Delaware Annual Beach Change Report:

Bay Coast

Prepared by:

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2023-2024 Seasons

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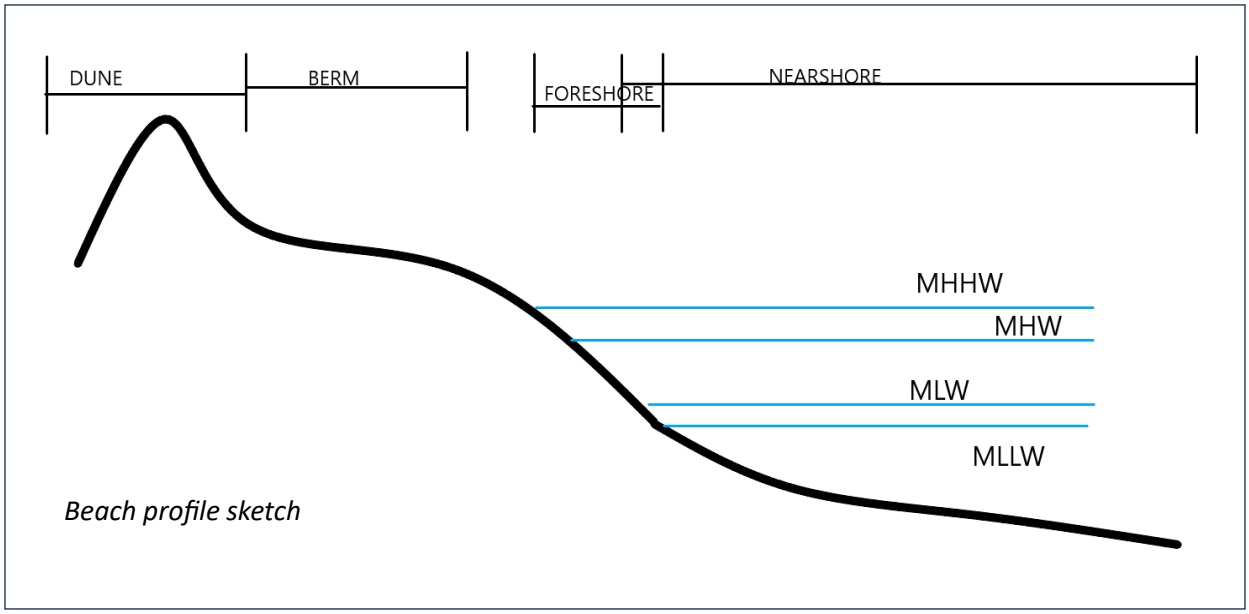
Abbreviations

CF/LF	Cubic Feet per Linear Foot (volume per unit length)
DNREC	Department of Natural Resources and Environmental Control
GPS	Global Positioning System
LRP	Location Reference Point
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MLW	Mean Low Water
NAVD	North American Vertical Datum
RTK	Real Time Kinematics
SWMS	Shoreline and Waterway Management Section
USACE	United States Army Corps of Engineers

Beach Profile Definitions

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

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.
MLLW	The average elevation reached by the lower of the two daily low tides over a 19-year tidal epoch.
MLW	The average elevation reached by all the low tides over a 19-year tidal epoch.
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.



Beach profile sketch

Executive Summary

Since 2022, DNREC's Shoreline and Waterway Management Section (SWMS) has published a yearly report titled, "Delaware Annual Beach Change Report: Bay Coast." The report shares the results of the Delaware Bay coast beach surveys and provides perspective on what causes the changes that are being observed. Survey data are compared to recent storm events, natural processes, and beach nourishment projects that are major drivers of shoreline change.

Twice per year, 43 beach profiles including the dune, berm, and nearshore bathymetry are surveyed from Pickering Beach, Kent County to Cape Shores, Sussex County at the northern and southern ends, respectively. The report presents data from the two most recent summer and winter surveys and describes seasonal changes as well as long-term erosion and accretion trends. Surveys were conducted on 7/27/2022, 2/16/2023, 5/31/2023, and 12/21/2023. Bay beach communities are organized from north to south, and all survey lines have been renamed since the last published report, dated October 2023.

Introduction

DNREC envisions the state of Delaware as a place where people embrace a commitment to the protection, enhancement, and enjoyment of the environment in their daily lives. Therefore, the Shoreline and Waterway Management Section (SWMS) is tasked with maintaining and improving Delaware's beaches and waterways. The shoreline is managed through regulation of coastal construction activities and implementation of dune and beach management practices. By protecting and improving eroded beaches, SWMS works to enable continued recreational use of Delaware's coastal resources and enhance resiliency to protect property and infrastructure from the effects of coastal storms and erosion.

Monitoring beach change over time is a key component to shoreline management. During summer and winter seasons, beach profiles are measured along the Delaware Bay coast. Topographic and bathymetry data are collected from the dune out to a nearshore wading depth of about 4-feet deep using a RTK Trimble System paired with GPS. This system tracks the location and elevation of the ground where data points are collected. Locations of the 43 profiles or Location Reference Point (LRP) lines from Pickering Beach, Kent County to Cape Shores, Sussex County are shown in Figure 1.

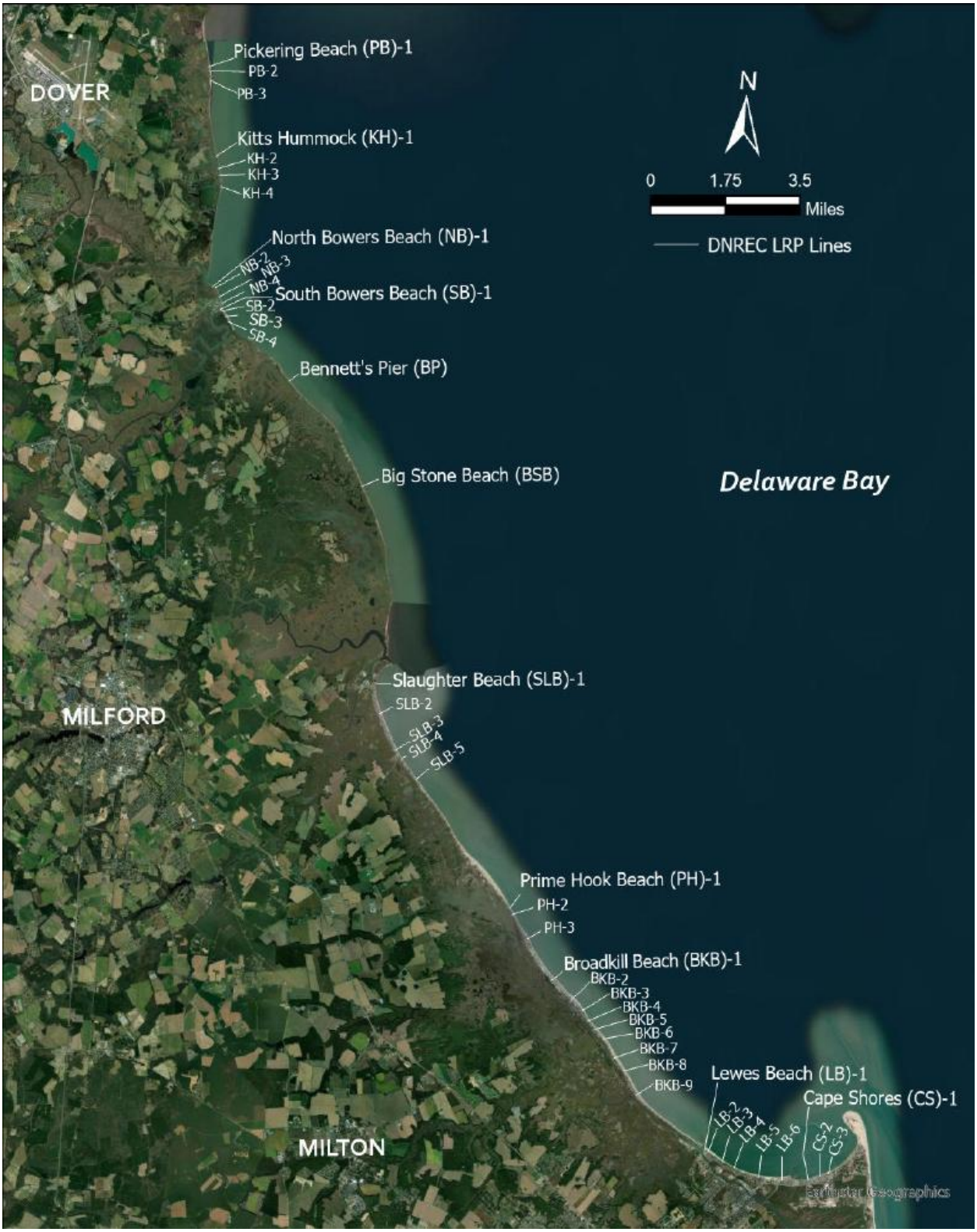


Figure 1: Bay Coast Survey Location Map

Delaware Bay Coastal Environments

Beaches are just one part of the coastal environment of the Delaware Bay. These beaches include the coastal communities from Pickering Beach, Kent County to Cape Shores, Sussex County and contain unpopulated areas such as Bennett's Pier. The Delaware Bay coastal communities are vulnerable to storm damage and erosion; therefore, protection of inland public and private infrastructure, including houses and roads, is critical. Beaches and dunes provide the first line of defense against wave action and the impacts of coastal storms and erosion, as well as offer recreational opportunities and habitat to a variety of organisms. Landward of the dune system are marshes and tidal creeks that also provide habitat for coastal wildlife.

While this report focuses on the Delaware Bay coast beaches, it is important to emphasize that the entire coastal system is connected through geologic history, oceanographic processes, and human influence. Therefore, changes to the coastal environment may impact nearby wetlands, tidal flats, and/or communities. Similarly, coastal construction along with natural or human-induced changes to wetlands and tidal flats may impact beaches and dunes. For example, coastal structures and developed lands restrict the natural movement of sand along the shoreline. Due to these impacts, regulations in the Beach Preservation Act were developed to balance preservation and development pressures along the Delaware shoreline.

Geologic History and Formation of Delaware Bay

The Delaware Bay formed thousands of years ago as glaciers in present-day New England and New York began melting and sea level rose. The former creeks, rivers, and low-lying uplands began to fill with meltwater, forming the Delaware Bay and coastal estuaries. Waves eroded cliffs and other sandy geologic layers, forming small beaches. Eventually, the continued wave action and tides moved sand to form dunes and deposited mud in wetlands and tidal flats. As sea level rise persisted, the entire system shifted landward as large, storm-induced waves naturally pushed sand overtop of the dunes and deposited it landward. Through this process called overwash [1], the entire bay coast eventually moved landward and overtopped the marshes and tidal flats. Similarly, tides flowing through coastal inlets allow sand to move landward and deposit in tidal flood shoals. These shoals provide a source of sand to be "recycled" within the Bay coast system over time.

The past informs our present understanding of the Delaware Bay beaches. Not only do the same geologic processes occur today, but past geologic deposits influence the amount of sand and gravel available to modern bay beaches. A generalized geologic cross-section of the Delaware Bay coast beaches from Port Mahon, Kent County to Broadkill Beach, Sussex County is shown in Figure 2 [2]. The oldest geologic deposits were former hills and necks that originated during the Pleistocene. The shallowest deposits ranged from 80,000 to 120,000 years old and primarily consisted of gravel and sand [3]. Above these former hills and necks—and often located in early Pleistocene creeks and river valleys—are mud (silt, clay) and peat (marsh roots, rhizomes, and inorganic mud) deposits that formed as sea level rose following the last glaciation (the Holocene epoch). Modern beaches and sand dunes

sit on top of the older geologic sediments; however, erosion of the underlying hills and necks will naturally supply Pleistocene-aged gravel and sandy material to the overlying beaches. For example, in many locations in Delaware Bay, Pleistocene deposits are exposed on the shoreface where waves break in the surf zone. These sediments are transported towards the beach and/or along the coastline in the same manner it has for thousands of years.

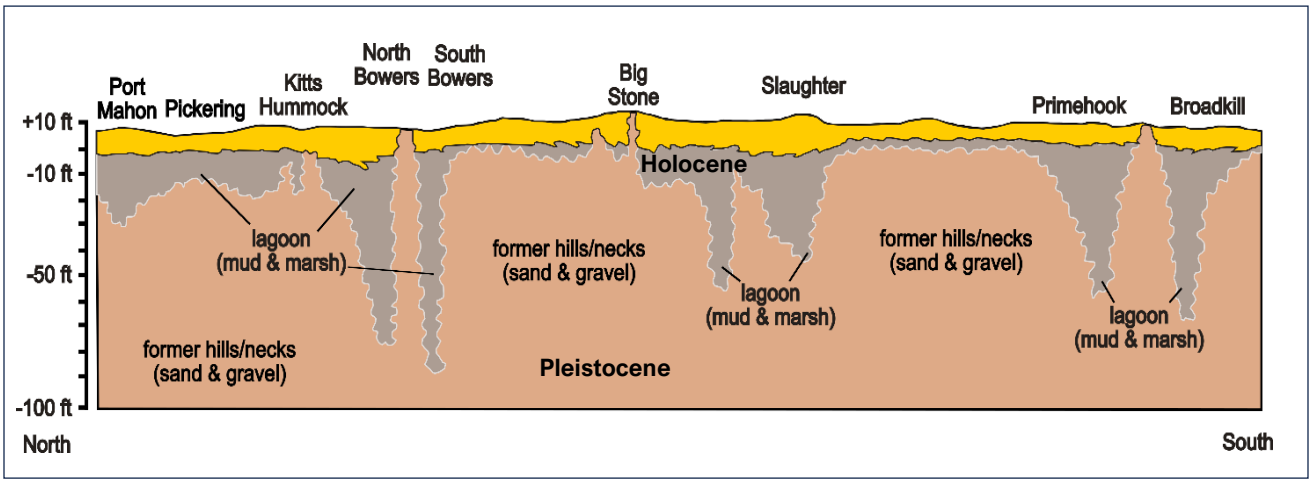


Figure 2: Geology of the Delaware Bay Coast from Port Mahon (north) to Broadkill Beach (south). Modified from French, 1990.

Additional sources of sand and gravel to the Delaware Bay coast beaches include: 1) the transport of material around Cape Henlopen (prior to the 20th century), 2) minor contributions from the Atlantic Ocean continental shelf, and 3) the recycling of sand from tidal ebb shoals of former inlets. The latter is the largest additional source of sand and gravel to the Bay coast. Historical data shows that sediment erodes from the ebb shoals of old inlets and is subsequently driven towards and/or along the beach through wave action. In addition, sand is transported along the coast via the longshore current and can represent a new source of sand for individual beaches; however, this is not a new supply of material to the Delaware Bay coast [1].

The 2023-2024 Storm Season

NOAA Coastal Flood Events

Coastal storm events and flooding can have significant impacts on Delaware's Bay coast beaches. The NOAA National Centers for Environmental Information (NCEI) Storm Event Database lists several Events within the "Delaware Beaches" and "Kent County" Zones that resulted in the Coastal Flood designation [4]. A Coastal Flood Event is defined as flooding of coastal areas due to the vertical rise above normal water level caused by strong, persistent onshore wind, high astronomical tide, and/or low atmospheric pressure, resulting in damage, erosion, flooding, fatalities, or injuries [5]. Listed below are the Coastal Flood Events recorded for the Delaware Beaches and Kent County Zones during the 2023-2024 storm season. Since New Castle County is outside of SWMS's jurisdiction, this zone was omitted from the report (Table 1).

Table 1: NOAA Coastal Flood Events Recorded for the Delaware Beaches & Kent County

Date	Description Of Event
October 2-3, 2022	Low pressure stayed off the Mid-Atlantic coast from Oct 2-5, before moving out to sea. The low maintained an onshore flow along the Delaware coast.
June 3, 2023	Low pressure centered well off the coast and strong high pressure resulted in a steady onshore wind. The pattern brought widespread moderate tidal flooding to the coast around the evening high tide.
September 23, 2023	**Tropical Storm Ophelia** drifted northward from North Carolina. Resulted in a steady onshore flow along the coast of Delaware, causing widespread tidal flooding.
September 26, 2023	Low pressure off the Mid-Atlantic & strong high pressure resulted in a steady onshore flow along the Delaware coast causing widespread tidal flooding.
December 18, 2023	An area of low pressure passing over the region resulted in strong onshore flow and a push of water onshore and up the Delaware Bay and River, where moderate coastal flooding was observed.

NOAA Water Level Stations

While significant storm events have impacted the Delaware Bay coastline, data from NOAA water level stations can be used to determine peak storm elevations. NOAA provides real-time water level information that is updated every six minutes from three locations in Delaware Bay [6]. Figure 3 below shows these stations from north to south as Ship John Shoal, NJ; Brandywine Shoal Lighthouse, DE; and Lewes, DE.

Figure 3: NOAA Water Level Stations in the Delaware Bay

To evaluate water levels in relation to the coastal flood events described above, Table 2 lists the three highest water elevations (in feet above MHHW) recorded at each station. Peak water levels coincide with coastal flood events recorded by NOAA. Particularly, the events on June 3rd and September 26th, resulted in the highest water levels reported across all Delaware Bay stations.

Table 2: Maximum water level elevations recorded at NOAA Stations in Delaware Bay			
Date	**Ship John Shoal**	**Brandywine Shoal**	**Lewes, DE**
	MHHW, feet	MHHW, feet	MHHW, feet
3-Oct-22	----	----	2.78
3-Jun-23	2.75	2.44	2.59
26-Sep-23	2.27	2.30	2.50
18-Dec-23	2.57	1.95	----

Typical Seasonal to Annual Beach Change

Storm-driven erosion and wave overtopping (overwash) of the dunes control seasonal-to-annual-scale beach change along the Delaware Bay coast. While storm events are episodic, increases in frequency and intensity promote the likelihood of coastal erosion [2]. Nor'easters typically cause the most annual erosion on Delaware Bay coast beaches. Hurricanes are less frequent and more transient, but would induce major shoreline change and erosion. During fall and winter months, energetic waves and storm surge cause erosion and overwash, resulting in beach profiles with upper beach face erosion and dune scarping. During spring and summer months, calmer waves and less frequent/intense storms commonly result in beach accretion. Figure 4 demonstrates a schematic of a typical beach profile during summer versus winter months. It is possible that some beaches may not fully recover between seasons [3]. Insufficient seasonal recovery is common on beaches along the Atlantic coast and in the world, leading to long-term erosion [7].

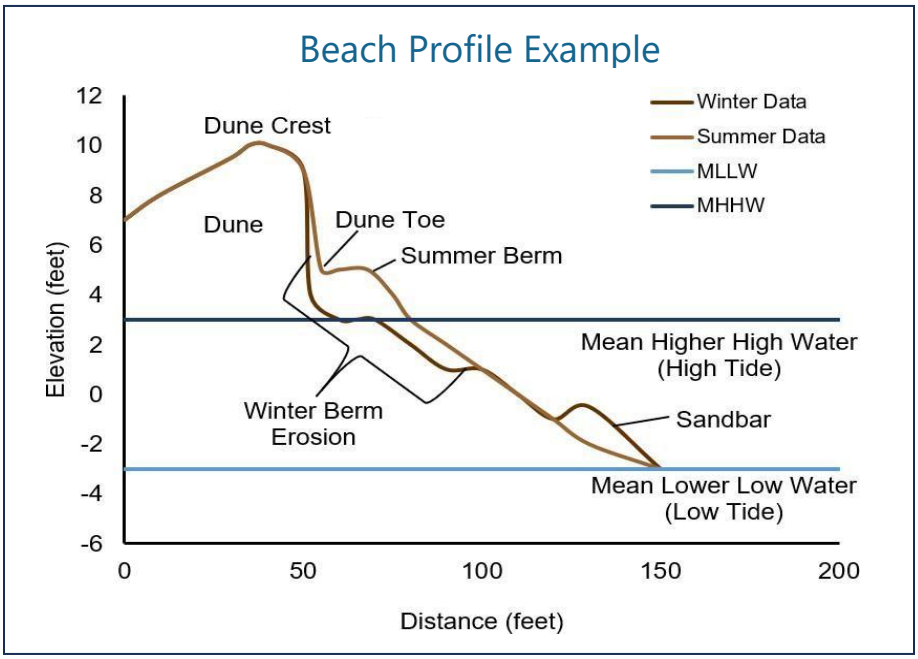


Figure 4: Schematic of a typical beach profile during summer vs winter seasons

Annual Beach Change by Community

Beach change is determined by calculating the measured volume difference between seasons for each transect or LRP line. Beach volume is measured along a 1-dimension transect and reported in cubic feet per linear foot of beach length (cf/lf). Two beach volumes are reported for each LRP line based on the mean high water (MHW) and mean low water (MLW) contours as demonstrated in Figure 5. The MHW volume represents the material between the crest of the dune and the intersection of the MHW contour. The MLW volume includes the material between the MHW and MLW contours, in addition to the MHW volume.

The upper extent of the beach, above the MHW contour, is only reached during storm tides and/or when powerful wave action is occurring. Therefore, the MHW volume is an indicator of beach resiliency to flooding, overwash, and hazardous wave action. The MLW volume and the comparison of the MHW and MLW volumes are better indicators of seasonal beach change. During the stormy season when the upper beach erodes, sand washes down to the intertidal zone or just offshore. Some of the eroded material that ends up in the intertidal zone may be captured in the MLW data. By comparing the MHW and MLW volumes, seasonal erosion and accretion trends can be identified.

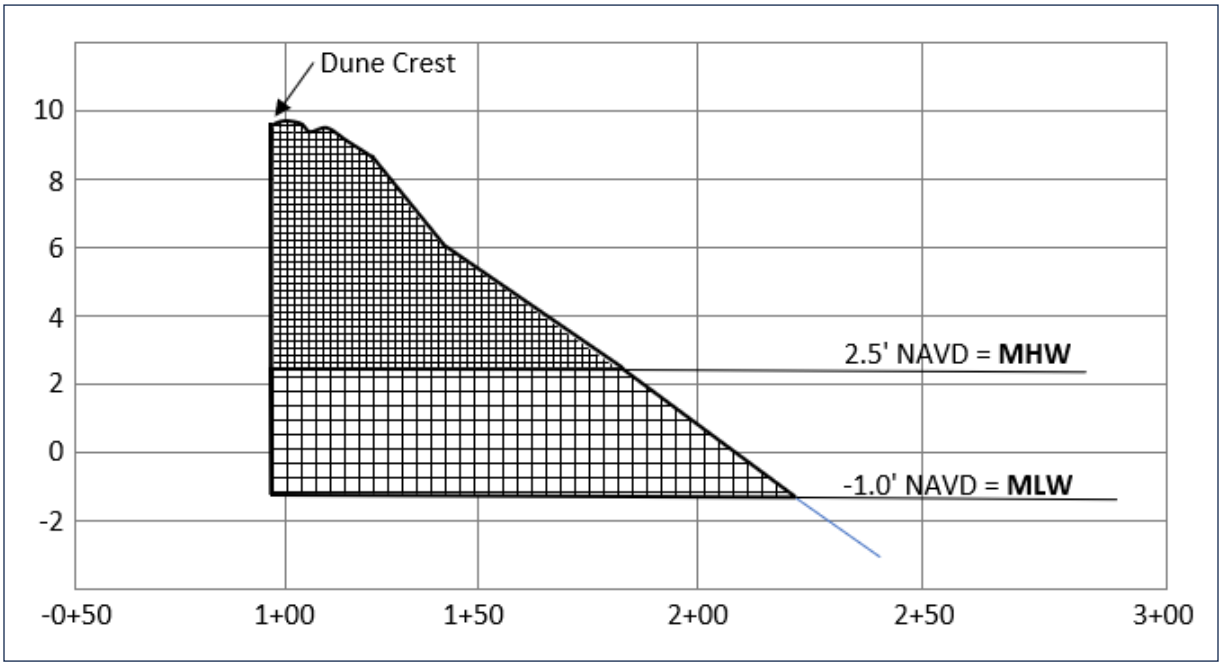


Figure 5: Sketch of beach profile and volume calculations

The following sections describe the average seasonal and annual beach change volumes determined for each of the Delaware Bay coast communities. Volume data are paired with a representative profile view and photograph per community. Profile views for all LRP lines are available in Appendix 1. Additional photos are included in Appendix 2.

Pickering Beach

Pickering Beach (PB) is located southeast of Dover and within the northernmost reach of SWMS's jurisdiction. This is a densely developed area that includes three LRP survey lines and about 2,300 feet of shoreline (Figure 6A).

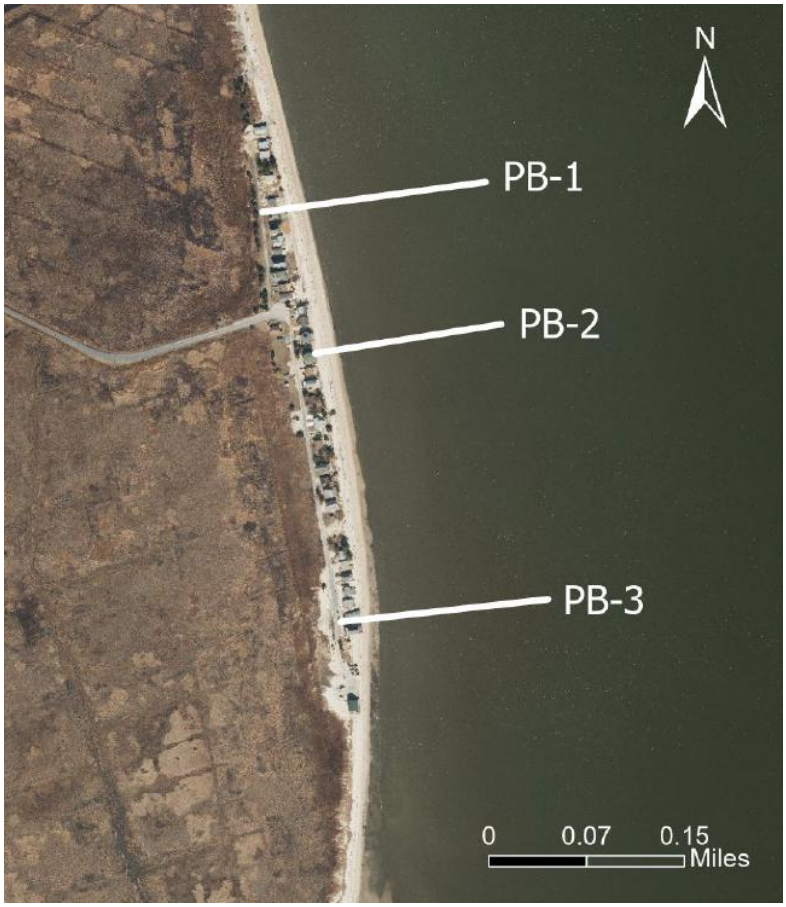


Figure 6A. LRP lines at Picking Beach

The average beach volumes determined for Pickering Beach are shown in Table 3. Sand was added in November 2022 to repair erosion at the southern end of the community; therefore, at LRP line PB-3 a large gain in volume was measured from Summer 2022 to Winter 2023. Immediately following the nourishment project, however, a storm caused substantial erosion in November 2022 and the beach did not fully recover in Summer 2023 as expected. The loss of volume between Winter 2023 and Summer 2023 suggests the southern part of Pickering Beach continues to erode each season.

Figure 6B demonstrates the large increase in volume at LRP line PB-3 after beach nourishment in Winter 2023. While the dune remains established in the Summer 2023 profile, some erosion is observed. By Winter 2024, however, LRP line PB-3 lost a significant volume of material and returned to a pre-nourished profile. Erosion at PB-2 and PB-3 between Summer 2023 to Winter 2024 was likely due to the impacts of TS Ophelia that occurred during September 2023, as described above.

Table 3: Beach volume calculations for Pickering Beach								
LRP		**PB-1**		**PB-2**		**PB-3**	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	189	593	204	639	71	374
Winter 2023	2/16/2023	183	583	N/A	N/A	152	473
Summer 2023	5/31/2023	N/A	N/A	228	621	117	407
Winter 2024	12/21/2023	140	528	148	578	58	336

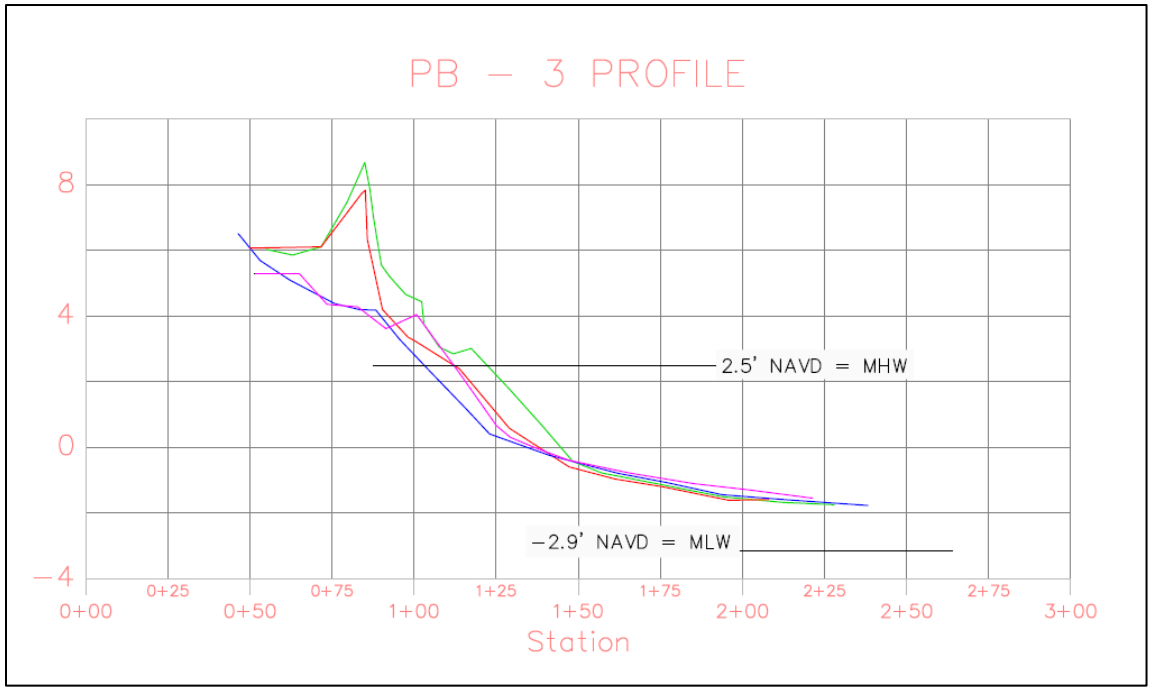


Figure 6B. Beach Profiles at Pickering Beach, Station PB-3.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

An aerial view of the Pickering Beach shoreline is shown in Figure 6C. The photo was taken one month following completion of an emergency beach fill job.

Figure 6C. Aerial view of Pickering Beach (04/04/2024 at 11:23) approaching low tide, looking north.

Kitts Hummock

Kitts Hummock (KH) is located south of Pickering Beach and densely developed. This area includes four LRP lines and 4,500 feet of shoreline.

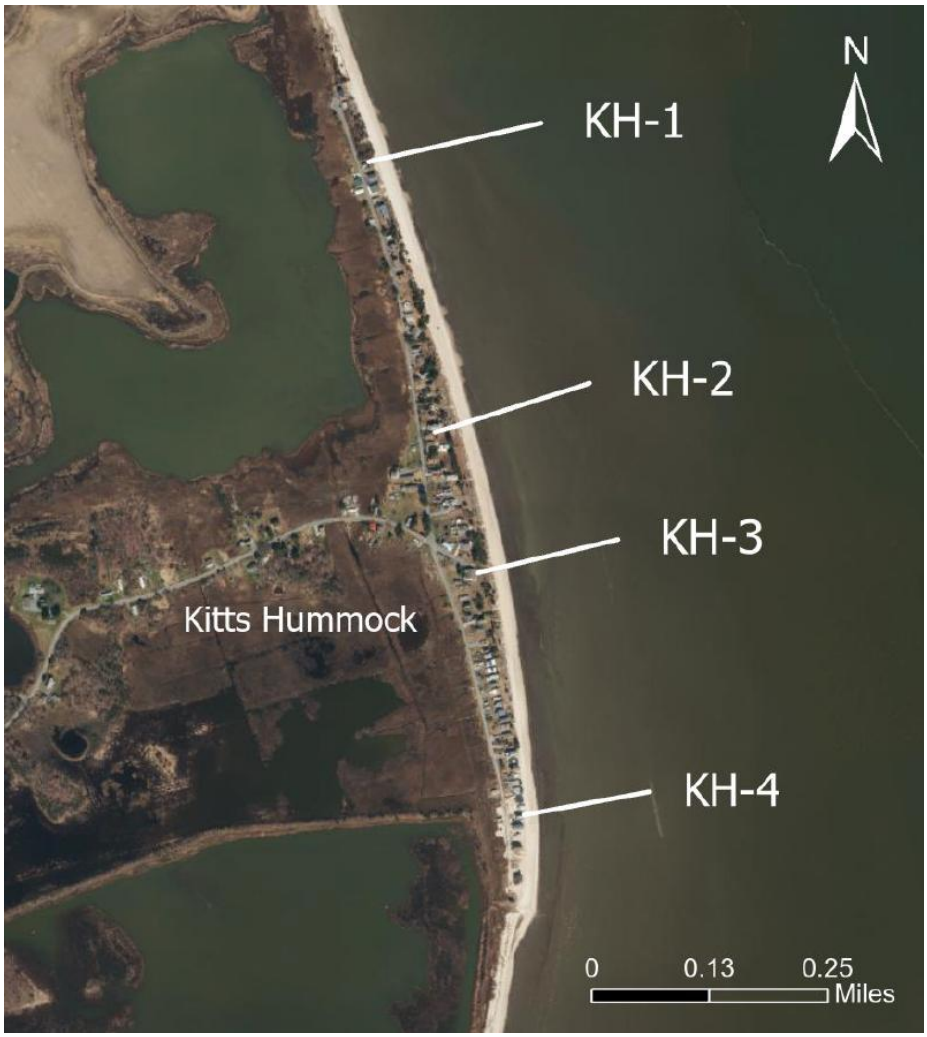


Figure 7A. LRP lines at Kitts Hummock

The average beach volumes determined for Kitts Hummock are shown in Table 4. A small-scale beach nourishment project added sand in November 2022; however similar to Pickering Beach, a storm immediately followed and three of four LRP lines lost volume between Summer 2022 and Winter 2023. The volume lost over winter was fully recovered by Summer 2023 in all Kitts Hummock beach profiles. In Figure 7B, the Winter 2023 and Summer 2023 profiles at KH-3 show a small mound of sand near station 1+25; however by Winter 2024, that sand had eroded from the upper dune face and KH-3 returned to a pre-nourished profile. The northernmost LRP line (KH-1) accreted between Summer 2023 and Winter 2024, while all profiles to the south (KH-2, KH-3, KH-4) eroded. Erosion is likely due to the impacts of TS Ophelia during Fall 2023, as described above.

Table 4: Beach volume calculations for Kitts Hummock									
LRP		**KH-1**		**KH-2**		**KH-3**		**KH-4**	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	263	578	202	473	207	470	154	350
Winter 2023	2/16/2023	258	553	211	484	207	458	149	347
Summer 2023	5/31/2023	262	555	216	482	223	474	167	368
Winter 2024	12/21/2023	252	560	198	445	215	469	147	341

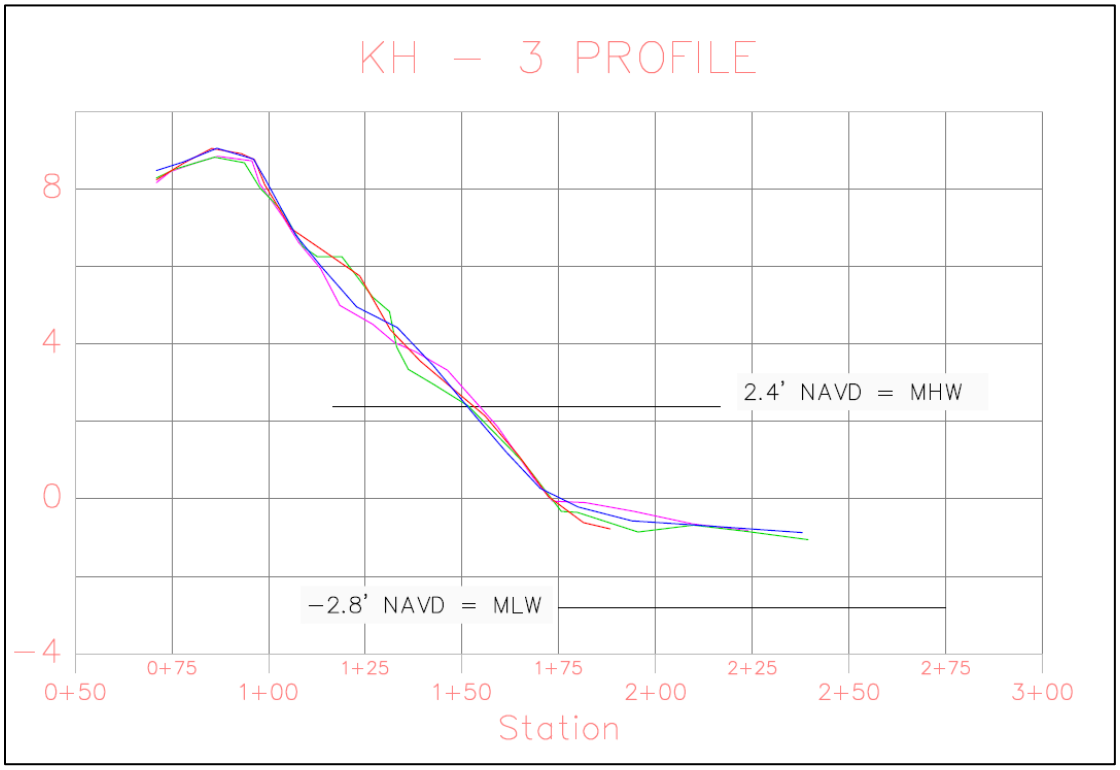


Figure 7B. Beach Profiles at Kitts Hummock, Station KH-3.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 7C shows an aerial view of the center section of Kitts Hummock during low tide. The Kitts Hummock Beach Road crossover can be seen in the foreground, which is nearest to LRP line KH-3.

Figure 7C. Aerial view of Central Kitts Hummock Beach (4/17/2024, 12:52) during low tide, looking north

North Bowers Beach

North Bowers (NB) Beach includes 2,300 feet of shoreline and is bound by the Saint Jones River to the north and the Murderkill River and jetty to the south. There is one LRP survey line (NB-1) located north of the northern groin where there is no coastal development (Figure 8A). The remaining three LRP lines are located within the densely developed portion of the community.

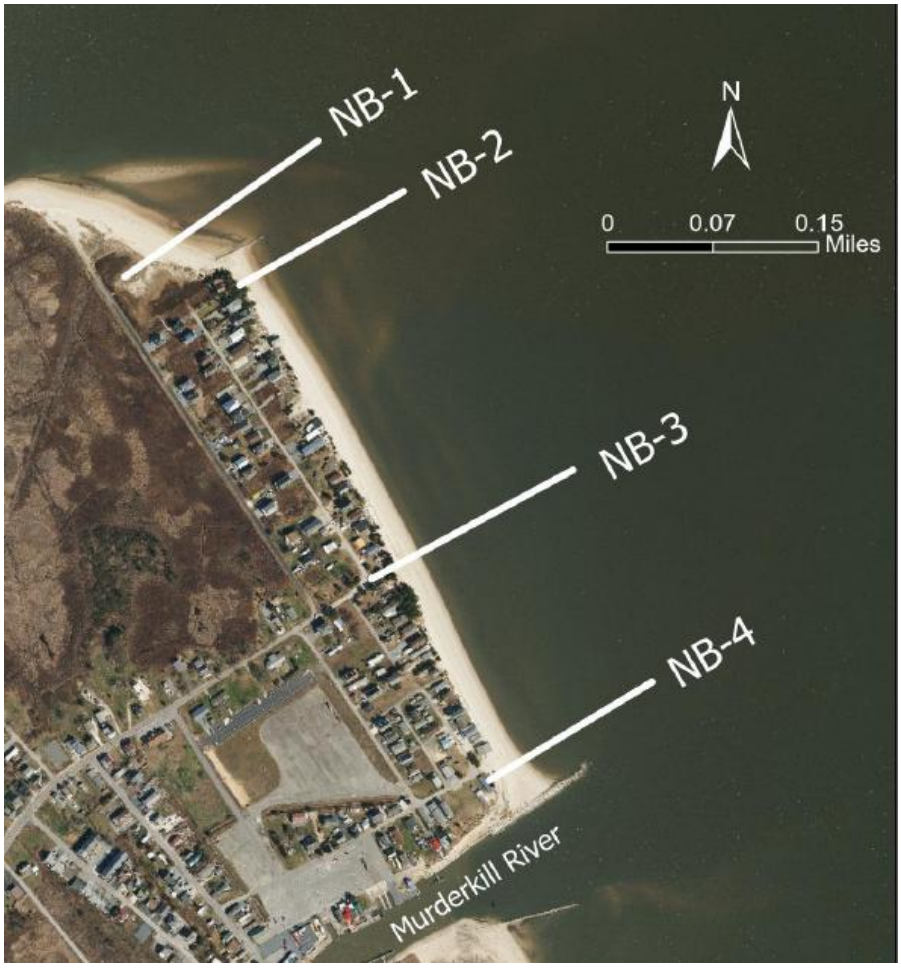


Figure 8A. LRP lines at North Bowers Beach

The average beach volumes determined for North Bowers Beach are shown in Table 5. Beach profiles are variable along the coast. The northernmost profile (NB-1) demonstrates the expected seasonal change with losses occurring during fall and early winter seasons and recovery during summer months. Alternatively, significant erosion was observed at NB-2 between Summer 2022 and Winter 2023. While some of this volume was recovered during Summer 2023, a substantial loss was measured between the 2022 and 2023 summer seasons. The profiles in Figure 8B demonstrate the erosion at NB-2, which is likely influenced by the northern jetty. Erosion was also measured at NB-3 from Winter 2023 through Winter 2024.

Significant accretion was observed near the southern jetty (NB-4) between Summer 2022 and Winter 2023, followed by volume losses during Summer 2022 and Winter 2023. Given the location, it is likely the southern jetty trapped sand that may have later washed out during subsequent seasons, and especially during storm events.

Table 5: Beach volume calculations for North Bowers Beach

LRP		NB-1		NB-2		NB-3		NB-4	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	202	733	180	520	336	790	192	465
Winter 2023	2/16/2023	212	711	128	400	324	768	253	616
Summer 2023	5/31/2023	182	752	153	456	326	762	254	583
Winter 2024	12/21/2023	210	697	164	450	304	719	150	418

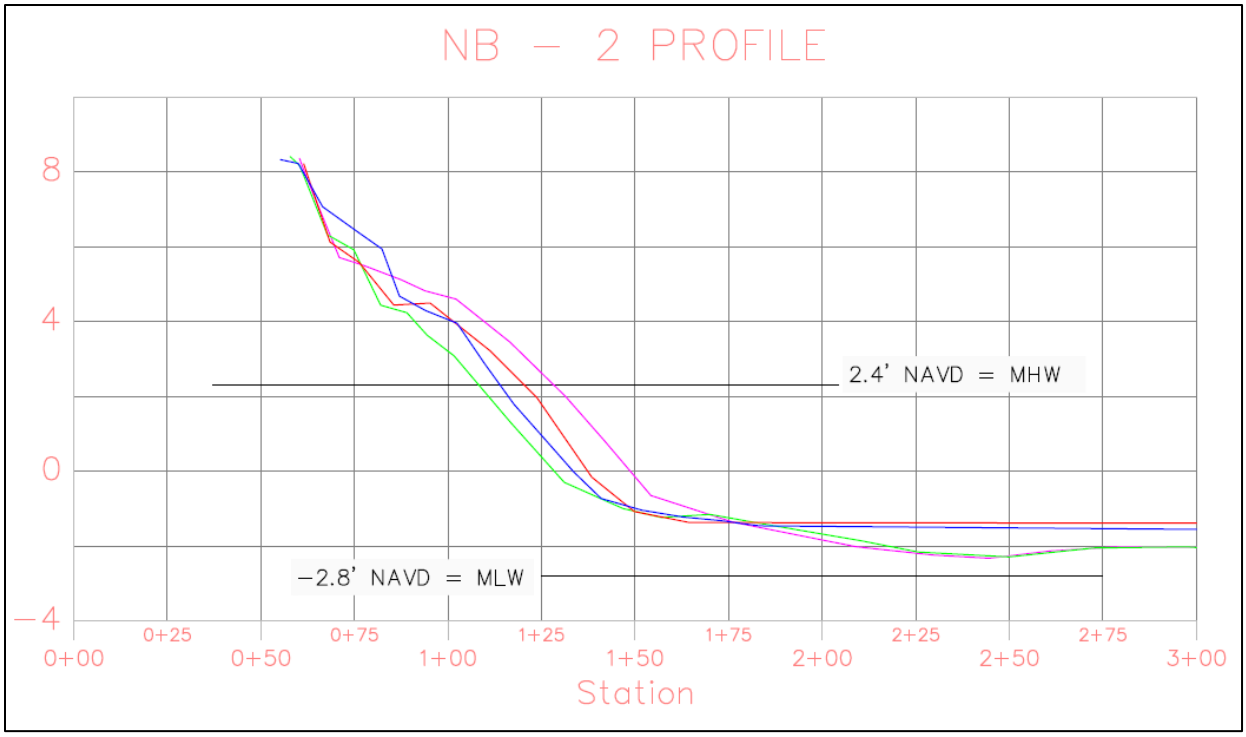


Figure 8B. Beach Profiles at North Bowers Beach, Station NB-2.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 8C shows an aerial view of North Bowers Beach. The southern jetty and Murderkill Inlet can be seen in the background, which is nearest to LRP line NB-4.

Figure 8C. Aerial view of North Bowers Beach (4/17/2024, 12:06) approaching low tide, looking south

South Bowers Beach

North and South Bowers (SB) Beach are separated by the Murderkill River. Four LRP survey lines and approximately 3,000 ft of shoreline makeup South Bowers Beach. Two LRP lines (SB-1, SB-2) are spaced closely together and located within the densely developed area near the Murderkill River. The remaining two LRP lines (SB-3, SB-4) are within the undeveloped area and spaced farther apart.

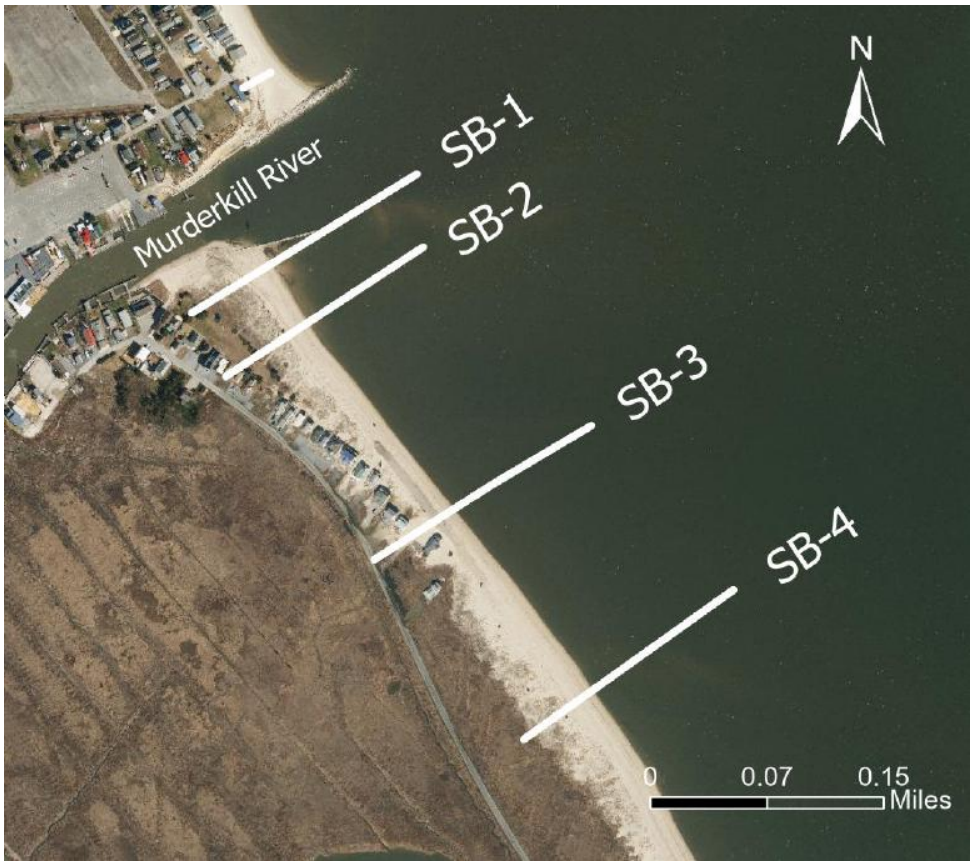


Figure 9A. LRP lines at South Bowers Beach

The average beach volumes determined for South Bowers Beach are shown in Table 6. A dredging and beach nourishment project in August 2022 delivered over 52,000 cubic yards of material from the Murderkill River to a quarter-mile section of South Bowers Beach. This nourishment project is reflected by the significant volume gain measured in the SB-3 profiles between Summer 2022 and Winter 2023. Figure 9B also demonstrates beach nourishment at SB-3; however subsequent surveys showed volumes decrease continuously from Winter 2023 through Winter 2024. Erosion at this site measured 22.5 feet between the winter seasons. The significant change between Summer 2023 and Winter 2024 profiles is likely due to the impacts of TS Ophelia that occurred in September 2023, as described above.

All other LRP lines (SB-1, SB-2, SB-4) appeared to indirectly benefit from the nourishment project based on the accretion trends observed during Winter 2024. Otherwise, these LRP

lines demonstrated the expected seasonal change with losses occurring during fall and early winter seasons and recovery during summer months.

Table 6: Beach volume calculations for South Bowers Beach

LRP		SB-1		SB-2		SB-3		SB-4	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	295	864	233	590	266	664	163	589
Winter 2023	2/16/2023	291	840	212	538	790	1616	157	571
Summer 2023	5/31/2023	316	897	210	543	752	1555	158	577
Winter 2024	12/21/2023	360	927	264	628	669	1407	213	653

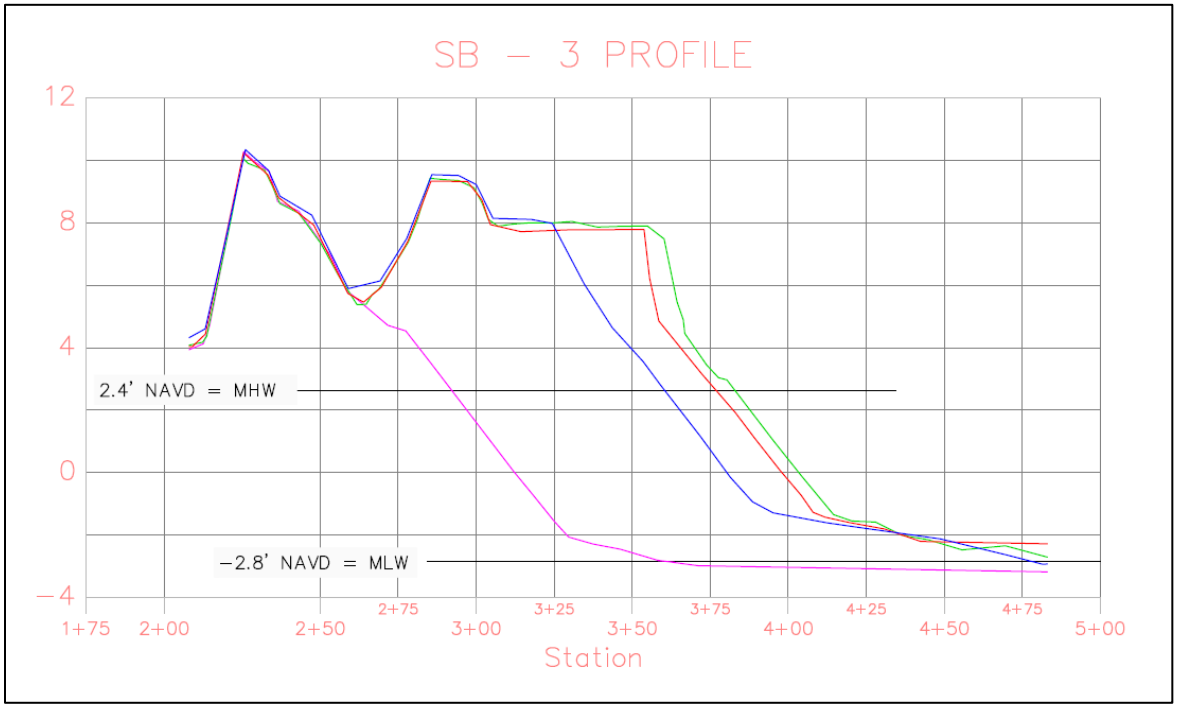


Figure 9B. Beach Profiles at South Bowers Beach, Station SB-3.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 9C shows an aerial view of South Bowers Beach. The Murderkill jetty, nearest LRP line SB-1, can be seen in the foreground.

Figure 9C. Aerial view of South Bowers Beach (4/17/2024, 12:15) approaching low tide, looking south

Bennett's Pier

Bennett's Pier (BP) is located south of South Bowers Beach and contains one LRP line. This beach is entirely privately owned, undeveloped, and adjacent to wetlands. DNREC collects data at Bennett's Pier through an agreement with the landowner, Delaware Wild Lands, Inc.

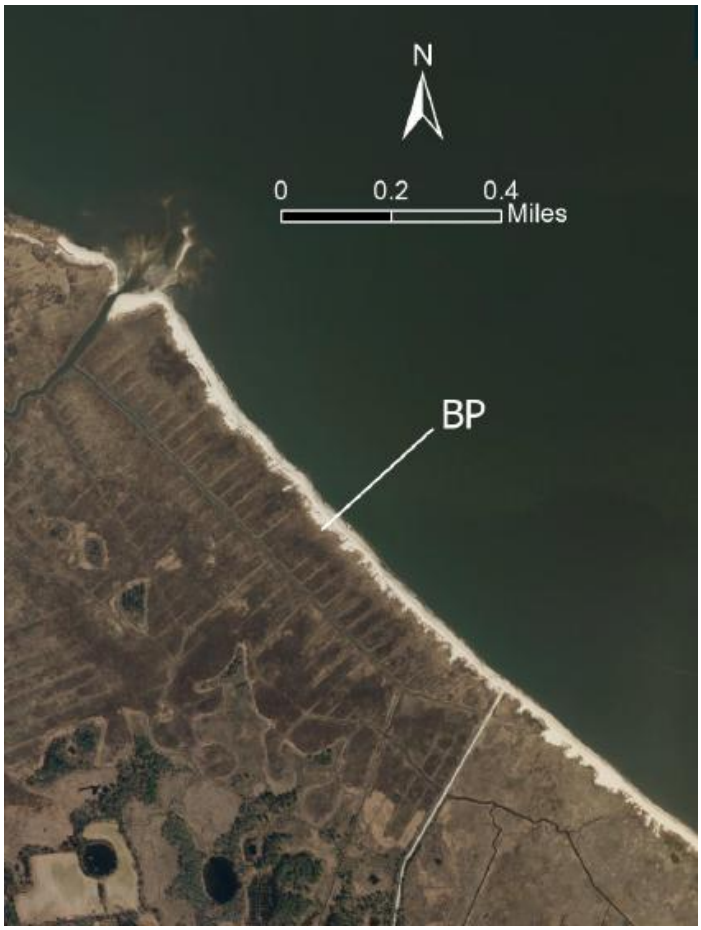


Figure 10A. LRP line at Bennett's Pier

The average beach volumes determined for Bennett's Pier are shown in Table 7. This beach showed accretion in Winter 2023, followed by erosion in subsequent Summer 2023 and Winter 2024 seasons. The profiles in Figure 10B show continuous erosion within the intertidal zone each season. In addition, dune scarping appears greater above MHW in Summer 2023 and Winter 2024 profiles.

Table 7: Beach volume calculations for Bennett's Pier			
LRP		BP	
Volume Limit		MHW	MLW
Season	Date	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	107	751
Winter 2023	2/16/2023	119	757
Summer 2023	5/31/2023	127	747
Winter 2024	12/21/2023	127	727

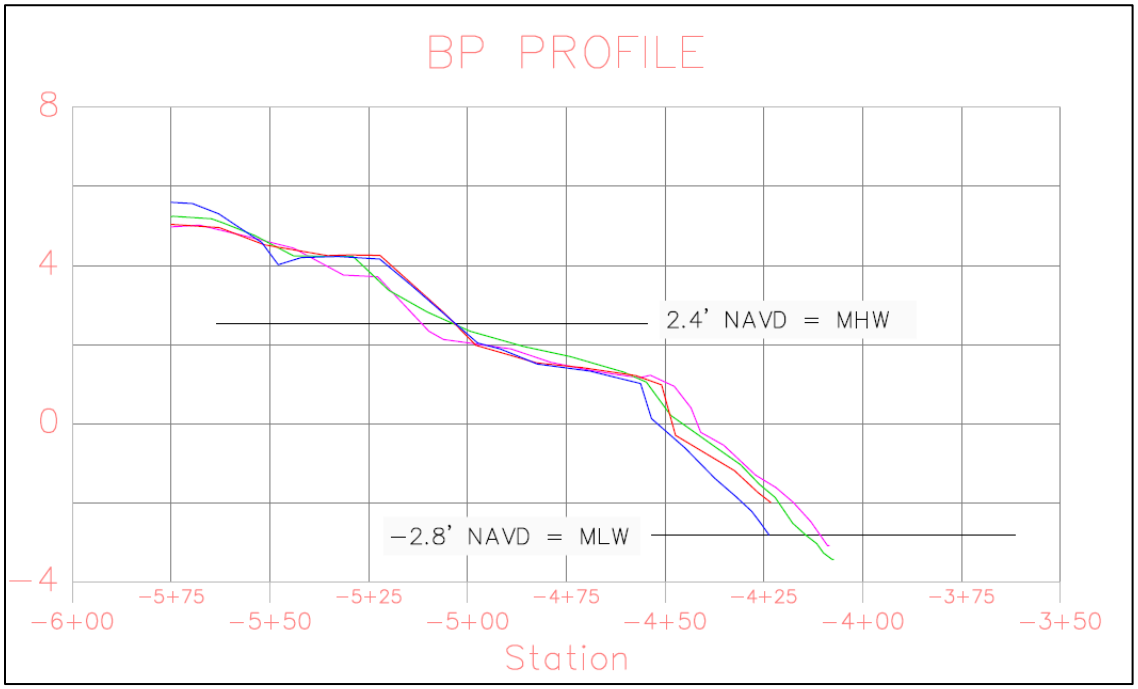


Figure 10B. Beach Profiles at Bennett's Pier Beach.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Big Stone Beach

Big Stone Beach (BSB) is bound by Bennett's Pier to the north and the Mispillion River to the south. One LRP survey line exists north of Big Stone Beach Road. This area is undeveloped and privately owned by Delaware Wild Lands, Inc. Similar to Bennett's Pier, DNREC collects data through an agreement with the landowner.

Figure 11A. LRP line at Big Stone Beach

The average beach volumes determined for Big Stone Beach are shown in Table 8. Beach volumes demonstrate the expected seasonal changes with erosion between Summer 2022 and Winter 2023, followed by recovery in Summer 2023. Additional accretion was measured in the Winter 2024 profile (Figure 11B).

Table 8: Beach volume calculations for Big Stone Beach

LRP		BSB	
Volume Limit		MHW	MLW
Season	Date	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	232	611
Winter 2023	2/16/2023	215	593
Summer 2023	5/31/2023	228	600
Winter 2024	12/21/2023	248	607

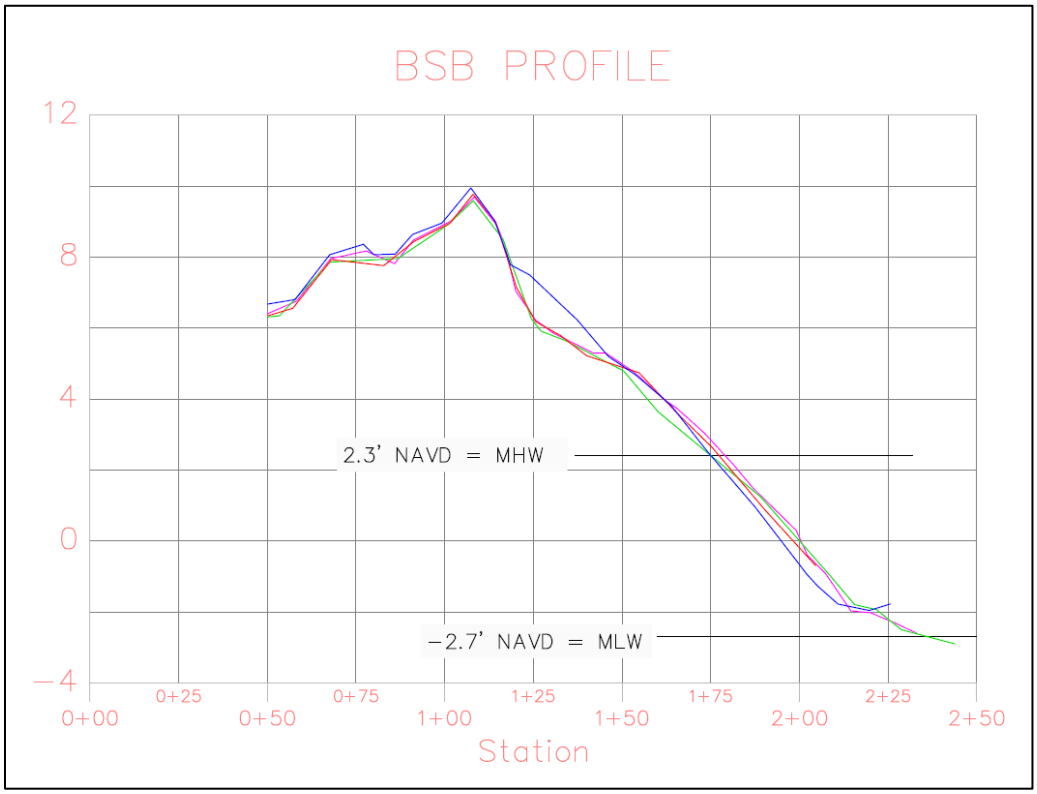


Figure 11B. Beach Profiles at Big Stone Beach.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Slaughter Beach

Slaughter Beach (SLB) is a densely developed coastal town located east of Milford. This area is situated between the Mispillion River and Cedar Creek to the north and Prime Hook National Wildlife Refuge to the south. Slaughter Beach includes five LRP survey lines and approximately 16,000 feet, or about three miles, of coastline.

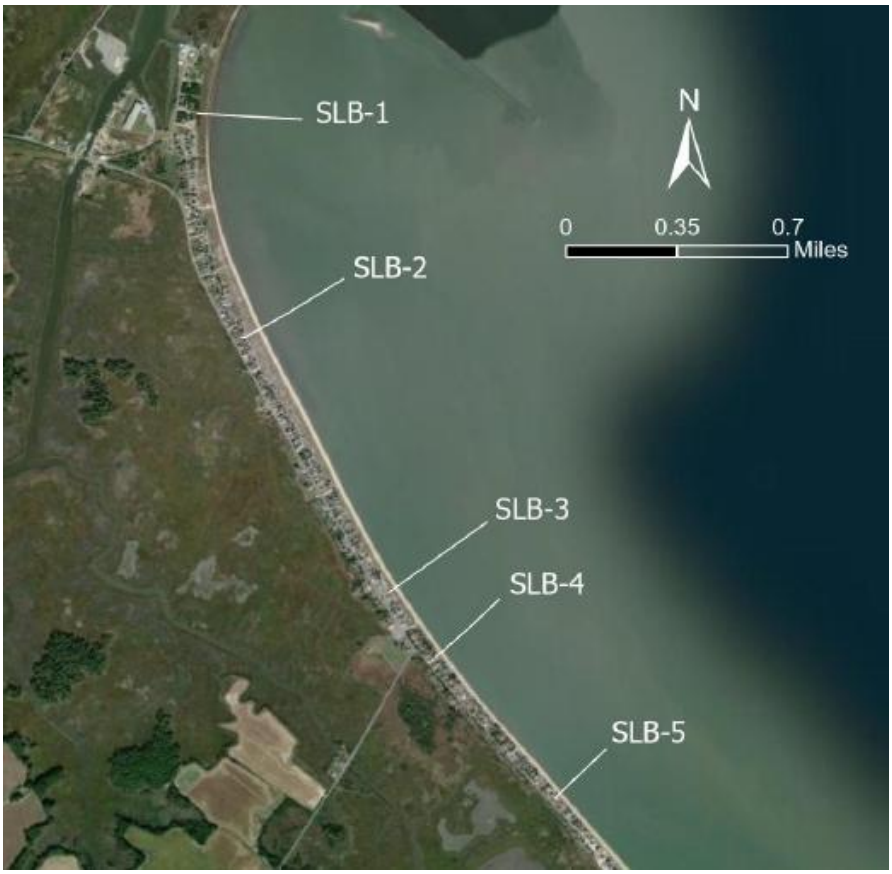


Figure 12A. LRP lines at Slaughter Beach

The average beach volumes determined for Slaughter Beach are shown in Table 9. A beach nourishment project in Fall 2022 added 40,000 cubic yards of sand to over 4,500 linear feet of shoreline. The nourishment area extended from north of Slaughter Beach Road, between profiles SLB-3 and SLB-4, to the south beyond SLB-5. However, the addition of sand did not result in volume gain at these LRP lines between Summer 2022 and Winter 2023 as expected. While some recovery occurred at SLB-4 during Summer 2023, the shoreline continued to erode just north (SLB-3) and south (SLB-5) of this profile. The southern part of the community appears prone to erosion as continued volume loss was seen in the Winter 2024 profile (SLB-5). Since the upland terrain in this area is greater in elevation, the dune scarp is steeper and more vulnerable to collapse. Conversely, the central part of Slaughter Beach (SLB-3, SLB-4) gained volume between Summer 2023 and Winter 2024 surveys. While the cause of this accretion is unknown, it may result from alongshore transport moving eroded sand northward.

Farther north in the Slaughter Beach community, SLB-1 and SLB-2 accreted between Summer 2023 and Winter 2024. The profiles in Figure 12B demonstrate continuous accretion at SLB-2 with an overall gain of 7 feet between Summer 2022 and Winter 2024. While the alongshore sediment transport may have contributed to an increase in volume, this area is also influenced by the Mispillion jetty to the north, which traps sand and partially shelters the coastline.

Table 9: Beach volume calculations for Slaughter Beach

LRP		SLB-1		SLB-2		SLB-3		SLB-4		SLB-5	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	118	269	298	604	279	759	283	751	287	703
Winter 2023	2/16/2023	111	263	303	613	275	739	279	730	259	652
Summer 2023	5/31/2023	120	277	313	625	275	719	290	734	260	641
Winter 2024	12/21/2023	130	295	341	670	282	734	291	736	251	635

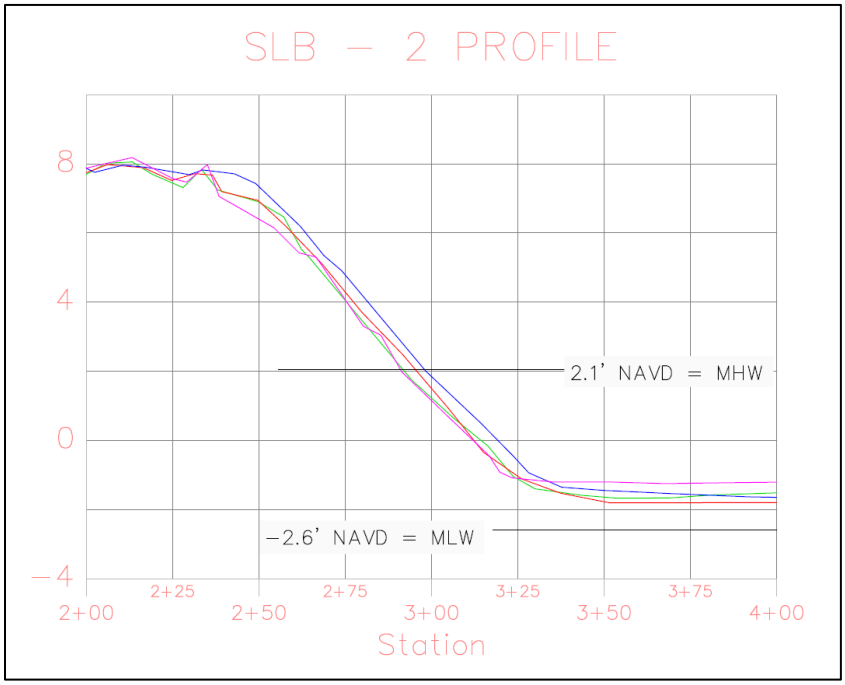


Figure 12B. Beach Profiles at Slaughter Beach, Station SLB-2.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 12C shows an aerial view of Slaughter Beach. The Slaughter Beach Road crossover can be seen in the foreground.

Figure 12C. Slaughter Beach (4/17/2024, 12:10) approaching low tide, looking north

Prime Hook Beach

Prime Hook (PH) Beach is a developed community bordered by the Prime Hook National Wildlife Refuge to the north and west. Prime Hook Beach contains three LRP survey lines and approximately 10,000 feet of shoreline.

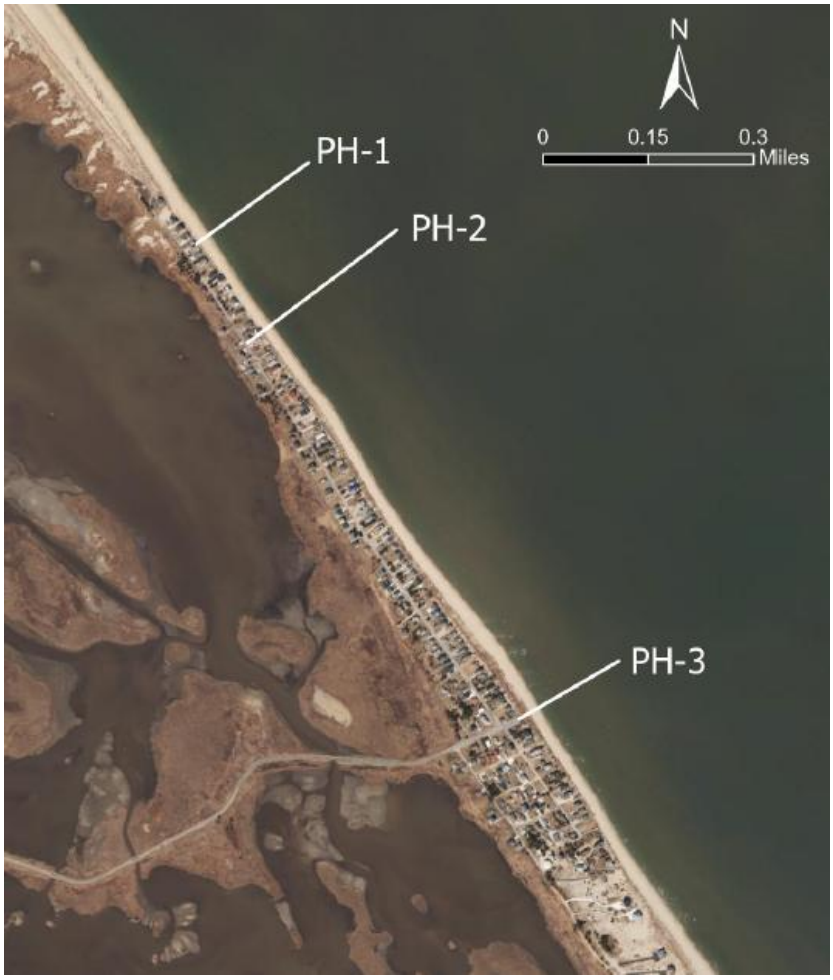


Figure 13A. LRP lines at Prime Hook Beach

The average beach volumes determined for Prime Hook Beach are shown in Table 10. The northernmost LRP survey line (PH-1) has been accreting overtime with a gain in volume measured from Summer 2022 through Winter 2024. The central (PH-2) and southernmost (PH-3) LRP lines demonstrate the expected seasonal change with volume loss measured between Summer 2022 and Winter 2023, and volume gain between Winter 2023 and Summer 2023. In addition, survey data indicate these areas accreted between Summer 2023 and Winter 2024; however, the reason is unknown. In Figure 13B, the Winter 2024 profile clearly demonstrates accretion within the intertidal zone at PH-3.

Table 10: Beach volume calculations for Prime Hook Beach							
LRP		**PH-1**		**PH-2**		**PH-3**	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	294	723	250	617	120	352
Winter 2023	2/16/2023	294	738	234	590	115	340
Summer 2023	5/31/2023	308	744	245	597	137	367
Winter 2024	12/21/2023	343	802	244	600	159	443

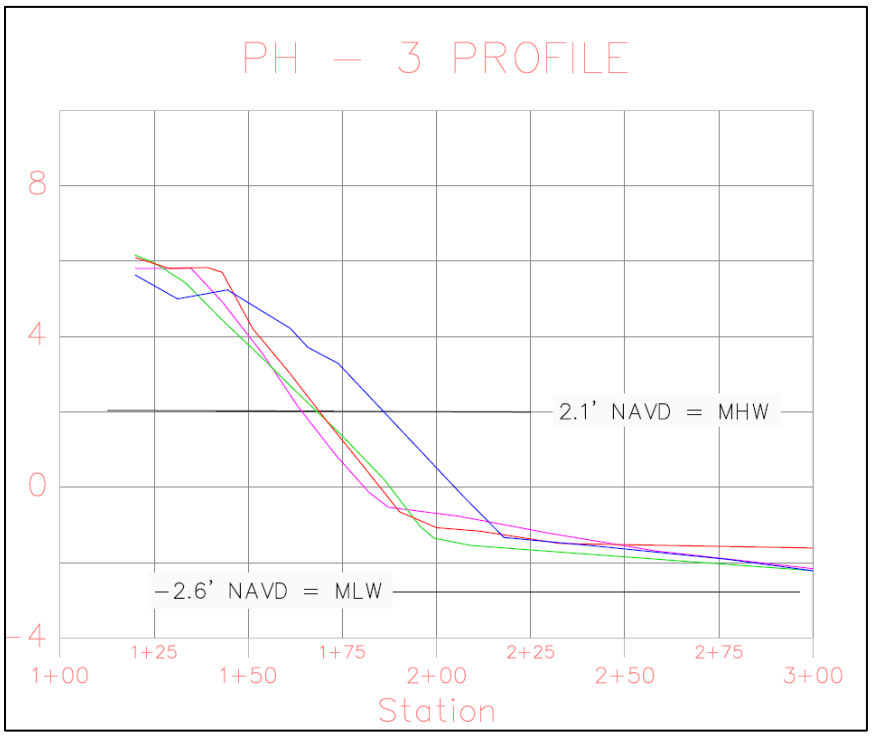


Figure 13B. Beach Profiles at Prime Hook Beach, Station PH-3.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Broadkill Beach

Broadkill Beach (BKB) is bound by Prime Hook Beach to the north and Lewes Beach to the south. There are nine LRP lines within the 18,000 feet or 3.4 miles of shoreline. New for this report is survey line BKB-1, which captures the most northern reach of Broadkill Beach. LRP lines BKB-2 to BKB-6 are spaced approximately 1,500 feet apart and within the more densely developed section of the community. The remaining three LRP lines (BKB-7 to BKB-9) at the southern end are spaced about 2,000 feet apart. The USACE previously nourished Broadkill in 2016, when 1.7 million cubic yards of sand was dredged from the Delaware River Main Channel and placed onto Broadkill Beach to widen it 150 feet and add a dune with a crest of 15-16 feet. Subsequent storm events, however, have greatly impacted the morphology of the shoreline.

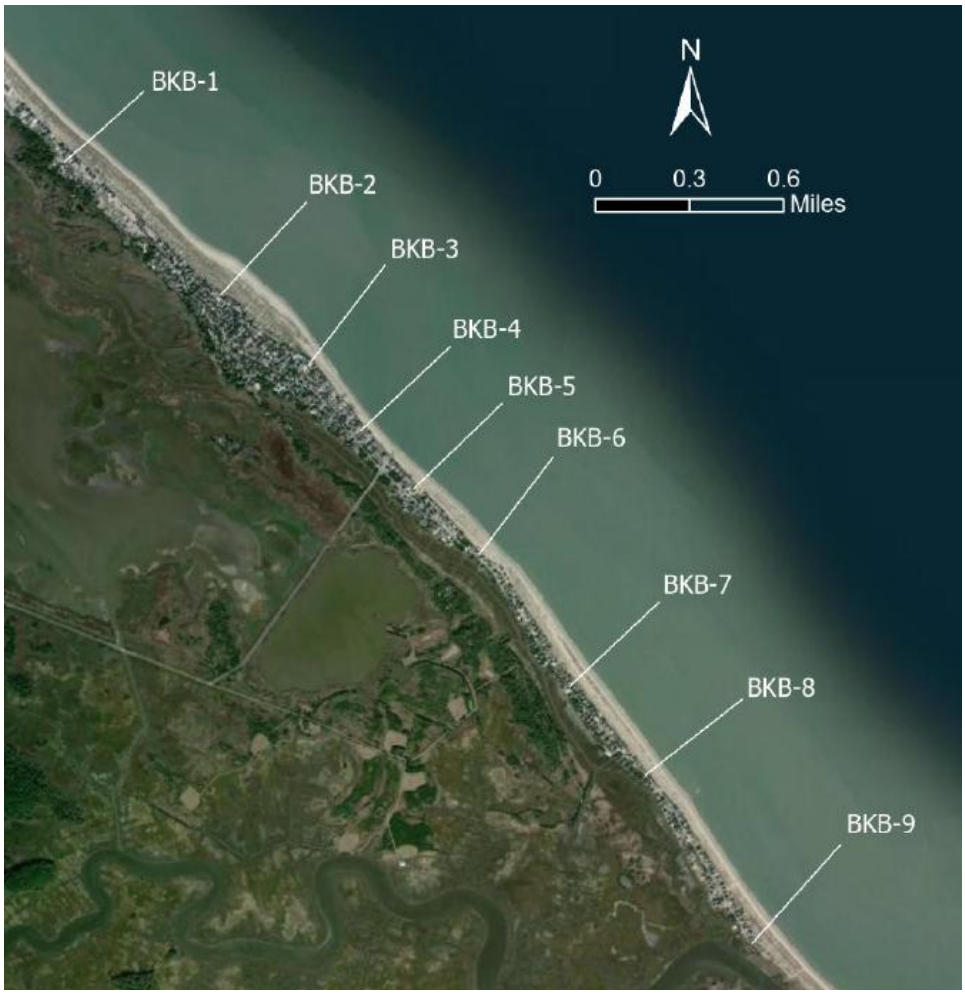


Figure 14A. LRP lines at Broadkill Beach

The average beach volumes determined for Broadkill Beach are shown in Table 11. Comparing Summer 2022 and Summer 2023 profiles shows the center of the Broadkill Beach community is eroding while the northern and southern sections are accreting. This is likely attributable to the orientation of the constructed beach. In the center of the

community, survey lines BKB-3, BKB-4, BKB-6, and BKB-7 continuously lose volume from Summer 2022 through Winter 2024. A significant loss of volume was also measured at BKB-5 between Summer 2022 and Winter 2023. This was likely due to the October 2022 storm that exacerbated the dune scarping in this area. While a lot of this material was recovered during Summer 2023, it is evident the central part of Broadkill Beach is losing volume. Erosion is most severe near the Route 16 beach access, between BKB-4 and BKB-5, where there is a near total loss of dune. Figure 14B demonstrates the continuous erosion at BKB-4, and the drastic difference between the Summer 2023 and Winter 2024 profiles that were likely influenced by TS Ophelia in September 2023. Overall, BKB-4 eroded over 26 feet between Summer 2022 and Winter 2024.

In the southern part of the community, LRP line BKB-8 appears to recover the volume lost in fall/winter during subsequent spring and summer seasons as expected. The gain of volume measured in profiles BKB-2 and BKB-9 demonstrates accretion in the northern and southern sections of the beach.

Table 11: Beach volume calculations for Broadkill Beach

LRP		BKB-1		BKB-2		BKB-3		BKB-4		BKB-5	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	200	513	1203	2371	522	922	714	1170	974	1525
Winter 2023	2/16/2023	212	530	1266	2398	483	842	704	1146	925	646
Summer 2023	5/31/2023	216	528	1305	2490	468	818	652	1069	896	1404
Winter 2024	12/21/2023	193	538	1369	2636	437	814	508	901	797	1301

Table 11 continued: Beach volume calculations for Broadkill Beach

LRP		BKB-6		BKB-7		BKB-8		BKB-9	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	805	1247	699	1495	934	1425	517	1016
Winter 2023	2/16/2023	728	1173	711	1453	912	1388	558	1103
Summer 2023	5/31/2023	709	1122	689	1433	923	1413	589	1131
Winter 2024	12/21/2023	601	1018	666	1404	893	1383	576	1126

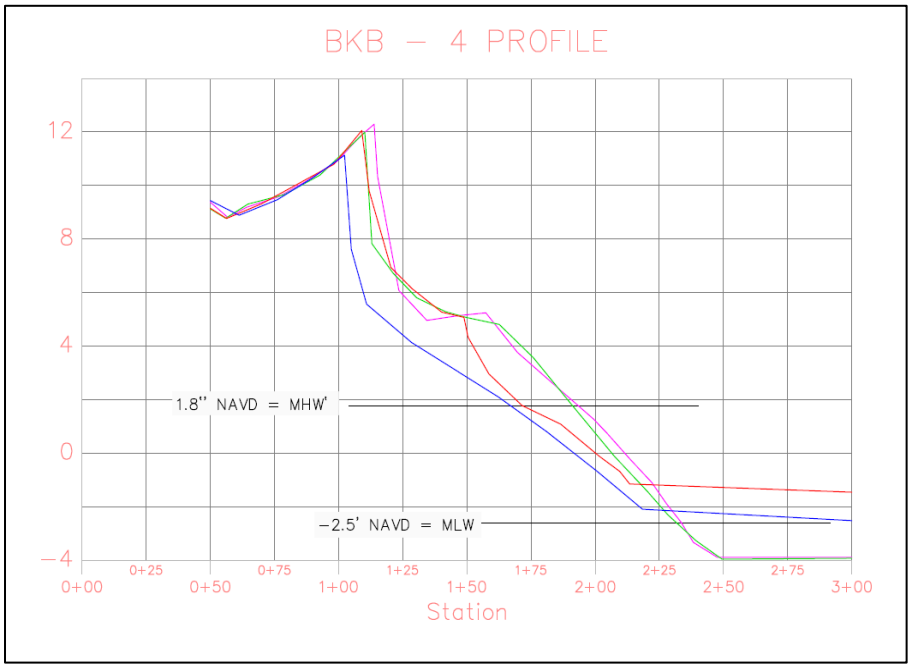


Figure 14B. Beach Profiles at Broadkill Beach, Station BKB-4.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 14C shows an aerial view of Broadkill Beach. The Route 16 crossover and severe scarping are visible in the foreground.

Figure 14C. Broadkill Beach (10/9/2024, 8:56) approaching high tide, looking south

Lewes Beach

Lewes Beach (LB) extends from Roosevelt Inlet to the Cape May-Lewes Ferry Terminal and accounts for approximately 12,000 ft or 2.3 miles of coastline. This area is a densely developed public beach with six survey lines (LB-1 to LB-6). For planning purposes, DNREC has divided Lewes Beach into three segments: proximal to the Roosevelt Inlet (LB-1 and LB-2); center of the developed shoreline (LB-3 and LB-4); and center of the community to the Cape May-Lewes Ferry Terminal (LB-5 and LB-6). Survey lines are spaced relatively evenly, expect for LB1 and LB2.

Figure 15A. LRP lines at Lewes Beach

The average beach volumes determined for Lewes Beach are shown in Table 12. The USACE completed a dredging and beach nourishment project in December 2023 that delivered 104,000 cubic yards of material from an offshore borrow source to the shoreline proximal to the Roosevelt Inlet (LB-1 and LB-2). Survey data is not available for Winter 2024, however, and this volume gain is not reflected in Table 11. Typically, the western end of Lewes Beach suffers the most damage from storms and tends to be erosional. This is evident by the significant loss of volume between the 2022 and 2023 summer seasons.

The center of the developed shoreline (LB-3 and LB-4) also erodes continuously as losses in volume were measured each season. The profiles in Figure 15B demonstrate erosion in this

segment of Lewes Beach, which lost 10.5 feet between Summer 2022 and Winter 2024.

The center of the beach community to the Cape May-Lewes Ferry Terminal (LB-5 and LB-6) appears to be accreting with volume gains observed during winter seasons. Accretion in this area is likely influenced by the eastern jetty that traps sand as it moves northward with the longshore current.

Table 12: Beach volume calculations for Lewes Beach

LRP		LB-1		LB-2		LB-3	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	410	919	445	857	596	1054
Winter 2023	2/16/2023	395	821	363	809	580	970
Summer 2023	5/31/2023	316	748	352	696	574	944
Winter 2024	12/21/2023	n/a	n/a	n/a	n/a	553	934

Table 12 continued: Beach volume calculations for Lewes Beach

LRP		LB-4		LB-5		LB-6	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	602	1026	1000	1584	661	1276
Winter 2023	2/16/2023	586	1000	1001	1605	677	1294
Summer 2023	5/31/2023	584	996	984	1596	674	1290
Winter 2024	12/21/2023	565	965	1029	1610	675	1295

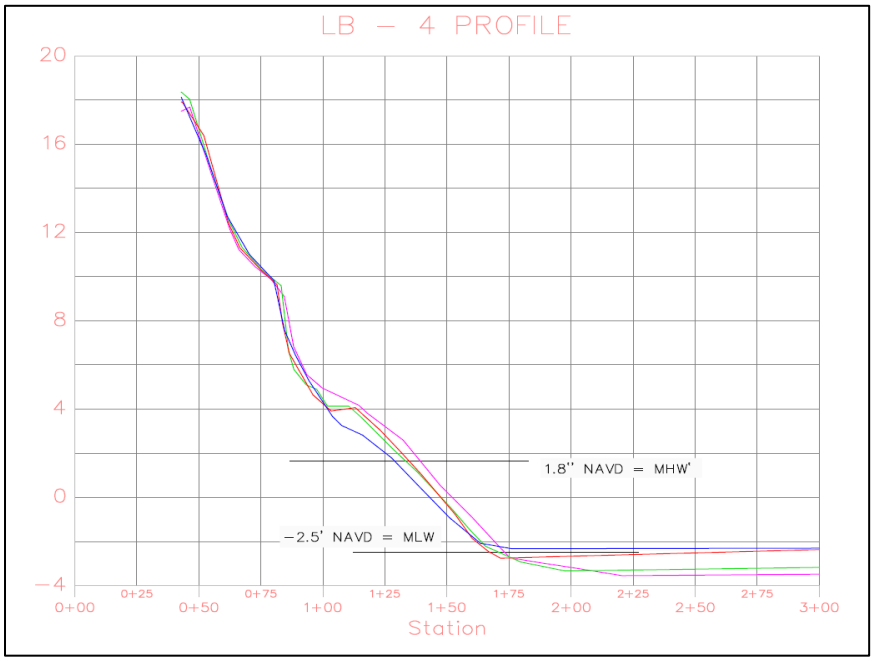


Figure 15B. Beach Profiles at Lewes Beach, Station LB-4.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 15C. Aerial view of Lewes Beach (1/8/24, 11:51) approaching low tide with 1.4-ft storm surge, looking west from the center of the developed shoreline.

Cape Shores

Cape Shores (CS) is private community located in Lewes, DE and situated between the Cape May-Lewes Ferry Terminal and Cape Henlopen State Park. The shoreline extends approximately 3,500 ft and consists of three survey lines (CS-1 to CS-3).

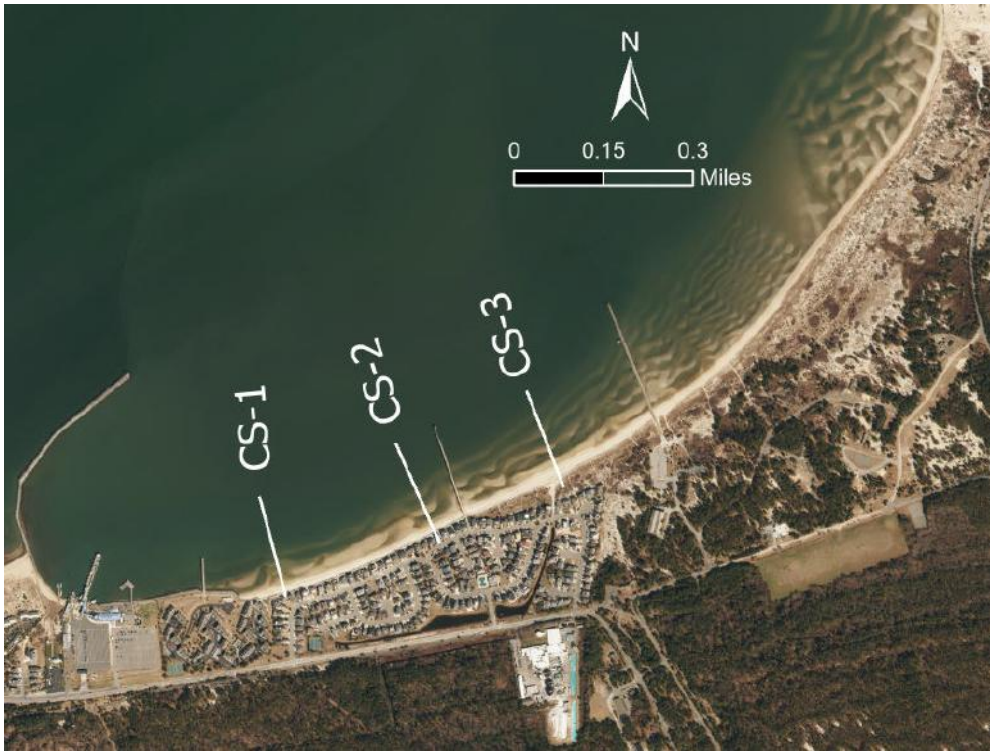


Figure 16A. LRP lines at Cape Shores

The average beach volumes determined for Cape Shores are shown in Table 13. The Cape Shores beach community was nourished during Winter 2023. While a volume gain was not initially measured in the CS-1 and CS-2 profiles, the seasonal recovery in Summer 2023 is evident along with the volume gain measured between the 2022 and 2023 summer seasons. The profiles in Figure 16B demonstrate the accretion measured in Summer 2023, and the subsequent seasonal loss during Winter 2024. The eastern end of Cape Shores (CS-3), however, accreted continuously between Summer 2022 and Winter 2024.

Table 13: Beach volume calculations for Cape Shores							
LRP		**CS-1**		**CS-2**		**CS-3**	
Volume Limit		MHW	MLW	MHW	MLW	MHW	MLW
Season	Date	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*	*cf/lf*
Summer 2022	7/27/2022	266	554	244	507	150	520
Winter 2023	2/16/2023	258	548	193	479	147	531
Summer 2023	5/31/2023	382	695	350	674	199	592
Winter 2024	12/21/2023	350	694	306	651	197	602

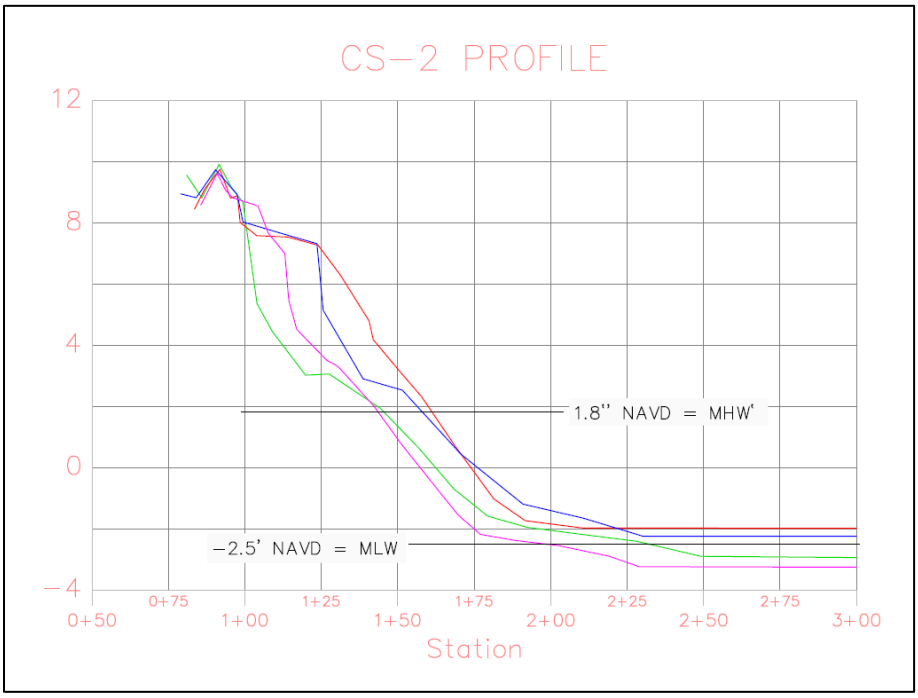


Figure 16B. Beach Profiles at Cape Shores, Station CS-2.
Pink: Summer 2022, Green: Winter 2023, Red: Summer 2023, Blue: Winter 2024.

Figure 16C. Aerial view of Cape Shores (1/8/24, 12:26) approaching low tide with 1.4-ft storm surge, looking east

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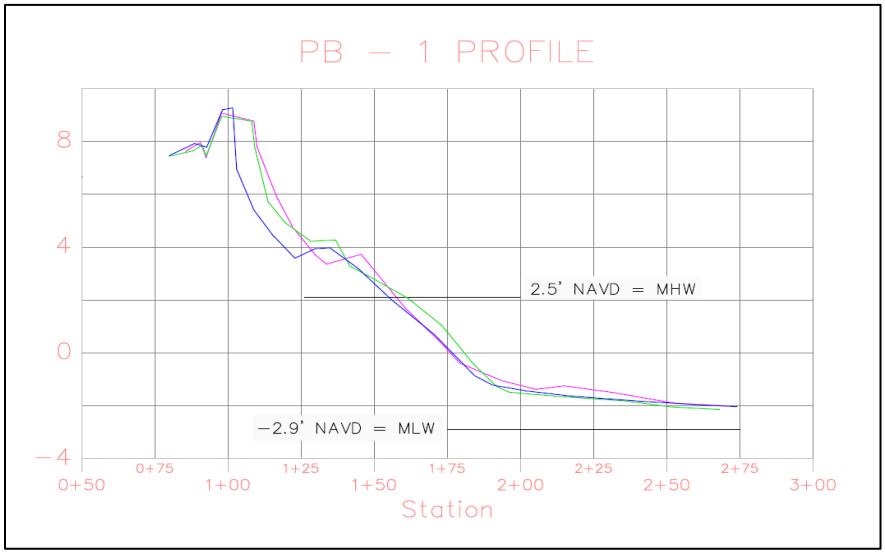
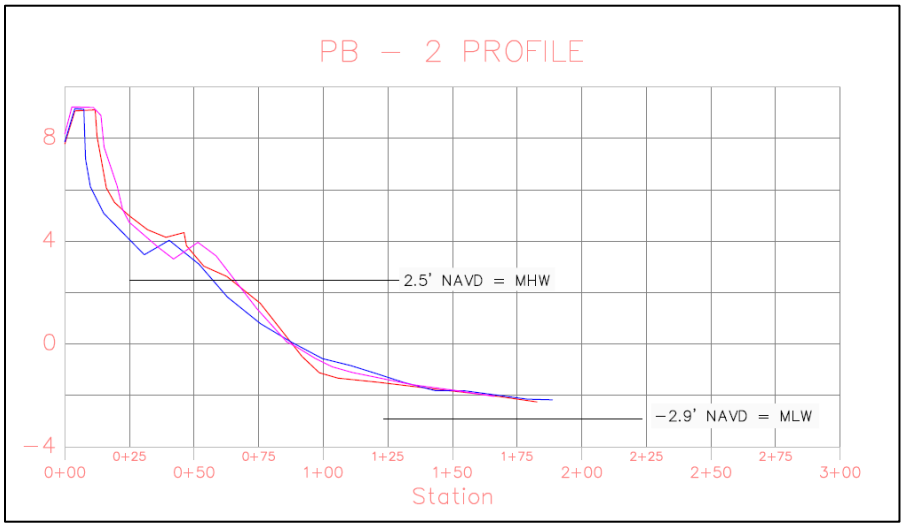
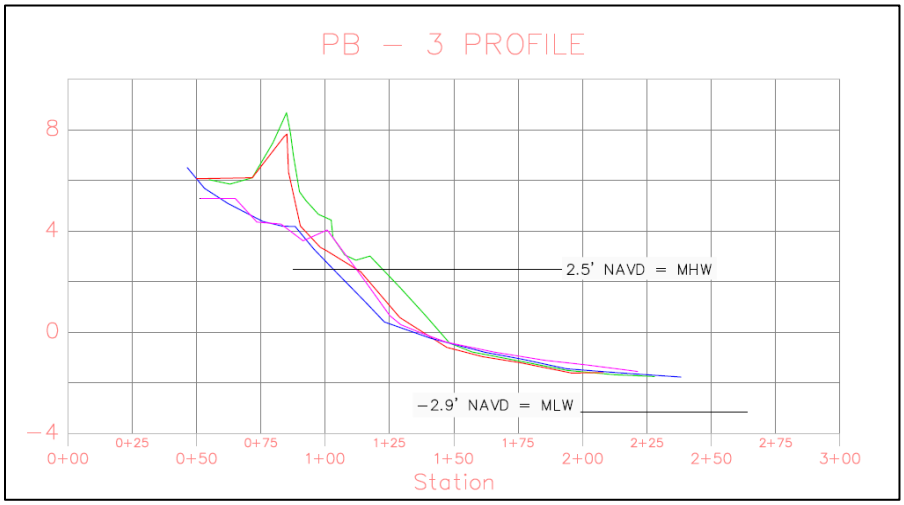
[7] Harris, D.L., Vila-Concejo, A., Austin, T. and Benavente, J., 2020, Multi-scale morphodynamics of an estuarine beach adjacent to a flood-tide delta: Assessing decadal scale erosion, Estuar. Coast. Shelf Sci., 241, https://doi.org/10.1016/j.ecss.2020.106759

Appendix 1: Bay Coast Profile Views







LEGEND

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Green: Winter 2023
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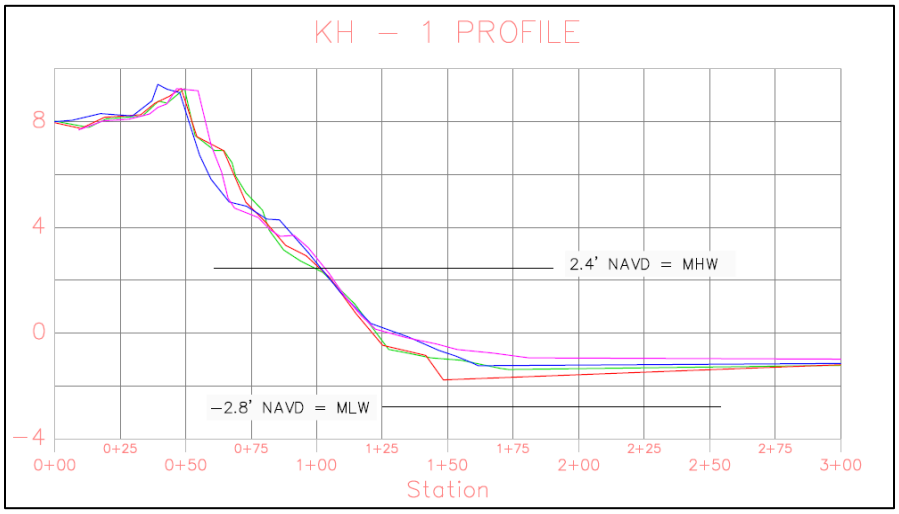

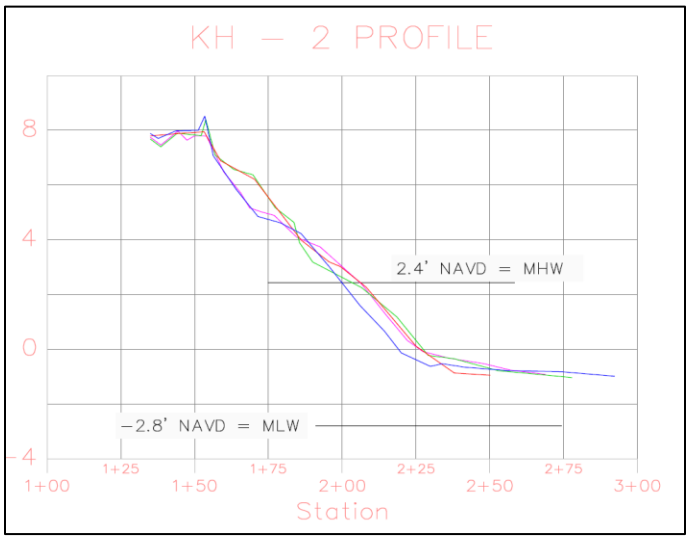

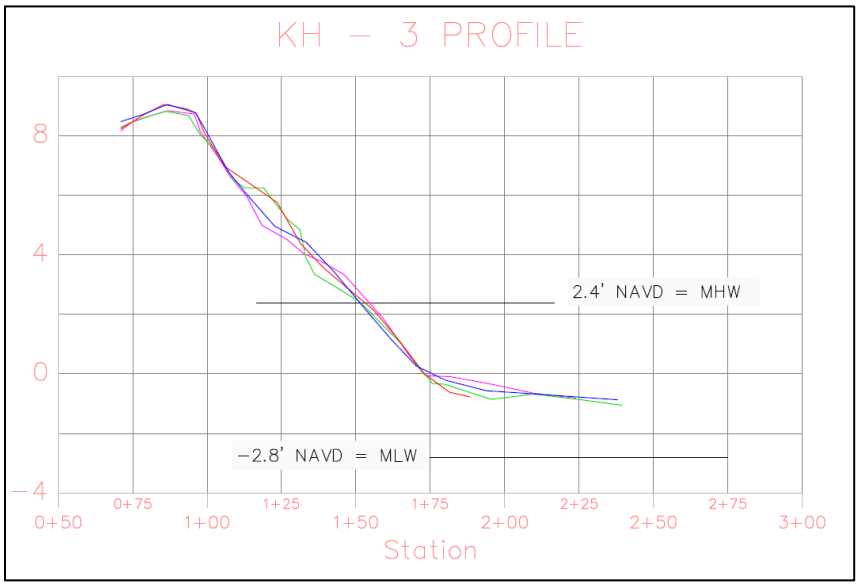

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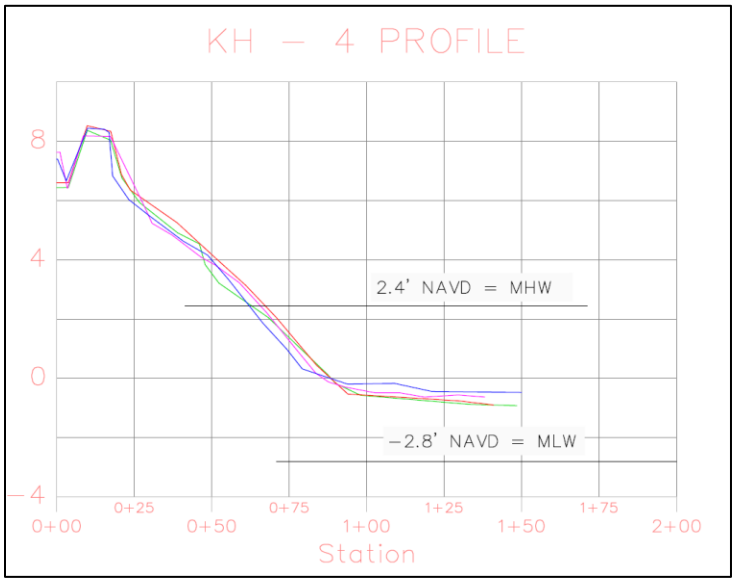
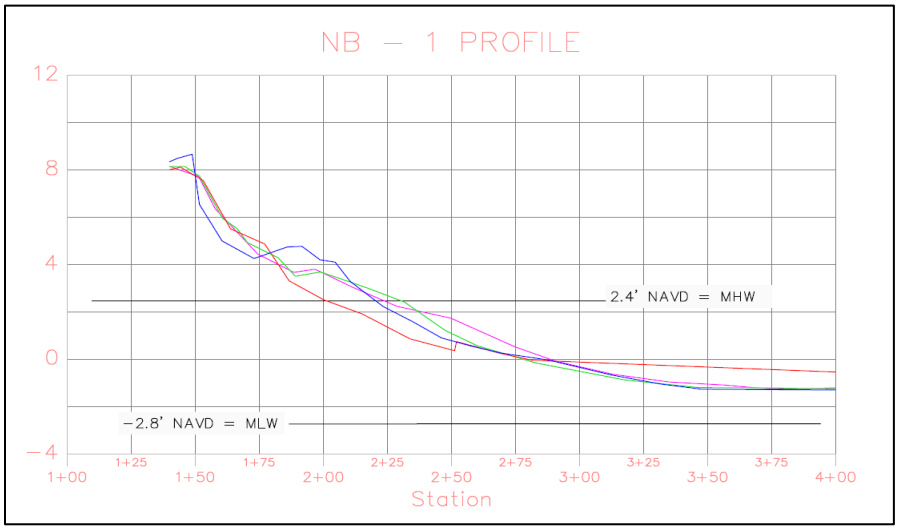
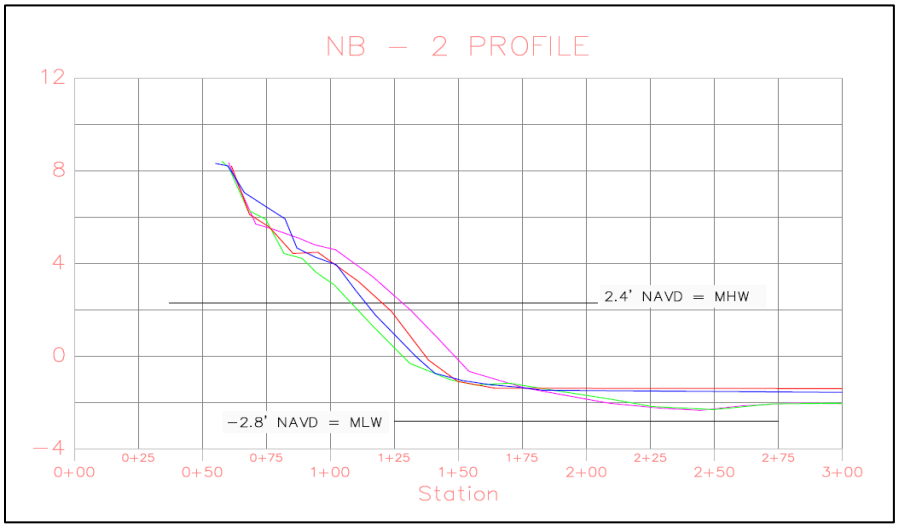
Blue: Winter 2024







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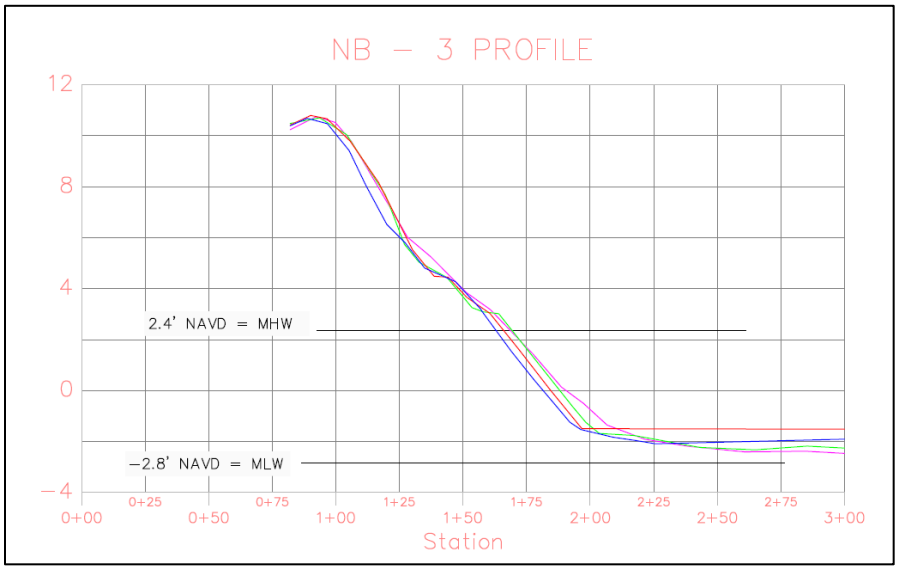
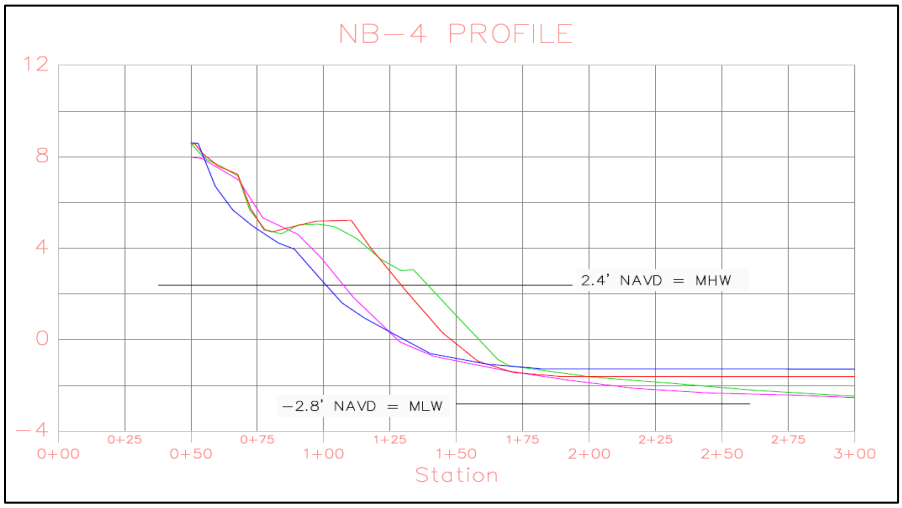
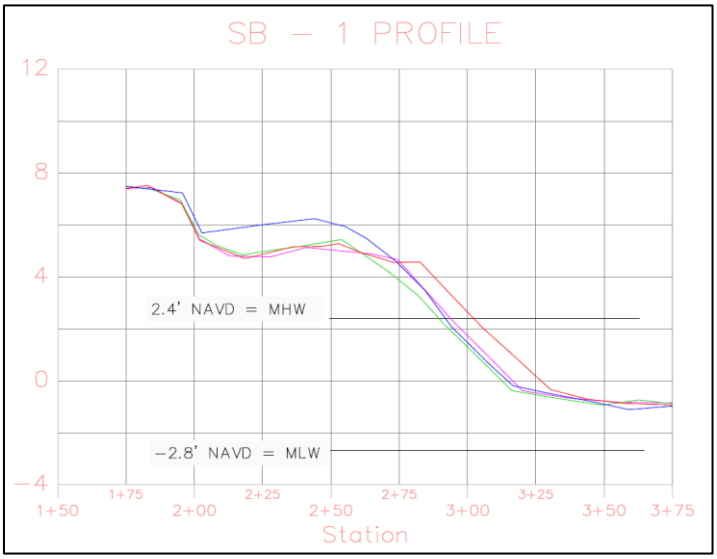
Blue: Winter 2024

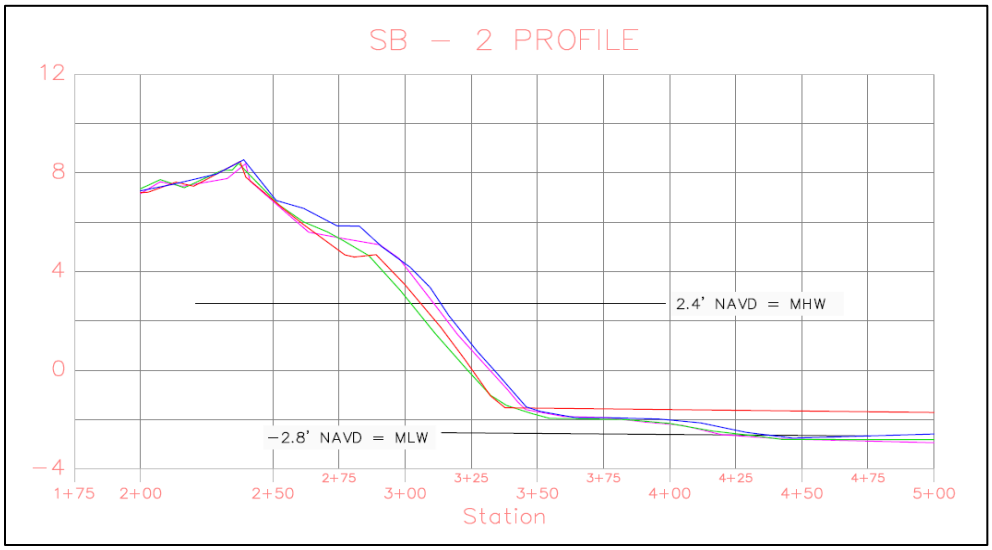


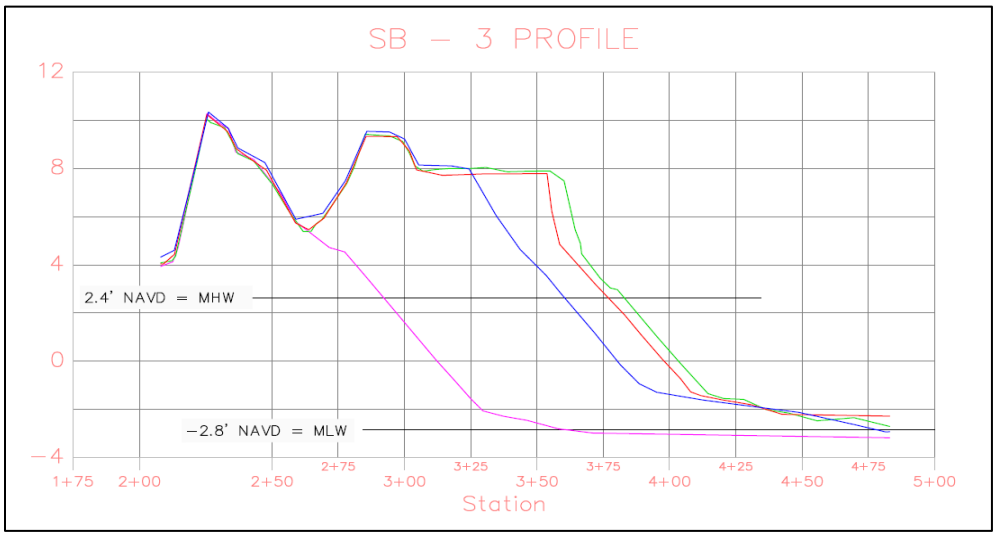


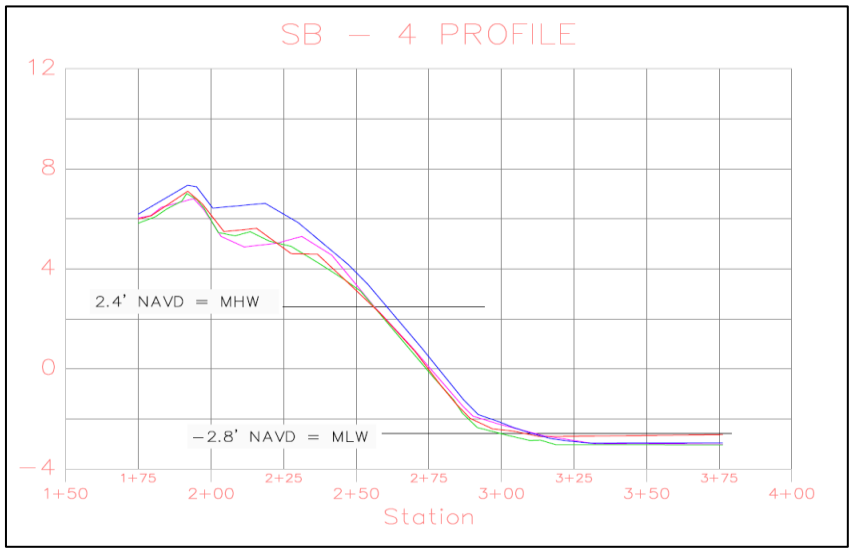


LEGEND

Pink: Summer 2022
Green: Winter 2023
Red: Summer 2023
Blue: Winter 2024







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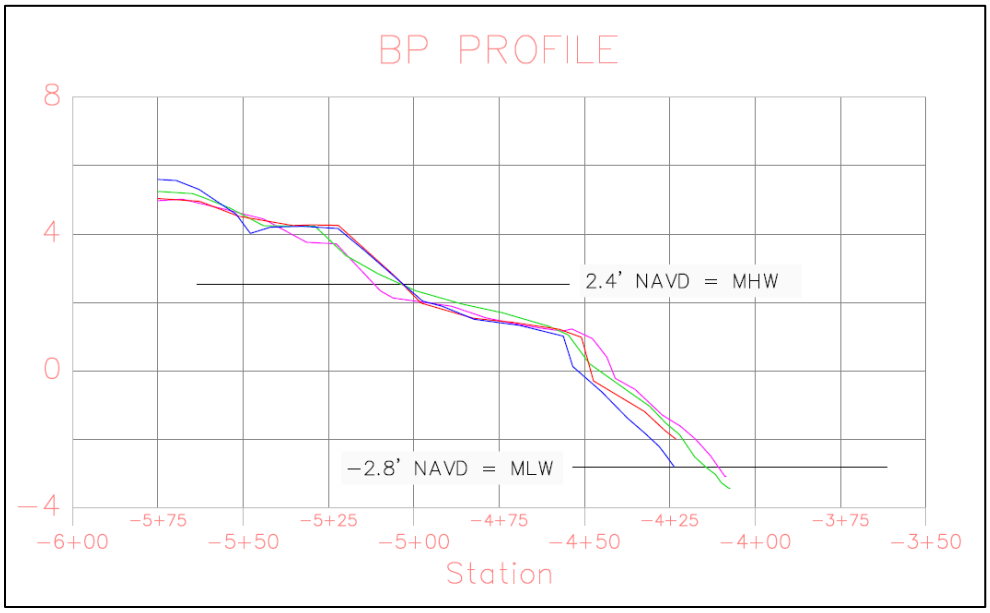
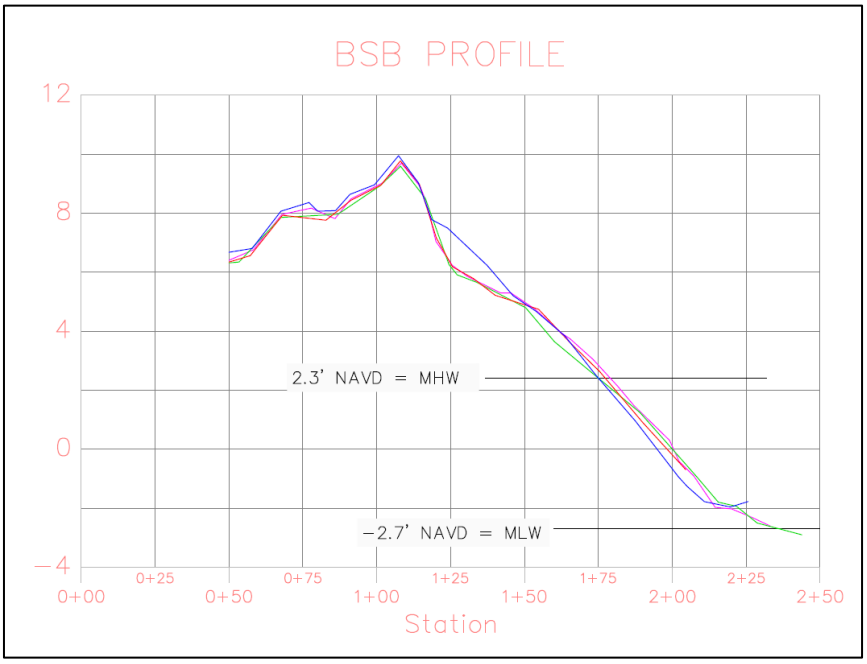
Green: Winter 2023
Red: Summer 2023
Blue: Winter 2024





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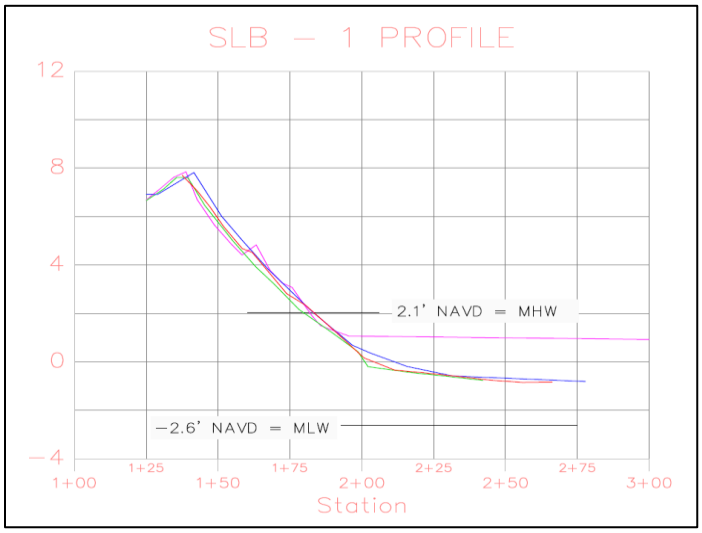

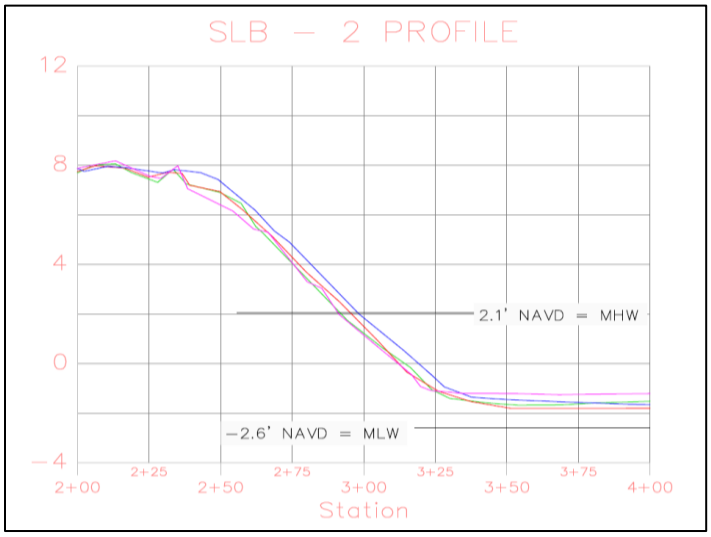

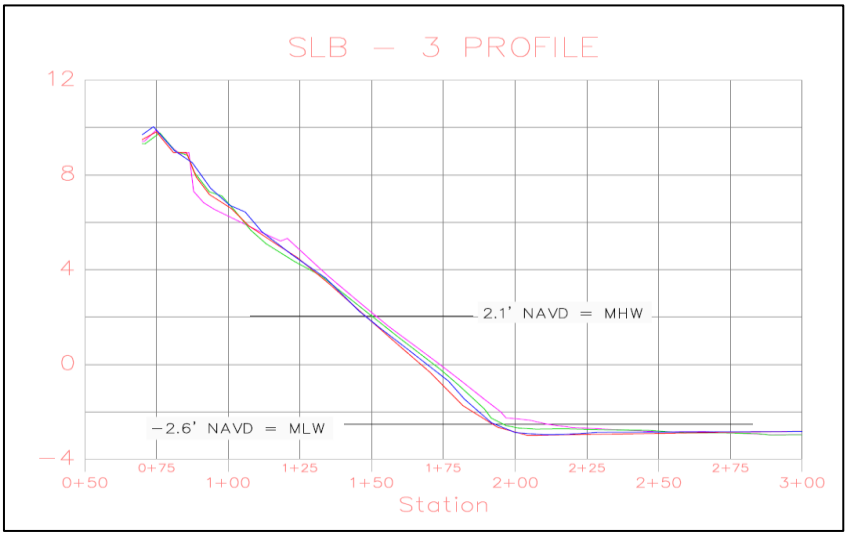

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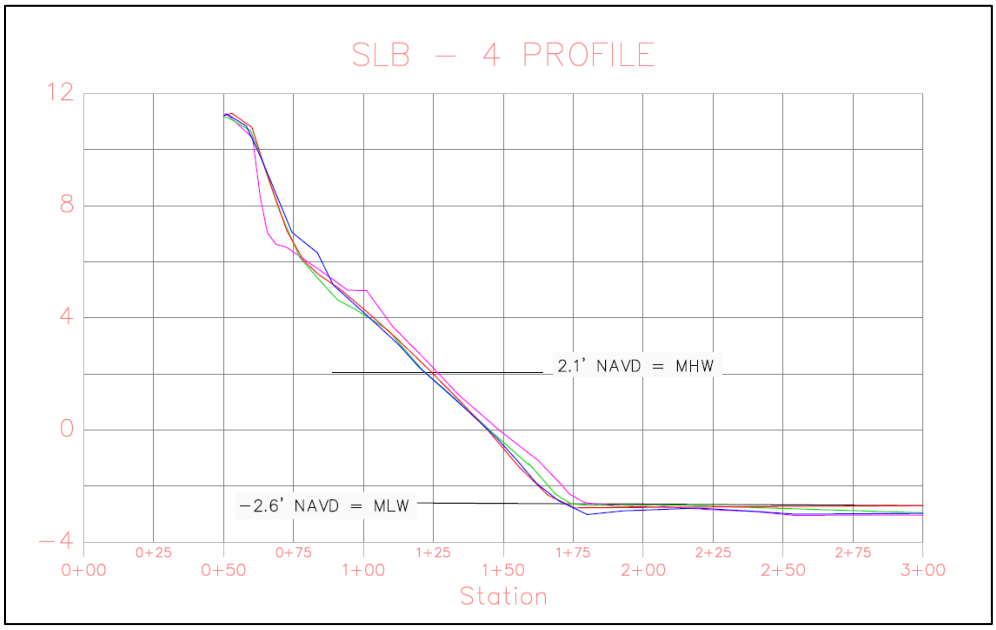

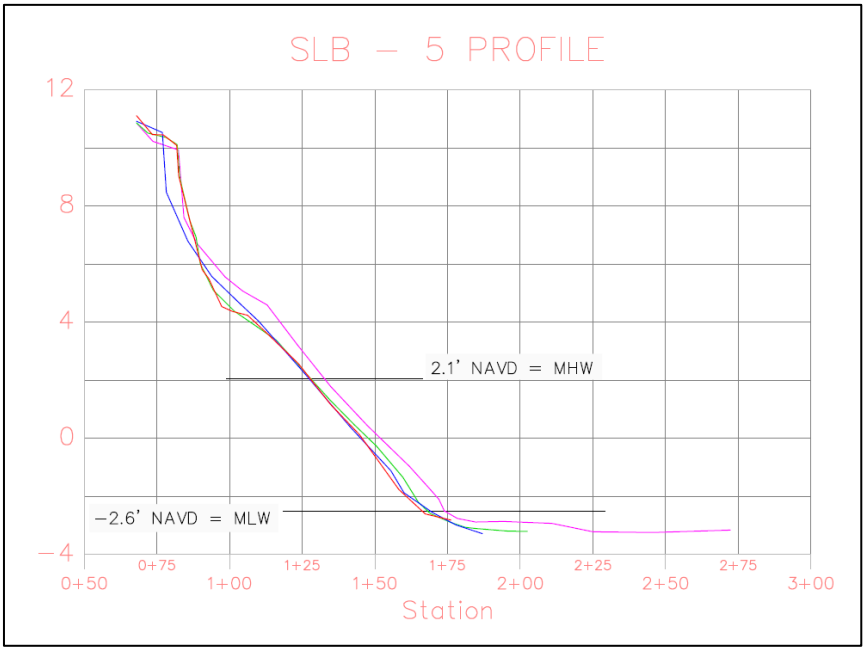

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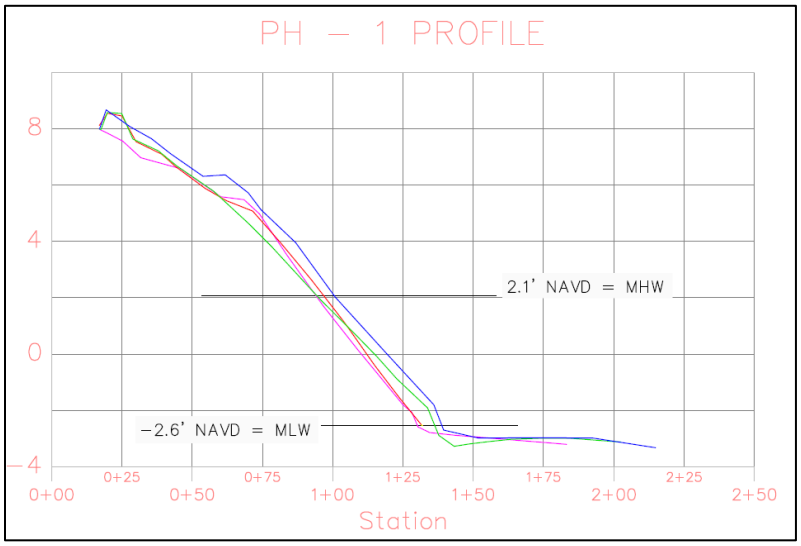

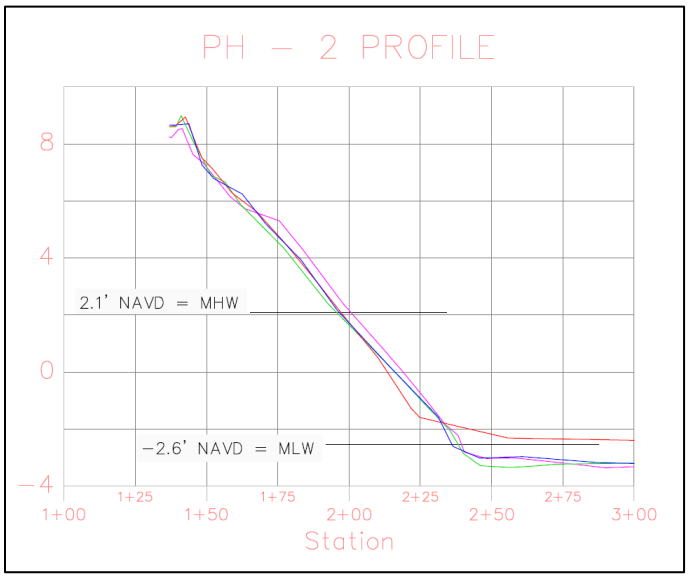

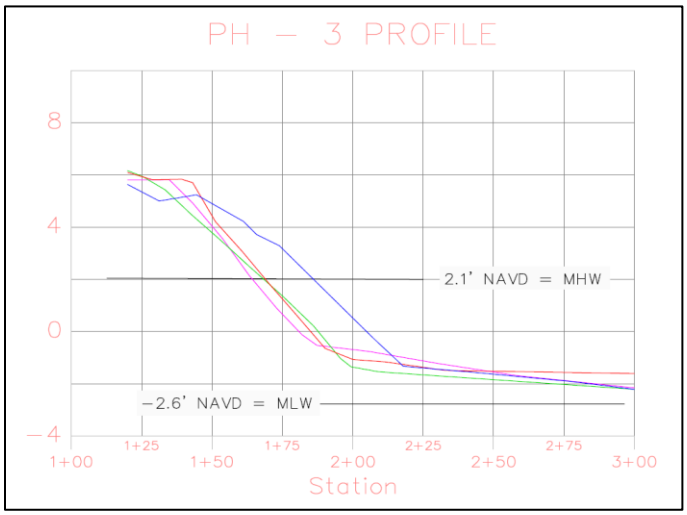

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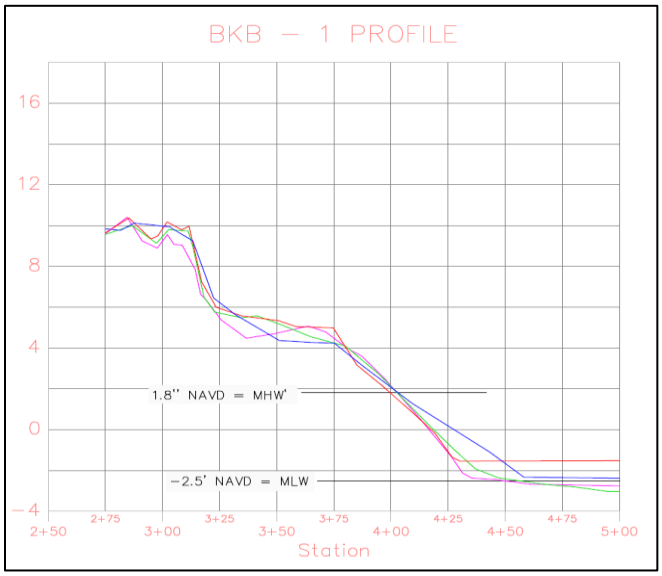

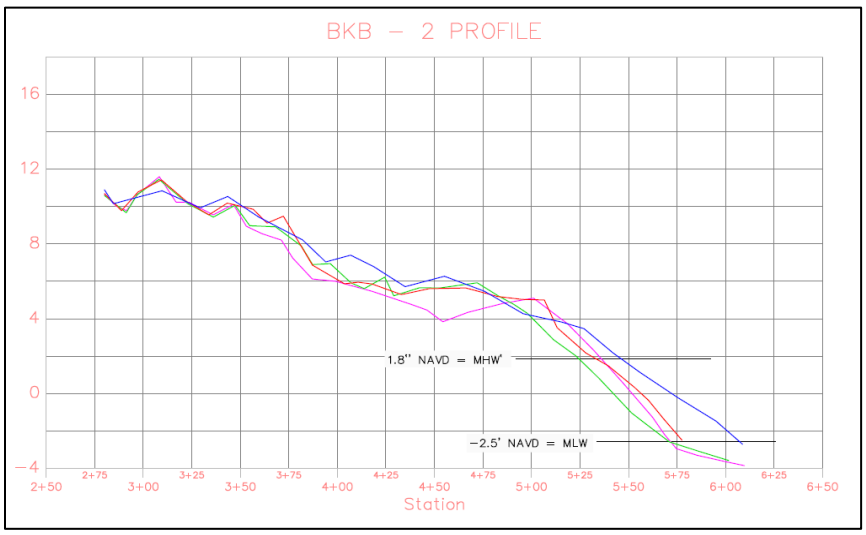

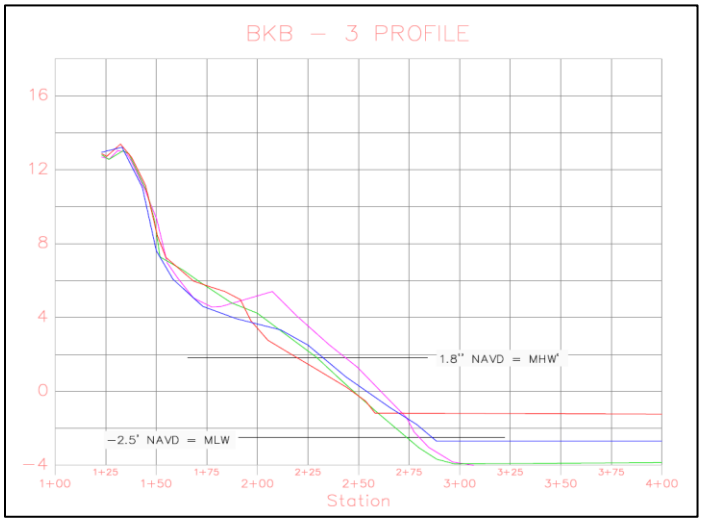

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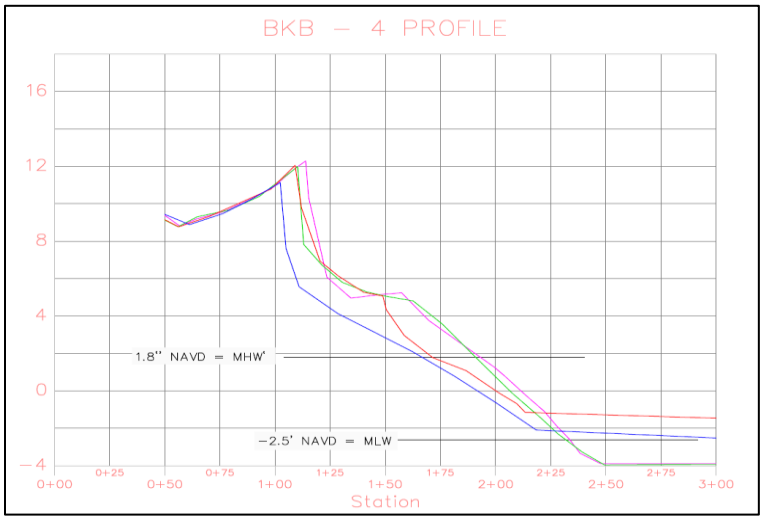

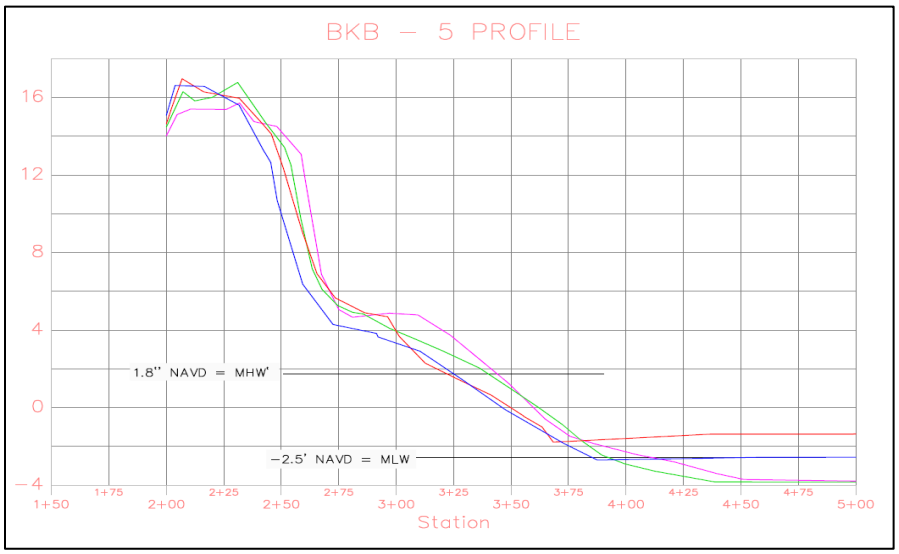

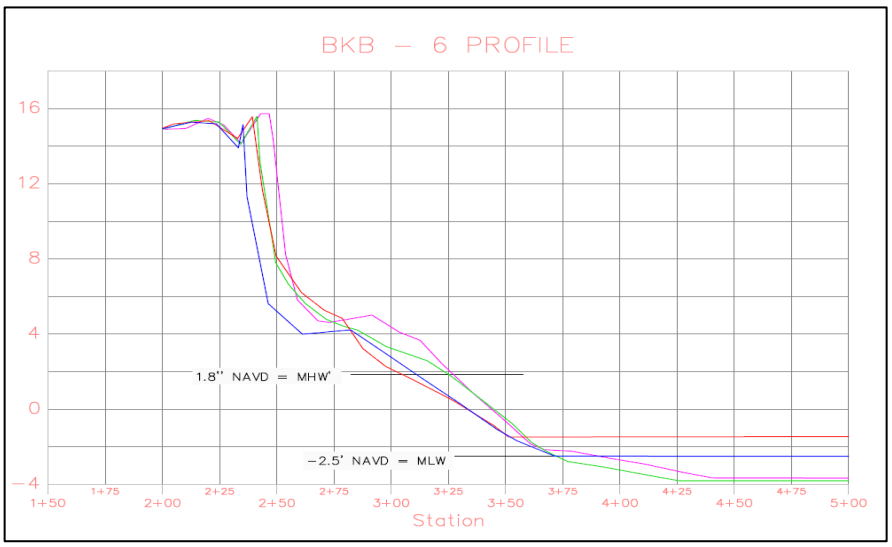

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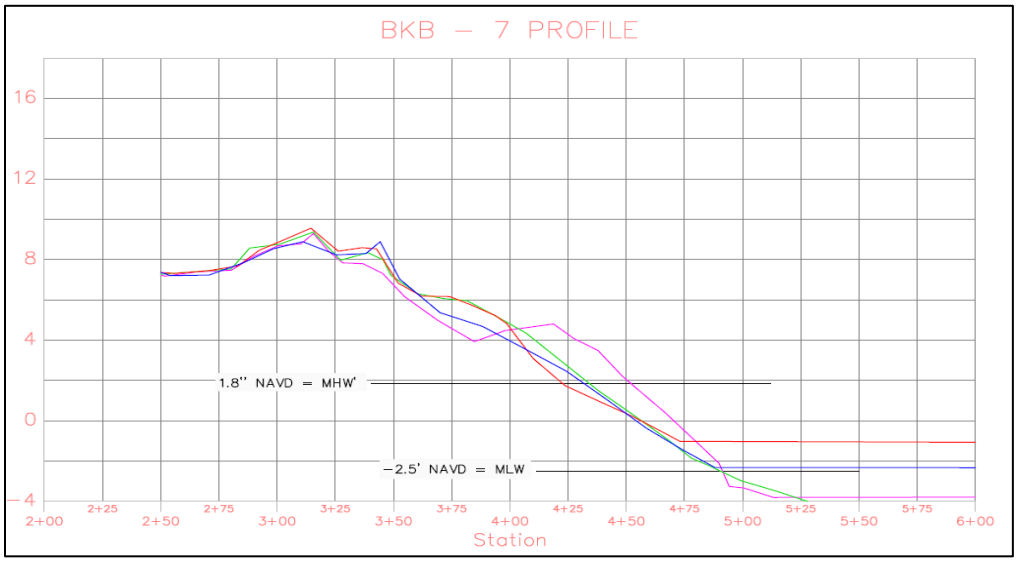

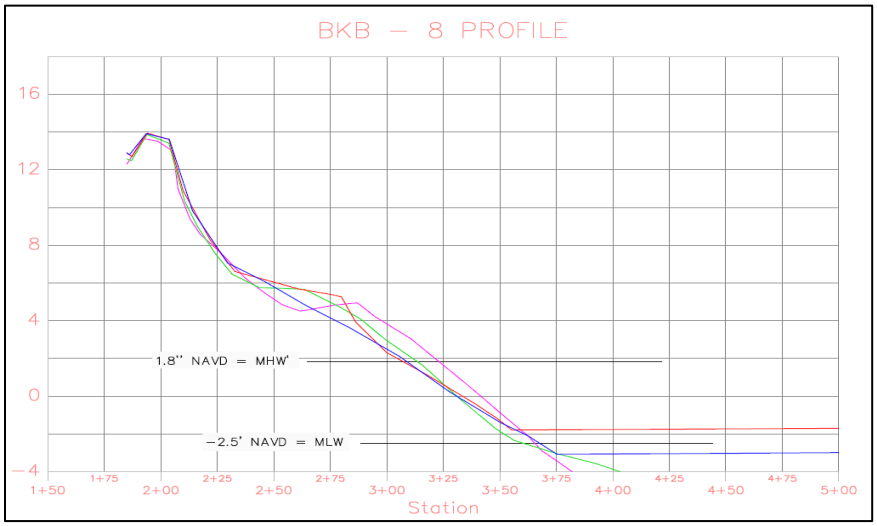

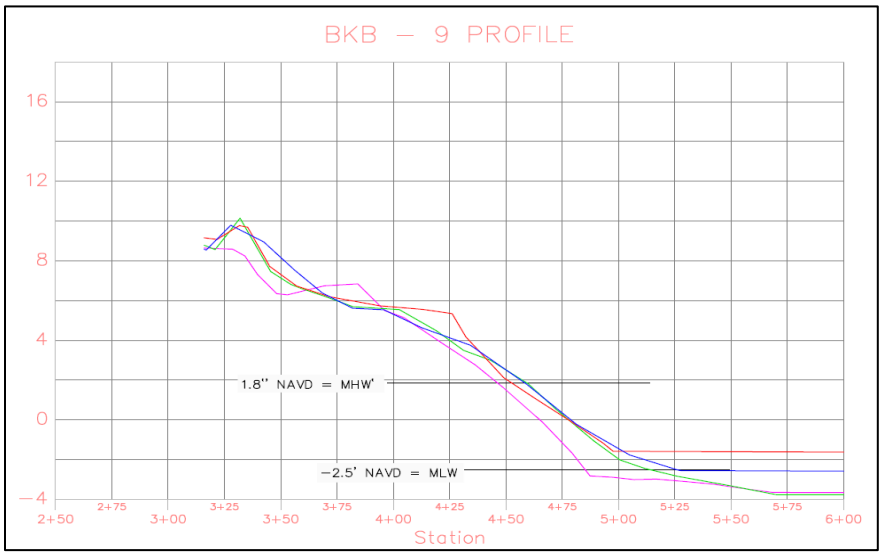

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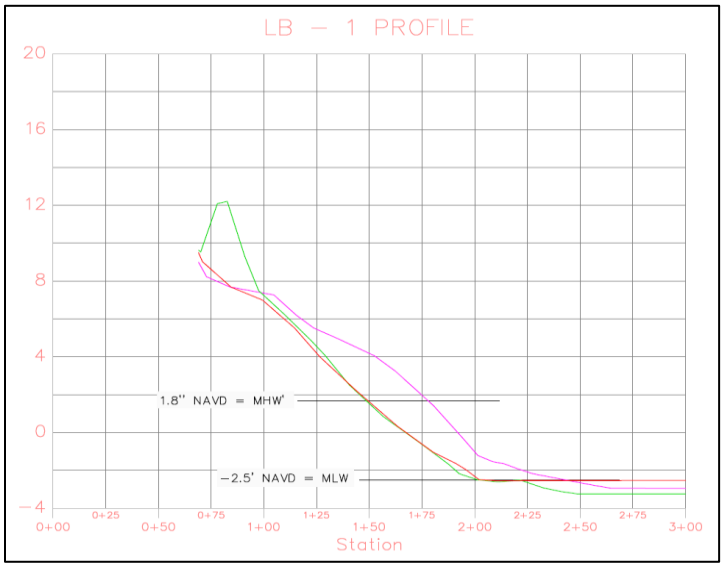

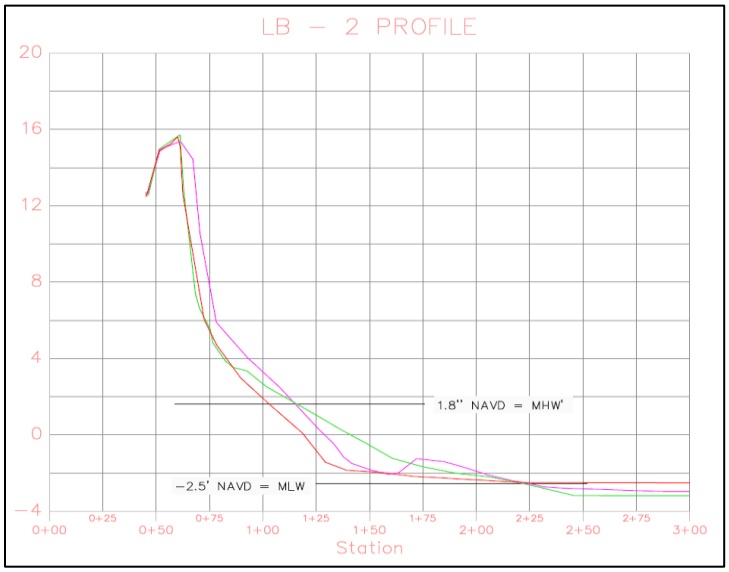

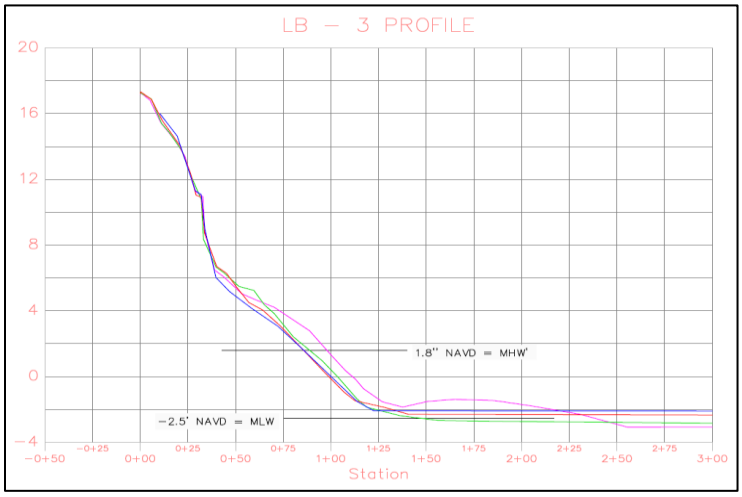

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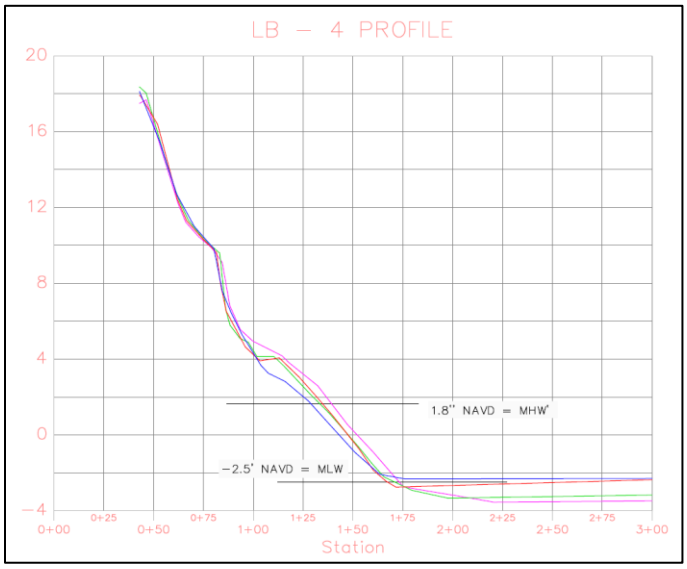

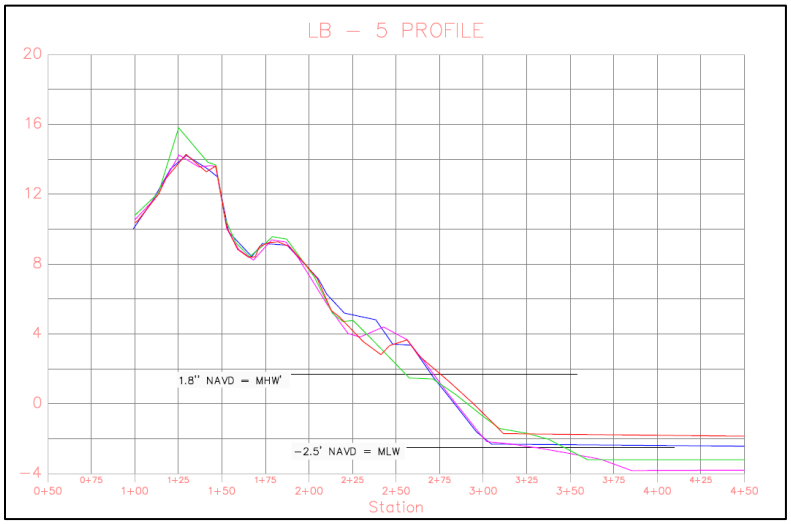

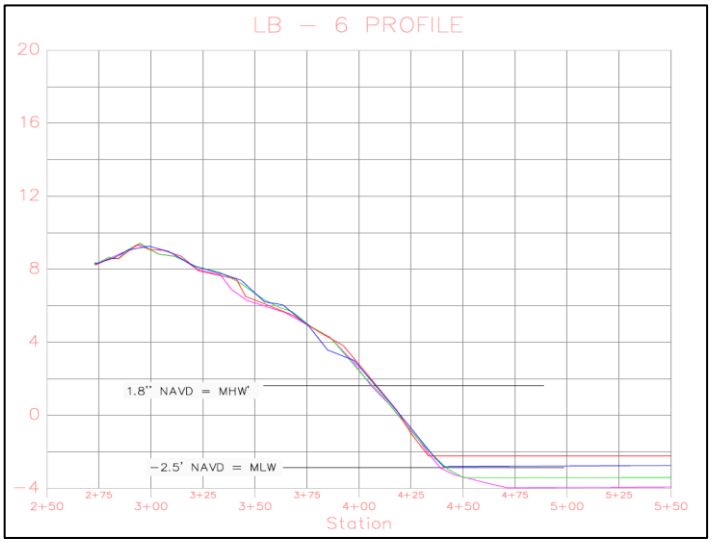

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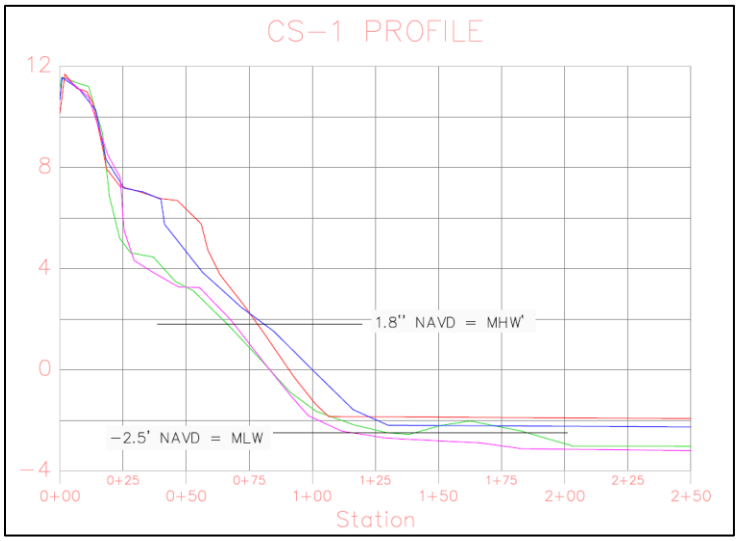

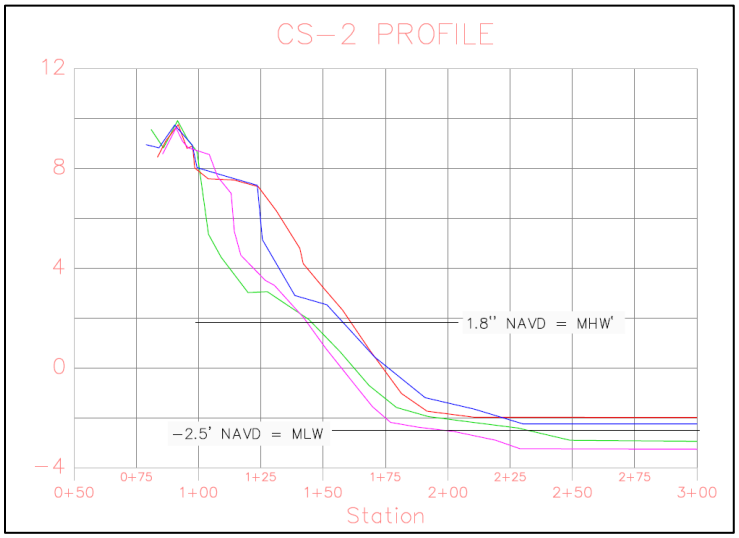

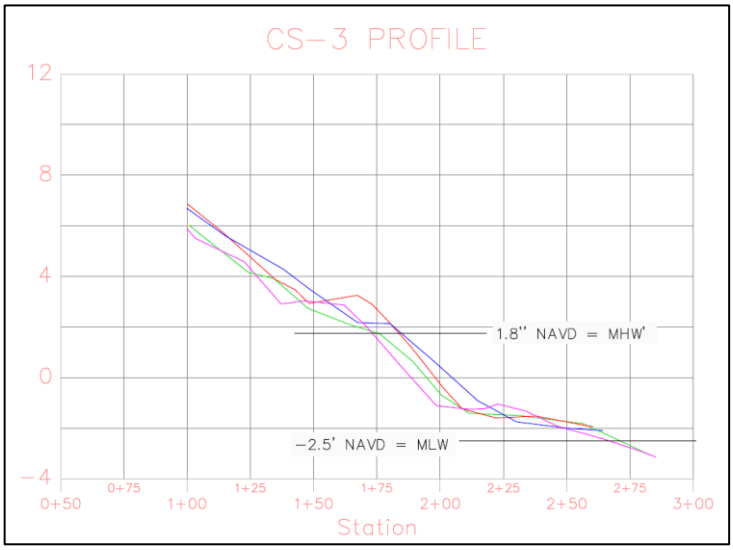

LEGEND

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Appendix 2: Bay Coast Photographs

Pickering Beach (4/4/2024 at 11:23)

Approaching low tide looking north. Photo taken a couple weeks after an emergency beach fill project.

Kitts Hummock (04/17/2024 at 12:52)

North Section: Photo taken at low tide looking north

Kitts Hummock (04/17/2024 at 12:52) continued.

North Section: Photo taken at low tide looking south

Middle Section: Photo taken at low tide looking north

Middle Section: Photo taken at low tide looking south

Kitts Hummock (04/17/2024 at 12:52) continued

South Section: Photo taken at low tide looking north

South Section: Photo taken at low tide looking south

North Bowers Beach (4/17/2024 at 12:06)

Photo taken approaching low tide looking north

Photo taken approaching low tide looking south

South Bowers Beach (4/17/2024 at 12:15)

Photo taken approaching low tide looking south

Slaughter Beach (4/17/2024 at 12:10)

North Section: Photo taken approaching low tide looking north

Slaughter Beach (4/17/2024 at 12:10) continued.

North Section: Photo taken approaching low tide looking south

Middle Section: Photo taken approaching low tide looking north

Middle Section: Photo taken approaching low tide looking south

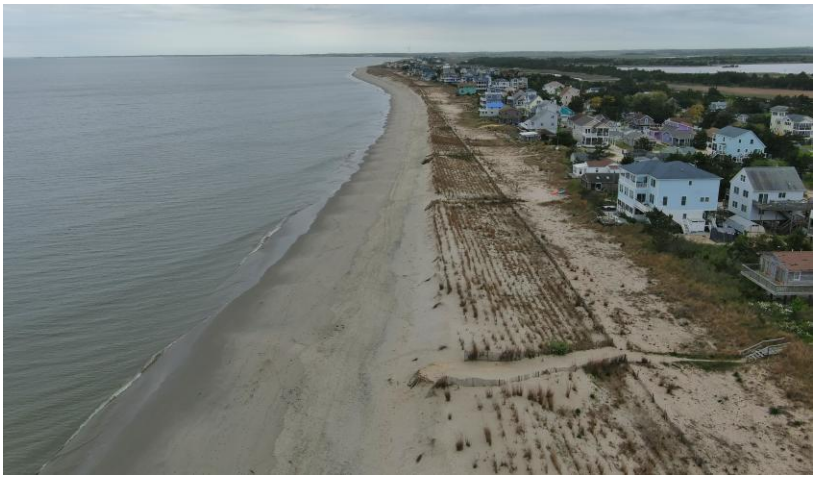
Slaughter Beach (4/17/2024 at 12:10) continued.

South Section: Photo taken approaching low tide looking north

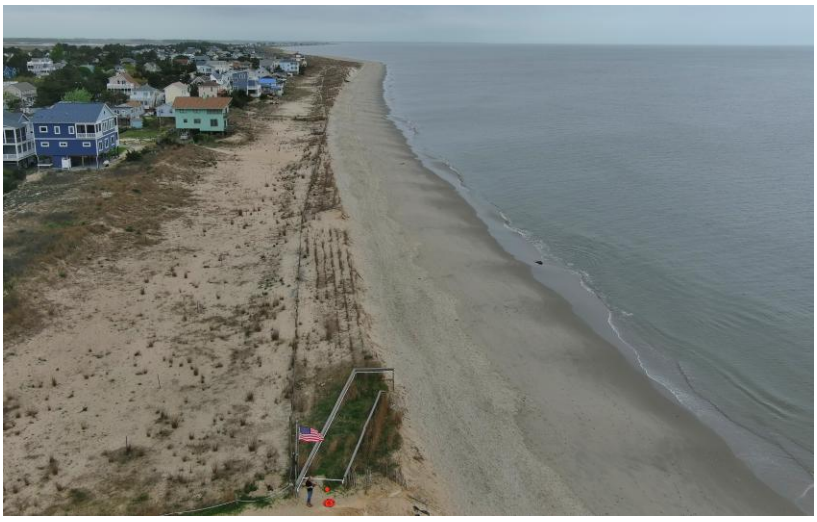
South Section: Photo taken approaching low tide looking south

Broadkill Beach (4/17/2024 at 11:30)

North Section: Photo taken approaching low tide looking north



North Section: Photo taken approaching low tide looking south



Middle Section: Photo taken approaching low tide looking north

Broadkill Beach (4/17/2024 at 11:30) continued.

Middle Section: Photo taken approaching low tide looking south

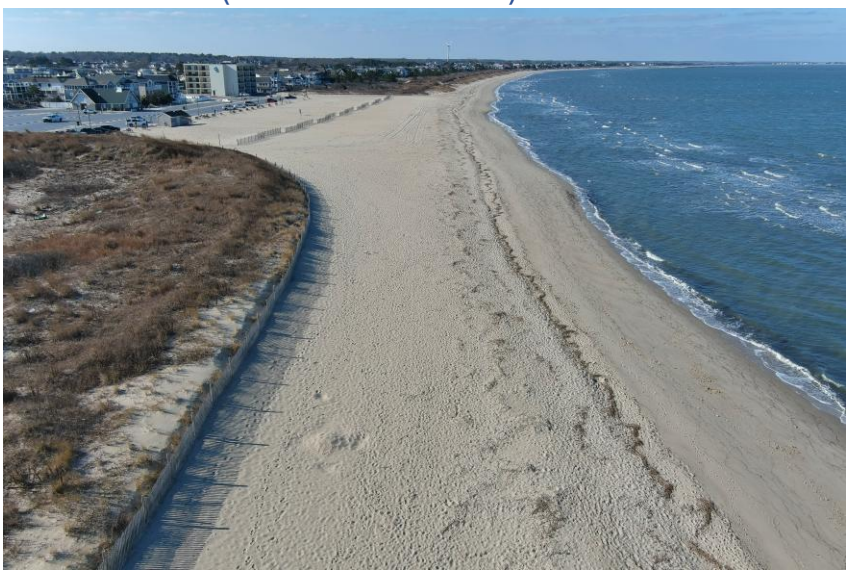
South Section: Photo taken approaching low tide looking north

South Section: Photo taken approaching low tide looking south

Broadkill Beach (10/9/2024 at 8:56)

Middle Section: Photo taken approaching high tide looking south

Lewes Beach (1/8/2024 at 11:51)



East Section: Photo taken approaching low tide with 1.4-feet of storm surge, looking west

Lewes Beach (1/8/2024 at 11:51) continued.

East Section: Photo taken approaching low tide with 1.4-feet of storm surge, looking east

Middle Section: Photo taken approaching low tide with 1.4-feet of storm surge, looking west

Cape Shores (1/8/2024 at 12:26)

Photo taken approaching low tide with 1.4-feet of storm surge, looking east