Delaware Annual Beach Change Report:

Bay Coast

Prepared by:

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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

Longitudal 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.

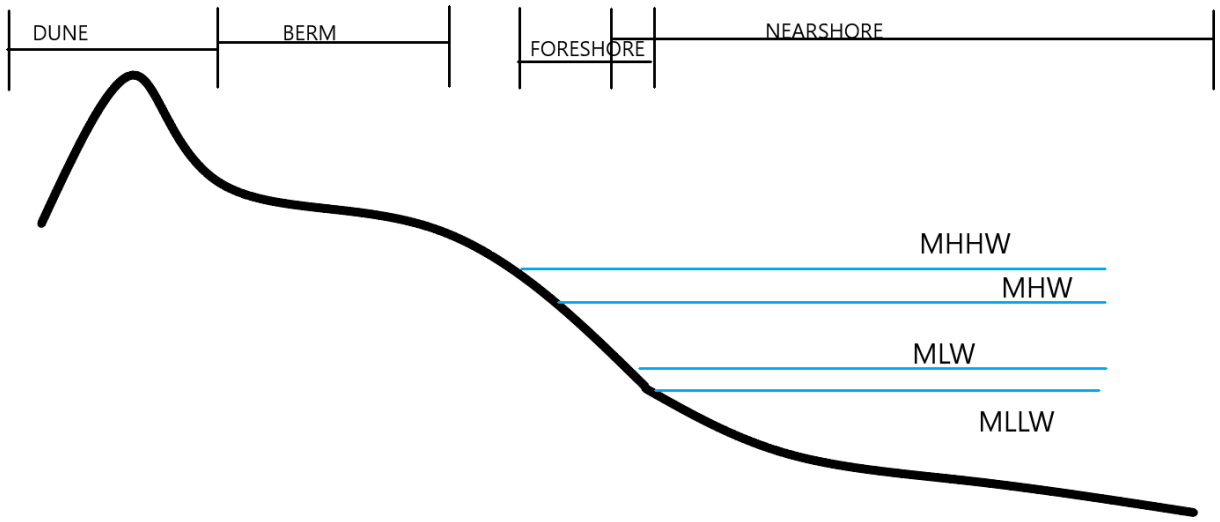


Figure 1: Beach profile definitions sketch

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.

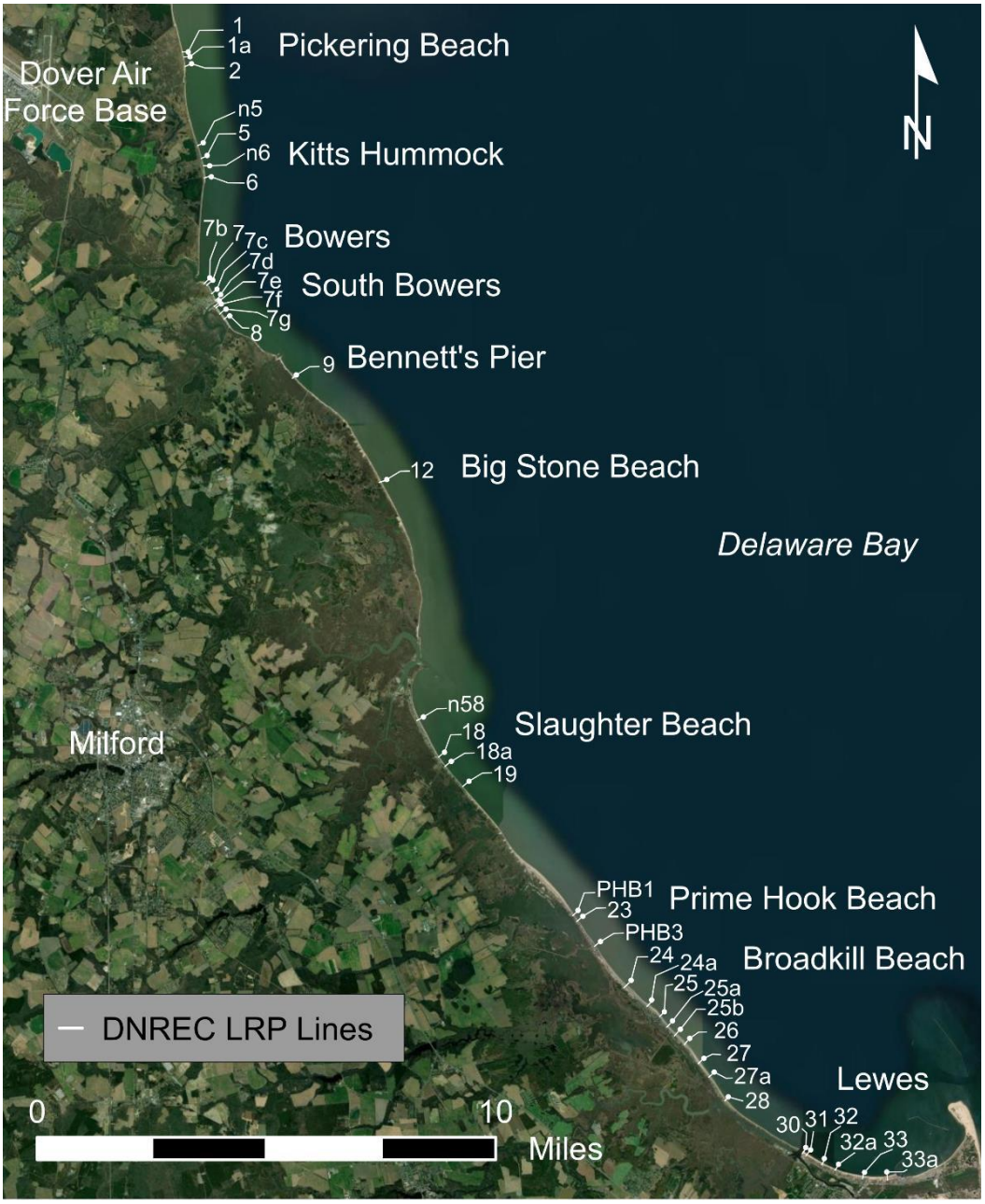


Figure 2: Bay coast LRP location map

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.

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.

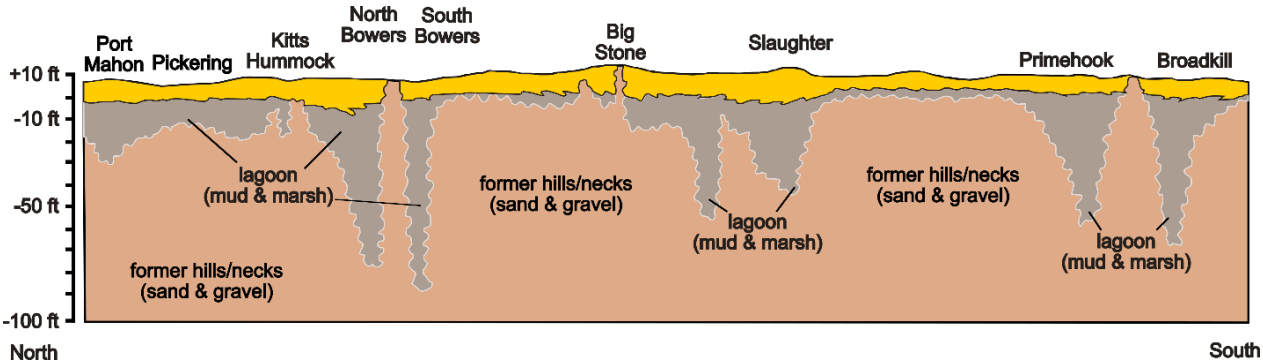


Figure 3Geology of the Delaware Bay coast from Port Mahon (north) to Broadkill Beach (south). Modified from French, 1990

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].

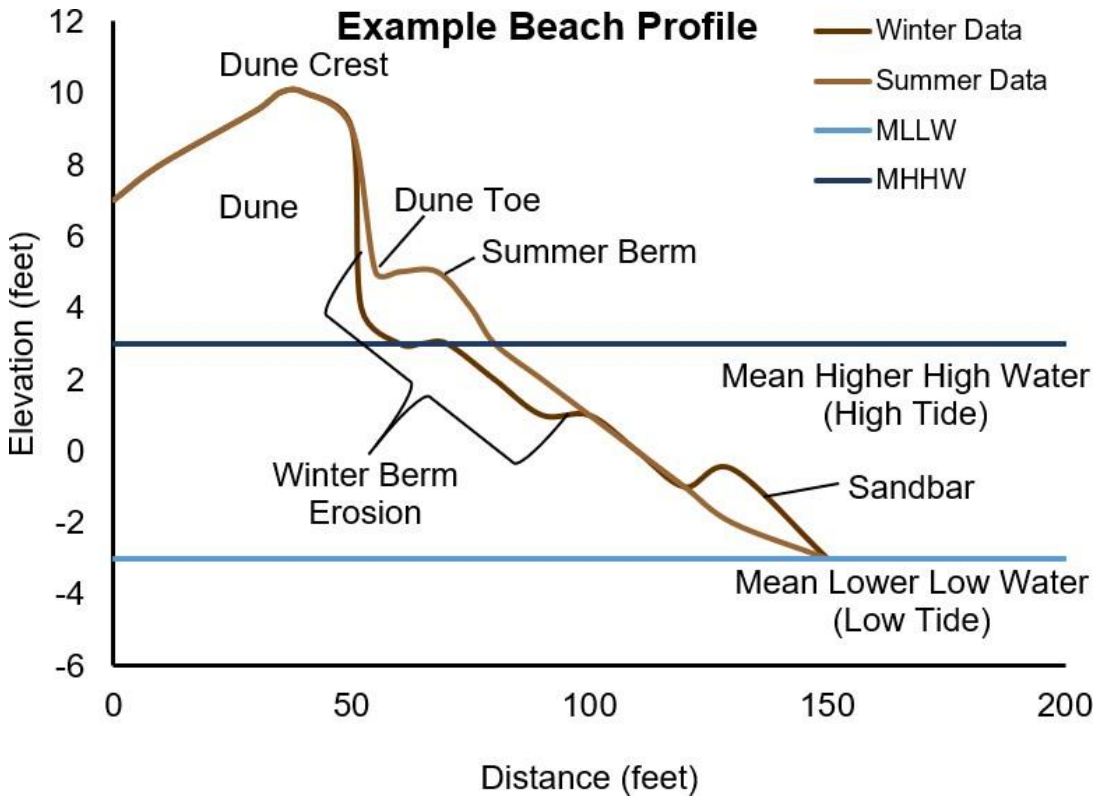


Figure 4: Example of summer and winter beach profiles, including key features observable in some of the real profiles below.

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 2022-2023 Storm Season

According to NOAA's National Centers for Environmental Information (NCEI) storm event database, there was one storm that led to a designation of a Coastal Flood along the Delaware Beaches zone:

Low pressure remained off the Middle Atlantic Coast from October 2nd through 5th, before moving out to sea on the 6th. The low maintained an onshore flow along the coasts of New Jersey and Delaware during that period of time.

The Delaware Beaches zone encompasses Delaware's ocean coast and barrier islands. It also includes the most of Lewes Beach. The storm database caused widespread roadway flooding and some property inundation in Sussex County. It is unclear the extent of any flooding caused along the Bay Coast.

The other storm event that caused coastal flooding along the Delaware Bay coast in Kent County was on April 18, 2022:

Strengthening low pressure moved slowly up the Middle Atlantic Coast from the 18th into the 19th. The resulting onshore flow caused moderate tidal flooding in parts of Delaware.

Another Coastal Flood event in Delaware during the season impacted the New Castle zone:

Low pressure moved northward from the eastern Carolinas on the 22nd to eastern Pennsylvania on the morning of the 23rd. It was then absorbed by a stronger low moving across the eastern Great Lakes. The system produced moderate tidal flooding in Delaware.

This caused flooding is in New Castle County, which is outside the Shoreline and Waterway Management Sections jurisdiction for maintaining, monitoring, and regulating the coast.

While it is unclear whether these events caused flooding along the Delaware Bay coast described by this report, the elevated water levels during these events did impact the coast. There are four NOAA water level gages that indicate the storm tide elevations along the Delaware Bay coast. These gages are shown in the map below:

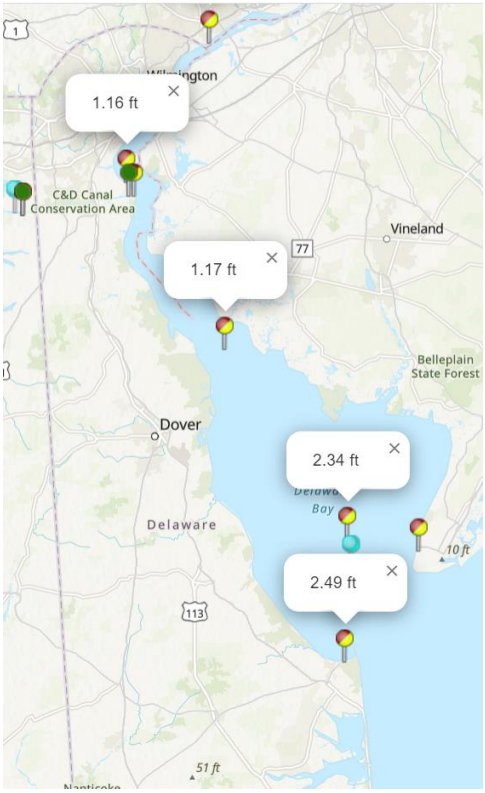


Figure 1: NOAA Water Level Gages in the Delaware Bay and River. Indicated by the pins with the text bubbles.

These water level gages, from north to south are: Reedy Point, Ship John Shoal, Brandywine Shoal, and Lewes. Of the events that caused the four greatest water levels at each of these gages, two are the Coastal Flood events described above. The table below shows the three greatest water levels observed at each of these gages, along with the date of observation, and the duration of the storm tide event. The duration is defined by the number of days the recorded high tide was greater than 1 foot above MHHW.

Table 1: Water Level Table - Peak Storm Tide elevations and durations.

Gage	Water Levels (MHHW, ft)	Dates	Duration (Days)
Reedy Point	2.45, 1.80, 1.79, 1.45	12/23/22, 09/09/22, 06/16/22, 4/19/22	2, 8, 9, 1
Ship John Shoal	2.57, 2.24, 2.16, 1.6	12/23/22, 06/16/22, 09/09/22, 4/19/22	3, 8 ,9, 1
Brandywine	2.26, 2.25, 1.98, 2.75	12/23/22, 10/03/22, 09/08/22, 04/19/22	3, 8, 8, 1
Lewes	2.78, 2.17, 2.13, 2.69	10/03/22, 12/23/22, 09/07/22, 04/19/22	9, 3, 8, 1

These elevated waters and wave action likely caused beach erosion.

Another indication of storm events that impacts the Delaware Bay coast is the decision by the Section to perform field visits to assess storm-induced erosion. Staff from the Section visited the bay coast beaches after all of the events described in the Table 1 as well as a 5th event in May. The event in May on Mother's Day weekend of 2022 did pronounced damage to the Atlantic coast beaches but lesser erosion along the bay cost.

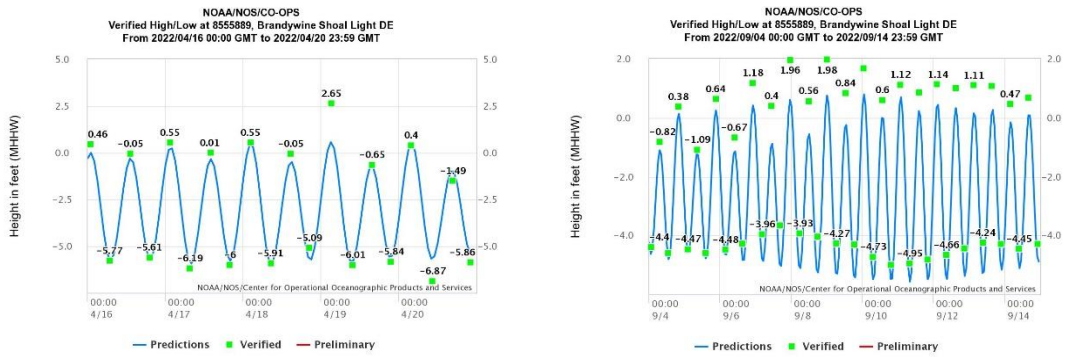


Figure 2: Measured High and Low Tides (green dots) vs Predicted Tides at the Brandywine Shoal Light Gage. Left is from April 2022 and the Right is from September 2022.

Annual Beach Changes

The following sections will describe the changes in beach volumes for each of the Bay Beach communities. Two beach volumes are reported for each LRP line. One is defined as the volume of material between the crest of the dune and the intersection of the MHW contour while the other is out to the intersection of the MLW contour. The volume calculation is sketched below:

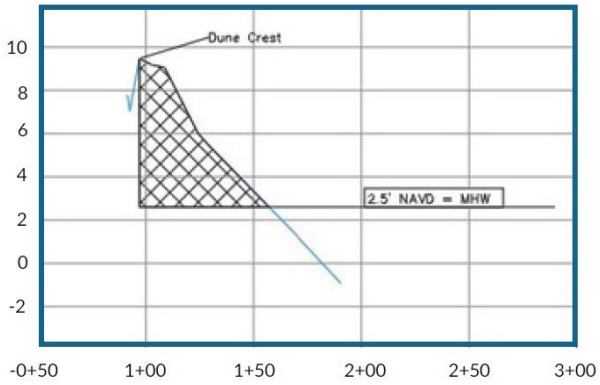


Figure 3: Sketch of beach profile calculations.

It should be noted that in the previous year's report, the volume was calculated out to the intersection of the MLW contour(MLW volume) only. The volume out to the MHW contour (MHW volume) is indicator of the beaches resiliency to flooding, overwash, and hazardous wave action propagation. The upper reaches of the beach above MHW are only reached during storm tides and/or when power wave action is present. The MLW volume and the comparison of the MHW and MLW volumes are better indicator of seasonal beach change. During the stormy season, the upper beach is eroded and typically washed down to the intertidal zone or just offshore thereof. The comparison of the two volumes helps determine how much of the sand eroded from the upper beach and dune is deposited in the intertidal zone.

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).

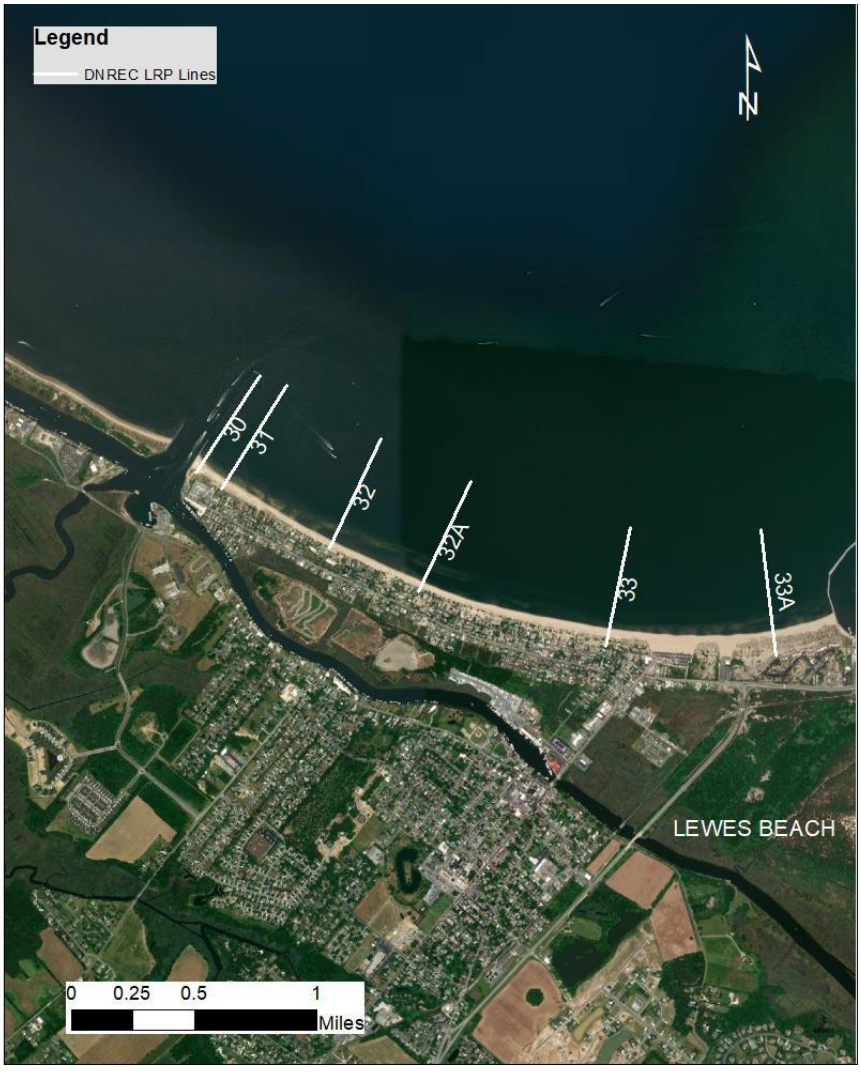


Figure 6: LRP location map in Lewes

Lewes Beach Volumes:

The average beach volumes of Lewes Beach are as shown in Table 1. Beach volumes are calculated along 1-Dimension profiles and are reported as cubic feet per linear foot of beach length (cf/lf). The volumes for each LRP survey line in the community is presented. The beach volume changes is indicative typical seasonal changes on beaches. The beach erodes in the winter but recovers in the summer. However, the beach is eroding as it has not fully recovered. The LRP lines close to the inlet do not show this seasonality and demonstrates continuous erosion. This is due to the proximity to the jetty at Roosevelt

Inlet which affect alongshore transport. It is also noteworthy that USACE dredges the Lewes and Rehoboth Canal and Roosevelt Inlet and places material on Lewes Beach at LRP 30 and 31. Over the past 20 years, the MHW shoreline of Lewes Beach has retreated 0-2 feet per year, on average.

Table 1: Average beach volumes in Lewes Beach

	Volume (cf/lf)											
LRP	LRP 30		LRP 31		LRP 32		LRP 32A		LRP 33		LRP 33A	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	630	1280	530	1000	640	1152	660	1205	850	1580	840	1540
Summer 2022 (07/27/2022)	600	1230	370	760	605	1165	665	1120	850	1530	875	1610
Winter 2022 (01/24/2022)	585	1195	425	920	530	1170	640	1235	830	1590	860	1585
Winter 2023 (02/16/2023)	580	1095	290	710	590	1040	660	1080	842	1570	890	1625

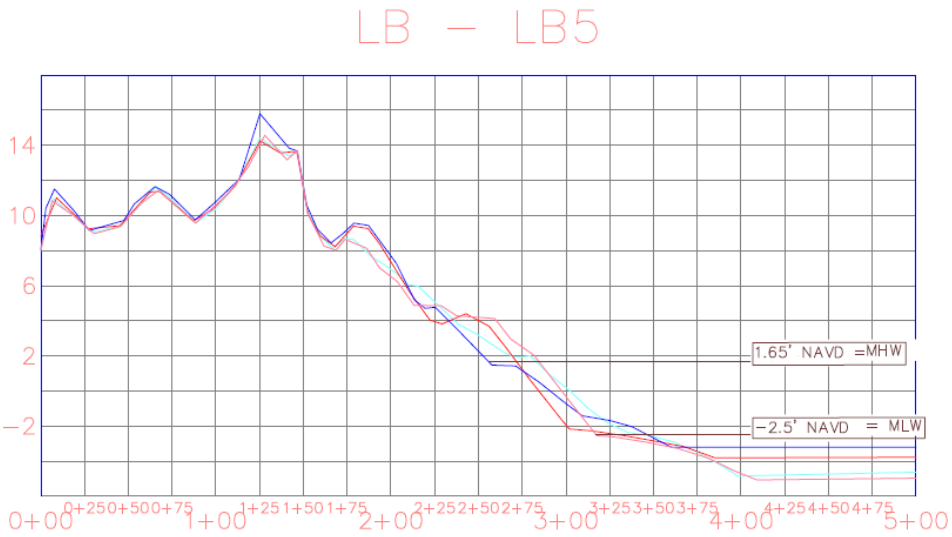


Figure 4. Beach profiles at Lewes Beach LRP 33. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

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 was stable from summer of 2021 to winter of 2022. However, the shoreline has retreat since winter 2022 by 12' in Summer 2022 and a total of 28' in Winter 2023. This suggest that the storms of 2022 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 in previous years, it may be the case that the beach naturally recovers from the fall storms.

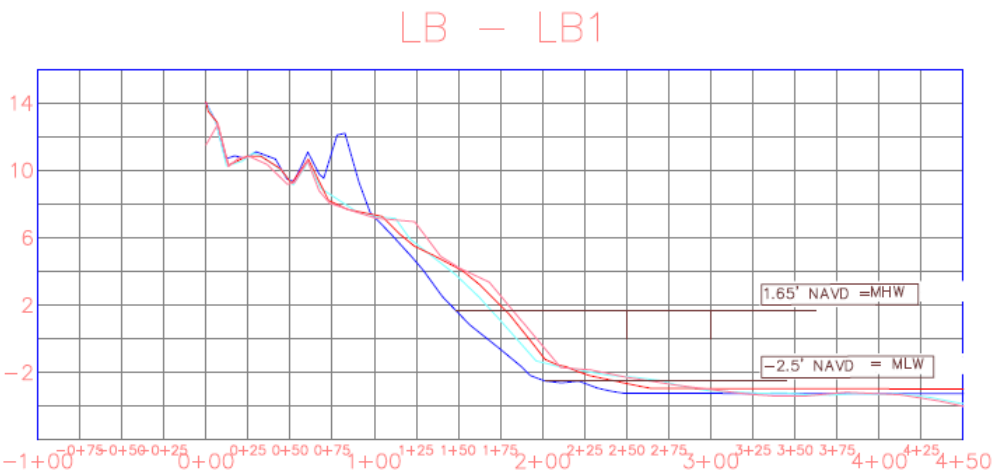


Figure 5: Beach profiles at Lewes Beach LRP 30. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The beach profiles at LRP 30, which is directly adject to the Roosevelt Inlet, is shown in Figure 5. There is a large mound of sand on the profile present in Winter of 2023 that was not present in other seasons. This is not a result of natural process, rather, was likely placed there from material attained from maintaining the vehicle access. The mound is shown in the picture shown in Figure6.

Figure 6: Picture take at LRP 30 taken during the Winter 2023 survey. There is a mound of sand just seaward of the dune that is not the result of natural accretion.

A representative photo of Lewes Beach is shown below in Figure 7; the remaining pictures are contained in Appendix A-2.

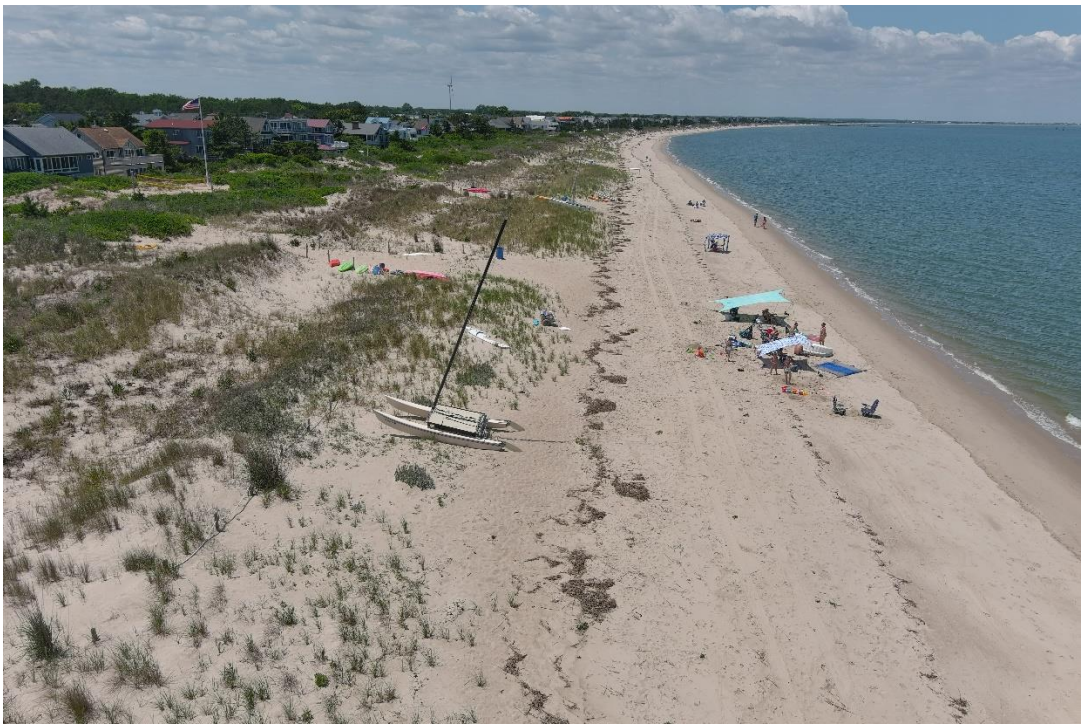


Figure 7: UAV image of Lewes Beach in the middle of the community taken on June 5th, 2023.

The Section's crew responded to three of the storm surge events that impacted Lewes Beach on 10/09/2021, 04/18/2022 and 10/03/2022. Typically, the western end of the beach, near the Roosevelt Inlet, suffers the most damage from storms and tends to be erosional. This is evident in the beach volumes as the beach has reduced in volume from season to season excluding the mound of material placed along LRP 30. The dune at this location was severely damaged in October of 2021. The dune was further damaged on 4/18/2022 but not 10/03/2023. The fact that no damage was observed on 10/03/2023 is likely because the previous storm eroded the dune to a point that this storm action could not reach it.

Figure 7: Scarped dune at the western end of town near the Inlet. An October 2021 storm damaged the dune as depicted in the photo on the left. The photo on the right was taken on 4/18/2022 which further damaged the dune.

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

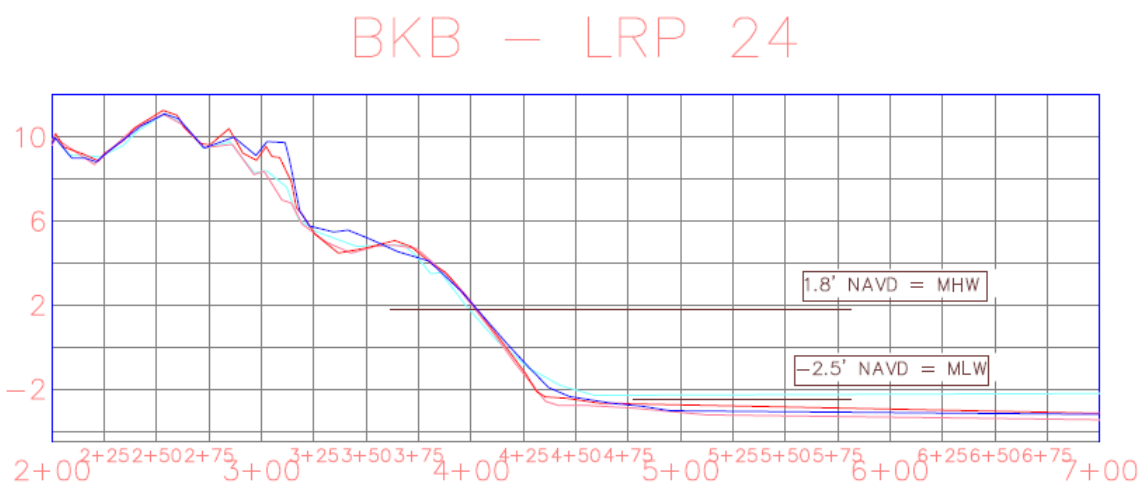


Figure 12. Beach profiles in northern Broadkill Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

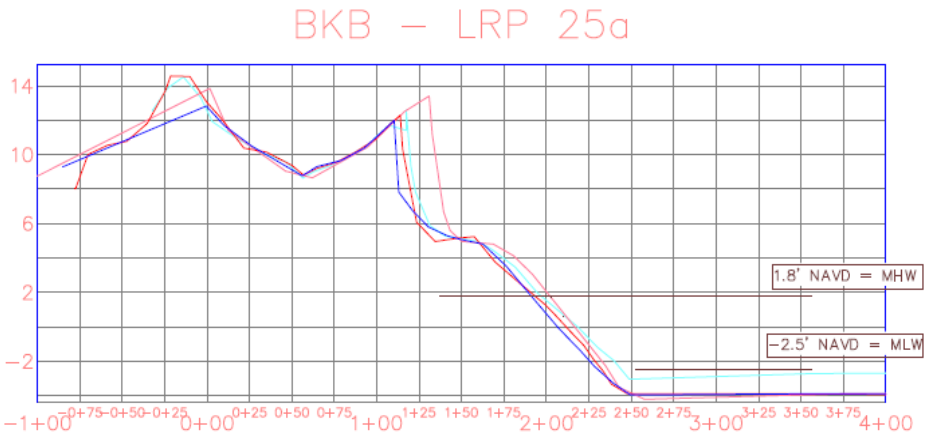


Figure 13 Beach profiles at Broadkill Beach near the dune crossing at Route 16. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid). The dune has experienced substantial erosion.

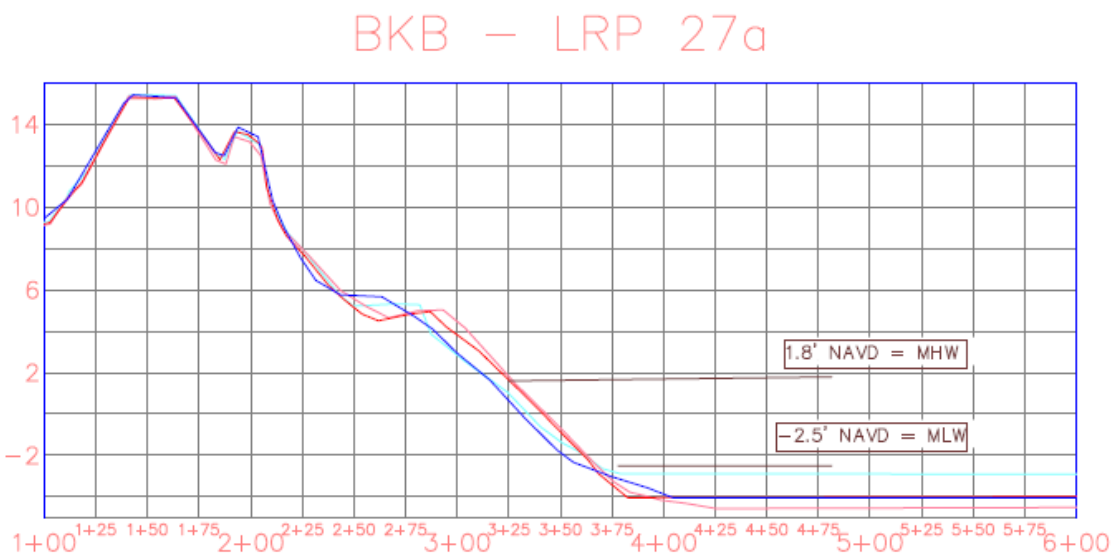


Figure 14: Beach profiles in southern Broadkill Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

Broadkill Beach Volumes:

The average beach volumes of Broadkill Beach are shown in the table below. Comparing the summer to summer profiles, the fact that the center of the Broadkill community is eroding while the northern and southern sections are accreting is evident. This is likely attributable to the orientation of the constructed beach. Similarly, these sections of the beach recover the material that is eroded during the winter months whereas the central section erodes season to season.

Table 2: Average beach volumes in Broadkill Beach

	Volume (cf/lf)											
LRP	LRP 24		LRP 24a		LRP 25		LRP 25a		LRP 25b		LRP 26	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	690	1400	1455	2705	1120	1905	450	920	1030	1755	595	1150
Summer 2022 (07/27/2022)	760	1445	1550	2850	1090	1880	280	730	935	1620	435	925
Winter 2022 (01/24/2022)	695	1430	1480	2700	1085	1875	320	800	940	1660	450	975
Winter 2023 (02/16/2023)	750	1480	1610	2870	1055	1790	265	695	880	1560	350	840

Table 2 continued: Average beach volumes in Broadkill Beach

	Volume (cf/lf)					
LRP	LRP 27		LRP 27a		LRP 28	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	1975	3390	1250	2135	1140	2135
Summer 2022 (07/27/2022)	1980	3370	1225	2105	1220	2205
Winter 2022 (01/24/2022)	1950	3335	1220	2075	1175	2190
Winter 2023 (02/16/2023)	2005	3340	1220	2055	1265	2315

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.

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

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

Broadkill Beach Overview:

The Section's crew responded to four storm events over the past 2 years(10/09/2021, 10/03/2022, 04/18/2022 and 05/09/2022). At the Rt. 16 crossing, the scarping of the dune was exacerbated by these events. 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 in October of 2022 likely induced based damage to the upper beach and dune in Broadkill Beach. Figure 15 shows the beach during the storm tide. This highwater indicators show that the high tides reached the toe of the scarped dune which likely caused erosion and collapse of this feature.

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 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 20-40 cubic feet per linear foot along the beach has been accreted within the survey extents in the northern and southern sections between summers. In the middle of the community, represented by LRP 23, the beach is essentially stable with small losses between the summer surveys. All profiles eroded between Summer 2021 and Winter 2022, which recovered during the spring and summer of 2022. The beach eroded less in Fall 2022 to Winter 2023.

Table 3: Beach volumes in Prime Hook Beach

Season	Volume (cf/lf)					
LRP	PHB 1		LRP 23		PHB 3	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	320	790	360	835	605	1420
Summer 2022 (07/27/2022)	360	855	350	815	630	1450
Winter 2022 (01/24/2022)	290	790	330	810	580	1395
Winter 2023 (02/16/2023)	360	875	335	785	620	1420

A representative profile from the center of the beach is shown in FIGURE. The profile demonstrates that there is variability in the beach profile, from season to season, from the intertidal zone to the upper beach to the 6' elevation. In the winter of 2022, the upper part of the beach is eroded with some of the eroded material accumulated in the intertidal zone.

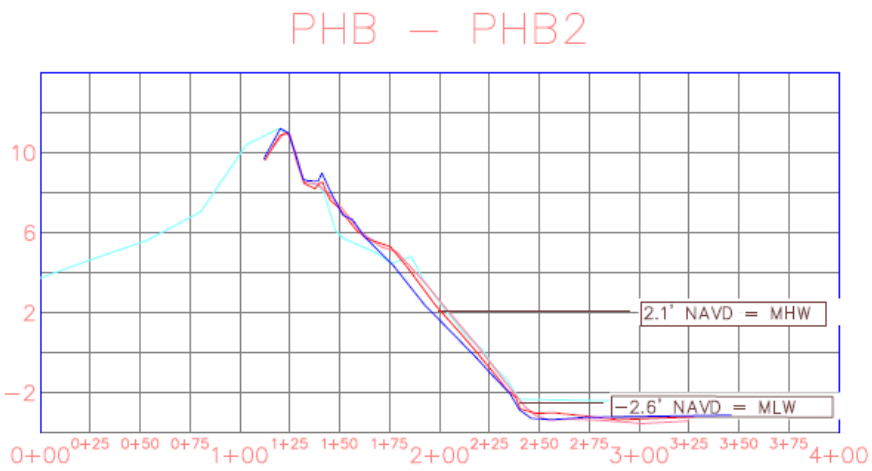


Figure 14: Beach profiles in the center of Prime Hook Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

On November 4th, 2021, Prime Hook Beach was inspected for damage due to a storm during the previous days. The storm cause scarping in the lower part of the dune. This scarping can also be seen on the profile plot for winter 2022 in FIGURE.

Figure 15: Upper beach and lower dune scarping in Prime Hook that occurred in the Fall of 2021. This accounts for the erosion observed between Summer of 2021 and Winter of 2022.

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

In the central area of the beach, there is erosion observed between the summer seasons. The northern portion, represented by SLB N58, demonstrates some accretion. This accretion may be due to alongshore sediment transport, which brings sand from the central part of the beach. This section of the beach is also partially sheltered by the jetty, which stabilizes the Mispillion Inlet. The gain of volume from Winter 2022 to Summer 2022 at LRP 19 is not a result of natural recovery. This profile is the only one that is in the 2000' section of the coast that received occasional nourishment. This gain is the result of one of these nourishments, completed in February 2022. This project bolstered the eroding bluff that is depicted in FIGURE.

Table 4: Beach volumes in Slaughter Beach

	Volume (cf/lf)							
LRP	SLB N58		LRP 18		LRP 18A		LRP 19	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	460	845	315	785	355	830	305	715
Summer 2022 (07/27/2022)	475	870	270	745	290	765	310	740
Winter 2022 (01/24/2022)	455	845	270	760	285	780	235	655
Winter 2023 (02/16/2023)	475	875	315	725	290	750	280	685

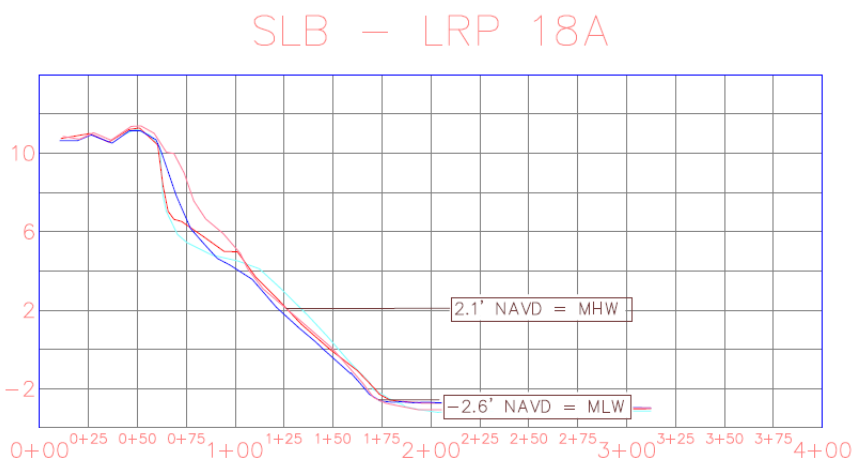


Figure 14: Beach profiles in the center of Prime Hook Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

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 15: Slaughter Beach bluff erosion during the Fall of 2021. In the southernmost 2000' of the community, from Simpson to Sussex Ave where the bluff encroaches closest to homes.

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. In response to these storms, the Section placed fill to bolster the eroding bluff.

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

The FIGURE shows the beach after this fill job. The lower part of the fill template was reshaped by the astronomical tides shortly after the project. This was because the fill template was steeper than the natural beach.

Figure 22: Slaughter after completion of the February 2022 nourishment job. The lower part of the steep template was reshaped into a relatively flat berm.

Big Stone Beach

Bennett's Pier is directly north of the Mispillion Inlet, which is the northern limit of Slaughter Beach. At present time, this segment of the coast is entirely privately owned, undeveloped and is backed by marshland. DNREC collects data along one LRP line through an agreement with the landowner, Delaware Wildlands Inc.

The average beach volume of Big Stone Beach is shown in TABLE. The beach demonstrates the expected seasonal change with losses over the fall and early winter and recovery during the summer months.

	Volume (cf/lf)	
LRP	LRP 12	
Volume Limit	MHW	MLW
Summer 2021 (08/18/2021)	235	695
Summer 2022 (07/27/2022)	225	695
Winter 2022 (01/24/2022)	185	670
Winter 2023 (02/16/2023)	210	680

Figure 24: Average beach volumes in Big Stone Beach

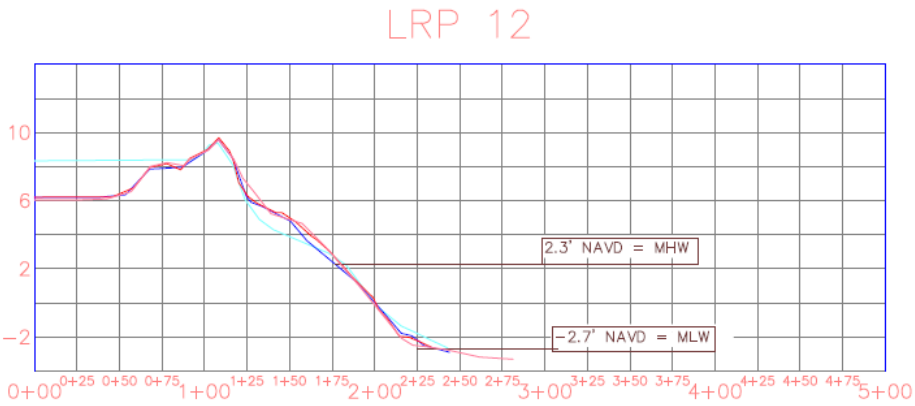


Figure 14: Beach profiles in Big Stone Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The storms during the Fall of 2021 caused major erosion in Big Stone Beach. It should be noted that the image in FIGURE is from the developed portion of Beach whereas the survey location is in the undeveloped land owned by Delaware Wildlands, Inc.

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 eroded, season to season, from Summer of 2021 to the Summer of 2022. However, the beach recovered between Summer 2022 and Winter 2023. The profiles in FIGURE demonstrate that a small mound of sand in Summer of 2021 was eroded down the beach into the intertidal zone.

Season	Volume (cf/lf)	
LRP	LRP 9	
Volume Limit	MHW	MLW
Summer 2021 (08/18/2021)	145	845
Summer 2022 (07/27/2022)	120	790
Winter 2022 (01/24/2022)	140	870
Winter 2023 (02/16/2023)	135	800

Figure 24: Average beach volumes in Bennett's Pier

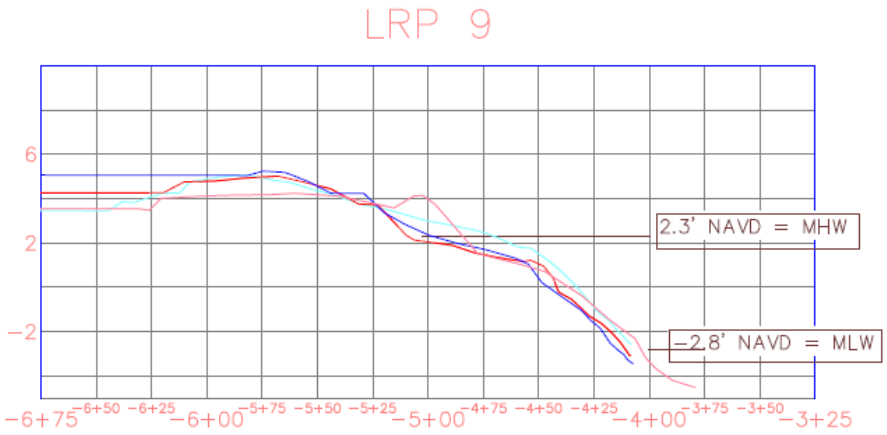


Figure 14: Beach profiles in Bennett's Pier. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

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 volumes depict the expected seasonal variability. However, most of the shoreline has lost volume since Summer of 2021. The exception is the section of the coast represented by S 11+00, which is located where a large beach fill project was completed using sand dredging from the Murderkill River channel. Generally speaking, shoreline at South Bowers beach has retreated at 0 – 2 feet/year, on average.

	Volume (cf/lf)							
LRP	LRP 7e		S 3+00		S 11+00		LRP 8	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	370	1440	255	845	240	715	200	595
Summer 2022 (07/27/2022)	330	1345	230	780	270	745	160	615
Winter 2022 (01/24/2022)	310	1335	210	770	200	670	140	625
Winter 2023 (02/16/2023)	330	1330	210	735	790	1765	155	595

As can be seen in the profile comparison in FIGURE, the upper beach erodes and recovers from season to season. However, the overall trend is erosion and shoreline retreat at this profile location. This trend is typical for the natural shoreline of South Bowers Beach

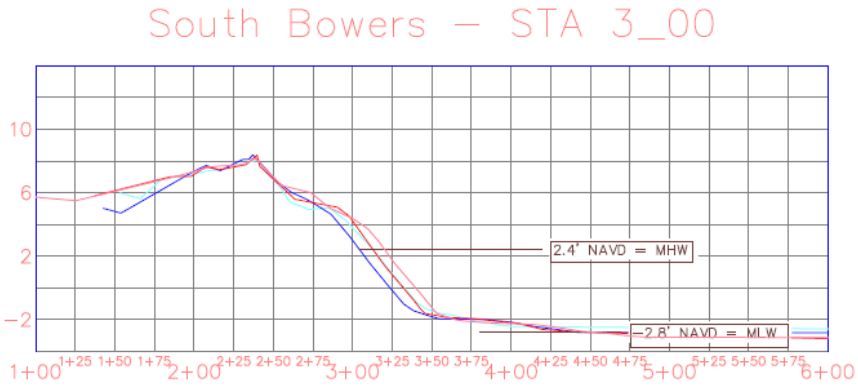


Figure 28. Beach profiles in South Bowers Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The profile comparison at S 11+00 is shown in FIGURE. These profiles are in the section of the beach that received sand dredged from the Murderkill River after the Summer 2022 survey. This nourishment project, placed a large volume of sand on the beach at South Bowers, extending the shoreline bayward by nearly 100'.

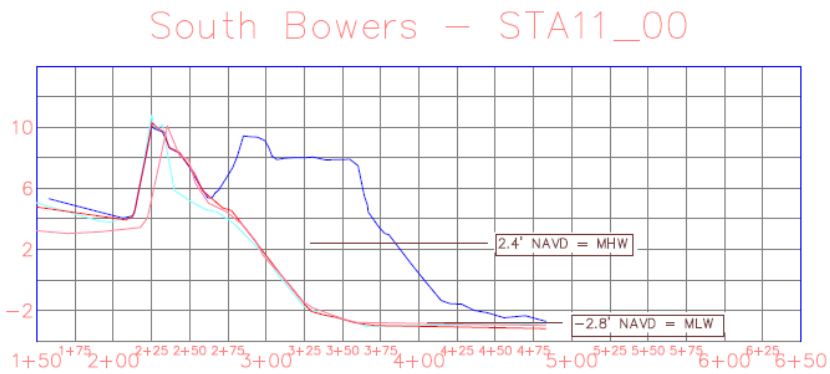


Figure 28. Beach profiles in South Bowers Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The only storm event for which the Section assessed the conditions of South Bowers Beach was the one occurring in late October of 2021. During that event, the storm tide nearly reached the dunes as depicted in FIGURE.

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

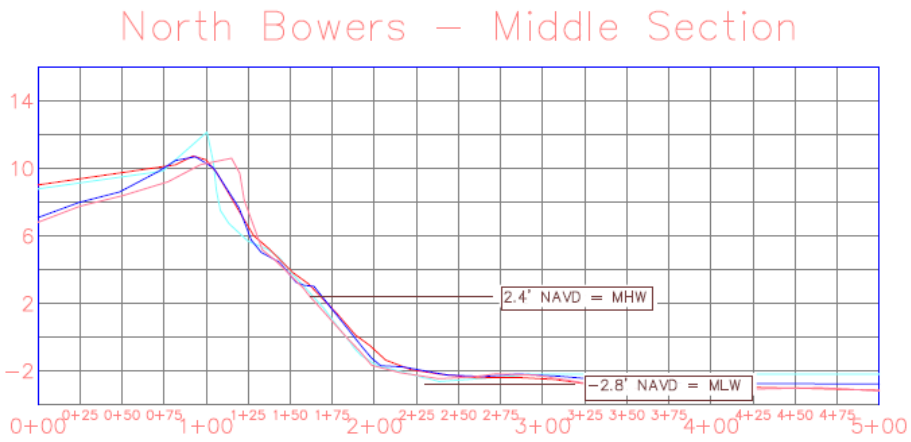


Figure 28. Beach profiles in Bowers Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The average beach volumes of Bowers are shown in TABLE. The beach profile trends vary along the coast. It is noted that the beach was nourished in the February of 2022. This project essentially repaired damage to the dune that was experience during the Fall of 2021 (See FIGURE). The loss observed between Summer 2021 and Winter 2022 is likely due, in large part, to the storms that occurred in the Fall of 2021. The recovery of the beach prior to the Summer 2022 is likely due to the beach fill project, rather than natural seasonal change. In FIGURE, the scarp incurred during Fall 2021 was captured by the Winter 2022 survey. The subsequent profiles shows that the beach nourishment project repaired the dune, which remains intact. It is noteworthy that LRP 7b is outside of the beach fill project area and is separate by a small concrete bag groin.

Table 5 Average beach volumes in Bowers Beach

Season	Volume (cf/lf)							
LRP	LRP 7b		N 25+00		LRP 7c		N 4+00	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	260	1040	190	650	325	925	170	735
Summer 2022 (07/27/2022)	220	1005	190	325	310	950	180	740
Winter 2022 (01/24/2022)	325	1235	145	560	280	890	130	670
Winter 2023 (02/16/2023)	230	950	250	660	290	940	130	830

The profiles surveyed north of the concrete bag groin (LRP 7b) is shown in FIGURE. The beach accreted substantially between Summer 2021 and Winter 2022. The cause of this accretion is uncertain; however, this survey line is proximal to the unstructured inlet to the St. Jones River. Unstructured inlets are very dynamic, which may be the source of change at this LRP location.

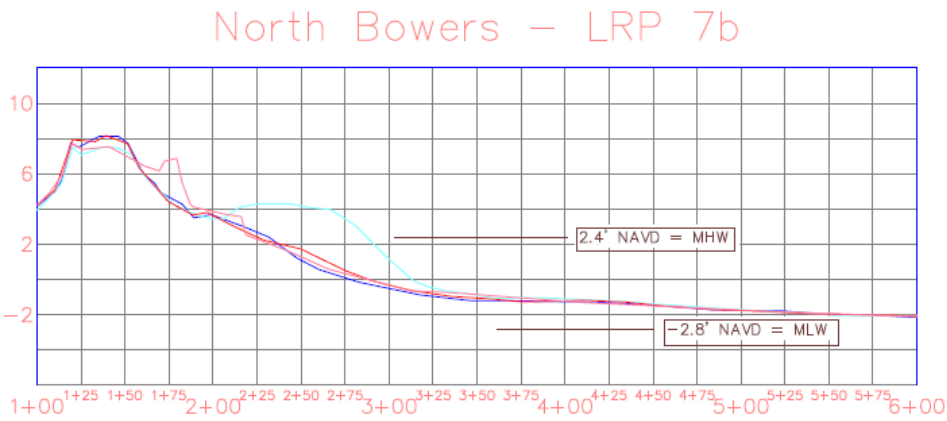


Figure 28. Beach profiles in Bowers Beach north of the concrete bag jetty. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

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 TABLE. This beach was also nourished after the Winter 2022 survey date to repair the erosion incurred by the storms during the Fall of 2021. All profiles lost a substantial amount of volume between Summer 2021 and Winter 2022. There was an additional fill project in November of 2022 that was of a smaller scale. Based on the volumes reported in TABLE, these nourishment activities have been successful in terms of repairing and maintained the upper beach and dune.

Table 6 Average beach volumes in Kitts Hummock

Season	Volume (cf/lf)							
LRP	LRP n5		LRP 5		LRP n6		LRP 6	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	150	445	420	865	230	520	180	515
Summer 2022 (07/27/2022)	200	610	440	935	210	520	160	520
Winter 2022 (01/24/2022)	100	435	375	815	170	465	100	425
Winter 2023 (02/16/2023)	200	580	450	945	220	515	160	510

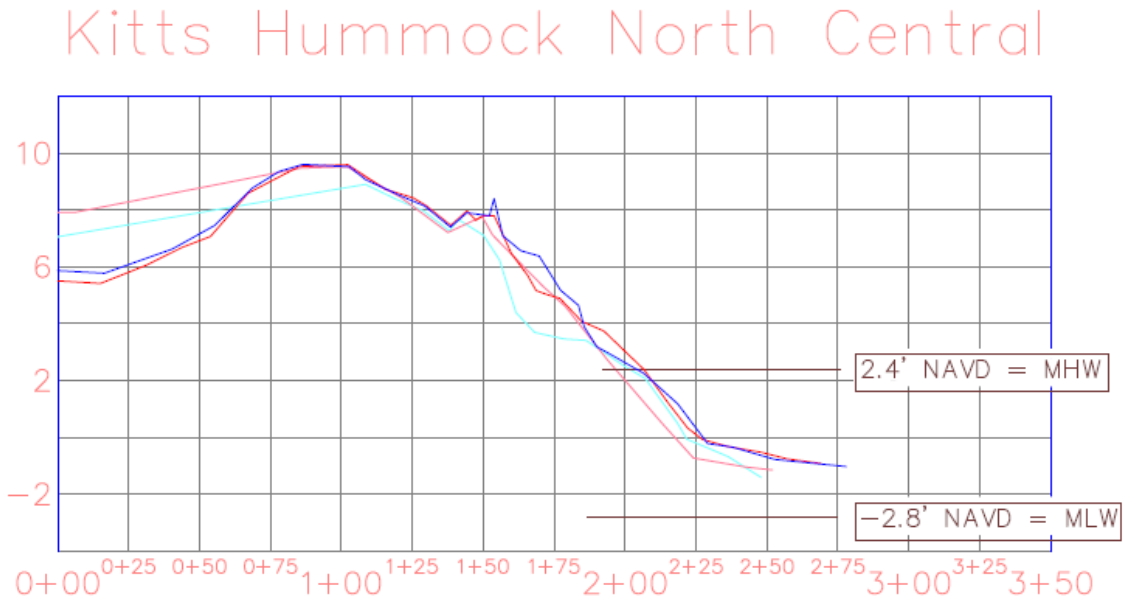


Figure 28. Beach profiles in Kitts Hummock. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The Section assessed the beach conditions in Kitt Hummock after several storm events in the period covered by this report. The pictures in FIGURE so beach conditions following some of these events. The upper left picture was taken during a storm event occurring on 11/05/2021. The upper right shows the scarping of the upper beach and dune that occurred in early October of 2022. The lower images were

taken after minor storm events in December of 2022. The lower left was taken about 1 week following the completion of the beach nourishment job. The lower right was taken about 2 weeks following the completion, and immediately following a storm tide event.

Figure 31: Images of Kitts Hummock beach conditions immediately after storms or, in the case of the lower left hand image, after a beach fill job.

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

The average beach volumes of Pickering Beach are shown in TABLE. Like Kitts Hummock, Pickering Beach was nourished in April of 2022 again in November 2022. The earlier nourishment repaired major damage to the upper beach and dune in Pickering Beach that occurred in the Fall of 2021 whereas the November project repaired minor losses of the berm. The November project did place a substantial volume of sand at the south end of the community, as represented by LRP 2. This accounts for the large gain in volume from Summer 2022 to Winter 2023.

Season	Volume (cf/lf)					
LRP	LRP 1		LRP 1A		LRP 2	
Volume Limit	MHW	MLW	MHW	MLW	MHW	MLW
Summer 2021 (08/18/2021)	170	535	160	540	40	300
Summer 2022 (07/27/2022)	210	625	180	640	50	370
Winter 2022 (01/24/2022)	110	495	75	490	10	280
Winter 2023 (02/16/2023)	200	610	170	620	120	455

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 profile data shown in FIGURE clearly demonstrates the major erosion of the dune captured by the Winter 2021 survey. The nourishment jobs have been successful in terms of rebuilding and maintaining the dune.

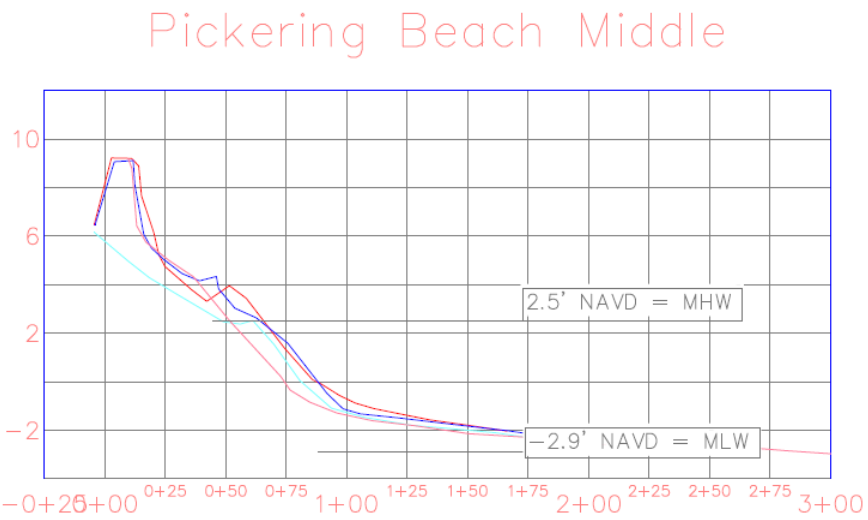


Figure 28. Beach profiles in Pickering Beach. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

The large dune that was constructed during the November beach fill job is demonstrated in FIGURE. This dune was scarped prior to the Winter 2023 the beach profile remains much higher and voluminous in comparison to previous years.

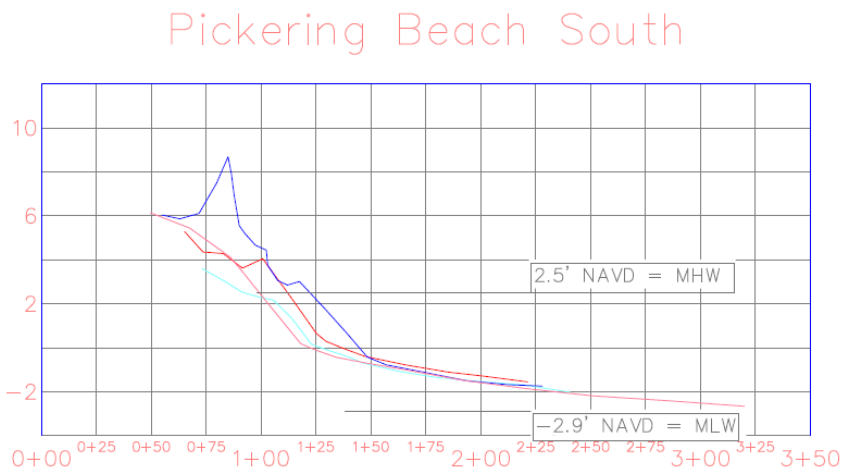


Figure 28. Beach profiles in Pickering Beach at the south end of the community. Data are from winter 2022 (light blue), summer 2021 (pink), winter 2023 (blue solid), and summer 2022 (red solid).

During the first nor' easter in October of 2021, there was minor impacts (erosion/scarping) in Pickering Beach. The storm in later in that 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

Following these Fall storms, the Section repaired the dune and upper beach at Pickering Beach. In subsequent months, storms caused erosion of that repair. The repaired dune remained intact though it was severely scarped.

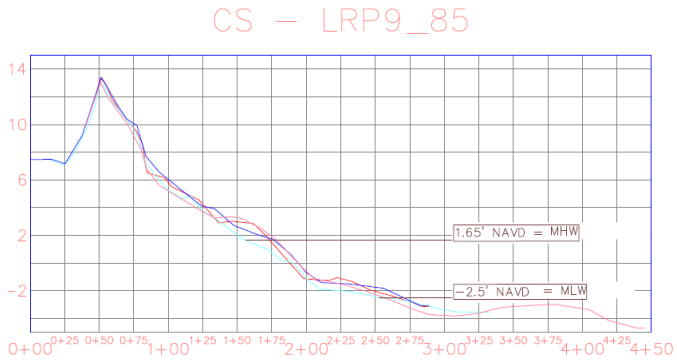
Figure 38 Pickering Beach conditions in October of 2022 which depicts the erosion of the beach fill project completed in April of 2022.

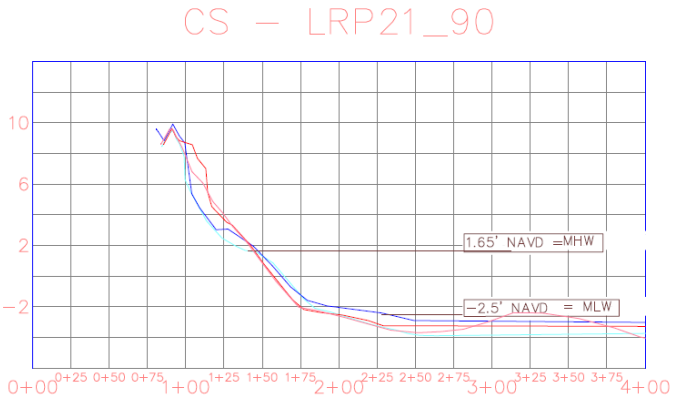
The Section also completed a smaller beach fill job in November of 2022. Immediately following the projects completion, a storm caused substantial erosion. The stake used to guide the construction of the November beach fill job is depicted in FIGURE. The painted portion of the stake is what was to be filled during the nourishment project. The exposed paint demonstrates the erosion in addition to any deficiencies during the construction of the project.

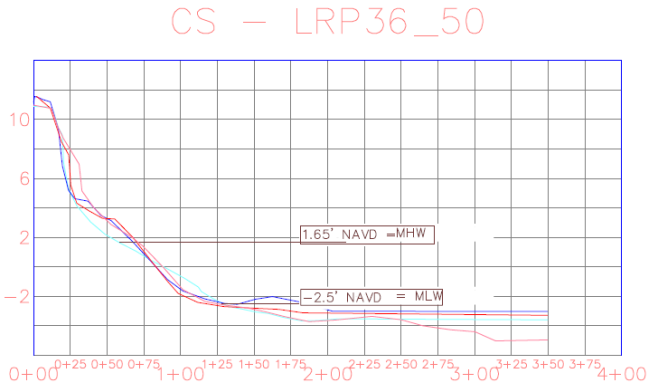
Figure 38 Conditions at Pickering Beach following a December 2022 storm that partially eroded the smaller beach fill job completed in November of 2022.

Appendix A-1: All Beach Profiles:

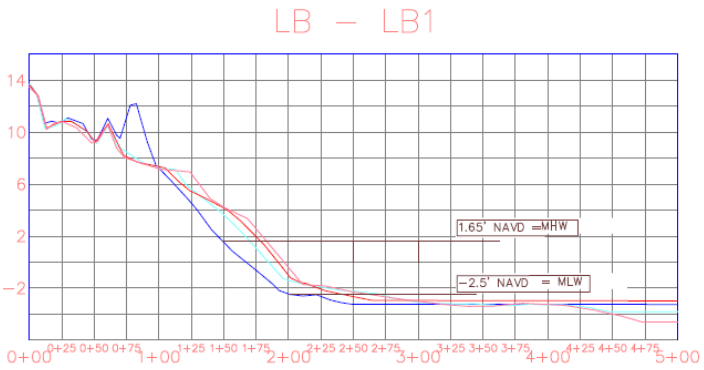
Cape Shores







Lewes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1+25 1+50 1+75
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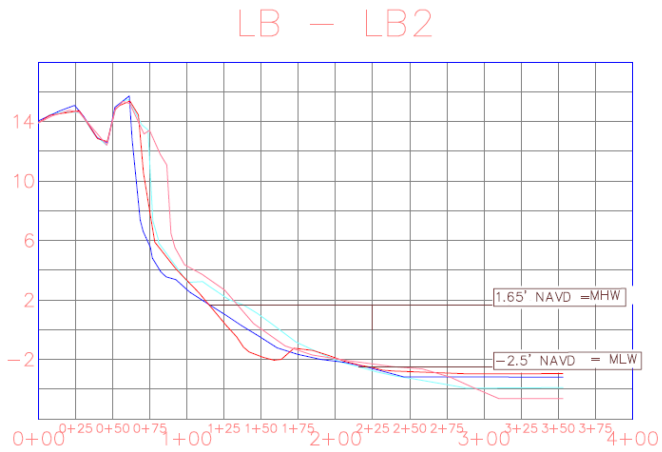
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3+00
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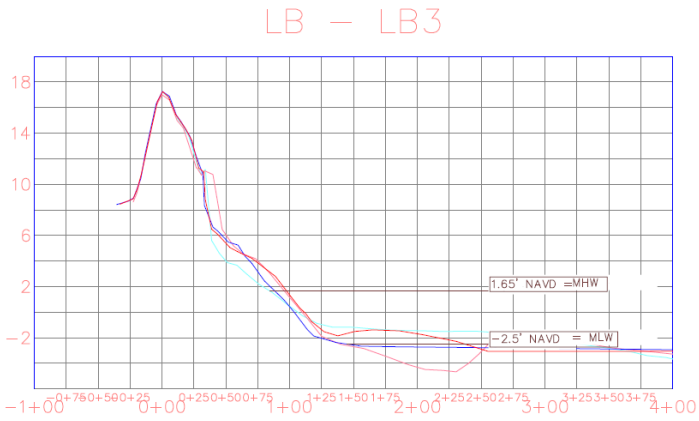
4+00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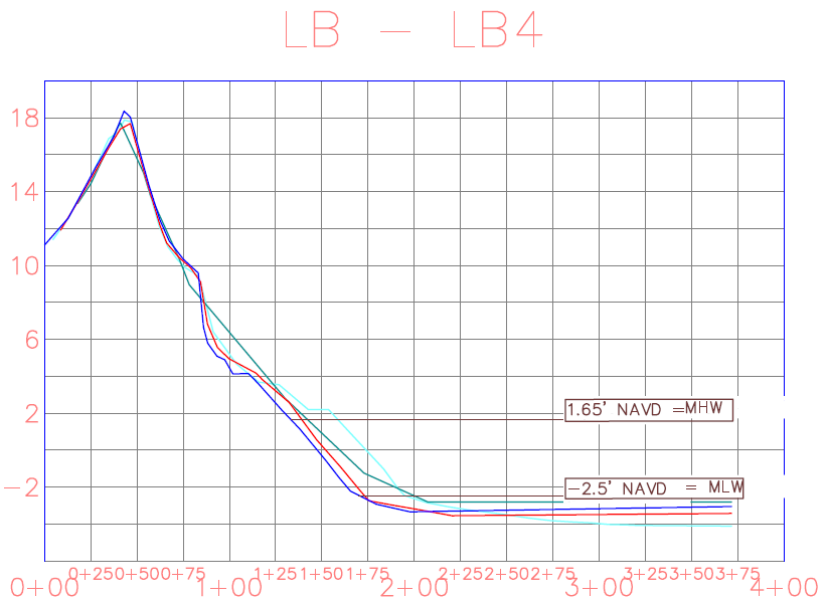
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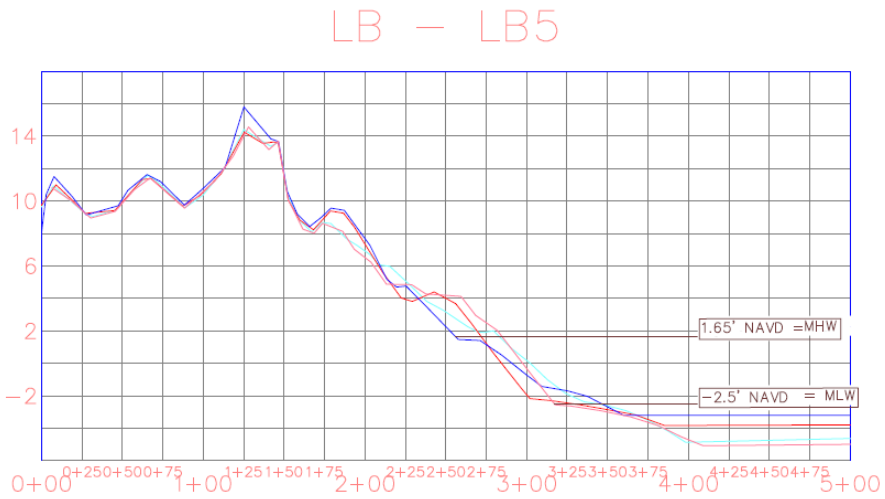
3+253+503+75
4+00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0+250+500+75
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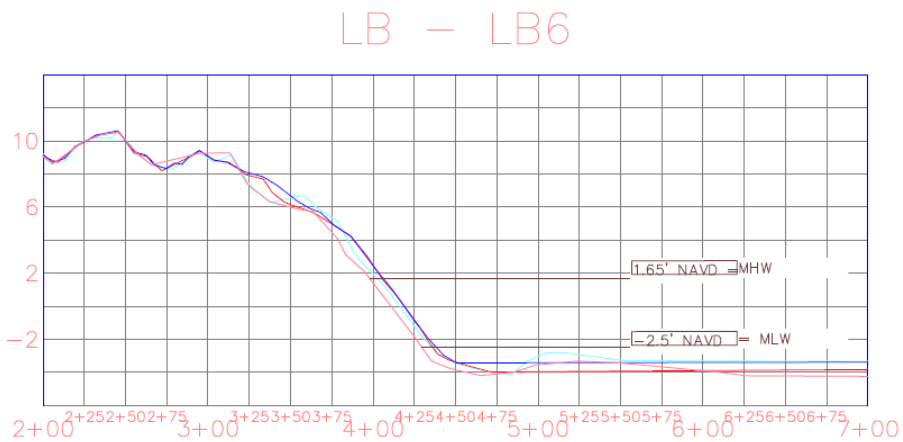
3+253+503+75
4+00
4+254+504+75
5+00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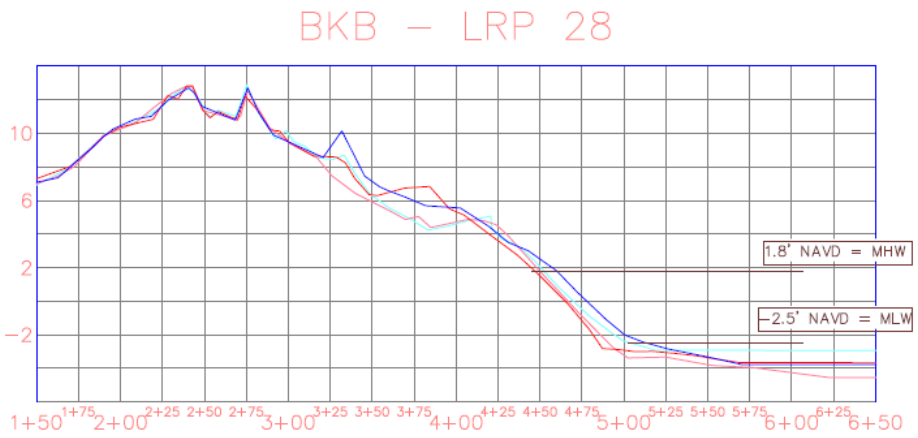
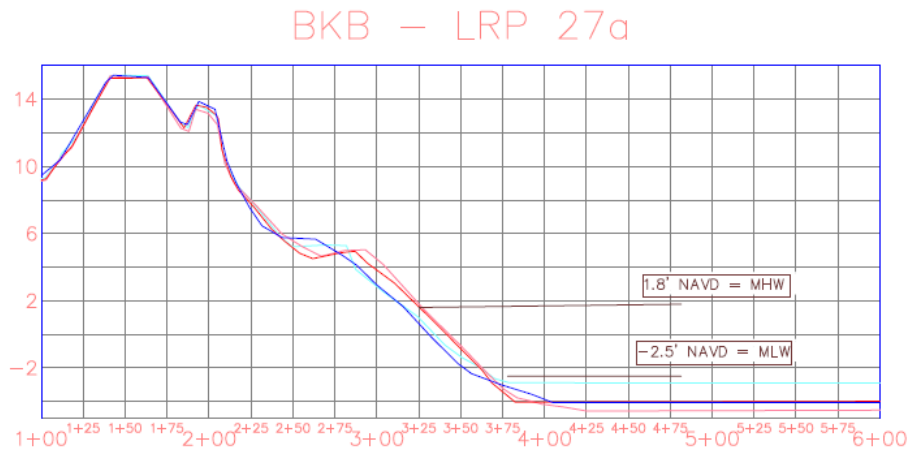
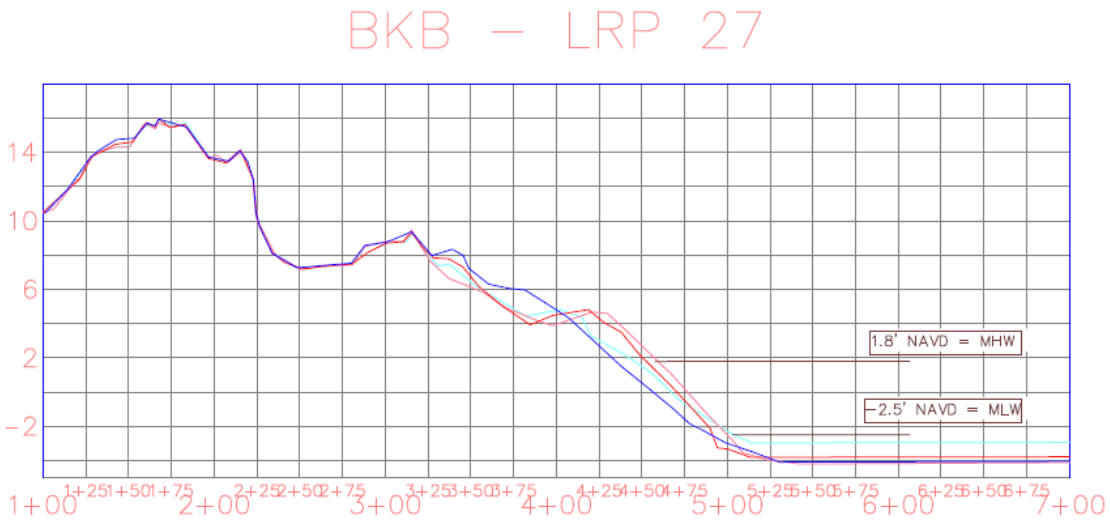
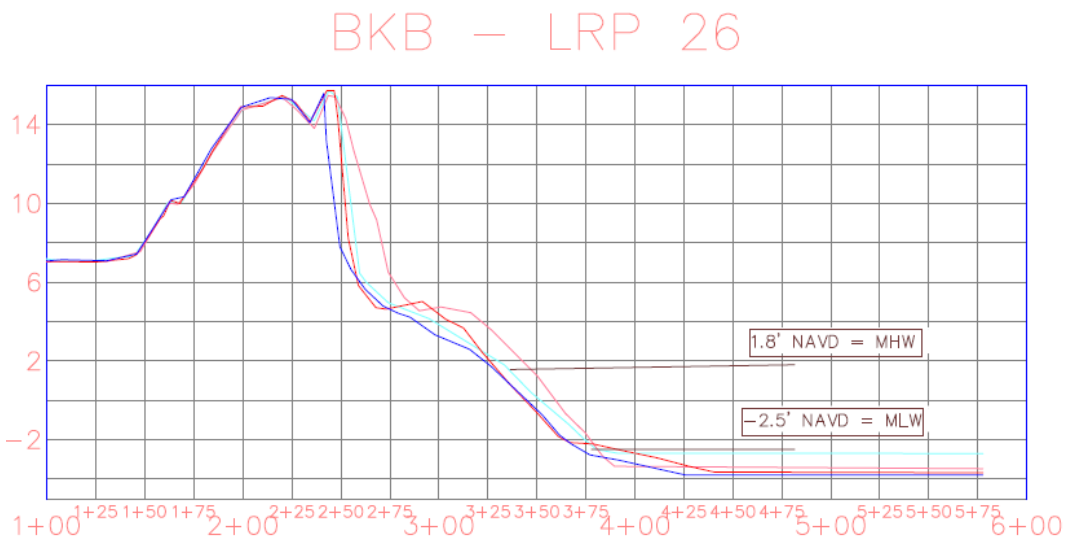
6+00
6+256+506+75
7+00

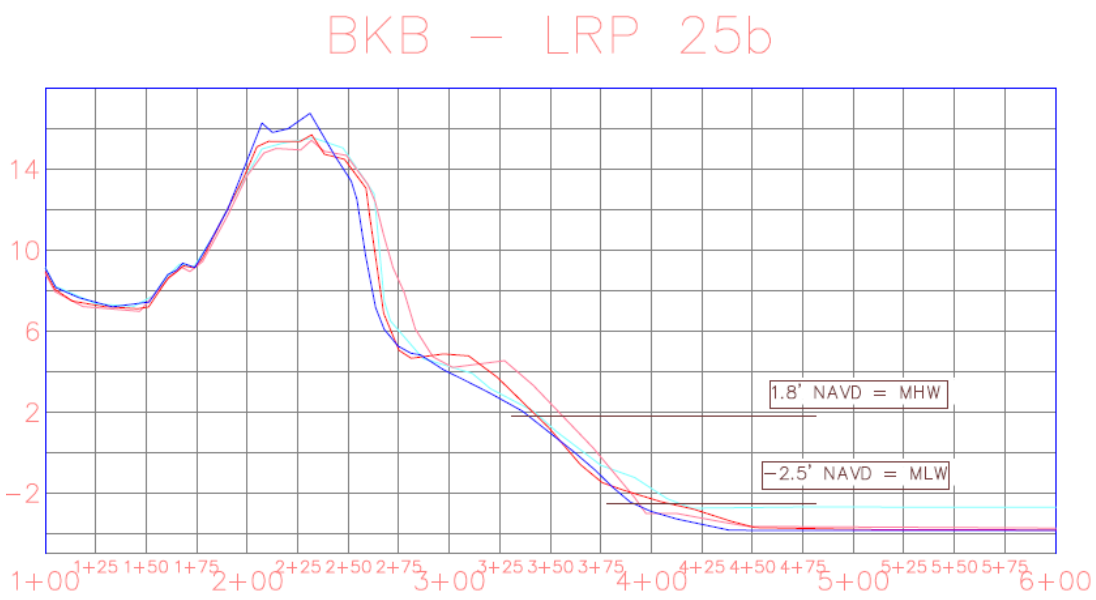
Broadkill Beach

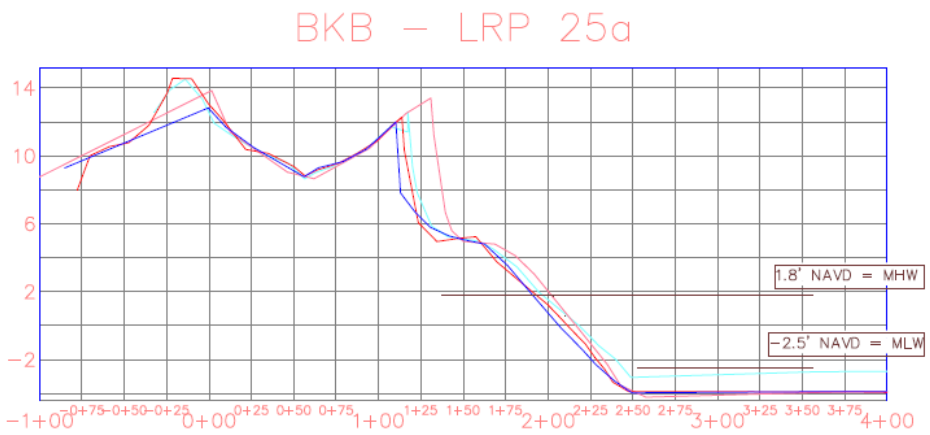


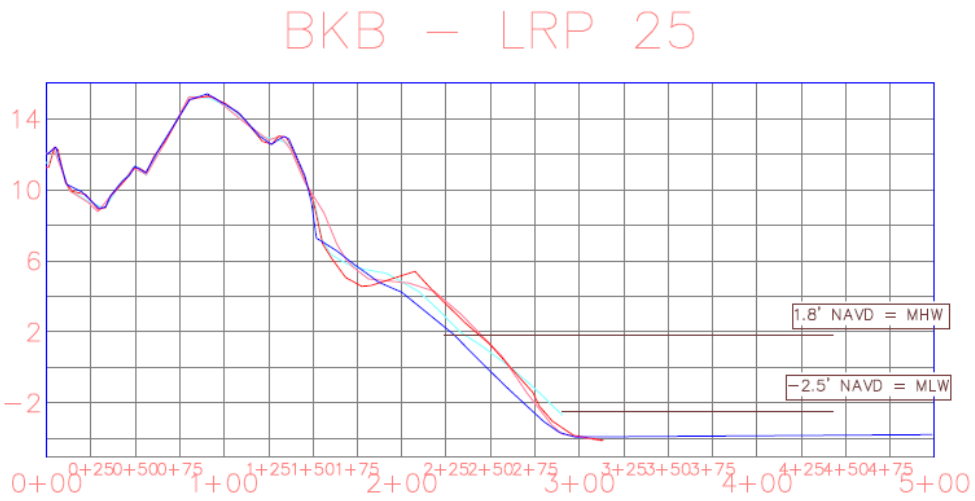


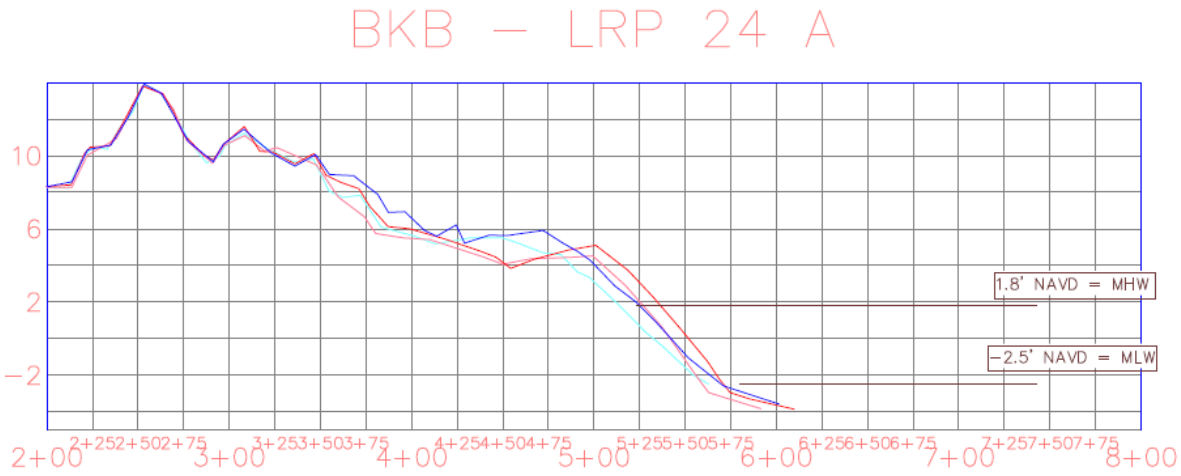


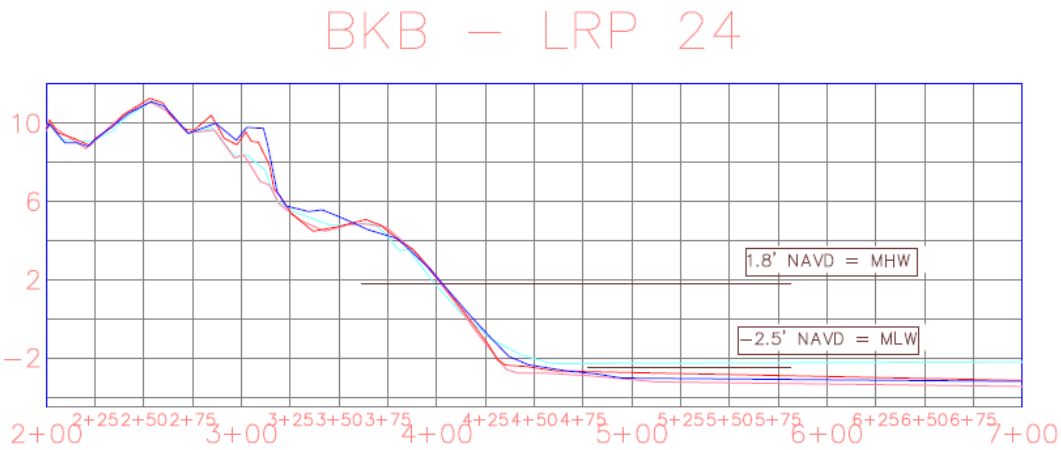

BKB – LRP 26
14
10
6
2
−2
1.8' NAVD = MHW
−2.5' NAVD = MLW
1+00
1+25
1+50
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50
3+75
4+00
4+25
4+50
4+75
5+00
5+25
5+50
5+75
6+00


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

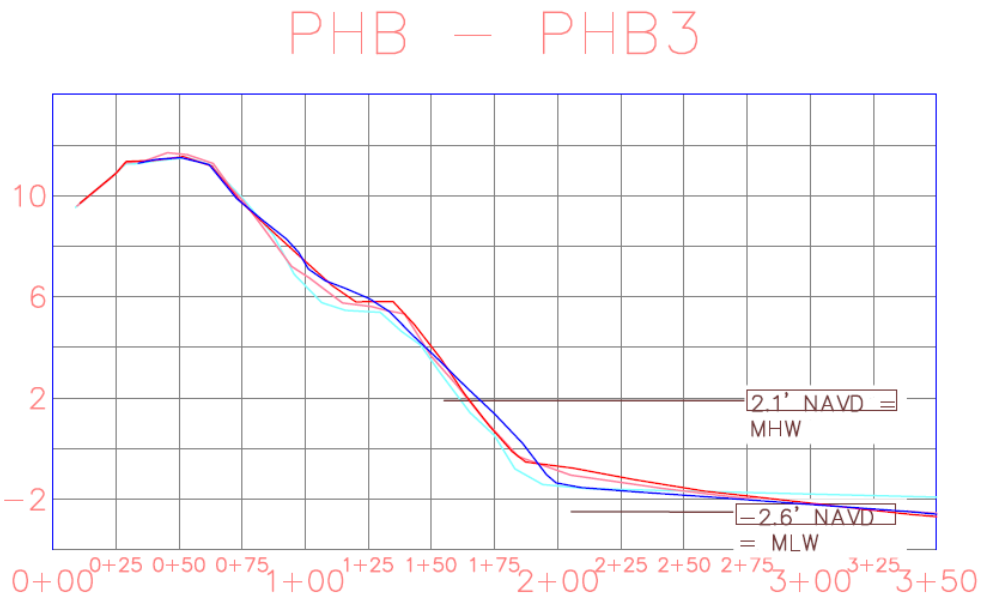

BKB – LRP 25a
14
10
6
2
−2
1.8' NAVD = MHW
−2.5' NAVD = MLW
−1+00
0+00
1+00
2+00
3+00
4+00

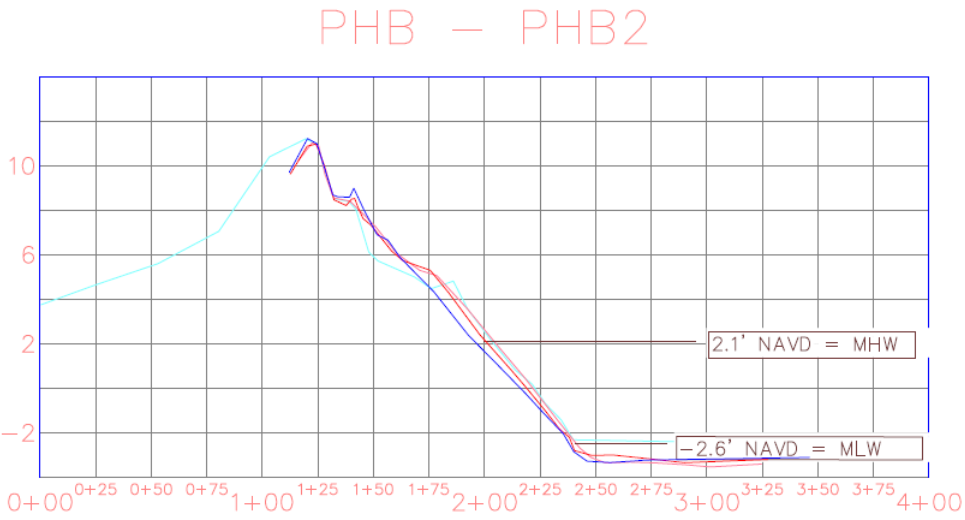

BKB – LRP 25
14
10
6
2
−2
1.8' NAVD = MHW
−2.5' NAVD = MLW
0+00
1+00
2+00
3+00
4+00
5+00

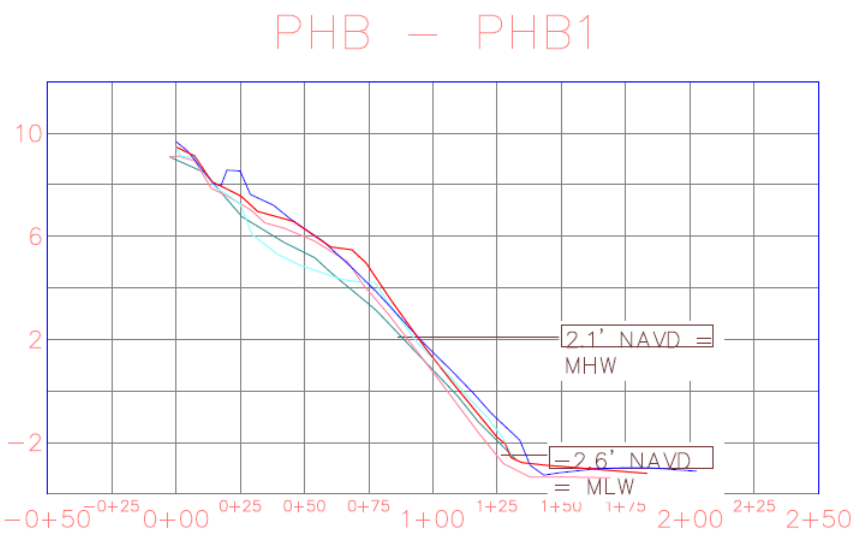

BKB – LRP 24 A
10
6
2
−2
1.8' NAVD = MHW
−2.5' NAVD = MLW
2+00
3+00
4+00
5+00
6+00
7+00
8+00


BKB – LRP 24
10
6
2
−2
1.8' NAVD = MHW
−2.5' NAVD = MLW
2+00
2+252+502+75
3+00
3+253+503+75
4+00
4+254+504+75
5+00
5+255+505+75
6+00
6+256+506+75
7+00

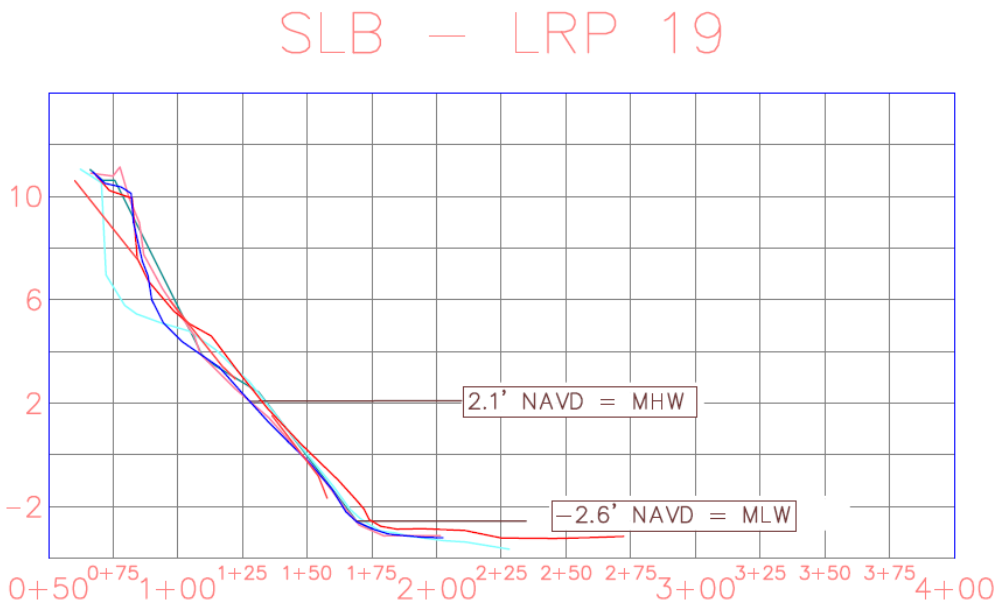
Prime Hook Beach

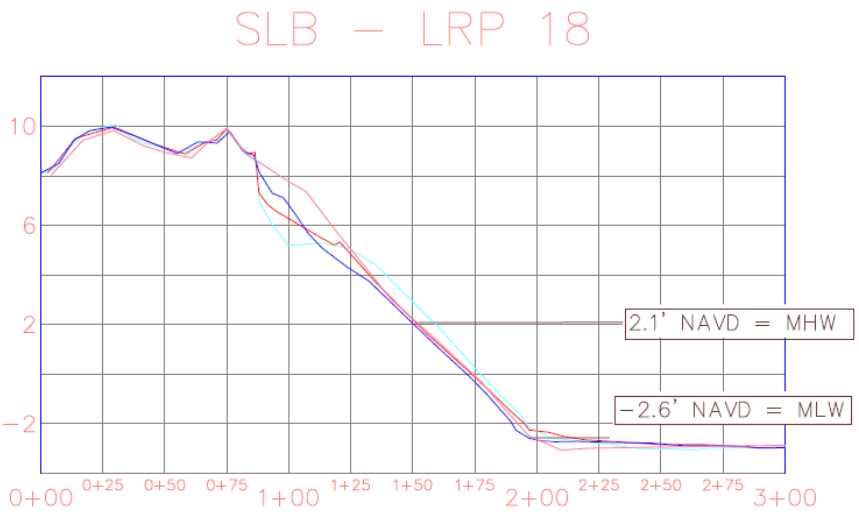


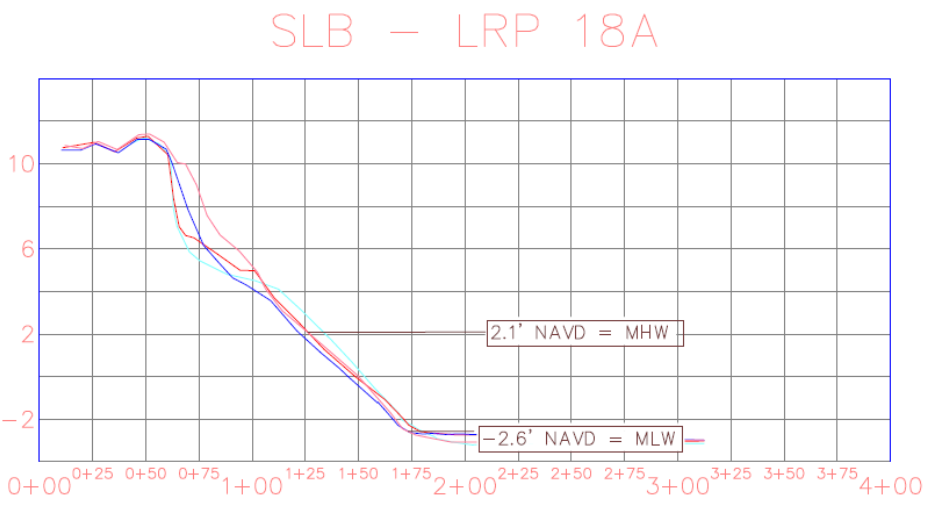


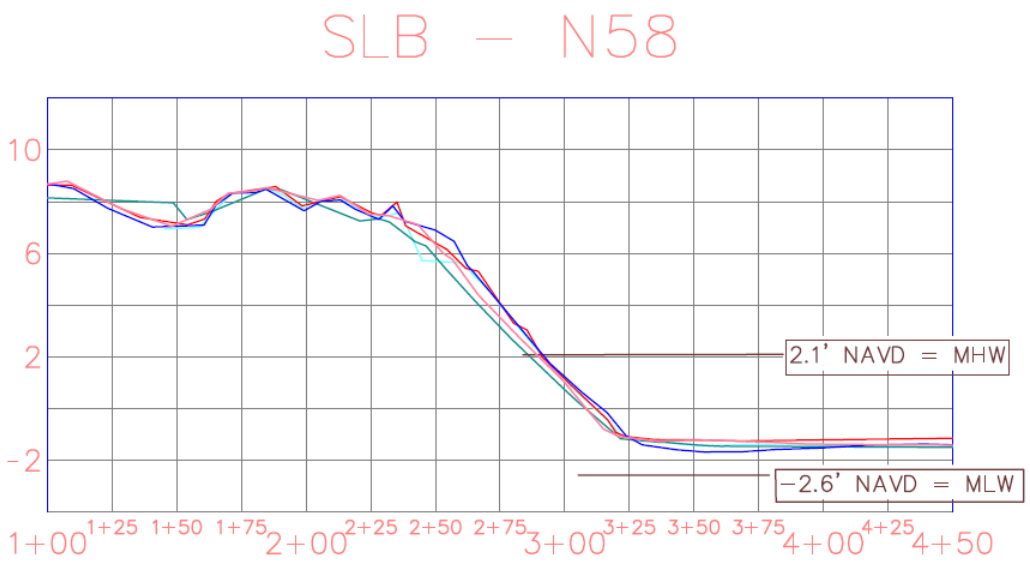

PHB – PHB1
10
6
2
−2
2.1' NAVD =
MHW
−2.6' NAVD
= MLW
−0+50
−0+25
0+00
0+25
0+50
0+75
1+00
1+25
1+50
1+75
2+00
2+25
2+50

Slaughter Beach

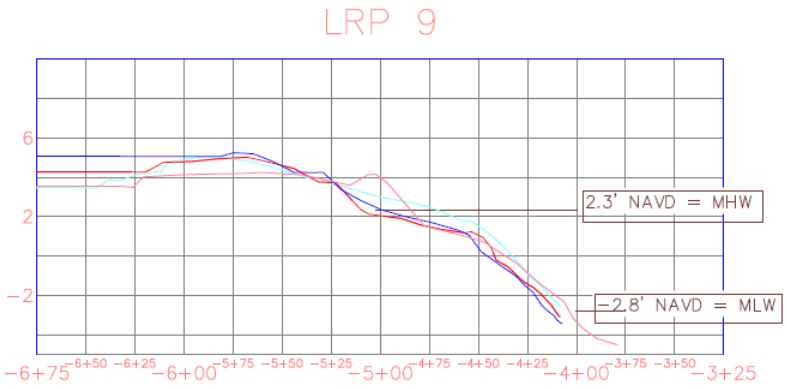




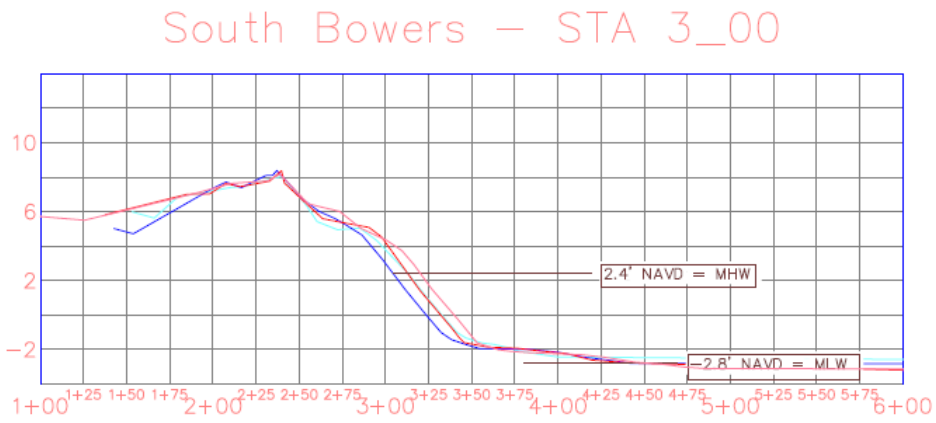


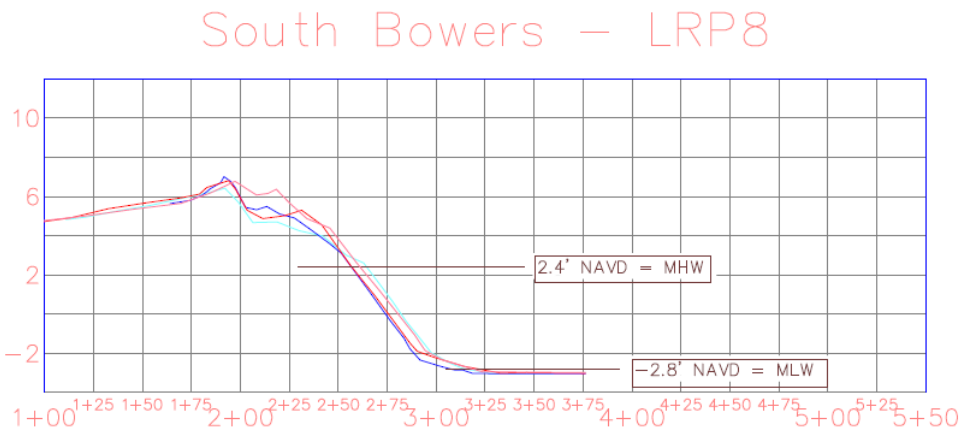

SLB – N58
10
6
2
-2
2.1' NAVD = MHW
-2.6' NAVD = MLW
1+00
1+25
1+50
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50
3+75
4+00
4+25
4+50

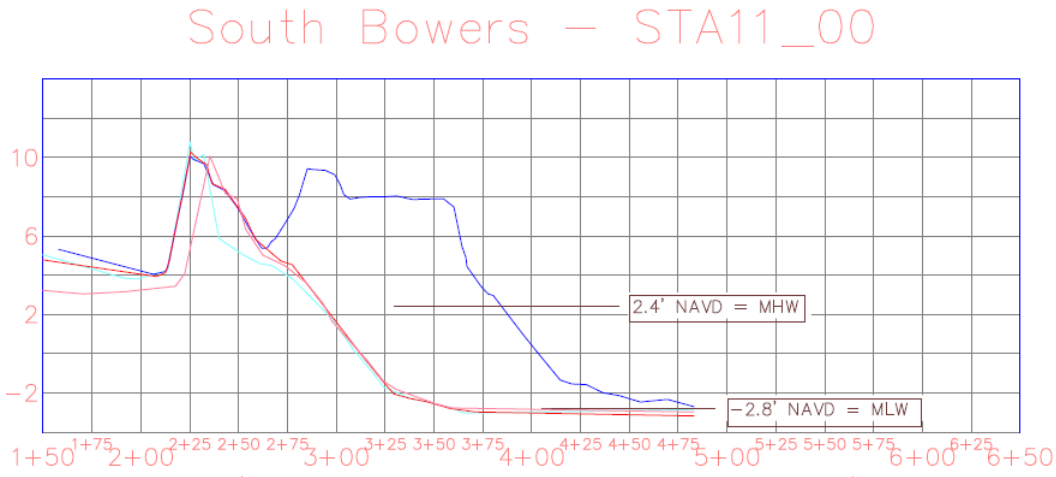
Bennett's Pier

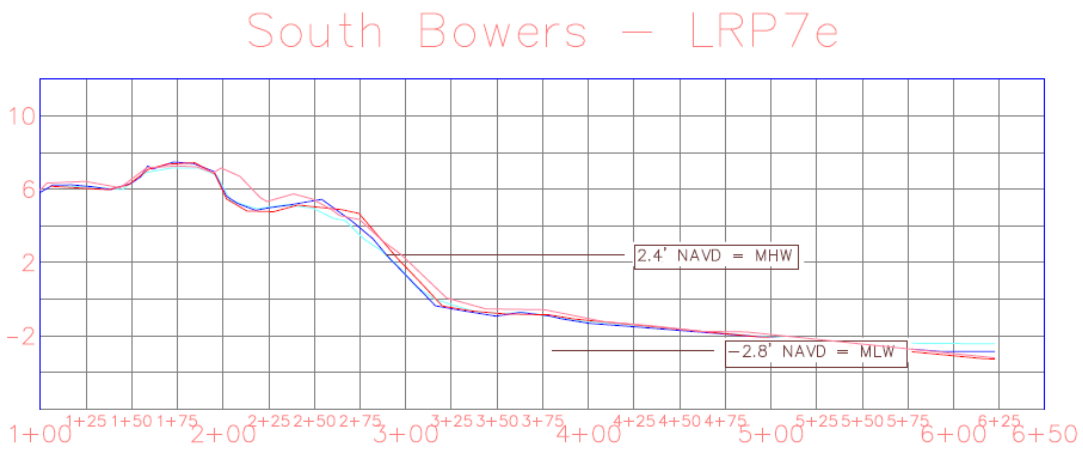


South Bowers Beach

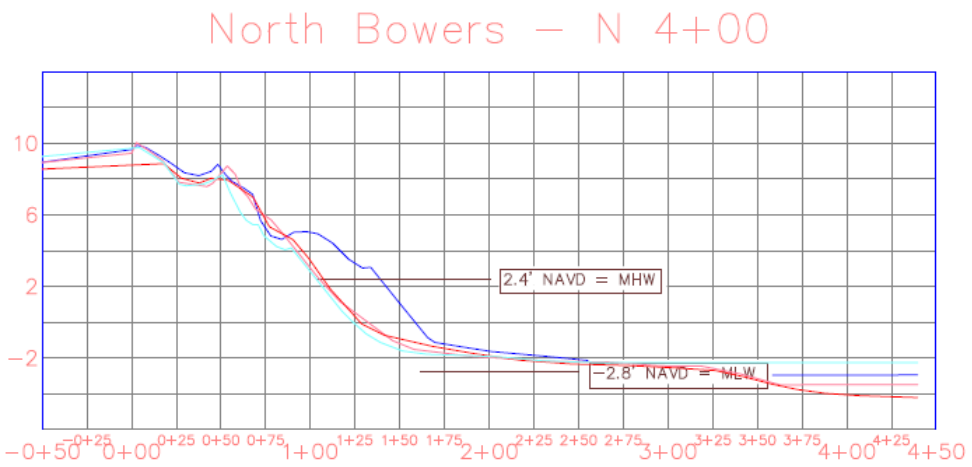


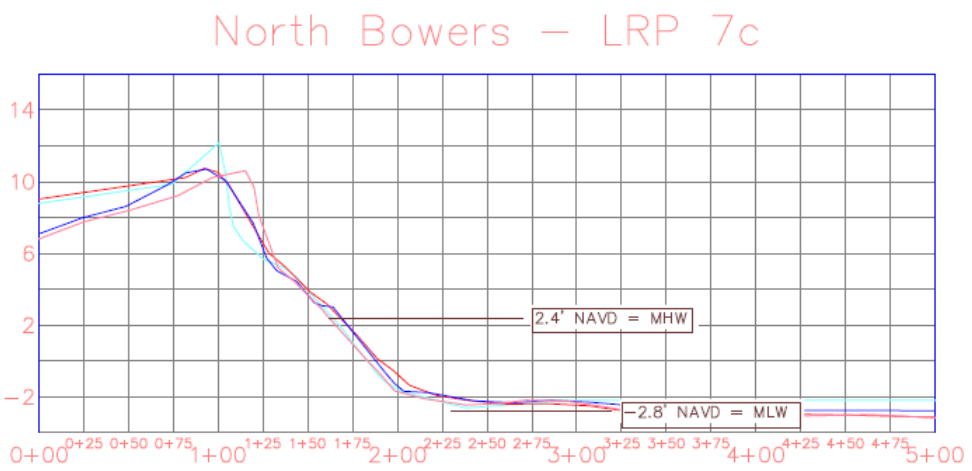


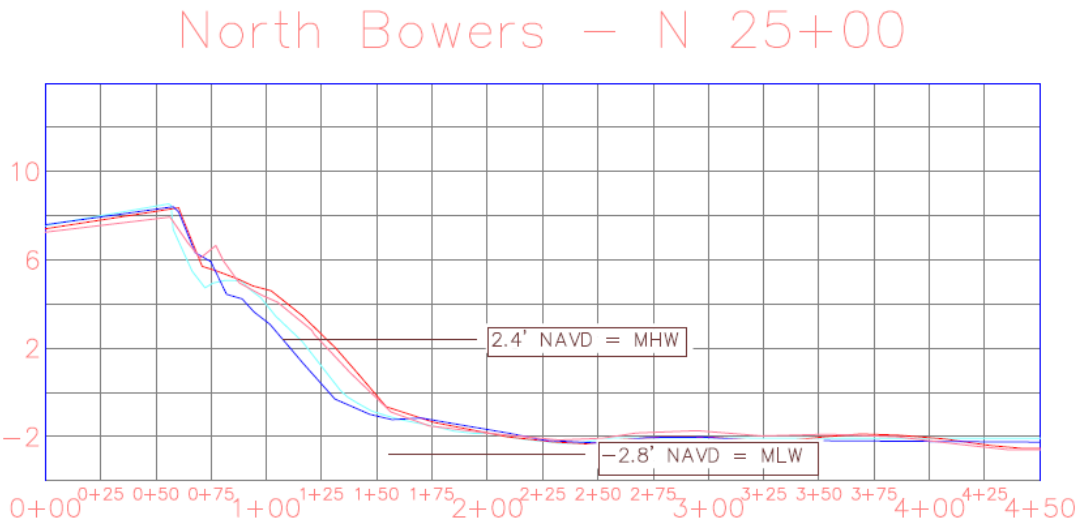



South Bowers – LRP7e
10
6
2
-2
2.4' NAVD = MHW
-2.8' NAVD = MLW
1+00
1+25
1+50
1+75
2+00
2+25
2+50
2+75
3+00
3+25
3+50
3+75
4+00
4+25
4+50
4+75
5+00
5+25
5+50
5+75
6+00
6+25
6+50

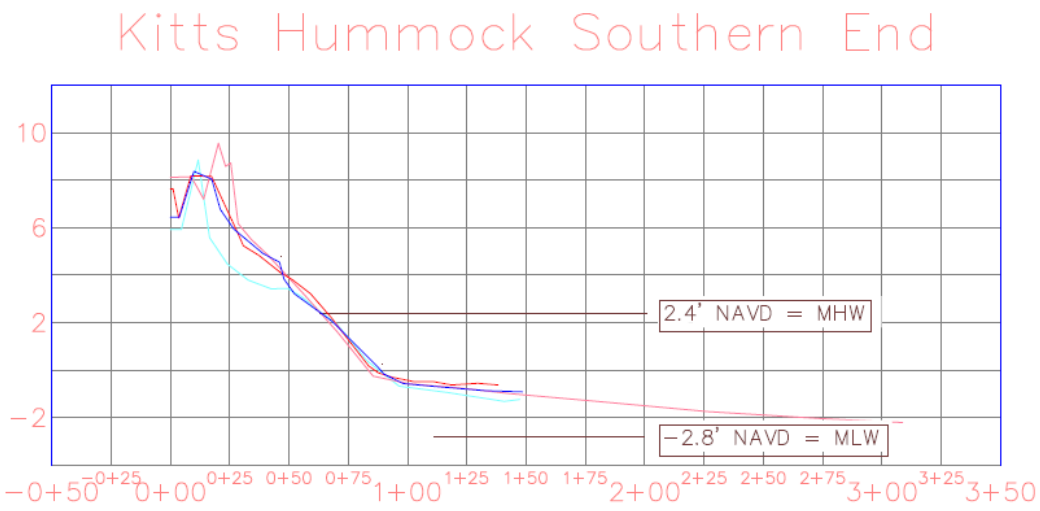
Bowers Beach

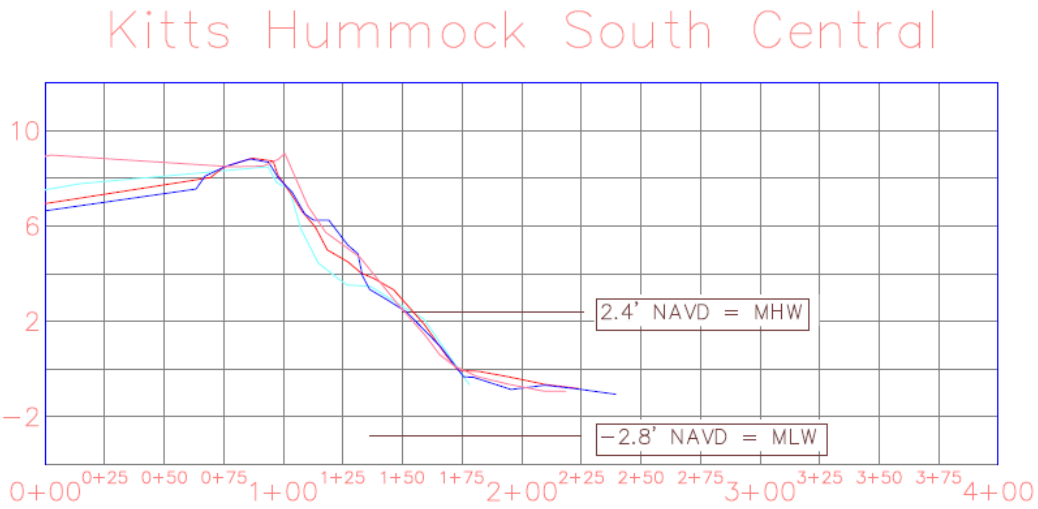


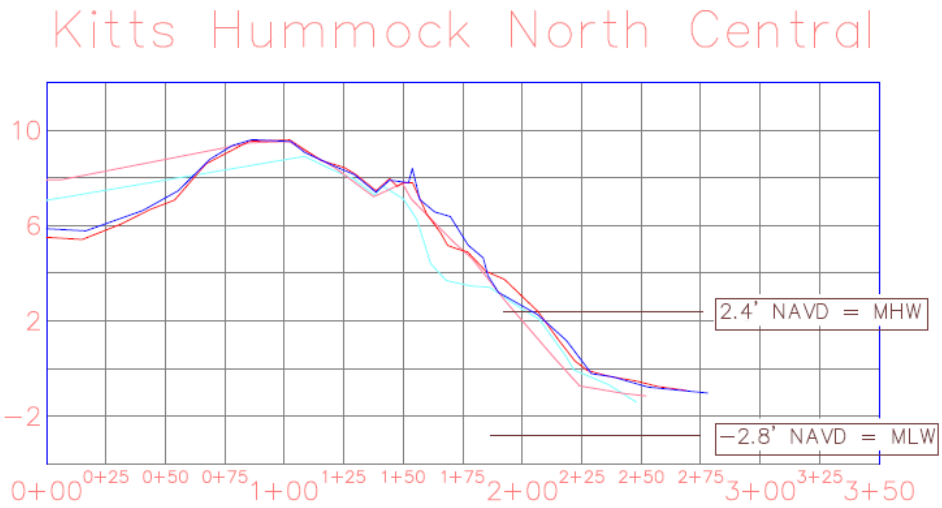




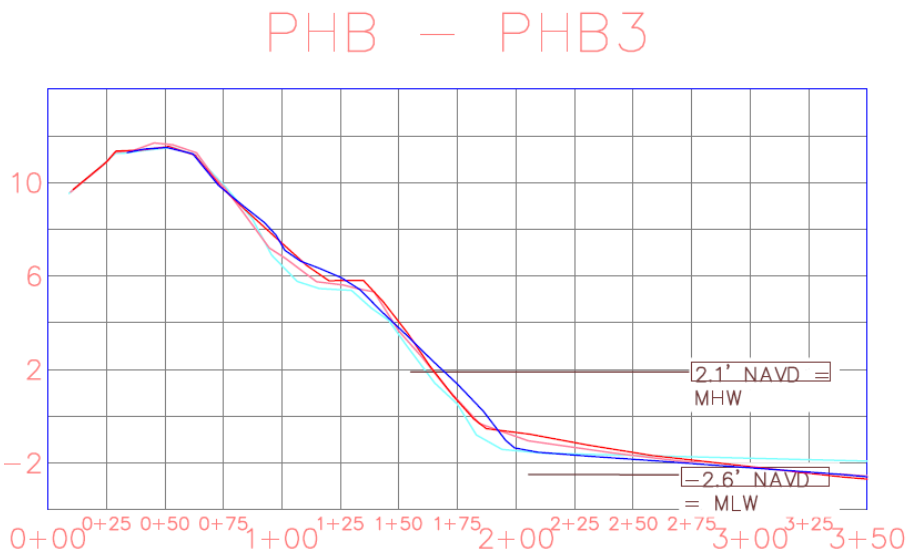
Kitts Hummock

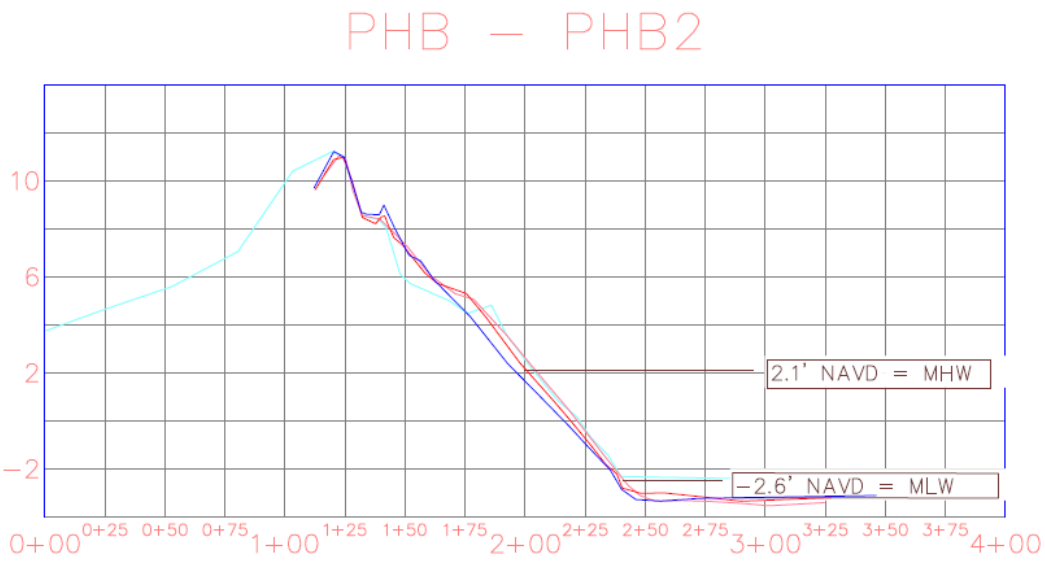


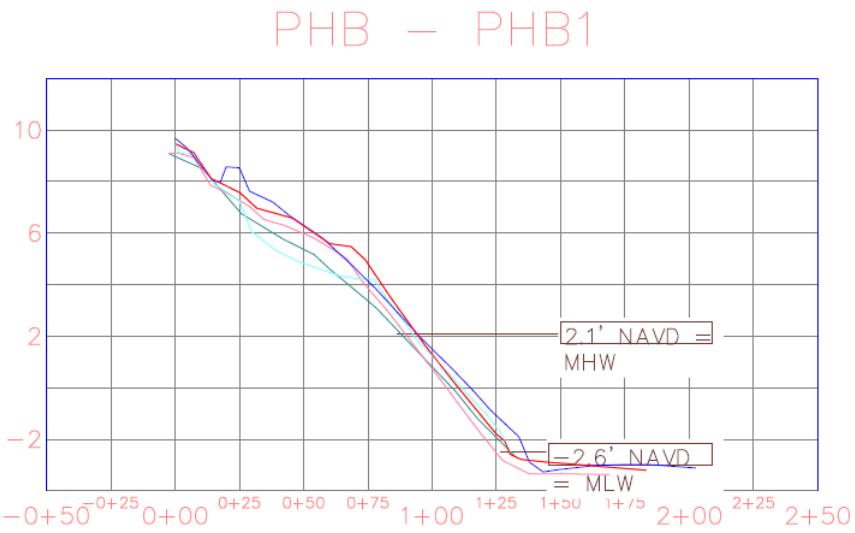




Pickering Beach



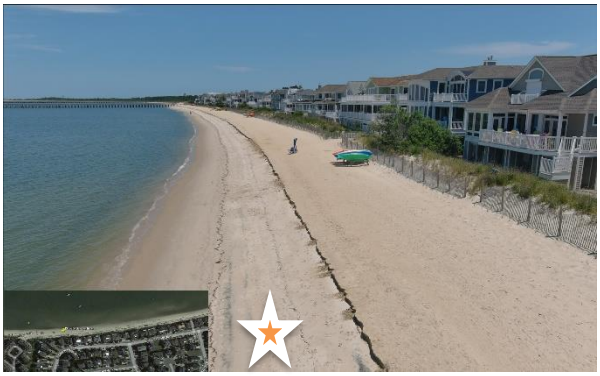



PHB – PHB1
10
6
2
−2
2.1' NAVD =
MHW
−2.6' NAVD
= MLW
−0+50
−0+25
0+00
0+25
0+50
0+75
1+00
1+25
1+50
1+75
2+00
2+25
2+50

Appendix A-2 Beach Condition Photos

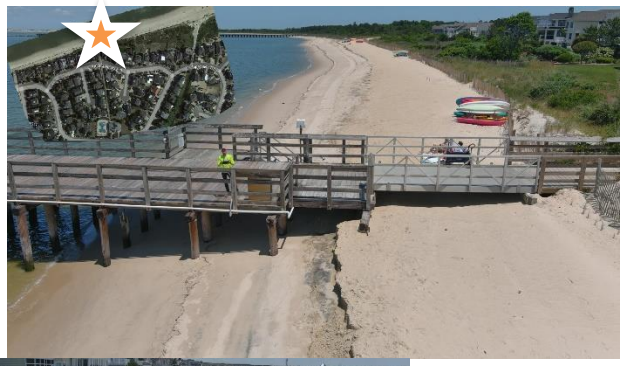
Cape Shores (06/05/2023)

South End



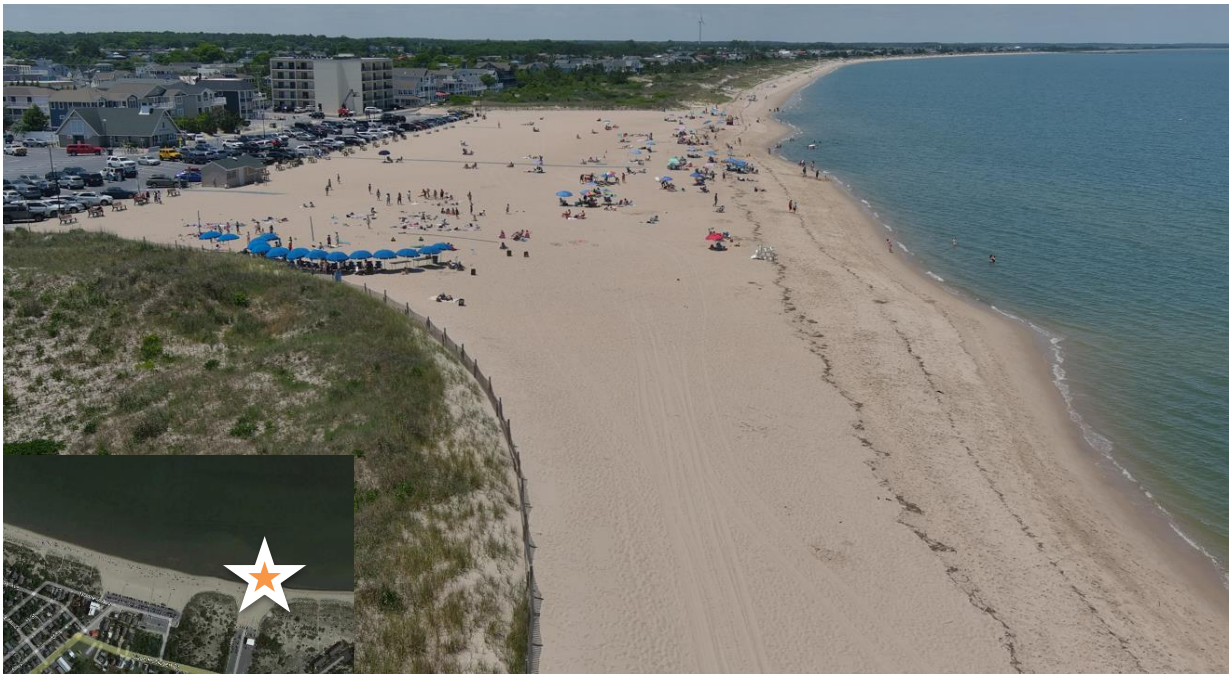
South Central

Near Pier

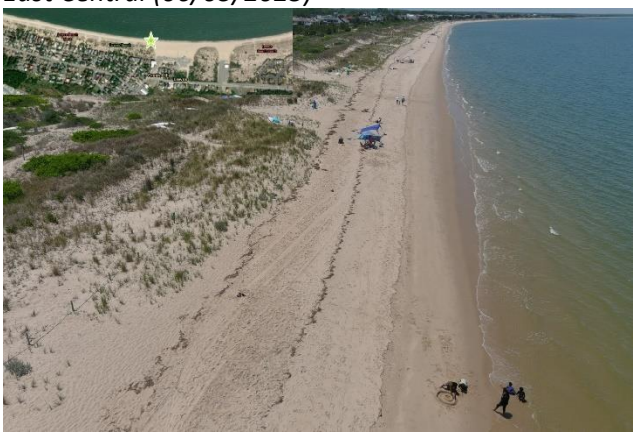


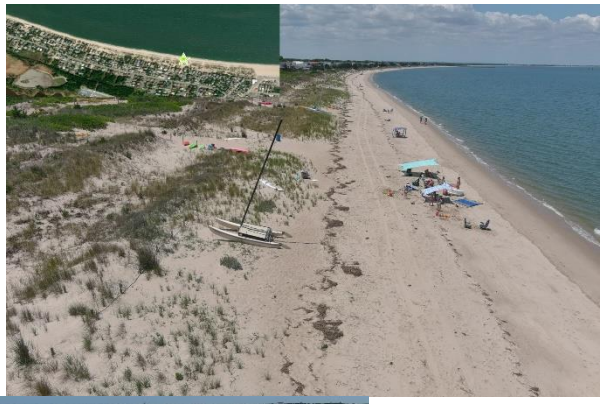
Lewes Beach

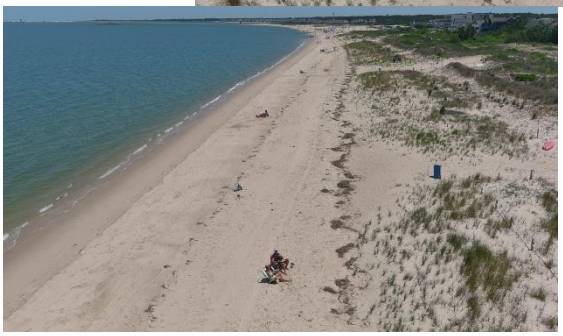
Overview (06/05/2023)



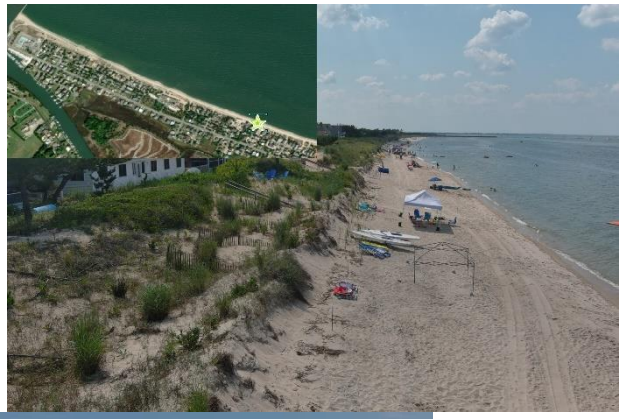
East Central (06/05/2023)

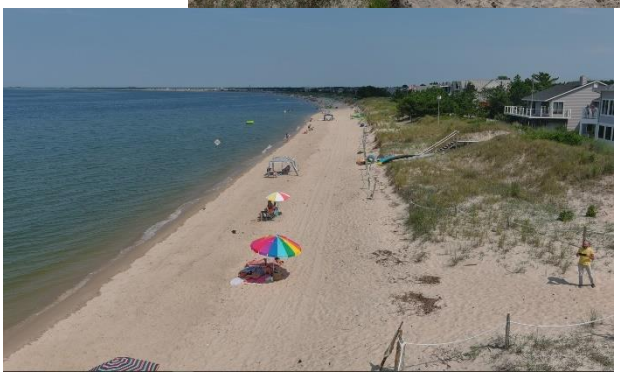


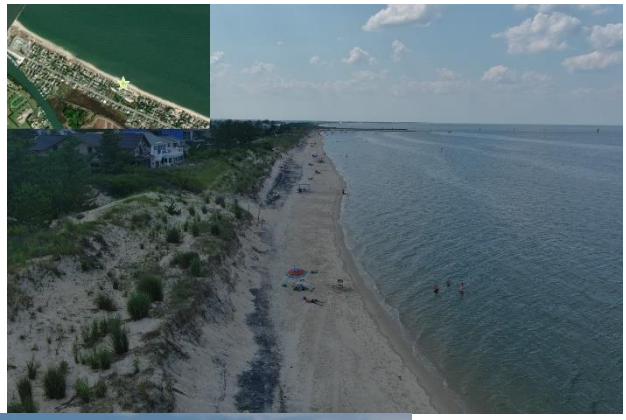


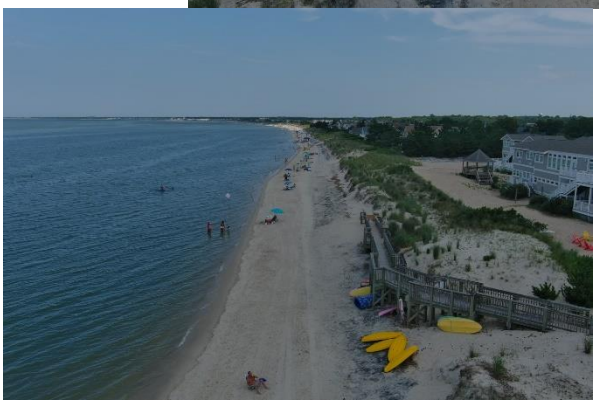


Western Central (07/13/2023)

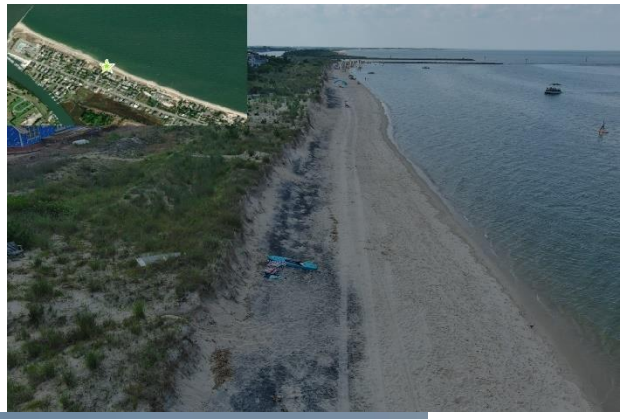


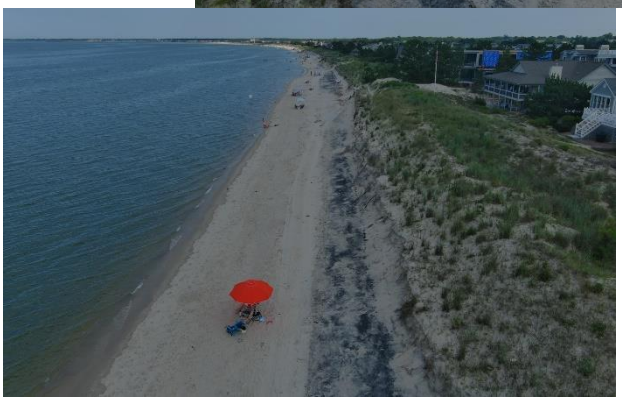






Western End (07/13/2023)





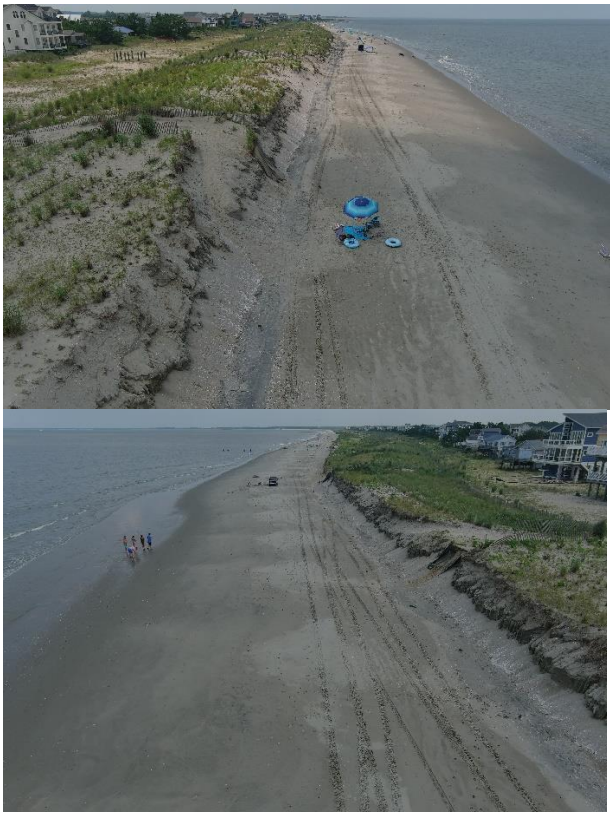
Broadkill Beach (7/17/2023)

Overview

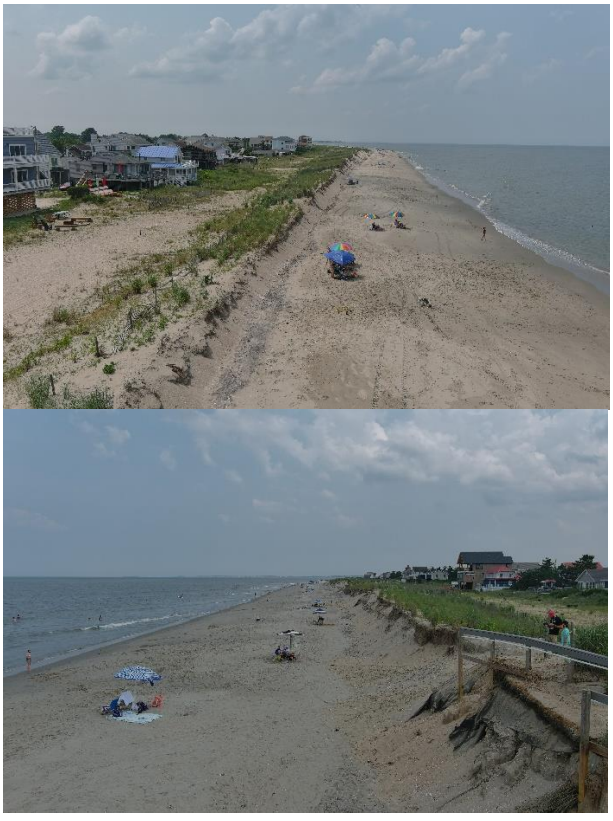

South End


South Central

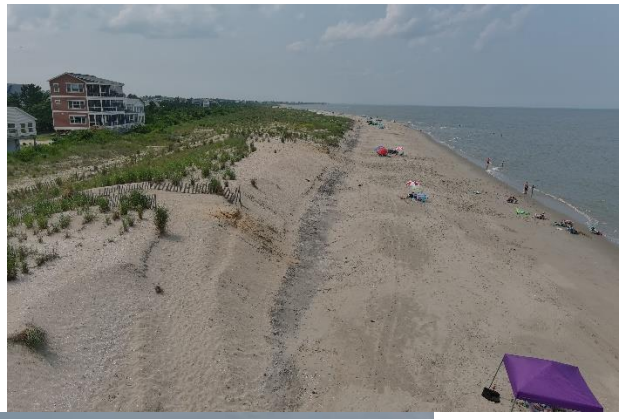

Central South

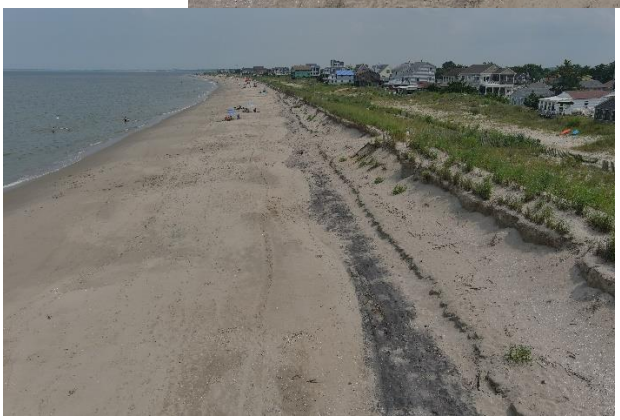


Central



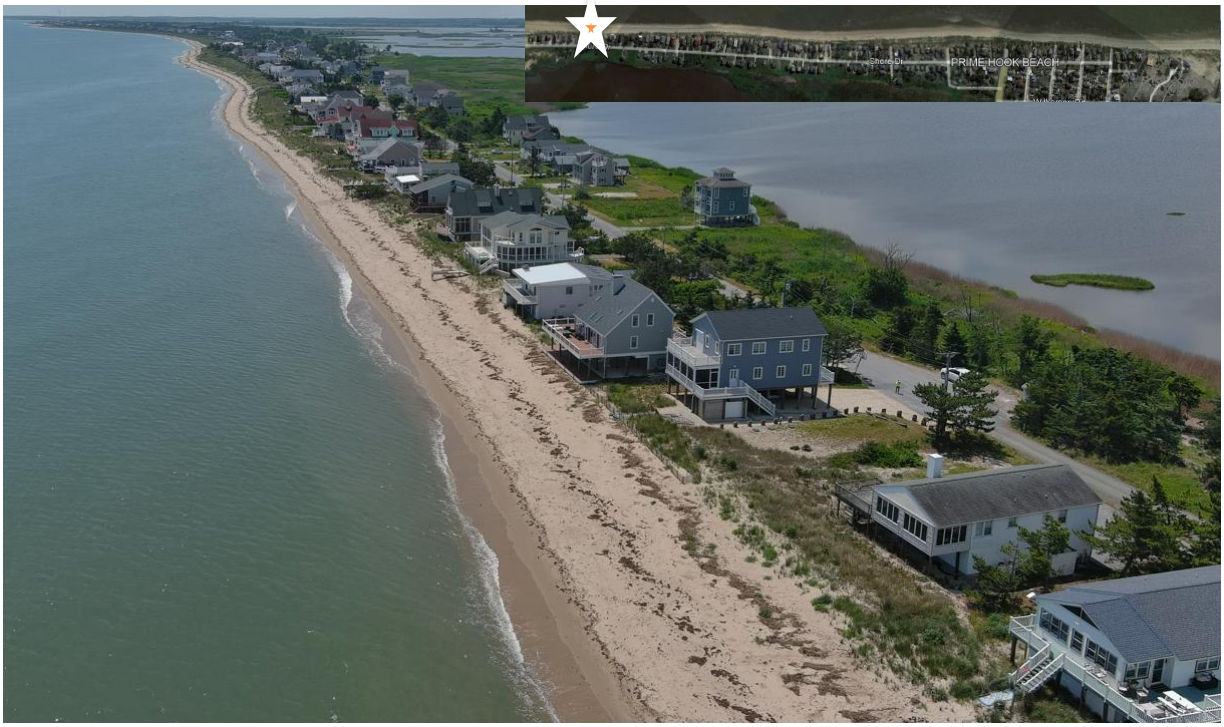
Central North





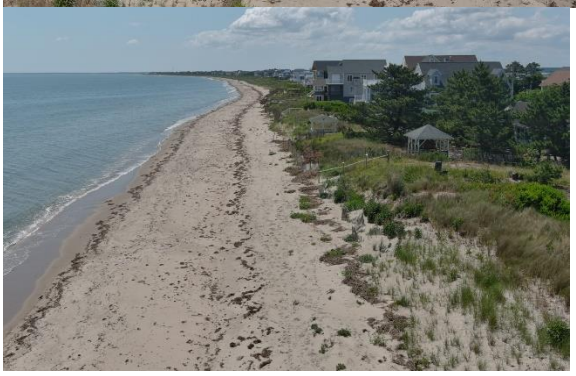
Prime Hook Beach (06/05/2023)

Overview

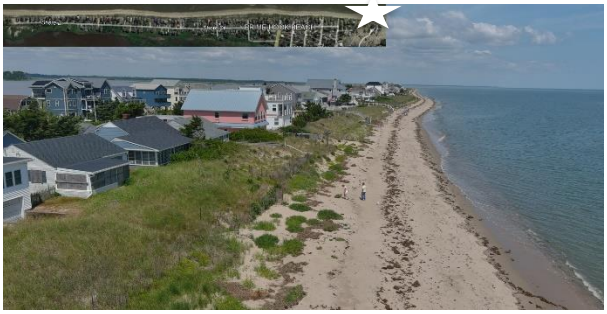


South End

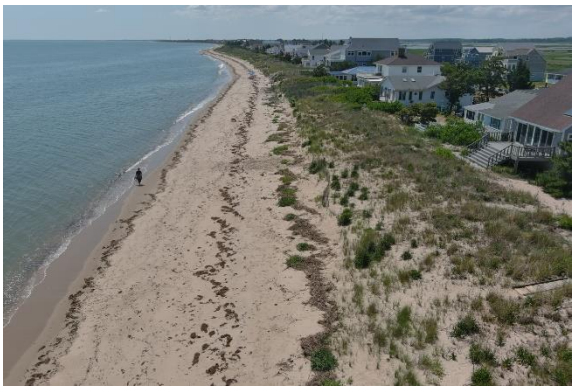
Near Prime Hook Road



Central



North Central

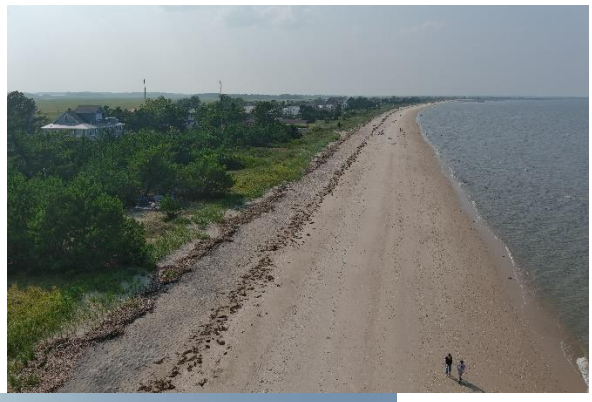


Slaughter Beach (7/18/2023)

Overview

South

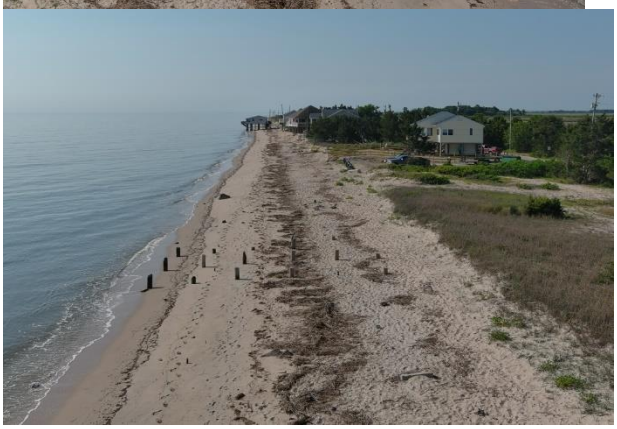
Near Fire Station



North Central

North End

Big Stone Beach (06/02/2023)



Bennett's Pier (06/02/2023)

South Bowers (06/02/2023)

Overview

South

Central

North

Bowers Beach (06/02/2023)

South End

Center

North End

St. Jones Inlet

Kitts Hummock (06/02/2023)

South End

South Central

North Central

North

Pickering Beach (06/02/2023)

Overview

South End

North Central

North End

Center