Delaware Annual Beach Change Report:

Bay Coast

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Abbreviations:

Cubic Feet per Linear Foot (Volume per unit Length) – cf/lf

Delaware Department of Natural Resources and Environmental Control – DNREC

Global Positioning System – GPS

Long-Range Planning – LRP

Mean Higher High Water – MHHW

Mean Higher Water – MHW

Mean Low Water – MLW

Mean Lower Low Water – MLLW

NAVD – North American Vertical Datum

Real Time Kinematics – RTK

Shoreline and Waterway Management Section – Section

United States Army Corp of Engineers – USACE

Definitions:

MHHW – The average elevation reached by the higher of the two daily high tides over a 19-year tidal epoch. The value is computed by and available from NOAA.

MHW – The average elevation reached by all the high tides over a 19-year tidal epoch. These elevations exclude any storm surge or non-tidal residuals caused by onshore winds.

MLW – The average elevation reached by all the low tides over a 19-year tidal epoch.

MHHW – The average elevation reached by the lowers of the two daily low tides over a 19-year tidal epoch.

Dune – Natural or man-made geological feature that is shoreward of the berm and is characterized by a steep slope to the highest elevations along the beach profile.

Berm – The relatively flat portion of the beach profile directly seaward of the dune that is typically above the MHHW elevation.

Foreshore Slope – The foreshore slope is the natural slope directly seaward of the berm that is causes by tides and up rushing waves.

Intertidal Zone – The portion of the foreshore slope and nearshore that is between the MHHW and MLLW elevations.

Nearshore – For the purposes of this report, the nearshore is considered to extend from the lower portions of the intertidal zone out beyond the surf zone where waves break but onshore of most boating traffic.

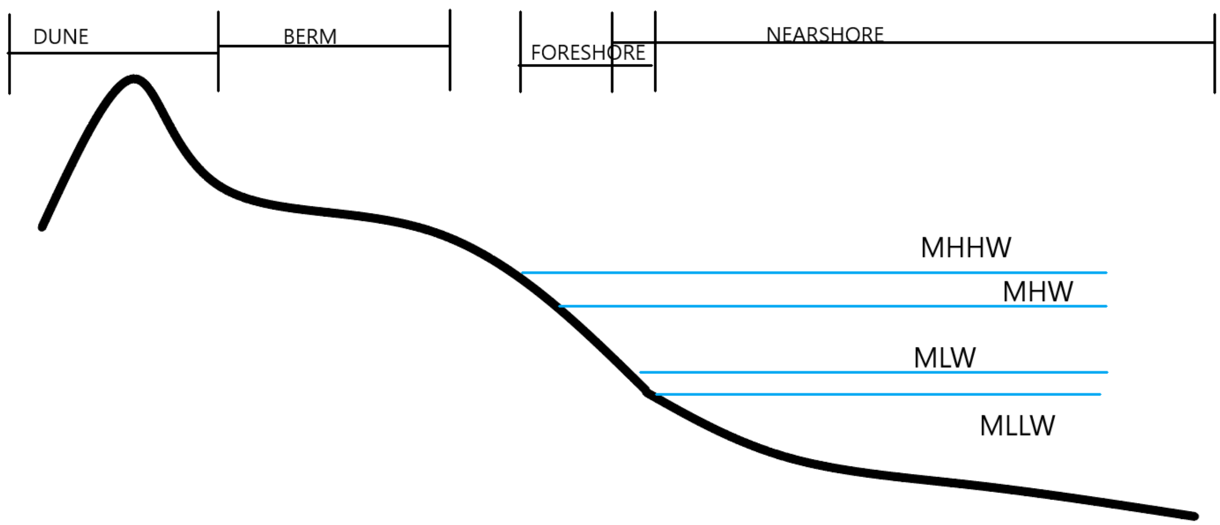


Figure 1: Beach profile definitions sketch

Introduction:

DNREC envisions Delaware as a place where people embrace a commitment to the protection, enhancement, and enjoyment of the environment in their daily lives. The Shoreline and Waterway Management Section works to maintain and improve Delaware's shoreline and waterways. The Section manages the shoreline through regulation of coastal construction activities and implementation of dune and beach management practices. It also works to protect and enhance eroded beaches to enable continued recreational use of this precious resource, and to improve the state's ability to endure severe coastal storms with minimal damage to public and private property and infrastructure.

Each winter and summer, the Section's survey crew measures the beach (berm, dune, and nearshore bathymetry) along the bay beaches. Bathymetry data are collected out to a wading depth. The crew measures 39 profiles or transects along the Bay Coast from Cape Shores to Pickering Beach using a RTK Trimble System paired with GPS. This system tracks the location and elevation of the ground where data points are collected. Comparisons between winter and summer surveys demonstrate how beaches change seasonally. Comparisons between summer surveys year-to-year demonstrate long term erosion or accretion trends along Delaware Beaches. These trends are used to track shoreline and beach change, as well as plan and monitor shoreline management projects.

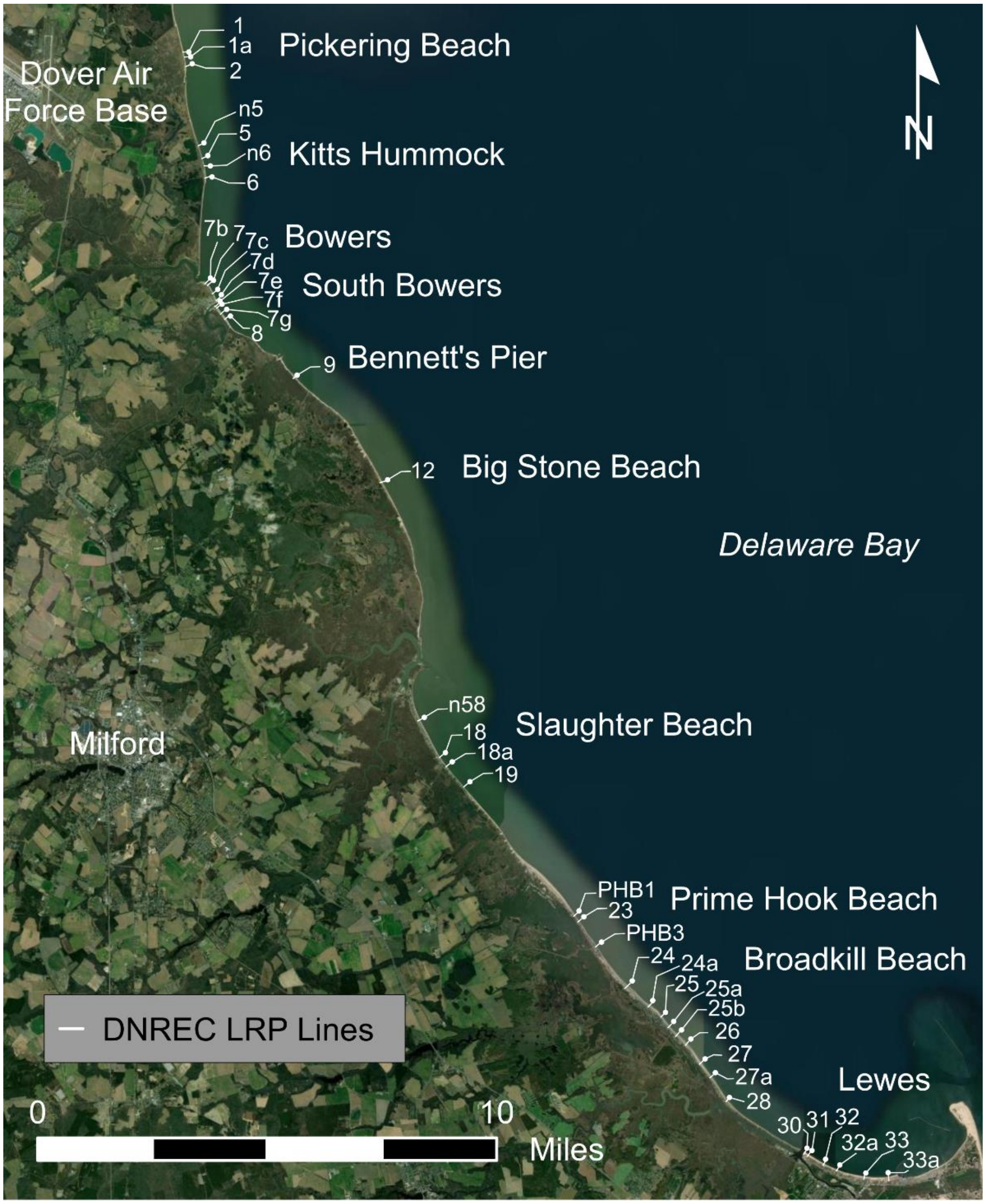


Figure 2: Bay coast LRP location map

The purpose of this report is to share the results of these surveys and provide perspective on what causes the changes that are observed. Survey data are paired with photographs of the beach at each survey location so that the reader may see the changes in the beaches and dunes from season to season. Information about recent storms and nourishment projects which impact beach erosion and accretion, respectively, are also described. Narratives and tables describing recent natural beach changes and nourishment, as well as the annual beach change are provided for each community along the bay. Beaches as defined in the Beach Preservation Act of 1972 from Pickering Beach, south, fall within the Section's jurisdiction. Beach changes are not reported for Cape Shores and Big Stone Beach owing to a lack of survey data in recent years.

Geology of the Delaware Bay Coast

Introduction to Delaware Bay's Coastal Environments

Beaches are just one part of the coastal environment of the Delaware Bay. These beaches include bay beach communities from Pickering Beach to Cape Shores and include unpopulated areas such as Bennett's Pier. Bay barriers are long, linear bodies of sand and gravel along portions of the Delaware Bay coast. Bay barriers contain a beach berm and often low dunes, and sandy flats called washover fans. Landward of the barriers are marshes and tidal creeks which, like the bay barriers, provide habitat for coastal wildlife.

Delawareans and our visitors value beaches not only for the beaches' recreational and ecological value, but also for the coastal communities. Humans—and the coastal communities and infrastructure they build—represent another component of Delaware's coastal environment.

While this report focuses on the beaches and dunes of Delaware Bay, it is important to emphasize that the entire coastal system is connected through geologic processes, oceanographic processes and human actions. Therefore, when change occurs to beaches and dunes it may impact nearby wetlands, tidal flats, and/or coastal buildings and communities. In turn, coastal construction along with natural or human-induced changes to wetlands and tidal flats may impact beaches and dunes. Coastal structures impede the movement of sand and developed lands restrict the natural migration of barrier beaches during rising seas and storm tides. Because of these impacts, regulations in the Beach Preservation Act were developed to balance preservation and development pressures along Delaware's beaches.

Delaware Bay Barriers: Geologic History and Formation

Delaware's bay barriers and their beaches and dunes formed thousands of years ago. As glaciers in present-day New England and New York starting melting around 20,000 years ago, sea levels rose. The former creeks, rivers, and low-lying uplands began to fill with water, forming the Delaware Bay and other estuaries. in the Delaware Bay, waves eroded small cliffs and other sandy geologic layers, forming small beaches. Eventually, the continued wave action and tides moved sand along and across the coast, built sand and gravel bay barriers, and deposited mud in wetlands and tidal flats. As sea level continued to rise, the entire system shifted continuously landward as large waves naturally pushed sand overtop of the bay barriers, moving sand from the beach and dune landward [1]. Through this process called overwash, the entire bay barrier eventually moved landward and overtopped marshes and tidal flats. Similarly, tides flowing through inlets allowed sand to move from the seaward side of a bay barrier to the landward side, where flood tidal delta shoals formed. These sandy shoals allowed sand to be "recycled" within the bay barrier through time.

The past informs our present understanding of the bay beaches. Not only do the same geologic processes occur today, but past geologic deposits and layers influence the amount of sand and gravel available to modern bay beaches. A geologic cross-section from Port Mahon to Broadkill Beach **(**Error! Reference source not found.**)** provides a generalized overview of the geology of some of the Delaware Bay barriers [2]. The oldest geologic units are former hills and necks (Pleistocene; shallowest deposits 80,000 to 120,000 years old [3]) primarily consisting of gravel and sand. Above these former hills and necks—and often located in former creeks and river valleys—are muds (silt, clay) and peat (marsh roots, rhizomes, and inorganic mud) formed as sea level rose in Delaware Bay. The bay barriers themselves sit over top of these older units and are typically made of sand and gravel. The erosion of the underlying hills and necks naturally feeds sand and gravel to some of the bay barriers. For example, in many locations the Pleistocene sand and gravel deposits are exposed on the shoreface where waves break (surf zone), transporting sediment towards the beach and/or along the coast in the same ways it has happened for thousands of years.

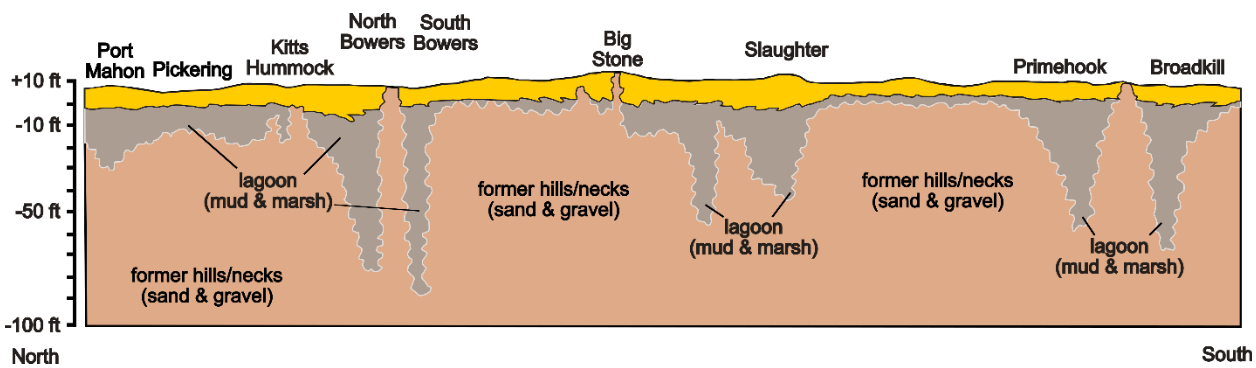


Figure 3Geology of the Delaware Bay coast from Port Mahon (north) to Broadkill Beach (south). Modified from French, 1990

Additional sources of sand/gravel to Delaware's bay beaches include: 1) transport of sand around Cape Henlopen (prior to the 20th century); 2) minor contributions from the Atlantic Ocean continental shelf; and 3) recycling of sand from the shoals of former inlets. The third is the largest additional source. In this case, the sand from shoals deposited by former inlets is slowly eroded and transported towards and/or along the beach. While sand moved by waves along the coast from one beach to another (longshore transport) is not a new source of sediment to the Delaware Bay coast, it can represent an important source of sand for individual beaches [1].

Typical Seasonal to Annual Beach Change

Storm-driven erosion and wave-overtopping (overwash) control seasonal-to-annual-scale beach change on the Delaware Bay barrier beaches. As such, shoreline change is episodic. Increases in storm frequency and intensity increase the likelihood of beach erosion [2]. Typically, nor'easters cause the most annual erosion on Delaware's bay beaches. Hurricanes are less frequent and more transient but may also induce shoreline change and erosion. Energetic waves and storm surge cause storm-driven erosion and overwash, resulting in fall and winter beach profiles that typically include upper beach face erosion and dune scarping. In the spring and summer, calmer waves and less frequent/intense storms commonly result in beach accretion **(**Figure 4**)**. However, some beaches may not fully recover between seasons [1]. In fact, insufficient seasonal beach profile recovery is common on many estuarine beaches around the world [4].

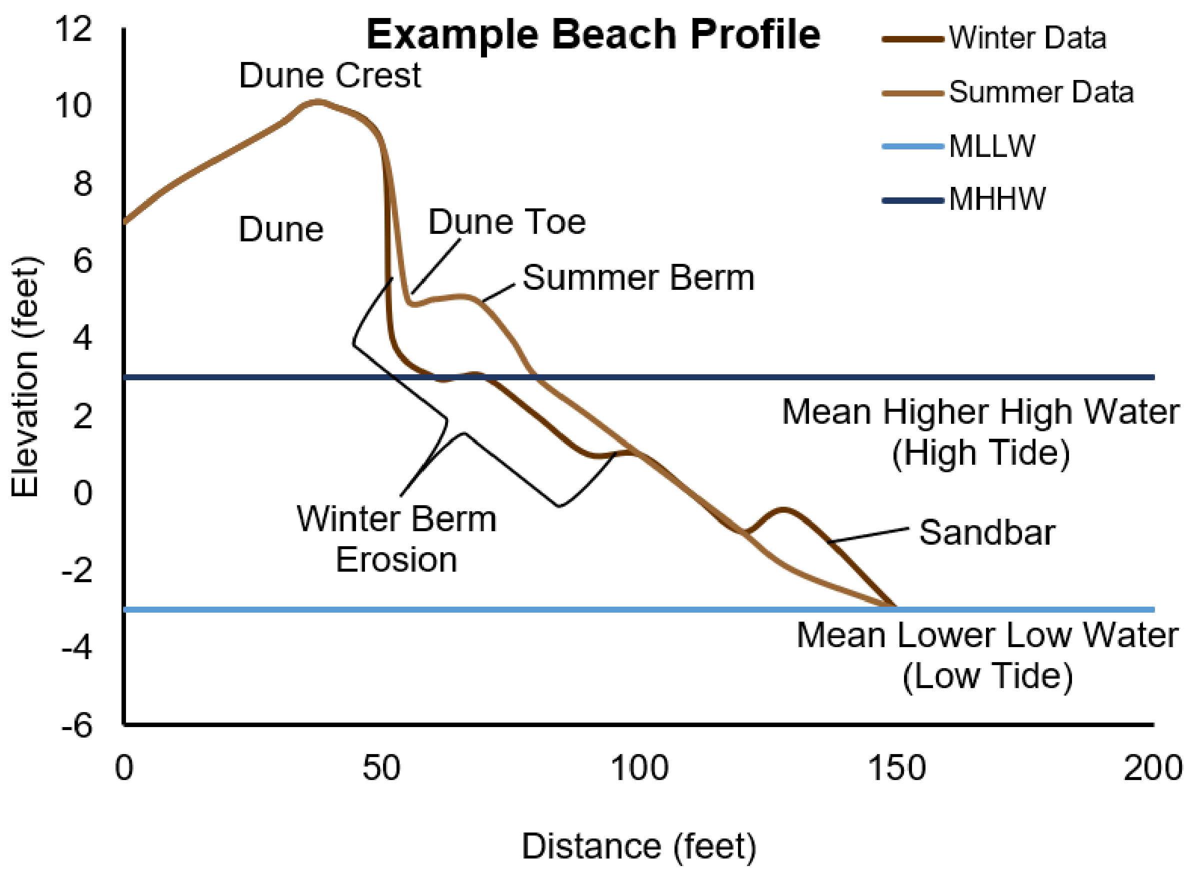


Figure 4: Example of summer and winter beach profiles, including key features observable in some of the real profiles below.

Sources:

[1] Maurmeyer, E.M., 1978, Geomorphology and evolution of transgressive estuarine washover barriers along the western shore of Delaware Bay, University of Delaware, Unpublished Doctoral Dissertation

[2] French, G.T., 1990, Historical shoreline changes in response to environmental conditions in West Delaware Bay, University of Maryland, Doctoral Dissertation, http://hdl.handle.net/1903/16876

[3] Ramsey, K.W., 2003, Geologic Map of the Lewes and Cape Henlopen Quadrangles, Delaware, Delaware Geological Survey, Geologic Map Series No. 12, https://www.dgs.udel.edu/sites/default/files/publications/geomap12.pdf

[4] Harris, D.L., Vila-Concejo, A., Austin, T. and Benavente, J., 2020, Multi-scale morphodynamics of an estuarine beach adjacent to a flood-tide delta: Assessing decadal scale erosion, Estuar. Coast. Shelf Sci., 241, https://doi.org/10.1016/j.ecss.2020.106759

Description of 2021-2022 Season

Throughout the months of October and November, there were Nor' easter storms or steady east winds, that impacted the Delaware Bay coastline. These storms and east winds kept water levels higher than the tide-based predicted levels. East winds and storms push water towards the coast, elevating water levels, which is referred to as storm surge. The combination of the storm surge and astronomical tide determines the water levels along the coast and is referred to as storm tide. Nor' easters and long-duration east/northeast winds create a storm surge that may last for several tide cycles. Tropical storms and hurricanes, on the other hand, produce a storm surge that lastsseveral hours rather than tide cycles. Therefore, if the surge impacts the coast at low tide, the storm tide elevation may not cause flooding or major erosion. The duration of Nor'easters makes them more destructive from a beach erosion perspective than some tropical storms.

According to the measured water levels at the Brandywine Shoal gage (Figure 5), the water levels were at least 0.5' higher than predicted throughout all of October and into the beginning of November. In mid and later October, there were stronger storms that caused surge greater than 2' lasting over several tide cycles. These fall events lead to erosion of the upper berm and dunes along most the bay beaches. The water levels shown in Figure 5 are measured relative to Mean Higher High Water (MHHW), which is the approximate water level during high tide on any given day.

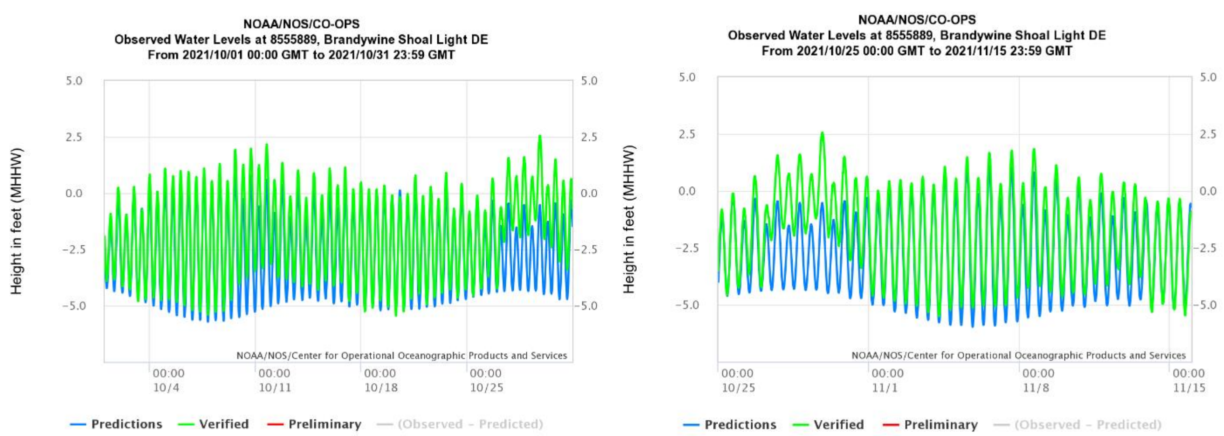


Figure 5: Measured (green) vs. Predicted (blue) water levels at the Brandywine Shoal Light from 10/01/2021 to 11/15/2021

In addition to these Nor' easters, there was a low pressure system that caused storm surge and flooding in Sussex County at the end of May 2021. According to NOAA's National Centers for Environmental Information (NCEI) storm event database, there were a total of four coastal flood events in Delaware in 2021. The only storm to produce widespread coastal flooding in Kent County according the NCEI database occurred on 10/29/2021:

> **Strong high pressure located in eastern Canada and slow-moving low pressure approaching from the southeastern states resulted in a prolonged onshore flow along the Middle Atlantic coast. Moderate to major flooding occurred in the tidal areas of Delaware on the afternoon and evening of October 29. Widespread moderate flooding occurred in the tidal areas of Kent County. There were many road closures with the flood waters affecting numerous homes and businesses.**

The storm surge associated with this event was about 3'. This led to water levels that were as high as 2.6' above MHHW. The Section's Staff visited the beaches to assess beach conditions following some of these storm events as well as an event on 11/05/2021. The observations of beach erosion will be described in the subsections for each beach below.

Lewes Beach

Lewes Beach is a public beach that extends from the Roosevelt Inlet to the Cape May Ferry Terminal. It is densely developed and consists of six survey lines. This segment of coastline is about 11,000 feet or two miles. Survey lines are spaced relatively evenly, except for two that are closer together near Roosevelt Inlet. For planning purposes, DNREC has divided the beach into three segments for planning purposes: proximal to the Roosevelt Inlet (LRP 30 and 31); center of developed shoreline (LRP 32 and 32A); center of community to the Cape May/Lewes Ferry terminal (LRP 33 and 33A).

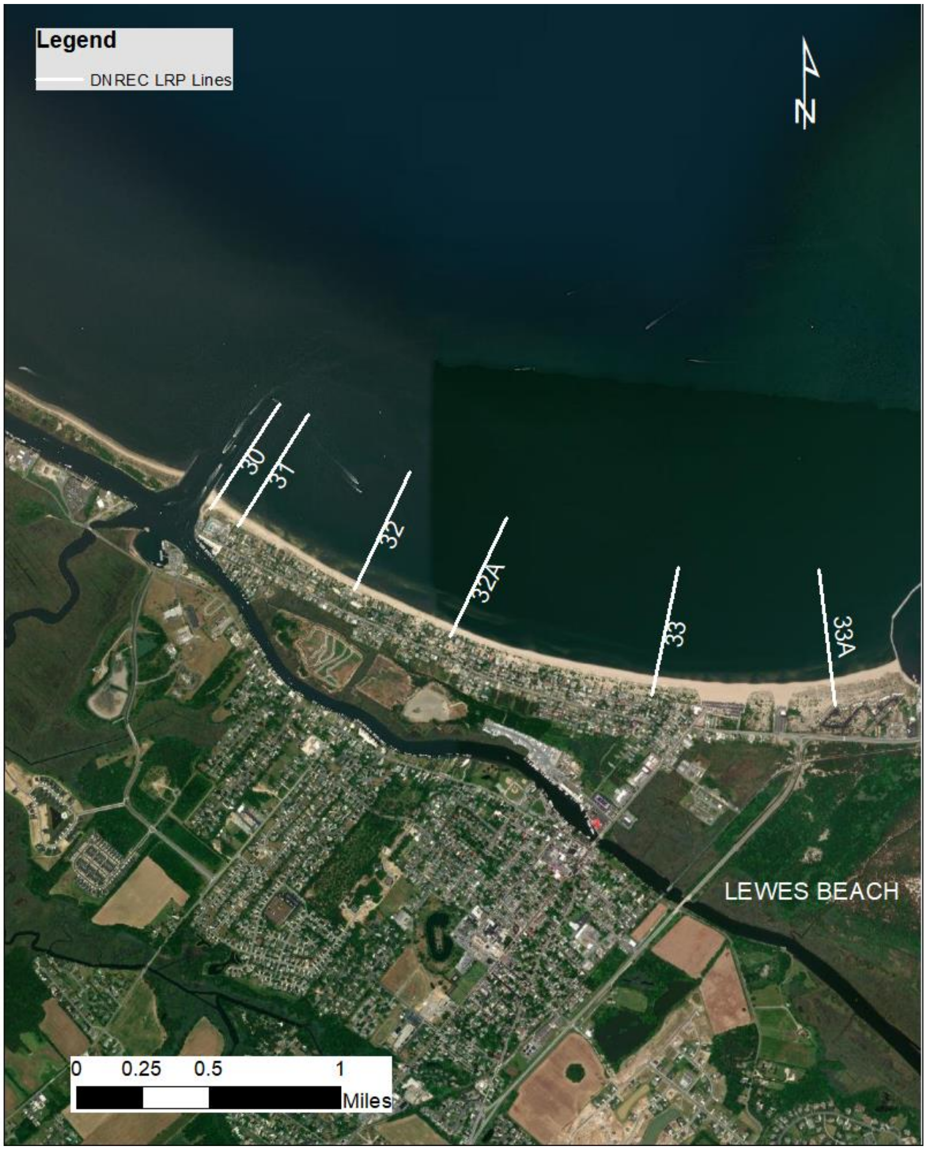


Figure 6: LRP location map in Lewes

Lewes Beach Volumes:

The average beach volumes of Lewes Beach are as shown in the table below. Beach volume is the amount of material of the beach above a reference water level, 0' contour in this case, from the landward limit of the dune to the 0' contour. Volumes are calculated along 1-Dimension profiles and are reported as cubic feet per linear foot of beach length (cf/lf). Two volumes are presented because sediment accretes and is sheltered by the jetty at the west end of the beach. The volume on the left is the average volume from LRP 30 and 31 whereas the one on the right is from LRP 32 and 33. The beach volume is greater in the winter season which is unexpected based on summer/winter profile theory, as seen in Table x. Over the past 20 years, the MHW shoreline of Lewes Beach has retreated 0-2 feet per year, on average. As seen in Table 1, the beach volume has been eroding since the summer of 2020 and has not fully recovered during calm summer months.

Based on volume calculations, the beach eroded during the winter of 2021. Some of the eroded volume was recovered near the jetty during the summer of that year. Oddly, there is more volume in the beach profile on average following the stormy fall of 2021. These volumes are correlated to the level of protection from coastal flooding that the beach provides as waves energy is dissipated in the intertidal zone and the upper reaches of the profile (berm and dune) prevent inland flooding.

Table 1: Average beach volumes in Lewes Beach

Season	Volume (cf/lf)
Summer 2020 (06/15/2020)	1230, 950
Summer 2021 (08/18/2021)	1190, 780
Winter 2021 (01/21/2021)	1160, 950
Winter 2022 (01/04/2022)	900, 750

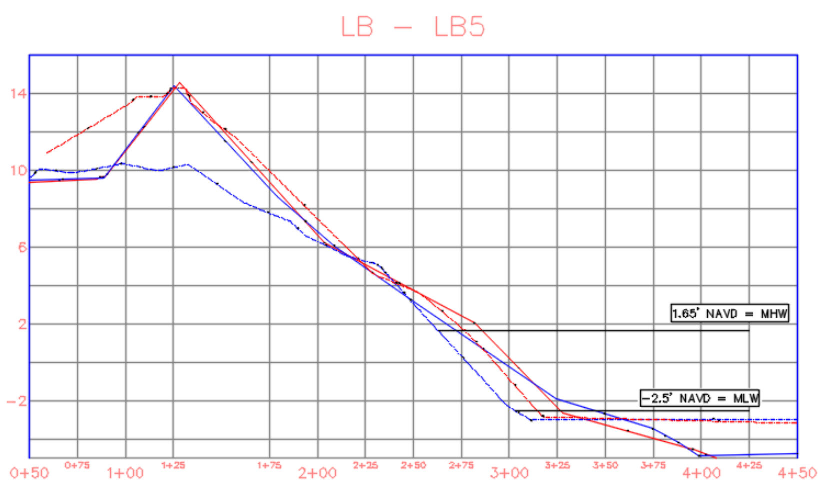


Figure 7. Beach profiles at Lewes Beach. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

The representative plot displaying LRP 33 (Figure 4) demonstrates the seasonal variability of the beach profile at Lewes Beach. The shoreline position, which is represented by the intersection of the Mean High Water (MHW) with the profile, retreated in the fall of 2020 by about 14'. The movement of the recovered, summer, shoreline was about 20'. This indicates the shoreline recovered to a position seaward of the previous summer's increasing the beach width by 6' at this location. The fall storms of 2021 appear to have eroded the beach and the upper tidal zone while depositing the eroded sand in the lower tidal and nearshore zones. Based on the recovery during the previous year, it may be the case that the beach naturally recovers from the fall storms.

A representative photo of the conditions at Lewes Beach along LRP 31 is shown below; the remaining pictures are contained in Appendix A-2. It can be seen in the photo that the dune is scarped, and the beach width varies along the coast. It is most narrow in a segment that is roughly 500’ east of the Roosevelt Inlet.

LRP 31 (Lewes Beach West):

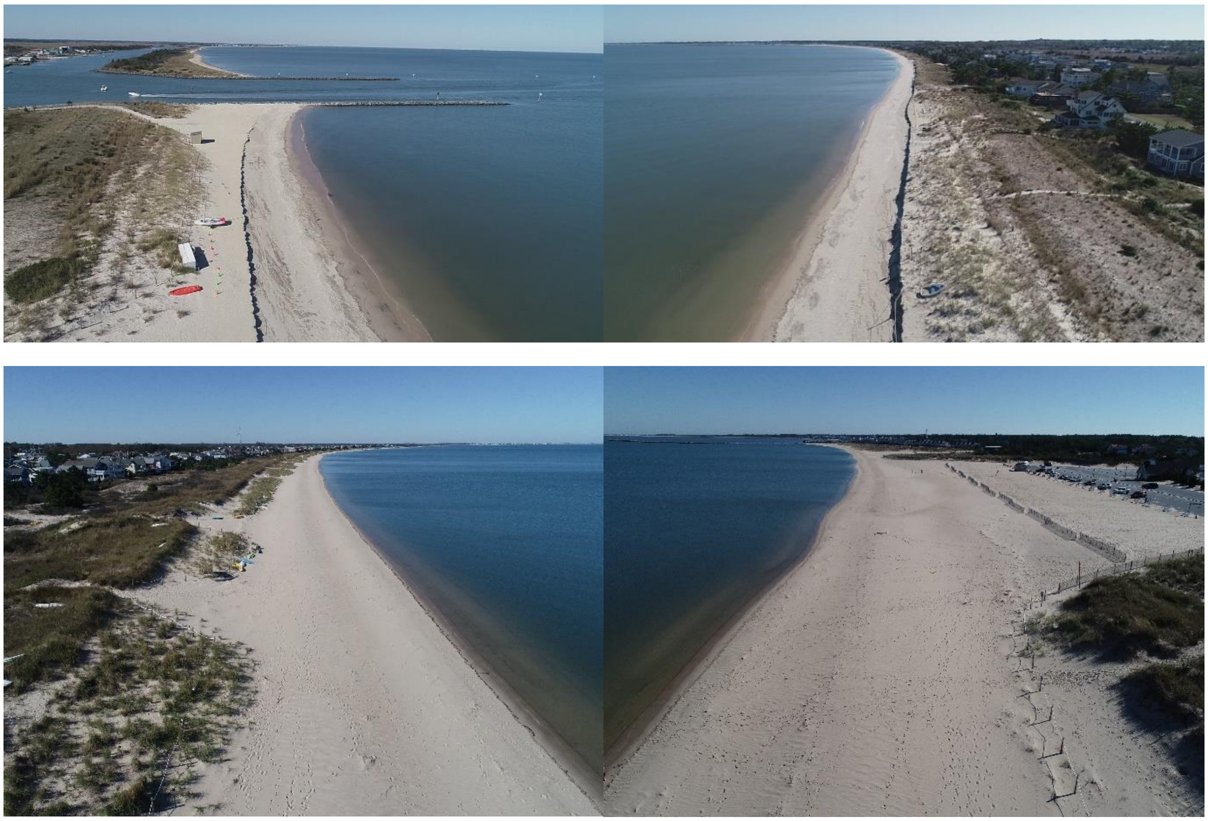


Figure 8: UAV image of Lewes Beach facing the Roosevelt Inlet (left) and middle of the community (right) taken on November 4th, 2020. The top two images were taken at the west end of the community while the bottom were taken on the eastern end.

The Section’s crew responded to one storm surge event that impacted Lewes Beach on 10/09/2021.this response occurred between the Summer 2021 and Winter 2022 surveys. There was significant scarping on the dune near the Yacht Club (about 23’ retreat) and erosion behind the dune fence south of the Yacht Club (Figure 7, left). There were no significant impacts to the beach at Delaware Ave (Figure 7, right). The highest wrack line was near the seaward edge of the dunes. The response of the beach to the October storm and the condition of the beach in the fall of 2021 indicates that the dune on the western end of the community is more vulnerable to erosion than elsewhere.

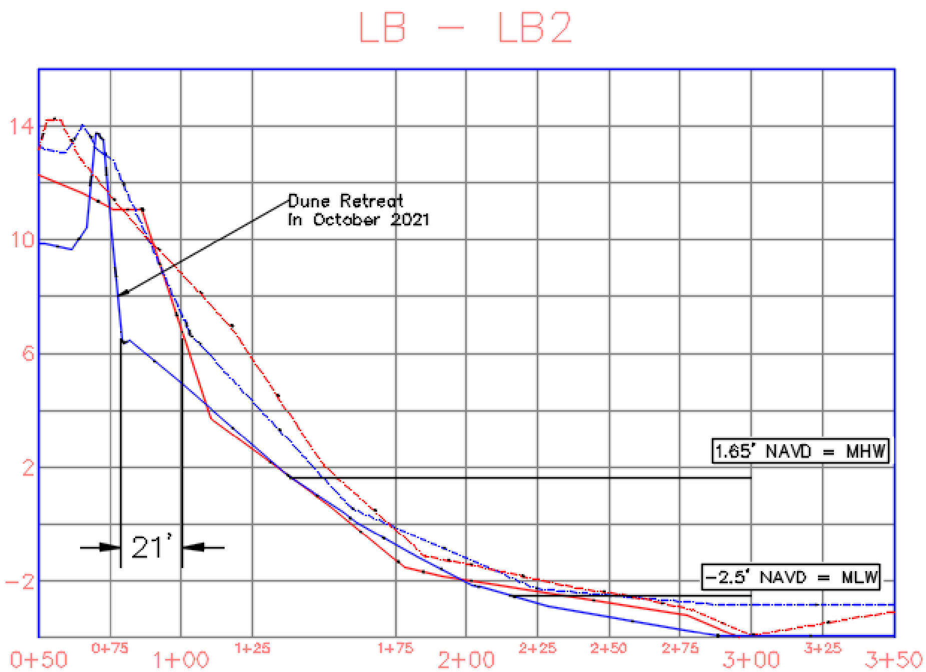


Figure 9: Profiles at LRP 31 demonstrating dune erosion between summer 2021 (solid red) and winter of 2022 (solid blue).

Figure 10: Scarped dune at the western end of town (left) and the intact dune profile in the center of the town (right) following an October 2021 storm.

Broadkill Beach

Broadkill Beach is situated between Lewes Beach and Prime Hook Beach. It is roughly 16,000' or three miles in length and includes nine survey lines. Survey lines are spaced roughly 2,000' at the south end of the community and 1,500' in the more developed northern end of the community. In 2016/2017, the USACE placed 1.7 million cubic yards (cy) of sand dredged from the Delaware River onto Broadkill Beach to widen the beach by 150' and to add a dune with a crest of 15-16'.

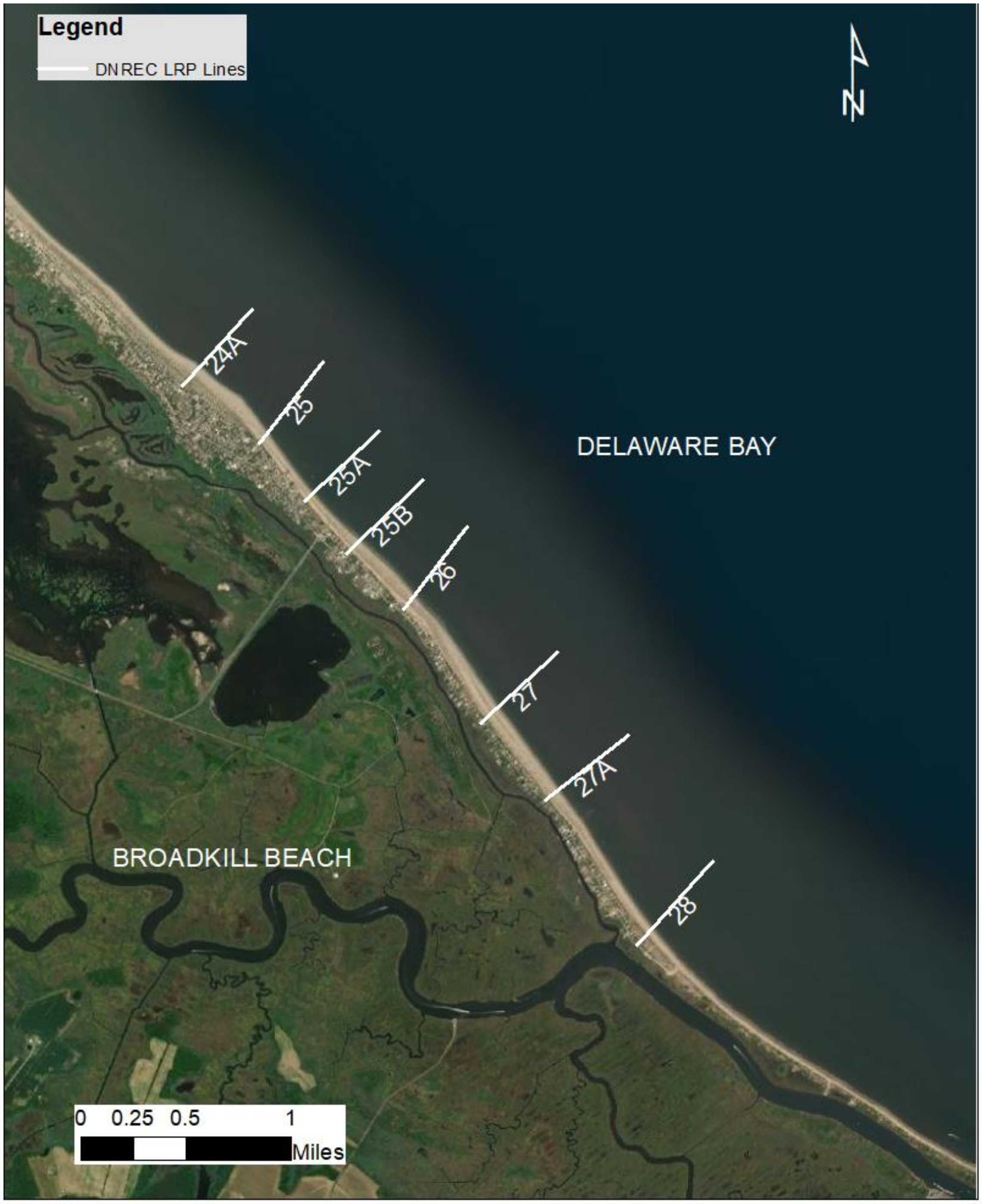


Figure 11: LRP location map in Broadkill Beach

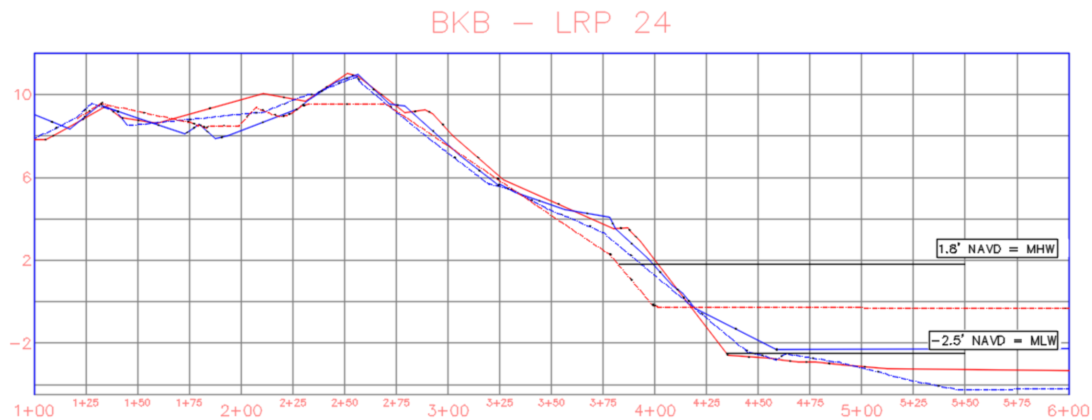


Figure 12. Beach profiles in northern Broadkill Beach. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

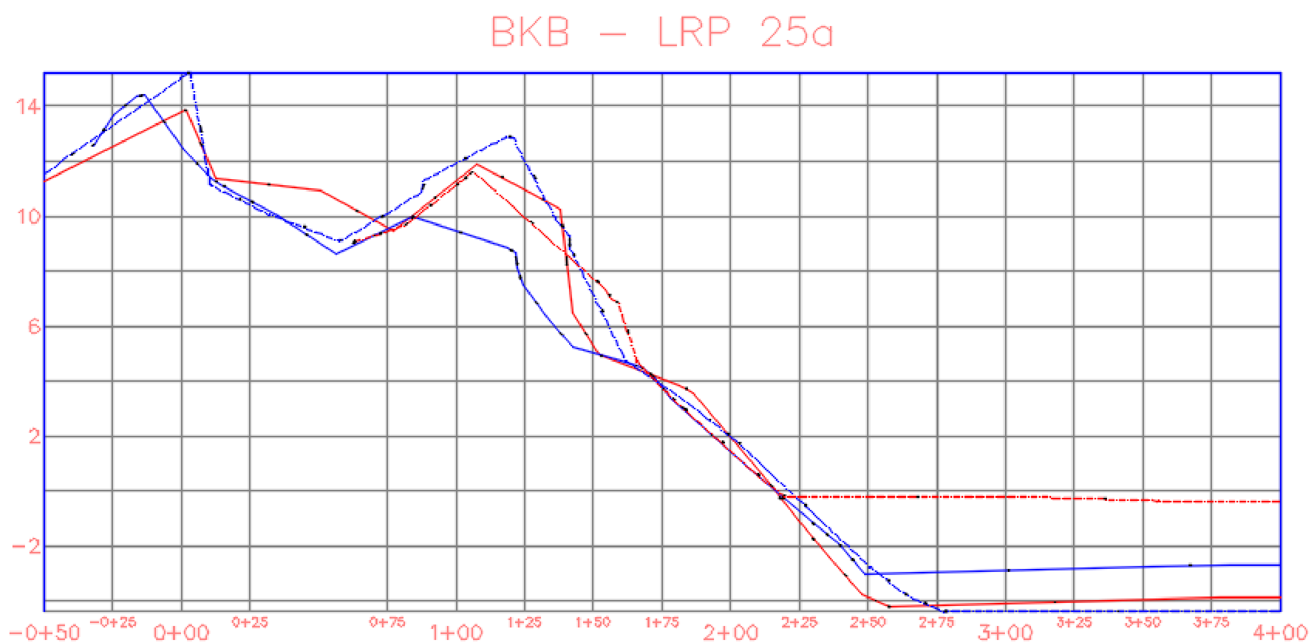


Figure 13 Beach profiles at Broadkill Beach near the dune crossing at Route 16. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid). The dune has experienced substantial erosion.

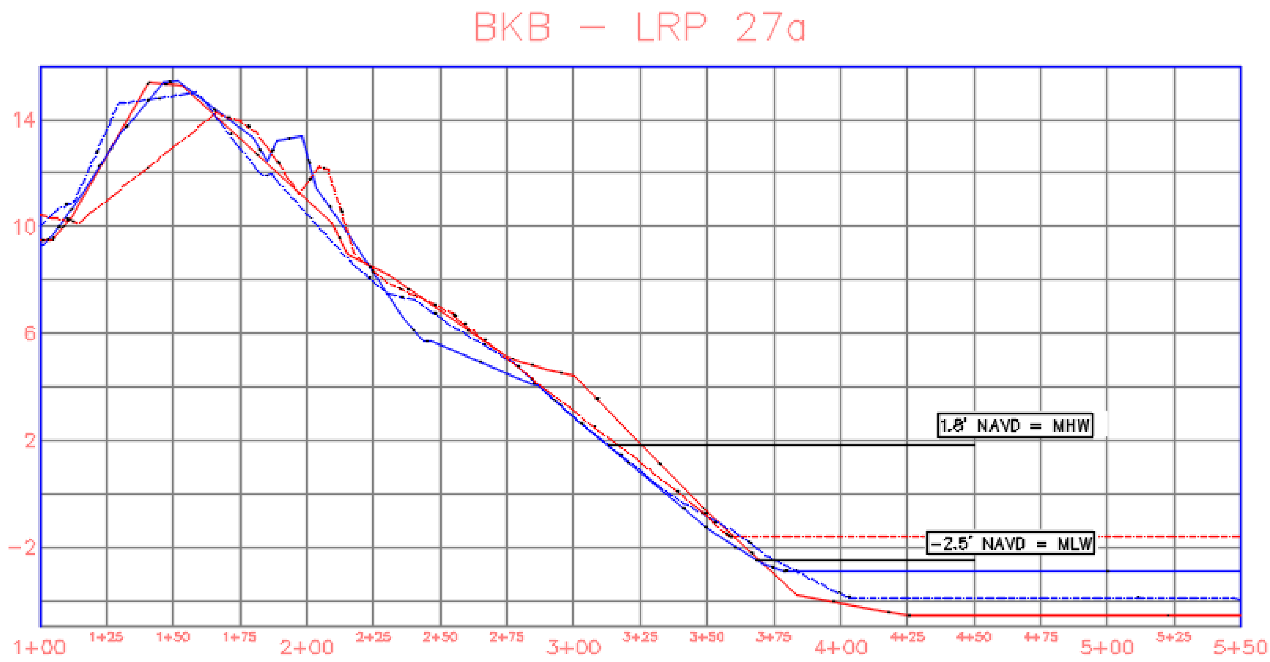


Figure 14: Beach profiles in southern Broadkill Beach. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

Broadkill Beach Volumes:

The average beach volumes of Broadkill Beach are shown in the table below. The beach volume changes only slightly from season to season. The greatest volume reduction between Summer 2021 and Winter 2022 occurred during the stormy fall of 2021. The large-scale nourishment project greatly impacted the shoreline and the morphology thereof. After the 2016/2017 nourishment project, the shoreline accreted at the north end and has maintained its position at the south end. In the middle of the community, the shoreline retreats from 9 – 18 ft/yr, on average, with the most rapid retreat being located along LRP 25B, which is closest to the main beach access adjacent to the end of Rt. 16. There is an erosional hotspot at the Rt. 16 access point. The alongshore variation in retreat rates suggests that the orientation of the beach fill plan was not in equilibrium with the hydrodynamic forces along Broadkill Beach.

On average, approximately 100 cubic feet of sand per linear foot, have eroded within the survey extents since Summer 2020. It has yet to be determined if the beach recovers to some degree, over the calmer spring and summer seasons.

Table 2: Average beach volumes in Broadkill Beach

Season[1]	Volume (cf/lf)
Summer 2020	1190

[1] See Lewes Beach table for dates of survey.

Summer 2021	1285
Winter 2021	1235
Winter 2022	1215

A representative photo of Broadkill Beach is presented below. Other photos of Broadkill are reported in Appendix A-2.

Broadkill Beach (LRP 26):

The Section's crew responded to three nor' easter events in October (10/09 and 10/26) and November (11/05) of 2021. At the Rt. 16 crossing, the scarping of the dune was exacerbated by this event; the scarp was approximately 2-3' tall and the geotextile fabric was further exposed (left). Along S. Bayshore Drive southward of Bayfront Road, the foredune on the berm was partially eroded but the berm and primary dune remained in good condition. The storm event in late October caused severe erosion at the Rt. 16 crossover (left side, bottom). The beach retreated along S. Bayshore Drive (right side, bottom). The event in November was not as erosive/destructive as the event in late October.

Figure 15: Beach and dune erosion in the middle portion of Broadkill Beach

Prime Hook

Prime Hook is directly north of Broadkill Beach and is approximately 10,000 feet long. It is a densely developed private beach and contains three survey lines.

Figure 16: LRP survey lines in Prime Hook

Prime Hook Volumes:

The average beach volumes of Prime Hook Beach are shown in the Table x, below. According to the changes in shoreline position in LRP data over the past 20 years, Prime Hook's shoreline retreats roughly 1 ft/year. Approximately 60 cubic feet per linear foot along the beach has been accreted within the survey extents between summers. However, the winter profile volumes also demonstrate accretion between the two winter seasons (10 cf/lf). This is likely attributable to the stormy Fall of 2021. The shoreline position is stable from season to season, as the few feet retreat in the winter profile recovers in the summer.

Table 3: Average beach volumes in Pickering Beach

Season	Volume (cf/lf) [1]
Summer 2020	810
Summer 2021	870
Winter 2021	810
Winter 2022	800

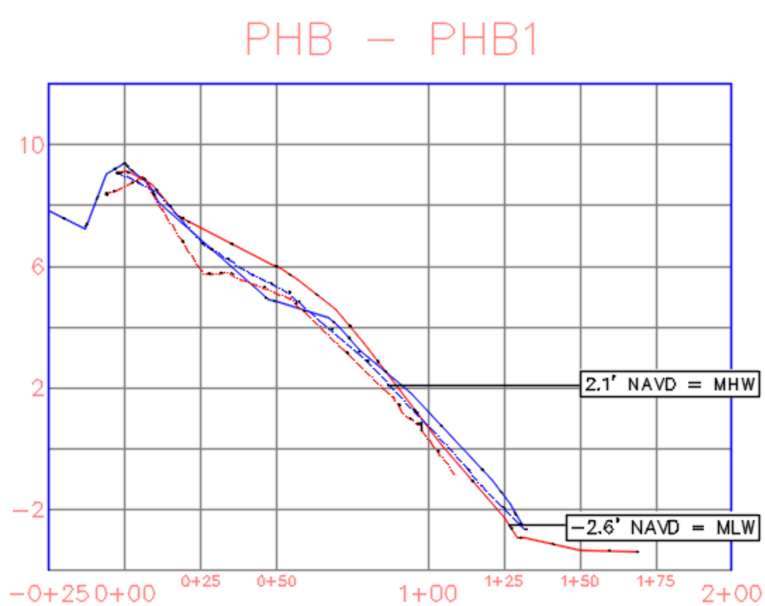


Figure 17. Beach profiles at Prime Hook Beach. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

It can only be assumed that Prime Hook was impacted by the nor' easters that occurred in October and November of 2021 due to the impacts seen at other locations because Prime Hook was not monitored during that time.

Slaughter Beach

Slaughter Beach is directly north of Prime Hook and contains five survey lines. It is roughly 16,000' or about three miles in length. Not all five lines were surveyed every season, therefore, the four lines that were surveyed are used for the calculations.

Figure 18: LRP locations in Slaughter Beach

The survey data indicate little seasonal variability and little annual change. On average, the beach lost 20 cf/lf of volume during each of the past two falls/winters with 10 cf/lf of material returning in summer of 2021. According to the 2015 Delaware Bay Beach Verification Report, Slaughter Beach's shoreline advances by about 3-10' in the northern end, at the municipal boundary and Evans Drive. The shoreline retreats at Slaughter Beach Road and N. Delaware Ave, with peak erosion of 12 feet at N. Virginia Ave. The longshore variability is likely attributable to the curvature of the shoreline. These shoreline change rates and alongshore trends are well supported by LRP data in recent decades. Based on the LRP survey, there has been negligible retreat from summer of 2020 to the winter of 2022 (about 4').

Table 4: Average beach volumes in Slaughter Beach

Season	Volume (cf/lf)
Summer 2020	810
Summer 2021	800
Winter 2021	790
Winter 2022	780

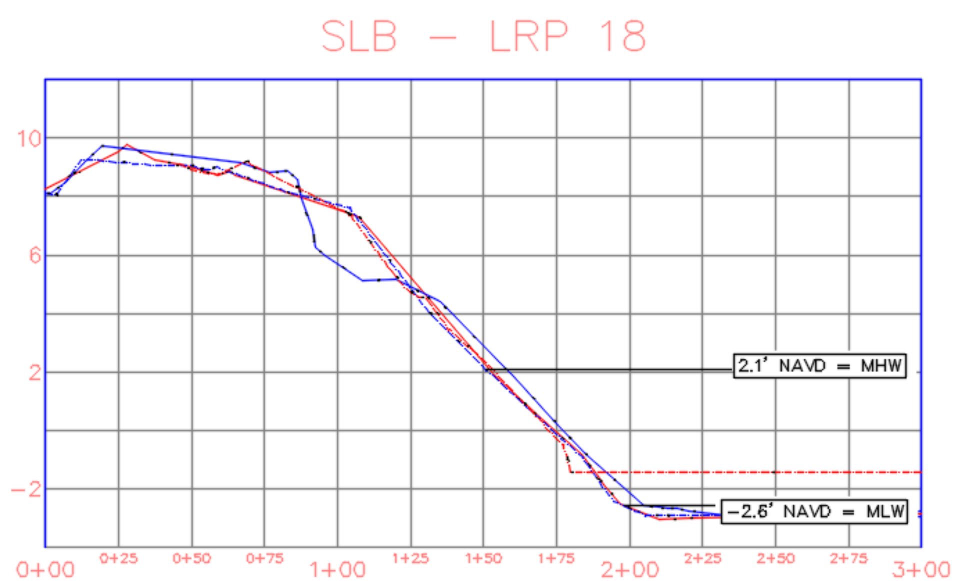


Figure 19. Beach profiles at Slaughter Beach. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

The nor' easter that occurred in early October caused the tide to reach the seaward edge of the dune, which induced a small scarp in the dune and caused erosion of the berm. The scarping of the dune was less stark near the center of the community at LRP 18. Further south, the upland terrain is greater in elevation making the scarp higher and more vulnerable to collapse. Erosion was not reported nor observed further north along the shoreline where the coast is sheltered due to the south/southeast orientation.

Figure 20: Slaughter Beach at high tide following an erosive storm

Additional dune and beach were likely eroded during the last October storm.

Figure 21: Sever erosion creating an unstable, vertical scarp in Slaughter Beach

The nor' easter in early November further damaged the beach and dune at Slaughter Beach leading to washed out trees, beach access structures and exposed bulkheads. A homeowner mentioned that this storm along with the previous nor' easter caused the most erosion he has seen in 40 years.

Figure 22: Slaughter at high tide (left) and a japanese black pine in Slaughter Beach that was undercut during fall storms.

Bennett's Pier

Bennett's Pier is directly north of Big Stone Beach and contains just one survey line. At present time, this segment of the coast is entirely privately owned, undeveloped and is backed by marshland. DNREC collects data at this location through an agreement with the landowner, Delaware Wildlands Inc.

Figure 23: Location of the single LRP line at Bennett's Pier

The average beach volumes of Bennett's Pier are shown in the table below. The beach volume is less in the Winter season, which is to be expected based on summer/winter profile variations. Oddly, the beach grew in volume between Summer 2021 and Winter 2022. Also, the shoreline position advanced 9' from an initial condition in Summer 2020 to the current conditions in Winter 2022.

Season	Volume (cf/lf)
Summer 2020	920
Summer 2021	880
Winter 2021	860
Winter 2022	910

Figure 24: Average beach volumes in Bennett's Pier

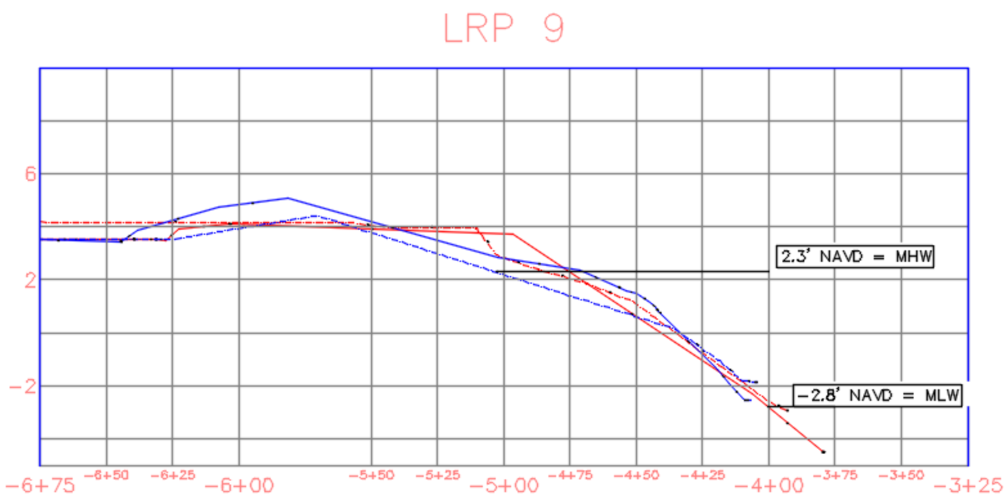


Figure 25. Beach profiles at Bennett's Pier. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

South Bowers Beach

Directly north of the Bennett's Pier is South Bowers Beach, which is undeveloped in the southern half of the community and densely populated near the inlet of the Murderkill River. The length of this segment of beach is roughly 3,000'. There are four survey lines in South Bowers; the lines are spaced more closely together where it is more densely developed.

Figure 26: LRP location map in South Bowers

The average beach volumes of South Bowers are shown in Table x, below. The beach volume is less in the 2021 Winter season, which is to be expected based on summer/winter profile theory. The shoreline at South Bowers beach has retreated at 0 – 2 feet/year, on average. Approximately 20 cubic feet per linear foot along the beach has been eroded within the survey extents between Summers.

Based on the profile comparison, the dune crest has steepened, increased in elevation, and moved landward since Winter of 2021. The increase in dune volume is balanced by the lower elevations in the intertidal zone. It is noted that beach volumes along LRP 7e were not included in the average volumes; the beach profile at LRP7e is far more voluminous than others owing to its proximity to the jetty, which traps alongshore sediment transport.

Season	Volume (cf/lf)
Summer 2020	870
Summer 2021	850
Winter 2021	800
Winter 2022	850

Figure 27: Average beach volumes in South Bowers

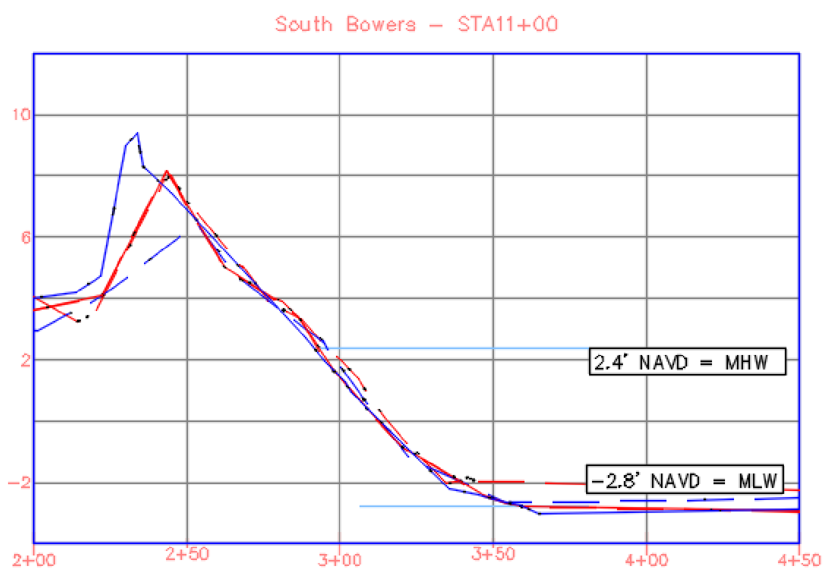


Figure 28. Beach profiles at South Bowers. Data are from winter 2021 (blue dashed), summer 2020 (red dashed), winter 2022 (blue solid), and summer 2021 (red solid).

Bowers Beach

Bowers is separated from South Bowers by the Murderkill River and is about 2,300' long. The north end of Bowers is bound by the Saint Jones River. Bowers Beach is densely developed. Profile lines are spaced roughly 1,000' in the southern end and densely (250') near the outlet of the St. Jones River. There are three LRP survey lines in the developed portion of the community. There is an additional LRP line north of the northern groin in Bowers where there is no coastal development.

Figure 29: Bowers Beach LRP location map

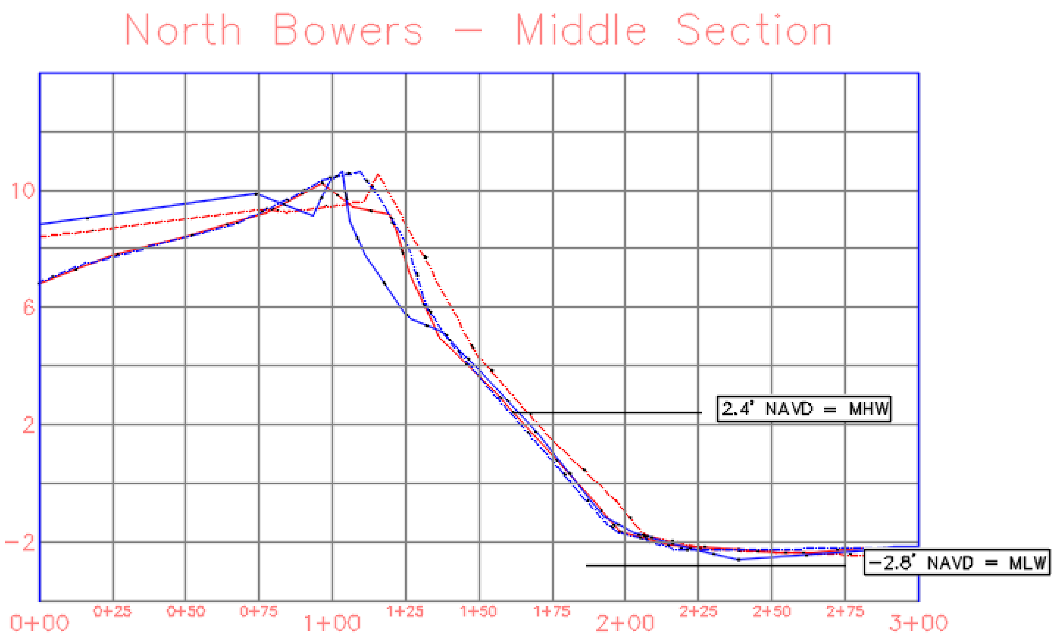


Figure 30. Beach profiles at Bowers Beach.

The average beach volumes of Bowers are shown in the table below. The beach volume has reduced since Summer 2020. On average, the largest reduction, on average, was 80 cf/lf during the Fall of 2021. Bowers beach retreats at 4.5 feet/year according to a review of survey data recorded over the past 20 years.

Table 5 Average beach volumes in Bowers Beach

Season	Volume (cf/lf)[1]
Summer 2020	1110
Summer 2021	1080
Winter 2021	1100
Winter 2022	1000

The early October storm caused minor erosion at Bowers Beach allowing water to lap under one home built upon stilts at the south end of the community. The second event in October caused a significant loss of the dune along the entire beach in Bowers.

Figure 31: High tides and erosion resulting from strong east winds

Kitts Hummock

Kitts Hummock is the next populated community north of the Town of Bowers. It is densely developed along Bay Drive and contains four survey lines in the 4,500’ length of shoreline.

Figure 32. Beach LRP lines at Kitts Hummock.

The average beach volumes of Kitts Hummock are shown in the table below. Since not all profiles extended to the MLW line, the volume of the beach above the 0' contour is calculated. On average, the volume of the beach has lost 10 cf/lf since the summer of 2020. This segment of beach retreats at roughly 2 ft/yr, on average. Between the two summers, the shoreline retreated 2 ft, which is consistent with average recent trends. The upper portion of the winter profile lost 30 cf/lf between the two winter seasons likely due to the storm activity during fall of 2021. The retreat of the upper beach is evident in the plot from the south central LRP line (n6). Since the survey does not extend to MLW, it is unclear whether the eroded material was deposited in the lower tidal zone.

Table 6 Average beach volumes in Kitts Hummock

Season	Volume (cf/lf)
Summer 2020	440
Summer 2021	430
Winter 2021	410
Winter 2022	380

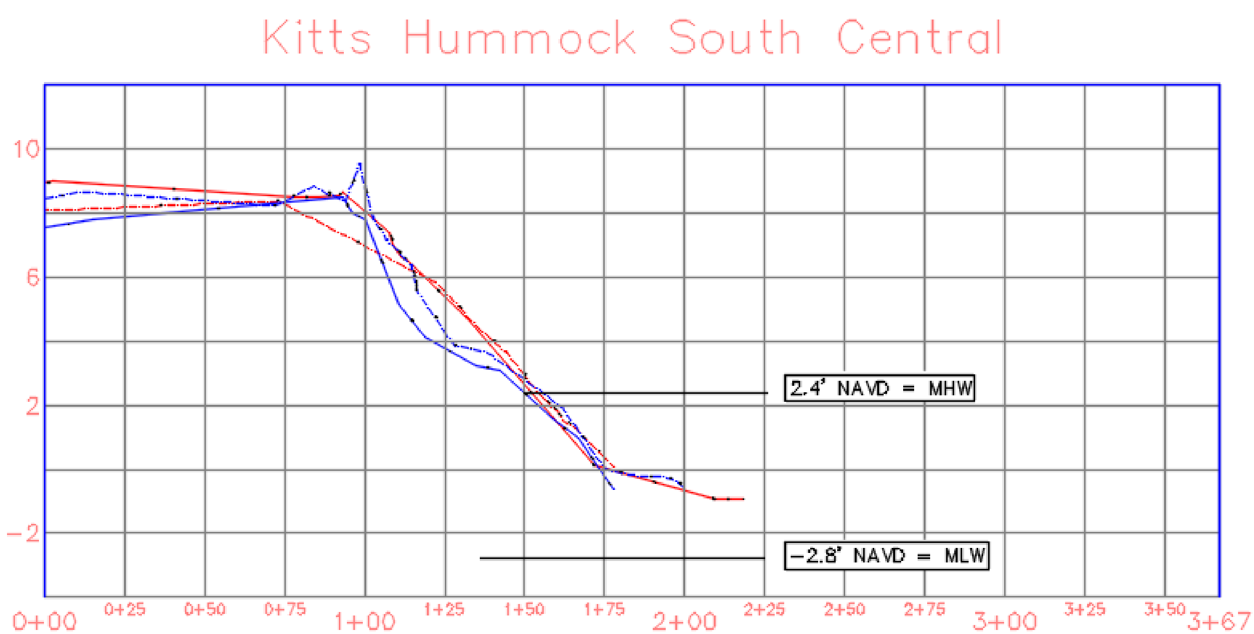


Figure 33: Kitts Hummock beach profiles. Data from summer 2020 (red, dashed), summer 2021 (red, solid), winter 2021 (blue, dashed), and winter 2022 (blue, solid).

The early October storm caused very minor scarping at the south end of the beach; the other October storm caused a minor loss of the dune. During the November storm, the high-water line, was about 15' away from the toe of the dune.

Figure 34 High tide at Kitts Hummock during a strong easterly storm

Pickering Beach

North of Kitts Hummock is Pickering Beach, which consists of three survey lines over 2,300’ and is densely developed.

Figure 35 Northernmost LRP located in Pickering Beach

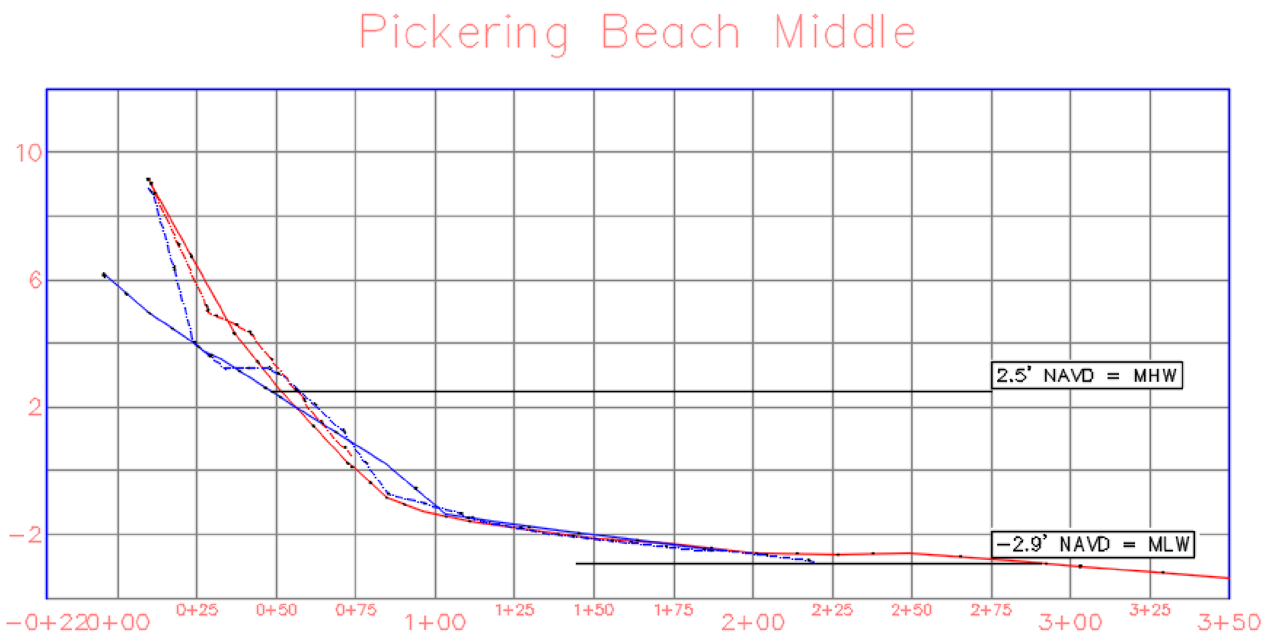


Figure 36. Beach profiles at Pickering Beach. Data are from summer 2020 (red, dashed), summer 2021 (red, solid), winter 2021 (blue, dashed), and winter 2022 (blue, solid).

The average beach volumes of Pickering Beach are shown in the table below. Volumes were calculated from the 0' contour rather than the MLW line since survey profiles did not extend to MLW. When computing volumes along the middle of Pickering Beach (LRP 1A), the profile volume was only calculated to station 0+08 to ensure the compared volumes overlapped. Also, the southernmost LRP line was excluded from the volume calculations since the winter 2022 profile did not extend far enough onshore.

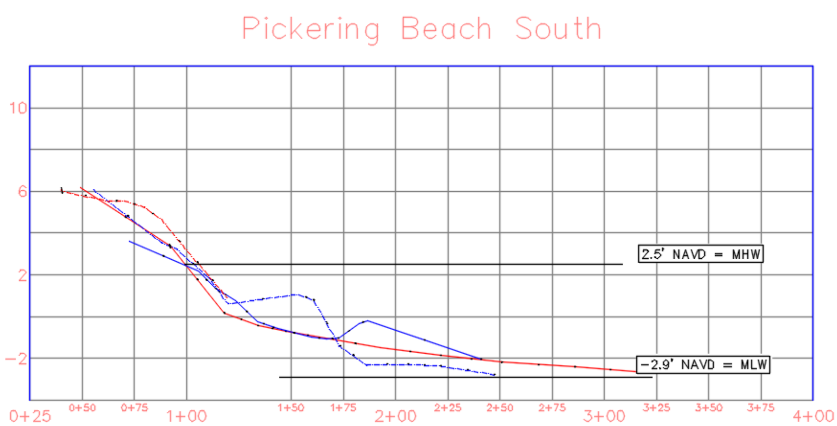


Figure 37 Comparison of seasonal profiles shows variation in the intertidal zone that is not fully captured by the survey data.

According to an evaluation of LRP data , the shoreline at Pickering Beach retreats at 2 - 4 feet/year, on average, over the recent decades. The shoreline in the middle of Pickering Beach retreated 5 ft between the two summer profiles. The profile volume of material eroded from the upper beach between summer and winter profiles was deposited lower on the dry beach and in the intertidal zone; most of this material was pushed back up the beach during the calmer summer conditions. The substantial beach erosion at Pickering resulting from the fall 2021 storms is evident in the profile comparison. The beach elevation at the inland limit is 3’ lower than previous seasons in the middle and southern locations.

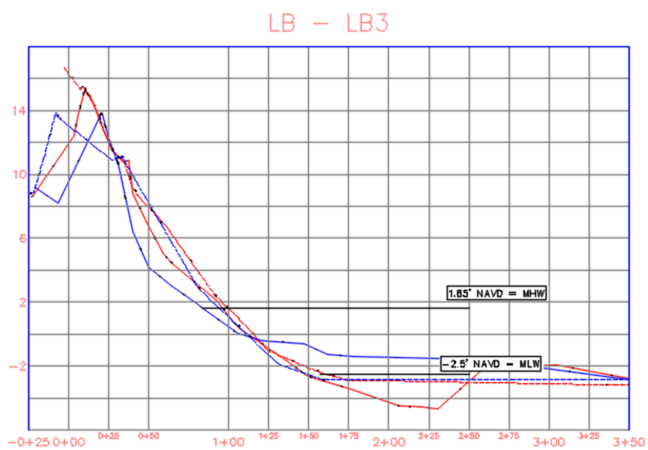
Season	Volume (cf/lf)[1]
Summer 2020	290
Summer 2021	260
Winter 2021	280
Winter 2022	250

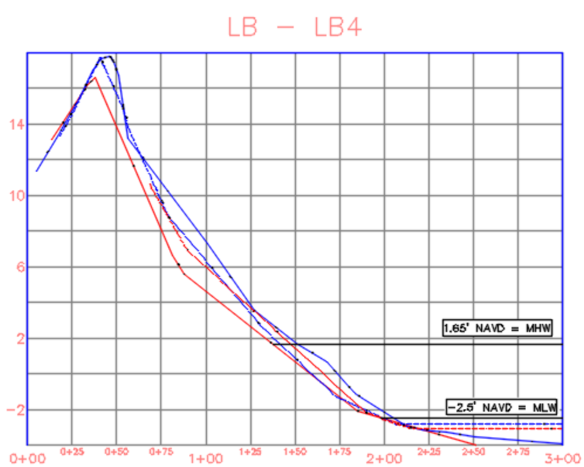
During the first nor’ easter in October, there was minor impacts (erosion/scarping) in Pickering Beach. The storm in later October caused the dune to erode entirely. During the November storm, the high tide was underneath the homes at the southern end of Pickering Beach causing scour along posts.

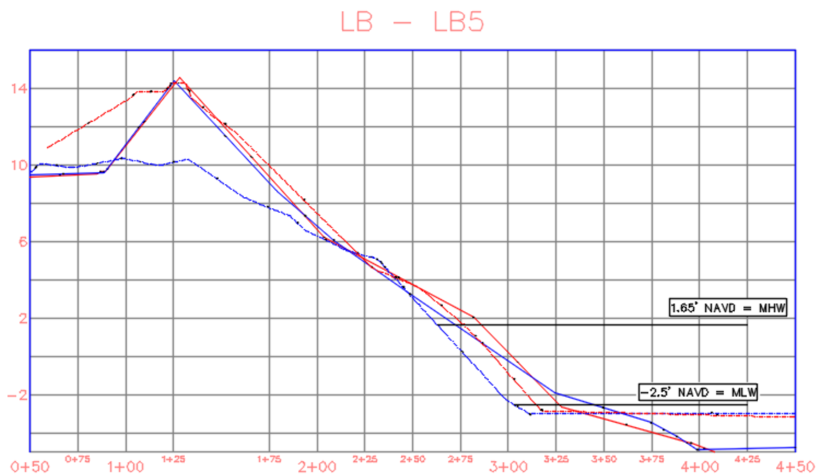
Figure 38 High tide reaching the pilings of homes in Pickering Beach

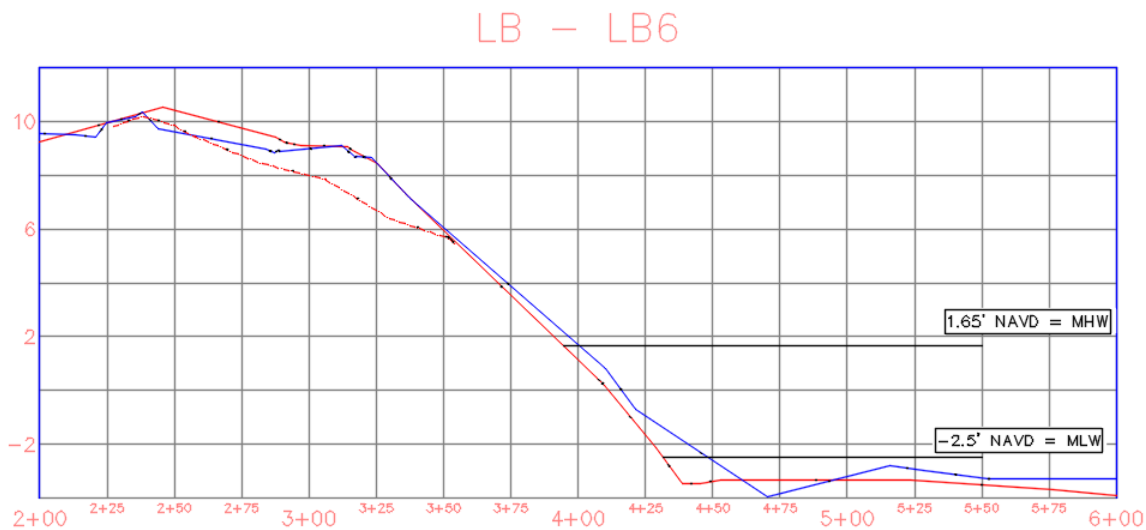
Appendix A-1: All Beach Profiles:

Lewes

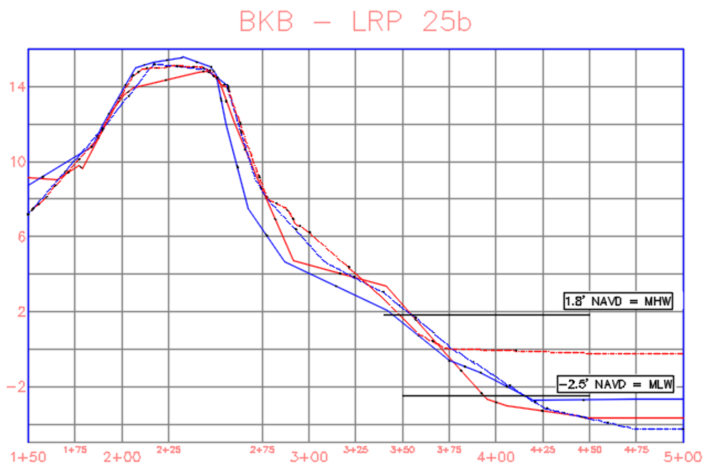


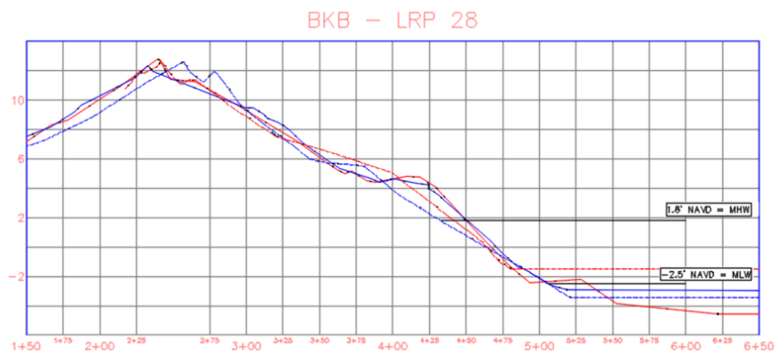






Broadkill Beach


BKB – LRP 25b
1.8' NAVD = MHW
-2.5' NAVD = MLW
14
10
6
2
-2
1+50
1+75
2+00
2+25
2+75
3+00
3+25
3+50
3+75
4+00
4+25
4+50
4+75
5+00


BKB – LRP 28
1.8' NAVD = MHW
-2.5' NAVD = MLW
10
6
2
-2
1+50
1+75
2+00
2+25
2+75
3+00
3+25
3+50
3+75
4+00
4+25
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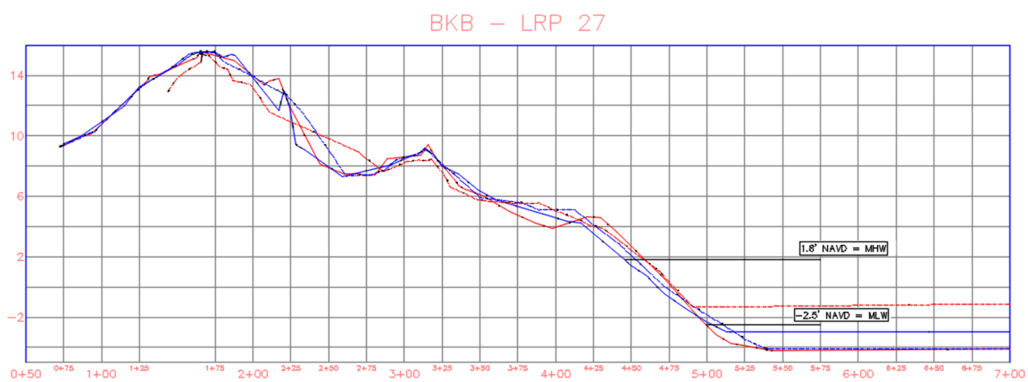
5+50
5+75
6+00
6+25
6+50


BKB – LRP 27
1.8' NAVD = MHW
-2.5' NAVD = MLW
14
10
6
2
-2
0+50
0+75
1+00
1+25
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50
3+75
4+00
4+25
4+50
4+75
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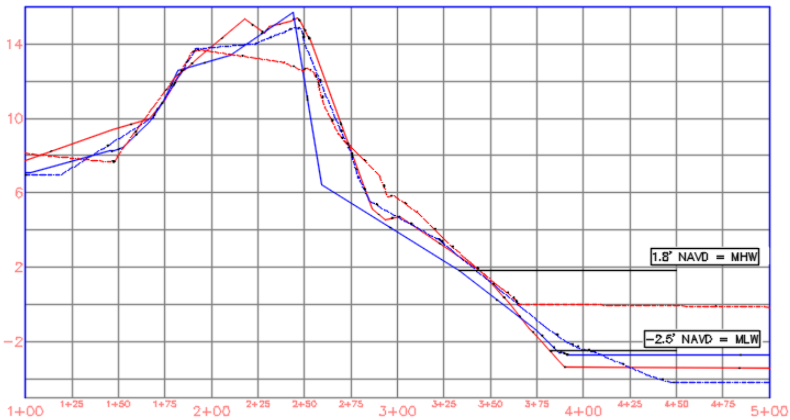
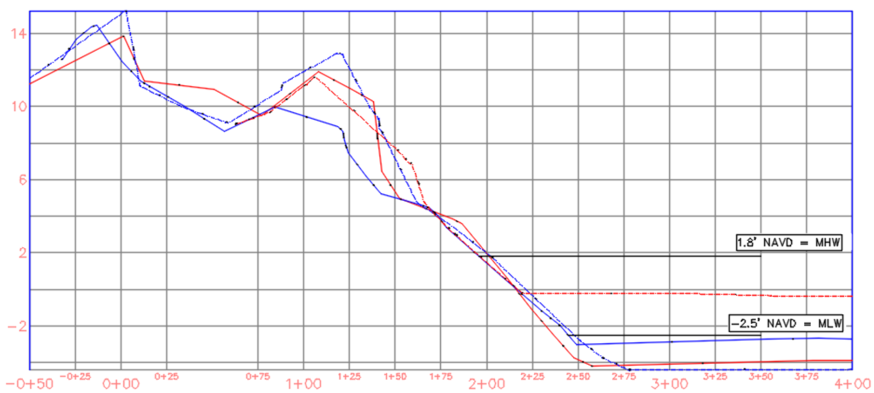
5+50
5+75
6+00
6+25
6+50
6+75
7+00

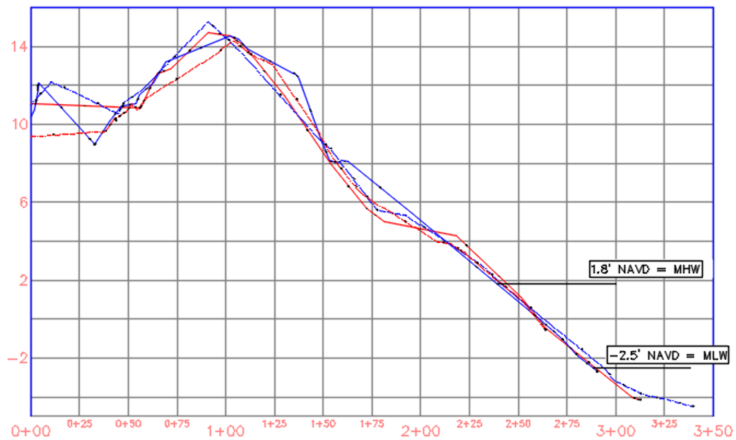
BKB – LRP 26



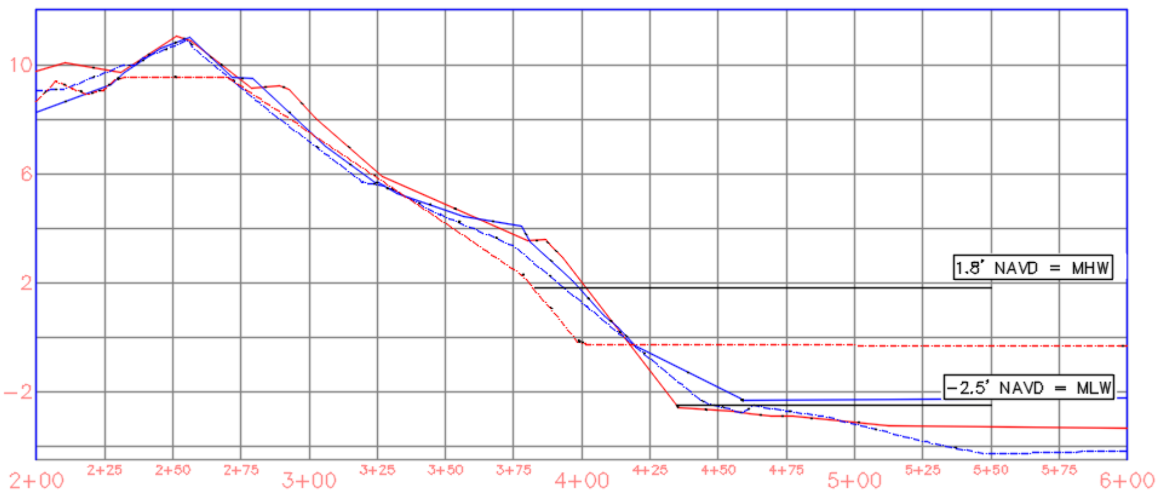
BKB – LRP 25a



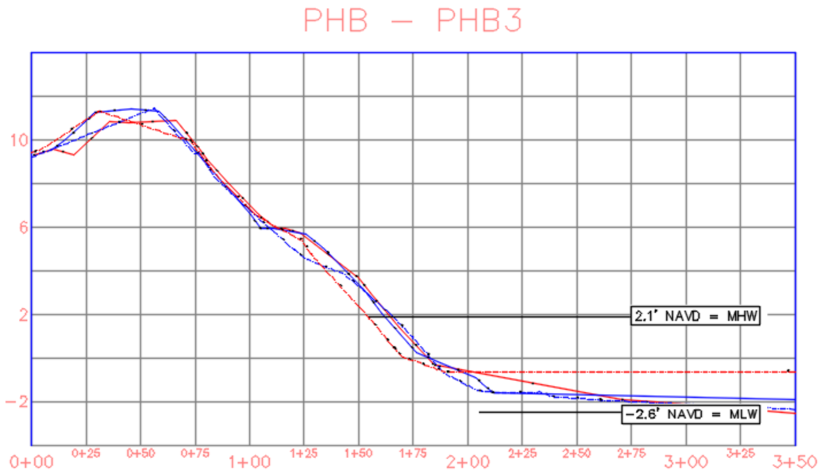
BKB – LRP 25

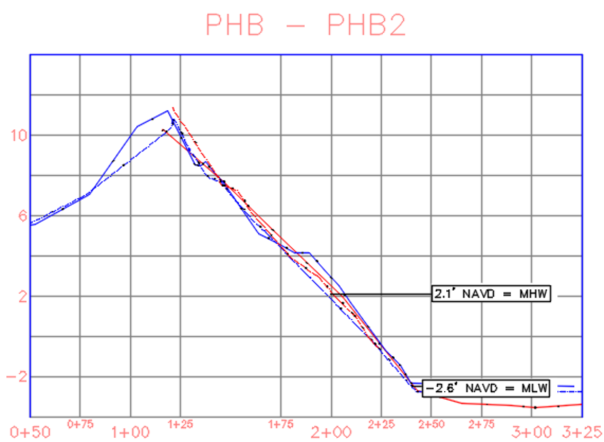


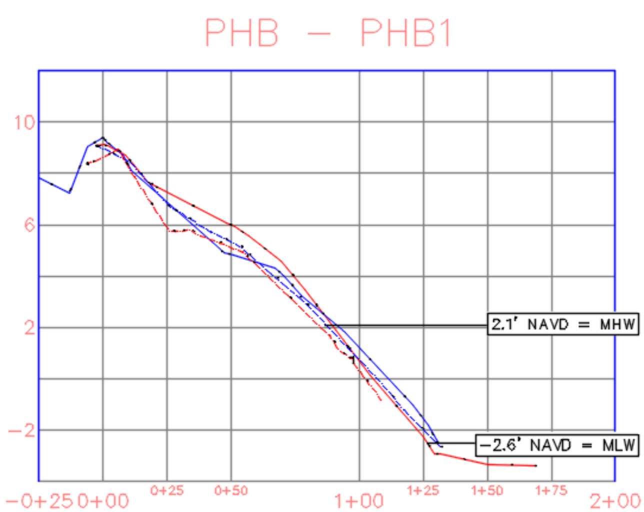
BKB – LRP 24



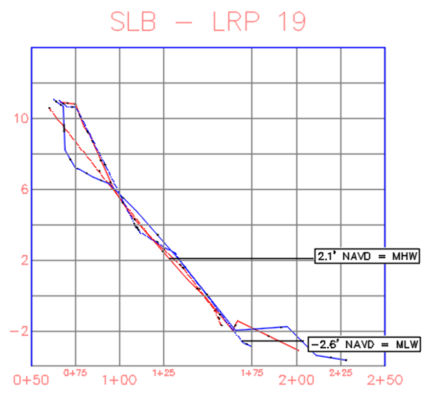
Prime Hook Beach

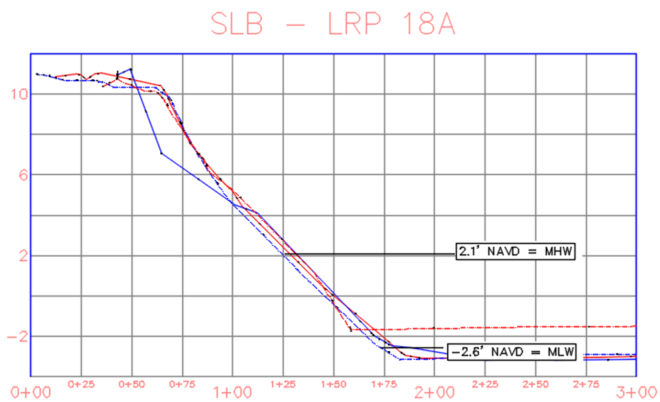


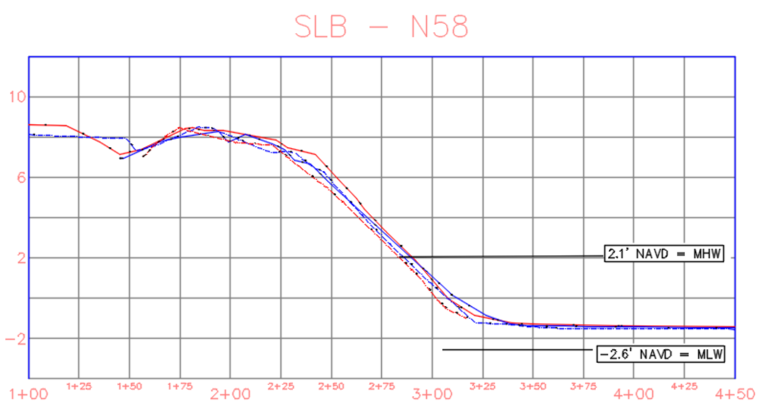




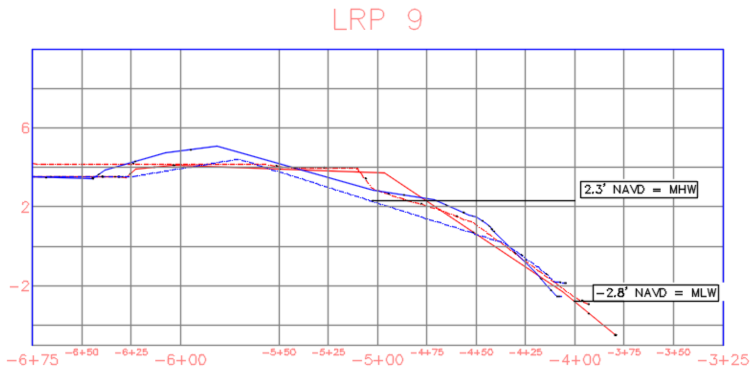
Slaughter Beach



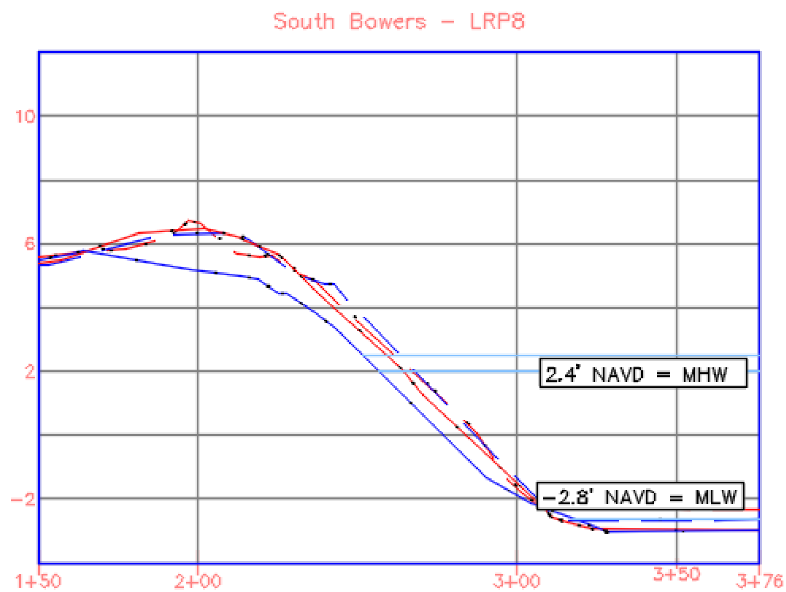


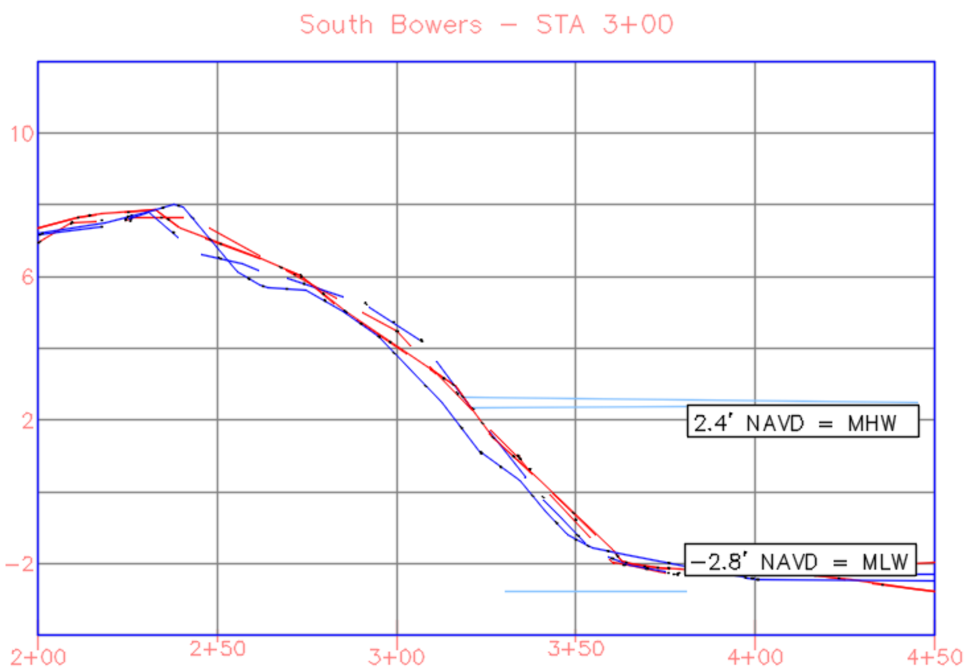


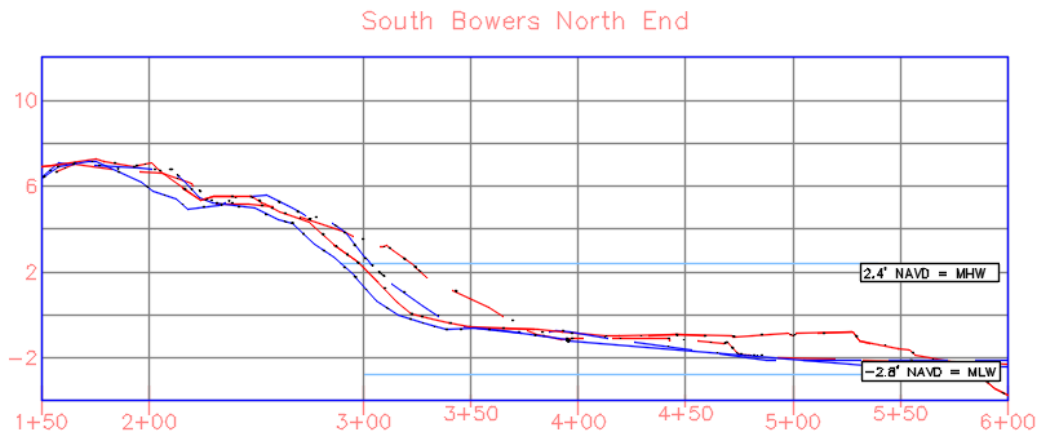
Bennett's Pier



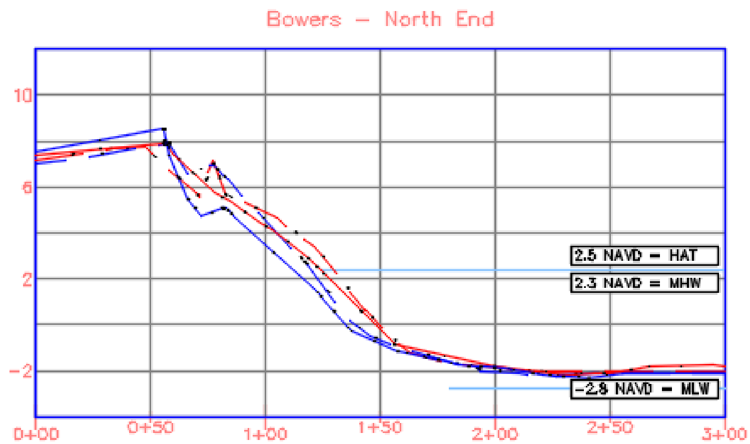
South Bowers Beach

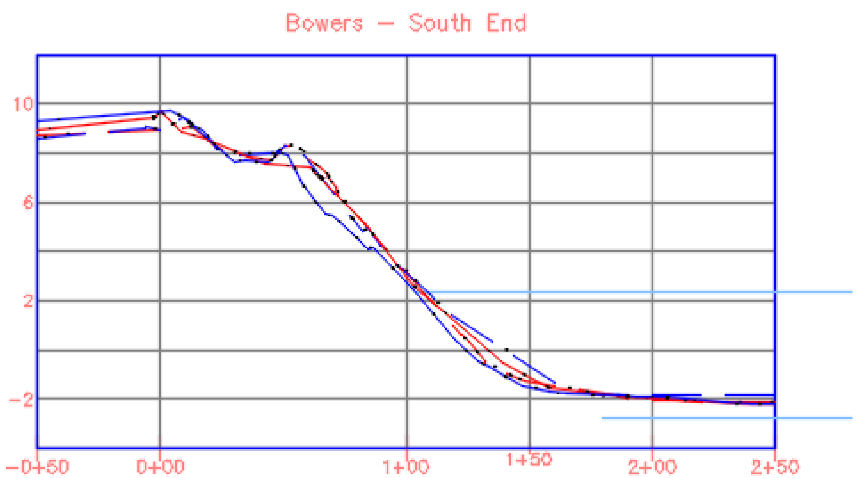

South Bowers – LRP8
10
6
2
–2
2.4' NAVD = MHW
–2.8' NAVD = MLW
1+50
2+00
3+00
3+50
3+76


South Bowers – STA 3+00
10
6
2
–2
2.4' NAVD = MHW
–2.8' NAVD = MLW
2+00
2+50
3+00
3+50
4+00
4+50



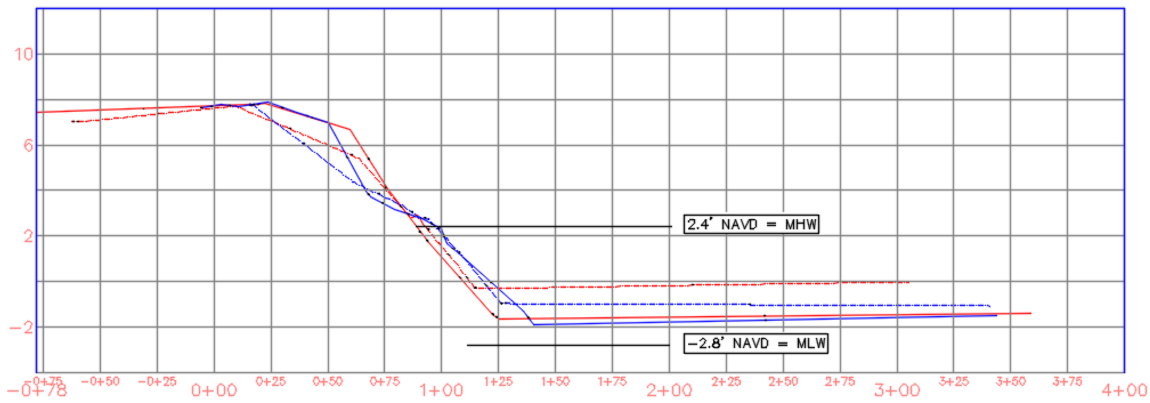
Bowers Beach



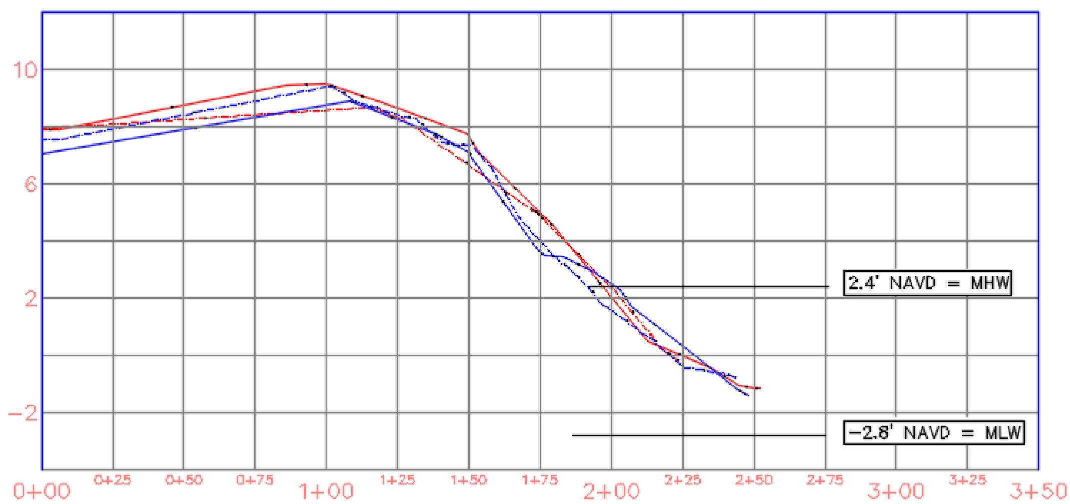


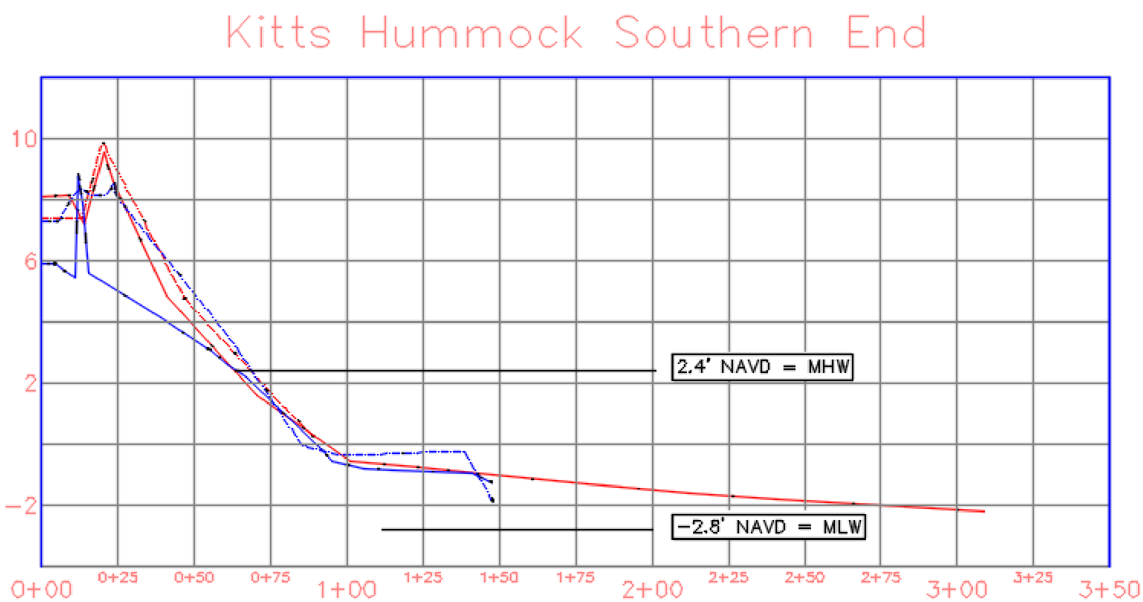
Kitts Hummock

Kitts Hummock Northern End



Kitts Hummock North Central

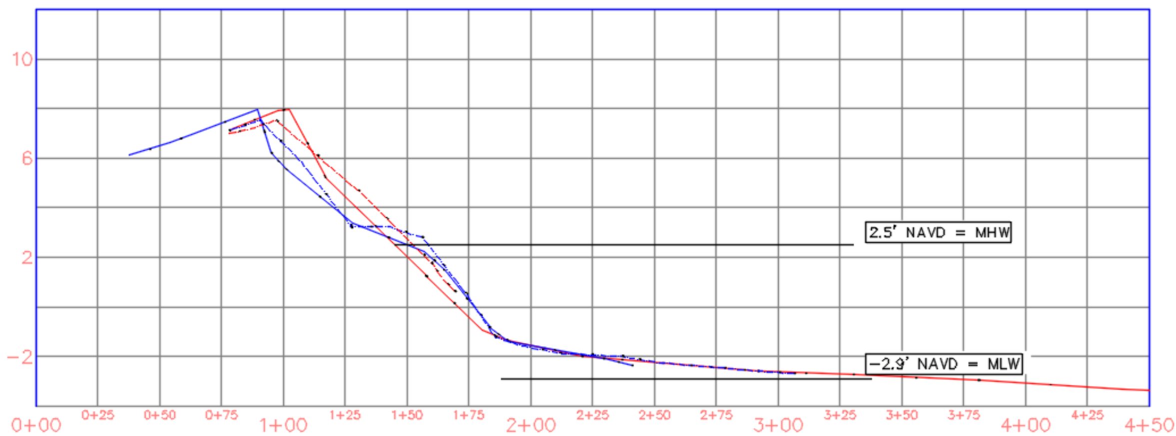




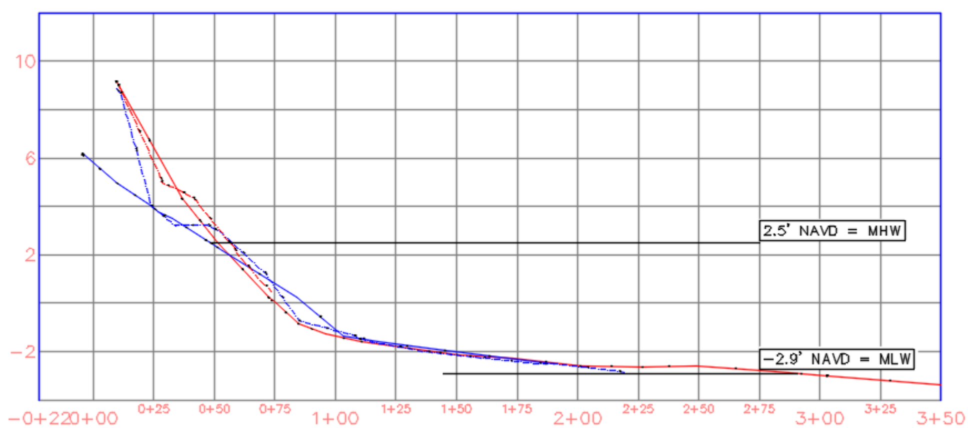
Kitts Hummock Southern End
10
6
2
−2
2.4' NAVD = MHW
−2.8' NAVD = MLW
0+00
0+25
0+50
0+75
1+00
1+25
1+50
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50

Pickering Beach

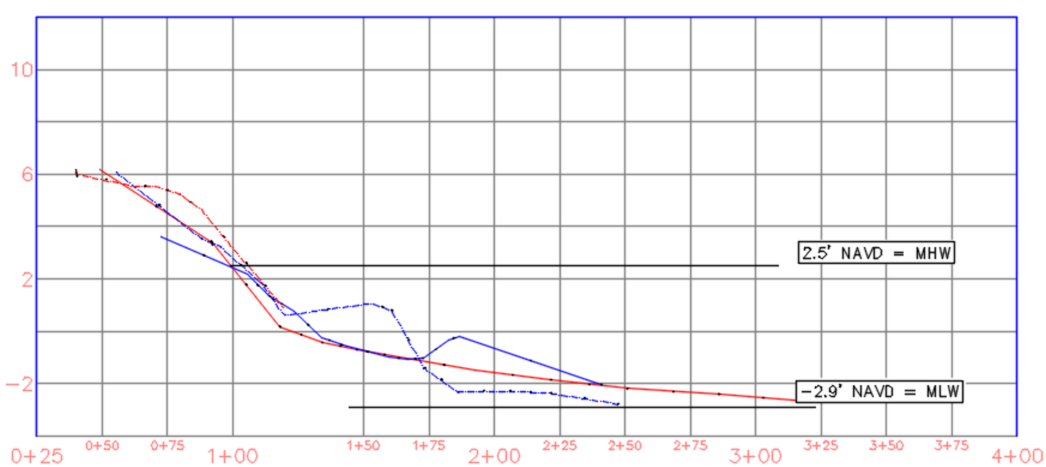
Pickering Beach North



Pickering Beach Middle



Pickering Beach South

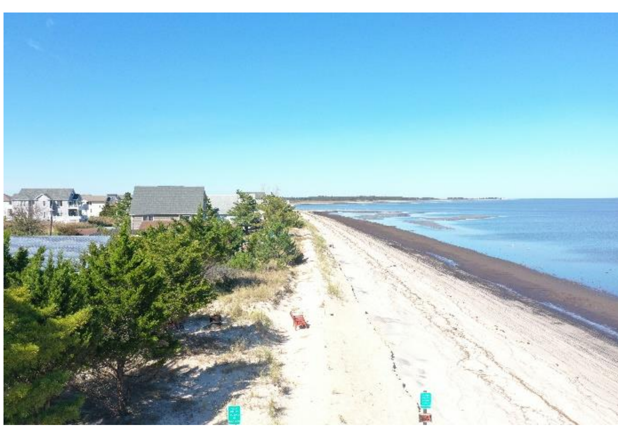


Appendix A-2 Beach Condition Photos (04/10/2020:

Note: Photos were not taken at Pickering nor Kitts Hummock Beaches owing to the restrictions on flying UAV (unmanned aerial vehicle) in the airspace of Dover Airforce Base.

LRP 7b:

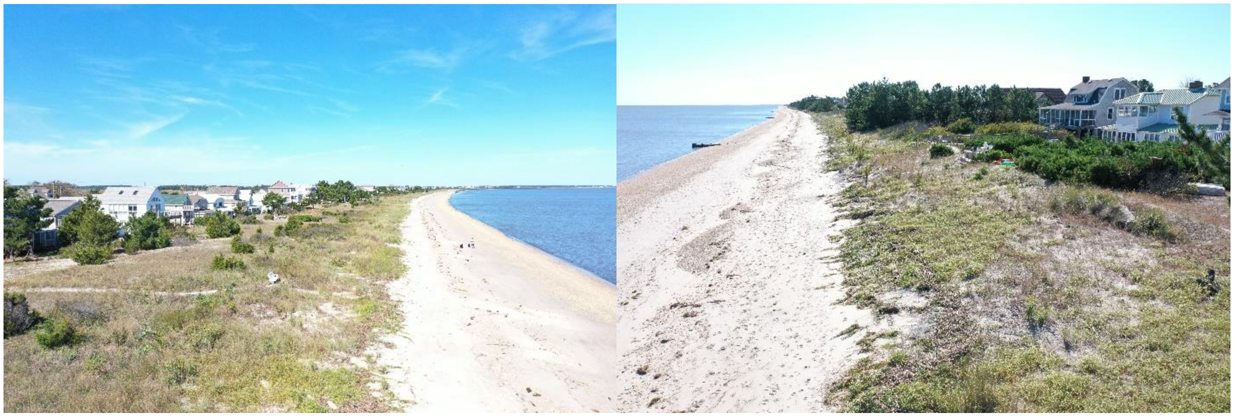

Long Range Planning 7c (LRP 7c):




South Bowers 3 (SB 3):

Slaughter Beach 2 (SLB 2):

Slaughter North Coast (SLB 3):



Slaughter Beach Mid Coast (SLB 5):

Broadkill Beach 5 (BKB5):

Broadkill Beach 7 (BKB7):

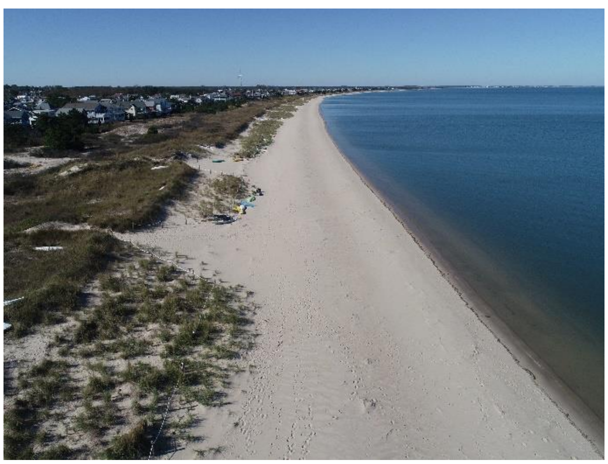
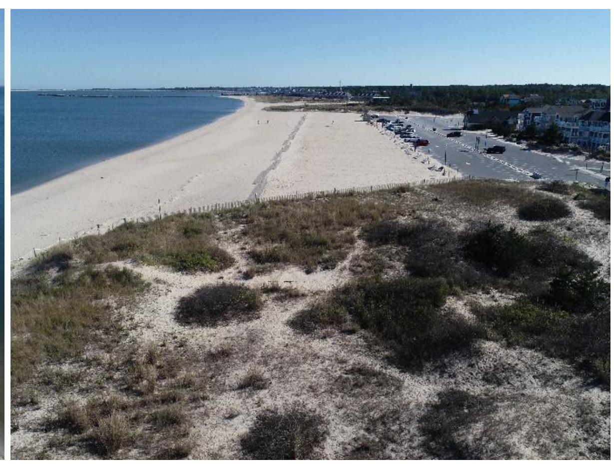
Bennett's Pier:

Big Stone Beach:

LRP 32:

LRP 33:

LRP 33a: