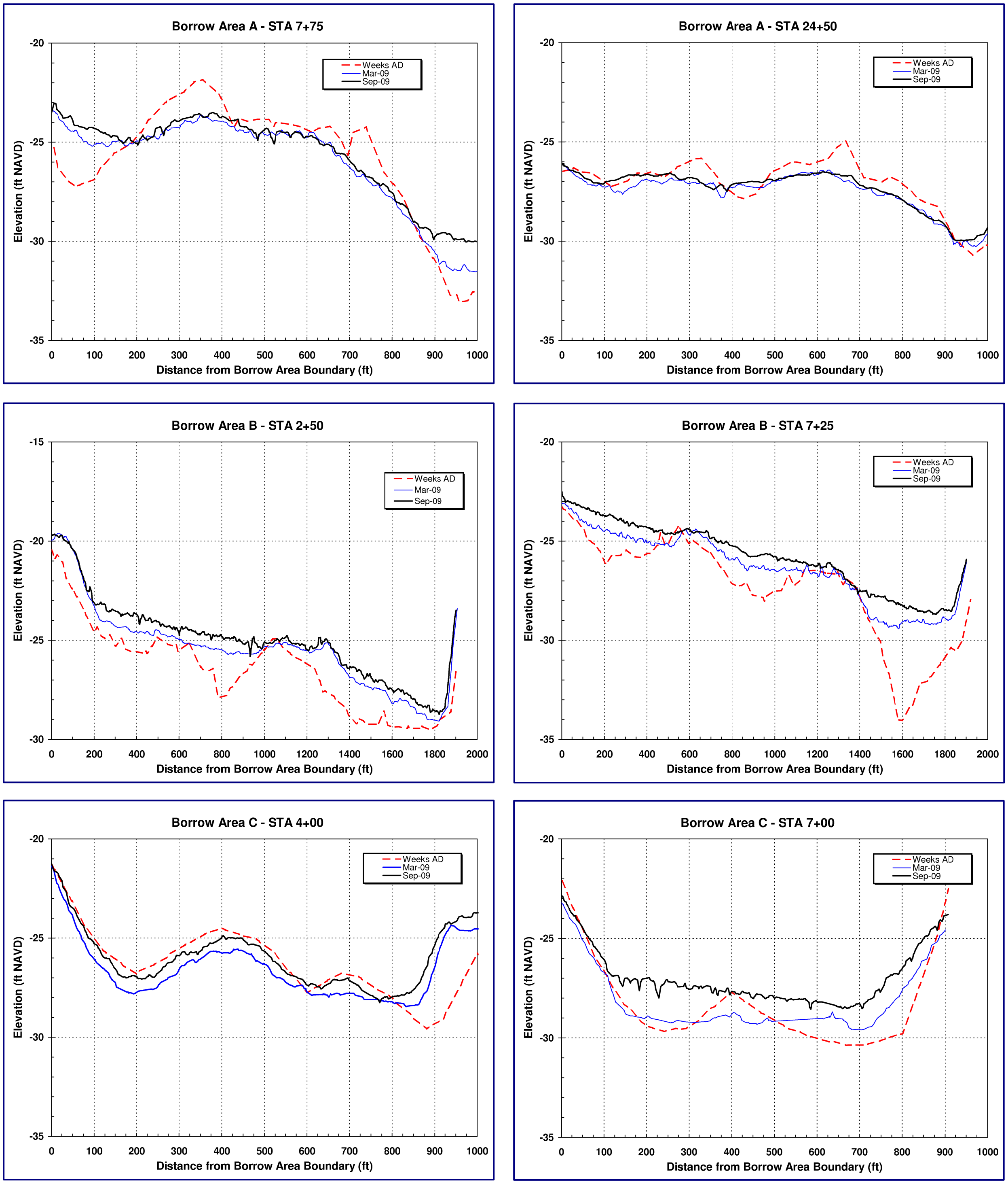


FIGURE 3.43. Profile sections of the three borrow areas used in the 2008 beach restoration project. Locations of profiles are shown in the DTMs of Figures 3.40 through 3.42. Note deeper portions have filled in, whereas some higher areas have eroded. Waves, currents, and gravity act to smooth the bathymetry which was left in an unnatural state after dredging. [AD = after dredging condition survey]

Sediment Quality

Part of the post-project monitoring efforts included collection and analysis of sediment samples over the length of the Isle of Palms. These analyses track changes in the quality of the nourishment sand as the fill continues to adjust and be reworked by waves. Samples were collected immediately post-project in July 2008 and in July 2009. The 2009 sampling also included stations in the central and southern portions of the island to provide a baseline for future comparisons. Samples were collected at five locations in the cross-shore direction (see Methods section). Grain-size distribution and descriptive statistics for each sample are given in Appendix D.

Prior to nourishment, CSE collected native beach samples in the project area for compatibility analyses with borrow sediments. These results showed a native grain size of 0.253 millimeter (mm) with 11.1 percent (by weight) calcium carbonate ($CaCO_3$). Following the nourishment, mean grain size increased to 0.384 mm in the project area (compared to 0.181 mm outside of the project area, Table 3.4). Average mean grain size decreased to 0.287 mm between July 2008 and July 2009. Shell ($CaCO_3$) content increased to 25.2 percent following nourishment, but has since decreased to 13.9 percent in the project area. Grain size was highest in the upper beach area (dune, mid berm, and berm crest) in July 2008 as wind-blown sand had not accumulated immediately after the project (Fig 3.44). Grain size decreased significantly in each of those areas by July 2009 and increased in the beach face. Coarser grain sizes are expected along the beach face, where wave energy is more focused for longer periods of time. The upper beach is expected to continue to become finer as more wind-blown sand accumulates and high waves and tides deposit finer material on the upper beach.

TABLE 3.4. Sediment grain size and shell content for the post-project and 1-year post-project sediment samples. Both grain size and shell content decreased between July 2008 and July 2009 in the project area, becoming closer to the pre-project values.

Isle of Palms Post Project Sediment Analysis		Jul-08		Jul-09	
		Mean (mm)	% $CaCO_3$	Mean (mm)	% $CaCO_3$
Dune	Non Project	0.164	4.2	0.195	3.0
	Project	0.455	24.5	0.269	7.4
Mid Berm	Non Project	0.170	2.7	0.213	3.8
	Project	0.482	31.1	0.359	24.4
Berm Crest	Non Project	0.175	2.8	0.210	5.1
	Project	0.408	29.4	0.268	8.4
Beach Face	Non Project	0.193	6.3	0.278	12.3
	Project	0.332	22.7	0.339	19.5
LTT	Non Project	0.201	10.4	0.231	11.5
	Project	0.246	18.1	0.198	9.6
Cross Shore Average	Non Project	0.181	5.3	0.225	7.1
	Project	0.384	25.2	0.287	13.9

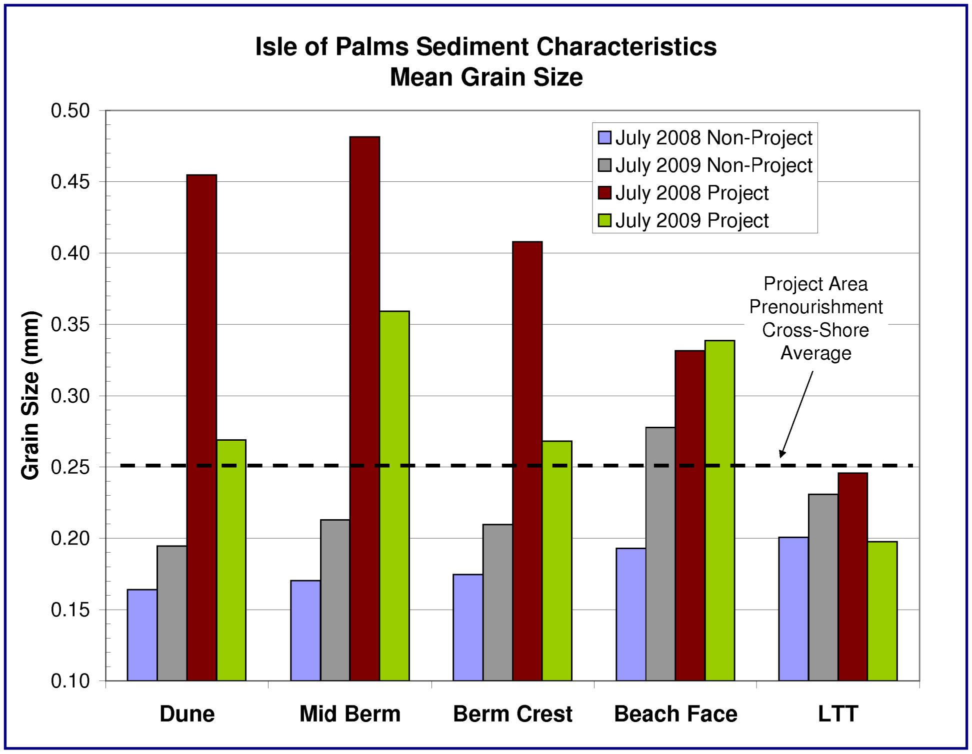


FIGURE 3.44. Cross-shore, grain-size distribution for Isle of Palms following the 2008 restoration project. Note how the upper beach became finer between 2008 and 2009. This is an expected trend associated with the natural mixing of sediment between nourished and unnourished areas.

The initial increase in grain size and shell content was expected as the borrow material was slightly more coarse and contained a higher percentage of shell than the native material. The coarser fill was placed to prolong the life of the nourishment, since larger grain sizes are more slowly eroded. Between July 2008 and 2009, wave action and sediment transport reworked the fill to produce a sediment-size distribution closer to the pre-nourishment condition. Sediment characteristics would be expected to eventually stabilize in the project area. However, recurring shoal-bypass events introduce new sand into the system and redistribute sediment along the beach. Thus, sediment texture at any given location will be influenced by shoal-bypassing events as well as the nourishment project.

Figure 3.45 shows the distribution of grain sizes and shell content over the length of the Isle of Palms. It is apparent from the graph that grain size is coarser at the northeastern end and tends to become finer in the downcoast direction (toward Breach Inlet). Finer grain sizes are more easily eroded and transported by wave action and it follows that finer material can travel farther than coarser material under similar wave action. The northeastern end is the sediment source for the rest of the island; therefore, finer material is eroded from the northeastern end and moves downcoast. Over time, it produces an alongshore gradient of mean grain size.

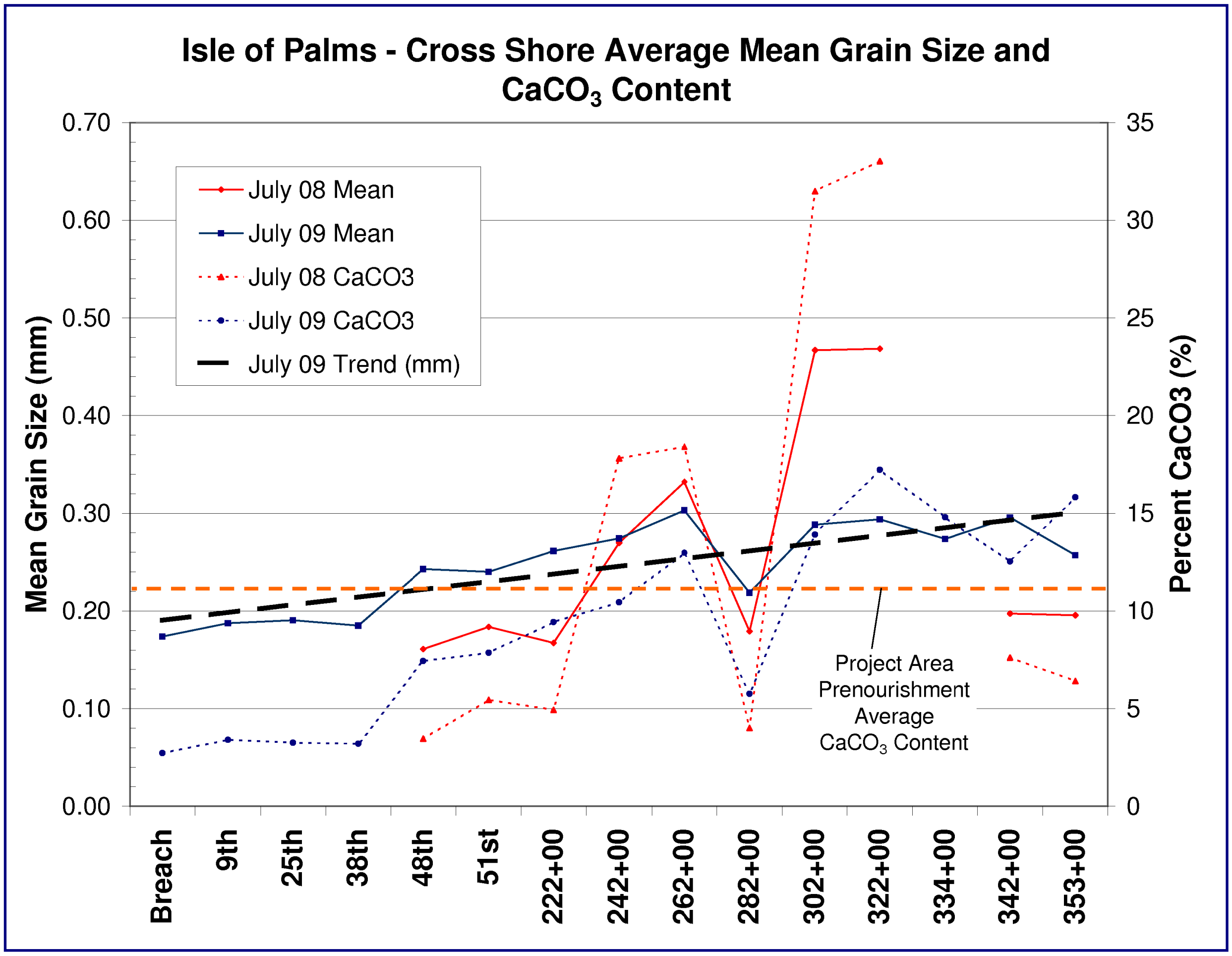


FIGURE 3.45. Alongshore distribution of average grain size (cross-shore average at each station). It is apparent from the graph that sediment becomes finer toward Breach Inlet. This is a function of nourishment sand being slightly coarser than the native sand supply as well as normal longshore transport of finer sand away from the northeastern end.

Compaction

The nourishment area was tilled in early July 2008, following completion of pumping. CSE measured sediment compaction in March 2009 at 500-ft intervals in the project area and surrounding areas (to establish a native value). Compaction measurements are provided in Appendix B. Compaction values measured in March 2009 were lower than the threshold set in the permit special conditions to trigger tilling. Results were sent to USFWS and SCDHEC-OCRM. Compaction measurements will be repeated in early 2010 and 2011.

Sand Fencing/Dune Growth

Installation of sand fencing was included in the project design in areas lacking existing dunes or vegetation. Fencing was installed in May 2009 between Beach Club Villas and Ocean Club as well as along the Dewees Inlet shoreline. Fencing was installed in "v-shaped" sections spaced ~10 ft apart (Fig 3.46). Dune vegetation was also installed in a 15-ft-wide swath surrounding the fencing. Sand fencing works to aid in dune building by accumulating wind-blown sand. Vegetation also acts to block wind and accumulate sand. While vegetation would naturally spread to the nourished areas, which would then begin to build dunes, installation of the fencing and vegetation speeds the process. A desirable goal is to build a dune line along the back beach as high and wide as possible to provide storm protection to buildings. A secondary benefit is creation of habitat for beach organisms.

As of September 2009, the sand fencing had accumulated over 1 ft of sand in many areas. The fence is expected to continue to trap sand as long as the areas are fronted by an area of dry-sand beach and are not regularly impacted by overwash. It is very likely that natural vegetation and dune growth will occur in nourishment areas seaward of the fencing, where a large platform of dry berm is situated between the fencing and the normal high-tide limit.

In areas of the island already possessing dunes and/or vegetation (nourished and unnourished areas), natural dune building was evident in many of the profiles. Of particular interest is the area in front of the Wild Dunes Grand Pavilion, which has lower and narrower dunes than most other areas of the island. Profile 248 shows that the dune here has grown ~0.5 ft between March and September 2009, and almost 2 ft since March 2008—the pre-nourishment condition (Fig 3.47). This dune is expected to continue to grow as the area is now fronted by a wide, protective beach following nourishment.

FIGURE 3.46. **[LEFT]** Sand fencing in the *Dewees Inlet* reach in May 2008, shortly after installation. **[RIGHT]** Sand fencing and vegetation in the *North Wild Dunes* reach (near Seascape Villas) in September 2009, ~4 months after installation. Note v-shaped configuration of sand fencing, opened toward the sea, with 10 ft gaps between sections—following design guidance by SCDHEC-OCRM.

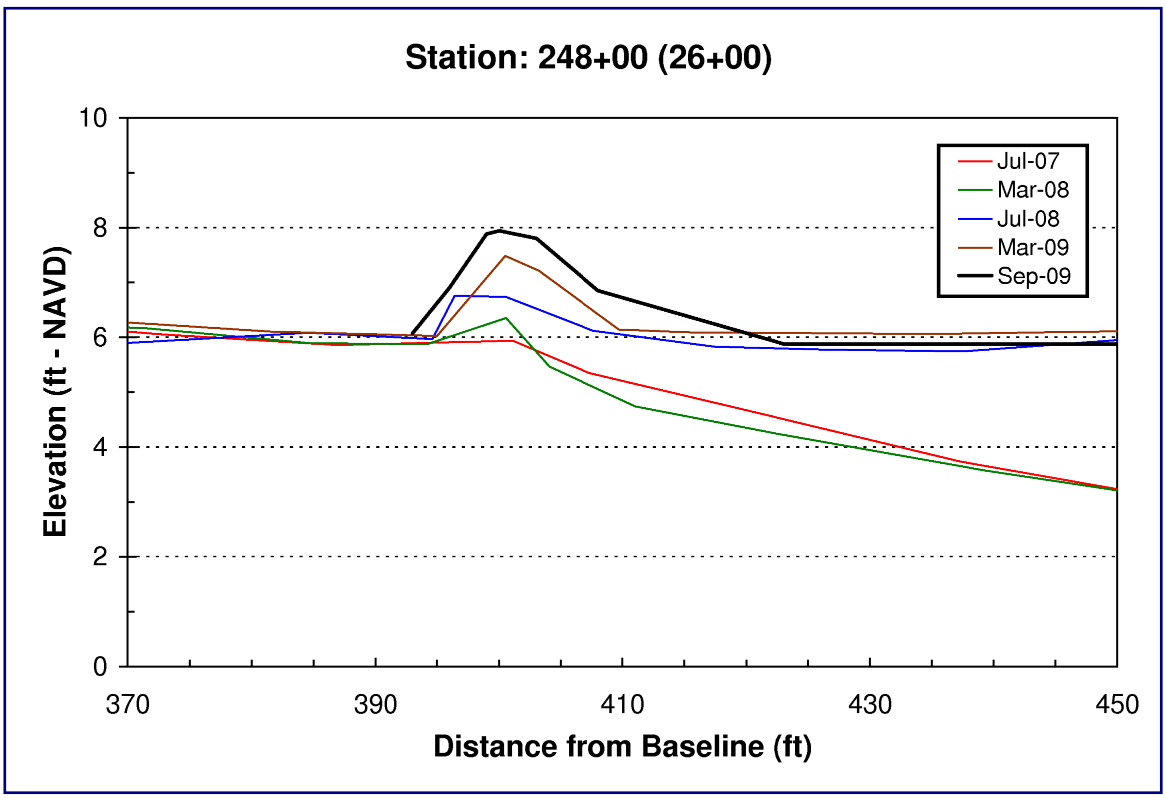


FIGURE 3.47. Evidence of dune growth at station 248+00 (adjacent to the Wild Dunes Grand Pavilion) following nourishment (May-June 2008). Elevation of the dune has increased ~2 ft naturally since the pre-project condition. Dune growth is expected to continue as long as the area maintains sufficient dry beach to continue feeding the dune line.

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4.0 DISCUSSION AND RECOMMENDATIONS

Monitoring efforts conducted before and after the 2008 beach restoration project at the Isle of Palms show that the condition of the beach over the entire island is dependent on the release of sand from the Dewees Inlet ebb-tidal delta. Periodically, sand in the downcoast portion of the delta is worked by waves into an exposed shoal, which then migrates landward until attaching to the beach. The shoal acts as a breakwater, causing the beach to build out in its lee. Sand accumulation in the lee of the shoal is produced through erosion of sand from adjacent areas. This process accounts for rapid shoreline changes, often measuring several hundred feet while the shoal is migrating to the beach. While offshore, the shoals interrupt normal sediment transport to downcoast areas, leaving the rest of the island deprived of sand. Once attached, sand spreads to eroded areas, and longshore transport is restored to the rest of the island. The extreme erosion and accretion associated with shoal-bypass events is temporary. In the long term, each event adds sand to the system and is responsible for the historical accretion observed over the length of the island.

CSE has obtained five detailed topographic data sets since 2007, when the severely eroded condition of the beach at the northeastern end of the island led the community to begin looking for a solution to the erosion problem. These data offer a detailed description of the morphology of the Dewees Inlet delta and changes in the size and position of the delta shoals. Surveys of the inlet are the key prerequisite for prediction of future changes along the beach at the Isle of Palms. Beach profiles, collected as part of the monitoring, detail volume changes in the 2008 project area before and after nourishment. They also provide analyses of the beach condition for the rest of the island, outside of the project area. The results of the post-project monitoring (March and September 2009) are the focus of this report and reveal the importance of shoal-bypass events on the island-wide condition of the beach. The underlying theme suggested by the data is that while shoals are migrating onshore, erosion occurs in the adjacent areas, and sediment transport to downcoast areas is interrupted. Once attached, sand from the shoal restores eroded areas, and sediment transport is restored to downcoast areas.

Observations from the post-project monitoring to date include:

- An incipient shoal formed in 2008 on the heels of the “2006” shoal which attached in 2007. The former shoal led to the need for the nourishment project. By March 2009, the “2008” shoal was ~100 ft from the beach. CSE estimated that, once the “2008” shoal attached to the beach, it added ~330,000 cy of sand to the Isle of Palms.

- The “2008” shoal caused erosion of the northern end of the *South Wild Dunes* reach, with some stations showing less sand than the pre-nourishment condition. It also contributed to erosion of the *North Wild Dunes* reach, where the most severely eroded areas lost ~50 percent of the nourishment volume.

- Sand from the *North Wild Dunes* reach also migrated northeast, building the area around the 18th fairway and the turn in the shoreline to Dewees Inlet.

- After attachment of the “2008” shoal, sand is spreading from the attachment site to adjacent areas to the north and south, partially rebuilding eroded areas.

- Erosion in the project area was initially rapid in some areas due to adjustment of the nourishment fill and erosion associated with the recent shoal attachment. Erosion slowed between March and September 2009 in most of the project area.

- Sand from the project area is beginning to move to downcoast portions of the Isle of Palms with profiles suggesting some nourishment sand has built up profiles at least ~2,000 ft to the south.

- The majority of the Isle of Palms stations were erosional, likely due to normal longshore transport of sand being interrupted while the last two shoal-bypass events trapped sand at the northeastern end.

- There is no incipient shoal developing off the northeastern end of the Isle of Palms at present. However, it is likely that another shoal, similar to the one which attached this year (“2008” shoal), will build from the extensive platform of sand offshore of the Wild Dunes Property Owners Beach House in the near future. This area should be monitored closely over the next several years because of anticipated erosion problems associated with each shoal-bypass event.

- During the past year, the main channel of Dewees Inlet (which presently turns south and parallels the oceanfront of Wild Dunes before exiting the ebb-tidal delta offshore of Beach Club Villas in Wild Dunes) migrated closer to the beach and decreased in cross-sectional area. A secondary entrance channel of the inlet has increased in width and become deeper. The secondary channel offers a more direct path for flows in and out of the inlet.

- The outer bar of the inlet on the seaward side of the outer end of the main channel moved toward the southwest, pinching off the main channel. There now appears to be more tidal flow entering and exiting the inlet through the secondary entrance channel. If this trend continues and the present main channel becomes smaller, it leaves the potential for total abandonment and a shift of the major tidal flows to the secondary entrance channel*.

- A marginal flood channel of Breach Inlet has encroached on the beach at the southern end of the Isle of Palms, causing erosion and scarping of the foredune near station 4+00. This should be temporary as this area has been historically accretional.

*The outer ends of main channels of natural South Carolina tidal inlets tend to meander and shift between breaks in the outer bar (ebb-tidal delta) (Hayes 1979, Kana et al 1999). If the outer bar builds up on the updrift (north) side of the main channel, it tends to cause a deflection of the main channel to the south. This explains why Breach Inlet as well as Dewees Inlet often have main channels which turn south as they enter the ocean between the barrier islands. With continued buildup of the "updrift" bar, the main channel "overextends" to the south and becomes less efficient for tidal flows. Periodically, a break will form in the outer bar on the updrift (north) side of the ebb-tidal delta and offer a shorter pathway for tidal flows. If the "short cut" secondary channel continues to enlarge, it may become the dominant entrance channel. Meanwhile, the overextended channel is gradually abandoned. This process has been inferred (by means of aerial photos) to occur at Dewees Inlet and Breach Inlet, but it has never been documented with closely spaced surveys such as the data in the present report. CSE believes that the process of channel abandonment and opening of the secondary channel is occurring at Dewees Inlet based on surveys between 2007 and 2009. The implication of this is that if the main channel shifts to the secondary channel, sand bars on the southern side of the secondary channel will merge with the shoal platform off the Wild Dunes Property Owners Beach House. This will add potentially several million cubic yards of sand to the platform (above and beyond the estimated 4+ million cubic yards that are landward of the present main channel). The potential addition to the platform of such a large sand volume will exacerbate its effect on wave patterns along the Wild Dunes shoreline. This has potential positive consequences (increases the likelihood that much more sand will shift onto the Isle of Palms beach over the next decade), but also means there will be negative consequences (focused erosion is likely to persist along the flanks of the shoal platform in a repeat of conditions that led to the 2008 nourishment project). The uncertainty about the process of a channel shift and addition of sand to the shoal platform mainly relates to the scale and timing of additional shoal-bypassing events which cannot be accurately predicted by any means.

The present monitoring effort focused closely on changes in the shoals of Dewees Inlet and Breach Inlet. CSE's surveys were modified within the project area and along Breach Inlet to provide more closely spaced transects so that DTMs (contour maps) could be developed. Four detailed maps of Dewees Inlet (encompassing the period July 2007 to September 2009) confirm the trends described above.

As additional surveys are obtained, it will be possible to create a time-lapse movie of the delta evolution. Few inlets in the United States have been surveyed in such detail to document rates of change in the shoals and channels. CSE surveys on the updrift side of Breach Inlet similarly provide clearer evidence of channel shifts that encroach on the Isle of Palms or that release sand bars for migration and attachment to the beach.

Since completion of the 2008 beach restoration project, measurable quantities of sand have shifted to the Dewees Inlet shoreline (counter to the prevailing southerly transport) and to the area ~0.5 mile south of the project area. Sand has shifted within these project areas largely because of the influence of a new shoal-bypass event ("2008" event).

Surveys confirm that:

- 81 percent of the nourishment volume remains within the fill placement limits. Much of the "lost" volume is accounted for in the buildup downcoast.

- The area between the Citadel Beach House to Cedar Creek Spit (stations 202-370) has gained ~12,000 cy since the project. The majority of this gain (above the volume excavated and placed on the beach by the project) is associated with the "2008" shoal-bypass event. Overall, the entire Isle of Palms beach lost ~120,000 cy of sand between March and September 2009.

- Within the project area, certain localities have sustained rapid loss of nourishment sand. Erosion has been greatest at station 270 (Dunecrest Lane), station 314 (Ocean Club), and station 310 (Seascape). Off the Ocean Club and 18^{th} hole (stations 312-316), sand losses have left only 50-60 percent of the fill in place. The erosion is made more obvious because the 18^{th} fairway reclaimed much of the nourishment area and a large walkover was placed seaward of Ocean Club (Fig 4.1).

Seascape, the Ocean Club, and the 18^{th} fairway areas bear close monitoring because of the continuing changes in Dewees Inlet. Erosion losses in this area are primarily due to the "2008" shoal-bypass event. The bulge of sand off the Wild Dunes Property Owners Beach House continues to inhibit northerly longshore transport. Another factor acting on the Ocean Club locality is enlargement of the secondary ebb channel of the inlet. The channel opens northeast of Ocean Club, thus exposing the shoreline to higher wave energy at present.

FIGURE 4.1. Walkover placed seaward of Ocean Club and reclamation of the 18th hole of the Wild Dunes Links Course following nourishment. [Photo by C Jones, 10 September 2009]

CSE believes that wave propagation through the secondary channel toward Ocean Club, the 18th hole, and nearby areas will change in relation to channel development and the evolution of the new outer bar. The combination of wave refraction around the shoal platform off the Wild Dunes Property Owners Beach House and wave diffraction through the secondary channel are the underlying reasons for irregular shoreline changes along Wild Dunes. Variations in wave energy and sediment transport inside the Dewees Inlet ebb-tidal delta are the root cause of the erosion and deposition patterns observed in this area of coast over the past 30 years. Any mitigation measures for dealing with short-term erosion events should seek to work in concert with the controlling wave and sediment-transport processes, recognizing that some of the natural controls dwarf all emergency beach restoration measures to date.

Status of Permit Compliance Measures

Borrow area surveys were completed in March and September 2009, and will be continued in 2010 and 2011. Results are included in this report and will be submitted to US Army Corps of Engineers (USACE) and National Marine Fisheries Service (NMFS).

Beach infauna surveys were conducted in May and October 2009. Results from the May survey have been submitted for review, and results from the October survey are being processed.

Beach compaction measurements were taken, and results were submitted to US Army Corps of Engineers and US Fish and Wildlife Service. Compaction measurements will be repeated prior to turtle nesting season in 2010 and 2011 in accordance with permit conditions.

Offshore benthic infauna surveys have been collected, and results have been submitted to SC Department of Health and Environmental Control – Office of Coastal Resource Management (SCDHEC-OCRM) and have been reviewed by the South Carolina Department of Natural Resources (SCDNR). After review of the first post-dredge benthic monitoring report, changes were made to the protocol and subsequent samplings were modified. As of this writing, SCDNR is reviewing results from the March 2009 (second post-dredge report) sampling to determine whether any additional sampling is necessary.

Recommendations

The results of the first year of monitoring, following the 2008 beach restoration project at the northeastern end of the Isle of Palms, indicate the shoreline remains subject to large-scale changes associated with shoal-bypassing events. A broad, triangular-shaped swash platform centered off the Wild Dunes Property Owners Beach House is the dominant shoreline feature. It continues to provide new sand to the beach, but also modifies waves and produces focused erosion along adjacent areas. This is the same process that produced extreme erosion between Shipwatch and the Wild Dunes Links Course, and ultimately led to the 2008 project.

While 90 percent of the project area remains in much better condition compared with pre-project, the area around Ocean Club and the 18th hole (stations 312 to 316) has already lost ~40-50 percent of the nourishment sand. CSE expects the rate of erosion to diminish based on the analysis of condition surveys for March and September 2009. Nevertheless, the combination of focused erosion at the Ocean Club, combined with reclamation of much of the nourishment berm by reconstruction of the 18th fairway, has left this section much narrower than other portions of the project. Conditions that cause erosion in the vicinity of the Ocean Club remain similar to the pre-project (ie – 2007) conditions, even if the rate of erosion appears to be diminishing.

CSE (2007) discussed two basic strategies for management and maintenance of the Isle of Palms shoreline, particularly in the area of shoal-bypass events:

1) Import new sand from an external source (eg – offshore deposits outside the active littoral zone).

2) Shift sand from accreting zones to eroding zones to keep pace with localized erosion hot spots.

The 2008 project accomplished the first strategy. It added over 900,000 cy of beach-quality sediment and advanced the shoreline between 200 ft and 300 ft. As of September 2009, 81 percent of the nourishment volume remained within the project limits (actual placement reaches); of the sand lost, at least 50 percent has shifted to adjacent areas and the remainder has been lost from the beach system (eg – losses to Dewees Inlet). The overall retention rate has been good, and it is further enhanced by new sand entering the beach zone in the form of bars, moving onshore near the Wild Dunes Property Owners Beach House. The second strategy has been implemented or suggested at various times since the 1980s (cf – Kana et al 1985, ATM 2006).

CSE believes it is now time for the City to begin looking into alternatives to combat short-term, localized erosion through one or more methods. There are multiple alternatives for addressing localized erosion, each with a varying degree of environmental, economic, and political influences. As part of the City's Long-Term Beach Management Plan, certain alternatives were discussed and evaluated by members of a citizen's advisory group. The advisory group's opinions on erosion control methods are shown in Table 4.1 (from Jones 2008). Certain alternatives suggested in the present report overlap with those listed in Table 4.1, although the opinion of CSE regarding each alternative may differ from that of the advisory group or Mr. Jones. To properly evaluate which alternative(s) may best accomplish the goals of a certain project, a feasibility study should be conducted to determine the scientific, environmental, economic, and political aspects of each alternative.

Table 4.1. Opinions of erosion control alternatives by the IOP Long-term Beach Management Advisory Group (from Jones 2008).

	Advisory Group Opinion			Jones Opinion
	Consensus	General Agreement	Divided	
Beach nourishment from offshore source	■			Desirable
Beach nourishment via management of approaching/attaching shoals		■		Essential
Beach nourishment by truck-hauling off-island sand		Discourage*		Undesirable
Beach nourishment by moving sand from a "wide" part of the beach to an "eroded" part of the beach (not an attaching shoal situation)			■	Neutral
Beach nourishment by mining an inlet ebb tidal delta (not an attaching shoal)			■	Neutral
Allow use of groins in conjunction with nourishment		No New Groins		Neutral

* Individual opinions were not sought from advisory group members on this alternative; however, general discussion revealed the Committee did not favor this alternative for large projects.

Potential alternatives for addressing localized erosion are as follows.

Sand Scraping from Shoal Attachment Area would involve periodic transfer of sand from accretion zones to erosion zones with such activities triggered by a specific beach and shoal condition (eg – when the shoreline along a particular section of the Isle of Palms recedes to some point and the shoal configuration shows a growing sand surplus which is exacerbating the problem). The optimal source of sand would be attached shoals (where the wet-sand beach is accessible to land-based equipment), provided the borrow area is well removed from existing development, monitored closely, and expected to continue accreting. The IOP long-term beach management advisory group was in general agreement regarding this alternative, while Mr. Jones considered it essential to a successful long-term beachfront management strategy. A permit was previously issued for a scraping permit but was challenged and never used. The challenge to the permit is currently unresolved.

Shoal Dredging would involve periodic transfer of sand from the seaward end of an incipient shoal using an ocean-certified, shallow-water dredge. The shoal may be attached or detached when dredged. The dredge would only excavate from the seaward end of the shoal or sand platform and would be restricted to a certain distance from the beach. A specific beach condition would trigger activities (likely a combination of distance of the high-tide line from buildings as well as shoal configuration and expected erosion trends). Sand would be pumped through pipe to eroded areas. This option was not specifically addressed by the advisory group (dredging from the seaward end of an attaching shoal is considered a separate activity from shoal management from the landward side of an attached shoal); however, it is likely to be generally agreed upon (C Jones, pers comm, January 2009).

Nourishment from Upland Sources — Beach nourishment using an upland source would involve importation and placement of material via land-based equipment. This alternative may satisfy small-scale projects, but would likely not be cost-effective for larger scale projects. Supply, cost, public safety, traffic, and road damage all impact the potential for this option for larger projects. This option was not favored by the advisory group.

Nourishment from Inland Waterways — Beach nourishment from inland waterways involves dredging and placement of sand from nearby tidal channels and creeks. Beach-quality sand, which could be used for nourishment, may exist in the area behind the Isle of Palms and Dewees Island. This alternative would be beneficial in that it would add sand from outside of the littoral system. It may also aid in navigation if material is removed from navigable channels (such as the Intracoastal Waterway). This alternative would require significant geotechnical and environmental studies to determine if sufficient compatible material is present and what environmental impacts removing the material might cause. This technique was implemented at the Isle of Palms in 1984, when ~350,000 cy of sand were excavated from the 41st Street marina basin and placed along areas which were eroded due to a shoal-bypass event (near Mariners Walk and Seagrove Villas, see Kana et al 1985). The advisory group did not consider this alternative.

Nourishment from Accreted Areas of the Beach (Not Shoals) — Sand transfers from accreting to eroding areas of a beach have been used as an interim measure in some jurisdictions prior to implementation of large-scale projects. This alternative is an option for emergency use. While likely to be controversial, it is considered to be an economical method for dealing with erosion events. A permit to excavate sand from Cedar Creek spit (along Dewees Inlet) was considered prior to the 2008 nourishment project, but objections to the project arose and the alternative was no longer considered.

Large-Scale Nourishment from the Inlet Delta or Offshore Sources (or inlet ebb-tidal deltas) is generally designed to provide enough sand to offset both short-term and long-term erosion. The two are distinctly different in that one provides a new sediment supply (offshore), while one borrows from sediment already in the littoral system (delta). Either involves detailed environmental studies and an extensive permitting process. The advisory group was divided on nourishment using the ebb-tidal delta, but supported nourishment via offshore sources.

Take-No-Action Alternative — This alternative would allow localized erosion to continue, meaning there would be little or no dry beach preserved at the site, which is not in the community's best interest. Should the City opt to take no action, individual property owners (groups) could seek to mitigate the erosion problem independently from the City. This may lead to one or more of the alternatives listed above being led by other parties, or it may lead to a situation similar to what was present prior to the 2008 project with each regime adding emergency sandbags for emergency protection. In the event no erosion control alternatives are implemented, erosion could undermine buildings, creating a public safety hazard. Ultimately, this leads to decreased tax revenues, environmental damage, and expenses associated with cleanup and legal fees. The advisory group did not consider this alternative.

All of the above-listed alternatives will require certain steps to be taken by the City. The first step should be a discussion of various alternatives and scenarios by City officials and determination as to whether a feasibility study is needed to identify the potential economic, environmental, and political concerns associated with each alternative. Once information about the alternatives is reviewed, the City could then determine which alternative(s) it would like to pursue. Following selection of an alternative, several steps would be required to implement a project, including one or more of the following:

1) Prepare a conceptual plan for remedial action and establish conditions which would trigger community response (eg – when the shoreline along a particular section of the Isle of Palms recedes to some point, remedial nourishment from some source would be implemented).

2) Review the plan with the community and enlist support of adjoining property owners.

3) Apply for federal and state permits which would allow remedial nourishment activities for a defined period of time. This may involve additional studies, such as sediment analysis, environmental assessments, and biological studies.

4) Implement remedial nourishment project(s) according to need, based on threshold conditions being reached.

CSE anticipates at least two years will be needed to plan and obtain permits for any alternative. This time frame would allow for planning, environmental, and community review and input. It is widely recognized that one or more of the alternatives for remedial nourishment may not be universally accepted. The key prerequisite is detailed monitoring and tracking of littoral sand volume so that use of potential borrow source(s) does not exacerbate erosion in other areas.

CSE's preference for an alternative is sand scraping using sand borrowed from an attaching shoal. This is generally considered to be the most economical alternative and is believed to have low environmental impacts if implemented in winter (relative to other alternatives). The Isle of Palms has a positive sand budget, which makes this recommendation viable. It is CSE's hope that the monitoring results herein and other obvious evidence of incoming sand in shoals will generate broad support for this recommendation. Experience at the Isle of Palms has shown that remedial sand scraping and redistribution to erosion zones by land-based equipment has a much lower cost than dredging from offshore deposits. Land-based operations do not incur large mobilization costs. The basic concept of sand redistribution from accreting shoals mimics the natural shoal-bypassing cycle, but accelerates the process for the benefit of the community. In the event the City determines that scraping is not in its best interest for remedial erosion control, CSE would recommend the City pursue other remedial nourishment options.

Because of the potential for rapid, large-scale changes around tidal inlets, planning for future remedial action should begin immediately. The present conditions (fall 2009) suggest that 95 percent of the Isle of Palms shoreline is in good condition. Planning is needed now to address the 5 percent of shoreline that is exhibiting localized erosion and adverse trends that are likely to persist in that area.

CSE makes this recommendation now in anticipation of the time it will take for community review and to obtain permits. No properties along the Isle of Palms are imminently threatened. However, it is in the community's interest to have in hand permits which provide for contingencies should any properties sustain severe, localized erosion.

CSE also recommends the City discuss additional monitoring of the northeast end of the island, specifically the area between the Wild Dunes Property Owners Beach House and Dewees Inlet. The additional monitoring would focus on two tasks:

1) Evaluating the beach condition at an erosion hotspot near Seascape Villas, Ocean Club Villas, and the 18th green.
2) Tracking movement of shoals surrounding Dewees Inlet.

The first task would offer knowledge on whether the rate of erosion following the nourishment project is changing near Ocean Club Villas. Reduction of the erosion rate would suggest sand from the "2008" shoal-bypass event is reaching the area, while no change or an increase in the rate would suggest the erosion problem will continue for a longer period of time than expected.

The second task would monitor whether the main channel of Dewees Inlet continues to narrow and shoal, and/or the secondary channel continues to become wider and deeper. Additional data of the shoal movement will allow for more certainty as to whether the main channel is being abandoned or whether the changes observed as reported herein are temporary. It will also allow for a better measure of the rate of shoal movement and will offer a better projection of when changes to the local shoreline may occur.

CSE believes that the significant changes at the northeastern end of the island warrant semi-annual monitoring. Channel abandonment has not been documented at the Isle of Palms, and any additional bathymetric data in Dewees Inlet will be useful in predicting the potential impacts to the island. Additionally, updated beach profiles showing changes in erosion rates associated with the ongoing shoal-bypass event will help establish the potential time frame over which remedial measures should be undertaken (such as sand scraping or additional nourishment). This scope of services would be beyond those in the present agreement (which calls for annual surveys in 2010 and 2011) between CSE and the City.

CSE's next scheduled condition survey of the Isle of Palms shoreline is July 2010.

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