

**INDIAN RIVER COUNTY, FL
SECTOR 5 BEACH & DUNE RESTORATION PROJECT**

**STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE**



Prepared for:
Indian River County, FL
Public Works Department
Coastal Engineering Division
1801 27th Street, Building A
Vero Beach, FL 32960

Prepared by:



**Aptim Environmental & Infrastructure, LLC
6401 Congress Avenue, Suite 140
Boca Raton, FL 33487**

April 2023

**INDIAN RIVER COUNTY, FL
SECTOR 5 BEACH & DUNE RESTORATION PROJECT**

**STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE**

EXECUTIVE SUMMARY

This report documents the changes in shoreline width and beach volume to the 3.1-mile Indian River County, FL, Sector 5 Beach and Dune Restoration Project caused by the effects of Hurricanes Ian and Nicole. On September 28, 2022, Hurricane Ian made landfall in the United States on Cayo Costa in Lee County. One day later, the eye passed over Brevard County, immediately north of Indian River County as a tropical storm, generating wave heights over 11 feet offshore of the County's coastline. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and passed. On November 10, 2022, Hurricane Nicole made landfall just south of Vero Beach in Indian River County as a Category 1 hurricane. The large wind field and direct impact with the County generated wave heights of nearly 19 feet offshore of the County's coastline. The result of both storms to the Sector 5 project area was appreciable erosion to the beach berm and dunes. As a regularly maintained local- and State-funded engineered beach restoration project, the Indian River County, FL, Sector 5 Beach & Dune Restoration Project qualifies for post-disaster relief from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category G).

During the storm inter-survey period, the Sector 5 engineered beach project experienced an average dune retreat of -19.4 ft, an average shoreline change of 1.8 ft, and a beach volume loss of -24,600 cy above the depth of closure. For the 5-month period between the pre-storm survey (September 2022) and post-storm survey (January 2023), a background sand loss of -11,564 cy was estimated for the project area. After removing the background loss from the measured loss, the Sector 5 engineered beach project is estimated to have lost -13,036 cy of sand directly attributed to the impacts of Hurricanes Ian and Nicole. Although the storm caused significant damage to the dry beach, the measured net volume over the entire active profile (to the depth of closure) was relatively low. It is unlikely that the dry beach will recover to pre-storm conditions based on the normal wave climate of the area. The changes for both project areas due to Hurricane Ian and Hurricane Nicole are described herein to provide FEMA with data needed to develop the Project Worksheets (PW). The estimated cost to repair the damages from the 2022 hurricane season ranges from \$2,202,694.65 to \$8,357,887.69 (with 10% added for contingency) depending on type of volume losses considered (total profile loss to the depth of closure versus losses from construction template).

**INDIAN RIVER COUNTY, FL
SECTOR 5 BEACH & DUNE RESTORATION PROJECT**

**STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE**

Table of Contents

EXECUTIVE SUMMARY	i
1. INTRODUCTION	4
2. BACKGROUND	5
2.1 Project Location and History.....	5
2.2 Project Design	6
2.3 Post-Construction Monitoring Program	7
2.4 Public Assistance Eligibility	8
3. 2022 HURRICANE SEASON.....	9
3.1 Hurricane Ian.....	9
3.2 Hurricane Nicole	13
4. BEACH PROFILE DATA COLLECTION.....	17
5. SHORELINE AND DUNE POSITION CHANGE.....	19
6. BEACH VOLUME CHANGE	22
7. COST ESTIMATE.....	29
8. SUMMARY	31
9. REFERENCES	32

List of Figures

<u>Figure No.</u>	
Figure 1. Sector 5 Project Location Map.....	5
Figure 2. Typical Beach Fill Construction Template.....	7
Figure 3. Radar Image of Hurricane Ian on September 28, 2022.	10
Figure 4. Hurricane Ian's Path and Cumulative Wind History.....	10
Figure 5. Oceanographic Data Collection Stations near Indian River County.	11
Figure 6. Significant Wave Heights Measured during Hurricane Ian.	12
Figure 7. Water Levels Measured during Hurricane Ian.	13
Figure 8. Path of Hurricane Nicole (NOAA 2022).....	14
Figure 9. Significant Wave Heights Measured during Hurricane Nicole.....	15
Figure 10. Water Levels Measured during Hurricane Nicole.....	16

Figure 11. Shoreline and Dune Position Change.....	21
Figure 12. Beach Volume Change.....	25
Figure 13. Post-Storm Profile Adjustment.....	27

List of Tables

Table No.

Table 1. Physical Monitoring Schedule.....	8
Table 2. Beach Profile Monument Control.....	18
Table 3. Tidal Datums Established at Vero Beach (Ocean), FL.....	19
Table 4. Contour Changes.....	20
Table 5. Seaward Limit of Volumetric Analysis (Depth of Closure).....	23
Table 6. Beach Volume Change	26
Table 7. Volume Lost Under Construction Template.....	28
Table 8. Estimated Construction Cost to Replace Volume Change to DOC.....	30
Table 9. Estimated Construction Cost to Replace Template Losses	30

List of Appendices

Appendix

- A Beach Profile Cross-Sections
- B Pre- and Post-Storm Photographs

**INDIAN RIVER COUNTY, FL
SECTOR 5 BEACH & DUNE RESTORATION PROJECT**

**STORM DAMAGE REPORT:
HURRICANES IAN & NICOLE**

1. INTRODUCTION

This report documents the changes in beach volume to the 3.1-mile Indian River County, FL, Sector 5 Beach & Dune Restoration Project caused by the effects of Hurricanes Ian and Nicole on September 28-29 and November 10, 2022, respectively. The eye of Hurricane Ian passed immediately north of Indian River County as a tropical storm with wind gusts up to 65 mph and offshore wave heights of 11 ft. Hurricane Nicole directly impacted Indian River County as a Category 1 hurricane with maximum sustained winds of 75 mph and offshore wave heights of nearly 19 ft. Elevated storm surge and large waves from both storms, resulted in appreciable erosion to the berm and dunes. As part of the monitoring and maintenance of the engineered beach project, Indian River County authorized the collection of post-storm beach profile surveys to document the storm damages. As a regularly maintained local- and State-funded engineered beach restoration project, the Indian River County, FL, Sector 5 Beach & Dune Restoration Project qualifies for post-disaster relief from the Federal Emergency Management Agency (FEMA) Public Assistance Program (Category G).

2. BACKGROUND

2.1 Project Location and History

The Sector 5 Beach and Dune Restoration Project is located on the east coast of Florida within Indian River County (**Figure 1**). The northern boundary of the project is located approximately 13.5 miles south of Sebastian Inlet and 15 miles north of Fort Pierce Inlet. The Sector 5 Dune Restoration Project, spanning from R-71 to R-85, was conducted in 2005 and 2006 with the placement of approximately 103,400 cubic yards (cy) of beach compatible sand. The project was authorized under the FDEP coastal construction control line (CCCL) Permit No. IR-717, dated February 3, 2005.

Following the Sector 5 Dune Restoration Project, the following sand placements were part of regular maintenance of the engineered dune project (Indian River County, 2017). Placement occurred at discrete properties throughout Sector 5, authorized under one-time FDEP field permits.

- 2009: 4,500 cy
- 2010: 3,000 cy
- 2012: 2,000 cy
- 2013: 15,600 cy (emergency repairs following Hurricane Sandy)
- 2016: 800 cy placed in October (emergency repairs following Hurricane Matthew)
- 2017: 26,593 cy placed in Jan-Feb (emergency repairs following Hurricane Matthew)

The most recent Sector 5 Beach and Dune Restoration Project was constructed by Indian River County between November 2019 and February 2020 under Florida Department of Environmental Protection (FDEP) Permit No. 0363427-001-JC. The project was constructed in accordance with the County's 2015 Beach Preservation Plan prescribed maintenance event in response to

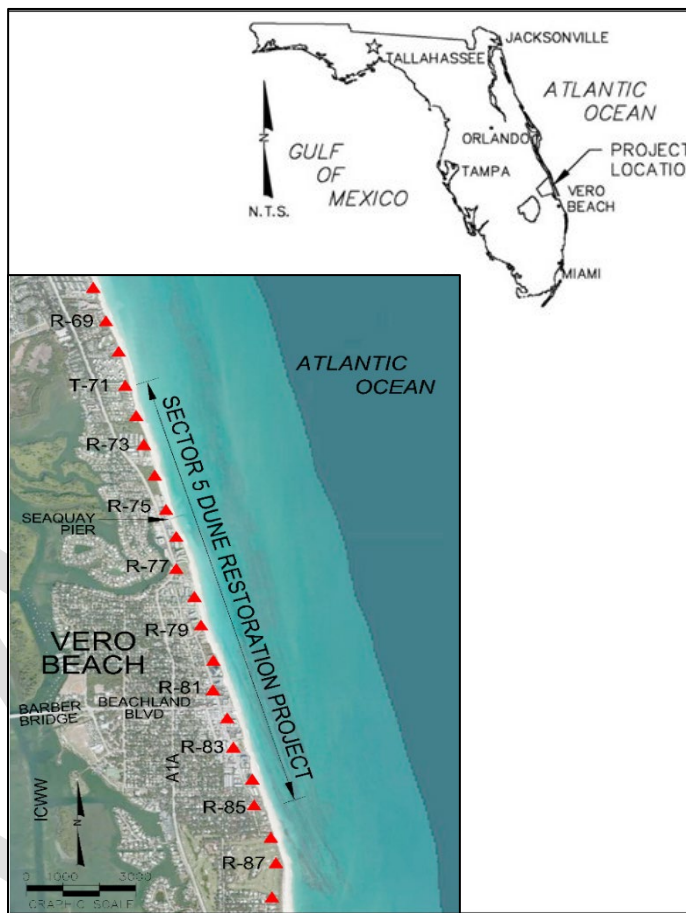


Figure 1. Sector 5 Project Location Map.

background erosion from 2015 to 2019. In addition, the project was constructed in response to the impacts of Hurricane Matthew (October 2016), Hurricane Irma (September 2017), and Hurricane Dorian (September 2019). The project area extended along approximately 3.1 miles of Vero Beach, Indian River Shores, and unincorporated Indian River County coastline from FDEP monument R-70 to R-86. The total placement of material in the project area was approximately 161,800 cy of upland sand. Additionally, dune vegetation was installed along the dune crest following sand placement.

2.2 Project Design

In 1998, the County formulated a conceptual plan for maintenance of County beaches as identified in the Indian River County Beach Preservation Plan (BPP). In 2007, the County updated the BPP to address the 2004 and 2005 hurricane impacts and to refine the County's overall plan for the beaches (Coastal Tech, 2008b; subsequently updated by CB&I, 2015 and Stantec, 2019). The 2015 BPP called for regular renourishment intervals every four (4) years within the Sector 5 Project limits. The 2019 BPP recommends a similar maintenance interval of 3 to 5 years. The first scheduled maintenance renourishment event began in November 2019 and was completed in February 2020. Per project permits, the Sector 5 Beach and Dune Restoration Project is designed to reconstruct the dune to a historical elevation of +16.0 feet (NGVD) with a 1V:3H slope from the dune crest to the existing berm and a maximum width of 65 feet. The average designed fill density was 8.3 cubic yards per foot (cy/ft). Sand for the project was obtained from an upland source and truck-hauled to the project site.

Figure 2 depicts the typical design construction template for the beach and dune restoration project. The design intent of the project was to replace sand lost due to Hurricane Matthew, Hurricane Irma, Hurricane Dorian, and to replace background erosion losses since 2015. The key elements of the project design, as permitted, are as follows:

- a. restoration of the beach berm from R-70 to R-86 from the toe of the restored dune extending seaward at a 1V:10H slope to match the existing grade,
- b. restoration of the dune from R-70 to R-86 to include:
 - a dune crest elevation of +15.0 feet NAVD88 from R-70 to R-82 that tapered down to a +13.0 feet NAVD88 dune crest elevation from R-83 to R-86 – with native dune vegetation planted on the restored dune crest,
 - a landward slope on the restored dune backslope at 1V:5H – where applicable, and
 - a seaward slope on the restored dune face at 1V:3H from the dune crest to the seaward toe of the restored dune.

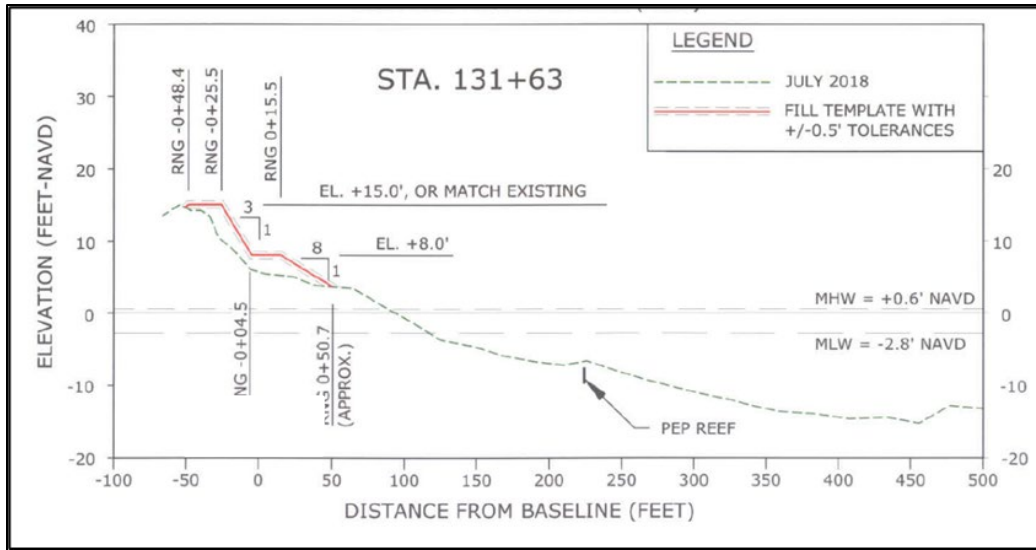



Figure 2. Typical Beach Fill Construction Template.

2.3 Post-Construction Monitoring Program

Physical monitoring for the project is required under the FDEP Permit No. 363427-001-JC. The Physical Monitoring Plan was approved by the FDEP, prior to construction of the 2019-2020 project. The plan consists of numerous elements that track the physical performance of the beach restoration project, including analysis of beach profile surveys, aerial photography, and beach sand sampling. Bathymetric surveys of the borrow area are not required due to the project being constructed from an upland source. **Table 1** lists the schedule of events required for physical monitoring. One post-construction monitoring report was completed in July 2022. Post-storm beach profile surveys are not required in the scope of the annual physical monitoring program; however, post-storm profiles were collected by the County to document storm damages following Hurricane Ian and Hurricane Nicole in winter 2022/2023.

Table 1. Physical Monitoring Schedule

Task	Schedule of Events						
Project Construction							
Beach Profile Surveys	▲	▲	▲	▲	▲		▲
Aerial Photography		⊕	⊕	⊕	⊕		⊕
Beach Sand Sampling		+					
Report		★	★	★	★		★
<i>Construction Phase</i>	Pre	Post	Year 1	Year 2	Year 3	Year 4	Year 5

This schedule continues biennially until the next beach nourishment event or the expiration of the project design life, whichever comes first.

2.4 Public Assistance Eligibility

The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as Amended (Stafford Act), Title 42 of the United States Code § 5121 et seq., authorizes the President to provide Federal assistance when the magnitude of an incident or threatened incident exceeds the affected State, Territorial, Indian Tribal, and local government capabilities to respond or recover.¹ Administered by the Federal Emergency Management Agency (FEMA) via its Public Assistance Program, restoration of a damaged public facility is eligible for assistance (Category G for beaches²). Section 102(9) of the Stafford Act defines a *public facility*, and Title 44 of the Code of Federal Regulations (CFR), Section 206.201(c) further defines a *facility* as “an improved and maintained natural feature.” 44 CFR. § 206.226(j) outlines eligibility criteria for *Beaches* as engineered infrastructure under the following conditions:

- The beach is not a federally constructed shoreline under the specific authority of USACE.
 - The Indian River County, FL, Sector 5 Beach & Dune Restoration Project is a non-Federal project.
- The beach was constructed by the placement of imported sand (of proper grain size) to a designed elevation, width, and slope.
 - The Indian River County, FL, Sector 5 Beach & Dune Renourishment Project has been constructed to design drawings and specifications using imported sand of proper grain

¹ For the Federal government to provide assistance, the President must declare that an emergency or major disaster exists (Emergency Declaration).

² To facilitate the processing of PA funding, FEMA separates Emergency Work into two categories and Permanent Work into five categories based on general types of facilities. Permanent work to restore engineered beaches falls under Category G – Parks, Recreation, Other.

size to establish elevations, widths, and slopes. Additionally, all imported sand followed and remained in compliance with all permit approved Sediment QA/QC plans.

- The Applicant has established and adhered to a maintenance program involving periodic renourishment with imported sand to preserve the original design.
 - The maintenance program for this project was most recently established in the County's Beach Preservation Plan (CB&I, 2015). The program was optimized to a 4-year renourishment interval with the placement of 52,000 cy of sand during each renourishment event. To perform the requisite monitoring and maintenance of the beach fill project, Indian River County has been fully committed to utilizing existing taxing mechanisms, including a Tourist Development Tax (a.k.a. "Bed Tax") and a potential Local Option Sales Tax, in combination with the cost-sharing contributions of the Florida Department of Environmental Protection Beach Management Funding Assistance Program. Concurrent with the prior commitment, the County has the capability and intent to continue to perform the requisite future monitoring and maintenance of the project. The County continues to monitor the project via analysis of beach profiles that were collected in 2006, 2012, 2013, 2014, 2015, 2016, 2017, 2020, 2021, and 2022 and after severe storm events.

3. 2022 HURRICANE SEASON

3.1 Hurricane Ian

On September 26, 2022, Hurricane Ian developed into a Category 1 hurricane approximately 300 miles south of Cuba. On the morning of September 27, 2022, Hurricane Ian had strengthened into a Category 3 hurricane, and hit Cuba, causing nationwide power outages. Hurricane Ian moved north and strengthened to a Category 4 while moving across the Gulf of Mexico.

Hurricane Ian made landfall on the United States in Lee County on September 28 around 3 p.m. as a Category 4 hurricane, delivering hurricane force winds and causing massive storm surge to the southwest coast of Florida. **Figure 3** shows a radar image of Ian's wind field after landfall in Florida. The cyclone slowly moved west across the Florida peninsula and weakened to a tropical storm. After reaching the Atlantic Ocean, it again intensified into a Category 1 hurricane before making landfall once more near Georgetown, South Carolina, on September 30. Hurricane Ian then weakened to a post-tropical cyclone as it moved into North Carolina. **Figure 4** plots the track of Hurricane Ian.

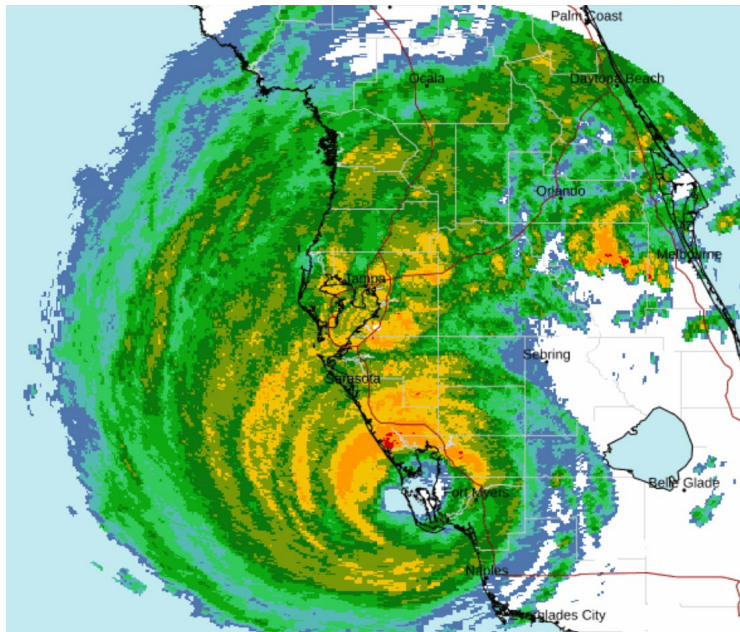


Figure 3. Radar Image of Hurricane Ian on September 28, 2022.
 (Source: National [Weather Service](#))

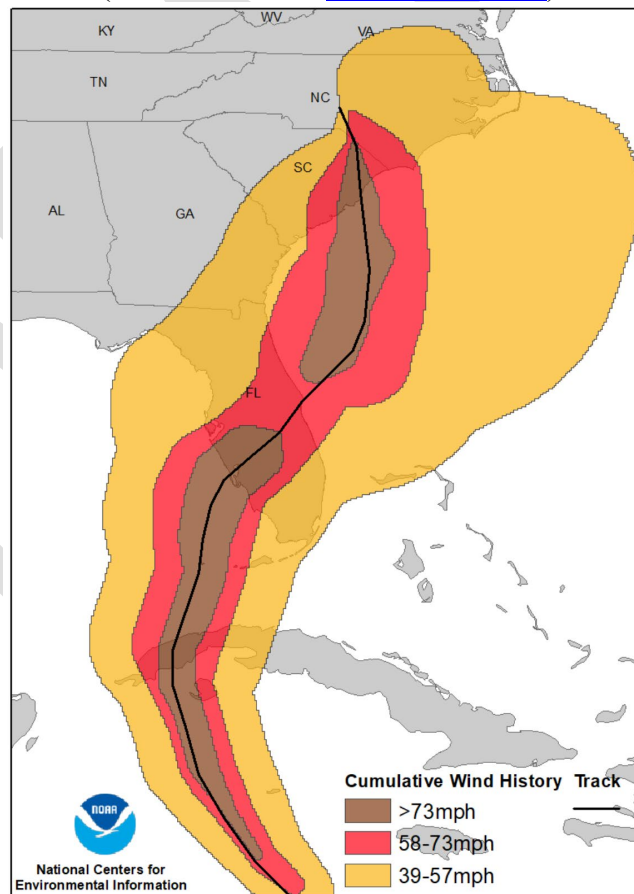


Figure 4. Hurricane Ian's Path and Cumulative Wind History.
 (Source: National Oceanic and Atmospheric Administration)

Hurricane Ian was a tropical storm when it hit Indian River County and developed into a Category 1 hurricane shortly after moving off the County's coast. The large wind field produced wave heights over 11 ft offshore of the County's coastline. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and passed offshore. The result was appreciable erosion to the beach berm and dunes of Sector 5. Post-storm photographs of the Sector 5 shoreline are found in **Appendix B**.

Figure 5 displays the location of oceanographic data collection stations in the vicinity of Indian River County. The wave climate offshore of Indian River County is assumed to be representative of data collected by an offshore waverider buoy, Station 41114 – Fort Pierce, FL (134), published by the National Data Buoy Center (NOAA, 2022a). The buoy is located about 5 nautical miles offshore of the Indian River County / St. Lucie County line, in a water depth of approximately 53 ft. Data collection from the buoy includes significant wave height, wave period, wave direction, and other standard oceanographic and meteorological data.

Water levels near the coast of Indian River County are assumed to be representative of data collected by a tidal station located in the Trident Basin of the interior of Port Canaveral; Trident Pier, FL – Station ID: 8721604 (NOAA, 2022b). The station is located about 35 nautical miles north of the northern Indian River County boundary. It is noted that the tide gage is not located on the open Atlantic Ocean coast. Rather, the station is somewhat sheltered and does not experience the dynamic storm surge (including wave setup) that occurs on the open coast.



Figure 5. Oceanographic Data Collection Stations near Indian River County.

Figure 6 displays the time series of significant wave height measured at the Fort Pierce Buoy as Hurricane Ian impacted the area. The significant wave heights reported at the buoy are an average of the largest 1/3rd of all wave heights during a 20-minute sampling period (thus, there were waves that passed the buoy during the 20-minute period that were larger than the reported height). Significant wave heights peaked at approximately 11 ft in the morning of September 29, as the storm passed offshore of the County.

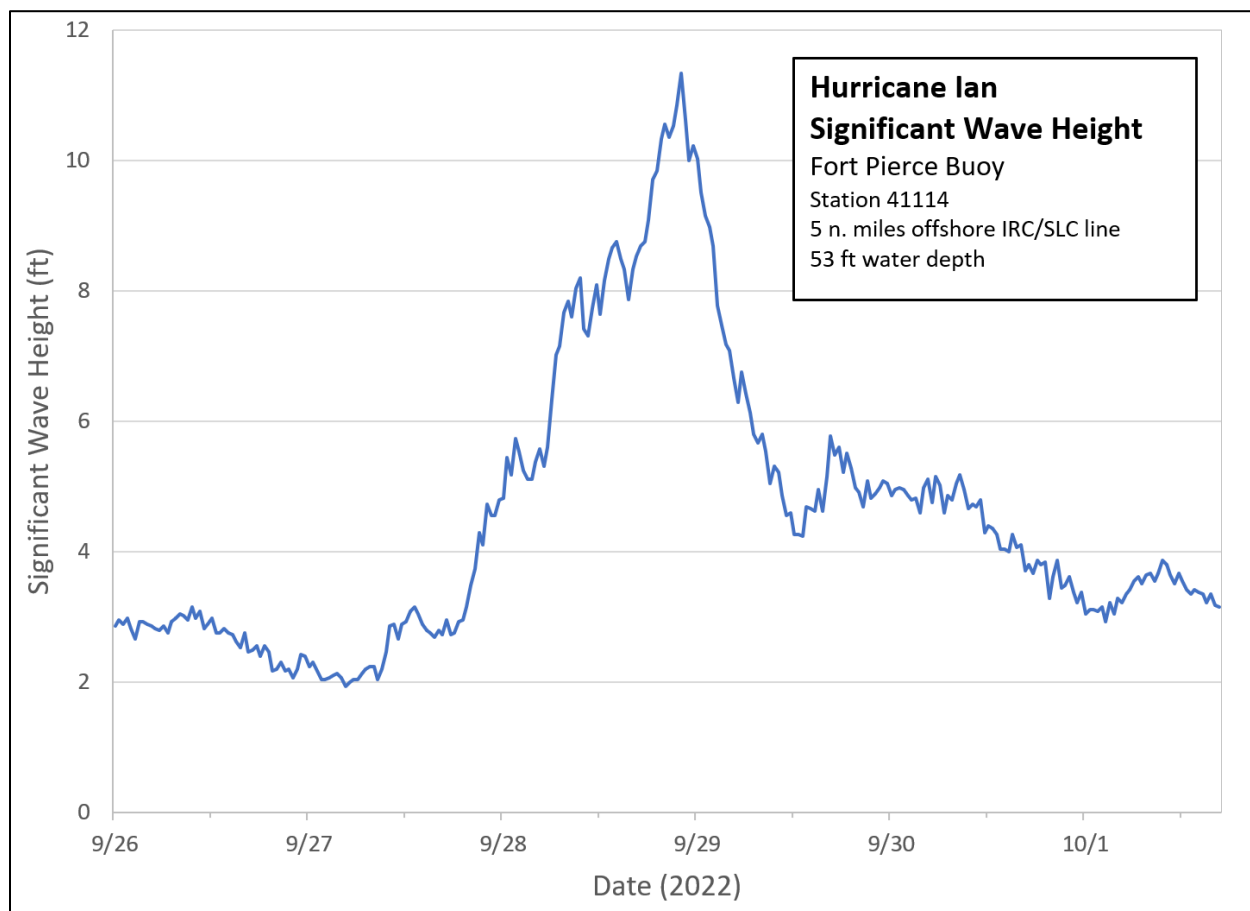


Figure 6. Significant Wave Heights Measured during Hurricane Ian.

Figure 7 displays the time series of water levels measured at the Trident Basin station as Hurricane Ian impacted the area. The greatest storm surge, calculated as the difference between the observed water level and the predicted tide, was +2.9 ft during the morning of September 29. The storm surge³ resulted in a storm tide⁴ of +3.9 ft NAVD at its peak. Based on pre- and post-storm profile

³ *Storm surge* is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum.

⁴ *Storm tide* is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88).

inspection, wave impacts and runup reached the toe of the dune in many places, which resides at around +7.5 ft NAVD along most of the County's coast.

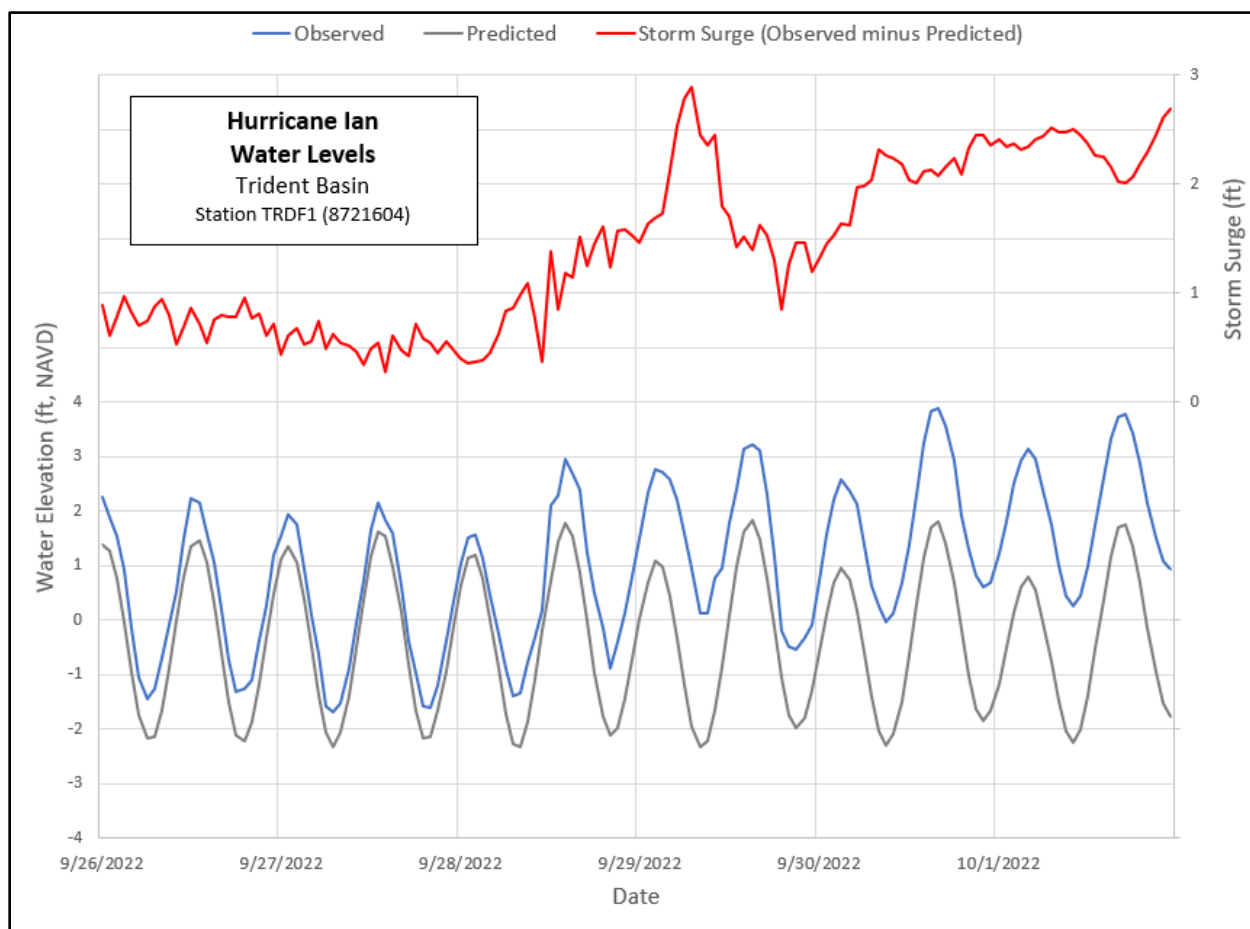


Figure 7. Water Levels Measured during Hurricane Ian.

3.2 Hurricane Nicole

Hurricane Nicole was a sprawling late-season Category 1 hurricane in November 2022, with storm-force winds extending approximately 970 miles in diameter. Nicole was the fourteenth named storm and eighth hurricane of the 2022 Atlantic hurricane season. Nicole formed as a subtropical cyclone on November 7, from a non-tropical area of low pressure near the Greater Antilles and transitioned into a tropical cyclone the next day. On November 9, Hurricane Nicole made landfall on Great Abaco Island, where it strengthened into a Category 1 hurricane with sustained winds of 70 mph (110 km/h). On November 10, Hurricane Nicole made landfall on North Hutchinson Island, just south of Vero Beach, Florida, with 75 mph winds. The storm made a direct impact with Indian River County as a Category 1 hurricane. Nicole subsequently made its second landfall at Cedar Key after briefly emerging over the Gulf of Mexico. Nicole then weakened to a depression while moving over the Florida Panhandle, and then was absorbed into a

mid-latitude trough and cold front over extreme eastern Tennessee the following day. The storm path is shown in **Figure 8**.

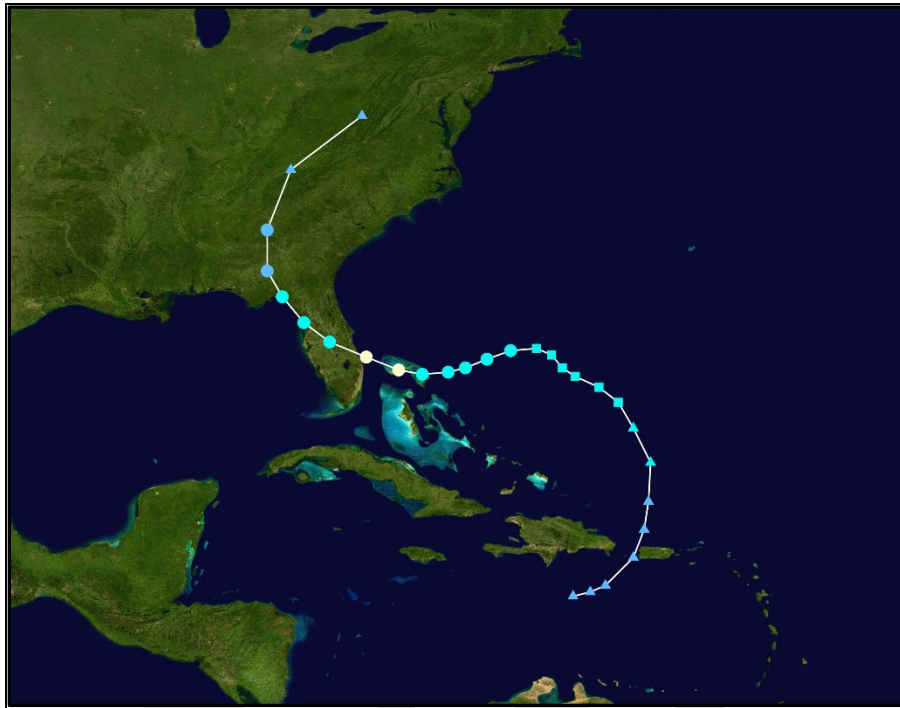


Figure 8. Path of Hurricane Nicole (NOAA 2022).

Nicole crossed the same region in Florida devastated six weeks earlier by Hurricane Ian, and was the first hurricane to make landfall on Florida's east coast since Katrina in 2005. Despite being relatively weak, Nicole's large size produced widespread heavy rainfall and strong winds across the Greater Antilles, the Bahamas, and Florida, knocking out power and inflicting significant damage in many areas. Days of strong onshore wind flow onto the east coast of Florida produced severe beach erosion, especially in Indian River County.

Figure 9 displays the time series of significant wave height measured at the Fort Pierce Buoy (NDBC #41114) as Hurricane Nicole impacted the area. Significant wave heights peaked at approximately 19 ft on November 9. The wave height readings went out shortly after the peak height was recorded. The storm's path relative to Indian River County resulted in elevated storm surge and large waves impacting the County's beaches for several days while the storm approached and impacted the County. The result was appreciable erosion to the beach berm and dunes of Sector 5. Post-storm photographs of the Sector 5 shoreline are found in **Appendix B**.

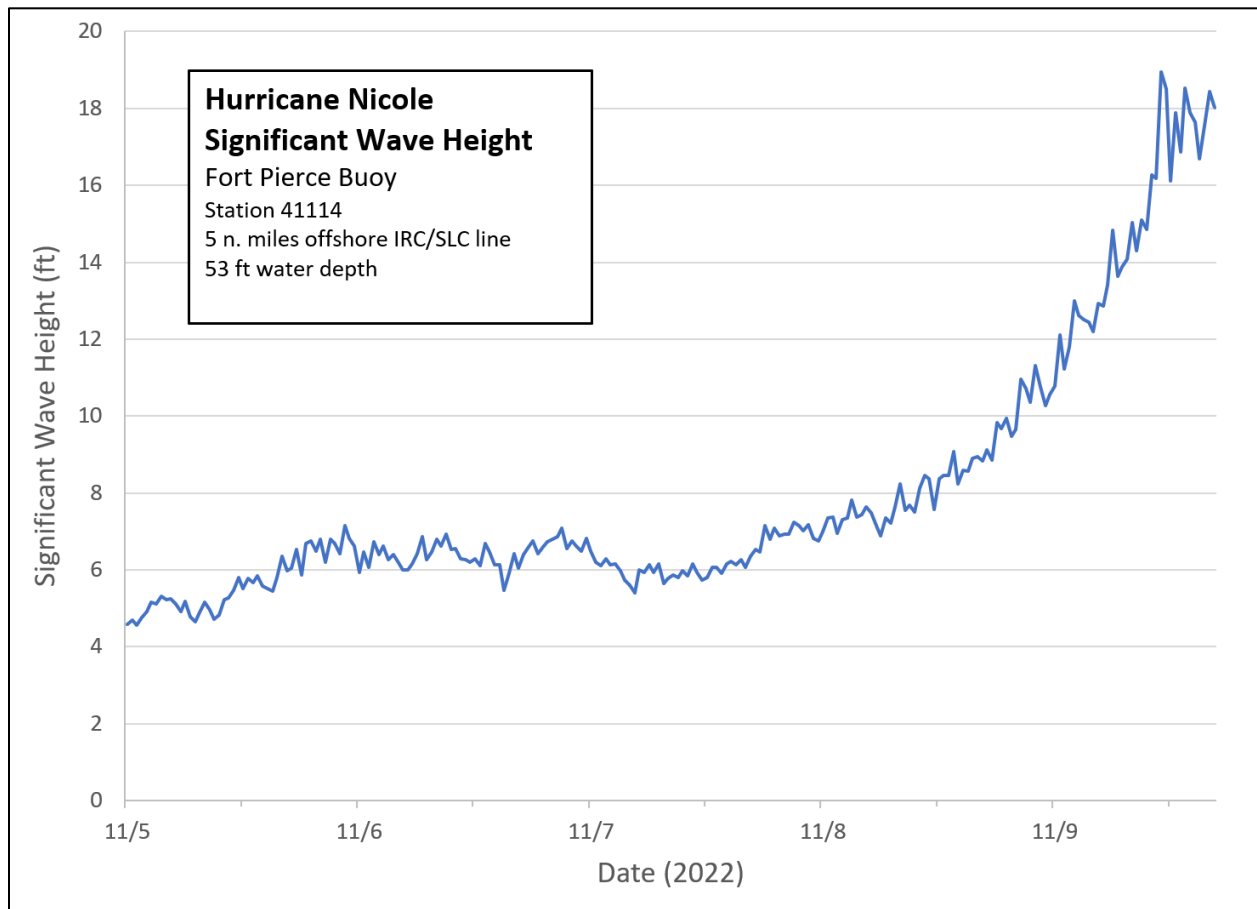


Figure 9. Significant Wave Heights Measured during Hurricane Nicole.

Figure 10 displays the time series of water levels measured at the Trident Basin station as Hurricane Nicole impacted the area. The greatest storm surge, calculated as the difference between the observed water level and the predicted tide, was +5.8 ft during the morning of November 10. The storm surge resulted in a storm tide of +4.7 ft NAVD at its peak. Based on pre- and post-storm profile inspection, wave impacts and runup reached the toe of the dune in many places and further exacerbated the conditions from Hurricane Ian.

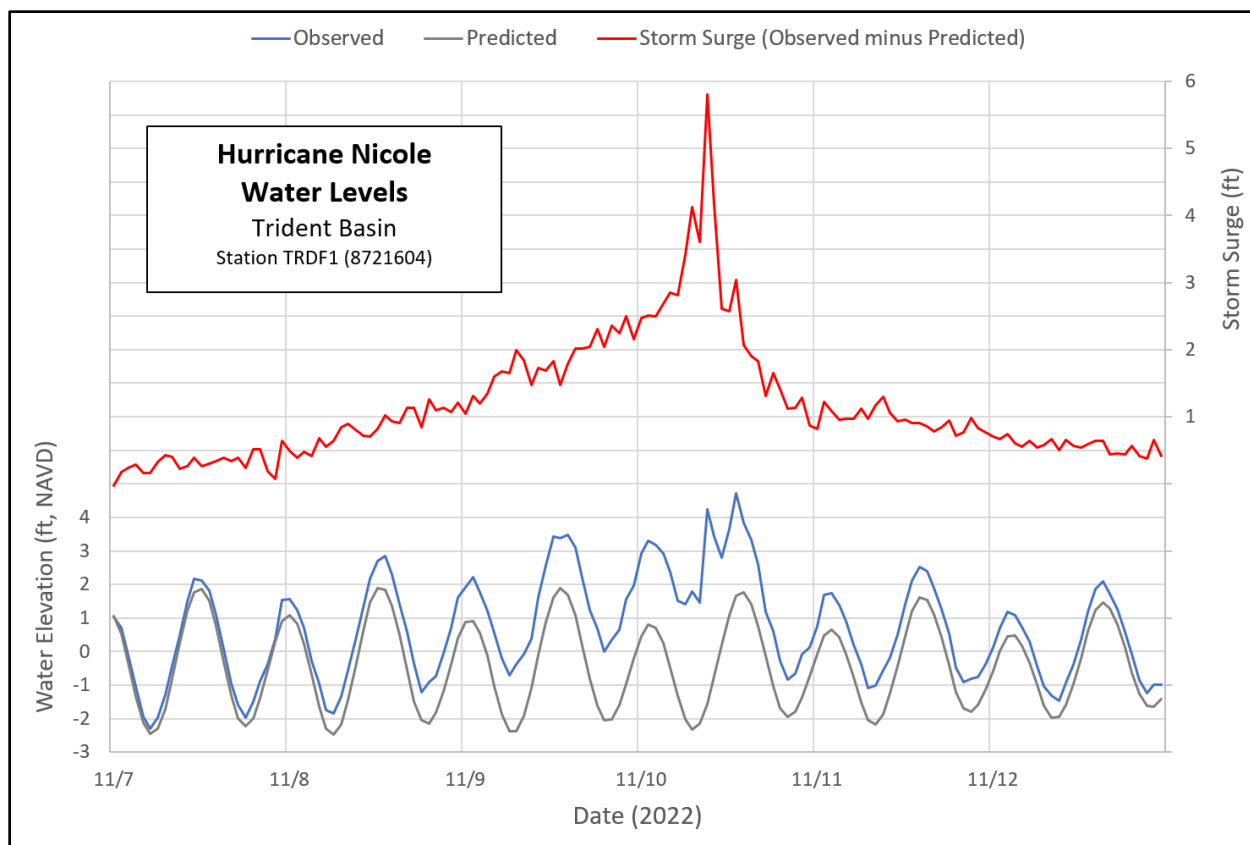


Figure 10. Water Levels Measured during Hurricane Nicole.

4. BEACH PROFILE DATA COLLECTION

Beach profile surveys collected before the passing of Hurricane Ian and after the passing of Hurricane Nicole were utilized to represent pre- and post-storm conditions. These profile sets are listed and described below. **Table 2** lists the survey control of the profiles. Cross section plots of the surveyed profiles are displayed in **Appendix A**. Due to the close proximity in the passing of the storms, no Post-Ian survey was able to be conducted for Sector 5; however, in order to determine losses for each storm, the method detailed in the Indian River County, FL Sector 3 Beach and Dune Restoration Project Storm Damage Report Hurricanes Ian and Nicole (APTIM, 2023) was utilized herein.

Pre-Ian Survey:

The pre-Ian survey was collected in September 2022, by Morgan & Eklund, Inc. as part of the County's 2022 annual physical monitoring effort.

Post-Nicole Survey:

The post-Nicole survey was collected between December 6, 2022, and January 9, 2023, by Morgan & Eklund, Inc. The onshore survey was collected on December 6 and 7, 2022, while the offshore survey was collected on January 5 and 9, 2023.

Table 2. Beach Profile Monument Control

FDEP R-Monument	Easting (ft, NAD83)	Northing (ft, NAD83)	Azimuth (deg. CCW from True N)	Distance (ft between monuments)
R-70	861,681.3	1,218,698.6	70.0	1108.5
R-71	861,861.7	1,217,604.9	70.0	1017.2
T-72	862,167.6	1,216,634.7	70.0	952.6
R-73	862,370.5	1,215,703.9	70.0	1031
R-74	862,670.9	1,214,717.7	70.0	1150.1
R-75	862,988.9	1,213,612.4	70.0	911.5
R-76	863,262.5	1,212,742.9	70.0	1030.2
R-77	863,264.9	1,211,712.7	70.0	1028.6
R-78	863,760.3	1,210,811.2	70.0	936.4
T-79	863,943.6	1,209,893.0	70.0	1183.6
R-80	864,286.1	1,208,760.0	70.0	954.4
R-81	864,272.1	1,207,805.7	70.0	983
R-82	864,665.4	1,206,904.8	70.0	952.5
R-83	864,829.4	1,205,966.6	70.0	1149.5
R-84	865,352.5	1,204,943.1	70.0	835.8
R-85	865,407.1	1,204,109.0	70.0	1142.1
R-86	865,867.3	1,203,063.7	70.0	
Total (R-70 to R-86):				16,367.0

Unless otherwise stated, the vertical datum utilized in this report is the North American Vertical Datum of 1988 (referred to as NAVD88 or NAVD). Tidal datums for the ocean shorefront of Vero Beach (Station ID 8722105) were obtained from NOAA Tides & Currents (NOAA, 2022b), and are summarized in **Table 3**. To conform to previous studies within the County, a MHW elevation of +0.6 ft NAVD is defined in this report. This MHW elevation is consistent with the elevation of the MHW line surveyed in 2009 to establish the Erosion Control Line in Sector 5.

Table 3. Tidal Datums Established at Vero Beach (Ocean), FL

Datum	Elevation (ft-NAVD)	Elevation (ft-MLLW)
Mean Higher-High Water (MHHW)	+0.88	+3.90
Mean High Water (MHW)	+0.55	+3.57
North American Vertical Datum of 1988 (NAVD88)	0	+3.02
Mean Sea Level (MSL)	-1.14	+1.88
Mean Tide Level (MTL)	-1.14	+1.88
National Geodetic Vertical Datum of 1929 (NGVD29)	-1.48	+1.54
Mean Low Water (MLW)	-2.83	+0.19
Mean Lower-Low Water (MLLW)	-3.02	0

VERO BEACH (OCEAN), FL - Station ID: 8722105; Latitude 27° 40.2' N, Longitude 80° 21.6' W; Epoch: 1983-2001

5. SHORELINE AND DUNE POSITION CHANGE

Beach profile surveys collected before and after the 2022 hurricane season were analyzed to quantify the change in the location of the Mean High Water Line (MHWL) and dune position.

- MHW Shoreline:** The MHW tidal datum for the ocean shorefront of Indian River County is identified by NOAA Tides & Currents (Station ID 8722105) to be at +0.55 ft NAVD. FDEP's Land Boundary Information System (LABINS) also provides interpolated MHW elevations along the County's ocean shorefront at approximate one-mile intervals. At the County's northernmost location, the MHW is specified at +0.63 ft NAVD, while it is +0.54 ft at the southernmost County location. Considering typical vertical survey accuracy (typically ± 0.2 ft), and to conform to previous studies within the County, a MHW elevation of +0.6 ft NAVD is used to define the shoreline location.
- Dune Position:** The dune position is defined as the seaward-most cross-shore location of the +10-ft contour. This contour typically corresponds to the seaward face of the dune and has been used to track the dune position in previous studies, including the County's Beach Preservation Plan (CB&I, 2015).

The results of the contour change analysis are summarized in **Table 4** and **Figure 11**. The dune position experienced an average landward retreat of -19.4 ft, with at least -25 ft of dune retreat experienced at six monuments throughout the Sector (R-71, T-72, R-74, R-78, R-80, and R-82). These dune impacts are not expected to recover naturally based upon environmental conditions and have diminished the storm protection provided by the dune to upland infrastructure. The MHW shoreline experienced an average landward advance of 1.8 ft between the pre- and post-storm surveys due to a cross-shore transfer of sand from the upland portion of the profile. The greatest retreat, averaging -12.6 ft, occurred along the northern portion of the project at R-73.

Table 4. Contour Changes

FDEP R-Monuments	Contour Change (feet)	
	MHWL ¹ (ft)	Dune ² (ft)
R-70	-6.0	-24.2
R-71	6.6	-32.2
T-72	-7.0	-28.0
R-73	-12.6	-24.8
R-74	3.4	-25.1
R-75	9.6	-19.9
R-76	-11.4	-1.2
R-77	-6.4	-21.7
R-78	20.7	-27.3
T-79	0.5	-20.8
R-80	-8.3	-28.5
R-81	2.4	-21.4
R-82	3.9	-26.7
R-83	2.3	-14.1
R-84	14.3	-17.1
R-85	12.8	-5.1
R-86	5.4	7.8
Average	1.8	-19.4

¹MHWL defined at +0.6 ft NAVD88.

²Dune defined at +9.0 ft NAVD88 for R-71 at +10.0 ft NAVD88 for all other profiles.

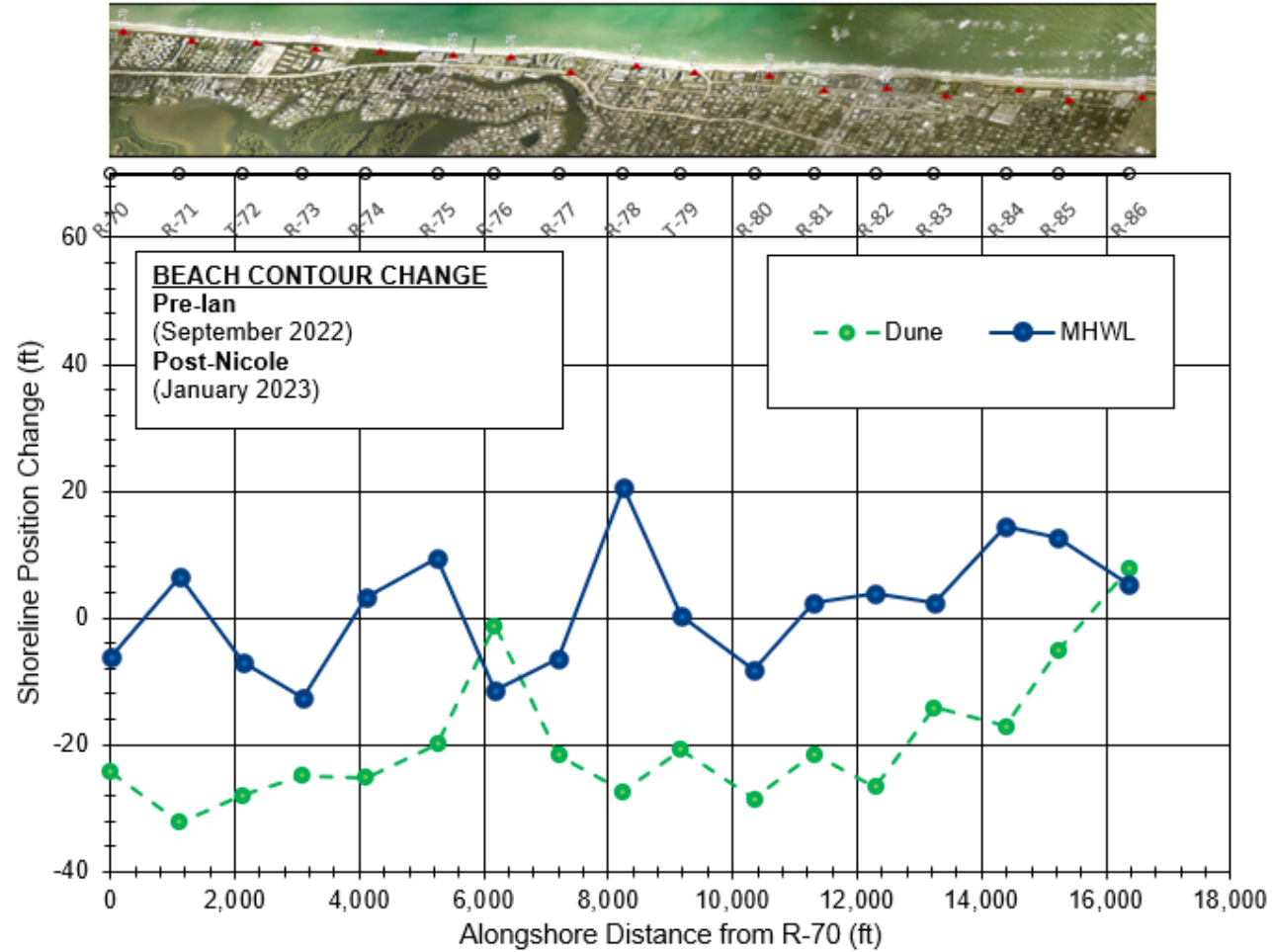


Figure 11. Shoreline and Dune Position Change.

6. BEACH VOLUME CHANGE

Pre- and post-storm beach profile surveys were directly compared to estimate volumetric changes. Volume changes at the profile transects are described in terms of volume density change, reported in cubic yards per alongshore foot of beach (cy/ft). Volume change between the roughly 1000-ft spaced transects are calculated by using the average-end-area method and reported in cubic yards (cy). Volume changes were calculated from the landward side of the dune out to an offshore depth of closure (DOC) in order to include the entire active beach profile.

- **Seaward Limit of Volumetric Analysis (Depth of Closure)**

Due to the jagged nature of the nearshore hardbottom found just offshore of the project beach, volume calculations are unreliable along this substrate; therefore, volume changes along the profiles are terminated at the landward extent of the hardbottom. Due to the highly variable nature of the offshore location of the hardbottom, a seaward limit of volume calculation is specified for each R-monument profile within the study area. As such, volume calculations represent seabed changes landward of the location at which movement of sediment could reasonably be estimated, while discounting the naturally irregular hardbottom seafloor. The seaward limit is specified at each R-monument in both the distance offshore and elevation (**Table 5**). That is, volume changes are not included offshore of a specified distance and not deeper than a specified elevation. The same calculation limits used in previous Sector 5 reports were used in this report for consistency with previous monitoring efforts and storm assessments (APTIM, 2022). For clarity of nomenclature within this report, the seaward limit of volumetric analysis is referred to as the *depth of closure* (or *DOC*).

Table 5. Seaward Limit of Volumetric Analysis (Depth of Closure)

FDEP R- Monument	Offshore Distance (ft)	DOC Elevation (ft, NAVD)
R-71	390	-17.4
T-72	330	-17.4
R-73	400	-17.4
R-74	430	-17.4
R-75	880	-17.4
R-76	420	-17.4
R-77	700	-17.4
R-78	450	-17.4
T-79	390	-17.4
R-80	450	-17.4
R-81	660	-17.4
R-82	720	-17.4
R-83	630	-17.4
R-84	420	-17.4
R-85	670	-17.4
R-86	370	-17.4
R-87	667	-17.4
R-88	1031	-17.4
R-89	1004	-17.4
R-90	1,425	-17.4
R-91	1,169	-17.4

• **Determination of Hurricane Ian vs. Hurricane Nicole Impacts**

Erosion estimates were required to determine losses attributable to both storms. Due to the close proximity in the passing of the storms, no Post-Ian survey was able to be conducted for Sector 5; however, in order to determine losses for each storm, the method detailed in the Indian River County, FL Sector 3 Beach and Dune Restoration Project Storm Damage Report Hurricanes Ian and Nicole (APTIM, 2023) was utilized herein. An evaluation was performed for Sector 5 project area. The intent of this evaluation was to establish a reasonable erosion contribution for each of the individual storms. As detailed in the report referenced above, the individual storm contributions are:

- Hurricane Ian: 22%
- Hurricane Nicole: 78%

These prorated distributions were then applied to total beach profile losses to the depth of closure in order to determine Hurricane Ian and Hurricane Nicole losses for the full beach profile, which is required by FEMA.

- **Volume Change During the Storm Inter-Survey Period**

The results of the volume change analysis are shown graphically in **Figure 12** and summarized in **Table 6**. Volume changes are computed above different vertical datums in order to assess the cross-shore changes in beach volume. The volume changes are plotted in bar chart form as interpolated volume changes between each profile transect. The bars indicate the volume changes measured between different vertical segments of the beach profile, while the black dashed-line represents the total profile volume change.

- Grey Bar: Sub-aerial change, from the dune to above MHW (+0.6 ft NAVD)
- Blue Bar: Sub-aquas change, from MHW out to the offshore DOC
- Black Dashed-Line: Total profile change, from the dune to the offshore DOC

Above MHW, the project lost -75,200 cy (average of -4.6 cy/ft) during the storm inter-survey period. Below MHW to the depth of closure, the project gained +50,600 cy (average of +3.1 cy/ft). Measured along the entire profile, from the dunes to the depth of closure, the engineered beach project lost a total of -24,600 cy (average of -1.5 cy/ft). This loss represents approximately 14% of the volume placed during initial construction of the County's Sector 5 renourishment. **Figure 13** illustrates the cross-shore transfer of sand that occurred pre-Ian and post-Nicole. From this plot, it can be observed that a large portion of the sand in the upper beach profile was transferred to the sub-aquas portion.

- **Background Erosion**

Background erosion was estimated to account for the beach volume changes other than losses due to Hurricanes Ian and Nicole that may have occurred during the time period between the pre- and post-storm surveys. Background erosion was analyzed in the study by calculating volume changes due to average wave conditions and storm events that occurred between July 2015 and July 2020 (5 years) and then accounting for sand volumes placed during that period. An average background erosion rate of -27,259 cy per year was calculated for the project area, which equates to -2,382 cy per month. Utilizing the background erosion rate of -2,382 cy per month for the 5-month period between the pre-storm survey (September 2022) and the post-storm survey (January 2023), a background change of -11,500 cy was estimated for the project area.

- **Beach Volume Change Attributed to Hurricanes Ian and Nicole**

After removing the background change (-11,500 cy) from the measured change (-24,600 cy), there is a difference of -13,036 cy. As such, it is estimated that the Sector 5 engineered beach fill project lost -13,036 cy of sand above the depth of closure directly attributed to the impacts of Hurricanes Ian and Nicole. Using the prorated distribution percentages described above, it is estimated that Hurricane Ian contributed to a volume loss of approximately -2,868 cy, and Hurricane Nicole contributed to a loss of -10,168 cy.

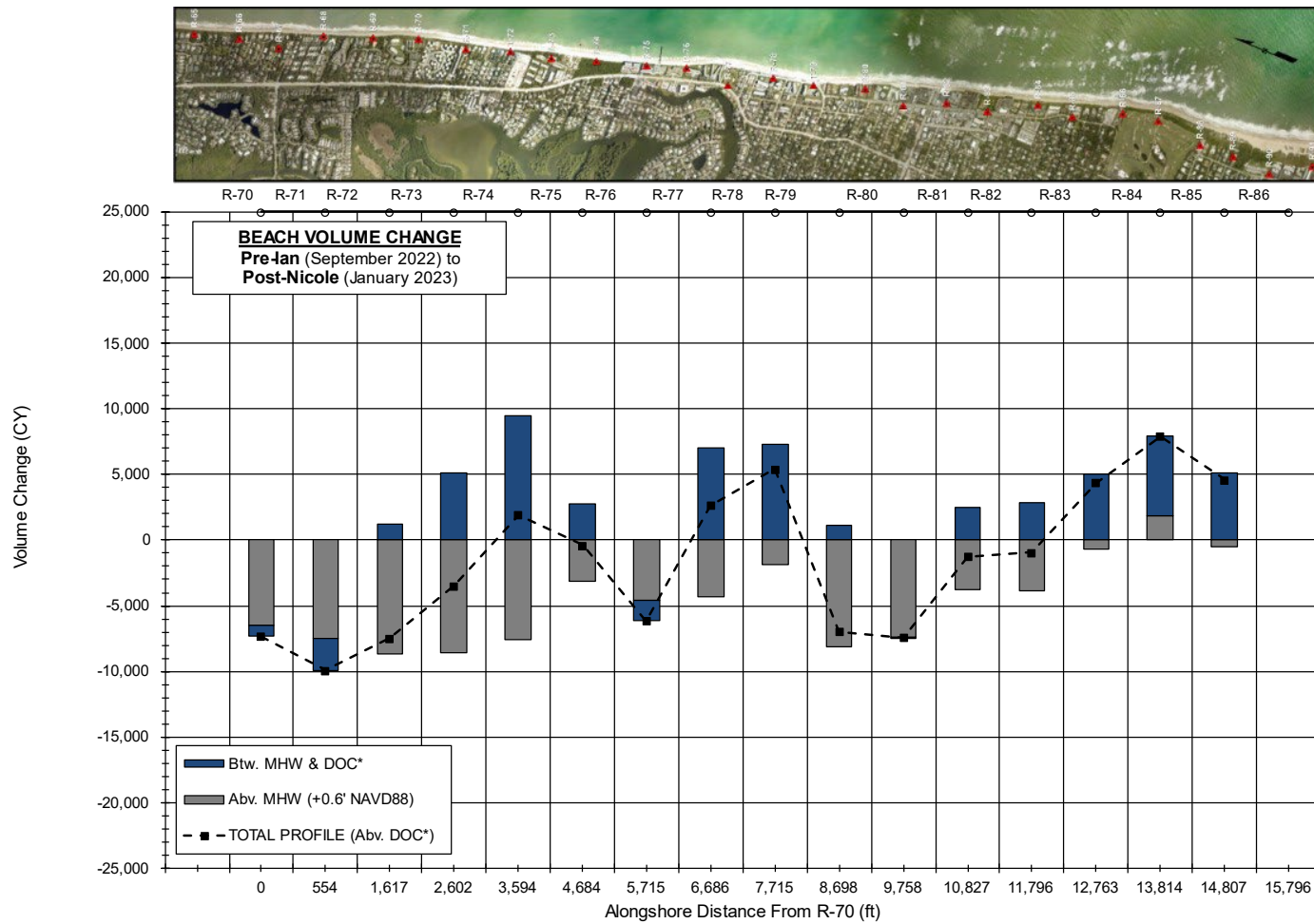


Figure 12. Beach Volume Change.

Table 6. Beach Volume Change

		Pre-Ian (Sept 2022) to Post-Nicole (January 2023)					
FDEP Monument	Distance (ft)	ABOVE MHW (+0.6 ft NAVD)		BETWEEN MHW AND DOC		TOTAL ABOVE DOC	
		Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)	Vol. Density (cy/ft)	Volume (cy)
R-70		-6.5		3.0		-3.5	
	1,108.5		-6,533		-782		-7,315
R-71		-5.3		-4.4		-9.7	
	1,017.2		-7,493		-2,412		-9,905
T-72		-9.4		-0.3		-9.7	
	952.6		-8,658		1,170		-7,488
R-73		-8.7		2.8		-6.0	
	1,031.0		-8,616		5,141		-3,474
R-74		-8.0		7.2		-0.8	
	1,150.1		-7,593		9,493		1,900
R-75		-5.2		9.3		4.1	
	911.5		-3,110		2,716		-394
R-76		-1.6		-3.3		-4.9	
	1,030.2		-4,593		-1,573		-6,166
R-77		-7.3		0.3		-7.0	
	1,028.6		-4,313		6,974		2,661
R-78		-1.1		13.3		12.2	
	936.4		-1,875		7,289		5,414
T-79		-3.0		2.3		-0.7	
	1,183.6		-8,099		1,113		-6,986
R-80		-10.7		-0.4		-11.1	
	954.4		-7,357		-73		-7,430
R-81		-4.7		0.3		-4.4	
	983.0		-3,751		2,487		-1,263
R-82		-2.9		4.8		1.9	
	952.5		-3,837		2,889		-948
R-83		-5.1		1.3		-3.8	
	1,149.5		-666		5,041		4,375
R-84		3.9		7.5		11.5	
	835.8		1,825		6,064		7,889
R-85		0.4		7.0		7.4	
	1,142.1		-529		5,107		4,578
R-86		-1.3		1.9		0.6	
Project Limits	Distance	ABOVE MHW		BTW. MHW & DOC*		ABOVE DOC*	
R-70 to R-86	16,367.0	-4.6	-75,200	3.1	50,600	-1.5	-24,600
		Estimated Background Change:					
		Change Attributed to Storms:					
		Change Attributed to Hurricane Nicole:					
		Change Attributed to Hurricane Ian:					

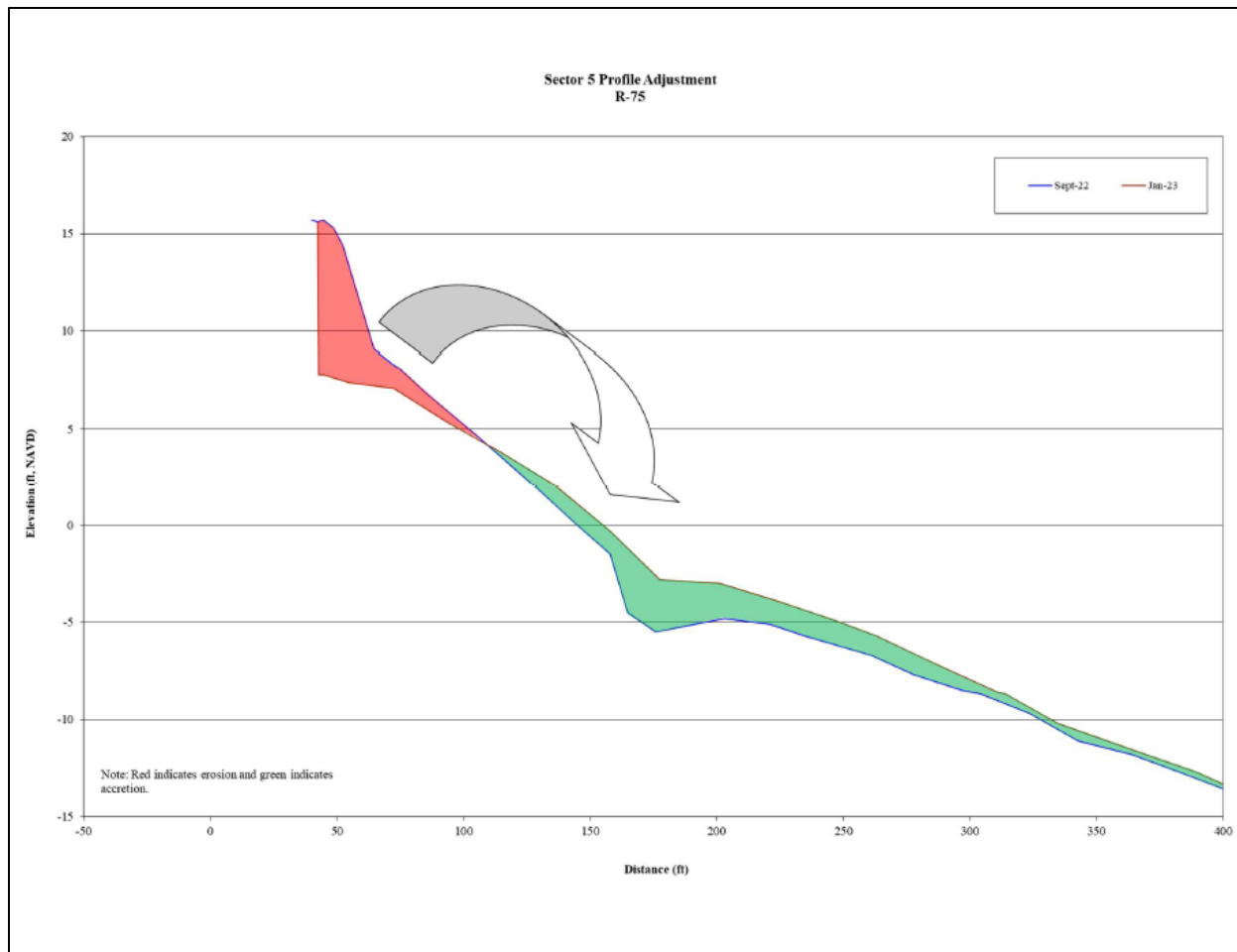


Figure 13. Post-Storm Profile Adjustment.

- **Volume Lost under Design/Construction Template**

Although FEMA only considers losses within the active beach profile from the landward limit of the dune to the depth of closure, it is important to note the impacts to the design/construction template due to the passage of Hurricanes Ian and Nicole. When comparing the post-Nicole profile to the permitted design and construction template, the Sector 5 project area lost 112,100 cy from the design profile, which equates to 69% of the volume placed during the most recent project. These impacts have greatly reduced the storm protection benefit provided by the design profile to neighboring upland infrastructure. **Table 7** summarizes losses observed at each R-monument along the Sector 5 shoreline.

Table 7. Volume Lost Under Construction Template

FDEP Monument	Distance (ft)	Post-Nicole (January 2023) to 2019 Construction	
		Vol. Density (cy/ft)	Volume (cy)
R-70		14.0	
	1,108.5		15,158
R-71		13.3	
	1,017.2		11,661
T-72		9.6	
	952.6		9,717
R-73		10.8	
	1,031.0		9,644
R-74		7.9	
	1,150.1		10,446
R-75		10.3	
	911.5		5,553
R-76		1.9	
	1,030.2		4,691
R-77		7.2	
	1,028.6		8,014
R-78		8.4	
	936.4		6,839
T-79		6.2	
	1,183.6		8,376
R-80		8.0	
	954.4		5,773
R-81		4.1	
	983.0		4,740
R-82		5.5	
	952.5		5,063
R-83		5.1	
	1,149.5		3,658
R-84		1.2	
	835.8		764
R-85		0.6	
	1,142.1		1,996
R-86		2.9	
Project Limits	Distance		
R-70 to R-86	16,367.0	6.8	112,100

7. DUNE VEGETATION

Indian River County has proactively managed the Sector 5 dune system since the first major restoration project. The 2019/2020 project placed approximately 128,800 dune plants along the project area dune crest. In addition to planned dune maintenance, the County fortified the Sector 5 dune in winter 2022 with approximately 135,000 additional dune plants at increased densities (Figure 14).



Figure 14. Newly planted sea oats from winter 2022.

The dune vegetation along the Sector 5 shoreline is in need of rehabilitation due to impacts from Hurricanes Ian and Nicole. The dune system provides valuable protection to coastal infrastructure in addition to serving as habitat. Based upon an analysis of the pre- and post-storm landward vegetation extents, there was an average overall cross-shore loss of vegetation of 19 ft. Utilizing dune retreat at each profile within the project area and the average loss of vegetated dune area, approximately 423,360 dune plants are required to fully replant the dune system.

8. COST ESTIMATE

The cost estimate to replace sand lost due to impacts from the 2022 hurricane season is based on obtaining material from upland sand mine(s) and transporting it to the project site via truck-haul method (Table 8). This was the method of construction utilized for the latest 2019/2020 renourishment. The itemized cost estimates are based on bids received previously. Engineering, Design, Permitting, and Construction Administration costs are estimated at 10% of the

construction cost, which is typical based on previous project experience. A 10% contingency is included to account for uncertainties such as inflation and fuel prices. The estimated cost to repair the damages from both storms is \$2,202,694.65 with 10% added for contingency. The costs associated with Hurricanes Ian and Nicole are \$484,592.82 and \$1,718,101.83, respectively.

Table 8. Estimated Construction Cost to Replace Volume Change to DOC

ITEM	PROJECT ELEMENT	UNIT	QUANTITY	UNIT COST*	COST
1)	Mobilization & Demobilization	LS	1	\$ 275,000.00	\$ 275,000.00
2)	Supply/Deliver/Place Sand	CY	13,036	\$ 51.35	\$ 669,398.60
3)	Beach Tilling	LS	1	\$ 28,560.00	\$ 28,560.00
4)	Environmental Compliance	LS	1	\$ 128,315.00	\$ 128,315.00
5)	Supply/Deliver/Plant Dune Vegetation	EA	423,360	\$ 1.07	\$ 452,995.20
6)	Site Restoration	LS	1	\$ 26,140.00	\$ 26,140.00
7)	Pre- and Post-Placement Surveys	LS	1	\$ 240,000.00	\$ 240,000.00
8)	Engineering, Design, Permitting, Construction Admin.			10% of Items 1-5	\$ 182,040.88
Subtotal Cost					\$ 2,002,449.68
Contingency				10%	\$ 200,244.97
Total Cost					\$ 2,202,694.65

*Unit cost estimates are based on bidding costs associated with the IRC Sector 3 project conducted in 2021/22

Additionally, construction costs to replace the volume lost under the design template are presented herein as the losses experienced within the dunes and upper contours of the dry beach are not expected to recover naturally (**Table 9**). As such, the estimated cost to repair the damages to the construction template from both storms is \$8,357,887.69 with 10% added for contingency. This methodology will return the project area to its intended storm protection.

Table 9. Estimated Construction Cost to Replace Template Losses

ITEM	PROJECT ELEMENT	UNIT	QUANTITY	UNIT COST*	COST
1)	Mobilization & Demobilization	LS	1	\$ 275,000.00	\$ 275,000.00
2)	Supply/Deliver/Place Sand	CY	112,100	\$ 51.35	\$ 5,756,335.00
3)	Beach Tilling	LS	1	\$ 28,560.00	\$ 28,560.00
4)	Environmental Compliance	LS	1	\$ 128,315.00	\$ 128,315.00
5)	Supply/Deliver/Plant Dune Vegetation	EA	423,360	\$ 1.07	\$ 452,995.20
6)	Site Restoration	LS	1	\$ 26,140.00	\$ 26,140.00
7)	Pre- and Post-Placement Surveys	LS	1	\$ 240,000.00	\$ 240,000.00
8)	Engineering, Design, Permitting, Construction Admin.			10% of Items 1-5	\$ 690,734.52
Subtotal Cost					\$ 7,598,079.72
Contingency				10%	\$ 759,807.97
Total Cost					\$ 8,357,887.69

*Unit cost estimates are based on bidding costs associated with the IRC Sector 3 project conducted in 2021/22

9. SUMMARY

During the storm inter-survey period, the Sector 5 engineered beach project experienced an average shoreline change of 1.8 ft, an average dune retreat of -19.4 ft, and a beach volume loss of -24,600 cy above the depth of closure. For the 5-month period between the pre-Ian survey (September 2022) and post-Nicole survey (January 2023), a background sand loss of -11,564 cy was estimated for the project area. After removing the background loss from the measured loss, the Sector 5 engineered beach project is estimated to have lost -13,036 cy of sand directly attributed to the impacts of Hurricanes Ian and Nicole. It is estimated that Hurricane Ian contributed to a volume loss of approximately -2,868 cy, and Hurricane Nicole contributed to a loss of -10,168 cy. The estimated cost to repair the damages from the 2022 hurricane season ranges from \$2,202,694.65 to \$8,357,887.69 (with 10% added for contingency) depending on type of volume losses considered (total profile loss versus losses from construction template). It is important to note that although FEMA's method of determining losses is minimal, the dune portion of the beach suffered severe damage following the 2022 hurricane season, which reduces the storm protection benefit of the engineered beach system. Due to the normal wave climate within the project area, it is unlikely that the dry beach will recover to pre-storm conditions.

10. REFERENCES

- APTIM, May 2022. Indian River County Sector 5 Beach & Dune Renourishment Project, Post-Construction Engineering Report. Prepared for Indian River County.
- CB&I Coastal Planning & Engineering, Inc. (CB&I) February 2015. Beach Preservation Plan, Indian River County. Prepared for Indian River County.
- Coastal Technology Corporation, December 2008a. Indian River County, Florida, Beach Preservation Plan. Prepared for Indian River County.
- Indian River County via James Gray, 2017. Indian River County Coastal Engineering Division. Email correspondence dated May 4, 2017.
- Indian River County Coastal Engineering Division, September 30, 2022. Beach Observation Report, Hurricane Ian.
- Indian River County Coastal Engineering Division, November 10, 2022. Beach Observation Report, Hurricane Nicole.
- National Hurricane Center, 2022 Tropical Cyclone Advisory Archive. National Oceanic and Atmospheric Administration (NOAA). <https://www.nhc.noaa.gov/archive/2022/>
- National Oceanic and Atmospheric Administration, 2022a. National Data Buoy Center. <http://www.ndbc.noaa.gov/>
- National Oceanic and Atmospheric Administration, 2022b. Tides & Currents. <http://tidesandcurrents.noaa.gov/>

APPENDIX A

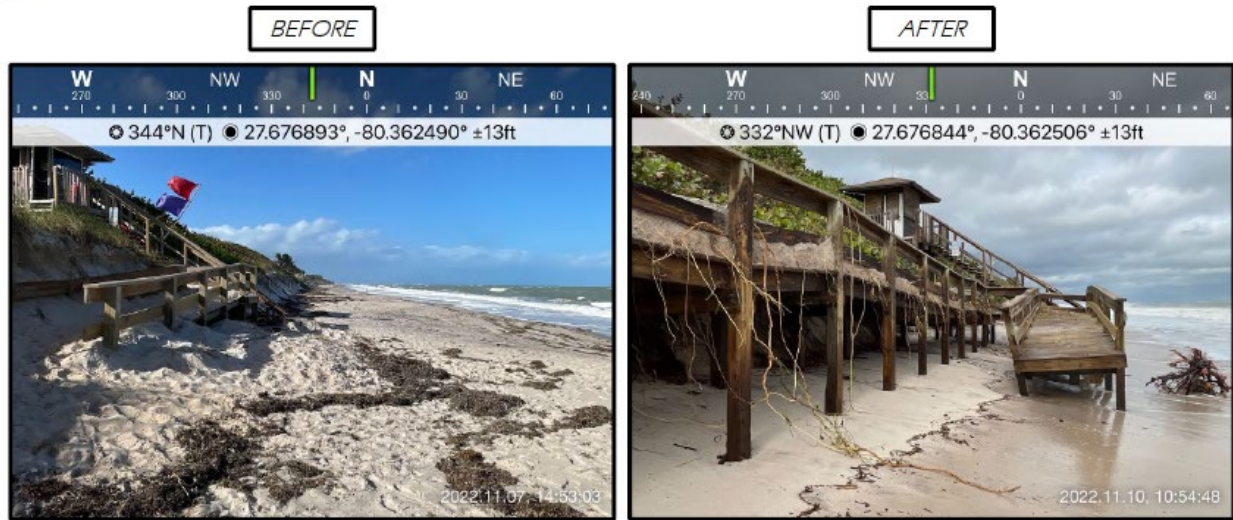
Beach Profile Cross-Sections

APPENDIX B

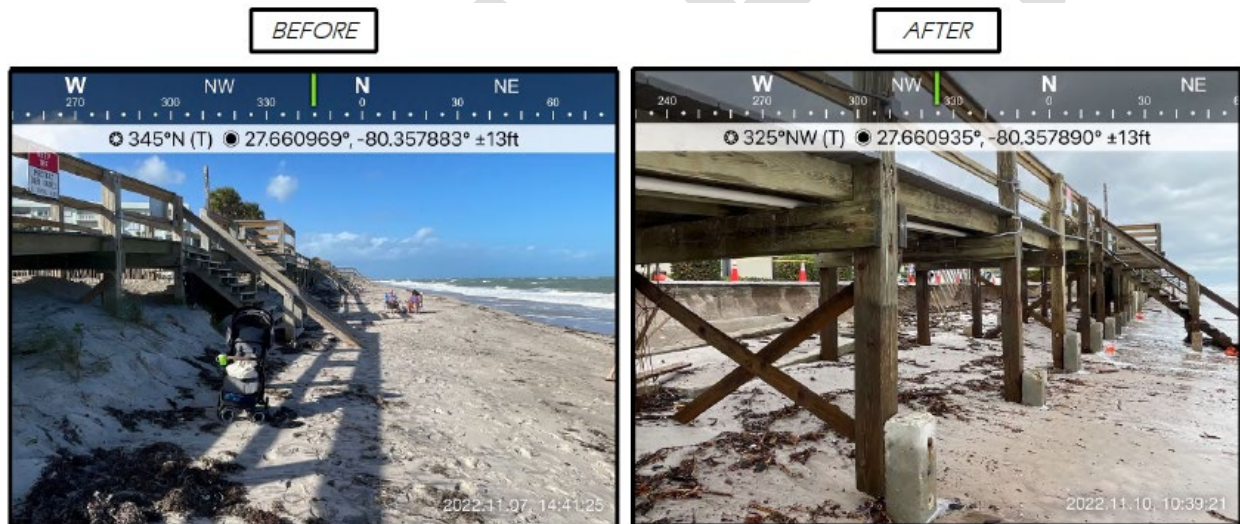
Pre- and Post-Storm Photographs

These photos are from Indian River County's Beach Observation Reports
for Hurricanes Ian and Nicole (IRC, 2022)

Hurricane Ian Before and After



Tracking Station Beach Park



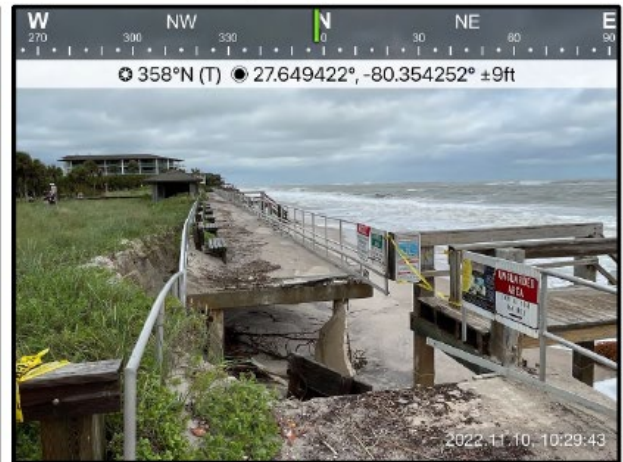
Staff observed a 3 ft lowering of the berm, with a dune retreat of 20 to 25 ft and an dune escarpment of 8 ft, resulting in Condition IV: Major Dune Erosion.

Jaycee Boardwalk

BEFORE



AFTER



Staff observed a 3 ft lowering of the berm, with a dune retreat of 12 ft and an dune escarpment of 6 to 8 ft, resulting in Condition IV: Major Dune Erosion.

Humiston Beach Park

AFTER



AFTER



Additional photos of the damaged COVB Humiston Boardwalk.

Humiston Beach Park Boardwalk