2024 BEACH MONITORING AND BEACH STABILITY ASSESSMENT

CURRITUCK COUNTY, NORTH CAROLINA

PREPARED FOR
CURRITUCK COUNTY

PREPARED BY
COASTAL PROTECTION ENGINEERING OF NORTH CAROLINA, INC.
4038 MASONBORO LOOP RD, WILMINGTON, NC 28409
ENGINEERING LICENSE CERTIFICATE #: C-2331

NORTH CAROLINA PROFESSIONAL SEAL 048852 ENGINEER ADAM TAFT PRIEST

ADAM T. PRIEST, PE NO. 048852

3/19/25
DATE

March 2025

EXECUTIVE SUMMARY

In 2020, Currituck County initiated a Beach Monitoring and Beach Stability Assessment to evaluate long-term and short-term shoreline and volumetric changes occurring along Currituck's oceanfront beaches. The initial study was completed in 2022 following three (3) consecutive years of monitoring. The stated goals of the Assessment were 1) to better understand the changes that are occurring in the beaches and 2) to assist the County in making informed decisions regarding beach management. At the conclusion of the initial Assessment, Currituck County requested that annual monitoring continue to track and assess long-term and short-term shoreline and volumetric changes along its oceanfront beaches.

This 2024 report serves to provide an update to the County in terms of data obtained through June 2024. The report provides an assessment of historical, long-term, and more recent shoreline change trends, an analysis of the impact of projected long-term shoreline change over 10-, 20-, and 30-year horizons, and an assessment of both long-term and recent volumetric change trends.

The Currituck County barrier island beaches extend approximately 22.6 miles along the Atlantic Ocean. The beaches extend from the North Carolina/Virginia border south-southeast to the Town of Duck in Dare County, North Carolina. The Currituck County beach is divided up into several segments of privately developed residential and commercial property and publicly owned property. The northernmost 10.9 miles of the Currituck County beach is only accessible via off-road driving. South of the off-road access at N. Beach Access Road and south of the "Horse Gate", the Currituck County beach extends approximately 11.7 miles to the southern County boundary with Dare County. This section of beach is almost entirely developed.

Given the differences in land use, land management, and geomorphology (changes in the dune and beach slope configuration over time), the Assessment Area has been divided into four (4) sections for reporting purposes. The northernmost section is referred to as the Carova Section, which encompasses approximately 4.9 miles of the Assessment Area from the northern County boundary to the northern boundary of the Currituck National Wildlife Refuge. The approximately 6.0-mile section of the Assessment Area that includes the Currituck National Wildlife Refuge, the Currituck Banks Estuarine Reserve, and the developed area along Sandpiper Road and Ocean Pearl Road is referred to as the Reserve/Refuge Section. The largest section, referred to as the Corolla Section, extends approximately 8.2 miles from approximately 250 feet south of the Horse Gate to approximately 500 feet north of Yaupon Lane. The southernmost 3.5 miles of the Assessment Area is referred to as the Pine Island Section.

Projected Shoreline Changes: Publicly available lidar data allowed for a historical shoreline change analysis to be conducted, which provides insight into overall trends. Shoreline change is calculated by comparing shoreline positions along shore perpendicular transects over time to evaluate the rate in which the shoreline moves landward or seaward. Nine (9) data sets collected between 2009 and 2024 were analyzed to determine shoreline change rates over the past 15 years. These historical rates were determined using a linear regression method that considers each of the nine data sets available over this 15-year period. The shoreline change rates computed were then used

to project future shoreline changes throughout the Assessment Area over a 10-, 20-, and 30-year time horizon.

Overall, the number of structures indicated as impacted based on the shoreline projections, is considerably lower than reported in 2023. The reduction in the number of structures identified was due to a large seaward advancement at the +4 ft contour during the 25-month and 12-month periods. The projections show the greatest number of impacts from projected shoreline changes were observed within the Corolla Section of the Assessment Area. In total, 56 houses were shown to be impacted over the 30-year horizon throughout the Corolla Section. All of these houses are located between the Horse Gate (station C-059) and Marlin Beach Access (station C-081). Of the 56 houses shown to be impacted over the 30-year horizon, 10 of the houses were shown to be impacted over the 20-year horizon and 0 were shown to be impacted over the 10-year horizon. The oceanfront houses along the Corolla Section are concentrated along three general areas. The northernmost area spans from the Horse Gate to Carotank Drive (station C-059 to C-065). Along this approximately 1.3-mile stretch of beach, approximately 40% of the oceanfront houses were shown to be impacted over the 30-year horizon. Approximately 15% of the oceanfront houses along this stretch were shown to be impacted over the 20-year horizon and none of the houses were shown to be impacted over the 10-year horizon along this stretch of beach.

The second concentrated section of oceanfront structures is within the Whalehead Beach community (station C-068 to station C-084) where structures have consistently been shown to be impacted in past reports. There were two areas within the Whalehead Beach community where structures were shown to be impacted in this year's analysis. The first area is between Sturgeon Beach Access (station C-071) and Mackerel Street (station C-076) along Lighthouse Drive. In this approximate 4,000-foot section, approximately 51% of the oceanfront structures were shown to be impacted over the 30-year horizon, and no houses were shown to be impacted over the 20-year or 10-year horizons.

The second area is located at the south end of Lighthouse Drive between Sailfish Street (station C-080) and Marlin Beach Access (station C-081). There are 5 houses in this approximate 1,000-ft section that are shown to be impacted over the 30-year horizon.

In addition to the areas in the Corolla Section mentioned above, three houses were shown to be impacted by the 30-year horizon in the Reserve/Refuge Section between stations C-041 and C-044. All three of these houses are seaward of Sandfiddler Road. One of these houses was shown to be impacted over the 20-year horizon. These three houses have consistently been identified as vulnerable in past reports.

Volume Changes:

A volumteric analyses was completed as part of the 2024 Assessment through a comparison of May 2020, May 2022, June 2023, and June 2024 data. Volume change rates measured between 2020 and 2024 continue to show an overall positive volumetric trend over the 4.1-year period. The average volumetric change rate along the entire Assessment Area was +2.2 cy/ft./yr. between 2020 and 2024; this equates to a net volume gain of approximately 1,094,600 cy. A positive

volumetric change of approximately 337,000 cy (3.1 cy/ft./yr.) was measured along the Carova Section during this time period, while a volume loss of approximately -67,100 cy (-0.5 cy/ft./yr.) was measured in the Reserve/Refuge Section. A positive volume change of approximately 587,900 cy (3.3 cy/ft./yr.) was measured in the Corolla Section while a positive volumetric change of approximately 236,800 cy (3.2 cy/ft./yr.) was measured in the Pine Island Section.

While the overall volumetric trend measured from May 2020 to June 2024 was positive, a key takeaway from this year's analysis was an inflection point in May 2022 of the overall volumetric trend. A positive volumetric trend was observed between May 2020 and May 2022; however, a negative volumetric trend was observed between May 2022 and June 2024.

The following conclusions were drawn from the results of both the shoreline projection analysis and volumetric change analysis:

- The northern 5,000 feet of the Carova Section (north of station C-005) has experienced higher rates of erosion between May 2022 and June 2024 when compared to the overall average rate of the Carova Section from May 2020 to June 2024. While the 2024 shoreline projections did not indicate any impacted structures along this portion of the beach, previous reports (CPE, 2020 & CPE, 2021) have indicated potential impacts to structures in this area. It should be noted that the higher volume change average along this section is heavily influenced by the losses measured at Station C-002.
- The structures indicated as impacted over the various time horizons that fall within the Reserve/Refuge Section, are located between approximately 1,200 feet north of Hidden Dunes Lane and approximately 300 feet north of Munson Lane (station C-041 and station C-046). While this area experienced modest volumetric gains (+6.4 cy/ft./yr.) between May 2020 and May 2022, large losses (>-20 cy/ft./yr.) were measured between May 2022 and June 2024. Due to the large losses over the 25-month period, the net volumetric change over the long-term monitoring period from May 2020 to June 2024 was an average loss rate of -8.5 cy/ft./yr.
- The northern portion of the Corolla Section, between the Horse Gate and Corolla Village Road (station C-059 to station C-065) within the Ocean Hill community is one that has continuously been called out as one of the most vulnerable areas of the County's oceanfront. Both the shoreline projections and previous SBEACH storm vulnerability analyses have indicated structures along this stretch of the County oceanfront are vulnerable both to long-term shoreline change and storms. While volumetric changes measured between May 2020 and June 2024 indicate this area has remained relatively stable, a closer look at the data reveals a similar pattern of gains followed by losses as previously discussed. Between May 2020 and May 2022, this area experienced an average volumetric change rate of +5.1 cy/ft./yr. In contrast, between May 2022 and June 2024 volumetric losses were experienced at an average rate of -4.1 cy/ft./yr., with the majority

of the losses occurring between June 2023 and June 2024 where an average loss of >-20 cy/ft./yr. was measured.

- Another area of concern is within the Whalehead Beach community along Lighthouse Drive (station C-070 to station C-077). The shoreline projection analysis has consistently identified this area as being more vulnerable. Similar to the Ocean Hill community, modest gains (2.4 cy/ft./yr.) have been measured here since May 2020 above the depth of closure, but modest losses (-3.5 cy/ft./yr.) were measured in this area between May 2022 and June 2024 with the majority of these losses occurring between June 2023 and June 2024.
- The Spindrift community (station C-101 to station C-103) is another area of concern, where shoreline projection analyses have identified this area to be vulnerable. While the most recent analysis performed with the updated 2024 conditions and rates did not indicate impacts along this community, previous analyses have shown impacts to the nine (9) oceanfront homes located along Land Fall Ct. The trends in this area are the opposite of the trend generally observed throughout the study area. The volume change analysis indicated modest losses between May 2020 and May 2022, followed by considerable volumetric gains at a rate of +10.8 cy/ft./yr.) between May 2022 and June 2024. The area experienced modest losses of -2.6 cy/ft./yr. on average, over the recent 12-month period. It should also be noted that approximately 7,000 cy of sand was placed to construct a dune in front of the Spindrift Community via a truck haul project in March 2023. The gains observed between May 2022 and June 2024 may be attributed to this project.

Recommendations: Based on the various beach assessments described in this report and conclusions drawn from those assessments, CPE provides the following recommendations for the County's consideration as they seek to make informed decisions regarding beach management:

1. Continue Monitoring of the Beach Profiles: The initial 3-year Beach Monitoring and Beach Stability Assessment (2020 through 2022) established a baseline of shoreline change and volumetric change rates. Given the results of the shoreline and volume change analyses, the distribution of potential impacts from the shoreline projections over 10 to 30 years and the distribution of houses identified through the vulnerability analysis, the County continued the monitoring plan through 2025. Beginning in 2023, the County, in alignment with the original recommendation (CPE, 2023a), authorized annual surveys of the Corolla and Pine Island Sections, with bi-annual surveys (every other year) for the Carova and Reserve/Refuge Sections for 3 additional years.

   The recommendation to only survey the Carova and Reserve/Refuge Sections (north of the Horse Gate) in the odd years, was based on the fact that only a small number of houses located north of the Horse Gate were indicated as vulnerable, and the amount of undeveloped beach north of the Horse Gate. The County contracted with CPE in early 2023 to continue monitoring as recommended through 2025. In 2023, beach monitoring surveys were conducted south of the Horse Gate in the Corolla and Pine Island Sections

only; whereas in 2024, the entire County oceanfront was surveyed (both north and south of the Horse Gate).

The current contract between CPE and the County includes a 2025 monitoring survey of the areas south of the Horse Gate (Corolla and Pine Island Sections). The County should consider if additional areas north of the Horse Gate should be included in the 2025 survey. Given the County's recent discussions on the several houses indicated as vulnerable in the portion of the beach between Canary Lane and just north of Malbon Drive (stations C-039 to C-048), and the potential impacts to ingress/egress along the offroad sections of the County beaches due to these vulnerable structures, collection of additional data in 2025 along this stretch of beach may be warranted.

Regardless of which profiles the County decides to survey in 2025, the same profiles established at the beginning of the County-wide assessment in 2020 should be collected at a similar time of year to reduce the impacts of seasonal changes on conditions of the profile, particularly the portion of the profile above Mean High Water (MHW).

2. <u>Coordinate with Dare County on Regional Sand Resource Investigation:</u> In 2023 Dare County commissioned a two-year regional sand investigation study to locate sand for future beach nourishment projects. The reconnaissance phase of this investigation was conducted in the summer of 2023 and the County, and its consultants are assessing data acquired. The geographic extent of the Study Area includes portions of southern Currituck County including portions offshore of the Corolla and Pine Island Sections as defined in this report. State and federal rules do not limit offshore sand resources to be used only by the adjacent local community. These resources are typically considered state and or federal resources for which permits can be applied for by neighboring municipalities to use these sediments for beach nourishment projects. If Currituck County anticipates the future development of a Beach Management Plan that may include offshore dredging for beach nourishment, CPE recommends that County staff coordinate with Dare County on this regional sand resource investigation.

2024 BEACH MONITORING AND BEACH STABILITY ASSESSMENT CURRITUCK COUNTY, NORTH CAROLINA

TABLE OF CONTENTS

Executive Summary i

1 Introduction 1

1.1 Project Location 1

2 Data Collection 3

2.1 NC DCM Long-Term Average Annual Shoreline Change Rates 12

2.2 USACE Lidar Data 12

2.3 CSE Beach Profile Data 12

2.4 CPE Beach Profile Data 13

3 Shoreline Analyses 15

3.1 12-Month Period (June 2023 to June 2024) 18

3.2 Historical Period (August 2009 to June 2024) 18

3.3 Long-term Rate (May 2020 to June 2024) 23

3.4 Shoreline Projections 24

4 Volume Analyses 26

4.1 Volumetric Change (-19 Ft. NAVD88 Depth of Closure) 27

4.2 Volumetric Change (Lens Calculations) 37

4.3 Pine Island Section Volumetric Change Rates 46

5 Conclusions 49

5.1 Shoreline Change and Projected Shorelines 49

5.2 Volume Change 50

6 Recommendations 55

7 References 57

LIST OF FIGURES

Figure 1. Currituck Project Location Map 2

Figure 2. Monitoring Transects Map Stations C-001 to C-016 4

Figure 3. Monitoring Transects Map Station C-016 to C-031 5

Figure 4. Monitoring Transects Map Station C-031 to C-046 6

Figure 5. Monitoring Transects Map Station C-046 to C-061 7

Figure 6. Monitoring Transects Map Station C-061 to C-076 8

Figure 7. Monitoring Transects Map Station C-076 to C-091 9

Figure 8. Monitoring Transects Map Station C-091 to C-106 10

Figure 9. Monitoring Transects Map Station C-106 to C-120 11

Figure 10. Beach Profile Cross Section Illustrating Shoreline Change. 15

Figure 11. Map showing the SBF for Reserve/Refuge and Carova Sections of Currituck County 16

Figure 12. Example of Linear Regression Slope 17

Figure 13. Shoreline Change Rate (+4 ft. NAVD88) North of the Horse Gate (C-001 to C-059) 21
Figure 14. Shoreline Change Rate (+4 ft. NAVD88) South of the Horse Gate (C-059 to C-120) 22
Figure 15. Beach Profile Cross Section Illustrating Volume Change 27
Figure 16. Volume Change Rate Above -19 ft. NAVD88 - North of the Horse Gate May 2020 to June 2024 and May 2022 to June 2024 31
Figure 17. Volume Change Rates Above -19 ft. NAVD88 - South of Horse Gate May 2020 to June 2024 and June 2023 to June 2024 33
Figure 18. Beach Profile Cross Section Illustrating Lenses 38
Figure 19. Volume Change Rate Lens 1 and Lens 2 - May 2020 to June 2024 42
Figure 20. View of Dune Scarping approximately 500 feet north of Sta. C-060. (Photo date 5/15/22). 43
Figure 21. Volume Change Rate Lens 3 and Lens 4 - May 2020 to June 2024 45
Figure 22. Pine Island (C-102 to C-120) Volume Change Rates Above -19.0 ft. NAVD88 – Sept. 2015 to June 2024 48
Figure 23. Graph showing Cumulative Volume Change along Currituck County since May 2020 51
Figure 24. Significant Wave Height data for waverider buoy located in 26 m of water offshore Duck, NC (Station 44100) prior to and during the monitoring period. 53

LIST OF TABLES

Table 1. Section Descriptions 3
Table 2. Dataset Descriptions 3
Table 3. Tidal Datums 3
Table 4. CPE and CSE Monitoring Station Comparison 13
Table 5. NC DCM 2019 Setback Factors 16
Table 6. Summary of Average Historical, Long-term, and 12-Month Shoreline Change Rates 18
Table 7. Summary of Historical and Long-Term Shoreline Change Rates North of the Horse Gate (C-001 to C-058) 19
Table 8. Summary of Historical and Long-Term Shoreline Change Rates South of the Horse Gate (C-059 to C-120) 20
Table 9. Number of houses shown to be impacted over the 10-, 20-, and 30-year time horizons 25
Table 10. Summary of Average Volumetric Change Rates and Total Volume Changes Measured to -19 ft. NAVD88. 28
Table 11. Volumetric Change Rates May 2020 to June 2024 (cy/ft./yr.). 30
Table 12. Volumetric Changes Rates (May 2022 to June 2024) (cy/ft./yr.). 35
Table 13. Volumetric Changes Rates (June 2023 to June 2024) (cy/ft./yr.). 37
Table 14. Summary of Average Volumetric Change Rates 40
Table 15. Lens Volumetric Change Rates (May 2020 to June 2024) (cy/ft./yr.) 41
Table 16. Pine Island Long-term Volume Change Rates 2015 to 2024 47

APPENDICES

A – 2024 Currituck County Data Acquisition Survey Report (with appendices)

B – Projected Shoreline Maps

1 INTRODUCTION

In 2020, Currituck County initiated a Beach Monitoring and Beach Stability Assessment to evaluate long-term and short-term shoreline and volumetric changes occurring along the County's oceanfront beaches. The initial study was completed in 2023 following three (3) consecutive years of monitoring (2020, 2021, and 2022). Based on recommendations from that initial Assessment (CPE, 2023a), Currituck County chose to continue the annual monitoring of the beaches from 2023-2025 to track and assess long-term and short-term shoreline and volumetric changes along the beach.

Based on recommendations from the 2022 Assessment, annual monitoring is focused on the Corolla and Pine Island Sections, south of the Horse Gate, while biennial monitoring is conducted north of the Horse Gate. This recommendation was based on the fact that the majority of vulnerable houses were located south of the Horse Gate and that Pine Island was the only section that saw negative volumetric changes over the initial monitoring period from 2020 to 2022 (CPE, 2023a). The June 2023 survey only covered the area south of the Horse Gate. The June 2024 survey discussed in this report was collected north and south of the Horse Gate. The 2022 Assessment and the 2023 monitoring report both noted that positive volumetric changes may be attributed to a temporary recovery of the beach that may have occurred between 2020 and 2023. Regular monitoring is important to identify whether the beach is still in recovery or if it has reverted to a trend of volume loss.

1.1 Project Location

Currituck County is located on the Outer Banks of North Carolina just south of the Virginia border. The County encompasses approximately 527 square miles, which includes a large portion of the Currituck Sound. This geographical division creates two distinct regions namely, the Currituck Mainland, and the Currituck Barrier Island Beaches. The Currituck Barrier Island Beaches extend approximately 22.6 miles along the Atlantic Ocean. The beaches extend from the North Carolina/Virginia border south-southeast to the Town of Duck in Dare County, North Carolina. A location map is provided in Figure 1.

The Currituck County beaches are divided up into several segments of privately developed residential and commercial property and publicly owned property. The Assessment Area has been divided into four sections referred to throughout the report, with consideration given to differences in land use, land management, and geomorphology (changes in the dune and beach slope configuration over time). The northernmost section is referred to as the Carova Section, which encompasses approximately 4.9 miles of the Assessment Area from the northern County boundary to the northern boundary of the Currituck National Wildlife Refuge. The approximately 6.0-mile section of the Assessment Area that includes the Currituck National Wildlife Refuge, the Currituck Banks Estuarine Reserve, and the developed area along Sandpiper Road and Ocean Pearl Road is referred to as the Reserve/Refuge Section. The largest section, referred to as the Corolla

Section, extends approximately 8.2 miles from approximately 250 feet south of the Horse Gate to approximately 500 feet north of Yaupon Lane. The southernmost 3.5 miles of the Assessment Area is referred to as the Pine Island Section. The sections are shown in Figure 1, and the length, geographical limits, and baseline stations for each section are provided in Table 1.

Several papers have described historic inlets that had existed along the Currituck County beaches (Mallinson et al., 2011 and Moran et al., 2015). Like many modern day, unmanaged inlets, these features were likely not stationary but rather migrated throughout their history. Though the exact locations of these inlets are unknown, the southernmost inlet, known as Caffey's Inlet, is believed to have existed in the area between the Hampton Inn (station C-110) and the southern County boundary (station C-120). Caffey's Inlet is believed to have been open between 1770 and 1811. Though little is known of the specifics of the inlet, it has been theorized that the extensive back barrier marsh west of this portion of the barrier beach is built upon the relic flood tide delta system of Caffey's Inlet. Research conducted by Moran et al., (2015) suggested that Caffey's Inlet "accommodated a significant tidal prism", meaning that it was a significant inlet for the region.

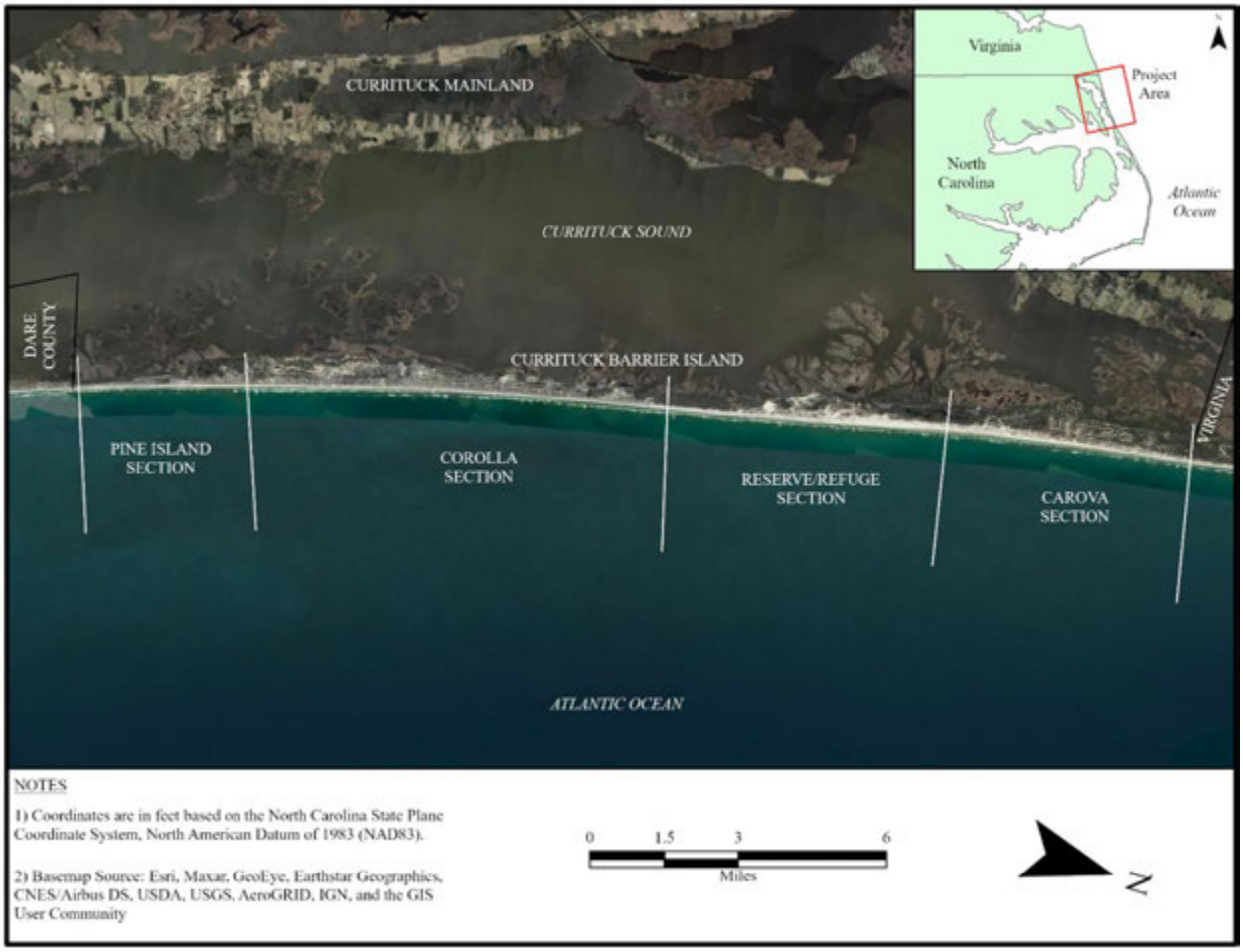

Figure 1. Currituck Project Location Map

Table 1. Section Descriptions

Section Name	Approximate Length	Geographic Extent	Baseline Stations
Carova	4.9 Miles	Northern County Boundary to Currituck Wildlife Refuge	C-001 to C-027
Reserve/Refuge	6.0 Miles	Northern boundary of Currituck Wildlife Refuge to 250 feet south of Horse Gate	C-027 to C-059
Corolla	8.2 Miles	250 feet south of Horse Gate to 500 feet north of Yaupon Lane	C-059 to C-102
Pine Island	3.5 Miles	500 feet north of Yaupon Lane to southern County boundary	C-102 to C-120

2 DATA COLLECTION

Data used in this study included twelve (12) different data sets including the most recent beach profile data acquired by CPE in 2024. See Table 2 below for dates and description of the datasets that were used.

Table 2. Dataset Descriptions

Agency/Firm	Survey Type	Date Range	Stations
USACE	Lidar	6/18/2009-6/25/2009	C-001 to C-120
CSE	Profile Survey	09/2015	C-097 to C-120
USACE	Lidar	6/9/2017-9/16/2017	C-001 to C-120
CSE	Profile Survey	10/2017	C-097 to C-120
USACE	Lidar	8/24/2018-8/28/2018	C-001 to C-120
USACE	Lidar	6/18/2019-6/25/2019	C-001 to C-120
CPE	Profile Survey/Offshore Bathymetry	4/24/2020-5/15/2020	C-001 to C-120
CPE	Profile Survey	6/1/2021-6/9/2021	C-001 to C-120
CPE	Profile Survey	5/14/2022-5/22/2022	C-001 to C-120
CPE	Offshore Bathymetry	5/21/2022-6/15/2022	C-001 to C-120
CPE	Profile Survey	6/06/2023-6/10/2023	C-059 to C-120
CPE	Profile Survey	5/28/2024-6/1/2024	C-001 to C-120

Throughout this report, elevations provided are referenced to the North American Vertical Datum (NAVD88). Table 3 provides tidal datums used in this study. The beach profiles are shown visually along the oceanfront in Figure 2 through Figure 9.

Table 3. Tidal Datums

Datum	Elevation (ft., NAVD88)
Mean High Water (MHW)	+1.24
Mean Tide Level (MTL)	-0.41
Mean Low Water (MLW)	-2.05

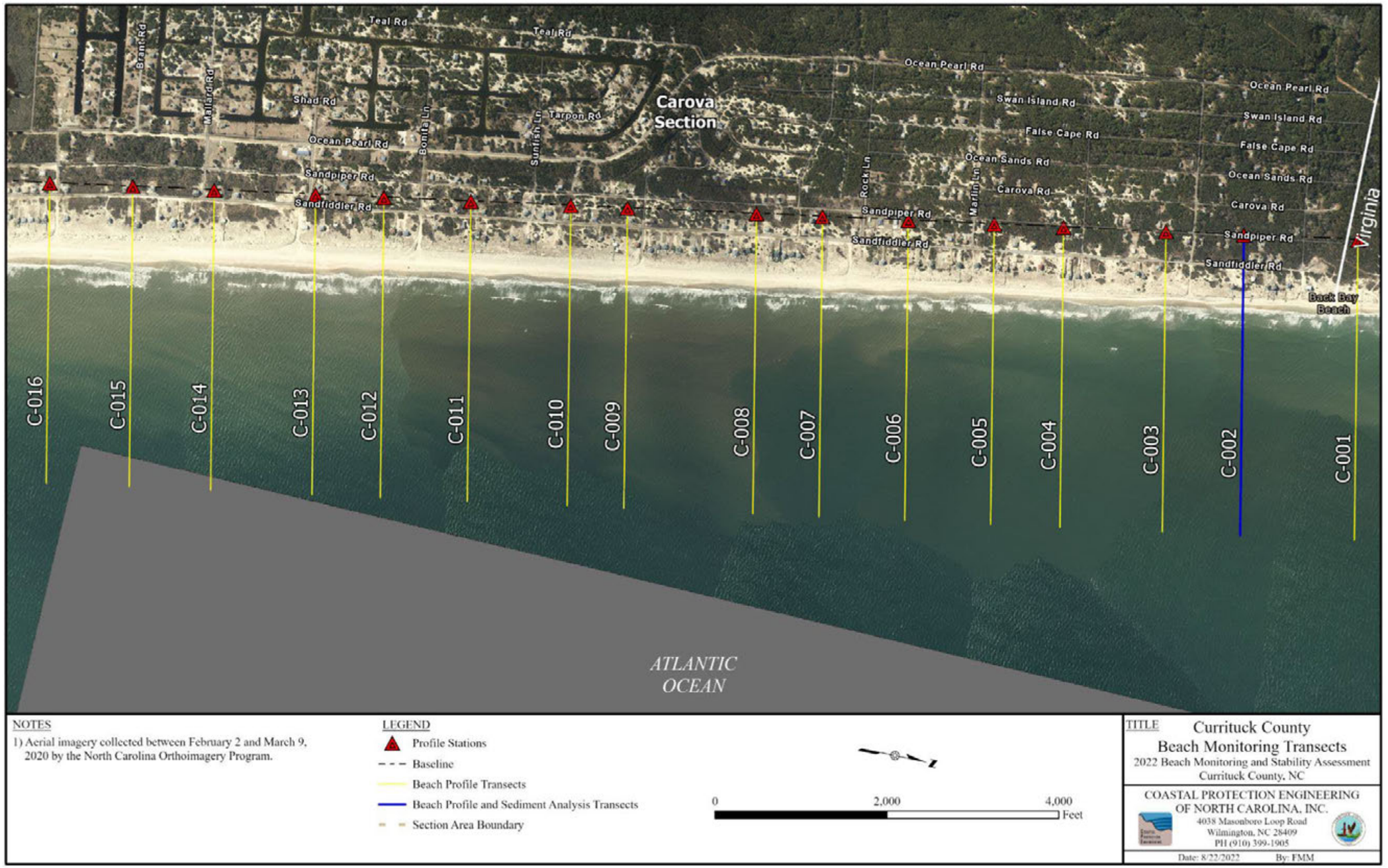

Figure 2. Monitoring Transects Map Stations C-001 to C-016

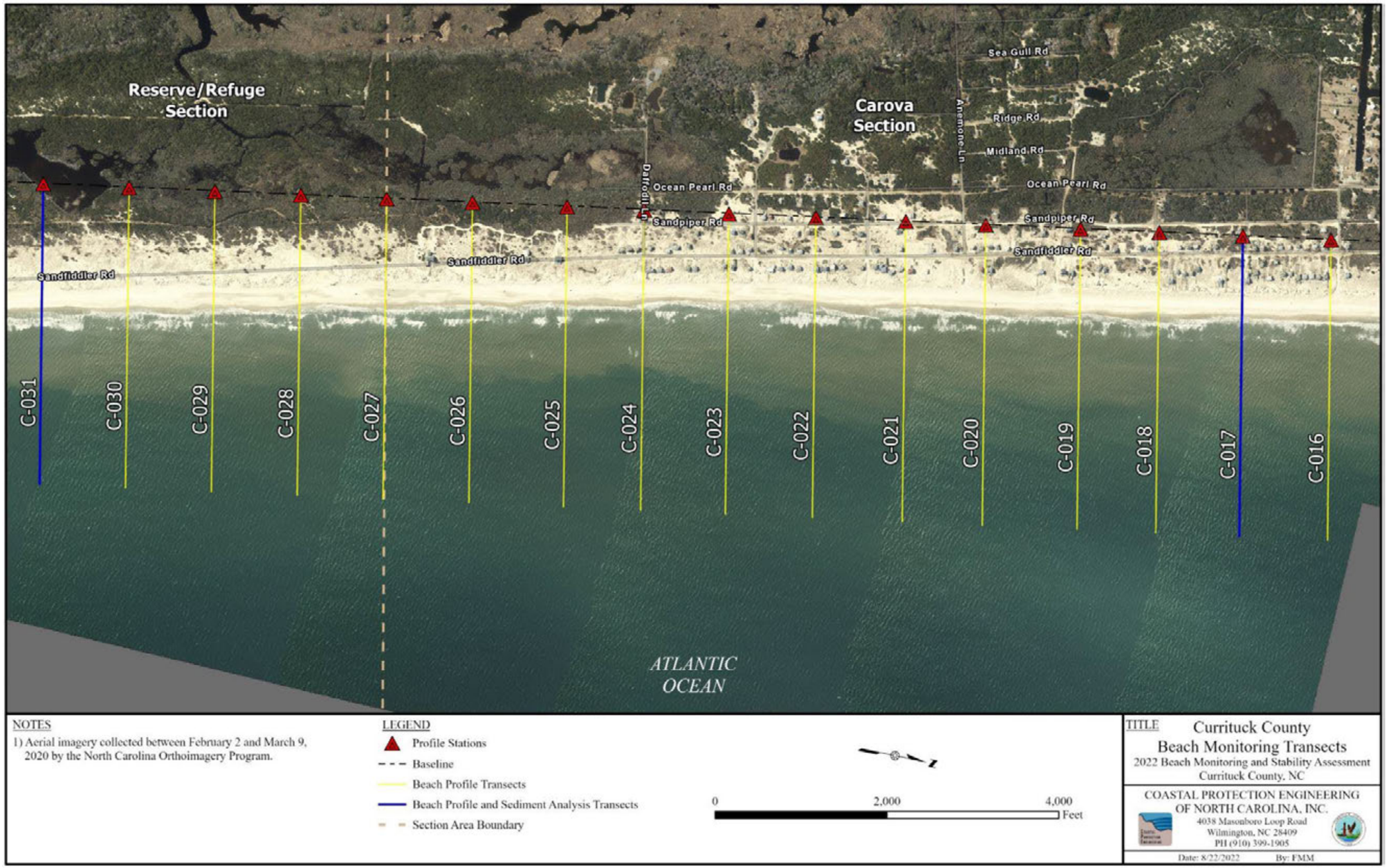

Figure 3. Monitoring Transects Map Station C-016 to C-031

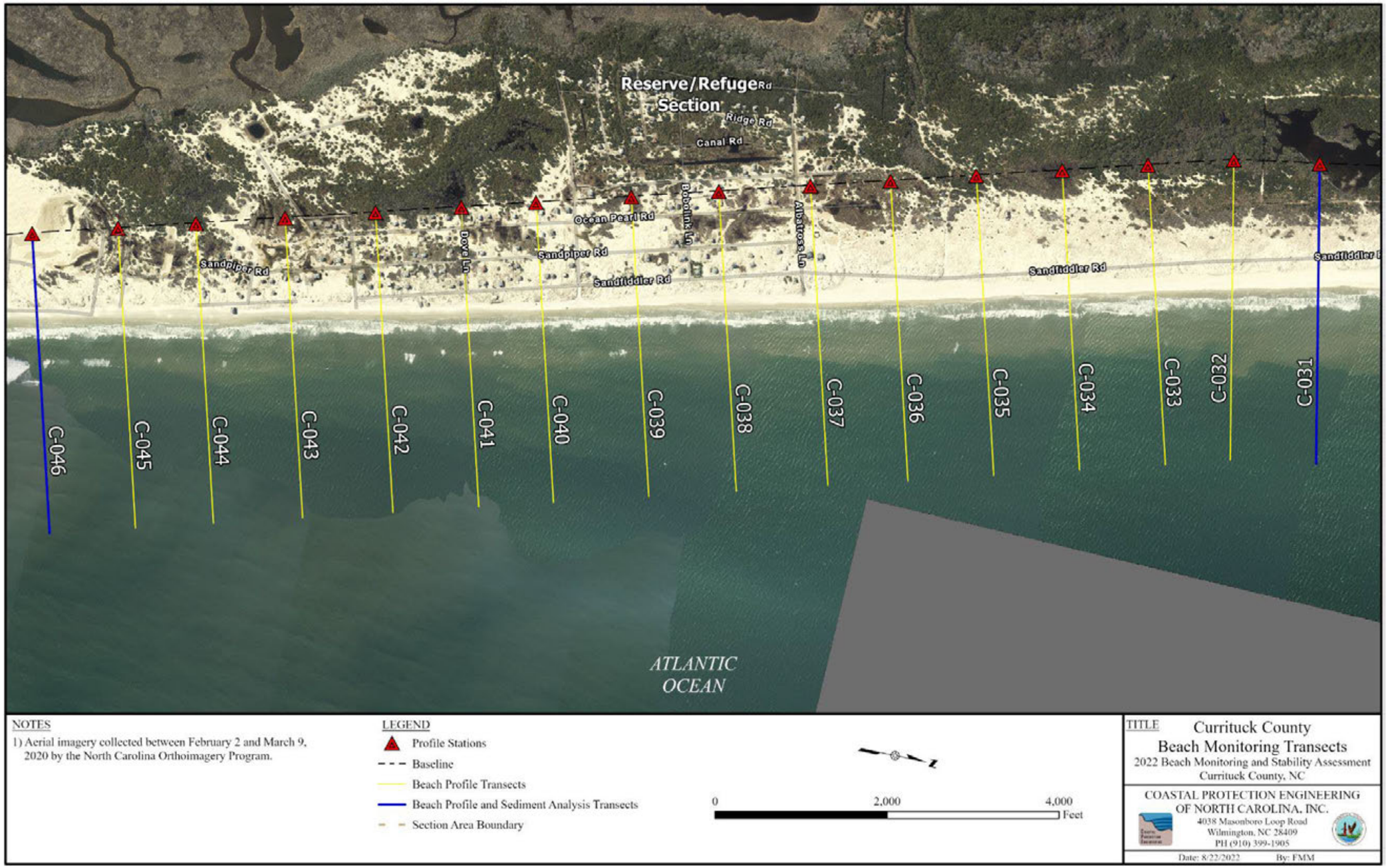

Figure 4. Monitoring Transects Map Station C-031 to C-046

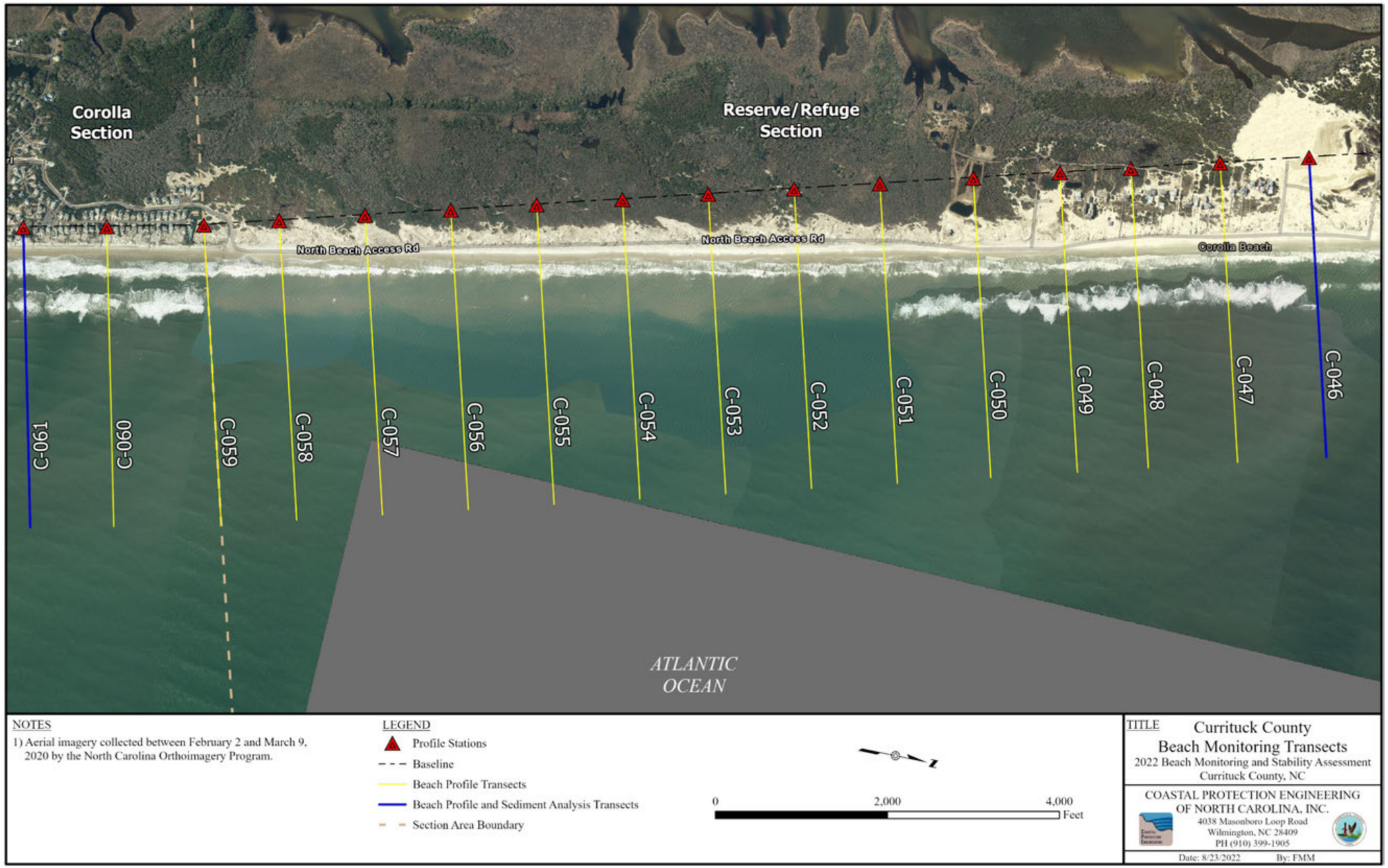

Figure 5. Monitoring Transects Map Station C-046 to C-061

Figure 6. Monitoring Transects Map Station C-061 to C-076

Figure 7. Monitoring Transects Map Station C-076 to C-091

Figure 8. Monitoring Transects Map Station C-091 to C-106

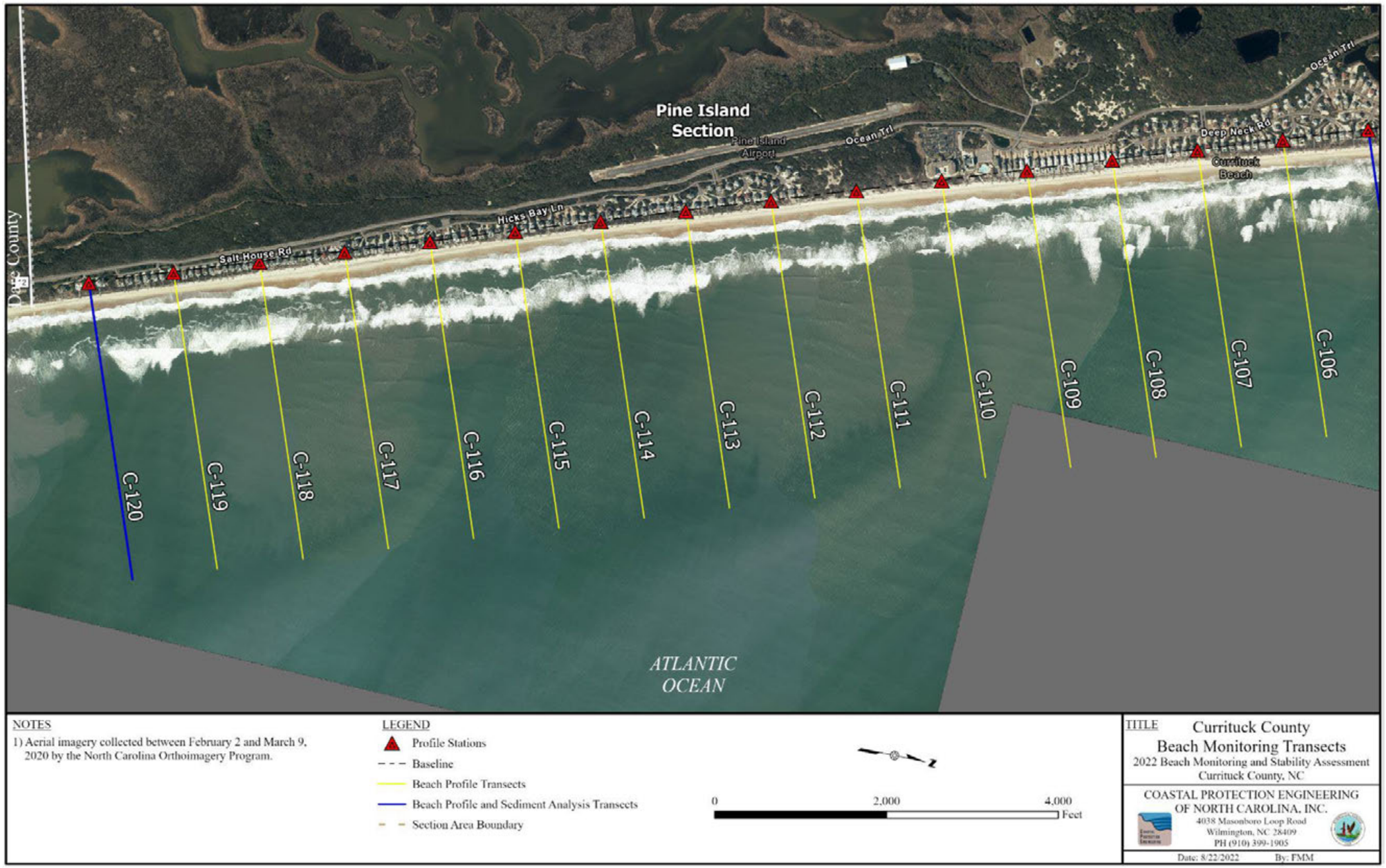

Figure 9. Monitoring Transects Map Station C-106 to C-120

2.1 NC DCM Long-Term Average Annual Shoreline Change Rates

As described on the North Carolina Division of Coastal Management's (NC DCM) website, long-term average annual shoreline change rates are computed for the sole purpose of establishing oceanfront construction setback factors. The change rates are calculated using the endpoint method, which uses the earliest and most current shoreline data points where they intersect a given shore-perpendicular transect. The distance between the shoreline position of the two data sets is computed and divided by the time between the data sets. Typically, the State rates represent a 50-year rate. The shoreline position change rate information provided by the State is admittedly not predictive, nor does it reflect the short-term erosion that can occur during storms. The change rates acquired from the North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Survey report created by the NC DCM (NC DCM, 2019) are compared to the shoreline change rates computed as part of this monitoring report (See Section 3).

2.2 USACE Lidar Data

Light Detection and Ranging (Lidar) is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth (NOAA, 2012). These light pulses, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

A Lidar instrument principally consists of a laser, a scanner, and a specialized GPS receiver. Airplanes are used for acquiring lidar data over broad areas. There are two types of Lidar, topographic and bathymetric. Topographic Lidar typically uses a near-infrared laser to map the land, while bathymetric Lidar uses water-penetrating green light to also measure seafloor and riverbed elevations.

Lidar systems allow scientists and mapping professionals to examine both natural and manmade environments with accuracy, precision, and flexibility. NOAA and USACE scientists are using lidar to produce more accurate shoreline maps, make digital elevation models for use in geographic information systems, assist in emergency response operations, and in many other applications. Lidar data from August 2009 was determined to be the earliest reliable topographic data and was selected for the long-term analysis include herein.

2.3 CSE Beach Profile Data

Beach profile survey data were collected by CSE in September 2015 and October 2017 as part of the Pine Island, Currituck County, Beach Condition Monitoring (CSE, 2018). The monitoring study initiated by the Pine Island Property Owners Association (PIPOA) included beach profile surveys encompassing approximately 5.3 miles of the beach, 1 mile north and south of the Pine Island community. These profiles were spaced every 500 feet alongshore extending from the foredune to a depth greater than 30 ft. CSE profiles 0+00 through 230+00 were used by CPE for the County

study. Table 4 shows a comparison between the CSE referenced stations and the names of the stations used in the County Study (C-097 through C-120).

Table 4. CPE and CSE Monitoring Station Comparison

CPE Station	CSE Station
C-097	000+00
C-098	010+00
C-099	020+00
C-100	030+00
C-101	040+00
C-102	050+00
C-103	060+00
C-104	070+00
C-105	080+00
C-106	090+00
C-107	100+00
C-108	110+00
C-109	120+00
C-110	130+00
C-111	140+00
C-112	150+00
C-113	160+00
C-114	170+00
C-115	180+00
C-116	190+00
C-117	200+00
C-118	210+00
C-119	220+00
C-120	230+00

2.4 CPE Beach Profile Data

CPE conducted beach profile surveys for Currituck County in May 2020, June 2021, May 2022, June 2023, and June 2024. The 2020 through 2022 surveys included 120 profiles (station C-001 to station C-120) along the beachfront of Currituck County. The June 2023 survey was limited to the 61 profiles (station C-059 to station C-120) along the beachfront of Currituck County south of the Horse Gate. The most recent survey, conducted in June 2024, included all 120 profiles (station C-001 to C-120) in Currituck County. All of the CPE beach profile surveys includes a topographic survey of the dune, berm, and foreshore section of the beach and a bathymetric survey of the offshore portion of the profile. See Appendix A for 2024 Currituck County Data Acquisition Survey Report. The data acquisition reports for 2020, 2021, 2022, and 2023 are included as appendices to the 2020, 2021, 2022, and 2023 beach assessment reports (CPE, 2020, CPE, 2021, CPE, 2023a, and CPE, 2023b).

Beach profiles extended landward from the beach toward the monitoring baseline until a structure was encountered or a range of 25 feet beyond the dune was reached, whichever was more seaward. Elevation measurements were also taken seaward along each profile to a range of 2,500 feet beyond the shoreline or to the -30-ft. NAVD88 contour, whichever was more landward.

Land-based or "upland" data collection included all grade breaks and changes in topography to provide a representative description of the conditions at the time of the work. The maximum spacing between data points along individual profiles was 25 feet. The upland work extended into wading depths sufficient to provide a minimum 50-foot overlap with the offshore data. This overlap between the topographic and bathymetric surveys provides quality control and quality assurance of the survey.

The nearshore portion of the profile data collection commenced from a point overlapping the upland data by 50 feet to ensure seamless transitions and extended seaward to a point overlapping the offshore data collected by the survey vessel by a minimum of fifty (50) feet. The nearshore portion of the profiles were surveyed by two (2) surveyors with an Extended Rod Trimble RTK GNSS rovers who entered the water wearing personal floatation devices. This system allowed for the collection of RTK GNSS data in the nearshore region while maintaining data accuracy and personal safety.

The offshore hydrographic survey was conducted using Teledyne Odom Hydrographic's ECHOTRAC E-20 (or equivalent) on a survey vessel with a centrally located hull-mounted transducer at a frequency of 200 kHz. Offshore data points were collected at 20-50 Hz (pings per second) and the data was sorted to a maximum spacing of 25 feet. An Applanix POS MV Inertia Navigation system was used onboard the survey vessel to provide instantaneous tide corrections as well as pitch, roll, and heave corrections. Tide corrections were checked at the beginning and end of the survey day using a Trimble RTK GNSS unit to measure the water surface elevation. During data processing a local tide gauge was compared with the tide collected to meet the requirements for the specific work. In order to maintain the vessel's track along the profile lines, HYPACK navigation software was used for real time navigation and data acquisition.

The sounder was calibrated with a sound velocity probe and conventional bar-check at the beginning and end of each survey day. The AML CTD Base X sound velocity probe provides a fast and accurate sounder calibration. Bar-checks were performed as a redundant calibration from a depth of five (5) feet to a minimum depth of twenty-five (25) feet.

Offshore profiles extended seaward, beyond the projected depth of closure. Depth of closure (DOC) is a theoretical depth along a beach profile where sediment transport is typically negligible. For more information pertaining to the determination of the depth of closure for this project, please refer to the 2020 Beach Monitoring and Beach Stability Assessment (CPE, 2020). The offshore data collection landward limit was based on a safe approach distance for the

survey vessel based on conditions. All offshore data had a minimum overlap of fifty (50) feet with the nearshore beach profile.

3 SHORELINE ANALYSES

Shoreline change is calculated by comparing shoreline positions along shore perpendicular transects over time. This linear change in the position of the shoreline moving either landward or seaward, is often easier for the general public to visualize; however, shoreline changes are not always synonymous with volumetric changes. Figure 10 shows a typical comparison plot of two beach profile surveys conducted approximately 10.6 years apart along station C-001, illustrating graphically how the shoreline change is measured.

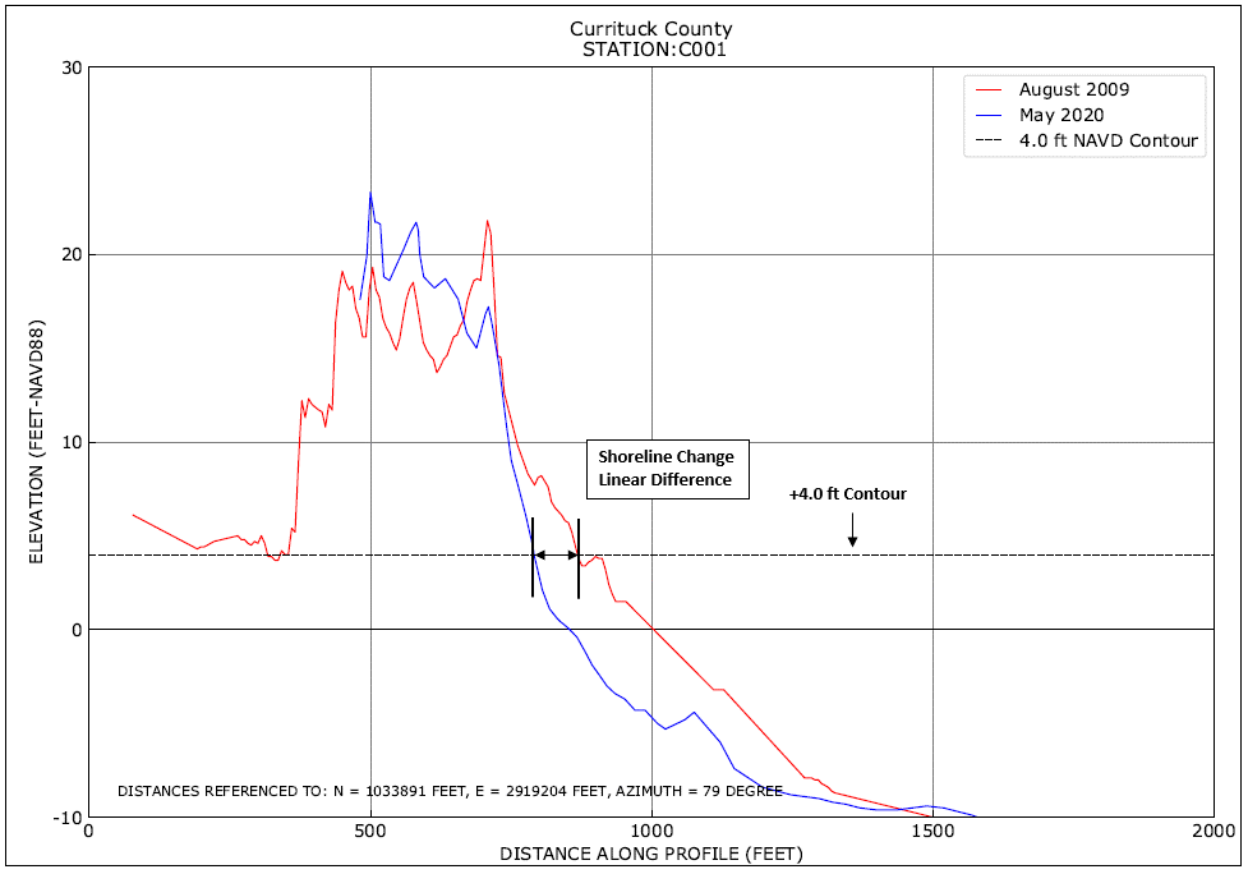

Figure 10. Beach Profile Cross Section Illustrating Shoreline Change.

As previously mentioned, the State of North Carolina maintains long-term shoreline change rates for the State's shoreline with the sole purpose of establishing construction setbacks. Figure 11 shows an example of the State long-term average shoreline change rates along a portion of the Currituck County oceanfront.

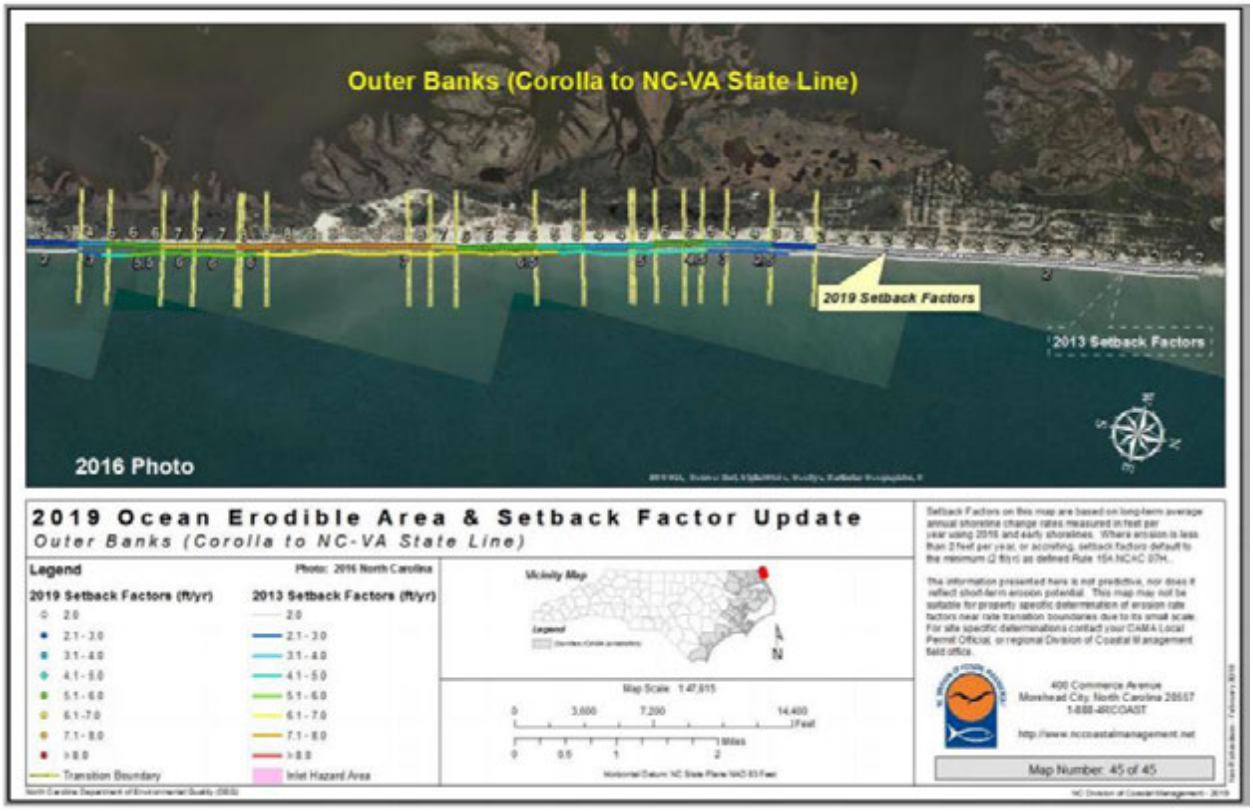

Figure 11. Map showing the SBF for Reserve/Refuge and Carova Sections of Currituck County

The average, maximum, and minimum Set Back Factor's (SBF's) for each of the 4 sections of the Assessment Area are provided in Table 5. As shown in the table, the average SBF for the Carova, Corolla, and Pine Island Sections are between 2 and 3 ft./yr., whereas the average SBF for the Reserve/Refuge Section is over 6 ft./yr. The SBF published by the State for the Pine Island Section (station C-102 located near Spindrift Trail to station C-120 located near Station 1 Lane) is 2 ft./yr. However, the State does not publish a SBF of less than 2.0 ft./yr. and therefore, this value may indicate shoreline change of less than 2 ft. per year, or accreting. This default SBF is defined by Rule 15 NCAC 07H. However, as noted by the State in their disclaimer, the shoreline position change rates are not predictive and do not reflect short-term erosion that can occur over shorter periods of time (i.e. decadal, seasonally or during storm events).

Table 5. NC DCM 2019 Setback Factors

Section	Average Setback Factor (ft./yr.)	Maximum Setback Factor (ft./yr.)	Minimum Setback Factor (ft./yr.)
Carova (C-001 to C-027)	2.49	6.00	2.00
Reserve/Refuge (C-027 to C-059)	6.57	8.00	4.00
Corolla (C-059 to C-102)	2.28	6.00	2.00
Pine Island (C-102 to C-120)	2.00	2.00	2.00
Total Assessment Area (C-001 to C-120)	3.37	8.00	2.00

Setback factors infer a recession rate or movement of the shoreline landward

Rates computed for the 2024 Assessment were calculated using a linear regression method. The rate is calculated by determining the slope of the linear trendline for a certain shoreline position (+4 ft. NAVD88) for all available survey events. Figure 12 illustrates the approach showing shoreline positions (black dots) and the trendline for station C-065. These rates are described in terms of positive (+) for advance (shoreline moving seaward) and negative (-) for recession (shoreline moving landward).

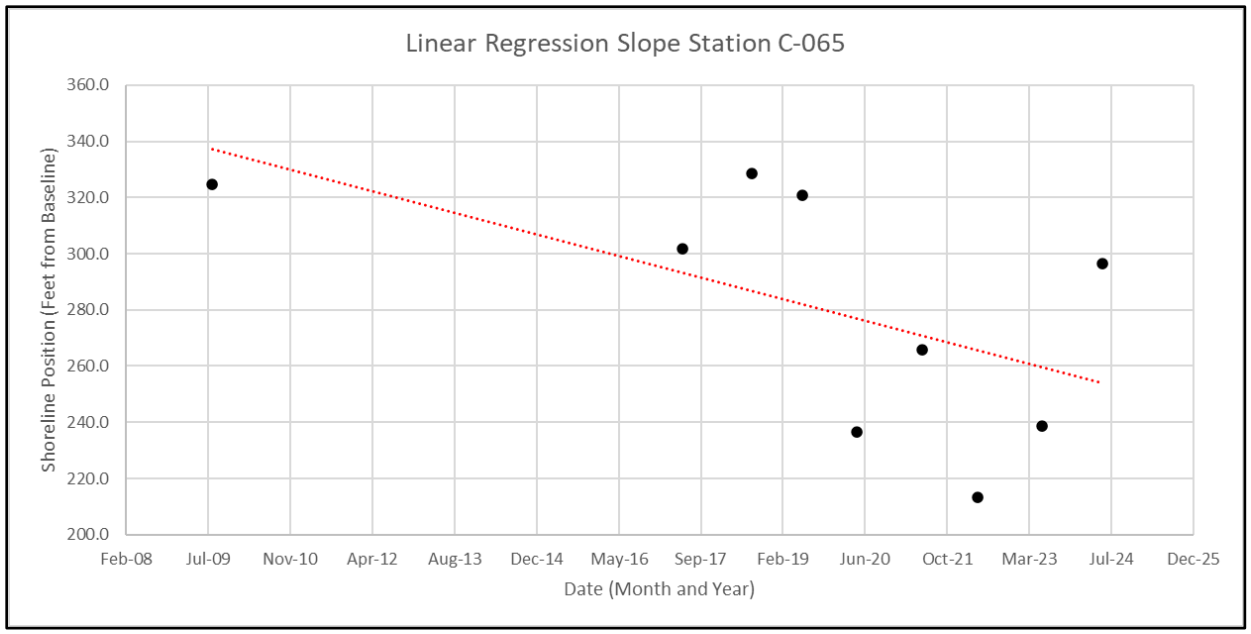

Figure 12. Example of Linear Regression Slope

Using available beach profile and Lidar data, a shoreline change analysis was conducted to assess shoreline advance and recession along the Assessment Area. As it relates to shoreline change, the "shoreline" is typically defined as a specified elevation contour. Often times the Mean High Water (MHW) contour is chosen as the representative contour. For this study, the shoreline was defined as the +4 ft. NAVD88 contour for two primary reasons. The first is that the older Lidar data sets used, such as the 2009 data, do not reliably capture the MHW contour on every profile. The +4 ft. NAVD88 contour appears to be consistently and reliably captured along the Assessment Area. The second reason the +4 ft. NAVD88 contour was used is that this contour more closely aligns with the shoreline position that is used by the State of North Carolina in their long-term shoreline change rates.

It is important for the reader to note that although shoreline change can be an indicator of loss or gain of beach width, the nature of sand movement in response to wave and water level conditions makes shoreline position highly variable temporally. The response of a beach due to storm conditions typically results in a steepening of the beach slope near the water line and the movement of sand in the seaward direction forming offshore sand bars. During calmer wave periods, the beach often recovers as sand moves landward. Along the Outer Banks, the beach exhibits a steeper slope and narrower dry sand beach in the winter; whereas the beach slope is less steep in the summer and the dry beach is generally wider.

3.1 12-Month Period (June 2023 to June 2024)

Data collected south of the Horse Gate between June 2023 and June 2024 were examined to compare the positions of the +4 ft. NAVD88 contour and determine shoreline change rates. The averages were determined by computing a weighted average based on distance. The 12-month shoreline change rate south of the Horse Gate was +43.6 ft./yr. The large positive change measured over the 12-month period resulted in a reduction in the historical and long-term rates discussed in Sections 3.2 and 3.3, respectively. A summary of the historical, long-term, and 12-month average annualized shoreline change rates computed for the +4 ft. NAVD88 contour for each section of the Assessment Area, as well as an overall project average, are provided in Table 6.

Corolla Section: The average 12-month shoreline change rate calculated for the Corolla Section was +43.9 ft./yr. This rate is nearly four (4) times greater than the positive rate measured between 2022 and 2023 which was +11.3 ft./yr. Negative shoreline change rates were measured at 5 of the 44 profiles in this section. The shoreline change rates in this section ranged from -34.4 ft./yr. at station C-067 to +83.6 ft./yr. at station C-068.

Pine Island Section: The average 12-month shoreline change rate calculated for the Pine Island Section was +42.9 ft./yr. This is a reversal in the negative erosion rate measured between 2022 and 2023 which was -16.0 ft./yr. A negative shoreline change rate was measured at 1 of the 19 profiles in this section. The shoreline change rates in this section ranged from -7.0 ft./yr. at station C-116 to +70.2 ft./yr. at station C-102.

3.2 Historical Period (August 2009 to June 2024)

Data collected throughout the Assessment Area between August 2009 and June 2024 were examined to compare the positions of the +4 ft. NAVD88 contour and determine shoreline change rates. Shoreline change rates were determined using a linear regression method given the various data sets available between August 2009 and June 2024. The averages were determined by computing a weighted average based on distance. Historical shoreline change rates at each station along the Assessment Area are provided in Table 7 and Table 8. Historical shoreline change rates are shown graphically in Figure 13 and Figure 14.

Table 6. Summary of Average Historical, Long-term, and 12-Month Shoreline Change Rates

Section	Historical Rate (ft./yr.) (Aug. 2009 to June 2024)	Long-term Rate (ft./yr.) (May 2020 to June 2024)	12-Month Rate (ft./yr.) (June 2023 to June 2024)
Carova (C-001 to C-027)	-0.9	3.0	-
Reserve/Refuge (C-027 to C-059)	-3.6	14.7	-
Corolla (C-059 to C-102)	-4.4	8.1	43.9
Pine Island (C-102 to C-120)	-0.6	5.8	42.9
Total Assessment Area (C-059 to C-120)	**-2.8**	**8.4**	**43.6**

Table 7. Summary of Historical and Long-Term Shoreline Change Rates North of the Horse Gate (C-001 to C-058)

Station	Historical Rate (ft./yr.) (Aug. 2009 to June 2024)	Long-Term Rate (ft./yr.) (May 2020 to June 2024)	Station	Historical Rate (ft./yr.) (Aug. 2009 to June 2024)	Long-Term Rate (ft./yr.) (May 2020 to June 2024)
C-001	-3.7	10.7	C-030	0.5	32.1
C-002	-4.2	11.9	C-031	-0.9	26.1
C-003	-4.5	-7.3	C-032	-0.7	17.9
C-004	-1.6	-4.9	C-033	-2.3	16.4
C-005	-2.0	-2.3	C-034	-2.8	15.0
C-006	-1.0	-2.3	C-035	-3.1	15.4
C-007	-0.8	0.4	C-036	-4.1	18.4
C-008	1.9	7.0	C-037	-2.1	6.5
C-009	1.2	-0.2	C-038	-2.6	14.6
C-010	1.2	2.7	C-039	-2.0	15.7
C-011	1.0	15.1	C-040	-3.0	1.3
C-012	0.5	5.7	C-041	-2.9	9.1
C-013	1.5	13.8	C-042	-4.7	6.8
C-014	-1.0	3.3	C-043	-2.6	17.0
C-015	-6.5	4.3	C-044	-2.4	8.5
C-016	-2.0	3.8	C-045	-3.9	16.9
C-017	0.6	1.0	C-046	-2.9	8.7
C-018	1.5	0.4	C-047	-1.8	15.3
C-019	2.3	-2.9	C-048	-3.3	20.7
C-020	1.1	1.4	C-049	-4.2	21.9
C-021	-0.1	2.3	C-050	-4.1	26.7
C-022	-1.5	-1.1	C-051	-6.6	19.2
C-023	-2.1	-1.1	C-052	-6.8	13.1
C-024	-0.3	1.2	C-053	-8.5	15.8
C-025	-3.5	1.3	C-054	-8.1	0.9
C-026	-1.6	10.3	C-055	-3.9	11.7
C-027	-1.5	12.3	C-056	-5.9	13.5
C-028	-2.2	8.6	C-057	-8.2	-4.9
C-029	0.1	28.3	C-058	-5.1	23.2

Table 8. Summary of Historical and Long-Term Shoreline Change Rates South of the Horse Gate (C-059 to C-120)

Station	Historical Rate (ft./yr.) (Aug. 2009 to June 2024)	Long-Term Rate (ft./yr.) (May 2020 to June 2024)	Station	Historical Rate (ft./yr.) (Aug. 2009 to June 2024)	Long-Term Rate (ft./yr.) (May 2020 to June 2024)
C-059	-7.7	5.9	C-090	-4.1	9.1
C-060	-7.8	11.7	C-091	-2.5	9.9
C-061	-7.4	12.7	C-092	-4.2	1.9
C-062	-7.6	4.3	C-093	-3.0	8.4
C-063	-6.5	5.4	C-094	-1.8	5.2
C-064	-4.2	3.1	C-095	-3.6	8.4
C-065	-5.6	9.4	C-096	-1.6	1.2
C-066	-3.5	14.3	C-097	-2.8	9.4
C-067	-5.2	-0.6	C-098	-1.9	5.4
C-068	-4.1	15.0	C-099	-6.2	12.3
C-069	-3.5	14.2	C-100	-1.3	15.2
C-070	-1.9	9.1	C-101	-3.3	11.2
C-071	-4.3	5.8	C-102	-3.3	10.3
C-072	-6.9	-5.6	C-103	-3.3	4.0
C-073	-5.5	-0.3	C-104	-0.8	8.1
C-074	-5.5	3.3	C-105	-0.1	2.9
C-075	-5.7	0.2	C-106	-0.7	9.5
C-076	-5.7	2.0	C-107	1.9	6.8
C-077	-3.6	3.0	C-108	-1.3	2.9
C-078	-4.9	1.8	C-109	1.2	11.1
C-079	-4.2	12.1	C-110	1.0	7.6
C-080	-8.2	9.9	C-111	-2.3	6.7
C-081	-5.4	7.5	C-112	-0.2	8.2
C-082	-3.7	17.0	C-113	-0.3	3.3
C-083	-4.0	14.6	C-114	-0.5	7.1
C-084	-2.8	14.8	C-115	-2.0	2.9
C-085	-4.8	12.7	C-116	-3.5	-3.1
C-086	-3.6	8.2	C-117	-0.7	7.4
C-087	-4.0	14.7	C-118	2.3	-0.6
C-088	-4.9	12.2	C-119	1.6	9.6
C-089	-3.0	8.7	C-120	-1.3	8.5

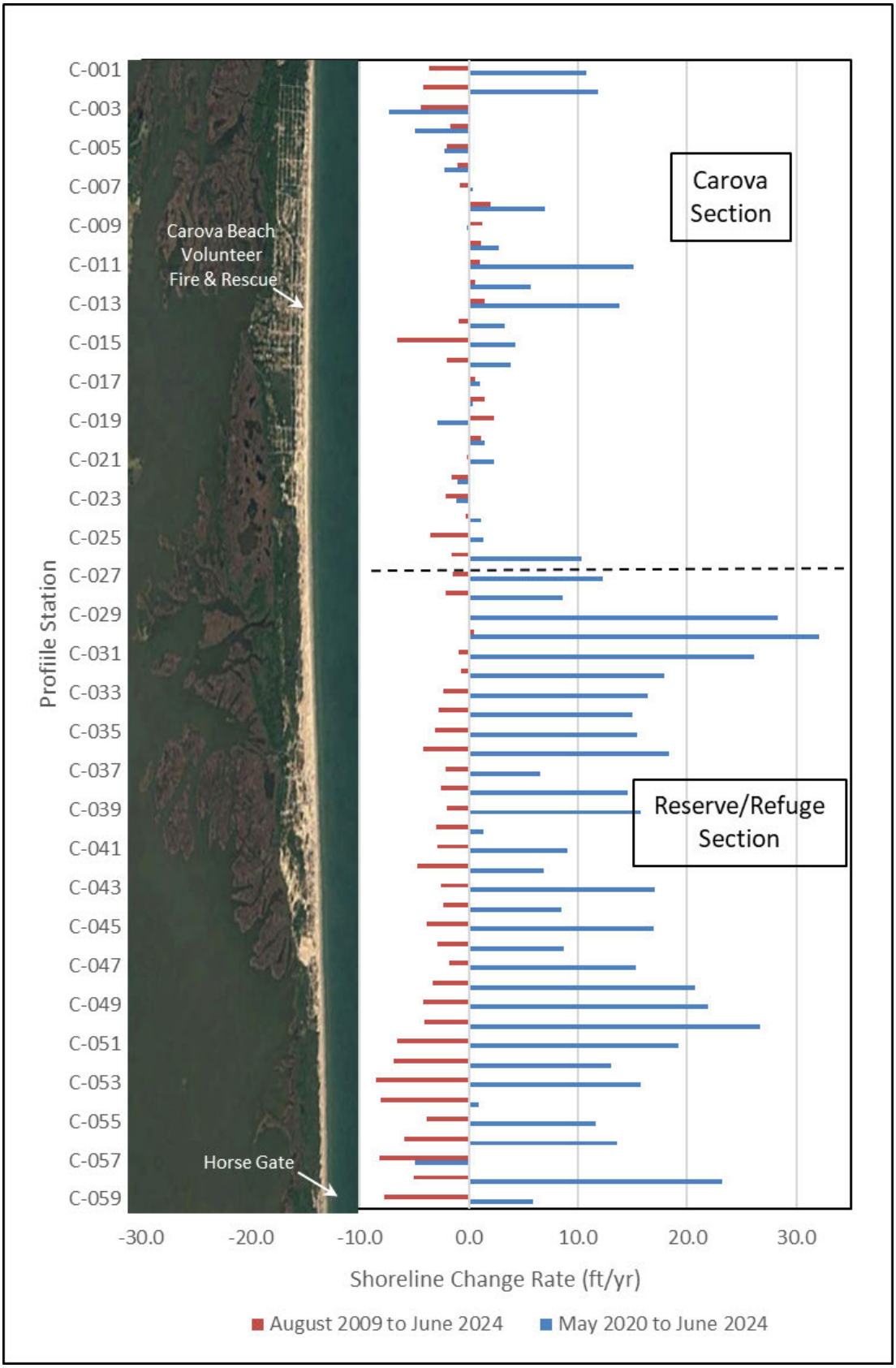

Figure 13. Shoreline Change Rate (+4 ft. NAVD88) North of the Horse Gate (C-001 to C-059)

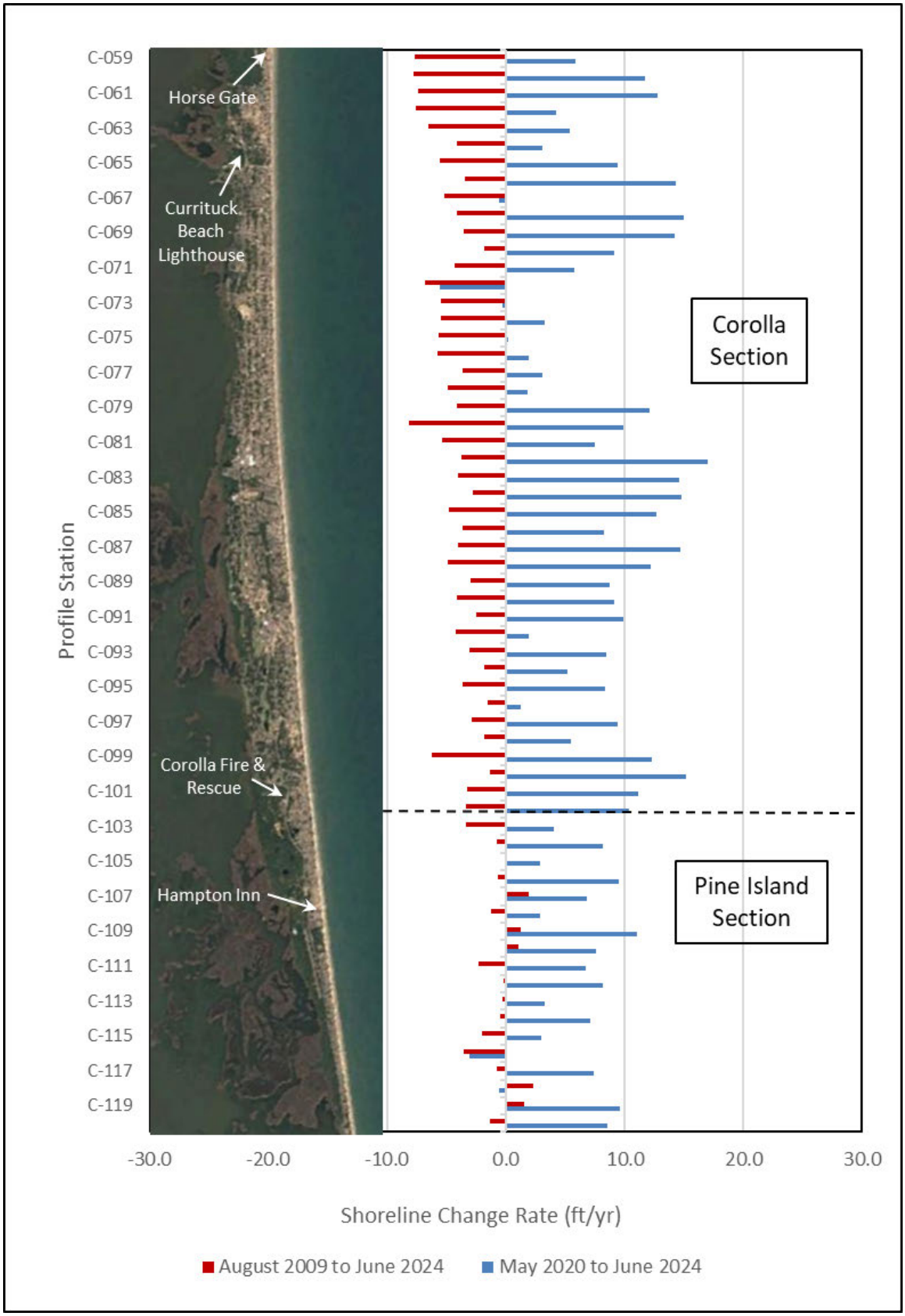

Figure 14. Shoreline Change Rate (+4 ft. NAVD88) South of the Horse Gate (C-059 to C-120)

Carova Section: The average historical (2009 to 2024) shoreline change rate calculated for the Carova Section was -0.9 ft./yr. This is an increase in the negative rate measured between 2009 and 2022 which was -0.3 ft./yr. The State determined the average SBF in the Carova Section to be 2.49 ft./yr. (note SBF's infer a recession rate or movement of the shoreline landward), meaning the shoreline retreat rate computed between 2009 and 2024 is less than the average rate used by the State for this area. A profile-by-profile comparison shows historical shoreline change rates in this section ranging from -6.5 ft./yr. at station C-015 to +2.3 ft./yr. at station C-019.

Reserve/Refuge Section: The average historical shoreline change rate calculated for the Reserve/Refuge Section was -3.6 ft./yr. This is a decrease in the negative rate measured between 2009 and 2022 which was -5.1 ft./yr. The State determined an average SBF of 6.57 ft./yr. in the Corolla Section (note SBF's infer a recession rate or movement of the shoreline landward), meaning the shoreline retreat rate computed between 2009 and 2024 is less than the average rate used by the State for this area. A negative shoreline change rate was measured at all but two profiles (C-029 and C-030) along the Reserve/Refuge Section of the Assessment Area. Rates ranged from -8.2 ft./yr. at station C-053 to +0.5 ft./yr. at station C-030.

Corolla Section: The average historical shoreline change rate calculated for the Corolla Section was -4.4 ft./yr. This is a decrease in the negative rate measured between 2009 and 2023 which was -5.6 ft./yr. The State determined an average SBF of 2.28 ft./yr. in the Corolla Section (note SBF's infer a recession rate or movement of the shoreline landward), meaning the shoreline retreat rate computed between 2009 and 2024 is nearly twice as high as the average rate used by the State for this area. A negative shoreline change rate was measured at each profile along the Corolla Section of the Assessment Area, ranging from -8.2 ft./yr. at station C-080 to -1.3 ft./yr. at station C-100.

Pine Island Section: The average historical shoreline change rate between August 2009 and June 2024, in the Pine Island Section was relatively stable, measuring -0.6 ft./yr. This is a decrease in the rate measured between 2009 and 2023 which was -1.3 ft./yr. The State determined an average SBF of 2.0 ft./yr. in the Pine Island Section (station C-102 to station C-120) (note SBF's infer a recession rate or movement of the shoreline landward), meaning the shoreline retreat rate computed between 2009 and 2024 is less than the average rate used by the State for this area. Shoreline change rates varied along the Pine Island Section from -3.5 ft./yr. at station C-116 (located on south end of Hicks Bay Lane) to +2.3 ft./yr. at station C-118 (located along the middle of Salt House Rd).

3.3 Long-term Rate (May 2020 to June 2024)

Shoreline change rates were also evaluated from May 2020, which was the first County-wide survey conducted as part of this ongoing annual Beach Monitoring and Beach Stability Assessment, and the most recent set of data collected in June 2024. The shoreline change rates over this "long-term" period were also determined using a linear regression method. The average shoreline change rate between May 2020 and June 2024 along the entire Assessment Area (station C-001 to station C-120) was +8.4 ft./yr. Long-term shoreline change rates at each station along the

Assessment Area are provided in Table 7 and Table 8. A summary of the long-term average annualized shoreline change rates computed for the +4 ft. NAVD88 contour for each section of the Assessment Area, as well as an overall average, are provided in Table 6. Long-term shoreline change rates are shown graphically in Figure 13 and Figure 14.

Carova Section: The average long-term shoreline change rate calculated for the Carova Section between May 2020 and June 2024 was +3.0 ft./yr. This is a considerable decrease from the rate measured in 2022 based on the period from May 2020 to May 2022, which was +20.7 ft./yr. A profile-by-profile comparison shows shoreline change rates in this section ranging from -7.3 ft./yr. at station C-003 to +15.1 ft./yr. at station C-011.

Reserve/Refuge Section: The average long-term shoreline change rate calculated for the Reserve/Refuge Section was +14.7 ft./yr. This is an increase from the previous positive shoreline change rate measured between May 2020 and May 2022, which was +12.9 ft./yr. A negative shoreline change rate was measured at only one profile (C-057) along the Reserve/Refuge Section of the Assessment Area between May 2020 and June 2024. Rates ranged from -4.9 ft./yr. at station C-057 to +32.1 ft./yr. at station C-030.

Corolla Section: The average shoreline change rate calculated for the Corolla Section between May 2020 and June 2024 was +8.1 ft./yr. This is a reversal of the average shoreline change rate trend measured between 2020 and 2023, which was -1.3 ft./yr. Only two stations measured landward movement in this section over this period. A profile-by-profile comparison shows shoreline change rates in this section ranging from -5.6 ft./yr. at station C-072 to +17.0 ft./yr. at station C-082.

Pine Island Section: The average shoreline change rate calculated for the Pine Island Section between May 2020 and June 2024 was +5.8 ft./yr. This is a reversal of the average shoreline change rate trend measured between 2020 and 2023, which was -2.0 ft./yr. Shoreline change rates varied along the Pine Island Section from -3.1 ft./yr. at station C-116 (located at south end of Hicks Bay Lane) to +11.1 ft./yr. at station C-109 (located near south end of Lindsey Lane). Only two stations (C-116 and C-118) had negative rates in Pine Island during this period.

3.4 Shoreline Projections

As part of this study, the shoreline change model previously developed to project shoreline change over a 10-, 20-, and 30- year period was updated to incorporate the June 2024 survey data. The June 2024 shoreline location of the +4 ft. NAVD88 contour was projected into the future for periods of 10-, 20-, and 30-years based on the historical shoreline change rates calculated between August 2009 and June 2024.

A three-point average was applied to the individual shoreline change rates that were measured at each station in order to smooth the data along the Assessment Area, while maintaining the observed trends. This is consistent with the method used for shoreline projections presented in the 2020 (CPE, 2020), 2021 (CPE, 2021), 2022 (CPE, 2023a), and 2023 (CPE, 2023b) reports. For

the stations on the north end of the Assessment Area (station C-001) and south end of the Assessment Area (station C-120), the actual measured shoreline change rate was used to determine projected shorelines. For those profiles on which the three-point average shoreline change rate was positive, indicating a seaward trend in the shoreline movement, no shoreline projection is shown. Maps showing the results of the projected shoreline change are included in Appendix B.

This analysis identified a house as "impacted" if any part of the footprint of the structure, as shown in the Currituck County GIS, was seaward of the 10-, 20-, or 30-year projected shorelines. Table 9 shows the number of houses in each of the four project sections shown to be impacted over the 10-, 20-, and 30-Year time horizons. The analysis does not include specific evaluations of damages to individual houses due to direct flooding, wave impacts, or wind impacts, nor will it quantify the economic impacts resulting from the damage or loss of such structures. If the County requires this type of economic impact, additional analyses will be required.

Table 9. Number of houses shown to be impacted over the 10-, 20-, and 30-year time horizons

Section	10-Year	20-Year	30-Year
Carova (C-001 to C-027)	0	0	0
Reserve/Refuge (C-027 to C-059)	0	1	3
Corolla (C-059 to C-102)	0	10	56
Pine Island (C-102 to C-120)	0	0	0
Total Assessment Area (C-001 to C-120)	**0**	**11**	**59**

In both the northernmost Section (Carova) and southernmost Section (Pine Island) of the Assessment Area, the projected shoreline change methodology did not indicate any impacts to oceanfront houses based on the 30-year projections.

In the Reserve/Refuge Section, where the average historical shoreline change rate was the second highest of the four sections, the projected shoreline change indicates several houses where impacts may occur. Three (3) houses located seaward of Sandfiddler Road along an approximately 3,000-foot portion of the oceanfront south of Canary Ln. (between station C-041 and station C-044), were shown to be impacted over the 30-year horizon. One of these houses between station C-043 and station C-044 was shown to be impacted over the 20-year horizon. With the amount of vehicular traffic transiting the oceanfront beaches along this section, the presence of oceanfront houses sitting on the open beach as shorelines retreat could impact vehicular traffic (including Emergency Vehicles) traveling north and south along the open beach. Although no other structural impacts are indicated by the shoreline projections along the Reserve/Refuge Section, the relatively high shoreline change rates measured between stations C-049 and C-059, along the Currituck Banks Estuarine Reserve, show that the 30-year shoreline projection may begin to impact maritime shrub and maritime forest habitat as they transition into more active dune environments.

In the Corolla Section of the Assessment Area, the projected shoreline change shown in Table 9 indicates extensive numbers of oceanfront houses may be impacted over a 30-year time horizon. Along the northern portion of the Corolla Section from Headwind Way (station C-060) to south of Carotank Drive (station C-065), a total of 26 houses were shown to be impacted over the 30-year horizon. Out of those 26 houses, 10 were impacted over the 20-year horizon and 0 were impacted over the 10-year horizon. Along the portion of the Corolla Section between the Sturgeon Beach Access (station C-071) and Mackeral St. (station C-076), a total of 25 houses were shown to be impacted over the 30-year horizon. No houses were shown to be impacted over the 20-year horizon along this portion. Along the central portion of the Corolla Section between Sailfish Street and Marlin Beach Access (station C-080 to station C-081), a total of 5 oceanfront houses were shown to be impacted over the 30-year horizon. No houses were shown to be impacted over the 20-year horizon along this portion.

To summarize, the northern two thirds within the Corolla Section (station C-059 to station C-081) included 56 oceanfront houses that were shown to be impacted over the 30-year horizon. The gap between impacted houses in the area did not exceed 8,000 feet. Out of these 56 houses, 10 were shown to be impacted over the 20-year horizon (all were just south of the Horse Gate and north of Carotank Drive) and 0 houses were shown to be impacted over the 10-year horizon.

4 VOLUME ANALYSES

As discussed in the previous section, changes in the shoreline position represented by a single elevation contour can vary considerably based on sea conditions leading up to the time in which the surveys were conducted. Sand on the beach is distributed by wind and wave action over the entire active profile. The dry beach often observed above the water represents only a fraction of the active beach profile. Therefore, the volume of sand measured on the entire active profile is an important parameter to track to gauge the health of the beach. As provided in previous monitoring reports, volumetric change was calculated between the dune and the depth of closure (-19 ft. NAVD88), this represents the landward and seaward limits of the active profile as defined for this particular assessment. Additional information on the determination of this depth can be found in the 2020 report (CPE, 2020). A volumteric analyses was completed as part of the 2024 Assessment through a comparison of May 2020, May 2022, June 2023, and June 2024 data. A long-term rate was calculated between May 2020 and June 2024, which is the longest period of time in which we have County-wide beach profile data. A 25-month rate was calculated between May 2022 and June 2024, and a 12-month rate was calculated between June 2023 and June 2024. These rates compare the two most recent surveys for the respective sections. The results of this volumetric analysis are detailed in Section 4.1. After reviewing the available data collected between May 2020 and May 2022, an additional method for evaluating volumetric changes was conducted. This additional method splits the active profile into 4 parts or “Lenses” in the cross-shore direction. Results of volumetric changes measured within each lens are provided in Section 4.2 and discussed further in Section 5.0.

4.1 Volumetric Change (-19 Ft. NAVD88 Depth of Closure)

As discussed above, volumetric change was computed using the 2024 data out to the -19 ft. NAVD88 depth contour, which was established as the "Depth of Closure" in the previous Beach Assessment reports (CPE, 2020, CPE, 2021, CPE, 2023a, and CPE, 2023b). Figure 15 shows the same profile shown in Figure 10 with areas between the profiles shaded to show areas of volume gains (green-accretion) and volumes losses (red-erosion) along the profile. The net difference between these gains and losses is referred to as the volumetric change.

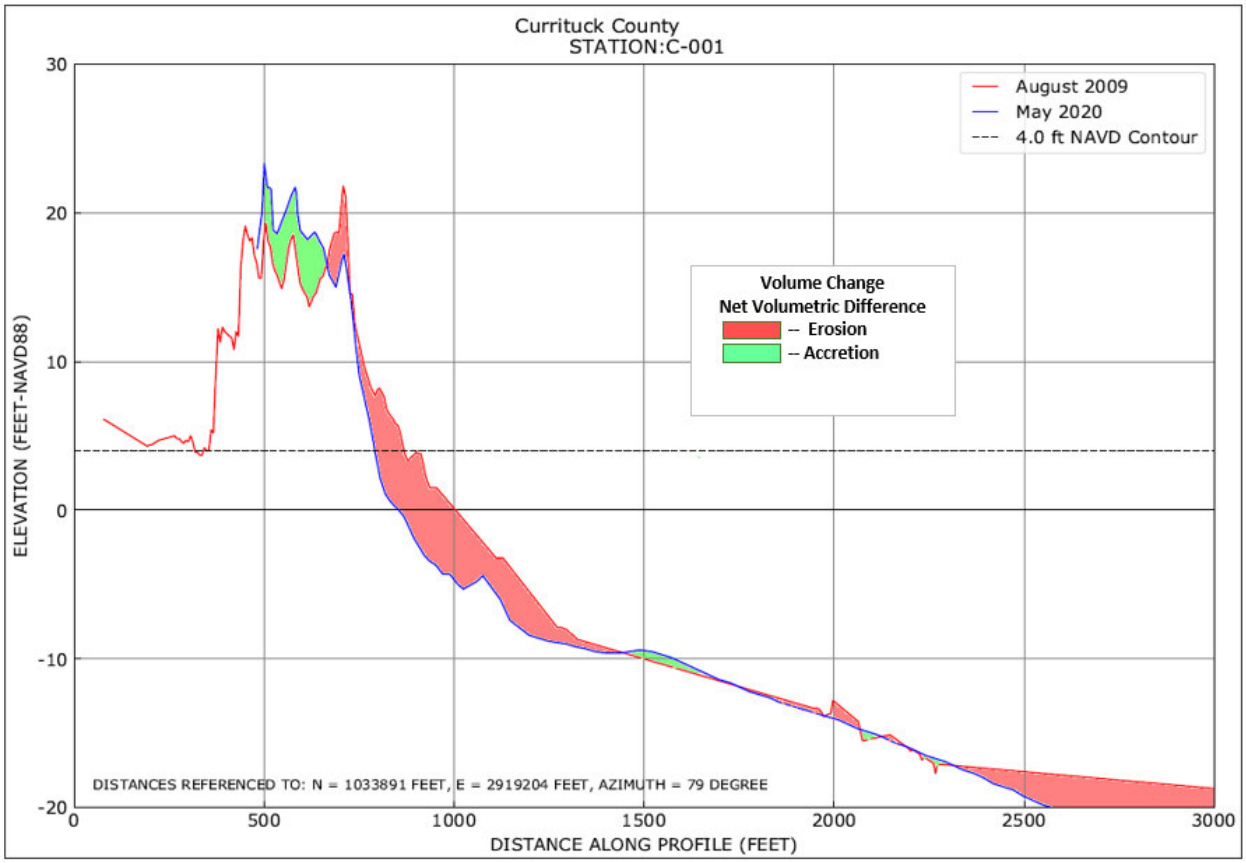

Figure 15. Beach Profile Cross Section Illustrating Volume Change

Volumetric changes along a profile, or volumetric changes averaged over multiple profiles, are provided in cubic yards per linear foot of beach. At times, this report also provides total volume change in cubic yards measured between certain profiles. These volumes are determined using the average end area method; whereby the average volume change between adjacent profiles is multiplied by the distance between those profiles. Volumetric change rates are given in cubic yards per linear feet of beach per year. The volumetric changes are calculated along the entirety of the profile from the depth of closure to the landward most point at which overlapping data between surveys exists.

With the collection of the June 2024 beach profile data along the entirety of the Currituck County beaches, long-term, 25-month, and 12-month volumetric changes were computed. Similar to the

shoreline change rates provided in Section 3.3, long-term rates reflect changes between May 2020 and June 2024. Changes between May 2022 and June 2024 (25-month) and June 2023 and June 2024 (12-month) are also provided, which reflect comparison of the two most recent data sets. Long-term changes were computed throughout the entirety of the County, while 25-month changes were only computed north of the Horse Gate and 12-month changes were computed south of the Horse Gate. The average volumetric change rate and total volumetric change for each section and the overall 2024 Assessment Area are provided in Table 10.

Table 10. Summary of Average Volumetric Change Rates and Total Volume Changes Measured to -19 ft. NAVD88.

Section	Average Volumetric Change Rate (cy/ft./yr.)			Total Volume Change (cy)		
	May 2020 to June 2024	May 2022 to June 2024	June 2023 to June 2024	May 2020 to June 2024	May 2022 to June 2024	June 2023 to June 2024
Carova	3.1	-5.3	-	337,000	-287,800	-
Reserve/Refuge	-0.5	-9.3	-	-67,100	-620,500	-
Corolla	3.3	2.5	-3.5	587,900	223,900	-152,500
Pine Island	3.2	12.4	-11.8	236,800	463,300	-211,800
Total Assessment Area	**2.2**	**-0.9**	**-6.2**	**1,094,600**	**-221,100**	**-364,200**

4.1.1 Long-term Period May 2020 to June 2024

The average long-term volumetric change rate along the entire County oceanfront measured between May 2020 and June 2024 was +2.2 cy/ft./yr., resulting in a cumulative positive volumetric change of approximately 1,094,600 cubic yards (Table 10). The Carova, Corolla, and Pine Island Sections experienced a similar positive volumetric change during this period. In contrast, the Reserve/Refuge Section was the only one of the four sections that experienced a negative volumetric change. Table 11 lists the individual volumetric change rates computed for each profile (C-001 to C-120) between May 2020 and June 2024. Figure 16 and Figure 17 show the 2020 to 2024 change rates graphically.

Carova Section: The average volumetric change rate in the Carova Section was +3.1 cy/ft./yr. This equates to a net volume gain of approximately 337,000 cy over the 4.1-year period, or a gain of 82,500 CY per year. In comparison, the average volume change rate measured between May 2020 and May 2022 in this section was +12.4 cy/ft./yr. (CPE, 2023a). Negative volumetric change rates were measured at 6 of the 27 profiles in this section (Table 11 and Figure 16). A profile-by-profile comparison shows volumetric change rates in this section ranging from -35.7 cy/ft./yr. at station C-002 (600 feet north of Bluefish Lane) to +16.8 cy/ft./yr. at station C-015 (800 feet south of Mallard Lane).

The Carova Section was analyzed further for observable trends within the section. The northernmost 4,200 feet of the Carova Section (station C-001 to station C-005), north of Marlin Lane, had a negative average rate of -14.7 cy/ft./yr. Between station C-005 (Marlin Lane) to station

C-010 (just south of Sunfish Lane), an average positive rate of 5.0 cy/ft./yr. was measured. Between station C-010 (just south of Sunfish Lane) to station C-018 (Crane Road), an average positive rate of 12.2 cy/ft./yr was measured. From Crane Road to 300 feet south of Sandfiddler Rd (station C-018 to station C-027), gains were measured, with an average volumetric change rate of +2.7 cy/ft./yr.

Reserve/Refuge Section: The average volumetric change rate in the Reserve/Refuge Section was -0.5 cy/ft./yr., which equates to a net volume loss of 67,100 cy over the 4.1-year period, or -16,400 CY per year. In comparison, the average volume change rate measured between May 2020 and May 2022 in this section was +8.8 cy/ft./yr. (CPE, 2023a). This was the only section that had an average negative change between May 2020 and June 2024. Negative and positive changes were measured at 17 of the 33 profiles within this section (Table 11 and Figure 16). A profile-by-profile comparison shows volumetric change rates in this section ranging from -19.0 cy/ft./yr. at station C-042 (280 feet north of Hidden Dune Lane) to +14.5 cy/ft./yr. at station C-050 (800 feet south of Malbon Drive).

The Reserve/Refuge Section was analyzed further for observable trends within the section. From 300 feet south of Sandfiddler Road to 2,600 feet north of 1780 Ocean Pearl Road (station C-027 to station C-032), the average volumetric change rate was +6.9 cy/ft./yr. From 2,600 feet north of 1780 Ocean Pearl Road to 700 feet south of Munson Lane (station C-032 to station C-047), the average volumetric change rate was -6.0 cy/ft./yr; this area had 5 stations with a negative volume change greater than -10 cy/ft./yr. The southern 11,800 ft. of the Reserve/Refuge Section, from 700 feet south of Munson Lane to approximately 250 feet south of the Horse Gate (station C-047 to station C-059), had an average volumetric change rate of +3.3 cy/ft./yr.

Table 11. Volumetric Change Rates May 2020 to June 2024 (cy/ft./yr.).

Station	May 2020 to June 2024	Station	May 2020 to June 2024	Station	May 2020 to June 2024
C-001	8.5	C-041	6.3	C-081	5.6
C-002	-35.7	C-042	-19.0	C-082	8.8
C-003	-13.7	C-043	-4.4	C-083	11.3
C-004	-10.7	C-044	-3.3	C-084	7.1
C-005	-8.1	C-045	-9.8	C-085	4.5
C-006	5.2	C-046	-16.3	C-086	2.1
C-007	9.2	C-047	4.0	C-087	1.5
C-008	5.3	C-048	4.8	C-088	5.7
C-009	5.9	C-049	7.0	C-089	-1.7
C-010	6.5	C-050	14.5	C-090	4.9
C-011	11.5	C-051	8.9	C-091	6.8
C-012	9.1	C-052	-3.1	C-092	-3.3
C-013	12.1	C-053	3.7	C-093	-1.5
C-014	13.7	C-054	1.0	C-094	-3.0
C-015	16.8	C-055	-0.8	C-095	0.4
C-016	15.1	C-056	-1.7	C-096	-3.7
C-017	11.5	C-057	-7.0	C-097	0.1
C-018	7.5	C-058	10.1	C-098	6.6
C-019	-3.1	C-059	-0.1	C-099	-0.9
C-020	3.9	C-060	2.7	C-100	3.4
C-021	0.2	C-061	0.3	C-101	5.0
C-022	-1.0	C-062	-3.7	C-102	7.8
C-023	4.5	C-063	2.3	C-103	1.0
C-024	7.0	C-064	-3.5	C-104	-4.3
C-025	5.7	C-065	8.5	C-105	-2.5
C-026	1.5	C-066	3.3	C-106	2.4
C-027	4.2	C-067	1.7	C-107	0.6
C-028	5.0	C-068	6.0	C-108	2.4
C-029	10.1	C-069	9.8	C-109	5.1
C-030	8.7	C-070	-0.2	C-110	3.9
C-031	8.0	C-071	2.1	C-111	6.7
C-032	0.8	C-072	-2.8	C-112	5.9
C-033	-2.1	C-073	2.9	C-113	4.0
C-034	-11.5	C-074	-0.8	C-114	9.4
C-035	-6.5	C-075	6.0	C-115	0.7
C-036	-2.0	C-076	4.4	C-116	-5.4
C-037	-10.5	C-077	10.8	C-117	4.1
C-038	-12.0	C-078	11.1	C-118	5.0
C-039	-1.9	C-079	12.5	C-119	13.4
C-040	2.1	C-080	6.3	C-120	3.1

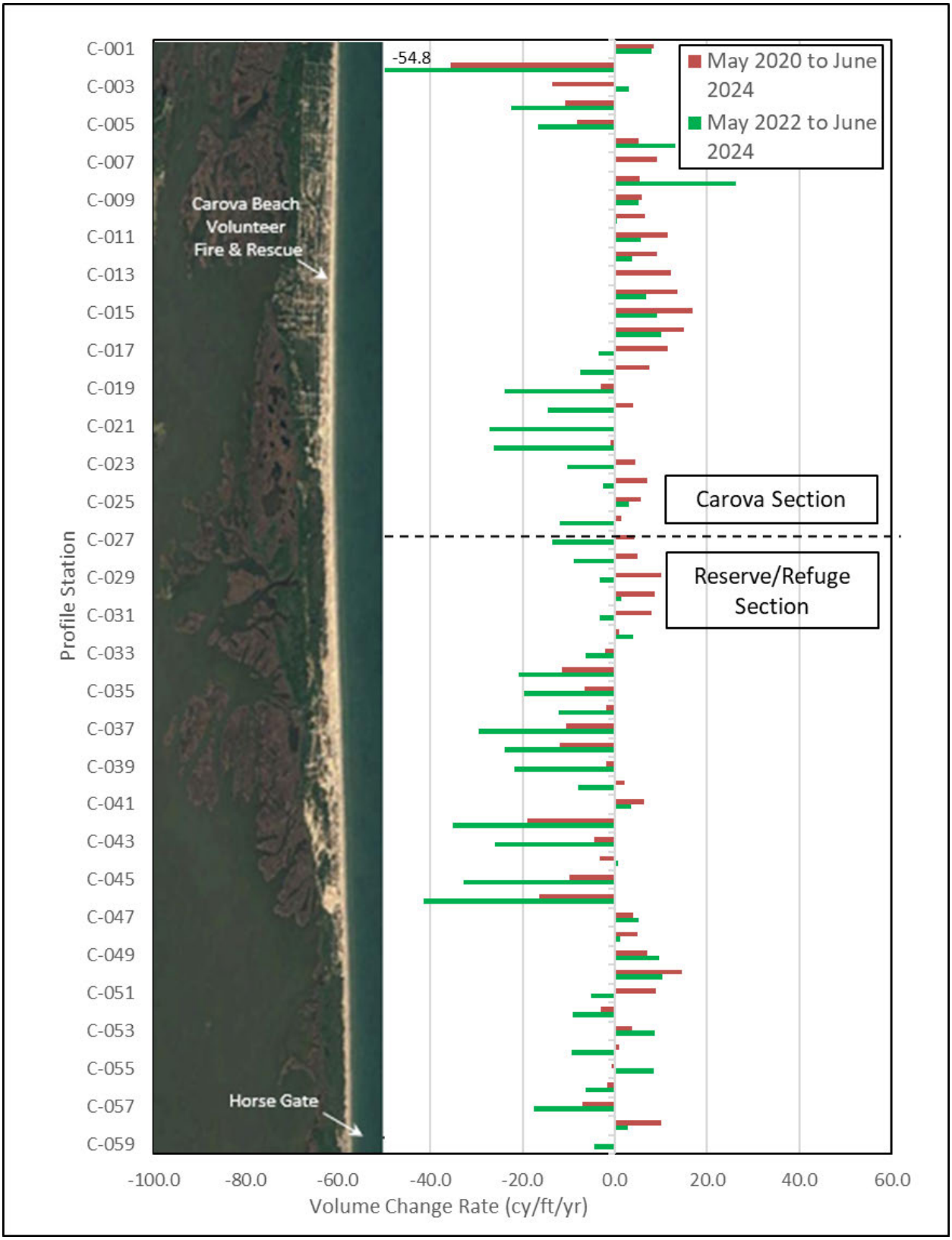

Figure 16. Volume Change Rate Above -19 ft. NAVD88 - North of the Horse Gate May 2020 to June 2024 and May 2022 to June 2024

Corolla Section: The average long-term volumetric change rate in the Corolla Section was +3.3 cy/ft./yr., which equates to a net volume gain of 587,900 cy or 144,000 CY per year. In comparison, the average volume change rate measured between May 2020 and June 2023 in this section was +5.6 cy/ft./yr. (CPE, 2023b). Negative volumetric change rates were measured on 12 of the 44 profiles in this section (Table 11 and Figure 16) between May 2020 and June 2024. A profile-by-profile comparison shows volumetric change rates in this section ranging from -3.7 cy/ft./yr. at stations C-062 and C-096 to +12.5 cy/ft./yr. at station C-079.

The Corolla Section was analyzed further for observable trends within the section. Between the northern boundary of the Corolla Section, which is located approximately 250 feet south of the Horse Gate, and the south end of Atlantic Avenue (station C-059 to station C-064), the average volumetric change rate was stable at 0.0 cy/ft./yr. From the south end of Atlantic Avenue to 1,200 feet north of Bonito Street (station C-064 to station C-076), the average volumetric change rate was +3.1 cy/ft./yr. From approximately 1,200 feet north of Bonito Street to 170 feet south of Albacore Street (station C-076 to station C-084), the average volumetric change rate was +9.0 cy/ft./yr. From station C-084 south to station C-102, 170 feet south of Albacore Street, approximately 500 feet north of Yaupon Lane, the average volumetric change rate was +1.9 cy/ft./yr.

Pine Island Section: The average long-term volumetric change rate in the Pine Island Section was +3.2 cy/ft./yr. This equates to a net volume gain of approximately 236,800 cy or 58,000 CY per year. In comparison, the average volume change rate measured between May 2020 and June 2023 in this section was +8.0 cy/ft./yr. (CPE, 2023b). Negative volumetric change rates were only measured at 3 of the 19 profiles: station C-104, station C-105, and station C-116 along this section (Table 11 and Figure 16). A profile-by-profile comparison shows volumetric change rates in this section ranging from -5.4 cy/ft./yr. at station C-116 to +13.4 cy/ft./yr. at station C-119.

The Pine Island Section was analyzed further for observable trends within the section. Between the northern boundary of the Pine Island Section, which is located approximately 500 feet north of Yaupon Lane, and the Hampton Inn (station C-102 to station C-110), the average volumetric change rate was +1.3 cy/ft./yr. From the Hampton Inn to approximately 101 Station 1 Lane, (station C-110 to station C-120), the average volumetric change rate was +4.7 cy/ft./yr.

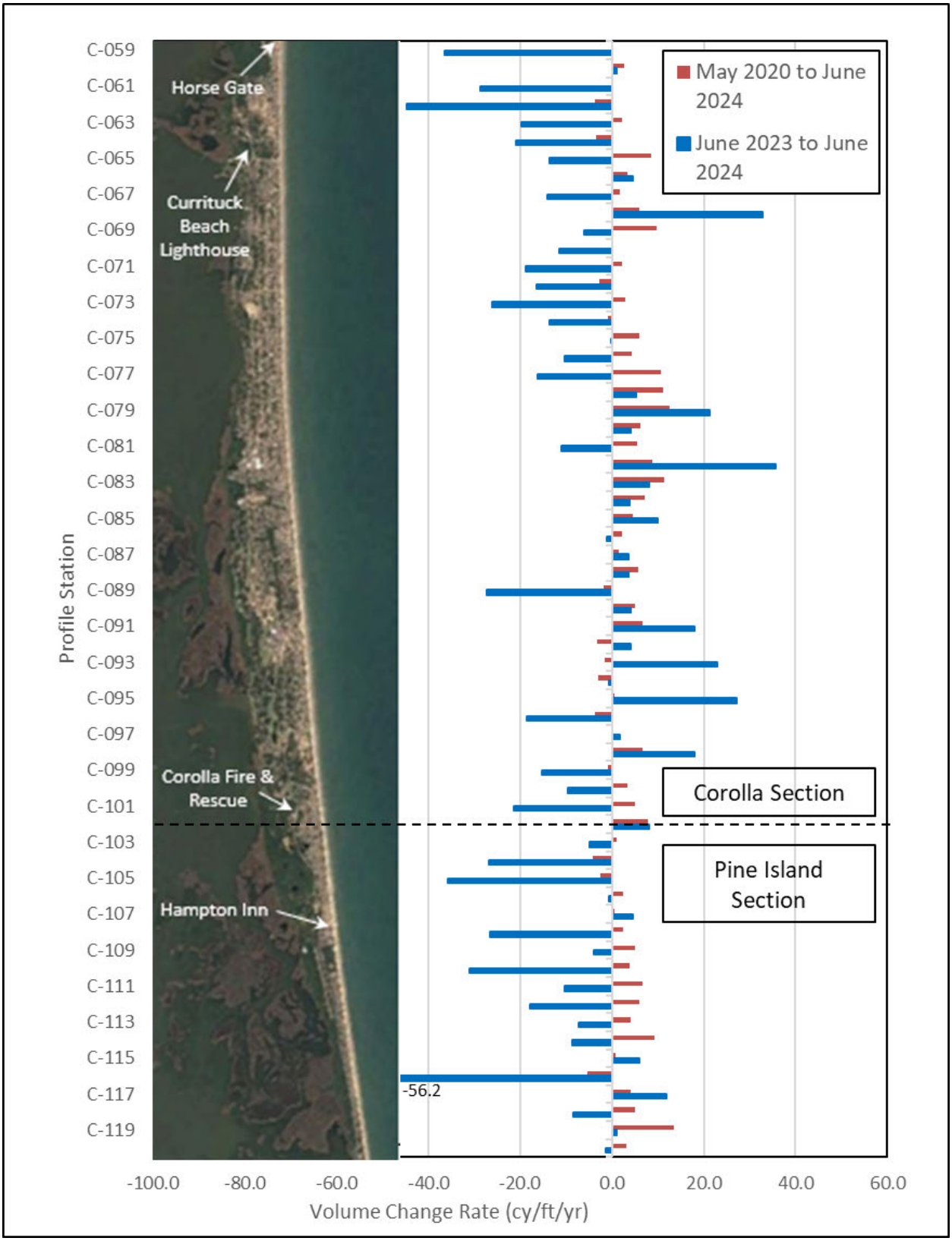

Figure 17. Volume Change Rates Above -19 ft. NAVD88 - South of Horse Gate May 2020 to June 2024 and June 2023 to June 2024

4.1.2 25-Month Period May 2022 to June 2024 (North of Horse Gate)

The current monitoring protocol implemented along the County oceanfront is to monitor the portion of the County oceanfront south of the Horse Gate (Corolla and Pine Island Sections) every year and the portion north of the Horse Gate (Carova and Reserve/Refuge Sections) every other year. As previously stated, in 2024, the entire County oceanfront was surveyed. However, the previous survey north of the Horse Gate was conducted in May 2022. The average volumetric change rate measured north of the Horse Gate, between May 2022 to June 2024 was -7.5 cy/ft./yr., resulting in a cumulative negative volumetric change of approximately 908,300 cubic yards, or -436,000 CY per year. Table 12 lists the individual volumetric rates computed for each profile in the Carova and Reserve/Refuge Sections between May 2022 and June 2024. Figure 16 shows the May 2022 to June 2024 volume change rates graphically.

Carova Section: The average volumetric change rate measured between May 2022 and June 2024 along the Carova Section was -5.3 cy/ft./yr. This equates to a net volume loss of approximately 287,800 cy over the 25-month period from May 2022 to June 2024, or -138,100 CY per year. A profile-by-profile comparison shows volumetric change rates in this section ranging from -54.8 cy/ft./yr. at station C-002 to +26.1 cy/ft./yr. at station C-008 (Figure 16).

Similar to the analysis of long-term trends, the Carova Section was analyzed further for observable trends within discrete portions of the section. Between the northern boundary of the Carova Section, which is located at the Virginia/North Carolina border, and just north of Marlin Lane (station C-001 to station C-005), the average volumetric change rate was -19.3 cy/ft./yr. The rate is heavily influenced by a large negative outlier of -54.8 cy/ft./yr. at station C-002. From approximately just north of Marlin Lane to just north Sunfish Lane (station C-005 to station C-010), the average volumetric change rate was +8.2 cy/ft./yr. From approximately just north of Sunfish Lane to Crane Road (station C-010 to station C-018), the average volumetric change rate was +3.6 cy/ft./yr. Along the southern portion of the Corolla Section, between station C-018 (Crane Road) and station C-027 (located approximately 300 feet south of Sandfiddler Road), the average volumetric change rate was -13.9 cy/ft./yr.

Reserve/Refuge Section: The average volumetric change rate in the Reserve/Refuge Section over the 25-month period from May 2022 to June 2024 was -9.3 cy/ft./yr. This equates to a net volume loss of approximately 620,500 cy, or -297,800 CY per year. A profile-by-profile comparison shows volumetric change rates in this section ranging from -41.5 cy/ft./yr. at station C-046 to +10.2 cy/ft./yr. at station C-050 (Figure 16).

Similar to the analysis of long-term trends, the Reserve/Refuge Section was analyzed further for observable trends within discrete portions of the section. Between the northern boundary of the Reserve/Refuge Section, which is located approximately 1,300 feet south of Coneflower Lane, and 4,100 feet north of Albatross Lane (station C-027 to station C-032), the average volumetric change rate was -3.7 cy/ft./yr. From approximately 4,100 feet north of Albatross Lane to approximately 700 feet south of Munson Lane (station C-032 to station C-047), the average volumetric change rate was -18.1 cy/ft./yr. Along the southern portion of the Reserve/Refuge Section, between

station C-047 (700 feet south of Munson Lane) and station C-059, located approximately 250 feet south of the Horse Gate, the average volumetric change rate was -0.6 cy/ft./yr.

Table 12. Volumetric Changes Rates (May 2022 to June 2024) (cy/ft./yr.).

Station	May 2022 to June 2024	Station	May 2022 to June 2024	Station	May 2022 to June 2024
C-001	8.0	C-021	-27.2	C-041	3.5
C-002	-54.8	C-022	-26.2	C-042	-35.1
C-003	3.0	C-023	-10.2	C-043	-25.9
C-004	-22.5	C-024	-2.6	C-044	0.7
C-005	-16.6	C-025	3.0	C-045	-32.8
C-006	13.1	C-026	-11.8	C-046	-41.5
C-007	0.2	C-027	-13.6	C-047	5.0
C-008	26.1	C-028	-9.0	C-048	1.0
C-009	5.1	C-029	-3.2	C-049	9.6
C-010	0.4	C-030	1.5	C-050	10.2
C-011	5.7	C-031	-3.2	C-051	-5.1
C-012	3.6	C-032	4.0	C-052	-9.2
C-013	0.1	C-033	-6.4	C-053	8.6
C-014	6.8	C-034	-20.8	C-054	-9.4
C-015	9.1	C-035	-19.8	C-055	8.5
C-016	10.0	C-036	-12.1	C-056	-6.4
C-017	-3.5	C-037	-29.5	C-057	-17.6
C-018	-7.5	C-038	-23.9	C-058	2.8
C-019	-23.9	C-039	-21.9	C-059	-4.5
C-020	-14.4	C-040	-7.9	-	-

4.1.3 12-Month Period June 2023 to June 2024

The average volumetric change rate measured south of the Horse Gate over the 12-month period between June 2023 to June 2024 was -6.2 cy/ft./yr., resulting in a cumulative negative volumetric change of approximately 364,200 cubic yards. Table 13 lists the individual volumetric rates computed for each profile in the Corolla and Pine Island Sections between June 2023 and June 2024. Figure 17 shows the June 2023 to June 2024 volume change rates graphically.

Corolla Section: The average volumetric change rate in the Corolla Section was -3.5 cy/ft./yr. This equates to a net volume loss of approximately 152,500 cy over the 12-month period from June 2023 to June 2024. This is the first time a negative change has been measured in the Corolla Section over a recent period since the surveying began in 2020. A profile-by-profile comparison shows volumetric change rates in this section ranging from -44.8 cy/ft./yr. at station C-062 to +35.6 cy/ft./yr. at station C-082 (Figure 17).

Similar to the analysis of long-term trends, the Corolla Section was analyzed further for observable trends within discrete portions of the section. Between the northern boundary of the Corolla Section, which is located approximately 250 feet south of the Horse Gate, and the south end of Atlantic Avenue (station C-059 to station C-064), the average volumetric change rate was -23.9 cy/ft./yr. From the south end of Atlantic Avenue to 1,300 feet north of Bonito Street (station C-064 to station C-076), the average volumetric change rate was -8.2 cy/ft./yr. From approximately 1,300 feet north of Bonito Street to just south of Albacore Street (station C-076 to station C-084), the average volumetric change rate was +5.4 cy/ft./yr. Along the southern portion of the Corolla Section, between station C-084 (Albacore Street) and station C-102 (located approximately 500 feet north of Yaupon Lane), the average volumetric change rate was +1.4 cy/ft./yr.

Pine Island Section: The average volumetric change rate in the Pine Island Section over the 12-month period from June 2023 to June 2024 was -11.8 cy/ft./yr. This rate is three times greater than the rate measured along the Corolla Section over the same time period and equates to a net volume loss of approximately 211,800 cy. The negative change rate for this 12-month period is a reversal from the large positive change rate measured between May 2022 and June 2023 (+36.6 cy/ft./yr.). Positive volume changes were only measured at 5 of the 19 profiles along the Pine Island Section between June 2023 and June 2024. A profile-by-profile comparison shows volumetric change rates in this section ranging from -56.2 cy/ft./yr. at station C-116 to +11.8 cy/ft./yr. at station C-117.

Similar to the analysis of long-term trends, the Pine Island Section was analyzed further for observable trends within discrete portions of the section. Between the northern boundary of the Pine Island Section, which is located approximately 500 feet north of Yaupon Lane, and the Hampton Inn (station C-102 to station C-110), the average volumetric change rate was -13.2 cy/ft./yr. Along the southern portion of the Pine Island Section, between station C-110 (Hampton Inn) and station C-120, located approximately at 101 Station 1 Lane, the average volumetric change rate was -10.6 cy/ft./yr.

Table 13. Volumetric Changes Rates (June 2023 to June 2024) (cy/ft./yr.).

Station	June 2023 to June 2024	Station	June 2023 to June 2024	Station	June 2023 to June 2024
C-059	-36.4	C-080	4.1	C-101	-21.3
C-060	1.1	C-081	-11.0	C-102	8.0
C-061	-28.6	C-082	35.6	C-103	-4.9
C-062	-44.8	C-083	8.1	C-104	-26.7
C-063	-19.7	C-084	3.9	C-105	-35.8
C-064	-21.0	C-085	10.1	C-106	-0.5
C-065	-13.6	C-086	-1.1	C-107	4.6
C-066	4.5	C-087	3.6	C-108	-26.6
C-067	-14.2	C-088	3.6	C-109	-4.0
C-068	32.9	C-089	-27.2	C-110	-31.1
C-069	-6.0	C-090	4.0	C-111	-10.3
C-070	-11.5	C-091	18.1	C-112	-17.8
C-071	-18.9	C-092	4.1	C-113	-7.2
C-072	-16.5	C-093	23.0	C-114	-8.5
C-073	-26.1	C-094	-0.7	C-115	5.9
C-074	-13.5	C-095	27.3	C-116	-56.2
C-075	-0.3	C-096	-18.6	C-117	11.8
C-076	-10.3	C-097	1.8	C-118	-8.4
C-077	-16.1	C-098	17.9	C-119	0.9
C-078	5.1	C-099	-15.1	C-120	-1.4
C-079	21.2	C-100	-9.6		

4.2 Volumetric Change (Lens Calculations)

As previously stated, a second volumetric analysis was incorporated into the annual monitoring assessment beginning in 2022 to further resolve volumetric changes occurring in various lenses of the beach from the dune out to depths beyond the established depth of closure (-19 ft. NAVD99). While the volumetric analysis reported in Section 4.1 provides a basis for measuring long-term, 25-month, and 12-month volumetric changes as is typically done out to a specific depth of closure, this additional method provides insight into cross-shore variability in volumetric change. This method splits the profiles into various lenses based on depth contours. For this analysis, the beach was divided into four discreet lenses, which include the Dune, Visible Beach, the Inner Nearshore, and the Outer Nearshore portions of the profile. Figure 18 provides an illustration of the limits of each lens. The elevation contours used as the limits of the lenses were determined by profile inspection and reviewing results of the initial volume change analysis. As part of that profile inspection and initial review of volume changes, cross-shore changes were observed beyond the established -19 ft. NAVD88 contour. However, the offshore limit of these changes appeared to vary along the original Assessment Area, which includes the entire Currituck County oceanfront. North of the Horse Gate, the average depth of closure between May 2020 and May 2022 was determined to be approximately -22 ft. NAVD88; whereas, south of the Horse Gate, the average

depth of closure was determined to be approximately -25 ft. NAVD88. Guidance on the determination of elevation limits for the lenses also comes from the "2017 Beach Condition Monitoring Pine Island, Currituck County, North Carolina" (CSE, 2018).

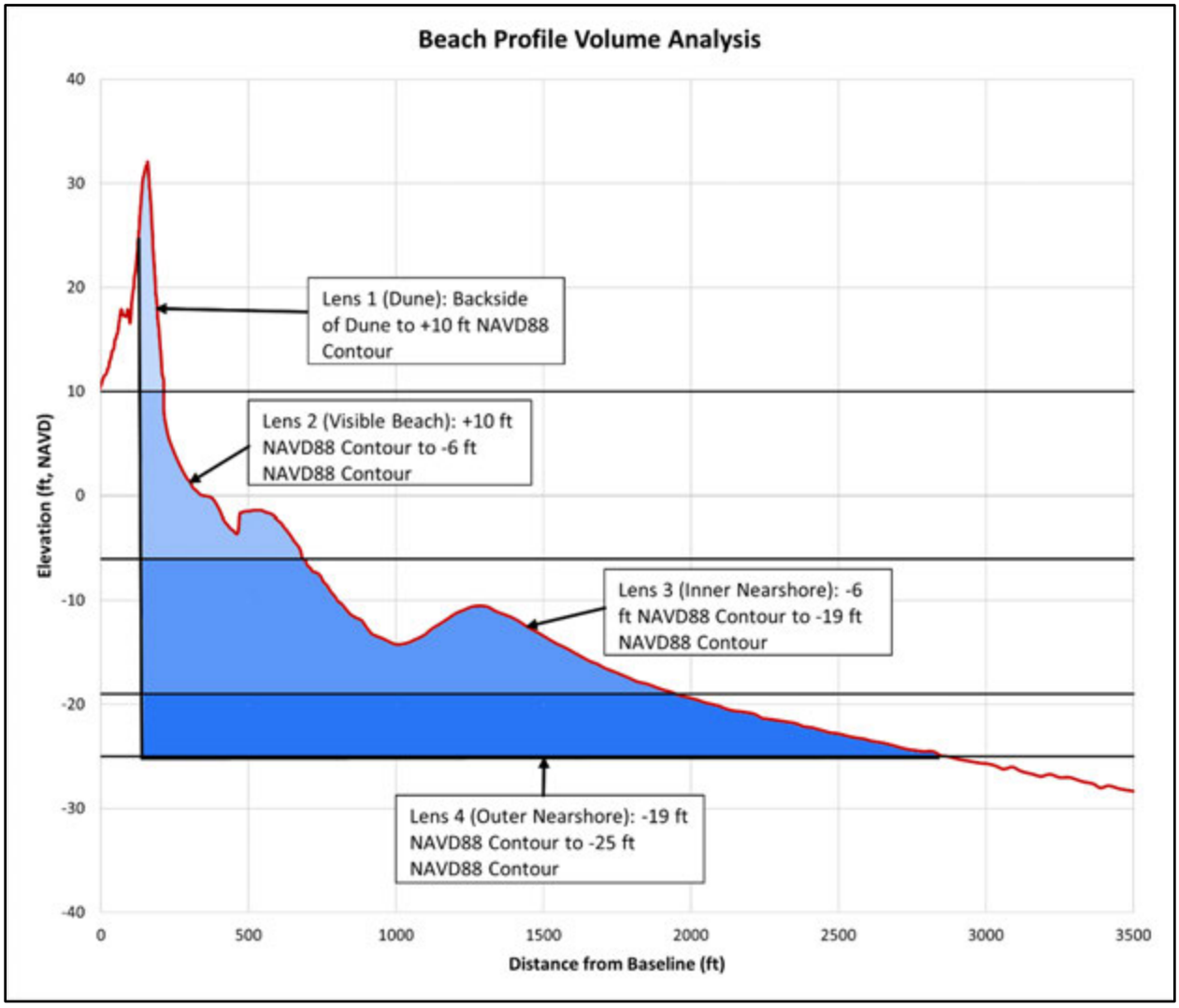

Figure 18. Beach Profile Cross Section Illustrating Lenses

- **Lens 1 (Dune):** Volume from Backside of the dune to +10 ft. NAVD88 — The volume between the backside of the primary frontal dune and the +10 ft. NAVD88 contour is a measure of the sand quantity in the dunes. The +10 ft. NAVD88 contour typically is representative of the toe of the dune though this elevation can change seasonally and spatially. This lens of sand would also be landward of runup experienced during minor storms.
- **Lens 2 (Visible Beach):** Usable Beach (+10 ft. to −6 ft. NAVD88) — This lens includes the dry-sand beach ("berm") and wet-sand beach (sloping wave swash zone) to low-tide wading depth at −6 ft. NAVD88. This is the primary recreational portion of the beach.

- **Lens 3 (Inner Nearshore):** Outer Surf Zone (−6 ft. to −19 ft. NAVD88) — This lens represents the underwater part of the beach extending seaward of the bar to the previously established depth of closure.
- **Lens 4 (Outer Nearshore):** Outer limits of the Active Beach Profile (−19 ft. to −22 ft. NAVD88 north of the Horse Gate and -19 ft. to -25 ft. NAVD88 south of the Horse Gate) — This lens represents the underwater part of the beach profile in and around the various observed depths of closure during this study.

4.2.1 Recent Period May 2020 to June 2024

Lens 1 (Dune): The average volumetric change rate measured between May 2020 and June 2024 in the Dune Lens was +0.6 cy/ft./yr., resulting in a cumulative positive volumetric change of approximately 302,200 cubic yards along the entire Assessment Area, or +74,000 cubic yards per year. Positive volumetric changes in the Dune were calculated in each of the four (4) sections of the Assessment Area. The average volumetric change rate calculated for the Carova Section was +1.3 cy/ft./yr. The average volumetric change rate calculated for the Reserve/Refuge Section was +0.9 cy/ft./yr. The average volumetric change rate in the Corolla Section was +0.0 cy/ft./yr., which is the lowest rate of any section over this period. The average volumetric change rate in the Pine Island Section was +0.5 cy/ft./yr. The rates of volumetric change calculated for the Dune Lens along the entire Assessment Area and each of the four (4) sections are provided in Table 14. The rates of volumetric change for each station are provided in Table 15 and are shown graphically in Figure 19.

A profile-by-profile comparison shows volumetric change rates computed for the Dune Lens range from -5.0 cy/ft./yr. at station C-034 (approximately 600 feet north of 1780 Ocean Pearl Road) to +5.4 cy/ft./yr. at station C-037 (located approximately 200 feet north of Albatross Lane). A graphical representation of the volumetric changes in the Dune and Visible Beach Lenses is provided in Figure 19. In general, volumetric changes were positive along the Assessment Area with only 25% of the profiles having negative changes. As shown in Figure 19, negative volumetric changes were measured in the Dune lens along all of the beach profiles from station C-056 (2,500 feet north of Horse Gate) to station C-067 (located approximately 1,200 feet south of Corolla Village Road). These negative volumetric changes are believed to be driven by volume loss that occurred between June 2021 and May 2022. This volume loss is exhibited as dune scarping which can be seen in Figure 20.

Table 14. Summary of Average Volumetric Change Rates

Sections	May 2020 to June 2024 Volumetric Change Rate (cy/ft./yr.)			
	Lens 1 Dune	Lens 2 Visible Beach	Lens 3 Inner Nearshore	Lens 4 Outer Nearshore
Carova	1.3	0.6	1.2	4.2[1]
Reserve/Refuge	0.9	-1.3	-0.1	3.2[1]
Corolla	0.0	0.1	3.2	7.2[2]
Pine Island	0.5	0.1	2.6	7.1[2]
Total	0.6	-0.2	1.8	5.4[3]
May 2020 to June 2024 Volume Changes (cy/yr.)				
Carova	34,600	16,700	31,300	110,800[1]
Reserve/Refuge	29,600	-41,100	-4,900	101,800[1]
Corolla	600	3,400	139,900	308,300[2]
Pine Island	9,300	2,500	46,300	127,700[2]
Total	74,000	-18,500	212,600	N/A[4]

[1] Calculations made between -19 ft. NAVD88 and -22 ft NAVD88

[2] Calculations made between -19 ft. NAVD88 and -25 ft NAVD88

[3] Average includes calculations made between -19 ft NAVD88 to -22 ft NAVD88 north of the Horse Gate and -19 ft NAVD88 to -25 ft NAVD88 south of the Horse Gate.

[4] No volume listed due to the differences in the offshore limits used north and south of the Horse Gate.

Lens 2 (Visible Beach): The average volumetric change rate measured between May 2020 and June 2024 within the Visible Beach Lens was -0.2 cy/ft./yr., resulting in a cumulative negative volume change of approximately 75,600 cubic yards, or -18,500 cubic yards per year. As shown in Table 14, the average rate of change was positive in the Carova (+0.6 cy/ft./yr), Corolla (+0.1 cy/ft./yr.), and Pine Island (+0.1 cy/ft./yr.) Sections. In contrast, the Reserve/Refuge Section measured a negative volumetric change of -1.3 cy/ft./yr.

While the rates of volume change within the Assessment Area were relatively low, several portions of the Assessment Area saw more significant changes as shown in Figure 19. Between station C-006 (located approximately 500 feet north of Rock Lane) and station C-017 (Eider Road) the average volumetric change rate of the visible beach was +2.6 cy/ft./yr. Between station C-033 (located approximately 1,600 feet north of 1780 Ocean Pearl Road) and station C-042 (located approximately 280 feet north of Hidden Dune Lane) the average volumetric change rate of the visible beach was -4.0 cy/ft./yr. Between station C-075 (located approximately 250 feet south of Perch Street) and station C-084 (located approximately 170 feet south of Albacore Street) the average volumetric change rate of the visible beach was +2.7 cy/ft./yr. Between station C-092 (located approximately 150 feet south of Sea Oats Court) and station C-096 (Sandhill Lane) the average volumetric change rate of the visible beach was -4.7 cy/ft./yr. The rates of volumetric change for each station are provided in Table 15.

Table 15. Lens Volumetric Change Rates (May 2020 to June 2024) (cy/ft./yr.)

Station	Lens 1 Dune	Lens 2 Visible Beach	Lens 3 Inner Nearshore	Lens 4 Outer Nearshore[1]	Station	Lens 1 Dune	Lens 2 Visible Beach	Lens 3 Inner Nearshore	Lens 4 Outer Nearshore[2]
C-001	1.5	3.6	3.5	-9.4	C-061	-2.8	-0.3	3.3	5.0
C-002	-0.5	2.2	-37.4	-2.6	C-062	-1.0	-4.4	1.8	3.1
C-003	-2.4	-7.1	-4.2	9.6	C-063	-0.3	-0.8	3.4	5.2
C-004	-0.3	-7.2	-3.2	5.8	C-064	-2.0	-1.3	-0.2	4.5
C-005	0.9	-4.0	-5.0	5.0	C-065	-0.4	2.0	6.9	6.7
C-006	1.3	1.1	2.8	2.8	C-066	-1.1	1.5	2.9	5.9
C-007	1.6	3.8	3.8	2.8	C-067	-1.1	-3.9	6.7	6.6
C-008	2.1	1.0	2.1	3.4	C-068	0.2	2.3	3.5	4.5
C-009	2.6	1.1	2.2	5.5	C-069	0.2	2.8	6.7	6.2
C-010	2.6	1.2	2.7	5.0	C-070	0.2	1.5	-1.8	4.0
C-011	3.0	3.5	5.0	5.4	C-071	0.2	0.0	2.0	5.9
C-012	2.6	2.6	3.9	5.3	C-072	0.2	-2.7	-0.2	4.4
C-013	2.3	2.1	7.7	5.4	C-073	0.5	0.5	1.9	6.2
C-014	3.6	3.3	6.8	5.8	C-074	-0.7	0.1	-0.3	4.9
C-015	2.4	4.0	10.4	6.6	C-075	0.4	2.7	2.9	5.9
C-016	1.5	4.3	9.2	6.1	C-076	-0.2	3.8	0.8	6.3
C-017	1.7	2.0	7.8	6.3	C-077	0.3	3.3	7.1	9.1
C-018	0.0	-0.1	7.5	4.5	C-078	0.6	6.2	4.2	8.8
C-019	2.2	-2.6	-2.6	5.6	C-079	0.3	5.4	6.8	10.4
C-020	1.6	2.0	0.2	1.3	C-080	0.2	0.6	5.5	8.5
C-021	3.0	-1.9	-0.9	5.2	C-081	0.1	-2.5	7.9	10.8
C-022	0.4	-0.3	-1.0	3.4	C-082	-0.6	2.8	6.6	9.3
C-023	1.9	-0.5	3.0	4.3	C-083	0.8	2.2	8.3	11.0
C-024	-2.5	2.6	6.9	4.7	C-084	0.4	1.0	5.8	9.6
C-025	0.3	0.4	5.0	4.4	C-085	-0.6	-0.9	6.0	9.9
C-026	0.4	0.3	0.7	3.7	C-086	0.0	-0.5	2.6	8.3
C-027	2.0	0.8	1.4	3.7	C-087	0.3	0.6	0.6	6.8
C-028	3.7	-0.7	2.1	3.6	C-088	0.8	2.6	2.3	9.2
C-029	2.5	5.2	2.4	3.9	C-089	0.5	-0.9	-1.3	7.4
C-030	1.8	5.5	1.4	3.4	C-090	0.9	0.0	4.1	7.9
C-031	5.0	2.7	0.3	4.1	C-091	2.0	3.8	1.0	6.6
C-032	2.6	-0.6	-1.2	4.4	C-092	0.2	-6.9	3.5	6.9
C-033	1.4	-1.8	-1.7	4.3	C-093	-0.4	-4.2	3.0	6.5
C-034	-5.0	-4.6	-1.9	3.7	C-094	-1.0	-5.5	3.4	7.6
C-035	0.7	-3.1	-4.1	3.9	C-095	-0.1	-2.3	2.8	6.5
C-036	5.1	-2.8	-4.3	4.1	C-096	0.8	-6.3	1.8	7.0
C-037	5.4	-6.2	-9.7	3.3	C-097	0.6	-0.9	0.4	6.5
C-038	2.7	-5.2	-9.5	1.5	C-098	2.6	-0.4	4.4	8.8
C-039	4.7	-1.6	-5.0	3.3	C-099	0.6	-1.0	-0.5	7.2
C-040	-0.2	-5.9	8.3	2.3	C-100	0.1	1.0	2.4	9.2
C-041	0.1	-2.0	8.3	6.7	C-101	0.1	0.1	4.8	9.8
C-042	-0.5	-7.8	-10.7	6.8	C-102	0.3	3.8	3.6	10.4
C-043	-0.7	0.2	-3.9	1.7	C-103	-0.3	2.1	-0.8	6.6
C-044	0.9	-0.8	-3.4	0.5	C-104	0.4	-2.3	-2.4	7.1
C-045	1.0	-4.3	-6.6	-1.2	C-105	0.4	-1.5	-1.4	5.8
C-046	-1.3	-7.7	-7.4	2.2	C-106	0.7	0.8	0.9	6.4
C-047	1.0	-1.6	4.6	2.2	C-107	1.7	0.1	-1.1	3.9
C-048	-1.6	1.3	5.2	2.5	C-108	0.7	-1.8	3.5	7.8
C-049	2.5	0.5	4.0	2.8	C-109	1.0	2.8	1.3	7.9
C-050	1.5	8.2	4.9	3.0	C-110	0.7	-1.0	4.3	9.2
C-051	1.7	-0.7	7.9	2.6	C-111	1.1	1.1	4.5	7.4
C-052	-2.7	-3.0	2.5	2.7	C-112	-0.1	0.9	5.1	9.2
C-053	3.0	0.3	0.4	3.0	C-113	0.2	-0.7	4.5	6.2
C-054	-0.9	-1.6	3.6	3.9	C-114	0.1	0.5	8.7	8.2
C-055	1.4	-2.5	0.3	4.0	C-115	-0.2	0.4	0.5	6.3
C-056	-2.2	0.0	0.5	2.3	C-116	-0.3	-8.9	3.7	9.1
C-057	-3.1	-5.5	1.6	3.9	C-117	0.6	-0.9	4.3	4.1
C-058	-1.0	5.2	5.8	3.7	C-118	1.3	2.8	1.0	8.3
C-059	-2.1	-1.2	3.3	3.1	C-119	1.1	5.6	6.8	5.0
C-060	-0.2	0.7	2.3	5.2[2]	C-120	0.0	1.0	2.1	7.9

(1) Calculations made between -19 ft. NAVD88 and -22 ft NAVD88

(2) Calculations made between -19 ft. NAVD88 and -25 ft NAVD88

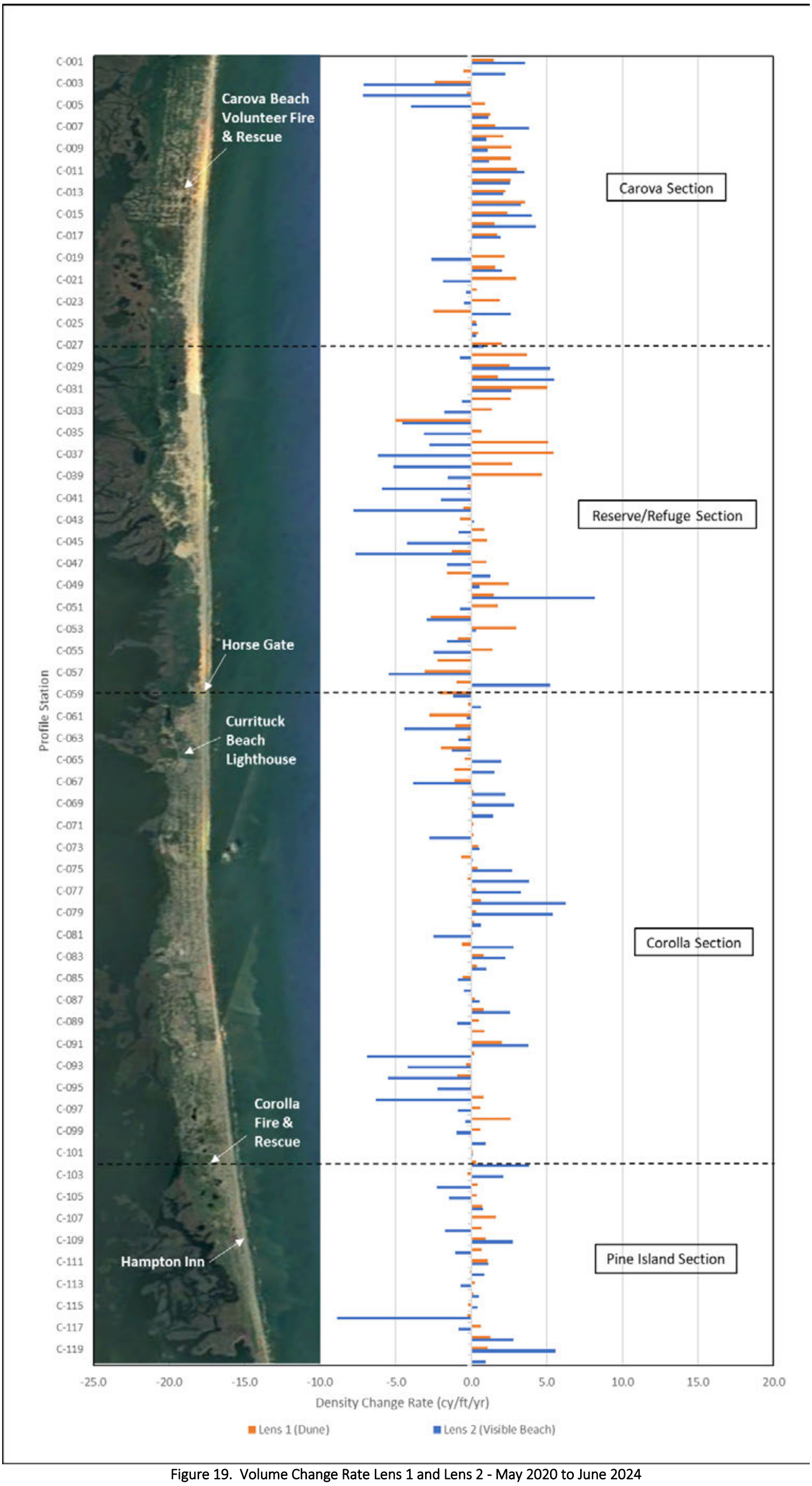

Figure 19. Volume Change Rate Lens 1 and Lens 2 - May 2020 to June 2024

Figure 20. View of Dune Scarping approximately 500 feet north of Sta. C-060. (Photo date 5/15/22).

Lens 3 (Inner Nearshore): The average volumetric change rate measured between May 2020 and June 2024 within the Inner Nearshore Lens was +1.8 cy/ft./yr., resulting in a cumulative positive volumetric change of approximately 868,000 cubic yards, or +212,600 cubic yards per year. As shown in Table 14, the volumetric change rates in Lens 3 (Inner Nearshore) were positive in all sections of the project, except for the Reserve/Refuge Section which was slightly negative (-0.1 cy/ft./yr.). The average volumetric change rate in the Inner Nearshore Lens along the Carova Section was +1.2 cy/ft./yr. The average volumetric change rates along the Corolla and Pine Island Sections were +3.2 cy/ft./yr. and +2.6 cy/ft./yr., respectively. The volumetric change rate calculated for the Inner Nearshore Lens along the entire Assessment Area and each of the four (4) sections are provided in Table 14. The rates of volumetric change for each station are provided in Table 15 and are shown graphically in Figure 21.

While the positive volumetric trend within the Inner Nearshore Lens was relatively consistent throughout the Assessment Area, several portions of the Assessment Area saw variations in these trends as shown in Figure 21. A large negative outlier of -37.4 cy/ft./yr. was measured at station C-002. Between station C-011 (located between Sunfish and Bonita Lane) and station C-018 (Crane Road) the average volumetric change rate of the Inner Nearshore Lens was +7.5 cy/ft./yr. Between station C-035 (located approximately 400 feet south of 1780 Ocean Pearl Road) and station C-046 (located approximately 300 feet north of Munson Lane) the average volumetric change rate was a loss of -4.0 cy/ft./yr. In contrast, between station C-047 (located approximately

700 feet south of Munson Lane) and station C-051 (located approximately 1,800 feet south of Malbon Drive) the average volumetric change rate was +5.1 cy/ft./yr. Similarly, between station C-065 (located 100 feet north of Carotank Drive) and station C-069 (located approximately 550 feet north of Tuna Street) the average volumetric change rate was +5.0 cy/ft./yr. Between station C-077 (located 420 feet north of Bonito Street) and station C-085 (located on the south end of Voyager Road) the average volumetric change rate was +6.4 cy/ft./yr. Between station C-110 (located at the Hampton Inn & Suites) and station C-119 (located near the south end of Cottage Cove Rd) the average volumetric change rate of the Inner Nearshore Lens was +4.2 cy/ft./yr.

Lens 4 (Outer Nearshore): The average volumetric change rate measured between May 2020 and June 2024 within the Outer Nearshore Lens was +5.4 cy/ft./yr. Note that the offshore limit of the Outer Nearshore lens is -22 ft. NAVD88 north of the Horse Gate and -25 ft. NAVD88 south of the Horse Gate. Positive volumetric changes in the Outer Nearshore Lens were calculated in all four (4) sections. The average volumetric change rates measured along the Carova and Reserve/Refuge Sections (between -19 ft. NAVD88 and -22 ft. NAVD88) were +4.2 cy/ft./yr. and +3.2 cy/ft./yr., respectively. The average volumetric change rates measured along the Corolla and Pine Island Sections (between -19 ft. NAVD88 and -25 ft. NAVD88) were +7.2 cy/ft./yr. and +7.1 cy/ft./yr., respectively. Figure 21 illustrates that a positive volumetric change rate was measured within Lens 4 (Outer Nearshore) along almost every profile in the Assessment Area between May 2020 and June 2024. The rates are generally consistent throughout. The only negative rates measured were at stations C-001, C-002, and C-045. The average rate between stations C-077 (located 420 feet north of Bonito Street) and C-088 (located at Wave Arch) was +9.3 cy/ft./yr., which is 39% higher than the overall average along the Assessment Area.

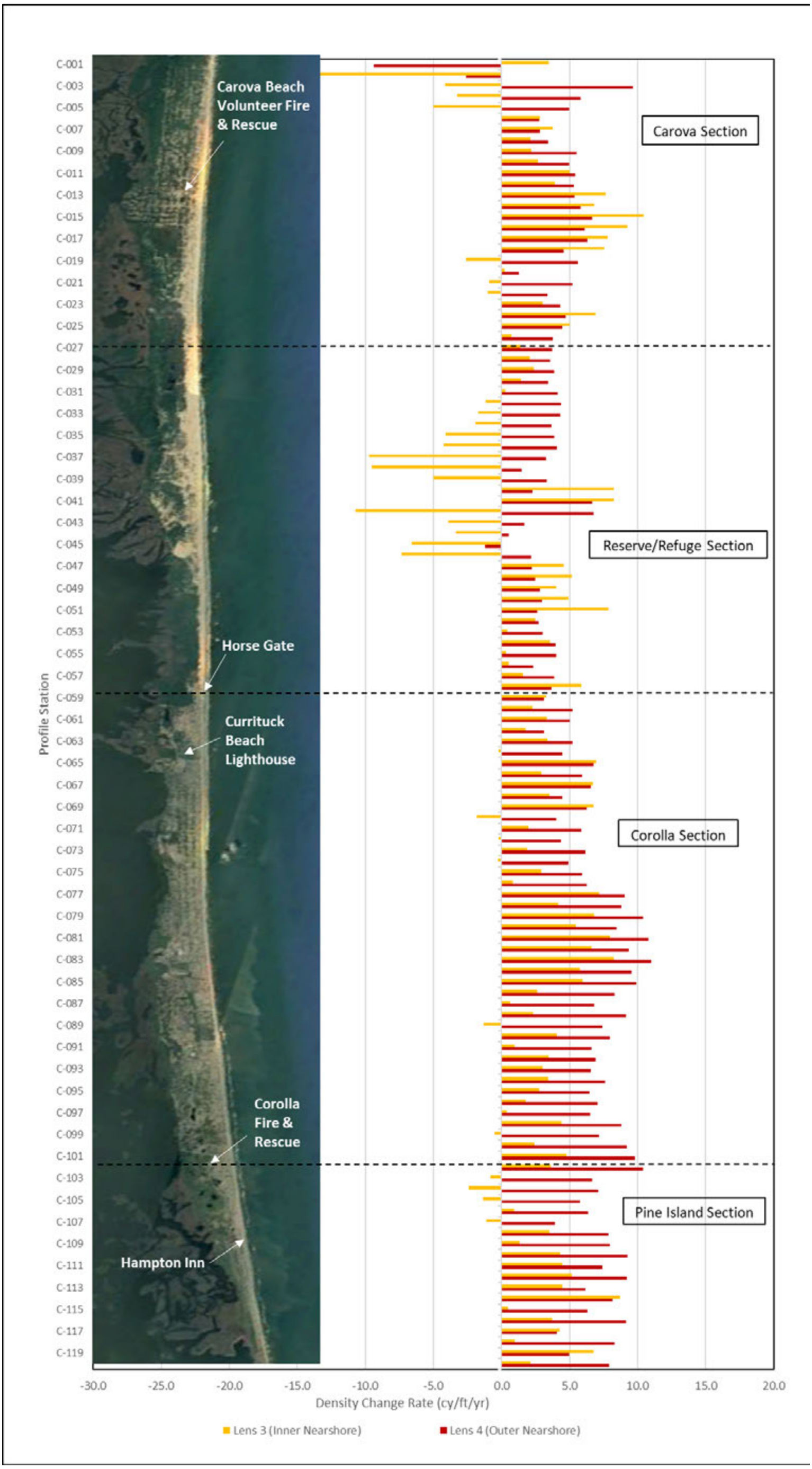

Figure 21. Volume Change Rate Lens 3 and Lens 4 - May 2020 to June 2024

4.3 Pine Island Section Volumetric Change Rates

As previously stated, two beach profile surveys were conducted along the Pine Island Section of the Assessment Area in September 2015 and October 2017 (CSE, 2018). That analysis employed a similar method as was described in Section 4.2 in which volumetric changes were examined within discreet lenses. The analysis showed that although volumetric losses were measured from the dune crest to the -6 ft. NAVD88 contour, the overall volumetric change was positive due to additional gains in the offshore portion of the profile (-6 ft. NAVD88 to -19 ft. NAVD88).

Given the availability of these additional data sets, volumetric change rates were computed between September 2015 (CSE) and June 2024 (CPE) to provide additional long-term volumetric change trends along the Pine Island Section. The average volumetric change rate between September 2015 and June 2024 along the Pine Island Section was relatively stable at -0.8 cy/ft./yr., resulting in a cumulative negative volumetric change of approximately 127,600 cubic yards, or -14,600 cubic yards per year. Table 16 lists the individual volumetric change rates computed for each profile out to the -19 ft. NAVD88 contour between September 2015 and June 2024. Figure 22 shows a graphical comparison of the 2015 to 2024 rates. Negative volumetric changes were measured along twelve (12) of the nineteen (19) profiles along the Pine Island Section.

Table 16. Pine Island Long-term Volume Change Rates 2015 to 2024

Stations	September 2015 to June 2024 (cy/ft./yr.)
C-102	-3.6
C-103	-2.8
C-104	-4.8
C-105	-2.8
C-106	-5.0
C-107	0.8
C-108	-0.6
C-109	1.3
C-110	-0.3
C-111	0.9
C-112	-0.3
C-113	0.8
C-114	0.6
C-115	-1.2
C-116	-5.0
C-117	0.0
C-118	1.5
C-119	5.1
C-120	-2.2
Average	**-0.8**
Max	**5.1**
Min	**-5.0**

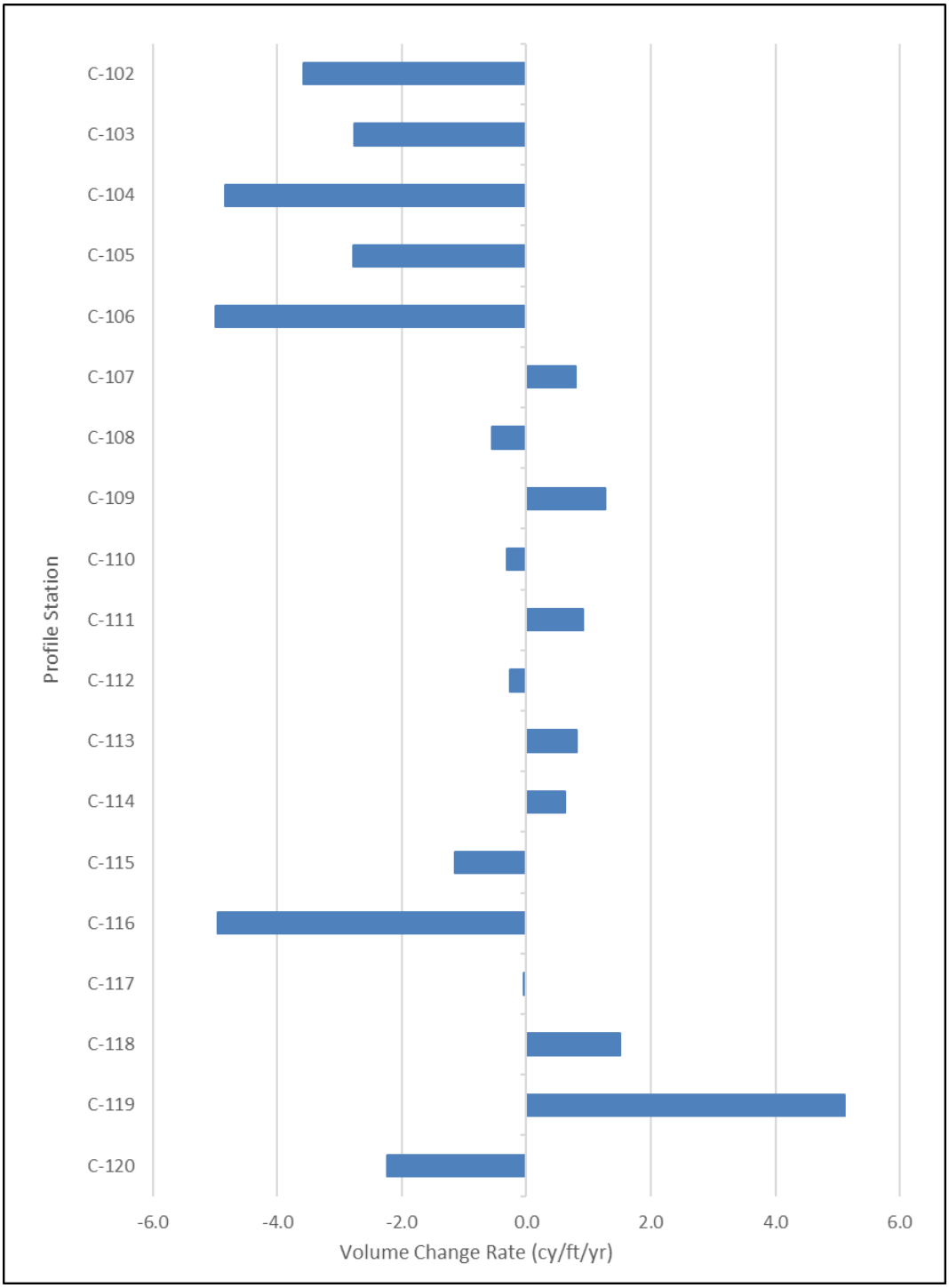

Figure 22. Pine Island (C-102 to C-120) Volume Change Rates Above -19.0 ft. NAVD88 – Sept. 2015 to June 2024

5 CONCLUSIONS

This 2024 Beach Monitoring and Beach Stability Assessment evaluated long-term and short-term shoreline and volumetric changes occurring along the County's beaches. The County initiated an annual monitoring program in 2020 with the initial goals of better understanding the changes occurring to the beaches and to assist the County in making informed decisions regarding beach management. The continued annual monitoring of the oceanfront beaches allows managers to track long-term and short-term trend and provides specific quantified data to facilitate informed management decisions. The conclusions provided in this section were drawn from the results of the various analyses described in this report.

5.1 Shoreline Change and Projected Shorelines

Shoreline change rates measured between 2009 and 2024 were computed using a linear regression method that considers various shoreline position data available between 2009 and 2024. The average shoreline change rates measured along the Carova Section (Northern County boundary to Currituck Wildlife Refuge) and the Pine Island Section (500 feet north of Yaupon Lane to Southern County boundary) were -0.9 ft./yr. and -0.6 ft./yr., respectively. The average shoreline change rates measured along the Reserve/Refuge Section (Northern boundary of Currituck Wildlife Refuge to 250 feet south of the Horse Gate) was -3.6 ft./yr. The average shoreline change rate measured in the Corolla Section (250 feet south of the Horse Gate to 500 feet north of Yaupon Lane) was -4.4 ft./yr.

Shoreline change rates measured along the Assessment Area between 2009 and 2024 were used to project future shoreline positions throughout the Assessment Area over a 10-, 20-, and 30-year time horizon. These projected shorelines are shown in the maps in Appendix B. The projected shorelines were then compared to the footprint of oceanfront houses and roads to evaluate potential impacts over the various time horizons.

In total, 59 houses were shown to be impacted over the 30-year horizon throughout the Assessment Area. All of these houses were located north of Marlin Beach Access (C-081) with 86% of them being in the Corolla Section and located north of Mackeral Street (C-076). Of the 59 houses shown to be impacted over the 30-year horizon, 11 of the houses were shown to be impacted over the 20-year horizon and 0 were shown to be impacted over the 10-year horizon.

The oceanfront houses indicated as impacted along the Assessment Area are concentrated along several general areas. The northernmost area spans from station C-041 to station C-044 in the Reserve/Refuge Section; three houses in this area were shown to be impacted over the 30-year horizon. All three of these houses were seaward of the dunes and Sandfiddler Road.

The most concentrated section of impacted oceanfront houses is within the Ocean Hills Community along Atlantic Avenue (Station C-061 to Station C-064) in the Corolla Section. Along this approximately 0.6-mile stretch of beach, nearly every oceanfront house was shown to be

impacted over the 30-year horizon. Approximately 30% of the oceanfront houses along this section were shown to be impacted over the 20-year horizon. The historical shoreline change rate in this area is -6.6 ft./yr. which is approximately 50% greater than the average for the Corolla Section during this timeframe.

Moving south, two concentrations of houses within the Whalehead Beach community (station C-068 to station C-084) within the Corolla Section were shown to be impacted over the 30-year horizon. The long-term change rate along with the entire Whalehead Beach Community is -4.8 ft./yr. The northernmost concentration of houses was located along a 0.9 mile stretch of beach fronting Lighthouse Drive (Station C-071 to Station C-076). Along this section between Sturgeon Beach Access and Mackerel Street, approximately 50% of the oceanfront houses were shown to be impacted over the 30-year horizon. None of these houses were shown to be impacted over the 20-year horizon. The historical shoreline change rate in this area is -5.7 ft/yr. which is approximately 30% greater than the average for the Corolla Section during this timeframe. The southern concentration of houses shown to be impacted within the Whalehead Beach community is located along Lighthouse Drive between Sailfish Street and Marlin St. Beach Access (station C-080 and C-081). Along this 0.2-mile section, 5 oceanfront houses were shown to be impacted over the 30-year horizon. The historical shoreline change rate in this area is -6.8 ft/yr. which is approximately 55% greater than the average for the Corolla Section during this timeframe.

The number of impacted structures identified in this year's analysis is significantly less than the total identified in the 2023 Assessment (CPE, 2023b). For example, in 2023, the number of structures indicated as impacted within the Whalehead Beach community was 75; whereas the 2024 analysis only indicated 30 oceanfront houses impacted over the 30-year horizon. The considerable decrease in the number identified in this most recent assessment was the result of both a modest decrease in the overall shoreline change rates throughout the monitoring area, and the relatively high positive shoreline change measured between June 2023 and June 2024. In essence, the starting point of where shorelines are projected moved seaward on average and the rates used to project shoreline change decreased, resulting in the considerable decrease in the total number of impacted structures identified.

While the shoreline projections provide useful information to evaluate trends and determine future potential impacts, oceanographic conditions that influence shoreline change are not constant (water levels, storm frequency, dominant wind direction). Temporary changes to the slope of the beach as a result of sea conditions that impact the area immediately prior to surveys, can have considerable impacts on shoreline position, resulting in significant variability when evaluating shoreline changes. In that regard, a thorough evaluation of volumetric changes is vital to fully assessing the beach.

5.2 Volume Change

An overall positive volumetric change was measured along the County oceanfront between May 2020 and June 2024. However, between May 2022 and June 2024, a negative volumetric trend has been observed along the County's oceanfront. Figure 23 shows the cumulative change in

volume along the entirety of Currituck County (purple line) between May 2020 and June 2024. Figure 23 also shows the cumulative change in volume along the portion of the County oceanfront North (green line) and South of the Horse Gate (blue line). While the long-term average volume change rate between May 2020 and June 2024 was +2.2 cy/ft./yr., or 268,100 cubic yards per year, the trend over the most recent two years (May 2022 to June 2024) was -0.9 cy/ft./yr or -106,100 cubic yards per year. Over the 12-month period between June 2023 and June 2024, the volumetric change rates in the Corolla and Pine Island Sections were -3.5 cy/ft./yr. (-152,500 cubic yards per year) and -11.8 cy/ft./yr (-211,800 cubic yards per year), respectively. In contrast, the long-term change rates measured along those two sections, between May 2020 and June 2024, were +3.3 cy/ft./yr (144,000 cubic yards per year) and +3.2 cy/ft./yr. (58,000 cubic yards per year), respectively.

North of the Horse Gate, between May 2022 and June 2024, the volumetric change rates in the Carova and Reserve/Refuge Sections were -5.3 cy/ft./yr. (-138,100 cubic yards per year) and -9.3 cy/ft./yr. (-297,800 cubic yards per year), respectively. In contrast, the long-term rates measured along these two sections between May 2020 and June 2024 were +3.1 cy/ft./yr. (82,500 cubic yards per year) and -0.5 cy/ft./yr. (-16,400 cubic yards per year), respectively. These trends are illustrated in Figure 23.

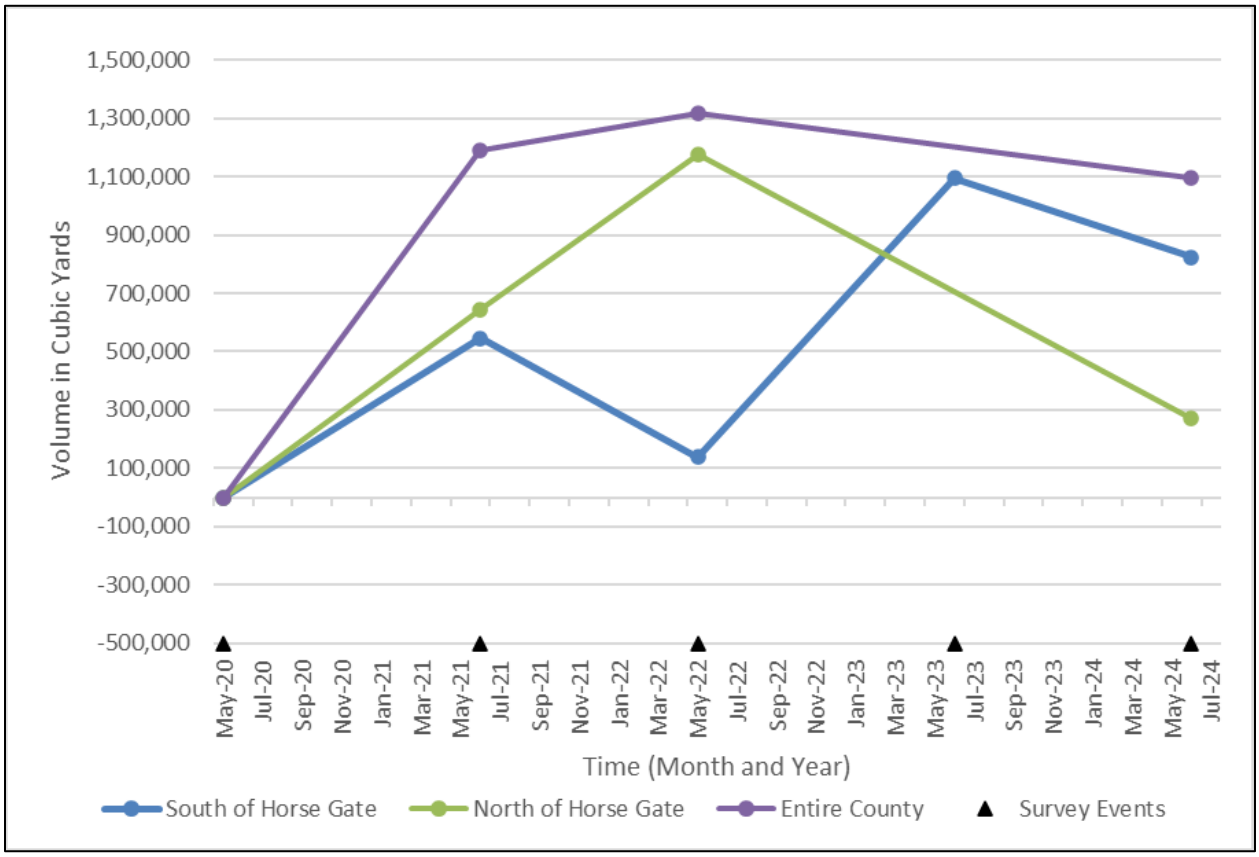

Figure 23. Graph showing Cumulative Volume Change along Currituck County since May 2020

Over the past several monitoring reports, hypotheses have been provided on the reasons for the volumetric gains measured over the entire Assessment Area since the initial baseline survey conducted in May 2020 (CPE, 2023a and CPE, 2023b). The primary hypothesis discussed in the previous reports suggested that the multi-year positive volumetric trend observed may be the result of landward sediment cross shore transport (sand moving from deeper water to shallower water). This effect has been documented and sometimes referred to as recovery following a previous period of storm induced seaward cross shore sediment transport (sand moving from shallower water to deeper depths). A review of wind and wave data over the past several years supported this hypothesis as well as the lens assessment that showed considerable gains in the inner nearshore lens and even the outer nearshore lens, which is beyond the depth of closure. These previous reports also theorized that if this explanation held true, then negative volume change trends could follow this temporary period of recovery. The negative volumetric trend observed between May 2022 and June 2024, as shown in Figure 23 may be an indication that the Currituck County beaches are reverting back to a negative volumetric trend.

A general review of wave data reflective of conditions offshore Currituck County was conducted to evaluate qualitative differences in the offshore wave climate prior to the study period (Jan. 2017 to Jan. 2020), during the period where the most significant gains in volume were measured (May 2020 to May 2022, and the 25-month period from May 2022 to June 2024. Figure 24 shows the measured significant wave heights from a waverider buoy located in approximately 26 m of water offshore of the Duck Field Research Facility pier.

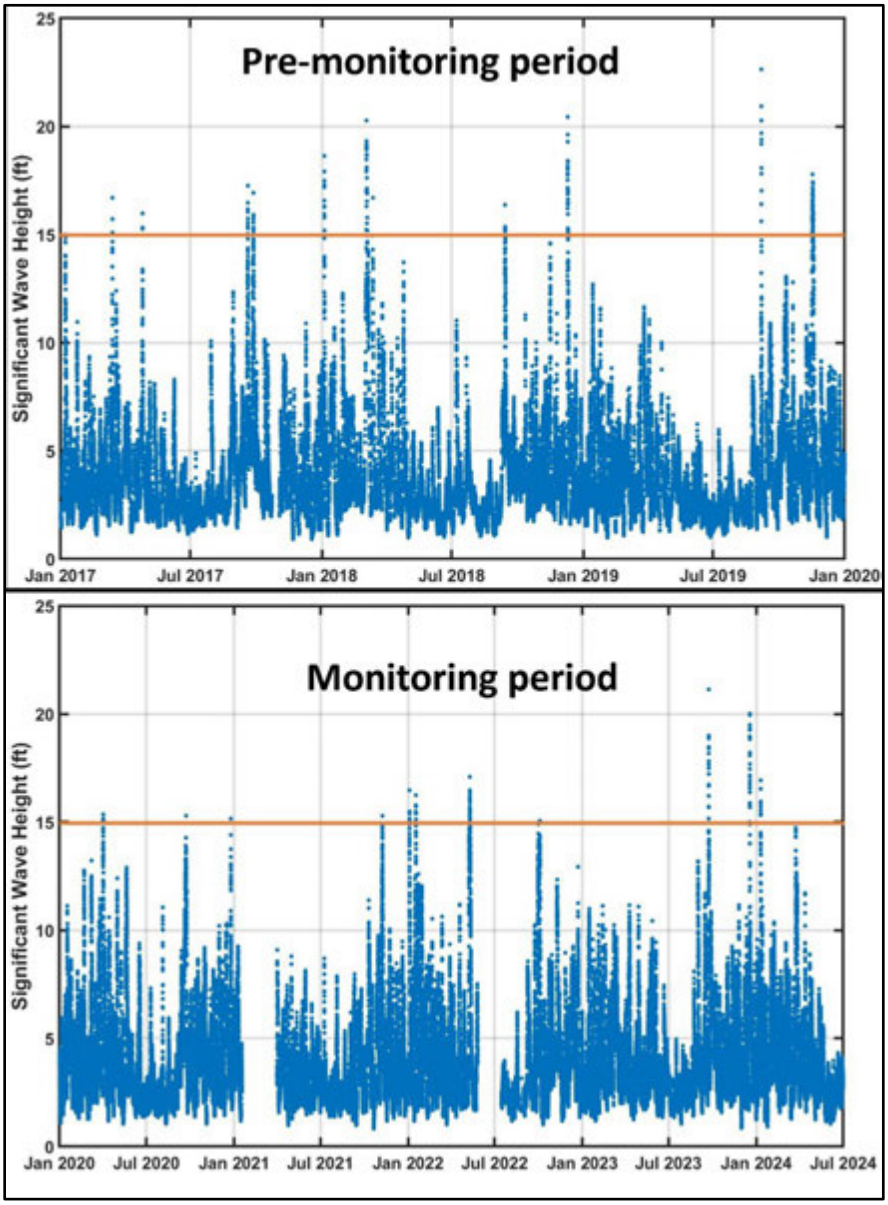

Figure 24. Significant Wave Height data for waverider buoy located in 26 m of water offshore Duck, NC (Station 44100) prior to and during the monitoring period.

The upper panel shows the wave data for the three-year period prior to the commencement of the Currituck County Beach Monitoring and Beach Stability Assessment (January 2017 to January 2020). The lower panel shows the wave data for the 4.5-year period from January 2020 to July 2024, which includes the monitoring conducted as part of this Assessment. These wave data indicate that the pre-monitoring period (January 2017 to January 2020) was more active in terms of wave events that produced significant wave heights greater than 15 feet. Specifically, there were three storm events during this three-year period where significant wave heights exceeded 20 ft. The first was a nor'easter in March 2018. This event was an extratropical cold front that brought strong winds, heavy snow, and tremendous coastal flooding to communities from the Mid-Atlantic to northern Maine. The second event with significant wave heights in excess of 20

ft. occurred in December 2018. The third event with significant wave heights in excess of 20 ft. was Hurricane Dorian, which occurred in September 2019. This storm caused significant impacts to the beach fill projects at Duck, Kill Devil Hills, Nags Head, and Buxton. Approximately two (2) months following the impacts of Hurricane Dorian, a major Nor'easter impacted the Outer Banks in mid-November of 2019 that produced significant wave heights at the same buoy of nearly 18 ft. A significant storm surge was also experienced during the November 2019 event.

An examination of the wave data shown in the lower panel of Figure 24, indicates that between January 2020 and July 2023, there were no wave events in which significant wave heights exceeded 20 ft. and less wave events in which significant wave heights exceeded 15 ft. Effectively, during this period the Currituck County oceanfront generally experienced an overall wave climate that was calmer than the preceding three years (January 2017 to January 2020). This corelates with the period in which positive volumetric change was observed. However, between July 2023 and June 2024, two wave events occurred in which significant wave heights exceeded 20 ft. The first event was Hurricane Ophelia which affected the Assessment Area from September 22nd – 24th, 2023. The second event was a nor'easter that impacted the Assessment Area between December 17th – 20th, 2023. This storm caused ocean overwashing along portion of highway NC-12 near Hatteras, NC. The period in which we saw these larger storms generally correlates with the period in which a negative volumetric change was observed.

The following conclusions were drawn from the results of both the shoreline projection analysis and volumetric change analysis:

- The northern 5,000 feet of the Carova Section (north of station C-005) has experienced higher rates of erosion between May 2022 and June 2024 when compared to the overall average rate of the Carova Section from May 2020 to June 2024. While the 2024 shoreline projections did not indicate any impacted structures along this portion of the beach, previous reports (CPE, 2020 & CPE, 2021) have indicated potential impacts to structures in this area. It should be noted that the higher volume change average along this section is heavily influenced by the losses measured at Station C-002 (-54.8 cy/ft./yr).
- The structures indicated as impacted over the various time horizons that fall within the Reserve/Refuge Section, are located between approximately 1,200 feet north of Hidden Dunes Lane and approximately 300 feet north of Munson Lane (station C-041 and station C-046). While this area experienced modest volumetric gains (+6.4 cy/ft./yr.) between May 2020 and May 2022, large losses (>-20 cy/ft./yr.) were measured between May 2022 and June 2024. Due to the large losses over the 25-month period, the net volumetric change over the long-term monitoring period from May 2020 to June 2024 was an average loss rate of -8.5 cy/ft./yr.
- The northern portion of the Corolla Section, between the Horse Gate and Corolla Village Road (station C-059 to station C-065) within the Ocean Hill community is one that has continuously been called out as one of the most vulnerable areas of the County's oceanfront. Both the shoreline projections and previous SBEACH storm vulnerability

analyses have indicated structures along this stretch of the County oceanfront are vulnerable both to long-term shoreline change and storms. While volumetric changes measured between May 2020 and June 2024 indicate this area has remained relatively stable, a closer look at the data reveals a similar pattern of gains followed by losses as previously discussed. Between May 2020 and May 2022, this area experienced an average volumetric change rate of +5.1 cy/ft./yr. In contrast, between May 2022 and June 2024 volumetric losses were experienced at an average rate of -4.1 cy/ft./yr., with the majority of the losses occurring between June 2023 and June 2024 where an average loss of >-20 cy/ft./yr. was measured.

- Another area of concern is within the Whalehead Beach community along Lighthouse Drive (station C-070 to station C-077). The shoreline projection analysis has consistently identified this area as being more vulnerable. Similar to the Ocean Hill community, modest gains (2.4 cy/ft./yr.) have been measured here since May 2020 above the depth of closure, but modest losses (-3.5 cy/ft./yr.) were measured in this area between May 2022 and June 2024 with the majority of these losses occurring between June 2023 and June 2024.
- The Spindrift community (station C-101 to station C-103) is another area of concern, where shoreline projection analyses have identified this area to be vulnerable. While the most recent analysis performed with the updated 2024 conditions and rates did not indicate impacts along this community, previous analyses have shown impacts to the nine (9) oceanfront homes located along Land Fall Ct. The trends in this area are the opposite of the trend generally observed throughout the study area. The volume change analysis indicated modest losses between May 2020 and May 2022, followed by considerable volumetric gains at a rate of +10.8 cy/ft./yr.) between May 2022 and June 2024. The area experienced modest losses of -2.6 cy/ft./yr. on average, over the recent 12-month period. It should also be noted that approximately 7,000 cy of sand was placed to construct a dune in front of the Spindrift Community via a truck haul project in March 2023. The gains observed between May 2022 and June 2024 may be attributed to this project.

6 RECOMMENDATIONS

Based on the various beach assessments described in this report and conclusions drawn from those assessments, CPE provides the following recommendations for the County's consideration as they seek to make informed decisions regarding beach management:

1. <u>Continue Monitoring of the Beach Profiles:</u> The initial 3-year Beach Monitoring and Beach Stability Assessment (2020 through 2022) established a baseline of shoreline change and volumetric change rates. Given the results of the shoreline and volume change analyses, the distribution of potential impacts from the shoreline projections over 10 to 30 years and the distribution of houses identified through the vulnerability analysis, the County continued the monitoring plan through 2025. Beginning in 2023, the County, in alignment with the original recommendation (CPE, 2023a), authorized annual surveys of the Corolla

and Pine Island Sections, with bi-annual surveys (every other year) for the Carova and Reserve/Refuge Sections for 3 additional years.

The recommendation to only survey the Carova and Reserve/Refuge Sections (north of the Horse Gate) in the odd years, was based on the fact that only a small number of houses located north of the Horse Gate were indicated as vulnerable, and the amount of undeveloped beach north of the Horse Gate. The County contracted with CPE in early 2023 to continue monitoring as recommended through 2025. In 2023, beach monitoring surveys were conducted south of the Horse Gate in the Corolla and Pine Island Sections only; whereas in 2024, the entire County oceanfront was surveyed (both north and south of the Horse Gate).

The current contract between CPE and the County includes a 2025 monitoring survey of the areas south of the Horse Gate (Corolla and Pine Island Sections). The County should consider if additional areas north of the Horse Gate should be included in the 2025 survey. Given the County's recent discussions on the several houses indicated as vulnerable in the portion of the beach between Canary Lane and Munson Lane (stations C-039 to C-048), and the potential impacts to ingress/egress along the offroad sections of the County beaches due to these vulnerable structures, collection of additional data in 2025 along this stretch of beach may be warranted.

Regardless of which profiles the County decides to survey in 2025, the same profiles established at the beginning of the County-wide assessment in 2020 should be collected at a similar time of year to reduce the impacts of seasonal changes on conditions of the profile, particularly the portion of the profile above Mean High Water (MHW).

2. <u>Coordinate with Dare County on Regional Sand Resource Investigation:</u> In 2023 Dare County commissioned a two-year regional sand investigation study to locate sand for future beach nourishment projects. The reconnaissance phase of this investigation was conducted in the summer of 2023 and design level surveys were conducted in 2024. The geographic extent of the Study Area includes portions of southern Currituck County including portions offshore of the Corolla and Pine Island Sections as defined in this report. State and federal rules do not limit offshore sand resources to be used only by the adjacent local community. These resources are typically considered state and or federal resources for which permits can be applied for by neighboring municipalities to use these sediments for beach nourishment projects. If Currituck County anticipates the future development of a Beach Management Plan that may include offshore dredging for beach nourishment, CPE recommends that County staff coordinate with Dare County on this regional sand resource investigation and begin to develop a framework on how to prioritize sand resources over the long-term.

7 REFERENCES

Coastal Science & Engineering (CSE), 2018. 2017 Beach Condition Monitoring Pine Island, Currituck County, North Carolina. Prepared by Coastal Science & Engineering, March 2018, 86 pgs.

CPE, 2020. Coastal Protection Engineering of North Carolina, Inc., Currituck County North Carolina, 2020 Beach Monitoring and Beach Stability Assessment. Prepared for Currituck County. Wilmington, NC. November 2020, 56 pgs.

CPE, 2021. Coastal Protection Engineering of North Carolina, Inc., Currituck County North Carolina, 2021 Beach Monitoring and Beach Stability Assessment. Prepared for Currituck County. Wilmington, NC. December 2021, 50 pgs.

CPE, 2023a. Coastal Protection Engineering of North Carolina, Inc., Currituck County North Carolina, 2022 Beach Monitoring and Beach Stability Assessment. Prepared for Currituck County. Wilmington, NC. January 2023, 82 pgs.

CPE, 2023b. Coastal Protection Engineering of North Carolina, Inc., Currituck County North Carolina, 2023 Beach Monitoring and Beach Stability Assessment. Prepared for Currituck County. Wilmington, NC. November 2023, 58 pgs.

Kraus, N.C., Larson, M., and Wise, R.A., 1998. Depth of Closure in Beach-Fill Design. Technical Note. U.S. Army Corps of Engineers, Vicksburg, MS.

Moran, K.; Mallinson, D.; Culver, S.; Leorri, E.; and Mulligan, R., 2015. Late Holocene Evolution of Currituck Sound, North Carolina, USA: Environmental Change Driven by Sea-Level Rise, Storms, and Barrier Island Morphology. Journal of Coastal Research, 31 – 4, pgs. 827 – 841.

National Oceanic and Atmospheric Administration, 2012. What is Lidar?. Prepared by National Ocean Service, October 2012: https://oceanservice.noaa.gov/facts/lidar.html

North Carolina Division of Coastal Management, 2019. North Carolina 2019 Oceanfront Setback Factors & Long-Term Average Annual Erosion Rate Update Study Methods Report. Prepared by North Carolina Division of Coastal Management, January 2019, 190 pgs.