VI. DISCUSSION

This monitoring report evaluated shoreline and volumetric changes along the Town of Duck over three timeframes. The longest timeframe ranges from the initial baseline survey conducted in September 2013 and spans through the most recent survey conducted in June 2025. Shoreline and volume change analyses were also performed for the entire Town of Duck oceanfront between the two most recent survey events, conducted in June 2024 and June 2025. Additionally, changes were evaluated for the period between May 2023 and June 2025 to quantify the changes following completion of the 2023 nourishment project.

Shoreline Change Analysis

Central Reach Project Area. During the period between December 2017 and January 2023, the position of the +6 ft. NAVD88 contour receded landward by an average of 88.3 ft. within the Central Reach Project Area. While this period is used to evaluate project performance between the construction of the initial 2017 beach nourishment project and the 2023 renourishment project, it is important to note that the December 2017 survey represents the beach condition approximately 6 months after completion of the 2017 Central Reach Project in Duck. This is an important consideration given a beach nourishment project experiences dramatic shoreline change in the months following construction as the profile equilibrates (Willson et al., 2017). Compared to the immediate After Dredge (AD) surveys that were conducted during the 2017 construction project, the January 2023 survey indicates an average shoreline change of approximately -229 feet. The shoreline changes associated with equilibration are also evident through comparison of the May 2023 and June 2025 surveys. While the 2023 beach renourishment project extended the position of the +6 ft. NAVD88 contour seaward an average of 139.3 ft. based on comparisons of the Before Dredge (BD) and After Dredge (AD) surveys, in the 25 months following the construction (June 2025), an average shoreline recession of 120.0 ft. was measured.

North Monitoring Area. The +6.0 ft. NAVD88 long-term shoreline changes north of the project (stations D-01 to D-10) were predominantly negative and variable from September 2013 to June 2025. The average change was -1.3 ft., equivalent to a rate of -0.5 ft./yr. when annualized, which includes the construction of the two beach nourishment projects constructed in 2017 and 2023. During the Post-project period, the shoreline change measured within the North Monitoring Area from May 2023 to June 2025 shows an average advance of the +6 ft. NAVD88 shoreline at a rate of 4.7 ft./yr. The average shoreline advance measured for the North Monitoring Area was +10.0 ft. Most of the advance was attributed to movement of sediment onto the upper portions of the profile in response to tide and wave conditions. During the period from May 2023 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. The wave data shows that between May 2023 and June 2025, the waves out of the southern quadrants accounted for 56% of the wave energy with 30% coming from the northern quadrants.

South Monitoring Area. The long-term average shoreline change rate computed along the South Monitoring Area (stations D-19 to D-34), based on all the various surveys conducted between September 2013 and June 2025, was -0.3 ft./yr. While the average shoreline change rate indicates stability along the South Monitoring Area since September 2013, there is a clear trend of positive changes immediately south of the Project Area and more fluctuation further south. The average long-term shoreline change rate from the southern boundary of the Central Reach Project Area to approximately 130 ft. north of the USACE FRF pier (stations D-19 to D-21) was a positive 4.0 ft./yr. (seaward movement). The positive average shoreline change rate along this section of the Town, directly adjacent to the Central Reach Project Area, may indicate a positive impact on the +6.0 ft. contour location due to the 2017 and 2023 projects. The average long-term shoreline change rate between 600 ft. south of the USACE FRF pier and the southern Town Boundary (station D-22 to D-34) was -1.0 ft./yr. (landward movement).

During the Post-project period, the shoreline change measured along the South Monitoring Area from May 2023 to June 2025 shows an average recession of the +6 ft. NAVD88 shoreline at a rate of -0.5 ft./yr.. The average shoreline recession measured for the South Monitoring Area was -1.6 ft. Similar to the long-term period, the average change indicates stability; however, there is no clear trend with changes ranging from a shoreline advance of 21.6 ft. at station D-22 to a recession of -35.3 ft. at station D-34.

Volumetric Change Analysis

Central Reach Project Area. The long-term average volumetric change rate between Sept. 2013 to June 2025 was +8.9 cy/ft./yr. This positive rate reflects the cumulative benefits of the 2017 and 2023 beach nourishment projects implemented within the Central Reach Project Area. The 2023 beach nourishment project placed approximately 576,800 cubic yards of fill along the Duck shoreline between stations D-10 and D-19 (Central Reach Project). As of June 2025, the total volume of sand within the Central Reach Project Area was approximately 870,000 cubic yards greater than the volume measured during the baseline survey conducted in September 2013, prior to any nourishment activities.

Between December 2017 and January 2023, a change rate of -12.3 cy/ft./yr. was recorded and represents the performance of the 2017 beach nourishment project over the initial 5-year maintenance interval. The desired outcome is that the 2023 project will not experience volume change rates greater than the 2017 beach nourishment project. The 2023 project employed an optimized beach fill design intended to reduce the rate of loss from the project compared to the 2017 project. Furthermore, it is not uncommon to observe a reduction in erosion rates along a beach after multiple nourishment cycles.

In the two years since the 2023 nourishment project was completed the Central Reach Project Area experienced an average erosion rate of -11.4 cy/ft./yr. As of June 2025, the 2023 project is exhibiting a slightly lower erosion rate relative to the 2017 nourishment project over the two-year post-construction period. The total volumetric change since May 2023 corresponds to an estimated net loss of approximately 202,400 cubic yards of sand. Overall, after 25 months post-construction, approximately 65 percent of the material placed during the 2023 project remains within the Central Reach Project Area. Beach nourishment projects often exhibit a non-linear pattern of erosion following construction with higher rates of erosion occurring immediately following construction and lower rates experienced in the latter years of a maintenance cycle. This pattern is illustrated in Figure 6 where the cumulative loss of sand between December 2017 and December 2019 was greater than the volumetric change measured between December 2019 and January 2023. Continued monitoring will allow for a better comparison of post-construction performance trends between the 2017 and 2023 nourishment projects.

During the recent period, June 2024 to June 2025, the Central Reach Project experienced an average rate of change of -21.7 cy/ft./yr. This equates to a loss of approximately 180,000 cy, indicating an increase in volume losses from the initial post-construction monitoring period between May 2023 and June 2024 (-23,300 cy). In the 12 months following the completion of the 2023 project, the Central Reach Project experienced positive changes (>+30 cy/ft./yr.) along the northern and southern approximate 1,000 feet of shoreline within the Project Area. This indicates that the project was gaining material at the northern and southern ends of the project rather than losses which are typically experienced following a project due to lateral spreading of the fill to ends of the project, known as diffusion.

North Monitoring Area. The long-term average volumetric change rate along the North Monitoring Area (September 2013 to June 2025) was +1.9 cy/ft./yr. While the North Monitoring Area experienced discrete periods of volumetric losses between 2013 and 2025, the overall trend during this time has been positive. Despite no direct sand placement in this area during the 2017 and 2023 beach nourishment projects, the monitoring data shows an increase of approximately 196,500 cy of sand over the 11.75-year period.

The assessment of whether the Town's oceanfront provides a reasonable level of storm damage reduction for public and private development has traditionally relied on the SBEACH storm simulation model. This model simulates storm scenarios equivalent to a modern-day version of Hurricane Isabel, which affected the Town in 2003. In 2019, simulations based on May 2019 beach conditions identified only one oceanfront structure and no oceanfront pools in the North Monitoring Area that would have been affected. An updated SBEACH analysis conducted in 2023, using May 2023 beach conditions, found that no oceanfront houses or pools in the North Monitoring Area would have been impacted by the design storm. Although the SBEACH analysis was not updated using June 2025 conditions, the North Monitoring Area experienced an additional volumetric gain of approximately 143,200 cy between May 2023 and June 2025. This continued positive volumetric change suggests that, as of June 2025, a reasonable level of storm damage reduction for public and private development remained in place along the North Monitoring Area.

In the short-term period between June 2024 and June 2025, the average volumetric change measured along the North Monitoring Area was a gain of approximately 52,700 cy, equivalent to an average change rate of +6.6 cy/ft./yr. These results indicate an above average period of positive volumetric change along the North Monitoring Area given the long-term average volume change rate was reported as +1.9 cy/ft./yr. Although the SBEACH analysis was not updated using the June 2025 conditions, the observed volumetric gain in the area suggests that, as of June 2025, the North Monitoring Area maintained a reasonable level of storm damage reduction for public and private development.

South Monitoring Area. The long-term average volumetric change rate along the South Monitoring Area (September 2013 to June 2025) was +3.4 cy/ft./yr. Despite periods of volumetric losses in the South Monitoring Area between 2013 and 2025, the overall trend during this timeframe has been positive. Although no sand was directly placed in the South Monitoring Area during this period as part of beach nourishment projects, the analysis indicates an increase of approximately 544,500 cy of sand over the 11.75-year monitoring period. With the implementation of the Town of Southern Shores beach nourishment project in 2022/2023, the South Monitoring Area is now bound by beach nourishment projects both to the north and the south. As stated above, over the 11.75-year long-term period the South Monitoring Area has experienced positive volume change at a rate of 3.4 cy/ft./yr.; however, since the completion of the 2022/2023 beach nourishment projects in Southern Shores and Duck an average rate of +7.7 cy/ft./yr. was measured as of June 2025. Given that the South Monitoring Area is located between the Southern Shores and Duck beach nourishment projects, it is reasonable to consider that the South Monitoring Area may be experiencing volume changes that are positively influenced by the presence of these adjacent nourishment projects.

Between June 2024 and June 2025, the South Monitoring Area experienced a short-term volumetric gain of approximately 92,700 cy. This corresponds to an average change rate of +6.8 cy/ft./yr., reflecting an above-average period of positive volumetric change for the area given the long-term average rate of +3.4 cy/ft./yr.

As previously noted, the evaluation of whether a reasonable level of storm damage reduction is being maintained along the oceanfront relies on the SBEACH storm simulation model. In 2019, simulations based on May 2019 beach conditions identified 28 oceanfront structures and 40 oceanfront pools in the South Monitoring Area, particularly south of the USACE Field Research Facility, as potentially impacted by the design storm. In 2023, an updated SBEACH analysis using May 2023 conditions showed a significant improvement, with no oceanfront structures and only nine (9) oceanfront pools identified as impacted by the design storm. This decrease in the number of impacted structures and pools aligned with a volumetric gain of approximately 202,000 cy between stations D-23 (just north of the southern boundary of the USACE Field Research Facility) and D-34 (at the southern Town boundary) from 2019 to 2023. Although the SBEACH analysis was not updated using June 2025 conditions, the same stretch of the South

Monitoring Area experienced an additional volumetric gain of approximately 180,400 cy between May 2023 and June 2025. This continued positive volumetric change suggests that, as of June 2025, a reasonable level of storm damage reduction for public and private development remained in place along the South Monitoring Area.

VII. RECOMMENDATIONS

CPE recommends that the Town continue to monitor the entire Town oceanfront to assess 1) the performance of the May 2023 beach renourishment project and 2) shoreline and volume change trends along the beach areas outside of the Central Reach Project Area. For continued monitoring of the Central Reach Project Area, the May 2023 survey should represent the post-construction conditions. Future annual monitoring reports should reference shoreline and volume changes in the Central Reach Project Area relative to the May 2023 condition to track the short- and long-term performance of the 2023 project and aid in the determination of when additional nourishment is needed in the Central Reach Project Area and surrounding beaches. Continued annual monitoring of the project will also provide a pre-storm condition survey that can be used to estimate damages if the project is impacted by a significant storm.

Continued monitoring of the North and South Monitoring Areas is vital to achieving the Town's goal of providing a reasonable level of storm damage reduction to public and private development along the entire Town oceanfront. This continued monitoring will allow the Town to evaluate future areas of concern and longshore transport trends, and to develop successful shoreline management strategies to deal with issues as they arise.