Orleans Outer Beach Management Plan
Orleans, MA

Prepared For:
Town of Orleans
19 School Road
Orleans, MA 02653

Prepared By:
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81 Technology Park Drive
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January 2016

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EXECUTIVE SUMMARY

An evaluation of Nauset Beach was conducted on behalf of the Town of Orleans to help inform future management of the public beach and natural resources. Ongoing erosion, exacerbated by climate change and sea level rise is threatening the Town of Orleans beach facilities including parking, beach access, and support buildings. Natural resources are also being lost, including coastal beaches, dunes and wildlife habitat. In response to past erosion at the beach, the Town proactively acquired nearby property in preparation for managed retreat of public facilities away from the shoreline. The focus of this evaluation was to develop indicators or thresholds that would trigger action. With these thresholds in mind, planning level recommendations were also developed for a phased retreat of the public beach facilities from Nauset Beach.

Key findings of the evaluation are summarized as follows:

- The dominant direction of longshore sediment transport, driven by wave and storm processes, is to the south. Sources of sediment are derived from erosion of nearby bluffs, dunes, and beaches.

- Long-term data indicate a steady increase in wave events (storminess) since the early 1990s.

- Rates of shoreline erosion have increased dramatically over the past two decades. Long-term rates of erosion between 1868 and 1994 were 2-3 ft/yr. Over the past two decades between 1994 and 2015 the rates increased to 12 ft/yr.

- Rates of long-term dune erosion are comparable to the rates of shoreline change.

- The current width of the coastal dune in front of the Nauset Beach support buildings (administration offices, restrooms, and snack bar) is approximately 80 ft. Assuming that current rates of erosion continue into the future, the dune width in front of the buildings will be reduced to 20 ft by 2020, and will be completely eroded by 2025.

- The current dune can provide protection for the buildings during storms up to the 20-yr event (5% chance of being exceeded in any given year). By 2020, the buildings will sustain damage during storms less than the 10-yr event (10% chance of being exceeded in any given year).

- The threshold for action by the Town is now, both in the form of adaptations that can make Nauset Beach more resilient to storm damage and the effects of climate change, and in the form of long-range planning.

- Strategies to reduce risk have been identified that include alteration of existing pedestrian and essential vehicle access, dune restoration, and phased retreat of beach facilities from the site.

- A four step plan for phased retreat from Nauset Beach over the next 30 years has been developed. Recommendations for specific activities during each phase are provided, including timeframes for action, and estimated costs.

1.0 INTRODUCTION

This report describes the Town of Orleans Outer Beach (Nauset Beach) coastal resources and provides a guide for short- and long-term management of one of the Town's most valuable assets. Ongoing erosion, exacerbated by climate change and sea level rise, currently threatens Town of Orleans Nauset Beach facilities. Parking facilities, and beach access for Town, emergency, and off road recreational vehicles are at risk, as are the beach facilities including the restrooms, beach offices and Liam's snack bar. Natural resources also are being lost, including coastal beaches and dunes and wildlife habitat.

To help address these concerns, the Town has proactively acquired landward property in preparation for managed retreat of Town facilities from the shoreline. Although the convenience of having facilities directly on the beach front is attractive, the ongoing erosion dictates a need to respond and retreat methodically. Delaying action will likely result in damage to facilities and access ways, or at least create conditions that compromise the ability to adjust and relocate in a controlled fashion. To better manage this retreat, the Town commissioned this study to identify indicators or threshold conditions that would trigger action. This study provides a phased plan for retreat of the beach facilities, including snack bar, parking, access points, and ORV access gates, based on these developed thresholds, along with recommendations for maintaining and/or restoring the natural resources to the extent practical.

This study takes full advantage of existing information and studies, and also leverages the valuable experience of Town officials and other local stakeholders. Information in Section 2.0 on Ocean and Beach Dynamics is provide to help fully understand the local conditions and to guide future decision-making. Summaries of wave and sediment transport processes are provided, as well as an update of prior shoreline change analyses. These data provide a quantitative basis for determining thresholds for action, which are described in Section 3.0 on Beach Management. The goal of this report is to provide the Town with feasible recommendations and planning thresholds for a safe and efficient use of the existing beach property along with the newly acquired 223 Beach Road location, so that present and future use of the beach for pedestrians, essential vehicles, and ORV's can be preserved through careful management of critical coastal resources.

2.0 OCEAN AND BEACH DYNAMICS

The dynamic setting of Nauset Beach, with its eroding shorelines and coastal dunes, and nearby migrating tidal inlets, results in complex and constantly changing management requirements. This section provides a discussion and analysis of the existing natural and man-made resources, the local wave climatology, longshore sediment transport, and the long- and short-term rates of shoreline change. The information described in this section provides important background data to support the management recommendations presented in Section 3.0.

2.1 SUMMARY OF EXISTING STUDIES

The outer coastline of Cape Cod, including Nauset Beach, the barrier beach, and Nauset Harbor has been the subject of numerous scientific studies. These past studies include analyses of the geology (Aubrey et al., 1982; Uchupi et al., 1996), evolution of the barrier beach and adjacent spits (Speer at al., 1982; Aubrey and Speer, 1983; Aubrey and Speer, 1984; Miller and Aubrey, 1985; Geise and Aubrey , 1987), tidal behavior at the entrance to Nauset Harbor (Aubrey and Speer, 1985; Speer and Aubrey, 1985; Hess and Aubrey, 1985; Aubrey, 1986; Aubrey and Friedrichs, 1988; Friedrichs and Aubrey, 1988; Fry and Aubrey, 1990; Speer et al., 1991; Aubrey et al., 1997), sediment transport along the coastline (Aubrey, 1986; Fry and Aubrey, 1990; Aubrey and Speer, 1983), and tidal inlet migration (Speer et al., 1982; Aubrey and Speer, 1984). The most recent studies of beach changes along the Nauset Beach system were conducted by Aubrey and Robertson (1998) and Woods Hole Group (2006) for the Town of Orleans. The key findings of these studies are summarized in the following paragraphs.

Historical charts dating back to 1779, as well as more recent aerial photography starting in 1938, show that Nauset Harbor inlet was located just north of Nauset Heights, at the southern edge of the bay drainage system (Figure 1). During the approximate 170-yr period that the inlet was located in the vicinity of Nauset Heights, spit formation extending to the north from the lower beach was non-existent. Although the studies agree that aperiodic coverage of historical maps may have under-sampled previous episodes of inlet migration, they do agree that the persistence of a southern location suggests a historically stable inlet configuration at Nauset Heights (Aubrey and Speer, 1984).

Figure 1. Aerial photograph showing southern end of Nauset Harbor drainage system with fronting Nauset spit. Site of historical inlet location is marked by the arrow (Photo source: Skypic.com).

Inlet activity at Nauset Harbor has been distinctly more active during the last 50 to 60 years. Starting in the 1950s, the inlet experienced three distinct cycles of northward migration (Aubrey and Speer, 1984). The first two of these (1952-1957 and 1965-1972) resulted in a pattern of overlapping spits. In both cases, the length of the northern spit extending from Coast Guard Beach remained relatively stable, while the southern spit extending from Nauset Heights continually grew northward. Between these two phases, a series of storms in the late 1950s and early 1960s re-established the inlet to its southernmost position immediately adjacent to Nauset Heights. The third cycle (1972-1984) involved substantial erosion of the north spit along with northward growth and extension of the south spit. Since this period, the barrier beach has breached numerous times, sometimes evolving into inlets that have remained for one or more years, and at other times closing immediately. As the inlet migrated and the adjacent barrier beaches evolved, significant changes also occurred in the tidal sand flats, vegetated flats, and tidal channels within the harbor.

Previous studies of shoreline and dune change along the Nauset Beach system have shown significant changes. In general, the reports show that the shoreline and dune have continued to retreat, at rates varying from 1 to 10 ft/yr, depending on location. The study performed by Aubrey and Robertson (1998) using data from 1938 to 1996, showed the greatest rates of shoreline erosion, on the order of -7.5 to -9.8 ft/yr, along the barrier beach in the vicinity of Nauset Harbor inlet. Further to the north near Coast Guard Beach, this study found shoreline and dune erosion rates of -5.1 to -6.5 ft/yr. At Nauset Heights the shoreline was found to be eroding at a rate of -5.4 ft/yr, and further to the south at the town beach, erosion rates of -1.9 ft/yr were reported. The lowest erosion rates of -1.7 ft/yr were found in the vicinity of Pochet Neck. The most recent study performed by Woods Hole Group (2006) using data from 1856 to 2005, found long-term rates of shoreline erosion between -4.1 and -4.6 ft/yr in the vicinity of Nauset Beach. The

Woods Hole Group (2006) study also found during the more recent time period from 1996 to 2005 that rates of erosion at the public beach had increased, with rates in front of the parking lot over 17 ft/yr.

Information on rates of shoreline and dune change compiled as part of this current study was used to update data published by these earlier studies. This analysis is presented in Section 2.5 below. Because of the dynamic nature of the Nauset Beach system, updates on beach response every 10 to 15 years can provide valuable timely information for assessing and developing management practices for the Town of Orleans.

2.2 EXISTING BEACH AND DUNE RESOURCES

An accurate understanding of present day conditions at Nauset Beach is critical to the effective management of coastal resources at the site. Nauset Beach is a nearly 12 mile long barrier beach complex. The barrier beach fronts Nauset Harbor to the north of the Town of Orleans public beach and Pleasant Bay estuary to the south, past the Pochet area of Orleans and into the Town of Chatham. Less than a mile of Nauset Beach is connected directly to upland and is not a barrier beach. This is the area where the Town of Orleans owns and operates the large public beach with associated administration offices, a bath house and concession facilities (Figure 2).

The Town of Orleans beach, within the Nauset barrier complex, serves as the only public beach for the Town with access to the Atlantic Ocean. The beach offers excellent swimming, surfing, sunbathing, bass and blues fishing, and other recreational opportunities. Because of its location, the public beach is one of the Town's most important natural assets, supporting nearly 1.2 million visitors each year and providing an annual income of nearly 1.1 million dollars for the Town. Amenities at the site include a 900 car parking lot, rest rooms, changing rooms, outside showers, snack bar, handicapped accessibility, and lifeguards. The public beach area also includes an off-road vehicle (ORV) trail that extends to the southern end of the Nauset barrier, serving as the only means of access to this portion of the beach and numerous seasonal cottages.

The developed portions of the Town of Orleans public beach (i.e. parking lot, rest rooms, etc.) are behind coastal dune and coastal beach resources. Despite the high number of visitors, the Town has managed pedestrian access well, by utilizing fencing and designated walkways to confine pedestrian traffic to three key paths from the parking lot to the beach. This has allowed the coastal dune to remain well vegetated; beach grass and beach pea are the dominant plants in the coastal dune (Figure 3). There are pedestrian pathways through the coastal dune at both the north and southern terminus of the parking lot; the northern access way also provides handicap access. Additionally, both of these paths are oriented at an angle, which reduces the vulnerability to the coastal dune and the resources and development behind the dune by not providing a straight pathway for storm waves. The third point of access is co-located with the main beach buildings in the center of the parking lot and serves not only as a pedestrian access point, but also a point of access for maintenance and emergency vehicles. Through supporting these multiple uses, this access point has grown to be the widest of the three, and is approximately 50 feet wide even at its narrowest part by the beach, and increases in width to more than 100 feet wide near the buildings. As a result, this location is the weakest point in the dune.

Figure 2. Existing conditions at the Town of Orleans public beach.

Figure 3. Coastal Dune habitat fronting the parking lot. The dune is (a) well vegetated, and dominated by (b) beach grass and (c) beach pea.

There are also two ORV entrances to the beach. The main entrance is at the southern end of the parking lot where vehicles access the ORV trail that runs along the western side of the coastal dune. The location and orientation of this ORV trail is such that it does not disturb the dune or reduce the protection the dune can provide the landward areas. The second ORV access point is approximately half a mile north of the parking lot, located at the end of Callanan's Pass. This northern entrance to the beach does cut directly through the coastal dune, but the orientation of the pathway is slightly skewed from shore normal, which helps to reduce the vulnerability of the areas landward of the dune to storm waves. There is also an alternative entrance to this ORV access point through Aspinet Road, approximately 1,500 feet south of Callanan's Pass. Because Callanan's Pass is a narrow private road, the Town has used Callanan's Pass as the "entrance", and then routed exiting ORV traffic along Inlet Road behind the dunes to Aspinet Road. The Town has an Order of Conditions from the Orleans Conservation Commission to utilize Inlet Road and Aspinet Road for ORV use during specific times and days. The permit also allows use of Inlet and Aspinet Rds. for emergency access; however, use of Aspinet Road is currently under dispute. The Town would like to retain use of both Aspinet Road and Callanan's Pass to more efficiently direct ORV traffic during the summer. Since Callanan's Pass can only handle one-way traffic, limiting ORV access to this single point would require intense traffic control, and the Town would prefer to maintain use of both access roads. Neither access point appears to be having a detrimental effect on the dune elevations or vegetation.

The dune crest elevations at the public beach vary between 20 and 25 feet (NAVD88). Although this dune height is relatively protective, recent storms and the resulting dune and beach erosion have left the beach facilities at the Town of Orleans public beach extremely vulnerable. Not only is there a large break in the dune immediately in front of these major facilities, but the width of the dune on both sides of the main path has been dramatically reduced due to erosion. At its narrowest, the coastal dune is only 75 feet wide (Figure 2). Near the south end of the parking lot, the coastal dune is more stable, and is approximately 215 feet wide. Although the height of the dune is relatively protective, there are two key factors contributing to the weakness of the coastal dune. The first, as discussed above, is the narrow width of much of the dune. The second is that the back side of the coastal dune has not been allowed to migrate landward as the front of the dune erodes, thus furthering reducing in the dune width. The edge of the parking lot, and continued removal of sand that has accreted there, has served as a hard barrier prohibiting natural dune migration.

A comparison of two different LiDAR elevation datasets shows some of the vertical changes that have taken place in the coastal dune in recent years. Figure 4 shows the difference between the elevations measured in 2011 and those measured in 2013. Red, orange, and yellow areas indicate reduced elevations (i.e. erosion), while green areas indicate increased elevations (i.e. accretion). That the dune and beach have eroded can clearly be seen by the strip of reds, oranges and yellows fronting the current dune. This occurs along the entire length of the beach. In all cases, the beach and what was the front of the dune in 2011, are significantly lower in elevation in 2013. This loss in elevation between these two years is the result of the dune transitioning into coastal beach, and the coastal beach continuing to erode through regular wave action and annual storms. However, the greens in the back dune area indicate that even though the seaward face of the coastal dune is eroding, there is some minor accretion taking place on the back side of the coastal dune. This is likely due to wind-blown sand being deposited in these locations, or via overwash processes. Signs of accretion in the dunes also indicate that regular use of the ORV and pedestrian access paths is not significantly reducing the dune elevations. Finally, areas with no color on Figure 4 indicate no significant elevation change between 2011 and 2013.

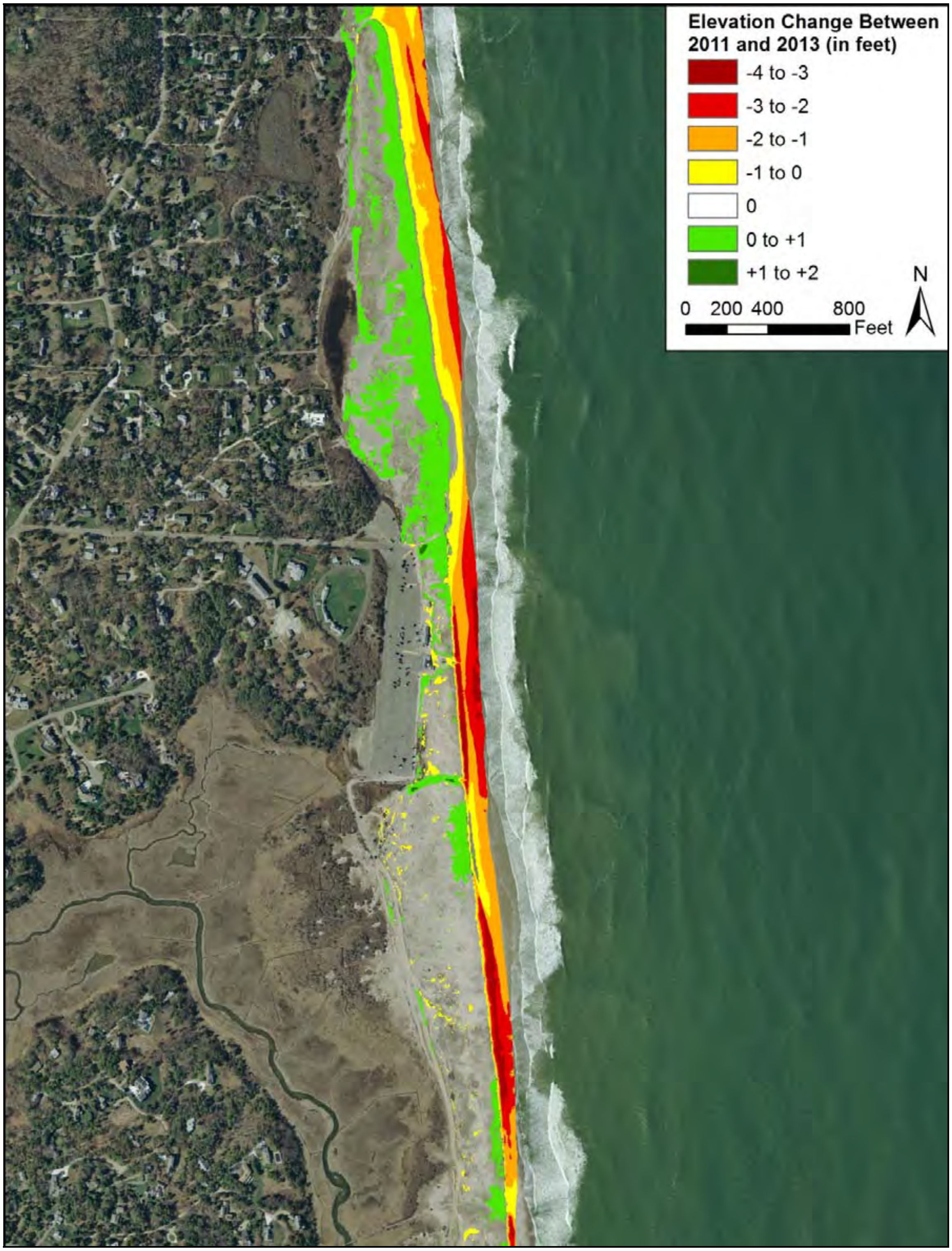

Figure 4. Change in coastal dune elevations (in feet) between 2011 and 2013.

2.3 WAVE CLIMATOLOGY

The US Army Corps of Engineers (USACE) maintains a data collection project called Wave Information Studies (WIS), which provides long-term (20+ years) wave hindcast data along all US coastlines. Unlike a forecast, which predicts what will happen in the future, a wave hindcast model predicts past wave conditions using actual, observed wind fields. This online WIS database provides access to hindcast wave information for a series of “virtual wave gauges”. Hindcast data available from each site include hourly wind speed, wind direction, and bulk wave parameters (significant wave height, period, and direction). This comprehensive dataset provides valuable information on changes in wave climatology and average and storm wave conditions. The data can also be used to infer directions of sediment transport.

Wave data for this project were taken from the USACE WIS station 63065, located offshore of Orleans Town Beach (Figure 5). A total of 32 years of wave data from 1980 to 2012 were generated by the USACE for this WIS station. To evaluate periods of storminess in the historical record, the dataset was searched to identify events where wave height exceeded 2.06 meters for 12 or more hours. These criteria were used to identify storm events based on the 90th percentile wave height calculated from the WIS database, as well as a time threshold that would be inclusive of all hurricanes, nor’easters, and other sustained high-wind events (Figure 6). The data indicate the average number of annual storm events has increased steadily since the early 1990s. In 1990, there was an average of about 16 storm events per year. By 2010 and 2013, the average number of storm events had increased to about 22. As will be discussed below in Section 2.5, this increased storminess since the early 1990s corresponds with a recent increase in the rate of shoreline erosion along the beach. The average shoreline erosion rate between 1868 and 1994 was -2.2 ft/yr compared to the -12.1 ft/yr measured between 1994 and 2015.

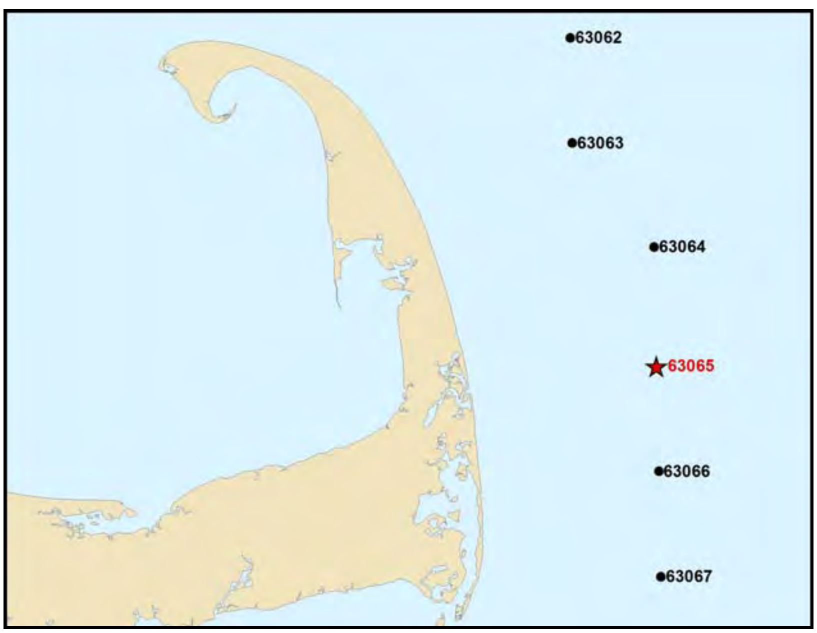

Figure 5. WIS station locations off Cape Cod (sta. 63065 used for this study shown in red).

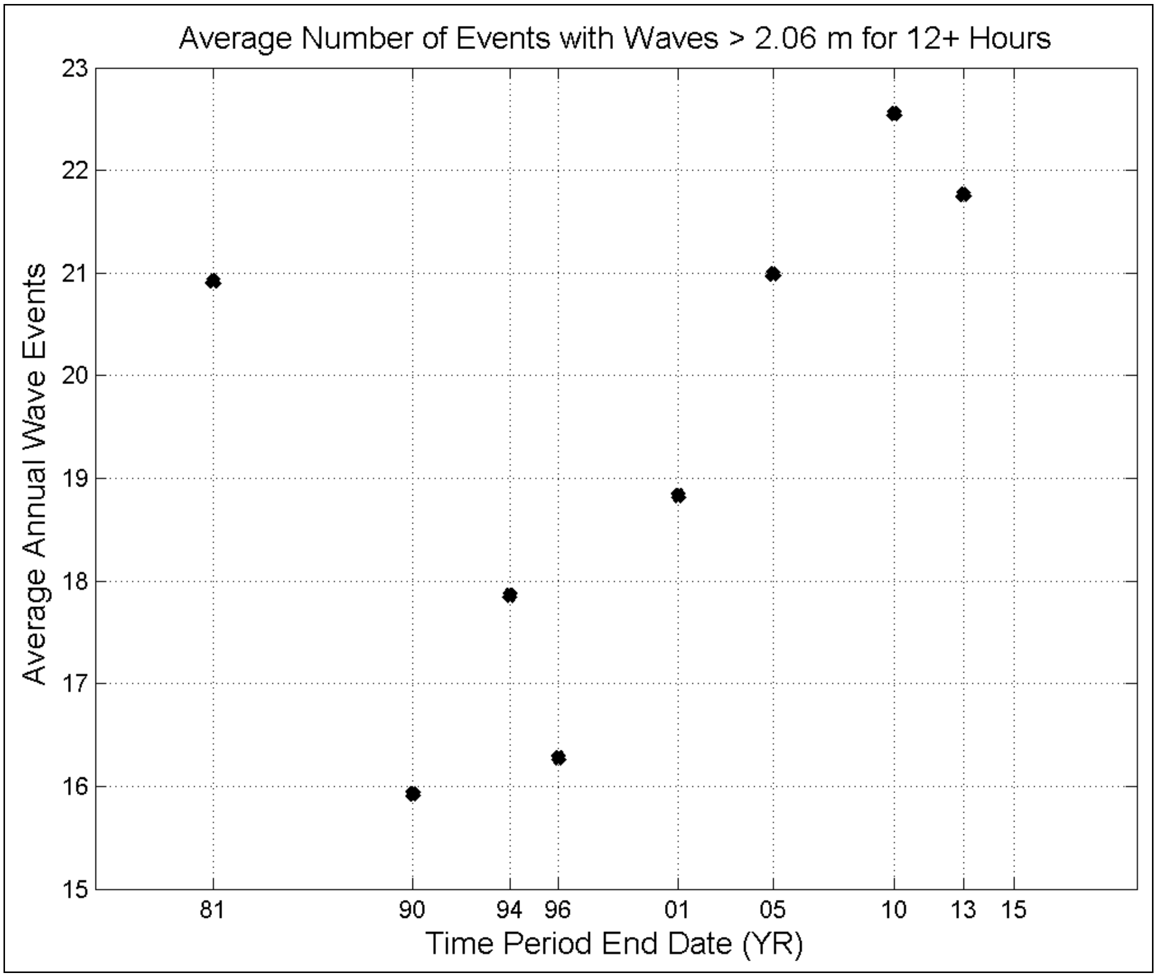

Figure 6. Average number of storm events at WIS station 63065.

Data from the USACE WIS database can also be used to determine the prevailing wave direction. Figure 7 shows a wave rose developed from the WIS station 63065 data. This figure clearly shows that waves approaching from the southeast have the highest frequency of occurrence (indicated by the fact that the longest bars are in the southeast direction), but these waves are predominantly small (0-1 and 1-2 meter waves) in size (indicated by the length of blue and green line segments). However, the largest waves (4 meters and higher) come predominantly from the northeastern and eastern directions (indicated by the pink, yellow, and grey line segments).

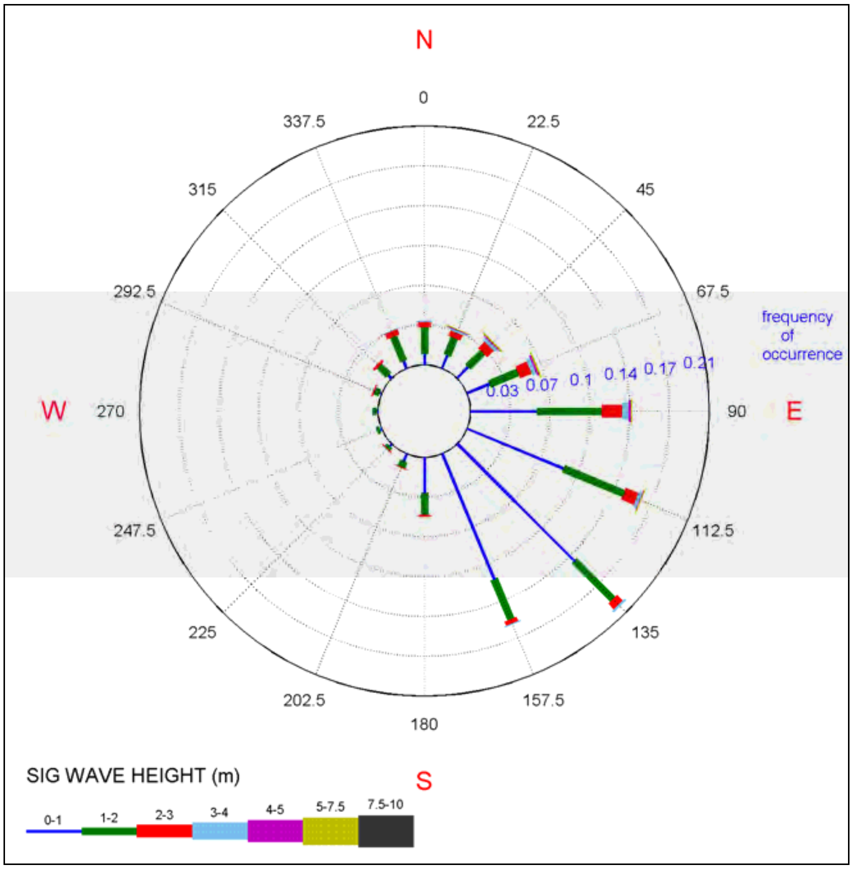

Figure 7. Wave rose from WIS station 63065.

2.4 SEDIMENT TRANSPORT PROCESSES

As with all Cape Cod beaches, the Orleans outer coast is a dynamic system, which is constantly being altered by wind and waves. Sediment transport is dominated by two factors. The first is through angled, wind-generated waves. Because the wind is often not oriented perpendicularly to the shore, it generates waves that run up the beach at an oblique angle. Over time, these angled waves transport sediment along the shore. The second component of sediment transport is the longshore current generated by this wave action. Longshore currents affect most of Cape Cod, but have the most significant impact on open ocean beaches of the Outer Cape, where they drive the longshore sediment transport process.

Although sediment transport can occur in both directions along the Orleans Town Beach shoreline, the dominant sediment transport direction is to the south (Figure 8), which would be expected given the prominently wave direction for large waves is from the northeast, as discussed in Section 2.3. Ultimately, the Outer Cape's southerly sediment transport is the major contributor to the terminal sand spit located at the southern end of Nauset barrier beach. The annual volume of sand moving southward by wave action has been calculated to be approximately 230,000 m^3 (Giese 1988).

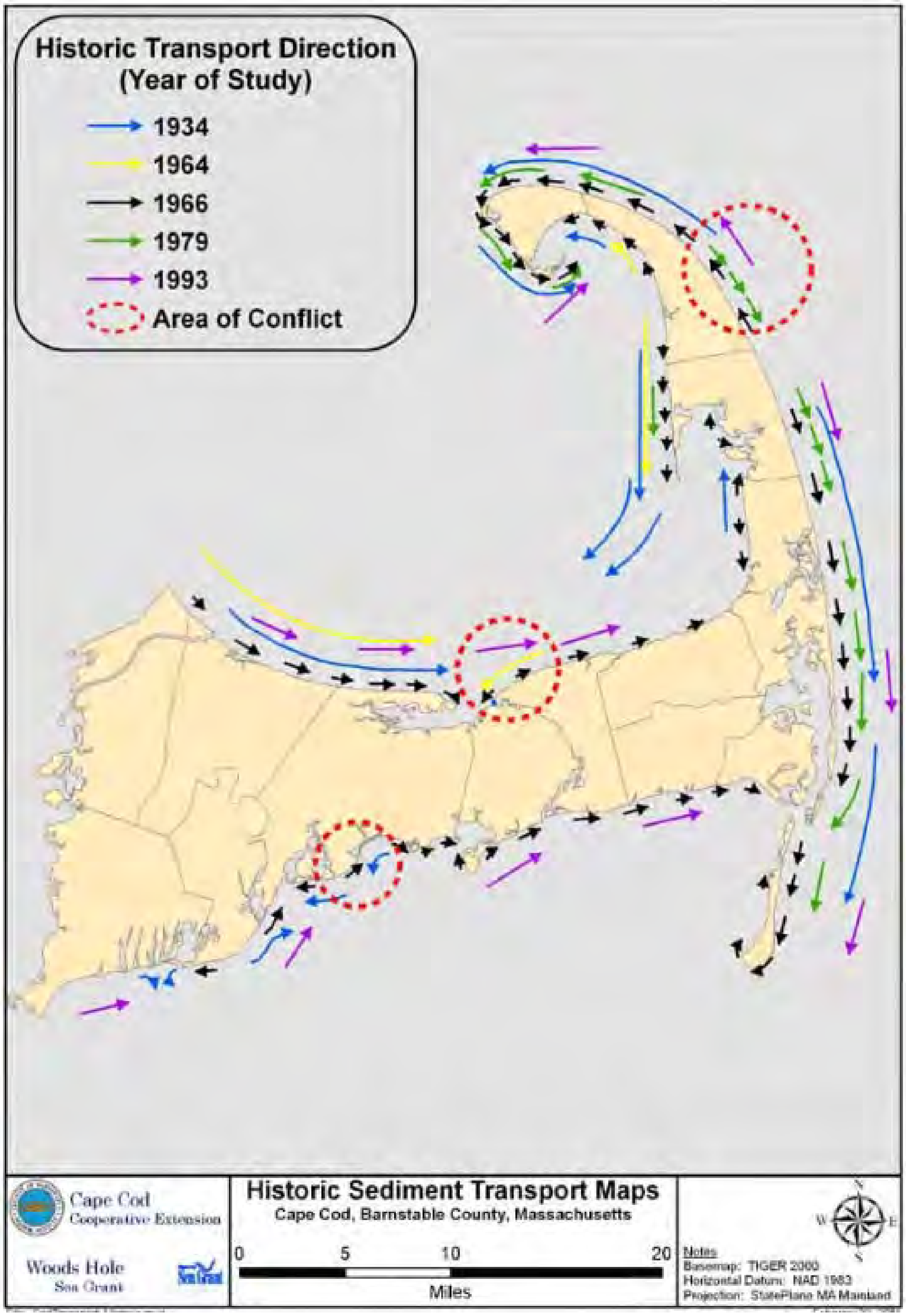

Figure 8. Historic sediment transport direction (Woods Hole Sea Grant Program, 2011).

2.5 SHORELINE CHANGE

A computer-based shoreline mapping methodology, within a Geographic Information System (GIS) framework, was used to compile and analyze changes in historical shoreline position and vegetation line for the Nauset Beach shoreline. The purpose of this task was to quantify changes in shoreline/vegetation position using the most accurate data sources and compilation procedures available, and to evaluate both long- and short-term rates of change. Because this information is critical to long-term planning for the Town of Orleans, emphasis has been placed on data accuracy and clear presentation of results. The following section provides a detailed description of the methods and data sources used in this study.

2.5.1 Data Sources and Methods

Shoreline change can be determined from accurately overlying historical shoreline positions as obtained from National Oceanographic Atmospheric Administration (NOAA) National Ocean Service (NOS) maps, vertical aerial photography, and more recent Global Positioning Survey (GPS) field surveys where available. The NOS T-sheets, which were compiled with field surveys, are the most accurate historical maps commonly available for the coastal zone, far exceeding the accuracy of United States Geological Survey (USGS) topographic maps (Shalowitz, 1964). Topographic surveys have been conducted by NOS since the early 1880s, and the high water line was found to be the best field indicator of the land-sea interface (e.g., the shoreline). Fortunately, the high water line is evidenced by a change in gray tone on black and white and color aerial photographs, and the position of this wetted boundary is identifiable on most air photos (Stafford and Langfelder, 1971).

One of the major disadvantages to the historical T-sheets is that the shoreline field studies used to produce them were so time consuming that long periods resulted between successive maps. Such infrequent data collection can make trends in historical shoreline change difficult to interpret. More recently, vertical aerial photographs, which have the benefit of a relatively synoptic view and potentially frequent collection and analysis, have been used to update historical maps. However, if air photos are to be treated as maps, the images must be rectified to eliminate the effects of distortions in the photographic process. Before the photographic data can be compared with historical cartographic data for quantitative studies of shoreline change, the photographs must also be geo-referenced.

The four sources of data used in this study to evaluate historical changes in shoreline and vegetation position were NOS T-sheets, large-scale aerial photography, recent orthoimagery, and modern day GPS surveys (Table 1). NOS T-sheet data were available for 1868 and 1886 from the Coastal Zone Management (CZM) Shoreline Change Project (SCP) database (Thieler et al., 2001). The 1868 data represent the earliest surveys on record for quantitative evaluation. These early data (1868 and 1886) were collected using standard plane-table surveying techniques and then used to produce the T-sheets, which were digitized for CZM. Additional T-sheet data for 1938 and 1952 were obtained from NOAA's Shoreline Data Explorer (NOAA, 2005). These shoreline data were vectorized under NOAA's NESDIS Environmental Data Rescue Program from raster maps originally published by the US Coast and Geodetic Survey (USC&GS). The more recent

NOS T-sheet data from 1938 and 1952 were originally compiled from rectified aerial photography covering Nauset Harbor and the adjacent shoreline areas.

Table 1. Summary of Shoreline Source Data Characteristics for Study Area

Date	Data Source	Comments
1868	USC&GS Topographic Map (1:10,000); digital shoreline obtained from Mass. CZM SCP	Surveyed shoreline using planetable surveying; Nauset Harbor and shoreline south of harbor entrance (T-1077)
1886	USC&GS Topographic Map (1:10,000); digital shoreline obtained from Mass. CZM SCP	Surveyed shoreline using planetable surveying; shoreline south of Nauset Harbor entrance (T-1704; T-1705)
Aug., 1938	USC&GS Topographic Map (1:10,000); digital shoreline obtained from NOAA (2005)	Aerial photographic survey of shoreline; Nauset Harbor and shorelines north and south of entrance (T-5734; T-5735)
Nov., 1952	USC&GS Topographic Map (1:10,000); digital shoreline obtained from NOAA (2005)	Aerial photographic survey of shoreline; Nauset Harbor and shorelines north and south of entrance (T-11183; T-11189)
Apr., 1970	Shoreline interpreted from orthophotos maps (1:5,000); digital shoreline obtained from Mass. CZM SCP	Aerial photographic survey of shoreline for Mass. DEP Wetlands Conservancy Program
Mar. 18, 1975	Shoreline interpreted from aerial photography georectified by Aubrey & Robertson (1998)	B & W photography (1:800) – Col-East, Inc.
Sep. 21, 1981	Shoreline interpreted from aerial photography georectified by Aubrey & Robertson (1998)	Color photography (1:18,000) - Col-East, Inc.
Feb. 18, 1990	Shoreline interpreted from aerial photography georectified by Aubrey & Robertson (1998)	B & W photography (1:600) – Col-East, Inc.
Mar. 21, 1994	Shoreline interpreted from aerial photography georectified by Aubrey & Robertson (1998)	B & W photography (1:5,000) – MassGIS
Mar. 30, 1996	Shoreline interpreted from aerial photography georectified by Aubrey & Robertson (1998)	B & W photography (1:500) - Col-East, Inc.
Apr. 5, 2001	Shoreline interpreted from MassGIS digital orthophotograph	Color photography (1:5,000) - Keystone Aerial Surveys, Inc.
Mar., 2005	Shoreline interpreted from geo-rectified aerial photos	B & W photography (1:12,000) – James W. Sewall Company
May 20, 2010	Shoreline interpreted from aerial photos georectified by WHG	Color photography – Google Earth
Apr., 2013	Shoreline interpreted from geo-rectified aerial photos	Orthoimagery obtained from the Town of Orleans
June 9, 2015	RTK-GPS survey of high water shoreline and dune crest	Survey performed by Woods Hole Group

More recent shoreline/vegetation position information was obtained from a series of large-scale aerial photographs for the following time periods: 1975, 1981, 1990, 1994, 1996, 2001, 2005, 2010, and 2013 (Table 1). Photographs from these years were selected based on scale of original photography (< 1:18,000), quality of photography, and spacing of time intervals. With the exception of the 2010 and 2013 photographs, these images represent the same photographic data set that was utilized in the previous study of beach changes and management options, prepared for the Town of Orleans by Woods Hole Group (2006). These data represent the highest quality and most reasonably spaced photographic data available for the site. The 2001 images were obtained as orthophotographs from MassGIS, and the 2005 and 2013 imagery was obtained as geo-referenced images from the Town of Orleans.

Finally, a field survey dataset was also incorporated into the analysis. A set of RTK-GPS data collected on June 9, 2015 by Woods Hole Group was converted into an ArcGIS shapefile to represent the location of the current high water line (shoreline) in the immediate vicinity of the Orleans public beach. The data were incorporated into the shoreline change analysis for the computation of shoreline retreat rates.

Once all photographs were geo-referenced and all data sources were brought to a common coordinate system, the location of the high water line (HWL) was identified and digitized from each of the fifteen (15) data sources. In addition, the seaward extent of vegetation was identified from the 1994, 1996, 2001, 2005, 2010, 2013 and 2015 imagery, as a proxy for the toe of the dune. Once these data were compiled, spatial and temporal changes in the data were computed. This was accomplished by identifying a series of shore normal transects along the coastline where discrete measurements of change could be made through time, and where rates of change could be determined. To analyze the shoreline change rates, a total of 57 shore normal transects were established at 50 meter (164 feet) evenly-spaced intervals along the coastline from the north end at Nauset Heights to the Pochet overwash area in the south. At each transect, the magnitude of shoreline and vegetation movement was calculated, and annual rates of change were determined using the various time intervals between the data sources. Long-term rates of change were calculated using the linear regression method. In this method, an average rate of change is based on a best-fit line to a series of points representing the shoreline/bank position over time. The linear regression method is most accurate when looking at long-term averages and is most often used for planning purposes and management decisions.

2.5.2 Historical change

The digitized locations of the shorelines, as well as the transect locations, are shown in Figure 9. Shoreline change rates were analyzed for the entire time period (1868 to 2015), as well as a more recent period (1994 to 2015). The linear regression rates of shoreline change from these time periods are presented in the graph in Figure 10. In general, all time periods analyzed show a trend of erosion across the entire study area; the one notable exception is in the area north of the ORV access, which shows significant accretion in the long-term shoreline change rate. This is due to historical infilling in the area of the 1938 tidal inlet to Nauset Estuary.

It is clear from Figure 10 that short-term erosion rates from 1994 to 2015 are higher than they were in the long-term; the green line is farther to the left (more negative) across the entire study area. The average long-term shoreline erosion rate for the entire study area was -4.1 ft/yr (1868 to 2015), as compared with the short-term average of -12.1 ft/yr (1994-2015). This same finding is shown Figure 11 which shows the change in shoreline position from the 1868 location along 11 transects centered on Nauset Beach. The average slope of the line, which is indicative of shoreline change rate, changes sharply around 1994, where the line becomes steeper. This indicates a much higher erosion rate in recent years. The average shoreline erosion rates between 1868 and 1994 was -2.2 ft/yr compared to the -12.1 ft/yr measured between 1994 and 2015.

Changes in the vegetation line were used to indicate stability/erosion of the coastal dune. This analysis was performed on the more recent photos from 1994 to 2015, where the image quality was high enough to identify the vegetation line. The digitized vegetation lines and the transects used for analysis are depicted in Figure 12. These data indicate similarly high levels of erosion in the coastal dune as seen on the beach. The linear regression rates of vegetation change from 1994 to 2015 are presented with the dashed green line in the graph in Figure 10. Although there is more variability with the vegetation change analysis, the overall trend is similar to the 1994 to 2015 shoreline change rates. Variability in the vegetation change rates may be due to sand deposited over dune vegetation or seasonal vegetation changes, rather than changes in the coastal dune itself. However, by looking at the averages over time, the variability of the vegetation is minimal compared to the changes actually occurring with the coastal dune location. The average rate in the seaward edge of vegetation, and therefore the likely average rate of change for the seaward toe of dune, between 1994 and 2015 was -10.5 feet/year. This rate is very similar to, but slightly less than the shoreline change rate. That the two are different indicates the shoreline is eroding slightly faster than the dune, effectively resulting in a narrower beach over time.

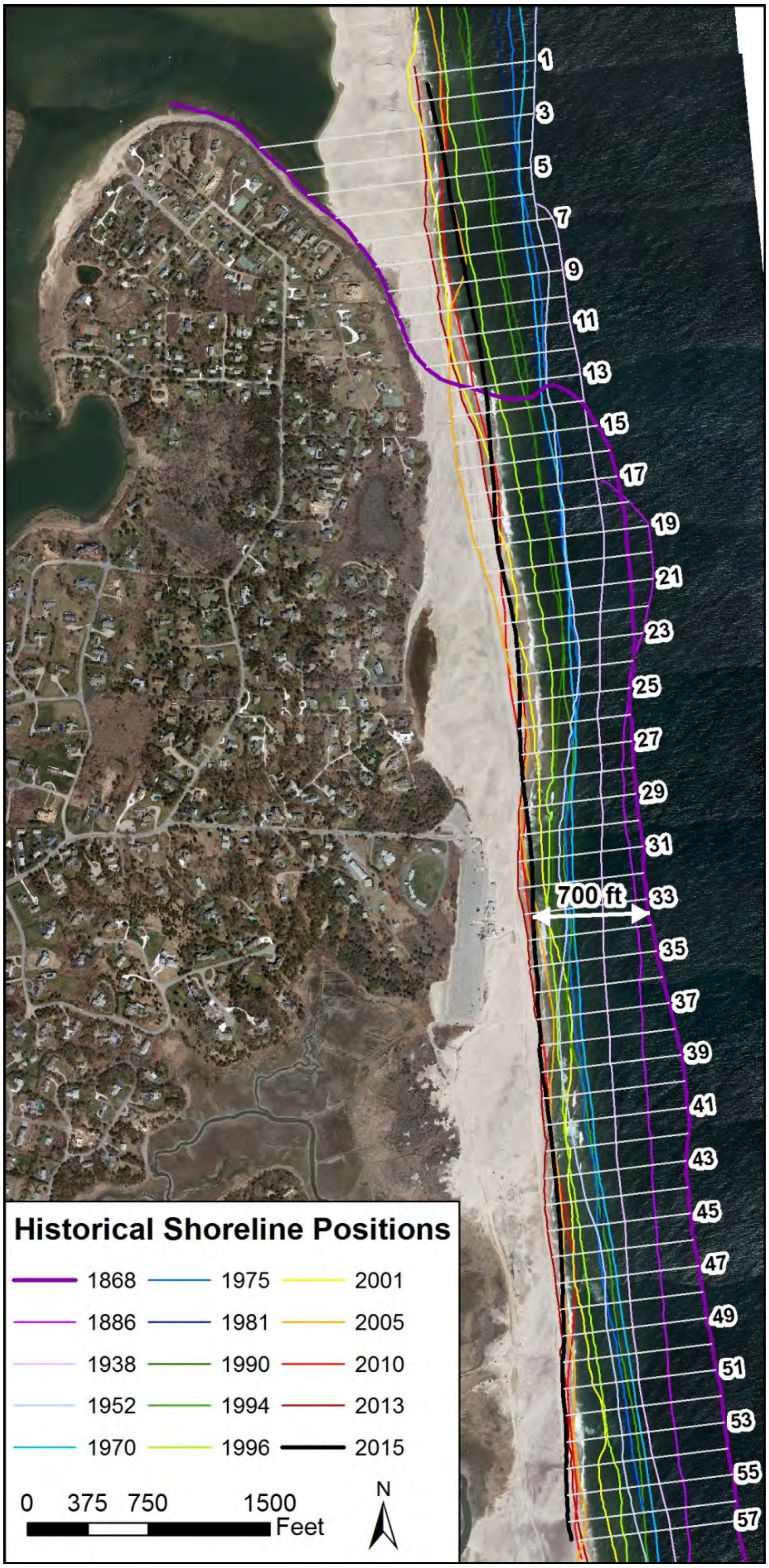

Figure 9. Shoreline and transect locations used in the shoreline change analysis.

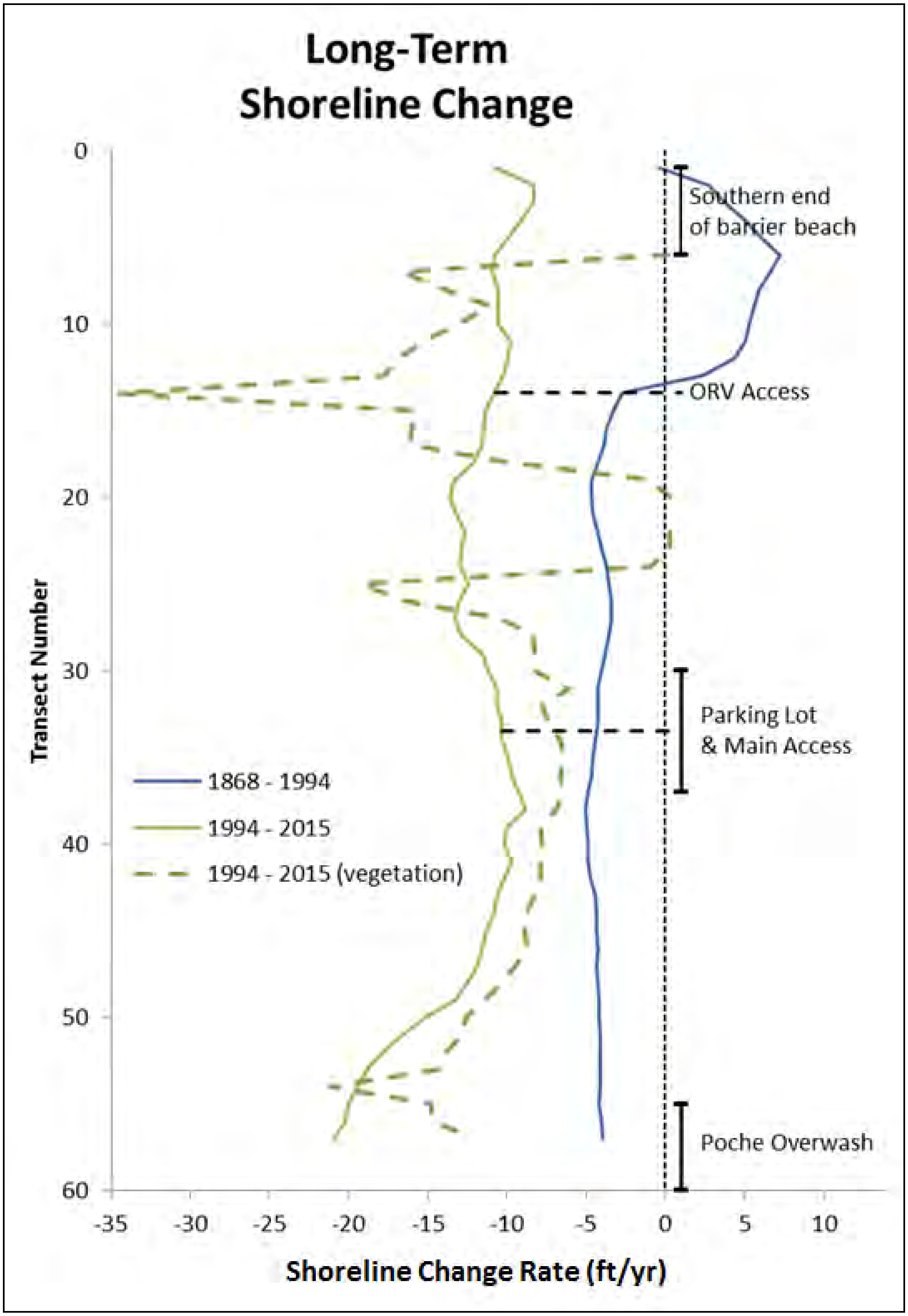

Figure 10. Long term (1868-2015) and recent (1994-2015) shoreline change rates for Nauset Beach.

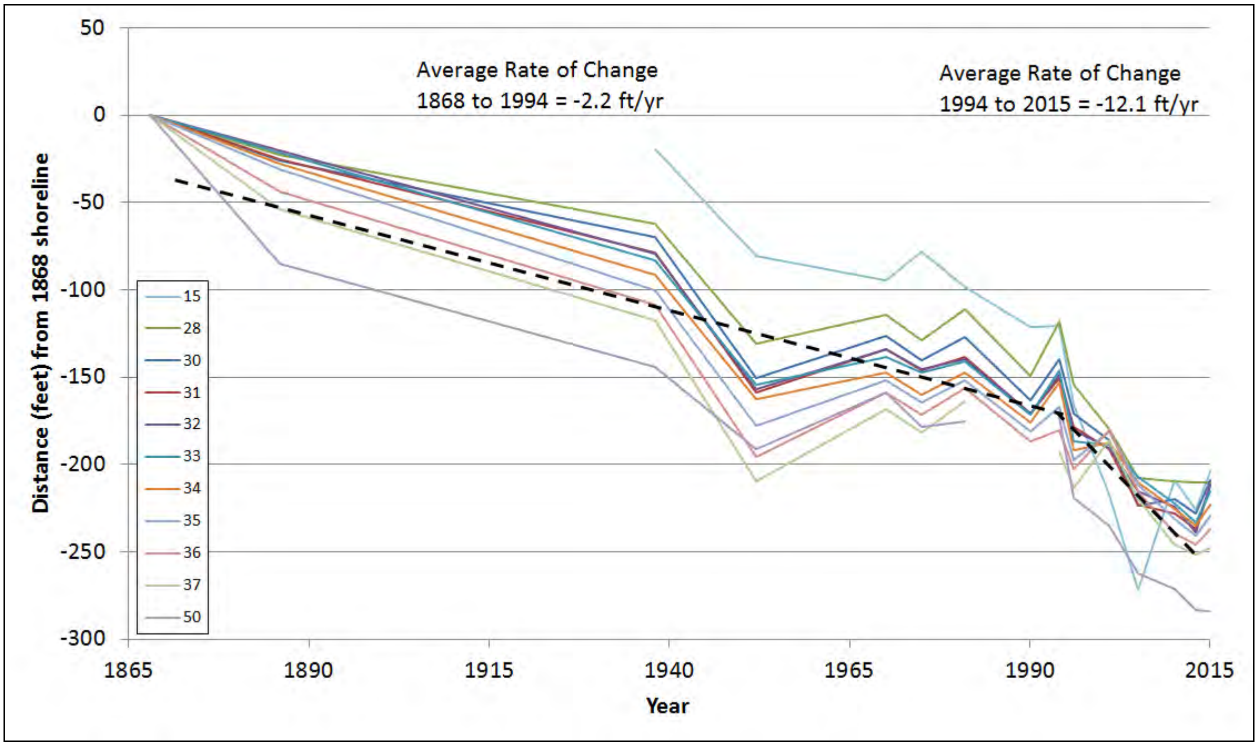

Figure 11. Distance from the 1868 shoreline along 11 example transects (noted in the legend). Negative values indicate erosion. Around 1994 the rate of change (seen by the steepness of the black dashed line) increases. As calculated from the shoreline change analysis, the average rate of change between 1868 and 1994 was -2.2 feet/year, while the average rate from 1994 to the present has been -12.1 feet/year.

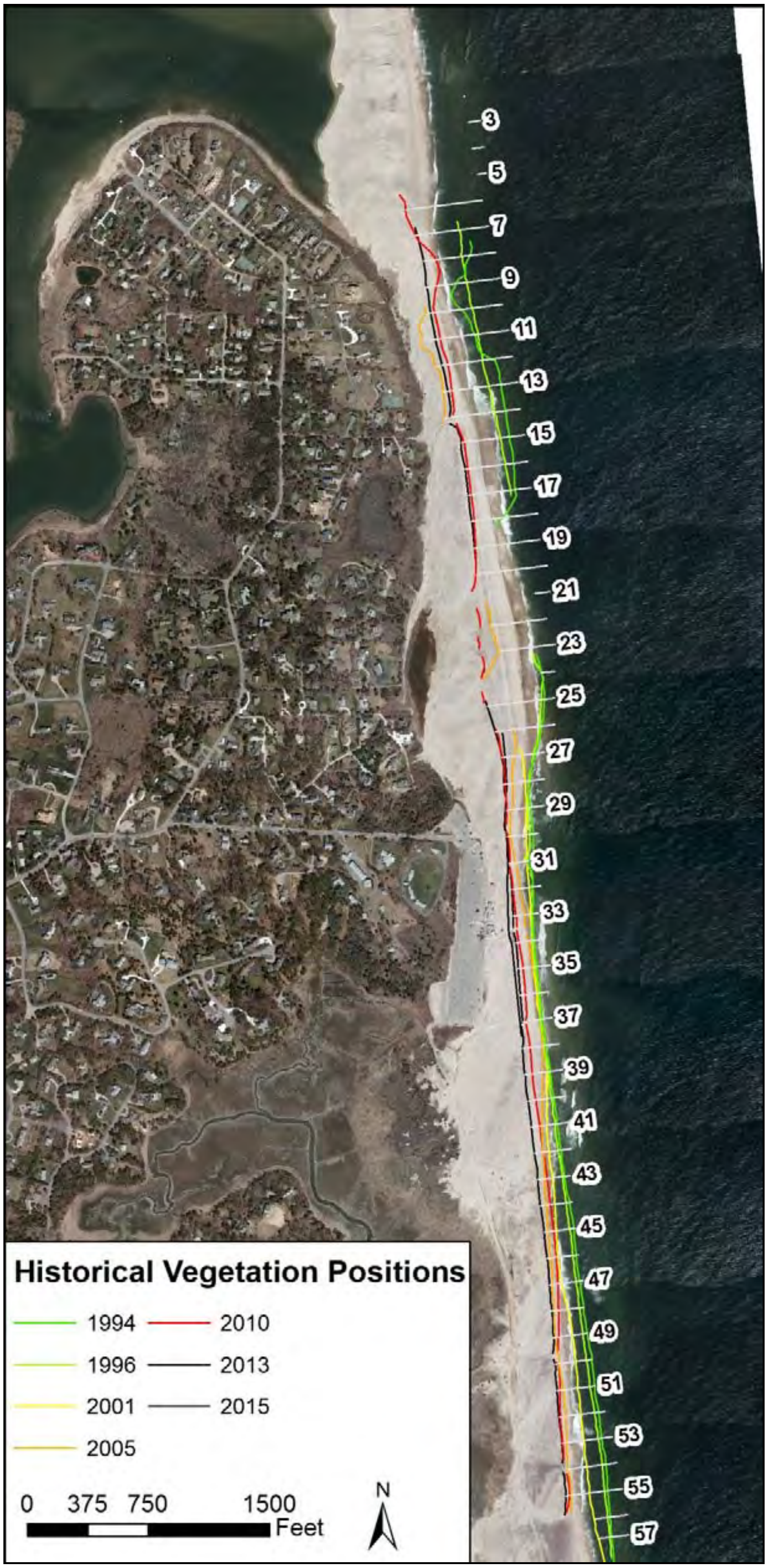

Figure 12. Vegetation and transect locations used in the vegetation change analysis.

2.5.3 Projected future change

Using the average of the more recent (1994-2015) shoreline change rates, likely locations for future shoreline, beach, and dune resources at 5-, 10-, and 20-year time horizons were developed. To start, current locations of the coastal beach and dune were delineated. These are shown for the entire study region as well as a close up of the public beach area in Figure 13. Currently, the dune in front of the buildings is approximately 80 feet wide, and the buildings are approximately 225 feet from the high water line. Based on results presented in Section 2.5.2 above, the average shoreline erosion rate from all transects over the past 21 years was -12.1 ft/yr (maximum erosion of -20.9 ft/yr; minimum erosion of -8.3 ft/yr). Although the average erosion rate calculated from the vegetation change analysis was slightly lower than that of the shoreline, the more conservative estimate of shoreline erosion (-12.1 ft/yr) was applied as both the shoreline and the dune retreat rate. These average erosion rates were then used to estimate the total distance that the shoreline will likely retreat over the 5-, 10-, and 20-year time horizons.

Shoreline retreat due to sea-level rise was also incorporated into these future projections. Intermediate-high and intermediate-low sea-level rise scenarios were used to provide a realistic range of the potential expected sea-level rise changes over the next 20 years. The top portion of Table 2 outlines the absolute vertical change in sea level projected by the intermediate-high and intermediate-low sea-level rise scenarios. Because the time frames considered are relatively short, even by 2035 the sea level is expected to rise only 0.31 to 0.56 feet, according to the intermediate-low and intermediate-high sea-level rise scenarios, respectively.

To translate these vertical changes in sea level into horizontal changes in shoreline position, the average slope of the beach based on the most recent LiDAR dataset available (2013) was determined (6.36 degrees). Using the angle of the beach and the vertical change in water due to sea-level rise, the projected horizontal shift in shoreline position was calculated. The horizontal shifts that result from both sea-level rise scenarios at the out-years of concern are itemized in the middle portion of Table 2. As seen in the table, by 2035, sea-level rise alone could produce a horizontal shift in shoreline position of 2.7 to 5.3 feet, given the intermediate-low or intermediate-high sea level rise scenarios, respectively.

Finally, these horizontal shifts projected from sea-level rise were combined with the horizontal shifts in shoreline position projected from erosion to calculate a total horizontal shift in shoreline location. These total horizontal shifts are listed in the bottom portion of Table 2. It is worth noting, however, that due to the extreme erosion occurring at this location (-12.1 ft/yr), the changes caused by shoreline erosion essentially dwarf any changes caused by sea-level rise. For example, without accounting for sea-level rise, the shoreline is expected to erode 121 feet by 2025 and 242 feet by 2035. With the effect of the intermediate-high sea-level rise scenario incorporated, these projected changes become 123.4 feet by 2025 and 247.2 feet by 2035. The difference of 2 to 4 feet over 10 to 20 years is almost irrelevant given the hundreds of feet of shoreline change caused by erosion. Although the effect of sea-level rise is dwarfed by the magnitude of erosion, for the purposes of future projections, the total horizontal shifts combining erosion and the intermediate-high sea-level rise scenarios were utilized moving forward.

Table 2. Calculations of projected horizontal shift in shoreline position due to sea-level rise and erosion.

Absolute Sea Level Elevation Change	5-year		10-year		20-year	
	2020		2025		2035	
Sea Level Rise Scenario	feet	meters	feet	meters	feet	meters
Intermediate-High	0.12	0.04	0.25	0.08	0.56	0.17
Intermediate-Low	0.07	0.02	0.14	0.04	0.31	0.09

Horizontal Shift from SLR	5-year		10-year		20-year	
	2020		2025		2035	
Sea Level Rise Scenario	feet	meters	feet	meters	feet	meters
Intermediate-High	1.21	0.37	2.36	0.72	5.25	1.60
Intermediate-Low	0.62	0.19	1.21	0.37	2.72	0.83

Total Horizontal Shift	Shoreline Change Rate ft/yr	5-year 2020	10-year 2025	20-year 2035
Erosion only	12.1	60.5	121.0	242.0
Erosion + Int-Low SLR	12.1	61.1	122.2	244.7
Erosion + Int-High SLR	12.1	61.7	123.4	247.2

Resulting predicted future resource area positions are displayed in Figures 14-16 for the 10-, 20- and 25-year time horizon projections, respectively. All projections assume the coastal dune will be allowed to migrate naturally (i.e. roll over and accrete on the back side of the dune as well). The results of this analysis are as follows:

- 2020: Based on the -12.1 ft/yr rate of change (with the intermediate-high sea-level rise projection), within 5 years, the dune will occupy the eastern 45 feet of the parking lot if allowed to retreat naturally (Figure 14). This would result in a loss of the seaward-most two rows of parking spaces. The illustration of the coastal dune in Figure 14 also assumes that by 2020, the buildings would be removed and the portion of the coastal dune they currently occupy would be restored. If the buildings were not removed, by 2020 it is projected that the dune remaining in front of the buildings would only be 25 feet wide, and the buildings would be approximately 135 feet from the high water line. Note that it is unlikely the current (2015) dune profile would weather a significant storm (see Section 3.1), and a 20-foot wide dune would provide even less protection.

- 2025: Within 10 years, the -12.1 ft/yr retreat rate (in combination with the intermediate-high sea-level rise scenario) projects that the coastal dune will occupy more than half of the space of the current parking lot, with only the 75 feet on the western side of the parking lot remaining (providing space for between 3 and 4 rows of parking) (Figure 15). At this rate, the seaward edge of the dune in 2025 would be landward of the existing buildings. In other words, if the buildings are left in place, by 2025 there would no longer be a dune to provide any storm protection to the structures, which would now be just over 100 feet from the high water line.

- 2035: After 20 years, the coastal dune is projected to retreat all the way back to the upland, leaving no remaining space for a parking lot at the current location (Figure 16). Additionally, the high water line would be in line with the existing buildings.

These projected retreat rates will result in rapid changes to the natural resource areas, as well as changes in how the public accesses and uses this site and how the beach is managed. A discussion of potential options and thresholds for retreat are presented in Section 3.1 below.

Figure 13. Current (2015) positions of the coastal beach and coastal dune at Nauset Beach.

Figure 14. Projected positions of the coastal beach and coastal dune at Nauset Beach after 5 years.

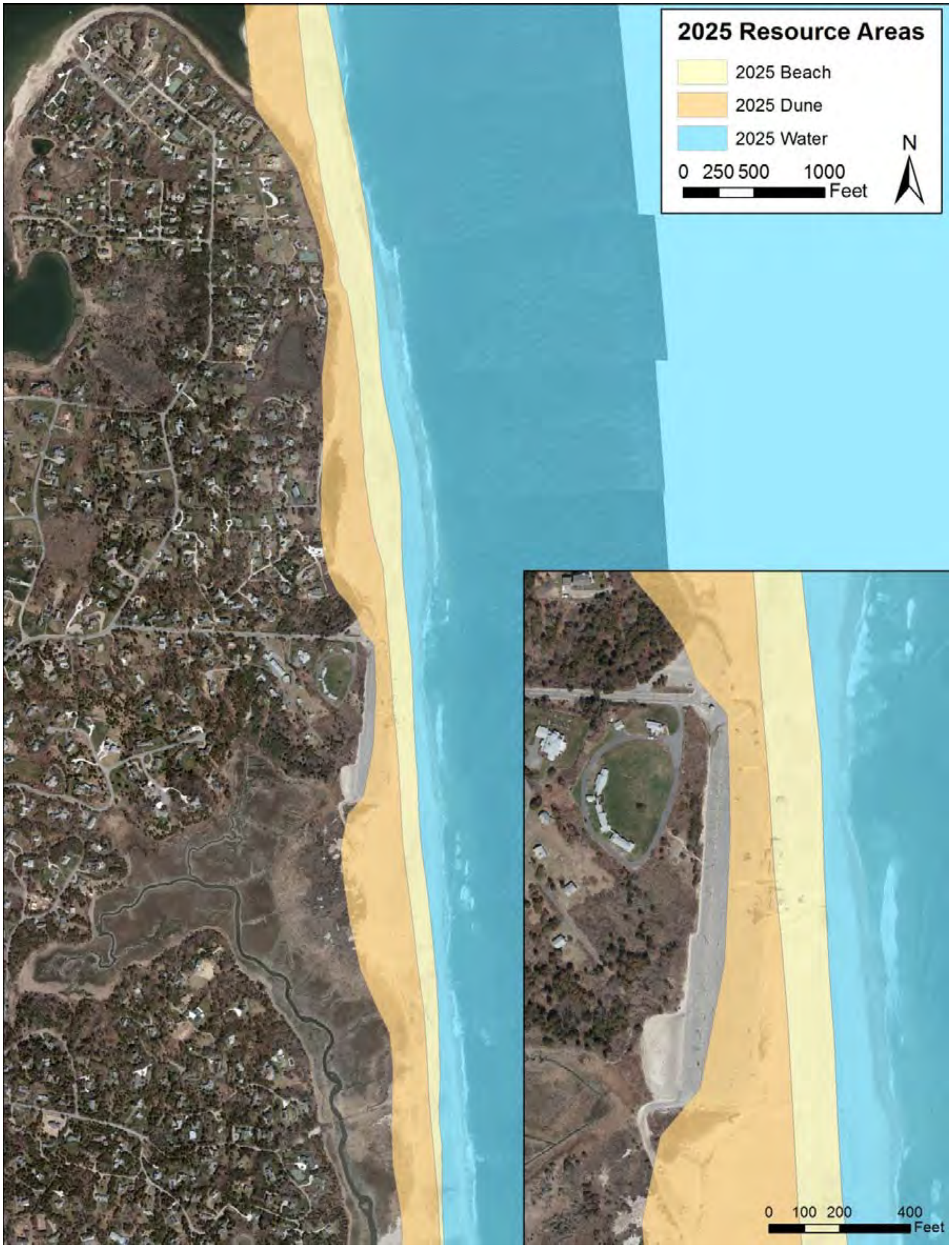

Figure 15. Projected positions of the coastal beach and coastal dune at Nauset Beach after 10 years.

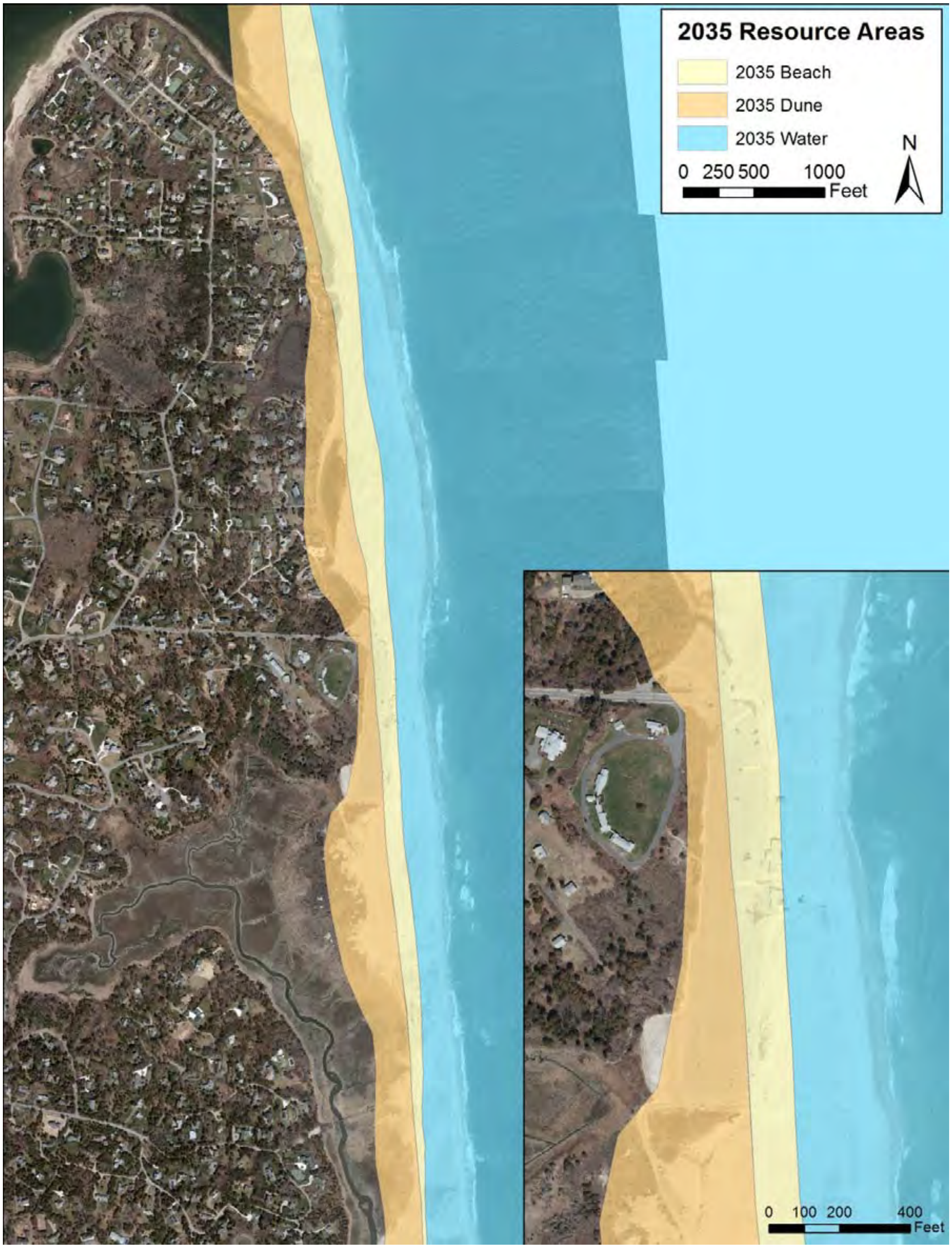

Figure 16. Projected positions of the coastal beach and coastal dune at Nauset Beach after 20 years.

3.0 BEACH MANAGEMENT

3.1 THRESHOLDS FOR RETREAT

In addition to the shoreline change rates presented above, it is also important to evaluate the protective capacity and resiliency of the existing coastal dune, as well as the projected future coastal dune. To analyze the potential concerns of storm damage and dune erosion in the vicinity of Orleans Town Beach, wave erosion and overtopping of the coastal dune under different storm conditions was assessed. Storm surge elevations and wave heights for the 10, 20, and 50-yr storm events were utilized in a cross-shore evolution model to predict changes to the beach and dune.

To evaluate wave overtopping of the beach and dune under storm conditions, the USACE beach profile evolution model SBEACH was utilized to simulate a number of different storm scenarios. The 10, 20 and 50-yr return period storms were simulated for a 24 hour time period. The stillwater surge elevations were taken from the Federal Emergency Management Agency's (FEMA) Flood Insurance Study (FIS) for Barnstable County (FEMA, 2014). Wave setup from the FEMA (2014) study was added to the stillwater surge elevations to develop a total water level for use with the SBEACH model. Table 3 shows the stillwater elevations referenced to NAVD88 from the FIS. Since the 20-year stillwater elevation is not reported in the FIS, the elevation was assumed to vary linearly between the 10-yr and 50-yr values. Wave height statistics for the various return period storms were taken from the USACE WIS database for Station 63065 (Figure 5).

Table 3. Stillwater elevations from FEMA FIS (2014) used for erosion simulations

Return Period (yrs)	Stillwater Elevation (ft, NAVD88)
10	5.6
20	6.2
50	7.5
100	9.1

Data describing the upland and nearshore intertidal topography were obtained from MassGIS's LIDAR database. These data were collected by the USGS during November 2013, and thus represent the most comprehensive up-to-date survey data for the Nauset beach area. Two transects, perpendicular to the barrier, were chosen for this analysis (Figure 17). Both transects correspond to transects from the shoreline change analysis presented in Section 2.5. Transect 32 represents a relatively narrow and vulnerable part of the coastal dune immediately in front of the existing beach buildings. Transect 36 is located towards the south end of the parking lot, and traverses a wider area of dune. Figures 18 and 21 show the 2013 cross-shore transect elevations obtained from the LIDAR data Transects 32 and 36 (blue solid line). Transect 32 has a maximum dune crest elevation of 21.9 ft NAVD88 (Figure 18), while Transect 36 has a primary dune crest elevation of 20.5 ft NAVD88 and a secondary dune crest elevation of 24.7 ft NAVD88 (Figure 21).

Figure 17. Locations of transects used for SBEACH modeling.

Representative beach/dune profiles at two different out-years (2020 and 2025) were generated from the 2013 LiDAR data. The average erosion rate of 12.1 ft/yr developed from the shoreline change analysis (Section 2.5) was applied to the LiDAR data, and the position of the high water line (HWL) was determined for both future time horizons. The profiles above the HWL were eroded back an appropriate distance, and the seaward facing slope of the dune was allowed to maintain the same slope as the starting topography. The resulting beach/dune profiles used for the SBEACH modeling are shown in the blue lines in Figures 19 and 20 for 2020 and 2025 at Transect 32, and

Figures 22 and 23 for 2020 and 2025 at Transect 36. Each figure displays the results of all three storm simulations for a 24-hour duration. Initial profiles are shown as a solid blue line. Post-storm elevations are shown as red, green, and purple lines for the 10-, 20-, and 50-year storms, respectively.

The model results indicate that a 10-yr storm event lasting for 24 hours results in approximately 25 ft of erosion, and the lowering of the primary dune crest elevation from 21.9 to 20.1 ft (NAVD88) at Transect 32 (Figure 19). A 20- or 50-year storm event occurring with 2013 topographic conditions would severely erode the coastal dune and push substantial amount of sand past the buildings into the parking lot, likely resulting in considerable damage and flooding to the beach buildings and structures. By 2020, it is projected that the pre-storm coastal dune would only be approximately 40 feet wide. Given these conditions, a 10-year storm event would completely erode the coastal dune at Transect 32, which would likely damage the buildings and cover the parking lot in overwashed sand (Figure 19). By 2025, however, the seaward edge of the dune is projected to be landward of the current building locations, indicating that damage is expected to occur to the buildings even in the absence of a particular storm (Figure 20). In summary, for Transect 32, the current dune provides some protection for the buildings and parking lot up to a 10-year storm. However, with a more intense storm, even the current dune is vulnerable to significant erosion and would be unable to protect the buildings. By 2020 and 2025, the dune will likely erode to a point where it is unable to provide protection to the buildings, even from a 10-year storm.

At Transect 36, the model results indicate a 10-yr storm event lasting 24 hours results in almost 100 ft of erosion, and the lowering of the primary dune crest elevation from 20.4 to 16.2 ft (NAVD88)(Figure 22). A 20-year storm would completely eliminate the primary dune, and a 50-year storm event occurring with 2013 topographic conditions would severely erode the entire coastal dune, and would push substantial amount of sand into the parking lot. By 2020, it is projected that the pre-storm primary coastal dune would only be significantly reduced, with a crest height of only 14.5 ft (NAVD88). Despite those reduced conditions, a 10-year storm event would completely erode the primary dune at Transect 36. However, due to the more substantial width of the dune at the southern end of the beach, this storm still would not impact the secondary dune (Figure 22). Given these same 2020 conditions, a 20-year storm would likely cause some erosion to the secondary dune, and like 2013 conditions, a 50-year storm would severely erode the entire dune pushing significant amounts of sand into the parking lot. Even in 2025, where the primary frontal dune is expected to have eroded away, the remaining secondary dune would provide substantial protection for the parking lot during a 24-hour 10- or 20-year storm (Figure 23).

The difference in storm response at these two transects provides valuable information for understanding what dune cross section (height, width, etc.) will provide adequate protection against storms. This can then be used as a model for designing any dune nourishment project. For example, although the existing dune profile at Transect 32 is extremely vulnerable, the profile from Transect 36 has a much wider dune, which provides additional resiliency against storm damage. A similarly wide profile should be considered if any dune restoration work is considered in the future, as it will be more resilient against storm damage.

Based on thresholds developed from the shoreline change results and projections of future shoreline and dune locations into the future (Section 2.5), as well as this analysis of the potential for the existing dunes to withstand a severe storm, a plan for phased retreat has been developed and is presented in the following section.

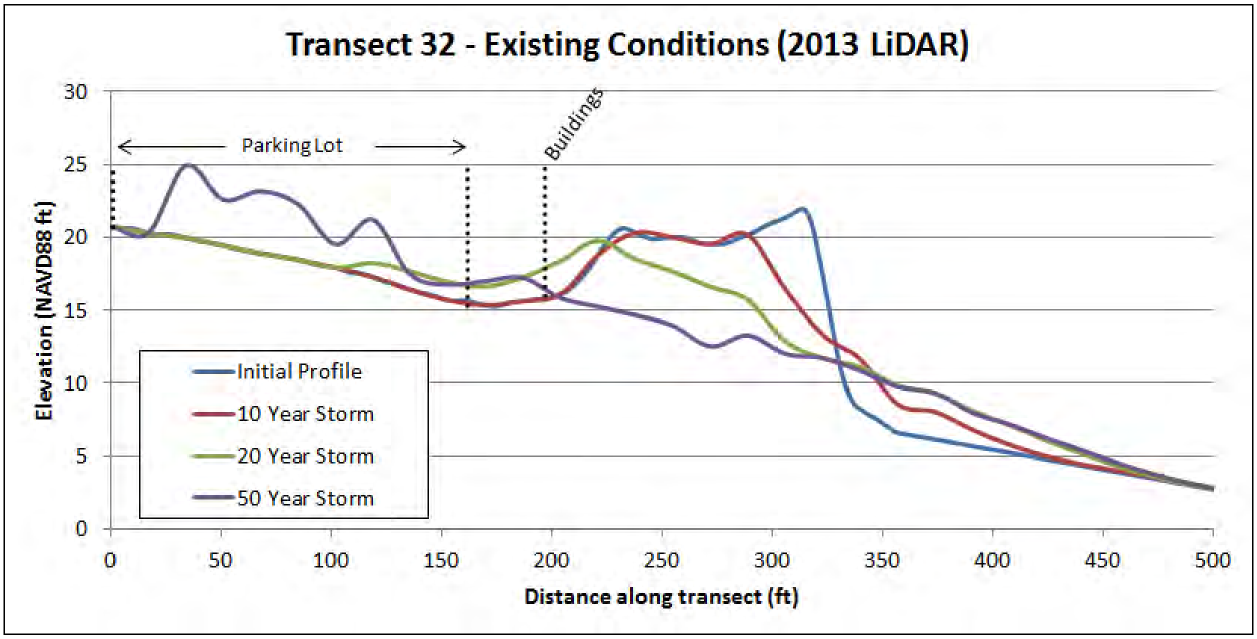

Figure 18. SBEACH modeling results of the effect of various storm intensities given current conditions at Transect 32.

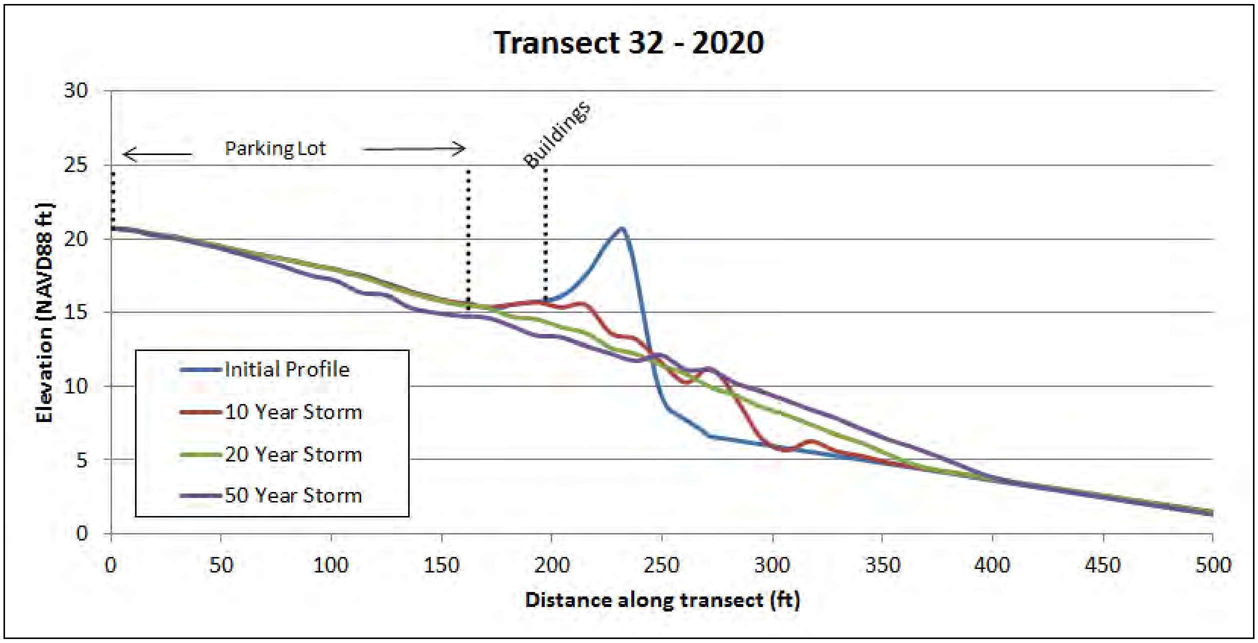

Figure 19. SBEACH modeling results of the effect of various storm intensities given 2020 conditions at Transect 32.

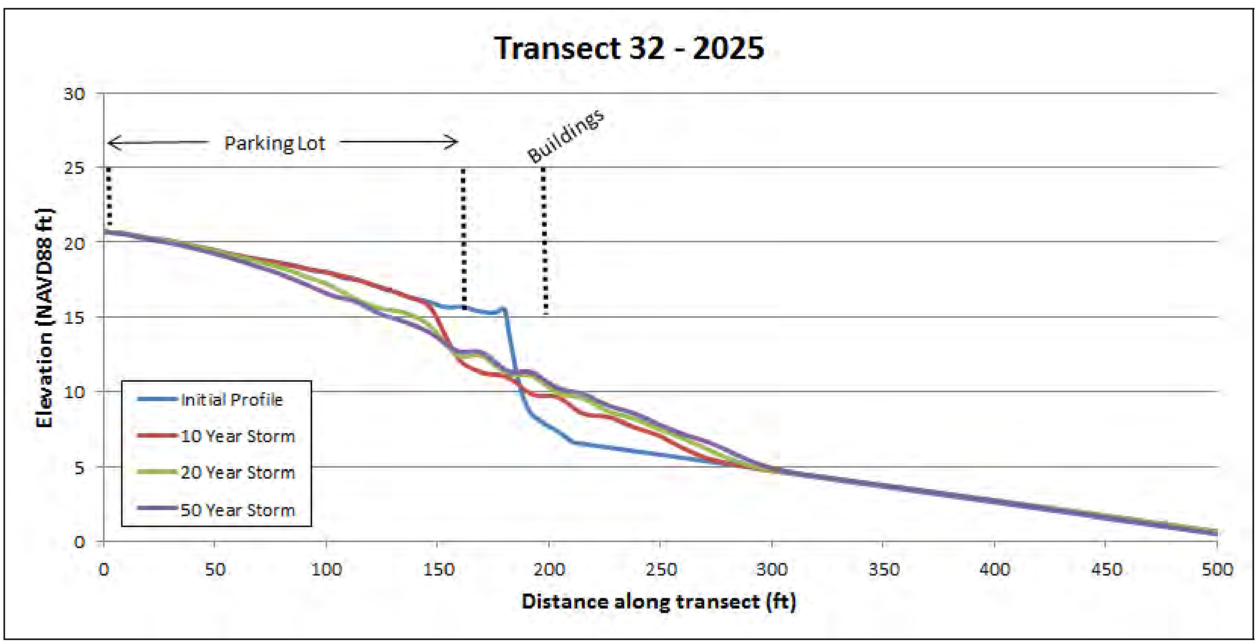

Figure 20. SBEACH modeling results of the effect of various storm intensities given 2025 conditions at Transect 32.

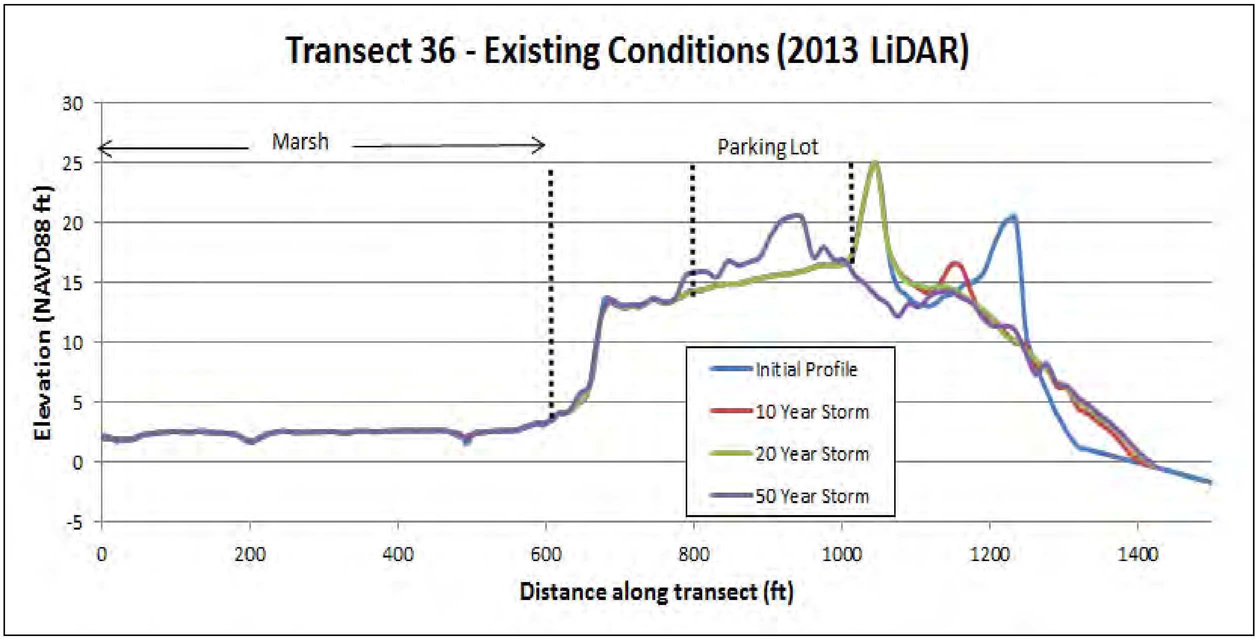

Figure 21. **SBEACH modeling results of the effect of various storm intensities given current conditions at Transect 36.**

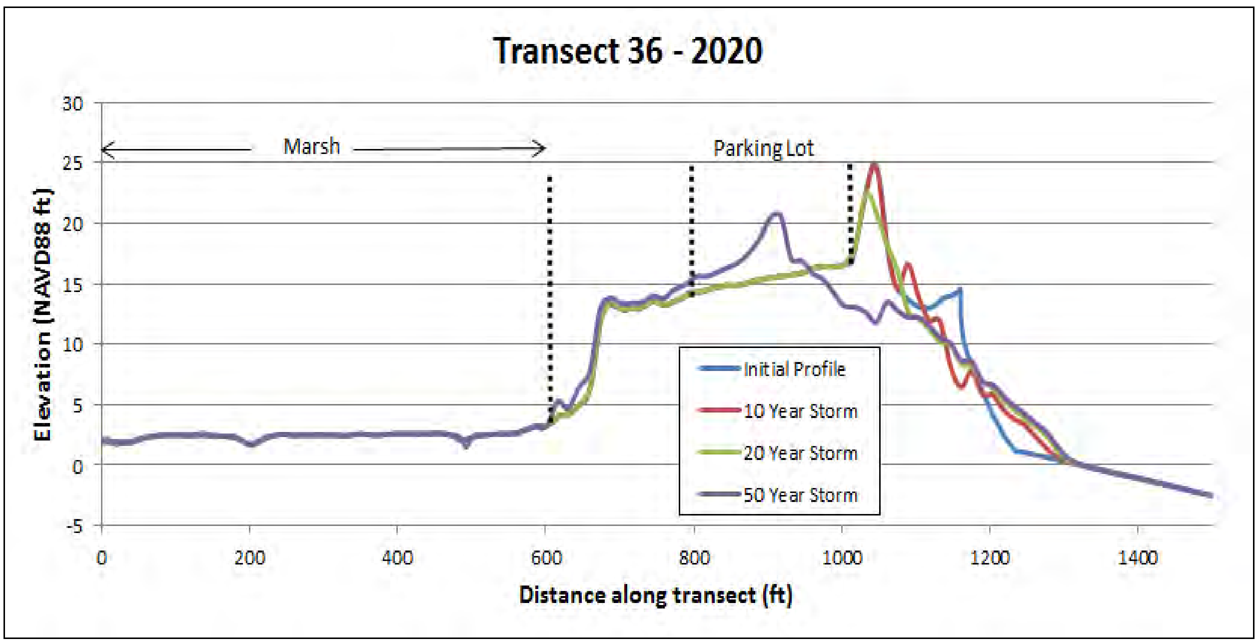

Figure 22. **SBEACH modeling results of the effect of various storm intensities given 2020 conditions at Transect 36.**

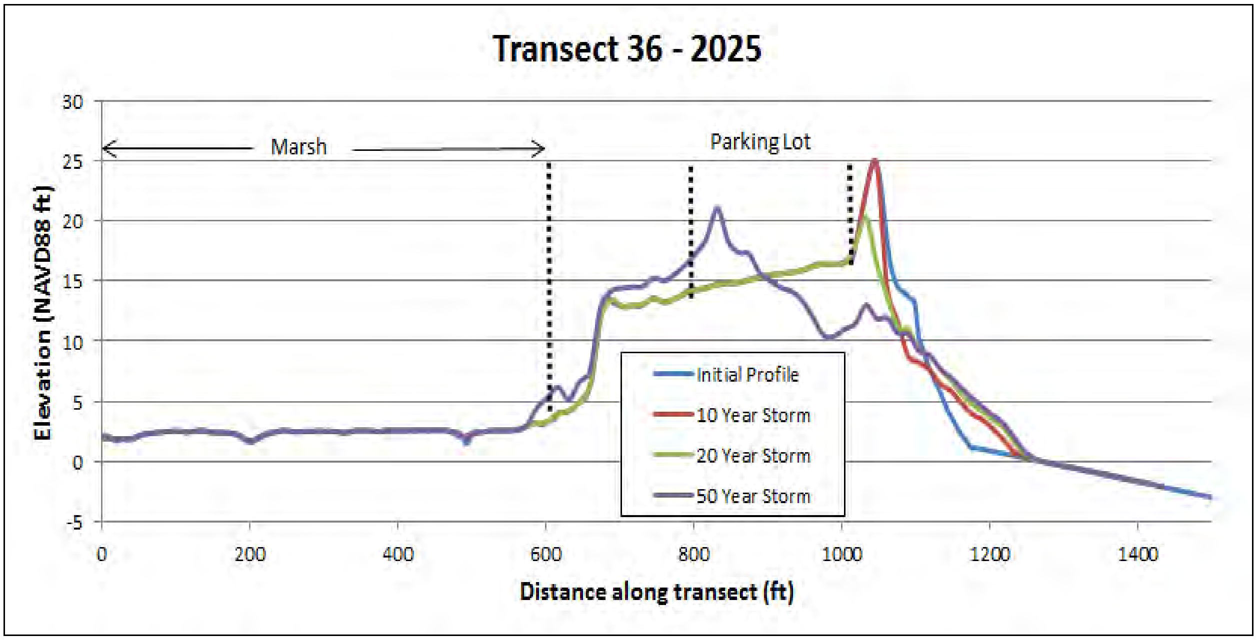

Figure 23. SBEACH modeling results of the effect of various storm intensities given 2025 conditions at Transect 36.

3.2 PHASED PLAN FOR RETREAT

Based on the above analyses, the Town of Orleans Beach facilities are currently at risk, and will be exposed to increased risks as the dune continues to erode, and will likely sustain substantial damage in the near future if no action is taken. Therefore, to protect valuable beach facilities, and to extend the lifetime of the recreational beach, we recommend a phased retreat plan. This phased retreat plan is intended to maintain the use of the site for public recreation as long as possible, enhance the ability of the existing coastal resources to provide storm damage protection and flood control, and to minimize the loss of infrastructure. In addition, this plan outlines estimated costs that would be involved with implementing various aspects of phased retreat, to help the Town plan financial resources appropriately.

The phased retreat plan involves activities concerning administration and facilities (i.e. beach administration offices, restrooms, concessions, parking), restoration of coastal resources (i.e. dune nourishment), and emergency and public beach access (i.e. pedestrian pathways, essential vehicle access, ORV access). These categories of activities are listed in Table 4, along with details on specific actions that should be taken within each category. The specific actions are broken out by the recommended time frame in which they should be performed. Actions listed under "Now (0 - 2 years)" represent those that should be done as soon as possible. As described above, even in its current state, the coastal dune in front of the existing beach buildings would not provide adequate protection in a major storm. Actions listed under "2-5 years", "5-15 years", and "15-30 years" are based on the projected retreat of the shoreline and dune, and provide recommendations for how to adapt to these changes and increase the resiliency of the coastal dune, while still maintaining the highest level of recreational usability possible.

Table 4. Phased retreat plan activities and timing

		Time frame			
		Now (0-2 years)	**2-5 years**	**5-15 years**	**15-30 years**
Administration and Facilities	**Beach Administration Buildings**	Relocate to 223 Beach Road.	No action.	No action.	No action
	Restrooms and Food	Utilize current structures, but do not invest in major upgrades.	Remove existing buildings and establish mobile restroom and concession facilities.	Continue the use of mobile restrooms and concession facilities.	Relocate all facilities to 223 Beach Road.
	Parking	No action	Remove first row of parking lot to allow for dune restoration. Expand use of 223 Beach Road to include overflow parking.	Remove pavement from additional parking lot area to allow for dune restoration. Begin using off-site parking and provide shuttle service.	Remove remaining pavement from existing beach parking lot. 223 Beach Road will be used for shuttle pickup and drop-off to and from an offsite parking location.
Restoration	**Dune restoration**	Targeted sand placement and planting at restored path locations, particularly at current central access point.	Restore landward side of dune.	Continue dune restoration by placing addition sand on the landward side of the dune.	Continue dune restoration by filling in area where parking lot has been removed.
Beach Access	**Pedestrian Pathways**	Reorient pathways so they are not perpendicular to the ocean. Consider the use of removable Mobimats.	Work with National Seashore to establish pedestrian path from 223 Beach Road through intermediate parcel.	Maintain all over-dune pedestrian paths.	Remove all but main pedestrian accessway over the dune.
	Essential Vehicle Access	Relocate to southern end of parking lot. Keep sinuous path orientation.	No action.	No action.	Consider merging with ORV trail.
	Southern ORV Access	No action	No action.	Dune erosion and overwash could cause potential disruptions to the ORV trail; occassional maintainence may be required.	Relocate ORV trail.

Although recommended actions are detailed above in Table 4 for the "5-15 year", and "15-30 year" time frames, the coastal beach and coastal dunes should be monitored and these activities and time frames adjusted accordingly. Because there is more uncertainty associated with longer time projections, an adaptive management approach should be utilized. Adaptive management is a systematic, but iteratively updated approach to management that learns from past results, and adjusts to future changes. This approach would integrate restoration design, natural resource and facilities management and planning, and ongoing monitoring to systematically test assumptions in order to refine and adapt the plan over time. Such an approach is well suited to a site like the Orleans Town Beach because there is a level of uncertainty associated with potential future environmental changes, and their potential impacts on changes at the site. For example, if storm frequency increases, causing additional erosion, the time frame of the proposed activities might have to be accelerated. However, if there are a number of calm years, the actual future erosion rate may in fact be less than projected, resulting in less erosion and allowing some more flexibility on some of the bigger changes suggested after 5 years.

3.2.1 Phase 1: 0 to 2 years

Planning and implementation of Phase 1 of the proposed retreat plan should begin immediately. Activities proposed during this phase of the plan are depicted in Figure 24. As discussed above, even the current coastal dunes are not substantial enough to protect the beach facilities from a severe storm if it were to happen today. Although some of the facilities and services are useful to have located in the parking lot for as long as possible, to help minimize potential damages, the beach administrative offices should be moved to a safer location at the 223 Beach Road location as soon as possible.

In addition to relocating the beach offices, Phase 1 also requires reconfiguring and reallocating the beach access paths, and restoring the large cuts created through the dune through heavy pedestrian and vehicle traffic over the years. The largest gap in the dunes is located in the center of the main beach area directly in front of the existing buildings. To restore this area and increase the resiliency of the coastal dune, this large open pathway should be filled and planted with beach grass. The path could still be used as the main point of public access; however, essential vehicle access should be rerouted through the access path at the southern end of the parking lot. As the central pedestrian access way is being reconfigured, it should be done in such a way as to follow a sinuous route through the dunes. In fact, all paths should be reoriented so they are not straight and oriented directly perpendicular to the shoreline. Straight paths should be avoided as they can increase the change of flooding during a storm, because they provide a direct access channel for the waves to flow through the dune. As the pedestrian paths are reconfigured, the areas of lower elevation should be filled in with sand to further restore and strengthen the coastal dune in those areas. Finally, the Town should consider utilizing a removable walkway system, such as Mobi-mats®. These roll-out footpath surfaces can provide easy handicap access, help protect the dune from extensive foot traffic, and can be rolled-up and removed prior to storm events to minimize damage to beach infrastructure.

Costs and permitting requirements for these activities are discussed in Sections 3.3 and 3.4.

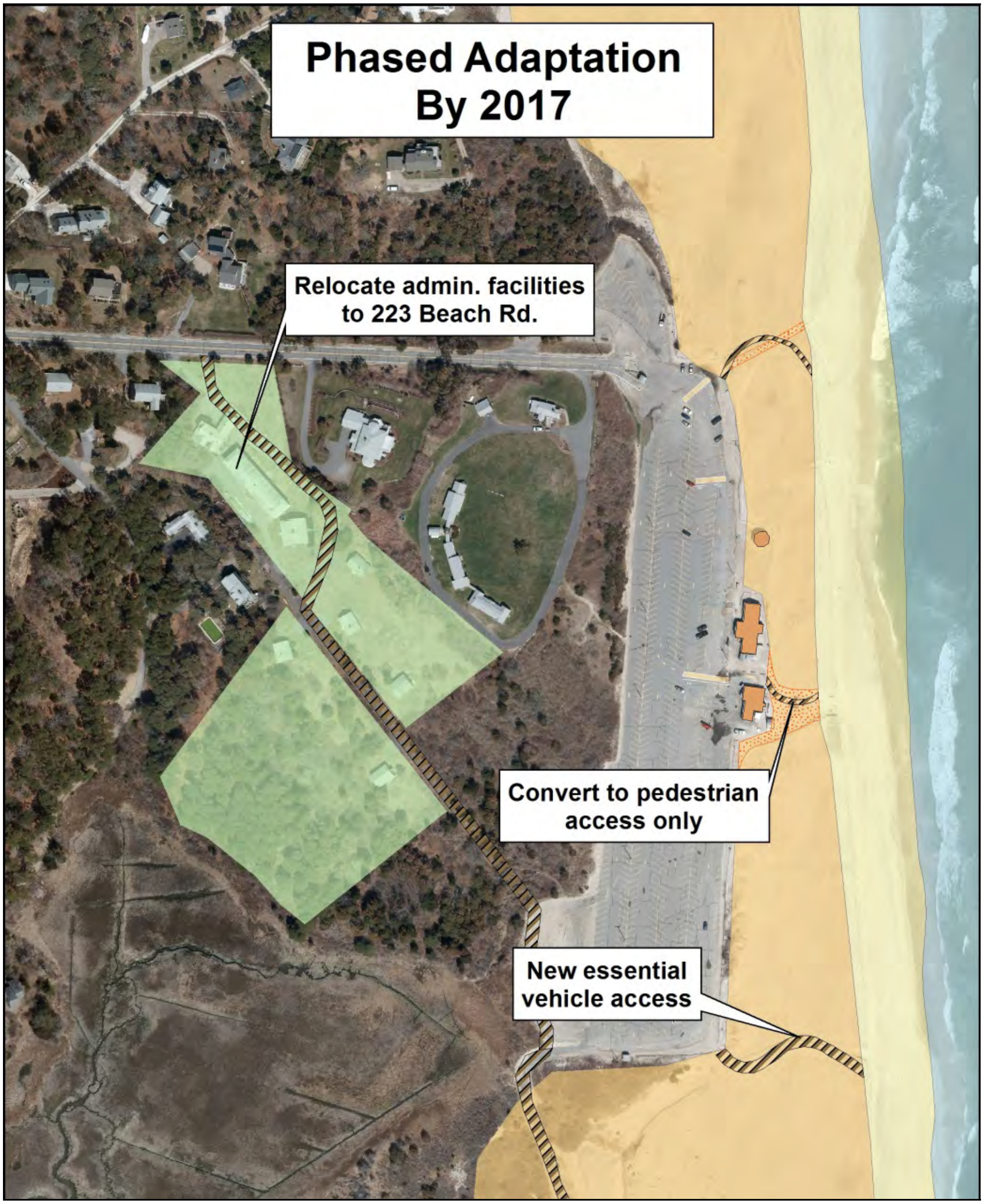

Figure 24. Phase 1 of the Proposed Retreat Plan to be completed by 2017.

3.2.2 Phase 2: 2 to 5 years

Planning for the second phase of the proposed retreat plan should also begin immediately. Many of these activities, however, are larger in scope and will likely take 2 to 5 years to implement even with proactive planning (Figure 25). The largest change proposed for this period is to remove all of the permanent buildings and structures that are currently located between the parking lot and the dune, as well as the seaward-most portion of the parking lot. Our recommendation is to fill in the area exposed by removal of the buildings and the first row of parking spaces to nourish the back side of the coastal dune (Figure 26). Section 3.3 provides cost estimates for two levels of dune nourishment. The first is a nourishment project with a smaller extent, covering just the area immediately across the front of the parking lot. This design includes a dune crest elevation of 23 feet (NAVD88), and dune widths between 100 and 200 feet, and would require approximately 32,700 cubic yards of sand. The second is a nourishment project with a slightly larger footprint that would extend approximately 300 to 400 feet north and south of the parking lot. This design has similar dune widths to the smaller design, but incorporates dune crest heights of 25 feet (NAVD88), and would require approximately 38,000 cubic yards of sand. The latter option is more protective, but would require the placement of a larger volume of sand and would therefore be more expensive. Dune nourishment will increase the width and height of the dunes, which will increase the dune system's coastal resiliency.

To continue to accommodate the needs of the beach's recreational users, mobile bathroom and concessions facilities should be established in a central location in the parking lot. These mobile services are extremely advantageous at a site like this because they can be removed for the winter or for an impending storm to avoid damage, and they are flexible enough to easily adapt and move with the changing beach and parking lot configuration as the different phases of the retreat plan are implemented.

To compensate for the parking spaces lost during the proposed removal of the first row of the parking lot, the 223 Beach Road property should be developed to serve as an overflow parking area by 2020. Since the vehicle entrance to the southern ORV ramp enters through this lot and queues along the current access road heading towards the beach parking lot, it is recommended to develop an alternate more direct access path for foot traffic to the beach. This would minimize safety concerns, but would also require negotiations with the National Park Service, who is the current owner of the adjacent parcel.

Costs and permitting requirements for these activities will be discussed in Sections 3.3 and 3.4.

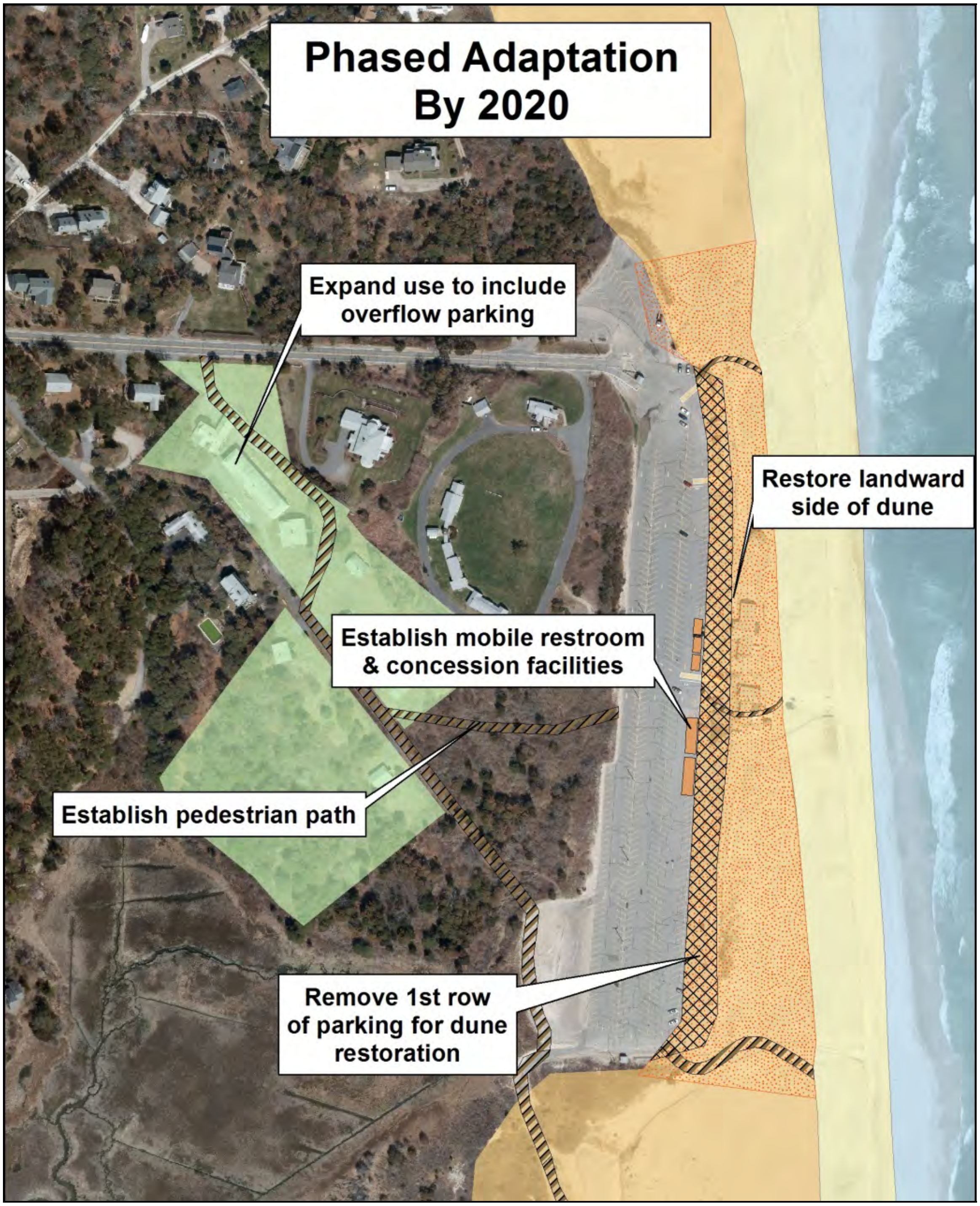

Figure 25. **Phase 2 of the Proposed Retreat Plan to be completed by 2020.**

Figure 26. Suggested area of parking lot to be removed to accommodate a dune restoration project during Phase 2 of the Phased Retreat Plan.

3.2.3 Phase 3: 5 to 15 years

Proposed actions in Phase 3 of the retreat plan are depicted in Figure 27 and should be implemented by 2030. This phase of the plan is largely focused on continuing the process of removing the parking lot and restoring the landward side of the dune that was started in Phase 2. Because the seaward side of the dune will continue to erode as the shoreline retreats, without regular dune nourishment, the width of the dune would be dramatically reduced and would ultimately be entirely eroded away. Given the high wave energy of this site, adding sand to the seaward side of the dune is not a sustainable solution for the dune. Also, adding sand to the back side of the dune as we have recommended mimics the natural tendency of a resilient coastal dune to "roll over" itself and move backwards after being hit with a severe storm.

To restore the dune as described about, however, requires the removal of another strip of the parking lot. Additional sand will then need to be brought in to complete the nourishment design, and the newly sculpted dune should again be planted with beach grass to increase the dune's stability, as well as its habitat value. Mobile restroom and concession facilities should continue to be used, and can be shifted back to accommodate the proposed dune nourishment. With the loss of so many additional parking spaces, however, it is likely that an offsite parking location will have to be located and a shuttle service established; it is unlikely that the 223 Beach Road location will be able to accommodate the additional needs at this point. Finally, as the coastal dune continues to erode and where possible, retreat, there will be an increased potential for disruption to the southern ORV trail. These disruptions will likely be episodic and storm related, and can likely be dealt with through targeted minor repairs to the trail following any storm damage.

Costs and permitting requirements for these activities will be discussed in Sections 3.3 and 3.4.

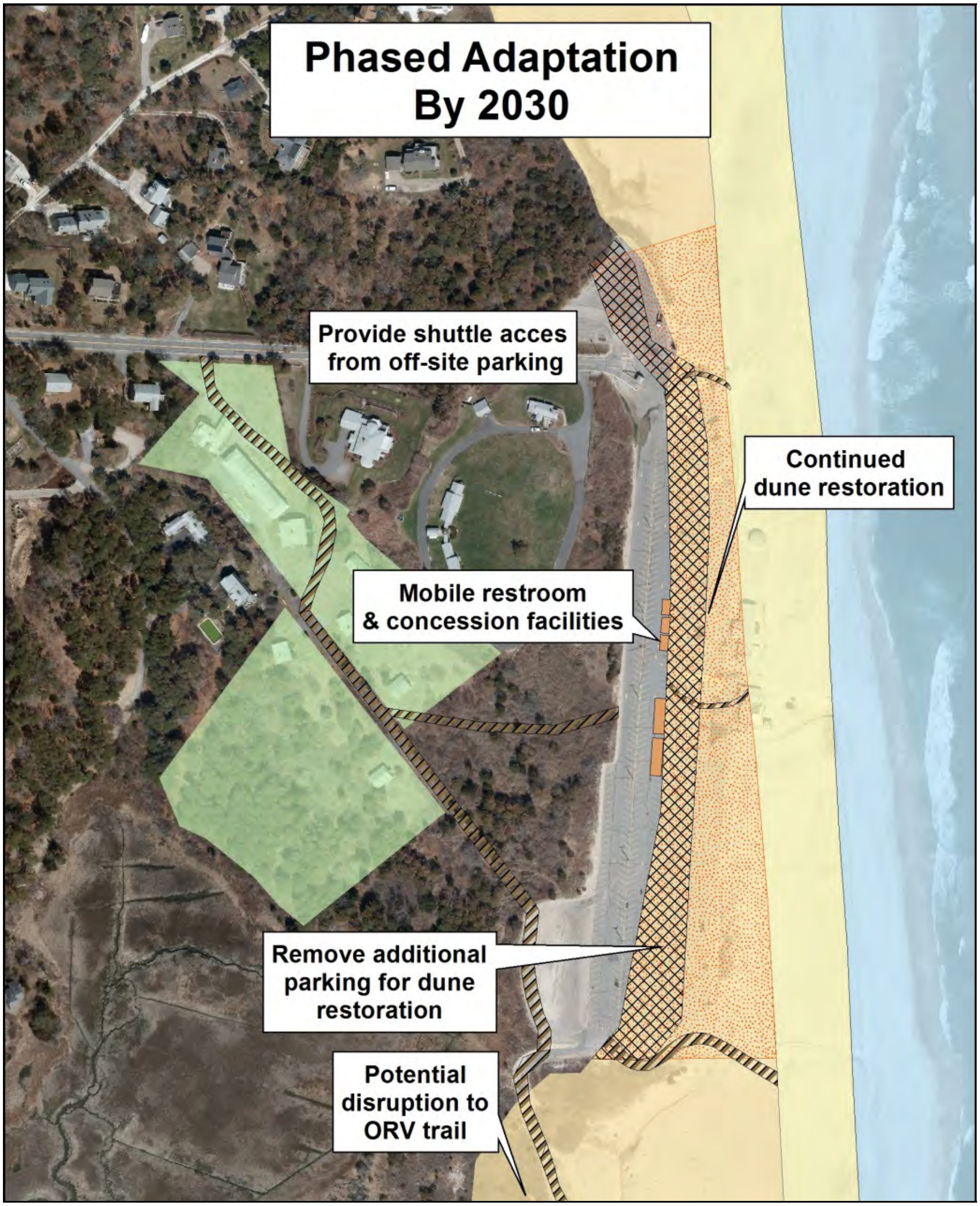

Figure 27. Phase 3 of the Proposed Retreat Plan to be completed by 2030.

3.2.4 Phase 4: 15 to 30 years

Proposed actions in Phase 4 of the retreat plan are depicted in Figure 28 and should be implemented by 2045. This is the final phase of the plan, as it completes the process of removing the parking lot and other manmade features from the dune area. All facilities, including restrooms and concessions, as well as the beach administrative offices should be moved to the 223 Beach Road location prior to 2045. This upland site can also contain some limited parking, but visitors will primarily have to park in off-site parking and the 223 Beach Road location can also serve as a shuttle drop-off and pick-up location. The main pedestrian path from the 223 Beach Road location down should be maintained, and the access path across the dunes should be adjusted annually to accommodate the shifting dune location.

By 2045, the coastal dune will have retreat landward enough that the coastal dune will likely be situated right up against the upland. This will affect the parking and facilities as described above, but it will also impact the southern ORV trail and access. By 2045, the pathway currently utilized by ORVs will likely be located in the middle, rather than behind the coastal dune. At this point, some rerouting of the trail may be necessary in order to locate the path in a more accessible and less environmentally sensitive area.

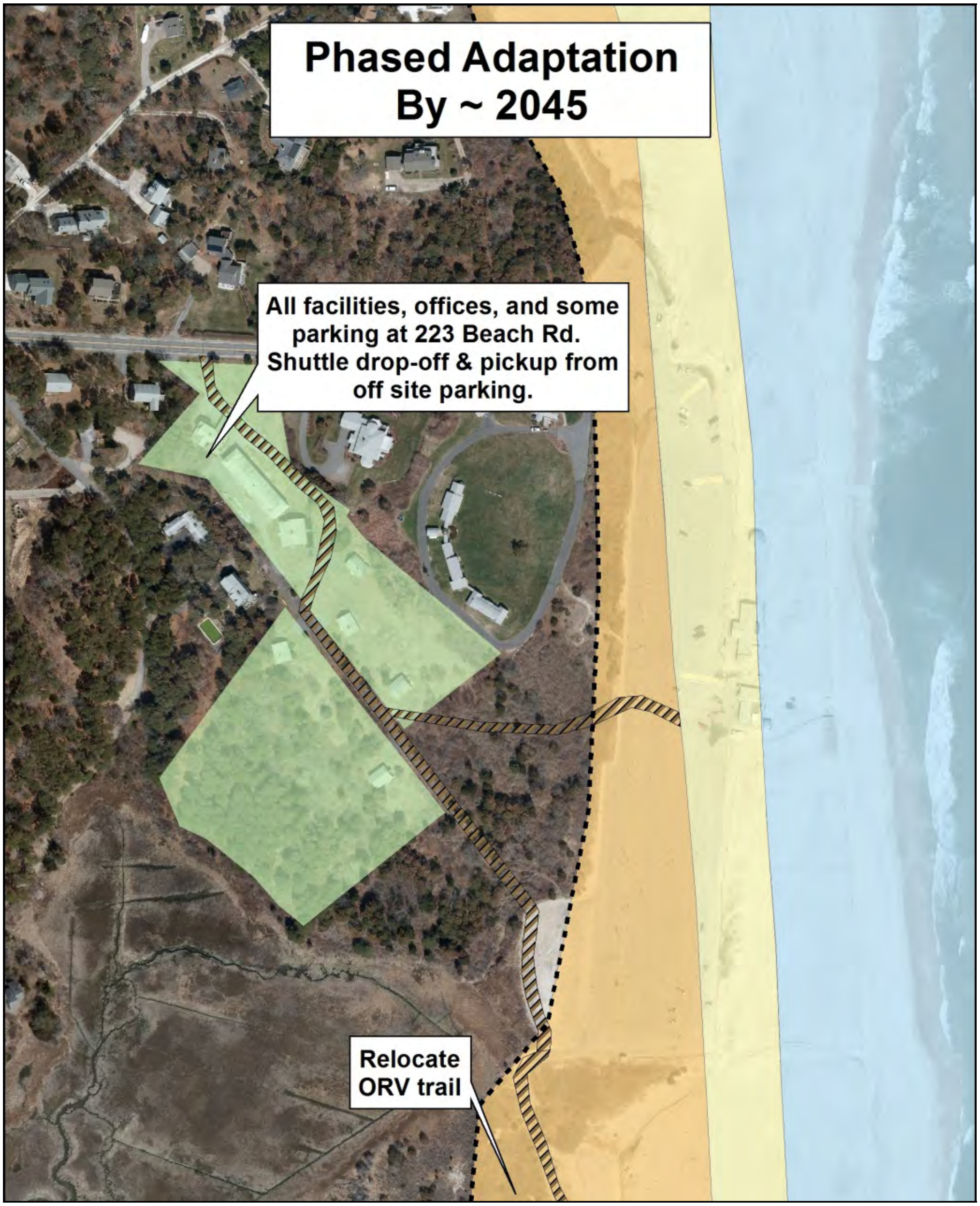

Figure 28. Phase 4 of the Proposed Retreat Plan to be completed by 2045.

3.3 COST CONSIDERATIONS

Financial planning will be required by the Town of Orleans to accomplish the plan of phased retreat. Some activities, such as reorienting the pedestrian paths and installing Mobi-mats® will be relatively low cost, while other activities, such as removing sections of the parking lot and restoring the coastal dune, will be relatively high cost. Projected costs for each of the recommended activities are listed in Table 5. Some activities, such as demolition of buildings and renting or purchasing mobile facilities, are outside the scope of this analysis, but should be taken into account as well when considering total costs for each phase of the project.

Table 5. Projected costs for the phased retreat plan.

Activity	By 2017	By 2020	By 2030†	By 2045†*
Sand fill/dune restoration	$25,000	$900,000 to $1,200,000	$1,210,000 to $1,610,000	$1,885,000 to $2,500,000
Beach grass	$3,000	$120,000	$160,000	$250,000
Mobimats	$27,300	NA	NA	NA
Permitting	$9,000	NA	NA	NA
Parking lot	NA	$25,000 to $30,000	$34,000 to $40,000	$52,000 to $63,000
Sand fencing	NA	$6,000	$8,000	$12,000
Admin. Building	TBD	NA	NA	NA
Building Demo	NA	TBD	NA	NA
Mobile facilities	NA	TBD	TBD	TBD
Total Cost	**$64,300** plus TBD costs	**$1,051,000 to $1,356,000** plus TBD costs	**$1,412,000 to $1,818,000** plus TBD costs	**$2,199,000 to $2,825,000** plus TBD costs

† Costs adjusted assuming a 3% inflation
* Dependent upon adaptive management plan

These costs do not factor in any changes to revenue resulting in the reduction of parking spaces available at the main beach parking lot, or the cost associated with acquiring an offsite parking location and running a regular shuttle service to the beach.

3.4 REGULATORY CONSIDERATIONS

Work for all proposed activities is located above mean high water. This will make the permitting and regulatory considerations easier, since none of the proposed activities will require State or Federal permits. It will be necessary however, to file a Notice of Intent application with the Orleans Conservation Commission to secure an Order of Conditions. The Notice of Intent should cover all activities included in the scope of phased retreat to ensure that the permit covers all of the necessary work. In the event the Order of Conditions is appealed and a Superseding Order of Conditions is required, it would be necessary to file an Environmental Notification Form (ENF) with the Massachusetts Environmental Policy Act (MEPA). If so, then the Town would be required to prepare an ENF in order to get a Certificate from the Secretary of Energy and Environmental Affairs and obtain a Superseding Order of Conditions. Expected costs for the Notice of Intent application are indicated in Table 5.

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