

IV. SHORELINE CHANGES

A shoreline change analysis was completed to assess shoreline advance and recession along the study area. The shoreline is typically defined as a specified elevation contour. For this study, the shoreline was defined as the +6.0 ft. NAVD88 contour, which represents the beach nourishment project design berm elevation (CPE, 2015). Shoreline change is calculated by comparing shoreline position along shore perpendicular transects or profiles. Typically, shoreline change is then annualized to describe recession and advance rates. Annualized shoreline change rates are calculated by dividing the shoreline change by the time period (number of years) between survey events (i.e. feet per year). These changes are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

The analysis discussed in this report for the Town of Duck evaluated the +6.0 ft. NAVD88 contour positions measured during the December 2017, June 2018, and May 2019 beach profiles surveys. Even though the 2017 beach nourishment project was completed in June 2017, the December 2017 survey has been adopted to represent the post-construction conditions within the project area due to large-scale profile adjustments that normally occur immediately following the placement of beach fill. This and future annual monitoring reports will reference shoreline changes and volume changes in the project area relative to the December 2017 condition. This report also includes a shoreline comparison of what are referred to as baseline surveys, which represent the initial surveys conducted by APTIM during the planning process for the projects. The first survey conducted along Duck by APTIM, was conducted in September 2013. The last survey conducted prior to the 2017 beach nourishment operation by APTIM was conducted in May 2015. The +6.0 ft. NAVD88 contour position for each survey was identified along shore perpendicular transects spaced at approximately 1,000-foot intervals at the profiles along the monitoring area identified in Table 1.

The changes in the position of the +6.0 ft. NAVD88 contour measured between the various surveys are provided in Table 2. Within the beach nourishment project (stations D-10 through D-19), shoreline changes are shown for the period from September 2013 to May 2015, which represents long-term changes prior to construction of the project. Also shown in Table 2, are the changes in the +6.0 ft. NAVD88 contour that occurred between December 2017 and May 2019 as well as an update of the long-term changes measured between September 2013 and May 2019. The updated long-term changes include the impacts of the beach nourishment project.

Outside the beach nourishment project area, long-term shoreline changes are also provided in Table 3 for the period from September 2013 to May 2019, which include the effects of the beach nourishment projects on adjacent shorelines. Furthermore, the short-term shoreline changes for the most recent survey interval (June 2018 to May 2019) are also provided in Table 3 for the area outside of the project area.

Table 2. +6.0 FT NAVD88 Shoreline Changes (ft.)

PROFILE	September 2013 to May 2015 (Baseline Surveys)	September 2013 (Baseline) to May 2019 (Year-2)	Dec. 2017 (Post- Con) to May 2019 (Year-2)
PI-17	-22.6	-1.5	11.2
PI-18	-22.3	-2.5	49.8
Area North of Project	D-01	4.6	-20.2
	D-02	9.1	1.4
	D-03	-34.1	-21.8
	D-04	-3.1	-9.4
	D-05	-30.6	-32.4
	D-06	0.7	-5.9
	D-07	-7.3	-22.0
	D-08	14.1	-0.5
	D-09	49.9	-13.4
	D-10	-44.8	33.3
Project Area	D-11	-25.0	54.1
	D-12	19.7	54.8
	D-13	38.5	87.7
	D-14	13.5	75.0
	D-15	42.6	85.0
	D-16	-36.8	32.2
	D-17	-6.0	45.3
	D-18	-2.5	35.4
	D-19	0.4	26.5
	D-20	12.8	47.0
Area South of Project	D-21	13.1	54.8
	D-22	-28.7	34.9
	D-23	7.7	5.9
	D-24	13.1	6.4
	D-25	12.3	-2.4
	D-26	-35.9	19.6
	D-27	-35.5	-25.0
	D-28	-7.3	-10.6
	D-29	-6.0	-17.6
	D-30	66.1	-19.6
	D-31	-11.7	2.8
	D-32	-7.7	-7.0
	D-33	-6.5	-22.1
	D-34	-14.4	5.6
	SS-01	5.5	-16.2
SS-02	10.7	-11.2	
AREA NORTH OF PROJECT (D-01 TO D-10)	-4.1	-9.1	5.5
PROJECT AREA (D-10 TO D-19)	0.0	52.9	-25.8
AREA SOUTH OF PROJECT (D-19 TO D-34)	-1.8	6.2	19.1

Table 3. +6.0 FT NAVD88 Shoreline Changes (ft.) Outside the Project Area

PROFILE		September 2013 (Baseline) to May 2019 (Year-2)	June 2018 (Year-1) to May 2019 (Year-2)
Area North of Project	PI-17	-1.5	18.3
	PI-18	-2.5	20.2
	D-01	-20.2	-9.1
	D-02	1.4	32.1
	D-03	-21.8	2.2
	D-04	-9.4	2.0
	D-05	-32.4	-12.2
	D-06	-5.9	-12.6
	D-07	-22.0	-40.2
	D-08	-0.5	-17.0
	D-09	-13.4	-43.5
D-10	33.3	11.5	
Beach Nourishment Project Area			
Area South of Project	D-19	26.5	6.6
	D-20	47.0	1.6
	D-21	54.8	36.7
	D-22	34.9	44.8
	D-23	5.9	20.9
	D-24	6.4	27.8
	D-25	-2.4	-6.1
	D-26	19.6	36.6
	D-27	-25.0	3.1
	D-28	-10.6	6.5
	D-29	-17.6	-10.6
	D-30	-19.6	-14.3
	D-31	2.8	-10.2
	D-32	-7.0	-13.2
	D-33	-22.1	-5.2
D-34	5.6	10.9	
	SS-01	-16.2	N/A
	SS-02	-11.2	N/A
AREA NORTH OF PROJECT (D-01 TO D-10)		-9.1	-8.7
AREA SOUTH OF PROJECT (D-19 TO D-34)		6.2	8.5

Figure 3 graphically displays the location of +6.0 ft. NAVD88 shorelines for the entire monitoring area relative to the September 2013 shoreline. The relative shorelines shown are for May 2015, December 2017 (Post-Construction), June 2018, and May 2019. A review of the graph shows the Project Area shoreline has remained relatively stable between June 2018 and May 2019, while the shoreline 5,000 ft. north of the Project Area (stations D-05 and D-10) receded between June 2018 and May 2019. South of the Project Area, between stations D-20 and D-25, the shoreline has undergone a trend of advancement from December 2017 through May 2019. In this regard, the characterization of shoreline changes within the monitoring areas is best represented by averaging shoreline trends for multiple profile lines within certain sections. As discussed below, average shoreline trends were computed for the three subareas within the monitoring area, namely; North of the Beach Project, the Project Area, and South of the Beach Project.

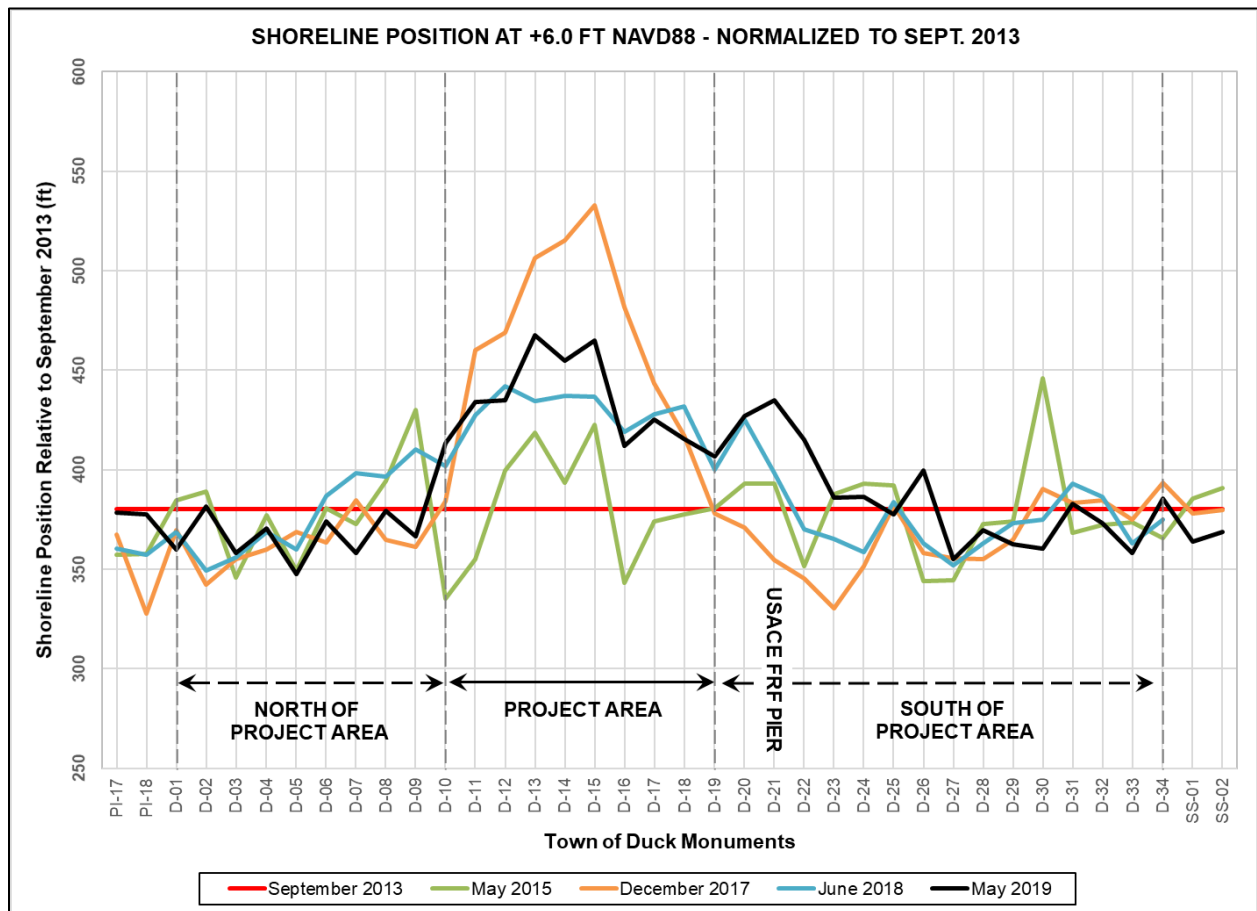


Figure 3. Historical +6.0 FT NAVD88 position relative to the September 2013 +6.0 FT NAVD88 position.

Project Shoreline Changes

Project Area. With the construction of the beach nourishment project in 2017, the +6 ft. NAVD88 contour was extended seaward +183 ft. based on comparisons of the before dredge (BD) and after dredge (AD) surveys. However, these numbers reflect the change based on the placement of the unequilibrated beach fill construction template. Between April 2017 and December 2017, the beach fill underwent immediate post-fill adjustments which reduced the initial advancement of the +6.0 ft. NAVD88 contour to an average of +89.5 feet. This seaward advance of the +6.0 ft. NAVD88 contour is more reflective of the effective advance as a result of the project.

Between December 2017 and May 2019, surveys indicated that the +6 ft. NAVD88 contour within the project area moved landward an average of -25.8 feet. Although the average shoreline change measured along the project area between December 2017 and May 2019 showed a shoreline recession (landward movement), a profile-by-profile comparison shows a wide range of changes in the position of the +6.0 ft. NAVD88 contour (Table 2). The shoreline changes within the Project Area ranged from an advance of +29.2 ft. at station D-10 (Skimmer Way) to a recession of -69.5 ft. at station D-16 (Pintail Dr.). A general trend of negative (landward) movement of the +6.0 ft. NAVD88 contour was apparent between D-11 and D-16 that generally increased from north to south. The average shoreline change from station D-11 (Ocean Pines Dr.) to D-16 (Pintail Dr.) was -49.4 ft. between December 2017 and May 2019. In contrast, the average shoreline change measured between December 2017 and May 2019 from station D-17 (located at the south end of Buffell Head Rd) to D-19 (northern USACE FRF boundary) was +3.0 ft. Table 2 includes measured shoreline change for each profile as well as the average shoreline change for the beach nourishment project and the monitored areas outside the project.

Figure 4 depicts the average cumulative change in the position of the +6.0 ft. NAVD88 contour within the project area (i.e. average change of stations D-10 to D-19) between September 2013 and May 2019. The spike in the cumulative average shoreline change in the Project Area by December 2017 reflects the 89-foot seaward advancement of the average shoreline associated with the beach fill project completed in July 2017. The spike in the Project Area was followed by a decrease resulting from the 33-foot average retreat of the +6.0 ft. NAVD88 contour between December 2017 and June 2018. This retreat of the shoreline was due to additional post-construction equilibration. Between June 2018 and May 2019, the average position of the +6.0 ft. NAVD88 shoreline within the Projects Area advanced 7 ft. seaward.

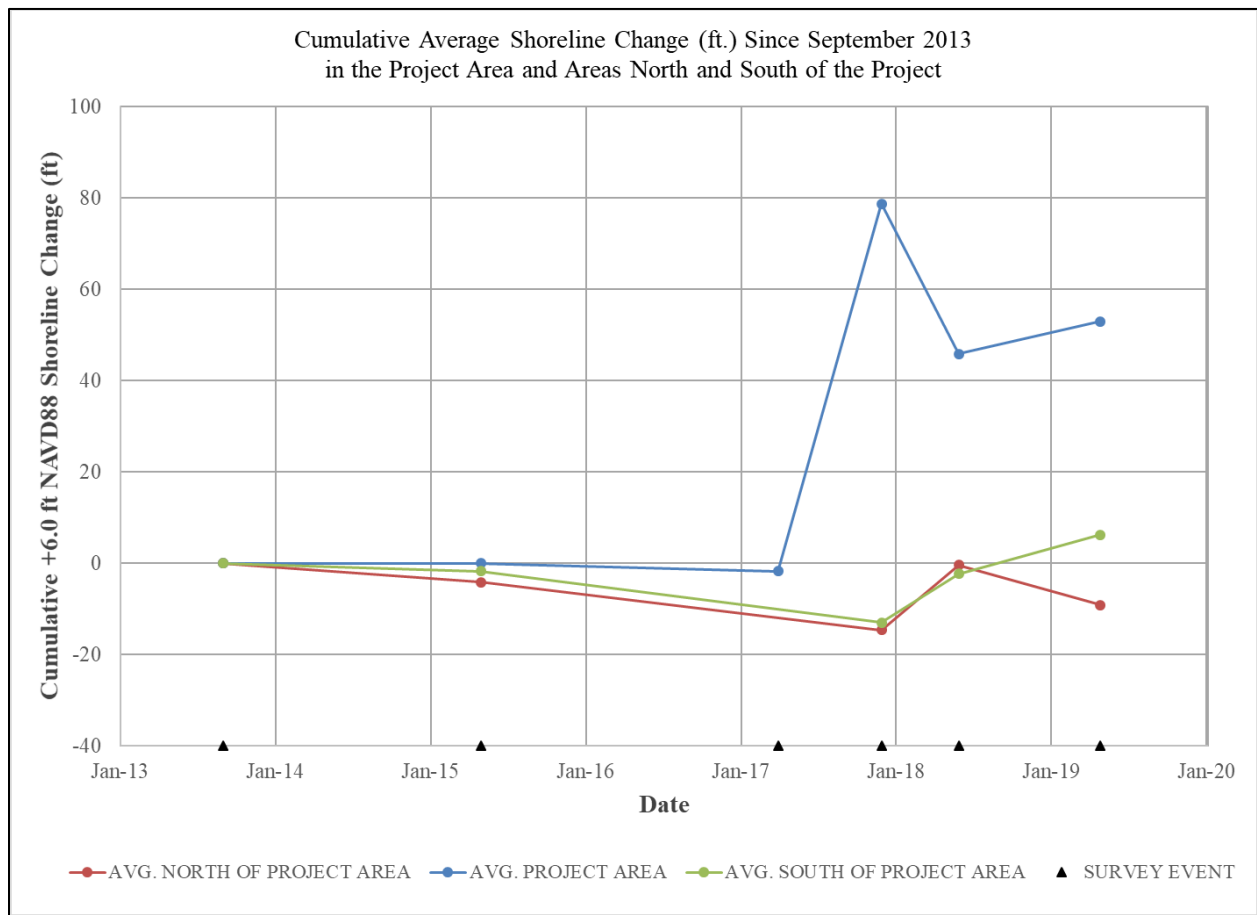


Figure 4. Average cumulative changes in the +6.0 ft. NAVD88 contour position since September 2013 in the Project Area and in the areas north and south of the Project Area.

Areas North and South of Project Area

Area North of Project. The average shoreline change measured at the +6.0 ft. NAVD88 contour between September 2013 and May 2019 north of the beach nourishment project (stations D-01 to D-10) was -9.1 ft. (landward movement). This is equivalent to a rate of -1.6 ft./yr. when annualized over the 5.7-year period. As seen in Table 3, the individual measurements from profile to profile vary considerably. The shoreline change at station D-10 (Skimmer Way) has experienced the greatest positive change of +33.3 ft. whereas the greatest negative change of -32.4 ft. was measured at station D-05 (S. Station Bay Dr.). Furthermore, over this 5.7-year period, the shoreline from stations D-03 to D-07 (S. Baum Trail to Waxwing Ln.) experienced relatively high shoreline recession, averaging -18.3 ft., equivalent to an annualized rate of -3.2 ft./yr. between September 2013 and May 2019. The average shoreline change at PI-17 and PI-18 within Pine Island was relatively minimal -2.0 ft.), indicating relatively stable conditions over the 5.7-year period.

During the recent survey interval from June 2018 to May 2019, the +6.0 ft. NAVD88 shoreline receded an average -8.7 feet. Although the average change was negative (landward movement), the measured shoreline change varied from north to south. The average shoreline change measured from station D-02 to D-04 (Baum Trail to Sanderling Resort) was +12.1 feet (seaward); whereas

the average shoreline change measured between stations D-05 and D-09 (S. Station Bay Dr. to Pelican Way) was -25.1 feet (landward). The most significant landward movement of the +6.0 ft. NAVD88 contour between June 2018 and May 2019 occurred between stations D-07 (Waxwing Ln.) and D-09 (Pelican Way), where the average measured shoreline change was -33.5 ft. Between June 2018 and May 2019, the average shoreline change at PI-17 and PI-18 was +19.2 ft. (seaward).

Area South of Project. The average shoreline change measured at the +6.0 ft. NAVD88 contour south of the project area (stations D-19 to D-34) between September 2013 and May 2019 was +6.2 ft. (seaward movement). This is equivalent to a rate of +1.1 ft./yr. when annualized. This average rate was heavily influenced by the positive shoreline change experienced directly south of the beach fill project between stations D-19 and D-22 (approximately 200 ft. north of the FRF pier to Shipwatch) as shown in Table 3. The average shoreline change measured from D-23 south along the Duck Shoreline was -5.3 ft., or a rate of -0.9 ft./yr. over the 5.7-year period. The individual measurements from profile to profile show the highest rates of shoreline recession occurred along stations D-27 to D-30 (Wampum Dr. to Four Seasons Ln.) averaging -18.2 ft. or -3.2 ft./yr. between September 2013 and May 2019. Shoreline change measured along the profiles at the southern end of the Town, between Plover Dr. and 13th Ave. (stations D-31 to D-34) varied with regards to seaward and landward movement. The average shoreline change at SS-01 and SS-02 within Southern Shores was -13.7 ft. (landward), which equates to a rate of -2.4 ft./yr. between September 2013 to May 2019.

The long-term shoreline trends were generally similar to those observed between the recent survey interval from June 2018 to May 2019 where the average rate was heavily influenced by the positive shoreline changes measured between stations D-21 to D-24 (approximately 200 ft. north of the FRF pier to Shipwatch). With the exception of D-25, where a negative 6.1 ft. shoreline change was measured between June 2018 and May 2019, profiles from station D-19 to D-28 experienced a positive shoreline change with respect to the +6.0 ft. contour. Conversely, profiles from station D-29 to D-33 experienced a negative shoreline change with respect to the +6.0 ft. contour. A positive shoreline change of 10.9 ft. was measured at station D-34. The average positive shoreline changes measured between June 2018 and May 2019 is reflected in the average cumulative changes shown in Figure 4.