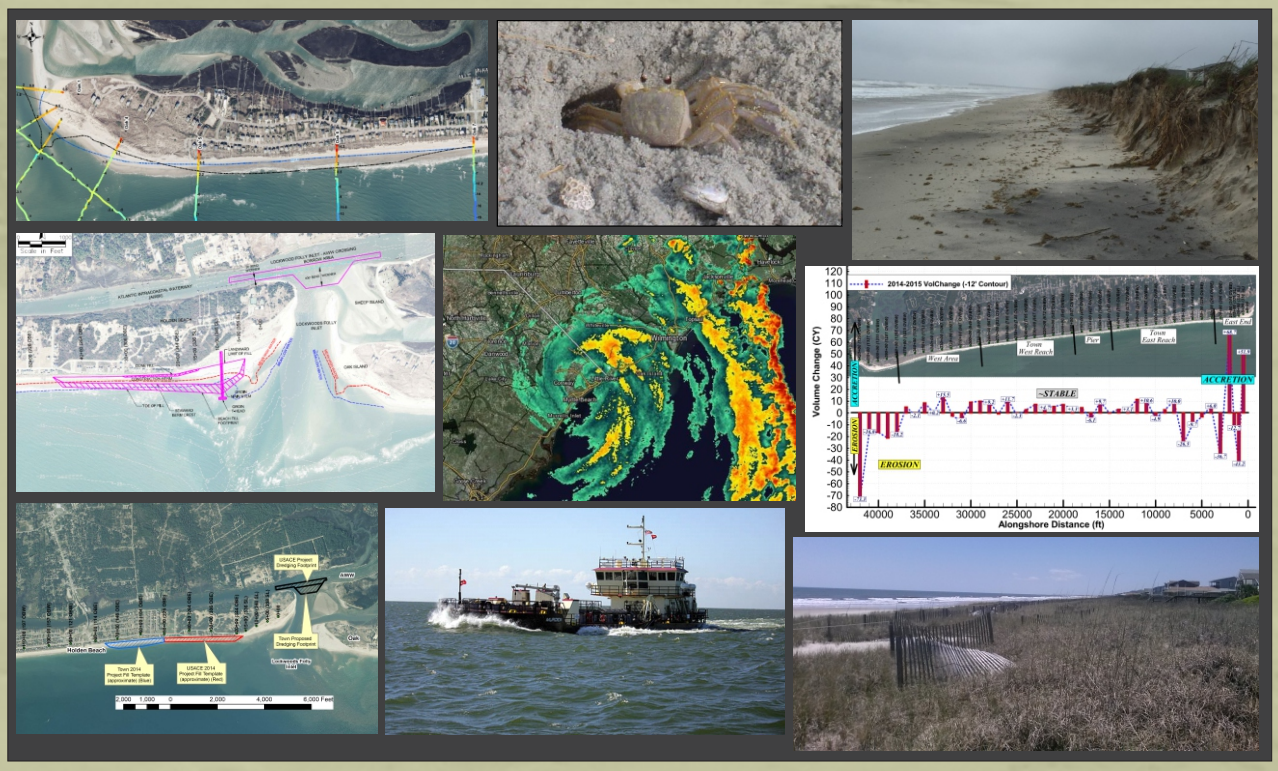
Holden Beach

Annual Beach Monitoring Report

Prepared For:
Town of Holden Beach, North Carolina



October 2015

APPLIED TECHNOLOGY & MANAGEMENT

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1.0 INTRODUCTION

Holden Beach is a 9-mile-long barrier island located in Brunswick County, North Carolina (see Figure 1-1), where long-term and episodic storm erosion continually threatens the coastal habitats, recreational beach, tourism, and upland developments on the island. Consequently, the Town of Holden Beach, referred to herein as the "Town," has undertaken a comprehensive beach management and maintenance program to protect and enhance its beach system. All nourishment and dune enhancement activities resulting from this program have proven valuable in providing a healthy beach system as well as a storm buffer to reduce losses to homeowners and to Town, State and Federal infrastructure.

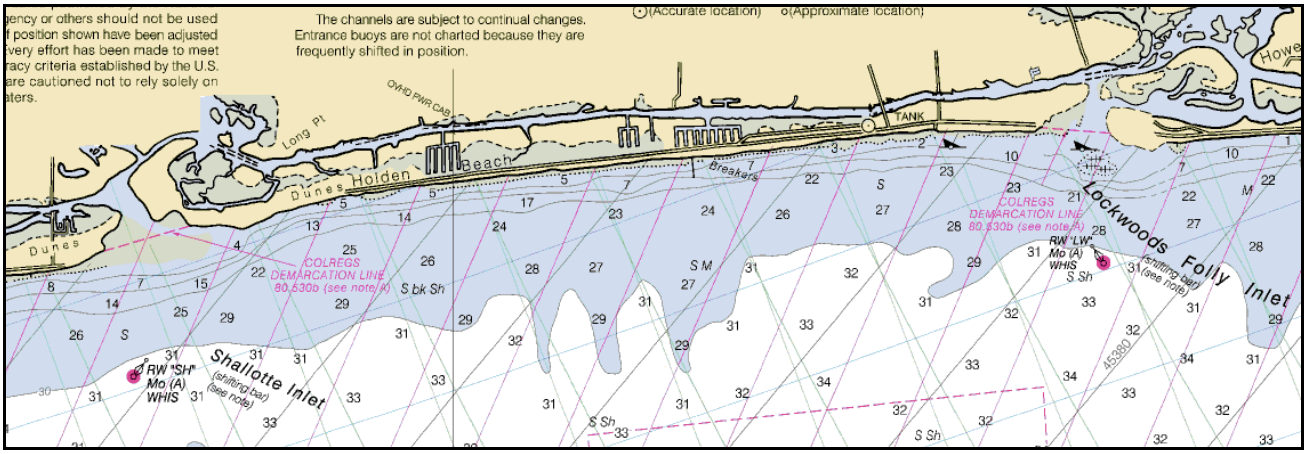


Figure 1-1. Project Location Map of Holden Beach, NC (NOAA Chart 11536)

The Town has been documenting nourishment and dune project performance and environmental effects through annual field surveys, analyses, and monitoring reports according to regulatory agency permit conditions, as well as to remain eligible for Federal Emergency Management Agency (FEMA) mitigation funding related to "engineered" beaches. Another objective is to identify erosional areas of shoreline that warrant future nourishment consideration.

This report summarizes the 2014 to 2015 beach management activities, as well as comparing the most recent survey (April 2015) with beach profile surveys collected from 2000 through 2014. Beach profile data is used to assess the status of the beach through an evaluation of volume and contour change and to establish rates of change with respect to nourishment projects and historical background erosion rates.

2.0 RECENT AND FUTURE PROJECTS

This section provides a brief project history, beginning with the 2001/2002 U.S. Army Corps of Engineers (USACE) Wilmington Harbor Deepening nourishment project. Prior to this event, Town and USACE beach management efforts were sporadic and on a smaller scale, with the first documented nourishment occurring in 1971. Beach scraping and dune repairs have been documented as far back as 1954, mitigating Hurricane Hazel impacts. Significant erosion and the loss of more than 30 houses on the eastern end of Holden Beach in the 1990s were major factors in establishing current beach management activities. Table 2-1 and Figure 2-1 present a summary of nourishment activities and locations.

Table 2.1. Summary of Holden Beach Nourishment Projects since 2001

Date	Completed By	Beach Stations Nourished	Approx. Volume of Material Placed (cubic yards)	Nourishment Material Source
12/8/01 – 2/20/02	USACE	87+00 – 192+00	525,000	Wilmington Harbor Deepening Project
3/7/02 – 4/30/02	Town of Holden Beach Phase I	66+00 - 90+00, 175+00 – 217+00	141,700	Oyster Harbor upland site
3/02-4/02	USACE	20+00 – 30+00[1)]	32,000	Lockwood Folly Inlet crossing of AIWW
Winter 2002-2003	Town of Holden Beach	90+00 – 175+00	30,000	Boyd Street Disposal Area
9/16/04 – 11/2/04	USACE	15+00 – 40+00	113,230	Lockwood Folly Inlet crossing of AIWW
12/03 – 4/04	Town of Holden Beach	46+00 – 68+00 and 215+00 – 238+00	123,000	Smith borrow site
5/5/06 – 5/24/06	USACE	15+00 – 40+00	62,853	Lockwood Folly Inlet crossing of AIWW
Early 2006	Town of Holden Beach	Eastern Reach	42,000	Smith borrow site
Early 2006	Town of Holden Beach	Western Reach	3,200	Smith borrow site
1/24/08 – 3/28/08	Town of Holden Beach	60+00 – 95+00 and 245+00 – 270+00	201,000	Smith borrow site
2008/2009	USACE	20+00 – 40+00	100,000	Lockwood Folly Inlet crossing of AIWW
03/24/09 – 4/30/09	Town of Holden Beach	55+00 – 110+00 and 210+00 – 255+00	190,000	Smith borrow site
Spring 2010	USACE	20+00 – 55+00	140,000	Lockwood Folly Inlet crossing of AIWW
February 2011	USACE	20+00 – 40+00	32,000	Lockwood Folly Inlet crossing of AIWW
January 2012	USACE	20+00 – 30+00	25,000	Lockwood Folly Inlet crossing of AIWW
2/10/14 - 2/27/14	USACE	18+00 – 50+00	93,000	Lockwood Folly Inlet crossing of AIWW
2/27/14 - 3/15/14	Town of Holden Beach	50+00 – 73+00	95,000	Lockwood Folly Inlet crossing of AIWW
9/4/15 - 9/15/15	Town of Holden Beach	Nearshore (60+00 - 90+00)	24,000	Lockwood Folly Outer Navigation Channel
		Approximate Total Volume since 2001	**1,972,983**	

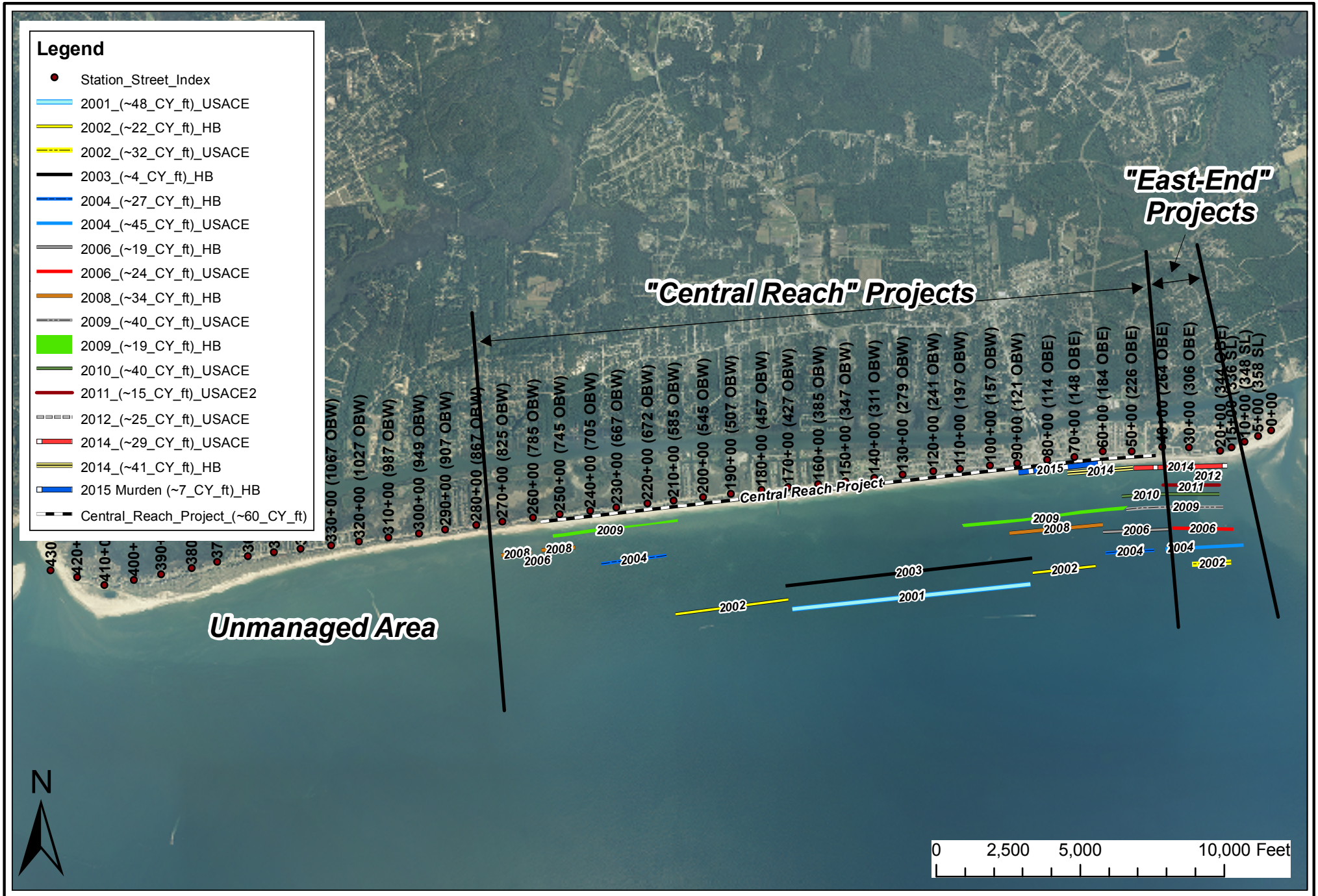


Figure 2-1
Holden Beach Historic Nourishment Activity (2001-2015)
HB= Holden Beach, USACE= U.S. Army Corps of Engineers

APPLIED TECHNOLOGY & MANAGEMENT

Following the spring 2002 completion of the USACE Wilmington Harbor Deepening nourishment project, the Town conducted six beach nourishment projects using upland borrow sources. The Town placed 190,000 cubic yards (cy) of upland fill along approximately 10,000 linear feet (LF) of shoreline in spring 2009. In addition to upland fill beach nourishments, the Town placed 95,000 cy from the Lockwood Folly (LWF) Inlet Atlantic Intracoastal Waterway (AIWW) Crossing (LWFIX) along approximately 2,300 LF of shoreline in 2014. The most recent nourishment project involved the nearshore placement of approximately 24,000 cy along 3,000 LF of shoreline in September 2015 (i.e., the Murden project – which is discussed in more detail in Section 2.4).

2.1 2009 TOWN UPLAND FILL PROJECT

The most recent major beach fill construction utilizing an upland borrow source by the Town occurred between March 24 and April 30, 2009. Approximately 115,000 cy was placed between Stations 55+00 and 110+00 (21 cy/LF average) along the Eastern Reach and 75,000 cy between Stations 210+00 and 255+00 (16.5 cy/LF average) along the Western Reach. Figure 2-2 illustrates the placed-fill footprint and the permitted footprint. Sand was obtained from the Smith upland borrow site. Although upland fill projects have not occurred since this project, upland fill remains a feasible and viable option for beach compatible sand due to nearby available upland borrow areas. Note that upland sand was used in emergency dune rebuilding following Hurricane Irene in 2011.

Figure 2-2. 2009 Constructed Project Reaches and Permitted Sand Placement (the existing permit was modified and expanded in 2009)

2.2 2014 USACE AND TOWN LWFIX PROJECT

Beginning in early February 2014 (approximately February 10), the USACE dredged the LWFIX, including a 50-foot (ft) bend widener, and placed about 93,000 cy of beach-compatible dredged material along approximately 3,200 ft of Holden Beach shoreline, generally between baseline stations 18+00 and 50+00 (29 cy/LF average). The USACE project was completed on February 27 (see Figure 2-3).

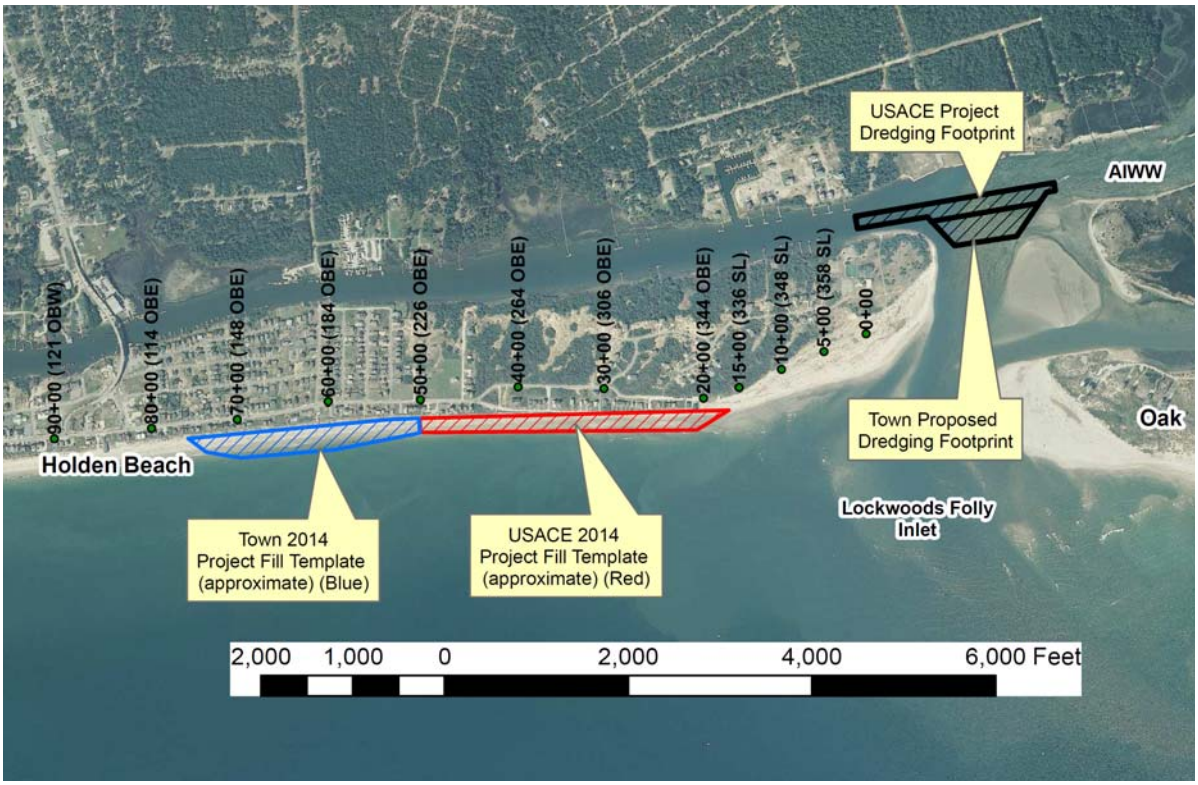


Figure 2-3. USACE and Town LWFIX 2014 Project Dredging and Beach Placement

The USACE typically performs this project every 2 years, depending on shoaling and funding. The primary goal of this annual/bi-annual project is navigation, while a secondary and important benefit is placement of this compatible material on the beach.

In 2010, the USACE used a 400-ft bend widener and placed approximately 150,000 cy of sand. The February 2011 and January 2012 USACE LWFIX projects provided only 32,000 cy and 25,000 cy of material placed, respectively. Since the USACE 2010 LWFIX project, which was supported with economic stimulus funding, the USACE has not had funds available to include the 400-ft bend widener, despite sufficient sand volume within the dredging template.

Consequently, the Town performed an independent project that "piggybacked" the 2014 USACE LWFIX project and expanded the borrow area to include the 400-ft bend widener so more material could be placed on the beach. The 400-ft bend widener is still within the authorized Federal navigation project footprint, which simplified the permitting process.

The Town's piggybacking of the USACE project maximized sand placement while minimizing costs by use of the dredge already onsite for the Federal project. The Town project placed approximately 95,000 cy of beach-compatible material along approximately 2,300 ft of Holden Beach shoreline, between baseline stations 50+00 and 73+00 (41 cy/LF average). The Town portion of the project spanned from February 27 to March 15, 2014 (about 17 days, including a few days of down time). Both the Town and USACE project footprints, as well as the respective LWFIX and bend widener borrow areas, are shown in Figure 2-3.

The USACE project placed sand volume densities of approximately 29 cy/LF, whereas the Town project placed approximately 41 cy/LF. This was due to two primary factors: 1) the USACE portion of the project placed smaller unit volumes than expected due to shallower nearshore bathymetry and 2) the dredge contractor's limitation on pumping distance due to booster power that required the dredger to "fatten up" the template along the Town project shoreline. The nourished shoreline reaches were both within the permitted footprints. Figures 2-4 through 2-8 present photos of the 2014 piggyback nourishment.

The Town's LWFIX project was very successful. Approximately 95,000 cy of material was placed for about $8/cy, which is a very favorable rate. Nourishment dredging costs are typically much higher than this (depending on the borrow area and pumping distance) and can range from $10/cy to $25/cy. The North Carolina Department of Environment and Natural Resources (NCDENR), recently renamed the North Carolina Department of Environmental Quality (NCDEQ), paid for half the project cost (via the Water Resources Development Project Grant Program), and Brunswick County also contributed to the funding of the project. Additionally, Town resources (staff, equipment, oversight) expended for this project were significantly less than those expended for upland fill projects.

Figure 2-4. Aerial Photograph of Ongoing 2014 Nourishment (source: NCDCM)

Figure 2-5. Photograph Looking East toward Nourished Beach near Station 40+00 (ATM Photo)

Figure 2-6. Photograph Looking West toward As Yet Un-Nourished Beach near Station 40+00 (ATM Photo)

Figure 2-7. Photograph near the East End of Holden Beach, Post-Nourishment (Station ~20+00) (ATM Photo)

Figure 2-8. Photograph near Ferry Road Access (Station ~62+00) Approximately 2 Weeks Post-Nourishment (ATM Photo)

As previously discussed, the USACE first utilized the 400-ft bend widener for the 2010 project largely because of the economic stimulus funds that were available to the USACE at the time. It is anticipated that the USACE will not have the funds available to perform the LWFIX project with the 400-ft widener in the future. As a result, the Town and Applied Technology & Management, Inc. (ATM) will continue to work closely with the USACE, NCDENR and other agencies to ensure that the Town can piggyback the USACE LWFIX project from now on. There are no USACE plans to dredge the LWFIX this winter (2015/2016). The USACE may try to dredge the LWFIX next year (2016/2017).

NCDENR has begun a Shallow Draft Inlet (SDI) program that includes five USACE-recognized shallow draft inlets in the state. The five inlets are LWF, Bogue, Carolina Beach, New Topsail and Shallotte (New River Inlet also qualified but North Topsail Beach has other plans). More information on this topic is provided in Section 2.3.

2.3 SHALLOW DRAFT INLET PROGRAM

Six shallow draft (less than 12 ft deep) inlets in North Carolina (LWF, Shallotte, Bogue, Carolina Beach, New Topsail, and New River) are traditionally dredged by the USACE sidecaster *Merritt*. In recent years, several concerns have arisen about the Federal government's continued maintenance of these inlets. The USACE has only one sidecaster dredge (the *Merritt*) since the sidecaster dredge *Fry* was decommissioned in 2010 and sold at auction with the stipulation it could not be used as a dredge in United States waters (SDI Reconnaissance Study, 2013). The *Merritt* is approximately 50 years old and is reaching the end of its service life (SDI Reconnaissance Study, 2013).

The USACE shallow draft split-hull hopper dredges (i.e., the *Currituck* and *Murden*) can dredge LWF Inlet, however, Federal funding for these projects has been significantly lacking over the last few years, while demand and funding for the *Currituck* (see Figure 2-9) and *Murden* remains strong in other USACE districts and states from Maine to Texas.

Figure 2-9. USACE Shallow Draft Split-Hull Hopper Dredge the Currituck Rarely Dredges the LWF Inlet

The lack of funding for North Carolina shallow draft inlet maintenance can result and has resulted in the Coast Guard removing navigation buoys from inlets and making navigation dangerous. In an attempt to mitigate this issue, the State, in conjunction with local county and municipal governments, has:

1. Obtained a memorandum of agreement (MOA) with the USACE to fund shallow draft inlet dredging, and

2. Begun the process of obtaining permits to maintain the navigability of the State's shallow draft inlets independently of the USACE.

More information on both of these initiatives is provided in the next sections.

2.3.1 STATE AND USACE SHALLOW DRAFT MOA

In November 2013, North Carolina signed an MOA that allows the State and local stakeholders to contribute funds to the USACE for shallow draft inlet maintenance dredging. The MOA contribution limit to the USACE is $4 million per year. The North Carolina General Assembly established the Shallow Draft Navigation Channel and Lake Dredging Fund to provide State funding, which will be endowed by both an increase in boat registration fees and an excise on motor fuel, to the North Carolina Wildlife Resources Commission's boating account. While the limit to the USACE is $4 million per year, the fund now produces approximately $6 million/year (March 2015 Joint Transportation Appropriations Committee Presentation). As of September 2015, the Dredging Fund has increased to approximately $18 million annually due to an increased share of the gas tax; however, Oregon Inlet and other shallow draft inlets can also use this fund[1].

The USACE and NCDENR have quarterly meetings regarding the implementation of the long-term MOA. Town staff have attended these meetings previously and Town and/or ATM staff will keep abreast of these meetings on a regular basis.

According to a USACE February 2015 memo, no funds were allocated for LWF for fiscal year (FY) 2015. In addition, no funds are anticipated[2] for FY 2016 funds for LWF inlet maintenance, however, this will not be known until the FY 2016 USACE budget is finalized in Washington, DC, in the next few months.

The USACE prefers to sidecast dredge LWF Inlet once per quarter, if adequate funding is available. Each sidecast dredge maintenance event costs between $225,000 and $250,000, including the associated pre-dredging and post-dredging surveys (USACE navigation communication, 2013). In recent years, the USACE has reduced the dredging frequency to

[1] http://luminanews.com/2015/09/budget-contains-more-money-to-dredge-shallow-inlets/
[2] http://www.saw.usace.army.mil/Portals/59/docs/review_plans/2016%20Congressional%20Fac%20Sheets/Coastal%20Inlets,%20NC%20(Shallow%20Draft%20Navigation)%20OM.pdf

once every 6 months or even longer. Additional effort can be required if the intervals between dredging events are longer.

2.3.2 STATE SHALLOW DRAFT INLET PERMITTING

The State has taken the lead in the shallow draft inlet permitting and, in October 2013, released the SDI reconnaissance study that assessed the feasibility of transferring the Federal permit to the local governments. This effort was predicated on two major factors: 1) the only sidecast dredge that remains in the federal government fleet (the *Merritt*) is 50 years old and could be decommissioned soon, and 2) Federal funding has been limited/absent and may never return.

In addition to the *Merritt*, the *Currituck* and *Murden* can work the LWF and Shallotte Inlets, however, they cannot safely navigate other shallow draft inlets. In any case, there will be a significantly limited availability of USACE dredges that can maintain the SDIs even if adequate local/State funding is generated. The results of the reconnaissance study estimate that it would cost $300,000 to transfer the Federal permits to local governments.

Following the reconnaissance study, the State has gathered the necessary materials (geotechnical data, biological reports, survey data, etc.) to apply for permits for locally held authorizations [North Carolina Division of Coastal Management (NCDCM) Major Permit/USACE General Permit 2878]. These authorizations would allow the Town an additional option for maintaining (at current USACE templates) the LWFIX crossing, the inlet throat, and the outer channel beyond the COLREGs line (refer to Section 2.3.3 for more on this topic). The authorizations would minimally include all currently approved dredge material management locations, including shoreline beneficial placement, nearshore placement and/or upland confined disposal placement. Town staff and ATM are assisting the State in the permitting process and have provided comprehensive geotechnical, survey and biological data at LWF Inlet and for the area in general.

According to the permitting consultant, O'Brien & Gere, the SDI-5 permit application was submitted on May 11, 2015. The Federal and State reviewing agencies provided comments on August 25, 2015, and the applicants submitted a comment-response letter on October 1, 2015. A draft Biological Assessment was submitted September 22, 2015 to the USACE

Wilmington District for review to support Formal Section 7 Consultation with the US Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS).

2.3.3 LOCKWOOD FOLLY INLET PROJECTS

Due to different and separate USACE funding sources, two basic routine maintenance activities occur at LWF Inlet:

1. Outer bar sidecast dredging, and
2. LWFIX cutter-head dredging and beach fill placement

Figure 2-10 provides a representation of these two regions.

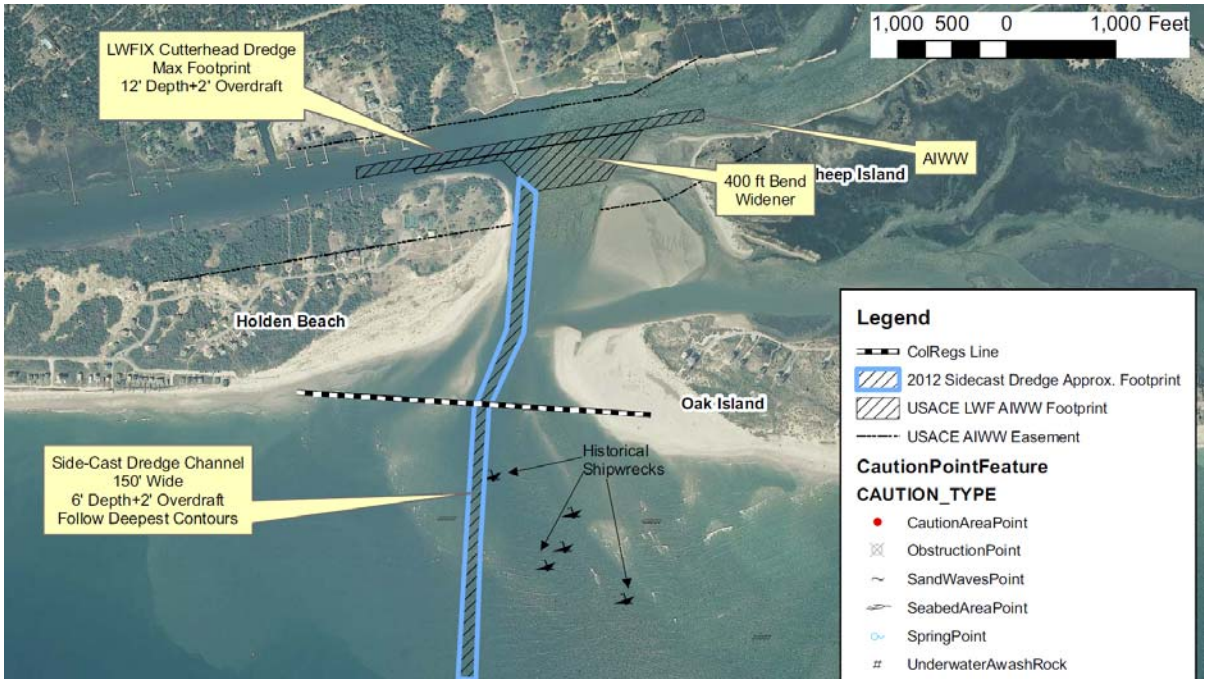


Figure 2-10. LWF Inlet USACE Dredging Projects Include the Outer Channel (sidecaster dredged) and the LWFIX (cutterhead dredged)

The authorizations currently being permitted will allow the Town (with State, County and potentially Oak Island funding assistance) to maintain both these areas. The COLREGs line is the Coast Guard collision regulation demarcation that only allows "ocean-certified" dredges seaward of this delineation. Ocean-certified dredges are typically larger dredges that are much more expensive to mobilize/demobilize (typically between $2 to $4 million per event). The USACE shallow draft dredges are specialized in that they are small enough to

navigate these small inlets, while also being Coast Guard ocean certified. As an example, the LWFIX dredge projects are predominantly awarded to smaller dredge companies with dredges that are not ocean certified (e.g., Southwinds, Cottrell).

Another goal of the SDI is to coordinate with private industry dredgers to ascertain interest in the SDI maintenance projects and to have several economically competitive options for these projects.

2.4 2015 MURDEN PROJECT

Directly related to the previous section on shallow draft inlet dredging, the Town recently led a pilot project for nearshore placement of dredged material from the LWF outer channel using the USACE's *Murden* shallow draft hopper dredge.

As previously mentioned, the USACE has performed dredging and nearshore placement with the *Murden* or *Currituck* in the past, however this has not occurred at LWF Inlet in at least 15 years (other than one test dredge/disposal load of the *Murden* at LWF Inlet approximately 9 months ago). Due to the project's purpose (i.e., shallow draft inlet dredging and nearshore disposal), the State funded half of the project costs and Brunswick County contributed funding also.

The Holden Beach Murden project represents a pilot project where the *Murden* worked for 10 days primarily dredging the outer channel and disposing material in the nearshore (in about 10 feet of water) fronting the bridge onto the island (which is the westward limit of placement according to USACE). Figure 2-11 presents the general disposal area outline. While the majority of excavation occurred within the outer channel, the *Murden* also performed some dredging of trouble spots within the LWFIX.

The *Murden* placed 106 loads between September 4 and September 15. The *Murden* holds 300 cy, therefore, up to 31,600 cy of material was dredged from the LWF outer channel and LWFIX.

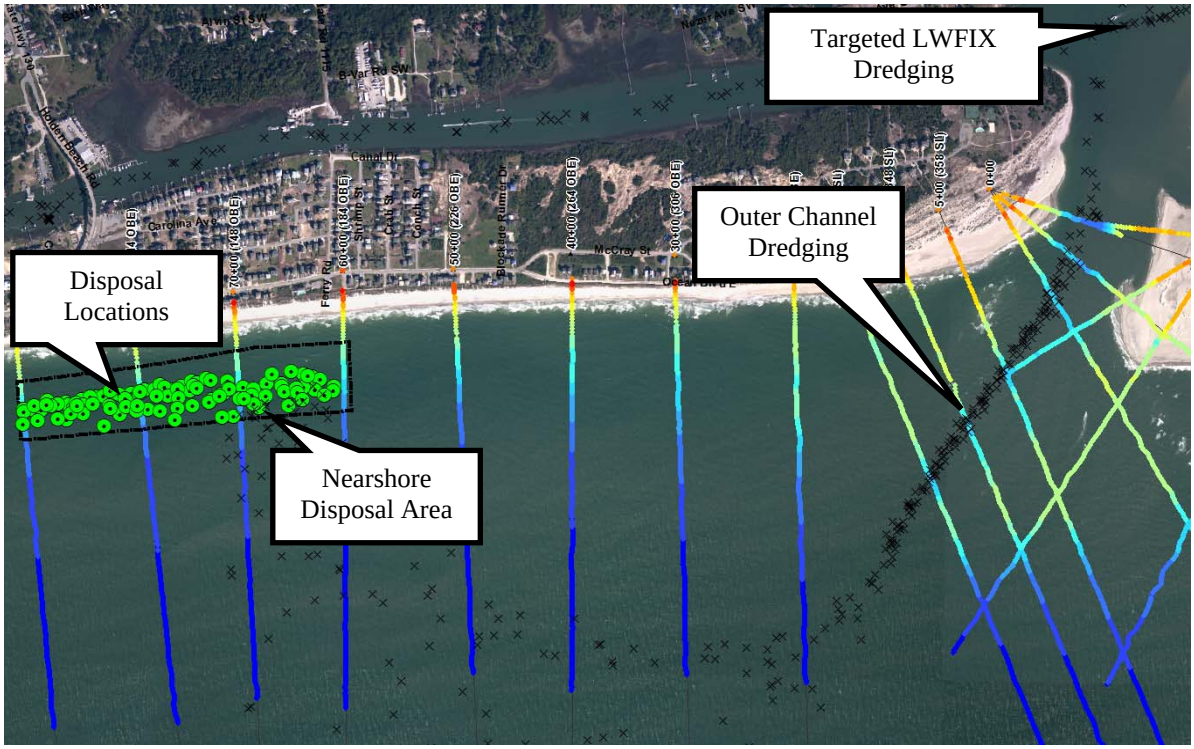


Figure 2-11: Murden Dredged and Placed Material Locations. "X" marks denote Murden location every ~3 minutes over the course of 2 days (source: marinetraffic.com). Circles denote disposal locations of dredged material.

The majority of this material will move onshore and annual monitoring will assess its progress. Surveying occurred pre- and post-project to document the volumes placed in the nearshore disposal area. Figure 2-12 presents the change in elevation within the disposal area. Mounds of sand as high as 4 feet were documented in the survey area. In general, elevations within the disposal area were 1 to 3 feet higher than pre-project conditions. The *Murden* dredged approximately 30,000 cy of material from the outer channel and the LWFIX. Post-project volume calculations can account for approximately 24,000 cy of material within the disposal area. Due to the split-hull nearshore disposal process, where the *Murden*'s hull literally splits open to empty its contents, some material will spread outside of the disposal area. As a result, the material dredged versus the material accounted for the in disposal area is typically 20 to 30 percent less, which is the case for this project. Additional minor deposition likely occurred out of the disposal area, while finer material can travel much farther as a dredge plume. Next year's monitoring will assess the movement of this deposited material. Based on the performance of this pilot project, the *Murden* inlet dredging and nearshore placement project may occur more frequently and with larger volumes.

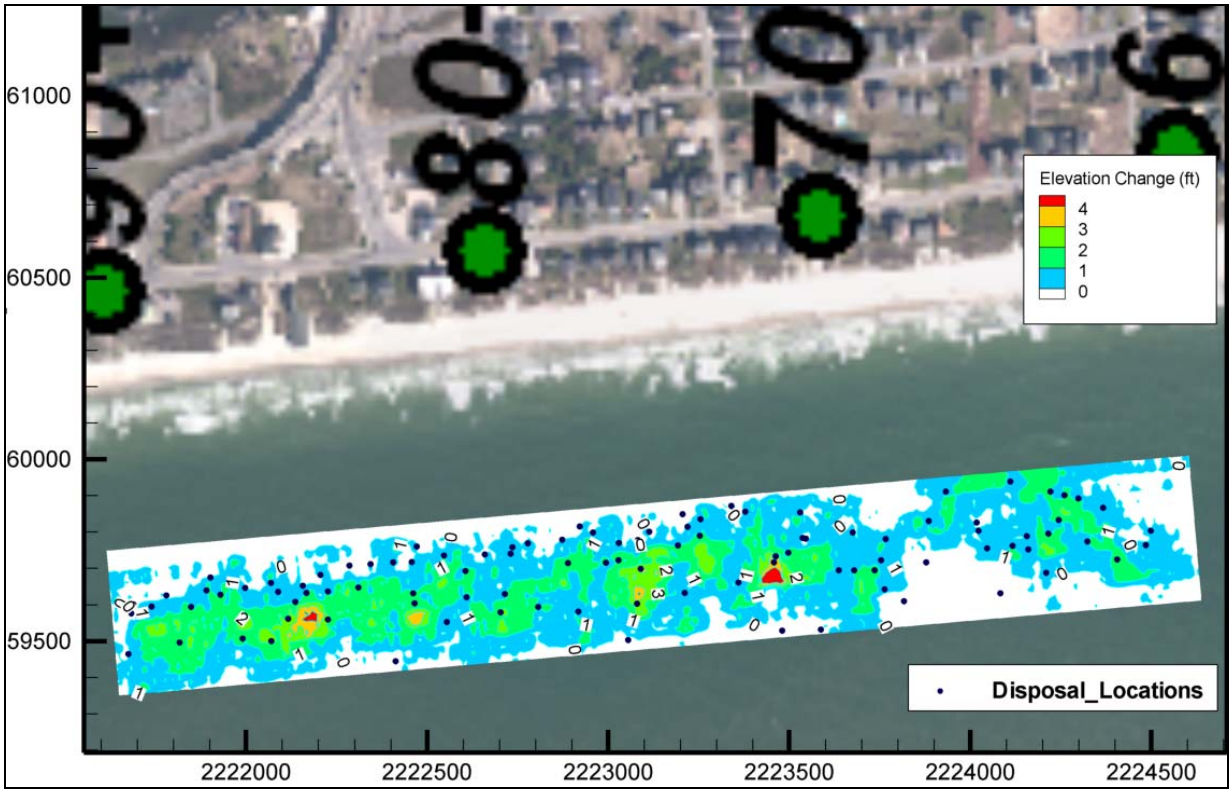


Figure 2-12: Nearshore Bottom Elevation Change from Murden Project.

2.5 DUNE ENHANCEMENT

In addition to placement of sand, the Town has been proactively enhancing dune habitat on an annual basis. The dune-building program includes:

- Vegetation planting (sea oats, American beach grass, bitter panicum, etc.)
- Fertilization
- Sand fence maintenance and expansion
- Dune walkover maintenance

In the winter of 2014/2015, 180,000 sprigs of American beach grass were planted between Stations 50+00 and 240+00 (about 19,000 ft). Fertilizer was applied island-wide three times over the last year [2 pounds (lb.)/1000 square feet (ft^2)].

A University of North Carolina at Wilmington (UNCW) fertilizer/microbe study on the east end of Holden Beach has largely concluded. The study included 3,000 sea oat sprigs and

investigated the effects of various fertilizer levels and types and mycorrhizae presence and absence on dune vegetation growth and overall health. Approximately 75 percent of the plants were lost due to erosion or flooding. However, some valuable lessons were gleaned from the experiment and, while this specific fertilizer/mycorrhizae study has concluded, additional UNCW graduate studies on the topic of dune enhancement continue.

The continued diligence and effort of Holden Beach has resulted in a stable and healthy dune system along a majority of the island. Figures 2-13 and 2-14 illustrate some of the recent efforts and resulting dune system.

2.6 STORM ACTIVITY

Despite having only eight named storms on record, the 2014 Atlantic hurricane season overall was relatively active, with six of those named storms being hurricanes. Figure 2-15 presents a summary of 2014 Atlantic Hurricane tracks. Holden Beach and other regional beaches were only mildly affected by storms Bertha and Cristobal, and most of the 2014 tropical storms remained well offshore. However, Hurricane Arthur made landfall on the North Carolina coast and was the most significant storm event for the Holden Beach shoreline in 2014.

Figure 2-13. Dune Vegetation and Sand Fencing along the East End of Holden Beach (Station ~40+00) (ATM photo, taken April 2015)

Figure 2-14. Dune Vegetation and Sand Fencing West of the Pier (~Station 280+00) (ATM photo, taken April 2015)

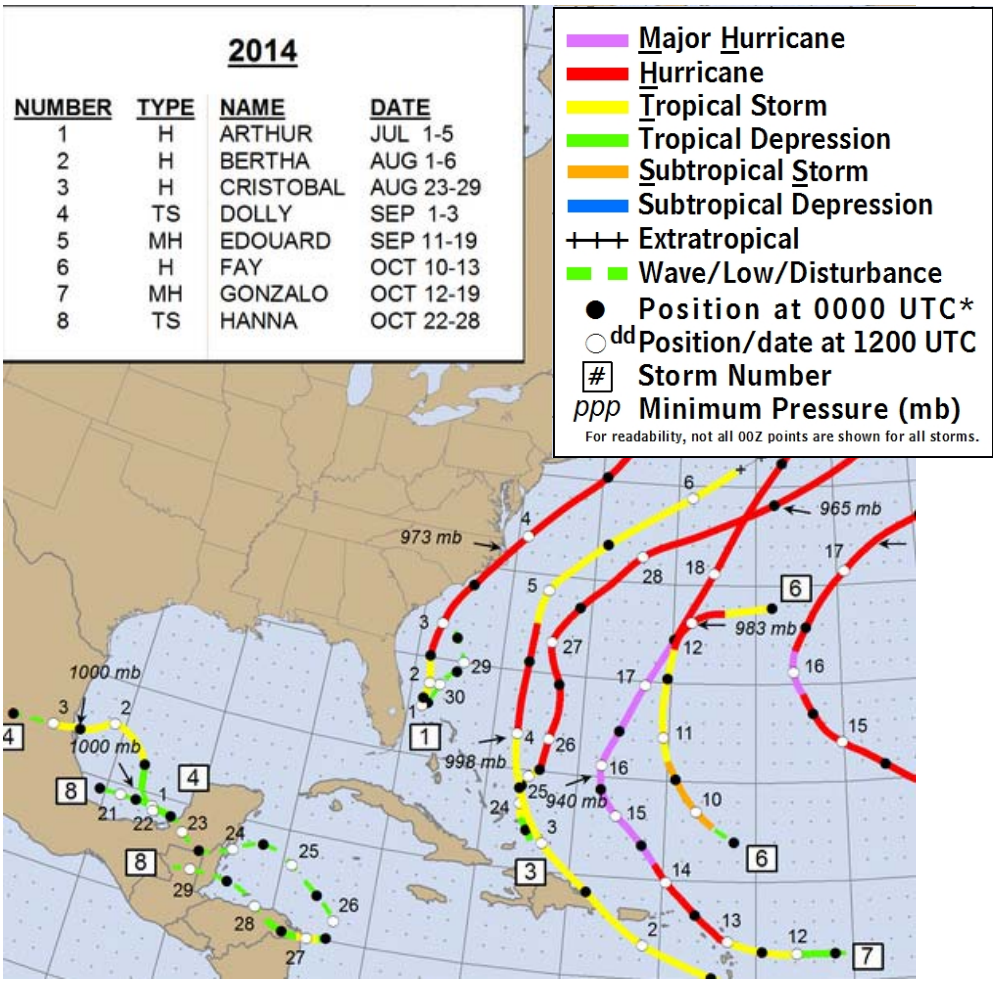


Figure 2-15. 2014 Hurricane Summary for Holden Beach. Bertha (2) and Cristobal (3) had mild/moderate affects to Holden Beach while the effects of Arthur (1) were relatively more severe

Hurricane Arthur began affecting Holden Beach shorelines on July 3, 2014, with long-period storm swell as a Category 1 offshore of Holden Beach. It strengthened to a Category 2 before making landfall on the North Carolina coast, just west of Cape Lookout on July 4. Hurricane Arthur's most significant impact was along the Outer Banks and other coasts northeast of Holden Beach, with a peak storm surge of 4.5 ft reported at Oregon Inlet.

Despite the fact that Arthur landfall was more than 100 miles away, the combination of storm surge and large swells can still create erosional conditions that directly impact the Holden Beach dune system. The same can be said for storms Bertha and Cristobal, although with milder affects to the Holden Beach shoreline than Arthur. Nor-easters and periods of sustained southeast winds can create highly erosive conditions also.

The 2015 hurricane season began early this year, with Tropical Storm Ana having a significant impact on the Holden Beach shoreline. On Sunday, May 10, 2015, Ana made landfall between Myrtle Beach and North Myrtle Beach, SC, making it the second earliest Atlantic tropical storm on record to make landfall in the United States. Figure 2-16 shows Tropical Storm Ana progressing along the South Carolina and North Carolina coasts after making landfall early Sunday morning. Peak wind gusts were recorded at up to 55 mph on Oak Island, just east of Holden Beach. The long period storm swell and surge from Tropical Storm Ana caused severe erosion to Holden Beach and nearby shorelines (Figure 2-17).

Figure 2-16. WLTX News Radar Image of Tropical Storm Ana on May 10, 2015

Figure 2-17. Holden Beach POA photograph of erosion on Holden Beach from Tropical Storm Ana

2.7 TOWN CENTRAL REACH PROJECT

The Town's permitted Central Reach nourishment project represents the largest beach fill project to date on Holden Beach. The Central Reach project allows for placement of up to 1.31 million cubic yards (MCY) along 4.1 miles (22,000 ft) of shoreline [Ocean Boulevard East (OBE) 262 to Ocean Boulevard West (OBW) 781]. The Town has received the NCDCM, the North Carolina Division of Water Quality (NCDWQ) and the USACE permits needed for this effort. Figure 2-18 presents the beach fill project limits, and Figure 2-19 presents a typical fill cross-section. This project will utilize an offshore borrow area as its sand source.

This project is designed to last up to 10 years (based on historical erosion rates), and project construction timing will be dictated by annual monitoring results and/or major storm events. The project is conceptually planned to occur either in winter 2016/2017 or winter 2017/2018. The Town has some flexibility in scheduling this major event, which makes it very beneficial from a bidding perspective. For example, Superstorm Sandy created a very high demand for dredging contractors for the 2013/2014 season and, therefore, projects were significantly more costly (e.g., the Folly Beach SC 2014 nourishment cost about $21/cy).

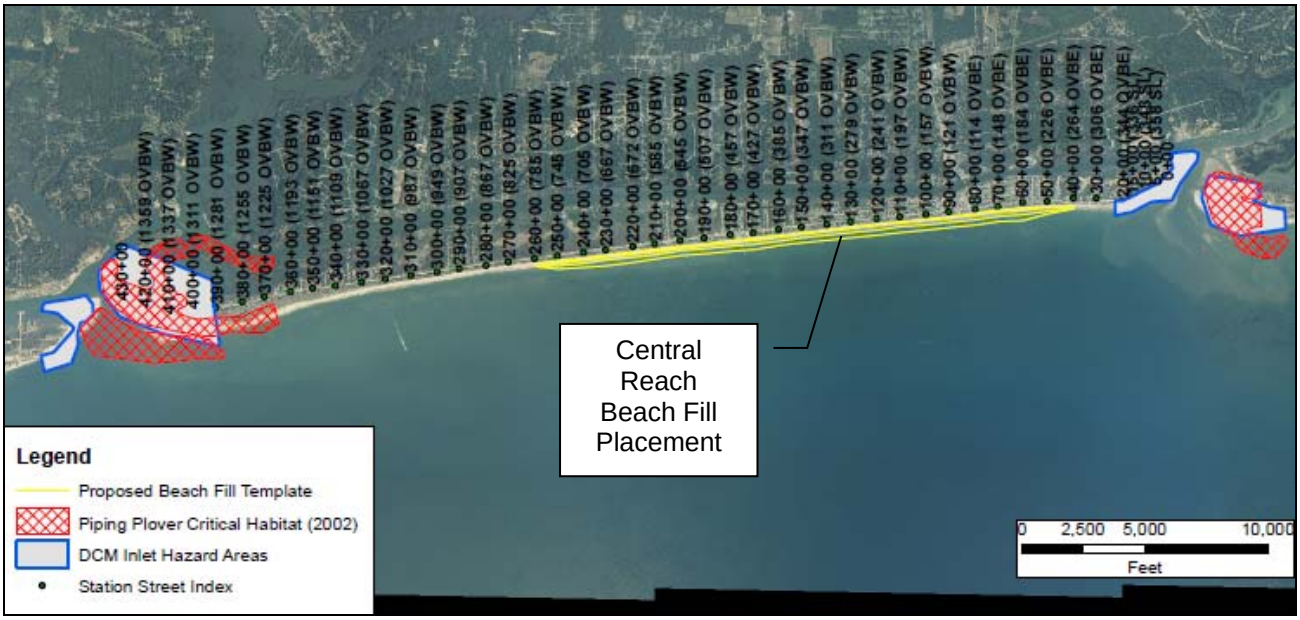


Figure 2-18. Central Reach Beach Permitted Fill Placement Footprint

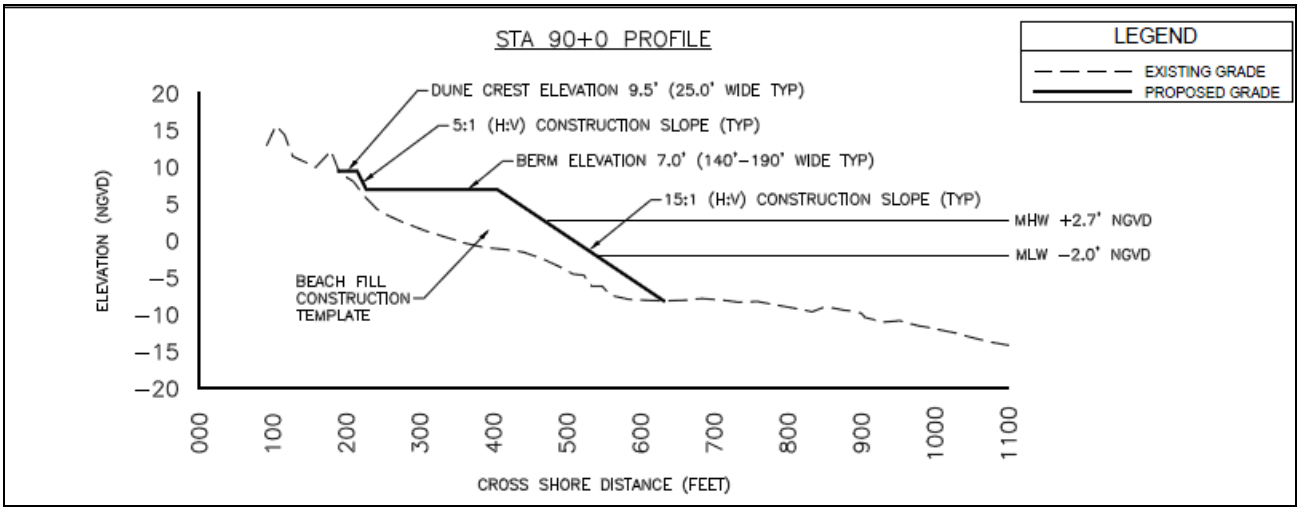


Figure 2-19. Central Reach Nourishment Typical Cross-Section

2.8 USACE BCB PROJECT

The USACE Brunswick County Beaches (BCB) project remains open, however, it has not advanced over the last year. The USACE has released several tomes of studies since the project's inception in approximately 1997. The project represents a USACE coastal storm damage reduction (CSDR) effort for Holden Beach, Caswell Beach and Oak Island. The project is several years behind schedule and is over budget. The USACE BCB project studies are 50/50 cost shared between the USACE and the participating communities (Holden Beach, Caswell Beach, and Oak Island).

In October 2012, the USACE released the BCB Draft Integrated General Reevaluation Report (GRR) and Environmental Impact Statement (EIS) for CSDR, Pre-Alternative Formulation Briefing (AFB) Submittal for agency technical reviews (ATR). The GRR/EIS report states that the initial Holden Beach BCB nourishment is slated to occur in 2020 and 2021 (extending across two dredging seasons) and will place 4.5 MCY of sand over 24,000 ft of shoreline. This represents a *tremendous* volume (approximately 8 to 9 times greater than the USACE 2001/2002 Holden Beach project).

The USACE Headquarters (in Washington D.C.) review of the AFB/GRR/EIS documents was not favorable and according to April 2014 communications with the Town and the Wilmington USACE, additional studies and study updates are required. Additional funding is also required by the USACE and the participating communities. At this time, the documents remain in draft status and will not be issued to the public. Project implementation is still many years away.

According to the USACE studies, the 50-year project was to initially nourish Holden Beach in 2020/2021, while the first BCB renourishment was slated to occur in 2025/2026 on Holden Beach (i.e., 5-year renourishment interval). However, according to the report, these timelines “could take longer” and are “subject to the availability in funds.” Holden Beach BCB renourishment volumes are estimated at 1.7 MCY and will occur every 5 years. As always, the Town and ATM will continue to coordinate with the USACE to ensure ongoing Town beach management projects are complementary.

ATM’s opinion is that the BCB project as proposed is too large and too costly to receive funding, based on current and recent Federal funding for beach nourishment projects. A CSDR project more similar in scope to the Ocean Isle Beach CSDR project (and the Town’s Central Reach Project) is much more likely to obtain funding. The Ocean Isle CSDR project placed approximately 1.8 MCY initially, and approximately 450,000 to 500,000 cy per renourishment project (Bill Dennis, USACE, personal communication). The USACE BCB project as proposed is not worth pursuing by the Town, in ATM’s opinion.

2.9 EAST END TERMINAL GROIN PROJECT

The east end of Holden Beach (LWF Inlet to Station 40+00) experiences the highest erosion rates on the island. Storm damage and property loss are also correspondingly historically high on the east end. As a result, the Town and the USACE have focused significant beach nourishment resources on the east end. However, the area still remains vulnerable.

While a terminal groin and nourishment program has always been a feasible option for this area from a technical standpoint, State regulations have only recently allowed the permitting and construction of terminal groins. Note that groin exceptions due to bridge protection and historic structure preservation were previously allowed (e.g., Oregon Inlet terminal groin, Hatteras Lighthouse groins).

As such, the Town has begun the analysis and permitting required to construct a terminal groin and institute an associated beach nourishment program on the east end. This program will allow longer time intervals between nourishments and allow for a more stable upper beach and dune system, resulting in reduced long-term nourishment costs as well as reduced risk to coastal infrastructure.

On behalf of the Town, ATM completed the *East End Shoreline Protection Project Engineering and Modeling Report* as part of the draft EIS, being prepared by the third party consultant, Dial Cordy & Associates (DC&A), under direction of the USACE. DC&A publically released the draft EIS in August 2015.

2.10 BEACH MANAGEMENT PERMITS

The Town currently has Central Reach permits from the USACE, NCDCM, and NCDWQ. NCDCM chose to modify the beach nourishment permit initially obtained by the Town in 2002 (permit number 14-02). Several modifications have occurred to this permit since. These modifications include the 2008 and 2009 Town nourishments using the Smith borrow site. Following the Central Reach modification, the permit expiration date was December 31, 2015. NCDCM chose to issue another permit modification for the 2014 LWFIX project that placed 95,000 cy of material; however, the permit expiration date remained December 31, 2015. Town and ATM staff are currently coordinating with NCDCM to obtain an extension to this permit.

The USACE typically creates new permits for each project (upland fill, LWFIX, Central Reach). The Central Reach project (permit number SAW-2012-00286) expires on December 31, 2017. The LWFIX project was issued under a General Permit (GP), which is simpler and faster than the typical Individual Permit (IP) Process. The LWFIX project (SAW-2013-02016 and GP No. 199602878) has been completed, although post-project compaction monitoring is required for 1 more year (performed in the spring prior to turtle nesting season). No tilling has been required by the regulatory agencies as yet due to the compaction monitoring results.

The USACE permit for the upland borrow area nourishment project (SAW 2005-00935) was extended in 2009 and again last year. This permit now expires on December 31, 2019 and currently allows the placement of 64,000 cy of upland borrow material.

The NCDWQ permits are project specific and generally follow the lead of NCDCM. The USACE, NCDCM and NCDWQ generally coordinate to avoid any permit condition conflicts. If any future modifications are needed, it is anticipated that coordination will be needed with all of these agencies. Agencies have been amenable to permit modifications and extensions related to beach fill placement location and permitted borrow areas (Turkey Trap, Smith Site, Boyd Site, and Central Reach) in the past.

On a similar note, the County's special exception permit to operate a mine in Brunswick County for the Turkey Trap Road borrow area has no expiration date. The Smith borrow site is a water feature for a residential development; therefore, a special exception permit is not needed (although this can be determined by regulatory interpretation). Upland borrow areas need to be reviewed by the Division of Land Resources, which oversees mining operations in the state.

3.0 ANNUAL SURVEY RESULTS

3.1 SURVEY RESULTS

Beach surveys are performed annually as a part of the Town's Beach Management Plan and span from LWF Inlet to Shallotte Inlet. Figure 3-1 presents the stationing and azimuths established by the monitoring plan. Survey data were collected in April 2015 at 48 transects along Holden Beach. An additional seven transects were also included on western Oak Island. The monitoring of these additional transects began with the 2012 survey to more closely monitor inlet-related effects and establish more consistent baseline data. Similar to historical trends on the west end of Holden Beach, the west end of Oak Island is generally stable; however, long-term inlet dynamics have the potential to affect this area.

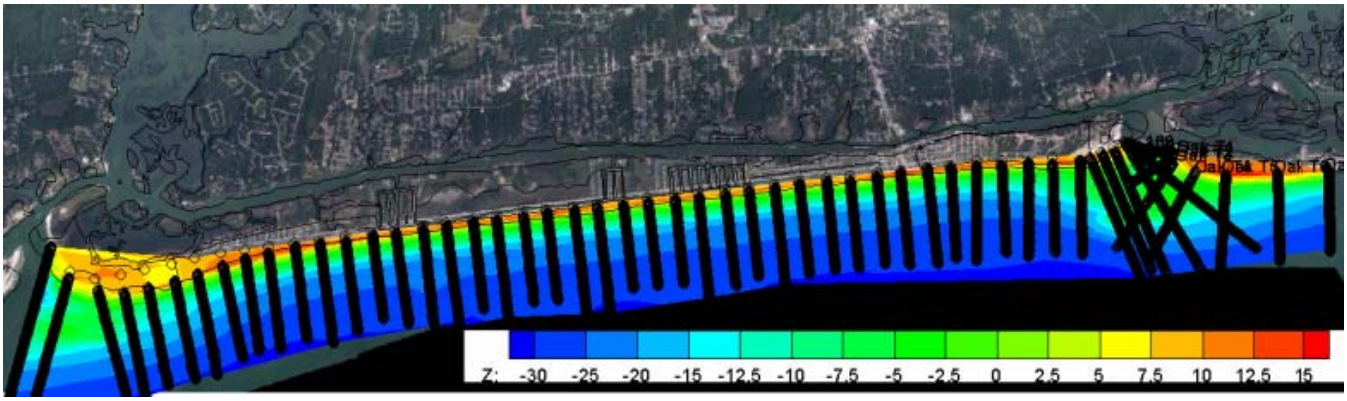


Figure 3-1. Holden Beach Monitoring Survey Transects, 2015. An additional seven monitoring transects have also been added to western Oak Island beginning with the 2012 survey. Note "Z" is in ft-NGVD29.

Figures 3-2 and 3-3 present example transect surveys comparing 2014 and 2015 survey data. Figure 3-2 also shows a 2013 and 2014 survey comparison to illustrate changing sediment transport patterns (discussed further in subsequent sections). Note that some differences in profiles may be related to recent wave activity and are not necessarily indicative of long-term trends. Appendix A contains all transect data for the 2014 and 2015 surveys.

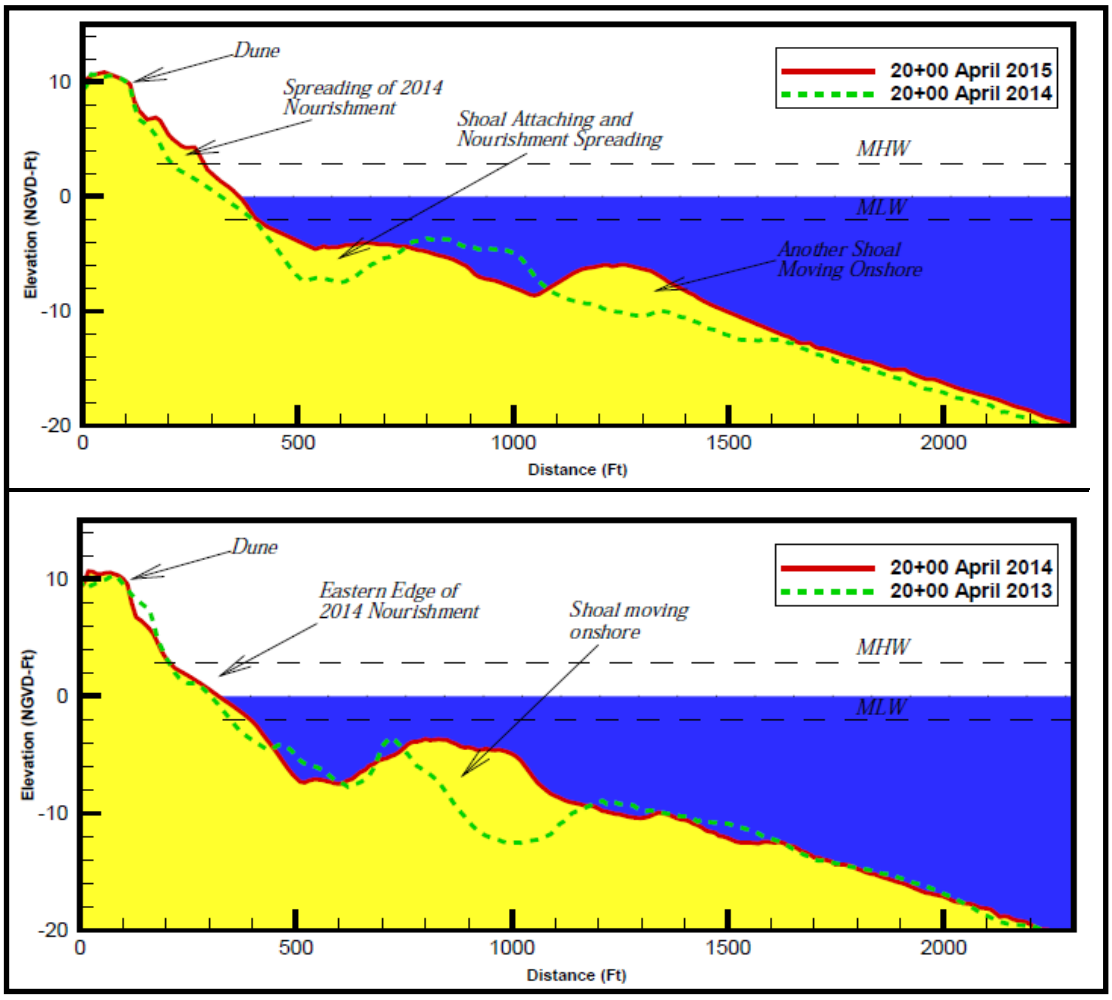


Figure 3-2. Station 20+00 Profile Transect Comparison on the East End of Holden Beach. Upper panel shows 2014-2015 survey comparison and a cross-shore redistribution of sediment. Lower panel shows 2013-2014 comparison.

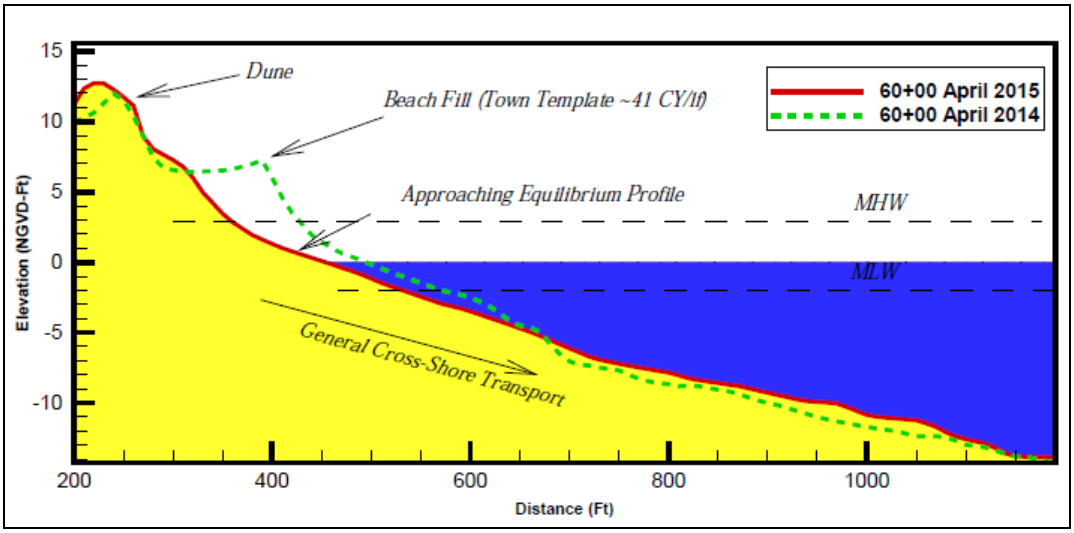


Figure 3-3. Station 60+00 Profile Transect near the East End of Holden Beach. Note 2014 Town Beach Fill is approaching an equilibrium profile in 2015.

In general, comparison of the 2014 and 2015 surveys reveals a stable/mildly erosional beach along much of the island, especially within the Central Reach. Figure 3-3 also illustrates the equilibration/adjustment of the 2014 piggybacked nourishment project. The east end typically displays more erosional conditions (consistent with historical trends), however, the recently completed 2014 USACE/Town LWFIX projects, which placed 188,000 cy of sand between stations 18+00 and 73+00, provided a much needed replenishment to the east end sand supply (documented in the 2014 Annual Report). Sections 3.2 and 3.3 present more information on volume and shoreline analysis, respectively.

3.2 VOLUME ANALYSIS

Figure 3-4 presents changes in volumes from 2014 to 2015 along the entire beach. Volumes are quantified by comparing profile volumes from successive surveys. The USACE Beach Morphology Analysis Program (BMAP) was used to compute changes in profile volumes for each profile and for all surveys during the monitoring period.

Figure 3-4 shows a generally stable shoreline, with some variation from station to station. Some of this variation is due to survey precision as well as seasonal variation, shoal attachment, and recent wave activity. Additional variation may also be attributed to undulating patterns along the shoreline, which have been documented along nearby beaches[3]. The 2014 USACE and Town nourishment placed about 30 to 40 cy/ft of sand between Stations approximately 18+00 and 73+00. Loss of volume within this area is expected since this material naturally spreads both east and west. As a result of this spreading, stations to the east and west of the 2014 fill placement generally exhibit accretion (Figure 3-4). The volumes calculated in Figure 3-4 are from the dune out to about the 12 ft National Geodetic Vertical Datum (NGVD) contour, which represents a typical depth-of-closure limit. The vast majority of sand transport and profile change occurs in waters shallower than the depth-of-closure.

[3] PARK, J.-Y.; GAYES, P.T., and WELLS, J.T., 2009. Monitoring beach renourishment along the sediment-starved shoreline of Grand Strand, South Carolina. *Journal of Coastal Research,* 25(2), 336–349. West Palm Beach (Florida), ISSN 0749-0208

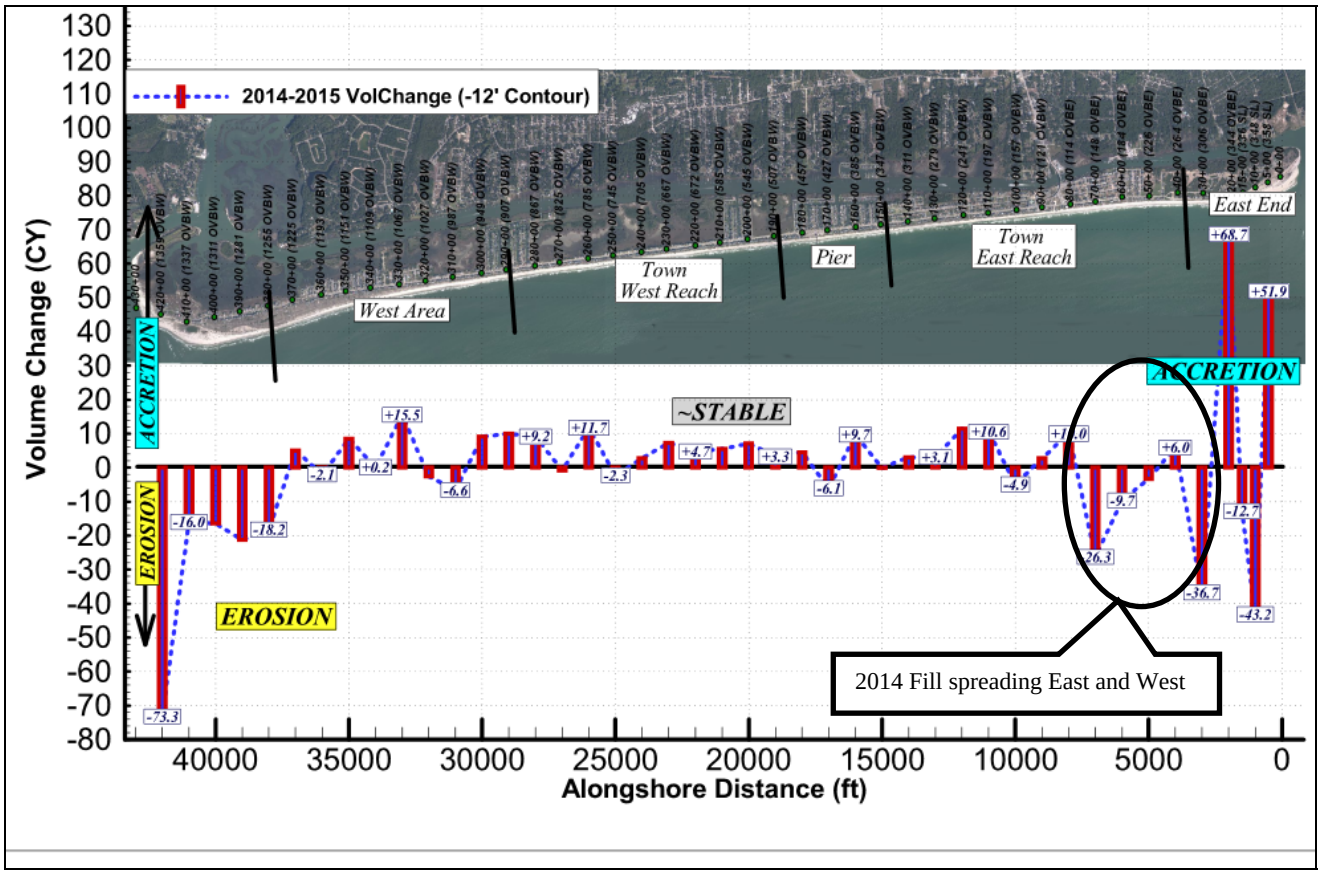


Figure 3-4. Volume Change Using April 2014 and April 2015 Surveys. Positive values indicate accretion, negative values indicate erosion. Note erosion on extreme west and variations of accretion and erosion on East End. Smaller yet significant accretion is seen throughout the center of the island.

Comparing 2015 and 2014 changes in volume out to the depth-of-closure, survey data indicate accretion has generally occurred over the last year within the middle of Holden Beach. Slight erosion has been observed near the western end of the island over the past 3 years (reaching as far east as Station 380+00). This erosion is likely due to inlet-related effects and is not of immediate concern due to the large and wide dune system in the area.

Volume calculations were also performed from the dune to the -5 ft NGVD contour, which represents the approximate typical surf-zone limit. Figure 3-5 presents the two different boundaries used for volume calculations.

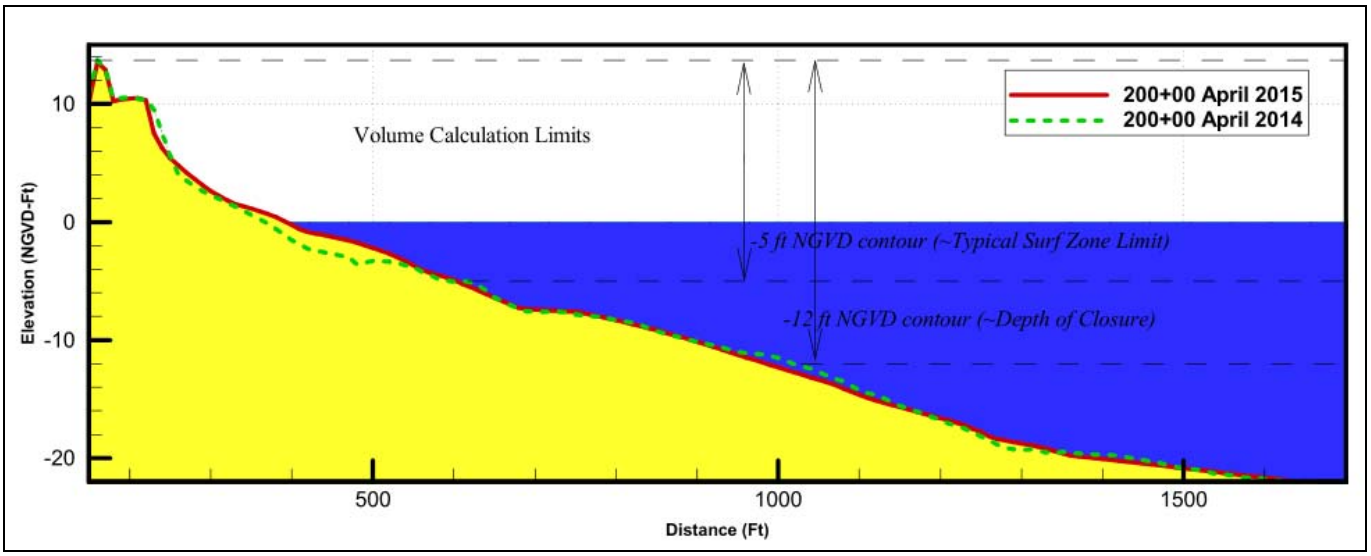


Figure 3-5. Two Different Volume Calculation Limits Used for this Analysis: 1) Dune to -12 ft NGVD and 2) Dune to –5 ft NGVD.

Table 3-1 presents volume changes estimated by the reaches identified in Figure 3-4 (i.e., east end, Town East Reach, pier, etc.) from 2014 to 2015. In general, significantly more accretion (or less erosion) occurred within the surf zone/depth-of-closure area (-5 ft to -12 ft region) compared to the dry beach/surf zone area (dune to -5 ft NGVD).

Table 3-1. Volume Change by Shoreline Reach for 2014 and 2015 Surveys

Reach Averages	Stations Included	Total Volume Change (cy) (Dune to -12 ft NGVD)	Dry Beach/Surf Zone Volume Change (cy) (Dune to -5 ft)	Surf Zone/Depth-of-Closure Volume Change (cy) (-5 ft to -12 ft NGVD)*
LWF Inlet	5 to 15	-12,000	-4,000	-8,000
USACE East	15 to 40	15,000	-16,000	31,000
Town East	40 to 150	0	-58,000	58,000
Pier	150 to 190	10,000	-5,000	15,000
Town West	190 to 290	52,000	19,000	33,000
West Area	290 to 380	23,000	14,000	9,000
Shallotte Inlet	380 to 420	-99,000	-73,000	-26,000
	TOTAL	*-11,000*	-123,000	112,000
Central Reach	40 to 290	62,000	-44,000	106,000

*Negative values indicate likely sediment movement from dry beach/surf zone area to surf zone/depth-of-closure area

This observed accretion is largely a result of cross-shore transport of material from the upper beach to the nearshore/surf zone, especially as the material from the 2014 east end nourishment moves offshore from the dry beach/ surf zone area and approaches an equilibrium beach profile (Figure 3-3). Beach nourishment construction requires mostly upper beach placement (bulldozers do not work well in several feet of water), which will

naturally “equilibrate” or adjust over the first few months. Note that in Table 3-1, the nourishment is within the “USACE East” and “Town East” and, as anticipated, beach fill equilibrated by moving from the upper beach to the nearshore (-5 ft to -12 ft depth).

As seen in Table 3-1, the beach has shown some mild volumetric erosion over the last year, -11,000 cy overall. However, note that no nourishment activity occurred between these two survey events, therefore, this result is relatively favorable and indicates a stable beach overall. Most upper beach accretion occurred towards the western reaches (with the exception of Shallotte Inlet Reach), as the sediment from the 2014 nourishment project has moved westward. The survey area is not a closed system and identifying sediment transport direction can only be inferred based on measured volume change and experience.

The east end area (Stations 5+00 to 40+00) is historically highly erosional. In general, monitoring stations east of Station 40+00 can exhibit highly variable changes based on inlet dynamics and annual USACE fill activities (timing, volume, placement, etc.). Sidecasting and outer inlet maintenance (or lack thereof) also have an effect. Volume change calculations show the east end area exhibited variations of accretion and erosion in the entire dune to the depth-of-closure zone. This is due in large part to LWF Inlet effects, the effects of the 2014 nourishment, and the shoal attachment processes.

Several recent shoal attachments (documented in the 2013 and 2014 Annual Reports) continue to contribute to localized dry-beach accretion. Figure 3-6 presents a recent shoal attachment in a September 2015 aerial photograph (a shoal attachment is also shown in the 2014 aerial in Figure 2-4). The bump in the shoreline created by this shoal attachment has begun to spread and will continue to smooth out over time. Benefits are being seen on the shoreline immediately adjacent to the shoal attachment (note the “hot-spot” feature in Figure 3-6), where the Station 20+00 shoreline accreted about 75 feet between the last two surveys. Figure 3-7 presents a photograph from July 9, 2013 that shows another shoal attachment feature on the east end.

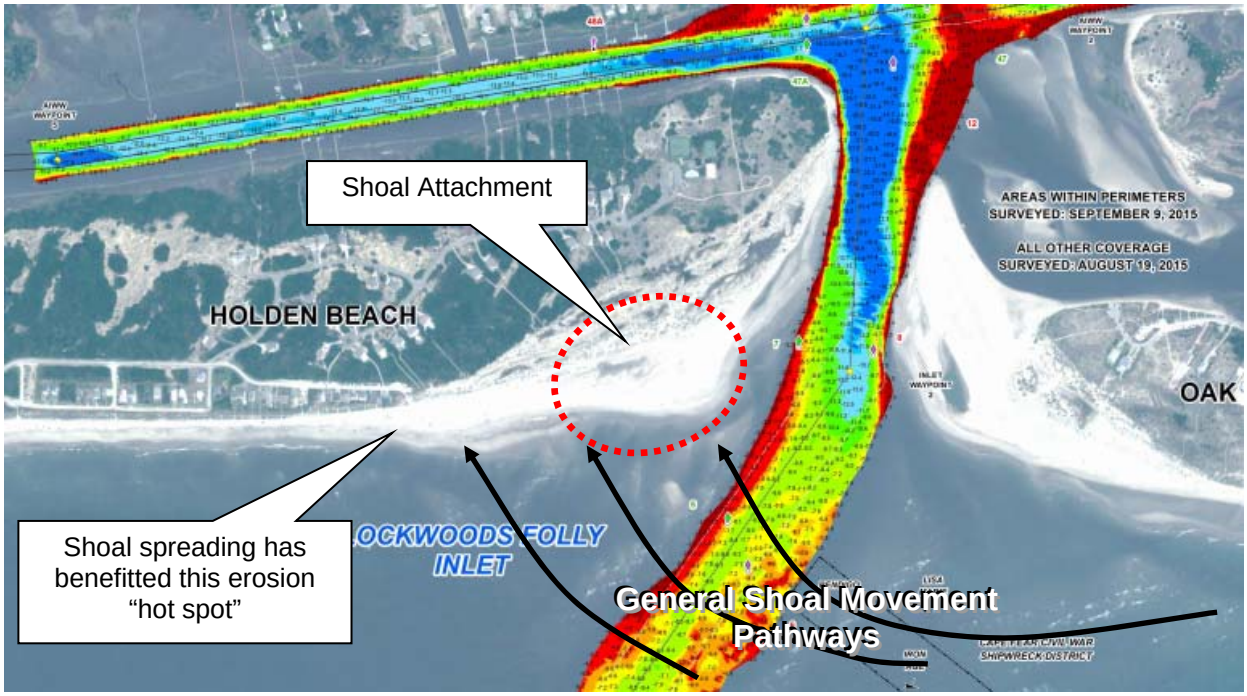


Figure 3-6. USACE Image from September 2015. Note "bump" in shoreline indicating a recent shoal attachment (~Station 10+00).

Figure 3-7. Ground-Level Photo from Approximately Shoal Attachment Site (~Station 10+00), Looking West (Photo date: 7-09-2013).

The Central Reach segment of shoreline from Station 40+00 to 290+00 exhibited erosion (approximately -44,000 cy) in the dry beach/surf zone area (dune to -5 ft NGVD) and

accretion (about +106,000 cy) in the surf zone/depth-of-closure area (-5 ft to -12 ft NGVD). This erosional/depositional pattern can generally be attributed to cross-shore sediment transport from the upper beach to the nearshore, as the 2014 east end nourishment (extending to Station 73+00) has begun to equilibrate and also migrate westward. This segment of shoreline continues to perform moderately well and allows some additional flexibility in performing the permitted Central Reach project.

The 2014-2015 cross-shore sediment transport pattern differs from the results of the 2014 monitoring study. The 2014 study found there was accretion (about +144,000 cy) in the dry beach/surf zone area (dune to -5 ft NGVD) and erosion (about -69,000 cy) in the surf zone/depth-of-closure area (-5 ft to -12ft NGVD). This change in transport pattern from the 2013-2014 study is likely due to the 2014 beach fill activities stabilizing over time and could partially be due to more severe wave conditions (which tend to delay the movement of sandbars onshore, especially during an active winter).

The west area (Stations 290+00 to 380+00) is historically stable and has never been nourished. Fluctuations in volumes in this region can be attributed to net westerly sand transport, shoreline undulations, and inlet-related processes (including shoreline orientation/curvature and shoal formation). Dune system widths in the West Area can be up to 600 ft (around Stations 370+00 to 390+00; see Figure 3-8); therefore, large fluctuations in volume and/or shoreline position in this area are still several hundred feet from residential structures.

Several homes on the extreme western end of the island near Station 420+00 (~1359 OBW) are close enough to Shallotte Inlet that close monitoring of inlet migration and USACE activities in Shallotte Inlet is warranted.

Some erosion of the mean high water (MHW) line is seen in Figure 3-8. Note that the Ocean Isle nourishment project began in March 2014. The Ocean Isle nourishment uses Shallotte Inlet as a borrow area, and shoreline monitoring will occur to assess any potential effects on the Holden Beach shoreline. Appendix B provides figures of the 2015 survey results for the entire Holden Beach shoreline.

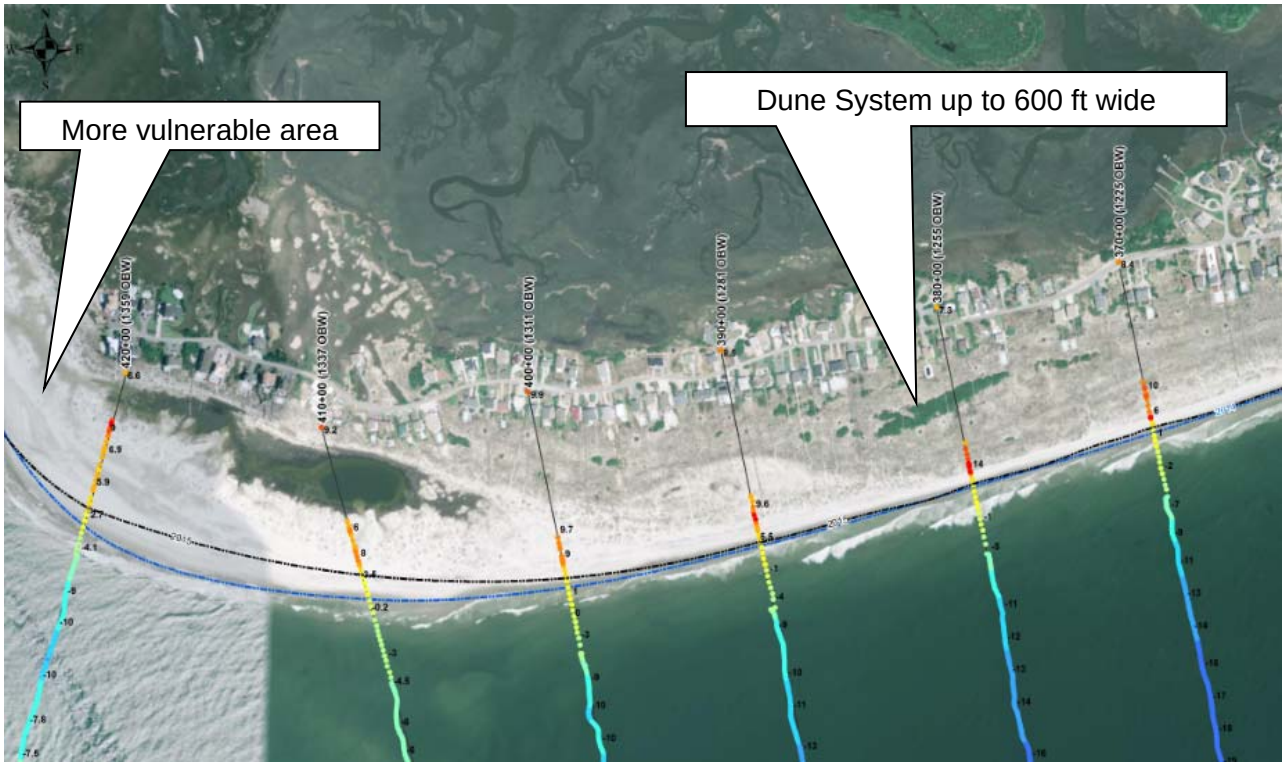


Figure 3-8. West End of Holden Beach Features a Very Large, Wide Dune Buffer (2014 aerial). 2014 (blue) and 2015 (black) smoothed mean high water (MHW) shorelines are also shown.

3.3 SHORELINE ANALYSIS

In addition to a volumetric analysis, shoreline analyses were also performed as another useful metric in gauging beach health. Figures 3-9 and 3-10 were developed to view annual changes in the MHW and toe of dune (TOD) (+7 ft NGVD) shoreline contours along Holden Beach. These shorelines are landward on the upper beach, where moderate erosion was documented in the volumetric analysis.

Average MHW shoreline change by reach is presented in Table 3-2. A general trend of slight erosion is seen in the Central and Western Reaches. Within the Central Reach, the MHW shoreline retreated by approximately 6 ft.

Figure 3-10 shows the TOD shoreline (7 ft NGVD contour), where variable erosion and accretion have occurred between the last two survey events. Proactive dune enhancements, discussed in Section 2.5, are an important activity related to maintaining a healthy dune system.

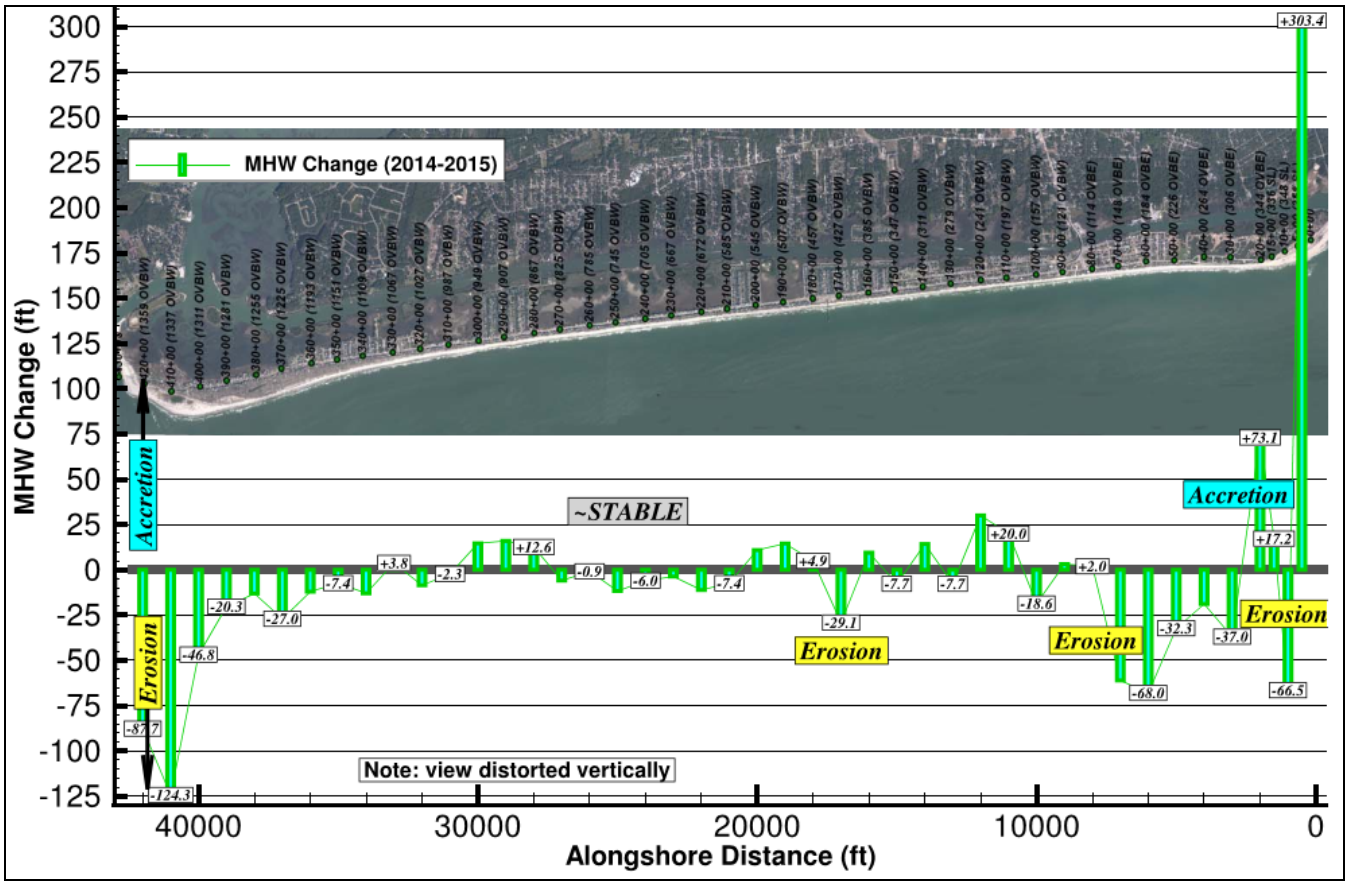


Figure 3-9. MHW Shoreline Change from 2014 to 2015. Overall stability is exhibited with slight erosion within the Central Reach and high erosion toward the west end near Shallotte Inlet. The variations between high accretion and high erosion rates on the eastern end are primarily due to the migration of 2014 USACE and Town fill activities and a recent shoal attachment (i.e., not representative of background erosion).

Table 3-2. MHW Shoreline Change by Reach for 2014 and 2015 Surveys

Reach Averages	Stations Included	2014 to 2015 MHW Change (ft)
LWF Inlet	5 to 15	84.7
USACE East	15 to 40	5.8
Town East	40 to 150	-12.1
Pier	150 to 190	-1.6
Town West	190 to 290	0.6
West Area	290 to 380	-4.9
Shallotte Inlet	380 to 420	-51.1
Central Reach	40 to 290	-5.9

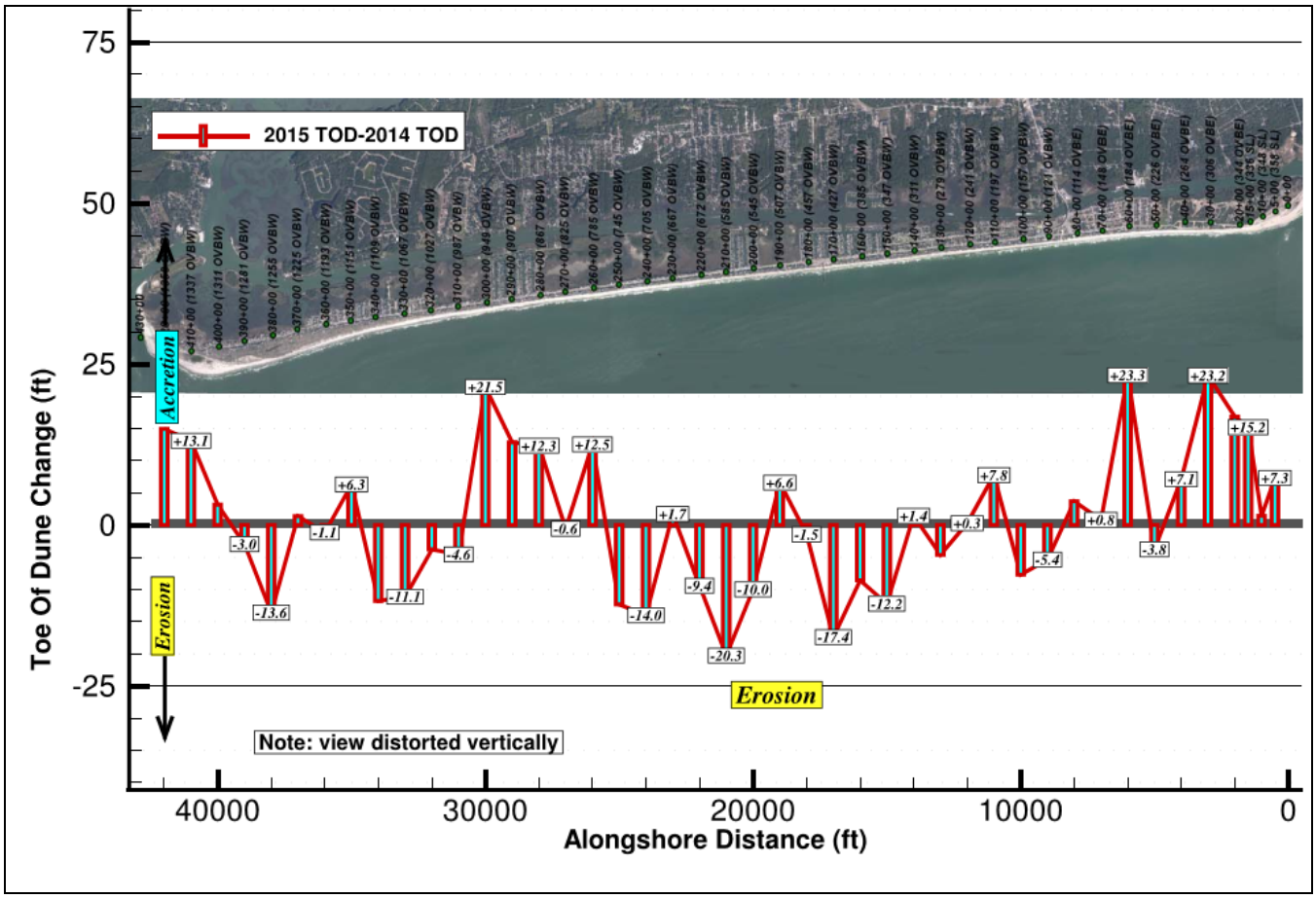


Figure 3-10. Toe of Dune (7 ft NGVD) Change from 2014 to 2015. Variable erosional/accretional trends are exhibited.

Figure 3-11 presents maximum dune heights for each Holden Beach station. Dune heights are generally healthy, although the east end stations show reduced dune heights and are more vulnerable to dune breaches during storms, especially under elevated water level conditions. Some lower dune elevations are also exhibited on the western end (Stations 400+00 and 410+00), however, the dune system is very wide in this area (as previously discussed).

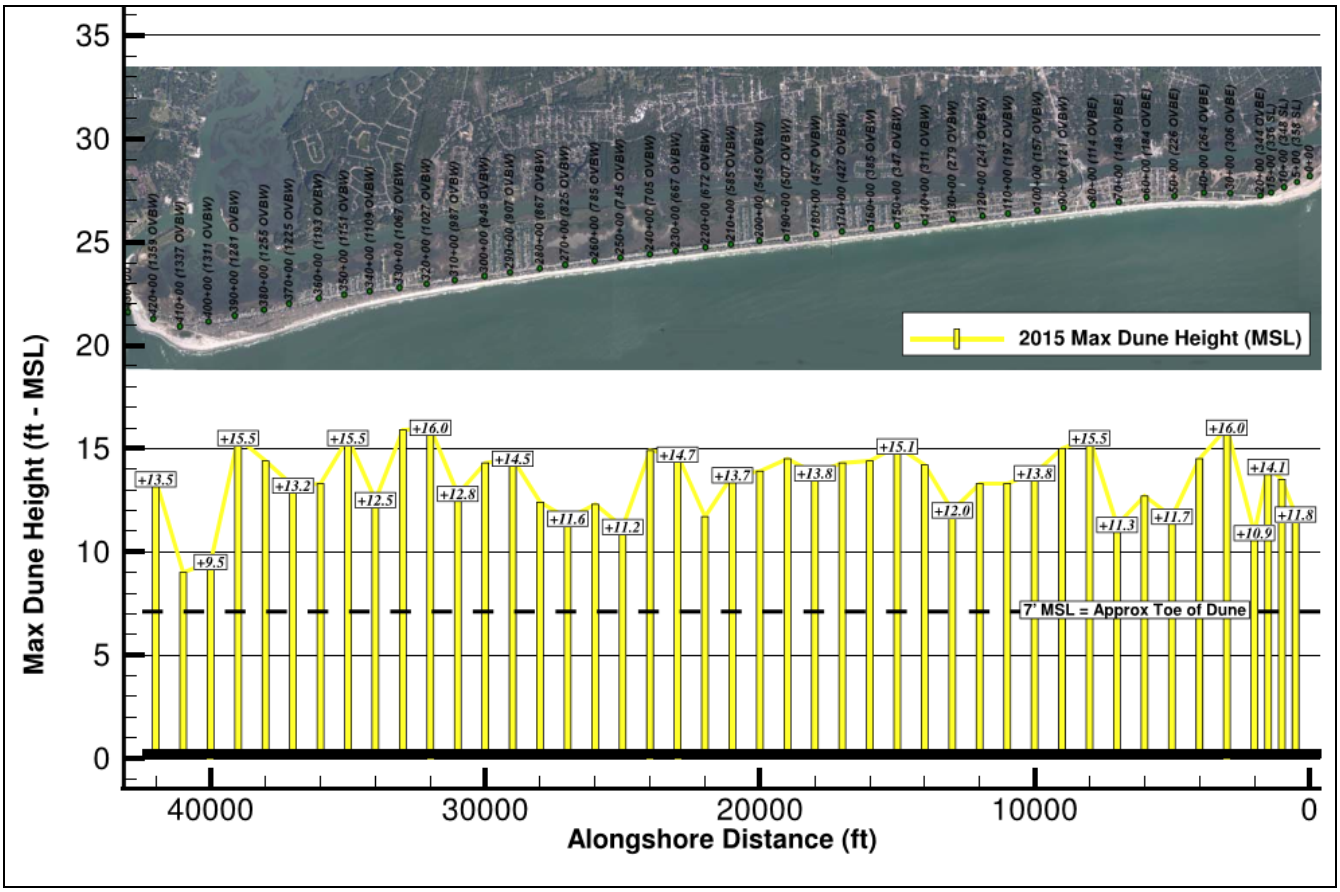


Figure 3-11. Maximum 2015 Dune Height. Using 7 ft NGVD as the dune base, dunes are generally 5' to 8' high.

3.4 HISTORICAL ANALYSIS

Figure 3-12 presents an approximately 15-year MHW shoreline comparison using 2000 and 2015 survey data. The 2000 survey represents a significantly erosional condition. A general accretional trend of 10 to 80 ft is exhibited for the MHW shoreline between 2000 and 2015 (not including the more variable inlet shorelines and recent east end nourishment).

The most recent NCDCM long-term background erosion rates from 2011 are included in Figure 3-12 for comparison purposes (NCDCM assigns a minimum long-term erosion of -2 ft/year). NCDCM 2011 erosion rates take into account recent fill activities and, therefore, reflect lower erosion rates. This is a benefit in terms of reduced setback distances for several areas of the island (when compared to the older 2004 NCDCM erosion rates).

The 2011 NCDCM erosion rate was converted to the same time span (January 2000 to April 2015) as the survey data in Figure 3-12. In comparison to NCDCM long-term erosion rates,

the shoreline has generally gained between 40 and 110 ft since the January 2000 survey. Table 3-3 presents average MHW change by reach over the last 15 years.

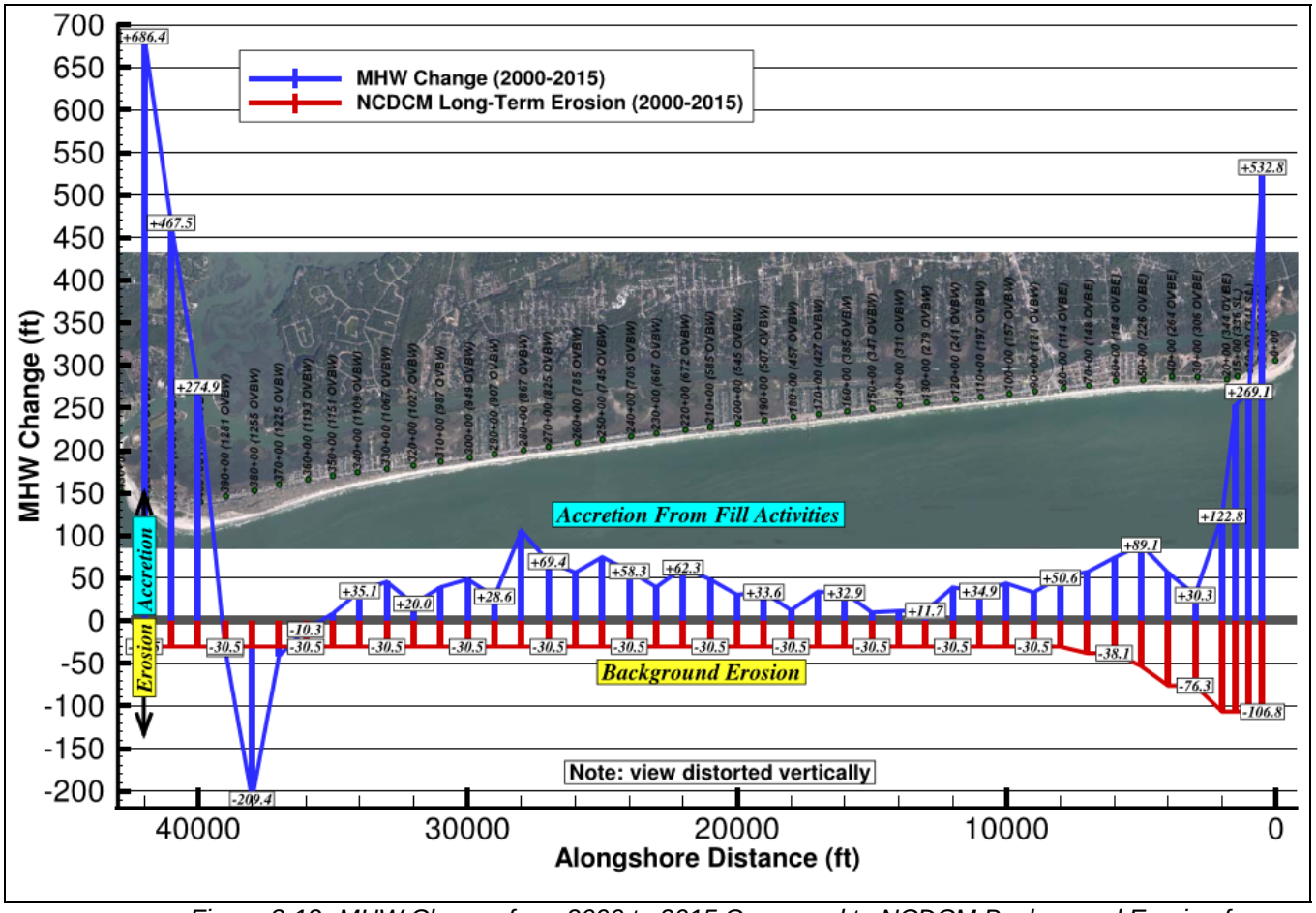


Figure 3-12. MHW Change from 2000 to 2015 Compared to NCDCM Background Erosion for the Same Period

Table 3-3. Historical MHW Shoreline Change by Reach (2000 to 2015)

Reach Averages	Stations Included	Historical MHW Change (2000 to 2015) (ft)
LWF Inlet	5 to 15	351.6
USACE East	15 to 40	69.8
Town East	40 to 150	42.6
Pier	150 to 190	24.6
Town West	190 to 290	55.2
West Area	290 to 380	-3.5
Shallotte Inlet	380 to 420	125.0
Central Reach	40 to 290	46.1

Table 3-3 results show that Town and USACE fill and dune enhancement activities have been successful in combating erosion over the last 15 years. The inlet reaches exhibit the largest increases in MHW change over the last 15 years, which also can be attributed to inlet dynamics and maintenance activities.

3.5 OAK ISLAND TRANSECTS

The Town of Holden Beach has been collecting additional survey data on the western end of Oak Island to establish baseline conditions for this area. Oak Island only performs annual surveys down to the mean low water, which are not sufficient to completely capture sediment movement. Additionally, because regional sediment transport is from east to west in this area, any changes in this area have the potential to affect Holden Beach shorelines (i.e., “downdrift”).

Oak Island monitoring transects are shown in Figure 3-13. As with the Holden Beach inlet transects, the Oak Island inlet transects 1 through 4 (i.e., not shoreline perpendicular) are excluded from some volume calculations.

The west end of Oak Island has more development closer to the active beach than the west end of Holden Beach (where the dune system is up to 600 feet wide) and, therefore, is more vulnerable to short-term erosional episodes (both west ends are stable/accretional in the long term). Tables 3-4 and 3-5 present volume and MHW change for the Oak Island transects since the spring 2012 survey.

Similar to the inlet-influenced transects on the west end of Holden Beach, large variation is exhibited for Oak Transects 1 through 4. Oak Transects 5 and 6 are transitional, while Oak Transect 7 is generally removed from inlet effects and has historically shown less variability and more stability. Oak Transects 5 and 6 show significant accretion over the last year due to a beach nourishment project (see Figure 3-14).

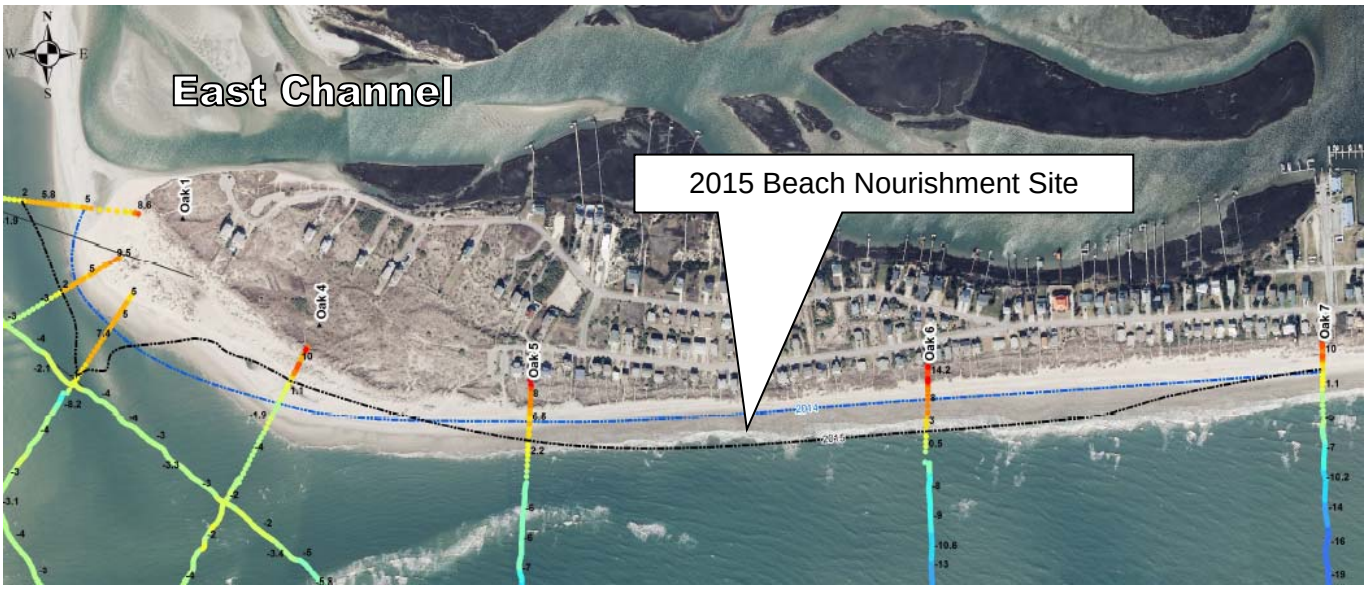


Figure 3-13. Oak Island Transects with 2014 MHW (blue) and 2015 MHW (black) Lines shown on a 2014 Aerial. "Oak 2" and "Oak 3" transects begin at the same location as "Oak 1."

Table 3-4. Oak Island Transect Volume Analysis from 2014 to 2015

Station	Distance to Next Monument (ft)	Volume Change (cy/ft) (Dune to -12 ft*)	Volume Change (cy/ft) (Dune to -5 ft)	Notes
Oak 1	0	82.5	98.2	LWF Inlet
Oak 2	0	32.4	41.0	LWF Inlet
Oak 3	890	41.2	62.3	LWF Inlet
Oak 4	1100	-33.2	-1.1	LWF Inlet Shoulder
Oak 5	2000	33.4	32.0	2015 Nourishment Project
Oak 6	2000	100.1	67.2	2015 Nourishment Project
Oak 7	-	4.1	-0.2	Oceanfront perpendicular

Table 3-5. Oak Island Transect MHW Change

Transect	2012-2013 MHW Change (ft)	2013-2014 MHW Change (ft)	2014-2015 MHW Change (ft)	Notes
Oak1	65.4	-51.9	331.3	
Oak2	-432.8	105.9	87.0	Nearshore Shoals
Oak3	-338.2	19.4	302.1	Nearshore Shoals
Oak4	-75.4	-51.9	-134.4	
Oak5	-91.7	-12.6	94.3	2015 Nourishment
Oak6	-7.5	-4.0	163.1	2015 Nourishment
Oak7	13.7	14.0	-16.9	

Figure 3-14. Eastern Channel Dredging/Beach Nourishment Project Overview. (From February 10, 2015 Town of Oak Island Council Meeting with Moffatt & Nichol). Oak Transect 5, 6 and 7 (which are surveyed by Holden Beach) are included for reference.

The Town of Oak Island recently completed a nourishment to its west end in April 2015. Construction for this project, named the Eastern Channel Dredging/Beach Nourishment Project, began in March 2015. The project included dredging of the Eastern Channel from LWF Inlet to Horse Island, and placing approximately 180,000 cy of sediment on the west end of Oak Island (Figure 3-14). The benefits of this nourishment project can be seen in the MHW increases for Transects 5 and 6 between the 2014 and 2015 surveys (Figure 3-13). Town staff and ATM will continue to follow this effort, as it has the potential to affect LWF Inlet and Holden Beach.

4.0 SUMMARY

The Holden Beach shoreline has historically exhibited moderate erosion rates (with the exception of the inlets). As a result, the Town has instituted a nourishment and beach management program to offset this erosion. Dating back to January 2000 (approximately 15 years), the Town and the USACE have placed an average of approximately 140,000 cy/year on the beach. This rate of sand placement has been effective at keeping pace with background erosion.

Over the last 5 years (2010 to present), annual placement rates have averaged approximately 100,000 cy/year [2010 (140,000 cy) and 2014 (188,000 cy) placements were significantly larger than 2011 (32,000 cy) and 2012 (25,000 cy)]. During this time, Hurricane Irene (2011) impacted the Holden Beach shoreline. Due to its "engineered beach" status and annual monitoring program, the Town qualified to receive FEMA aid to mitigate erosion caused by the storm. However Irene mitigation was for only 26,000 cy and for only a small section of beach west of the pier (i.e., the beach held up well to Irene and only 26,000 cy could be directly attributed to Irene losses). The Town also received FEMA assistance for Hurricane Hanna erosion in 2008 and placed 190,000 cy of material, with FEMA reimbursing 75 percent of the total project cost.

The most recent annual shoreline survey occurred in April 2015. In comparing this survey to the April 2014 survey, the entire island experienced a net loss of approximately 11,000 cy. Considering that no nourishment activity occurred over this time span, the Holden Beach shoreline can be characterized as stable overall. Historical annual losses have been documented at about 100,000 cy/year for Holden Beach.

The 2014 LWFIX nourishment project continued to spread east and west and a recent shoal attachment on the east end were also evidenced in comparing the last two survey events. Relatively extreme volumetric erosion was observed near the west end (about a 106,000 cy loss between STA 370+00 and 420+00). This loss was mainly observed in the upper beach region (dune to -5 ft NGVD) and the sediment likely moved into the nearshore or toward Shallotte Inlet.

From a shoreline contour perspective, approximately the center 5 miles of island (Central Reach STA 40+00 to 290+00) exhibited an average MHW erosion of -6 ft between surveys. This mild erosion agrees with the volumetric analysis. The TOD line exhibited an average erosion of

approximately 1.4 ft along the entire Central Reach, with more severe erosion west of the pier (STA 170+00 to 230+00) and accretion along the east end and also adjacent to Shallotte Inlet.

In comparing the April 2015 survey with the January 2000 survey (15-year span), the MHW shoreline exhibits approximately 46 ft of accretion. Therefore, the shoreline is still in a generally healthy condition, and the Town holds all permits necessary for the Central Reach nourishment project. The Central Reach nourishment project proposes to place up to 1.31 MCY between Stations 40+00 and 260+00 (OBE 262 to OBW 781).

The Central Reach nourishment project represents the largest nourishment project on Holden Beach (approximately twice the size of the 2001-2002 USACE 933 project) and will advance the MHW shoreline approximately 60 to 80 ft. The purpose of the proposed project, which is a component of the Town's comprehensive beach management program, is to provide beach restoration along eroding sections of shoreline sufficient to maintain the island's restored protective and recreational beachfront and natural dune system.

The Town's 2014 LWFIX piggyback project was exceedingly successful and has reduced the immediate need for the larger and more costly Central Reach project however, this project is anticipated to occur in the next few years. It is recommended that the Town continue to piggyback projects in the future whenever the USACE plans a project that does not fully utilize the LWFIX borrow area (which is expected to happen most of the time due to USACE funding restrictions).

The NCDENR SDI program will provide the Town with permits to dredge the inner and outer portions of LWF Inlet. These permits would essentially allow the Town, with potential help from the County and State, to perform the same inlet maintenance activities that the USACE currently performs (i.e., LWFIX dredging, outer channel sidecasting). The State has established an annual funding source for these projects with the new State Shallow Draft Navigation Channel and Lake Dredging Fund, which will be endowed by both an increase in boat registration fees and an excise on motor fuel to the North Carolina Wildlife Resources Commission's boating account. The Town and ATM will continue to coordinate with NCDENR and its subcontractors as they are currently in the permitting process

The Town recently contracted with the USACE to use the *Murden*, a split-hull shallow draft hopper dredge, to dredge approximately 30,000 cy of material and place it in the nearshore between Stations 60+00 and 90+00. This material was dredged from the LWF outer channel and placed in about 10 ft of water where it will slowly migrate onshore. The state funded half of this project as a component of the SDI program. Monitoring this created shoal will continue to assess its effectiveness in reducing erosion (another obvious benefit is a deeper and more navigable inlet channel). This project could potentially occur more frequently or in larger quantities in the future. In general, use of the shallow draft hoppers is much more effective than the sidecasters in maintaining the LWF outer channel, as well as in placing dredged material closer to the beach.

In summary, the 2011 North Carolina Beaches and Inlets Management Plan (NC BIMP) report estimated the 2008 Beach Recreation *Annual* Total Impact Output for Holden Beach at $92.9 million, which accounted for 1,299 jobs. Additionally, the NC BIMP conducted a study of losses attributed to 50 percent beach width loss and found that, for Holden Beach, the 2008 estimated *annual loss* (including output/sales/business activity) would be $14.6 million. The Town's beach management and maintenance program strives to maintain and enhance this important economic and environmental benefit.

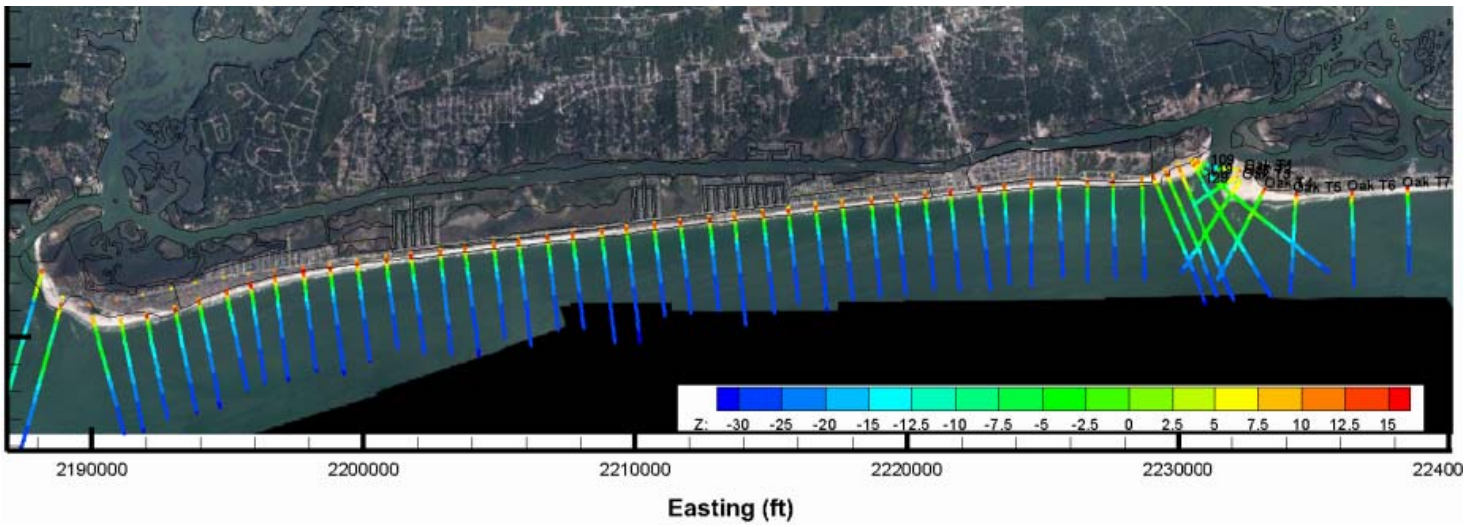
Recommendations for future and ongoing beach management activities include:

- Continue annual island-wide monitoring with beach profiles
- Continue Central Reach nourishment planning
- Continue terminal groin and beach nourishment permitting for the east end
- Continue research toward conducting a pilot project with recycled glass as a sand source, which can likely be conducted under the existing upland fill permit
- Continue to coordinate with USACE and NCDWR on future outer LWF Inlet channel sidecast/hopper dredging and nearshore sand placement
- Continue proactive dune enhancement activities (planting, fertilizing, fencing, etc.).
- Work closely with Congressional representatives to assure continued support of future USACE nourishment projects for Holden Beach
- Continue coordination and support of the State's SDI program and quarterly SDI MOA meetings held by the USACE and NCDENR/NCDWR

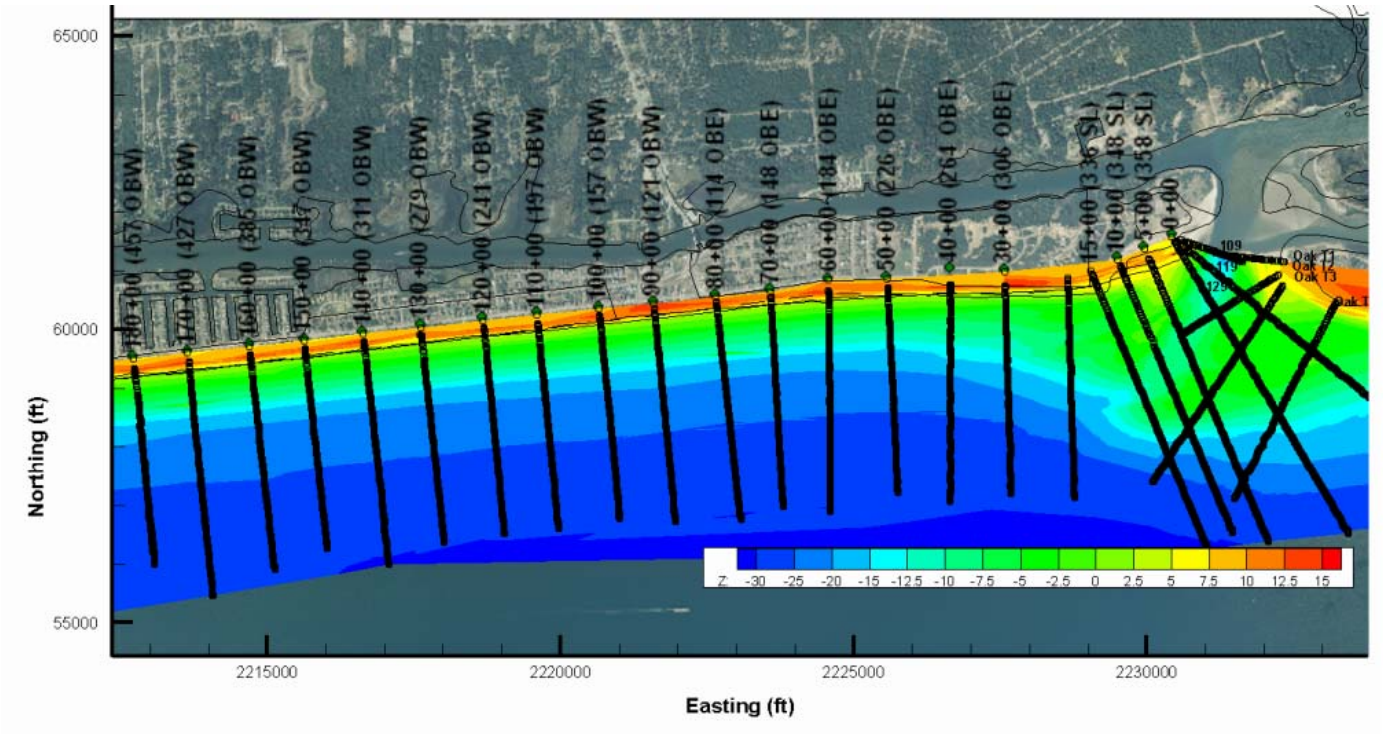
Appendix A

Station Profile Analysis

APPENDIX A – ELEVATION PROFILE TRANSECTS



Survey Stationing Figure. Plots below are from east (Lockwoods Folly Inlet) to west (Shallotte Inlet). Profile plots are zoomed in to nearshore area (typically from the dune to ~-20ft NGVD depth). Oak Island Transects are at the end of the section. Note "Z" is in ft-NGVD29.

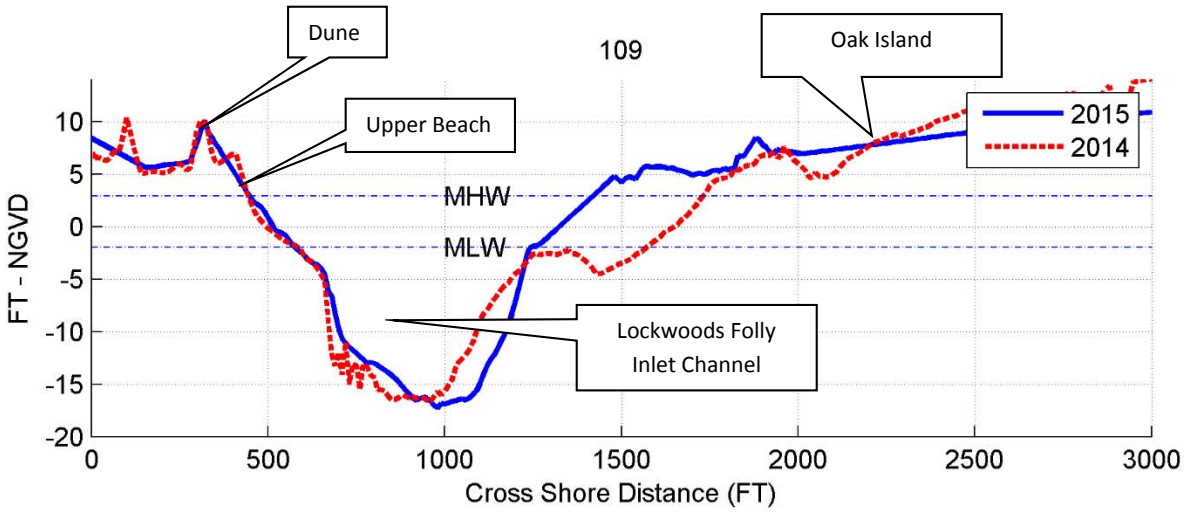


Zoomed in to eastern half of island (station 170+00 is to the far left and just east of the pier). Note "Z" is in ft-NGVD29.

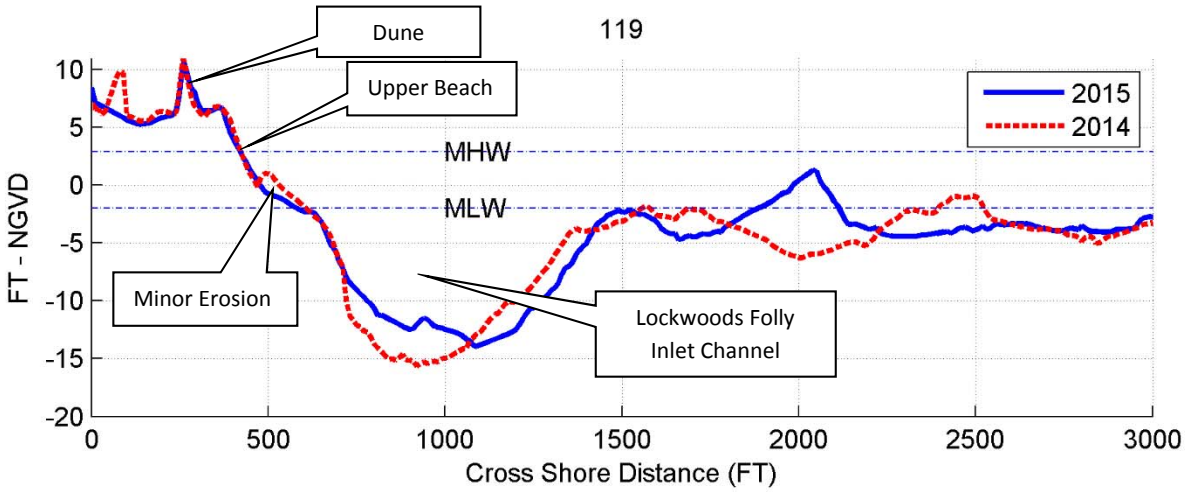
Please Note:

In the following cross sections, the Station Number is shown at the center top of the figure.

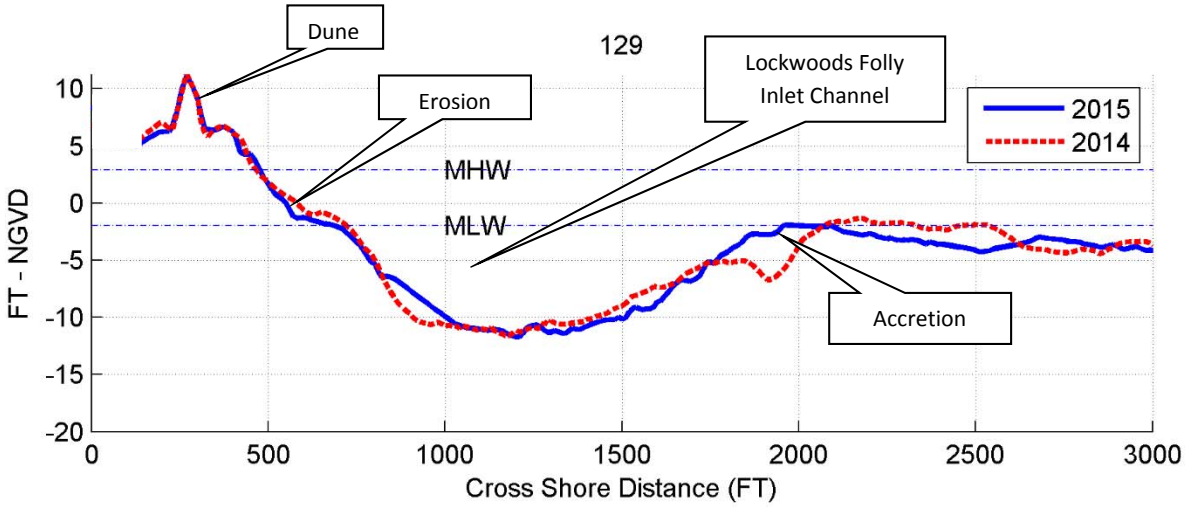
Any notable features are described in "call-outs" or in blue below the figure.



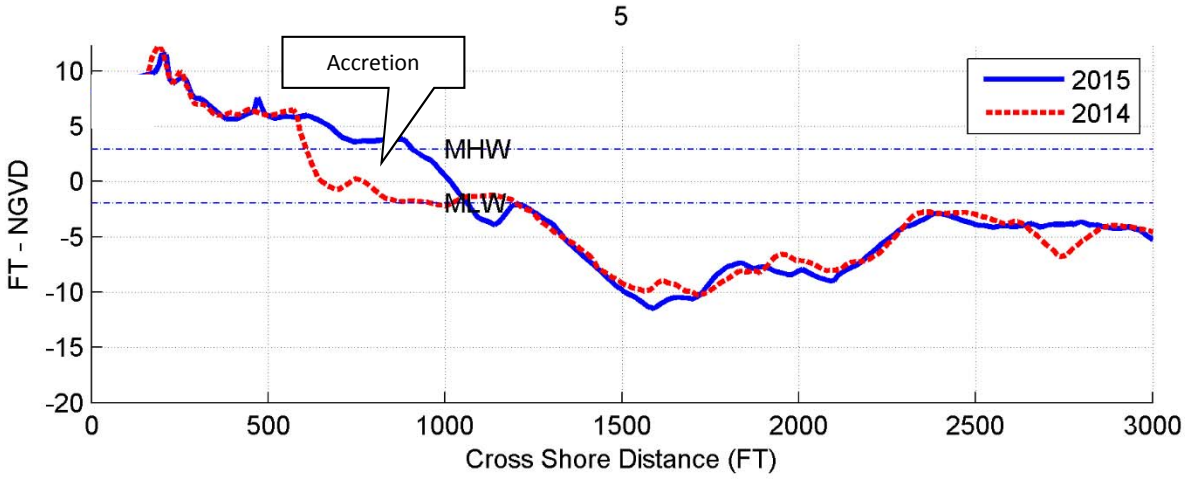
Station 109+00 (far east). Plots typically show from dune (between ~7' and ~15' NGVD) out to ~-20' NGVD. MHW=Mean high water, MLW=mean low water.



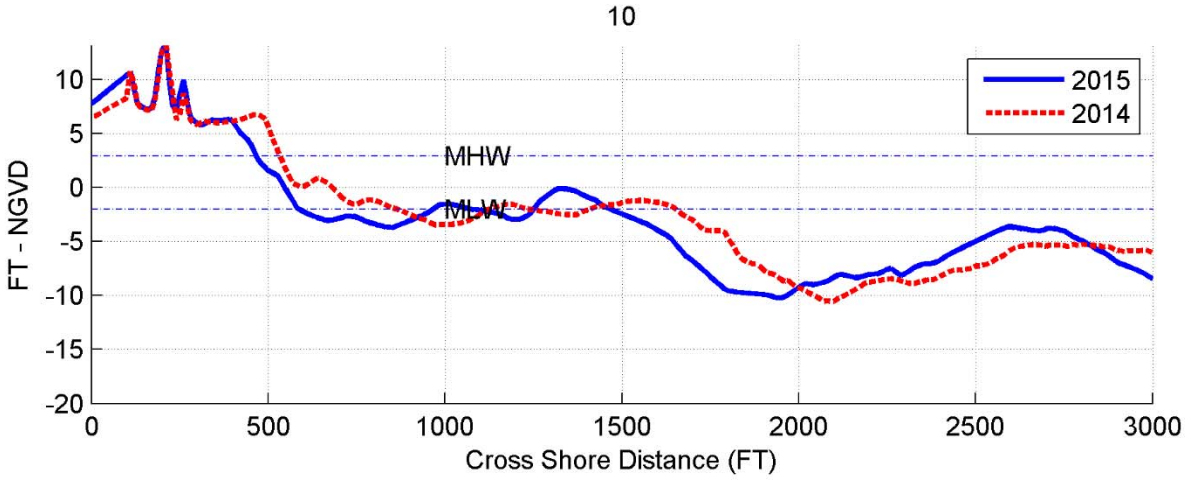
Station 119+00. Inter-tidal beach showing some minor erosion since 2014 survey.



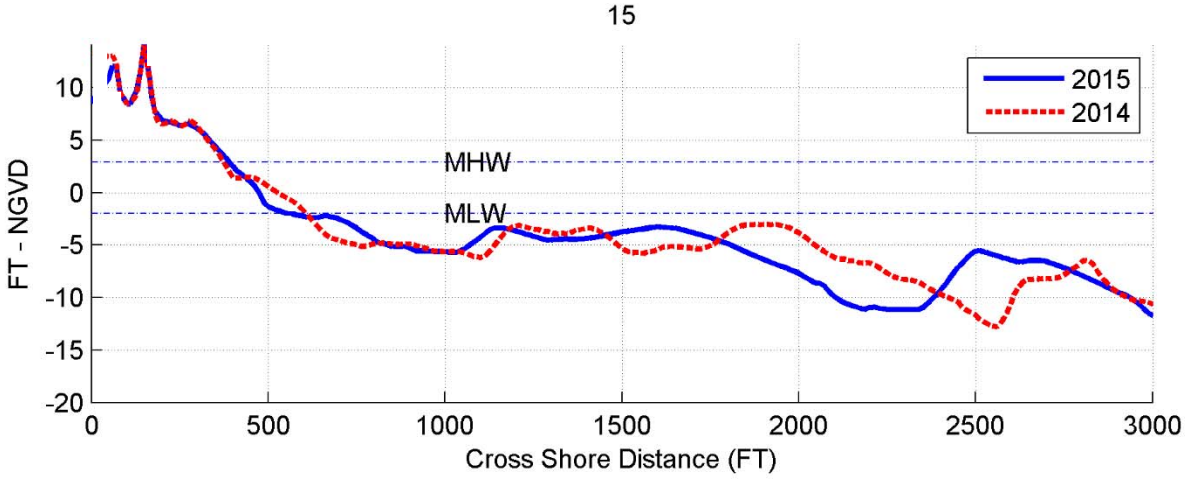
Station 129+00. LWF Inlet Channel Approximately 900 ft from baseline. Some minor intertidal erosion and accretion below MLW is seen.

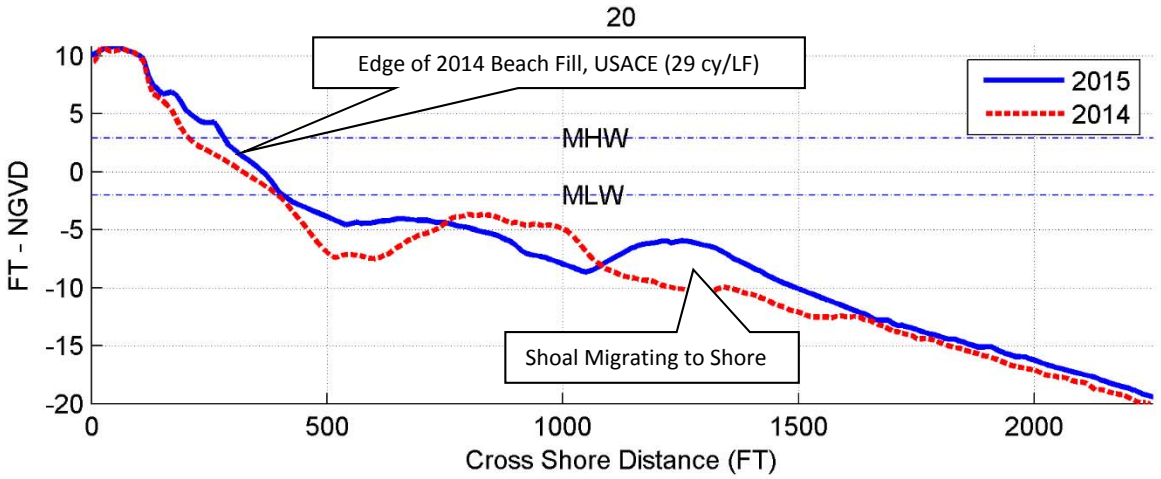


Station 05+00. Some significant upper beach and intertidal accretion is seen due to a shoal attachment

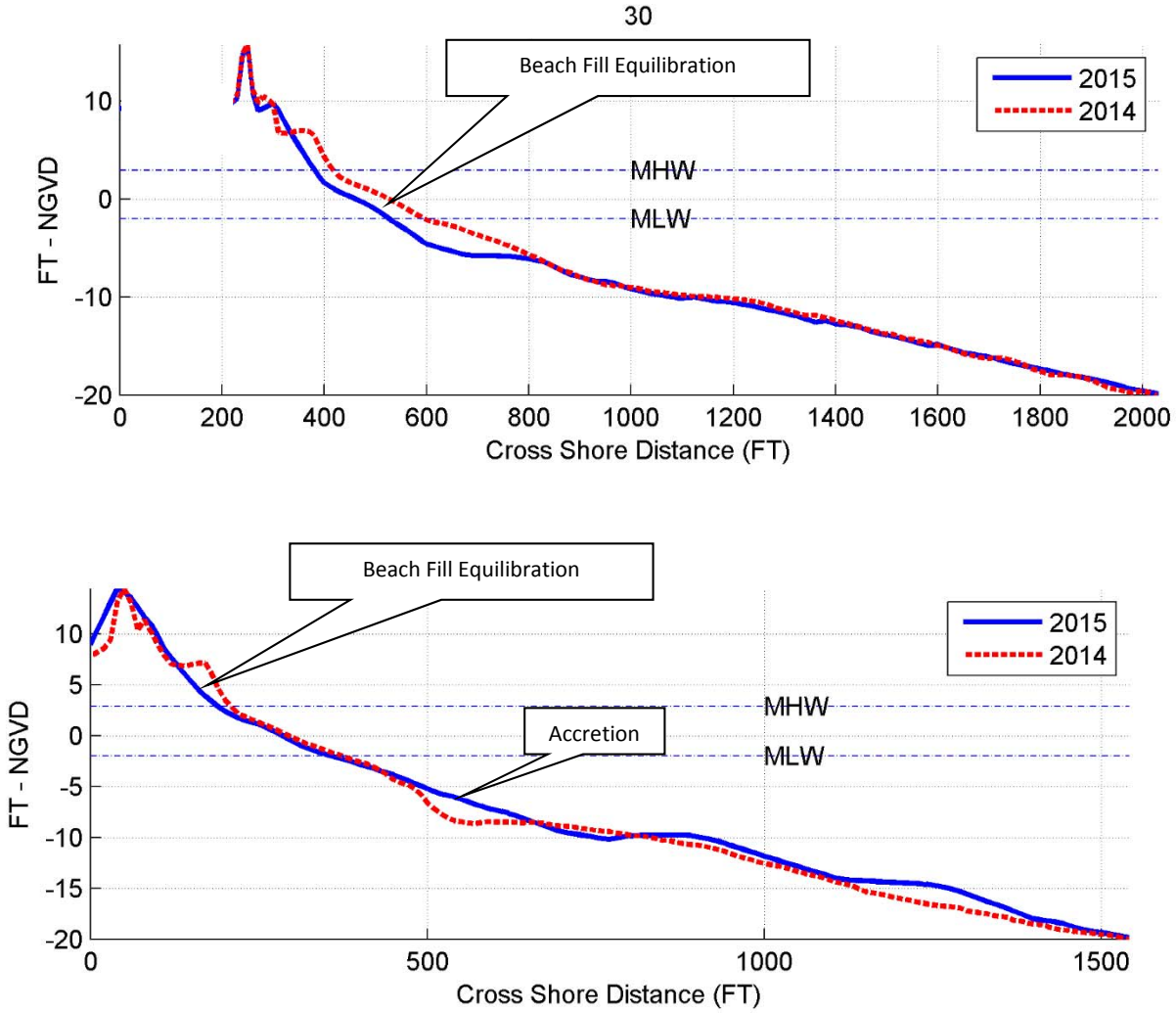


Station 10+00. Some dry beach erosion; variable nearshore.

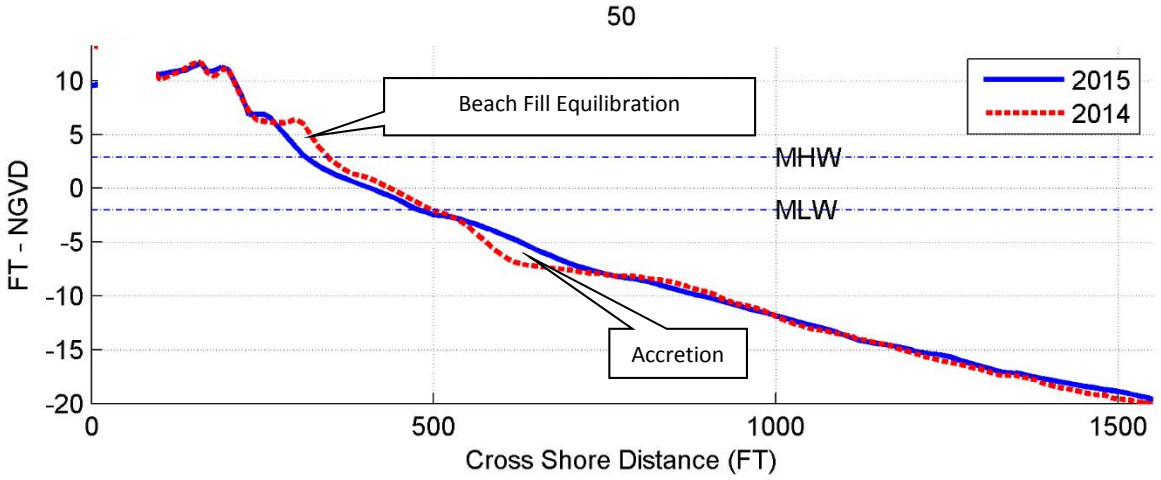




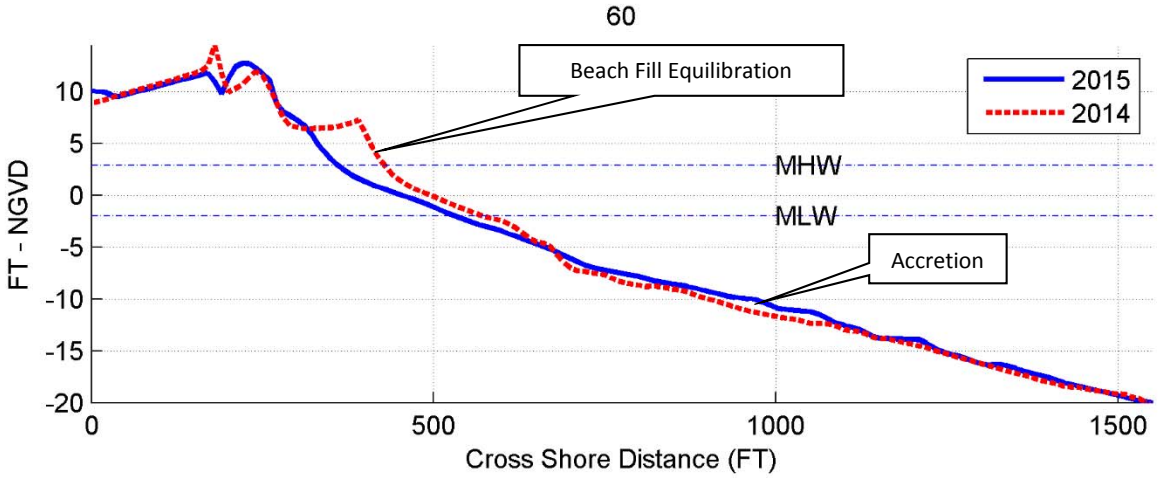
Station 20+00. Note some dry beach and intertidal accretion since 2014 survey.



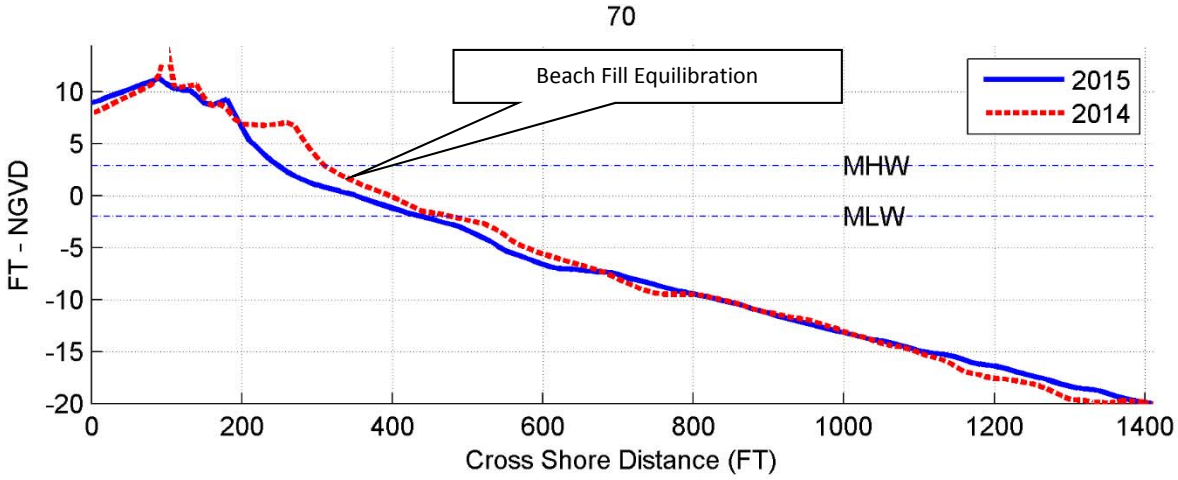
Station 40+00. Note cross shore transport from upper beach into the nearshore region since 2014 survey (after 2014 beach fill).

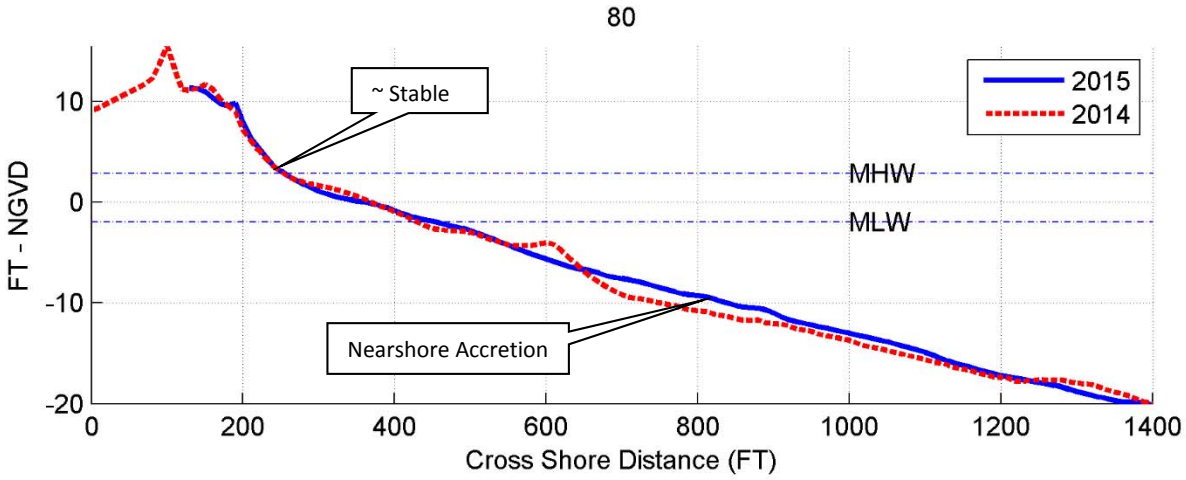


Station 50+00. End of USACE template (29cy/LF) and beginning of Town template (41yc/LF) for 2014 Survey

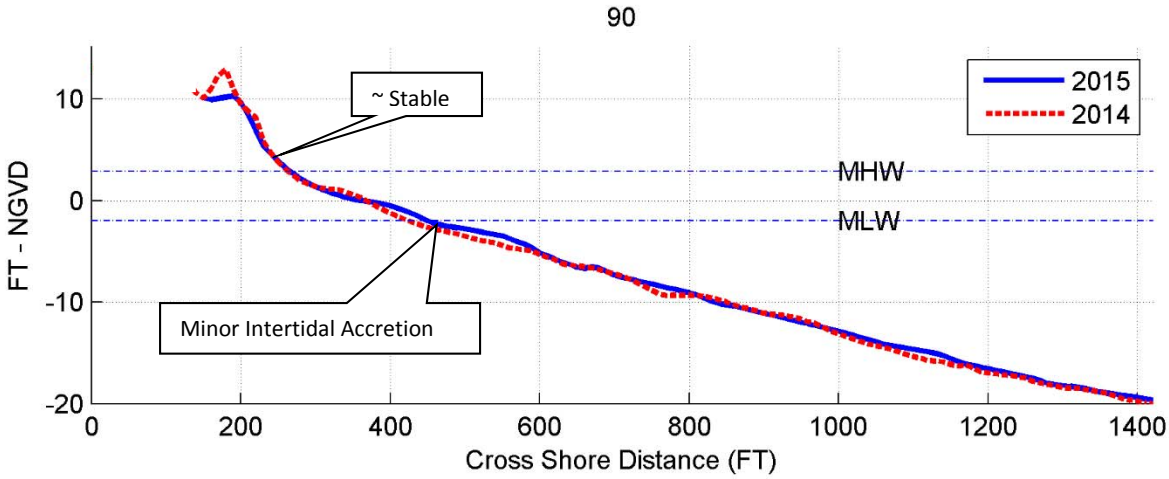


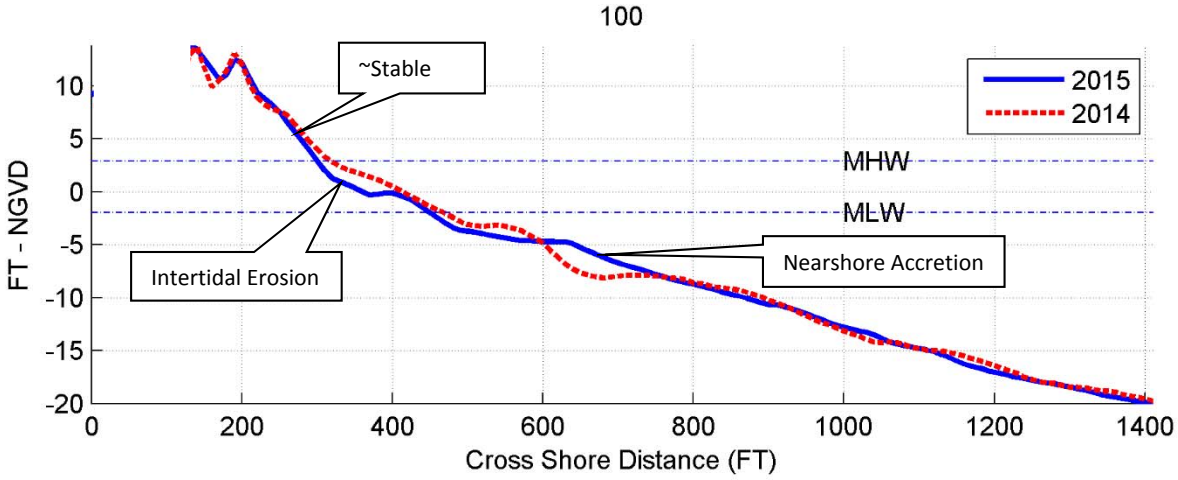
Station 60+00. Note dry beach equilibration and nearshore accretion since 2014 survey (which occurred after 2014 beach fill).

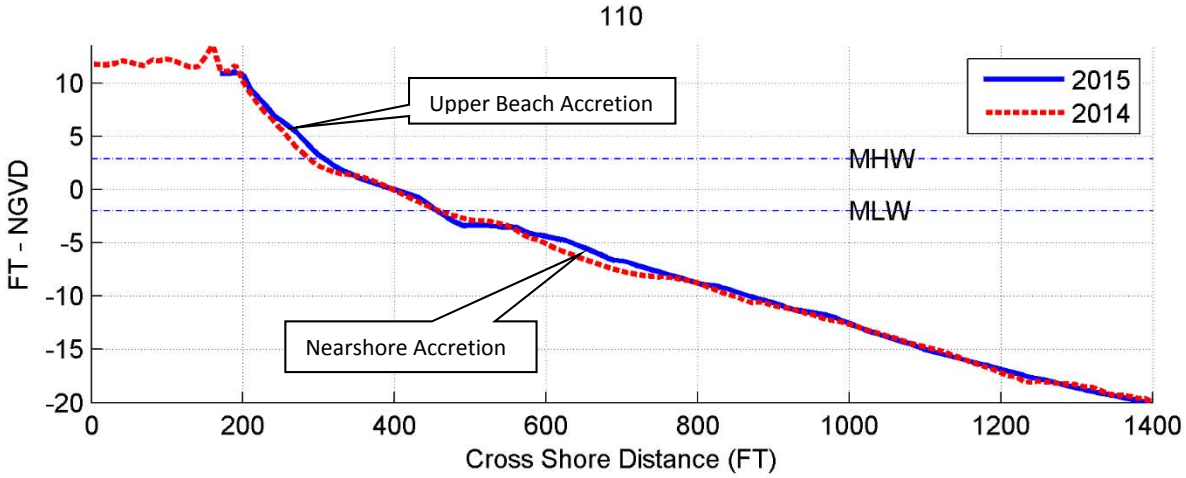


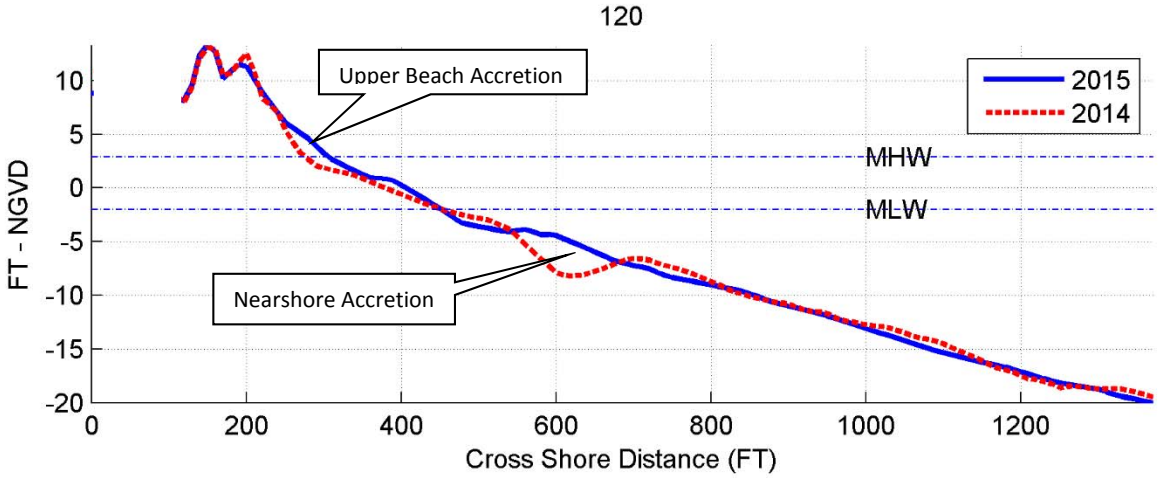


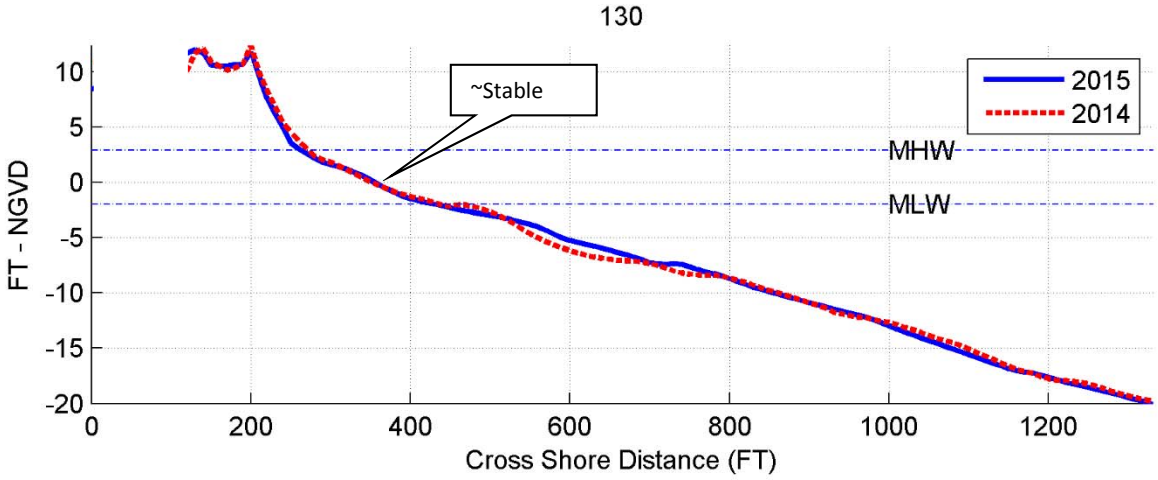
Station 80+00. Note end of 2014 Town Nourishment at Station 73+00.

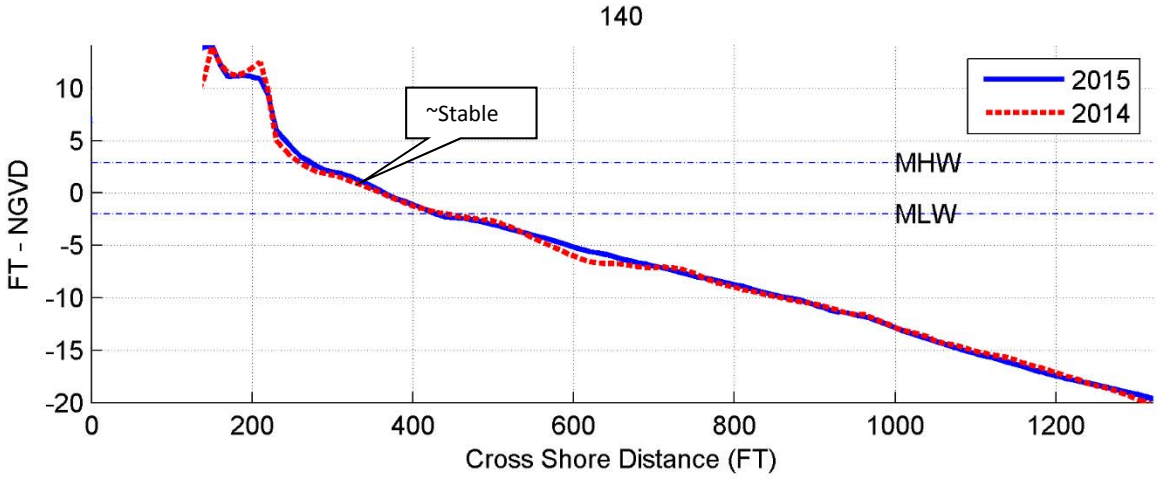


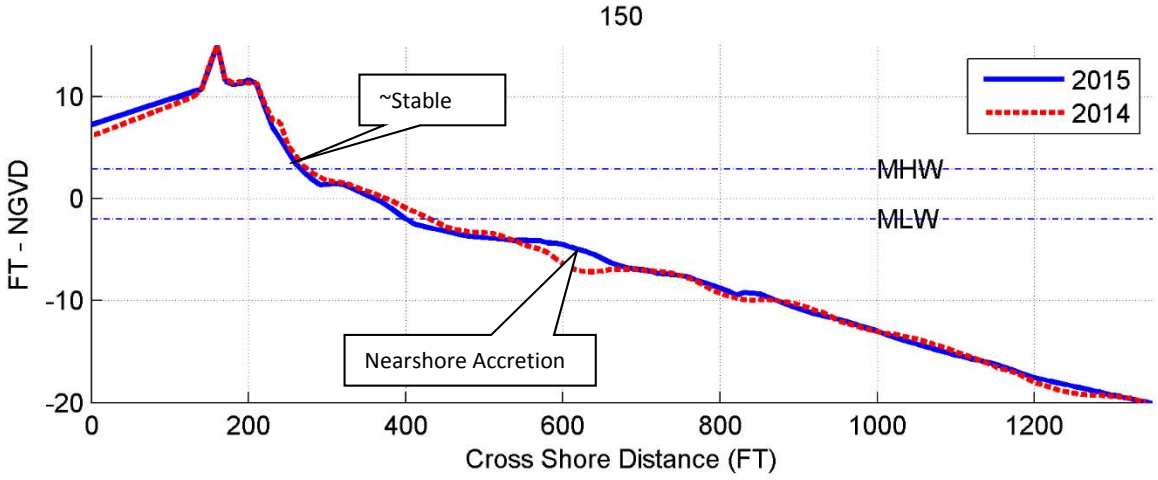

100
~Stable
Intertidal Erosion
Nearshore Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

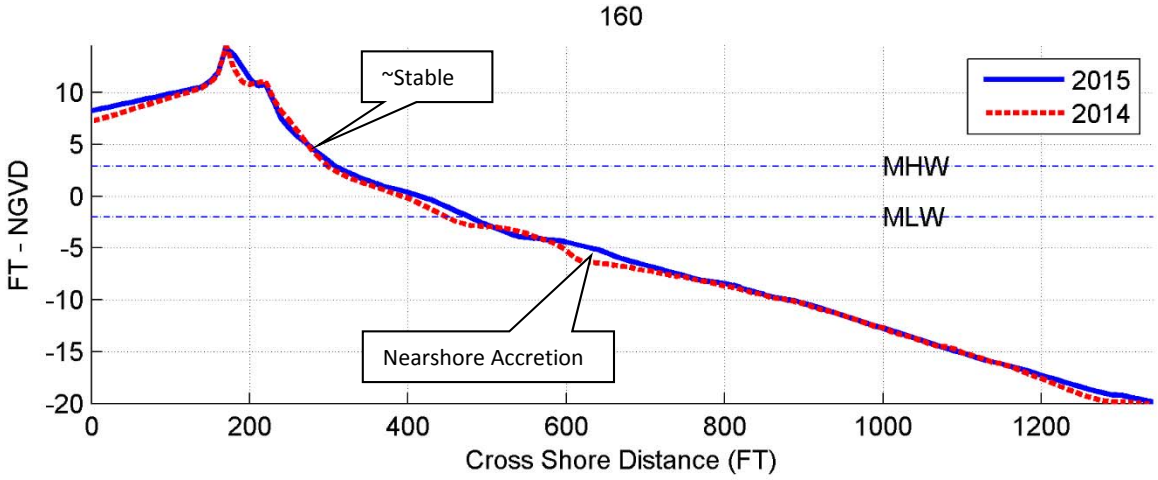

110
Upper Beach Accretion
Nearshore Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

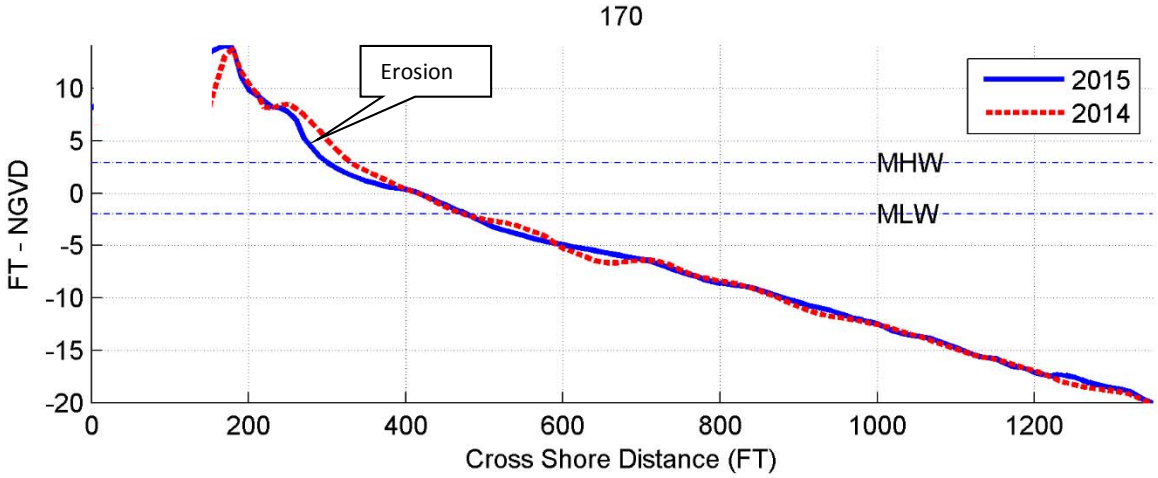

120
Upper Beach Accretion
Nearshore Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

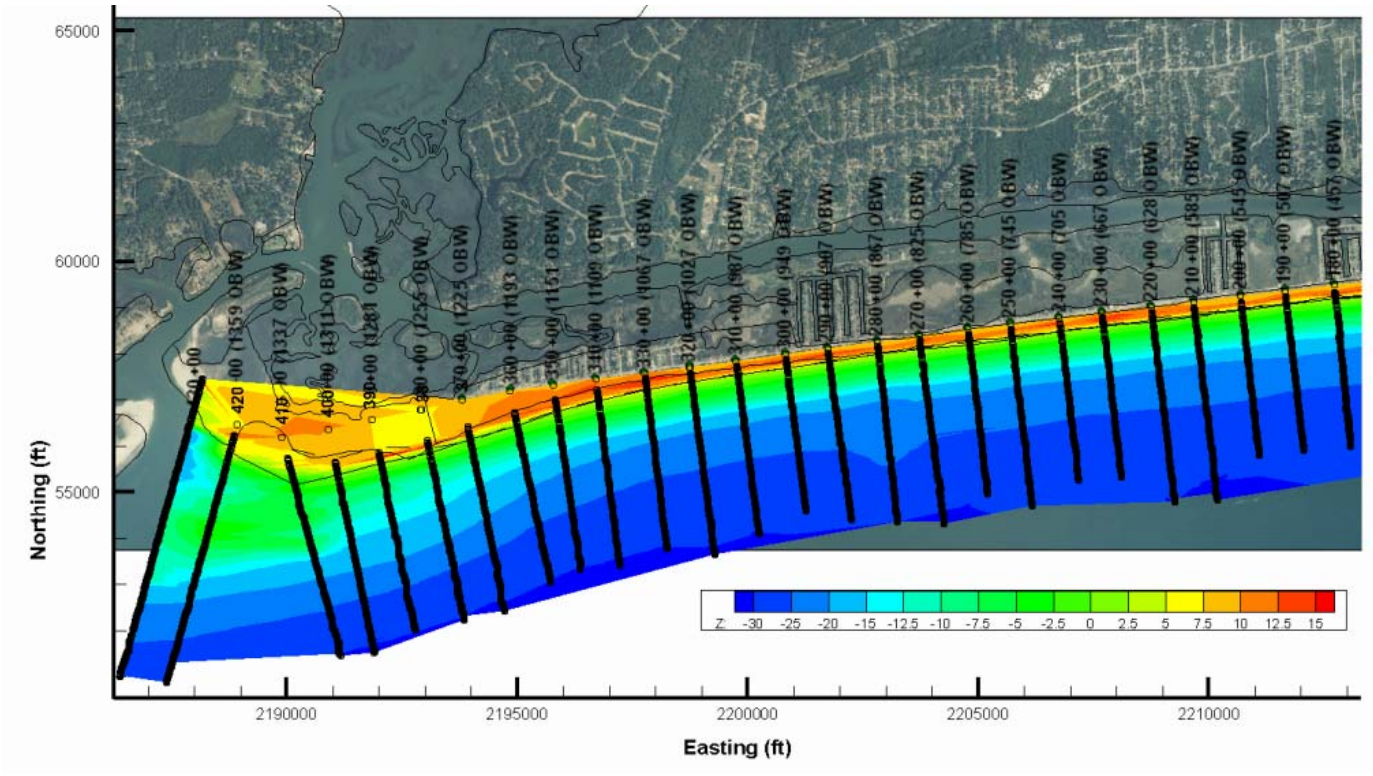

130
~Stable
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)


140
~Stable
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

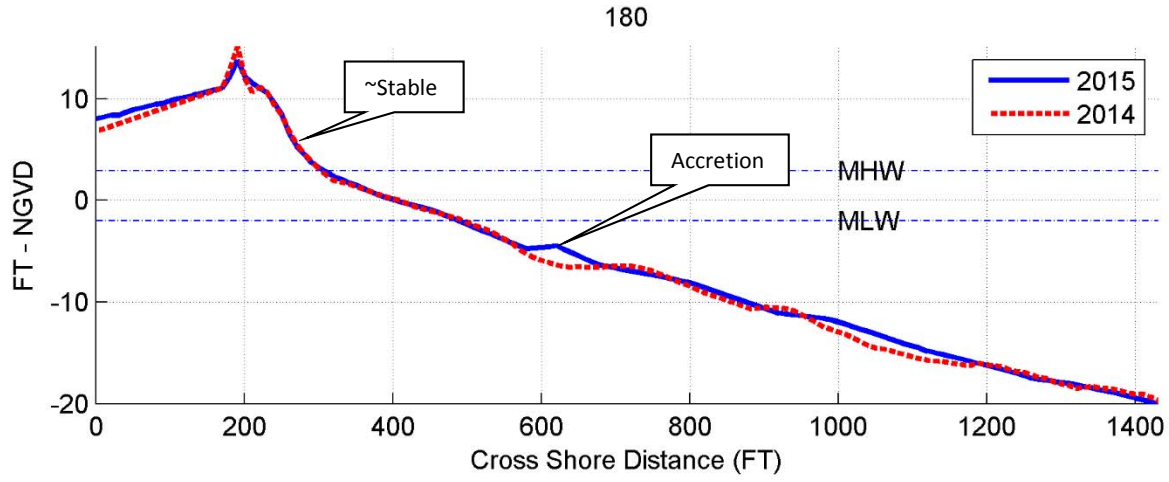

150
~Stable
2015
2014
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

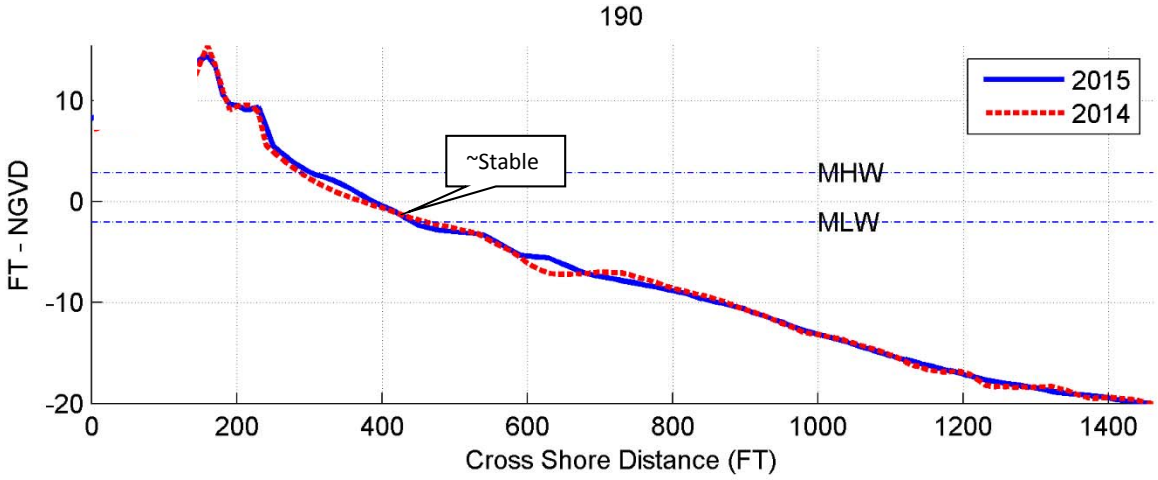

160
~Stable
Nearshore Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

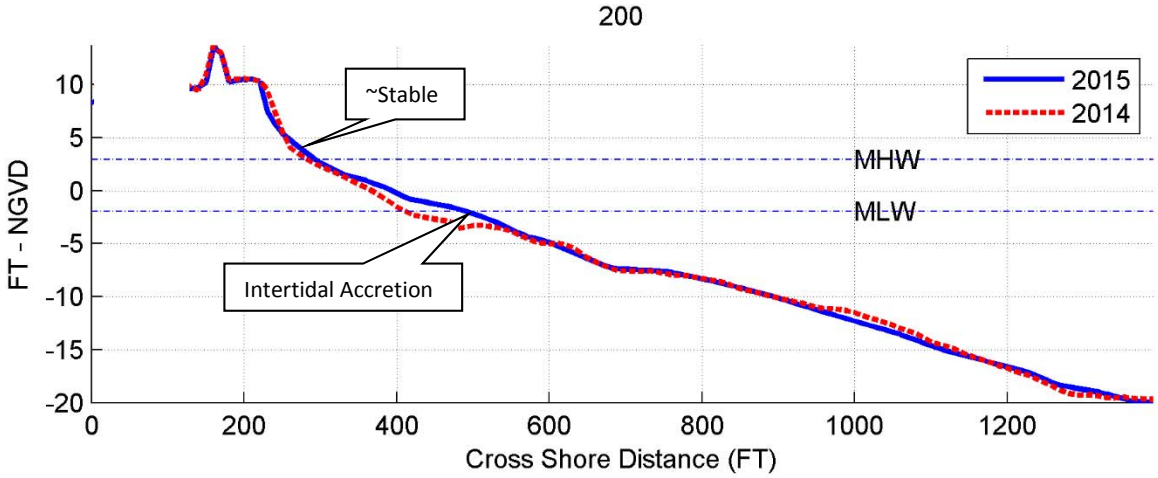

170
Erosion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

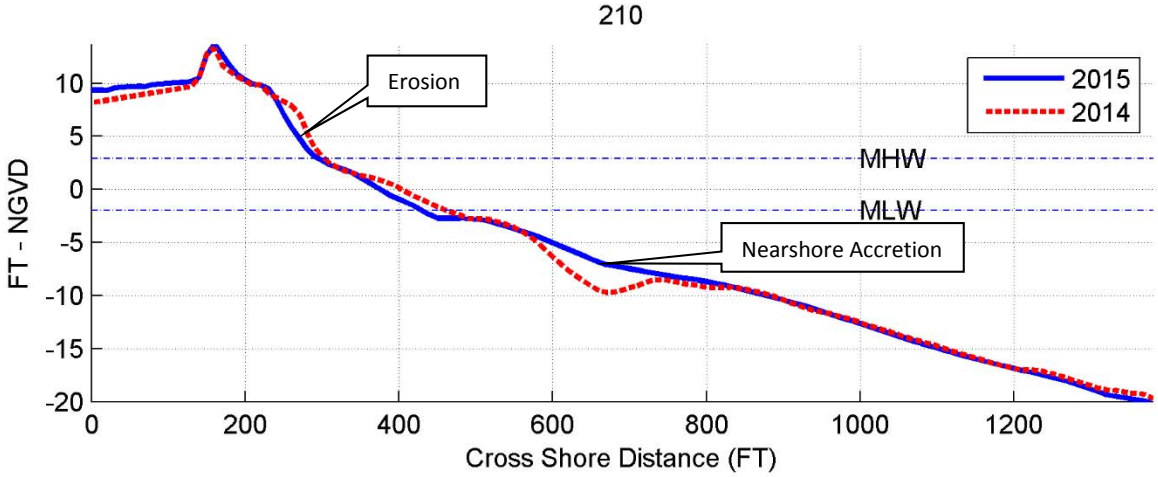


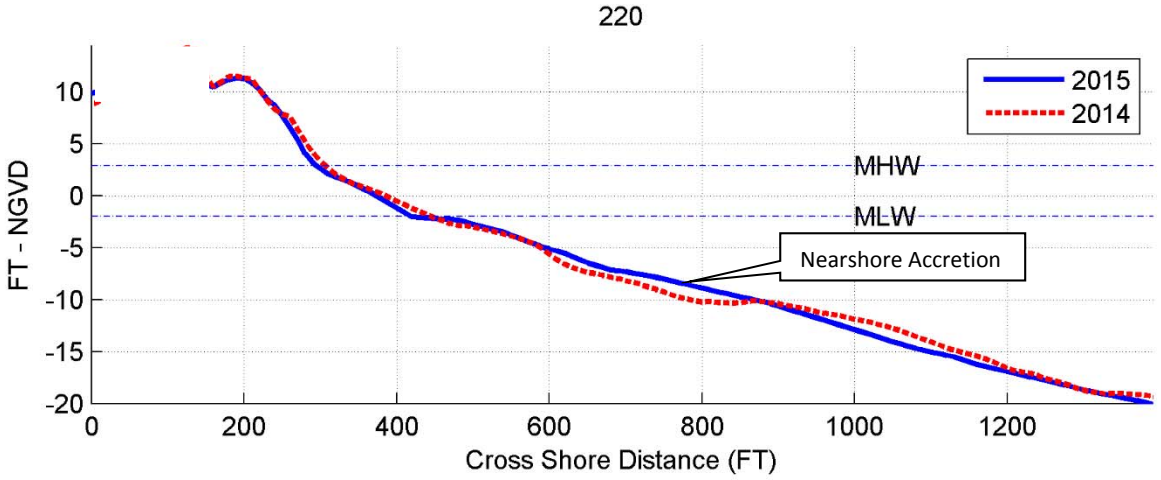
Zoom in of western end (Station 180+00 near the pier to Station 430+00 at Shallotte Inlet). Note "Z" is in ft-NGVD29.

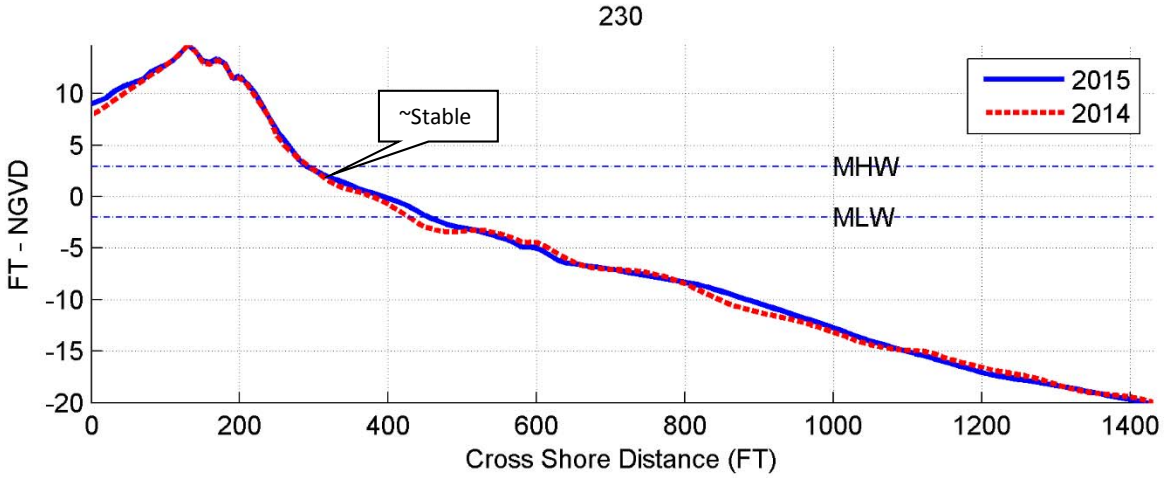


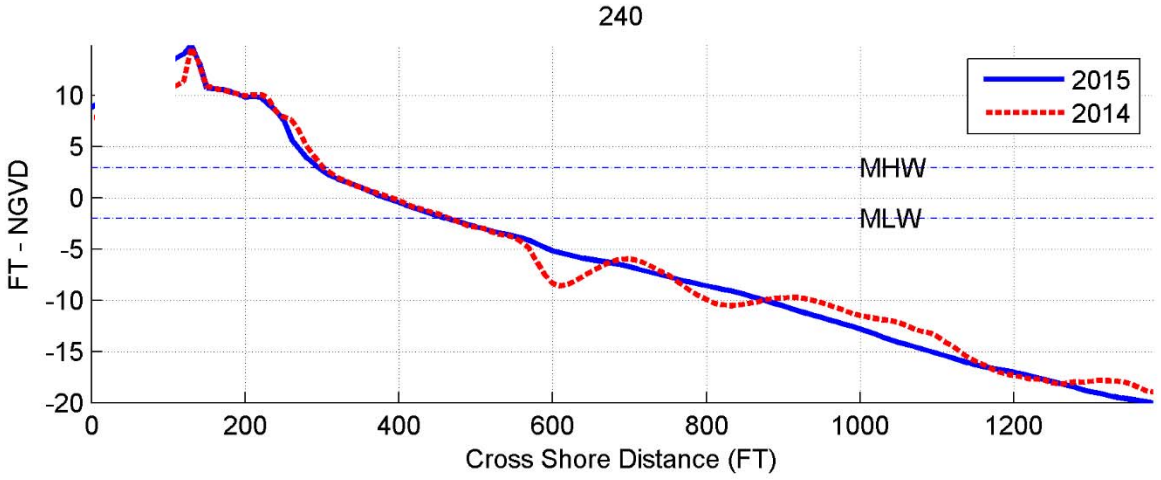

190
2015
2014
~Stable
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

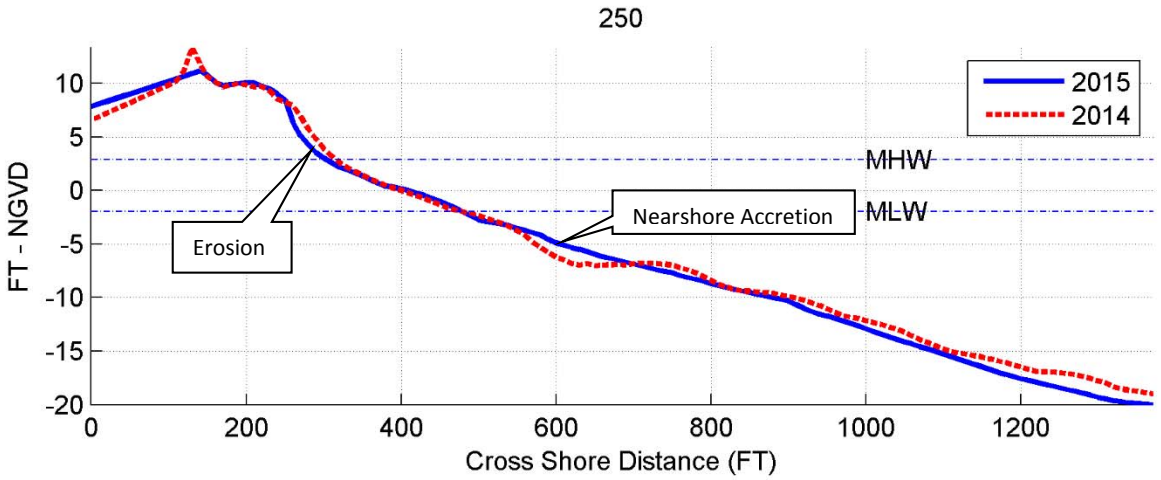

200
2015
2014
~Stable
MHW
MLW
Intertidal Accretion
FT - NGVD
Cross Shore Distance (FT)

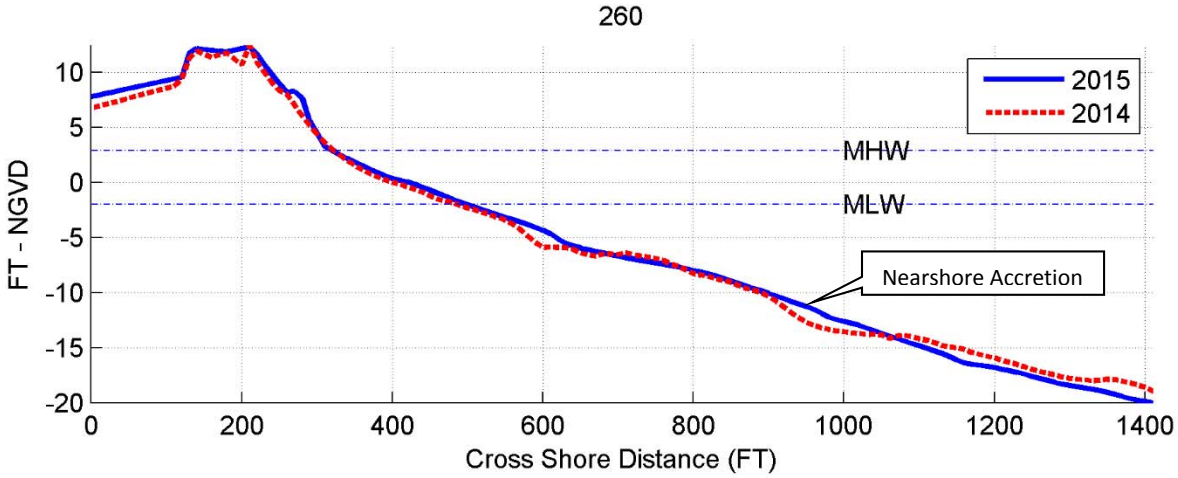

210
2015
2014
Erosion
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

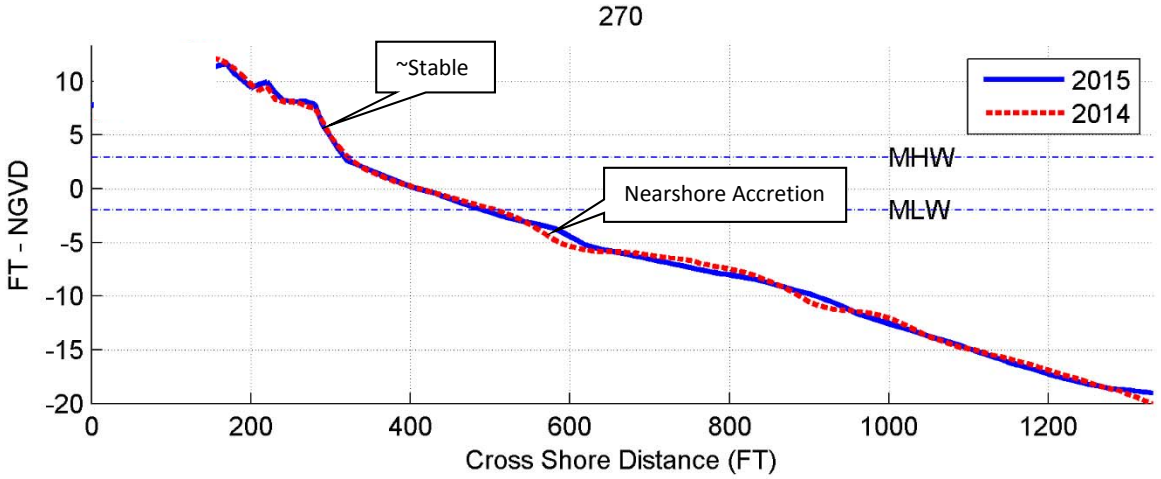

220
2015
2014
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

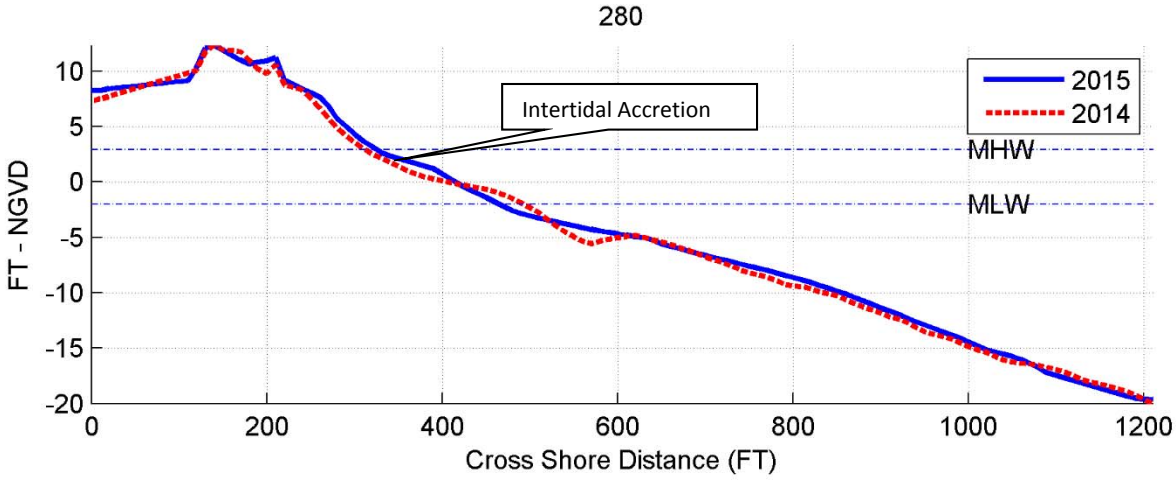

230
2015
2014
~Stable
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

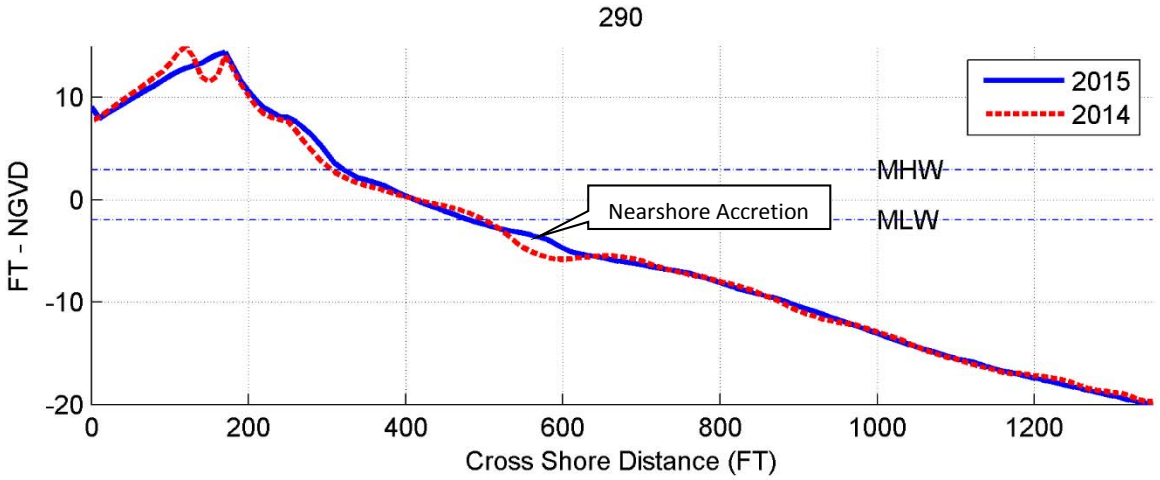

240
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

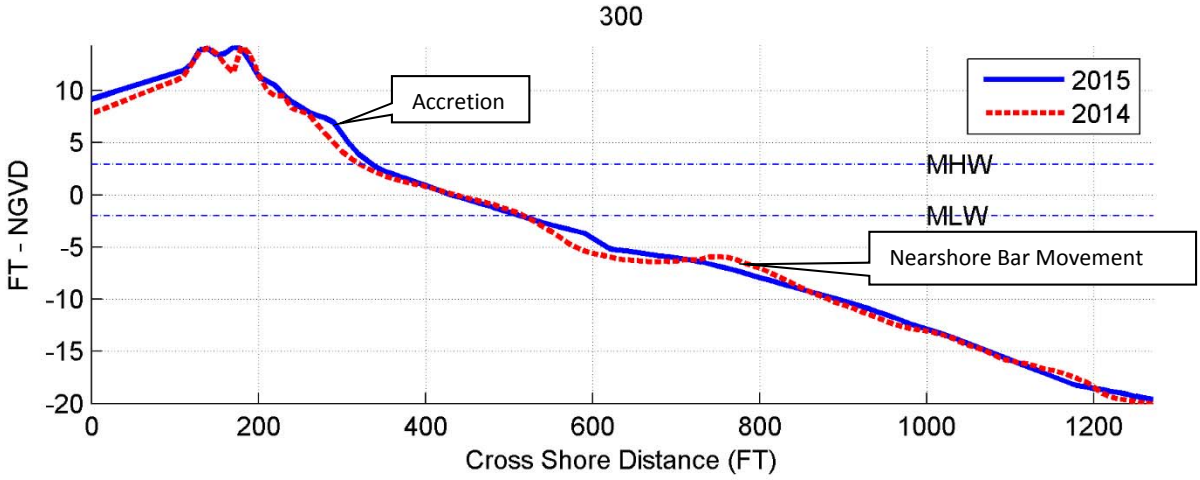

250
2015
2014
MHW
MLW
Erosion
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

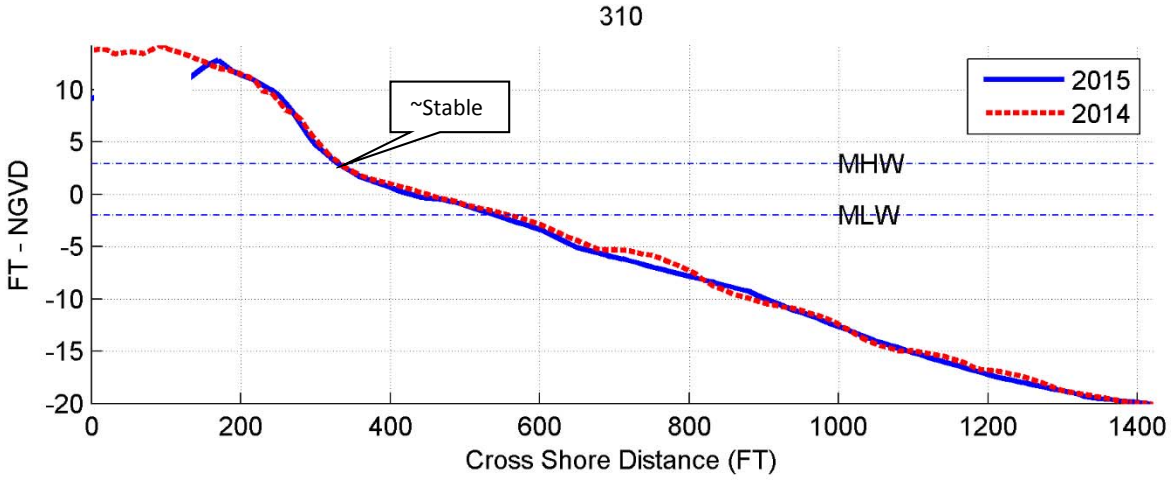

260
2015
2014
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

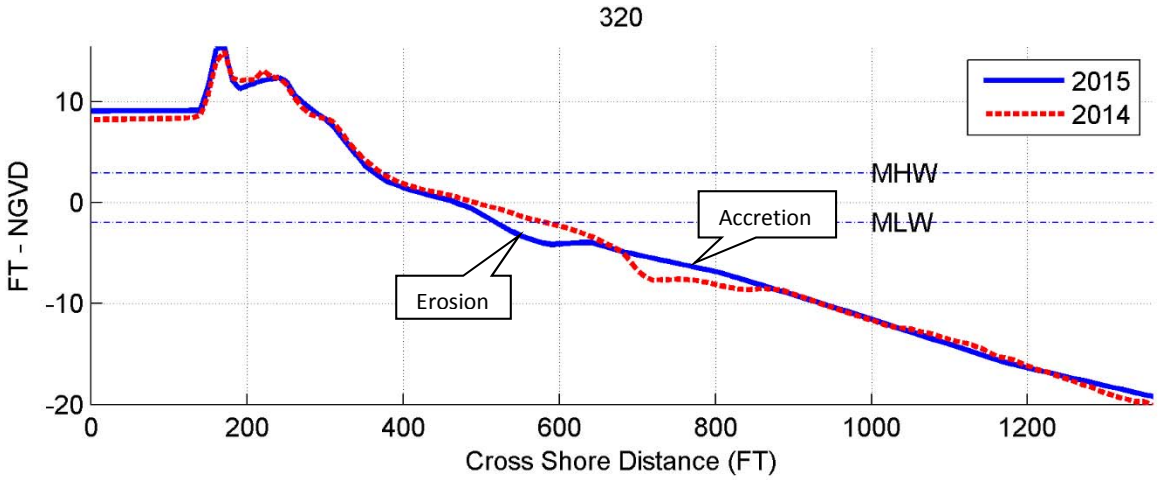

270
~Stable
2015
2014
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)


280
Intertidal Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

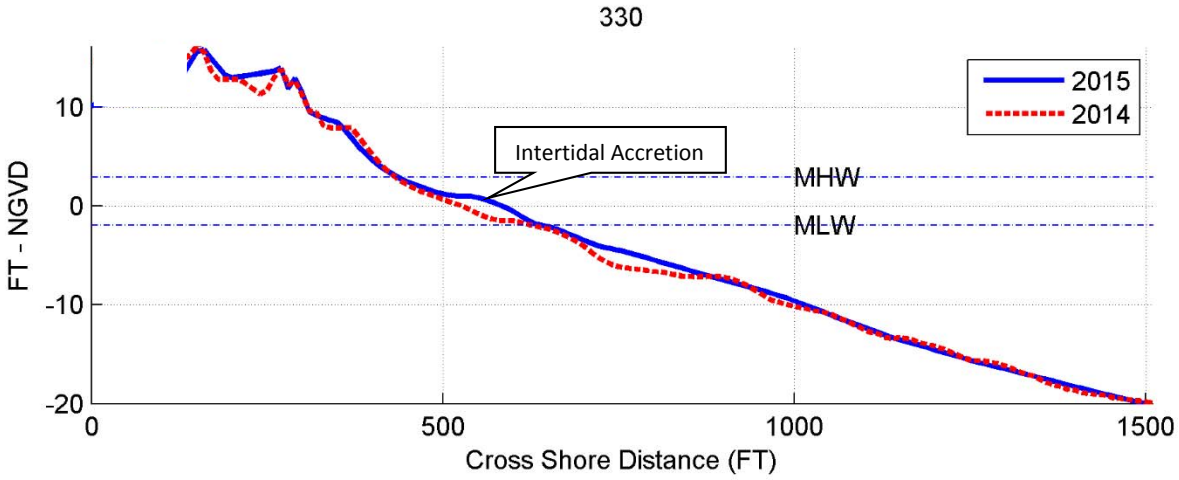

290
Nearshore Accretion
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

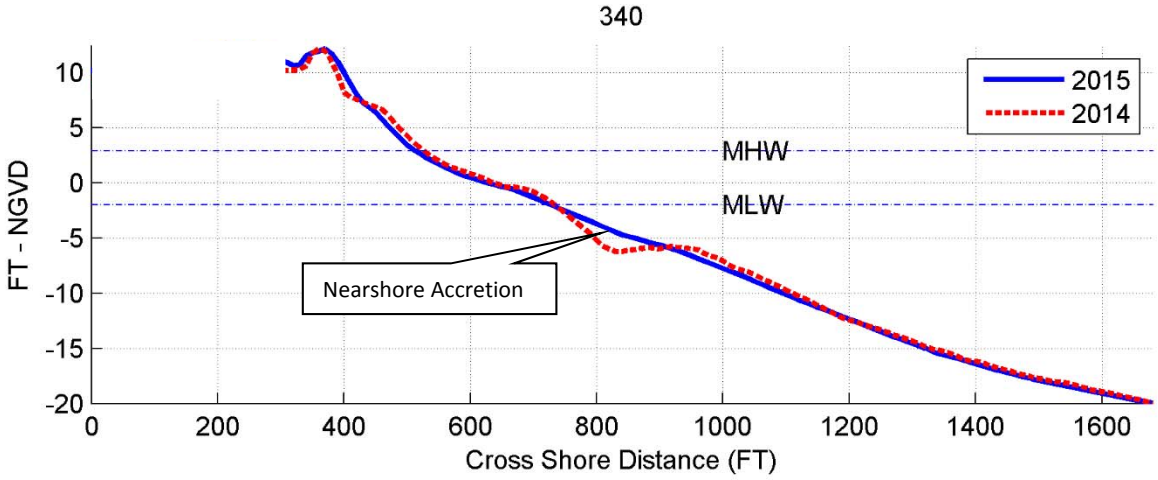

300
Accretion
Nearshore Bar Movement
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

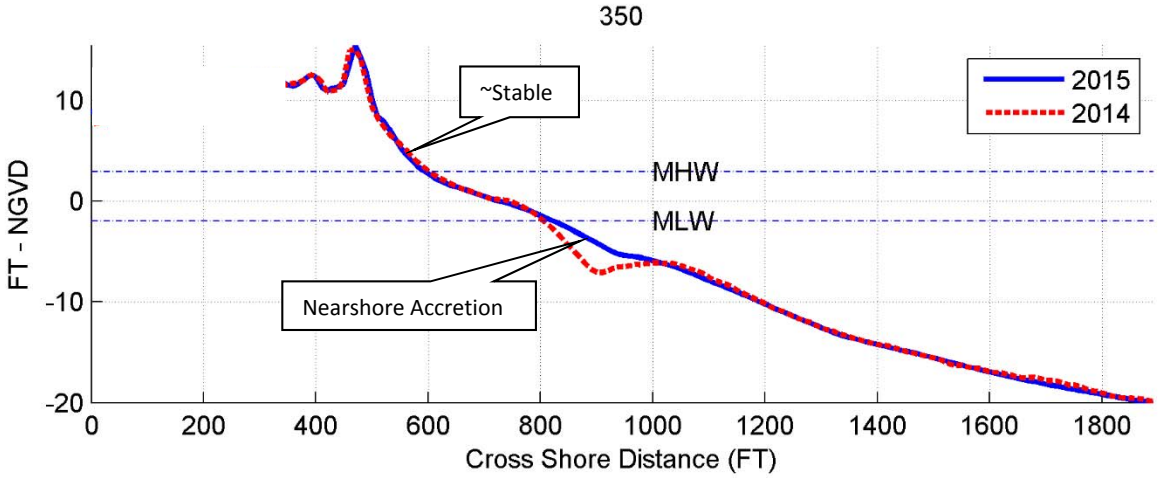


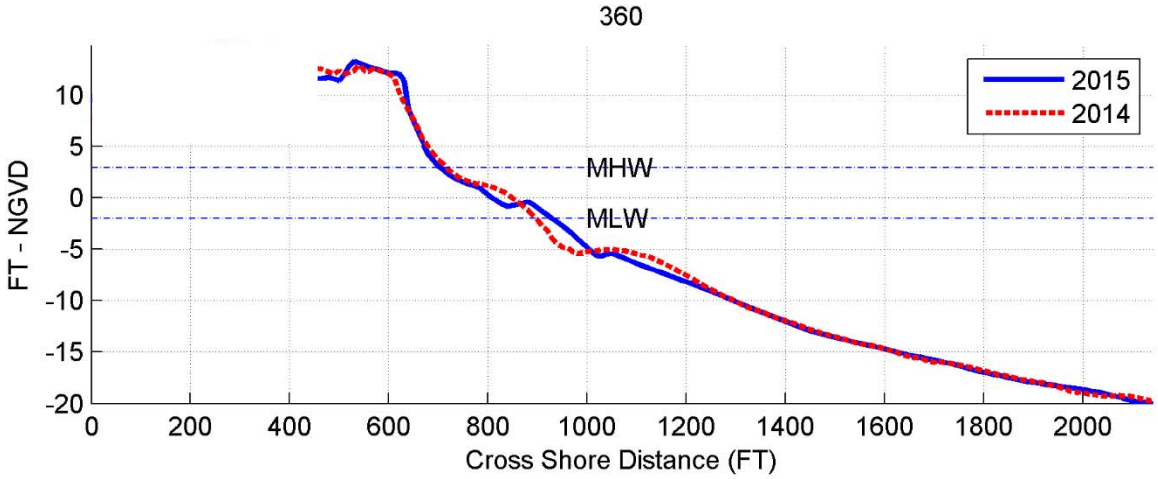


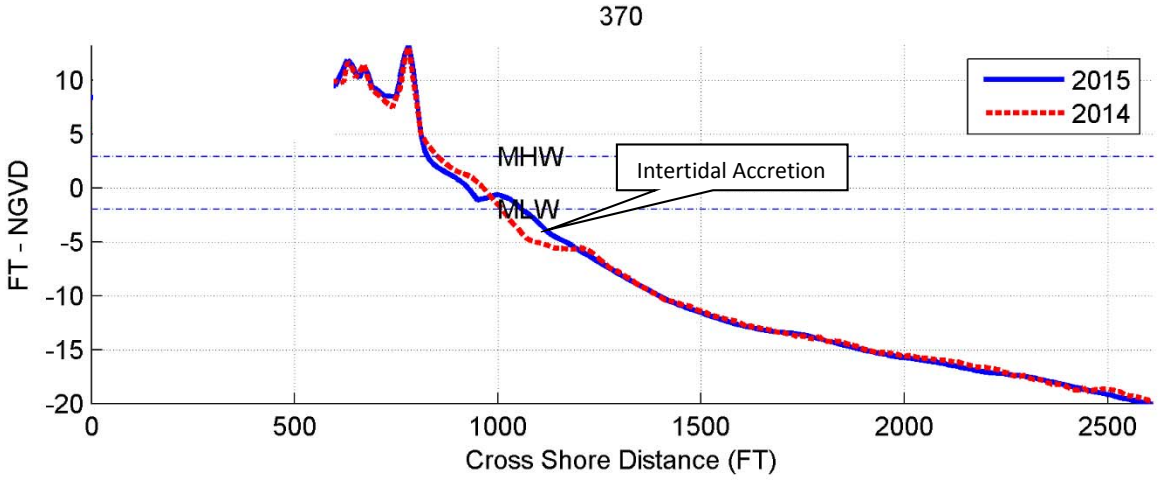
Station 320+00. Cross shore transport from intertidal zone to nearshore region.

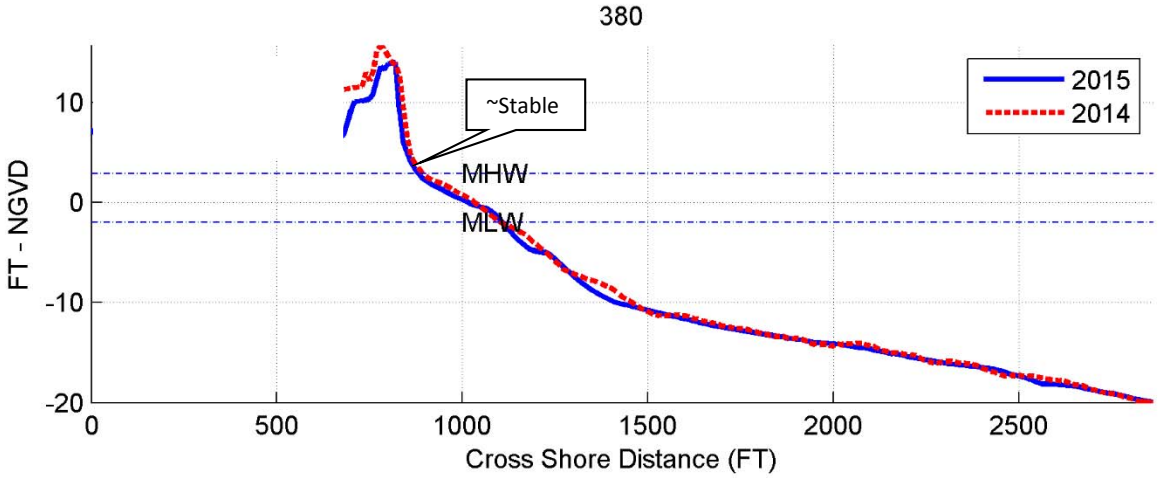


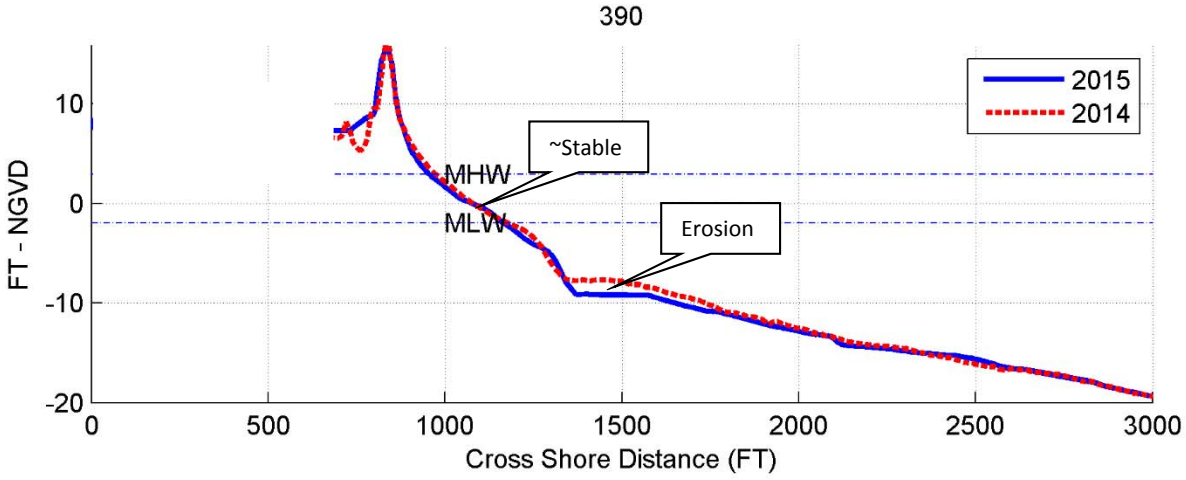

340
2015
2014
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

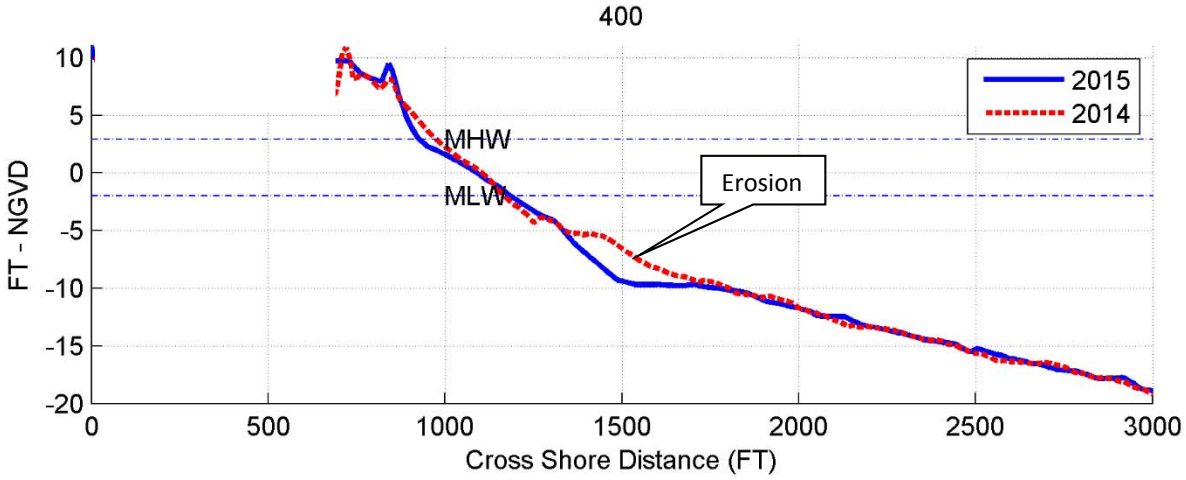

350
2015
2014
~Stable
MHW
MLW
Nearshore Accretion
FT - NGVD
Cross Shore Distance (FT)

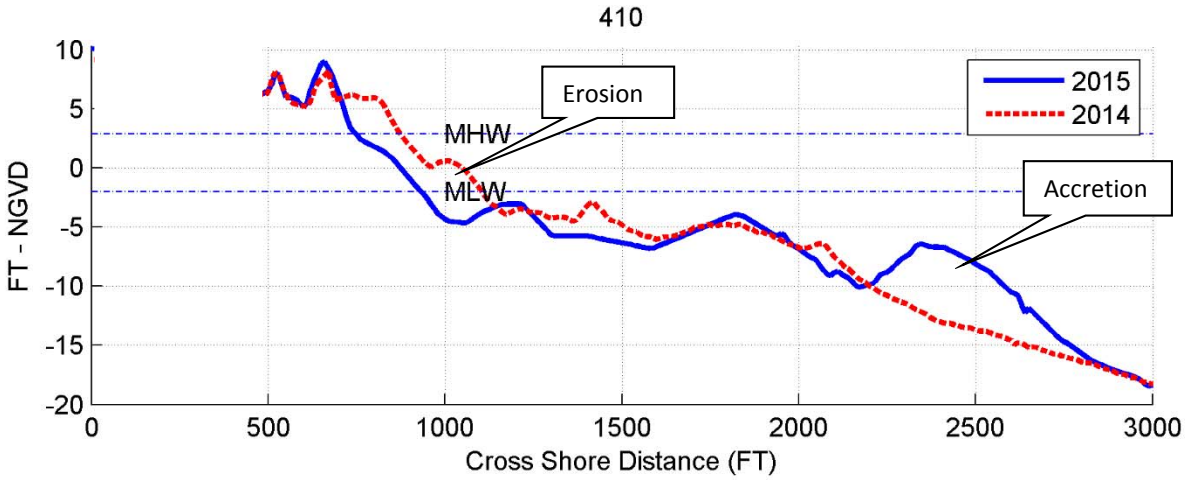

360
2015
2014
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)

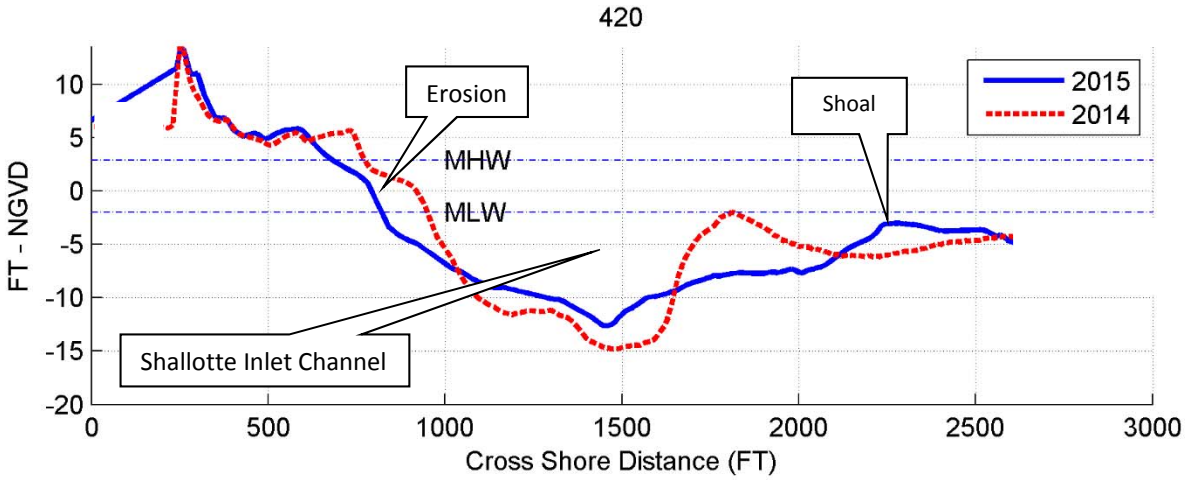

370
2015
2014
MHW
MLW
Intertidal Accretion
FT - NGVD
Cross Shore Distance (FT)

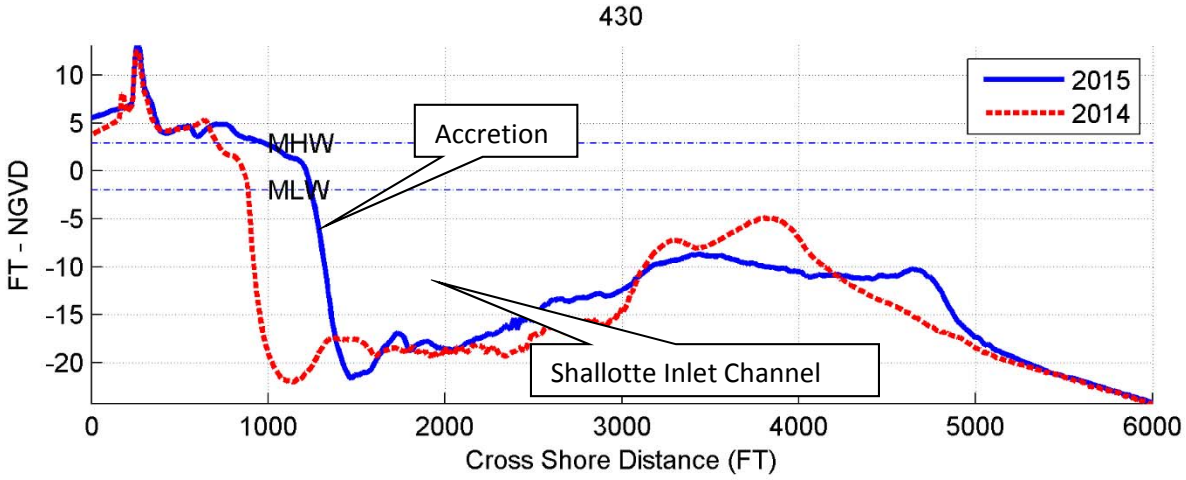

380
2015
2014
~Stable
MHW
MLW
FT - NGVD
Cross Shore Distance (FT)


390
2015
2014
~Stable
MHW
MLW
Erosion
FT - NGVD
Cross Shore Distance (FT)

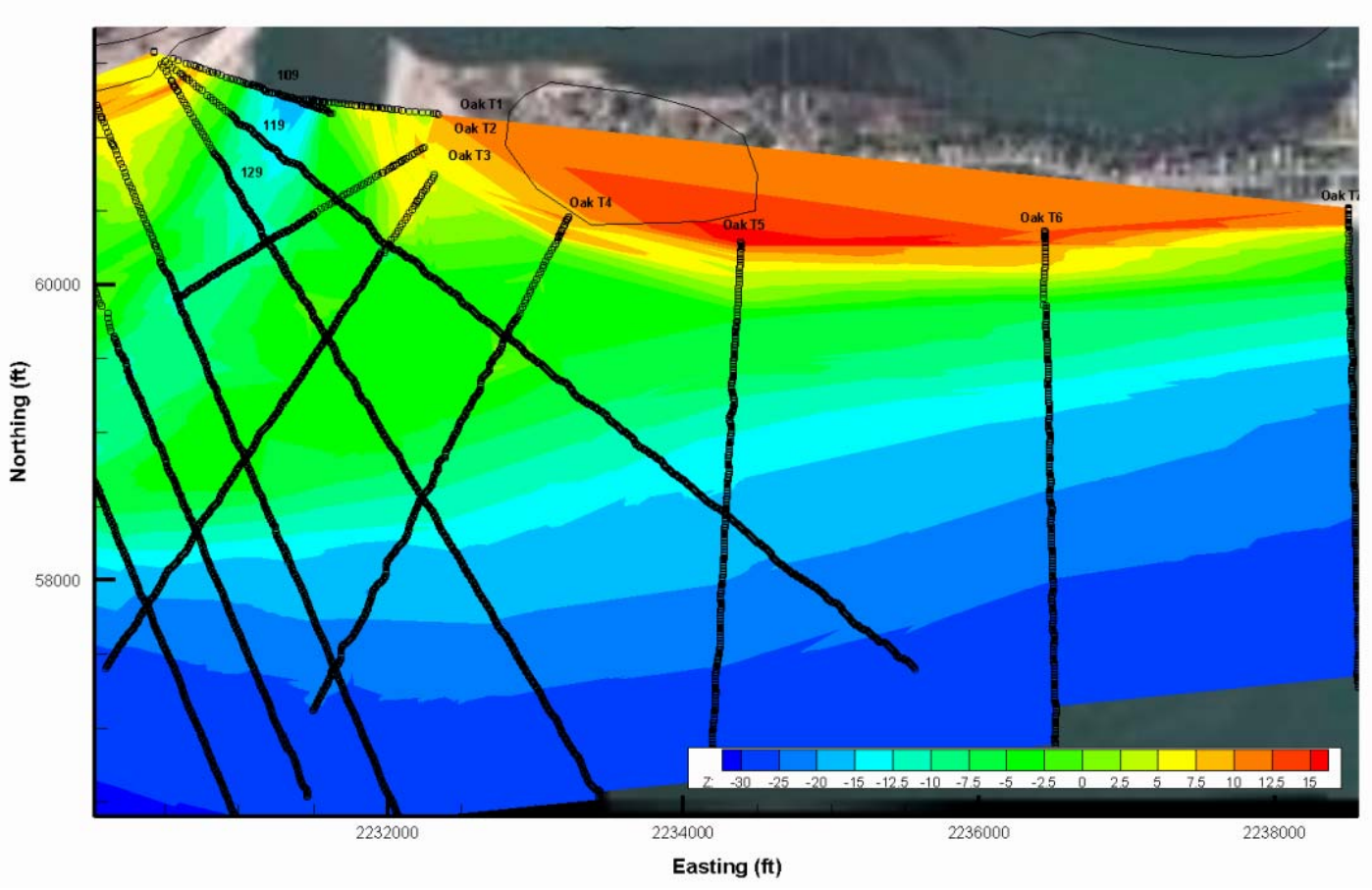

400
2015
2014
MHW
MLW
Erosion
FT - NGVD
Cross Shore Distance (FT)


410
2015
2014
Erosion
MHW
MLW
Accretion
FT - NGVD
Cross Shore Distance (FT)

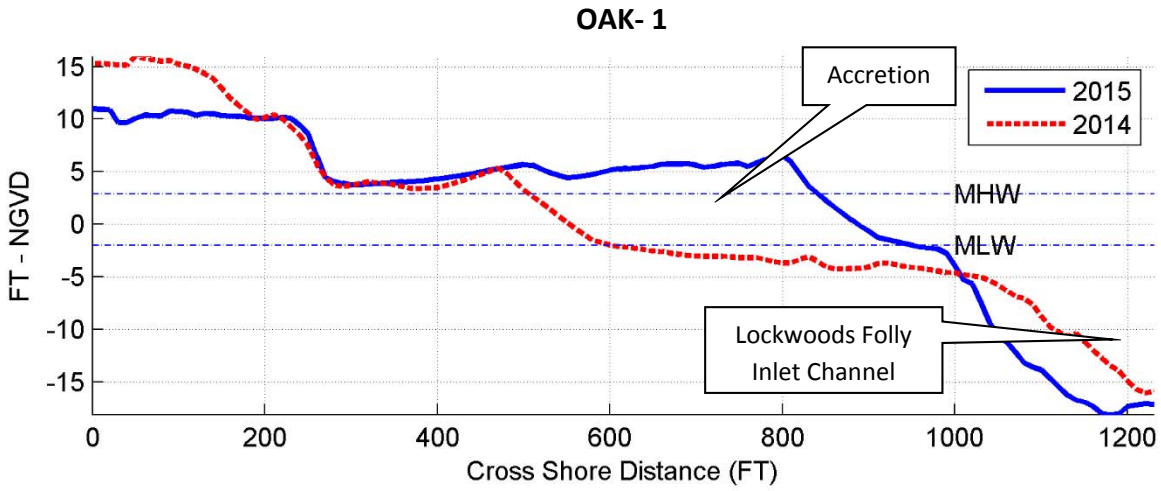

420
2015
2014
Erosion
Shoal
MHW
MLW
Shallotte Inlet Channel
FT - NGVD
Cross Shore Distance (FT)



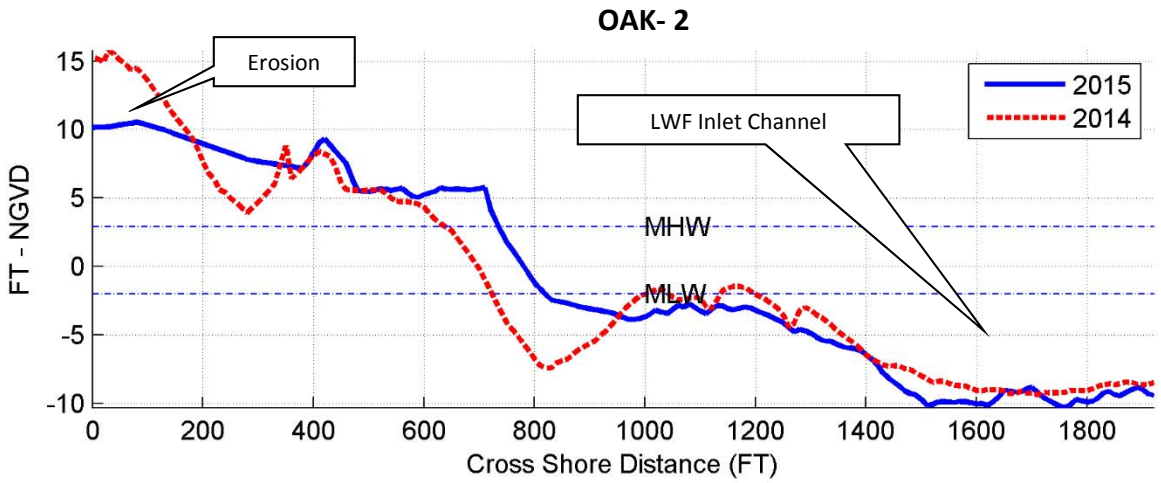
Station 430+00. Shallotte Inlet Channel migrating away from Holden Beach

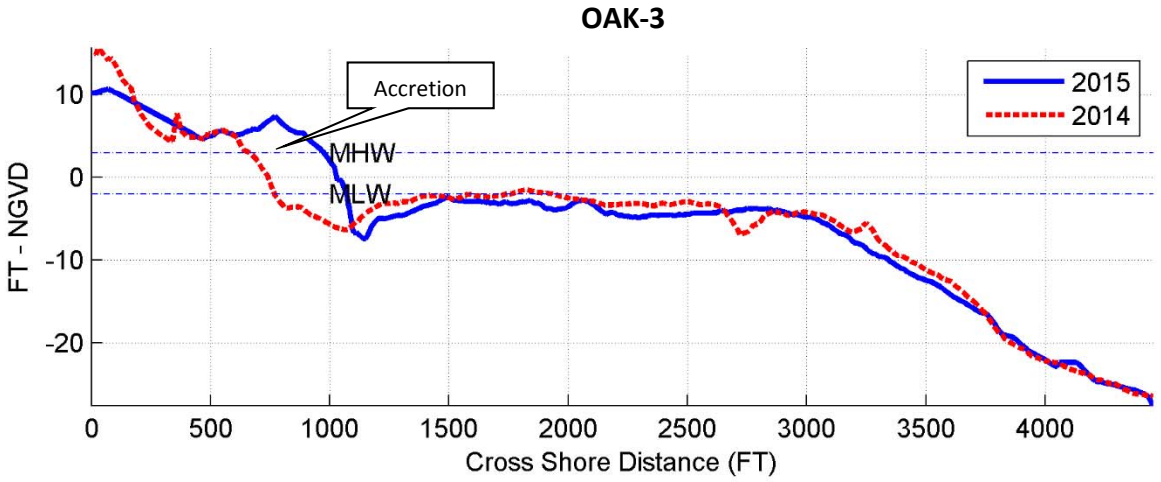


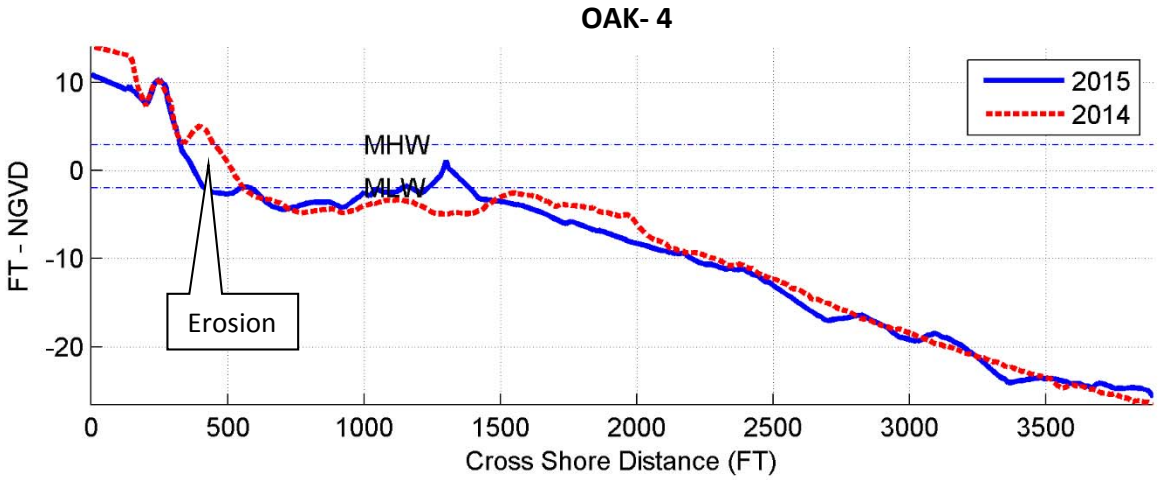
Oak Island Transects

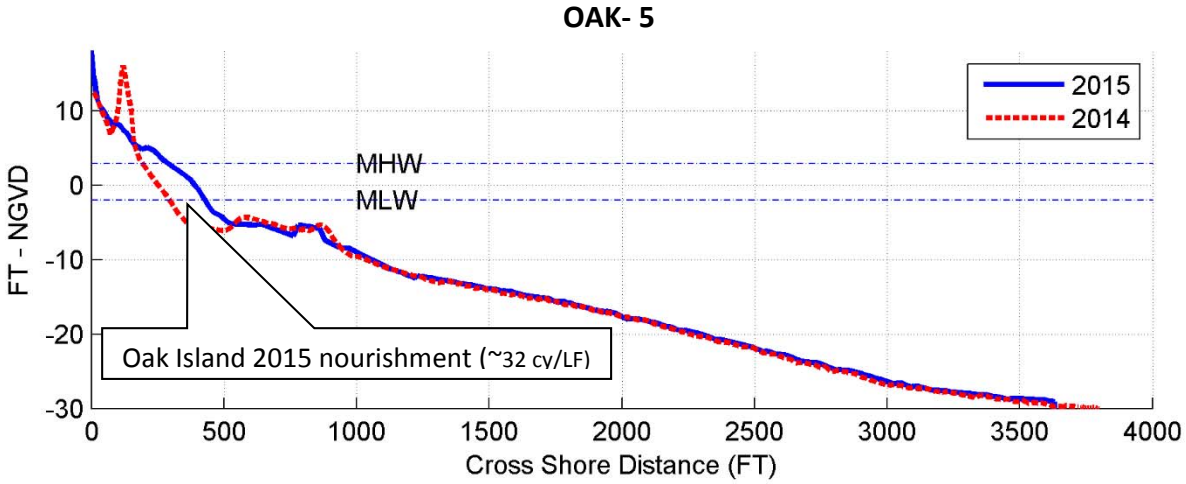


Station OAK- 1. Note LWF Inlet Channel moving toward Oak Island. Some significant accretion is seen.



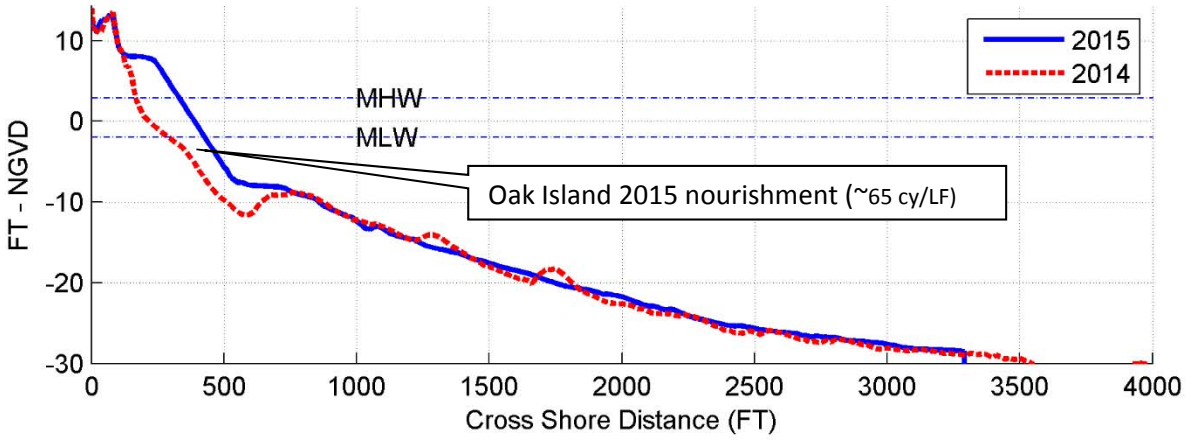






Station OAK- 5. Note accretion in the upper beach and intertidal region due to the Eastern Channel Dredging/ Beach Nourishment Project completed in April of 2015.

OAK- 6


2015
2014
MHW
MLW
Oak Island 2015 nourishment (~65 cy/LF)
FT - NGVD
Cross Shore Distance (FT)
10
0
-10
-20
-30
0
500
1000
1500
2000
2500
3000
3500
4000

OAK- 7

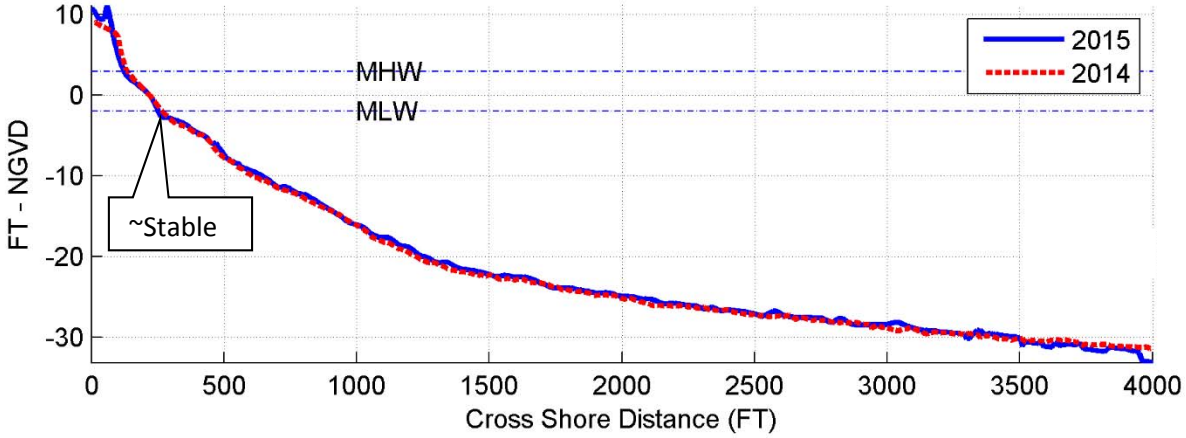

2015
2014
MHW
MLW
~Stable
FT - NGVD
Cross Shore Distance (FT)
10
0
-10
-20
-30
0
500
1000
1500
2000
2500
3000
3500
4000

TABLE A-1: 2014 to 2015 Survey Transect Analysis

General Note - Transects are primarily oceanfront perpendicular and parallel except for inlets and inlet shoulder transects

Unit Volume (cy/ft) changes at inlet and inlet shoulder transects cannot use "average end" method for calculating volumes

MHW change at inlet and inlet shoulder is not necessarily perpendicular to the shoreline due to variable orientation

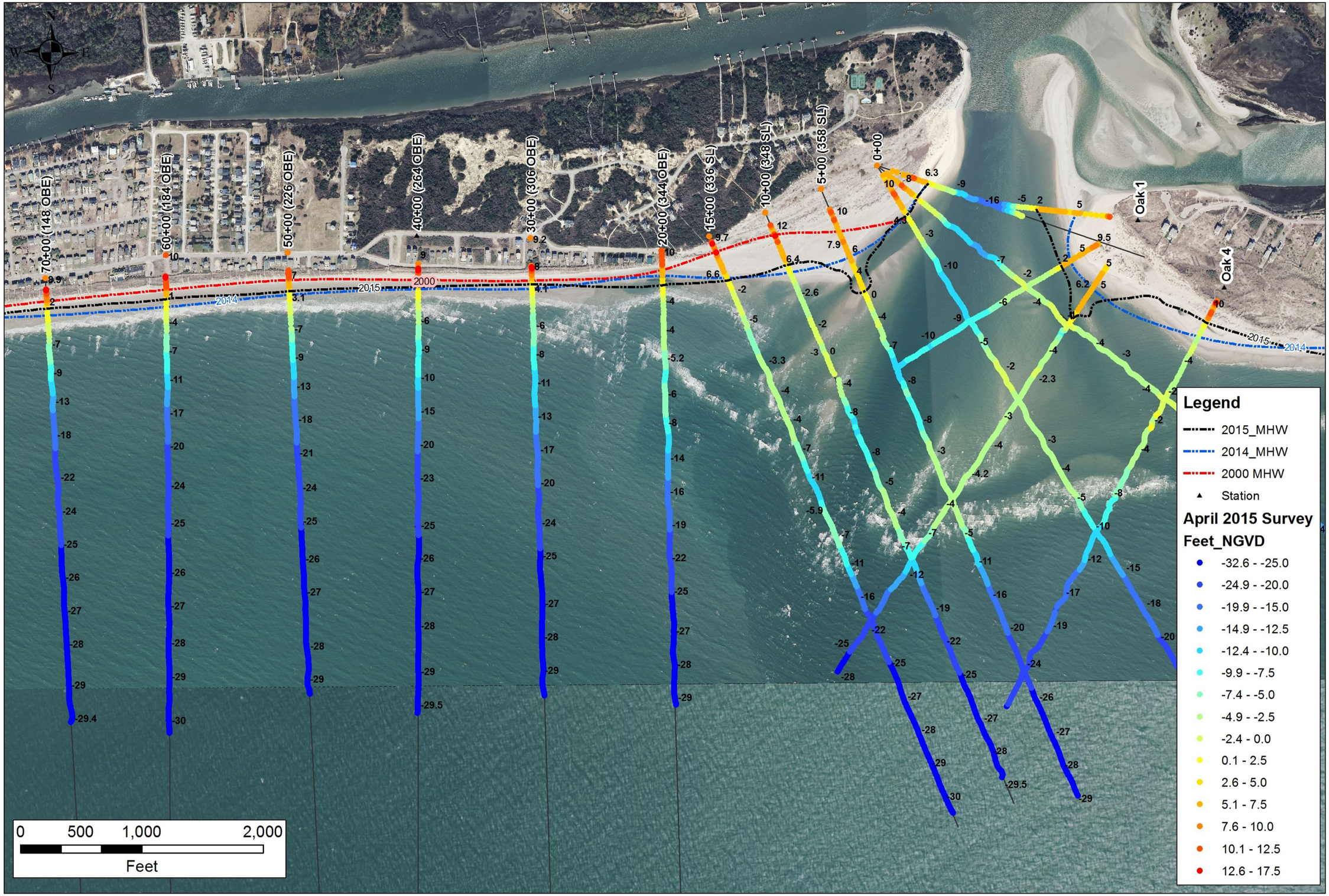
*all elevations relative to NGVD29

2014 to 2015 Survey Analysis					
STATION	**Distance to Next Monument (ft)**	**Volume Change (cy/ft) (Dune to -12 ft*)**	**Volume Change (cy/ft) (Dune to -5 ft)**	**MHW Change (ft)**	**Notes**
109+00	0	10.4	4.0	4.7	LWF Inlet
119+00	0	2.0	-5.2	-1.1	LWF Inlet
129+00	500	3.3	-6.9	9.7	LWF Inlet
5+00	500	51.9	61.0	303.4	LWF Inlet Shoulder
10+00	500	-43.2	-37.6	-66.5	LWF Inlet Shoulder
15+00	440	-12.7	-0.6	17.2	LWF Inlet Shoulder
20+00	1000	68.7	20.7	73.1	Oceanfront Perpendicular
30+00	1000	-36.7	-28.9	-37.0	
40+00	1000	6.0	-5.4	-18.9	
50+00	1000	-3.3	-6.8	-32.3	
60+00	1000	-9.7	-20.5	-68.0	
70+00	1000	-26.3	-24.8	-61.1	
80+00	1000	10.0	-1.4	2.0	
90+00	1000	2.8	2.1	3.2	
100+00	1000	-4.9	-10.6	-18.6	
110+00	1000	10.6	4.0	20.0	
120+00	1000	11.5	6.1	30.0	
130+00	1000	3.1	-1.6	-7.7	
140+00	1000	3.1	1.5	14.2	
150+00	1000	-0.1	-5.6	-7.7	
160+00	1000	9.7	4.9	9.4	
170+00	1000	-6.1	-9.3	-29.2	
180+00	1000	4.5	0.3	4.9	
190+00	1000	3.3	3.2	14.5	
200+00	1000	7.1	8.5	10.9	
210+00	1000	5.5	-6.3	-7.4	

220+00	1000	4.7	-3.3	-11.2	
230+00	1000	7.3	4.3	-3.7	
240+00	1000	2.7	-2.0	-6.0	
250+00	1000	-2.3	-1.8	-11.7	
260+00	1000	11.7	8.2	-0.9	
270+00	1000	-0.8	0.4	-6.0	
280+00	1000	9.2	4.7	12.6	
290+00	1000	9.9	8.6	16.0	
300+00	1000	9.1	8.3	14.6	
310+00	1000	-6.6	-3.6	-2.3	
320+00	1000	-2.6	-11.6	-8.6	
330+00	1000	15.5	9.1	3.8	
340+00	1000	0.2	1.4	-13.0	
350+00	1000	8.5	4.1	-7.4	
360+00	1000	-2.1	3.5	-12.1	
370+00	1000	5.0	5.3	-27.0	
380+00	1000	-18.2	-12.9	-13.1	
390+00	1000	-21.3	-4.1	-20.3	
400+00	1000	-16.4	9.4	-46.8	Oceanfront perpendicular
410+00	1000	-16.0	-53.5	-124.3	Shallotte Inlet Shoulder
420+00	1000	-73.3	-36.1	-87.7	Shallotte Inlet
430+00	-	77.5	54.6	268.5	Shallotte Inlet
	OAK ISLAND TRANSECTS				
OAK 1	0	82.5	98.2	331.3	LWF Inlet
OAK 2	0	32.4	41.0	87.0	LWF Inlet
OAK 3	890	41.2	62.3	302.1	LWF Inlet
OAK 4	1100	-33.2	-1.1	-134.4	LWF Inlet Shoulder
OAK 5	2000	33.4	32.0	94.3	Oceanfront perpendicular
OAK 6	2000	100.1	67.2	163.1	
OAK 7	-	4.1	-0.2	-16.9	

Appendix B

2015 Survey Plan View Figures



APPLIED TECHNOLOGY & MANAGEMENT

FIGURE B-1
April 2015 Survey Data. 2015 Mean High Water (MHW) Shoreline, 2014 MHW Shoreline and 2000 MHW Shoreline on 2014 Aerial

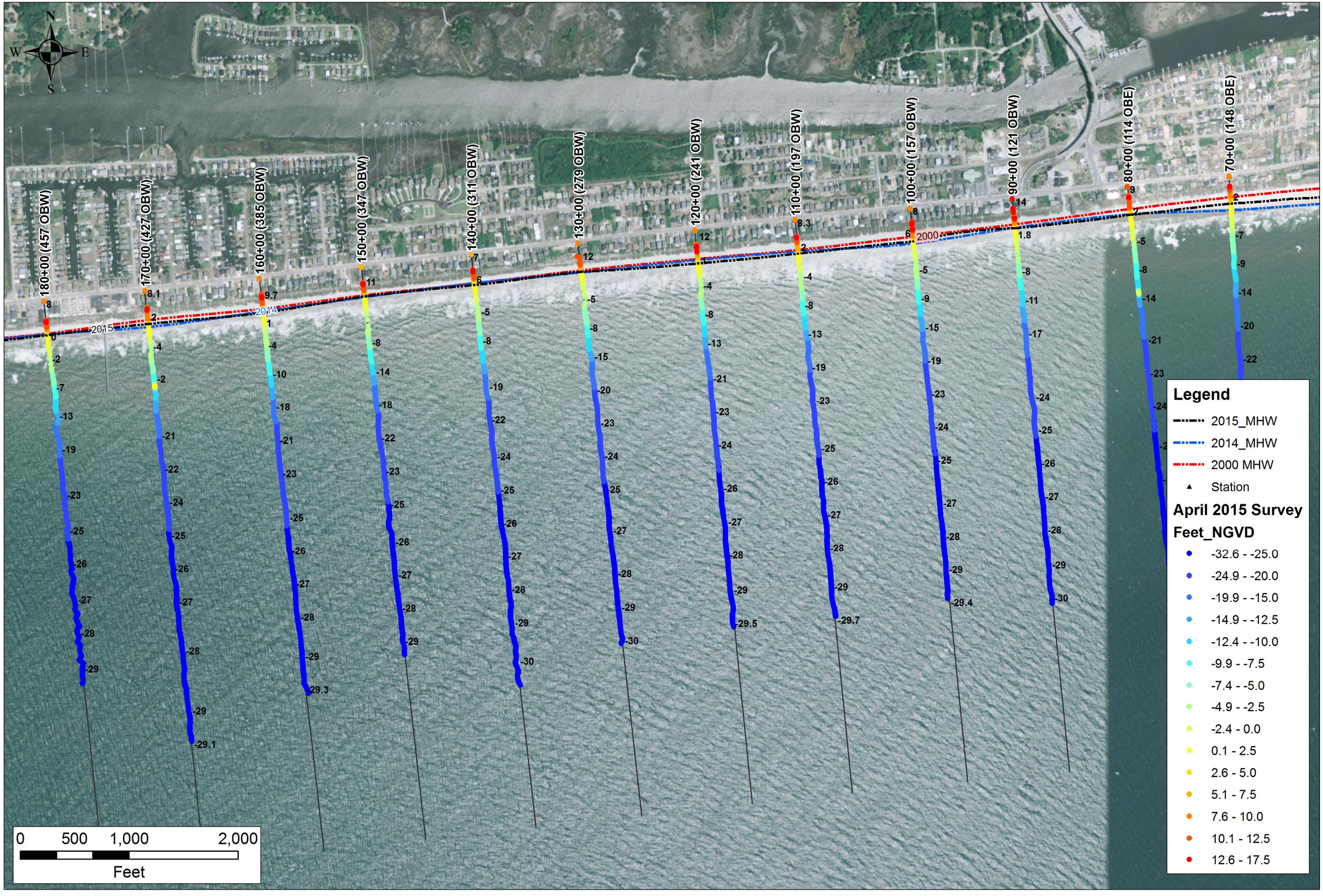
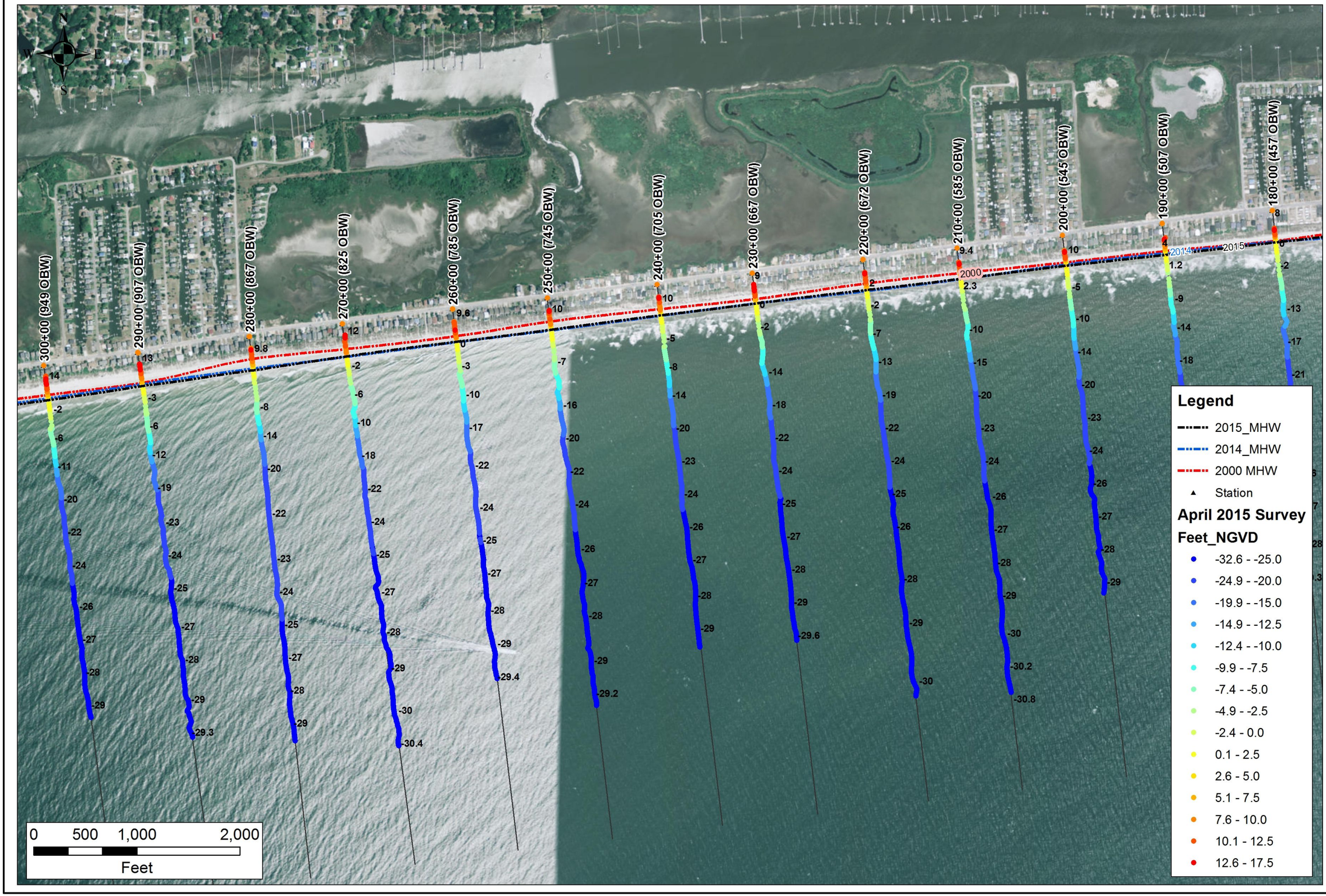
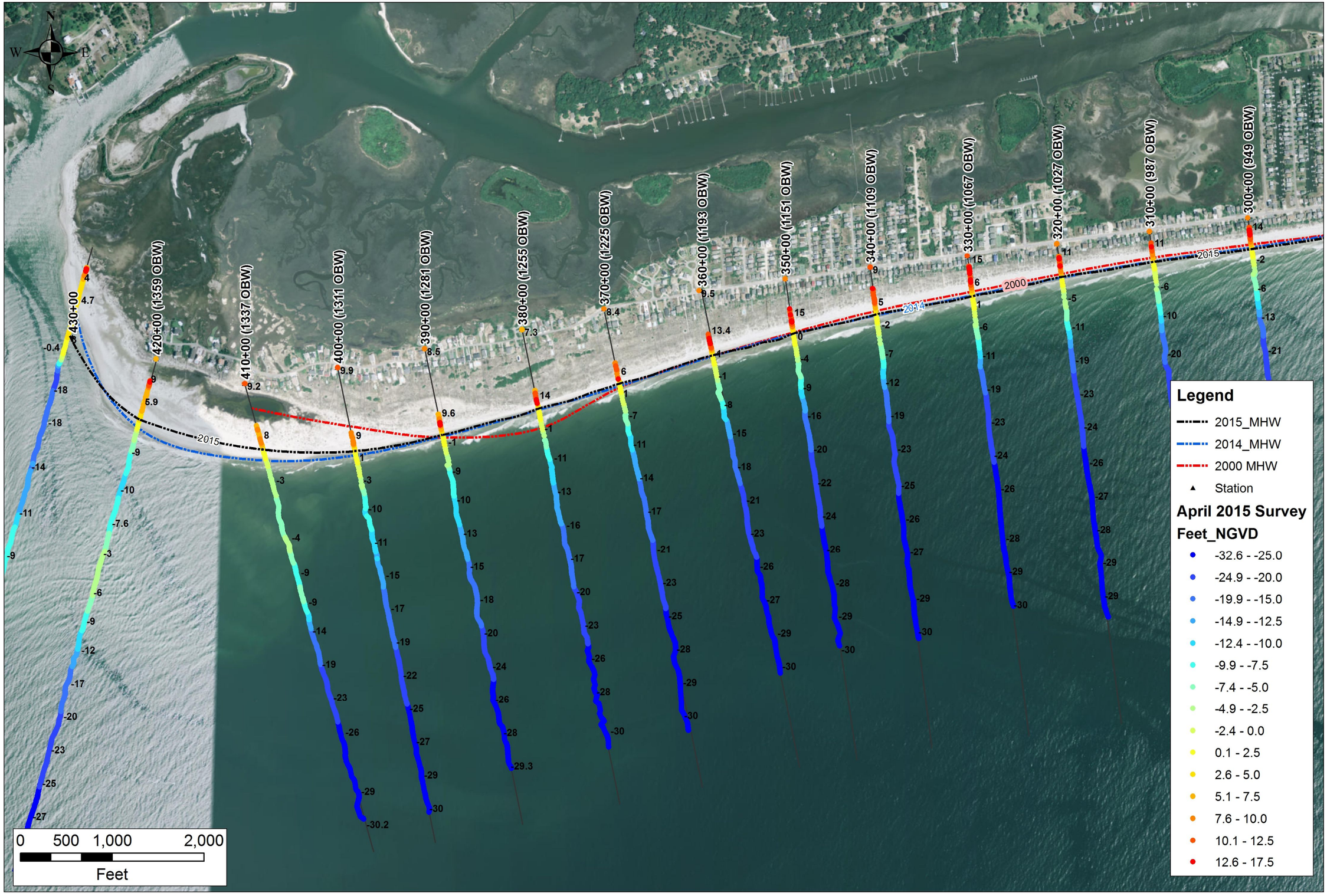


FIGURE B-2
April 2015 Survey Data. 2015 Mean High Water (MHW) Shoreline, 2014 MHW Shoreline and 2000 MHW Shoreline on 2014 Aerial



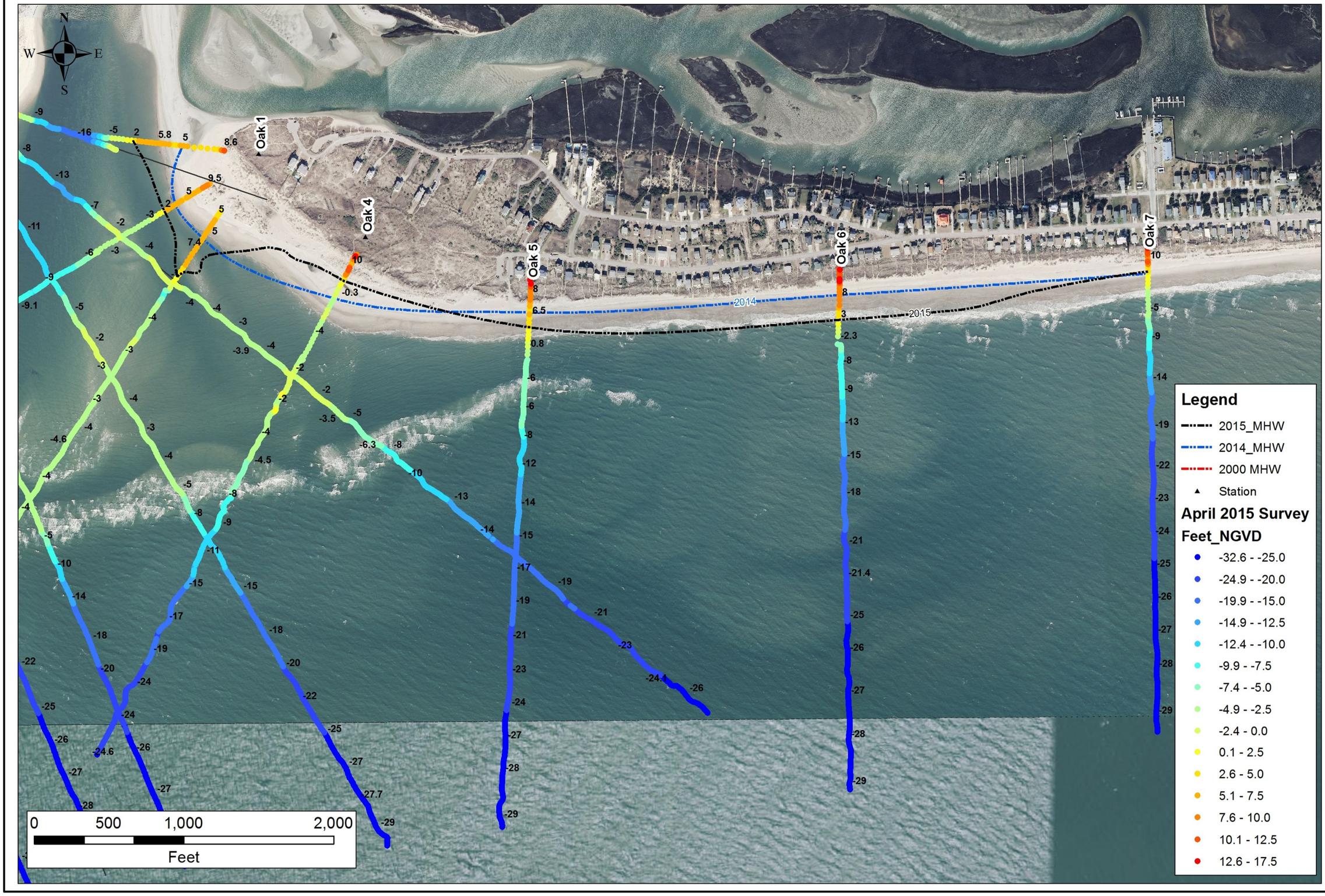
APPLIED TECHNOLOGY & MANAGEMENT

FIGURE B-3
April 2015 Survey Data. 2015 Mean High Water (MHW) Shoreline, 2014 MHW Shoreline and 2000 MHW Shoreline on 2014 Aerial



APPLIED TECHNOLOGY & MANAGEMENT

FIGURE B-4
April 2015 Survey Data. 2015 Mean High Water (MHW) Shoreline,
2014 MHW Shoreline and 2000 MHW Shoreline on 2014 Aerial



APPLIED TECHNOLOGY & MANAGEMENT

FIGURE B-5
April 2015 Survey Data. 2015 Mean High Water (MHW) Shoreline,
2014 MHW Shoreline and 2000 MHW Shoreline on 2014 Aerial

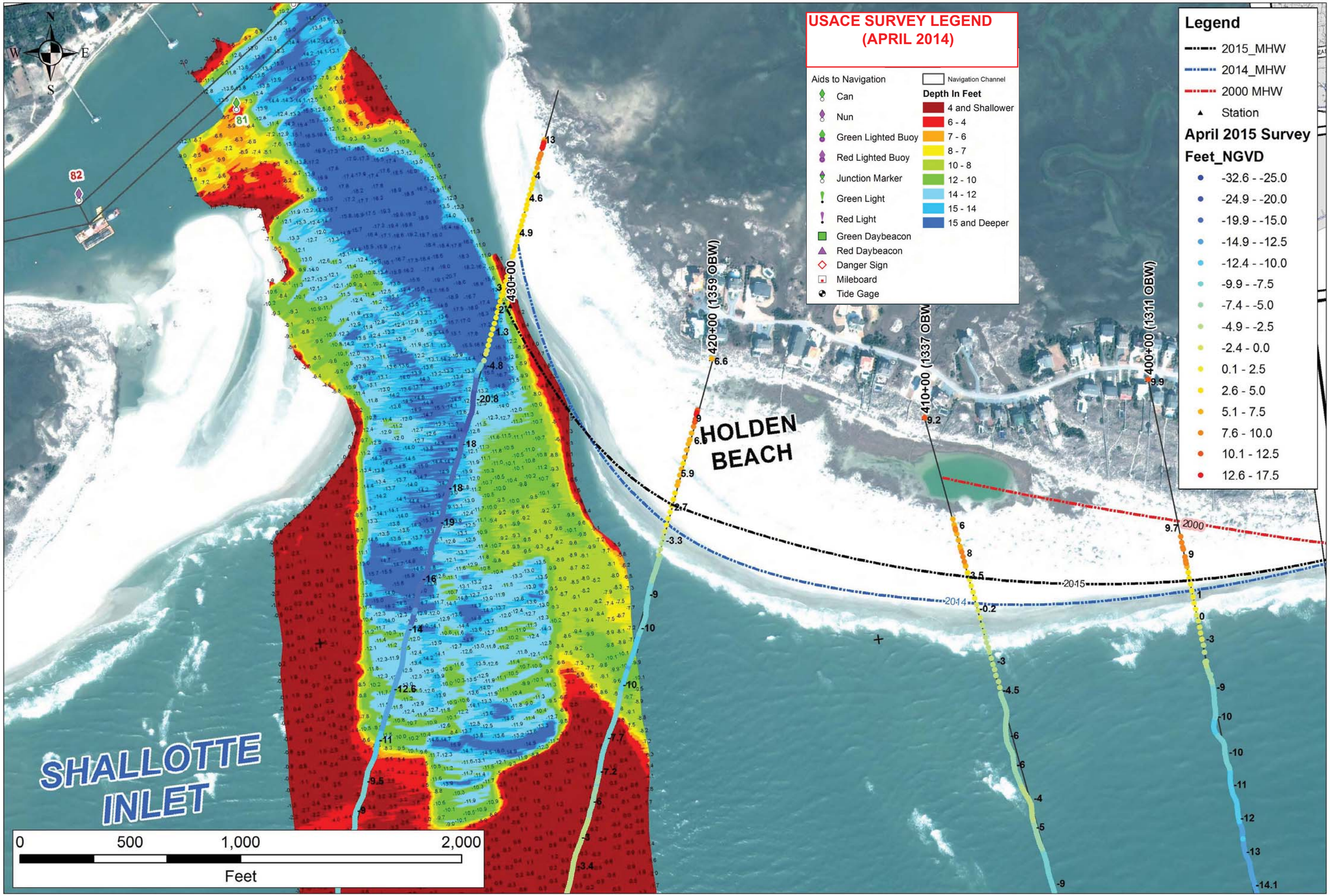


FIGURE B-6
April 2015 Survey Data. Most recent USACE Survey data shown on February, 2014 Aerial

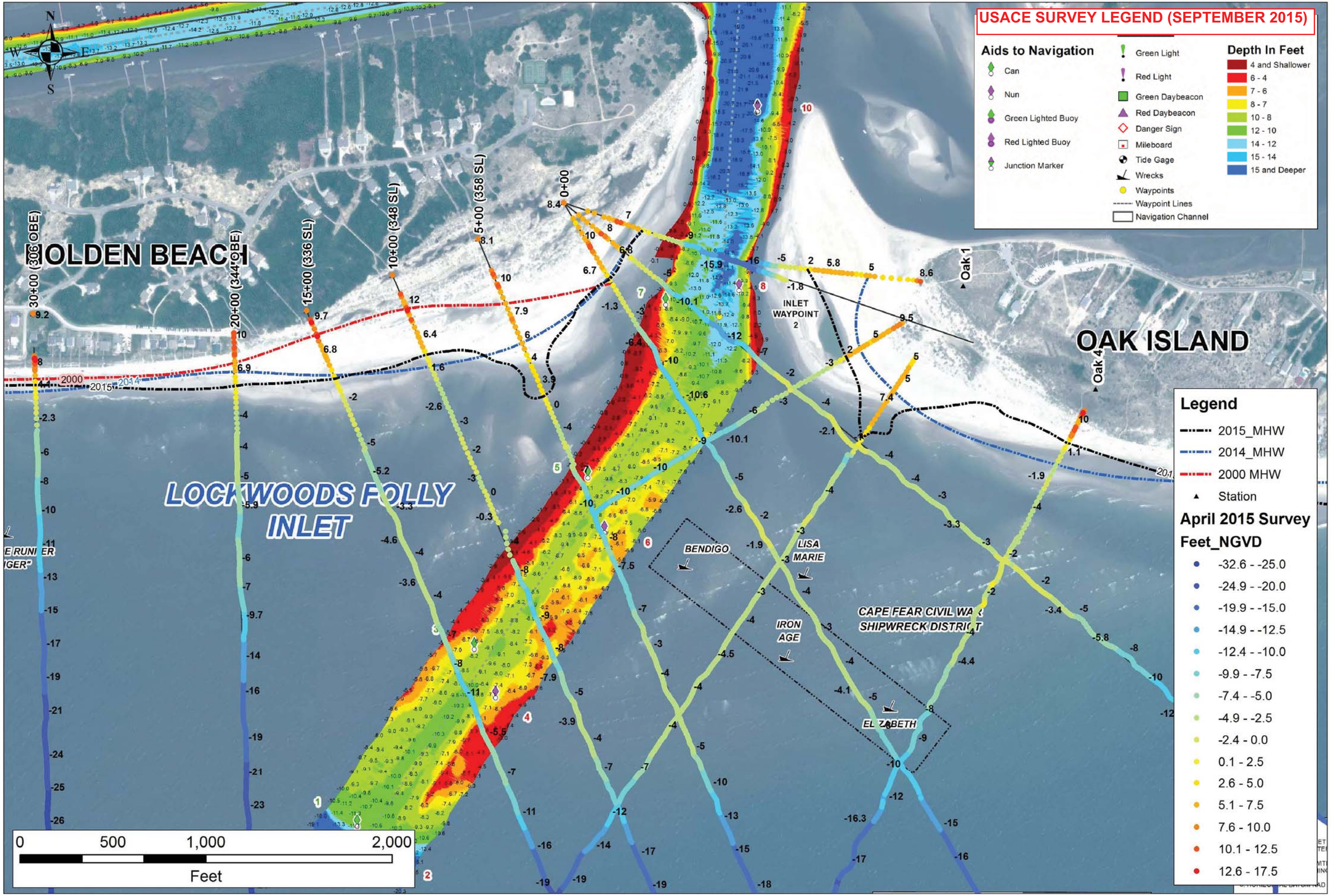


FIGURE B-7
April 2015 Survey Data. Most recent USACE Survey data shown on August, 2015 Aerial