



Town of Kill Devil Hills

North Carolina

Town of Kill Devil Hills Shore Protection Project



Photograph obtained by Aptim Coastal Planning & Engineering of North Carolina, Inc. (July 19, 2017).

Beach Maintenance Plan

August 2017
Updated February 2018

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TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

EXECUTIVE SUMMARY

The Town of Kill Devil Hills has initiated a shore protection project aimed at sustaining the beaches that support a significant portion of their local economy, maintaining the tax base of the Town, retaining existing recreational resources, and protecting existing natural resources. The project has, and will continue to provide increased protection to the Town's economy and coastal development. A key aspect to the long term success of the project is the implementation of a maintenance program to document construction achievements and project performance. This document details the maintenance program established by the Town.

The Town successfully completed the initial construction of the Shore Protection Project in July 2017. Periodic maintenance or renourishment is included in the Town's maintenance plan for the Shore Protection Project. The renourishments are expected to occur on a 5 year cycle and will initially involve dredging of Borrow Area A offshore Kill Devil Hills and Nags Head. The Dept. of the Army and North Carolina Division of Coastal Management permits issued for the initial construction will require modifications to use Borrow Area A for future maintenance. Likewise, the Town will be required to obtain a new lease from the Bureau of Ocean Energy Management (BOEM) to use Borrow Area A for maintenance events. The Town has already made these agencies aware of their intentions to use Borrow Area A in the future. The estimated volume of material required for maintenance of the Kill Devil Hills project is 407,000 CY every five (5) years. Post-construction surveys of Borrow Area A show that sufficient sand is available for future maintenance.

Project monitoring has been implemented to track performance of the placed material and is used to update nourishment requirements. The initial baseline monitoring event was conducted in December 2017 and the Year-1 annual monitoring event was conducted in June 2018. The maintenance plan may be updated throughout the monitoring phase to reflect changes in the overall project. Given the presence of nearshore depressions or troughs located offshore of the project area, the Town has also incorporated shore parallel bathymetric surveys into their monitoring protocol to track movement of sand within the system. The beach profile surveys and supplemental shore-parallel bathymetric surveys have been designed and are conducted to capture changes along the active profile of the beach both within the project area and adjacent to the project.

This Maintenance Plan serves as documentation that the Town of Kill Devil Hills' Shore Protection Project meets the criteria established by 44 CFR 206.226(j)(2). The Maintenance Plan has been developed in a way consistent with the Public Assistance Program and Policy Guide – FP-104-009-2 (January 2018). This Maintenance Plan will be updated regularly to reflect results of monitoring, construction of additional projects, maintenance events and changes in schedules.

TOWN OF KILL DEVIL HILLS
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TABLE OF CONTENTS

	Pg.
INTRODUCTION	1
CONSTRUCTION EVENTS	2
MAINTENANCE	5
RENOURISHMENT REQUIREMENTS	6
MONITORING PROTOCOL.....	7
CONCLUSION.....	8

LIST OF FIGURES

	Pg.
Figure 1. Map showing the extent of the project including the main fill construction template, the southern taper, and the construction baseline..	3
Figure 2. Map showing the location of the offshore borrow area used for the construction of the July 2017 Kill Devil Hills Shore Protection Project.....	4
Figure 3. Map of Kill Devil Hills Shore Protection Project Monitoring Beach Profiles.....	6

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

INTRODUCTION

The Town of Kill Devil Hills is focused on a long-term shoreline management program that will serve to sustain the beaches that support a significant portion of their local economy, maintain the tax base of the Town, retain existing recreational resources, and protect existing natural resources. In order to accomplish these stated goals, the Town has taken steps to maintain its oceanfront beach and dune to a configuration that provides a reasonable level of storm damage reduction to public and private development and mitigates long-term erosion impacts.

An Erosion and Shoreline Management Design study was completed for the Town of Kill Devil Hills in 2015 (CPE-NC, 2015A). The study evaluated potential management options for the oceanfront shoreline. The recommendation of the resulting design report was a beach nourishment project along a portion of the Town's shoreline that was vulnerable to impacts of a design storm with wave and water level characteristics matching Hurricane Isabelle, which impacted the coast in 2003. The project was also designed to include 5 years of advanced nourishment to account for predicted background erosion of the project during the maintenance interval.

Initial construction of the beach nourishment project was completed in July 2017. The project included placement of 817,359 cy of beach compatible sand, which equates to an average fill density of approximately 60 cy/lf, along 13,666 feet or approximately 2.6 miles. Sand used to construct the project was dredged from an offshore borrow source. Following the construction of the project, the Town implemented a maintenance program to monitor the performance of the Shore Protection Project and determine when periodic renourishment is needed to maintain the project.

Documentation of the construction and subsequent monitoring events has been archived as evidence of the Town's commitment towards maintaining the Shore Protection Project. This information is required for eligibility under the Public Assistance (PA) program administered by FEMA. If the project is impacted by a presidentially declared disaster or emergency, justification that the maintenance plan has been implemented must be provided to receive federal aid. This stipulation is mandated by 44 CFR 206.226(j)(2), which states:

Work on an improved beach may be eligible under the following conditions:

- (i) The beach was constructed by the placement of sand (of proper grain size) to a designed elevation, width, and slope; and,*
- (ii) A maintenance program involving periodic renourishment of sand must have been established and adhered to by the applicant.*

The amount of sand replacement eligible for FEMA funding is limited to the material volume lost as a result of the declared disaster or emergency. Pre- and post-storm profiles are used to determine the eligible volume of sand. According to the Public Assistance Program and Policy Guide – FP-104-009-2 (January 2018), profile surveys must extend at least to the seaward edge of the subaqueous nearshore zone (closure depth). The Kill Devil Hills monitoring surveys generally extend to a depth of -30 ft. NAVD88; whereas the established depth of closure for the project is -24 ft. NAVD88.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

This Maintenance Plan serves as documentation that the Town of Kill Devil Hills' Shore Protection Project meets the criteria established by 44 CFR 206.226(j)(2). The Maintenance Plan has been developed in a way consistent with Public Assistance Program and Policy Guide – FP-104-009-2 (January 2018). The Maintenance Plan includes a description of the project design, construction activities to date, anticipated volume and cost for maintenance, schedule of maintenance and the monitoring protocols being employed by the Town of Kill Devil Hills. This Maintenance Plan will be updated regularly to reflect results of monitoring, construction of additional projects, maintenance events and changes in schedules.

CONSTRUCTION EVENTS

Beach Fill

The initial construction of the Town of Kill Devil Hills Shore Protection Project was completed in July 2017. The project included the construction of a dune and berm beach fill design along the northern 12,592 feet of the Town of Kill Devil Hills Shoreline. In addition to the 12,592 ft. design fill section, the project also included a 1,074-foot long taper on the south end. To the north of the Town boundary, the Town of Kitty Hawk constructed a beach nourishment project along the entirety of their shoreline. In total, the Kill Devil Hills project placed sand from baseline station 189+00 (northern Town boundary) to 325+66 (Prospect Ave. Public Access). Figure 1 shows the extent of the project including the main fill construction template, the southern taper, and the construction baseline. Sand used to construct the project was dredged from the permitted offshore borrow area referred to as Borrow Area A, using trailing suction hopper dredges (Figure 2).

The beach fill constructed in July 2017 included placement of 817,359 cy of beach compatible sand, which equates to an average fill density of approximately 60 cy/lf, along 13,666 feet of beach (approximately 2.6 miles). The volume placed included both the volume necessary to construct the designed dune and berm as well as the volume needed for advanced fill. Advanced fill is the sacrificial portion of the fill required to protect the design section from anticipated sediment losses during the time between subsequent maintenance cycles. The volume of advanced fill needed was based on background erosion rates, anticipated diffusion losses and a five (5) year maintenance cycle. Ultimately, the performance of the beach fill dictates when constructed sections require maintenance, which is referred to as renourishment.

Dune Vegetation

The Town planted American Beach Grass in the nourishment area to promote trapping of wind-blown sand. American Beach Grass was planted at 18 inch spacing along both the crest of the dune and the seaward face of the dune. Plants were fertilized at the time of planting. The planting of the American Beach Grass occurred in late fall and winter of 2017.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

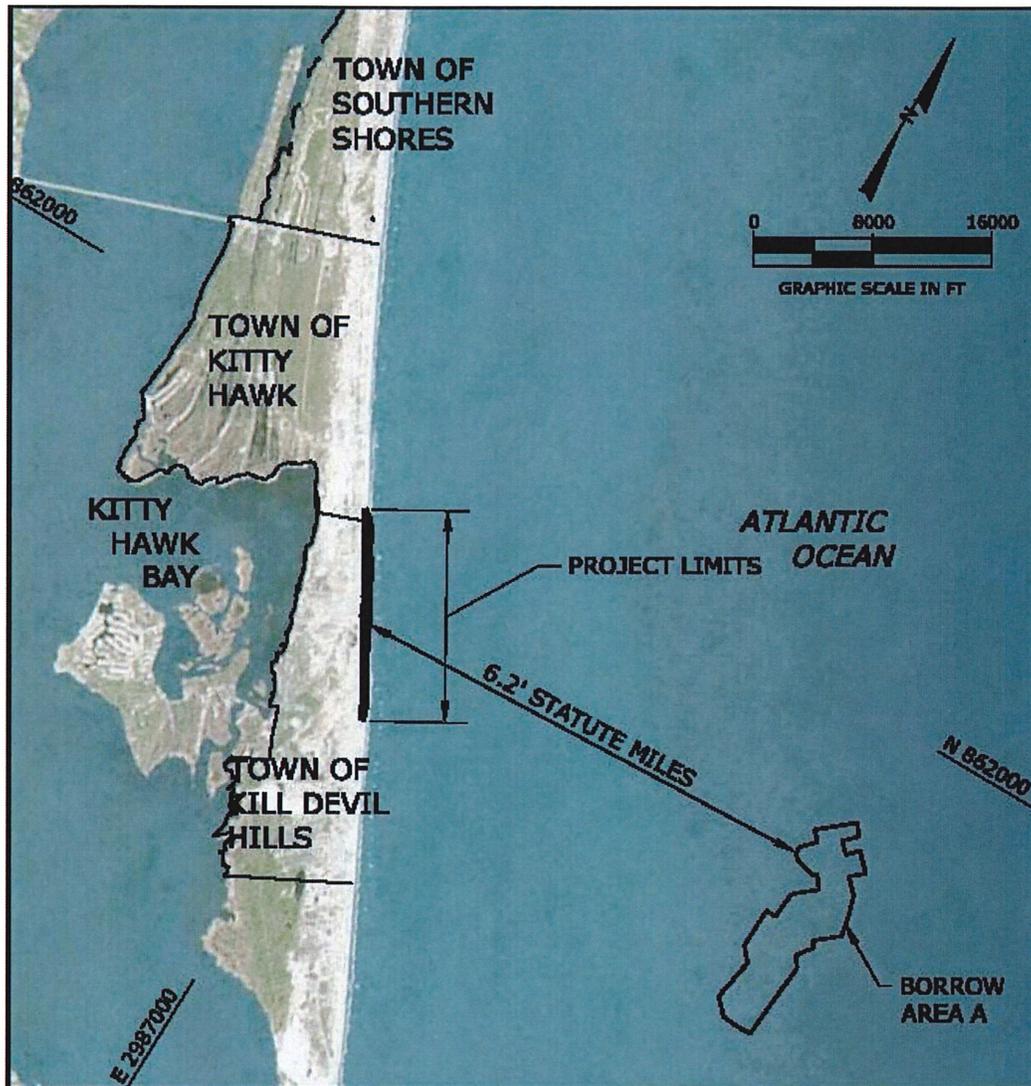


Figure 2. Map showing the location of offshore borrow area used for the construction of the July 2017 Kill Devil Hills Shore Protection Project.

The Town also planted Sea Oats in the nourishment area to promote trapping of wind-blown sand. Sea Oats were planted at 18 inch spacing along both the crest of the dune and the seaward face of the dune. Plants were fertilized at the time of planting. The planting of the Sea Oats occurred in August and September of 2017 and in Spring 2018.

Sand Fencing

The Town installed two rows of angled 10-foot sand fencing sections staggered along the landward and seaward edge of the dune crest oriented at 45-degree angles from the shoreline. The sand fence was installed along the entire length of the beach nourishment project, a distance of 2.6

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

miles. Sand fence was evenly spaced thin wooden vertical slats connected with twisted wire. The sections were four feet in height and supported by three wooden stakes or posts per 10-foot section, one stake at each end and one in the middle. The sand fencing was untreated, unfinished, biodegradable, and neutral in color (beige. tan, natural wood finish).

Funding

The project was funded through revenue derived from the Dare County Beach Nourishment Fund and the Town of Kill Devil Hills. The Town of Kill Devil Hills portion of the project was raised through a combination of General Fund appropriation and Municipal Service Districts (MSDs). In essence, the Town of Kill Devil Hills portion of the cost of the project was funded by an increase in the ad valorem tax rate on all properties within the Town of Kill Devil Hills with additional funding provided at a higher rate through the MSDs by oceanfront property owners in the project area.

MAINTENANCE

Beach profile surveys are conducted annually to assess the performance of the Shore Protection Project. As-built surveys of the Kill Devil Hills Shore Protection Project were provided by the construction contractor, which represents conditions along each profile as sections of the project were constructed. The first post-construction survey of the project was conducted in December 2017 following completion of the Duck, Southern Shores, Kitty Hawk, and Kill Devil Hills projects. Data from the December 2017 survey represents the baseline condition of the project (APTIM, 2018). The Year-1 beach profile surveys were conducted in June 2018 and the annual monitoring report was completed in February 2019 (APTIM, 2019).

Beach profile surveys are conducted along beach profiles at approximately 1,000-foot intervals. Figure 3 shows the location of these beach profiles. The monitoring surveys generally extend to a depth of -30 ft. NAVD88; whereas the established depth of closure for the project is -24 ft. NAVD88.

The ocean floor offshore of the Kill Devil Hills project area is characterized by nearshore depressions or troughs. The presence of these troughs were evident based on data plotted from a 2009 multibeam survey conducted by the US Army Corps of Engineers Field Research Facility (USACE-FRF). The features were also present on a plot of the data collected by Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM) during a single-beam bathymetric survey conducted in December 2017/February 2018. Comparison of the 2009 USACE-FRF survey with the 2017/2018 APTIM survey indicated the troughs were mobile, i.e., they appeared to migrate north to south along the coast. Given the potential influence of the troughs on the volume change results computed using beach profile surveys only, the Town of Kill Devil Hills has incorporated a supplemental bathymetric survey into their monitoring protocol. This survey is conducted annually with the beach profile surveys. The supplemental bathymetric survey includes a series of shore parallel survey lines spaced approximately 200 feet apart. The survey area generally covers the offshore bottom from about the -10-foot NAVD88 contour seaward for a distance of about 3,000 feet.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

The Kill Devil Hills Shore Protection Project includes a 20 ft. wide dune with height of 15.0 ft. NAVD, and a 40 foot wide berm at elevation +6.0 ft. NAVD. The project included five (5) years of advanced fill. Annual monitoring will assess the volume of sand in excess of the design that remains in place to determine the timing of, and volume needed for, subsequent beach renourishment. Construction of the July 2017 project, which was combined with construction of projects within the Towns of Duck, Southern Shores and Kitty Hawk, used sand from Borrow Area A located offshore of Kill Devil Hills and Nags Head (Figure 2); however, sufficient sand is anticipated to be available in Borrow Area A to provide maintenance of the Kill Devil Hills Shore Protection Project, as well as similar projects in Duck and Kitty Hawk.

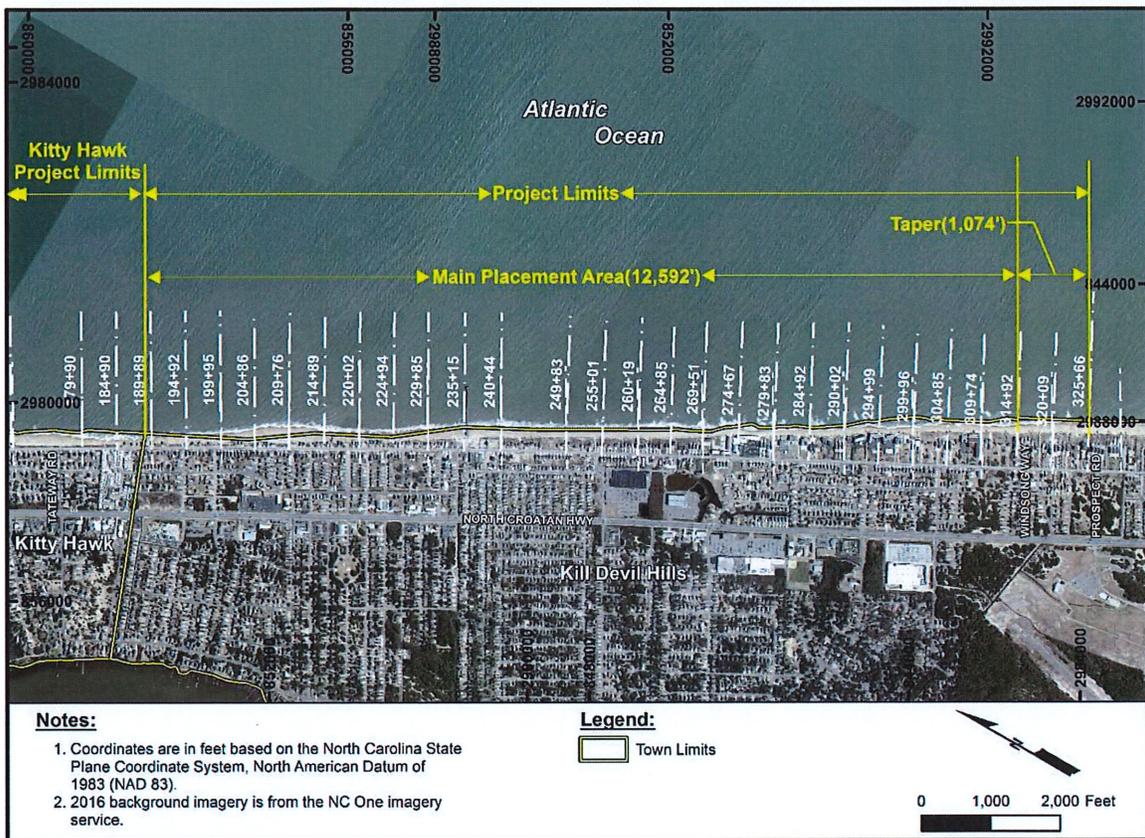


Figure 3. Map of Kill Devil Hills Shore Protection Project Monitoring Beach Profiles.

RENOURISHMENT REQUIREMENTS

During the design of the Kill Devil Hills Shore Protection Project, APTIM (formerly CPE-NC) conducted an analysis of background erosion losses and diffusion losses to determine the volume of advanced fill to include in the project design. Based on these analyses, the design included 138,000 cy of advanced fill (CPE-NC, 2015A). More recent analysis conducted by APTIM for the Town of Kill Devil Hills and Dare County to determine future re-nourishment costs assumed

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

a renourishment volume of 407,000 cy. This volume assumes an average fill density of 30 cy/ft. APTIM has estimated that the cost to conduct maintenance of the Kill Devil Hills Shore Protection project in 2022 would be \$6,171,000. This cost estimate only accounts for the construction cost to place 407,000 cy of sand. This cost does not reflect engineering or environmental permitting costs for the maintenance event.

During the permitting of the Kill Devil Hills Shore Protection Project, APTIM conducted a comprehensive marine sand search and borrow area design (CPE-NC, 2015B). Two borrow sites, referred to as Borrow Areas A and C, were designed during the investigation. Borrow Area A, shown in Figure 2, is located on the Outer Continental Shelf (OCS) between 5.0 and 6.5 miles offshore of the Towns of Kill Devil Hills and Nags Head in water depths between 50 and 60 ft. (NAVD88). The borrow area covers 1,173 acres and initially contained approximately 16,335,000 cy of sand. The mean grain size of the sand was found to be 0.36 mm with a sorting value of 0.90. The sand in the borrow area was characterized as fine to medium grained quartz sand with trace silt, shell hash, and shell fragments. The average wet Munsell color value was determined to be 5 and dry color value 6. The borrow area was broken up into 6 different cuts with cut depths ranging from -58.5 to -68.0 ft. NAVD88.

The U.S. Army Corps of Engineers and North Carolina Division of Coastal Management issued permits for the Towns of Kill Devil Hills as well as Duck, Southern Shores and Kitty Hawk to use this borrow area for the initial construction of their Shore Protection Project. Furthermore, since the borrow site is located in Outer Continental Shelf (OCS) waters, a lease from the Bureau of Ocean Energy Management (BOEM) was required to use the sand in the permitted borrow site. A sufficient volume of sand is still present within the permitted dimensions of Borrow Area A to provide sand for future maintenance events.

MONITORING PROTOCOL

A monitoring plan has been developed and is being implemented for the Kill Devil Hills Shore Protection Project. Topographic and hydrographic surveys of the beach profiles will be conducted to monitor project performance and potential impacts. The beach profile surveys include the fill area and adjacent shoreline within a minimum distance of 5,000 feet.

The Town of Kill Devil Hills has also incorporated a supplemental bathymetric survey into their monitoring protocol. This survey is conducted annually with the beach profile surveys. The supplemental bathymetric survey includes a series of shore parallel survey lines spaced approximately 200 feet apart. The survey area generally covers the offshore bottom from about the -10-foot NAVD88 contour seaward for a distance of about 3,000 feet.

Annual monitoring surveys will be conducted along the constructed project on an annual basis to monitor the performance of the project. Supplemental beach profile surveys may also be required following significant storm events. Reports for each monitoring event will be archived by the Town. The reports will contain volumetric and shoreline change calculations to describe how the project is performing. Erosion rates and shoreline change rates along the beach will be documented

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

throughout the monitoring process. The monitoring results will also be used to identify erosion 'hot spots' and to estimate sediment needs for future maintenance events.

CONCLUSION

The Town of Kill Devil Hills has initiated a shore protection project aimed at sustaining the beaches that support a significant portion of their local economy and maintaining the tax base of the Town. The project has and will continue to provide increased protection to the Town's economy and coastal development. Part of the project includes implementing a maintenance program to document construction achievements and project performance. Anticipated future costs have been estimated and are also included in the maintenance plan.

The Town successfully completed the initial construction of the Shore Protection Project in July 2017. Periodic maintenance or renourishment is included in the Town's maintenance plan for the Shore Protection Project. The renourishments are expected to occur on a 5 year cycle and will initially involve dredging of Borrow Area A offshore Kill Devil Hills and Nags Head. The Dept. of the Army and North Carolina Division of Coastal Management permits issued for the initial construction will require modifications to use Borrow Area A for future maintenance. Likewise, the Town will be required to obtain a new lease from BOEM to use Borrow Area A for maintenance events. The Town has already made these agencies aware of their intentions to use Borrow Area A in the future. The estimated volume of material required for maintenance of the Kill Devil Hills project is 407,000 CY every five (5) years. Post-construction surveys of Borrow Area A show that sufficient sand is available for future maintenance.

Project monitoring has been implemented to track performance of the placed material and is used to update nourishment requirements. The initial baseline monitoring event was conducted in December 2017 following the completion of beach nourishment projects in Southern Shores and Kitty Hawk. Year-1 beach profile surveys were conducted in June 2018. The Town of Kill Devil Hills has also incorporated a supplemental bathymetric survey into their monitoring protocol. The beach profile and shore parallel bathymetric surveys that will result in acquisition of data needed to assess the project, have been designed and will be conducted to capture changes along the active profile of the beach both within the project area and adjacent to the project.

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TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

REFERENCES

Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM), 2018. 2017 Dare County Beach Nourishment Project – Project Completion Report. Prepared For: The Town of Kill Devil Hills, North Carolina. Prepared For: The Towns of Duck, Southern Shores, Kitty Hawk, and Kill Devil Hills, Wilmington, NC.

Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM), 2019. Town of Kitty Hawk & Kill Devil Hills, North Carolina 2018 Shoreline & Volume Change Monitoring Report. Prepared For: The Towns of Kitty Hawk and Kill Devil Hills, North Carolina, 34 pgs.

CPE-NC, 2015A. Town of Kill Devil Hills Erosion and Shoreline Management Design Report. Prepared For: The Town of Kill Devil Hills, North Carolina, 77 pgs.

CPE-NC, 2015B. Comprehensive Marine Sand Search and Borrow Area Design Report. Prepared For: The Towns of Duck Kitty Hawk and Kill Devil Hills, North Carolina, 49 pgs.

FEMA, 2018. Public Assistance Program and Policy Guide FP-104-009-2 / January 2018, 207 pgs.



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Beach Maintenance Plan

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TABLE OF CONTENTS

	Pg.
INTRODUCTION	1
CONSTRUCTION EVENTS	2
MAINTENANCE	5
RENOURISHMENT REQUIREMENTS	6
MONITORING PROTOCOL.....	7
CONCLUSION.....	8

LIST OF FIGURES

	Pg.
Figure 1. Map showing the extent of the project including the main fill construction template, the southern taper, and the construction baseline..	3
Figure 2. Map showing the location of the offshore borrow area used for the construction of the July 2017 Kill Devil Hills Shore Protection Project.....	4
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INTRODUCTION

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TOWN OF KILL DEVIL HILLS
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CONSTRUCTION EVENTS

Beach Fill

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The beach fill constructed in July 2017 included placement of 817,359 cy of beach compatible sand, which equates to an average fill density of approximately 60 cy/lf, along 13,666 feet of beach (approximately 2.6 miles). The volume placed included both the volume necessary to construct the designed dune and berm as well as the volume needed for advanced fill. Advanced fill is the sacrificial portion of the fill required to protect the design section from anticipated sediment losses during the time between subsequent maintenance cycles. The volume of advanced fill needed was based on background erosion rates, anticipated diffusion losses and a five (5) year maintenance cycle. Ultimately, the performance of the beach fill dictates when constructed sections require maintenance, which is referred to as renourishment.

Dune Vegetation

The Town planted American Beach Grass in the nourishment area to promote trapping of wind-blown sand. American Beach Grass was planted at 18 inch spacing along both the crest of the dune and the seaward face of the dune. Plants were fertilized at the time of planting. The planting of the American Beach Grass occurred in late fall and winter of 2017.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

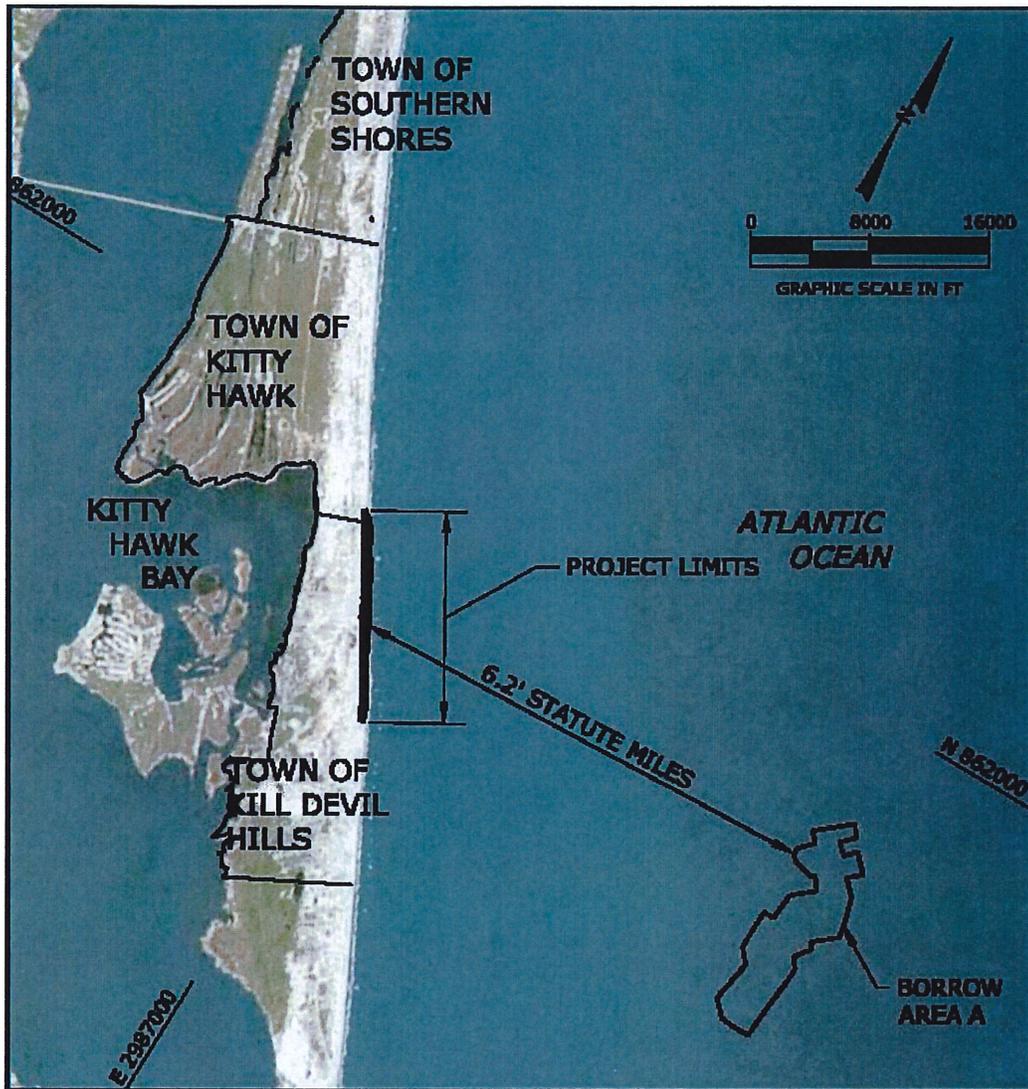


Figure 2. Map showing the location of offshore borrow area used for the construction of the July 2017 Kill Devil Hills Shore Protection Project.

The Town also planted Sea Oats in the nourishment area to promote trapping of wind-blown sand. Sea Oats were planted at 18 inch spacing along both the crest of the dune and the seaward face of the dune. Plants were fertilized at the time of planting. The planting of the Sea Oats occurred in August and September of 2017 and in Spring 2018.

Sand Fencing

The Town installed two rows of angled 10-foot sand fencing sections staggered along the landward and seaward edge of the dune crest oriented at 45-degree angles from the shoreline. The sand fence was installed along the entire length of the beach nourishment project, a distance of 2.6

TOWN OF KILL DEVIL HILLS
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Funding

The project was funded through revenue derived from the Dare County Beach Nourishment Fund and the Town of Kill Devil Hills. The Town of Kill Devil Hills portion of the project was raised through a combination of General Fund appropriation and Municipal Service Districts (MSDs). In essence, the Town of Kill Devil Hills portion of the cost of the project was funded by an increase in the ad valorem tax rate on all properties within the Town of Kill Devil Hills with additional funding provided at a higher rate through the MSDs by oceanfront property owners in the project area.

MAINTENANCE

Beach profile surveys are conducted annually to assess the performance of the Shore Protection Project. As-built surveys of the Kill Devil Hills Shore Protection Project were provided by the construction contractor, which represents conditions along each profile as sections of the project were constructed. The first post-construction survey of the project was conducted in December 2017 following completion of the Duck, Southern Shores, Kitty Hawk, and Kill Devil Hills projects. Data from the December 2017 survey represents the baseline condition of the project (APTIM, 2018). The Year-1 beach profile surveys were conducted in June 2018 and the annual monitoring report was completed in February 2019 (APTIM, 2019).

Beach profile surveys are conducted along beach profiles at approximately 1,000-foot intervals. Figure 3 shows the location of these beach profiles. The monitoring surveys generally extend to a depth of -30 ft. NAVD88; whereas the established depth of closure for the project is -24 ft. NAVD88.

The ocean floor offshore of the Kill Devil Hills project area is characterized by nearshore depressions or troughs. The presence of these troughs were evident based on data plotted from a 2009 multibeam survey conducted by the US Army Corps of Engineers Field Research Facility (USACE-FRF). The features were also present on a plot of the data collected by Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM) during a single-beam bathymetric survey conducted in December 2017/February 2018. Comparison of the 2009 USACE-FRF survey with the 2017/2018 APTIM survey indicated the troughs were mobile, i.e., they appeared to migrate north to south along the coast. Given the potential influence of the troughs on the volume change results computed using beach profile surveys only, the Town of Kill Devil Hills has incorporated a supplemental bathymetric survey into their monitoring protocol. This survey is conducted annually with the beach profile surveys. The supplemental bathymetric survey includes a series of shore parallel survey lines spaced approximately 200 feet apart. The survey area generally covers the offshore bottom from about the -10-foot NAVD88 contour seaward for a distance of about 3,000 feet.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

The Kill Devil Hills Shore Protection Project includes a 20 ft. wide dune with height of 15.0 ft. NAVD, and a 40 foot wide berm at elevation +6.0 ft. NAVD. The project included five (5) years of advanced fill. Annual monitoring will assess the volume of sand in excess of the design that remains in place to determine the timing of, and volume needed for, subsequent beach renourishment. Construction of the July 2017 project, which was combined with construction of projects within the Towns of Duck, Southern Shores and Kitty Hawk, used sand from Borrow Area A located offshore of Kill Devil Hills and Nags Head (Figure 2); however, sufficient sand is anticipated to be available in Borrow Area A to provide maintenance of the Kill Devil Hills Shore Protection Project, as well as similar projects in Duck and Kitty Hawk.

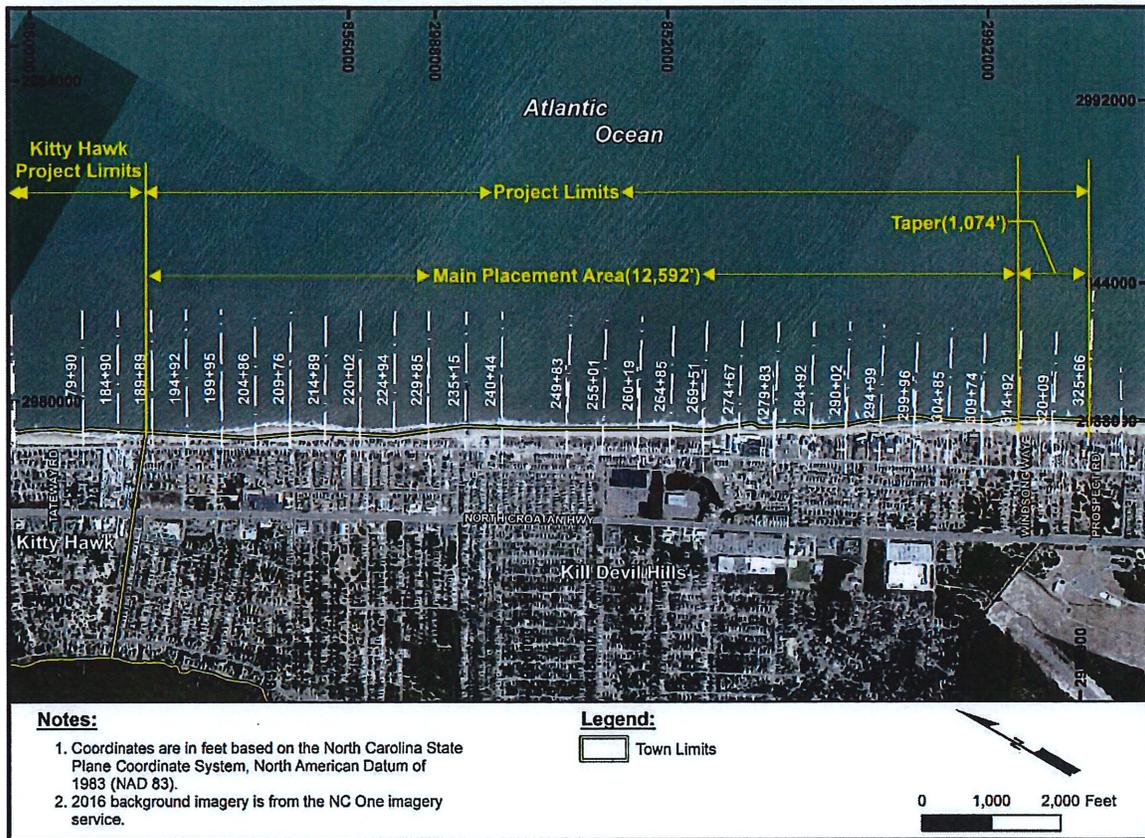


Figure 3. Map of Kill Devil Hills Shore Protection Project Monitoring Beach Profiles.

RENOURISHMENT REQUIREMENTS

During the design of the Kill Devil Hills Shore Protection Project, APTIM (formerly CPE-NC) conducted an analysis of background erosion losses and diffusion losses to determine the volume of advanced fill to include in the project design. Based on these analyses, the design included 138,000 cy of advanced fill (CPE-NC, 2015A). More recent analysis conducted by APTIM for the Town of Kill Devil Hills and Dare County to determine future re-nourishment costs assumed

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

a renourishment volume of 407,000 cy. This volume assumes an average fill density of 30 cy/ft. APTIM has estimated that the cost to conduct maintenance of the Kill Devil Hills Shore Protection project in 2022 would be \$6,171,000. This cost estimate only accounts for the construction cost to place 407,000 cy of sand. This cost does not reflect engineering or environmental permitting costs for the maintenance event.

During the permitting of the Kill Devil Hills Shore Protection Project, APTIM conducted a comprehensive marine sand search and borrow area design (CPE-NC, 2015B). Two borrow sites, referred to as Borrow Areas A and C, were designed during the investigation. Borrow Area A, shown in Figure 2, is located on the Outer Continental Shelf (OCS) between 5.0 and 6.5 miles offshore of the Towns of Kill Devil Hills and Nags Head in water depths between 50 and 60 ft. (NAVD88). The borrow area covers 1,173 acres and initially contained approximately 16,335,000 cy of sand. The mean grain size of the sand was found to be 0.36 mm with a sorting value of 0.90. The sand in the borrow area was characterized as fine to medium grained quartz sand with trace silt, shell hash, and shell fragments. The average wet Munsell color value was determined to be 5 and dry color value 6. The borrow area was broken up into 6 different cuts with cut depths ranging from -58.5 to -68.0 ft. NAVD88.

The U.S. Army Corps of Engineers and North Carolina Division of Coastal Management issued permits for the Towns of Kill Devil Hills as well as Duck, Southern Shores and Kitty Hawk to use this borrow area for the initial construction of their Shore Protection Project. Furthermore, since the borrow site is located in Outer Continental Shelf (OCS) waters, a lease from the Bureau of Ocean Energy Management (BOEM) was required to use the sand in the permitted borrow site. A sufficient volume of sand is still present within the permitted dimensions of Borrow Area A to provide sand for future maintenance events.

MONITORING PROTOCOL

A monitoring plan has been developed and is being implemented for the Kill Devil Hills Shore Protection Project. Topographic and hydrographic surveys of the beach profiles will be conducted to monitor project performance and potential impacts. The beach profile surveys include the fill area and adjacent shoreline within a minimum distance of 5,000 feet.

The Town of Kill Devil Hills has also incorporated a supplemental bathymetric survey into their monitoring protocol. This survey is conducted annually with the beach profile surveys. The supplemental bathymetric survey includes a series of shore parallel survey lines spaced approximately 200 feet apart. The survey area generally covers the offshore bottom from about the -10-foot NAVD88 contour seaward for a distance of about 3,000 feet.

Annual monitoring surveys will be conducted along the constructed project on an annual basis to monitor the performance of the project. Supplemental beach profile surveys may also be required following significant storm events. Reports for each monitoring event will be archived by the Town. The reports will contain volumetric and shoreline change calculations to describe how the project is performing. Erosion rates and shoreline change rates along the beach will be documented

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

throughout the monitoring process. The monitoring results will also be used to identify erosion 'hot spots' and to estimate sediment needs for future maintenance events.

CONCLUSION

The Town of Kill Devil Hills has initiated a shore protection project aimed at sustaining the beaches that support a significant portion of their local economy and maintaining the tax base of the Town. The project has and will continue to provide increased protection to the Town's economy and coastal development. Part of the project includes implementing a maintenance program to document construction achievements and project performance. Anticipated future costs have been estimated and are also included in the maintenance plan.

The Town successfully completed the initial construction of the Shore Protection Project in July 2017. Periodic maintenance or renourishment is included in the Town's maintenance plan for the Shore Protection Project. The renourishments are expected to occur on a 5 year cycle and will initially involve dredging of Borrow Area A offshore Kill Devil Hills and Nags Head. The Dept. of the Army and North Carolina Division of Coastal Management permits issued for the initial construction will require modifications to use Borrow Area A for future maintenance. Likewise, the Town will be required to obtain a new lease from BOEM to use Borrow Area A for maintenance events. The Town has already made these agencies aware of their intentions to use Borrow Area A in the future. The estimated volume of material required for maintenance of the Kill Devil Hills project is 407,000 CY every five (5) years. Post-construction surveys of Borrow Area A show that sufficient sand is available for future maintenance.

Project monitoring has been implemented to track performance of the placed material and is used to update nourishment requirements. The initial baseline monitoring event was conducted in December 2017 following the completion of beach nourishment projects in Southern Shores and Kitty Hawk. Year-1 beach profile surveys were conducted in June 2018. The Town of Kill Devil Hills has also incorporated a supplemental bathymetric survey into their monitoring protocol. The beach profile and shore parallel bathymetric surveys that will result in acquisition of data needed to assess the project, have been designed and will be conducted to capture changes along the active profile of the beach both within the project area and adjacent to the project.

This Maintenance Plan serves as documentation that the Town of Kill Devil Hills' Shore Protection Project meets the criteria established by 44 CFR 206.226(j)(2). The Maintenance Plan has been developed in a way consistent with the Public Assistance Program and Policy Guide – FP-104-009-2 (January 2018) This Maintenance Plan will be updated regularly to reflect results of monitoring, construction of additional projects, maintenance events and changes in schedules.

TOWN OF KILL DEVIL HILLS
SHORE PROTECTION PROJECT MAINTENANCE PLAN

REFERENCES

Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM), 2018. 2017 Dare County Beach Nourishment Project – Project Completion Report. Prepared For: The Town of Kill Devil Hills, North Carolina. Prepared For: The Towns of Duck, Southern Shores, Kitty Hawk, and Kill Devil Hills, Wilmington, NC.

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CPE-NC, 2015B. Comprehensive Marine Sand Search and Borrow Area Design Report. Prepared For: The Towns of Duck Kitty Hawk and Kill Devil Hills, North Carolina, 49 pgs.

FEMA, 2018. Public Assistance Program and Policy Guide FP-104-009-2 / January 2018, 207 pgs.

**TOWN OF KITTY HAWK & KILL DEVIL HILLS, NORTH CAROLINA
2018 SHORELINE & VOLUME CHANGE MONITORING REPORT**



SUBMITTED TO:

**TOWN OF KITTY HAWK
&
TOWN OF KILL DEVIL HILLS**

SUBMITTED BY:



APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

February 2019

TOWN OF KITTY HAWK & KILL DEVIL HILLS 2018 SHORELINE & VOLUME MONITORING REPORT

EXECUTIVE SUMMARY

The Towns of Kitty Hawk and Kill Devil Hills are located on the Outer Banks of North Carolina roughly 37 and 40 miles south-southeast of the North Carolina and Virginia border, respectively. The Town of Kitty Hawk extends along 3.6 miles of Atlantic Ocean shoreline. The Town of Kill Devil Hills, located immediately south of Kitty Hawk, extends along approximately 4.7 miles of Atlantic Ocean Shoreline. Kitty Hawk is bordered to the north by the Town of Southern Shores, whereas Kill Devil Hills is bordered to the South by the Town of Nags Head.

The Towns of Kitty Hawk and Kill Devil Hills, in cooperation with Dare County, completed a beach nourishment project in October 2017. During the latter stages of the design for the Kitty Hawk and Kill Devil Hills projects, the Town of Southern Shores experienced a severe erosion episode that negatively impacted the southern 1,500 feet of its shoreline. In response, the Dare County project was modified to include the southern 1,500 feet of shoreline in Southern Shores.

While construction of the projects was completed in October 2017, the conditions of the projects as measured by the December 2017 post-construction survey were used to represent post-construction conditions. During the period between actual placement of beach fill and December 2017, the projects were undergoing initial adjustments that included migration of fill material from the upper portion of the beach to deeper depths. These initial adjustments typically are not indicative of how projects behave in the long run.

The project in the Town of Southern Shores extends from profile station 0+00, which is located approximately 120 feet north of the pier at the Hilton Garden Inn, north to station -25+00, which is located approximately 400 feet north of Skyline Rd. The project includes a 1,500-foot main fill section and a 1,000-foot taper on the north end. The Kitty Hawk project extends from profile station 0+00 south to profile station 189+87, which is located between East Sibbern Drive and East Arch Street. The project in the Town of Kill Devil Hills extends from profile station 189+87, which is located at the north Town limit, south to approximately profile station 325+66, which is located at Prospect Avenue Public Access.

Comparison of the June 2017 (Pre-construction) and December 2017 (Post-construction) profile surveys indicated an increase of 3,227,241 cubic yards of sand fill within the limits of the beach nourishment projects, which is assumed to be directly attributed to the beach fill project. The relative volumes of fill within each project area included: 211,633 cubic yards for Southern Shores, 2,120,195 cubic yards for Kitty Hawk, and 895,413 cubic yards for Kill Devil Hills. These volumes are used as the basis of tracking the performance of the projects.

Data collected in June 2018 (1-year monitoring survey) was compared to survey data collected in December 2017 (Post-construction survey) to monitor project performance. Between, December 2017 and June 2018, profile surveys indicate that the beach fill project area of Southern Shores lost approximately 32,000 cubic yards or about 15.0% of the fill measured within the project area as of December 2017. Profile surveys indicated that the Kitty Hawk and Kill Devil Hills project

areas lost approximately 587,000 cubic yards and 179,000 cubic yards, respectively. These surveys indicate the volume of beach fill remaining within both projects as of June 2018 was 72.3% for Kitty Hawk and 72.6% for Kill Devil Hills. Some of the material lost from the project areas is believed to have been transported both north and south out of the project areas. However, a number of anomalous features consisting of wide and deep troughs or depressions were observed across several profiles. The volumetric loss from the area proximate to the nearshore depression accounted for approximately 60% of the volumetric losses observed in the Town of Kitty Hawk.

The presence of these anomalous features may be affecting the ability to resolve volume change measurements using 1,000-foot spaced beach profile surveys. Analysis of several supplemental surveys conducted by APTIM, which involved the collection of shore parallel single beam bathymetric data along the project area, suggested that volume changes computed using only 1,000-foot spaced beach profile surveys was approximately 32% greater than the volume change measured using the shore parallel offshore bathymetric surveys.

Future monitoring of the project areas will aim to determine what impact the trough features may have on the long-term project performance and whether design modifications can be made to mitigate any determined impacts.

The following tables summarize the shoreline and volumetric changes measured between December 2017 and June 2018 based on beach profile surveys.

Average Mean High Water (+1.2' NAVD) Shoreline Changes (feet)

	June 2017 to December 2017	December 2017 to June 2018
North of Project (-50+00 to -20+00)	---	+8.7
Southern Shores Project (0+00 to -20+00)	+60.1	-20.7
Kitty Hawk (0+00 to 189+87)	+97.8	-8.9
Kill Devil Hills (189+87 to 320+05)	+34.8	-6.9
South of Project (329+88 to 369+89)	---	+2.6
Monitoring Area (-50+00 to 369+89)	+71.2	-6.4

Volumetric Changes above -24' NAVD (cubic yards)

	June 2017 to December 2017	December 2017 to June 2018
North of Project (-50+00 to -25+00)	---	-3,234
Southern Shores Project (0+00 to -25+00)	+211,633	-31,766
Kitty Hawk (0+00 to 189+87)	+2,120,195	-586,659
Kill Devil Hills (189+87 to 325+56)	+895,413	-245,656
South of Project (325+56 to 369+89)	---	-46,699

**DRAFT: TOWN OF KITTY HAWK & KILL DEVIL HILLS
2018 SHORELINE & VOLUME MONITORING REPORT**

Table of Contents

EXECUTIVE SUMMARY i

I. INTRODUCTION 1

II. PROJECT LOCATION 5

III. SURVEY DATA COLLECTION 7

IV. SHORELINE CHANGES 8

V. VOLUMETRIC CHANGES 14

VI. SUMMARY 29

VII. RECOMMENDATIONS 30

VII. REFERENCES 31

List of Figures

Figure No.

Figure 1. Map showing the extent of the project including the Kitty Hawk main fill area, the Southern Shores fill area, the northern taper and the construction baseline. 3

Figure 2. Map showing the extent of the project including the Kill Devil Hills main fill construction template, the southern taper, and the construction baseline 4

Figure 3. Project location map. 5

Figure 4. Project map showing northern half of monitoring area. 6

Figure 5. Project map showing southern half of monitoring area. 7

Figure 6. Annual Volumetric Change above -24 FT NAVD (CY/FT). 17

Figure 7. Aerial photo looking south along Kill Devil Hills toward Windsong Way, showing exposed shipwreck in the nearshore. 21

Figure 8. Map illustrating the shore-parallel nearshore singlebeam bathymetric data collected by APTIM between December 2017 and February 2018. 20

Figure 9. Map illustrating the shore-parallel nearshore singlebeam bathymetric data collected by APTIM in October 2018 between baseline stations -50+00 and 80+15. 24

Figure 10. Map illustrating the shore-parallel nearshore singlebeam bathymetric data collected by APTIM in October 2018 between baseline stations 80+15 and 235+15. 25

Figure 11. Map illustrating the shore-parallel nearshore singlebeam bathymetric data collected by APTIM in October 2018 between baseline stations 235+15 and 329+88. 26

Figure 12. Map of the portion of the Kitty Hawk and Kill Devil Hills project covered by both the Dec. 2017/Feb 2018 and October 2018 bathymetric surveys, illustrating changes in elevation between the two surveys. 27

List of Tables

Table No.

Table 1. Profile Survey Baseline and Azimuth..... 10
Table 2. MHW Shoreline Changes for Southern Shores and Kitty Hawk..... 12
Table 3. MHW Shoreline Changes for Kill Devil Hills..... 13
Table 4. Volumetric Changes (CY) North of Project area and along Southern Shores and Kitty Hawk, above -24 FT NAVD 15
Table 5. Volumetric Changes (CY) along Kill Devil Hills and South of Project Area, above -24 FT NAVD 16

List of Appendices

Appendix No.

A 2018 Town of Kitty Hawk and Kill Devil Hills Monitoring Survey Report

TOWN OF KITTY HAWK & KILL DEVIL HILLS 2018 SHORELINE & VOLUME MONITORING REPORT

I. INTRODUCTION

The Town of Kitty Hawk has initiated a shore protection project aimed at: 1) reducing the vulnerability of public infrastructure including NC 12, town roads between NC 12 and U.S. Highway 158 as well as utilities to storm-induced erosion; 2) reducing flooding in many non-oceanfront areas throughout the Town during ocean over wash conditions, including portions of NC 12 and U.S. Highway 158; and 3) reducing the vulnerability of homes within the Town that front the Atlantic Ocean and are exposed to wave events during nor'easters and other large storm events. In order to accomplish these goals, the Town of Kitty Hawk is taking steps to maintain its oceanfront beach and dune to a configuration that: provides a reasonable level of storm damage reduction; provides a reasonable level of flood reduction; and mitigates long term erosion that could threaten public infrastructure and private property as well as recreational opportunities and biological resources.

Likewise, the Town of Kill Devil Hills is focused on a long-term shoreline management program that will serve to sustain the beaches that support a significant portion of their local economy, maintain the tax base of the Town, retain existing recreational resources, and protect existing natural resources. In order to accomplish these stated goals, the Town of Kill Devil Hills has taken steps to maintain its oceanfront beach and dune to a configuration that provides a reasonable level of storm damage reduction to public and private development and mitigates long-term erosion impacts.

The Town of Southern Shores initiated a beach nourishment project to respond to an erosion episode that manifested along the southern 1,500 feet of its shoreline between 2015 and 2017. The Southern Shores portion of the project was added during the latter stages of the final design for the Kitty Hawk and Kill Devil Hills projects. Southern Shores is presently considering expanding their project to cover a larger portion of its shoreline.

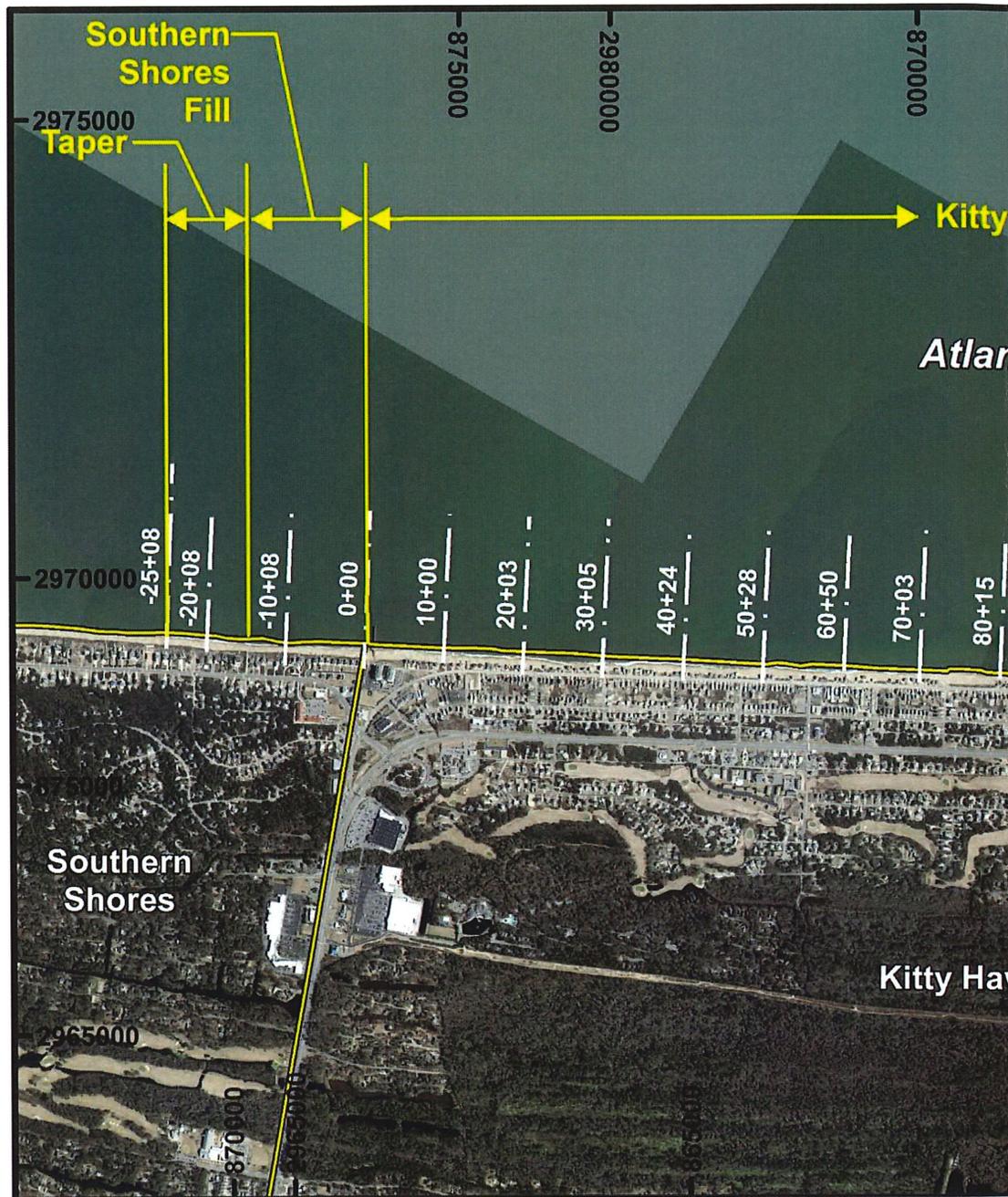
All three Towns, in cooperation with Dare County and neighboring Town of Duck, successfully completed the initial construction of their shore protection projects in October 2017. The design for the Southern Shores project consisted of the construction of an approximately 77-foot wide berm at elevation +6.0 feet NAVD along the southern 1,500 feet of its shoreline with a 1000-foot taper on the north end. The Kitty Hawk shore protection project included a 10-foot wide dune at elevation +12.0 feet NAVD fronted by a 60-foot wide berm at elevation +6.0 feet NAVD. A main fill section was constructed covering 18,990 feet of shoreline beginning in the north at profile station 0+00, which is located approximately 120 feet north of the pier at the Hilton Garden Inn, and ending at the southernmost profile near station 189+87, which is located between East Sibbern Drive and East Arch Street. Since the Kitty Hawk project was constructed in conjunction with Kill Devil Hills, a taper at the southern Town boundary was not necessary.

Initially, the design of the Kitty Hawk project included a 1,000 ft. taper at the northern town boundary, which would have extended the fill north of its town limits into the southern portion of the Town of Southern Shores. However, after the erosion hot-spot developed along the southern 1,500 feet of Southern Shores in early 2017, the subsequent addition of this 1,500-foot section of the shoreline and the 1000-foot northern taper of the overall project eliminated the need for a north taper of the Kitty Hawk project. Figure 1 shows a map depicting the extent of the Kitty Hawk main fill section, the Southern Shores fill, and the taper.

The design for the Kill Devil Hills shore protection project included the construction of a dune and berm beach fill design along the northern 12,592 feet of the Town's oceanfront beach. In addition to the 12,592 ft. design fill section, the project also included a 1,074-foot long taper on the south end. Since the Kill Devil Hills project was constructed in conjunction with Kitty Hawk, a taper north of the Town boundary was not necessary. In total, the Kill Devil Hills project placed sand from baseline station 189+00 (northern Town boundary) to station 325+66 (Prospect Ave. Public Access). Figure 2 shows the extent of the project including the main fill construction template, the southern taper, and the construction baseline.

Construction of the Kitty Hawk and Southern Shores projects was accomplished between June 26 and October 21, 2017 while construction of the Kill Devil Hills project occurred between June 22 and August 18, 2017. To account for post-construction changes that immediately follow the placement of a beach fill, a profile survey taken in December 2017 along the entire project area was selected to represent post-construction conditions. Based on a comparison of the June 2017 pre-construction survey and the December 2017 post-construction survey, the volume of fill material residing on the Southern Shores project area (stations 0+00 to -25+00) as of December 2017 was 211,633 cubic yards. The volume of fill material residing within the Kitty Hawk Project (stations 0+00 to 189+87) and Kill Devil Hills Project (stations 189+87 to 325+56) were 2,120,195 cubic yards and 895,413 cubic yards, respectively. The equivalent density of the beach fill as of December 2017 was approximately 85 cy/ft. for Southern Shores and 112 cy/ft. for Kitty Hawk while the density along Kill Devil Hills was equivalent to 66 cy/ft.

The analysis described in this report focusses on assessing the performance of the beach fill project constructed in 2017 and providing guidance on planning for future maintenance events.



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Coordinate System, North American Datum of 1983 (NAD 83).
2. 2016 background imagery is from the NC One imagery service.

Figure 1. Map showing the extent of the project including the Kitty Hawk main fill a



Figure 2. Map showing the extent of the project including the Kill Devil Hills marina

II. PROJECT LOCATION

The Towns of Kitty Hawk and Kill Devil Hills are located on the Outer Banks of North Carolina roughly 37 and 40 miles south-southeast of the North Carolina and Virginia border, respectively. The Town of Kitty Hawk extends along 3.6 miles of Atlantic Ocean shoreline. The Town of Kill Devil Hills, located immediately south of Kitty Hawk, extends along approximately 4.7 miles of Atlantic Ocean Shoreline. Kitty Hawk is bordered to the north by the Town of Southern Shores; whereas Kill Devil Hills is bordered to the South by the Town of Nags Head. A regional location map is provided in Figure 3. This location map highlights the nourishment projects along the Town's oceanfront shoreline and the two Outer Continental Shelf (OCS) borrow areas used to construct the beach nourishment project in 2017. All sand placed along Southern Shores, Kitty Hawk, and Kill Devil Hills was dredged from Borrow Area A.

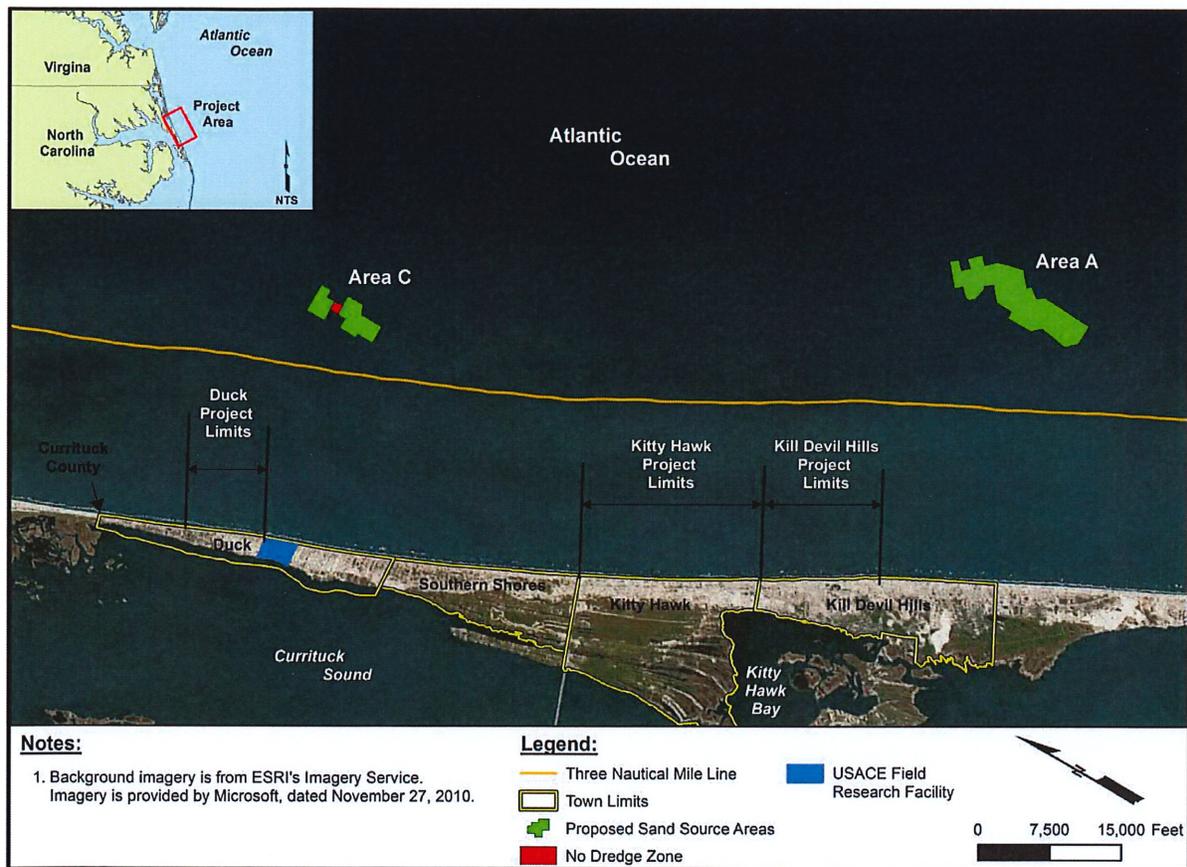


Figure 3. Project location map.

For the purpose of monitoring, this report has separated the oceanfront beaches of Southern Shores, Kitty Hawk, and Kill Devil Hills into the “Southern Shores Project Area”, the “Kitty Hawk Project Area” and the “Kill Devil Hills Project Area”. The areas north and south of the project areas have been designated as “North of Project” and “South of Project”. The additional profile lines north and south of the project areas are intended to show longshore sediment transport along the beachfront. The entire monitoring area is referred to as the “Study Area”. These distinct areas are depicted in Figure 4 and Figure 5. The Southern Shores Project Area extends from station -25+00 to 0+00, the Kitty Hawk Project Area includes the beach between the southern boundary of the Town of Southern Shores (Profile 0+00) to the northern boundary of Kill Devil Hills (approximately Profile 189+87) while the Kill Devil Hills Project Area spans from the southern boundary of the Town of Kitty Hawk to the southern terminus of the beach nourishment project (Profile 325+56). “North of Project” area includes the beach from profile -25+00 to -50+00, which lies within the town limits of Southern Shores. “South of Project” area includes an additional 4,433 ft. of beachfront (from Profile 325+56 to Profile 369+89) located within Kill Devil Hills, but outside of the beach nourishment project area.

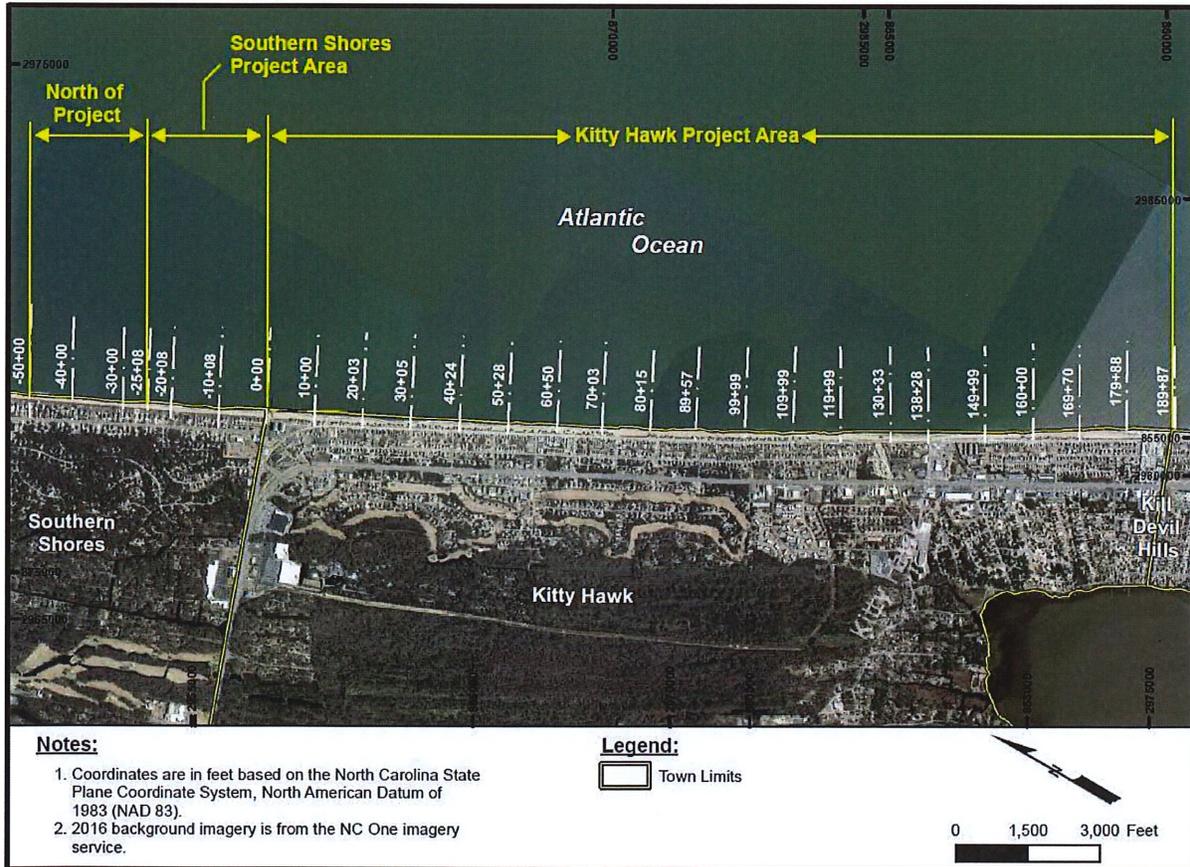


Figure 4. Project map showing northern half of monitoring area.

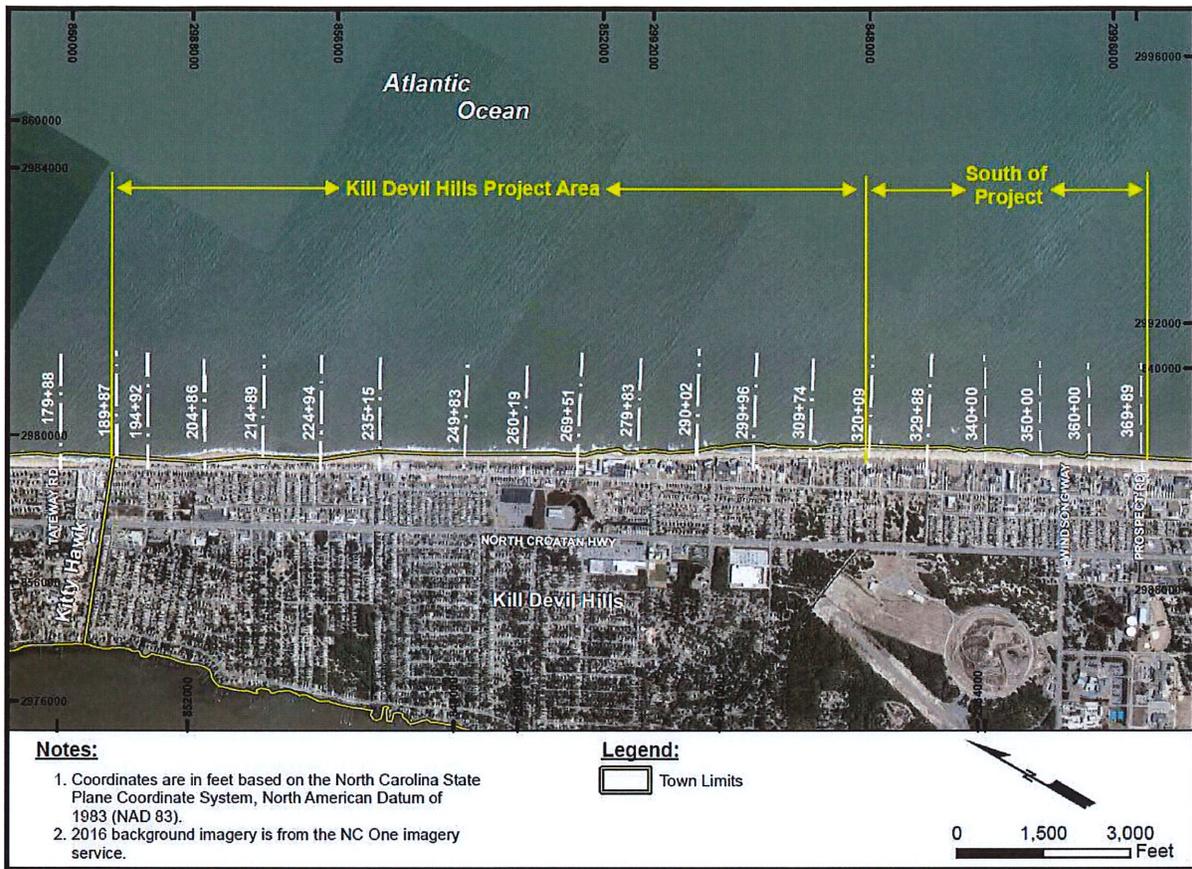


Figure 5. Project map showing southern half of monitoring area.

III. SURVEY DATA COLLECTION

Beach profile surveys were conducted along the oceanfront beaches in Southern Shores, Kitty Hawk, and Kill Devil Hills in June 2017 and December 2017 in the areas where sand was placed during the 2017 project. The area includes 35 beach profiles from station -20+00 to 320+05 (Figure 1 and Figure 2). The coordinates of each profile line, referenced to the North Carolina State Plane coordinate system in feet NAD83 and the azimuth of the profile relative to true north are provided in Table 1. Detailed information on the surveys is provided in Appendix A – Town of Kitty Hawk and Kill Devil Hills Monitoring Survey Report. Appendix A also includes detailed survey methodology, monument information, profile plots, ground digital photography, and field book notes.

The surveys conducted after the 2017 beach fill project in December 2017 and June 2018 included three (3) additional profiles north of the project area in Southern Shores (stations -50+00 to -30+00) and five (5) additional profiles south of the project area in Kill Devil Hills (329+89 to

369+89). The collection of profile data along these additional profile lines are meant to be used in the monitoring of longshore sediment transport both north and south of the project sites.

The profile surveys used in this analysis were collected by APTIM (formerly CPE-NC), with the exception of the pre-construction surveys (June 2017), which were collected by the dredge contractor's surveyor, TI Coastal. The surveys extended landward until a structure was encountered or to a range 50 feet beyond the landward toe of dune, whichever was more seaward. Elevation measurements were also taken seaward along the profile to at least the -30-foot NAVD contour. Upland data collection included all grade breaks and changes in topography to provide a representative description of the conditions at the time of the work. The maximum spacing between data records along individual profiles was 25 feet. The upland survey extended into wading depths sufficiently to allow the offshore portion to overlap the upland portion by a minimum of 50 feet.

During the evaluation of volumetric changes that occurred between December 2017 and June 2018, relatively large volume changes, particularly seaward of the -6-foot NAVD88 contour, were indicated between stations 119+99 and 138+27 as well as between stations 179+87 and 189+87. Upon closer examination, the ocean floor in this portion of the project area is characterized by near shore depressions or troughs.

The presence of these troughs were evident based on data plotted from a 2009 multibeam survey conducted by the US Army Corps of Engineers Field Research Facility (USACE-FRF). The features were also present on a plot of the data collected by APTIM during a single-beam bathymetric survey conducted in December 2017/February 2018. Comparison of the 2009 USACE-FRF survey with the 2017/2018 APTIM survey indicated the troughs were mobile, i.e., they appeared to migrate north to south along the coast. Given the potential influence of the troughs on the results indicated by the profile surveys, APTIM requested and obtained approval from the Town of Kitty Hawk and the Town of Kill Devil Hills, to conduct a shore parallel bathymetric survey of the entire project area from station -50+00 in Southern Shores to station 329+88 in Kill Devil Hills. The APTIM survey was completed in October 2018 and generally covered the offshore bottom from about the -10-foot NAVD88 contour seaward for a distance of about 3,000 feet. The October 2018 survey consisted of survey lines spaced 200-feet apart running parallel to the shoreline. APTIM used this new survey data to evaluate changes in the volume of material within the area surveyed during both the October 2018 survey and the December 2017/February 2018 survey. Section V (Volumetric Changes) of this report provides details and results of the evaluation.

IV. SHORELINE CHANGES

A shoreline change analysis was completed to assess shoreline advance and recession along the study area. The shoreline is typically defined as a specified elevation contour. For this study, the shoreline was defined as the Mean High Water (MHW) contour, which represents the +1.2 feet NAVD elevation (CPE, 2015). Shoreline change is calculated by comparing shoreline position at shore perpendicular transects. Typically, shoreline change is then annualized to describe advance

and retreat rates. These changes and rates of change are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“-”) or recession (shoreline moving landward).

The analysis discussed in this report for the Towns of Southern Shores, Kitty Hawk, and Kill Devil Hills evaluated the MHW positions as measured during the December 2017 and June 2018 beach profiles surveys. We have also included shoreline change data as measured during the Pre-construction surveys (June 2017) and Post-construction surveys (December 2017). The MHW position for each survey was identified at each shore perpendicular transect spaced at approximately 1,000-foot intervals.

The linear changes in the shoreline position represented by the MHW contour can vary considerably along the monitoring area and can sometimes differ from volume change trends along sections of a beach. This difference is often due to variations in the slope of the foreshore along the beach from one end of the monitoring area to the other. Furthermore, these variations in foreshore slope can display a strong seasonal trend, which can also affect the MHW water position of the shoreline. During the winter months (harsher wave climate), an offshore migration (seaward) of sand is typically observed whereas during the summer months (milder wave climate) an onshore migration (landward) of sand is typically observed.

Pre-and Post-Project Shoreline Changes

Southern Shores. Pre-construction Surveys performed by Great Lakes Dredge and Dock in June 2017 and post-construction surveys conducted by APTIM in December 2017, indicated the MHW shoreline along the southern 2,000 feet of Southern Shores (station -20+00 to 0+00) experienced an average seaward shift of +60.1 feet as a result of the beach fill project. Between December 2017 and June 2018, the profile surveys indicated that the Southern Shores Project Area receded an average of 20.7 feet.

Table 1. Profile Survey Baseline and Azimuth

Town	Profile	Easting	Northing	Azimuth
So. Shores	-50+00	2968838.0	876228.0	62.6
	-40+00	2969249.0	875440.0	62.6
	-30+00	2969731.6	874496.1	62.6
	-20+00	2970189.7	873607.2	62.6
	-10+00	2970653.0	872721.0	62.6
	0+00	2971224.2	871890.8	62.6
	9+99	2971685.8	871003.3	62.6
	20+02	2972153.2	870116.7	62.2
	30+05	2972621.7	869230.0	62.2
	40+24	2973097.5	868329.7	62.2
Kitty Hawk	50+28	2973566.7	867441.7	62.2
	60+50	2974044.0	866538.4	62.2
	70+03	2974489.1	865695.8	62.2
	80+15	2974725.6	865248.3	62.2
	89+57	2974962.0	864800.8	62.2
	99+99	2975401.9	863968.2	62.2
	109+99	2975900.2	863052.2	61.5
	119+99	2976406.1	862189.9	59.6
	130+33	2976911.9	861327.7	59.6
	138+28	2977435.1	860436.0	59.6
	149+99	2977811.3	859735.5	59.6
	159+99	2978430.3	858740.1	59.6
	169+70	2978966.6	857895.3	59.6
	179+87	2979427.7	857040.4	59.6
	189+87	2979942.7	856163.1	59.6
	199+93	2980448.6	855301.2	59.6
	209+74	2980957.8	854433.7	59.6
	219+99	2981440.4	853579.1	60.5
	229+83	2981944.6	852686.2	60.5
	240+41	2982428.6	851830.2	60.5
249+81	2982949.5	850908.8	60.5	
Kill Devil Hills	260+17	2983384.8	850076.1	61.9
	269+49	2983879.6	849166.0	61.9
	279+80	2984314.0	848341.7	62.2
	289+99	2984795.0	847429.1	62.2
	299+92	2985305.3	846547.0	62.2
	309+71	2985733.2	845649.7	62.2
	320+05	2986193.1	844785.8	62
	329+88	2986679.0	843873.0	62
	340+20	2987139.0	843003.8	62.1
	349+69	2987621.2	842092.3	62.1
359+82	2988097.3	841269.6	62.1	
369+89	2988539.2	840357.5	62.1	

Kitty Hawk. With the construction of the beach nourishment project, the MHW shoreline in Kitty Hawk was moved seaward an average of 97.8 feet between June 2017 and December 2017. The Kitty Hawk MHW shoreline receded an average of 8.9 feet between December 2017 and June 2018.

Although the average shoreline change measured between December 2017 and June 2018 showed a shoreline recession (landward movement of the shoreline) for the Kitty Hawk project area, a profile-by-profile comparison shows a wide range of changes in the position of the MHW shoreline along the project area (Table 2). The shoreline changes within the monitored project area ranged from an advance of +53.9 ft. at profile 159+99 to a recession of -80.0 ft. at profile 138+28. The highest recession was measured at Profiles 138+28 (-80.0 ft.), 130+33 (-67.4 ft.) and 119+99 (-55.4 ft.). The profiles that experienced higher shoreline retreat rates are located within an area constructed after September 2017 and had not undergone as much initial equilibration at the time of the December 2017 survey. Profiles constructed prior to October 1, 2017 were impacted by the passing of several tropical storms during the month of September 2017. The average shoreline change measured between December 2017 and June 2018 along those profiles constructed prior to the October 1, 2017 was +1.4 ft. The profiles with the highest measured shoreline retreat are also in the vicinity of one of the nearshore troughs or depressions discussed later in this report.

Kill Devil Hills. With the construction of the beach nourishment project, the MHW shoreline in Kill Devil Hills was moved seaward an average of 34.8 feet between June 2017 and December 2017. As reported in the Project Completion Report for the 2017 project, the average shoreline change measured based on the AD and BD surveys was +121.6 ft. (APTIM, 2018). The difference between these numbers is in part due to the equilibration of the beach fill.

Between December 2017 and June 2018, the MHW shoreline along the Kill Devil Hills project area (189+87 to 325+56) receded an average of -6.9 ft. Table 3 shows the measured change rates at each profile location. The profile-by-profile analysis of the Kill Devil Hills project area also showed a wide range of behavior ranging from an advance of +27.9 ft. at profile 240+41 to a recession of -42.6 ft. at profile 289+99.

Table 2. MHW Shoreline Changes for Southern Shores and Kitty Hawk

PROFILE		MHW SHORELINE CHANGES (FT)	
		Pre-Con (June 2017) to Post-Con (December 2017)	Post-Con (December 2017) to Year-1 Monitoring (June 2018)
North of Project Area	-50+00	---	20.9
	-40+00	---	4.7
	-30+00	---	0.4
So. Shores Prj. Area	-20+00	28.4	-13.3
	-10+00	73.2	-29.5
	0+00	78.8	-19.4
	9+99	40.5	-26.9
	20+02	78.0	-39.4
Kitty Hawk Project Area	30+05	102.7	-32.6
	40+24	97.4	19.5
	50+28	64.9	21.8
	60+50	63.8	38.5
	70+03	107.5	53.8
	80+15	88.3	30.7
	89+57	119.6	-14.1
	99+99	134.7	-39.0
	109+99	108.3	8.6
	119+99	134.0	-55.4
	130+33	180.7	-67.4
	138+28	189.0	-80.0
	149+99	152.0	-33.6
	159+99	53.1	53.9
	169+70	49.6	18.7
179+87	61.8	-12.9	
189+87	52.0	-3.6	
NORTH OF PROJECT (-50+00 TO -20+00)			8.7
SOUTHERN SHORES (-20+00 TO -0+00)		60.1	-20.7
KITTY HAWK (0+00 TO 189+87)		97.8	-8.9

Table 3. MHW Shoreline Changes for Kill Devil Hills

PROFILE		MHW SHORELINE CHANGES (FT)	
		Pre-Con (June 2017) to Post-Con (December 2017)	Post-Con (December 2017) to Year-1 Monitoring (June 2018)
Kill Devil Hills Project Area	189+87	52.0	-3.6
	199+93	31.0	27.0
	209+74	32.0	-2.8
	219+99	-19.0	-38.1
	229+83	22.2	6.6
	240+41	39.9	27.9
	249+81	39.5	-2.8
	260+17	39.5	-7.8
	269+49	48.6	-25.6
	279+80	63.2	-20.4
	289+99	57.7	-42.6
	299+92	54.8	4.6
	309+71	20.6	-41.2
320+05	4.5	21.5	
South of Project Area	329+88	---	29.0
	340+20	---	-49.6
	349+69	---	34.5
	359+82	---	29.0
	369+89	---	-30.0
KILL DEVIL HILLS (189+87 TO 320+05)		34.8	-6.9
SOUTH OF PROJECT (329+88 TO 369+89)		---	2.6

Areas North and South of Project Area

Area North of Project. The shoreline change between December 2017 and June 2018 north of the beach nourishment project in Southern Shores (profile stations -50+00 to -30+00) was +8.7 ft. Although each of the shoreline changes calculated for the Area North of Project between December 2017 and June 2018 were positive, a profile-by-profile comparison shows a wide range in the actual changes measured (Table 2). Station -50+00 saw the largest seaward shoreline change at 20.9 feet. Whereas stations -40+00 and -30+00 had measured shoreline changes of +4.7 feet and +0.4 feet, respectively.

Area South of Project. The shoreline change between December 2017 and June 2018 south of the project in Kill Devil Hills (between stations 329+88 and 369+89) was +2.6 ft. Although the average shoreline changes calculated for the Area South of Project between December 2017 and June 2018 were positive, a profile-by-profile comparison shows a wide range in the actual changes measured (Table 3). Stations 340+20 and 369+89 experienced negative shoreline changes of

-49.6 feet and -30.0 feet, respectively. The other three stations experienced positive shoreline changes ranging from +29.0 feet to +34.5 feet.

V. VOLUMETRIC CHANGES

Volumetric changes discussed in this report represent the change in the quantity of sediment measured through comparison of the December 2017 and June 2018 beach profile monitoring surveys. As previously discussed, although the projects were constructed between June and October 2017, the December 2017 survey was selected to represent post-construction conditions for all three.

Beach fill projects typically undergo an initial period of profile adjustment in which material placed on the upper portion of the profile is redistributed to lower portions of the profile in response to tide and wave conditions. In addition to the onshore-offshore profile adjustments, some of the beach fill material is removed from the ends of the fill and distributed to the adjacent shorelines through littoral transport. Once these initial adjustments occur, the performance of the beach fill typically begins to mimic the behavior of a natural beach. Therefore, for purposes of monitoring the performance of the beach fill, the volume of the beach fill material on the active profile determined from comparison of the Pre-construction survey obtained in June 2017 with the December 2017 (Post-construction) monitoring survey was used to represent the initial volume of material in the beach fill project areas.

Profile by profile and average volume changes measured between June 2017 (Pre-construction) to December 2017 (Post-construction) and between December 2017 and June 2018 along each profile, are provided in Table 4 and Table 5. The measured volumetric changes for each profile are also shown graphically in Figure 6.

Initial Beach Fill Volumes.

Based on volume changes computed between the June 2017 Pre-construction survey and the December 2017 Post-construction survey, approximately 212,000 cubic yards of beach fill material resided along the southern 2,500 feet of the Southern Shores shoreline with approximately 2,120,000 cubic yards retained along the 18,988 feet of the Kitty Hawk shoreline. The Kill Devil Hills project contained approximately 895,000 cubic yards of fill along 13,578 feet of its shoreline measured south of the Kill Devil Hills/Kitty Hawk town limits. In all, as of December 2017, approximately 3,227,000 cubic yards of beach fill material resided on the active profile (above the -24-foot NAVD88 contour) along the shoreline from Profile -25+00 in Southern Shores to Profile 325+56 in Kill Devil Hills. Note that due to the way volumes were computed between adjacent stations the volume reported for station 0+00 was divided between Southern Shores and Kitty Hawk. Similarly, the volume change for station 189+87, which is located at the town limits of Kitty Hawk and Kill Devil Hills, was evenly distributed to each town.

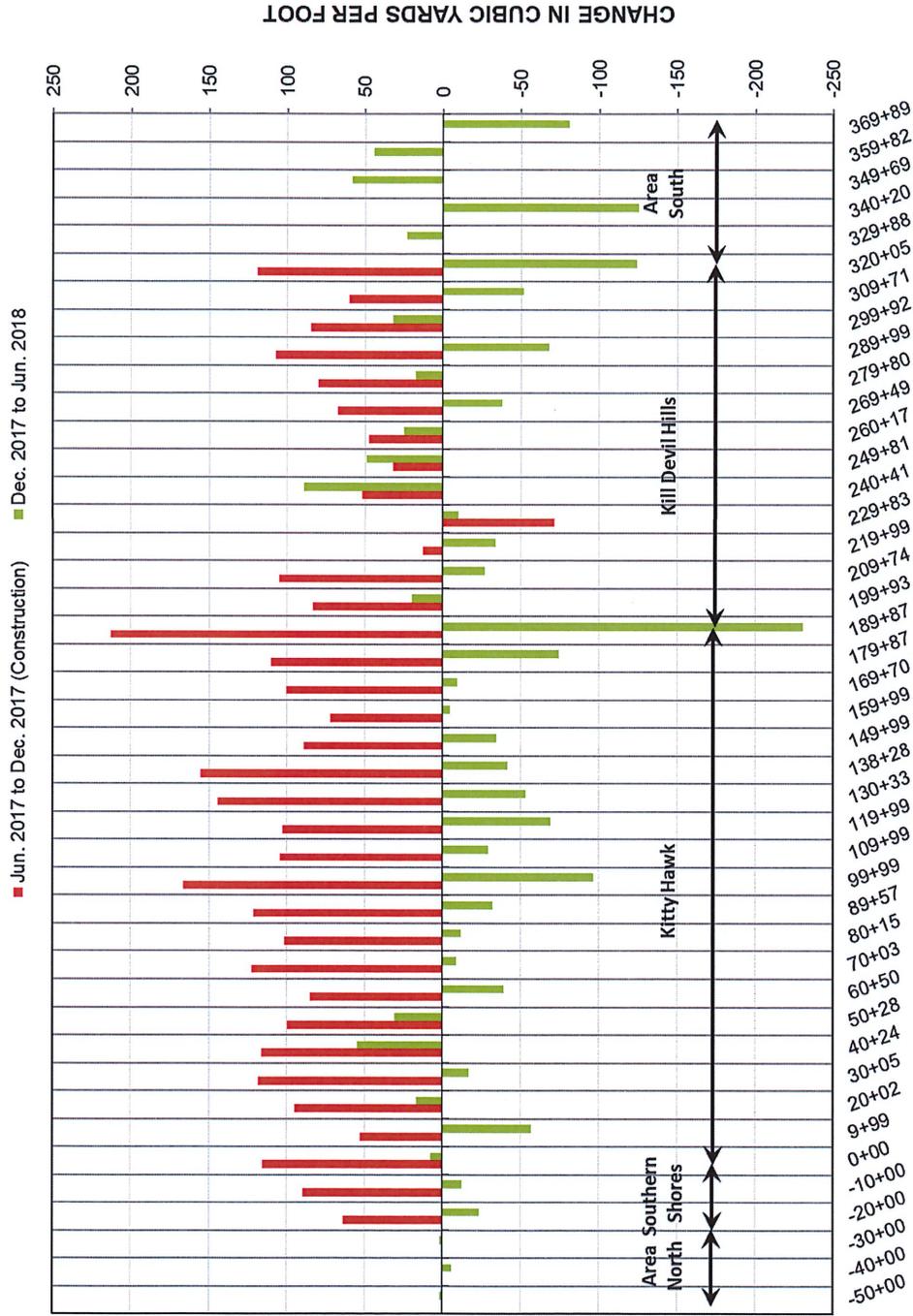
Table 4. Volumetric Changes (CY/FT.) North of Project area and along Southern Shores and Kitty Hawk, above -24 FT NAVD.

PROFILE		VOLUMETRIC CHANGES (CY/FT.)	
		Jun 2017 to December 2017	December 2017 to June 2018
North of Project Area	-50+00	---	1.8
	-40+00	---	-6.0
	-30+00	---	1.8
So. Shores Proj. Area	-20+00	64.0	-23.3
	-10+00	89.7	-12.2
	0+00	115.8	7.5
Kitty Hawk Project Area	9+99	53.2	-56.9
	20+02	95.1	16.7
	30+05	118.5	-17.0
	40+24	116.3	55.0
	50+28	99.9	31.1
	60+50	85.4	-39.1
	70+03	122.8	-8.7
	80+15	101.9	-12.0
	89+57	121.3	-32.1
	99+99	166.6	-96.5
	109+99	104.3	-29.4
	119+99	102.8	-68.9
	130+33	144.4	-53.2
	138+28	155.7	-41.4
	149+99	89.1	-34.6
	159+99	72.7	-4.6
169+70	100.4	-9.6	
179+87	110.2	-74.4	
189+87	212.8	-230.1	
NORTH OF PROJECT (-50+00 TO -30+00)		---	-0.8
Southern Shores (-20+00 TO 0+00)		89.8	-9.3
KITTY HAWK (0+00 TO 189+87)		114.5	-34.9

Table 5. Volumetric Changes (CY/FT.) along Kill Devil Hills and South of Project Area, above -24 FT NAVD

PROFILE	VOLUMETRIC CHANGES (CY/FT.)		
	Jun 2017 to December 2017	December 2017 to June 2018	
Kill Devil Hills Project Area	189+87	212.8	-230.1
	199+93	83.8	19.6
	209+74	105.1	-26.8
	219+99	12.6	-33.7
	229+83	-71.2	-9.8
	240+41	51.8	89.5
	249+81	32.2	48.9
	260+17	47.2	25.3
	269+49	68.0	-38.1
	279+80	80.3	17.5
	289+99	107.8	-67.8
	299+92	84.8	32.2
	309+71	60.4	-51.8
320+05	119.1	-124.0	
South of Project Area	329+88	---	23.1
	340+20	---	-125.0
	349+69	---	58.5
	359+82	---	44.1
	369+89	---	-80.6
KILL DEVIL HILLS (189+87 TO 320+05)	71.0	-24.9	
SOUTH OF PROJECT (329+88 TO 369+89)	---	-16.0	

VOLUMETRIC CHANGE ABOVE -24 FT NAVD (CY/FT)



Survey Profiles

Figure 6. Volumetric Change above -24 FT NAVD (CY/FT).

Beach Fill Performance.

Southern Shores. For the 2,500-foot project along the southern end of the Town of Southern Shores (which includes the 1000-foot taper), beach profile surveys indicate that the beach fill project lost a total of approximately 32,000 cubic yards between December 2017 and June 2018, or approximately 12.8 cy/ft. As of June 2018, the Southern Shores beach fill project still had 85% of the initial fill volume remaining on the active profile out to the -24-foot NAVD88 depth of closure.

Kitty Hawk. Based on a comparison of the December 2017 and June 2018 beach profile surveys, the total volumetric change observed in the Town of Kitty Hawk (0+00 to 189+87) calculated above the -24 ft. NAVD contour between December 2017 and June 2018 was a loss of approximately 587,000 cubic yards or 27.7% of the initial fill volume. The average density change measured along profiles 0+00 through 189+87 was 34.9 cy/ft.; however, the measured loss of beach fill was not uniform along the length of the Kitty Hawk project. Figure 6 shows the volume change measured along each profile based on beach profile surveys conducted in December 2017 and June 2018. The analysis of the beach profiles suggests a gain of approximately 18,000 cy between stations 0+00 and 50+28 which equates to an average of +3.5 cy/ft., while the area between stations 50+28 and 169+70 lost approximately 409,000 cubic yards or an average of approximately -34.3 cy/ft. The south end of the Kitty Hawk project, located between stations 169+70 and 189+87 lost approximately 195,000 cubic yards or an average of -96.8 cy/ft.

Certain areas offshore of the Kitty Hawk and Kill Devil Hills projects are characterized by deep depressions or troughs. These features were surveyed by APTIM following construction of the beach fill project between December 2017 and February 2018. **Figure 7** shows a map of the area surveyed between December 2017 and February 2018. The trough features seen in the plot of the offshore bathymetric data, seem to correlate strongly with the locations along the beach in which high volume losses were measured. This initial observation prompted the conduct of a second bathymetric survey completed by APTIM in October 2018. This survey included the entire project area from station -5+00 in Southern Shores to station 329+88 in Kill Devil Hills. This survey was conducted to create a project wide baseline to compare to future surveys and to assess the potential influence the nearshore troughs or depressions may have had on the performance of the Kitty Hawk/Kill Devil Hills project along the area surveyed between December 2017 and February 2018 (station 75+79 to 216+07). The results of this assessment are provided in a later section of this report.

Kill Devil Hills. Based on a comparison of the December 2017 and June 2018 beach profile surveys, the total volumetric change observed along the Kill Devil Hills project (station 189+87 to 325+56) calculated above the -24 ft. NAVD88 contour was a loss of approximately 246,000 cubic yards or 27.4% of the initial fill volume. The average density change measured along profiles 189+87 through 320+05 was -24.9 cy/ft.; however, the measured loss of beach fill was not uniform along the length of the Kill Devil Hills project (Figure 6). The analysis of the beach profiles suggests the portion of the project between stations 199+93 and 260+17 gained approximately 89,000 cubic yards, which equates to approximately +15 cy/ft. The highest volume losses were measured along the approximately 1,000-foot area between stations 189+87 and

199+93. Along this area, surveys indicated a loss of approximately 106,000 cubic yards or an average of approximately -105 cy/ft.; while the area between stations 260+17 and 320+05, at the south end of the Kill Devil Hills project, lost approximately 162,000 cubic yards or an average of approximately -27 cy/ft.

The measured volume loss along the southern portion of the Kill Devil Hills project was largely driven by the volume change measured along profile 320+05. Significant scarping of the dune at Windsong Way, which is located approximately 450 feet north of station 320+05, was reported by residents at the end of April 2018. During the June 2018 profile survey, APTIM conducted a survey at station 315+00, located in the vicinity of Windsong Way, to track any future changes in this section of the project. As discussed in later sections of this report, the volume changes taking place in this section may be driven by nearshore troughs or depressions; however, during research of potential causes for the scarping that occurred along Windsong Way, the presence of a nearshore shipwreck in the vicinity of the Croatan Surf Club was identified. The wreck is believed to be the remains of the *Irma* which is shown on the photo taken by APTIM on June 16, 2018 (Figure 8). The intermittent burial and exposure of the wreck in the nearshore could impact erosion patterns occurring in the vicinity of Windsong Way.

As previously mentioned, certain areas offshore of the project area are characterized by deep depressions or troughs (Figure 7). One of the features seem to correlate strongly with the locations along the northern part of the Kill Devil Hills project in which high volume losses were measured. A second bathymetric survey completed by APTIM in October 2018 included the entire project area from station -5+00 in Southern Shores to station 329+88 in Kill Devil Hills. As previously mentioned and discussed in a later section of this report, this survey was conducted to create a project wide baseline to compare to future surveys and to assess the potential influence the nearshore troughs or depressions may have had on the performance of the Kitty Hawk/Kill Devil Hills project along the area covered by both surveys.

Areas North of the Project. Volumetric changes measured between December 2017 and June 2018 based on beach profile surveys were also calculated along the 2,500 feet of shoreline north of the project area (stations -50+00 to -25+00) and the approximately 4,400 feet south of the project (between stations 325+56 and 369+89). The measured volume change along the 2,500 feet section north of the project between December 2017 and June 2018 was a loss of approximately 3,000 cubic yards which represents an average loss of approximately 1.2 cy/ft. The volume change measured along stations -50+00 and -30+00 indicated a positive volume change of approximately 1.8 cy/ft. while the volume change measured along station -40+00 was a loss of -6.0 cy/ft.

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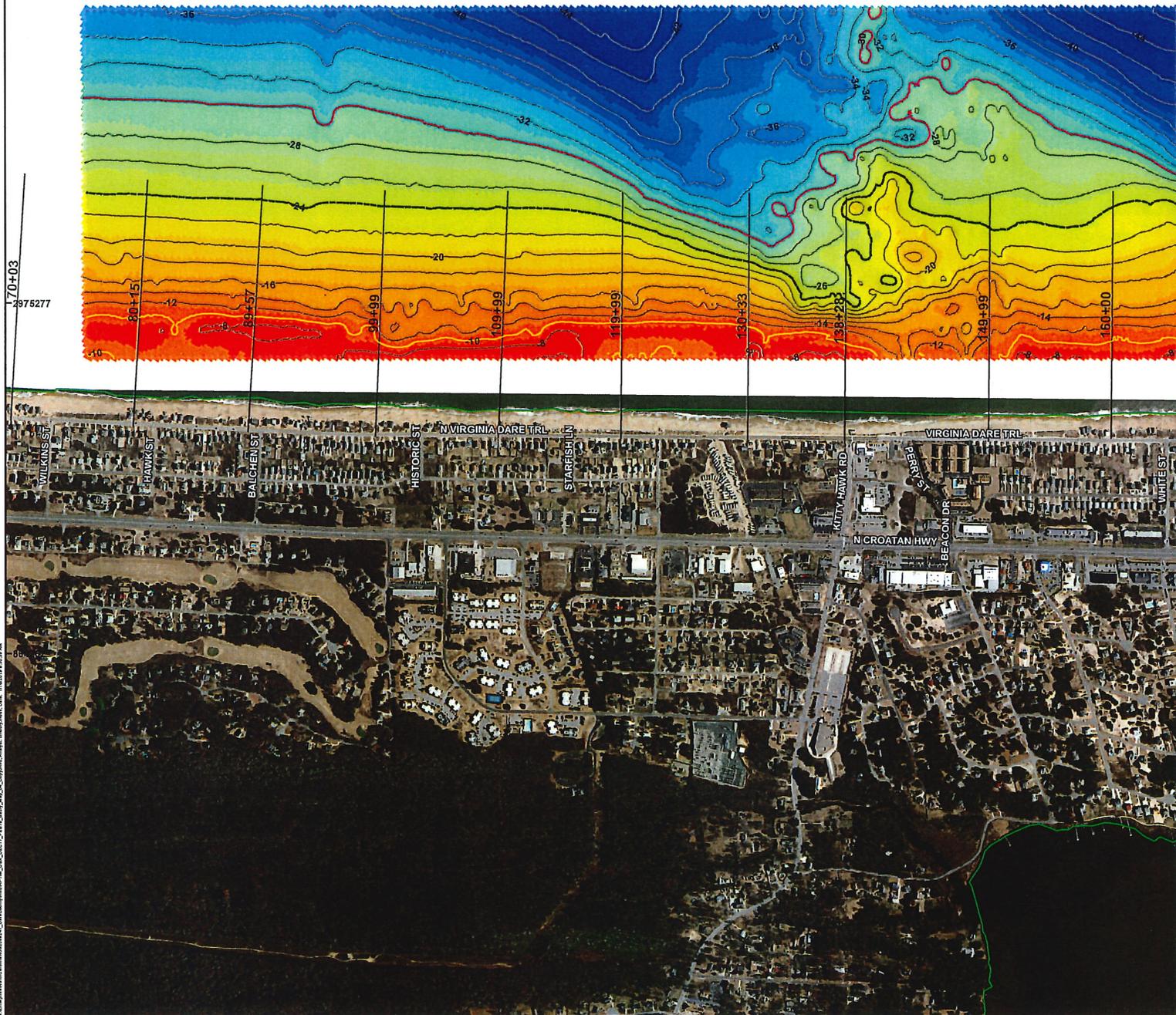




Figure 8. Aerial photo looking south along Kill Devil Hills toward Windsong Way, showing exposed shipwreck in the nearshore.

Areas South of the Project. South of the project (between stations 325+56 and 369+89), the total volume change measured was a loss of approximately 47,000 cubic yards, which represents an average loss of approximately 11 cy/ft. As was characteristic for the other portions of the monitoring area, the Area South of the project saw a wide range of volume change. Stations 329+88, 349+69 and 359+82 experienced positive volume change averaging approximately +42 cy/ft. However, surveys conducted along stations 340+20, and 369+89 indicated high losses averaging approximately 103 cy/ft. Based on the nearshore bathymetric surveys conducted in October 2018, discussed in the following section, these relatively large volume losses measured in this vicinity, may be due to the presence of nearshore troughs similar to those found offshore of the Kitty Hawk and Kill Devil Hills projects.

Nearshore Depressions.

Certain areas offshore of the Kitty Hawk and Kill Devil Hills projects are characterized by deep depressions or troughs and shore oblique sandbars. Similar features were first discovered offshore the Town of Duck in 1999 during an exploratory bathymetric survey conducted by staff of the USACE Field Research Facility (McNinch, 2004). The investigation area was later expanded to include the Kitty Hawk and Kill Devil Hills project areas in 2002 (McNinch, 2004). McNinch (2004) suggested a correlation between the spatial alignment of erosional hotspots and the bathymetric features he referred to as “outcrops/shore-oblique bar regions”. While debate is ongoing as to the degree in which the underlying geology or the bathymetric features themselves are more of an influence on the shoreline, there does seem to be strong alignment between the location of these features and erosional hotspots.

APTIM obtained a data set from the USACE FRF that was collected in 2009. This data set covers a portion of the project area between approximately stations 70+03 and 220+02. Following the completion of the beach nourishment project in 2017, APTIM conducted a survey of a similar area covered by the 2009 USACE FRF survey. This survey was conducted between December 2017 and February 2018 (**Figure 7**). A comparison of the bathymetric data collected by the USACE FRF in 2009 and the data collected by APTIM in 2017 and 2018 indicated the continued presence of nearshore troughs or depressions and associated bar systems.

The initial assessment of volume change based on beach profiles collected in December 2017 and June 2018, indicated a strong correlation between the location of the nearshore depressions and locations along the beach in which high volume losses were measured. For example, as shown in Figure 7 the profiles proximate to the nearshore depressions offshore Kitty Hawk are located at stations 119+99, 130+33, 138+28, 179+87, and 189+87. The total volumetric loss measured along these five (5) profiles was approximately -350,000 cubic yards computed landward of the -24.0-foot NAVD contour. This represents approximately 60% of the total volumetric losses observed within the Kitty Hawk project area based on the profile surveys.

This initial observation prompted the conduct of an additional bathymetric survey completed by APTIM in October 2018. This survey included the entire project area from station -5+00 in Southern Shores to station 329+88 in Kill Devil Hills. Figure 9, Figure 10, and Figure 11 are bathymetric charts of the nearshore region surveyed in October 2018. This survey was conducted to create a project wide baseline to compare to future surveys and to assess the potential influence the nearshore troughs or depressions may have had on the performance of the Kitty Hawk/Kill Devil Hills project along the area surveyed between December 2017 and February 2018 (station 75+79 to 216+07). Changes in elevation over the surveyed area between the December 2017/February 2018 survey and the October 2018 survey are shown on Figure 12. The green shaded areas on Figure 12 represent areas of sediment deposition while the brown/red shaded areas indicate volume losses. The alternating sequence of green and brown/red shaded areas indicates the nearshore trough features are migrating from north to south.

An examination of the survey data collected during the October 2018 nearshore survey indicated nearshore depressions or troughs and associated bar systems between the -10.0 and -30.0-foot NAVD contours in the following portions of the Kitty Hawk and Kill Devil Hills project areas:

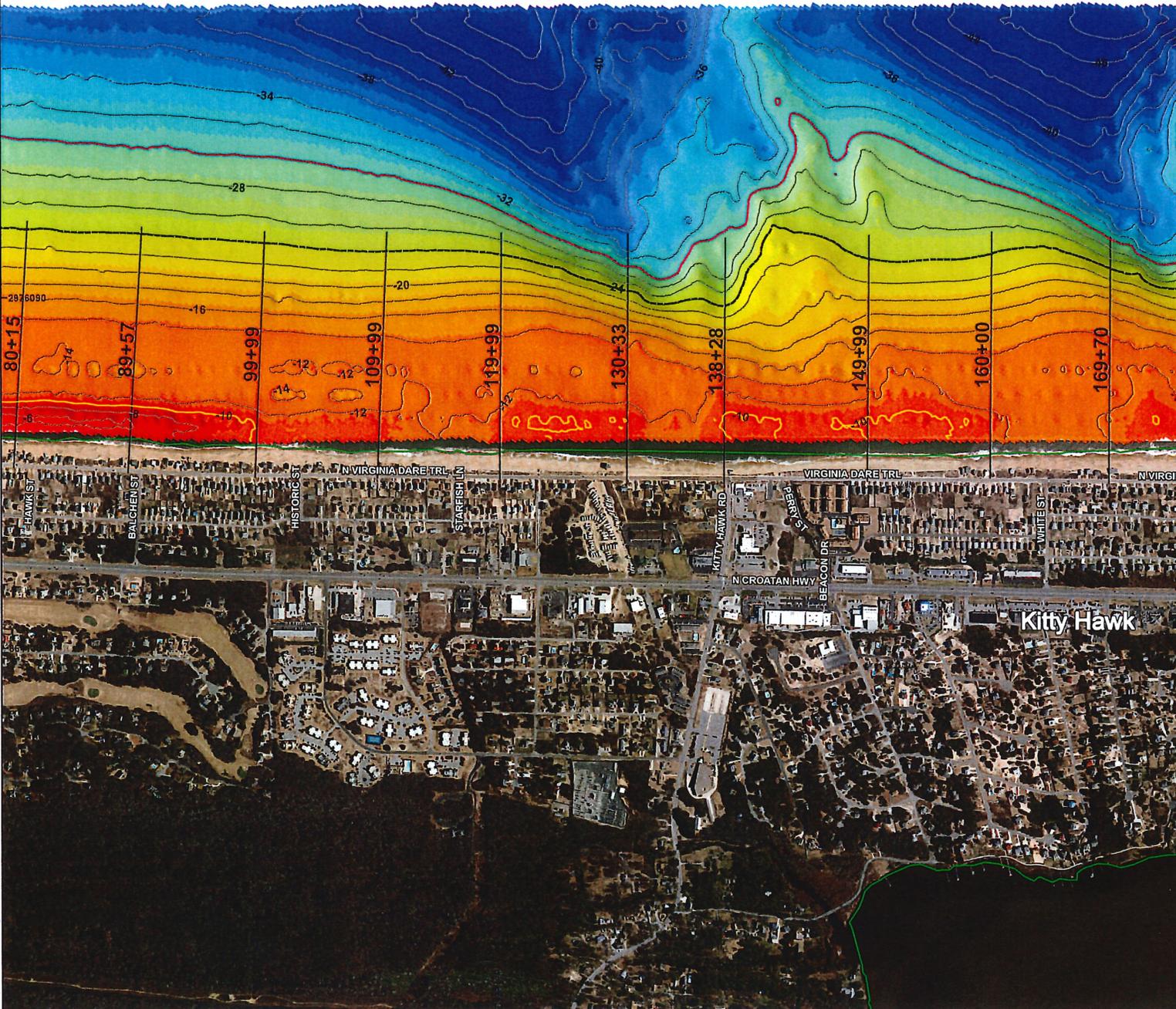
- Between Stations 40+24 and 50+28
- Between Stations 119+99 and 150+00
- Between Stations 160+01 and 199+95
- Between Stations 209+76 and 249+83
- Between Stations 275+00 and 305+00; and
- Between Stations 309+74 and 329+88.

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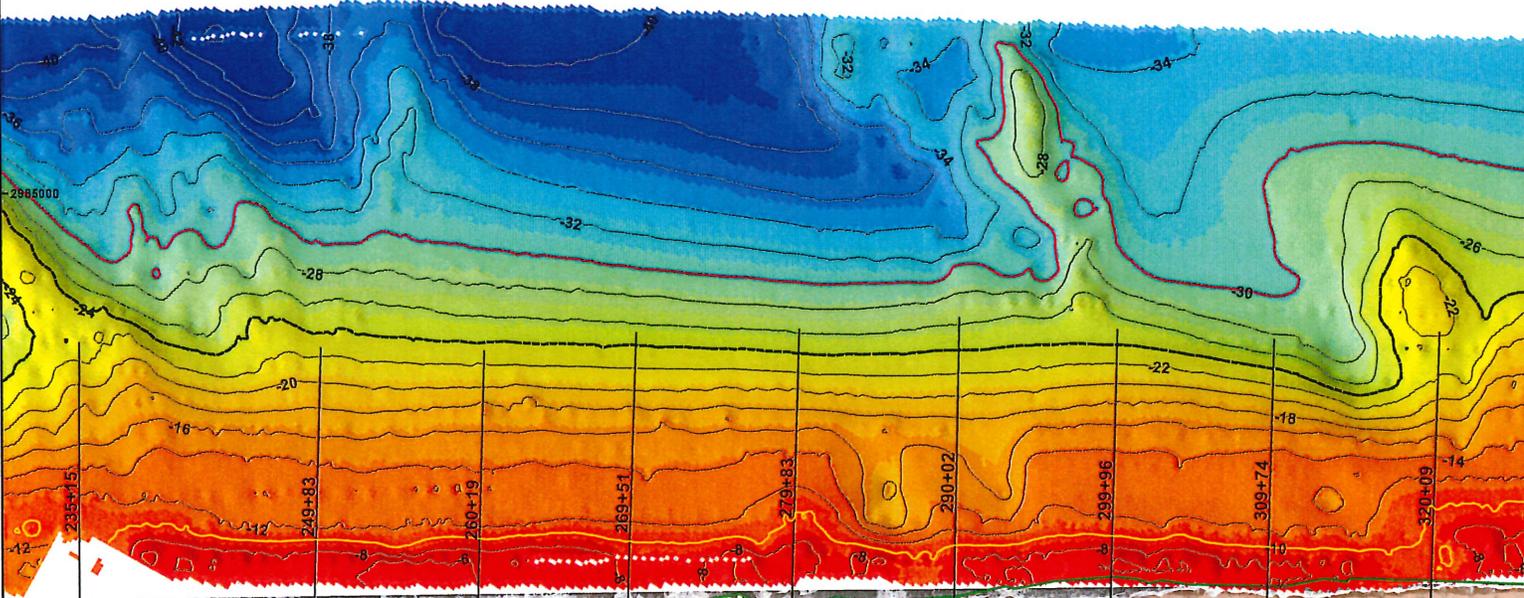
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Kill Devil Hills

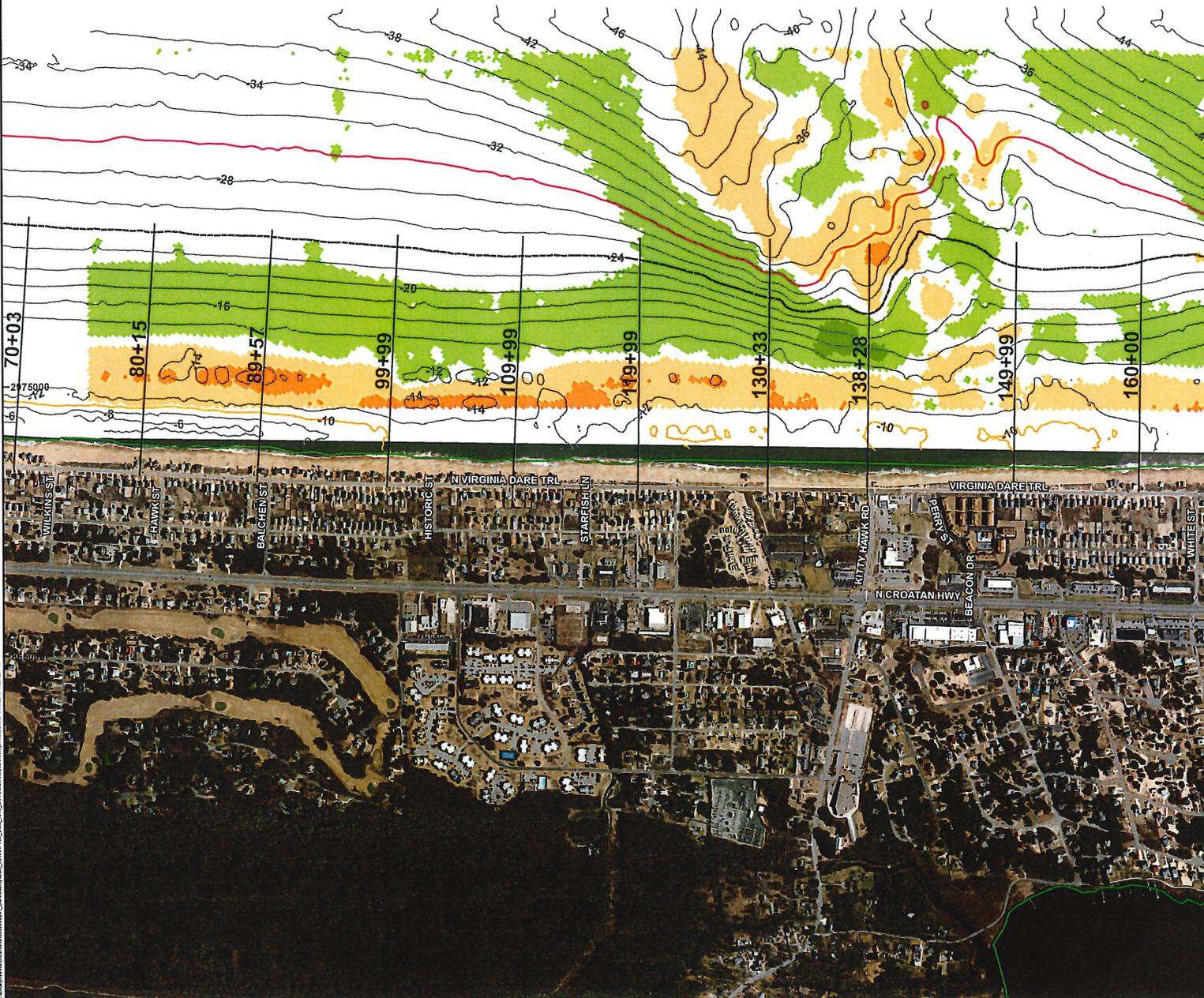
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Comparison of Bathymetric Surveys with Beach Profile Surveys. The bathymetric survey data collected by APTIM in December 2017/February 2018 and in October 2018 were used to determine volumetric changes between the -10-foot NAVD contour and the -24-foot NAVD contour. Volume change comparisons were limited to the area between approximately E. Wilkens St. in Kitty Hawk and approximately E. Sothel St. in Kill Devil Hills. The limiting factor was the data coverage from the December 2017/February 2018 survey, which is shown in Figure 7. The volumetric change measured within this area was an increase of approximately 61,000 cubic yards.

The beach profile survey data collected in December 2017 and June 2018 were used to determine volume changes along the same section of beach from the -10 ft. NAVD88 contour to the landward limits of the profile surveys. The calculated volume change landward of the -10 ft. NAVD88 contour was a loss of approximately 591,000 cubic yards. Combining the offshore volume changes determined from the bathymetric surveys (+61,000 cy) with the estimated nearshore volume changes obtained from the profile surveys (-591,000 cy) results in a total volume change of approximately -530,000 cubic yards.

As a comparison, volumetric changes computed above the -24 ft. NAVD88 contour, along the same portion of the beach (between approximately E. Wilkens St. in Kitty Hawk and approximately E. Sothel St. in Kill Devil Hills), based only on profile survey data collected in December 2017 and June 2018, suggested a loss of approximately -698,000 cubic yards. Thus, the volume change computed using only beach profile data was approximately 32% greater than the volume change measured using the shore parallel offshore bathymetric surveys.

The dates of the bathymetric survey and the profile survey differ by about 4 months and include the period in September in which Hurricane Florence impacted the region. A comparison of several tie lines run along seven (7) profiles from station -20+00 to 309+71 were compared to profile data collected during the June 2018 survey. The comparison showed relatively minimal changes within the surveyed area seaward of the -20-foot NAVD contour, suggesting there may not have been considerable sand movement on the outer portions of the beach profiles during this 4-month period. While comparing the two data sets do not provide a definitive comparison of profile-based volume changes and shore parallel nearshore bathymetric surveys, our analysis suggests that the shore parallel nearshore bathymetric surveys provide a higher level of resolution, which allows for better tracking of offshore changes.

The disparity in the volumetric change results obtained from the profile surveys and bathymetric surveys is primarily due to the three-dimensional changes in the offshore bottom that are occurring as a result of the mobile nature of the nearshore depressions whereas the profile lines are only capable of identifying two-dimensional changes. In this regard, profiles located close to the nearshore depressions, as is the case for the profiles listed above, any movement of the depressions along the coast can have a significant impact on the configuration of the profiles and hence the indicated volume change. Since the profiles used in the monitoring program are spaced approximately 1,000 feet apart, any change in the offshore between the profile lines due to the movement of the depressions would not be captured by the two-dimensional profile lines. Therefore, future monitoring of the Dare County projects should include bathymetric surveys similar to what was done for Kitty Hawk and Kill Devil Hills in October 2018.

VI. SUMMARY

This monitoring report evaluated shoreline and volumetric changes along the portions of shoreline renourished in 2017 within the Towns of Southern Shores, Kitty Hawk, and Kill Devil Hills, as well as the adjacent shorelines to the north and south. Data collected in June 2018 was used to evaluate shoreline and volumetric changes that have occurred following the 2017 beach nourishment project. Based on the comparison of the June 2017 Pre-construction survey and the December 2017 Post-construction survey, the volume of beach fill retained within the project area between stations -25+00 and 325+56 was approximately 3,227,000 cubic yards. This volume was used as the baseline to compare future monitoring of the project, including the analysis detailed in this report.

The monitoring area extends south from Profile -50+00, located within the Town of Southern Shores, to Profile 369+89, located within the Town of Kill Devil Hills. With the construction of the beach nourishment project in 2017, the monitoring area was divided into five sections; The Southern Shores Project Area (-25+00 to 0+00), the Kitty Hawk Project Area (0+00 to 189+87), the Kill Devil Hills Project Area (189+87 to 325+56), Area North of the Project (-50+00 to -25+00), and Area South of the Project (325+56 to 369+89).

Volume Change Results

Southern Shores: Based on a comparison of the December 2017 and June 2018 beach profile surveys, the Southern Shores project area lost approximately 32,000 cubic yards or about 15.0% of the fill measured in the project area between June and December 2017. Some of the material placed within Southern Shores appeared to have migrated south and deposited along the Kitty Hawk shoreline between stations 0+00 and 50+28 (Table 5).

Kitty Hawk: Based on a comparison of the December 2017 and June 2018 beach profile surveys, the Kitty Hawk project area lost approximately 587,000 cubic yards or about 27.7% of the fill measured in the Project Area between June 2017 and December 2017. The loss of beach fill was not uniform along the length of the Kitty Hawk project as the project between station 0+00 and 50+28 gained approximately 18,000 cubic yards (3.5 cy/ft.) while the area between stations 50+28 and 169+70 lost approximately 409,000 cubic yards (-34.3 cy/ft.). The south end of the Kitty Hawk project, located between stations 169+70 and 189+87 lost approximately 195,000 cubic yards (-96.8 cy/ft.). The relatively high rate of loss of material from the Kitty Hawk project area measured by the profile surveys appeared to be impacted by the presence of nearshore depressions offshore the project area (See Nearshore Depression section below for additional information)

Kill Devil Hills: Based on a comparison of the December 2017 and June 2018 beach profile surveys, the Kill Devil Hills project area lost approximately 246,000 cubic yards or about 27.4% of the fill material residing within the Kill Devil Hills project area in December 2017. The analysis of the beach profiles suggests the portion of the project between stations 199+93 and 260+17 gained approximately 89,000 cubic yards, which equates to approximately +15 cy/ft. The highest volume losses were measured along the approximately 1,000-foot long area between stations 189+87 and 199+93. Along this area, surveys indicated a loss of approximately 106,000 cubic

yards or an average of approximately -105 cy/ft.; while the area between stations 260+17 and 325+56, at the south end of the Kill Devil Hills project, lost approximately 229,000 cubic yards or an average of approximately -35 cy/ft.

This report concludes that most of the negative volume change observed within the Kill Devil Hills project area may be driven by changes measured along profiles proximate to nearshore depressions. However, the presence of a shipwreck located in the nearshore area along the south end of the project near station 309+71 (Croatan Surf Club) may be playing a role in the high rates of erosion observed between stations 309+71 (Croatan Surf Club) and 340+20 (near Raleigh Ave.)

Nearshore Depressions: An offshore bathymetric survey conducted in October 2018 indicated some of the apparent loss of material was due to the inability of the 1,000-foot spaced beach profile surveys to capture volume changes due to the proximity of the survey lines to the mobile nearshore depressions. A comparison was made between the volume losses indicated by the beach profile surveys and volume changes measured by the higher density shore parallel bathymetric surveys and found losses obtained from the beach profile surveys were about 32% greater than the losses computed from the bathymetric surveys.

North and South of the Project Areas: Volumetric changes measured between December 2017 and June 2018 along the 2,500 feet of shoreline north of the project area (stations -50+00 to -25+00) was a loss of approximately 3,000 cubic yards, which represents an average loss of approximately -1.2 cy/ft. South of the project (between stations 325+56 and 369+89), the total volume change measured was a loss of approximately 47,000 cubic yards or approximately -11.0 cy/ft.

The volume changes measured along the areas north and south of the project area over the relatively short 6-month period between December 2017 and June 2018 may not be indicative of how the areas will respond over a longer period of time. Given the large volume of fill placed along the project, the long-term expectation would be for some of the material to migrate both north and south out of the area and deposit along the adjacent shorelines. Since relatively high rates of volume loss was observed not only in the areas north and south of the project but along the project area as well, the entire area was responding to the same environmental factors (tides, waves, and wind) in a similar manner.

VII. RECOMMENDATIONS

APTIM recommends that the entire project area within the Towns of Southern Shores, Kitty Hawk, and Kill Devil Hills continue to be monitored in order to assess if the trends measured in the volume change analysis persist in those regions identified. For future monitoring events, APTIM recommends that both 1,000-foot beach profile surveys and supplemental single beam survey data be collected along lines running parallel to the shoreline similar to the procedures used in October 2018. These parallel lines should extend from station -50+00 to station 369+89 and cover the offshore area from about the -10-foot NAVD88 contour to at least 3,000 feet offshore. The monitoring surveys should be conducted in the same timeframes from year to year in an effort to mitigate seasonal discrepancies.

Monitoring of the projects will be instrumental for the Towns to evaluate future areas of concern and to develop successful shoreline management strategies to deal with issues as they arise. With the greater density of bathymetric surveys, analysis of the data should provide further insight as to how the nearshore troughs are impacting the performance of the beach fill. These data may also reveal whether volumetric losses observed during the 6-month period (December 2017 to June 2018) were permanent or whether the fill material remains within the system. The monitoring program will also serve as the basis for determining when and what volume of additional nourishment is needed in the project area.

The surveys will also be used to evaluate losses associated with coastal storms that are designated as natural disasters. In this regard, post-disaster relief programs available through the Federal Emergency Management Agency (FEMA) for “improved or engineered beaches”, specifically Category G, could provide funding to restore sand lost due to a declared disaster. In order to be eligible for Category G assistance, the projects must have a maintenance plan that includes periodic re-nourishment. Both the Town of Kitty Hawk and Kill Devil Hills have documented maintenance plans. Monitoring surveys are a key element of these plans as they provide information on project performance and can be used to determine the magnitude of the volume loss due to the declared event.

VII. REFERENCES

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APPENDIX A

**2018 TOWN OF KITTY HAWK AND KILL DEVIL HILLS MONITORING SURVEY
REPORT**