



V. VOLUMETRIC CHANGE ANALYSIS

Volumetric changes measured over the entire monitoring area for various time periods are provided in Table 5, given in terms of cubic yards/foot of shoreline/year (cy/ft./yr.) and Table 6, given in term of cubic yards (cy). The beach profile data is used to compute volumetric change out to the depth of closure, which has been established as -24 ft. NAVD88 for the sake of this monitoring program (CPE-NC, 2015a). Volume changes were evaluated for the periods from September 2013 to June 2025, May 2023 to June 2025, and June 2024 to June 2025. The September 2013 to June 2025 surveys present the long-term volume changes. These changes are mainly focused on evaluating the changes outside of the Central Reach Project Area since the volumes in the Central Reach Project Area are heavily influenced by the construction of the 2017 and 2023 projects. The May 2023 to June 2025 surveys show changes occurring since the beach nourishment project was completed whereas the June 2024 to June 2025 surveys present the most recent volume changes. Future annual monitoring reports will reference volume changes in the Central Reach Project Area relative to the May 2023 condition to track the performance of the 2023 project. Table 5 and Table 6 provide the volume change rates (cy/ft./yr.) and volumes (cy), respectively, at each monitoring station along the Town of Duck for each of the monitoring periods. Figure 5 graphically depicts the volumetric changes calculated above -24 ft. NAVD88 between September 2013 and June 2025 as well as changes measured following the 2023 construction from May 2023 to June 2025.

Table 5. Volumetric Change Rates (cy/ft./yr.) along Duck above -24 ft. NAVD88

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	1.6	20.3	12.6
	D-02	3.4	7.4	40.5
	D-03	4.6	13.4	14.2
	D-04	3.5	18.7	33.9
	D-05	2.5	14.7	2.4
	D-06	-0.9	-3.3	18.2
	D-07	-0.6	-5.9	-17.9
	D-08	0.0	9.2	-5.1
	D-09	1.9	5.3	-23.0
Central Reach Project Area	D-10	3.4	0.5	-31.5
	D-10.5	-	2.1	-33.3
	D-11	7.7	2.8	-27.9
	D-12	8.6	-0.9	0.2
	D-13	10.7	-21.9	-6.8
	D-14	9.4	-14.7	-36.6
	D-15	8.9	-16.8	-15.2
	D-16	9.2	-28.8	-27.4
	D-17	9.6	-15.7	-2.6
	D-18	10.2	-4.5	-35.9
D-19	7.0	2.2	-72.2	
South Monitoring Area	D-20	7.3	1.1	-98.9
	D-21	7.0	2.4	95.1
	D-22	7.3	22.7	64.2
	D-23	0.6	-7.0	34.2
	D-24	2.2	-5.4	12.8
	D-25	3.0	8.9	10.5
	D-26	3.9	8.9	19.3
	D-27	2.0	10.8	2.2
	D-28	-1.2	4.4	-21.3
	D-29	0.5	11.0	-14.4
	D-30	2.1	10.7	8.0
	D-31	5.3	2.9	-3.3
	D-32	4.6	12.4	17.0
	D-33	3.2	19.6	-9.5
	D-34	4.0	13.9	25.7
NORTH MONITORING AREA (D-01 TO D-10)		1.9	7.7	6.6
CENTRAL REACH PROJECT AREA (D-10 TO D-19)		8.9	-11.4	-21.7
SOUTH MONITORING AREA (D-19 TO D-34)		3.4	7.7	6.8

Table 6. Volumetric Changes along Duck (CY), above -24 ft. NAVD88

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 to D-02	27,800	25,200	27,300
	D-02 to D-03	48,000	28,000	22,200
	D-03 to D-04	47,400	24,100	33,400
	D-04 to D-05	33,900	17,700	33,900
	D-05 to D-06	9,100	10,100	11,600
	D-06 to D-07	-8,600	100	-9,300
	D-07 to D-08	-3,500	-11,200	3,300
	D-08 to D-09	11,000	-13,700	14,700
	D-09 to D-10	31,300	-27,500	6,100
	Central Reach Project Area	D-10 to D-10.5	25,700	-12,800
D-10.5 to D-11		40,400	-18,900	3,200
D-11 to D-12		74,800	-10,800	1,600
D-12 to D-13		115,500	-3,300	-24,200
D-13 to D-14		115,300	-21,100	-37,100
D-14 to D-15		104,700	-25,200	-32,000
D-15 to D-16		103,600	-20,800	-46,300
D-16 to D-17		107,500	-14,600	-45,000
D-17 to D-18		122,200	-20,200	-22,200
D-18 to D-19		60,000	-32,100	-1,400
South Monitoring Area	D-19 to D-20	51,100	-51,900	2,100
	D-20 to D-21	72,800	-1,700	3,200
	D-21 to D-22	65,600	62,300	20,500
	D-22 to D-23	34,800	37,000	12,300
	D-23 to D-24	13,500	19,400	-10,700
	D-24 to D-25	30,000	11,400	3,500
	D-25 to D-26	39,700	14,600	18,200
	D-26 to D-27	33,800	10,500	20,100
	D-27 to D-28	4,700	-9,300	15,500
	D-28 to D-29	-3,900	-17,400	15,700
	D-29 to D-30	14,900	-3,100	22,000
	D-30 to D-31	42,300	2,300	13,800
	D-31 to D-32	61,200	7,200	16,700
	D-32 to D-33	41,300	3,400	30,000
	D-33 to D-34	42,800	8,200	35,500
	NORTH MONITORING AREA (D-01 TO D-10)		196,500	52,700
CENTRAL REACH PROJECT AREA (D-10 TO D-19)		869,700	-180,000	-202,400
SOUTH MONITORING AREA (D-19 TO D-34)		544,500	92,700	218,500

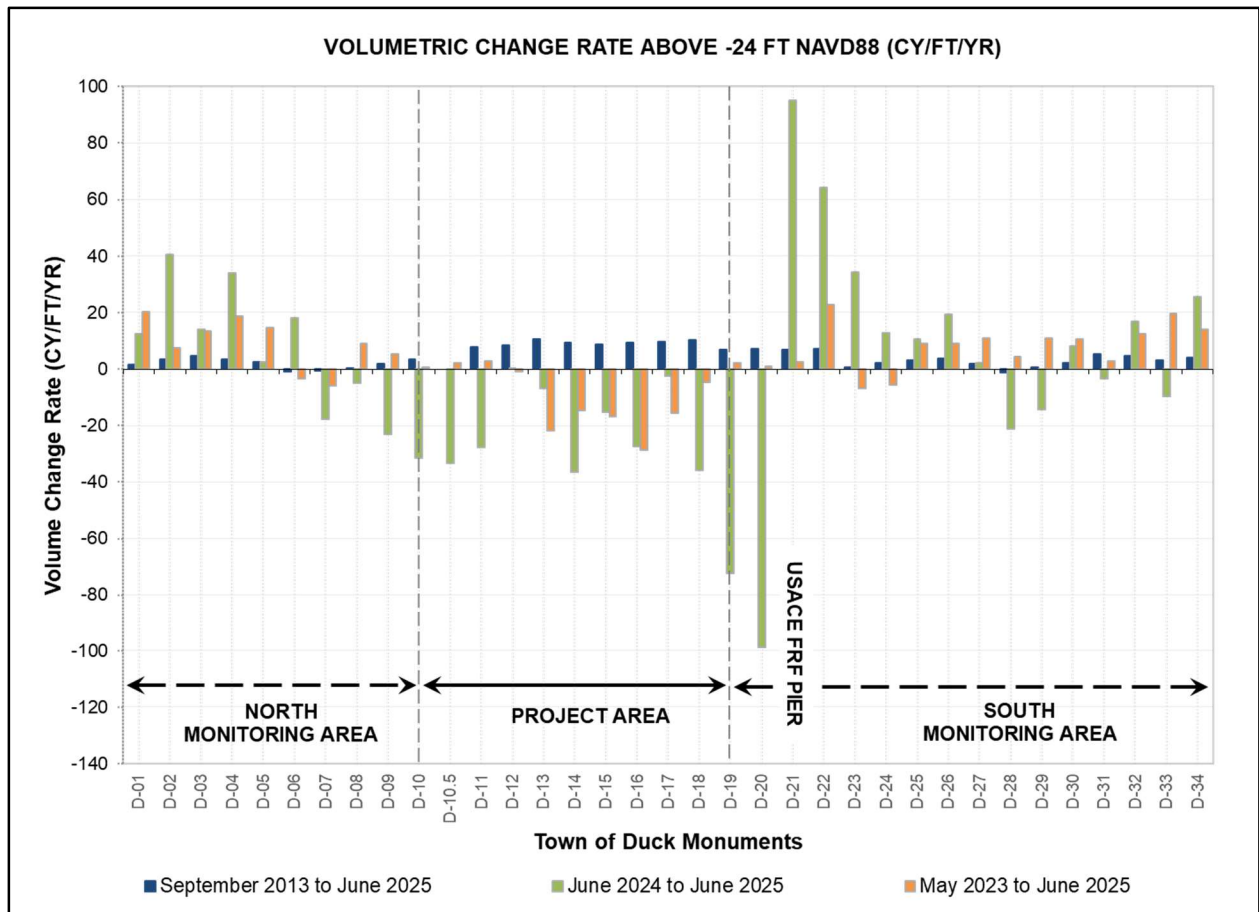


Figure 5. Volume Change Rates (cubic yards/foot/year) measured between Sept. 2013 to June 2025, June 2024 to June 2025, and May 2023 to June 2025.

2017 Beach Fill Volumes

Based on comparisons of Before Dredge (BD) and After dredge (AD) surveys, between May and June 2017, a total of 1.26 million cubic yards of fill were placed along the Duck shoreline between stations D-10 and D-19 (Central Reach Project) (APTIM, 2020). Based on volume changes computed between April 2017 (Pre-con) and December 2017 (Post-con), a volume change of approximately 963,100 cubic yards was measured on the active profile (above the -24-foot NAVD88 contour) within the Project Area (APTIM, 2020). For more information on why this method of assessing volume was used, please refer to the 2018 Shoreline and Volume Change Monitoring Report (APTIM, 2018).

2023 Beach Fill Volumes

Between April and May 2023, the 2023 beach renourishment project placed a total of 576,800 cubic yards of fill along the Duck oceanfront within the Central Reach Project Area. The May 2023 survey has been adopted to represent the post-construction conditions within the Central Reach Project Area. Future annual monitoring reports will reference volume changes in the Central Reach Project Area relative to the May 2023 condition to track the performance of the 2023 project.

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

Beach profile monitoring surveys indicate a volume change within the project area of -202,400 cubic yards between May 2023 (Post-construction) and June 2025 (Table 6). This equates to a rate of -11.4 cy/ft./yr. when annualized. This average rate is heavily influenced by the negative volume changes experienced on the central 4,00 ft. of the beach fill project between stations D-13 and D-17 as seen in Figure 5. The average volume change from D-13 south to D-17 was calculated to be a loss of -19.8 cy/ft./yr., equivalent to 160,500 cubic yards, or 79% of the total volume lost since May 2023. **As of June 2025, the analysis indicates that the Town of Duck beach nourishment project had approximately 65% of the initial fill volume remaining as measured above the -24-foot NAVD88 contour.** 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 Central Reach Project Area, North Monitoring Area, and South Monitoring Area. The large increases in the Central Reach Project Area (blue line) between April 2017 and December 2017, and between January 2023 and May 2023 reflects the volume gain associated with the 2017 and 2023 projects. In the intermittent period between the projects, December 2017 and January 2023, the project area mainly experienced erosion. After approximately 576,800 cy of sand were added to the beach between April and May 2023, the June 2024 data shows a volume loss of approximately 23,300 during the first monitoring year, followed by a loss of approximately 180,000 cy between D-10 and D-19 from June 2024 to June 2025.

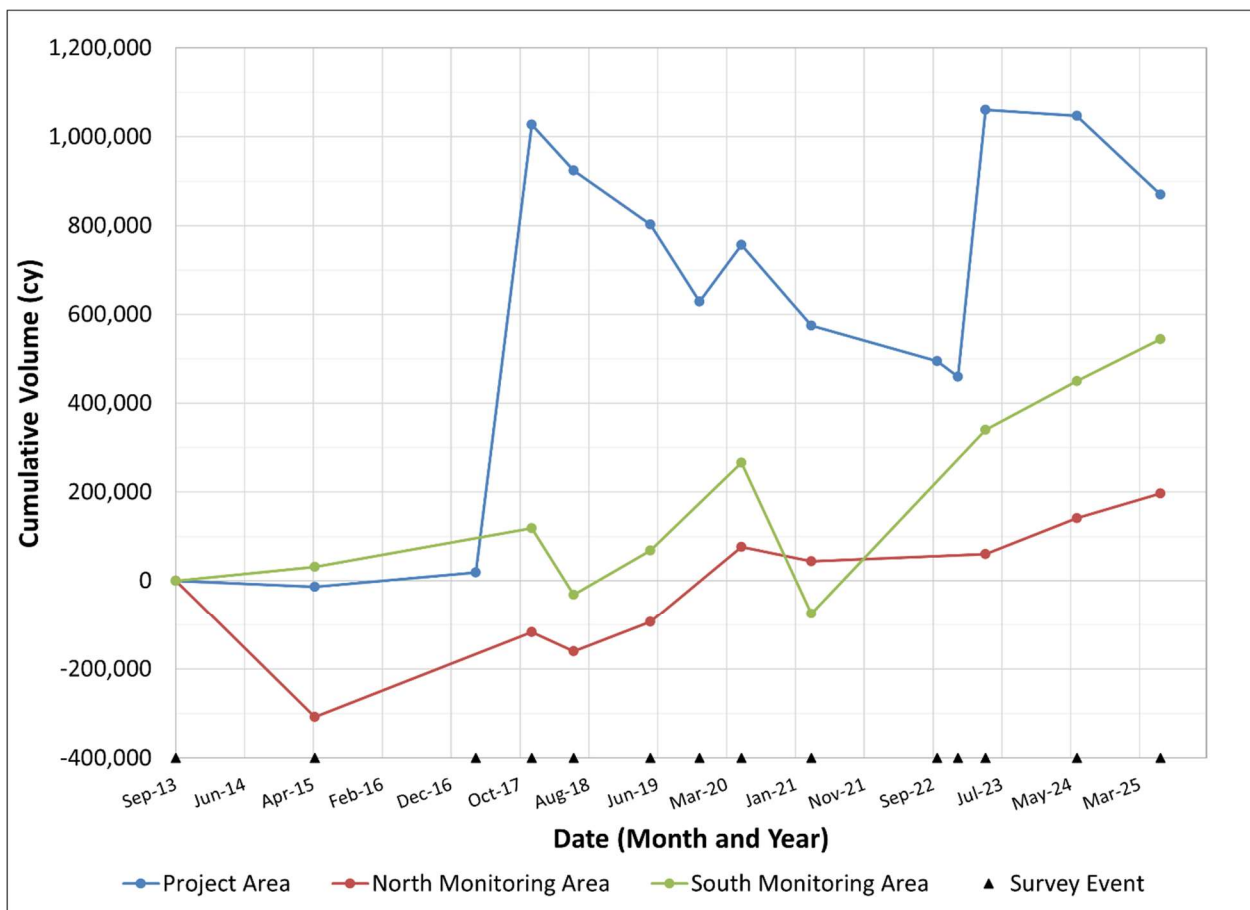


Figure 6. Cumulative Volumetric Changes above the -24 ft. NAVD88 contour since September 2013 in the Central Reach Project Area and the North and South Monitoring Areas

From September 2013 to June 2025 the Central Reach Project Area experienced a net positive volumetric change of approximately 869,700 cy (Table 6). This change is equivalent to an annual average density change rate of +8.9 cy/ft./yr. when annualized over the 11.75-year period. This positive trend shown in Figure 5 is reflective of both the 2017 and 2023 beach nourishment projects.

Over the 12-month period between June 2024 and June 2025, the volume of material within the Central Reach Project Area decreased by approximately 180,000 cubic yards (Table 6). The average volume change measured along the profiles from D-10 to D-19 was -21.7 cy/ft. However, as shown in Figure 5 and Table 5 there is considerable variation in the volume changes measured along the project area. The only positive volume change was measured along Profile D-12 (0.2 cy/ft.); whereas the greatest negative volume change was measured along Profile D-19 (-72.2 cy/ft.).

The relatively high losses along the southern end of the Project Area between stations D-18 and D-19 occurred during the same period in which substantial gains were recorded on the profiles at stations D-21, D-22, and D-23 south of the Project Area, as can be seen in Figure 5. The analysis shows a significant buildup of sand on profiles between stations D-21 and D-23, located immediately north and south of the pier, compared to the changes measured between May 2023 and June 2024. In that regard, during the period from June 2024 to June 2025, a check of the wave conditions measured by Gage 630 operated by the USACE FRF indicates there was a predominance of wave energy out of the southern quadrants that would have tended to move littoral sediment to the north. During this time, the waves out of the southern quadrants accounted for 65% of the wave energy with 35% coming from the northern quadrants. More discussion is included regarding the sediment transport in the subsequent section of this report under the heading South Monitoring Area (D-19 to D-34).

The overall changes measured in the Project Area show a moderate trend of volume loss along the northern portion of the project between D-10 and D-11, whereas the southern portion of the project between D-14 and D-19 exhibited slightly higher trends during the recent 12-month period. The higher trend of erosion in the southern portion of the project may be influenced by the continued profile adjustments following the beach nourishment project as a result of additional material that was placed along the southern portion of the project in order to allow wave action to naturally form the southern transition. As discussed below, some of the material lost out of the Project Area may have been transported to the north and south.

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

From September 2013 to June 2025 the North Monitoring Area experienced a net positive volumetric change of approximately 196,500 cy, as shown in Table 6. This equates to an annual average density change rate of +1.9 cy/ft./yr and is reflective of relative stability within the area over the 11.75-year period. As shown in Table 5, the rates of change varied from profile to profile within the North Monitoring Area ranging from a positive rate of 4.6 cy/ft./yr. at station D-03 (South Baum Trail) to a negative rate of -0.9 cy/ft./yr at station D-06 (Martin Lane). Consequently, the volume change measured within the North Monitoring Area from May 2023 (Post-construction) to June 2025 was a positive average volume change rate of 7.7 cy/ft./yr. Over the 12-month period between June 2024 and June 2025, a positive trend in volume change of 6.6 cy/ft./yr. was measured.

In the previous monitoring report (CPE, 2024), the analysis of the changes along the 3,000 ft. of shoreline immediately north of the Project Area between Waxwing Ln. and Skimmer Way (stations D-07 and D-10) from May 2023 to June 2024 measured a gain of 24.6 cy/ft. (+22.7 cy/ft./yr.) or approximately 74,000 cubic yards. However, the recent trends measured between June 2024 and June 2025 show this 3,000 ft. section lost an average 16.9 cy/ft., equivalent to approximately -52,400 cubic yards during the 12-month period. Some of the gains may still be associated with the northward spreading of the nourishment material during

the recent 12-month period and attributed to the predominance of wave energy out of the southern quadrants (65%) that would have tended to move littoral sediment to the north for the time period between June 2024 and June 2025.

In contrast, the area along the northern approximately 5,000-foot section of the monitoring area from D-06 through D-01, gained an average of 21.3 cy/ft. during the same 12-month period between June 2024 and June 2025, which equates to a gain of approximately 105,000 cubic yards. However, most of the accretion within the 5,000-ft section is attributable to anomalously high gains of 40.5 cy/ft. at station D-02 and 33.9 cy/ft. at station D-04. Even when the gains at stations D-02 and D-04 are excluded, the 5,000-foot section still shows an average gain of 10.7 cy/ft.

In Figure 6, the cumulative volumetric changes in the North Monitoring Area (red line) indicates a relatively steep erosional trend between September 2013 and May 2015, prior to the 2017 Central Reach Project. This erosional trend represents a negative volumetric change of approximately 308,000 cy. A positive volumetric trend was measured between May 2015 and June 2020 which more than offset the losses measured between September 2013 and May 2015 and resulted in a cumulative positive volumetric change of approximately 76,000 cy in June 2020, relative to the September 2013 condition. Figure 6 also shows that the cumulative volume change trend along the North Monitoring Area between June 2020 and May 2023 remained relatively stable with a modest increase in volume between May 2023 and June 2024. The positive trend continued through June 2025. As of June 2025, the North Monitoring Area had approximately 196,500 cy more volume than measured at the time of the September 2013 baseline survey.

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

From September 2013 to June 2025 the South Monitoring Area experienced a net positive volumetric change of approximately 544,500 cy above the -24 ft. NAVD88 contour (Table 6). This equates to an annual average density change rate of +3.4 cy/ft./yr. over the 11.75-year period. As shown in Table 5, the rates of change varied from profile to profile within the South Monitoring Area ranging from a positive rate of 7.3 cy/ft./yr. at station D-20 (approximately 1,000 feet north of the FRF pier) and station D-22 (approximately 600 feet south of the FRF Pier) to a negative rate of -1.2 cy/ft./yr. at station D-28 (Duck Landing Ln). Of the 16 profiles included in the South Monitoring Area, the four profiles most proximate to the Central Reach Project Area (D-19 through D-22) experienced the greatest positive density change rates, averaging 7.2 cy/ft./yr. This is likely associated with the spreading beach fill placed in the Central Reach Project Area. During the 25-month period from May 2023 to June 2025, since the construction of the beach nourishment project, the South Monitoring Area gained an average of 7.7 cy/ft./yr. During the recent 12-month period from June 2024 to June 2025 the South Monitoring Area gained an average rate of 6.8 cy/ft./yr.

In Figure 6, the cumulative volumetric changes in the South Monitoring Area (green line) illustrates a relatively modest accretional trend between September 2013 and May 2015, prior to the construction of the project. This accretional trend resulted in a positive volumetric change of approximately 31,000 cy. A negative volumetric change was measured between December 2017 and June 2018, to the degree that in June 2018, the net volumetric change from the baseline survey in September 2013 to June 2018 was negative. From June 2018 to June 2020, the South Monitoring Area experienced a positive volumetric change of approximately 298,000 cy. The South Monitoring Area experienced a considerable negative volumetric change between June 2020 and April 2021. However, between April 2021 and June 2024, the Area experienced a positive volumetric change. The South Monitoring Area continued to gain volume between June 2024 and June 2025. As of June 2025, the South Monitoring Area had approximately 544,500 cy more volume than measured at the time of the baseline survey in September 2013.

During the 12-month period from June 2024 to June 2025, the South Monitoring Area experienced positive volume change at an average rate of 6.8 cy/ft./yr., which is equivalent to a gain of approximately 92,700 cubic yards. However, an examination of volume changes in the 1,500 section between stations D-21 and D-23 (the FRF pier is located approximately 150 ft. south of station D-21), shows this area experienced an average 65.0 cy/ft./yr. gain over the 12-month period. In contrast, the adjacent profiles at stations D-19 and D-20 (located north of the FRF pier) measured losses of -72.2 cy/ft./yr. and -98.9 cy/ft./yr., respectively. The losses at stations D-19 and D-20 were due to erosion of the berm and nearshore slope down to the -8 ft. NAVD88 contour and the deflation of the offshore bar. An examination of volume changes measured station to station shows anomalous volume gains of 95.9 cy/ft./yr., 64.2 cy/ft./yr., and 34.2 cy/ft./yr. at stations D-21, D-22, and D-23, respectively (Table 5). The anomalous changes between D-21 and D-23 appear to be influenced by an increase of material on the berm and by the formation of a bar that was not present on the profiles at those stations in June 2024 as shown on Figure 7. The USACE FRF Pier may play a part in the sediment transport patterns that have been observed along the FRF property and may at times impact the southern portion of the Town’s project. A previous analysis completed by APTIM in 2013, using wave data from (1998 to 2008), found that based on the results of an Even-Odd Analysis, the USACE FRF pier had a limited longshore transport barrier effect that was limited to the FRF property.

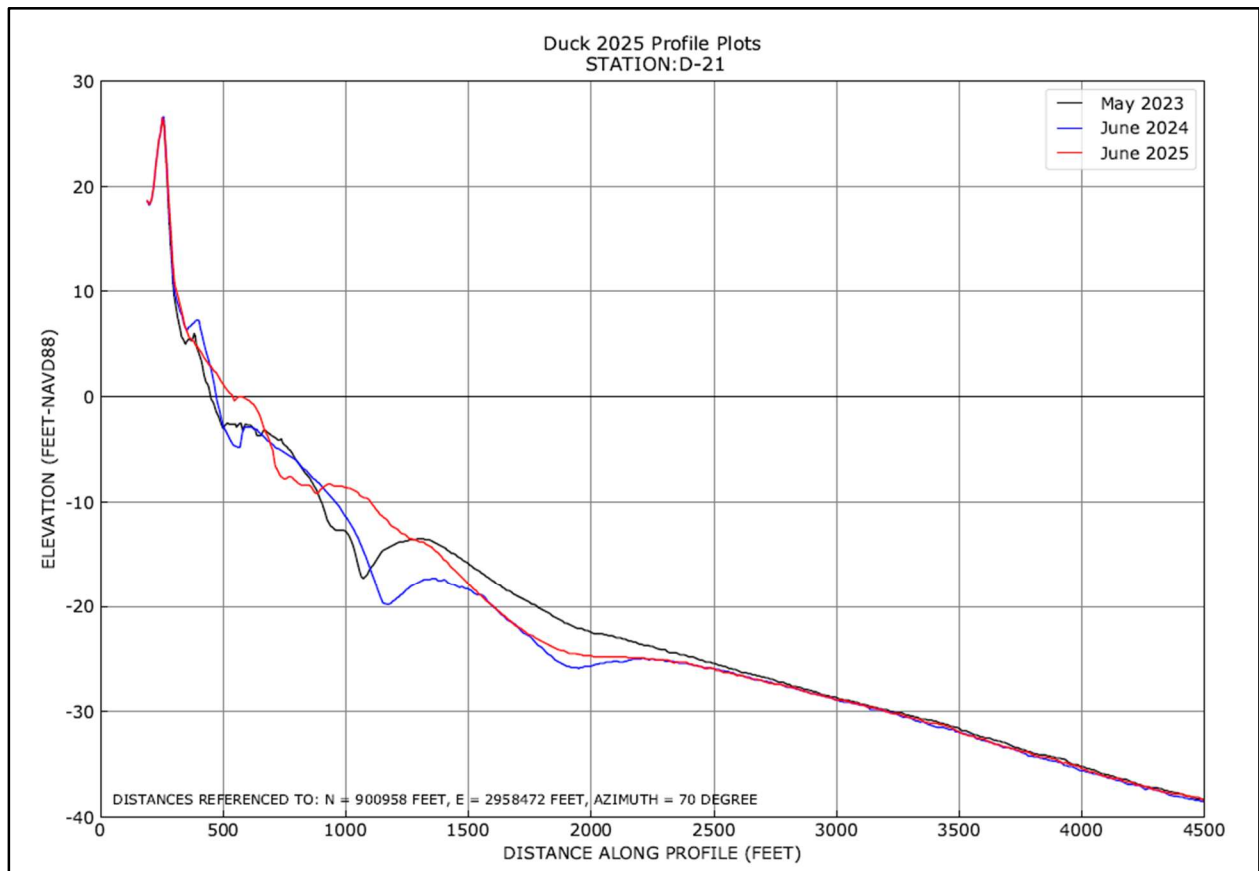


Figure 7. Profile D-21 showing progression of nearshore changes measured during the May 2023, June 2024, and June 2025 surveys.