IV. SHORELINE CHANGE ANALYSIS

A shoreline change analysis was completed to assess shoreline advance and recession along the monitoring 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-NC, 2015A). Shoreline change is calculated by comparing shoreline position along shore perpendicular stations or profiles. Typically, shoreline change is then annualized to describe recession and advance rates per year. Average shoreline changes for the monitoring areas were determined by computing a weighted average based on distance between the monitoring stations relative to the overall distance of the area. Annualized change rates computed for the monitoring were calculated using a linear regression method. The rate is calculated by determining the slope of the linear trendline for a certain shoreline position (+6 ft. NAVD88) for all available survey events. All available data for each survey listed in Table 1 were used in the linear regression calculation. These changes are described in terms of positive ("+") or advance (shoreline moving seaward) and negative ("-") or recession (shoreline moving landward).

The May 2023 survey has been adopted to represent the post-construction condition within the Central Reach Project Area. Future annual monitoring reports will reference shoreline changes in this area relative to the May 2023 condition to evaluate the performance of the 2023 project. This report also includes a comparison to the baseline survey, which represents the initial survey conducted by CPE during the project planning process. The first survey of the Duck shoreline by CPE was completed in September 2013, and the data from that survey were used to define the existing condition for the berm and dune design associated with the initial Central Reach Project construction in 2017. The shoreline changes measured between September 2013 (baseline survey) and June 2025 (Year-2 Post-construction) represent the cumulative changes that have occurred since the initial baseline survey and include the effects of the 2017 and 2023 beach nourishment projects. The changes measured between May 2023 (Post-construction) and June 2025 represent the post-project changes that have taken place within the Central Reach Project Area following completion of the 2023 nourishment project, including the short-term shoreline changes of the +6.0 ft NAVD88 contour measured during the most recent survey interval between June 2024 and June 2025.

Table 3 provides the measured shoreline changes between various surveys for each station where data exists and provides averages for the various areas monitored. All values in Table 3 represent actual changes and not rates. Table 4 shows rates of change determined using a linear regression method that considers each of the data sets available for the long-term period between September 2013 (baseline survey) and June 2025, the Post-project period between May 2023 (Post-construction) and June 2025, and the recent period from June 2024 to June 2025.

Table 3. Summary of Shoreline Changes (ft.)

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (Year-2)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01	-15.3	15.0	0.3
	D-02	-5.1	15.6	31.5
	D-03	0.2	17.5	8.5
	D-04	13.1	22.2	8.8
	D-05	-1.0	27.2	15.2
	D-06	-5.5	-3.3	39.7
	D-07	0.3	26.9	33.8
	D-08	3.0	10.6	7.2
	D-09	-10.9	-20.5	-21.8
Central Reach Project Area	D-10	4.4	-40.3	-17.9
	D-10.5	10.3	-60.6	-28.3
	D-11	24.6	-85.3	-30.1
	D-12	19.3	-99.4	-28.5
	D-13	30.2	-134.8	-37.9
	D-14	38.2	-131.2	-60.1
	D-15	30.8	-138.0	-53.8
	D-16	3.2	-149.1	-64.9
	D-17	13.1	-172.3	-42.6
	D-18	14.5	-137.7	-77.0
	D-19	13.9	6.9	-91.2
South Monitoring Area	D-20	35.3	14.9	-104.8
	D-21	4.4	-26.2	-57.1
	D-22	-1.1	21.6	32.9
	D-23	-36.6	-17.7	-17.3
	D-24	-26.6	-6.7	-51.9
	D-25	4.2	5.5	-8.2
	D-26	-4.1	6.5	13.0
	D-27	-6.5	19.3	-14.5
	D-28	-22.3	-1.0	-8.9
	D-29	-29.9	2.5	-24.7
	D-30	-20.0	0.3	10.9
	D-31	-11.7	-9.4	-15.2
	D-32	-16.9	-4.2	-0.7
	D-33	-11.6	-11.2	-19.6
	D-34	-14.8	-35.3	-5.1
NORTH MONITORING AREA (D-01 TO D-10)		-1.3	10.0	13.1
CENTRAL REACH PROJECT AREA (D-10 TO D-19)		20.1	-120.0	-48.5
SOUTH MONITORING AREA (D-19 TO D-34)		-10.5	-1.6	-18.8

Table 4. Summary of Shoreline Change Rates (ft./yr.)

MONITORING STATION		Sept. 2013 (Baseline) to June 2025 (2-Year)	May 2023 (Post-Con) to June 2025 (Year-2)	June 2024 (Year-1) to June 2025 (Year-2)
North Monitoring Area	D-01	-1.8	7.3	0.3
	D-02	-1.9	7.2	31.5
	D-03	1.3	8.4	8.5
	D-04	1.1	10.7	8.8
	D-05	0.8	13.0	15.2
	D-06	-1.7	-2.1	39.7
	D-07	-1.8	12.6	33.8
	D-08	-0.5	5.1	7.2
	D-09	-1.5	-9.7	-21.8
Central Reach Project Area	D-10	2.6	-19.3	-17.9
	D-10.5	2.5	-29.0	-28.3
	D-11	3.4	-41.0	-30.1
	D-12	1.0	-47.9	-28.5
	D-13	1.8	-64.9	-37.9
	D-14	4.1	-62.9	-60.1
	D-15	1.7	-66.3	-53.8
	D-16	3.4	-71.5	-64.9
	D-17	3.7	-83.1	-42.6
	D-18	4.5	-65.8	-77.0
	D-19	2.7	4.6	-91.2
South Monitoring Area	D-20	6.1	8.6	-104.8
	D-21	2.5	-11.9	-57.1
	D-22	-0.6	10.0	32.9
	D-23	-2.6	-8.4	-17.3
	D-24	-1.0	-2.6	-51.9
	D-25	0.0	2.8	-8.2
	D-26	0.4	3.0	13.0
	D-27	1.3	9.6	-14.5
	D-28	-1.5	-0.4	-8.9
	D-29	-1.9	1.5	-24.7
	D-30	-4.7	0.0	10.9
	D-31	-0.4	-4.4	-15.2
	D-32	-1.6	-2.0	-0.7
	D-33	0.3	-5.2	-19.6
	D-34	-0.1	-17.1	-5.1
NORTH MONITORING AREA (D-01 TO D-10)		-0.5	4.7	13.1
CENTRAL REACH PROJECT AREA (D-10 TO D-19)		2.9	-57.6	-48.5
SOUTH MONITORING AREA (D-19 TO D-34)		-0.3	-0.5	-18.8

Figure 3 graphically displays the position of +6.0 ft. NAVD88 contour for the December 2017, January 2023 (Pre-construction), May 2023 (Post-construction), June 2024 (Year-1 Post-construction), and June 2025 (Year-2 Post-construction) surveys along the entire monitoring area relative to the September 2013 +6.0 ft. NAVD88 contour position.

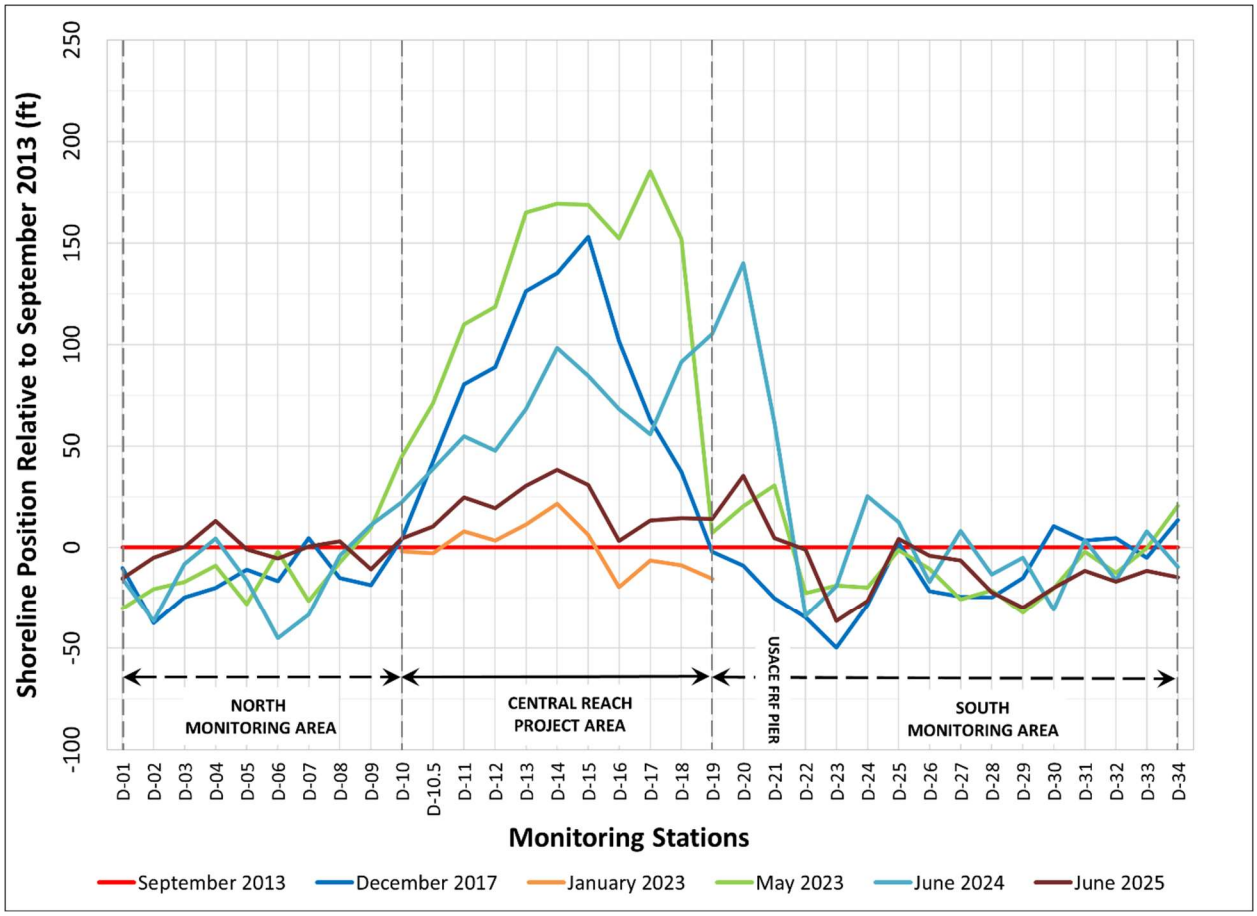

Figure 3. Long-term Shoreline Positions (+6.0 ft. NAVD88) Relative to September 2013

A review of Figure 3 illustrates several notable trends throughout the different years and monitoring areas. In the Central Reach Project Area, the shoreline positions in December 2017 and May 2023 are significantly seaward of the shoreline position in September 2013 due to the beach nourishment projects constructed in 2017 and 2023. The shoreline position observed in May 2023 is actually seaward of the shoreline position in December 2017. However, this is primarily due to the timing of when the post-construction surveys were completed following construction. In 2017, the Central Reach Project was completed in June 2017 with post-construction surveys completed 6 months later in December. In 2023, the post-construction surveys were conducted within 2 weeks following beach fill placement. In the year following the 2023 project, the Central Reach Project Area showed recession, with notable landward movement between stations D-13 and D-17, which is primarily attributed to the equilibration of the beach fill that typically occurs within 6 to 12 months following construction along the Outer Banks. The June 2025 shoreline position relative to June 2024 shows the shoreline continued a trend of recession throughout the Central Reach Project Area, with notable recession between stations D-14 and D-19. Similarly, the majority of the North and South Monitoring Area shorelines remain consistently landward of the 2013 position; however, on average, the shoreline along South Monitoring Area is further landward than the North Monitoring Area shoreline. In comparison of the June 2025 shoreline to the June 2024 shoreline positions, the North Monitoring Area shows mostly seaward movement, while the South Monitoring Area is mostly landward movement. Outside the Central Reach Project Area, the June 2025 monitoring data shows the most seaward shoreline position was in the North Monitoring Area at station D-04, whereas the landward most shoreline position was in the South Monitoring Area at station D-23.

Figure 3 also highlights the landward retreat of the June 2025 shoreline relative to September 2013, in the South Monitoring Area along the approximately 2,500 ft. of shoreline immediately south of the Central Reach Project Area and within the USACE FRF property. The data clearly indicates notable retreat of the shoreline between stations D-23 and D-24 in contrast to moderate shoreline recession observed along the remainder of the South Monitoring Area between stations D-25 and D-34. This is also apparent in the average shoreline change values shown in Table 3. Table 3 also shows the position of the +6.0 ft. contour between stations D-23 and D-24 moved landward by an average 31.3 ft. between September 2013 and June 2025. In contrast, during the same time period the average shoreline change measured along the South Monitoring Area from station D-25 to station D-34 (Town boundary with Southern Shores) was -13.3 ft.

Another noteworthy observation from Figure 3 is the landward retreat of the June 2025 shoreline in the South Monitoring Area along the 1,500 ft. of shoreline immediately south of the Central Reach Project Area and within the USACE FRF property. The data between June 2024 and June 2025 clearly indicates notable recession of the shoreline between stations D-19 and D-21 in contrast to shoreline recession observed to the south within the remainder of the South Monitoring Area. This is also apparent in the average shoreline change values shown in Table 3. Table 3 shows the position of the +6.0 ft. contour between stations D-19 and D-21 moved landward by an average -81.5 ft. between June 2024 and June 2025, which is likely associated with the continued spreading of the beach fill placed along the Central Reach Project Area in May 2023. In contrast, during the same time period the average shoreline change measured along the remainder of the South Monitoring Area from station D-22 to station D-34 (Town boundary with Southern Shores) was -8.9 ft. In this regard, the characterization of shoreline changes within the monitoring areas is best represented by averaging shoreline trends for multiple stations within certain sections. As discussed below, average shoreline trends were computed for the three subareas within the overall monitoring area, namely, North Monitoring Area, the Central Reach Project Area, and South Monitoring Area.

Central Reach Project Area (D-10 to D-19)

The construction of the 2023 beach renourishment project extended the +6 ft. NAVD88 contour seaward an average of 139.3 ft. (stations D-10 through D-19). This number reflects the change in the position of the +6 ft. NAVD88 contour based on the placement of mostly unequilibrated fill within the construction beach fill template.

Beach profile data indicated that between December 2017 and January 2023, the average shoreline change of the +6 ft. NAVD88 contour within the Central Reach Project Area was -88.3 ft., which is equivalent to a rate of change of -15.7 ft./yr. Thees values are provided as they reflect the measured shoreline change trend between the 2017 project and the 2023 project. A profile-by-profile comparison shows the rate of change in the position of the +6.0 ft. NAVD88 contour varied across the Central Reach Project Area as shown in Table 4. The greatest shoreline changes were measured in the central portion of the Central Reach Project Area. The average shoreline change measured from station D-13 through D-16 was -124.1 ft. The average shoreline changes between December 2017 and January 2023, in the northern portion of the Central Reach Project Area from stations D-10 (Skimmer Way) through D-12 (Sound Sea Ave.) was -52.3 ft.; whereas the average shoreline change in the southern part of the Central Reach Project Area measured from stations D-17 (located at the south end of Buffell Head Rd.) through D-19 (northern USACE FRF boundary) was -43.1 ft.

The changes measured between May 2023 (Post-construction), and June 2025 represent post-project changes that occurred within the Central Reach Project Area over the approximate 2-year period since the 2023 beach nourishment project was constructed. The average shoreline change measured along the Central Reach Project Area during this period between the May 2023 and June 2025 surveys was -120.0 ft. The average shoreline change rate measured between May 2023 and June 2025 was -57.6 ft./yr. While this

average rate is considerably higher than the average rate measured between the 2017 and 2023 projects, it is not uncommon to see considerable shoreline change retreat immediately following the construction of a beach fill project as the fill equilibrates, and it is expected that future monitoring data will provide a more representative comparison of the rate of project performance.

In the most recent monitoring period between June 2024 and June 2025, beach profile data indicates that the average shoreline change of the +6 ft. NAVD88 contour within the Central Reach Project Area moved -48.5 ft. landward in the second year following completion of the 2023 project. The greatest shoreline change rates were experienced between D-14 (Dianne St.) and D-19 (located at the south end of Spindrift Lane.), averaging recession at a rate of -60.9 ft./yr. The northern portion of the Project Area between D-10 (Skimmer Way) and D-13 experienced less recession at an average rate of -30.4 ft./yr.

The long-term shoreline changes within the Central Reach Project Area calculated from Sept. 2013 to June 2025, which are provided in Table 3 and Table 4 are influenced by both the 2017 and 2023 projects. In the Central Reach Project Area, the shoreline experienced an average positive shoreline change rate of 2.9 ft./yr.

Figure 4 depicts the average cumulative change in the position of the +6.0 ft. NAVD88 contour within the Central Reach Project Area (i.e. average change of stations D-10 to D-19) between September 2013 and June 2025, identified by the blue line. The large increase in the cumulative average shoreline change in the Central Reach Project Area between April 2017 and December 2017 reflects the average shoreline seaward advance associated with the 2017 project. The variation in the location of the average +6 ft. NAVD88 contour between December 2017 and January 2023 reflects the changes in the average shoreline position that occurred during the nourishment interval between the 2017 and 2023 projects. The large seaward advance between January 2023 and May 2023 reflects the seaward advance associated with the 2023 project. For the most recent period, Figure 4 depicts the Project Area shoreline experienced an average negative cumulative shoreline change between June 2024 and June 2025. As previously stated, this relatively dramatic decrease in width since the May 2023 project is associated with the equilibration process.

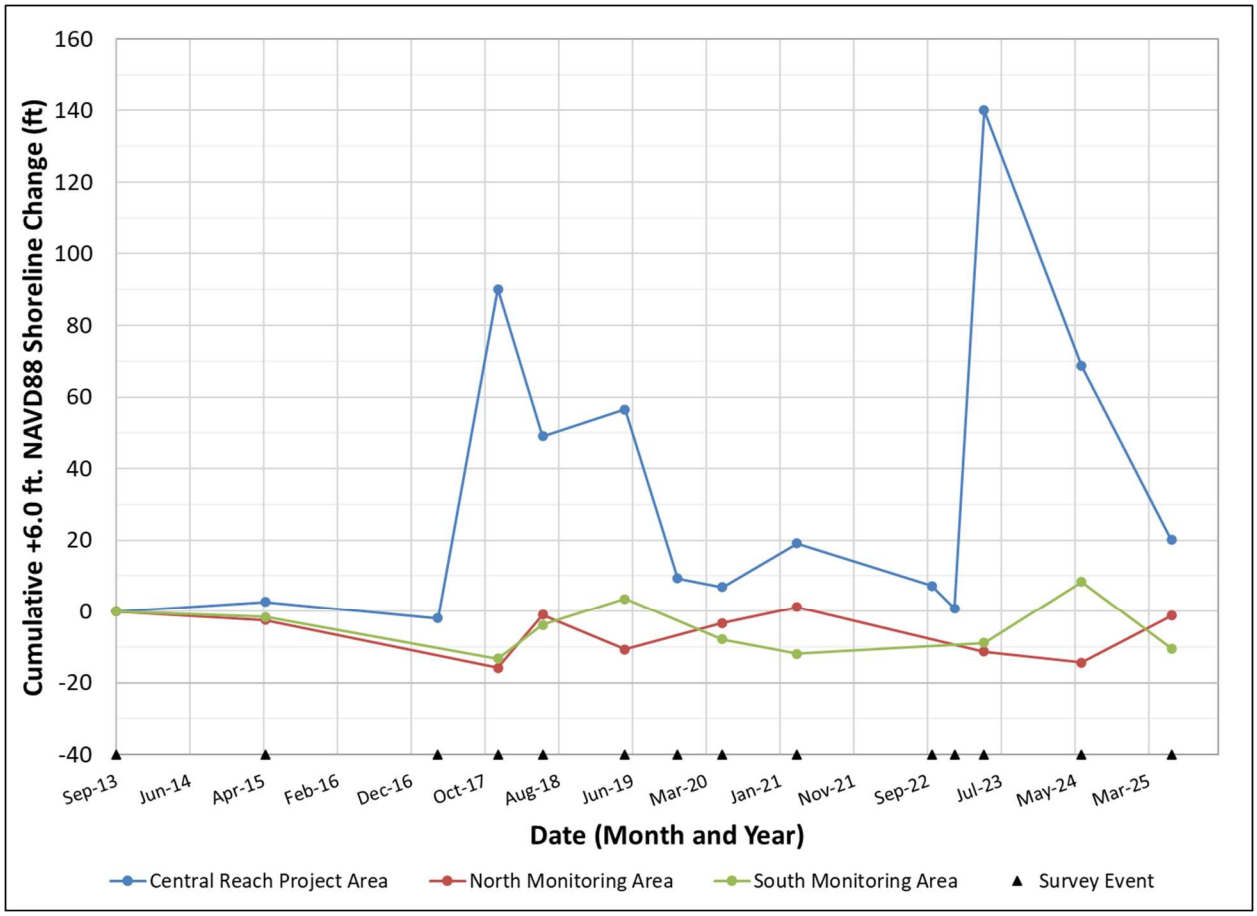

Figure 4. Cumulative Average Shoreline Changes in the +6.0 ft. NAVD88 Contour Position since September 2013 in the Central Reach Project Area and North and South Monitoring Areas

North Monitoring Area (D-01 to D-10)

From the baseline survey in September 2013 to the recent monitoring in June 2025, the average position of the +6.0 ft. NAVD88 contour along the North Monitoring Area moved landward 1.3 feet (Table 3). An average rate of -0.5 ft./yr was measured when annualized over the 11.75-year period (Table 4). This trend for the North Monitoring Area (red line) is illustrated in Figure 4. The North Monitoring Area experienced negative shoreline change between September 2013 and December 2017. Between December 2017 and June 2018, the shoreline position experienced a positive change resulting in a similar average position of the +6.0 ft. NAVD88 contour to what was measured in September 2013. Though moderate recession was observed between June 2018 and May 2019, an average shoreline advance was observed between May 2019 and April 2021 resulting in a similar average position as was measured in September 2013 and June 2018. Between April 2021 and May 2023, the average position of the +6.0 ft. NAVD88 contour retreated. Similarly, from May 2023 to June 2024, the recessional trend continued. In contrast, from June 2024 to June 2025, the trend reversed, with a positive average shoreline change of 13.1 ft. over the 12-month monitoring period. As a result of the positive change measured between June 2024 and June 2025, the June 2025 cumulative shoreline position was similar to the average position of the +6.0 ft. NAVD88 contour to what was measured in September 2013, June 2018, and April 2021.

While Figure 4 depicts the average shoreline change, Table 3 shows variability at each profile in the short and long term. For example, between September 2013 and June 2025, the shoreline change rate at station D-10 (Skimmer Way) has experienced the greatest positive trend advancing at 2.7 ft./yr. whereas the

greatest negative trend of -1.9 ft./yr. was measured at station D-02 (N. Baum Trail). On the other hand, from June 2024 to June 2025, station D-06, experienced the greatest positive (seaward) shoreline change rate (39.7 ft./yr.). Station D-09 experienced the greatest negative (landward) shoreline change rate of 21.8 ft./yr.

South Monitoring Area (D-19 to D-34)

Since the initial baseline survey of the Duck shoreline in September 2013 to June 2025, the average position of the +6.0 ft. NAVD88 contour along the South Monitoring Area (D-19 to D-34) moved landward 10.5 ft. (Table 3). The average shoreline change rate measured between September 2013 and June 2025 was -0.3 ft./yr. when annualized. As shown in Figure 4, between September 2013 and December 2017, the South Monitoring Area experienced negative shoreline change. Between December 2017 and May 2019, the area experienced an average positive shoreline change followed by a general trend of shoreline recession between May 2019 and May 2023. Between May 2023 and June 2024, the shoreline change was positive, whereas the trend reversed between June 2024 and June 2025 with a negative shoreline change relatively comparable to the positive change measured between May 2023 and June 2024.

Table 3 and Table 4 demonstrate the variability in shoreline change on a profile-to-profile basis. Between September 2013 and June 2025, the greatest negative change in the position of the +6.0 ft. NAVD88 contour was observed at station D-30 (approximately 100 ft. north of LaLa Ct. beach access) which experienced shoreline recession at a rate of -4.7 ft./yr. Over the same time, the greatest positive shoreline change was observed at station D-20 (approximately 1,000 ft. north of the FRF pier), which experienced shoreline advance at an annualized rate of +6.1 ft./yr. over the 11.75-year period.

During the recent monitoring period from June 2024 to June 2025 the average shoreline change in the South Monitoring Area was -18.8 ft. Between June 2024 to June 2025, the greatest positive change in the position of the +6.0 ft. NAVD88 contour was observed at station D-26 (Cook Dr.) of 13.0 ft. over the approximate 12-month period. Over the same time, the greatest negative shoreline change was observed at station D-20 (1,000 ft. north of FRF pier), which experienced -104.8 ft. of change in the position of the +6.0 ft. NAVD88 contour. The average shoreline change measured within the FRF property between station D-19 (northern boundary of FRF property) and D-21 (130 ft. north of FRF pier) was -81.5 ft. (landward movement) between June 2024 to June 2025. During this same 12-month period, an average shoreline change of -8.9 ft. was measured between stations D-22 (630 ft. south of FRF pier) and D-34 (southern Town boundary).