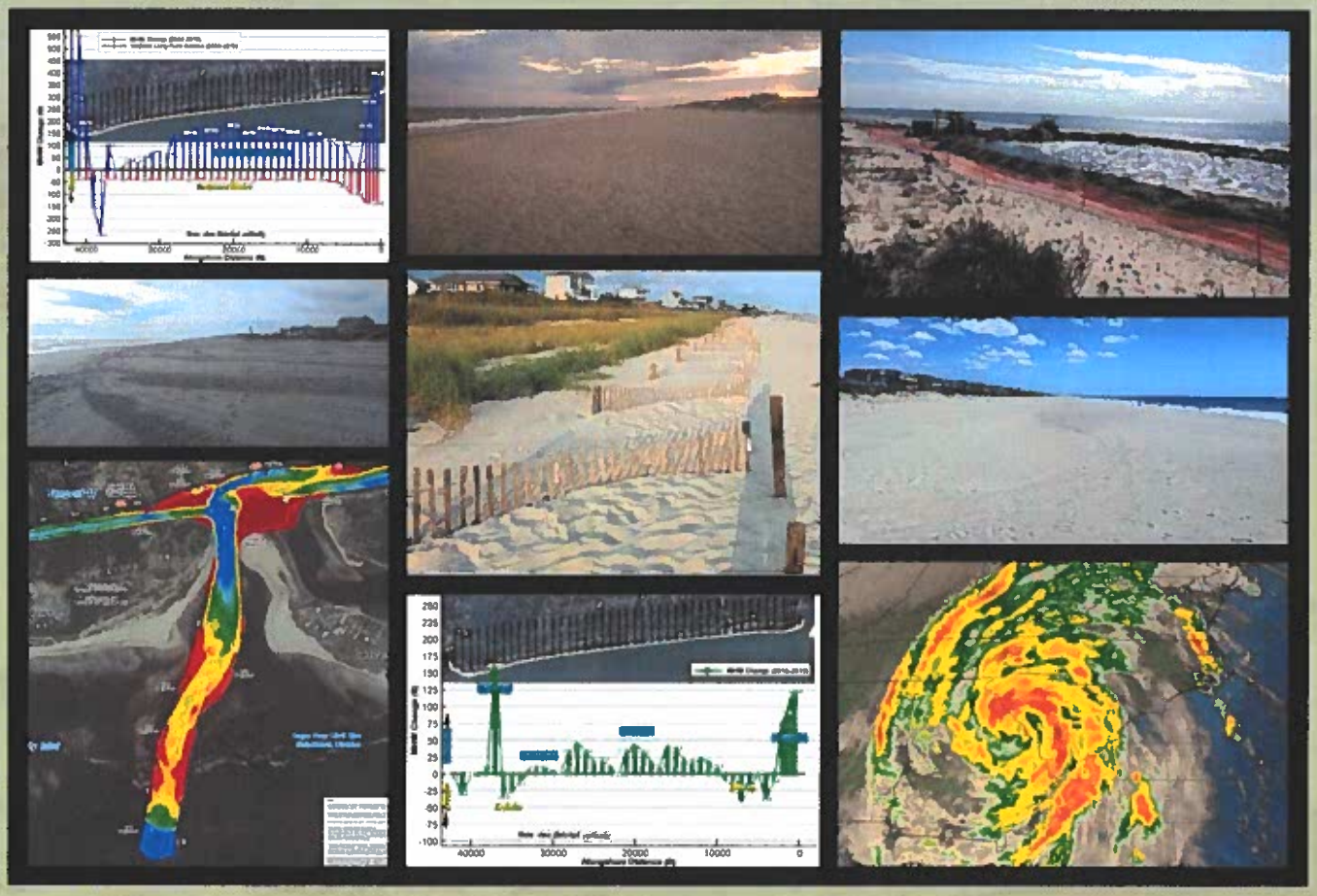
Holden Beach

Annual Beach Monitoring Report

Prepared For:
Town of Holden Beach, North Carolina



November 2019

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ATM

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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. 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.

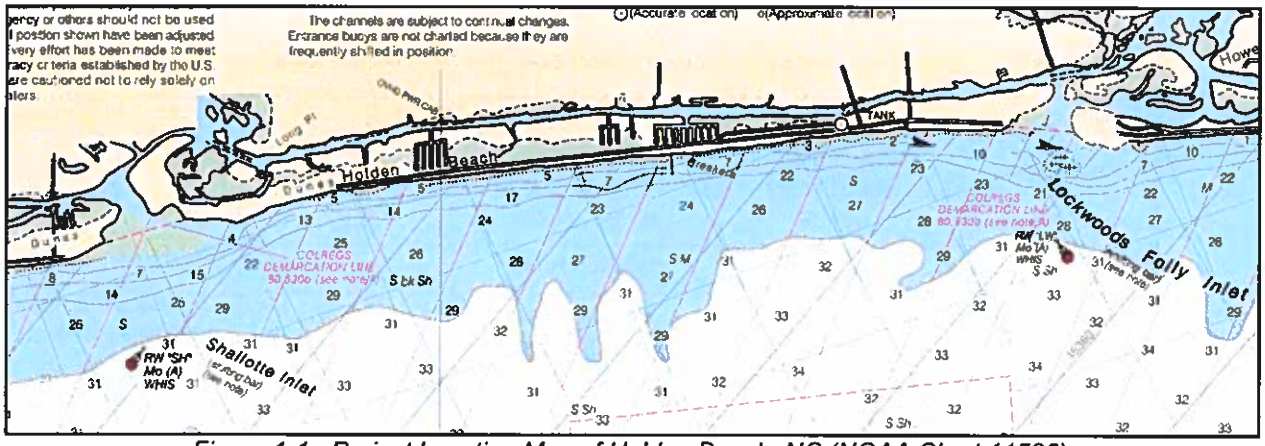

Figure 1-1. Project Location Map of Holden Beach, NC (NOAA Chart 11536)

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 2018 to 2019 beach management activities and compares the most recent survey (April 2019) with beach profile surveys collected from 2000 through 2018. 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 site 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 summarize nourishment activities and locations since 2001.

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
1/3/17 – 3/17/17	Town of Holden Beach	45+00 – 257+00	1,310,000	Offshore borrow area
March 2017	Town / USACE	20+00 – 45+00	120,000	Lockwood Folly Inlet crossing of AIWW
		Approximate Total Volume since 2001	**3,402,983**	

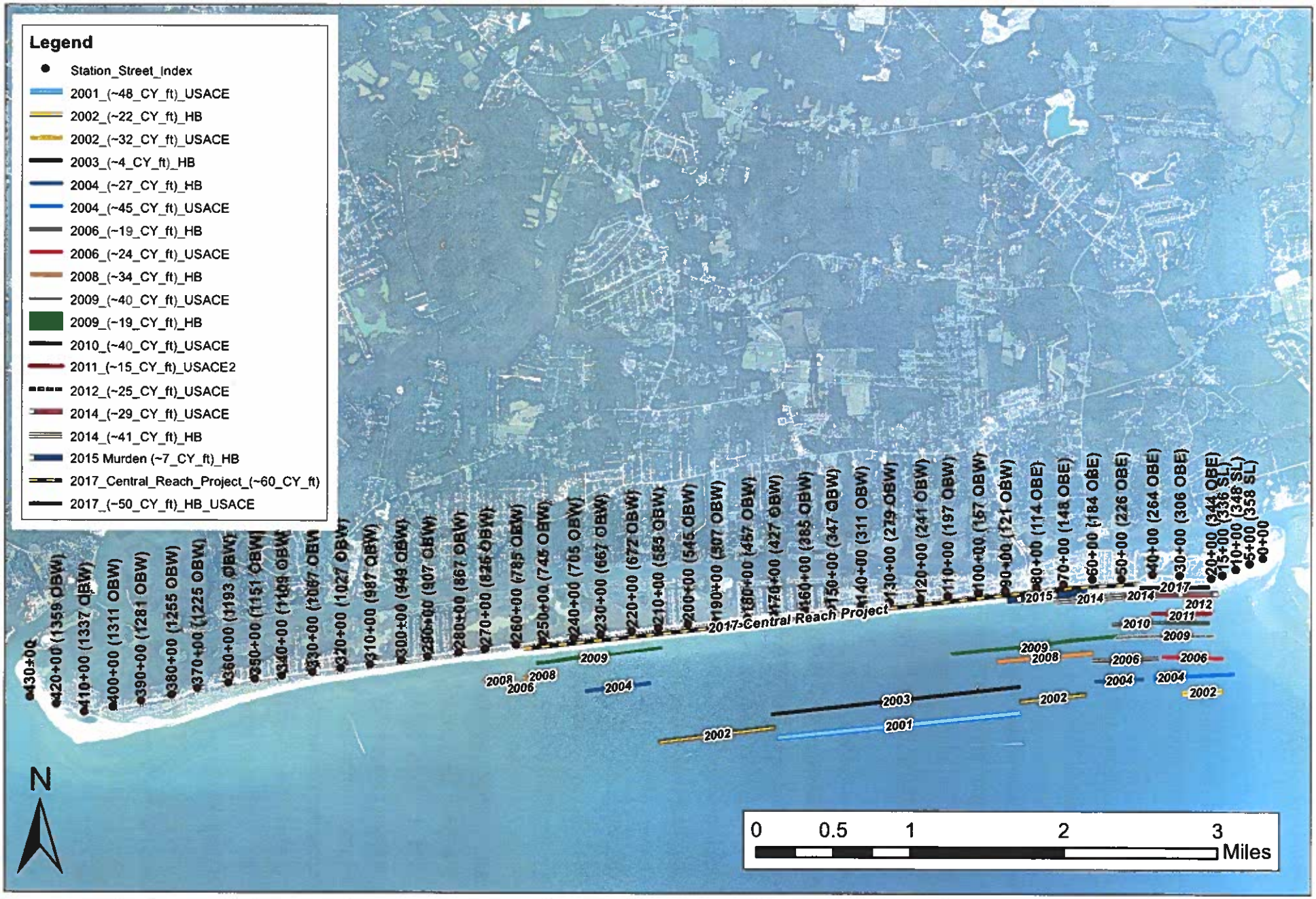

Figure 2-1
Holden Beach nourishments since 2001 and beach stationing for surveying.
Survey stations begin at LWF Inlet (0+00) and are generally at 1,000 foot intervals, ending at Shallotte Inlet (430+00).

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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 most recent upland truck haul project occurred in spring 2009, when the Town placed 190,000 cubic yards (cy) of upland fill along approximately 10,000 linear feet (lf) of shoreline.

In addition to upland fill beach nourishments, the Town has also taken a more active role in working with the USACE to maximize fill placement from dredging the Lockwood Folly (LWF) Inlet Atlantic Intracoastal Waterway (AIWW) crossing (LWFIX) and the "bend-widener" (which is discussed in Section 2.4.4).

As seen in Table 2-1, no nourishment activity occurred in 2018 or in the first half of 2019 on Holden Beach. The most recent project occurred in March 2017, when the Town participated in the LWFIX Project that placed approximately 120,000 cy of material dredged from the LWFIX and the bend widener along about 2,400 lf of shoreline. Of course, the major nourishment activity of 2017 was the Town's Central Reach Project (CRP), which placed approximately 1.31 million cubic yards (mcy) along approximately 4.1 miles of shoreline from January to mid-March 2017. The 2-year post-project movement and spreading of the fill placements from these two nourishment projects are reflected in the 2019 survey (discussed in Section 3). Further details of these projects are provided in subsequent sections.

2.1 TOWN UPLAND FILL PROJECTS

The Town has a history of successful upland fill projects, with the most recent occurring in 2009, primarily as Hurricane Hanna mitigation. Approximately 115,000 cy was placed between Stations 55+00 and 110+00 [21 cubic yard per linear foot (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. Note that upland sand has been used in emergency dune rebuilding following Hurricane Hanna in 2008 and Hurricane Irene in 2011.

Figure 2-2. 2009 Constructed Project Reaches and 2009 Permitted Sand Placement (the permitted placement has been modified over the years)

While the last upland-sourced beach nourishment occurred about a decade ago, the use of upland borrow areas remains a feasible alternative for Holden Beach. Fill projects utilizing upland borrow areas can be extremely valuable for unplanned/emergency mitigation efforts, such as the responses to Hurricanes Hanna and Irene. Additionally, truck haul projects do not involve the expensive mobilization/demobilization costs associated with offshore dredges and can occur much more quickly.

Potential negative aspects of upland borrow areas include variations in sand color, practical volume limitations, and placement methods (i.e., trucking). Additionally, the North Carolina Department of Transportation (NCDOT) requires permitting and has the ability to shut down operations or require roadway mitigation.

The Town owns the Turkey Trap Road upland borrow site whereas other potential borrow area sites include the Smith borrow site (Figure 2-3) and the Tripp site. The Turkey Trap Road and Smith borrow sites have been successfully permitted, which significantly enhances post-storm mitigation response.

Figure 2-3. Smith Upland Borrow Area during 2009 Holden Beach Nourishment Project

2.2 TOWN CENTRAL REACH PROJECT

The Town CRP nourishment occurred in winter/spring 2017 and represents the largest beach fill project to date on the island. Project construction began on January 3, 2017 and was completed on March 17, 2017 (74 days) by Weeks Marine. The nourishment utilized an offshore borrow area and placed approximately 1.31 mcy along 4.1 miles (22,000 ft) of shoreline [Ocean Boulevard East (OBE) 240 to Ocean Boulevard West (OBW) 781].

Figure 2-4 presents the beach fill project footprint, and Figure 2-5 presents a typical fill cross-section following construction. On average, constructed berm widths were about 150 ft wide and fill placements were about 60 cy/lf (with a range typically varying between 50 and 70 cy/lf).

Construction was scheduled to begin in mid-December 2016, but winter storms caused some minor delays and the project officially began on January 3, 2017. Fortunately, two hopper dredges were utilized simultaneously for the majority of the project's duration. These dredges were the R.N. Weeks and the B.E. Lindholm (Figure 2-6). The use of two hopper dredges helped move the project along very efficiently and allowed work to progress without delay since the dredges periodically would have to leave the project site and return to the maintenance yard in Wilmington for equipment changes or services.

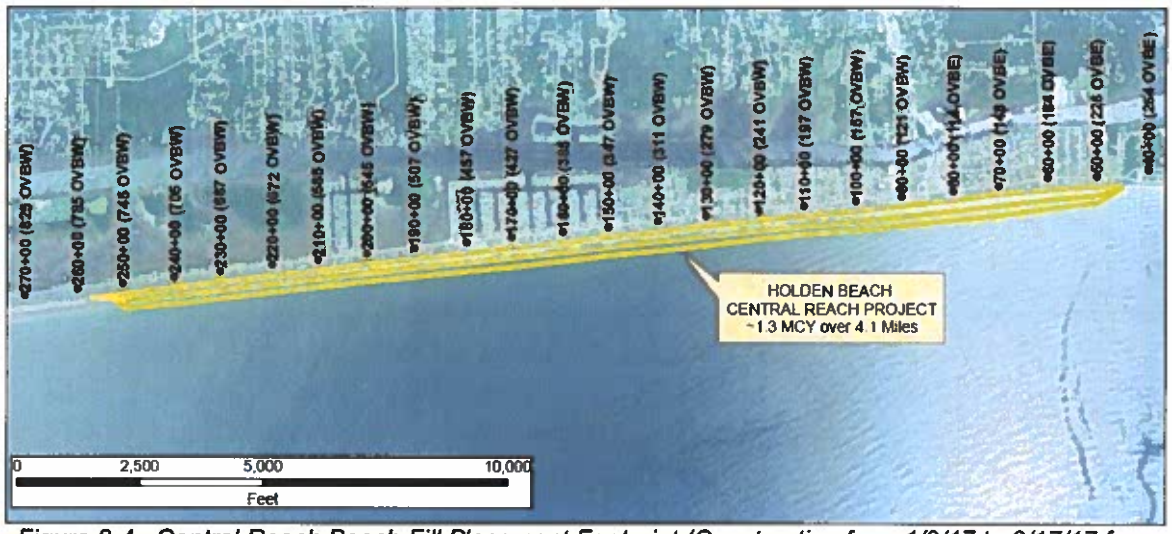


Figure 2-4. Central Reach Beach Fill Placement Footprint (Construction from 1/3/17 to 3/17/17 from Approximately Station 45+00 to Station 257+00)

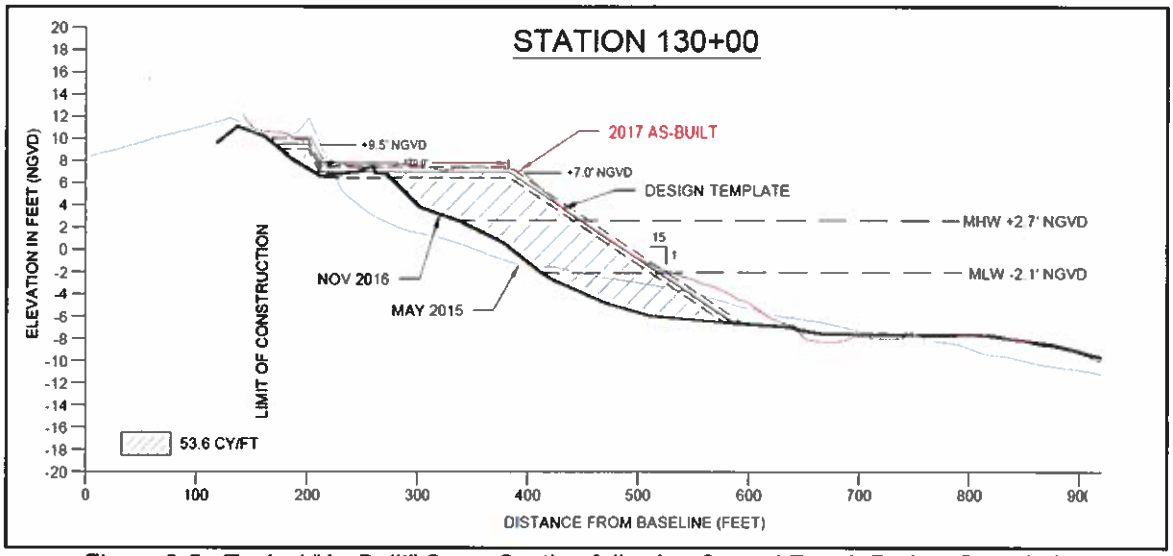


Figure 2-5. Typical "As Built" Cross Section following Central Reach Project Completion

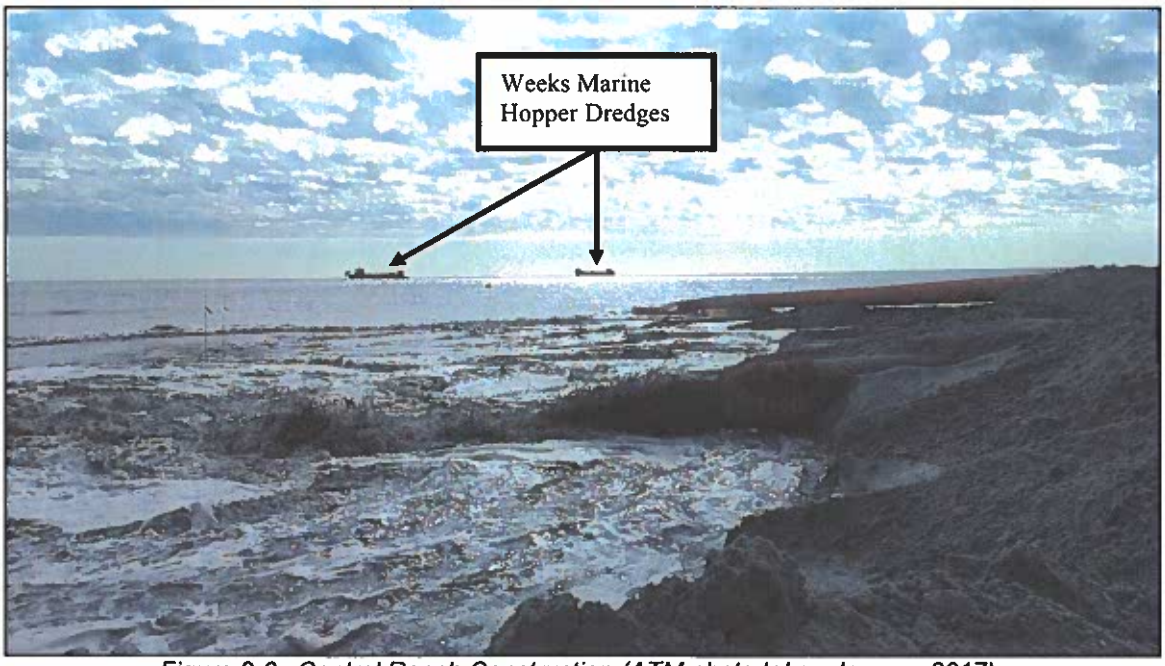


Figure 2-6. Central Reach Construction (ATM photo taken January 2017).

With the help of the two hopper dredges, the Weeks Marine crew worked quickly, pumping sand on the beach and progressing at an average rate of about 300 ft of shoreline per day. Despite the minor delays towards the beginning and near the end of the project, the entire nourishment took approximately 74 days and was completed on March 17. Aerial and ground photographs taken during construction are provided in Figures 2-7 and 2-8.

Figure 2-7. Aerial Photograph during Central Reach Construction West of Pier, Approximately Station 180+00 (Weeks Marine/Aerophoto Photo 2/22/17).

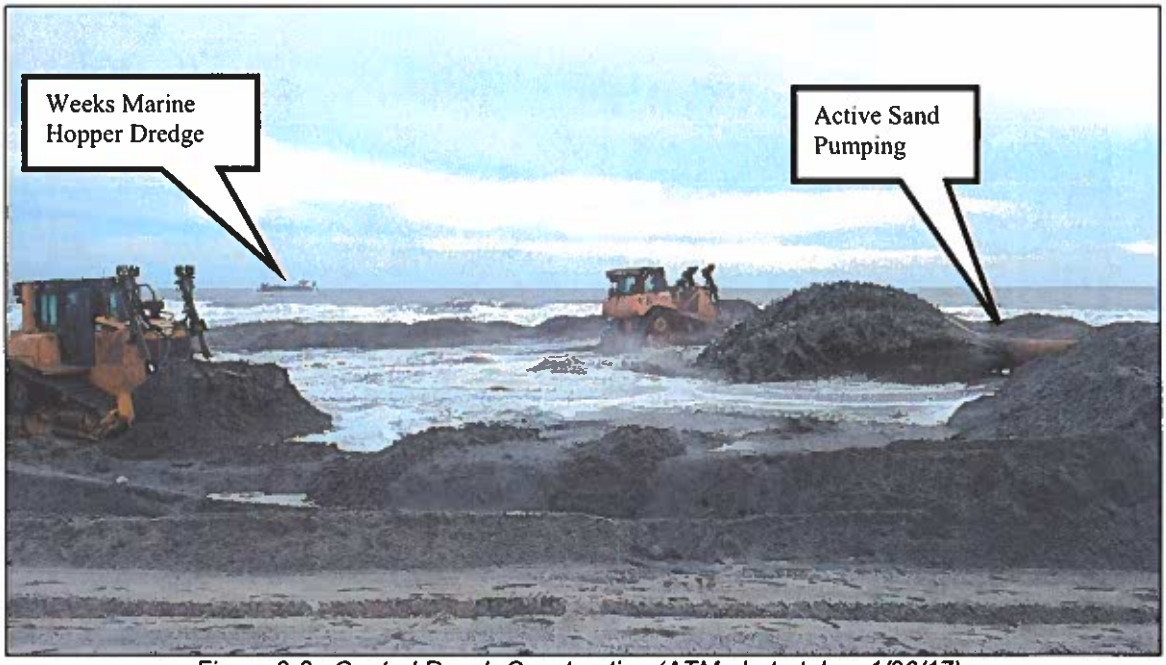


Figure 2-8. Central Reach Construction (ATM photo taken 1/26/17).

2.2.1 BORROW AREA

The CRP utilized an offshore borrow area approximately 5 miles southeast of the Holden Beach project shoreline. Figure 2-9 presents a figure of the post-project dredge cut depths. Hopper dredges work by making long shallow cuts (typically only 6 inches to 1 ft deep) along the borrow area, and the cut depths shown are typical. Dredging was generally only 2 to 4 ft deep in most areas.

The offshore borrow area for the CRP was delineated based on the need for enough sand for at least 2 large nourishments. The borrow area was allocated into different zones for the dredgers to work, in order to conserve some zones for future projects. However, the dredger encountered some isolated pockets of incompatible material - generally rock or hard clay that damaged the dredge (hoppers have debris screens on board that prevent rocks from reaching the beach). Weeks coordinated closely with ATM and Town staff to ensure beach-compatible material was placed while leaving some areas for future projects.

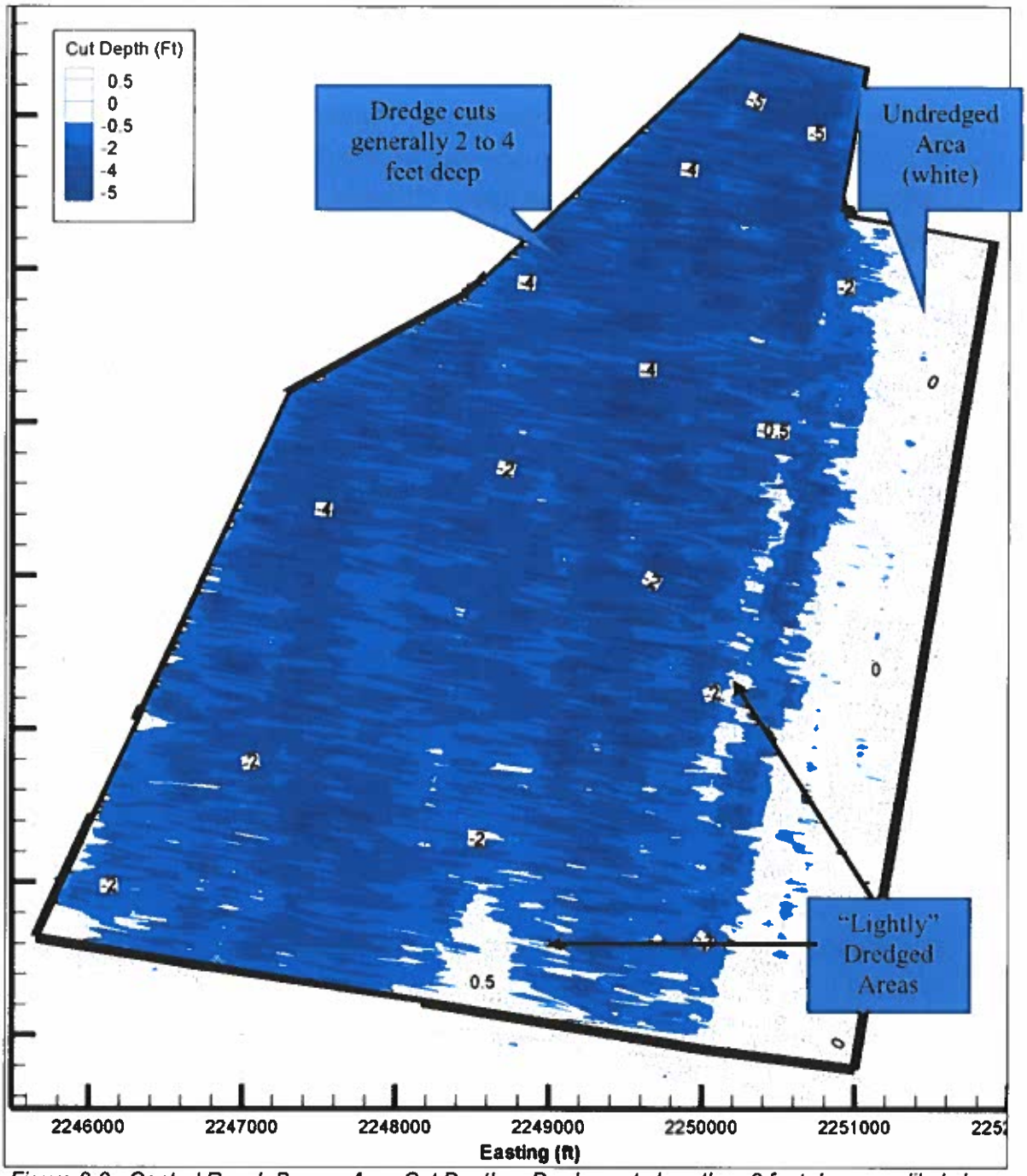


Figure 2-9. Central Reach Borrow Area Cut Depths. Dredge cuts less than 2 feet deep can likely be used for future nourishments.

Following the project, it is estimated that at least 500,000 cy of material is still available for future nourishments. The 2002 USACE project placed about 525,000 cy of material,

therefore, while there is enough sand in the borrow area for a large project, there is not enough for another CRP.

Additionally, due to the CRP borrow area location offshore (2 to 3 miles) and depths (about 35 to 40 feet), it is not anticipated that any substantial amount of sand will "fill in" the used portions of the borrow area in the near future. Therefore, the portions of the CRP borrow area that have been dredged more than 2 ft deep likely cannot be reused in the future.

As a result of Hurricanes Florence and Michael, a Central Reach Reimbursement (CRR) project has begun where the Town can place about 1.1 mcy in FEMA "engineered beach" mitigation. ATM has begun additional offshore borrow area reconnaissance and has preliminarily identified about 1.5 mcy of sand (in addition to the CRP borrow area). More discussion on borrow area reconnaissance is provided in Section 2.3

2.2.2 STATIC VEGETATION LINE

Due to the project's size, the Division of Coastal Management (DCM) required a Static Vegetation Line (SVL). The SVL is basically the seaward limit of stable dune vegetation prior to a large beach nourishment, and the SVL is the baseline for the Coastal Area Management Act (CAMA) setback distances. The SVL is only along the CRP shoreline (not the east end or western areas of the beach), and the SVL was delineated prior to Hurricane Matthew dune erosion.

The SVL line may not be an issue for Holden Beach because of the Town's proactive and beneficial dune enhancements over the years. However, if the SVL becomes an issue in the future, two options are available to the Town to exempt itself from the SVL. The first is to develop an SVL exception document that provides data for 30 years' worth of future beach nourishments. This exception must be re-visited every 5 years as well. The second and more recent alternative is for the Town to propose and create a Development Line. The Development Line alternative is a simpler and faster process. Town and ATM staff have already coordinated with DCM staff regarding the Development Line process and several other towns have used this process since it became effective in 2016.

2.2.3 CENTRAL REACH PERFORMANCE

The CRP nourishment took place just months after Hurricane Matthew and vastly revitalized the beach and dune system. The newly constructed beach has and continues to provide added protection from future storms. The latest 2019 survey shows that the project has held up well considering impacts from Hurricanes Florence and Michael.

Post-construction monitoring photos are presented in the following figures . Figure 2-10 (A) shows the widened beach conditions immediately following construction. Recent photographs taken 1 to 2 years following construction are presented in Figure 2-10 (B), Figure 2-10 (C), and Figure 2-10 (D).

The results of the latest survey and fill volume measurements are discussed in detail in Section 3.

Figure 2-10 (A). Central Reach Immediate Post-Construction Approximately Station 50+00 (ATM photo taken January 2017)

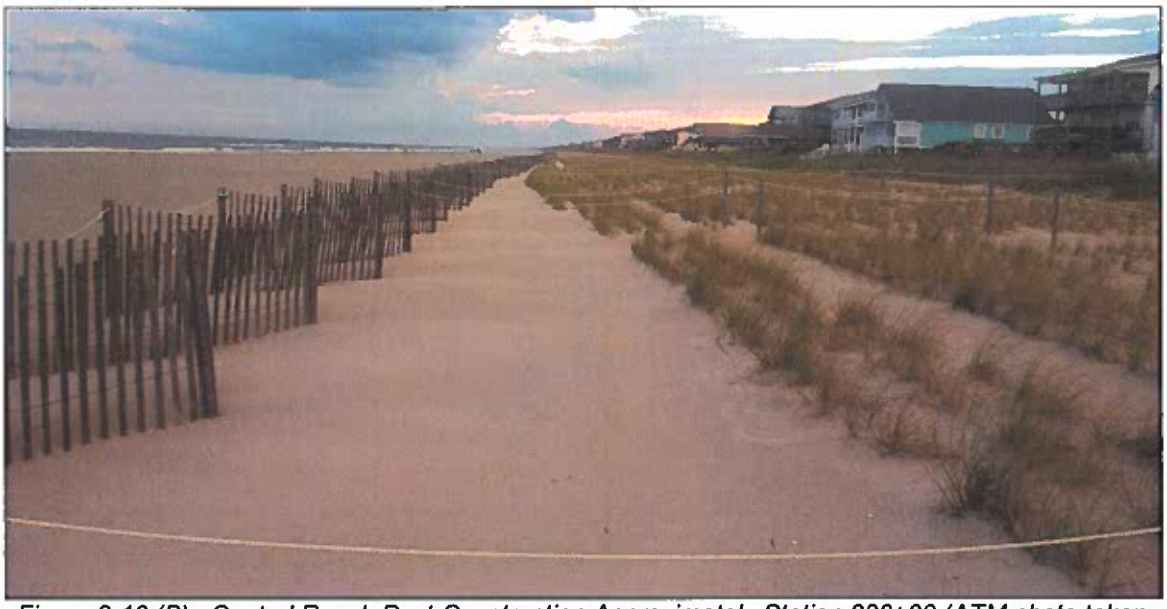


Figure 2-10 (B). Central Reach Post-Construction Approximately Station 230+00 (ATM photo taken August 2018). Note sand fencing, starter dune, and plantings.

Figure 2-10 (C). Central Reach Post-Construction Approximately Station 170+00 (ATM photo taken March 2019).

Figure 2-10 (D). Central Reach Post-Construction Approximately Station 170+00 (ATM photo taken September 2019). Note plantings have matured and grown.

2.3 CENTRAL REACH REIMBURSEMENT PROJECT

The CRR project is a direct result of the Town's significant investments in its beach management program. The CRR is a FEMA mitigation project that will place about 1.1 mcy of material along the CRP shoreline. The CRR project is 100% reimbursable where FEMA will reimburse 75 percent and the State will reimburse 25 percent. Note that submitted reimbursable costs are thoroughly reviewed/evaluated and that this process can take years.

2.4 USACE AND TOWN LWFIX PROJECTS

The LWFIX borrow area has acted as a beneficial use of dredged material (i.e., a borrow area for beach nourishment) since the 1970s. The primary reason for the USACE LWFIX dredging project is navigation; however, the dredged material is beach compatible and

Station 20+00 on the east end (beginning of the beach fill placement) is less than 4,000 feet away.

The USACE typically performs this project every 1 to 2 years, depending on shoaling and funding. The primary goal of this project is navigation, while a secondary and important benefit is placement of this compatible material on the beach.

The LWFIX project typically includes the AIWW itself as well as a "bend widener." The bend widener typically varies from 50 ft wide (Figure 2-11) to 400 ft wide (Figure 2-12). The 400-ft bend widener is the largest widener allowed by USACE permit conditions. The 400-ft bend widener is rarely dredged by the USACE due to limited Federal funding, however, the USACE did include it for the 2010 project. The 140,000-cy project in 2010 resulted from economic stimulus funding (i.e., American Reinvestment and Recovery Act).

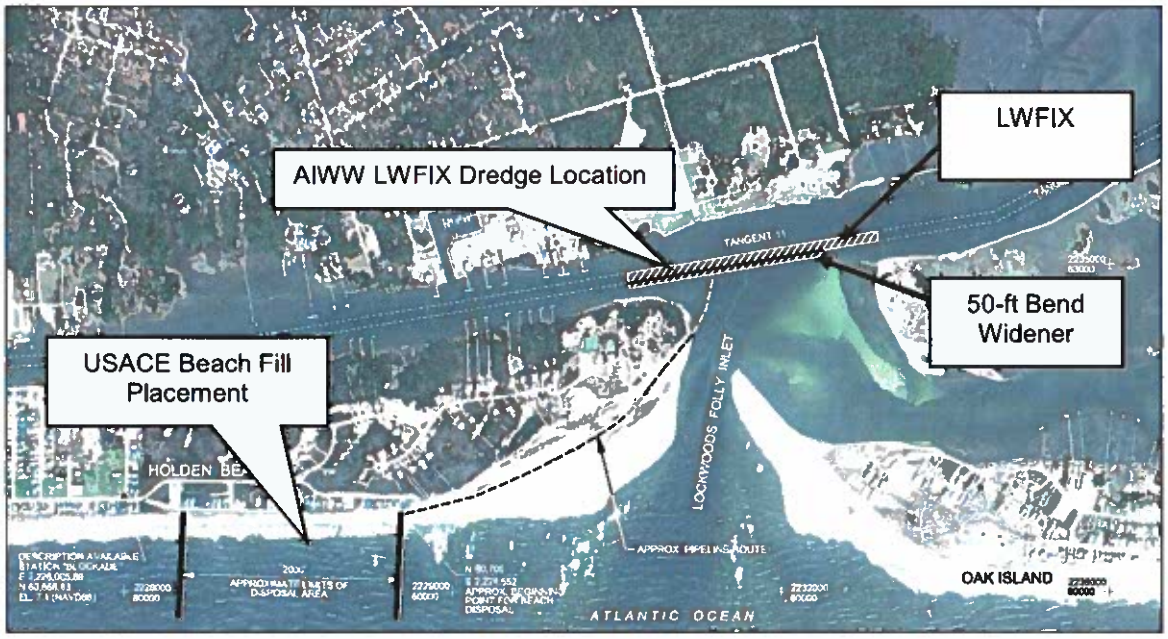


Figure 2-11. USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement typically occurs between Holden Beach Stations 20+00 and 40+00.

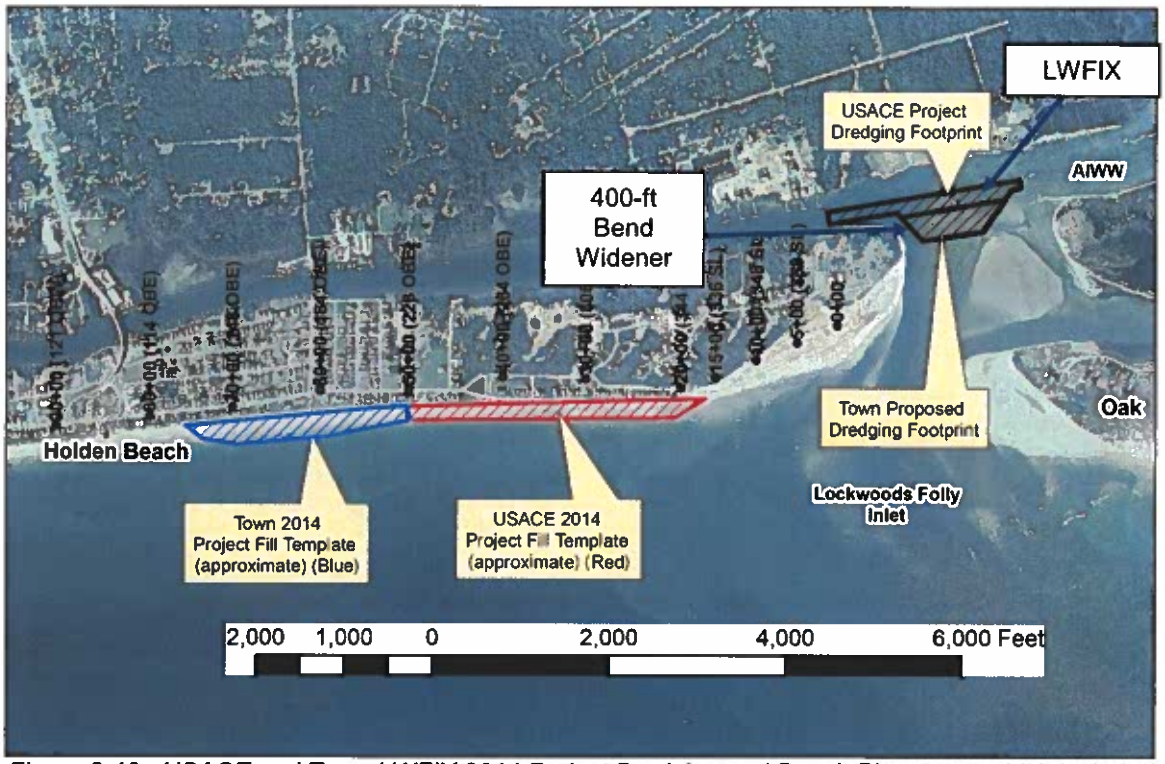


Figure 2-12. USACE and Town LWFIX 2014 Project Dredging and Beach Placement which included the 400-ft bend widener.

It is anticipated that future USACE LWFIX projects will include only minimal Federal effort/cost to maintain the AIWW, despite sufficient sand volume within the bend widener dredge footprint. As a result, USACE LWFIX dredge projects can be relatively small. For example, the February 2011 and January 2012 USACE LWFIX projects provided only 32,000 cy and 25,000 cy of material placed, respectively.

The increased benefits of the bend-widener for the 2010 project in comparison to the 2011 and 2012 reduced volume projects prompted the Town and ATM to actively pursue use of the bend-widener for future projects. In correlation with this effort, the State established a shallow draft dredging fund in 2013, which was a "game changer" for LWFIX and outer ebb shoal channel dredging (refer to Section 2.4).

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. Since the 400-ft bend widener is within the authorized Federal navigation project footprint, the Town's separate permitting process was simplified.

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). Figure 2-13 provides an aerial photograph taken during the 2014 LWFIX project.

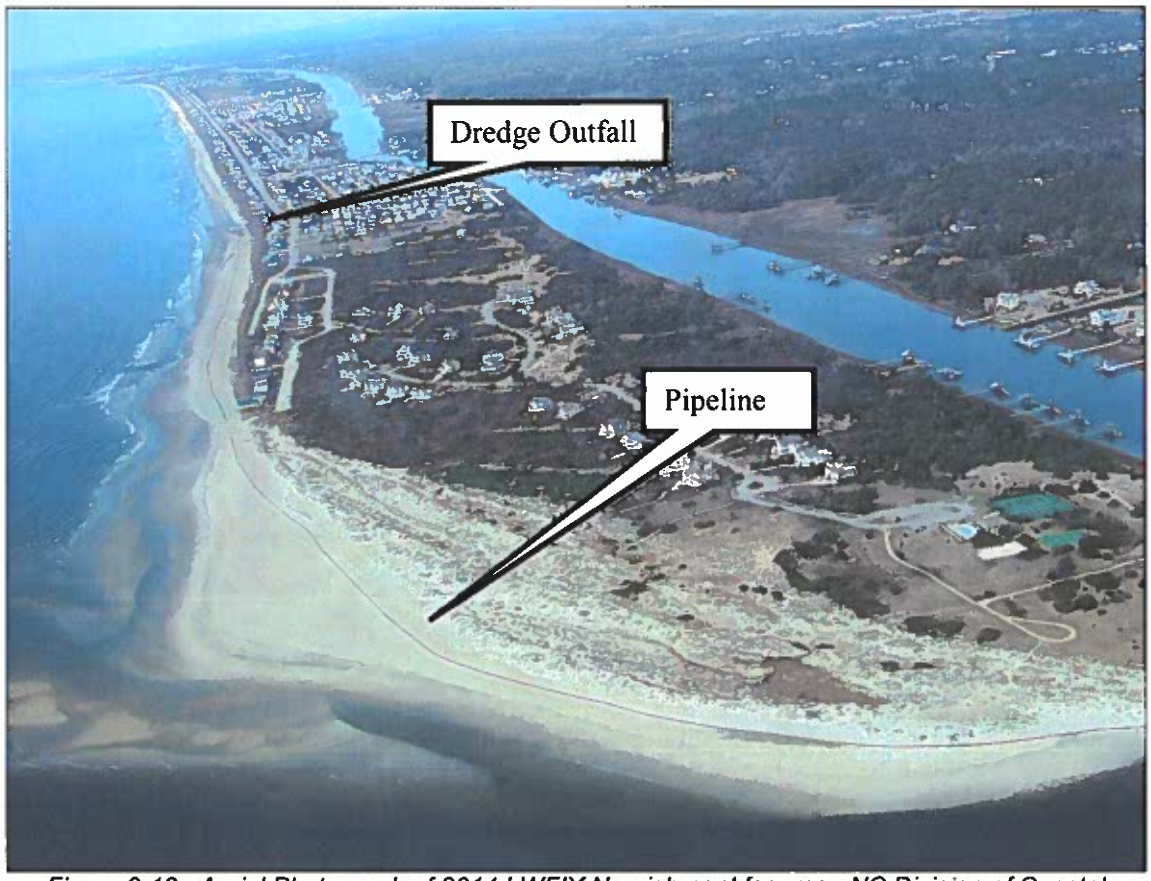


Figure 2-13. Aerial Photograph of 2014 LWFIX Nourishment [source: NC Division of Coastal Management (DCM)].

The Town's 2014 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 Environmental Quality (NCDEQ) paid for half the project cost, 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.

2.4.1 2017 USACE AND TOWN LWFIX PROJECT

Due to the successes of the 2010 and 2014 LWFIX projects using the 400-ft widener, the Town has been more involved in the LWFIX projects. Following a slightly different course of action than the 2014 LWFIX project, the Town and ATM staff coordinated with the USACE Navigation Branch personnel in charge of this dredging project to include the 400-ft widener under the USACE permit authorizations (not the Town's permits). The project was completed in mid-March 2017 and is also referred to as the Eastern Reach Project.

Figure 2-14 presents a plan view schematic of the 2017 LWIFX dredging and Town nourishment project. Including the 400-ft widener resulted in a total of approximately 130,000 cy that was dredged and approximately 120,000 cy placed along the Eastern Reach Project area (a small percentage of material is always lost during the dredging and construction process). To ensure maximum benefits to the central and eastern reaches of Holden Beach, the dredged material was placed immediately adjacent to the Town's CRP's eastern taper, where CRP construction began in January 2017.

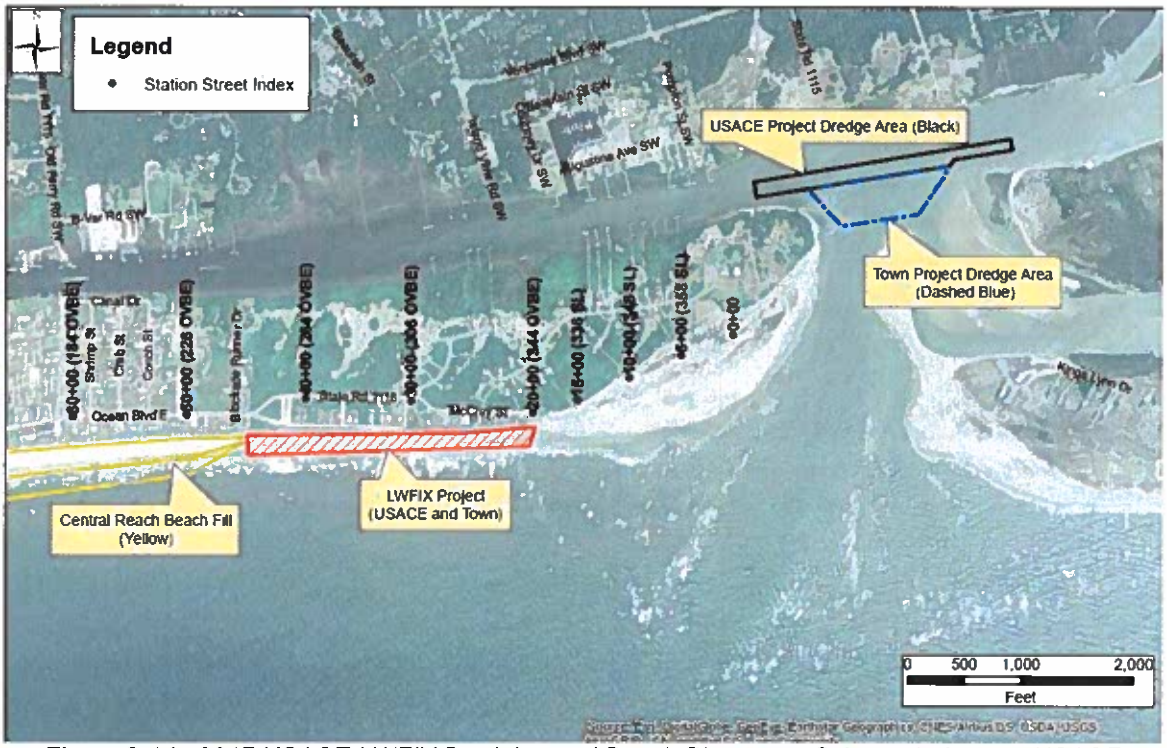


Figure 2-14. 2017 USACE LWFIX Dredging and Beach Placement Schematic (source USACE request for proposal). Placement of Approximately 120,000 cy occurred in March 2017 between Holden Beach Stations 20+00 and 45+00 to meet in with the Central Reach Project.

The Eastern Reach Project was very successful, and photographs taken during construction are presented in Figures 2-15 and 2-16. The Town involvement allowed for the placement of an additional 60,000 cy at a very inexpensive rate. The cost for the project was $465,000, and the Town's portion was only about $76,000 (with the State providing 66.7 percent). The timing of this nourishment coincided very well with the CRP and helped fill out much of the remaining shoreline of Holden Beach east of the larger CRP. Moreover, the Town's involvement helped maximize the restoration effort needed following the recent hurricanes and has helped mitigate more recent storm activity. The eastern end of shoreline has historically shown the highest erosion rates on the island, and LWFIX dredging projects and piggybacking opportunities on the east end are a crucial part of the Town's proactive management strategies to mitigate this.

Figure 2-15. Holden Beach POA Photograph Taken near 323 McCray Street (approximately Station 26+00) during 2017 Eastern Reach Project construction.

Figure 2-16. Holden Beach POA Aerial Photograph taken during 2017 Eastern Reach Project Construction (pumping just west of Station 30+00).

Figure 2-17 presents a 2-year post-project photograph monitoring the progression of the 2017 Eastern Reach Project. In general and based on site observations, the east end is continuing to benefit from the recent nourishment, however, it does need nourishing every 2 years to avoid extreme erosional conditions that have occurred in past decades. More detail on beach survey monitoring are provided in Section 3.

Figure 2-17. Two-Year Post Construction Photo of the 2017 Eastern Reach Project (ATM photo taken April 2018, at Station 20+00). The most eastern oceanfront house, Amazing Grace, is shown. Dune growth has occurred however this is still a vulnerable area.

2.4.2 2019 USACE LWFIX PROJECT

The USACE's most recent LWFIX project occurred in spring 2019 and, unfortunately, the USACE chose to place this material onto Oak Island. Figure 2-18 presents an overview of the project. The project placed about 120,000 cy of material from the LWFIX with only a small 25-ft bend widener. The bend-widener was not a realistic option for this project as the winter/spring dredging window did not allow for additional dredging. The LWFIX project is combined by the USACE with several other NC shallow draft inlet dredging projects to obtain more competitive pricing. The base-bid projects get priority and delays due to weather (e.g., Hurricanes Florence and Michael) and dredger scheduling/mechanical issues can also limit additional work like bend-widener dredging.

Town and ATM staff have met with USACE and Oak Island staff on several occasions over the last year regarding placement options, however, Holden Beach was never notified in advance that the east end would not receive any sand from the upcoming project. The USACE maintained that an easement issue from another USACE project had led them to re-evaluate *all* easements for *all* Wilmington District projects.

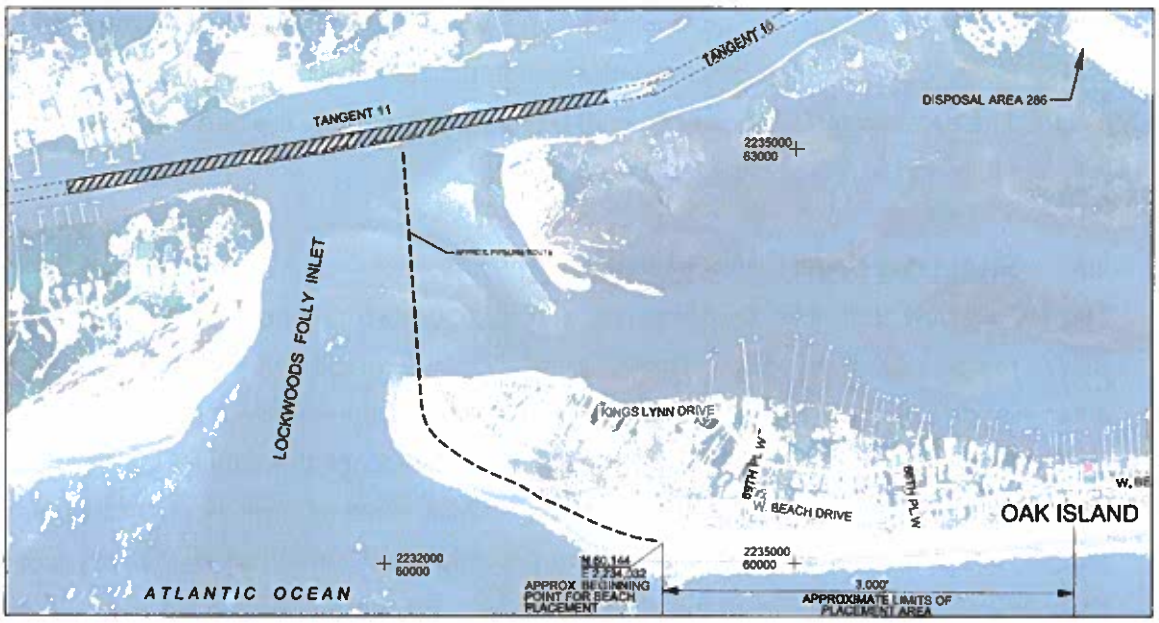


Figure 2-18. Planned 2019 LWFIX Placement on Oak Island. Actual Final Placement Area Approximately 2,500 ft. Refer to Section 3.5 for more information on 2019 LWFIX and Oak Island west end volume changes.

According to the USACE, Oak Island fill placement only required easements from the Town of Oak Island (i.e., not from individual homeowners). For the east end of Holden Beach, the USACE identified more than 50 homeowner easements needed, with many of these on active beach (not buildable lots, see Figure 2-19). However, Holden Beach staff were not notified of this new requirement until the last shallow draft inlet meeting on August 29, 2018. Easements have been obtained and placement on the east end can now again occur.

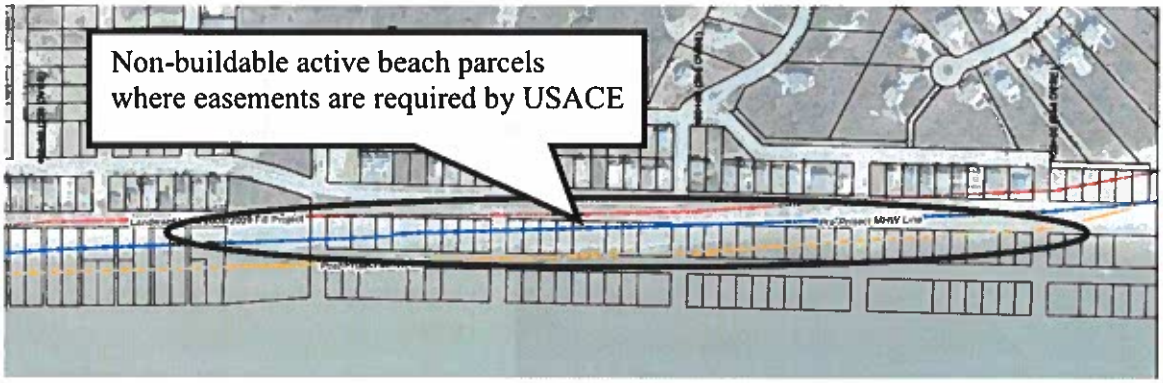


Figure 2-19. In 2018, the USACE Required Easements for numerous lots before East End LWFIX Placement Can Resume Easements have since been obtained.

2.4.3 2020 LWFIX PROJECT

A LWFIX dredging project is scheduled for this winter/spring, with placement on the east end of Holden Beach. The bend-widener is not included in the base-bid, however, it was included as an alternative bid. Based on the dredger's progress, the bend-widener dredging will hopefully occur.

2.5 SHALLOW DRAFT INLET PROGRAM

The NC shallow draft inlet dredging program includes two primary elements: 1) inlet and AIWW reaches landward of the Coast Guard COLREGs (collision regulation) line and 2) outer inlet dredging where small dredges must also be "ocean-certified" by the Coast Guard for potentially rough/dangerous inlet conditions (seaward of the COLREGs line). The USACE side-caster the *Merritt* and the two USACE shallow draft hopper dredges, the *Murden* and the *Currituck* (Figure 2-20), are the only vessels that can realistically work the shallow draft inlets seaward of the COLREGs line. Private dredgers have been consulted for these projects, but their equipment generally consists of large cutterhead ocean dredges (high mobilization fees), ocean-going hopper dredges (draft too deep), or barges with clamshell excavator dredges (no pipeline disposal and low productivity).

Figure 2-20. USACE Shallow Draft Split-Hull Hopper Dredge the Currituck Rarely Dredges the LWF Inlet

Dare County and the State have recently come up with funding to form a public-private partnership with a Dare County contractor to build a shallow draft hopper dredge that would primarily serve Dare County (Oregon and Hatteras Inlets). At a minimum, this dredge will

ease demand for other USACE shallow draft dredging projects (i.e., LWF Inlet). It is not known whether this new dredge will be available for future LWF Inlet work.

The State Shallow Draft Navigation Channel Dredging and Aquatic Weed Fund allocated $15,000,000 to Dare County (local partner) to provide a forgivable loan to a private partner for the construction and purchase of the proposed shallow draft hopper dredge.

The historical lack of USACE funding for North Carolina shallow draft inlet maintenance led the State, in conjunction with local county and municipal governments, to accomplish the following:

1. Obtain a memorandum of agreement (MOA) with the USACE to fund shallow draft inlet dredging,
2. Obtain permits to maintain the navigability of the State's shallow draft inlets independently of the USACE, and
3. Establish the Shallow Draft Navigation Channel and Lake Dredging Fund; (which has recently been renamed the Shallow Draft Navigation Channel and Aquatic Weed Fund - effective July 1, 2016). Funds can be used for the MOA or independently of Federally sponsored projects.

More information on all these initiatives is provided in the following sections.

2.5.1 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 North Carolina General Assembly established the Shallow Draft Navigation Channel and Aquatic Weed 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 under the MOA is $12 million per year, additional funding is available for shallow draft dredging projects independent of the MOA.

The USACE and NCDEQ 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.

The USACE typically dredges the LWFIX and AIWW every 1 to 2 years, whereas the USACE typically sidecast dredges the outer 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 once every 6 months or even longer. Additional effort can be required if the intervals between dredging events are longer.

2.5.2 STATE SHALLOW DRAFT INLET PERMITTING

The State took the lead in the shallow draft inlet permitting following the 2013 Shallow Draft Inlet (SDI) report. This effort was predicated on two major factors: 1) there is only one sidecast dredge that remains in the Federal government fleet, the refurbished *Merritt*, and 2) Federal funding has been limited/absent and this trend is likely to continue.

Following the reconnaissance study, the State gathered the necessary materials (geotechnical data, biological reports, survey data, etc.) to apply for permits for locally held authorizations. These authorizations 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 2.5.4 for more on this topic).

The permits for this effort were issued in May 2016 and will expire in 2019 (with the ability to obtain extensions). The authorizations include all currently approved dredge material management locations, including shoreline beneficial placement, nearshore placement and/or upland confined disposal placement. Note that there are some additional monitoring requirements when compared to the USACE authorizations (which were originally developed decades ago).

2.5.3 STATE DREDGING FUND

Independent of the MOA, dredging funds can be obtained directly from the State via the Water Resources Development Grant process. The Town has used this mechanism for the 2014 LWFIX project. In 2014, the State cost-sharing was 50 percent while it is now 66.7 percent for non-tier-one counties. The dredging fund has expanded in scope since its inception and funding has also increased. More than 12 Federally authorized inlets and

associated channels are included, and some non-Federal channels are also included (mostly related to State ferry routes). Of course, there is also a lake/freshwater component of the fund (as identified in the fund's name). The fund has shown robust growth and availability since its inception.

2.5.4 LOCKWOOD FOLLY INLET PROJECTS

As previously discussed, LWFIX projects are eligible for State dredging funding however other elements of LWF Inlet maintenance are also eligible. LWF Inlet is a Federally authorized shallow draft inlet. Due to different and separate historical USACE funding sources, two basic routine maintenance activities historically occur at LWF Inlet:

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

Figure 2-21a provides a representation of these two regions. The LWFIX projects are described in detail in Section 2.4. This section focuses on the outer shoal, seaward of the COLREGs line.

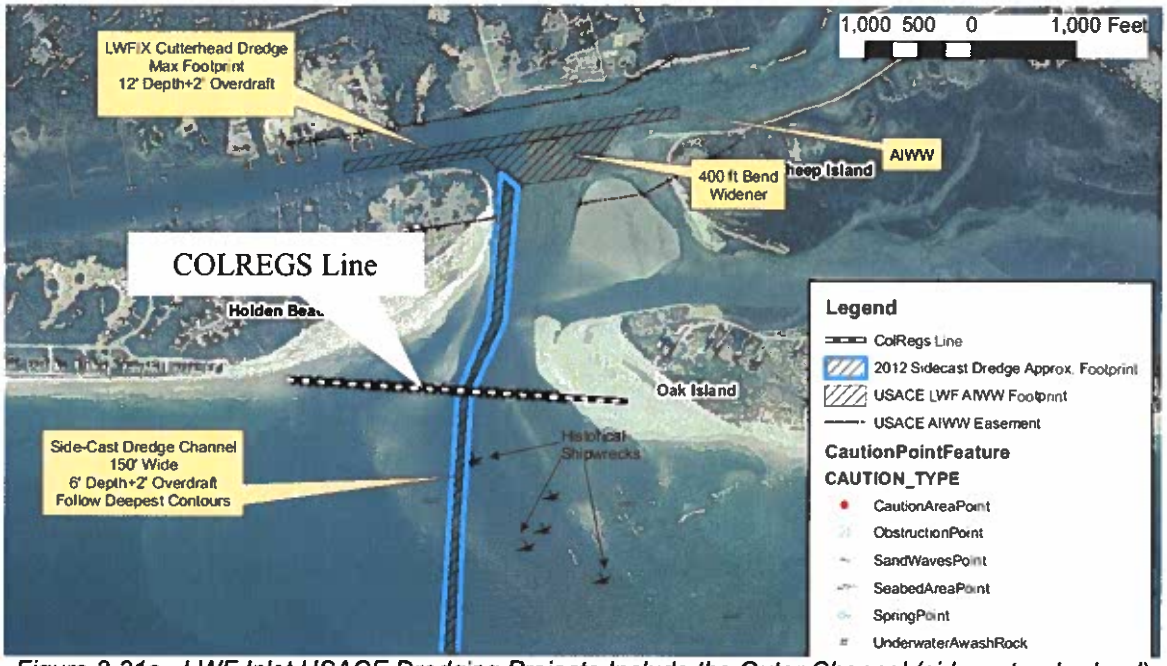


Figure 2-21a. LWF Inlet USACE Dredging Projects Include the Outer Channel (sidecaster dredged) and the LWFIX (cutterhead dredged)

The SDI permit authorizations allow the Town (with State, County and potentially Oak Island funding assistance) to dredge/maintain LWF Inlet both landward and seaward of the COLREGs line. 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 $3 to $4 million per event). The LWFIX dredge projects are predominantly awarded to smaller dredge companies with dredges that are not ocean certified (e.g., Southwinds, Cottrell) since this area is landward of the COLREGs line.

Figure 2-21b on the next page presents a recent USACE LWF Inlet survey identifying several major features involved in sediment transport, including the flood shoal, ebb shoal, and inlet throat. The inlet throat is consistently deep [18-20 feet above mean lower low water (MLLW)] on USACE surveys. The ebb and flood shoals are consistently shallow and typically require dredging for safe navigation. The ebb shoal typically consists of several shallow sandbars that slowly migrate across the inlet from the Oak Island side to the Holden Beach side.

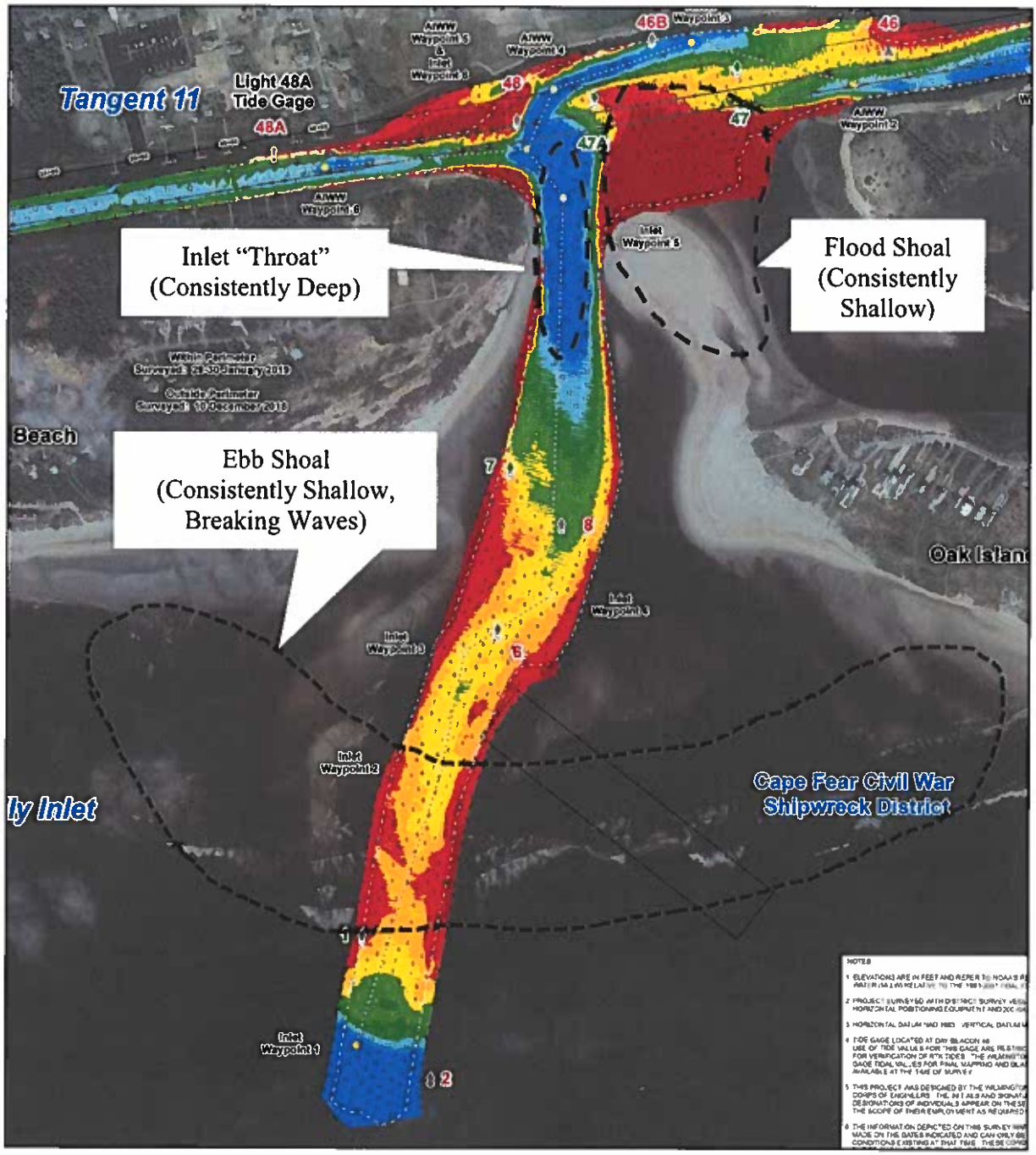


Figure 2-21b. Inlet Throat, Flood Shoal and Ebb Shoal at LWF Inlet (Image Source: USACE Wilmington Navigation Branch)

2.6 LWF OUTER EBB SHOAL DREDGING

Outer ebb shoal (see Figure 2-21b) dredging is typically performed by the *Merritt*, which is the USACE's only remaining sidecaster; however, the *Murden* is also used. The *Murden* was used exclusively when the *Merritt* was in extended drydock in 2017/2018. All three shallow-draft dredges (*Merritt*, *Murden*, and *Currituck*) typically spend 1 to 2 months in drydock per year, with some extended drydock maintenance occurring every 5 to 20 years.

The *Merritt* dredged about 17,000 cy in February, followed by *Murden* dredging in March (about 24,000 cy). The *Merritt* also worked LWF Inlet in June (about 30,000 cy) and August/September (about 17,000 cy).

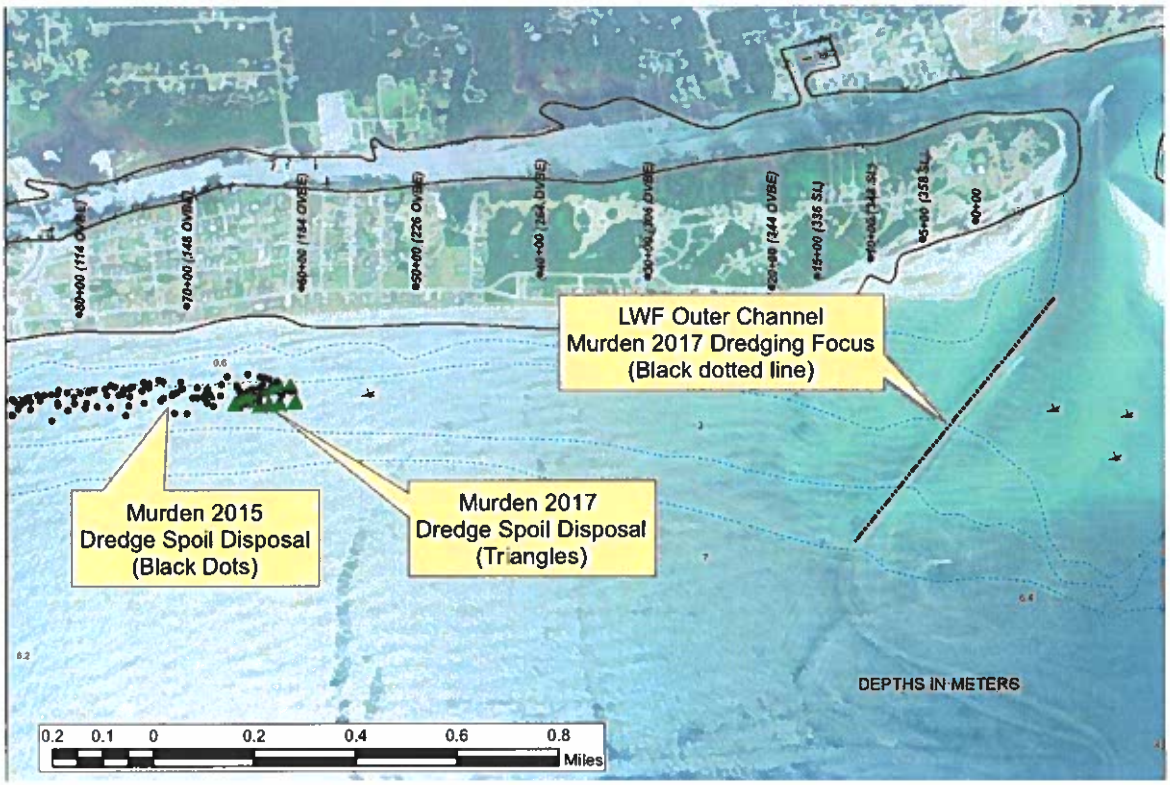


Figure 2-22. LWF Outer Channel USACE Dredging Projects by the Murden in 2015 and 2017. The 2019 Murden project also placed material in this general area however did not provide drop-point locations for each load.

While the *Merritt* merely sidecasts material about 100 feet to the side, the *Murden* places material nearshore in approximately 8 to 15 feet of water between 500 and 1,000 feet from shore. The nearshore placement generally occurs between Ferry Road (approximately

Station 60+00) and the Holden Beach bridge (approximately Station 90+00). The USACE generally refers to this area as the authorized placement location as determined by its analysis/review decades ago.

Figure 2-22 presents a figure of the 2017 LWF outer bar dredging and nearshore placement in comparison to the 2015 nearshore placement. Placement locations for each load (about 300 cy) are shown for the 2015 and 2017 efforts. The 2019 *Murden* dredging also placed material in the same location, however, it did not provide drop-point locations for each load.

Due to the project's purpose (i.e., shallow draft inlet dredging and nearshore disposal), the State funded 66.7 percent of the project costs and Brunswick County contributed funding also.

The nearshore placement results in mounds generally 2 to 3 feet high. Subsequent surveys found the mounds to have dispersed; however, their onshore movement could not be detected as these are relatively small amounts of material that quickly assimilate into the littoral system. Nonetheless, ATM believes this nearshore placement is the best disposal option for the *Murden* or *Currituck* and is favored over sidecaster dredging.

2.6.1 COUNTY LWF OUTER SHOAL DREDGING PROJECT

Brunswick County has rescinded its proposal to dredge a deeper and wider outer LWF ebb channel and to place this material either on Holden Beach or Oak Island. The outer ebb channel is currently authorized to 150 feet wide and 8 feet deep. The County was proposing to deepen the channel to 12 to 14 feet deep and widen it by 50 to 150 feet. The County estimated that at least 250,000 cy would be available for beach nourishment.

ATM was never enthusiastic about this project. In general, utilizing large ebb shoal borrow areas is typically discouraged because it can interrupt the natural sediment bypassing process by creating a "sediment trap." Shallotte Inlet ebb shoal dredging has been cited as acting as an "effective sediment trap" (USACE OCTI report, 2008). Modeling and analysis also indicated that a deeper/wider channel could detrimentally affect estuarine shorelines and habitat (and significantly more long-term monitoring/analysis would be required). The project qualified for State shallow-draft inlet funding due to its dredging-for-navigation component. Without this State funding, this project would likely not be cost-effective.

2.7 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 the following:

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

The continued diligence and effort of Holden Beach has resulted in a stable and healthy dune system along a majority of the island, although Hurricane Matthew removed approximately 41 acres of dunes in 2016. Dune vegetation planting and sand fencing was a planned component of the CRP and has stabilized and largely restored the dune system along Holden Beach since Hurricane Matthew. Older dune fencing has gradually been buried as a result of dune growth (see Figure 2-25).

Figures 2-24(A) and (B) present example sections of sand fencing put in place just seaward of the constructed "starter dune" immediately following the 2017 nourishment projects. One-year and two-year post-project monitoring photographs of the starter dunes and plantings are provided in Figures 2-25(A) and (B).

Figure 2-24 (A). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~60+00. Vegetation has been planted on the starter dune since photograph date. (ATM photo, taken May 2017).

Figure 2-24 (B). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~230+00. Vegetation has been planted on the starter dune since photograph date. (ATM photo, taken May 2017).

Figure 2-25 (A). Sand Fencing along the Seaward Edge of the Starter Dune for the Central Reach Project at Station ~60+00 Showing Planted Dune Vegetation. (ATM photo, taken August 2018).

Figure 2-25 (B). Sand Fencing for the Central Reach Project at Station 60+00 showing dune vegetation and sand growth about 2-years post project. (ATM photo, taken September 2019).

Dune planting over the last year consisted of about 142,000 plants (sea oats and bitter panicum). The Holden Beach Renourishment Association is funded this planting effort. In addition, the project includes fertilization of the entire beach from the east end to the escarpment on the west end in three applications, each 30 days apart.

Some areas of shoreline on the west end experienced dune erosion and vegetation loss in recent years and could benefit from proactive dune enhancement efforts. A large dune system is present along the west end, so planting of more mature vegetation could help to promote growth of a thick maritime forest and increase accretion steadily over the years to come. Recent studies have shown maritime forest vegetation (wax myrtles, holly, shrubs, etc.) build up the ground, creating "green barriers" as formidable defense against future erosion from rising seas and storm surge.

2.8 STORM ACTIVITY

Figure 2-26 presents a summary of 2018 Atlantic Hurricane tracks. The 2018 hurricane season had 15 named storms, with 2 storms reaching major hurricane status (i.e., a Category 3 hurricane or greater and noted as MH in Figure 2-26). Hurricanes Florence and Michael had direct impacts on the Holden Beach shoreline.

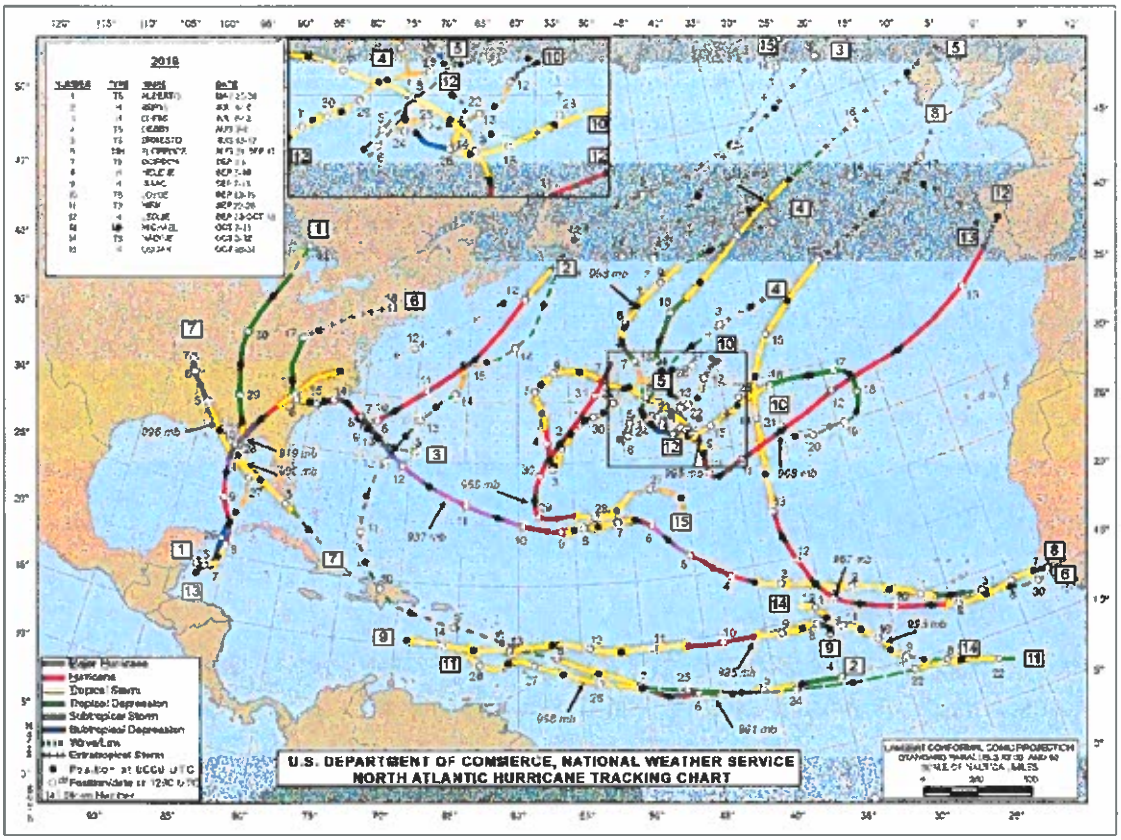


Figure 2-26. 2018 Atlantic Hurricane Summary Overview.

2.8.1 HURRICANE FLORENCE

Hurricane Florence began as a tropical disturbance around September 1, 2018 and progressed very slowly on a west-northwestward path across the Atlantic as it experienced periods of weakening and strengthening. By September 10, Hurricane Florence became a Category 4 major hurricane as it barreled toward the coast of North Carolina and remained a Category 4 hurricane for several days. The Town of Holden Beach declared a state of emergency on Monday, September 10, ordering voluntary evacuations the same day, with a following mandatory evacuation of all residents by Wednesday, September 12.

Prior to making landfall, Hurricane Florence stalled as a Category 2 storm, moving only 5 miles per hour (mph) towards the NC coast on Thursday, September 13. Florence weakened to a Category 1 hurricane, with maximum sustained windspeeds of 90 mph before making landfall on September 14, near Wrightsville Beach. Figure 2-27 presents a radar image of Hurricane Florence prior to landfall. Florence then slowly tracked along the

North Carolina and South Carolina coasts as a Category 1 hurricane for 2 days before turning inland in South Carolina.

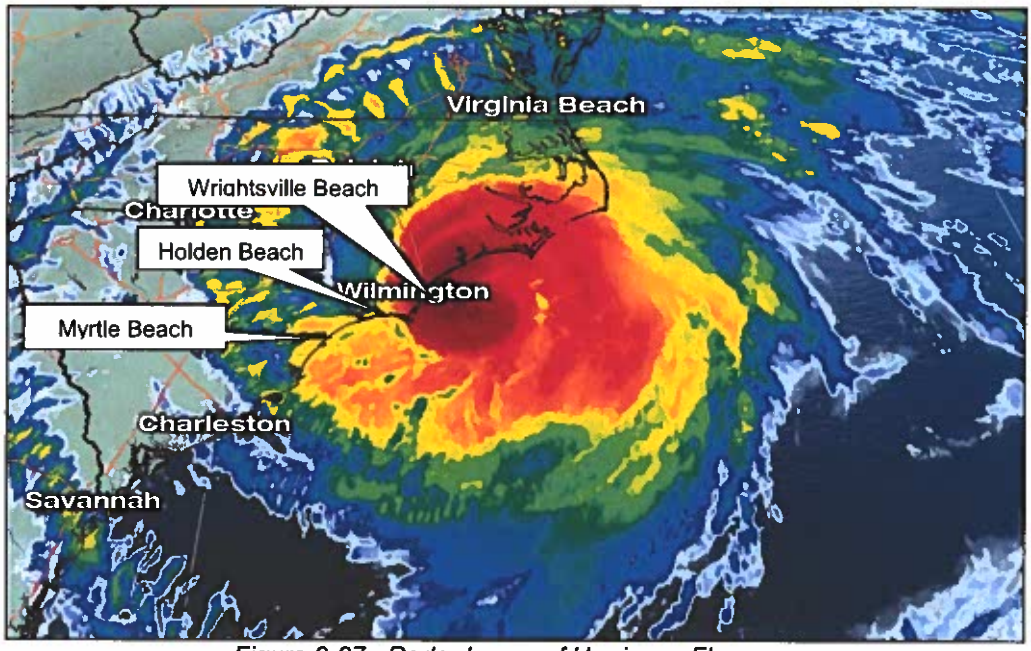


Figure 2-27. Radar Image of Hurricane Florence.

Despite being only a Category 1 hurricane, this storm was very large and slow moving and subjected the Holden Beach shoreline to intense wave and extreme storm surge conditions for multiple days as it approached and passed. The combination of storm surge and large swells created wave run-up conditions that directly impacted the upper beach berm and dune system along Holden Beach.

Bob Henson at weather.com described Hurricane Florence this way:

> Although Florence had become a Category 1 hurricane on the Saffir-Simpson wind scale, it remained a Category 5 heavy rain and inland flooding threat, and a Category 3 storm surge threat.

The NC coast was subject to elevated water level conditions for several days before and after Hurricane Florence arrived. A peak water level of 8.59 ft MLLW was recorded the morning of Friday, September 14 at the National Oceanic and Atmospheric Administration (NOAA) tidal station in Wrightsville Beach (about 30 miles northeast of Holden Beach). A tide gauge in Myrtle Beach recorded a peak water level of 7.48 ft MLLW approximately 24

hours after the peak surge was recorded at Wrightsville Beach. Hurricane Florence brought the third-highest water level on record at Wrightsville Beach, behind Hurricane Hazel (1954) and Hurricane Fran (1996), but surpassing Hurricane Matthew in 2016.

The NOAA Frying Pan Shoals buoy recorded maximum offshore significant wave heights of up to approximately 18.7 feet and dominant wave periods of up to 17 seconds on September 12, 2018.

As the storm tracked south along the Holden Beach shoreline, the winds turned onshore, with maximum sustained winds of up to 72 mph reported at Oak Island, just east of Holden Beach. Fortunately, windspeeds were below hurricane strength, however, due to the storm's extremely slow track, Florence's winds were relentless, increasing waves and surge along the regional shoreline near the North Carolina / South Carolina border for several days.

2.8.2 HURRICANE MICHAEL

Hurricane Michael began as a low-pressure system on October 2nd, 2018 and slowly organized to a tropical depression in the southwestern Caribbean around October 7. Michael then rapidly intensified as it progressed northward into the Gulf of Mexico and continued gaining strength and speed (see Figure 2-28). By October 9, Hurricane Michael became a Category 4 major hurricane as it barreled toward the Florida Panhandle.

Michael made landfall near Mexico Beach, FL on Wednesday, October 10, as a strong Category 4 hurricane, with maximum sustained winds of 155 mph, and then tracked northeastward as it quickly moved inland toward Georgia and the Carolinas. Hurricane Michael weakened as it tracked over land and decreased to a tropical storm as it passed over Georgia and continued to move quickly (traveling at more than 20 mph), remaining still at tropical storm strength as it progressed northeastward across South Carolina and North Carolina.

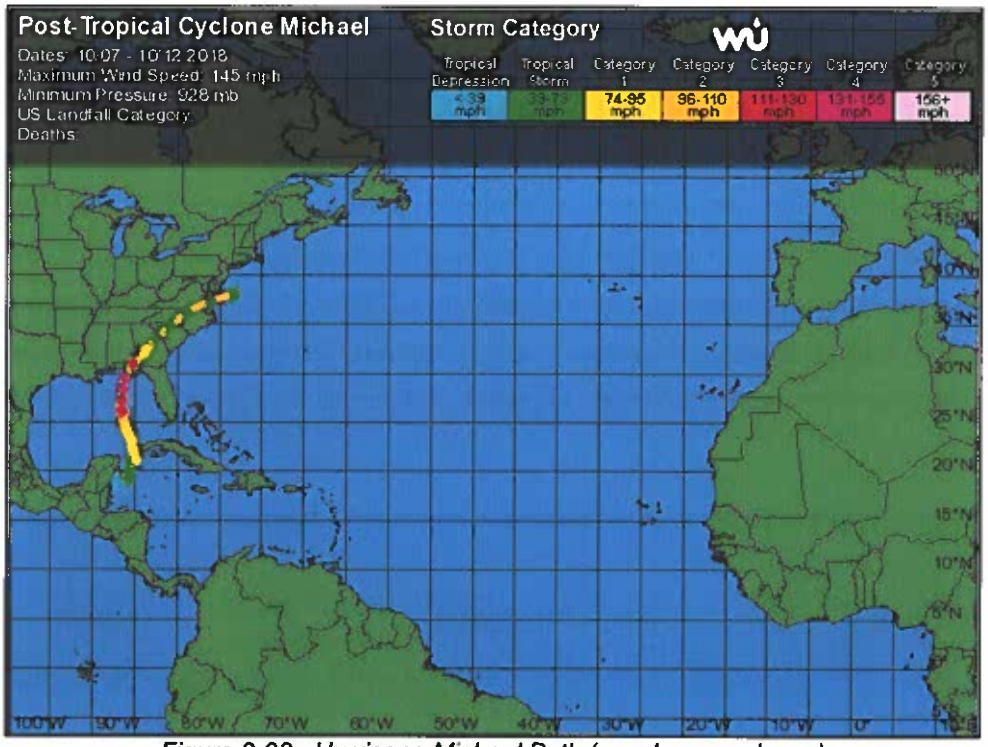


Figure 2-28. Hurricane Michael Path (wunderground.com)

Figure 2-29 shows a radar image of Hurricane Michael as it moved into South Carolina as a well-organized tropical storm. Stronger over-water winds and outer storm bands directly impacted Holden Beach.

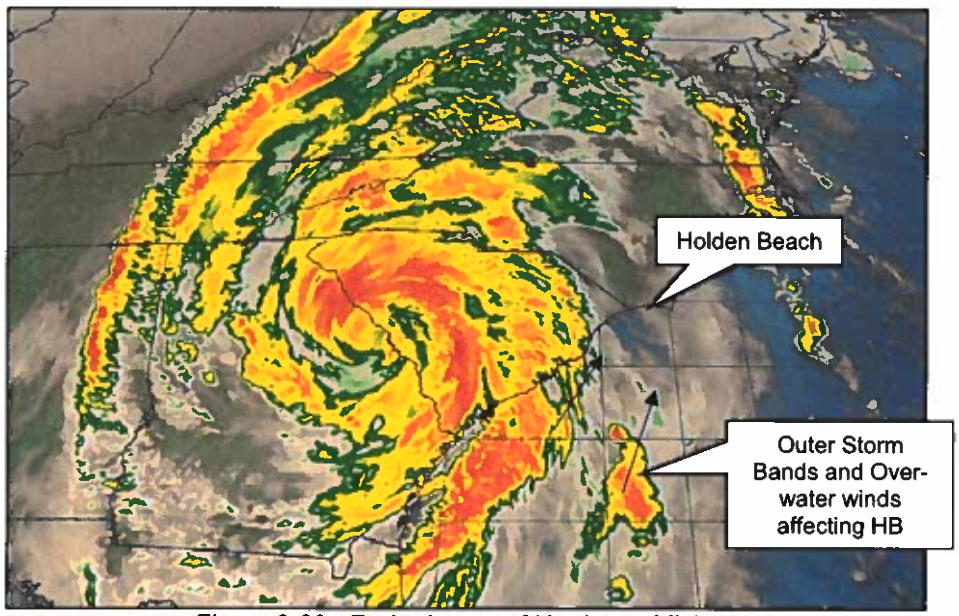


Figure 2-29. Radar Image of Hurricane Michael

Although Michael had lost hurricane strength and was only a tropical storm as it passed near Holden Beach on October 11, this storm was very large and was able to remain well developed as it moved over the southeastern United States, subjecting the Holden Beach shoreline to intense wave and storm surge conditions as it approached and passed. Figure 2-30 presents a screen capture of Hurricane Michael winds modeled by the European Centre for Medium-Range Weather Forecasts (ECMWF). Much stronger over-water winds (red and orange colors) are evident when compared with over-land winds. Winds are also directly onshore, which exacerbate shoreline erosion by increasing wave heights and water levels.

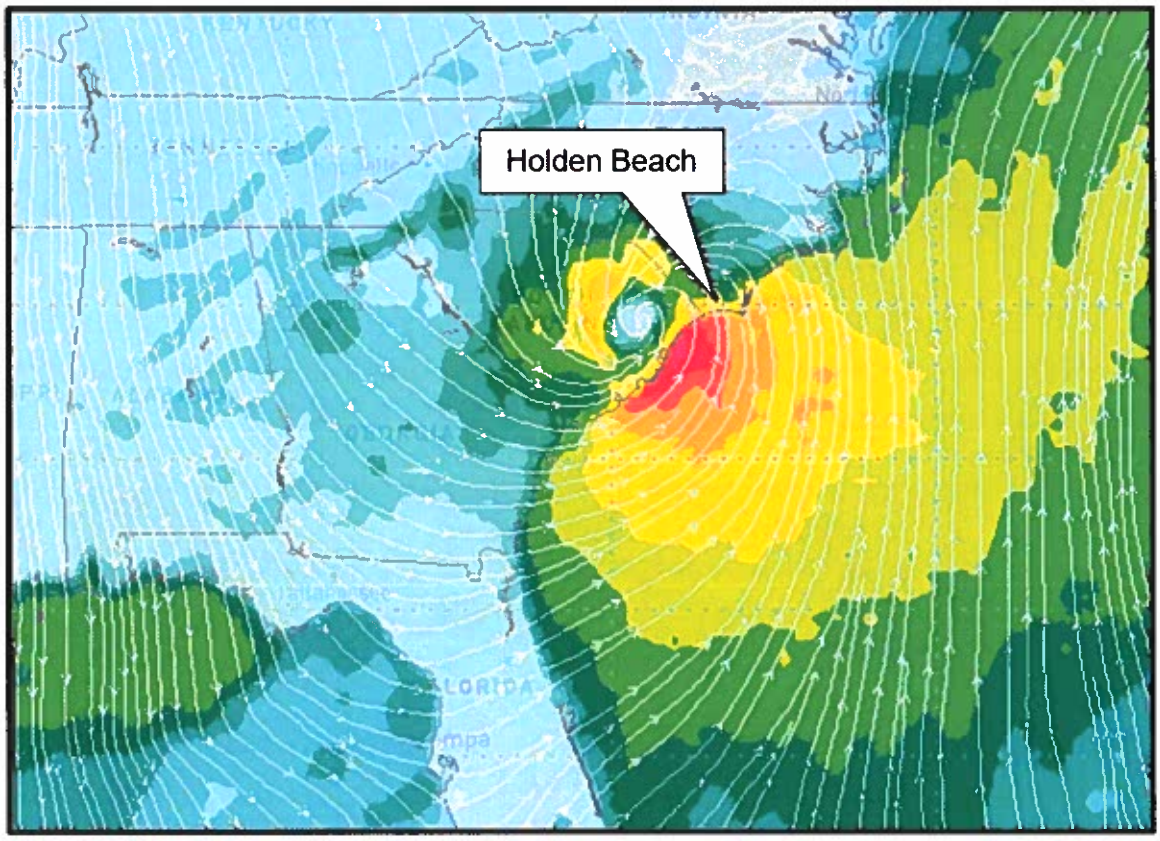


Figure 2-30. Hurricane Michael ECMWF Model-Sustained Wind Screen-Capture (red indicates sustained winds over 45 knots)

As Michael moved through NC, the highest sustained tropical storm force winds of around 50 mph were observed mainly in coastal areas, and storm surge heights were between 1 to 1.5 ft along the coast of North Carolina (Masters, J., Henson, B., wunderground.com).

NOAA tide gauge stations at Myrtle Beach and Wrightsville Beach showed elevated water levels for days leading up to and following Hurricane Michael. Recorded water levels from the two NOAA stations are provided in Appendix B. Moreover, Michael's impacts came during the spring tide cycle when water levels were already high, resulting in peak water levels of about 7.5 ft above MLLW recorded at Myrtle Beach (about 35 miles southwest of Holden Beach) on October 11. Although storm surge along the NC and SC coast from Michael was lower than what was observed during Hurricane Florence in September, the peak water levels recorded during both storms at Myrtle Beach were almost the same as a result of Michael moving through during the spring high tide. Figure 2-31 presents a photograph showing some of the impacts these conditions had on Holden Beach.

Figure 2-31. West End Dune Erosion and Vegetation Loss

Also similar to Hurricane Florence, Michael brought extreme wave conditions to the Holden Beach shoreline. The NOAA Frying Pan Shoals buoy recorded maximum offshore significant wave heights of up to about 14.8 feet and dominant wave periods of around 9 seconds on October 11, 2018.

As a result of the extreme wave and water level conditions from both Hurricanes Florence and Michael, the entire area suffered damage and FEMA has become involved to assess the damages and potential support for damage mitigation. Beach surveys were conducted immediately after each storm and approximately 723,000 cy of material was lost from the engineered portions of beach (Stations 40+00 to 280+00) following Hurricane Florence, and about 389,000 cy was lost from the engineered beach following Michael. Post-storm volume calculations went out to the -20 ft National Geodetic Vertical Datum (NGVD) contour [beyond the typical depth-of-closure (DOC) limit of -12 ft NGVD for Holden Beach]. More discussion on DOC is provided in Section 3. The most recent beach survey (April 2019) shows a recovering beach, and material moved out beyond the -20 ft contour has begun returning closer to shore in the calmer months following Hurricanes Florence and Michael. More detail is provided in Section 3.

Discussions on Hurricane Dorian, which occurred this past September (2019), are not included in this annual report but a separate memo has been developed to assess impacts and to facilitate FEMA mitigation. This hurricane will be detailed in next year's annual monitoring report.

2.9 USACE BCB PROJECT

The USACE Brunswick County Beaches (BCB) project has been re-initiated over the last year. This is a 50-year coastal storm damage reduction (CSDR) project similar to the USACE CSDR projects up and down the coast (e.g., Ocean Isle, Wrightsville Beach, Carolina Beach, etc.). The BCB project has historically included Holden Beach, Caswell Beach and Oak Island.

The USACE Wilmington District received additional funding for Hurricane Florence recovery efforts and is researching alternatives to use this funding for Holden Beach as well as other NC beaches. This USACE funding is officially from the "Additional Supplemental Appropriations for Disaster Relief Act, 2019" and more commonly referred to as PL116-20. While cost sharing for these studies and projects is typically 50/50 between the USACE and the participating communities, the USACE will provide 100 percent funding thanks to PL 116-20. Town staff are in constant coordination with the USACE on the potential for either a large-scale nourishment or an updated 50-year project analysis. Based on coordination with the USACE, the Town is currently moving forward alone in this process (i.e., nourishment on

Holden Beach only) as are the other historical BCB communities. More information on this process and potential outcomes will occur over the next year.

2.10 EAST END TERMINAL GROIN PROJECT

The Board of Commissioners (BOC) had several meetings related to the terminal groin in 2018, when a reanalysis of costs and benefits occurred. BOC meeting minutes are available on the Town's website. The terminal groin design and permitting process began in 2011, when recent storms such as Hanna (2008) and Irene (2011) had shown the east end to be the most vulnerable section of shoreline. However, with the additional bend-widener projects and the CRP since that time, a reanalysis of costs and benefits was appropriate. As a result, the Town withdrew from the permitting process and is no longer pursuing a terminal groin on the east end. The BOC created and signed a resolution to this effect. The additional sand provided by the 400-ft bend widener in 2010, 2014 and 2017 was a key component in building up the east end upper beach. The Town and ATM staff will continue to work with the USACE to ensure that the bend-widener project continues.

2.11 INLET HAZARD AREA UPDATE

DCM has developed new State inlet hazard areas (IHAs) that include Shallotte and LWF Inlets. The current IHAs were established in 1978. IHAs are defined as shorelines especially vulnerable to erosion and flooding, where inlets can shift suddenly and dramatically. IHAs do not affect FEMA flood maps or the National Flood Insurance Program (NFIP), however, they do affect some State regulations related to erosional setbacks.

Revised IHAs were previously introduced around 2010, however, these were never implemented. The currently proposed IHAs are scheduled to be implemented in 2020. The proposed IHAs are expanded for Shallotte and LWF Inlets (as with most of the IHAs statewide). In general, the new methodology for the IHA determination appears reasonable for the east end of Holden Beach bordering LWF Inlet, however, the west end (adjacent to Shallotte Inlet) is accretional and the IHA methodology is overly conservative. The "hybrid-vegetation" line along the west end is decades old. Figures 2-32 and 2-33 present the proposed IHAs affecting Holden Beach. More information on this topic is available at https://deq.nc.gov/about/divisions/coastal-management.

Figure 22. Shallotte Inlet at Holden Beach Hybrid-Vegetation Line and the recommended IHA boundary with the 30- and 90-Year Risk Lines. Black dashed line indicates Transect-90 where the IHA boundary was adjusted to match the existing IHA line (yellow dashed line).

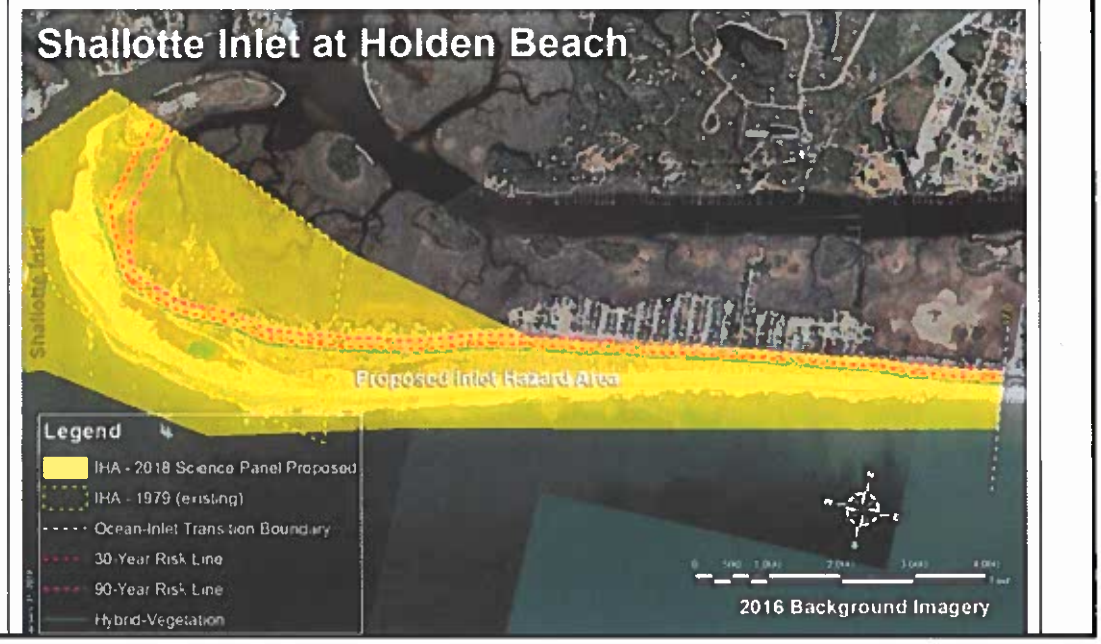


Figure 2-32. Proposed IHA for the west end of Holden Beach (image source: 2019 DCM IHA report)

Figure 26. Lockwood Folly Inlet at Holden Beach Hybrid Vegetation Line and the recommended IHA boundary with the 30- and 90-Year Risk Lines.

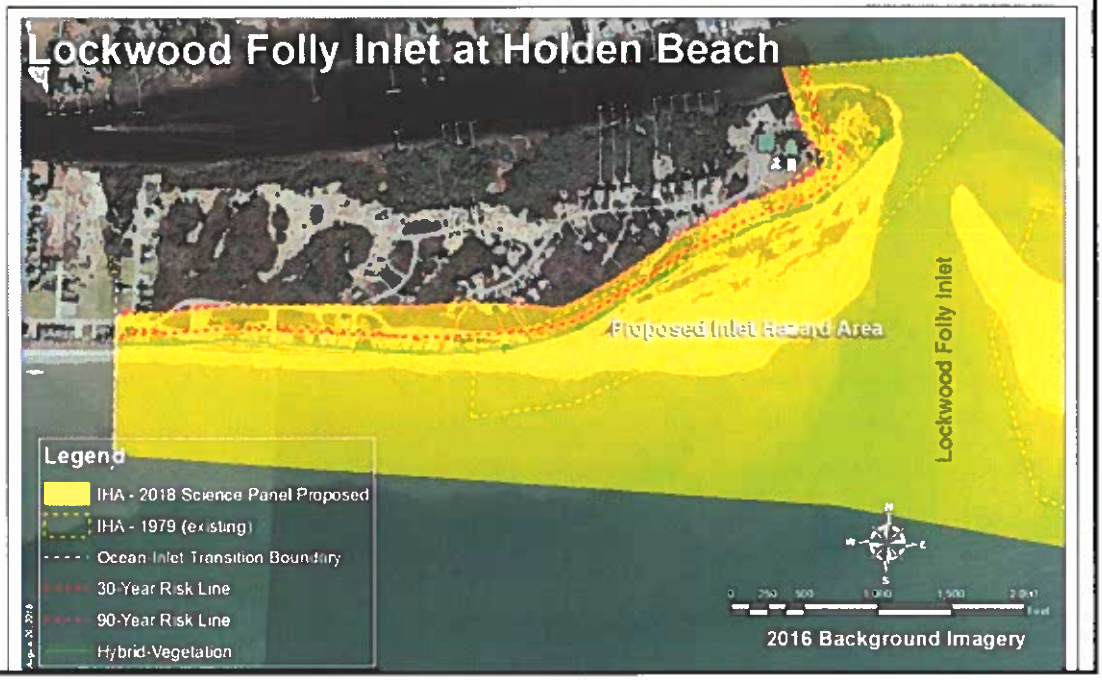


Figure 2-33. Proposed IHA for the east end of Holden Beach (image source: 2019 DCM IHA report)

2.12 BEACH MANAGEMENT PERMITS

The Town currently has several projects that have required or do require permits, including:

- Central Reach Project (CRP)
- LWFIX and Bend-Widener
- LWF Outer Bar (side-casting, shallow draft hopper)
- Upland Borrow Area
- Central Reach Reimbursement (CRR) Project (using offshore borrow area)

The CRP nourishment has been completed, although some offshore borrow area volume is still available (as planned). DCM chose to modify the beach nourishment permit initially obtained by the Town in 2002 (permit number 14-02) for the CRP. This follows modifications that included the 2008 and 2009 Town nourishments using the Smith borrow site. DCM is now requiring permit extensions every year; therefore, an extension will be required this year.

In contrast to DCM, the USACE typically creates new permits for each project (upland fill, LWFIX, CRP). 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, 2021, 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 DCM. The USACE, DCM and DWQ generally coordinate to avoid any permit condition conflicts. If any future modifications are needed, it is anticipated that coordination will be needed with all 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. The Town renewed the mining permit in 2018.

As discussed in Section 2.5, the Town has recently obtained permits to perform SDI projects, including LWFIX dredging and beach placement, as well as outer-channel sidecast dredging. The State permits (DCM 52-16) were issued in May 2016 and will expire on December 31, 2019. ATM staff have already begun coordination with DCM and USACE staff regarding permit extensions for the SDI permits.

2.13 WILMINGTON HARBOR DEEPENING

The State Port Authority (SPA) would like to deepen the Wilmington Harbor by 5 ft (from 42 ft to 47 ft MLLW) to allow for largest vessels and remain competitive with other ports along the eastern seaboard. The SPA recently released a preliminary report on the proposed project. While annual maintenance dredging is typically composed of mud and fines, "new work" dredging can contain beach-compatible material. This was the case for the 2001/2002 Wilmington Harbor deepening, where 525,000 cy of material was placed on Holden Beach (in addition to other nearby beaches). In reviewing the preliminary report, no official volume of beach-compatible material was provided, however, Town staff have participated in deepening meetings and have made it known that the Town would like to receive beach-compatible sand, if feasible quantities are available.

See the following link for more information:
https://www.saw.usace.army.mil/Missions/Navigation/Dredging/Wilmington-Harbor/WHNIP_203_Study/

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 transects established by the monitoring plan. Survey data were collected in April 2019 at 48 transects along Holden Beach. This survey also included an additional seven transects on western Oak Island. The monitoring of these additional Oak Island 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, inlet dynamics have the potential to affect this area.

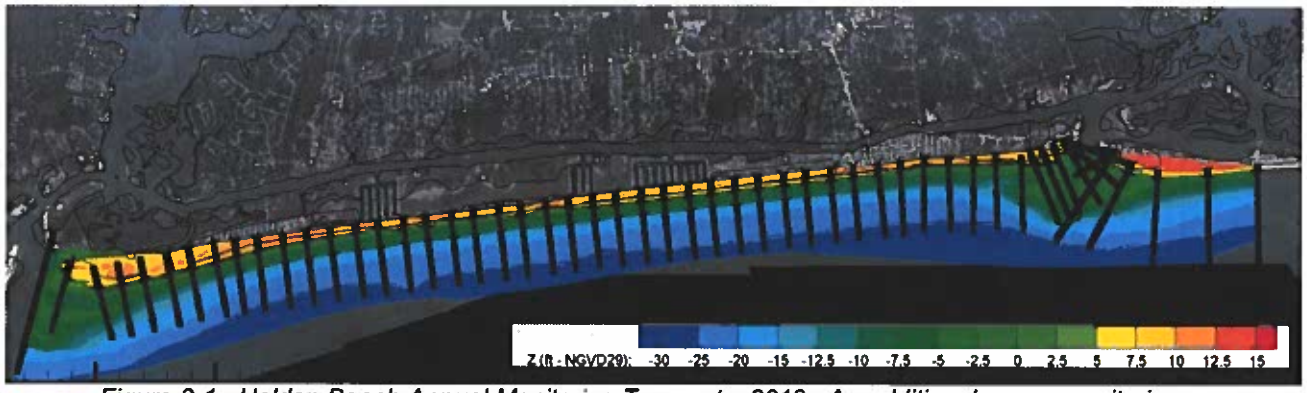


Figure 3-1. Holden Beach Annual Monitoring Transects, 2019. An additional seven monitoring transects have also been added to western Oak Island beginning with the 2012 survey. Note "Z" is in ft-NGVD29.

Figures 3-2 and 3-3 present example transect surveys comparing 2018 and 2019 survey data. Figure 3-2 also shows a 2017 and 2018 survey comparison to illustrate typical changing sediment transport patterns and monitoring of the 2017 nourishment projects. As both the CRP and the Town Eastern Reach / USACE LWFIX Project were completed in spring 2017, the 2019 survey represents 2-year post-construction conditions. Note that some differences in profiles may be related to recent wave activity and/or nourishment activities and are not necessarily indicative of long-term trends. Appendix A contains all transect data for the 2018 and 2019 surveys.

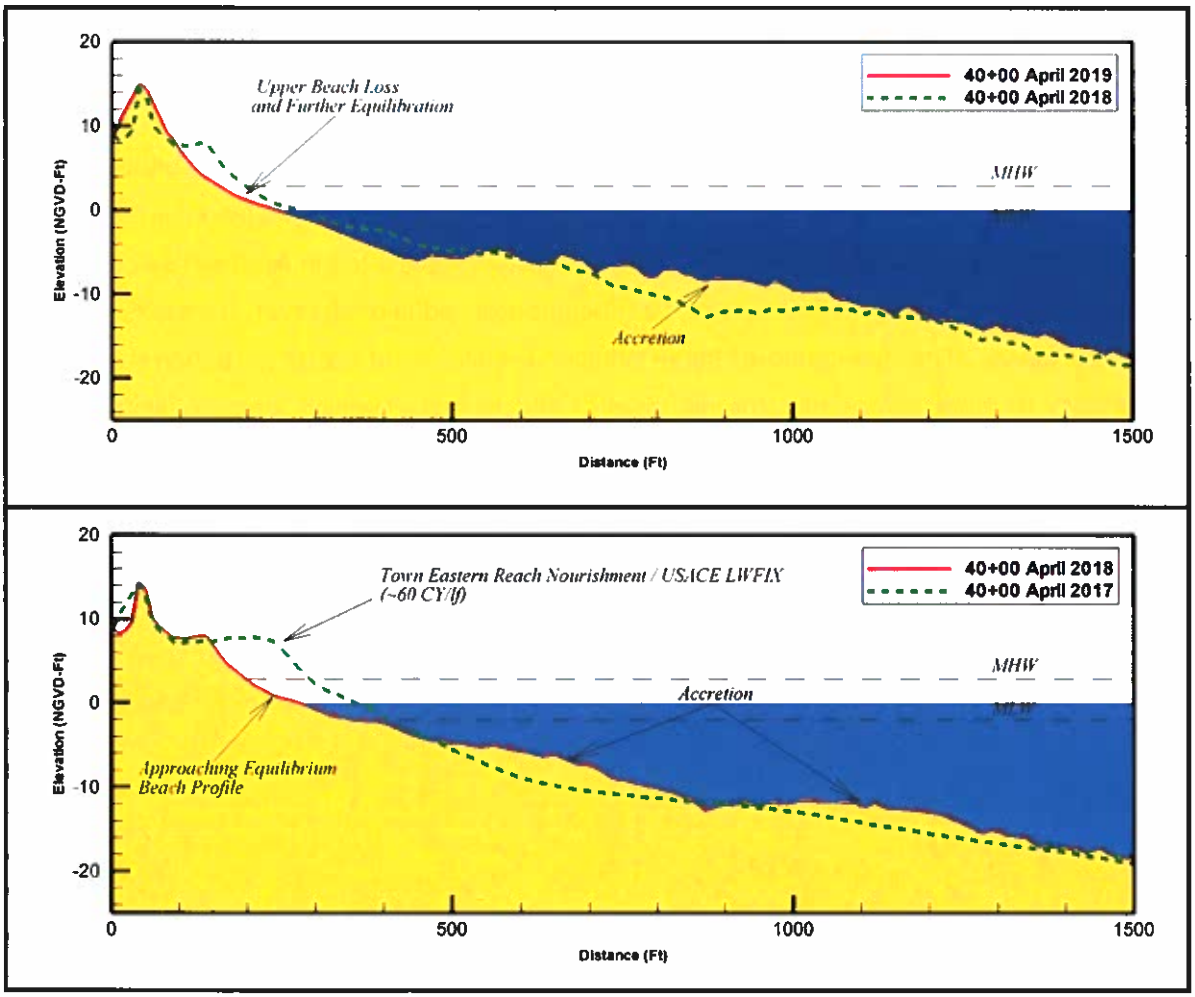


Figure 3-2. Station 40+00 Profile Transect Comparison on the Town East Reach of Holden Beach. Upper panel shows 2018-2019 survey comparison showing the 2-year post-project adjustment of the 2017 LWFIX / Town Eastern Reach nourishment material. Lower panel shows 2017-2018 comparison, displaying the immediate post project profile of the 2017 LWFIX / Town Eastern Reach nourishment and the 1-year post project profile (April 2018). Placed project volumes typically ranged between 40 and 60 cubic yards / linear foot (cy/lf).

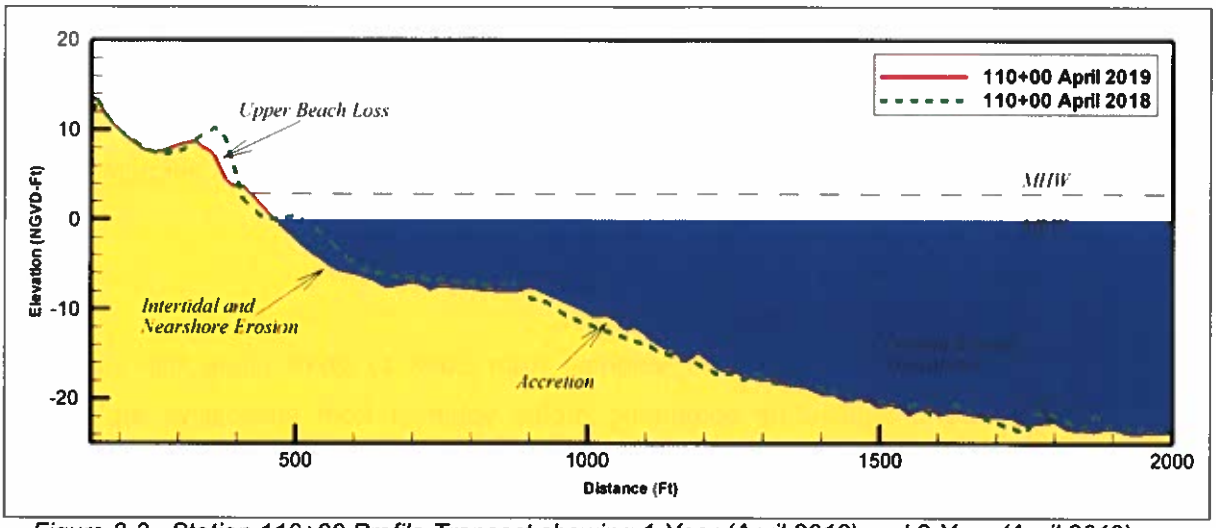


Figure 3-3. Station 110+00 Profile Transect showing 1-Year (April 2018) and 2-Year (April 2019) post-project profiles following the Town Central Reach Project. Central Reach Nourishment placed approximately 60 cy/lf in this area. Note continued project equilibration is observed along with upper beach loss and intertidal and nearshore erosion from the 2018 Hurricane Season (Hurricanes Florence and Michael).

In general, comparison of the 2018 and 2019 surveys reveals an overall erosional beach along much of the island and particularly within the Central Reach. However, substantial accretion did occur at both the east and west ends. Continued beneficial downdrift spreading of nourishment material is observed in areas west of the CRP area. The east end of Holden Beach, which historically has shown a strong erosional long-term trend, experienced significant accretion over the past year. This is likely due to spreading of Central Reach and Town / USACE LWFIX project sand and inlet dynamics (e.g., shoal movement).

As anticipated for the years following the 2017 Town Eastern Reach Nourishment / USACE LWFIX Project nourishment, the cross-shore changes at Station 40+00 in Figure 3-2 show the movement of material from the upper beach into the nearshore, forming an equilibrium beach profile in the April 2019 survey. Figure 3-3 shows a typical profile view within the CRP area and displays a sediment transport pattern similar to Station 40+00. Continued adjustment/equilibration of the nourishment material has taken place over the past year.

This equilibration and observed upper beach loss have been somewhat accelerated due to recent storms. Figure 3-3 reveals that some material has accreted in areas farther offshore as well, and relatively significant changes are observed beyond the -12 ft contour. The

-12-ft contour has historically been considered the DOC for Holden Beach, barring major hurricanes.

Sections 3.2 and 3.3 provide more information on volume and shoreline analysis, respectively.

3.2 VOLUME ANALYSIS

Figure 3-4 presents changes in volumes from 2018 to 2019 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.

With the exception of the inlet reaches, the majority of the shoreline has been mostly stable to erosional, with some variation from station to station (see Figure 3-4). This variation is due to survey precision as well as seasonal variation, and recent wave activity. Additional variation may also be attributed to undulating patterns along the shoreline, which have been documented along nearby beaches[1].

The most significant erosion over the past year was observed within the Central Reach shoreline, though much of this material has moved westward, outside of the 2017 project footprint to benefit the downdrift (i.e., western) beaches. The western extent of the 2017 CRP nourishment ended at about Station 260+00. The 2019 survey reveals that the anticipated downdrift spreading of the project sand to the western shorelines is continuing to take place, as indicated by the exhibited accretion in these areas.

The volumes calculated in Figure 3-4 are from the dune out to about the -12-ft NGVD contour, which represents the typical DOC limit. The DOC essentially represents the depth limit where sand along the seabed stops moving. In general, the vast majority of sand transport and profile change typically occurs in waters shallower than the DOC, such as the surf zone and intertidal beach. However, during periods of significant energetic wave conditions, changes to the beach profile can occur beyond the DOC limit. Therefore, the DOC can vary annually depending on storm activity, and extreme storms can move material

[1] 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

out to depths of 30 ft. The 2018 and 2019 surveys have shown more significant changes in locations seaward, deeper than the -12-ft contour and even beyond -20-ft contour as well, due to Hurricane Florence and Hurricane Michael.

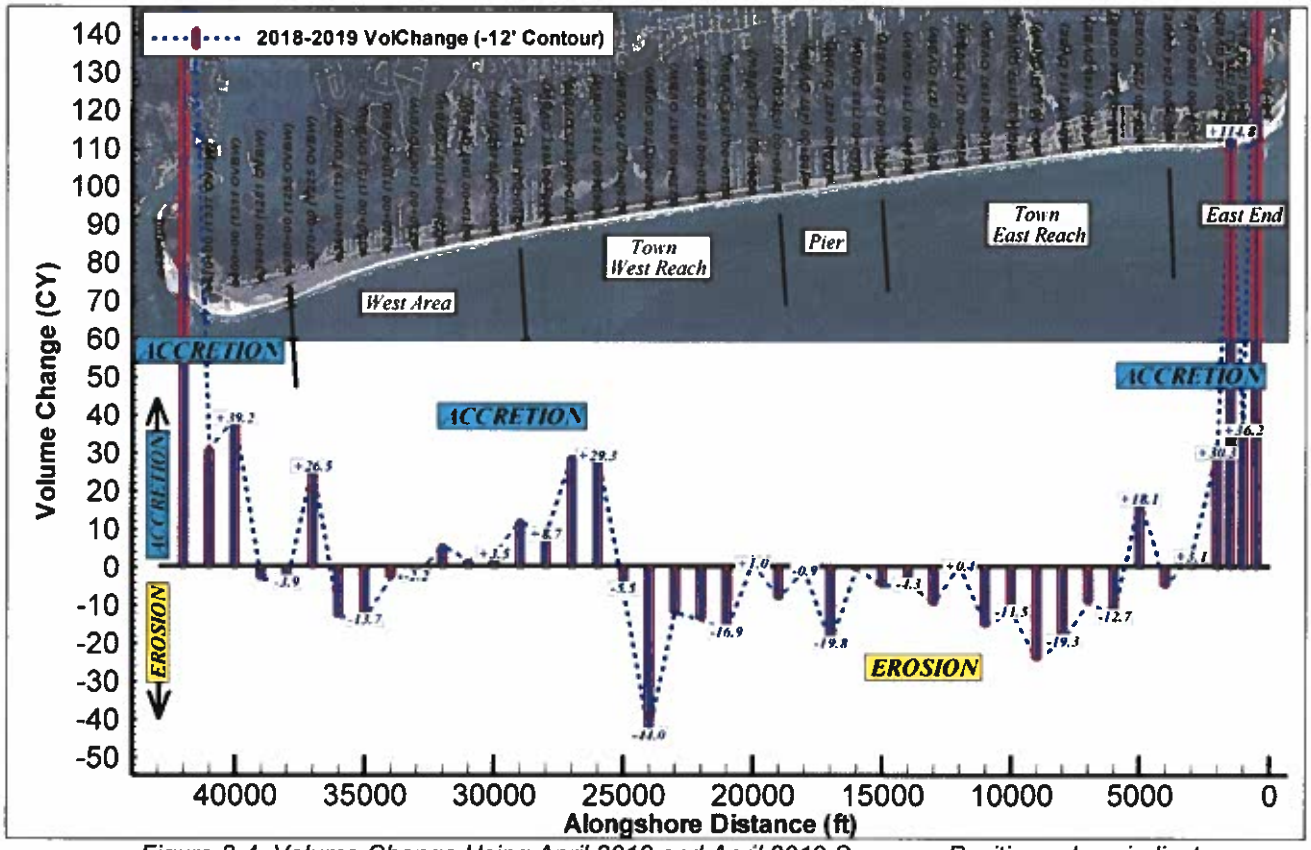


Figure 3-4. Volume Change Using April 2018 and April 2019 Surveys. Positive values indicate accretion, negative values indicate erosion. Note erosion observed throughout most of Central Reach and continued accretional/spreading of the two 2017 nourishment projects can be observed. The combined nourishment project templates spanned from about Station 20+00 to about Station 260+00. The most significant accretion is seen near the inlets, on both the east end and the west end.

As a result, some of the sand lost during the recent storms has moved far offshore (farther than 1,000 ft), and beyond the typical DOC limit (-12 ft NGVD). This material can still be mostly accounted for in the April 2019 survey when considering volumetric calculations beyond the -12-ft contour. Note that for FEMA mitigation calculations for Hurricanes Florence and Michael, FEMA representatives did not want to use the -12-ft DOC and a -20-ft DOC was mutually agreed upon.

The beach has shown signs of recovery since the 2018 hurricane season, as indicated in the relatively mild erosional losses observed in the 2019 survey compared to losses observed immediately following Hurricanes Florence and Michael. With continued calmer conditions, material is slowly moving from offshore back into the typical DOC area. Changes in these deeper areas (beyond -12 ft, and even beyond -20 ft) will continue to be monitored to assess any potential future volumetric impacts of sediment transport for Holden Beach.

As seen in Figure 3-4, 2018 and 2019 changes in volume out to the typical DOC (-12 ft) indicate that mild erosion has generally occurred within the middle of Holden Beach and primarily within the 2017 CRP area. Figure 3-4 identifies several smaller shoreline reaches (e.g., West Area, Town West Reach, Pier, Town East Reach) along Holden Beach.

The most significant erosion occurred within the Town West Reach, near the western extent of the 2017 CRP placement. This is an expected response since the nourishment sand equilibrates and spreads alongshore as is indicated by the accretion seen just west of the CRP footprint.

The West Area (see Figure 3.4) is largely stable to accretional between the 2018 and 2019 surveys. The most significant accretion over the past year is observed on the extreme ends of the island, closest to the inlets. This is likely due to continued spreading of nourishment material, as well as inlet dynamics and recent shoal movement.

Slight erosion had been observed near the western end of the island in recent years (reaching as far east as Station 380+00) and, fortunately, the progression of the CRP sand is helping to reverse the erosional trend, as this area has shown healthy accretion in the last year. The west end also has a large and wide dune system that can buffer several years of erosion.

Despite the accretional trends observed over the past 2 years, as with any inlet, this area can be susceptible to episodic erosion. Additionally, Shallotte Inlet dredging activities have been documented to have adverse impacts on Holden Beach shorelines in the past and, therefore, this area will be monitored for any potential impacts related to the borrow area and any continuing erosional patterns.

Similarly, the east end also showed some of the largest accretion over the past year. The east end is historically highly erosional and has continued to show an erosional trend in recent years, especially at the known erosional hotspot near Station 20+00 (near the Town's eastern-most oceanfront house called *Amazing Grace*). However, over the past year, the majority of the east end shoreline experienced significant and much-needed accretion.

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 and illustrates upper beach accretion observed downdrift/west of the 2017 CRP at Station 270+00. The -5-ft volume limit is more characteristic of visible/tangible beach conditions than the deeper -12-ft or -20-ft limits that can occur more than a quarter-mile offshore.

Although upper beach erosion occurred along the majority of the island, the predominant cross-shore sediment transport pattern observed over the past year showed material eroding from areas just beyond and deeper than the surf-zone limit and being deposited/accreting about 1,000 ft offshore. This cross-shore movement can be attributed to the 2018 hurricane season as well as typical nourishment equilibration.

Since Hurricanes Florence and Michael, generally calmer conditions have allowed material that had previously moved significantly far offshore (beyond even the -20-ft NGVD contour) to now gradually move closer to shore. As a result, an overall accretional trend is observed in the April 2019 at these depths, about 1,000 ft offshore along the majority of Holden Beach.

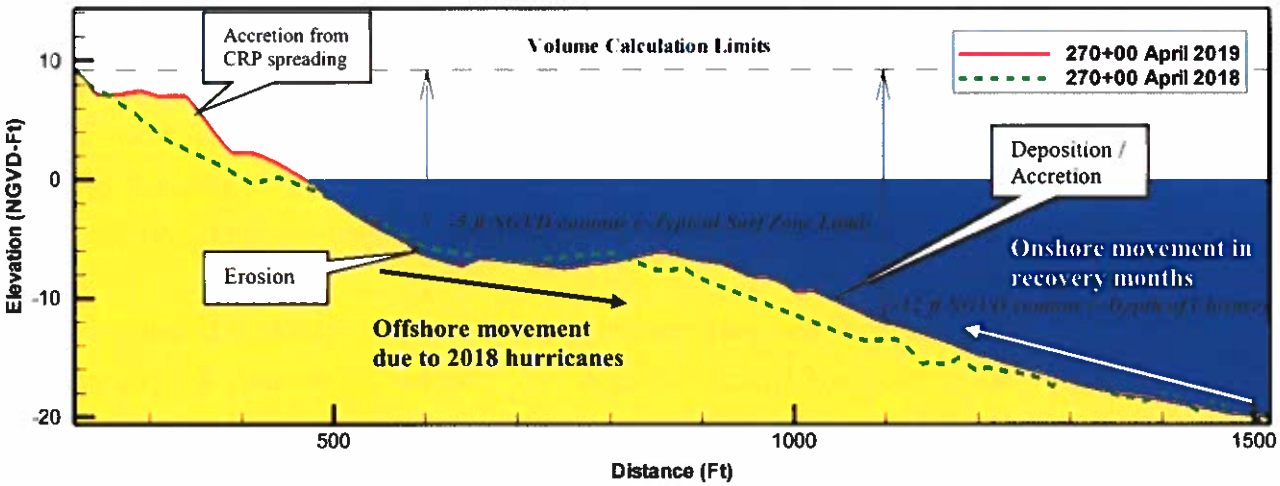


Figure 3-5. Two Different Volume Calculation Limits Used for this Analysis: 1) Dune to -12 ft NGVD and 2) Dune to –5 ft NGVD.

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 2018 to 2019. In general, the most significant erosion (or least amount of accretion) occurred within the dry beach/surf zone area (dune to -5 ft NGVD) and specifically within the Town East, Pier, and Town West reaches. This is indicative of continued beach nourishment equilibration as well as nearshore beach erosion caused by the energetic wave conditions and elevated water levels from Hurricanes Florence and Michael.

Table 3-1. Volume Change by Shoreline Reach for 2018 and 2019 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	+95,000	+44,000	+51,000
USACE East	15 to 40	+52,000	+24,000	+28,000
Town East	40 to 150	-92,000	-103,000	+11,000
Pier	150 to 190	-28,000	-18,000	-10,000
Town West	190 to 290	-22,000	-48,000	+26,000
West Area	290 to 380	+10,000	+17,000	-7,000
Shallotte Inlet	380 to 420	+176,000	+43,000	+133,000
	TOTAL	**+191,000**	**-41,000**	**+232,000**
Central Reach	40 to 290	-142,000	-169,000	+27,000

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

Accretion was observed out to the -12-ft DOC limit, with an island-wide gain of 191,000 cy. This is a large gain in a year following an active hurricane season and when no nourishments occurred. It can be attributed largely to the significant accretion observed near both inlets as well as the cross-shore sediment transport described above and shown on Figure 3-5. As Table 3-1 shows, the Central Reach lost 142,000 cy of sand out to the -12-ft DOC limit. Note that the survey area is not a closed system and identifying sediment transport direction can only be inferred based on measured volume change and engineering judgment.

Accretion at all depths is most prominently observed at both inlet reaches and is likely due to lateral spreading of the 2017 nourishment projects as well as inlet dynamics.

Historical volume changes back to 2012 for the Central Reach (Stations 40+00 to 290+00) and the total Holden Beach shoreline, calculated from the dune to the -12-ft NGVD DOC are provided in Table 3-2. The most significant volume losses were observed between 2015 and 2016, largely due to a year of higher-than-normal wave activity, as well as Hurricane Joaquin in October 2015.

Table 3-2. Historic Volume Changes (cy) (Dune to -12 ft NGVD) by Year

Reach Averages	2012-2013 Total Volume Change (cy)	2013-2014* Total Volume Change (cy)	2014-2015 Total Volume Change (cy)	2015-2016 Total Volume Change (cy)	2016-2017* Total Volume Change (cy)	2017-2018 Total Volume Change (cy)	2018-2019 Total Volume Change (cy)
Central Reach	-14,000	+94,000	+62,000	-238,000	+1,386,000	+231,000	-142,000
TOTAL	-73,000	+235,000	-11,000	-358,000	+1,479,000	+440,000	+191,000

*2013-2014 and 2016-2017 show large gains in total volume due to nourishment activities

Overall, the volume changes in Table 3-2 reveal that Holden Beach has experienced milder-than-average erosion over the last few years (with the exception of the 2015/2016 time span). Of course, nourishment activities have considerably ameliorated conditions along the Holden Beach shoreline, as seen following the 2014 east end nourishment and the recent 2017 nourishments.

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 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 (Stations 5+00 to 40+00) overall exhibited accretion of about 147,000 cy of material in the entire dune to the DOC zone. The 2017 Town Eastern Reach / USACE LWFIX project and recent shoal movement has contributing to dry beach growth in this area over the past year. Figure 3-6 presents a recent photograph of beach conditions at the east end, where a wide healthy beach and dune system is present.

Figure 3-6. Recent Photograph of Beach Conditions near East End, Just West of Station 20+00, where Accretion and Upper Beach Growth Has Occurred Over the Past Year in What Is Typically an Erosional Hotspot Area (ATM Photo Taken September 2019).

Several past shoal attachments (documented in previous annual reports) have contributed to localized low-tide beach expanses on the east end. These shoal attachments have been estimated to be between 5,000 and 50,000 cy and can provide a significant benefit to the sand (littoral) system. These shoals can also create erosional hotspots, depending on their distance from shore, size, attachment location, etc.

The West Area (Stations 290+00 to 380+00) is historically stable and has never been nourished but is receiving much of the CRP sand as it migrates westward. The 2019 survey showed the West Area overall gained about 10,000 cy of material in the dry beach to the DOC area (dune to -12 ft), with the majority of accretion (about +17,000 cy) taking place in the dry beach to surf zone area (dune to -5 ft NGVD).

The beach west of Station 380+00 to Shallotte Inlet is subject to episodic erosion, however, this reach experienced some of the largest volumetric accretion observed along Holden Beach between 2018 and 2019, with a total gain of 176,000 cy. Fluctuations in volumes in this region can be attributed to net westerly sand transport, shoreline undulations, inlet-related processes (including shoreline orientation/curvature and shoal formation), and extreme storm conditions.

3.3 SHORELINE ANALYSIS

In addition to a volumetric analysis, shoreline analyses were also performed as another useful metric in gauging beach health. Figure 3-7 was developed to view annual changes in the mean high water (MHW) shoreline contour along Holden Beach.

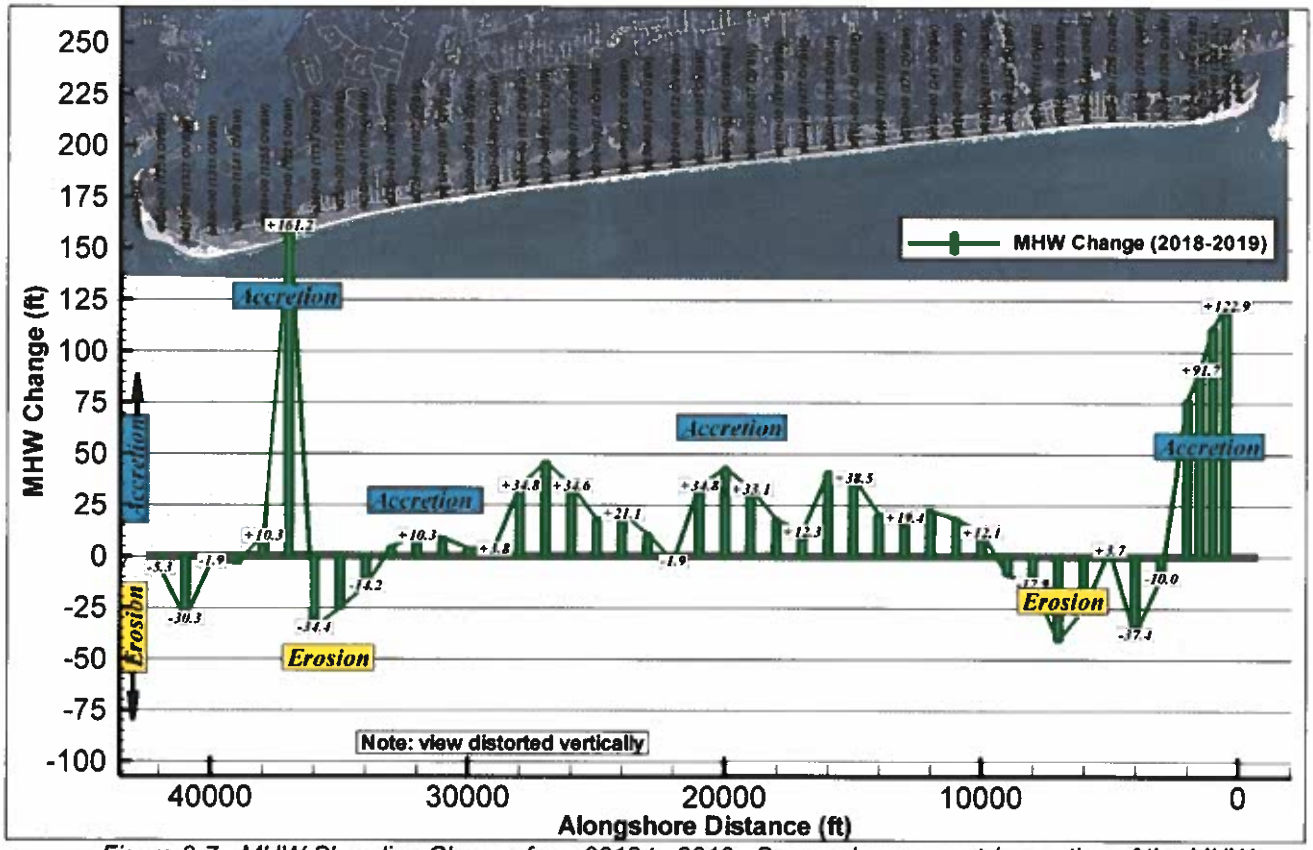


Figure 3-7. MHW Shoreline Change from 2018 to 2019. Seaward movement / accretion of the MHW shoreline is observed within the Central Reach and along the eastern end of Holden Beach. Erosion / landward movement is observed in the more eastern and western portions of Holden Beach and near Shallotte Inlet.

Average MHW shoreline change by reach is presented in Table 3-3. Over the past year, the majority of the beach has experienced accretion of the MHW shoreline. As the upper beach experienced impacts from Hurricane Florence and Hurricane Michael, much of this material moved into the intertidal zone, pushing the MHW shoreline seaward.

Table 3-3. MHW Shoreline Change by Reach for 2018 and 2019 Surveys

Reach Averages	Stations Included	2018 to 2019 MHW Change (ft)
LWF Inlet	5 to 15	+108.9
USACE East	15 to 40	+9.8
Town East	40 to 150	+0.9
Pier	150 to 190	+28.6
Town West	190 to 290	+25.3
West Area	290 to 380	+12.9
Shallotte Inlet	380 to 420	-6.2
Central Reach	40 to 290	+13.9

This pattern was observed most frequently in the Central Reach, where upper beach sand in the berm and dune was moved into the intertidal zone as a result of recent storms, and where adjustment of nourishment material into an equilibrium beach profile is continuing to take place. Figure 3-8 presents a photograph in the western portions of the Central Reach, where lateral spreading of the CRP has contributed to some significant upper beach growth and accretion of the MHW line.

Figure 3-8. March 2019 Photo Taken Near Station 260+00 Looking East

The MHW shorelines in the western reaches are generally stable to erosional, though upper beach growth is exhibited from the Central Reach up to Station 330+00 from downdrift spreading of nourishment material over the past year. Figure 3-9 presents the changes in the MHW position from 2018 to 2019 along the westernmost shorelines of Holden Beach.

Appendix B provides figures of the 2019 survey MHW results for the entire Holden Beach shoreline.

Despite the large volumetric gains observed in this area, the MHW line here has remained relatively stable over the past year, with the exception of Station 370+00, which accreted substantially. This localized accretion is possibly due to sediment movement during energetic wave conditions and/or inlet related processes.

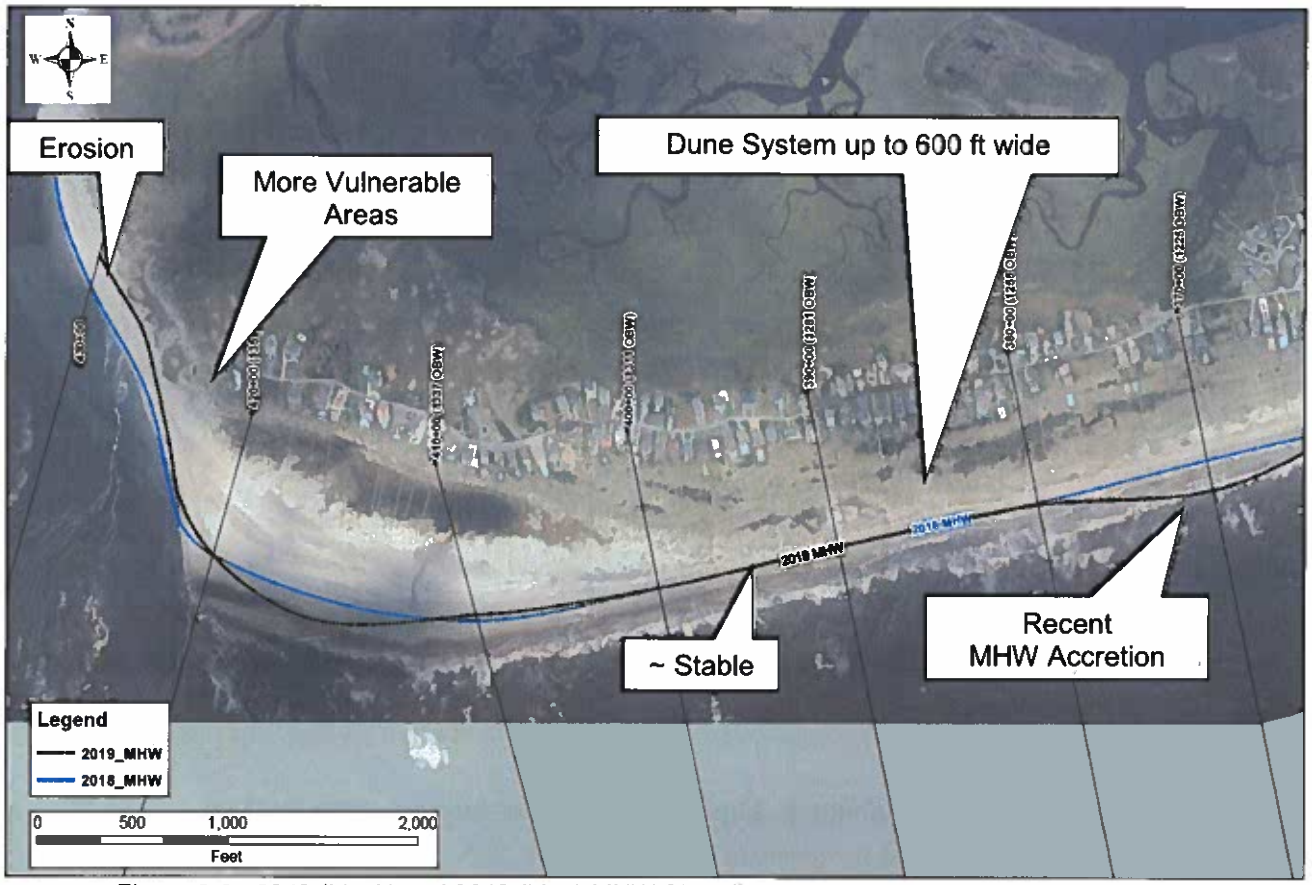


Figure 3-9. 2019 (black) and 2018 (blue) MHW Shoreline Positions along the West End of Holden Beach near Shallotte Inlet. (NOAA 2018 Post-Florence aerial shown).

Although the MHW shoreline here was relatively stable over the past year, erosion has been documented in recent years, and some significant dune scarping and vegetation loss was observed near this area following Hurricane Michael (refer to Section 2.8). Dune system widths in the West Area can be up to 600 ft (around Stations 370+00 to 390+00; see Figure 3-9); therefore, large fluctuations in volume and/or shoreline position in this area are still several hundred feet from residential structures.

This area will continue to be closely monitored and future efforts to enhance vegetation may be implemented as a proactive measure to mitigate erosion. Also, the substantial addition of material into the system from the 2017 CRP is expected to promote beach growth in this region as it continues downdrift spreading in years to come.

Several homes on the extreme western end of the Holden Beach, near Station 420+00 (approximately 1359 OBW) are close enough to Shallotte Inlet that close monitoring of inlet migration and USACE/Ocean Isle activities in Shallotte Inlet is warranted. The Ocean Isle nourishments typically use Shallotte Inlet as a borrow area.

The most recent of these nourishment events occurred in April 2018 as part of the USACE Federal CSDR project, which involved dredging about 370,000 cy from Shallotte Inlet and placement onto the eastern shoreline of Ocean Isle. No noticeable changes to the Holden Beach shoreline have been observed based on April 2019 survey data, however, shoreline monitoring will continue to assess any potential effects of this and future activities on the Holden Beach shoreline.

Additionally, information and activity related to the Town of Ocean Isle's ongoing efforts to permit and construct a terminal groin (on the east end of Ocean Isle at Shallotte Inlet) will continue to be monitored. Ocean Isle had recently won an appeal in favor of the terminal groin. However, another appeal has just been filed (in October 2019), so the appeal process will continue, and project construction will not occur in the near future.

The eastern reaches experienced some relatively minor erosion of the MHW shoreline, but, in general, these areas were relatively stable.

Similar to the volumetric analysis, the extreme eastern end near LWF Inlet shows some of the largest accretion occurred in this area. Figure 3-10 presents the changes in the MHW position from 2018 to 2019 along the easternmost shorelines of Holden Beach. Stations 30+00 to 50+00 are mostly stable, and a large seaward movement of the MHW shoreline of over 100 ft can be observed from Stations 30+00 to LWF Inlet.

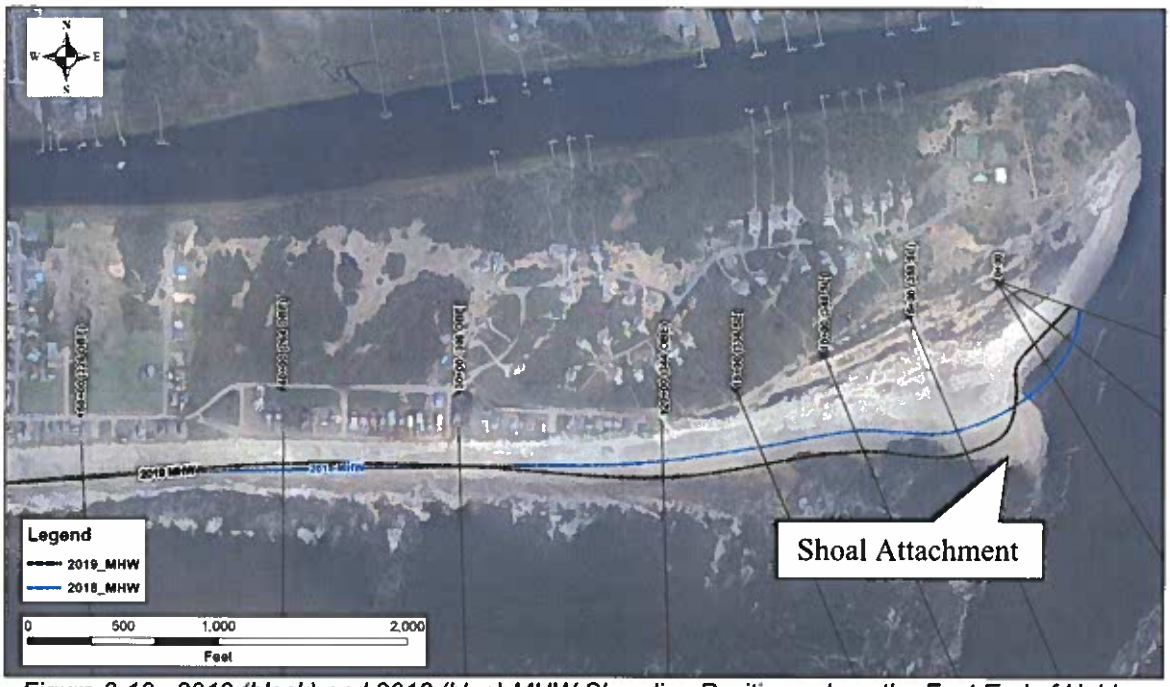


Figure 3-10. 2019 (black) and 2018 (blue) MHW Shoreline Positions along the East End of Holden Beach near Lockwood Folly Inlet. (NOAA 2018 Post-Florence aerial shown).

This can be attributed to alongshore movement from the 2017 Town/USACE LWFIX nourishment project, LWF Inlet dynamics, and the shoal attachment between Station 0+00 and Station 5+00. The 2019 survey and more recent aerials and site observations reveal this shoal to be flattening and spreading out, which is benefitting the east end.

The toe-of-dune (TOD) shoreline (7 ft NGVD contour) is shown on Figure 3-11 and generally represents the seaward edge of the dune. The TOD shoreline change shows variable erosion and accretion but has eroded along the majority of Holden Beach between the last two survey events. Dune loss from Hurricanes Florence and Michael in 2018 was documented for the majority of the beach as well as many nearby beaches immediately following the storm's passing.

Accretion of the TOD location occurred on the extreme east end, which can likely be attributed to LWF Inlet dynamics, 2017 nourishment material, and the recent shoal attachment.

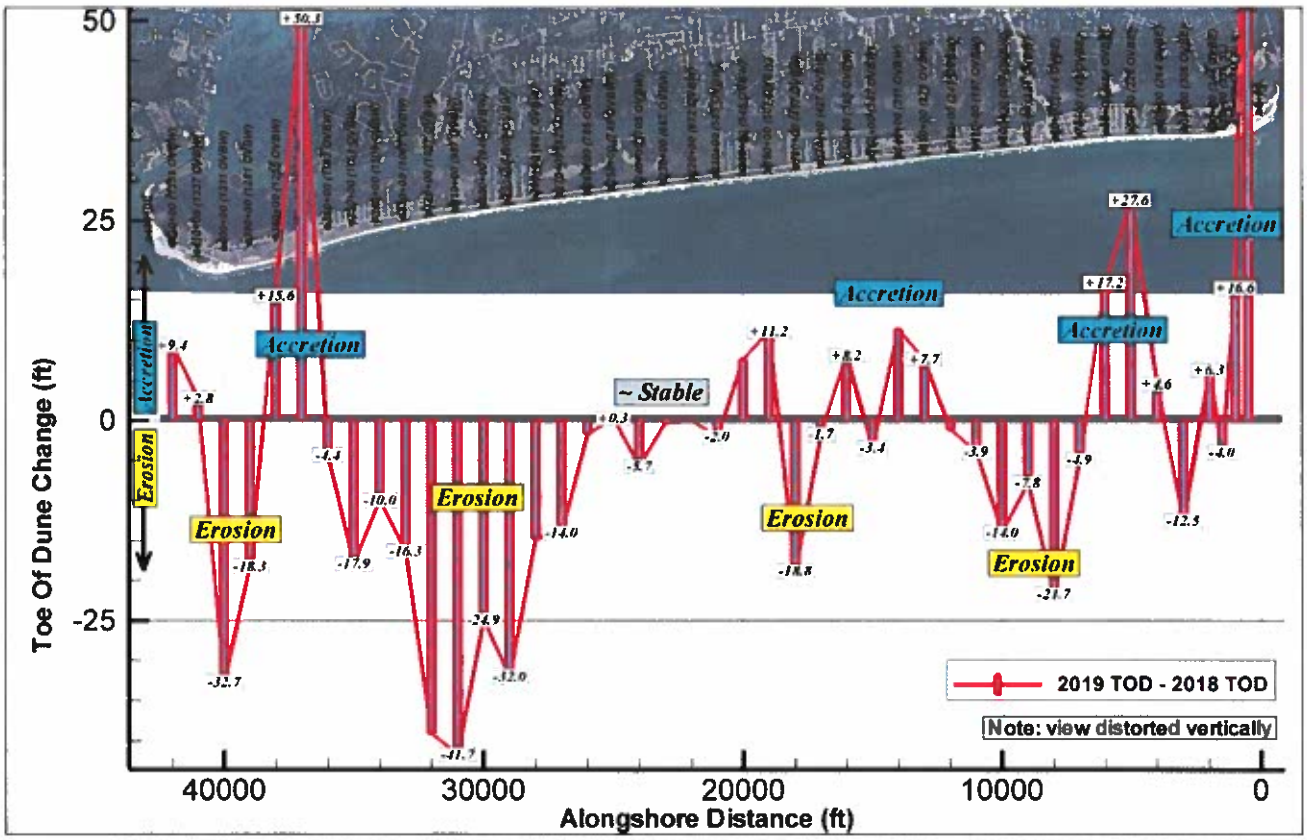


Figure 3-11. Toe of Dune (TOD, +7 ft NGVD) Change from 2018 to 2019. A mostly erosional beach trend is exhibited, though with much variability throughout the reaches.

Figure 3-12 presents maximum dune heights for each Holden Beach station. Despite losses in dune volume and observed scarping following Hurricanes Florence and Michael, dune heights are generally healthy and were mostly stable over the past year. Proactive dune enhancements, discussed in Section 2.7, are an important activity related to maintaining a healthy dune system.

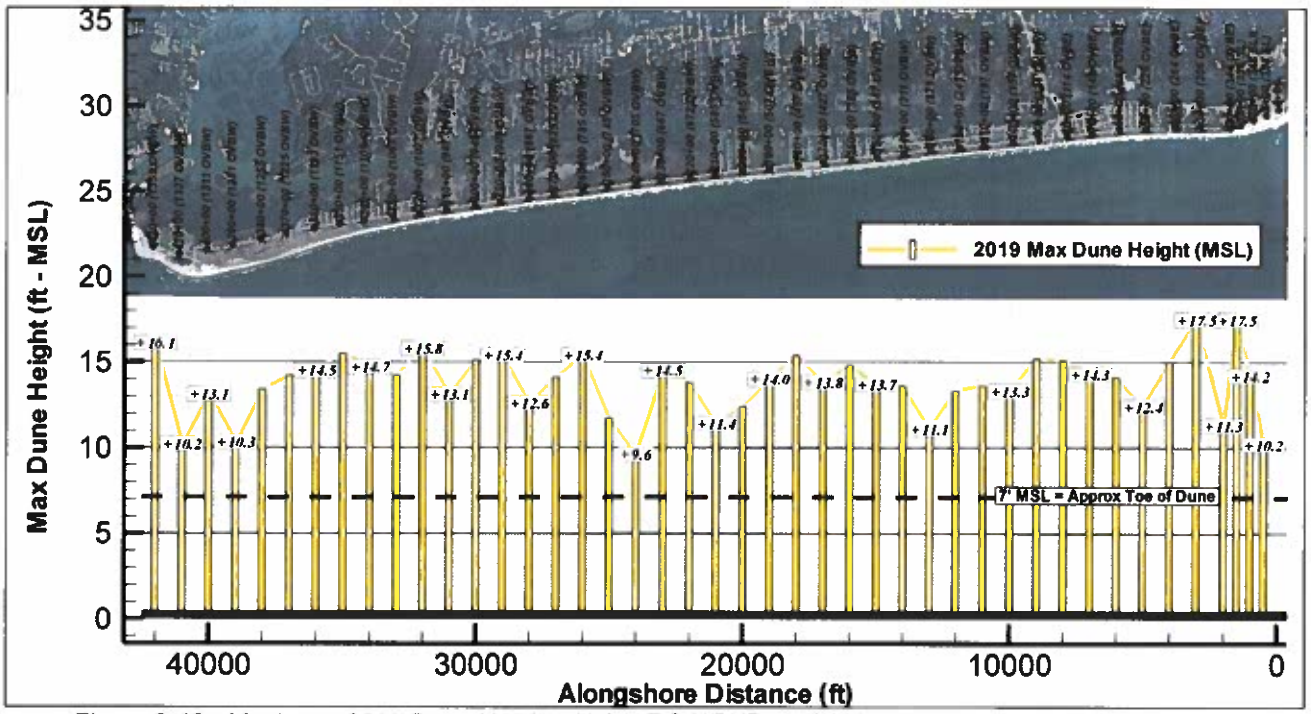


Figure 3-12. Maximum 2019 Dune Height. Using 7 ft NGVD as the dune base, dunes are generally 5' to 8' high.

3.4 HISTORICAL ANALYSIS

Figure 3-13 presents an approximately 19-year MHW shoreline comparison using 2000 and 2019 survey data. The 2000 survey represents a significantly erosional condition. A general accretional trend of 50 to 150 ft is exhibited for the MHW shoreline between 2000 and 2019 (not including the more variable inlet shorelines and east end nourishments).

The most recent DCM long-term background erosion rates from 2019 are included in Figure 3-13 for comparison purposes (DCM assigns a minimum long-term erosion of -2 ft/year). DCM 2019 erosion rates consider 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 or 2011 DCM erosion rates). The 2019 DCM erosion rate was converted to the same time span (January 2000 to April 2019) as the survey data in Figure 3-13.

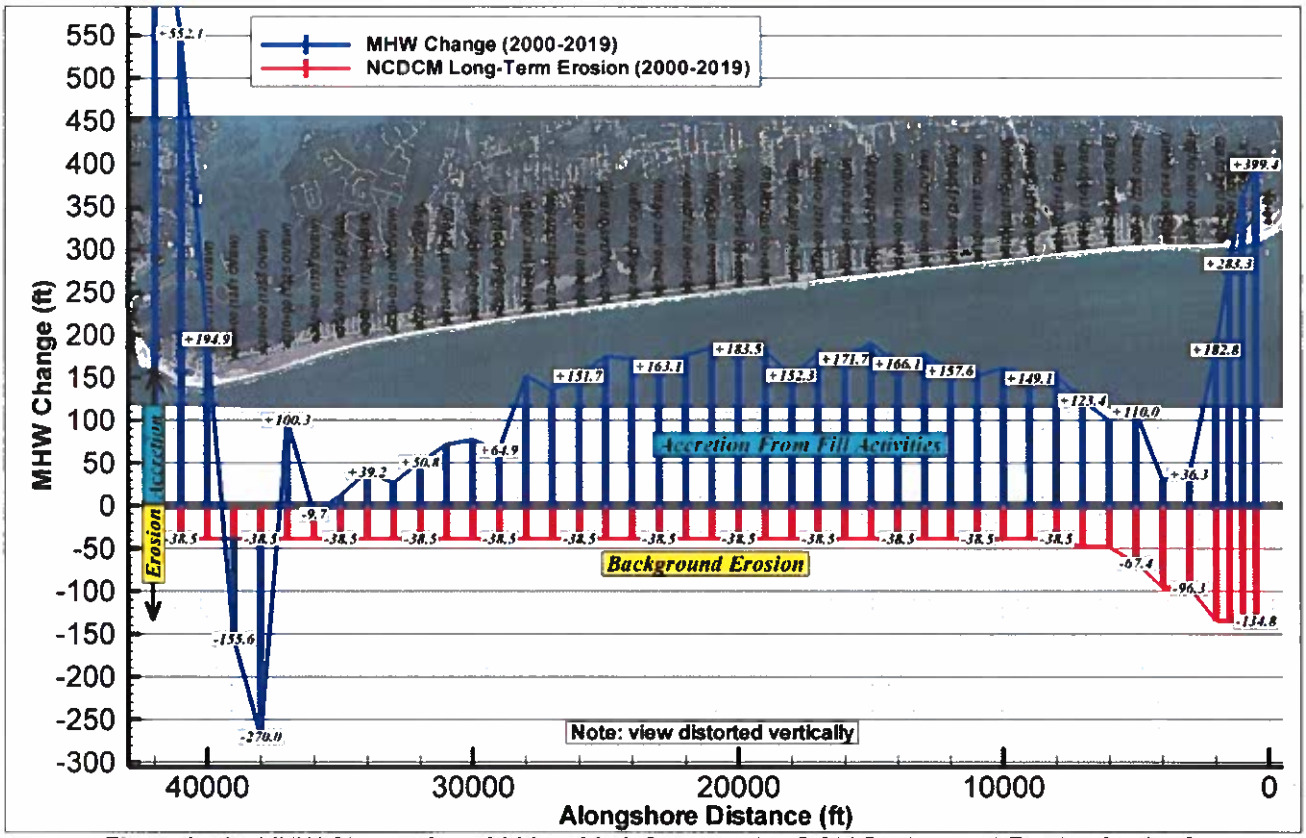


Figure 3-13. MHW Change from 2000 to 2019 Compared to DCM Background Erosion for the Same Period

Table 3-4 presents average MHW change by reach over the last 19 years. Results show that Town and USACE fill and dune enhancement activities have been successful in combating erosion over the last 19 years and the CRP was constructed with this goal in mind. As a result of the continued equilibration and progression of the 2017 nourishment, the Pier exhibits the largest increases in MHW change over the last 19 years and, similarly, the Town East and Town West reaches show large increases as well. The increases within the inlet reaches can be attributed to inlet dynamics and channel maintenance activities. The West Area is the only reach of shoreline where actual long-term change (over the last 19 years) is worse at some stations than the extrapolated DCM long-term erosion.

Table 3-4. Historical MHW Shoreline Change by Reach (2000 to 2019)

Reach Averages	Stations Included	Historical MHW Change (2000 to 2019) (ft)
LWF Inlet	5 to 15	+348.0
USACE East	15 to 40	+83.0
Town East	40 to 150	+139.3
Pier	150 to 190	+175.0
Town West	190 to 290	+158.3
West Area	290 to 380	+16.3
Shallotte Inlet	380 to 420	+80.4
Central Reach	40 to 290	+150.6

Figure 3-14 on the next page presents a figure comparing a 1993 aerial of Holden Beach with a 2019 aerial. The 2019 MHW line is shown on both aerials for comparison purposes. Figure 3-14 clearly shows that the overall health of the Holden Beach shoreline is better than it was decades ago.

Figure 3-14
1993 and 2019 Aerial Comparison with 2019 Mean High Water (MHW) line.
2019 aerial shows overall accretion in comparison wth 1993 conditions.

ATM DESIGN ENGINEERING CONSULTING

3.5 OAK ISLAND TRANSECTS

The Town has been collecting additional survey data on the western end of Oak Island to establish baseline conditions for this area. 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). Surveying was needed because Oak Island only performed annual surveys down to the mean low water (MLW) from 1998 to 2013, which is not sufficient to completely capture sediment movement. More recently, Oak Island has conducted some surveys to DOC.

Oak Island monitoring transects are shown in Figure 3-15. 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).

Similar to the inlet-influenced transects on the west end of Holden Beach, large variation is typically exhibited for Oak Transects 1 through 4. Oak Transects 5 and 6 are transitional (i.e., partially inlet-influenced), while Oak Transect 7 is generally removed from inlet effects and has historically shown less variability and more stability.

The most recent Oak Island west end nourishment project occurred this past spring (2019), as part of the USACE LWFIX Inlet dredging (see Figure 3-16), which, in the past, has been used to replenish the habitually eroding east end of Holden Beach. The placement location is shown also on Figure 3-15 for reference. Approximately 120,000 cy of material was placed on the beach during the 2019 LWFIX project according to the Town of Oak Island's "Beach and Inlet Projects Update" (Moffatt and Nichol, Inc, May 2019).

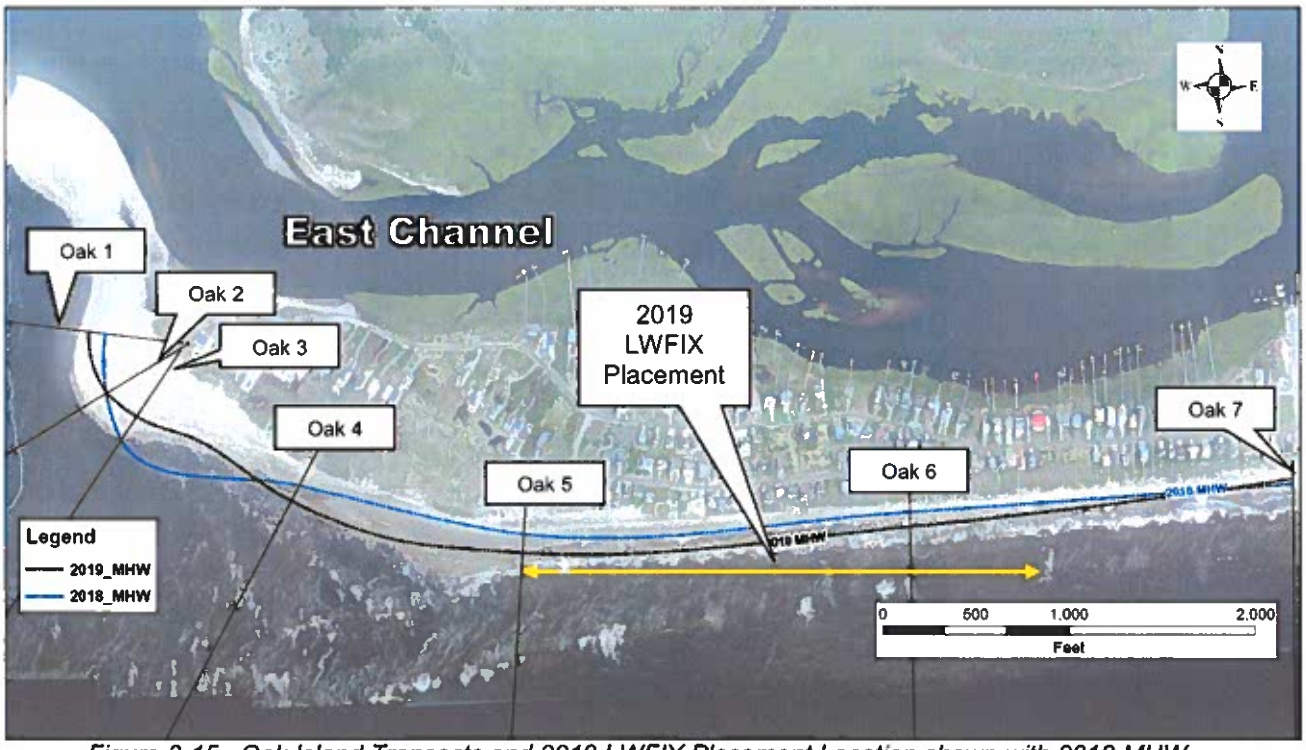


Figure 3-15. Oak Island Transects and 2019 LWFIX Placement Location shown with 2018 MHW (blue) and 2019 MHW (black) Lines. "Oak 2" and "Oak 3" transects begin at the same location as "Oak 1." (NOAA 2018 Post-Florence aerial shown).

As Figure 3-15 shows, Oak Island Transects 5 and 6 show accretion of the MHW line over the past year, as a direct result of the nourishment. Transect 4, which is downdrift of the nourishment template, also experienced some relatively significant seaward movement / accretion of the MHW shoreline, possibly from lateral spreading of the project sand and/or inlet dynamics.

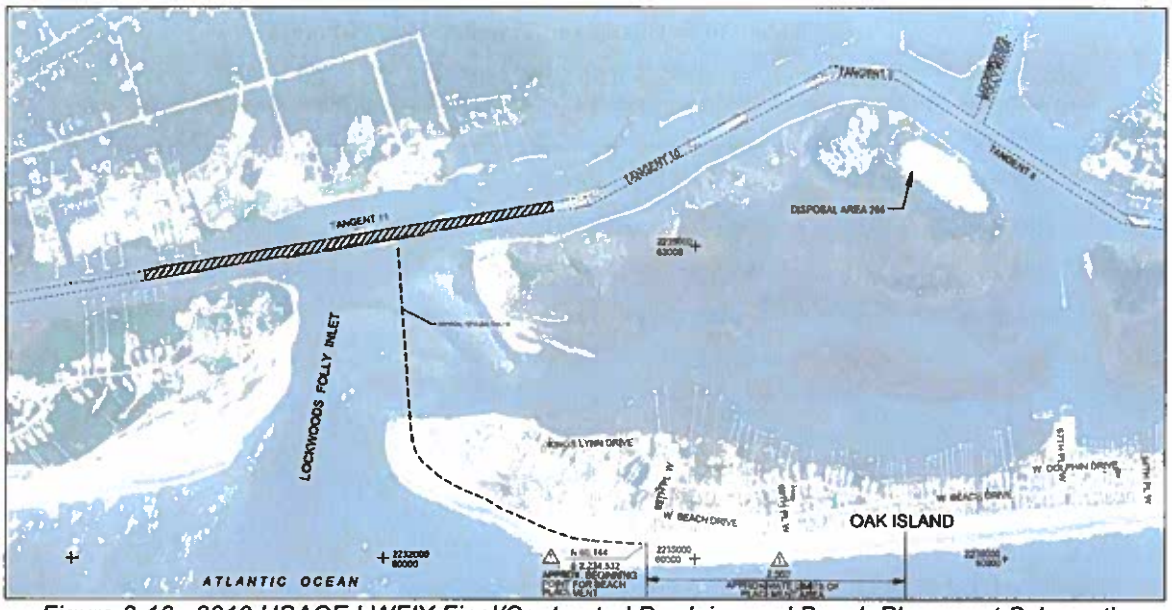


Figure 3-16. 2019 USACE LWFIX Final/Contracted Dredging and Beach Placement Schematic (source: USACE request for dredging proposal).

Table 3-5 presents the volume changes for the Oak Island transects between the 2018 and 2019 surveys, and Table 3-6 presents the annual MHW shoreline changes since the spring 2012 survey.

Table 3-5. Oak Island Transect Volume Analysis from 2018 to 2019

Station	Distance to Next Monument (ft)	Volume Change (cy/lf) (Dune to -12 ft*)	Volume Change (cy/lf) (Dune to -5 ft)	Notes
Oak 1	0	+30.3	+48.4	LWF Inlet
Oak 2	0	-56.5	-3.6	LWF Inlet
Oak 3	890	+63.9	-29.4	LWF Inlet
Oak 5	2000	+42.0	+27.5	Oceanfront perpendicular
Oak 6	2000	+9.1	+10.2	Oceanfront perpendicular
Oak 7	-	-24.0	-15.1	Oceanfront perpendicular

Table 3-6. Oak Island Transect MHW Change

Transect	2012-2013 MHW Change (ft)	2013-2014 MHW Change (ft)	2014-2015* MHW Change (ft)	2015-2016 MHW Change (ft)	2016-2017 MHW Change (ft)	2017-2018 MHW Change (ft)	2018-2019* MHW Change (ft)	Notes
Oak1	+65.4	-51.9	+331.3	-224.8	-103.7	-68.6	+90.8	
Oak2	-432.8	+105.9	+87.0	-27.0	-168.1	-26.4	-8.8	
Oak3	-338.2	+19.4	+302.1	-371.5	-57.6	+84.4	-155.6	Channel Shoaling
Oak4	-75.4	-51.9	-134.4	+91.1	-242.8	+69.7	+89.4	
Oak5	-91.7	-12.6	+94.3	-64.6	+49.7	-110.8	+102.6	2019 Nourishment
Oak6	-7.5	-4.0	+163.1	-68.9	-13.1	-112.9	+78.3	2019 Nourishment
Oak7	+13.7	+14.0	-16.9	+37.1	-15.7	-48.6	-26.0	

*Nourishment activities to west end of Oak Island occurred in 2015 and 2019

The most substantial volumetric accretion occurred near Oak Transect 5, as a result of the 2019 nourishment. Similar to the MHW change analysis, Oak Transects 4 and 6 generally showed volumetric accretion as benefits from the recent project. Significant accretion is also observed at Oak Transect 1, primarily taking place in the intertidal beach (between MLW and MHW) and upper dry portions of the beach, due to recent shoal movement and LWF Inlet dynamics.

Oak Transects 2 and 3 showed mostly erosion between 2018 and 2019, though some accretion and shoaling into the channel was observed to have taken place at Oak Transect 3. Erosion is also observed at Oak Transect 7, east of the 2019 LWFIX project, but will likely receive material from the project as it equilibrates and spreads outside of the template.

Town staff and ATM will continue to follow shoreline changes and any upcoming nourishments along the western end of Oak Island since these have 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 19 years), the Town and the USACE have placed an average of approximately 200,000 cy/year on the beach. This rate of sand placement has been effective at keeping pace with background erosion.

Holden Beach suffered significant erosion and damage to the upper beach and dune systems from Hurricanes Florence and Michael in September and October 2018. Similar to "engineered beach" mitigation projects following Hurricanes Hanna (2008), Irene (2011), and Matthew (2016) FEMA assistance was implemented following the 2018 hurricane season and a CRR project is planned for the 2020/2021 winter/spring dredging window. The CRR project represents a combined total of about 1.1 mcy of sand lost that was directly attributed to Hurricanes Florence and Michael.

Fortunately, the beach is already showing some signs of recovery. The recent 2017 CRP and the 2017 LWFIX / Town Eastern Reach Project helped to provide a significant buffer during the extreme conditions the beach was subject to in the 2018 hurricane season.

The most recent annual shoreline survey occurred in April 2019. *In comparing this survey to the April 2018 survey, due to the 2018 hurricanes, an island-wide net loss of the upper portions of the beach and surf zone (i.e., from the dune out to -5 feet) is observed. However, the entire island experienced a net gain of approximately 191,000 cy out to the -12-ft DOC limit.* This gain is due to onshore movement of material from deeper water (deeper than and beyond -12 ft) and represents a recovery from Hurricane Florence and Michael erosion, which moved significant amounts of material offshore, beyond even the -20-ft contour. Additionally, significant volumetric gains occurred near both inlets (due to inlet dynamics), and a recent shoal attachment occurred on the east end contributing to dry beach accretion along this reach.

The CRP and the 2017 LWFIX Eastern Reach Project brought a much-needed addition of material into the Holden Beach littoral system in 2017. A mostly erosional beach was

observed in the center approximately 5 miles of island (Central Reach STA 40+00 to 290+00) in comparing the 2018 and 2019 surveys. Over the past year, a total net loss of approximately 142,000 cy of sand was observed in the Central Reach, with the majority of this material being lost from the upper portions of the beach and surf zone (i.e., from the dune out to -5 feet). This is, in large part, due to continued cross-shore equilibration of the nourishment, accelerated from Hurricanes Florence and Michael, and both eastward and westward lateral spreading of this material. Due to the anticipated continued lateral/longshore spreading of the project sand, the erosion in the Central Reach has contributed to accretion and beach growth along the shorelines outside of the Central Reach, indicated by the volumetric accretion seen in these areas in the 2019 survey.

From a shoreline contour perspective, the majority of the island, including the Central Reach, exhibited MHW accretion between surveys. The energetic wave and high-water level conditions experienced during the recent 2018 hurricanes moved material from the upper beach into the intertidal zone and caused a seaward movement of the MHW line. This pattern was observed in the Central Reach and West Area and again is reflective of the continued equilibration and spreading of the 2017 nourishment and the shoreline's response to the 2018 storm events. Due to recent shoal movement, the east end near LWF Inlet also experienced significant MHW accretion and a relatively wide low tide beach is observed over the past year in this area, which is prone to episodic erosion. Without any nourishment activities, accretional trends do not last long on the east end due to the dynamics of LWF Inlet. ATM and Town staff will continue to monitor the movement and spreading of this shoal. Fortunately, the upcoming 2020 LWFIX project will provide additional sand to this reach to mitigate future erosion.

The TOD line within the Central Reach was generally more erosional, largely due to Hurricanes Florence and Michael. However, dune heights are healthy, and the continued growth of the starter dunes and planted vegetation as part of the CRP was observed over the past year. Significant sand fencing and dune vegetation planting occurred following the nourishment projects, which have helped mature and enhance these dunes over the past year.

In comparing the April 2019 survey with the January 2000 survey (19-year span), the MHW shoreline exhibits approximately 150 ft of accretion, in part due to the recent 2017 large-

scale nourishment activities. The CRP and other future planned projects of this scale are designed to enhance the beach and dune system, which will result in protective, ecological, recreational, and economic benefits.

The CRP nourishment, completed in March of 2017, represents the largest nourishment project on Holden Beach (more than twice the size of the 2001-2002 USACE 933 project). The purpose of the 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 2019 survey represents the 2-year post-project survey of the nourishment, and continued monitoring will assess the continued equilibration and movement of the project sand.

The 2017 LWFIX / Town Eastern Reach Project was similar to the 2014 piggyback project. It came at an opportune time to supplement the Central Reach nourishment. Due to the proximity to LWF Inlet, the east end is relatively dynamic, and some erosional hotspots have been observed over the years. The 2019 survey showed that the additional 120,000 cy from the Eastern Reach Project has created a wide recreational beach and storm buffer to abate future erosion along this stretch of shoreline. A 2020 LWFIX project is planned for the east end of Holden Beach.

ATM and Town staff will continue to evaluate the potential piggybacking and/or use of the 400-ft bend widener for any future USACE LWFIX projects that do not fully utilize the LWFIX borrow area (which is expected to happen most of the time due to USACE funding limitations).

The NCDEQ SDI program has provided the Town with permits to dredge the inner and outer portions of LWF Inlet. These permits 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 Aquatic Weed Fund, which has shown growth and stability since its inception.

In summary, the 2016 North Carolina Beaches and Inlets Management Plan (NC BIMP) report estimated the 2013/2014 Beach Recreation Annual Total Impact Output for Holden Beach at $80.4 million, which accounted for 942 jobs. Additionally, the NC BIMP conducted a study of losses attributed to 50 percent beach width loss and found that, for Holden Beach, the 2013/2014 estimated *annual loss* (including output/sales/business activity) would be $12.6 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 the following actions:

- Continue annual island-wide monitoring with beach profiles
- Continue CRR offshore borrow area investigation, design and permitting
- Continue to coordinate with USACE and NCDEQ on future outer LWF Inlet channel sidecast/hopper dredging and nearshore sand placement
- Continue coordination and support of the State's SDI program and quarterly SDI MOA meetings held by the USACE and NCDEQ/NCDWR (regarding LWFIX, etc.)
- Continue proactive dune enhancement activities (planting, fertilizing, fencing, etc.).
- Work closely with Congressional representatives and lobbyists (Poyner Spruill) to assure continued support of future USACE nourishment projects for Holden Beach
- Extend DCM and USACE permits as necessary

Specific needs in regard to ongoing beach management in the near future are related to 1) Oak Island receiving LWFIX sand that has traditionally been placed on Holden Beach's east end, 2) locating, designing and permitting an offshore borrow area for the CRR project.

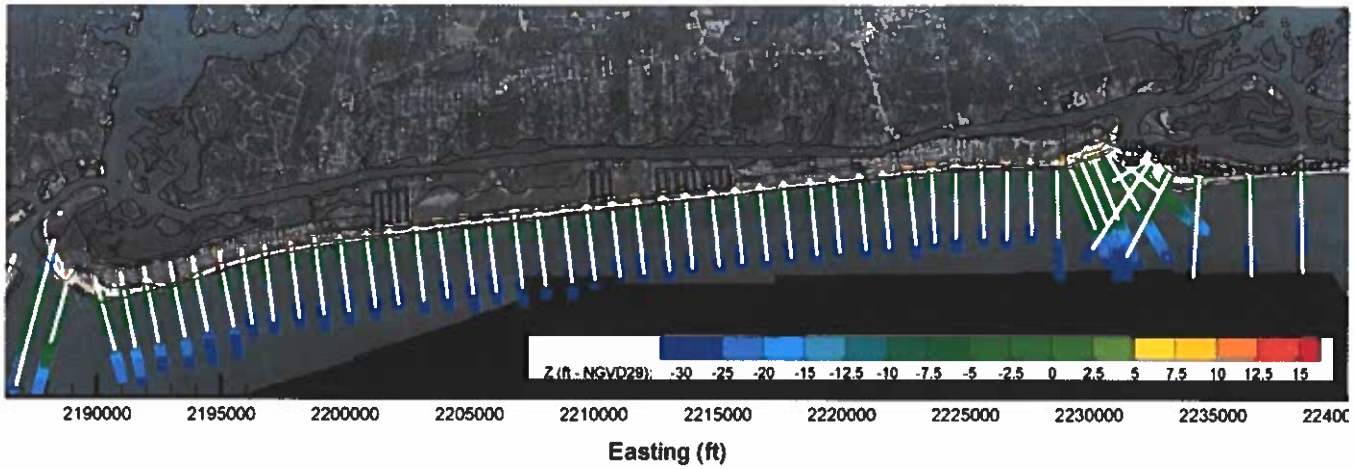
The Town worked proactively with the USACE to maximize the use of the LWFIX borrow area and bend-widener, even before shallow-draft dredging funds were available from the State. With the State SDI dredging fund now available, Oak Island and Brunswick County have expressed increased interest in using LWF Inlet sand resources. Holden Beach is the downdrift beach to LWF Inlet, therefore, the east end of Holden Beach is the most affected and most vulnerable to LWF Inlet processes (including any manmade changes to this system). Town and ATM staff will continue to actively engage in these projects and monitor their potential effects.

Following the 2017 CRP, it is estimated that at least 500,000 cy of material is still available in the CRP borrow area for future nourishments, however, about 1.1 mcy is required for the CRR FEMA-sponsored project. This offshore borrow area reconnaissance is currently underway and some potential sand sources have been preliminarily identified. CRR design and permitting will occur over the next few months.

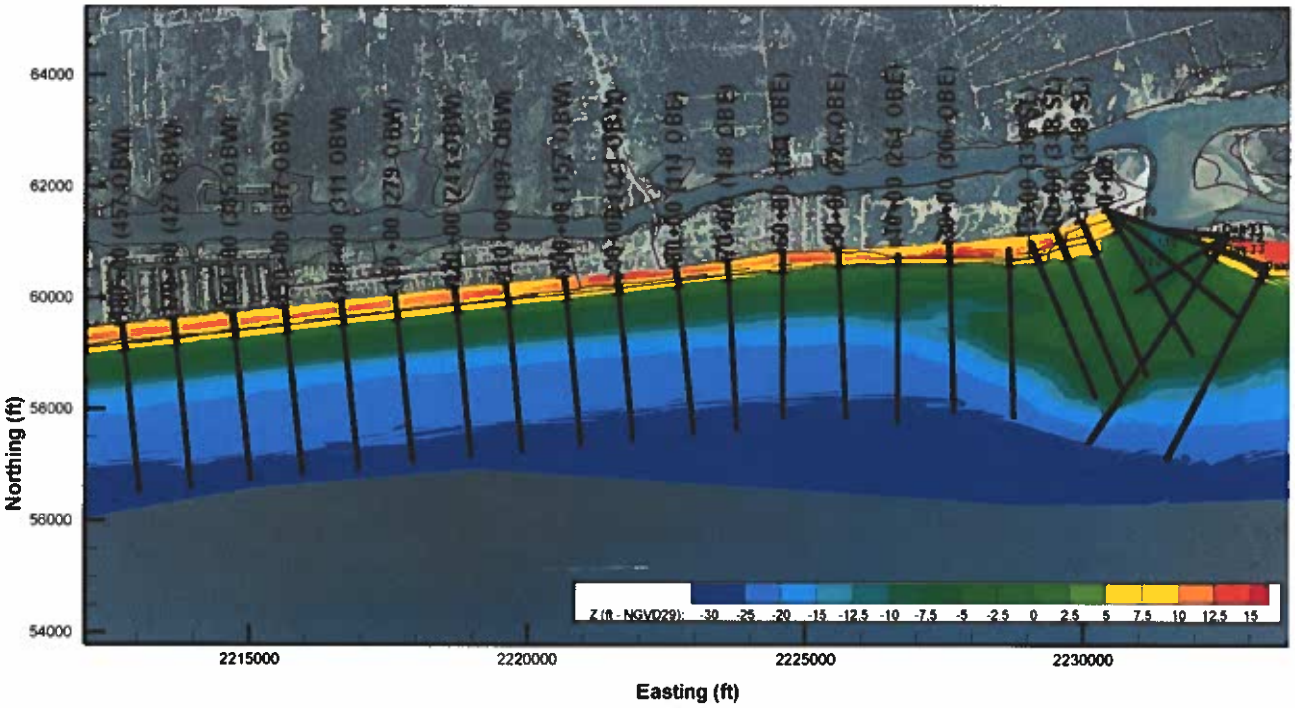
Appendix A

Station Profile Analysis

APPENDIX A – ELEVATION PROFILE TRANSECTS



Survey Stationing Figure. Profile Transect Stationing shown in white and actual survey points shown with color legend on above figure. Plots below are from east (Lockwood 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.

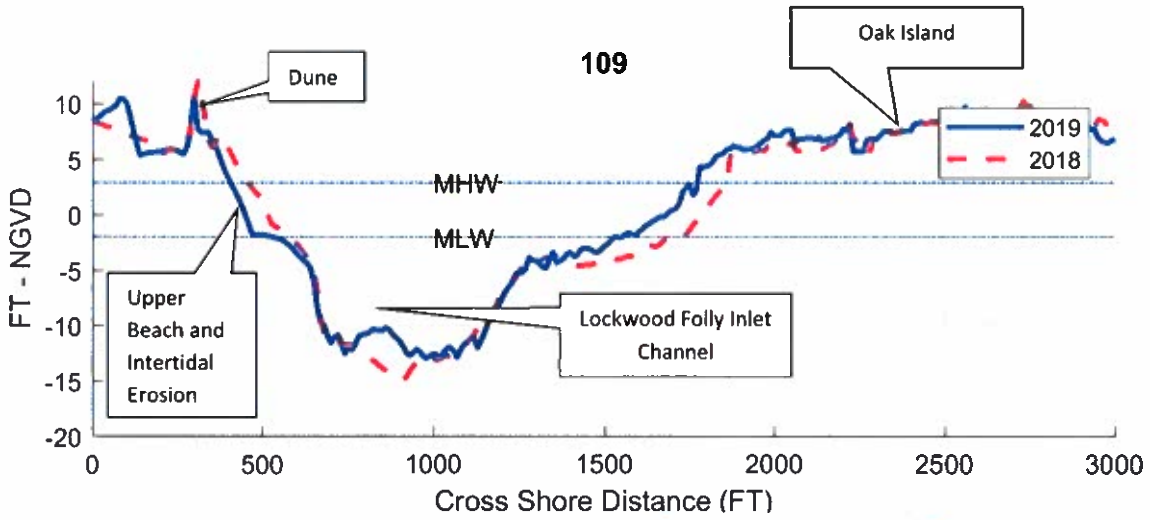


Zoomed in to eastern half of island (station 170+00 is to the left and just east of the pier). Note "Z" is in ft-NGVD29.

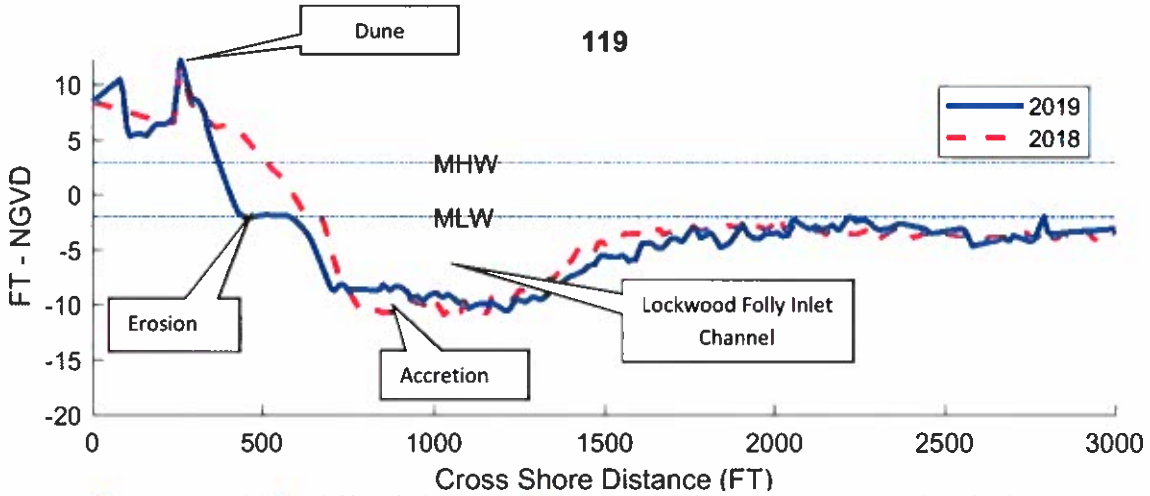
Please Note:

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

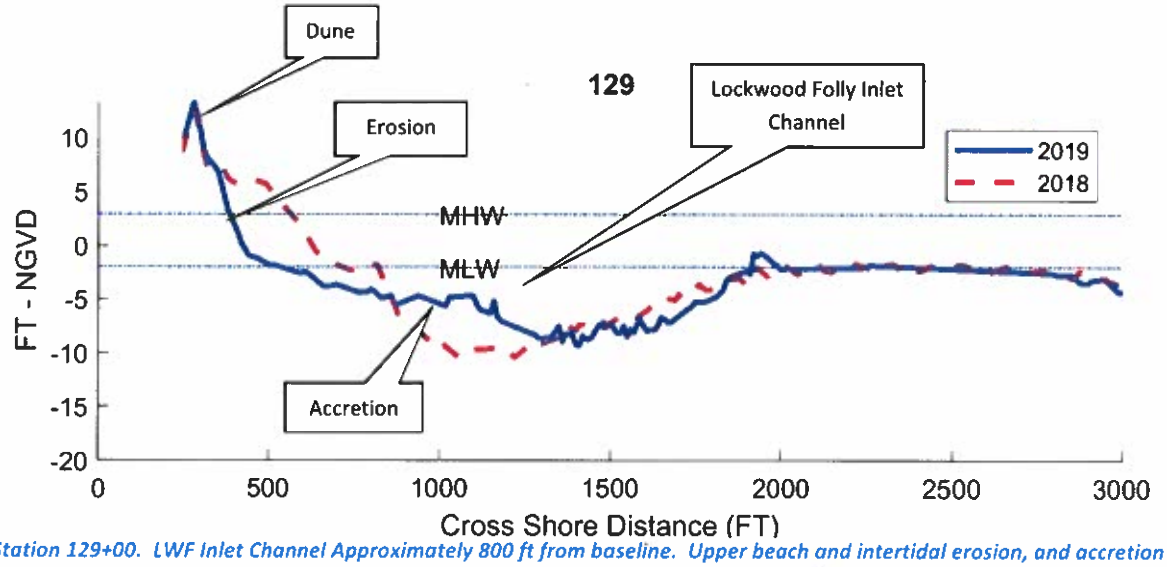
Any notable features are described in "call-outs" or in blue below the figure.



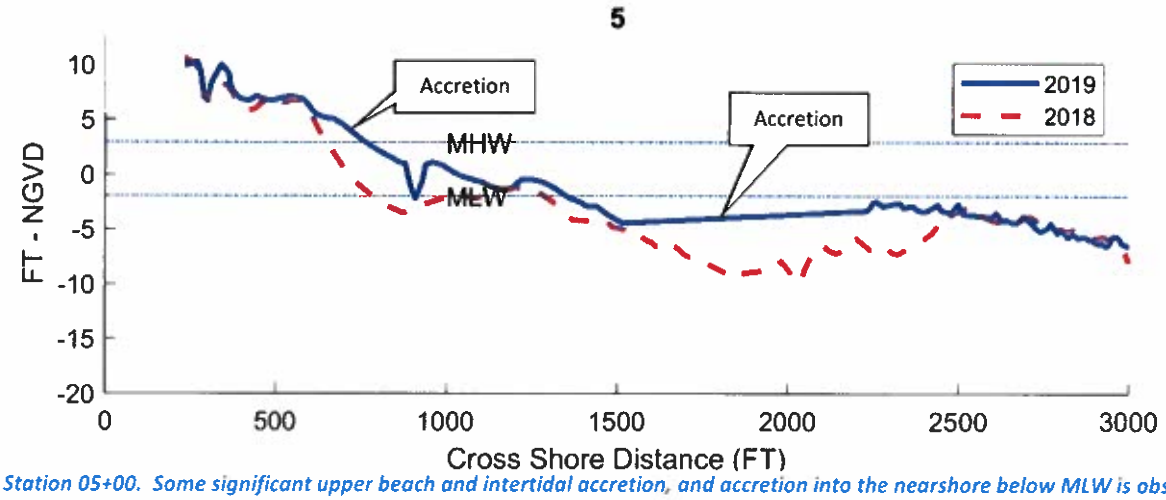
Station 109+00 (far east). Plots typically show from dune (between ~7' and ~15' NGVD) out to ~-20' NGVD. MHW=Mean high water, MLW=mean low water. LWF Inlet Channel appears relatively stable but some "filling in" of sand is observed since the 2018 survey.



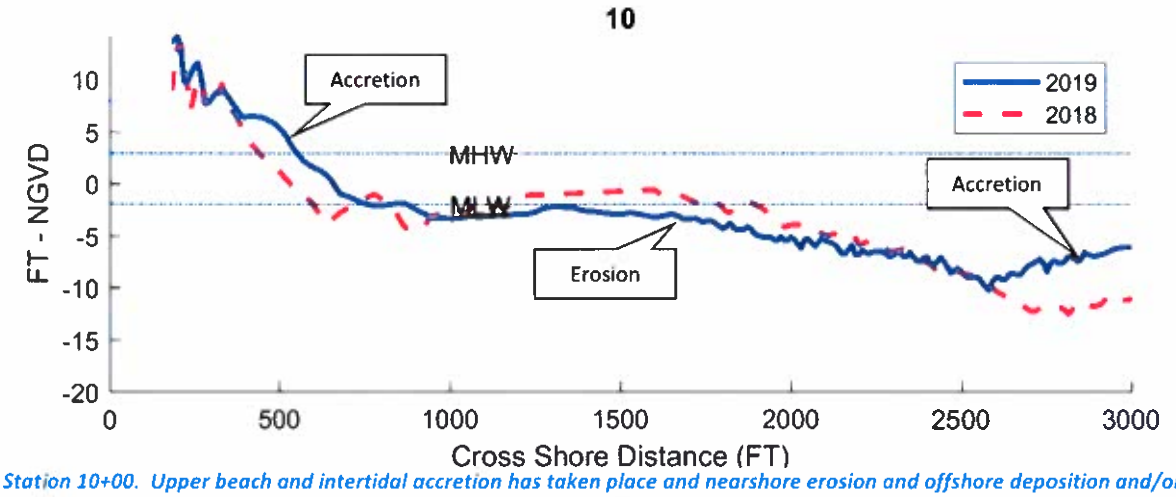
Station 119+00. Upper and intertidal beach showing erosion. LWF Inlet Channel appears relatively stable but some "filling in" of sand is observed as the channel has become shallower since the 2018 survey.



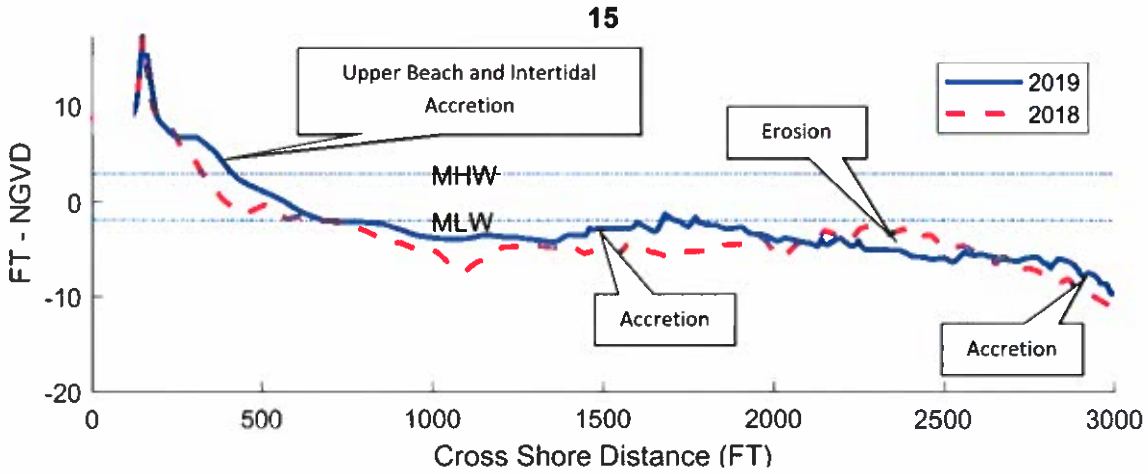
Station 129+00. LWF Inlet Channel Approximately 800 ft from baseline. Upper beach and intertidal erosion, and accretion below MLW into the LWF Inlet Channel is seen. Channel is "filling in" since 2018 survey.

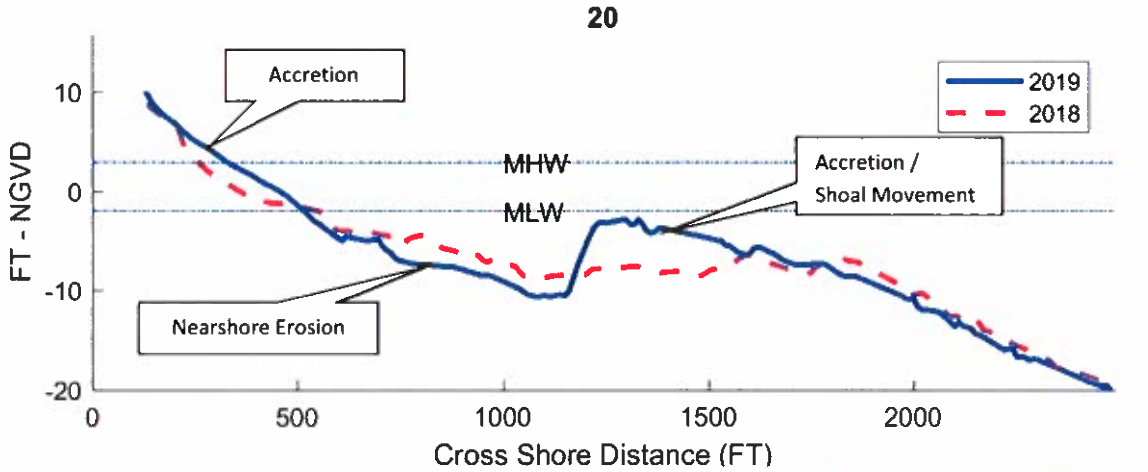


Station 05+00. Some significant upper beach and intertidal accretion, and accretion into the nearshore below MLW is observed.

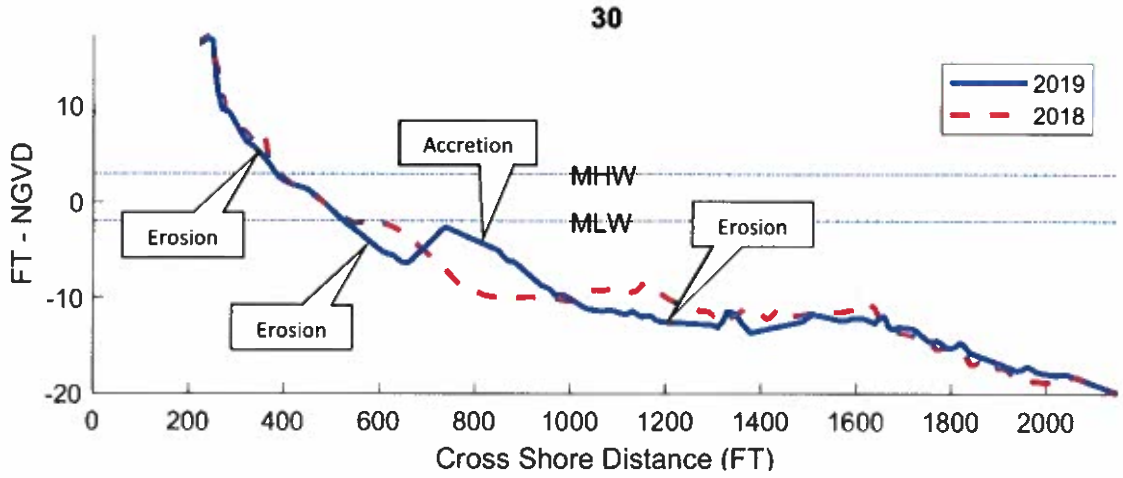


Station 10+00. Upper beach and intertidal accretion has taken place and nearshore erosion and offshore deposition and/or shoal movement is observed.

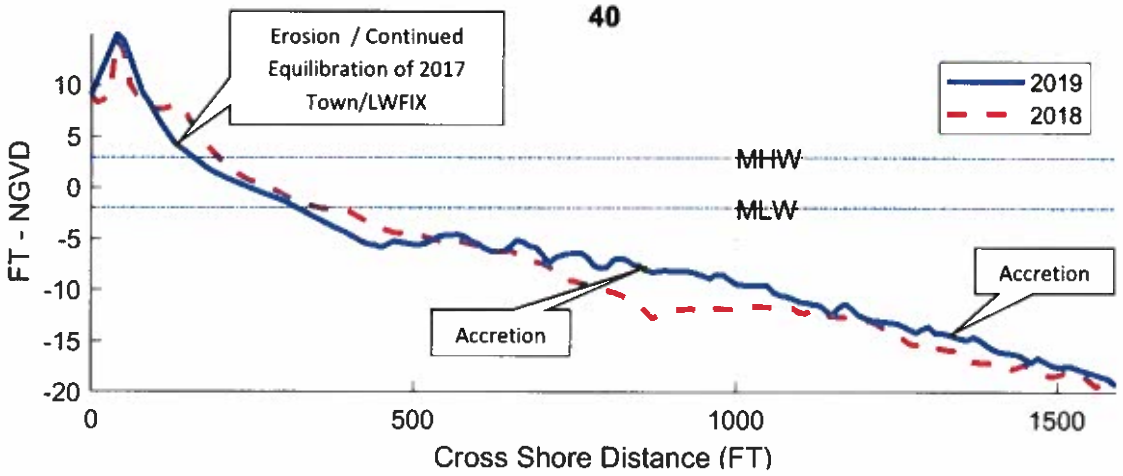




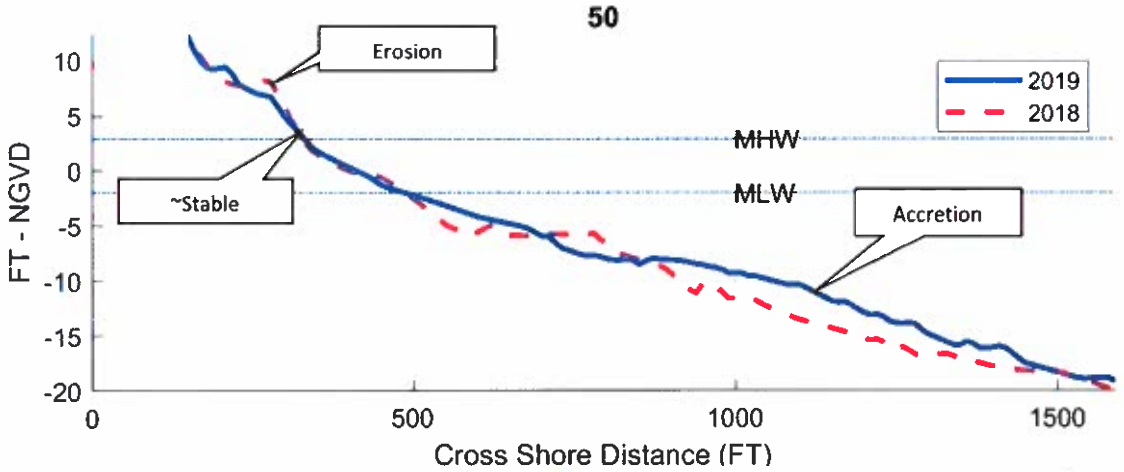
Station 20+00. Note some upper beach accretion, nearshore erosion and offshore accretion / shoal movement since 2018 survey.



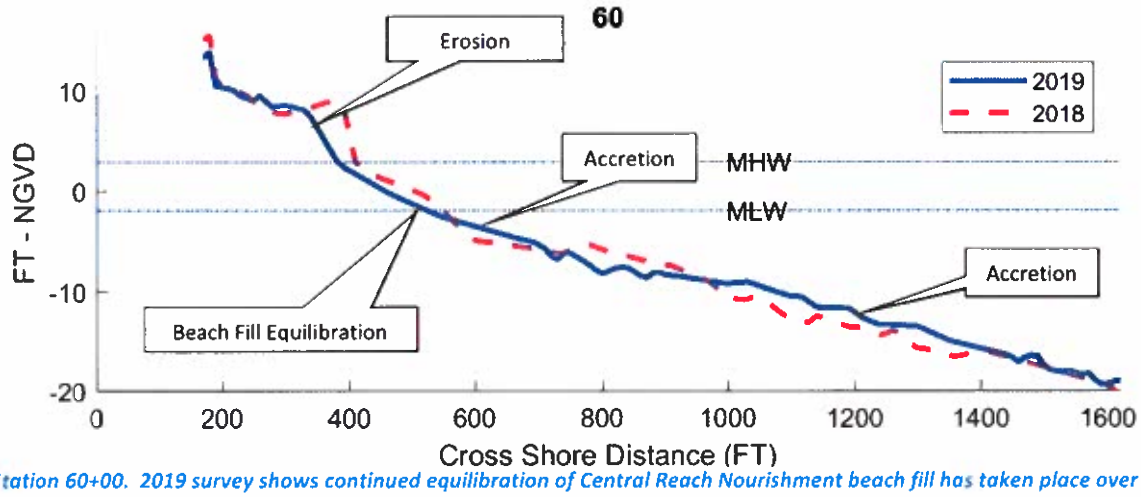
Station 30+00. Stable upper beach and variable changes in the nearshore.



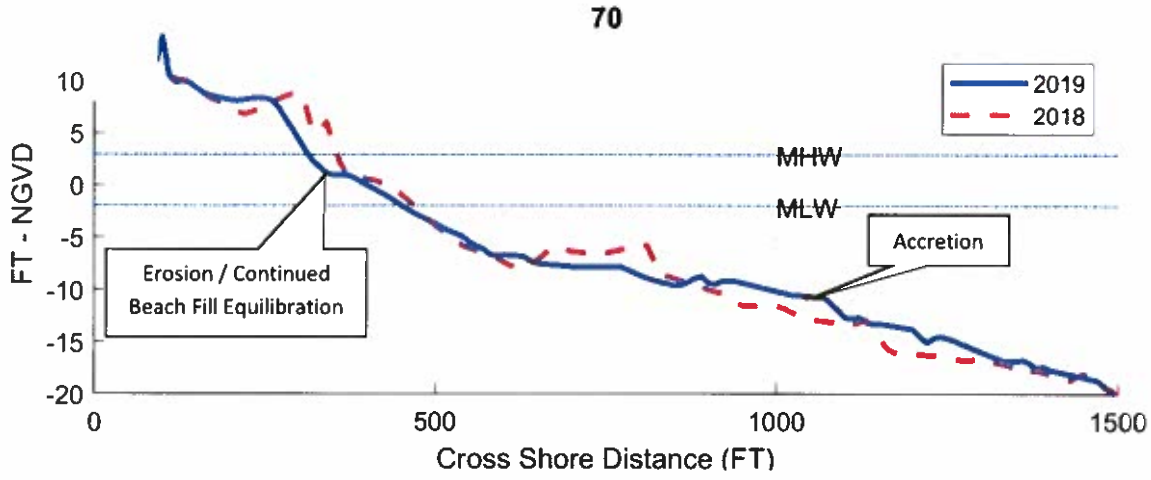
Station 40+00. Upper beach and intertidal erosion and accretion into the nearshore below MLW as the 2017 Town/LWFIX Beach Nourishment approaches an equilibrium beach profile. Significant accretion observed offshore and below -12 due to offshore movement of material from recent storms during the 2018 (Hurricanes Michael and Florence), which is beginning to move more onshore as the beach recovers and exhibits accretion in these areas.

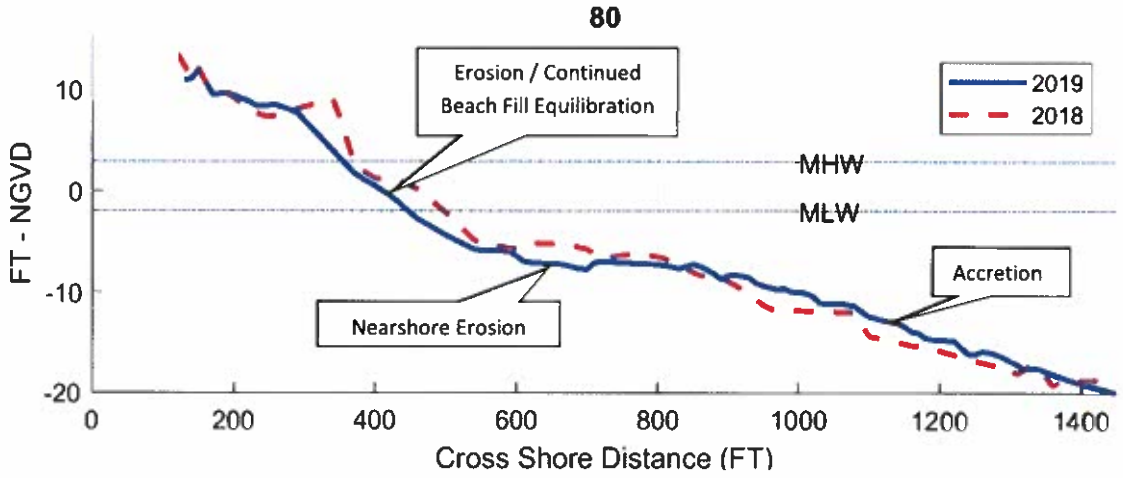


Station 50+00. Note a mostly stable upper and intertidal beach, near the east taper of the Central Reach Nourishment Project completed in early 2017. The Sand placement extended from Station 45+00 to Station 260+00. Accretion in the offshore (~1000 ft offshore) is observed here and throughout most of the 2019 survey profiles.

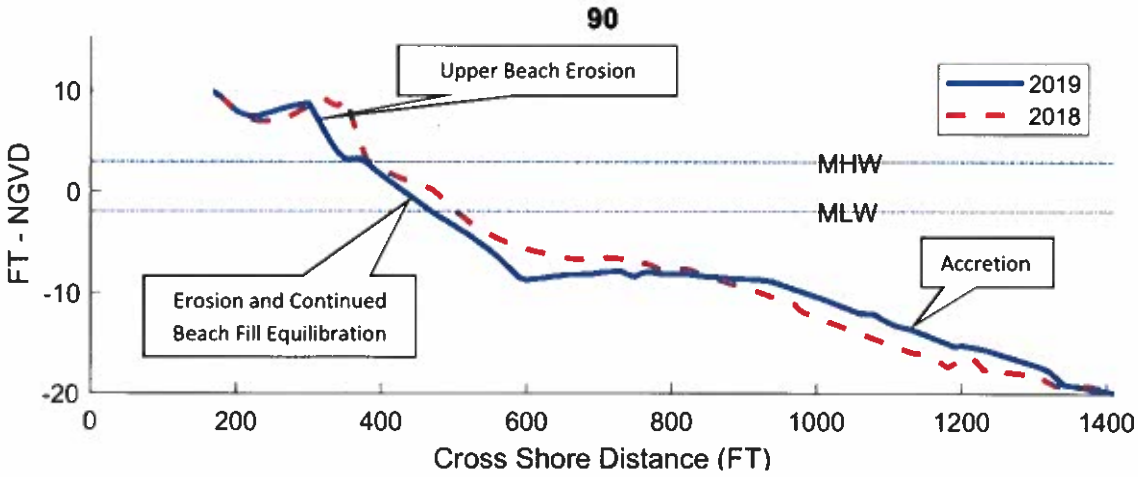


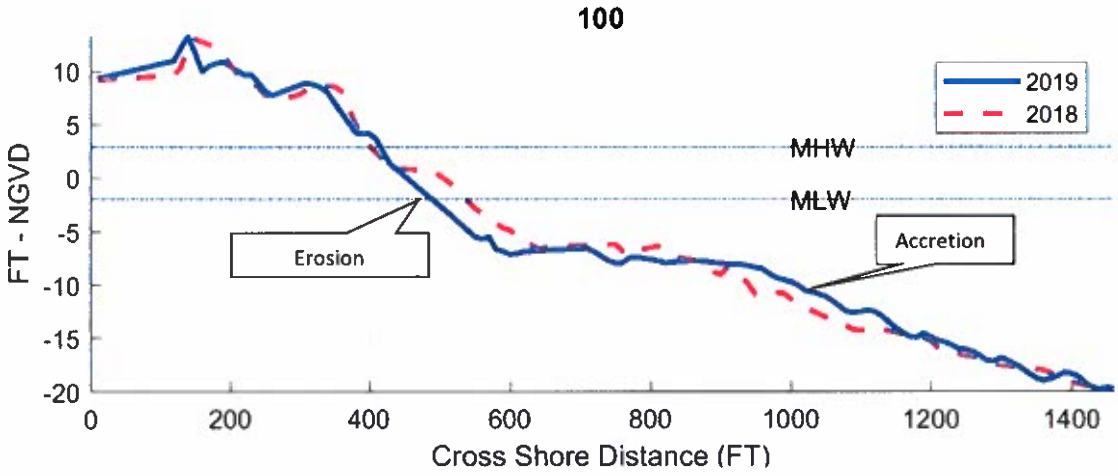
Station 60+00. 2019 survey shows continued equilibration of Central Reach Nourishment beach fill has taken place over the past year, where material has eroded from the upper beach into the nearshore.

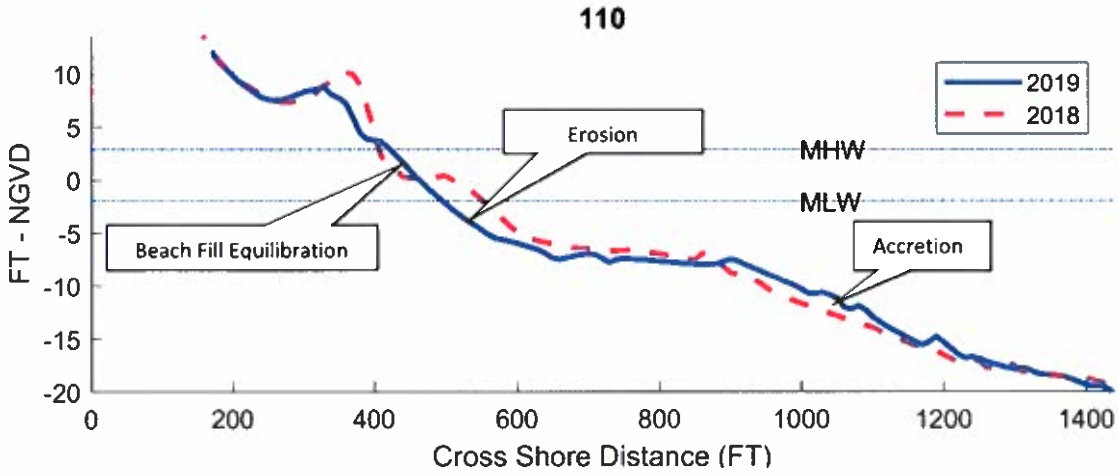


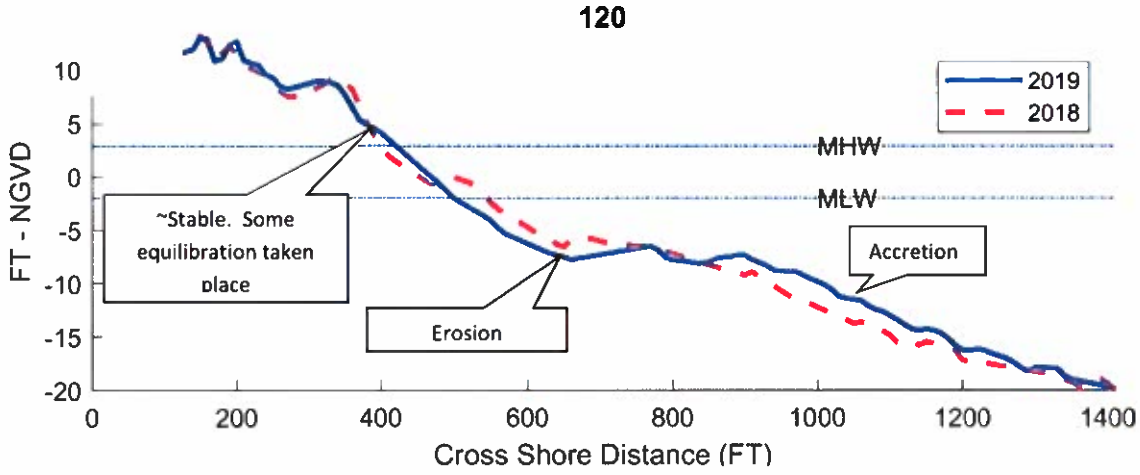


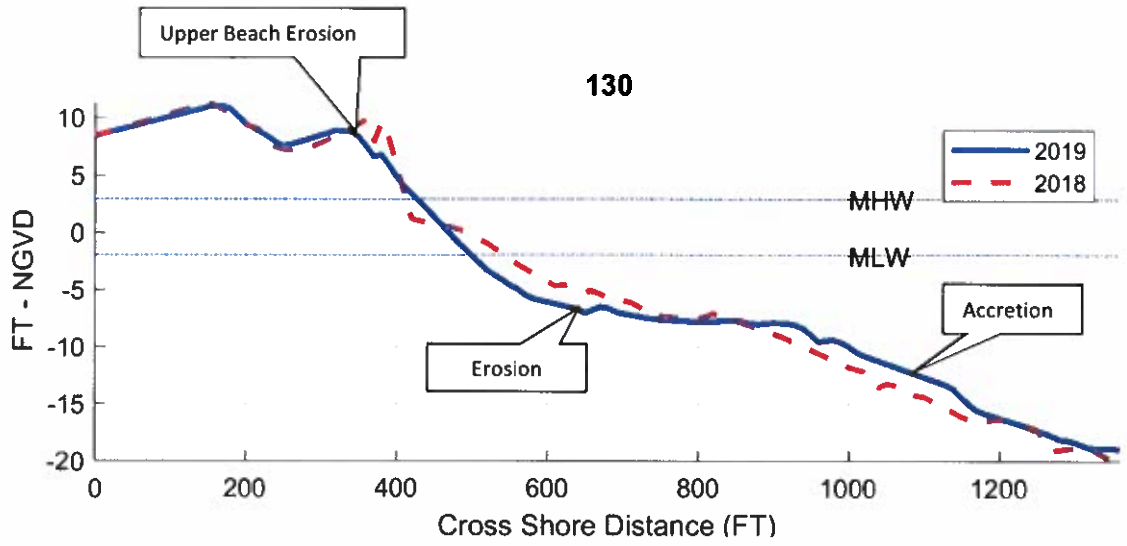
Station 80+00. Note upper beach, intertidal, and nearshore erosion below MLW, and accretion only observed beyond -12 ft reflecting the highly active 2018 hurricane season along Holden Beach. Intertidal and nearshore erosion, and offshore accretion seen throughout much of the Central Reach over the past year.

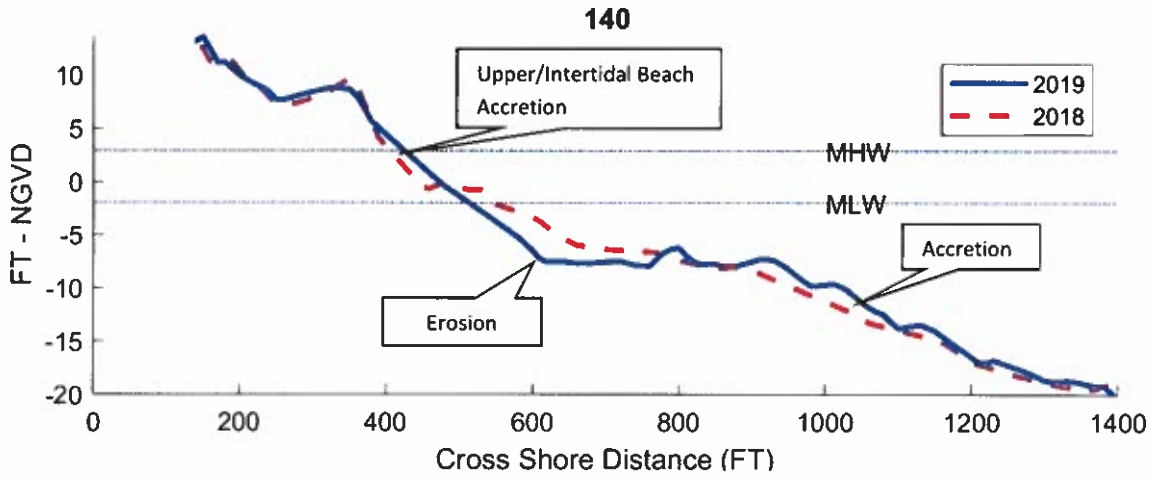


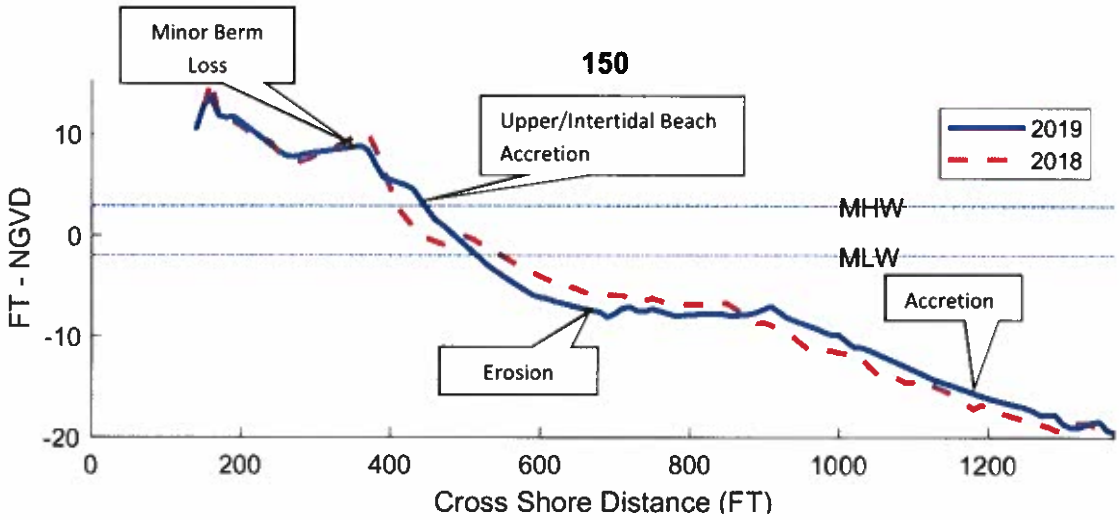

100
2019
2018
MHW
MLW
Erosion
Accretion
FT - NGVD
Cross Shore Distance (FT)

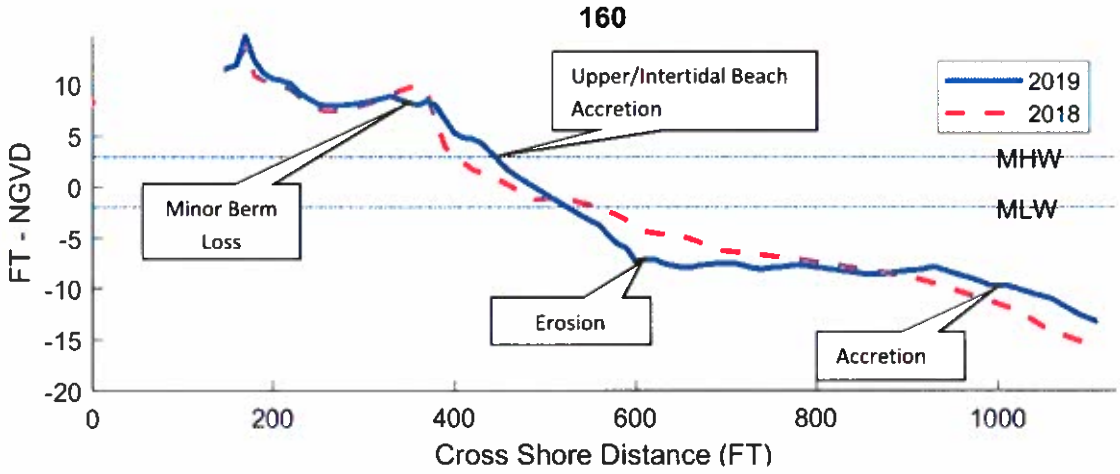

110
2019
2018
Erosion
MHW
MLW
Beach Fill Equilibration
Accretion
FT - NGVD
Cross Shore Distance (FT)

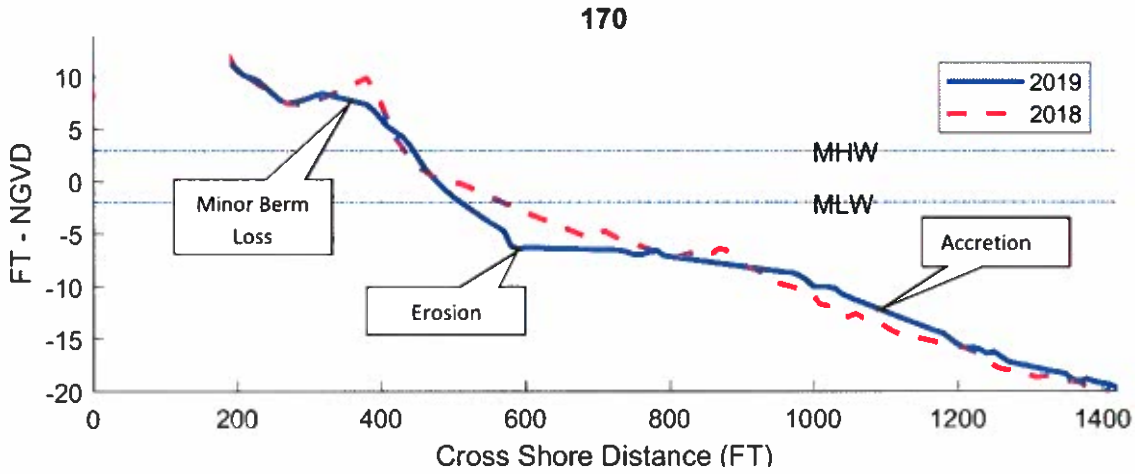

120
2019
2018
MHW
MLW
~Stable. Some equilibration taken place
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)

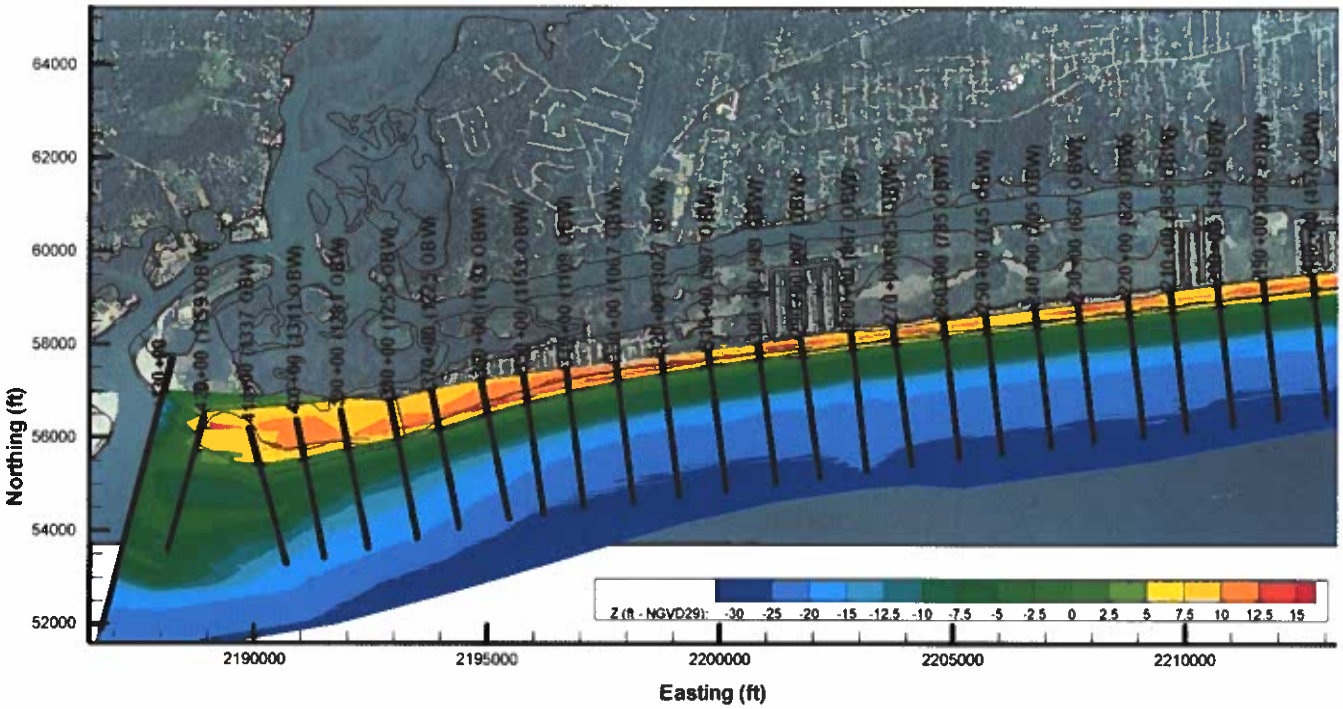

130
Upper Beach Erosion
2019
2018
MHW
MLW
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)


140
Upper/Intertidal Beach Accretion
2019
2018
MHW
MLW
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)

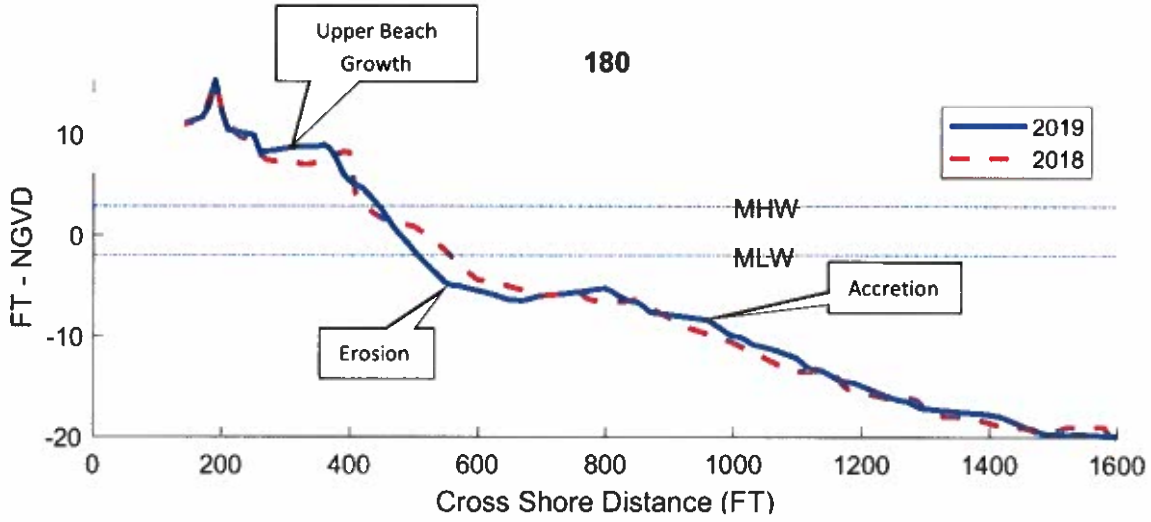

150
Minor Berm Loss
Upper/Intertidal Beach Accretion
2019
2018
MHW
MLW
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)

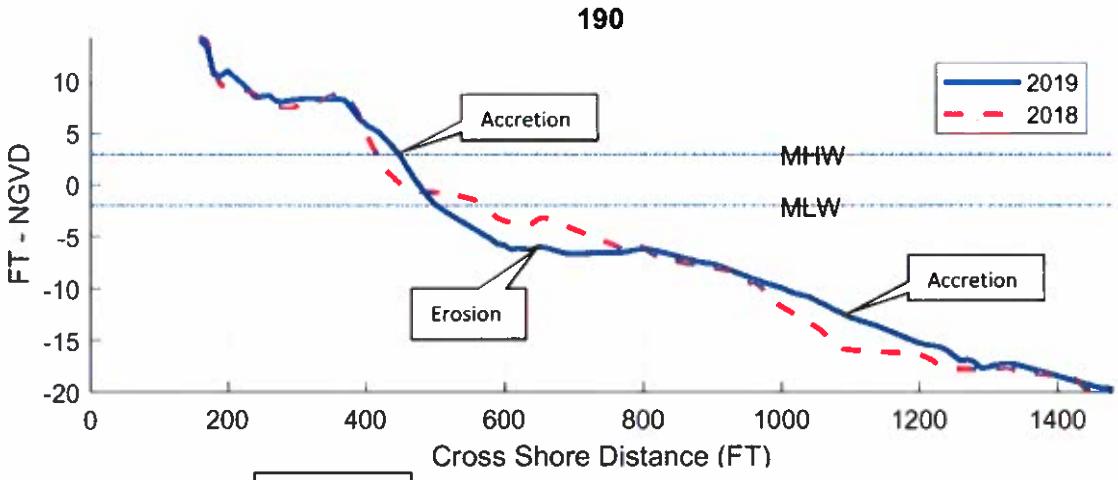

160
Upper/Intertidal Beach Accretion
2019
2018
MHW
MLW
Minor Berm Loss
Erosion
Accretion
FT - NGVD
Cross Shore Distance (FT)

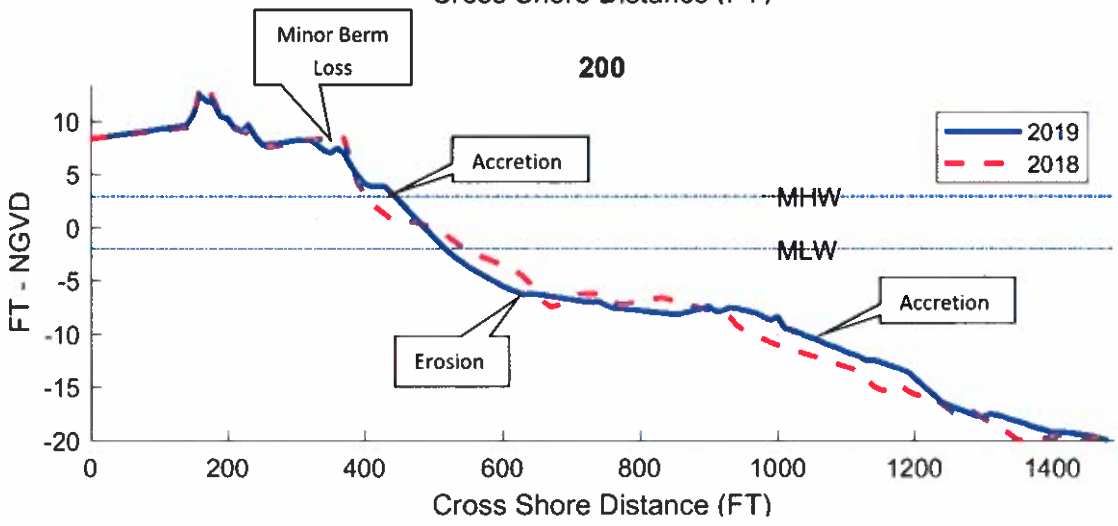

170
2019
2018
MHW
MLW
Minor Berm Loss
Erosion
Accretion
FT - NGVD
Cross Shore Distance (FT)

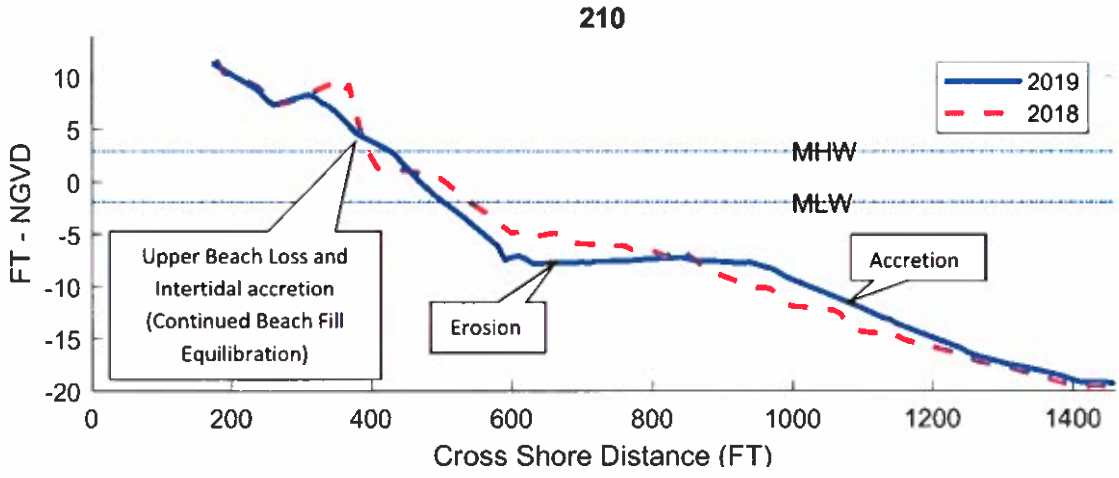


Zoom in of western end (Station 180+00 near the pier to Station 430+00 at Shallotte Inlet). Note "Z" is in ft-NGVD29.

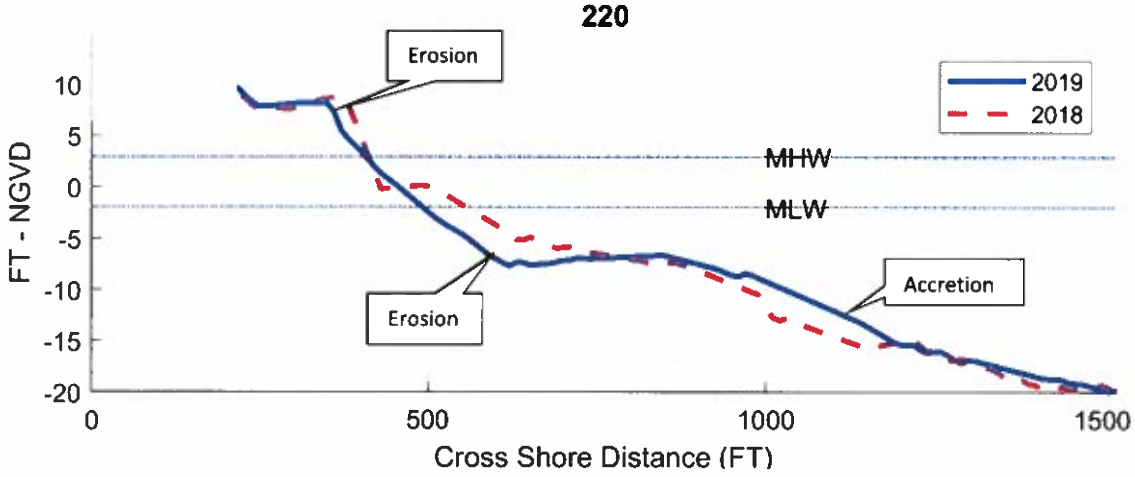



190
2019
2018
Accretion
MHW
MLW
Erosion
Accretion
FT - NGVD
Cross Shore Distance (FT)

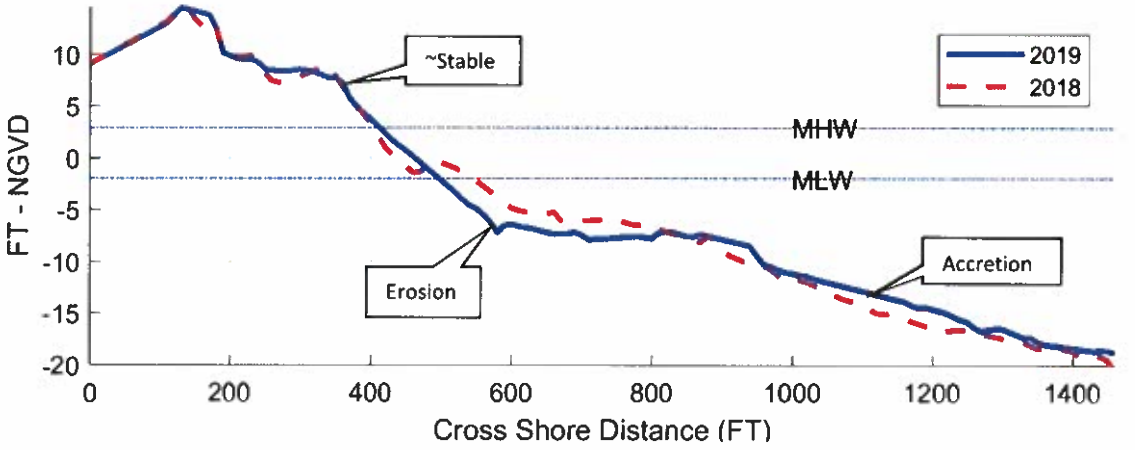

Minor Berm Loss
200
2019
2018
Accretion
MHW
MLW
Accretion
Erosion
FT - NGVD
Cross Shore Distance (FT)

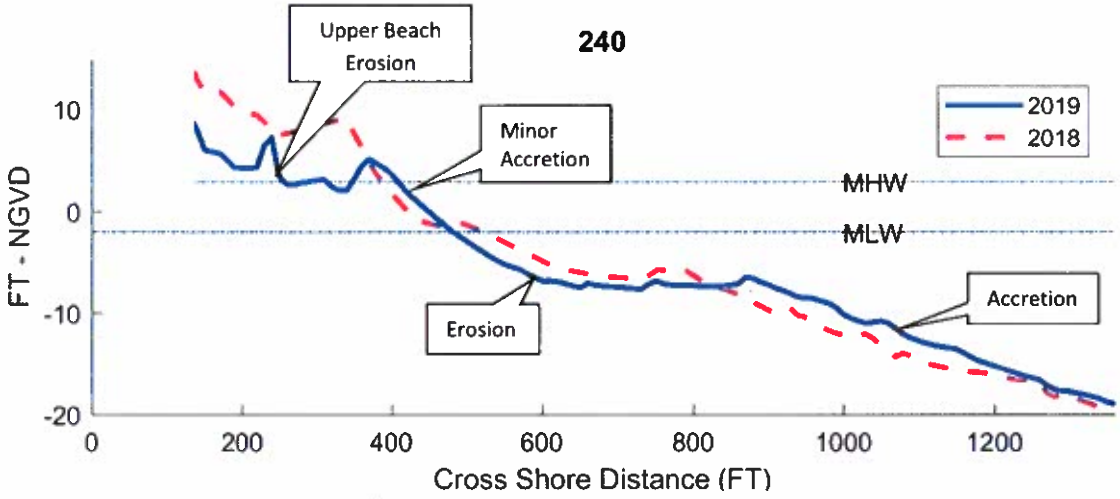

210
2019
2018
MHW
MLW
Upper Beach Loss and Intertidal accretion (Continued Beach Fill Equilibration)
Erosion
Accretion
FT - NGVD
Cross Shore Distance (FT)

220

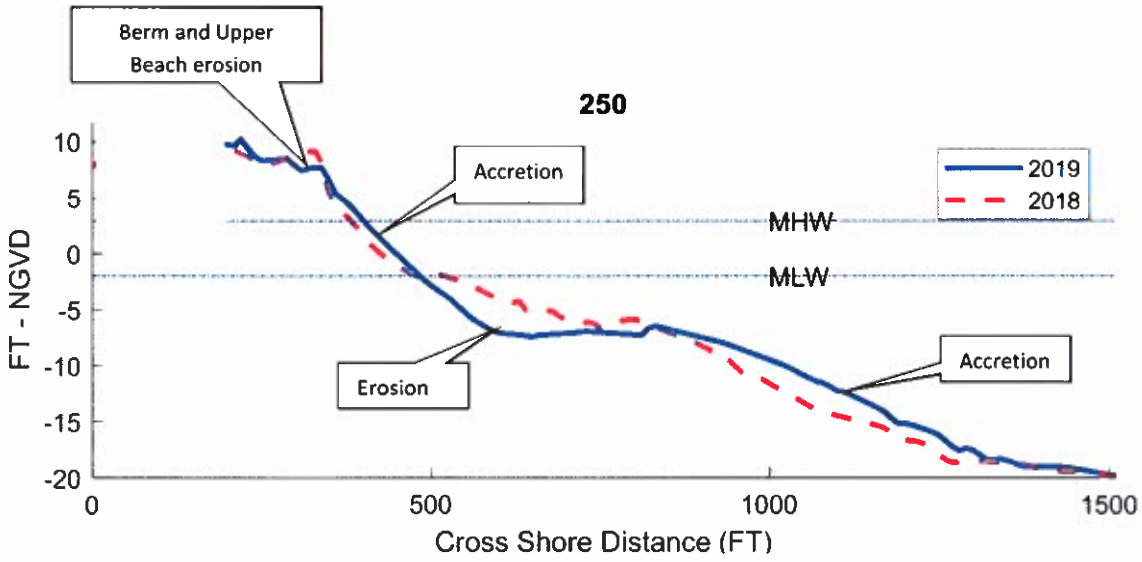

Erosion
2019
2018
MHW
MLW
Accretion
Erosion
10
5
0
-5
-10
-15
-20
FT - NGVD
0
500
1000
1500
Cross Shore Distance (FT)

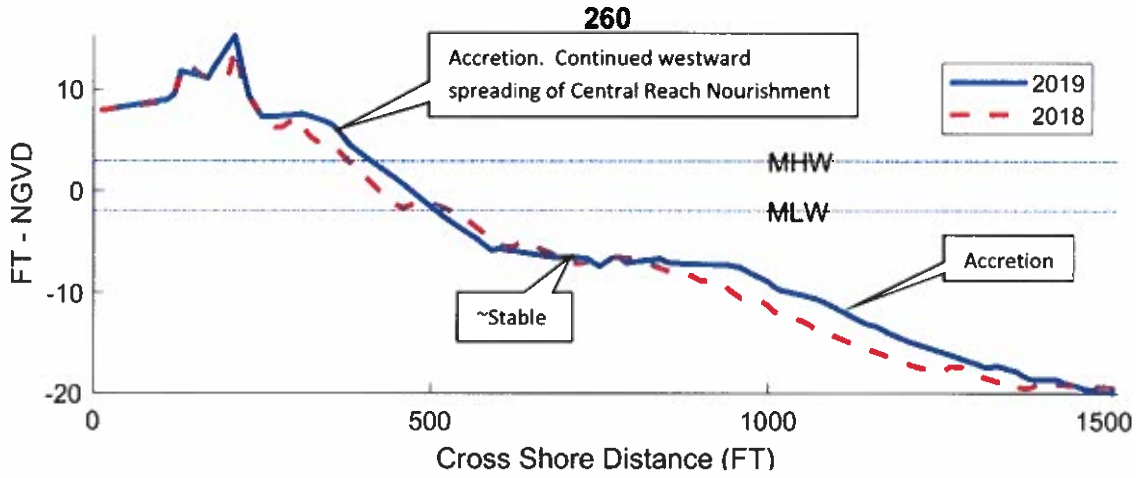
230


~Stable
2019
2018
MHW
MLW
Accretion
Erosion
10
5
0
-5
-10
-15
-20
FT - NGVD
0
200
400
600
800
1000
1200
1400
Cross Shore Distance (FT)

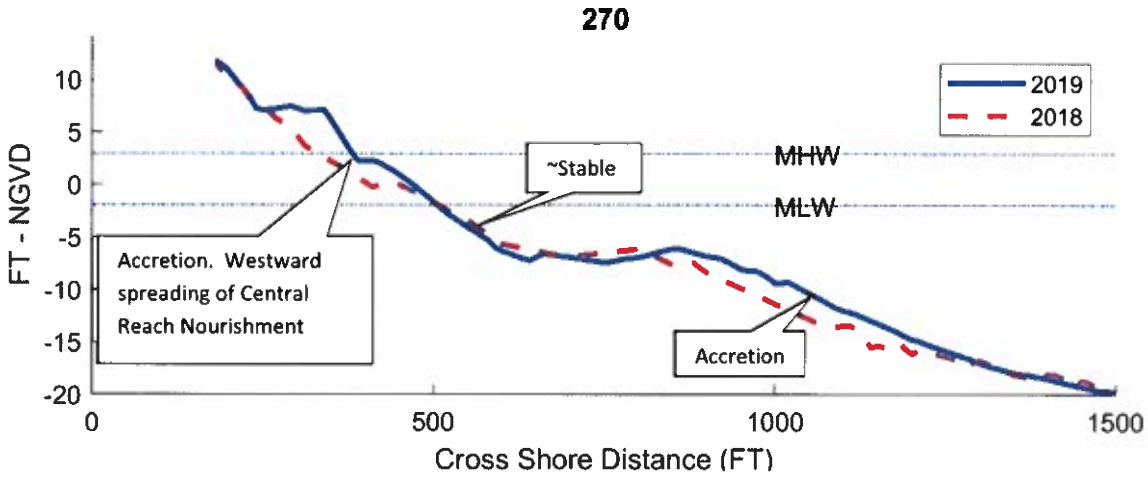


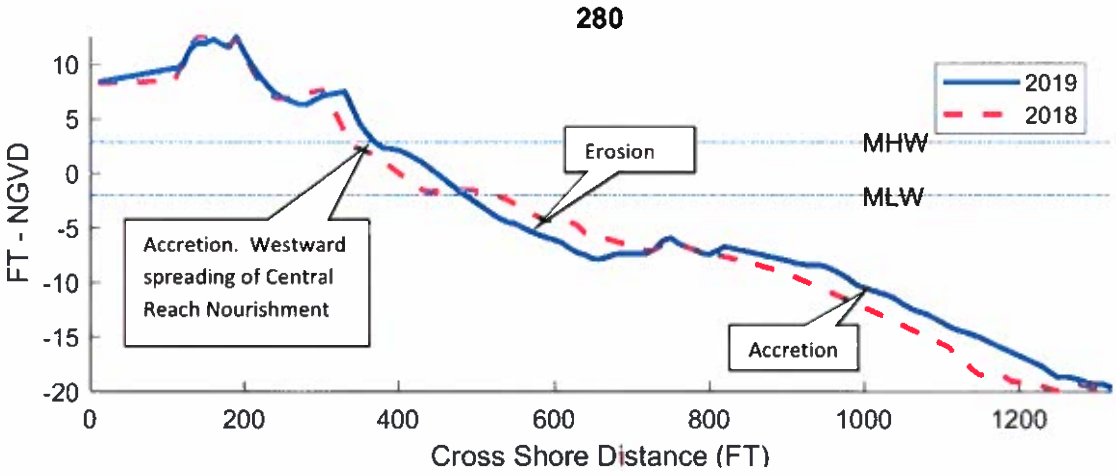
Station 240+00. 2019 survey reveals significant beach loss right around and just above MHW. Areas such as these are observed as isolated pockets along the beach where during times of elevated water levels (such as the 2018 hurricane season and other more recent high-water events) water is able to rush in and forms "inlets" and "outlets" during the storm which erodes the upper beach in these specific locations. These will slowly fill (grades will even out) and recent visual observations show this occurring.

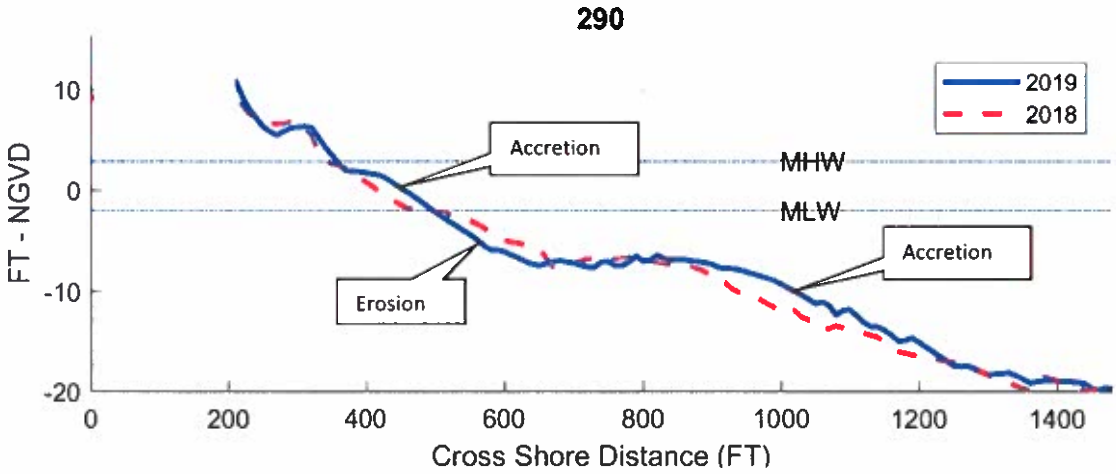


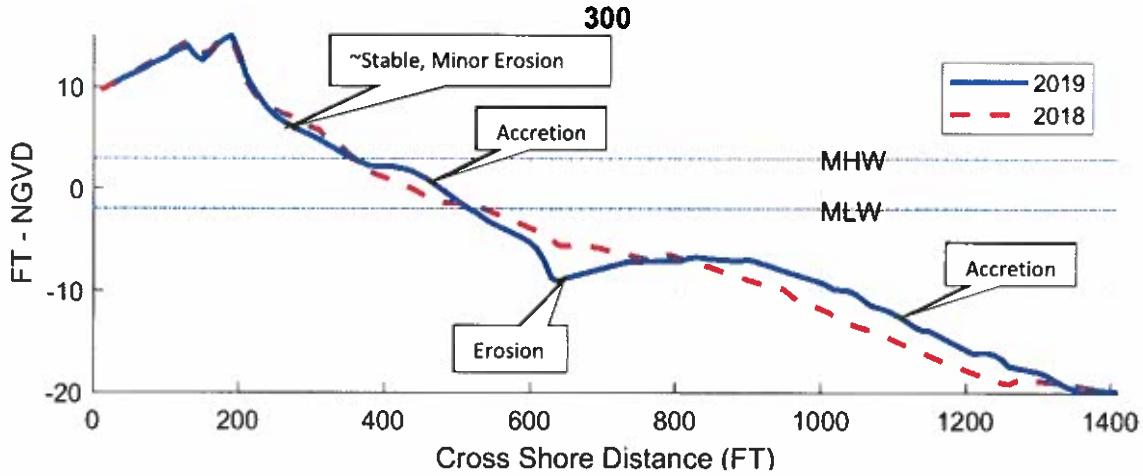


Station 260+00. 2019 survey shows the benefits of continued downdrift spreading of the 2017 Central Reach Project outside of the original fill template placement.

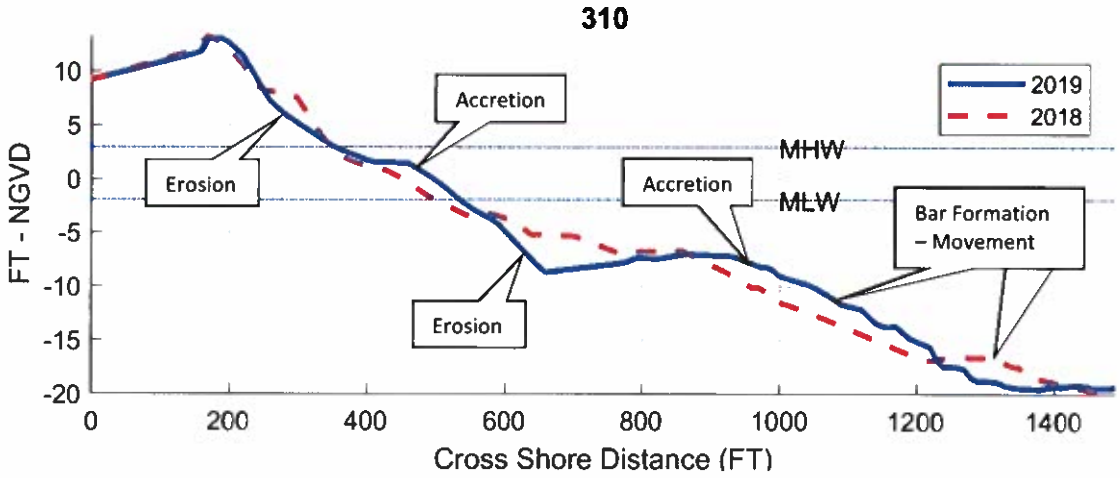


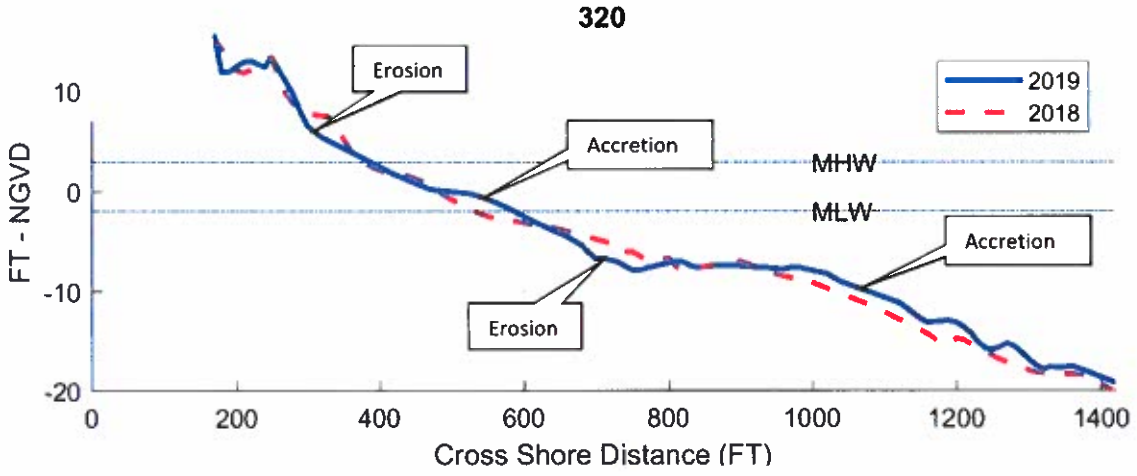

280
10
5
0
-5
-10
-15
-20
FT - NGVD
0
200
400
600
800
1000
1200
Cross Shore Distance (FT)
2019
2018
MHW
MLW
Erosion
Accretion. Westward spreading of Central Reach Nourishment
Accretion

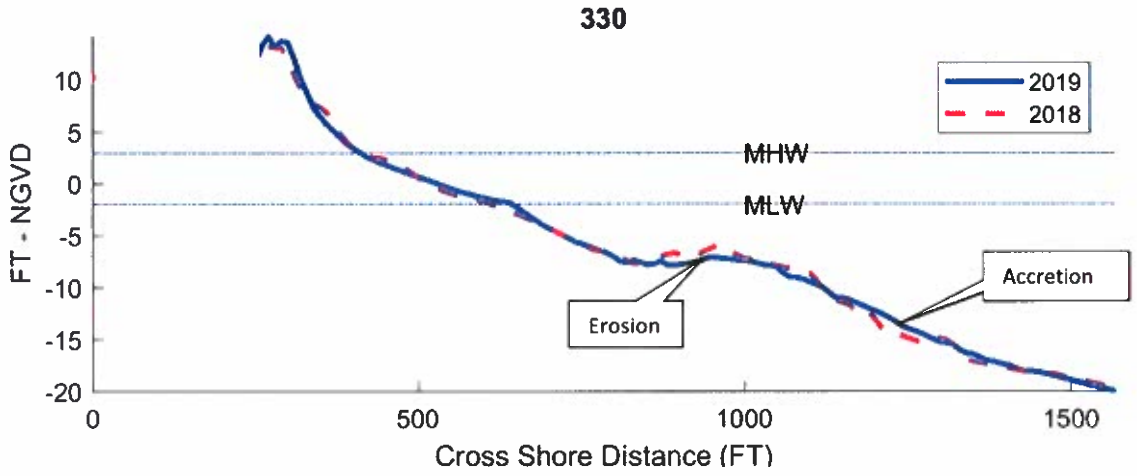

290
10
0
-10
-20
FT - NGVD
0
200
400
600
800
1000
1200
1400
Cross Shore Distance (FT)
2019
2018
MHW
MLW
Accretion
Erosion
Accretion



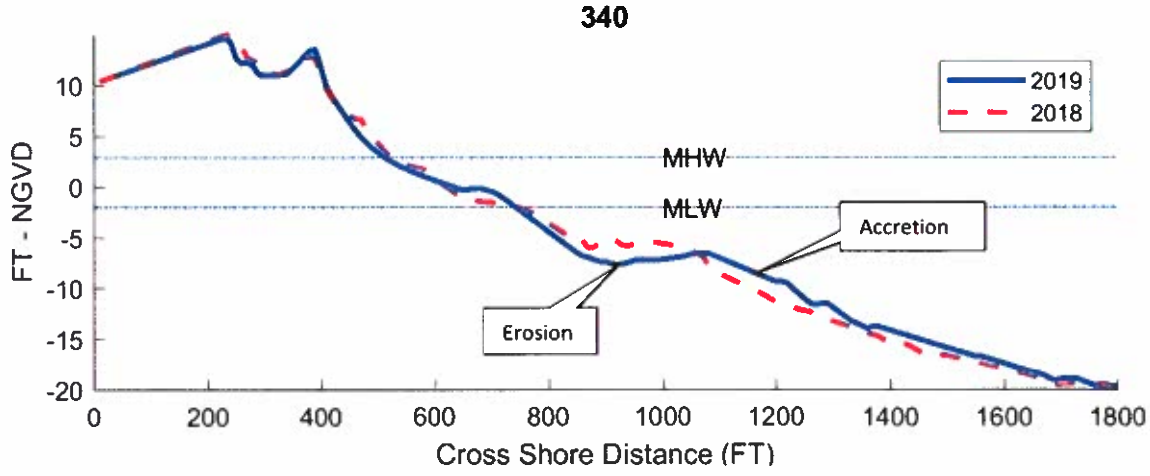
Station 300+00. Similar to the Central Reach and eastern reaches, many of the western stations show upper beach loss and nearshore erosion, as well as significant offshore accretion ~1,000 ft offshore. This pattern is again reflective of the highly energetic 2018 hurricane season and the beach is now slowly recovering as material lost offshore is showing some signs of onshore movement in the April 2019 survey.

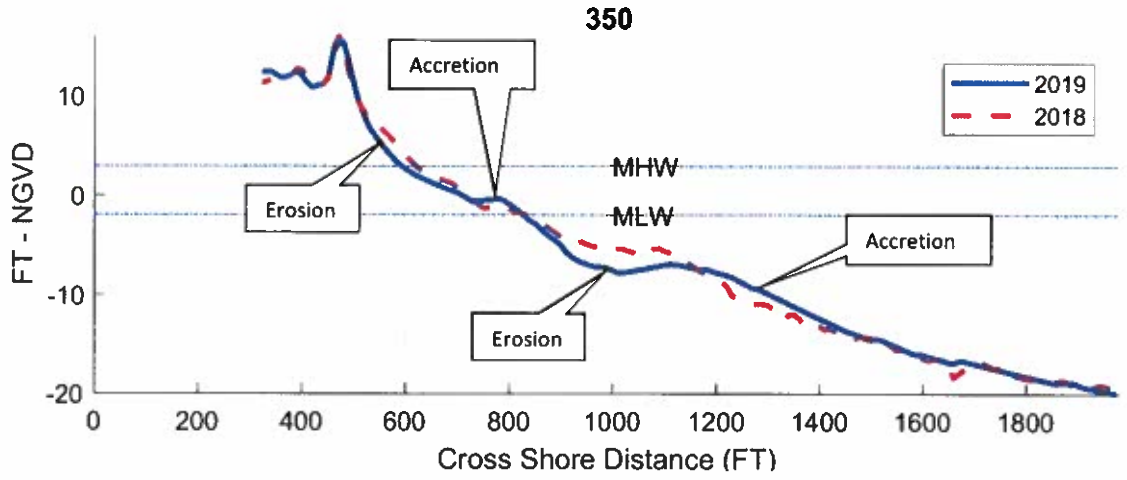


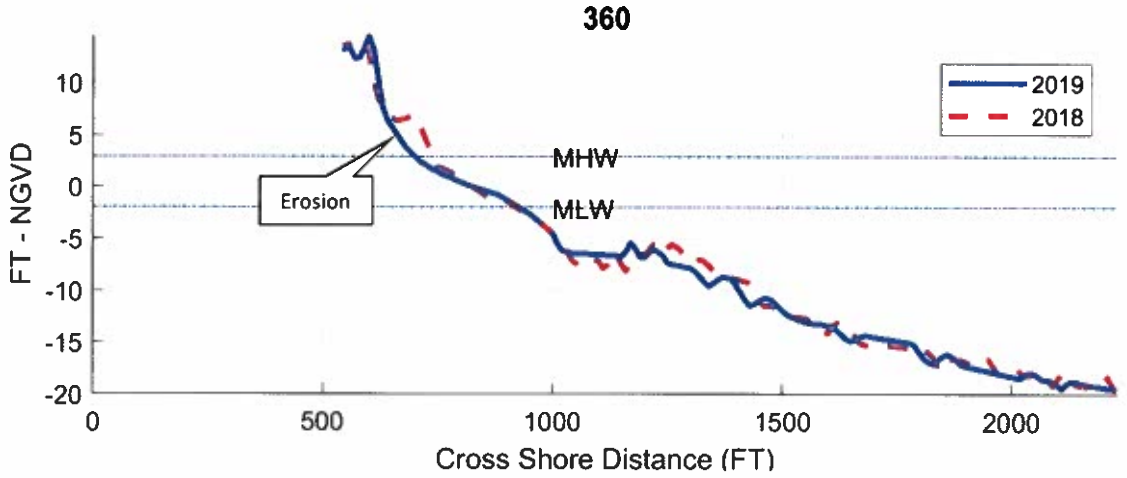


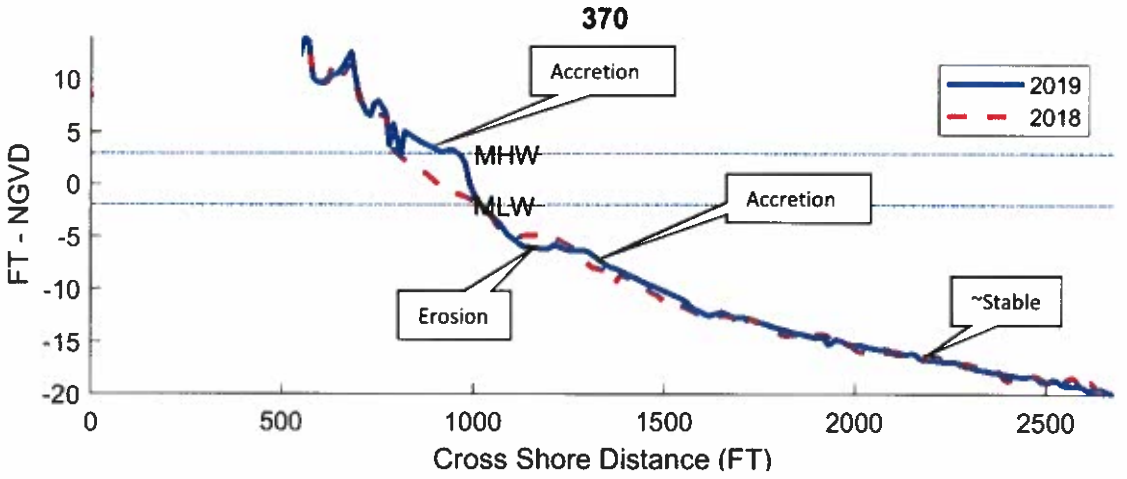


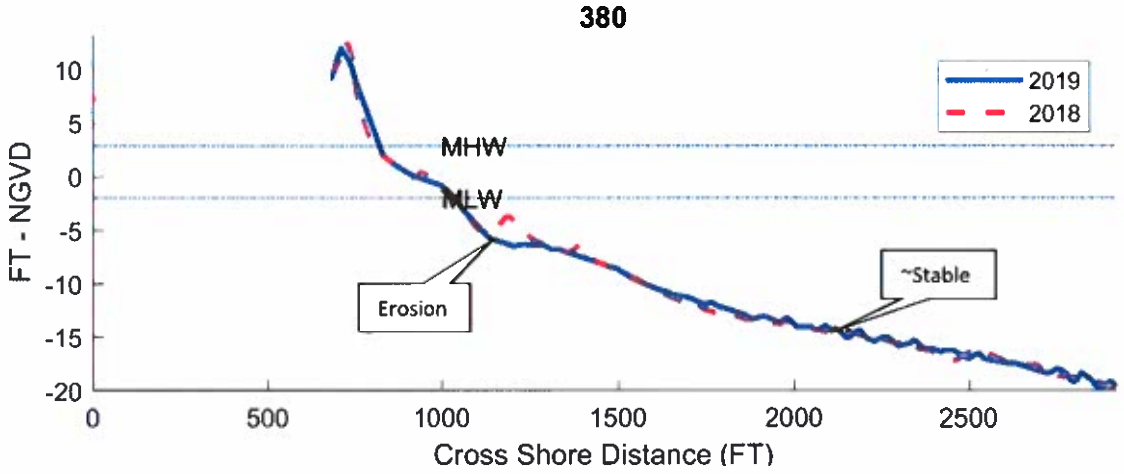
Station 330+00. 2019 survey shows a generally stable beach profile with some offshore movement of sand.

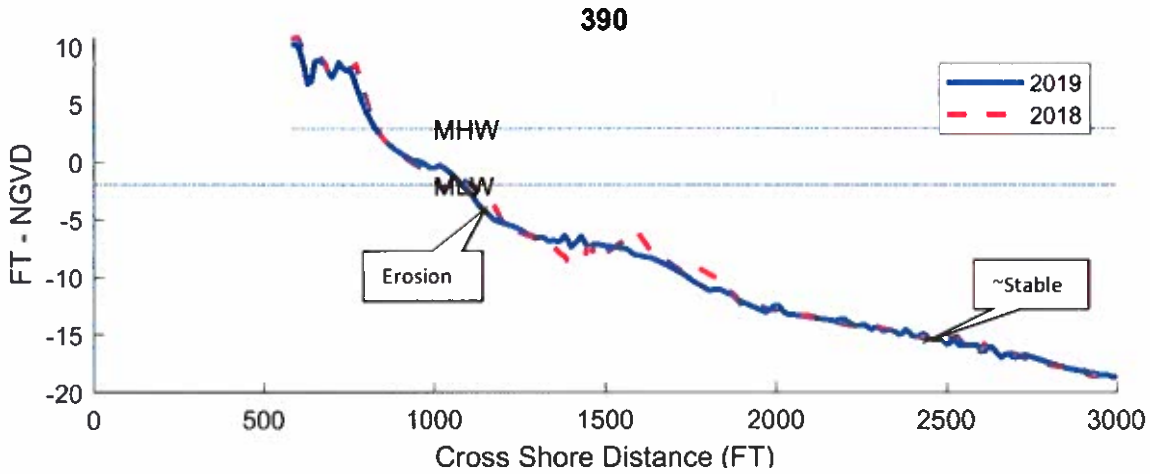


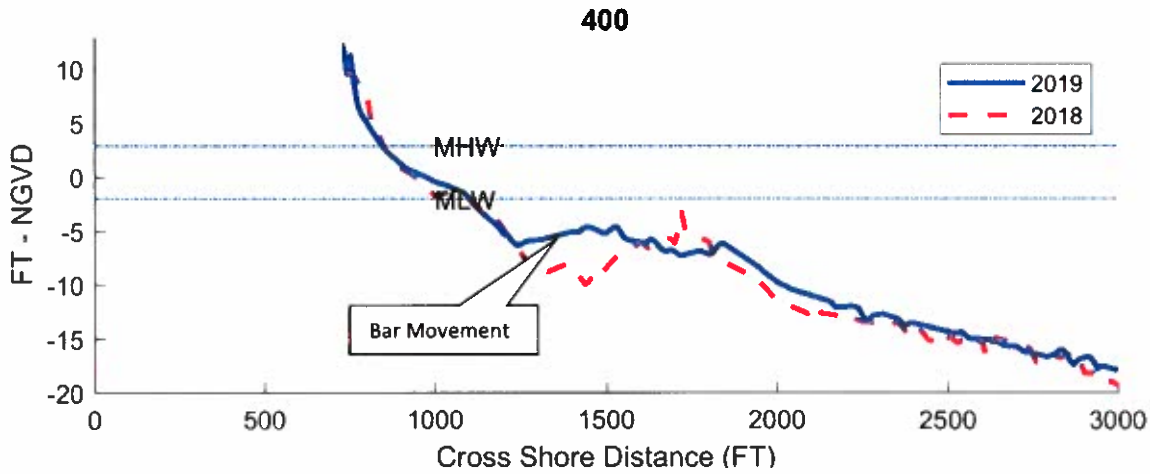

350
Accretion
Erosion
MHW
MLW
Accretion
Erosion
2019
2018
FT - NGVD
Cross Shore Distance (FT)

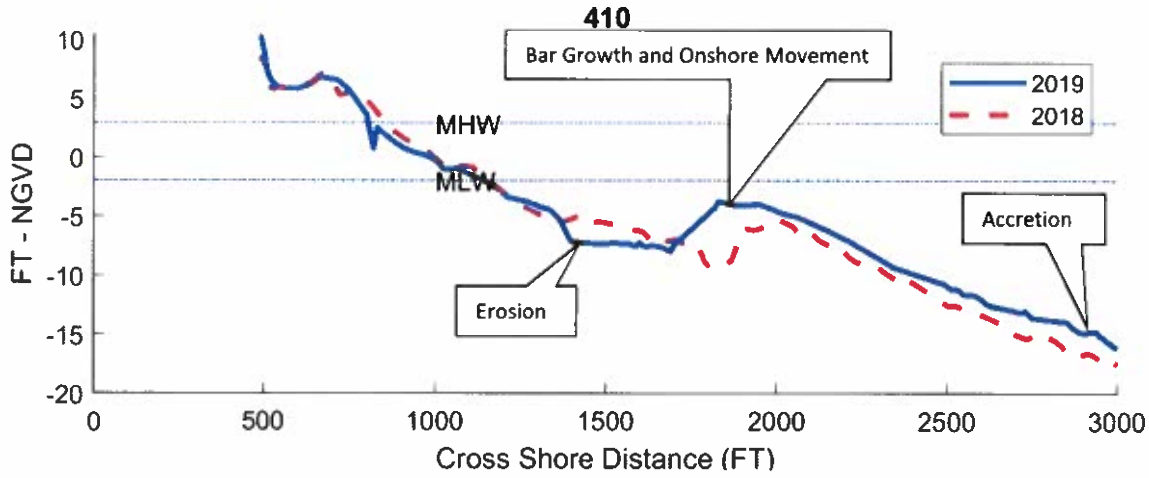

360
Erosion
MHW
MLW
2019
2018
FT - NGVD
Cross Shore Distance (FT)


370
Accretion
MHW
MLW
Accretion
Erosion
~Stable
2019
2018
FT - NGVD
Cross Shore Distance (FT)

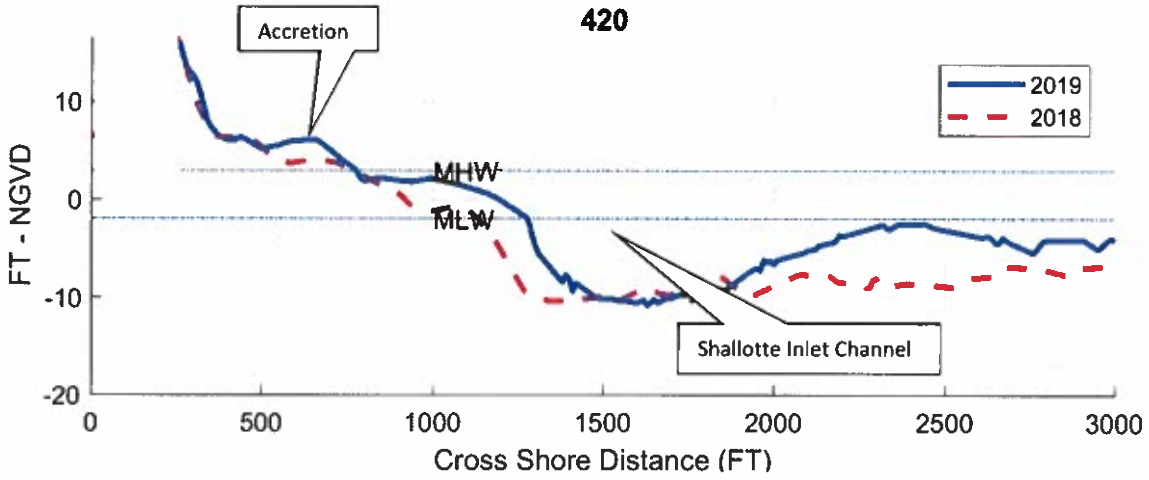

380
2019
2018
MHW
MLW
Erosion
~Stable
FT - NGVD
Cross Shore Distance (FT)

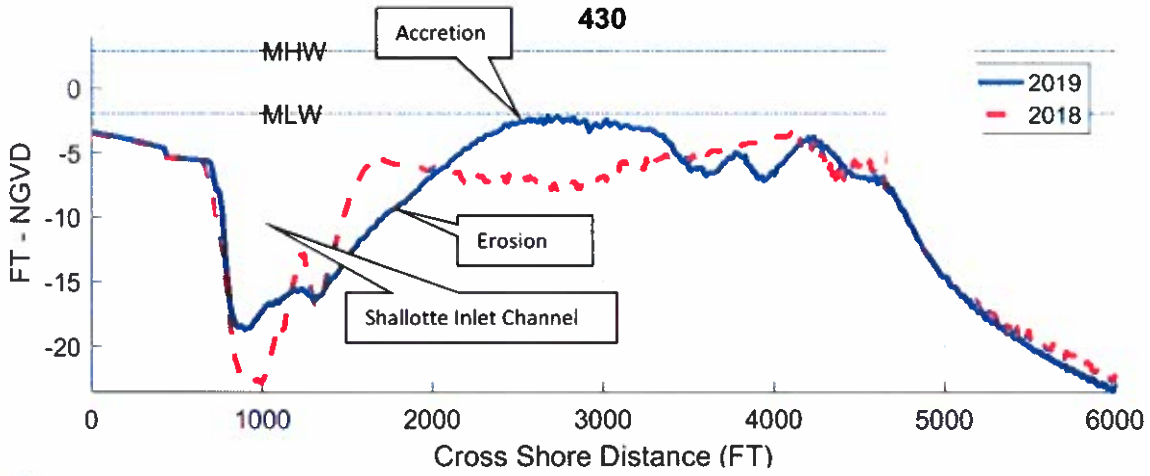

390
2019
2018
MHW
MLW
Erosion
~Stable
FT - NGVD
Cross Shore Distance (FT)


400
2019
2018
MHW
MLW
Bar Movement
FT - NGVD
Cross Shore Distance (FT)

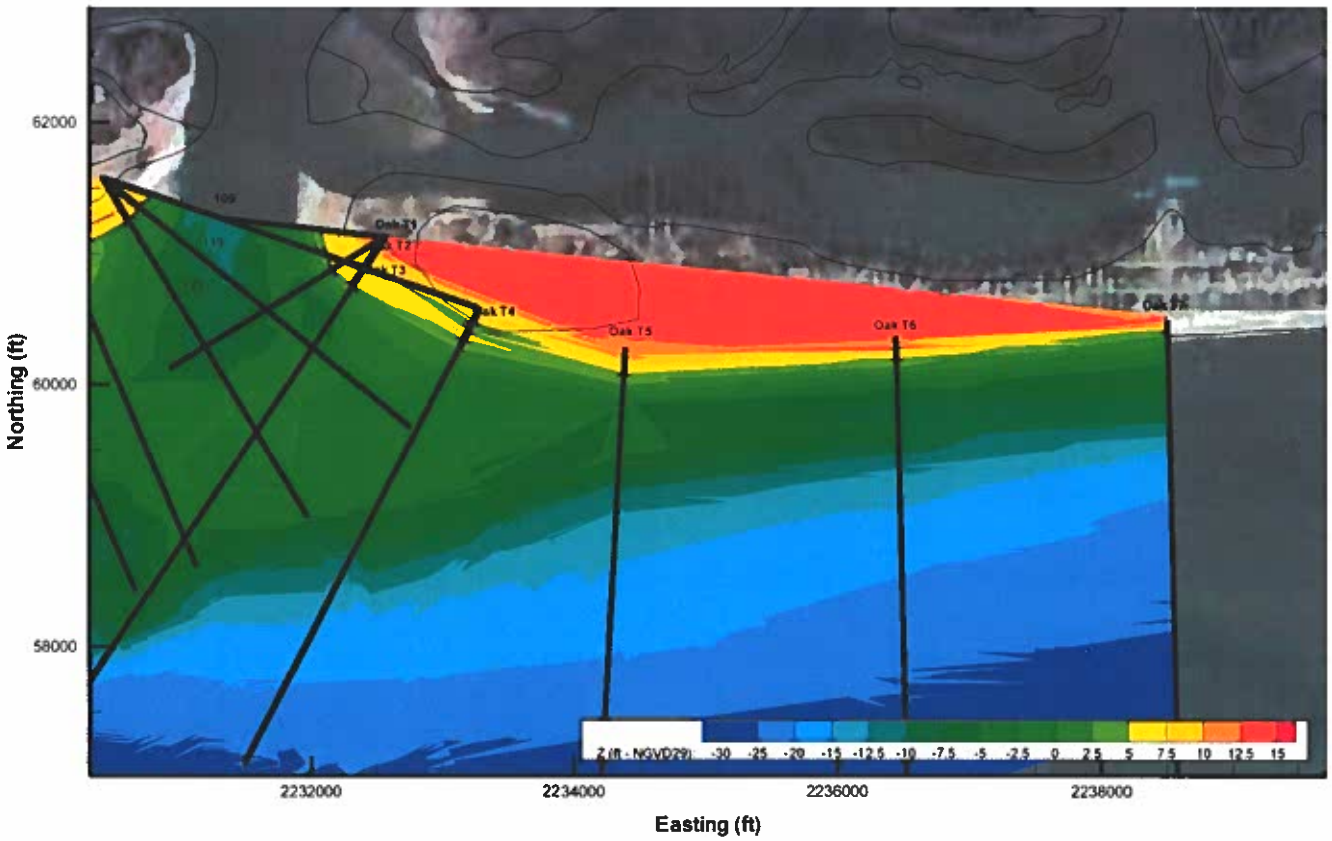


Station 410+00. 2019 survey shows some significant bar formation and onshore movement 2018.

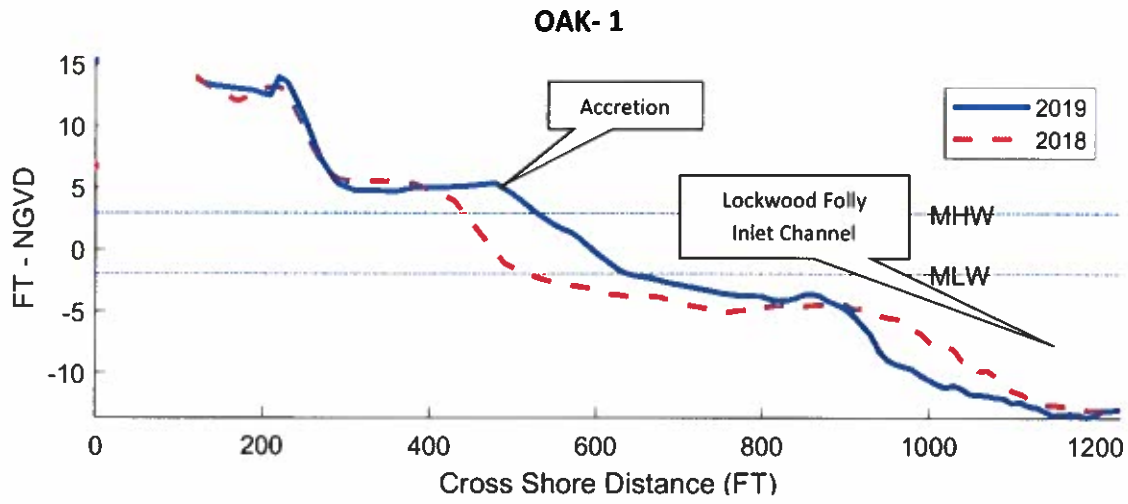




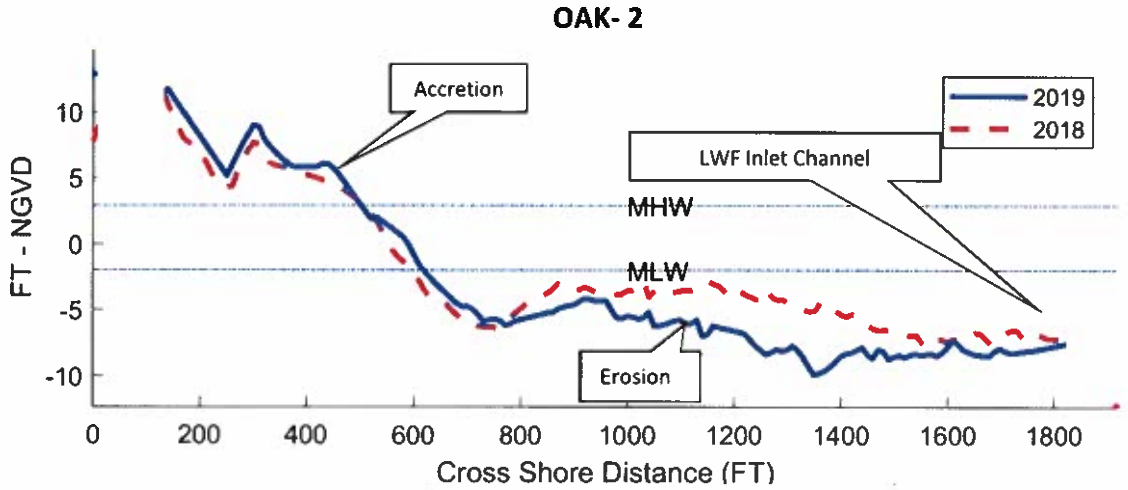
Station 430+00. The beach appears mostly stable on the Holden Beach side of the Shallotte Inlet Channel, though some filling in has taken place. Channel appears to be shallowing and widening.



Oak Island Transects

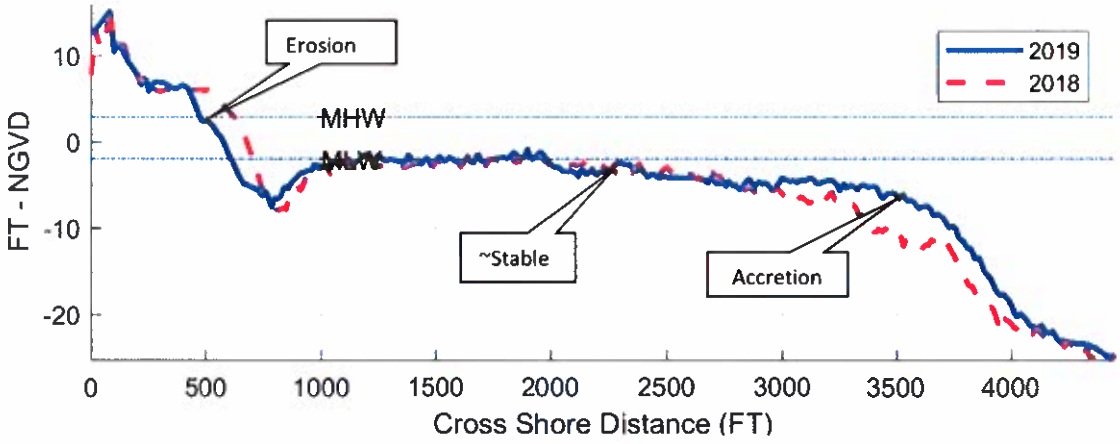


Station OAK- 1. The dune system is relatively healthy and some significant accretion is seen in the upper beach and intertidal zones. A widening of the LWF Inlet Channel is observed since the 2018 survey and may indicate the channel is migrating east towards Oak Island.

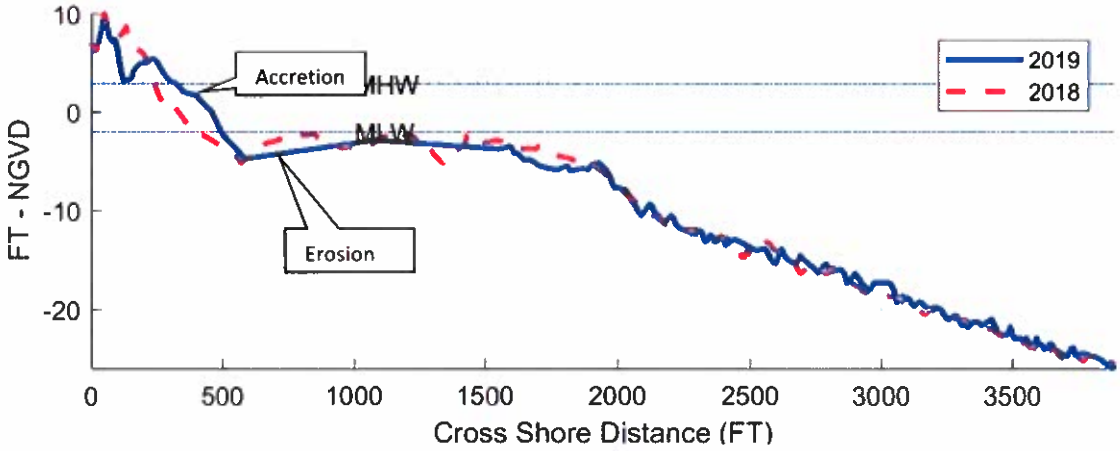


Station OAK- 2. Some upper beach accretion is observed. The 2019 survey generally shows deepening nearshore beach and inlet depths at this location.

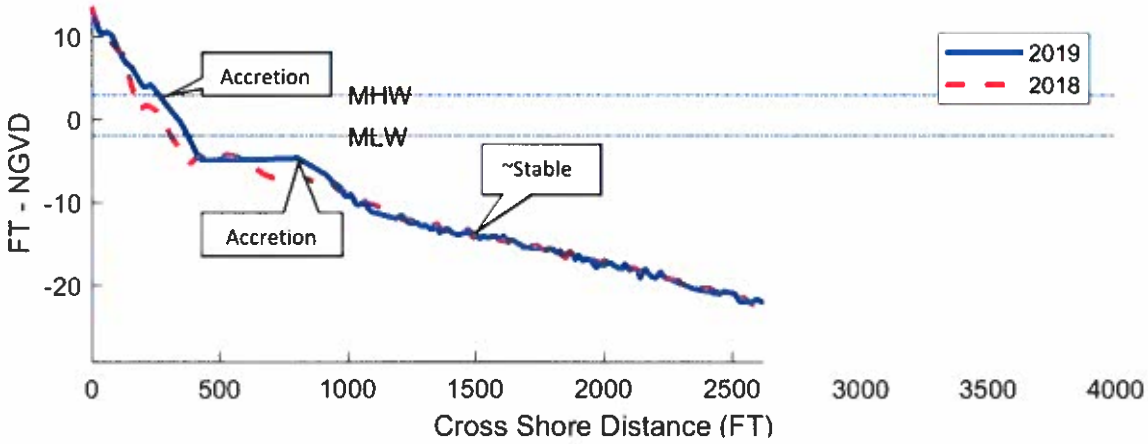
OAK-3



OAK- 4

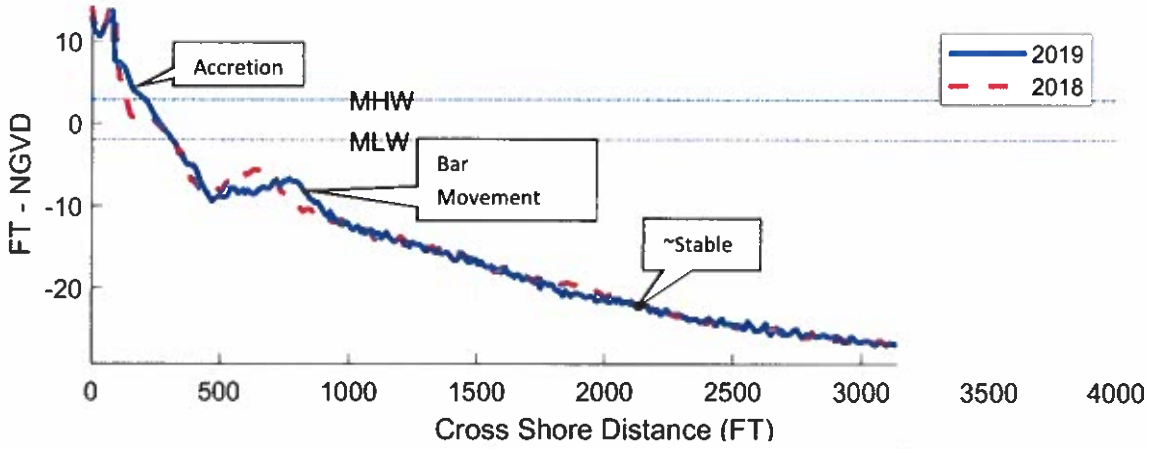


OAK- 5



Station OAK- 5. Accretion observed here primarily due to the 2019 USACE LWFIX dredging and beach placement.

OAK- 6



Station OAK- 6. Accretion observed here primarily due to the 2019 USACE LWFIX dredging and beach placement.

OAK- 7

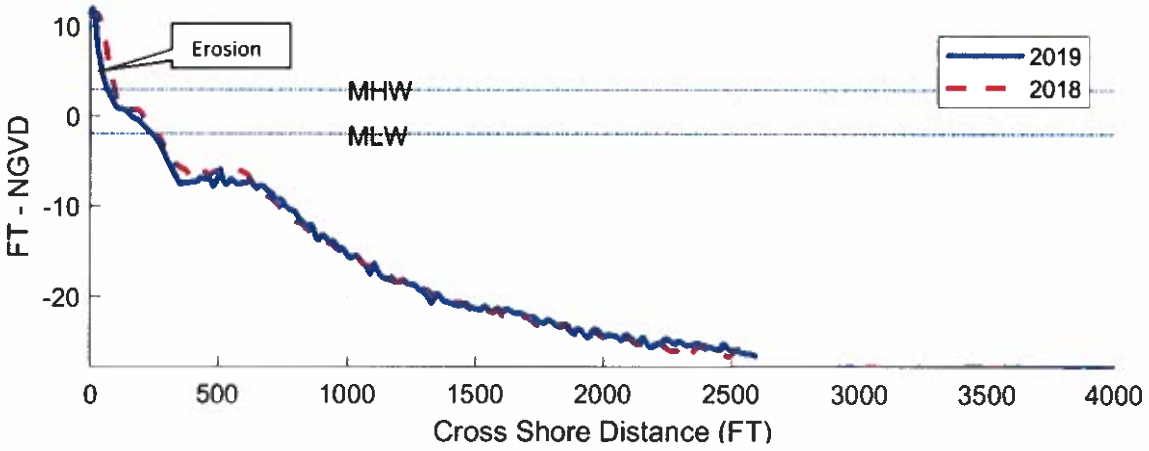


TABLE A-1: 2018 to 2019 Survey Transect Analysis

General Notes –

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

2018 to 2019 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	-22.8	-22.7	-50.2	LWF Inlet
119+00	0	-52.9	-50.2	-145.5	LWF Inlet
129+00	500	-56.4	-68.9	-185.0	LWF Inlet
5+00	500	193.4	116.7	122.9	LWF Inlet Shoulder
10+00	500	36.2	-14.9	112.1	LWF Inlet Shoulder
15+00	440	114.8	88.9	91.7	LWF Inlet Shoulder
20+00	1000	30.3	23.4	76.9	Oceanfront Perpendicular
30+00	1000	3.1	-5.6	-10.0	
40+00	1000	-4.9	-20.5	-37.4	
50+00	1000	18.1	4.4	3.7	
60+00	1000	-12.7	-13.0	-25.4	
70+00	1000	-9.1	-10.2	-40.6	
80+00	1000	-19.3	-17.9	-12.9	
90+00	1000	-24.0	-15.4	-8.6	
100+00	1000	-11.5	-11.1	12.1	
110+00	1000	-15.2	-14.1	18.5	
120+00	1000	0.4	-2.8	22.6	
130+00	1000	-9.5	-8.9	19.4	
140+00	1000	-4.3	-3.5	20.9	
150+00	1000	-4.9	-0.4	38.5	
160+00	1000	-0.5	4.2	41.2	
170+00	1000	-19.8	-14.3	12.3	
180+00	1000	-0.9	-5.2	18.0	
190+00	1000	-8.1	-6.0	33.1	
200+00	1000	1.0	-3.5	43.2	
210+00	1000	-16.9	-13.3	34.8	

220+00	1000	-13.7	-13.5	-1.9	
230+00	1000	-11.9	-2.7	10.9	
240+00	1000	-44.0	-47.4	21.1	
250+00	1000	-5.5	-2.4	18.3	
260+00	1000	29.3	14.5	34.6	
270+00	1000	28.9	17.9	46.0	
280+00	1000	8.7	4.1	34.8	
290+00	1000	12.1	3.7	3.8	
300+00	1000	3.5	-0.2	4.0	
310+00	1000	1.7	3.8	9.1	
320+00	1000	5.7	3.1	10.3	
330+00	1000	-2.2	3.0	4.6	
340+00	1000	-2.8	-2.9	-14.2	
350+00	1000	-13.7	-7.9	-25.3	
360+00	1000	-12.9	-7.6	-34.4	
370+00	1000	26.5	23.1	161.2	
380+00	1000	-3.9	1.4	10.3	
390+00	1000	-3.1	-0.3	-2.9	
400+00	1000	39.2	-5.5	-1.9	Oceanfront perpendicular
410+00	1000	31.0	3.8	-30.3	Shallotte Inlet Shoulder
420+00	1000	222.4	87.6	-5.3	Shallotte Inlet
430+00	-	9.4	1.0	-	Shallotte Inlet
	OAK ISLAND TRANSECTS				
OAK 1	0	30.3	48.4	90.8	LWF Inlet
OAK 2	0	-56.5	-3.6	-8.8	LWF Inlet
OAK 3	890	63.9	-29.4	-155.6	LWF Inlet
OAK 4	1100	8.0	10.8	89.4	LWF Inlet Shoulder
OAK 5	2000	42.0	27.5	102.6	Oceanfront perpendicular
OAK 6	2000	9.1	10.2	78.3	
OAK 7	-	-24.0	-15.1	-26.0	

Appendix B

2019 Survey Plan View Figures

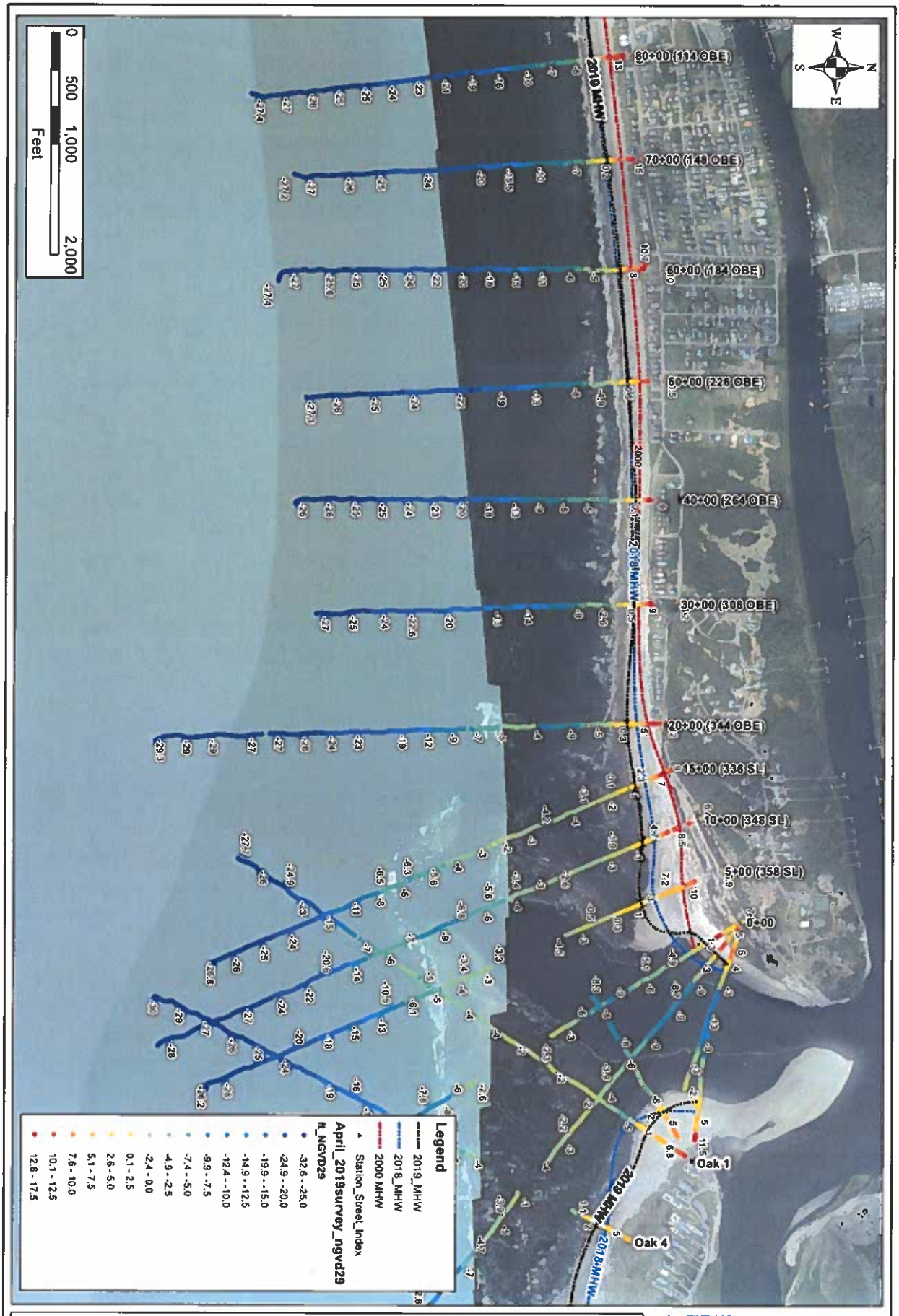


FIGURE B-1
2019 Survey Data and Established Monitoring Stations Shown. 2019 Mean High Water (MHW) Shoreline, 2018 MHW Shoreline, and 2000 MHW Shoreline.
NOAA September, 2018 Post-Florence Aerial Imagery.

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FIGURE B-2
2019 Survey Data and Established Monitoring Stations Shown. 2019 Mean High Water (MHW) Shoreline, 2018 MHW Shoreline, and 2000 MHW Shoreline.
NOAA September, 2018 Post-Florence Aerial Imagery.

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FIGURE B-3
2019 Survey Data and Established Monitoring Stations Shown. 2019 Mean High Water (MHW) Shoreline, 2018 MHW Shoreline, and 2000 MHW Shoreline.
NOAA September, 2018 Post-Florence Aerial Imagery.

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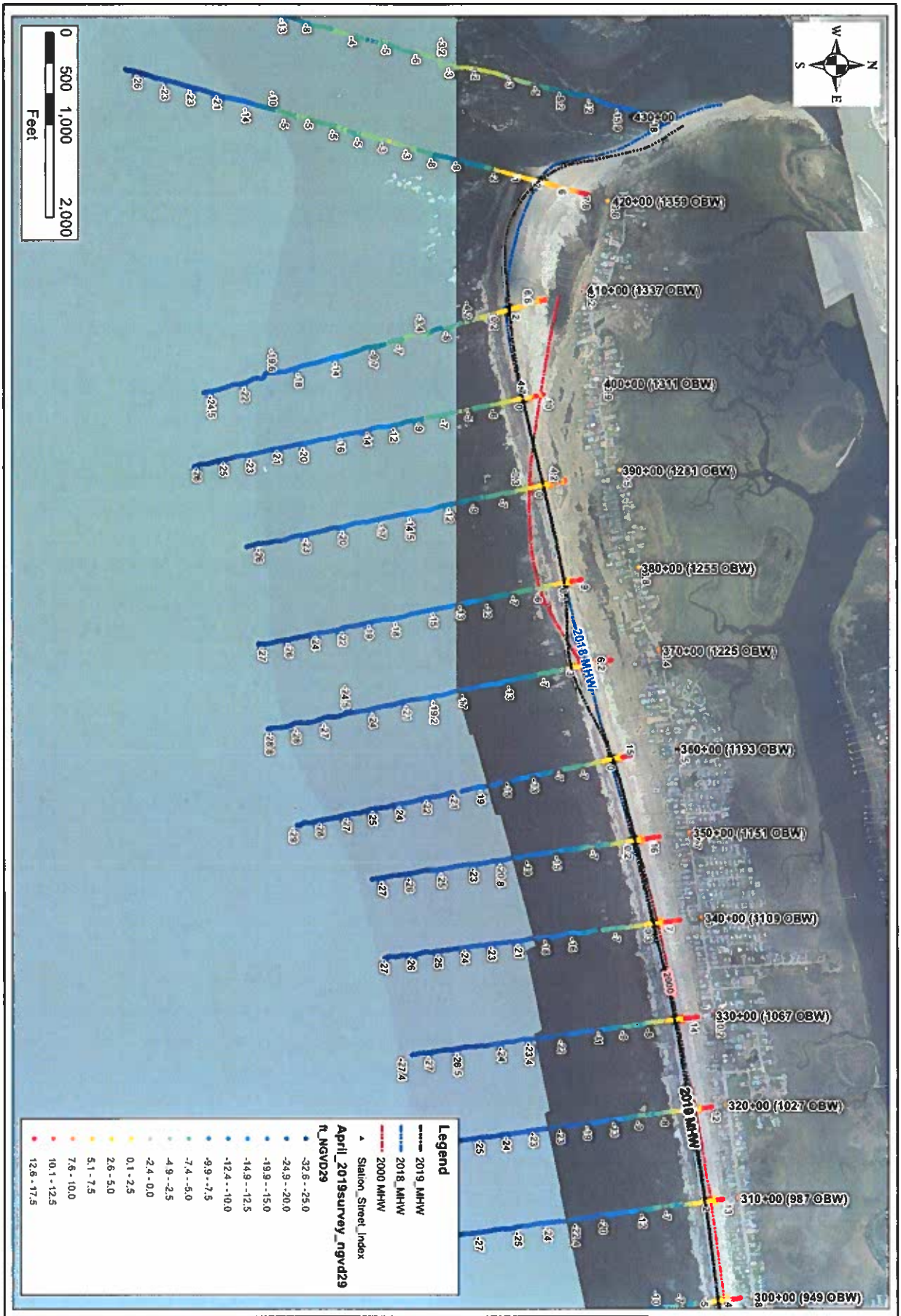

FIGURE B-4
2019 Survey Data and Established Monitoring Stations Shown. 2019 Mean High Water (MHW) Shoreline, 2018 MHW Shoreline, and 2000 MHW Shoreline.
NOAA September, 2018 Post-Florence Aerial Imagery.

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FIGURE B-5
2019 Survey Data and Established Monitoring Stations Shown. 2019 Mean High Water (MHW) Shoreline, 2018 MHW Shoreline, and 2000 MHW Shoreline.
NOAA September, 2018 Post-Florence Aerial Imagery.

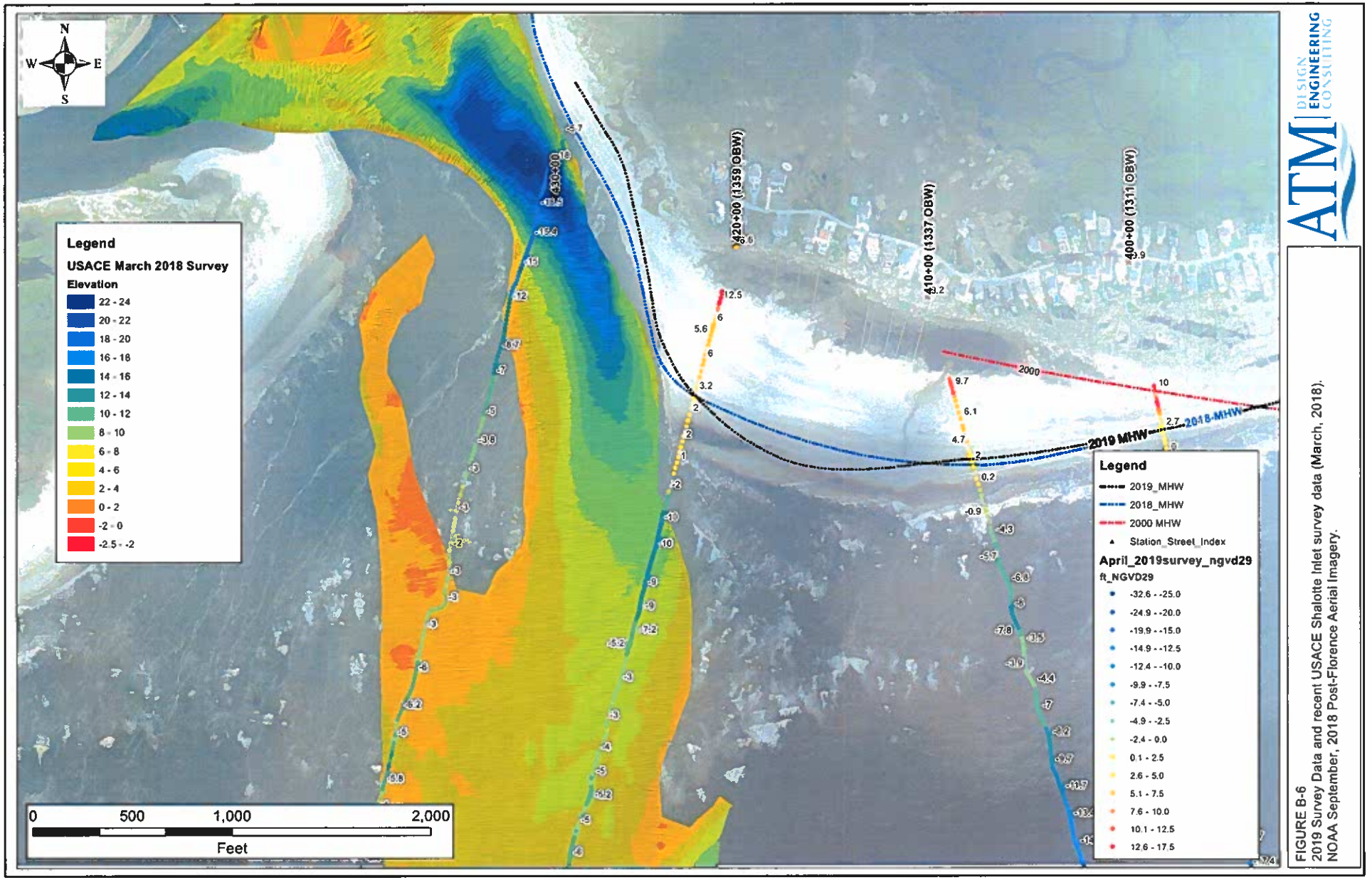

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FIGURE B-6
2019 Survey Data and recent USACE Shallotte Inlet survey data (March, 2018).
NOAA September, 2018 Post-Florence Aerial Imagery.

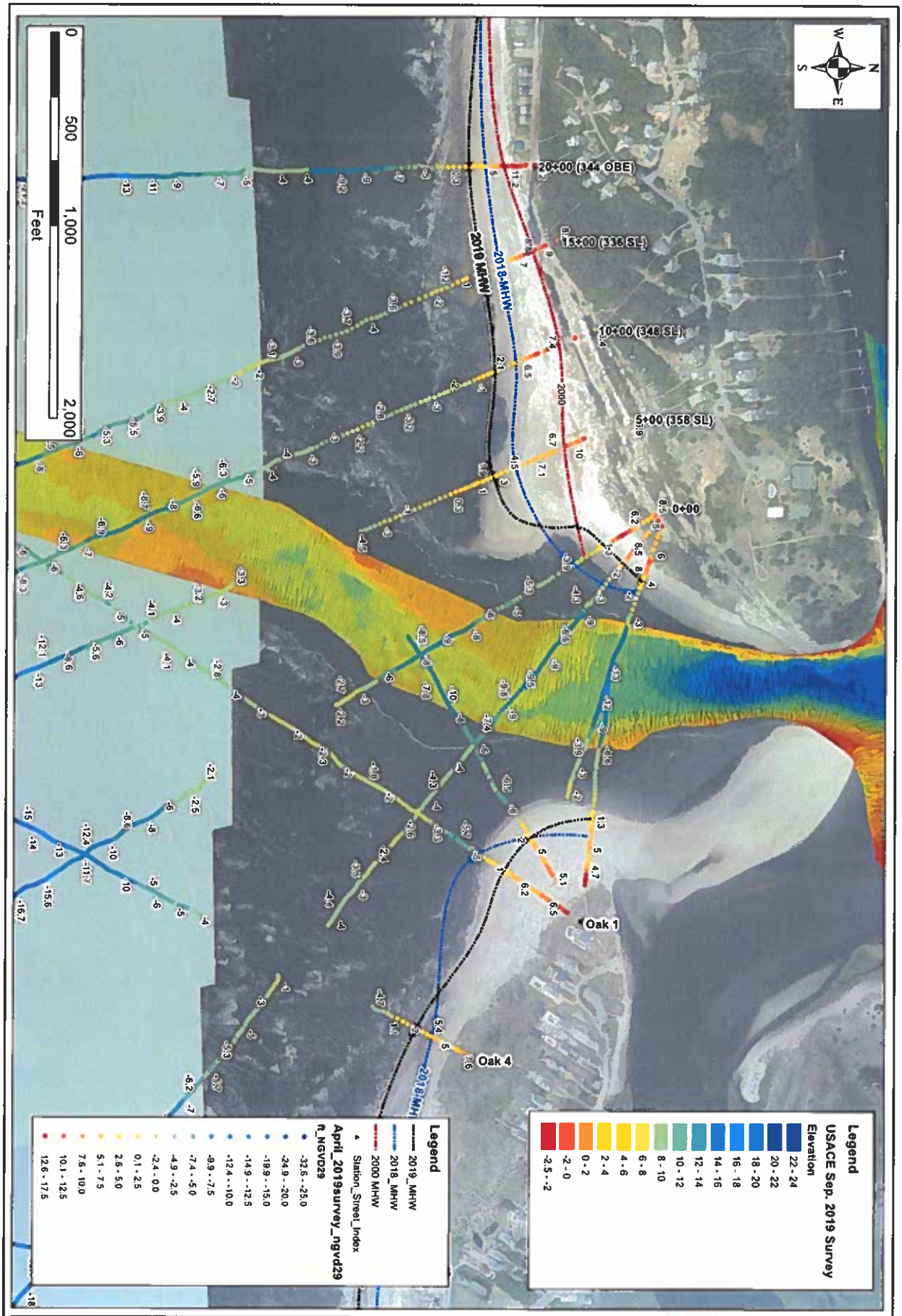

FIGURE B-7
2019 Survey Data and recent USACE Lockwood Folly Inlet survey data (September, 2019).
NOAA September, 2018 Post-Florence Aerial Imagery.

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