

V. VOLUMETRIC CHANGE RESULTS

Volumetric changes measured over the entire monitoring area for various time periods are provided in Table 4. The volume changes are given in terms of cubic yards/foot of shoreline/year (cy/ft./yr.). Volume change rates were evaluated for the periods from September 2013 to April 2021 (long-term), December 2017 (Post-construction) to April 2021, and June 2020 to April 2021. Volume change rates for the period from September 2013 to May 2015 area also included in Table 4 and represent trends occurring prior to construction of the project. The December 2017 to April 2021 surveys show changes occurring since the beach nourishment project was completed whereas the June 2020 to April 2021 surveys present the recent volume changes measured between the last two monitoring events.

The discussion of volume changes focuses on changes occurring within the beach nourishment Project Area (stations D-10 to D-19) as well as changes that are occurring north and south of the Project Area. Figure 5 graphically depicts the volumetric changes calculated above -24 ft. NAVD88 between September 2013 and April 2021 as well as changes measured from June 2020 to April 2021 and between December 2017 and April 2021.

Initial Beach Fill Volumes

Between May and June 2017, the 2017 beach nourishment project placed a total of 1.26 million cubic yards of fill along the Duck shoreline between stations D-10 and D-19 (APTIM, 2020). However, the performance of the 2017 project along the Town of Duck is based on changes that have occurred relative to the conditional monitoring survey conducted in December 2017. For purposes of monitoring the performance of the beach fill, the initial volume of material within the limits of the Project Area is defined as the volume change measured between April 2017 and December 2017 (APTIM, 2018). Based on volume changes computed between the April 2017 and December 2017, a volume change of approximately 963,100 cubic yards were measured on the active profile (above the -24-foot NAVD88 contour) from station D-10 to station D-19 (APTIM, 2020). For more information on why this method of assessing volume is used, please refer to the 2018 Shoreline and Volume Change Monitoring Report (APTIM, 2018).

Project Area (D-10 to D-19)

Beach profile monitoring surveys indicate a volume change within the Project Area of approximately -450,000 cubic yards between December 2017 (Post-construction) and April 2021. This equates to a rate of -14.2 cy/ft./yr. when annualized. **As of April 2021, the analysis indicates that the Town of Duck beach nourishment project had approximately 53% of the initial fill volume remaining as measured above the -24-foot NAVD88 contour in December 2017.** Figure 6 shows the cumulative volumetric changes for the Town of Duck measured since the baseline survey was conducted in September 2013. Cumulative volumetric changes are displayed for the Project Area, North of Project Area, and South of Project Area. The large increase in the Project Area curve (blue line) between April 2017 and December 2017 reflects the addition of volume due to the project construction. Since then, a relatively linear trend in erosion has been measured from December 2017 to April 2021.

Table 4. Volumetric Change Rates (cy/ft./yr.) along Duck above -24 ft. NAVD88

PROFILE		September 2013 to May 2015 (Baseline Surveys)	September 2013 to April 2021 (Long-Term)	December 2017 (Post- Con) to April 2021 (Year-4)	June 2020 (Year-3) to April 2021 (Year-4)
Area North of Project	D-01	-10.5	-0.2	3.5	0.7
	D-02	0.3	-2.7	0.5	-16.4
	D-03	-33.2	3.1	4.7	-0.6
	D-04	-16.0	-0.5	5.2	-7.7
	D-05	-52.4	3.8	14.2	4.6
	D-06	-18.3	-1.3	8.5	7.4
	D-07	-28.4	0.4	3.5	-11.3
	D-08	-37.2	-0.9	0.6	-11.9
	D-09	25.1	2.3	8.3	-12.2
	D-10	-44.6	3.6	6.1	18.1
Project Area	D-11	-69.9	7.7	-8.6	-13.7
	D-12	30.3	9.3	-8.6	-18.1
	D-13	33.1	11.7	-15.6	-21.9
	D-14	1.5	9.7	-32.8	-92.7
	D-15	12.3	7.8	-28.9	-41.0
	D-16	-19.5	9.2	-22.9	-39.3
	D-17	19.5	11.7	-8.9	-4.0
	D-18	5.2	8.5	-17.2	-10.7
	D-19	-4.4	7.5	-4.7	29.0
	D-20	3.9	7.8	-1.4	5.5
Area South of Project	D-21	27.1	7.7	3.7	-9.5
	D-22	-9.4	4.3	3.3	-28.5
	D-23	67.1	2.6	4.5	-9.5
	D-24	38.0	-5.4	-11.7	-32.0
	D-25	-1.1	-6.3	-15.5	-68.0
	D-26	-28.2	-4.5	-17.7	-55.9
	D-27	-30.6	-3.3	-4.0	-19.3
	D-28	-10.9	-3.8	2.0	-12.2
	D-29	-55.3	-3.2	-1.1	-10.3
	D-30	80.2	0.9	0.9	5.7
	D-31	-7.1	-1.7	-9.3	-75.9
	D-32	-2.8	-1.8	-8.0	-54.1
	D-33	-12.9	-1.1	4.0	-50.1
	D-34	-35.1	-0.8	-2.6	-12.7
AREA NORTH OF PROJECT (D-01 TO D-10)		-21.5	0.7	5.5	-2.9
PROJECT AREA (D-10 TO D-19)		-3.7	8.7	-14.2	-19.4
AREA SOUTH OF PROJECT (D-19 TO D-34)		1.1	-0.1	-3.6	-24.9

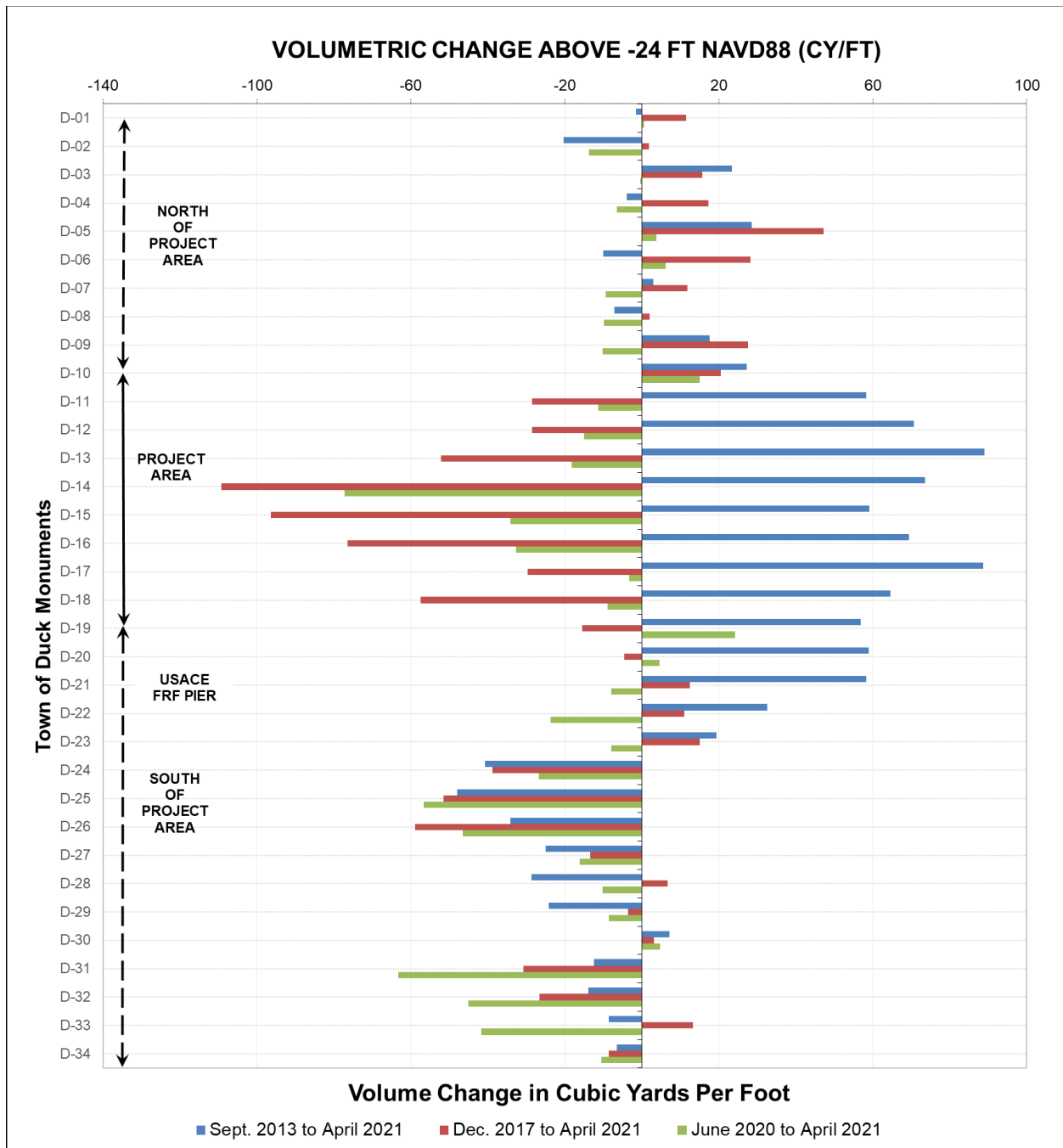


Figure 5. Volume Changes (cubic yards/foot) measured between Sept. 2013 to April 2021, Dec. 2017 to April 2021, and June 2020 to April 2021

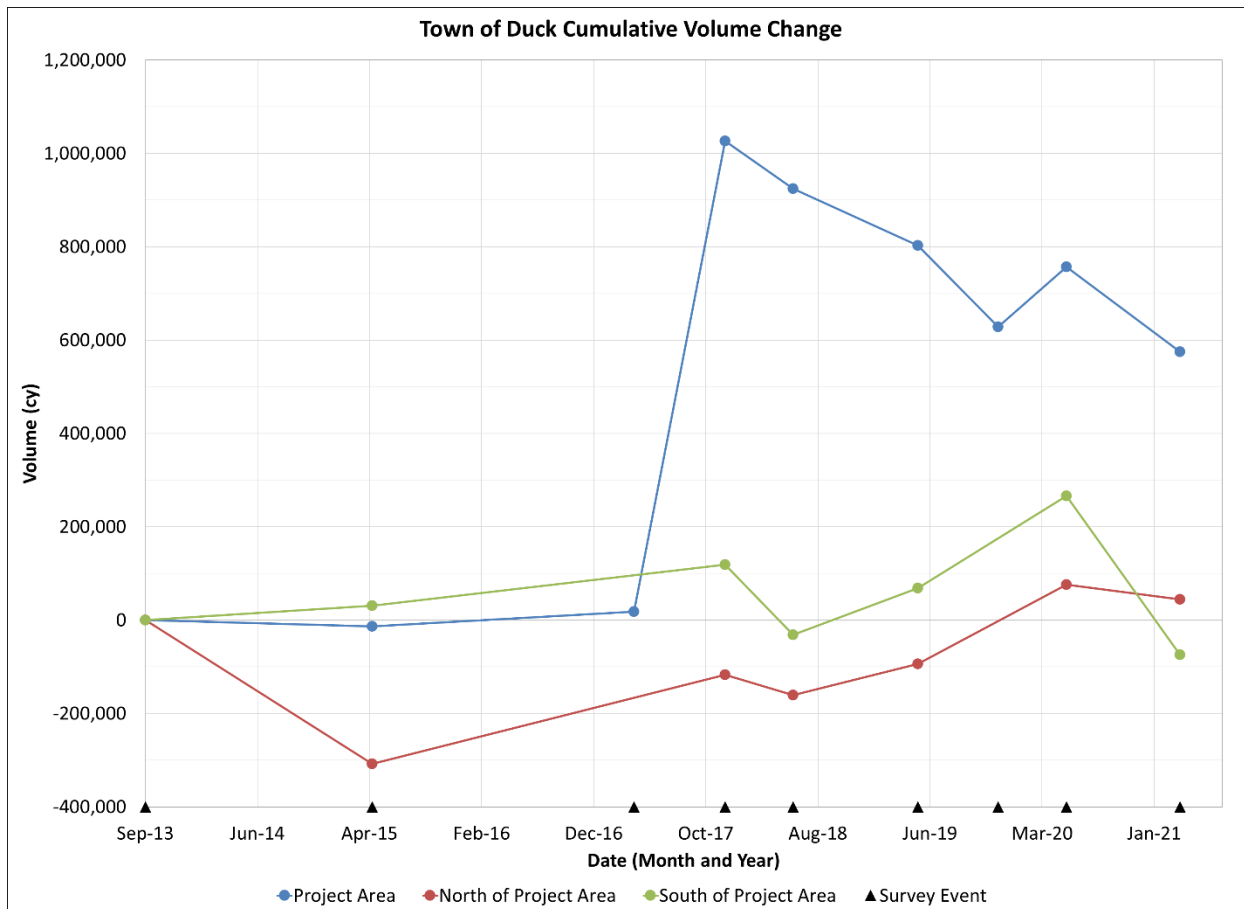



Figure 6. Average Cumulative Volumetric Changes above the -24 ft. NAVD88 contour since September 2013 in the Project Area and in the Areas North and South of the Project Area

The net volumetric change measured from June 2020 to April 2021, was a negative volumetric change of approximately 178,000 cubic yards. This is equivalent to an average loss of approximately -19.4 cy/ft./yr. and equates to approximately 40% of the total volumetric change measured between December 2017 and April 2021. The greatest negative volumetric change was measured along station D-14 (-77.3 cy/ft.), located at Sea Tern Drive E. The largest positive volumetric change was measured at station D-19 (+24.1 cy/ft.), located at the northern border of the USACE FRF property. Only the northernmost and southernmost profiles within the Project Area (stations D-10 and D-19) measured a positive volumetric change over the 10-month period. Figure 5 illustrates both the individual short-term volumetric change trends along each profile as well as changes that have occurred since September 2013 and December 2017.

Area North of Project (D-01 to D-10)

Volumetric changes in the monitoring Area North of the Project, prior to the construction of the beach nourishment project (September 2013 to May 2015), indicated an average volume change rate of -21.5 cy/ft./yr. Since the project was constructed (December 2017 to April 2021), the average volumetric change rate measured within the Area North of the Project was +5.5 cy/ft./yr. The recent period between June 2020 to April 2021 (10-months) measured an average loss of -2.9 cy/ft./yr. within the area. In Figure 6, the curve representing the cumulative volumetric changes north of the Project Area (red) shows the relatively steep erosional trend observed between September 2013 and May 2015, prior to the construction of the project. The next data point for the Area North of the Project is the cumulative volume measured in December 2017, which shows an increase in volume between May 2015 and December 2017. It is noteworthy to report that



even after the project, the cumulative volumetric change curve shows less volume in the Area North of the Project in December 2017 than what was present in September 2013. Between December 2017 and June 2018, the Area North of the Project experienced a modest reduction in volume followed by a 2-year period (June 2018 to June 2020) of volumetric increase. This was followed by a 10-month period (June 2020 to April 2021) of volume decrease. As of April 2021, the Area North of the Project has a net positive volumetric change of approximately 44,000 cy compared to the area in September 2013. Since the project was constructed in 2017, the Area North of the Project has experienced a positive volumetric change of approximately 165,000 cy.

In the previous monitoring report (CPE, 2020), the analysis of the changes along the shoreline immediately north of the Project Area between Station 1 Ln. and Skimmer Way (stations D-01 and D-10) measured a positive volumetric change of 18.2 cy/ft. between May 2019 and June 2020. The more recent volumetric change trend measured between June 2020 and April 2021 show this Area North of the Project lost an average -2.4 cy/ft., equivalent to approximately 32,000 cy.

Area South of Project (D-19 to D-34)

Volumetric changes in the monitoring Area South of the Project, prior to the construction of the beach nourishment project (September 2013 to May 2015), were relatively stable indicating modest positive volumetric changes at a rate of 1.1 cy/ft./yr. However, a review of the changes from station to station indicates the behavior of the shoreline was highly variable. Within this area, volume changes between profile stations varied from an accretion rate of 80.2 cy/ft./yr. at station D-30 to an erosion rate of -35.1 cy/ft./yr. at station D-34. During the 40-month period from December 2017 to April 2021, since the construction of the beach nourishment project, this area lost an average of 3.6 cy/ft./yr. During the recent 10-month period, from June 2020 to April 2021, this area eroded at an average rate of -24.9 cy/ft./yr. In Figure 6, the curve representing the cumulative volumetric changes south of the Project Area (green) illustrates the relatively modest accretional trend observed between September 2013 and May 2015, prior to the construction of the project. The next data point for the Area South of the Project is the cumulative volume measured in December 2017, which shows an increase in volume between May 2015 and December 2017. Between December 2017 and June 2018, the Area South of the Project experienced negative volumetric changes followed by a 2-year period (June 2018 to June 2020) of volumetric increase. This was followed by a 10-month period (June 2020 to April 2021) of volume decrease. This trend was similar to the trend observed in the Area North of the Project over the same period of time. As of April 2021, the Area South of the Project has experienced a net volumetric loss of approximately 75,000 cy compared to the area in September 2013. Since the project was constructed in 2017, the Area South of the Project experienced a net volume loss of approximately 176,000 cy.

During the recent survey interval from June 2020 to April 2021, only three profiles south of the Project experienced a positive volumetric change: D-19 (located 55 feet south of the northern boundary of the USACE FRF), D-20 (1600 ft north of USACE FRF pier) and D-30 (Four Seasons Ln). An examination of volume changes measured station to station shows the highest volumetric losses of 68.0 cy/ft./yr. and 75.9 cy/ft./yr. occurred at stations D-25 and D-31, respectively (Table 4). Figure 5 illustrates both the individual short-term volumetric change trends along each profile as well as changes that have occurred since September 2013 and December 2017.