

V. VOLUMETRIC CHANGES

Volumetric changes discussed in this report represent the change in the quantity of sediment measured through comparison of the September 2013, May 2015, and December 2017 beach profile monitoring surveys. The volumetric changes for this monitoring period were evaluated between the May 2015 and December 2017 surveys, a span of 2.6 years; whereas the long-term changes were calculated over the 4.3 year period between September 2013 and December 2017. All volumetric changes are given in cubic yards and volumetric change rates have been normalized to an annual rate and are given in cubic yards per linear foot of shoreline per year. Volumetric changes are calculated between the dunes (upland) and the -24.0 foot NAVD contour. The volumetric changes for the Town of Duck are listed in **Error! Reference source not found.** and illustrated in **Error! Reference source not found.**

Volumetric changes provided in this report include the impact of the Town of Duck beach fill project, constructed between May and June 2017 with the placement of 1,263,181 cubic yards of sand in the project area (Stations D-10 to D-19).

May 2015 to December 2017 (2.6 years)

The total volumetric change in the monitoring area (PI-17 to SS-02) calculated above the -24 ft. contour between May 2015 and December 2017 was a gain of approximately 1,343,100 cubic yards, or an annual rate of 519,800 cy/yr. This is equivalent to an average volume change rate of 14.7 cy/ft./yr. (accretion) throughout the monitoring area over the 2.6 year period. The individual rates of volume change along the monitoring area (excluding the beach fill project area) were predominantly positive, but varied from a gain of 14.6 cy/ft./yr. between Stations D-03 and D-08 (S. Baum Trl. to Waxwing Ct.) to a loss of -50.2 cy/ft./yr. at Station D-30 (LaLa Ct.). The highest erosion rates were measured at Stations D-09 (-19.3 cy/ft./yr.), D-23 (-41.3 cy/ft./yr.), D-24 (-24.8 cy/ft./yr.) and D-30 (-50.2 ft./yr.), as shown in Table 3.

The profile at D-30 exhibited the highest rate of erosion between May 2015 and December 2017. During the previous monitoring period (September 2013 to May 2015) this profile saw a positive volume change rate of +80.4 cy/ft./yr, which was the highest positive volume change measured. The profile to the north (D-29) experienced a negative rate of -55 cy/ft./yr. during that same period. The recent results show a reversal of volume change at these two profiles where D-29 experienced a positive volume change rate of -27.6 cy/ft./yr. between May 2015 and December 2017 and D-30 experienced a negative volume change rate of -50.2 cy/ft./yr. during the same period. Inspections of the beach profile cross sections indicate the erosion at profile D-30 is a result of the berm eroding and a lowering of the nearshore profile between May 2015 and December 2017. In May 2015, the width of the berm at D-30 was significantly larger than on the adjacent profiles, due to the significant accretion that took place between September 2013 and May 2015. The December 2017 profiles generally appear more uniform. This may be due to seasonal changes or the natural redistribution of the accreted material to adjacent portions of the beach.

Table 3. Volumetric Changes above -24 FT NAVD

PROFILE	EFFECTIVE DISTANCE (FT)	VOLUMETRIC CHANGES (CY/FT/YR)	
		MAY 2015 TO DEC. 2017	SEPT. 2013 TO DEC. 2017
PI-17	497	12.6	3.3
PI-18	985	-5.6	-16.4
D-01	963	2.3	-3.1
D-02	986	-8.7	-5.2
D-03	1,012	24.4	1.8
D-04	988	2.1	-5.0
D-05	975	28.1	-4.3
D-06	975	-2.9	-9.0
D-07	975	15.3	-1.9
D-08	976	20.3	-2.2
D-09	993	-19.3	-1.9
D-10	1,012	30.6	1.7
D-11	897	78.7	20.4
D-12	900	18.9	23.4
D-13	997	33.0	33.0
D-14	975	69.5	42.9
D-15	975	52.2	36.6
D-16	973	69.4	34.6
D-17	1,010	33.1	27.8
D-18	823	45.1	29.4
D-19	601	31.8	17.1
D-20	737	22.4	15.0
D-21	825	0.2	10.8
D-22	767	15.0	5.1
D-23	787	-41.3	1.2
D-24	899	-24.8	-0.2
D-25	976	7.0	3.9
D-26	977	27.5	6.1
D-27	975	16.1	-2.3
D-28	975	-6.6	-8.3
D-29	975	27.6	-4.9
D-30	975	-50.2	0.9
D-31	1,013	11.5	4.3
D-32	975	6.7	3.0
D-33	959	0.0	-5.2
D-34	1,007	23.5	0.5
SS-01	998	-0.9	-2.5
SS-02	500	-7.8	-1.4
PROJECT AREA (D-10 TO D-19)	8,357	46.2	26.7
MONITORING AREA (PI-17 TO SS-02)	34,808	14.7	6.6

Project Area

VOLUMETRIC CHANGE RATE ABOVE -24 FT NAVD (CY/YR/YR)

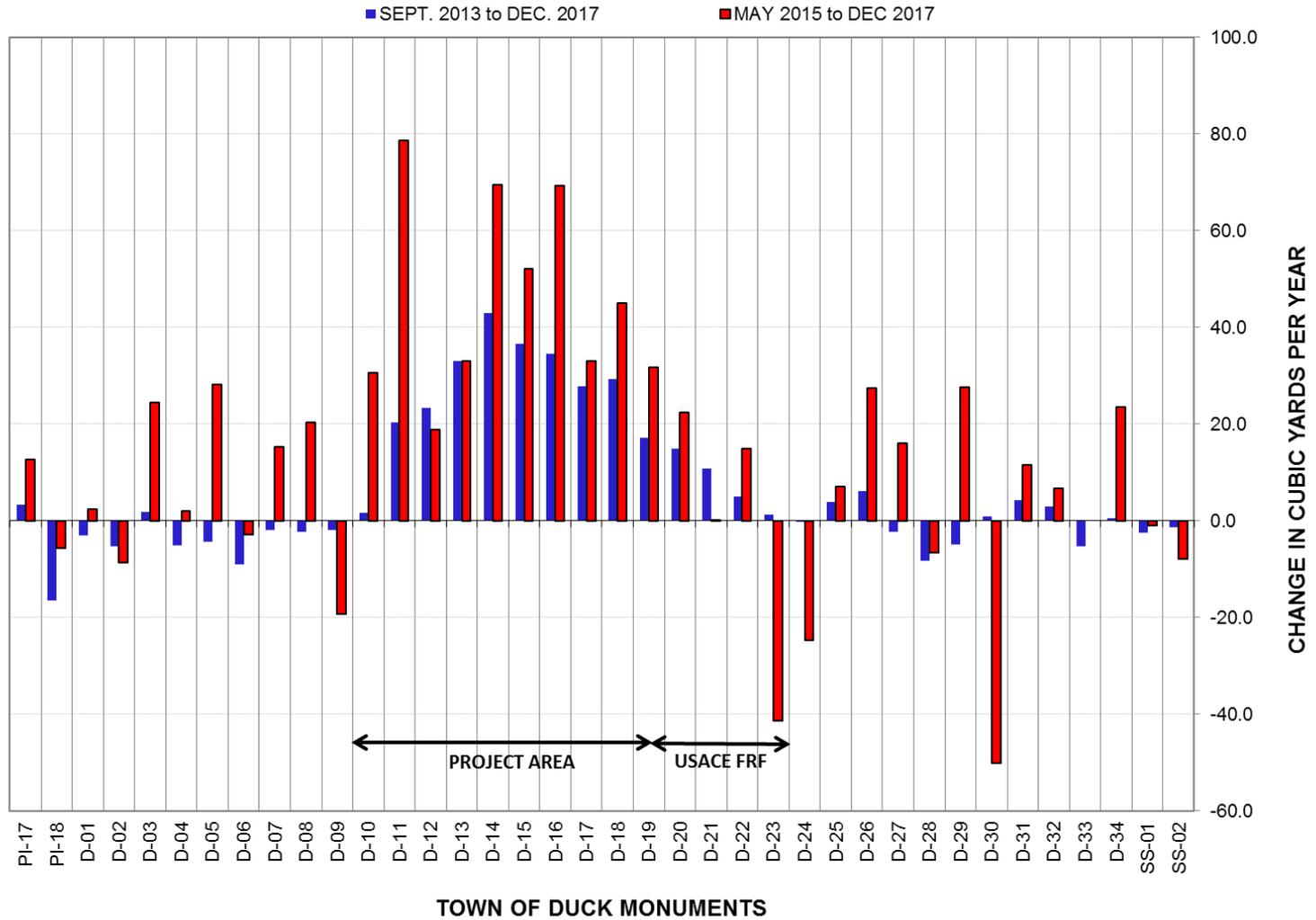


Figure 8. Annual Volumetric Change Rates Above -24 FT NAVD (CY/FT/YR).

Recent investigations performed by APTIM of the offshore areas adjacent to the Towns of Kitty Hawk and Kill Devil Hills suggest that topographic features (shoals and depressions) located offshore of the depth of closure may be influencing local areas of beach erosion and accretion. At present, it is unclear if such features are present in this particular location offshore of the Town of Duck; however, such features could be contributing to the changes observed in the vicinity of profiles D-29 and D-30.

Within the project area (D-10 to D-19), which as noted above received 1,263,181 cubic yards of beach fill between May and June 2017, there was a volumetric gain of approximately 1,039,200 cubic yards in the 2.6 year span. **Error! Reference source not found.** includes the individual rates calculated along each profile. A profile-by-profile comparison of the volume change rate in cy/ft./yr. is provided in **Error! Reference source not found.** **Error! Reference source not found.** also includes volume change rates measured between September 2013 and December 2017, which are discussed later in this report.

The 2016 monitoring report (CPE-NC, 2016) identified two (2) main areas of erosion within the monitoring area. One area was in the northern portion between PI-17 and D-11 (-25.6 cy/ft./yr.) and the second along the southern portion between D-25 and SS-01 (-9.9 cy/ft./yr.). Based on the volume changes computed between the May 2015 and December 2017 monitoring surveys, the volume change trends in these two areas reversed. For the area between PI-17 and D-11 (Pine Island to Ocean Pines Dr.) and the area from D-25 to SS-01 (Sea Colony Dr. to Southern Shores) volumetric changes were accretionary at rates of 13.7 cy/ft./yr. and 5.7 cy/ft./yr., respectively.

The previous Town-wide monitoring report (CPE-NC, 2016) updated the SBEACH storm vulnerability analysis based on the May 2015 beach profile survey data. The updated analysis identified the beach areas between Stations D-9 to D-11 (Pelican Way to Ocean Pines Dr.) and D-25 to D-29 (Sea Colony Dr. to Ocean Front Dr.) as having experienced an increase in the number of vulnerable structures compared to the analysis performed during the feasibility study (CPE-NC, 2013). The recent changes computed between May 2015 and December 2017 show a gain of approximately 212,700 cubic yards between Stations D-9 and D-11, equivalent to an average volume change rate of 30 cy/ft./yr. (accretion). The recent changes are a reversal from the -29.8 cy/ft./yr. average volume change rate measured between September 2013 and May 2015, which is attributed primarily to the construction of the beach fill project completed in June 2017. The area between Stations D-25 to D-29 experienced an approximate gain of 180,300 cubic yards, equivalent to an average volume change rate of 14.3 cy/ft./yr. (accretion) between May 2015 and December 2017. These recent changes between Stations D-25 to D-29 are a reversal from the average -25.2 cy/ft./yr. erosion rate calculated between September 2013 and May 2015; however, these changes are not directly attributed to the beach fill project completed in June 2017.

While the SBEACH analysis was not updated for this report, the positive volumetric changes observed between Pelican Way and Ocean Pines Dr. (D-9 to D-11) and between Sea Colony Dr. and Ocean Front Dr. (D-25 to D-29), has likely reduced the number of vulnerable structures previously identified.

September 2013 to December 2017 (4.3 years)

The total volumetric change in the monitoring area (PI-17 to SS-02) between September 2013 and December 2017 was calculated to be a gain of approximately 947,400 cubic yards, or 222,900 cubic yards per year. This translates into an average volume change rate of 6.6 cy/ft./yr. (accretion) throughout the monitoring area. The changes within the project area (D-10 to D-19) also measured a volumetric gain of approximately 1,027,100 cubic yards in the 4.3 year span, or 241,600 cubic yards per year. This translates into an average volume change rate of 26.7 cy/ft./yr. (accretion) throughout the project area. These volumetric changes are illustrated in Figure 8. Table 3 includes the individual rates calculated along each profile.

Although the average volume changes calculated between September 2013 and December 2017 were positive for the monitoring and project areas, a review of the changes at each profile shows the rate of change along the shoreline outside of the 2017 project area (Stations D-10 to D-19) varied between September 2013 and December 2017. The volume change rates within the monitoring area (Stations PI-17 to SS-02) range from 4.5 cy/ft./yr. (accretion) between Stations D-21 and D-26 (the USACE Field Research Facility Pier to Cook Dr.) to -8.2 cy/ft./yr. (erosion) between Stations PI-18 and D-02 (Pine Island and N Baum Trl.). The highest erosion rates were measured at Stations PI-18 (-16.4 cy/ft./yr.), D-06 (-9.0 cy/ft./yr.) and D-28 (-8.3 cy/ft./yr.).

As previously mentioned, two (2) main areas of erosion were identified within the monitoring area in the previous monitoring report (CPE-NC, 2016). These areas were between Stations PI-17 and D-11 (Pine Island to Ocean Pines Dr.) and D-25 and SS-01 (Sea Colony Dr. to Southern Shores). Annualized erosion rates between September 2013 to May 2015 were -25.6 cy/ft./yr. and -9.9 cy/ft./yr., respectively. The volumetric changes calculated for the 4.3-year period from September 2013 to December 2017 show a significantly lower erosion rate. For the area between PI-17 and D-11, the long-term rate between September 2013 and December 2017 was -1.7 cy/ft./yr. while the long-term volume change rate between Stations D-25 and SS-01 was -0.4 cy/ft./yr.

Beach Fill Performance

The performance of the 2017 beach fill project along the Town of Duck will be based on changes that occur relative to the conditions depicted by the December 2017 monitoring survey. While the beach fill project was completed in June 2017, beach fill projects typically undergo an initial period of profile adjustment in which material placed on the upper portion of the profile is redistributed to lower portions of the profile in response to tide and wave conditions. In addition to the onshore-offshore profile adjustments, some of the beach fill material is removed from the ends of the fill and distributed to the adjacent shorelines. Once these initial adjustments occur, the performance of the beach fill typically begins to mimic the behavior of a natural beach. Therefore, for purposes of monitoring the performance of the beach fill, the volume of the beach fill material on the active profile determined from comparison of the Pre-Construction survey obtained in April 2017 with the December 2017 monitoring survey will be used to represent the initial volume of material in the beach fill project. In this regard, the volume of beach fill material remaining on the active beach profile as of December 2017 was 966,300 cubic yards.