Myrtle Beach (2001-2010) – Another Decade of Beach Monitoring Surveys after the 1997 Federal Shore-Protection Project

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ABSTRACT

Situated in the center of a 25-mile (40-km) arcuate shoreline between Little River Inlet and Murrells Inlet, Myrtle Beach, South Carolina, is the heart of a booming tourist area. However, Myrtle Beach suffered beach degradation in the 1980s. As recently as 1985, much of Myrtle Beach was armored by seawalls and there was little or no high-tide beach. Myrtle Beach was also found to have lost sand between the 1950s and 1980s at rates of 0.5–2.5 cubic yards per foot per year (cy/ft/yr) (1–6 m3/m/yr). Despite the poor natural condition of the beach and constant loss of sand year after year, Myrtle Beach has become one of the best beaches in the United States due to the nourishment efforts by the City of Myrtle Beach (1986-1989) and the federal government (1997 and 2008).

The federal nourishment project was constructed by hydraulic dredge in 1997 using an offshore deposit. Approximately 2.2 million cubic yards (1.7 million cubic meters – m3) were placed along the 9.23-mile-long (14.85 kilometers) shoreline of Myrtle Beach. The average fill density was ~45 cy/ft (113 m3/m). Annual surveys have been performed by the authors since 2001 using a network of 70 profile lines, most of which extend beyond 15-ft (4.6-m) depths (the estimated Depth of Closure) in this setting. In 2008, as planned by the federal government, an additional 1.5 million cubic yards (1.15 million cubic meters) were added to Myrtle Beach, further advancing the shoreline. The average fill density of the 2008 project was ~33 cy/ft (83 m3/m). Survey results show that the net gain between January 1997 and May 2010 represents 83 percent of the nourishment volume placed. Therefore, nourishment losses have been moderate, totaling ~17 percent of the federal fill. The average annual loss rate since 1997 has been ~1.15 cy/ft/yr (2.9 m3/m/yr), which is below the loss rate for the 1986-1989 project (measured within the visible beach to low-tide wading depth). The lower rate partly reflects an incrementally coarser sediment placed in 1997 (~0.3 mm versus ~0.25 mm mean grain size) and no major storms.

PROJECT HISTORY

Like many eroding beach communities in the U.S., the City of Myrtle Beach requested federal assistance to restore and maintain the beach in 1977. The vicinity map of Myrtle Beach is shown in Figure 1. To bridge the typical 20-year period between federal authorization and construction, the City of Myrtle Beach completed an interim beach nourishment project between 1986 and 1987 via trucks hauling sand from inland borrow sources. At the end of the project, a total of 853,350 cubic yards (cy) (652,433 m3) of sand were placed along Myrtle Beach's 8.5-mile-long (13.7 kilometers – km) shoreline at a cost of (~)$4.5 million. At that time, it was the second largest nourishment project ever performed in the United States using trucks and an inland source of sand (CERC, 1984). The interim project was impacted by Hurricane *Hugo* (1989) and a severe northeaster storm in March 1993. The City qualified for FEMA post-storm renourishment funds. Thus, between 1986 and 1990, a total of 1.25 million cubic yards (~1 million cubic meters) were placed on the beach at a cost of (~)$7 million. The average fill density for the two nourishment events combined was ~28 cubic yards per foot (cy/ft) (~70 m³/m). Annual monitoring for ten years (1986 to 1996) confirmed average annual volumetric losses of ~1.6 cy/ft/yr (~4 m³/m/yr), closely matching the predicted loss rate to low-tide wading depth. Approximately 25 percent of the nourishment remained in place on the visible beach by 1996. Kana et al (1997) summarized the ten-year performance (1986-1995) of the interim beach nourishment project.

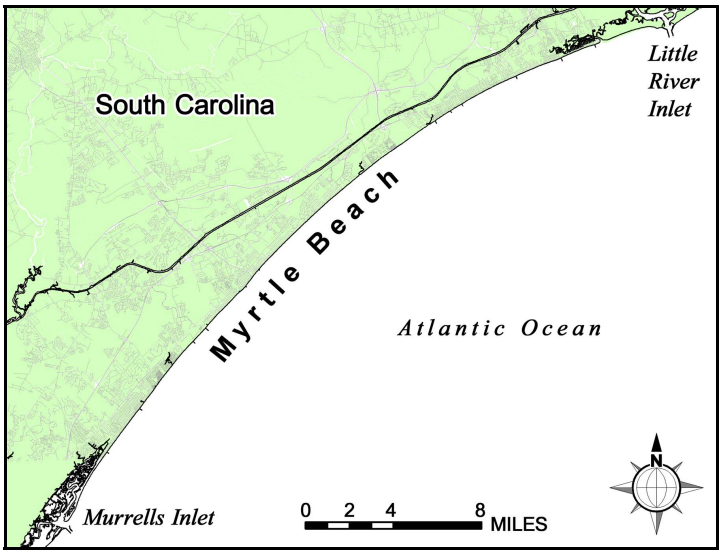

FIGURE 1. Vicinity map of Myrtle Beach (SC).

After the 1986-1987 Myrtle Beach interim nourishment project reached its tenth anniversary, the U.S. Army Corps of Engineers implemented a 22-mile-long (35 km) federal project which encompassed North Myrtle Beach (Reach 1), Myrtle Beach (Reach 2), and Garden City/Surfside Beach (Reach 3) (USACE, 1993). Reach 2 is a 9.23-mile (14.85 km) length of ocean shoreline between 82nd Avenue North and 29th Avenue South (Figure 2). This paper will focus on the 1997 federal project and its performance at Reach 2 (i.e., Myrtle Beach).

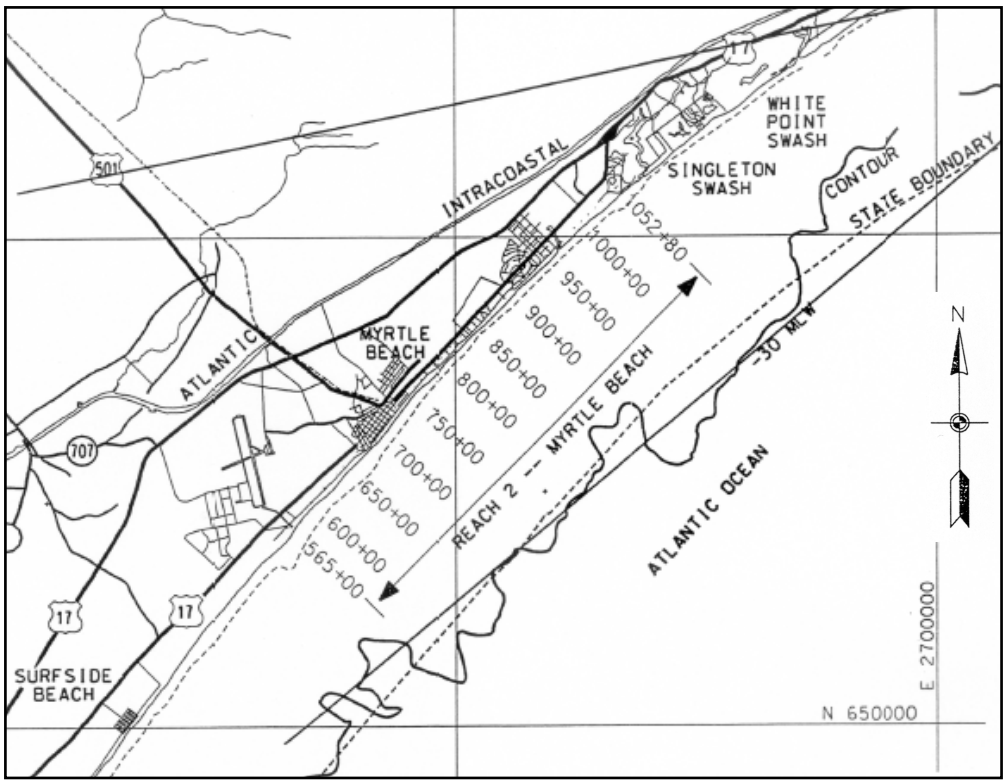

Figure 2. Federal project limits for Reach 2 – Myrtle Beach Shore Protection Project (from USACE 1993).

The federal project was constructed under the authority of the Water Resources Development Act (WRDA) of 1990 (Public Law 101-640). Section 934 of the WRDA of 1986 (Public Law 99-662) authorized federal participation in a 50-year Myrtle Beach shore-protection project, which includes periodic beach nourishment along Myrtle Beach until the year 2046. The first nourishment under this authorization was initiated on 29 January 1997 and was completed 31 December 1997. The 1997 federal project was constructed by hydraulic dredge using an offshore borrow area. Approximately 2.2 million cubic yards (~1.7 million cubic meters) were placed at a cost of (~)$17 million. The average fill density was ~45 cy/ft (113 m3/m).

PROJECT MONITORING REQUIREMENT

The Project Cooperation Agreement (PCA) between the federal government and the City of Myrtle Beach governs construction and maintenance responsibilities. In accordance with the PCA, annual monitoring of the nourishment project is required. The USACE is responsible for the first three annual observations, the City of Myrtle Beach thereafter. The City has retained Coastal Science & Engineering (CSE) since 2001 to complete the annual monitoring. Annual monitoring reports are submitted to the City and the USACE regulatory and listed in the reference section (e.g., CSE 2002,

2010). The present paper is a summary of the project performance between 2001 and 2010 based on the annual surveys.

Project monitoring is performed to track the fate of beach nourishment and document the movement of sand out of the nourishment area. Monitoring provides estimates of shoreline movement trends and identifies areas of erosion and accretion after nourishment, providing important design guidance for future beach projects. Beach monitoring aids in documenting the condition of the protective storm berm and the enhancement of the dune habitat.

The goal of annual monitoring activities is as follows:

- Satisfy USACE requirements under the PCA so that the City remains eligible for federal cost-sharing of nourishment projects.
- Quantify the beach-fill volume and berm width to determine whether the threshold for a renourishment project has been met.
- Evaluate the beach condition and performance of the 1997 nourishment project.

PROJECT SETTING

Annual surveys have been performed by the authors since 2001 using a network of 70 profile lines, most of which extend beyond 15-ft (4.6 m) depths (the estimated Depth of Closure) in this setting. Four reaches (phases) are referenced from north to south following an earlier division of the shoreline (Siah et al 1985) for the 1986–87 nourishment project. Survey stations are shown in Table 1 and Figure 3 along with reach divisions.

Table 1. Project setting.

Reaches	Federal Names	Reach Length		Boundaries
		ft	m	
North	Phase IIN	12,950	3,947	82nd Avenue N to 52nd Avenue N
Residential	Residential	7,762	2,366	52nd Avenue N to 31st Avenue N
Central	Phase IIS	12,257	3,736	31st Avenue N to 2nd Avenue N
South	Phase I	12,314	3,753	2nd Avenue N to ~29th Avenue S
Totals		45,283	13,802	82nd Avenue N to 29th Avenue S

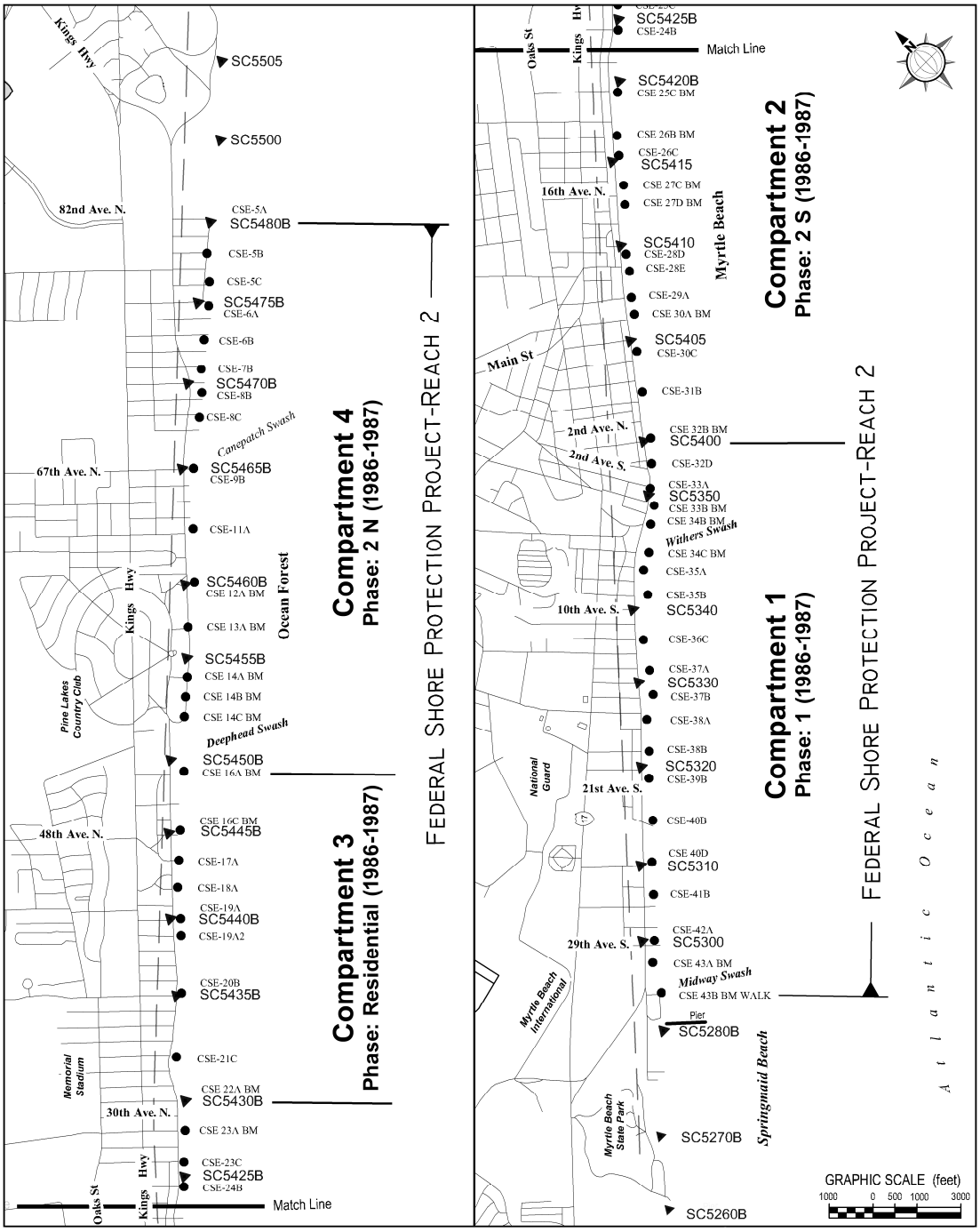

Figure 3. Vicinity map showing the location of permanent state profile stations (5200-5500 series), CSE profiles, and project compartments and reaches.

PERFORMANCE STANDARDS

Standard 1 — Storm-Berm Width

The renourishment criteria of the federal project contains the following:

- Storm protection consists of a berm with a minimum top width of 15 ft (4.6 m) at +9 ft (+2.7 m) NGVD elevation.
- Renourishment is deemed necessary when 25 percent of the berm length is reduced to 15 ft (4.6 m) of width at the +9 ft (+2.7 m) NGVD elevation.

The reason for the above-noted renourishment criteria is historical. Many federal projects were in states that did not have systematic programs for monitoring the coastline with topographic surveys. The storm-berm width can be determined using a one-person set of observations that does not require volumetric topographic surveys. Therefore, in the Project Cooperation Agreement (PCA), the Corps of Engineers established the criteria of storm berm width to estimate remaining protection from storms.

The average storm-berm widths at the state stations are listed in Table 2. Deficit berm widths are defined with respect to the 15-ft (4.6-m) width criteria; therefore, estimated shoreline lengths lacking storm-berm protection can be calculated.

Table 2. Storm-berm widths.

	May-01	Dec-02	Jun-03	Jun-04	May-05	Jun-06	May-07	Jun-08	Jun-09	May-10
Average (ft)	41.6	45.6	40.4	36.1	43.5	47.5	39.7	40.7	62.0	63.6
Average (m)	12.6	13.8	12.2	10.9	13.2	14.4	12.0	12.3	18.8	19.3
Deficit (m)	2,107	780	673	2,551	1,341	629	3,171	3,171	1,908	1,304
Deficit (%)	15.4	5.7	4.9	18.6	9.8	4.6	23.2	23.2	13.9	9.5

For the 2007 and 2008 monitoring seasons, 10,403 ft (3,171 m) of beach failed to meet the minimum 15-ft (4.6-m) storm-berm width requirement, which in this case is 23.2 percent of the entire beach. As stated in the PCA, a failure of 25 percent would trigger renourishment under federal guidelines. As planned by the federal government, an additional 1.5 million cubic yards (1.15 million cubic meters) were added to Myrtle Beach between November 2008 and January 2009. The 2008 renourishment project further advanced the shoreline. The average storm-berm width in June 2009 increased 22 ft (6.7 m) compared to the condition in the previous survey season before the renourishment project. The two federal nourishment events have placed a

total of 3.76 million cubic yards (2.83 million m3) of sand along the Myrtle Beach shoreline, which is about four times the volume placed during the interim projects (1980s).

Standard 2 — Profile Volumes

A more accurate and reliable measure of beach nourishment performance is the computation of remaining sand volume on the beach within certain depth limits. Unit volume (often given in cubic yards per linear foot) is a measure of the amount of sand contained in a unit length of beach. Sand volumes are computed within this one-foot-wide wedge of sand extending from the dune line or seawall to a particular depth offshore.

Unit volumes for each survey date and unit volume changes between selected dates were calculated to determine the quantity of sand in one linear foot of beach at each survey station. These unit volumes were used to calculate the station-to-station net volumes, the subreach net volumes, and finally the net volume for the entire project area. The calculated station-to-station net volumes are proportional to the distance between stations and represent the alongshore distribution of sand volume. These net volumes by reach were subsequently divided by the applicable reach lengths to yield weighted average unit volumes, where the weighting takes into account the variations in applicable shoreline distances from station to station.

Myrtle Beach served as a prototype for applying the concept of profile volumes as a measure of beach conditions (Kana 1993). The methodology was adopted into law under the 1988/1990 South Carolina Beach Management Act.

Volume Computation Boundaries

The calculation limits for volume computations at Myrtle Beach are defined by horizontal lenses. The upper lens is from +10 ft to −5 ft (+3 m to −1.5 m) NGVD and the lower lens is from −5 ft to −15 ft (−1.5 m to −4.6 m) NGVD. The upper lens encompasses the active beach to low-tide wading depth. The majority of the nourishment sand volume was placed in the upper lens, which is the recreational portion of the beach. The lower lens represents the outer surf zone extending to the estimated closure depth which is defined as the theoretical water depth below which there is little measureable change in the seabed elevation due to waves and currents. The estimated closure depth of Myrtle Beach is −15 ft (−4.6 m) NGVD (Kana 1997).

Volume Changes and Volume Remaining

The unit volumes of the two lenses were calculated and compared, and the sum of the volumes of the two lenses was also calculated yielding the total sand volume present in the entire survey zone [+10 ft to −15 ft (+3 m to −4.6 m) NGVD] as shown in Figures 4 to 6. The effect of the federal nourishments can be clearly seen in the increase in volume between January and December 1997 and June 2008 and 2009 in Figure 4. Figure 5 shows the trends in underwater volume between −5 ft and −15 ft (−1.5 m and −4.6 m) NGVD for the four reaches. In this lens, the profile volumes

remained relatively stable in the ten-year period between 2001 and 2010. The volume changes in the underwater region due to nourishment are not as pronounced as in the upper beach region (compare those shown in Figure 4) because a majority of the volume was placed above the low-tide wading depth.

Figure 6 combines the wading depth and underwater unit volumes. These data tend to show smoother trends because they integrate changes over most of the littoral zone. Thus, gains occurring above low water offset losses occurring below low water and vice versa. Between December 1997 and June 2008, there was a net project-wide reduction of 11.5 cy/ft (28.75 m3/m) in unit volume; equating to an average annual loss of ~1.1 cy/ft/yr (~2.7 m3/m/yr) over the ~10.5-year time span. In June 2008, the estimated unit volume calculated from the upper lens was ~305 cy/ft (~762.5 m3/m). In June 2009, the unit volume for the entire survey zone was ~338 cy/ft (~845 m3/m). The 2008 renourishment of Myrtle Beach increased the unit volume by 33 cy/ft (83 m3/m) as made evident by the June 2009 survey. The May 2010 survey found that the unit volume was ~336 cy/ft (~840 m3/m) which indicates 2.6 cy/ft (6.5 m3/m) in unit volume were lost since the previous survey (June 2009). Such faster than average volume loss rate may have been the result of the continuous sand adjustments after the 2008 nourishment project.

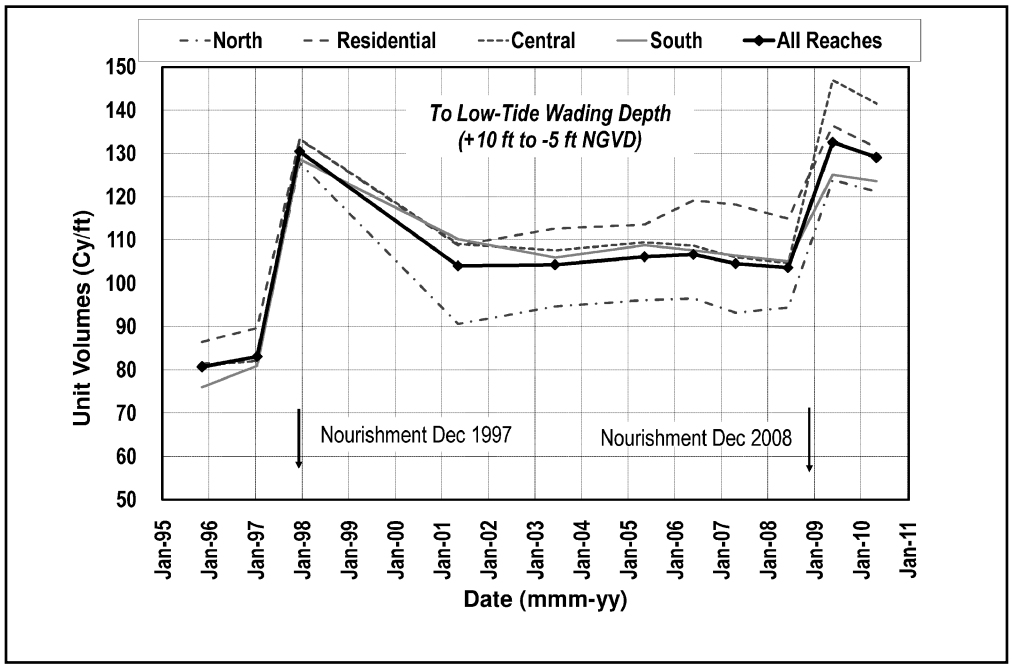

Figure 4. Unit volumes by reach measured between +10 ft and −5 ft (+3 m and −1.5 m) NGVD. [1 cy/ft equals ~ 2.5 m3/m]

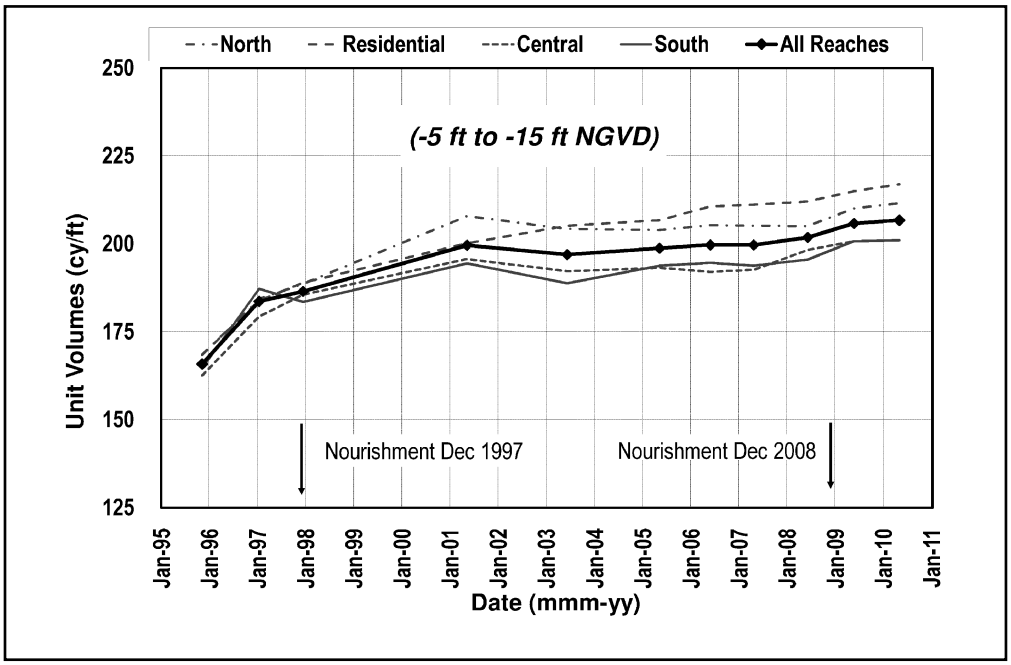

Figure 5. Unit volumes by reach measured between −5 ft and −15 ft (−1.5 m and −4.6 m) NGVD. [1 cy/ft equals ~2.5 m3/m]

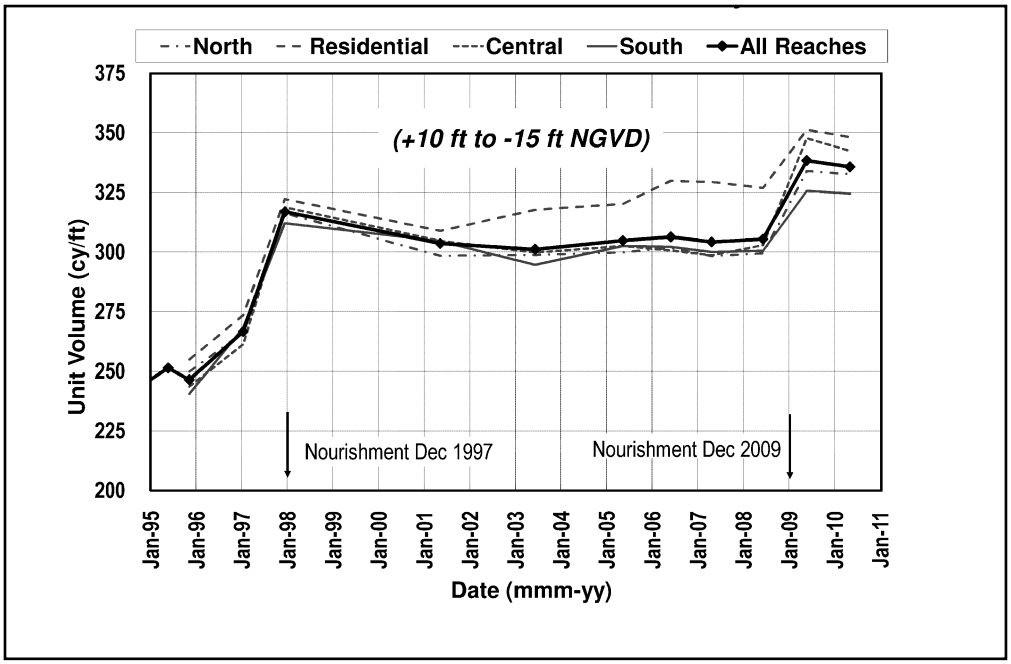

Figure 6. Unit volumes by reach measured in entire survey zone between +10 ft and −15 ft (+3 m and −4.6 m) NGVD. [1 cy/ft equals ~2.5 m3/m]

The net volume of sand remaining was estimated by applying the unit volume calculated at each measured profile over an applicable shoreline distance. The method (known as the average-end-area-method) uses the average unit volume of two adjacent profiles multiplied by the distance between the profile stations to estimate

the volume of sand remaining between the two profiles. The total volume of sand remaining in the project area is simply the sum of the individual section volumes measured to a common vertical datum.

The total sand volumes remaining on the beach in the entire survey zone between +10 ft to −15 ft (+3 m to −4.6 m) NGVD are shown in Figures 7 and 8. Results indicate there has been a net gain of ~1.46 million cubic yards or 3.57 cy/ft/yr of sand (~1.12 million cubic yards or 8.9 m3/m/yr) between May 2001 and May 2010. From the 3.57 cy/ft/yr (8.9 m3/m/yr) net gain, the authors estimate that an average gain in sand volume of 2.78 cy/ft/yr (~7 m3/m/yr) occurred on the recreational beach above low-tide wading depth, while only 0.79 cy/ft/yr occurred in the underwater lens from low-tide wading depth to the closure depth.

It should be observed that before the 2008 renourishment project, the average loss of sand on the recreational beach above low-tide wading depth was only −0.06 cy/ft/yr (−1.5 m3/m/yr) between May 2001 and June 2008. Low rates of change during this period left Myrtle Beach with a relatively healthy sand supply prior to this renourishment.

If the December 1997 post-nourishment condition is used as a reference point, then between December 1997 and June 2008, there was a total loss of 518,685 cy (396,563 m3) over the entire project area, which is equivalent to an average loss of −1.1 cy/ft/yr (−2.7 m3/m/yr) over the 10.5-year period. The Residential Reach performed better than average with a net gain of +0.45 cy/ft/yr (+1.1 m3/m/yr), while the remaining three reaches showed a net loss of sand with the North Reach performing the poorest at −1.6 cy/ft/yr (−4 m3/m/yr). Between May 2007 and June 2008, the North, Central, and South Reaches accumulated sand while the Residential Reach lost sand. Between June 2008 and June 2009, all four reaches gained sand due to the renourishment project, and one year after the renourishment project in May 2010, there was an average loss of −2.88 cy/ft/yr (−7.2 m3/m/yr) in all reaches as illustrated in Figure 7.

Using the January 1997 condition as a reference point, Figure 8 details the nourishment volumes remaining for the project area relative to this pre-nourishment condition for the respective survey dates. Myrtle Beach had an estimated net gain of 3,127,181 cy (2,391,666 m3) of sand in the littoral zone out to the closure depth between January 1997 and May 2010 [measured between +10 ft and −15 ft (+3 m and 4.6 m) NGVD]. Pre- and post-nourishment surveys indicate that the actual sand volume placed during the two most recent projects (1997 and 2008) was closer to 3.76 million cubic yards (2.87 million m3). The net volume remaining in May 2010 represents ~83 percent of the total nourishment volume. Because of the relative coarseness of the remaining sand (compared to pre-nourishment conditions), the lost material is believed to be mostly the fine to medium sand placed during nourishment projects. The lost sand likely migrated downdrift of the project limits, while very fine sand and silt would have migrated offshore beyond the −15 ft (−4.6 m) closure depth.

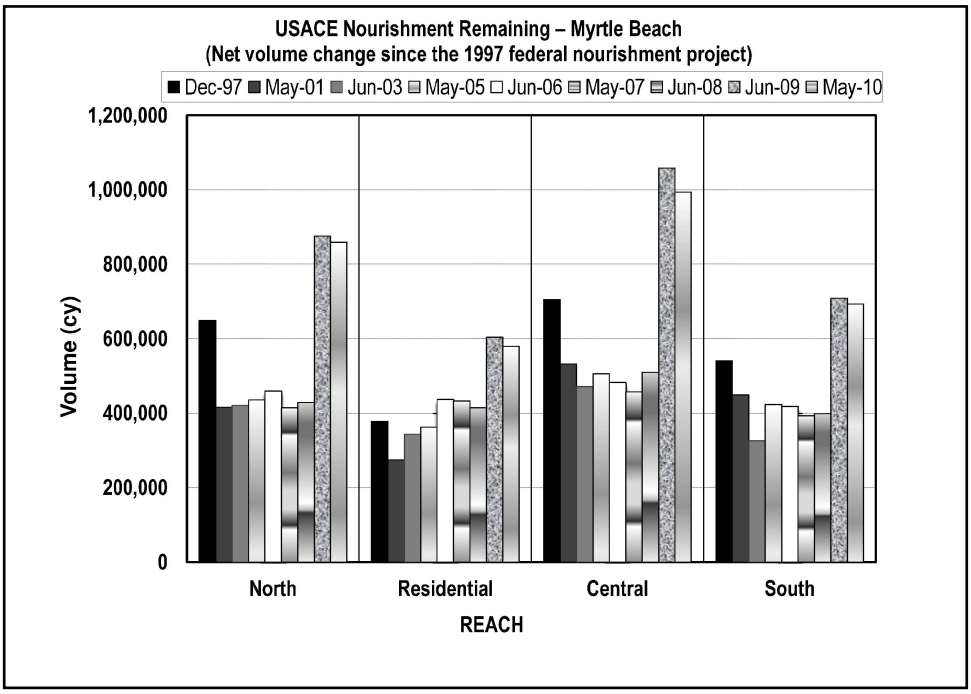

Figure 7. Nourishment volume remaining by reach between the foredune/seawall at +10 ft (+3 m) to closure depth at −15 ft (−4.6 m) NGVD compared with January 1997 conditions (with total volume of ~12.1 million cubic yards) along Myrtle Beach. [1 cy equals ~0.75 m3]

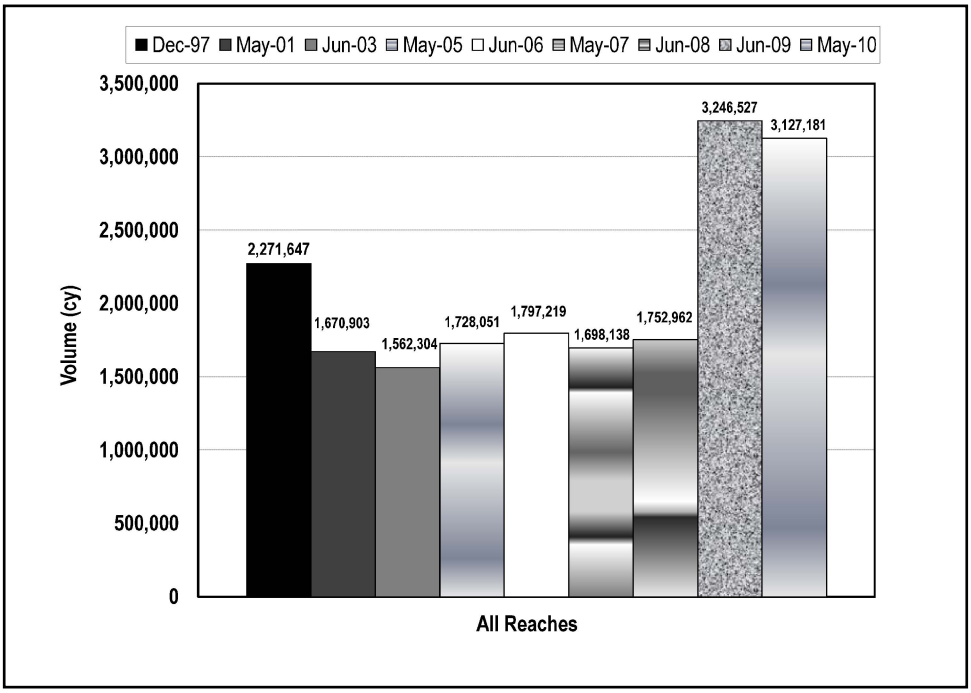

Figure 8. Total nourishment volume remaining between the foredune/seawall at +10 ft (+3 m) to closure depth at −15 ft (−4.6 m) NGVD compared with January 1997 conditions (with total volume of ~12.1 million cubic yards) along Myrtle Beach. [1 cy equals ~ 0.75 m3]

OTHER PERFORMANCE STANDARDS

Another requirement under the PCA is a yearly visual observation of the beach along with submission of standard USACE inspection forms. These observations and inspections document the general conditions along the beach. Evidence of erosion or accretion and occurrence of escarpments in the fill, beach cleanliness, public access, and dune vegetation conditions are noted.

Sediment samples at representative stations and several cross-shore positions have also been collected during each yearly survey. The composite texture and grain size at the beach are determined and compared with corresponding values from the previous year. More details can be found in annual survey reports (e.g., CSE 2002, 2010).

CONCLUSION

Survey results show that Myrtle Beach had an estimated net gain of 1.46 million cubic yards or 3.57 cy/ft/yr of sand (1.12 million m3 or 8.9 m3/m/yr) between May 2001 and May 2010. There has been a net gain of 3,127,181 cy (2,391,666 m3) of sand in the littoral zone out to the closure depth between January 1997 and May 2010. The net gain between January 1997 and May 2010 represents 83 percent of the nourishment volume placed. Therefore, nourishment losses have been lower than projected in the USACE (1993) planning documents, totaling ~17 percent of the federal fill. Overall, the beach condition is healthy, and the dune and vegetative cover have matured over this period. Twenty five years after its first nourishment and thirteen years after the 1997 federal project began, the condition of Myrtle Beach is considerably better than pre-project conditions with a wider dry beach, restored protective dune, and buried seawalls (Figure 9). The cost of these improvements has totaled (~)$40 million (2010 adjusted value). This equates to (~)$33/ft/yr ($110/m/yr). The typical oceanfront property value along Myrtle Beach is presently in the range $25,000–$50,000 per linear foot.

Figure 9. Photo sequence shows the incredible improvement of the beach conditions after the beach nourishment projects.

REFERENCES

CERC. (1984). *Shore Protection Manual*. Fourth Edition, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, VA; U.S. Government Printing Office, Washington, D.C., 2 vols.

CSE. (2002). "Monitoring and analyses of the 1997 Myrtle Beach–Reach 2 shore protection project – 2002 beach monitoring report." Final Report for City of Myrtle Beach; Coastal Science & Engineering, Columbia, SC, 38 pp + appendices.

CSE. (2010). "Monitoring and analyses of the 1997 Myrtle Beach–Reach 2 shore protection project – 2010 beach monitoring report." Final Report for City of Myrtle Beach; CSE, Columbia, SC, 65 pp + appendices.

Kana, T.W. (1993). "The profile volume approach to beach nourishment." In D.K. Stauble and N.C. Kraus (eds.), *Beach Nourishment Engineering and Management Considerations*, ASCE, New York, NY, pp. 176-190.

Kana, T.W., R.E. Katmarian, and P.A. McKee. (1997). "The 1986-1995 Myrtle Beach nourishment project ten-year performance summary." *Shore & Beach*, Vol 65(1), pp. 8-23.

Siah, S.J., E.J. Olsen, and T.W. Kana. (1985). "Myrtle Beach nourishment project." Engineering Report for City of Myrtle Beach. CSE (Columbia, SC), and Olsen Associates, Inc. (Jacksonville, FL), 160 pp. + appendices.

USACE. (1993). Myrtle Beach, South Carolina, shore protection project. *Draft General Design Memorandum*, US Army Corps of Engineers, Charleston District, SC, 46 pp. + appendices.