Hurricane Irma
Post-Storm Beach Conditions and
Coastal Impact in Florida

Division of Water Resource Management
Florida Department of Environmental Protection

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I. Introduction

Hurricane Irma made landfall on September 10, 2017, in the Florida Keys, and again on the Florida mainland at Marco Island. At landfall, Irma was a strong Category Four hurricane on the Saffir-Simpson Hurricane Wind Scale. This was Florida's first landfall of a major hurricane in 12 years since Hurricane Wilma made landfall in 2005 just south of Marco Island at Cape Romano. With the track of Irma northerly up the peninsula of Florida, most of the state felt some impact from either the winds, rain or storm surge. Given the strongest winds, waves, and storm surge of Irma were from the east, the entire east coast of Florida was substantially affected. Beach erosion and coastal damage was the greatest along the northeast coast and central Atlantic coast of Florida, as well as in the Florida Keys and along the coast of Collier County in southwest Florida. This report documents the post-storm beach conditions and coastal impact of Hurricane Irma.

The Florida Department of Environmental Protection (Department) developed this Post-storm Beach Conditions and Coastal Impact report to quantify the coastal damages caused by Hurricane Irma. This report provides an assessment of storm impact, beach and dune erosion, and structural damages to the coastal regions of Florida fronting the Atlantic Ocean, Gulf of Mexico and Straits of Florida. Although extensive structural damage occurred well inland of the coast, the damage assessment in this report specifically focuses on damage within the coastal building zone, as defined in Chapter 161, Florida Statutes.

Following the impact of Hurricane Irma, two damage assessment teams from the Department's Engineering, Hydrology and Geology Program (EHG) were dispatched in September 2017 to the coastal areas affected by Irma, with the exception of the Florida Keys. Given the extent of damage and emergency recovery activities being conducted within the Keys, damage assessments were postponed a few weeks for Monroe County until October 2017. The EHG damage assessment teams from the Department were as follows:

- Team 1: Ralph Clark, P.E., Coastal Engineer; Mike Manausa, Coastal Engineer; Tyler Boland, Surveyor
- Team 2: Guy Weeks, Planning Manager; Peter Bacopoulos, P.E., Coastal Engineer; Shane Duinkerken, Surveyor

These EHG damage assessment teams conducted detailed damage assessments for the following counties – St. Johns, Flagler, Volusia, Collier, Lee, Charlotte, Sarasota and Manatee. Subsequently, a damage assessment team consisting of Ralph Clark and Guy Weeks conducted detailed damage assessments for

Brevard and Monroe counties. Initial post-storm inspections of the Florida Keys were conducted by Elizabeth Yongue from the Department's Marathon Branch Office. Additional data, information, and assistance was provided to the teams by Volusia County, Brevard County, Indian River County, Martin County, Monroe County, Collier County, Sarasota County, Pinellas County, City of Key West, Town of Jupiter Island, South Ponte Vedra-Vilano Beach Property Owners Association, various private coastal engineering firms, and various staff of the U.S. Army Corps of Engineers (USACE), Jacksonville District. Post-storm vertical aerial photography provided by the National Oceanic and Atmospheric Administration (NOAA) greatly assisted with the damage assessments of this report.

This post-storm report provides photographs taken by the damage assessment teams of some of the damage and beach erosion conditions relevant to the hurricane impact discussions. For additional Hurricane Irma photography obtained by the damage assessment teams, readers are referred to the Department's "Collection of Aerials and Shoreline Trends System" (C.O.A.S.T.S.) webpage at http://prodenv.dep.state.fl.us/DwrmCoasts/search.

II. Hurricane Irma (August 30 – September 11, 2017)

Hurricane Irma, the fourth hurricane of the 2017 hurricane season for the Atlantic Ocean, Caribbean Sea and Gulf of Mexico, spawned from a tropical wave that moved off the west coast of Africa. Satellite imagery indicated a large low-pressure area had become organized in the far eastern Atlantic, and Irma became the season's ninth tropical storm on Wednesday, August 30, 2017. Further intensification continued, and Irma reached hurricane strength on August 31, with a track that continued west-northwestward at over 10 miles per hour (mph). Throughout the day, Irma intensified rapidly and reached major hurricane status as a Category Three hurricane, with maximum sustained winds of 115 mph. Irma continued tracking westward as a Category Three major hurricane until Monday, September 4, when it underwent further rapid intensification to a Category Four major hurricane, with maximum sustained winds of 138 mph. Figure 1 illustrates the track history of Hurricane Irma combined with satellite imagery. This composite was developed by the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin – Madison.

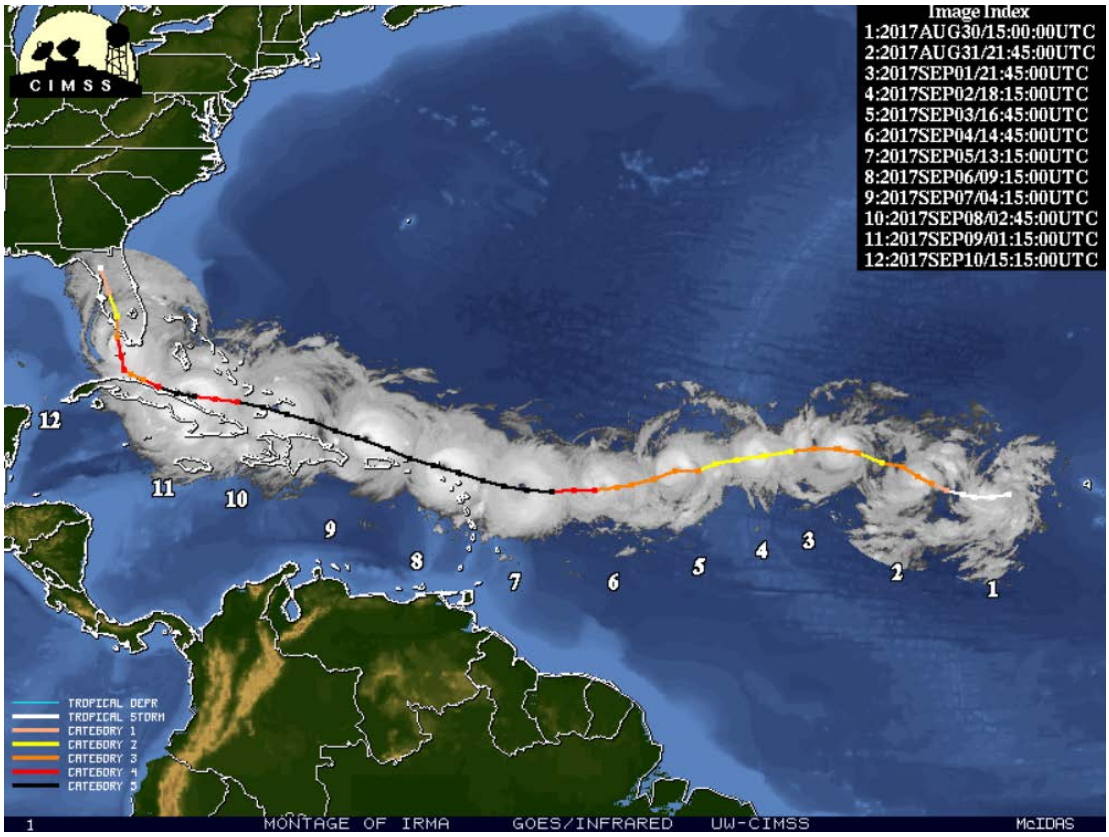


Figure 1. *Hurricane Irma track with landfall in the Florida Keys and the southwest coast of Florida (Source: CIMSS/University of Wisconsin – Madison).*

On Tuesday, September 5, Irma strengthened further becoming a large Category Five major hurricane, with maximum sustained winds of 185 mph. Hurricane advisories were announced for the northern Lesser Antilles, Virgin Islands and Puerto Rico. During the morning of Wednesday, September 6, the eye of Irma passed over the island nations of Barbuda, St. Barthelemy, and St. Martin, causing catastrophic damage. On St. Barthelemy at landfall as a Category Five hurricane, a minimum barometric pressure of 915.9 millibars was measured. A NOAA weather station on Barbuda measured a maximum sustain wind of 119 mph, and a maximum wind gust of 156 mph before the anemometer failed to record. Through the day, Irma passed over the British and U.S. Virgin Islands.

Irma passed north of Puerto Rico Wednesday night into Thursday morning, September 7, and just north of Dominican Republic and Haiti through Thursday evening, bringing major damage along the northern coasts of these island nations. Some weakening occurred as the storm went through an eyewall replacement cycle, and Irma was reclassified as a Category Four hurricane on Friday, September 8, with maximum sustained winds of 156 mph. However, U.S. Air Force measurements indicated Irma re-intensified Friday evening to Category Five status, with maximum sustained winds of 162 mph as it brushed the Turks and Caicos Islands and the southern Bahamas.

On Saturday, September 9, Irma passed over the Cuban Keys along the northern coast of Cuba. Throughout the day, the eye of Irma tracked west-northwesterly across land along the northern coast of Cuba, bringing catastrophic damages to the affected area. Late Saturday afternoon, the eye of Irma began to move away from the coast of Cuba into the Florida Straits. Given its nearly 24-hour track over land, Irma weakened somewhat to a Category Three hurricane, with maximum sustained winds of 111 mph.

In the morning hours on Sunday, September 10, Irma made a turn to the north and re-strengthened to a Category Four hurricane, with maximum sustained winds of 133 mph. The eye of Irma passed over the Florida Keys with official landfall on Cudjoe Key at 9:10 a.m. To the west of the eye, a National Ocean Service station in Key West measured sustained winds of 71 mph with a gust to 90 mph. The Key West Weather Service Forecast Office reported a gust to 91 mph. The eye of Irma moved away from the Keys in the late morning. A 75-mph sustained wind and an 87-mph gust were reported at the National Data Buoy Center (NDBC) C-MAN station at Fowey Rocks, adjacent to Biscayne Bay. A 109-mph gust was reported at Pines Middle School in Pembroke Pines.

By noon on Sunday, September 10, Irma's eye had substantially crossed Florida Bay. A 92-mph wind gust was reported at the Federal Aviation Administration station at Miami International Airport. At 3:35

p.m., the eye of Irma made landfall again on the southwestern coast of Florida at Marco Island, with an estimated intensity of 115 mph. A 130-mph wind gust was reported by the Marco Island Police Department. Sustained winds of 55 mph and a gust of 82 mph were reported at Naples Municipal Airport. Sustained winds of 63 mph and a gust of 84 mph was reported at Opa-Locka Executive Airport. At 6:00 p.m., a wind gust of 142 mph was reported at the Naples Municipal Airport. At 7:00 p.m., a wind gust of 88 mph was reported at the Southwest Florida International Airport in Fort Myers.

Throughout Sunday evening, Irma continued to track northerly through the Florida peninsula. At 10:00 p.m., the Juno Beach Pier in northern Palm Beach County reported a wind gust of 83 mph. The 11:00 p.m. advisory issued by the National Hurricane Center indicated that Irma had weakened to a Category Two hurricane with 98 mph winds. Irma continued to weaken as it tracked northward along the western Florida peninsula during the morning on Monday, September 11. The eye dissipated, and by 5:00 a.m., Irma had weakened to a Category One hurricane with maximum sustained winds of 75 mph. Hurricane force winds continued to occur in a band well northeast of the center along the northeast Florida coast, with sustained winds of 69 mph reported in the Jacksonville area. Irma continued to weaken to tropical storm strength and then to a depression Monday evening as it tracked north-northwesterly out of Florida and across Georgia. Irma brought flooding rains to northeast Florida, Georgia and South Carolina.

Irma was a hurricane for nearly 12 days, which included over three days as a Category Five hurricane. When Irma made landfall in the Florida Keys, it was a Category Four major hurricane and caused widespread damage across Monroe County. It made a second landfall at Marco Island in southwest Florida as a Category Three hurricane and had a devastating impact on coastal communities of Collier County fronted by the Ten Thousand Islands (Figure 2). As it tracked northward across the Florida peninsula, Irma weakened. Inland wind and flooding damages occurred throughout the peninsula to Orlando as Irma weakened to a Category Two and then a Category One hurricane. Irma continued to track northward across Florida and into Georgia as a strong tropical storm bringing widespread wind damages, particularly to trees. As the large rain bands blew into north and central Florida off the Atlantic Ocean, the northeastern coast of Florida experienced elevated storm tides, large waves, and gale force winds causing major beach and dune erosion and widespread damage to coastal structures. These rain bands also carried numerous small tornadoes, as tornado damage was clearly discernable on the coast of St. Johns, Volusia and Brevard counties. In addition, the storm tide coupled with stormwater runoff caused major flooding of the lower St. Johns River, which flooded Jacksonville (GEER, 2017).

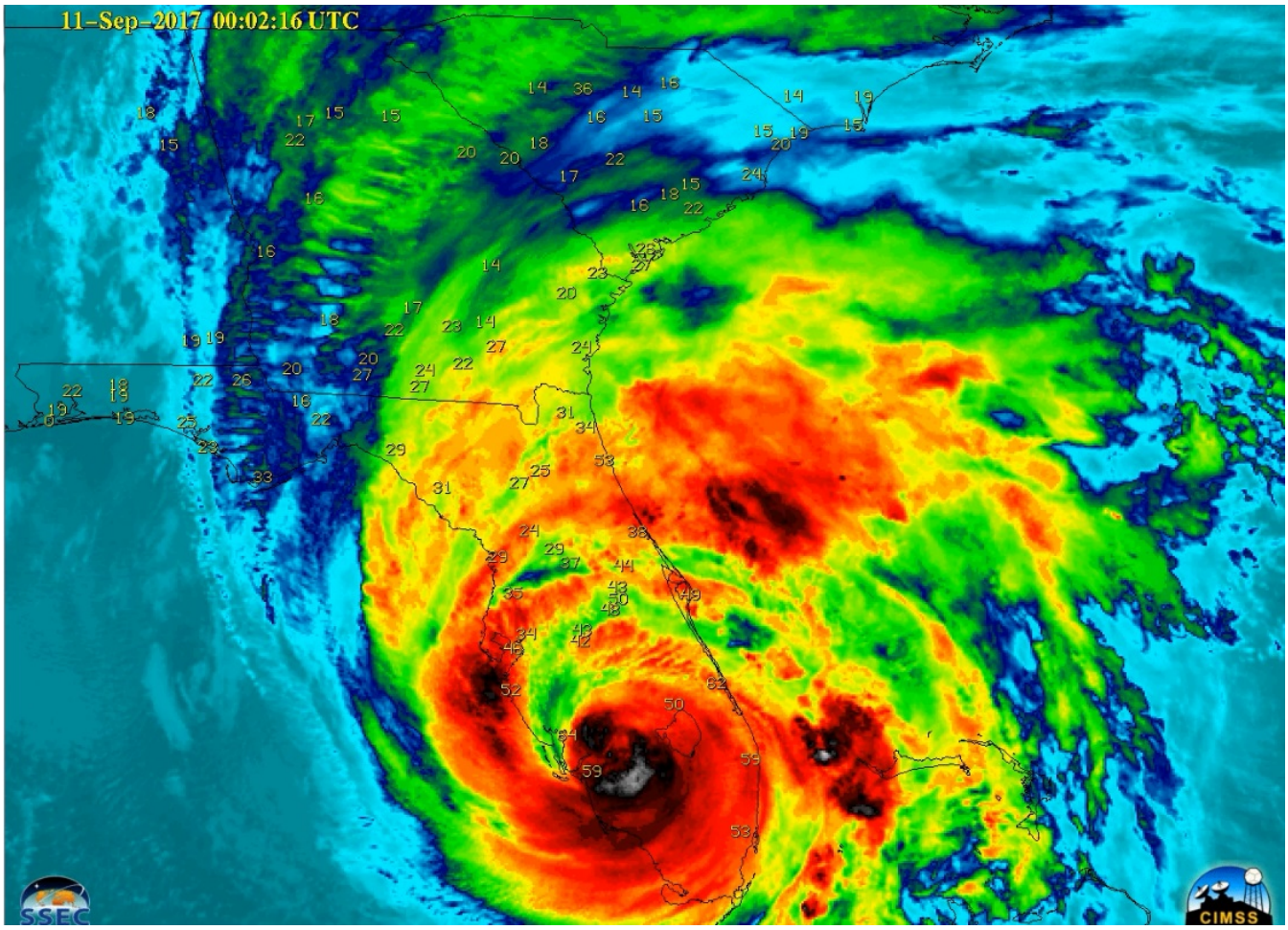


Figure 2. *Hurricane Irma wind field after landfall in Florida on September 11, 2017 (Source: CIMSS/University of Wisconsin – Madison).*

Substantial wind data are available from reporting stations throughout Florida. As this document presents the coastal impact on Florida, Figure 3 maps strategic wind data reports by presenting peak wind gusts and maximum sustained winds from selected weather monitoring stations around the coast of Florida.

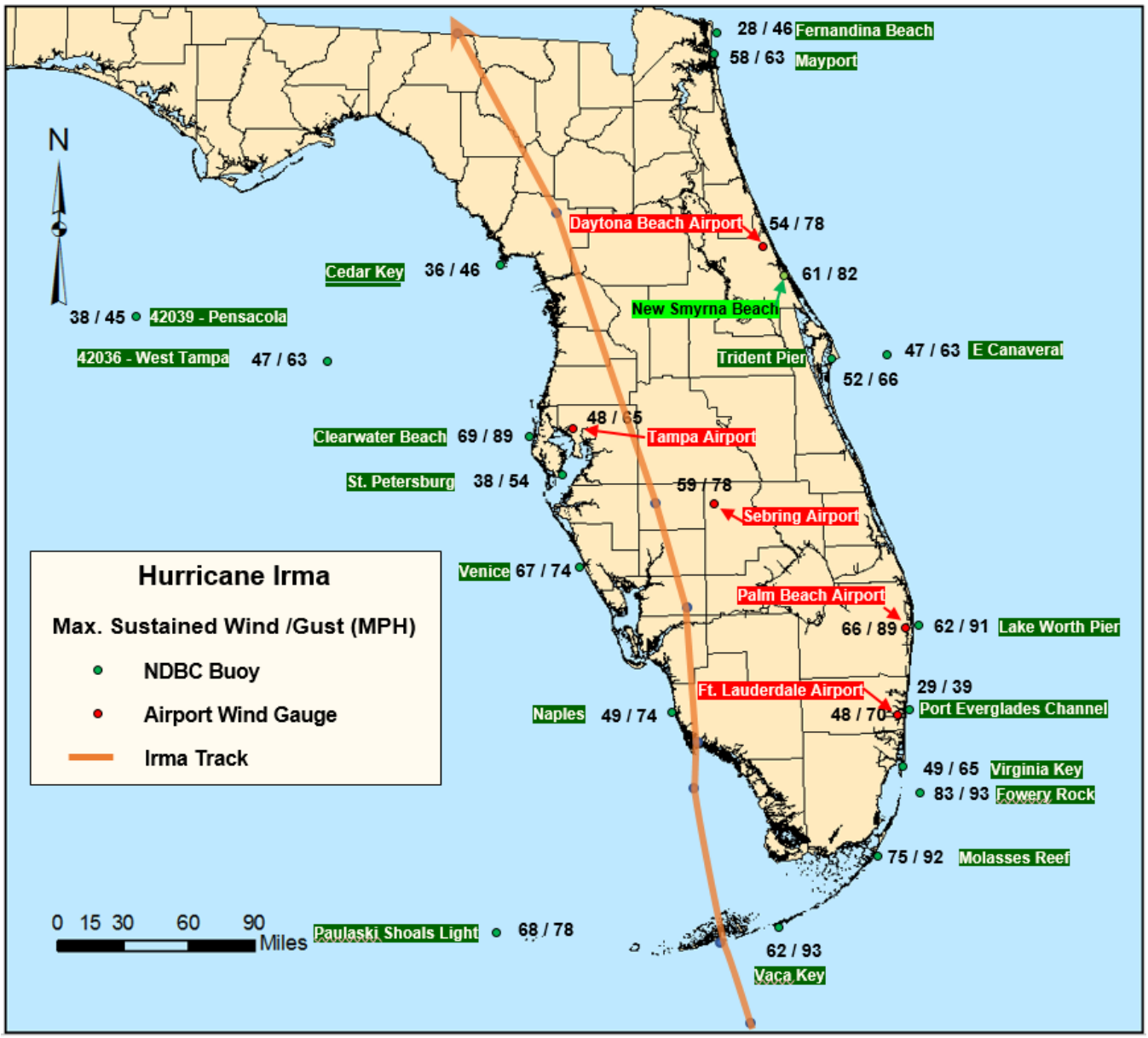


Figure 3. *Hurricane Irma wind data from recording stations (Sources: NDBC; National Weather Service).*

Storm tide data around the coast of Florida is available from several of the NOAA's recording tide gauges. In addition to these NOAA tide gauges, special storm-tide sensors that can measure the height, extent, and timing of the storm tide were deployed by the U.S. Geological Survey (USGS). Additional high-water marks from surveyed seaweed wrack lines and mud lines inside of buildings were also obtained by the USGS. Wave data from seven NDBC buoy stations, located in the Gulf of Mexico and Atlantic Ocean, are available. A graphic depiction of the peak storm tide levels, high-water marks and wave heights during Irma is presented in Figure 4.

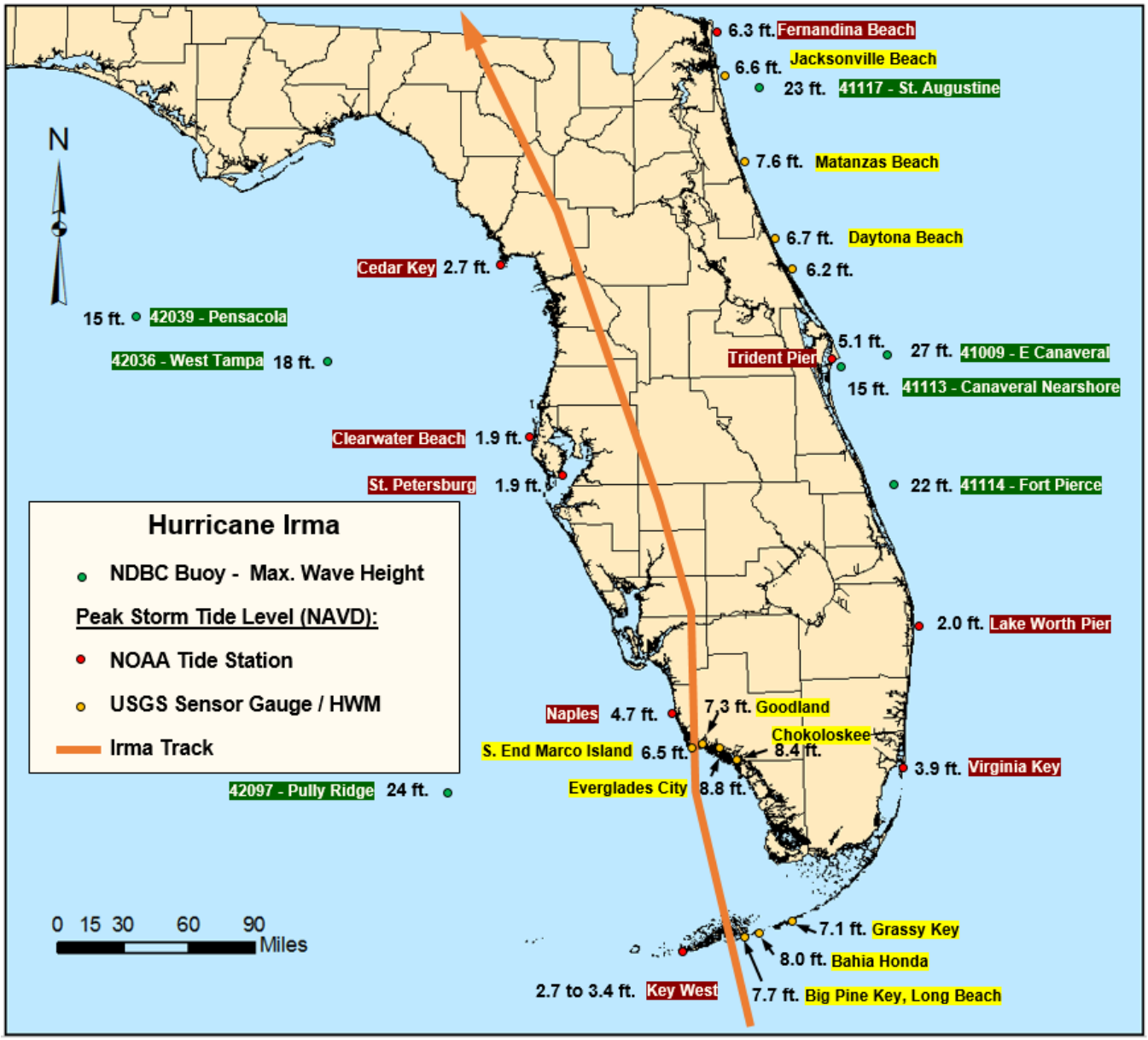


***Figure 4**. Hurricane Irma peak storm tide levels, high-water marks, and maximum offshore wave heights (Sources: NDBC; National Ocean Survey, NOAA; USGS).*

The highest measured storm tide along the southwest gulf region's barrier beaches was measured at the National Ocean Survey tide station located on the Naples Fishing Pier shortly after Hurricane Irma's landfall at Marco Island (Figure 5). Noteworthy with the Naples measured tide data is the nearly 10-foot swing between the extreme low tide and the peak storm tide. North of Marco Island, including Naples, the position of the coast to the west of the hurricane's eye passage resulted in the initial winds blowing offshore. This resulted in a set-down, or squat, of the Gulf water level, which was measured at approximately -5.0 feet NAVD at Naples. As the eye of the hurricane passed inland, the wind field rotating around the eye shifted onshore, resulting in the eventual peak surge of +4.7 feet NAVD. Along the entire

Gulf Coast north of Marco Island, this squat and surge cycle continued to a lesser scale as the hurricane tracked northward and weakened over land.

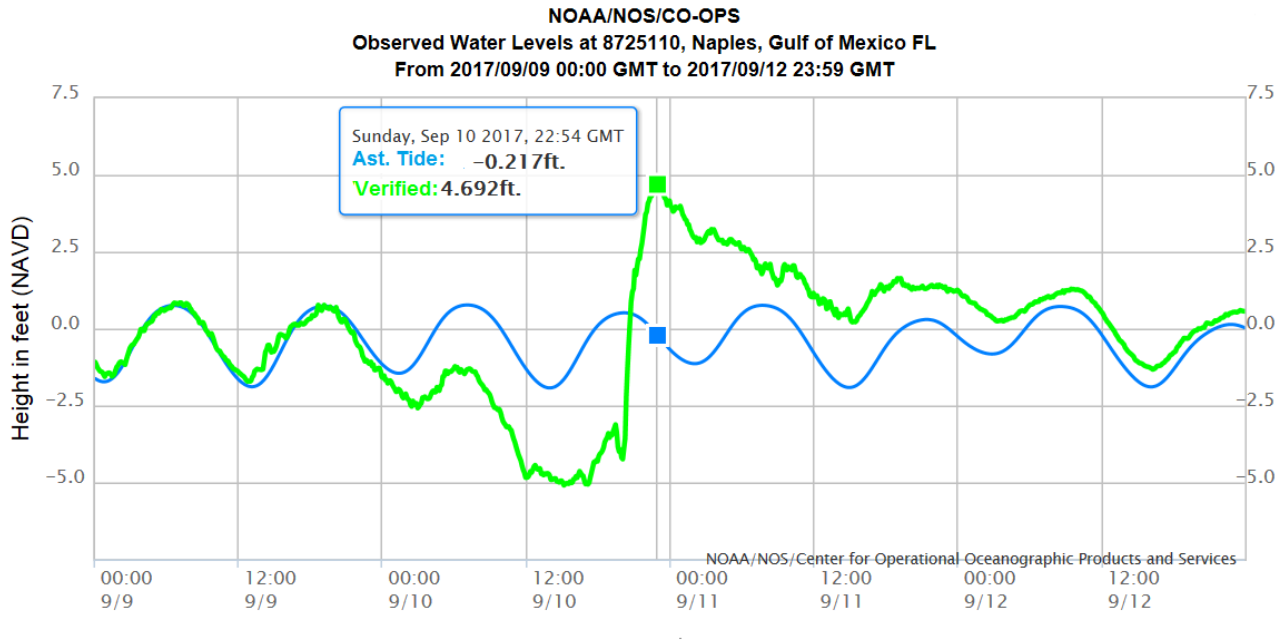


***Figure 5**. Measured gulf storm tide levels at Naples during Hurricane Irma (Sources: National Ocean Survey, NOAA).*

The USGS obtained peak storm tide measurements of Hurricane Irma at landfall located to the east of the eye at Everglades City adjacent to the Ten Thousand Islands. The storm tide was measured to be +8.78 feet NAVD in Everglades City, +8.39 feet NAVD in Chokoloskee, +7.306 feet NAVD in Goodland, and +6.47 feet NAVD at the southern end of Marco Island. In the Florida Keys, among the peak storm tide measurements by the USGS were +7.1 feet NAVD on Grassy Key, +8.04 feet NAVD on Bahia Honda Key, +7.723 feet NAVD on Big Pine Key, and between +3.371 and +2.735 feet NAVD on Key West. The Atlantic coast of Florida north of Cape Canaveral experienced storm tides of 6 to 7 feet. The astronomical tides are higher in this region of the Florida coast, and when coupled with the persistent westward wind field of Irma and storm wave setup along the northeastern Florida beaches, significantly higher water levels were experienced. These higher water levels with onshore winds and waves resulted in major beach and dune erosion along Florida's east coast, as well as widespread structural damages, primarily north of Sebastian Inlet.

III. Hurricane Irma Impact Summary and Overview

This section provides a summary of the beach and dune erosion, and structural damage that occurred in the more substantially effected coastal counties.

Table 1 lists beach and dune erosion conditions around state, starting with northeastern Florida and continuing southward, and then crossing to southwestern Florida and continuing northward. In a few coastal areas, qualified local government staff provided sufficient information to the Department to allow inclusion of specific beaches. Areas not assessed are listed as 'NA,' and areas with no erosion are listed as '- '. Reference or Range ("R") monuments are historical survey markers established by the Department that are spaced approximately every 1,000 feet along the shore as a point of reference to measure beach erosion. A graphic depiction of the classification of beach erosion conditions is provided in Figure 6.

Table 1. *Beach and Dune Erosion Summary.*

Nassau County

Locations	Reference Monuments	Erosion Condition
Amelia Island	R1 - R59	NA
Amelia Island Plantation	R59 - R79	II

Duval County

Locations	Reference Monuments	Erosion Condition
Little Talbot Island	R1 - R30	NA
Mayport, Hanna Park	R31 - R43	NA
Atlantic, Neptune and Jacksonville Beaches	R43 - R80	II - III

St. Johns County

Locations	Reference Monuments	Erosion Condition
Ponte Vedra	R1 - R46	II - IV
Guana Reserve	R46 - R67	IV
South Ponte Vedra	R67 - R101	IV
Vilano Beach	R101 - R119	III - IV
Porpoise Point	R120 - R122	II
Anastasia State Park	R123 - R141	IV
St. Augustine Beach, Crescent Beach	R141 - R196	III - IV
Summer Haven	R197 - R209	IV

Flagler County

Locations	Reference Monuments	Erosion Condition
Marineland to Washington Oaks	R1 - R16	IV
Palm Coast	R16 - R44	IV
Painters Hill	R44 - R60	IV
Beverly Beach and Flagler Beach	R60 - R100	II

Volusia County

Locations	Reference Monuments	Erosion Condition
Tomoka Preserve	R1 - R16	II
Ormond by the Sea	R16 - R57	II
Ormond Beach, Daytona Beach, Daytona Beach Shores	R57 - R118	II
Wilbur by the Sea, Town of Ponce Inlet	R118 - R135	II
North of Ponce de Leon Inlet	R135 - R148	III - IV
South of Ponce de Leon Inlet	R149 - R151.5	IV
New Smyrna Beach and Bethune Beach	R152 - R208	II
Cape Canaveral National Seashore	R208 - R234	II

Brevard County

Locations	Reference Monuments	Erosion Condition
Cape Canaveral National Seashore	V1 - V62	NA
Kennedy Space Center	V63 - V167	NA
Canaveral Beach	R1- R5	IV
Canaveral Beach	R6 - R15	II - III
Cocoa Beach	R16 - R55	I - II
Patrick Air Force Base	R56 - R75	I
Satellite Beach	R76 - R96	II - III
Indian Harbor Beach (Shell Street)	R97 - R99	IV
Indian Harbor Beach	R100 - R109	III
Indialantic, Melbourne Beach	R110 - R139	I - II
South Brevard Beaches	R140 - R213	II - IV
Sebastian Inlet State Park	R214 - R219	II

Indian River County *(Reference – Indian River Co., 2017)*

Locations	Reference Monuments	Erosion Condition
Sebastian Inlet State Park, Ambersand Beach	R1 - R17	III
Wabasso Beach	R17 - R55	III
John’s Island	R55 - R72	III - IV
Vero Beach	R72 - R86	III
South Beach	R86 - R97	I
Seagrove to Moorings	R97 - R108	III
Moorings to Round Island Beach Park	R108 - R119	I

St. Lucie County

Locations	Reference Monuments	Erosion Condition
North St. Lucie	R1 – R33	I-II
South of Ft. Pierce Inlet	R34-R37	III
Ft. Pierce and Hutchinson Island	R37-R97	I-II
South St. Lucie County	R97-R104	III
South St. Lucie County	R105-R115	I-II

Martin County

Locations	Reference Monuments	Erosion Condition
Hutchinson Island	R1 – R34	I
Hutchinson Island	R34.5	III
Hutchinson Island	R35-R42	I
Northern Jupiter Island	R43 - R76	NA
Town of Jupiter Island (Reference – Town of Jupiter Island, 2017)	R77 - R127	I

Palm Beach County

Locations	Reference Monuments	Erosion Condition
Coral Cove, Tequesta, Jupiter Inlet Colony	R1 – R12	I-III
Jupiter Carlin	R13-R19	I-II
South Jupiter	R19-R26	I-III
Juno Beach	R26-R38	I
Turtle Beach and John D. MacArthur State Park	R39-R60	I-III
Singer Island	R61-R75	I-III
Town of Palm Beach	R76-R116	I-II
Palm Beach, Lake Worth, South Palm Beach	R116.5-R137	I
Lantana and Manalapan	R137-R151	I-II
Ocean Ridge	R152-R160	I-II
Briny Breezes and Gulf Stream	R160-R170	NA
Delray Beach	R171-R192	I
Highland Beach	R193-R200	NA
Highland Beach	R201-R204.5	II
Boca Raton	R205-R227	I

Broward County

Locations	Reference Monuments	Erosion Condition
Hillsboro Beach – Ft. Lauderdale Beach	R1 – R85	I
Dr. Von D. Mizell – Eula Johnson State Park	R86-R89	IV
Dr. Von D. Mizell – Eula Johnson State Park	R90-R98	I
Dania Beach	R98-R102	II
Hollywood Beach	R102-R115	I

Miami-Dade County

Locations	Reference Monuments	Erosion Condition
Golden Beach – Miami Beach	R1 – R74	I
Virginia Key	R79-R88	I
Key Biscayne	R92-R113	I

Monroe County

Island	Erosion Condition
Lower Matecumbe Key – Sea Oats Beach, Anne's Beach	IV
Long Key	IV
Grassy Key	I - IV
Little Crawl Key	III - IV
Coco Plum Beach	I - IV
Key Colony Beach	IV
Vaca Key – Sombrero Beach	IV
Little Duck Key	IV
Missouri Key	IV
Ohio Key	IV
Bahia Honda Key	IV
Spanish Harbor Keys	IV
Big Pine Key – Long Beach	IV
Newfound Harbor Keys	IV
Sugarloaf Key – Sugarloaf Beach	II
Boca Chica Key	II
Key West	I - II

Collier County

Locations	Reference Monuments	Erosion Condition
Barefoot Beach	R1 - R16	I - II, IV
Delnor-Wiggins Pass State Park	R17 - R22	II - III
Vanderbilt Beach	R22 - R39	I - II
Pelican Bay Beach	R39 - R41	I
Naples	R42 - R89	II
Keewaydin Island	R90 - R127	I
Sea Oat Island	V304 - V308	NA
Hideaway Beach	R128 - V311	II
Marco Island	R128 - R148	I - II
Kice Island	V323 - V332	NA
Morgan Island	V333 - V339	NA
Cape Romano	V341 - V344	IV
Ten Thousand Islands	No Monumentation	NA

Lee County

Locations	Reference Monuments	Erosion Condition
Gasparilla Island	R1 - R17	-
Gasparilla Island	R18 - R21	I
Gasparilla Island	R22 - R26	IV
Cayo Costa Island	R27 - R65	NA
North Captiva Island	R66 - R83	NA
Captiva Island	R84 - R98	II
Captiva Island	R99 - R109	-
Sanibel Island	R110 - R130	-
Sanibel Island	R131 - R154	II
Sanibel Island	R155 - R174	-
Estero Island (Fort Myers Beach)	R175- R180	I
Fort Myers Beach Pier	R181	IV
Estero Island (Fort Myers Beach)	R182- R189	I
Estero Island (Fort Myers Beach)	R190 - R194	IV
Estero Island (Fort Myers Beach)	R195 - R199	I
Lovers Key	R213 - R221	I
Lovers Key	R221- R222	III
Big Hickory Island	R222 - R225	NA
Bonita Beach	R226 - R239	-

Charlotte County

Locations	Reference Monuments	Erosion Condition
Manasota Key – Englewood Beach	R1 - R15	I
Manasota Key – Englewood Beach	R16 - R21	II
Knight Island and Don Pedro Island	R22 - R57	NA
Gasparilla Island	R58 - R68	I

Sarasota County

Locations	Reference Monuments	Erosion Condition
Longboat Key	R1 - R37	-
Lido Key	R37 - R42	II
Lido Key	R43 - R44	III
Siesta Key	R45 - R62	-
Siesta Key	R63 - R75	-
Siesta Key	R76 - R77	NA
Casey Key	R78 - R91	II
Casey Key	R92 - R99	-
Casey Key	R100 - R107	II
Venice Beach	R108 – R114	-
Venice Beach	R115 – R137	NA
Manasota Key	R138 - R149	IV
Manasota Key	R150 - R174	II
Manasota Key	R175 - R176	IV
Manasota Key	R176 - R183	-

Manatee County

Locations	Reference Monuments	Erosion Condition
Anna Maria Island	City Pier - R2	II
Holmes Beach, Bradenton Beach, Cortez Beach	R2 - R33	-
Coquina Beach	R34 - R36	II
Longboat Key	R42 - R45	IV
Longboat Key	R45 - R67	-

Pinellas County *(Reference – Pinellas County, 2017)*

Locations	Reference Monuments	Erosion Condition
Anclote Key	No Monumentation	NA
Honeymoon Island	R1 - R15	I
Caladesi Island	R16 - R28	NA
Clearwater Beach Island	R29 - R50	I
Northern Sand Key: Clearwater, Bellaire Beach, Indian Rocks Beach	R51 - R85	II
Southern Sand Key: Indian Shores, Redington Shores, North Redington Beach, Redington Beach, Madeira Beach	R86 - R125	I
Treasure Island	R126 - R143	I
Long Key	R144 - R166	I
Shell Key	No Monumentation	NA
Mullet Key	R167 - R192	I

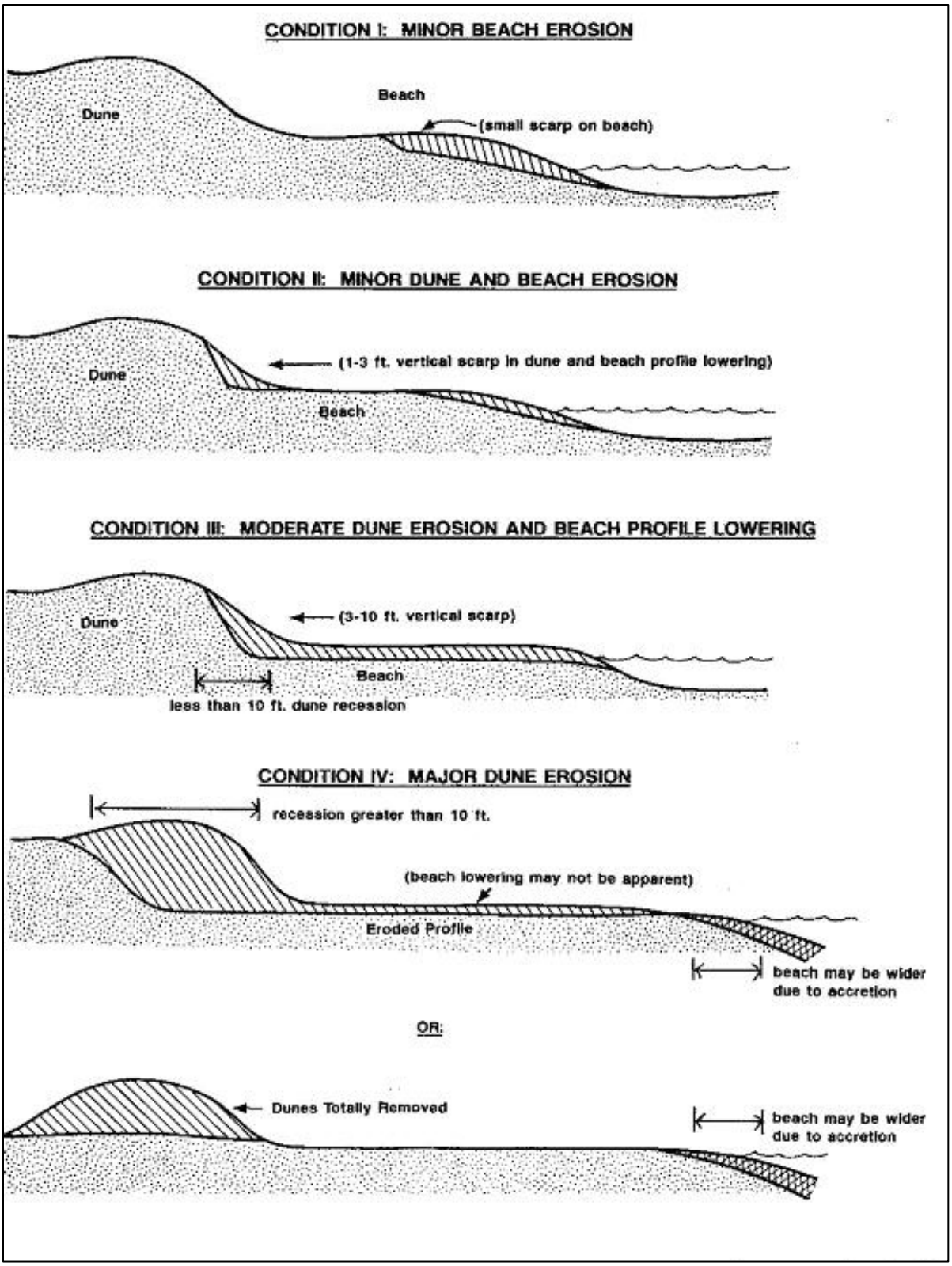


Figure 6*. Beach and dune erosion conditions, I to IV.*

Major Structural Damage

The most severe structural damage from Irma occurred in the Florida Keys and five small coastal communities adjacent to the Ten Thousand Islands. The NOAA flew vertical aerial photography a few days after the storm for selected areas of Florida. Although the Department's EHG damage assessment teams did not assess damages on the ground at the five coastal communities adjacent to the Ten Thousand Islands, a rough assessment of the damage has been made using NOAA post-storm aerial photography.

The county and municipal building departments of Monroe County have determined that 1,179 buildings were destroyed by Hurricane Irma. In Monroe County, the Department's EHG damage assessment team did not assess the impact to all upland structures, which would have duplicated the large volume of work of the local government building departments. Therefore, the damage assessment team in Monroe County only assessed the erosion conditions of the beaches and the damage to coastal armoring. An assessment of the damage to development along the Straits of Florida based upon the incidental observations of the damage assessment team is provided in the discussion for individual islands in Section V of this report.

The northeastern and central coastal counties with the greatest structural damages were St. Johns, Flagler, Volusia and Brevard. Dwellings and other coastal structures within these counties were left highly vulnerable following the impact of Hurricane Matthew in October 2016. An overall summary of structural damage to major structures is given in Table 2. A summary of damage to coastal armoring, including seawalls, bulkheads, retaining walls, revetments, sills, or other rigid coastal protection structures, is provided in Table 3. Not included in this table are rigid shore-protection structures like groins and breakwaters, or navigation structures like jetties.

A more detailed description of the beach and dune erosion conditions and impacts to coastal armoring and development is provided in Sections IV and V of this report. Section IV provides a detailed discussion of the erosion conditions and coastal impacts on a county-by-county basis for the eastern coastal counties of St. Johns, Flagler, Volusia and Brevard, and the western coastal counties of Collier, Lee, Charlotte, Sarasota and Manatee. County maps are provided showing the existing beach management projects and the post-Irma beach and dune erosion conditions. The maps are followed by a discussion of the erosion conditions and damage along with ground photographs that highlight the impacts. Section V provides a detailed discussion of the erosion conditions and coastal impacts to the Florida Keys. Individual islands are discussed starting with Lower Matecumbe Key in the middle keys and continuing westward through the islands of the middle and lower keys to Key West.

Table 2. *Summary of Major Structural Damage to Major Structures by Hurricane Irma along the Coast of Peninsula Florida (Florida Keys not included).*

County	# Single-Family Dwellings with Major Damage	# Multifamily Dwellings[1] with Major Damage	# Other Major Structures[2] with Major Damage	Total # of Structures with Major Damage[3]
St. Johns	136	32	3	171
Flagler	61	7	10	78
Volusia	69	26	11	106
Brevard	55	126	36	217
Palm Bch	0	0	1	1
Collier	188	24	19	231
Lee	1	2	3	6
Charlotte	1	0	0	1
Sarasota	0	0	1	1
Manatee	0	0	1	1
TOTAL	**511**	**217**	**85**	**813**

1) Multifamily dwellings include condominiums, townhouses, apartment buildings, hotels and motels.
2) Other major structures include commercial buildings (restaurants, stores, beach bars, etc.), recreational buildings and non-habitable major structures (i.e., piers, pools, pavilions and parking lots).
3) Not included in this summary are minor structures (i.e., walkways, decks, driveways, patios, etc.), coastal and shore protection structures (i.e., seawalls, revetments, sills, groins, jetties), minor damage to major structures, structures located inland of the coastal building zone, or structures with hydrostatic flooding damage caused by the storm surge or stormwater runoff.

Table 3. *Summary of Coastal Armoring Damage Caused by Hurricane Irma.*

County	Armoring Damage in Feet
St. Johns	3,470
Flagler	160
Volusia	100
Brevard	50
Broward	60
Monroe	8,725
Collier	3,575
Lee	30
TOTAL	**16,170 (3.06 miles)**

Southeast Florida was not without damage to coastal structures. In Palm Beach County, the Lake Worth Pier sustained damage due to the breaking wave loads of Irma. At Hillsboro Inlet in Broward County, 60 feet of concrete seawall was destroyed (Level IV damage). And at Port Everglades, the south jetty sustained minor damage (Level II damage), which involved the relocation of jetty boulders and damage to the concrete jetty cap. The south jetty spur also sustained Level II damage through the relocation of boulders from the crest of the structure. Figure 7 provides a graphic depiction of coastal damage levels for coastal and shore protection structures.

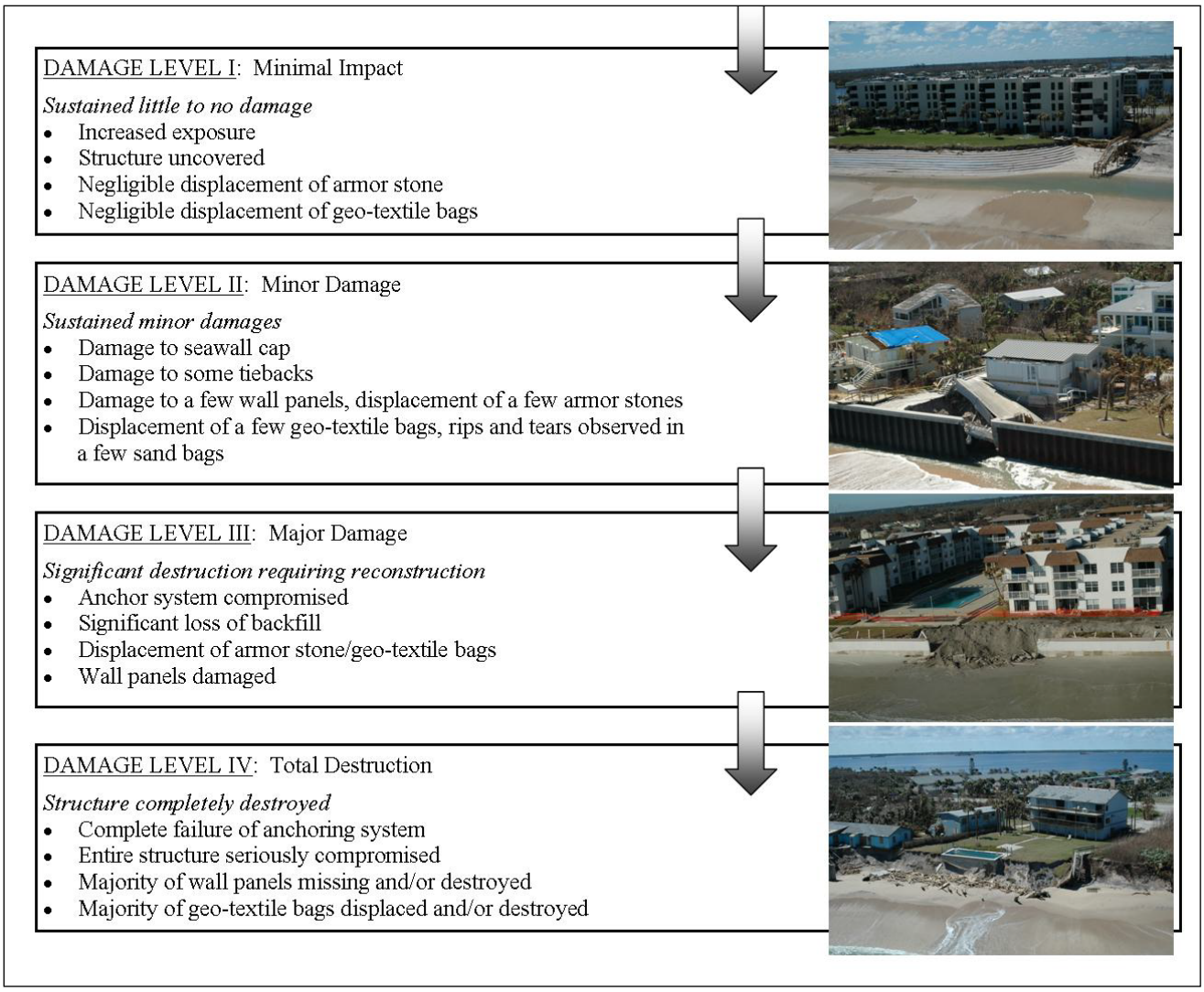


Figure 7. *Levels of damage to coastal and shore protection structures (seawalls, bulkheads, revetments, groins, breakwaters, etc.)*

IV. Detailed Assessment by County



***Figure 8**. St. Johns County beach and dune erosion conditions from Hurricane Irma.*

St. Johns County

The St. Johns County coast extends for 41.1 miles between Duval and Flagler counties and includes the barrier beach communities and major park systems of Ponte Vedra Beach, Guana River State Park, South Ponte Vedra Beach, Vilano Beach, Porpoise Point, Conch Island (Anastasia State Park), St. Augustine Beach, Crescent Beach, Fort Matanzas National Monument, and Summer Haven (see Figure 8 above). St. Augustine Inlet between Vilano Beach and Conch Island has a federal navigation project, which likely experienced significant shoaling due to Hurricane Irma. Continued shoaling was also observed at Matanzas Inlet between Anastasia Island and Summer Haven near the southern end of the county.

The net direction of longshore transport along the St. Johns County coast is generally to the south, with some drift reversals in the vicinity of the inlets. The northern St. Johns County coast is characterized by moderate to high wave energy and relatively narrow, steep beaches. Anastasia Island to the south has relatively broad, gradually sloping beaches and large dynamic dune fields. At the south end of the county, the Summer Haven beaches and dunes are a narrow strand between the Atlantic Ocean and the Matanzas River Lagoon (this segment of the Matanzas River is called the Summer Haven River by locals).

There are four critically eroded areas (15.3 miles) and one non-critically eroded area (0.5 mile) in St. Johns County. Near the center of the county north of St. Augustine Inlet is a critically eroded beach segment along South Ponte Vedra Beach and Vilano Beach (R76-R117; 8.1 miles), threatening private development and State Road AIA. South of St. Augustine Inlet, the northern 1.0 mile of Conch Island (R123-R128) is critically eroded, threatening beach mouse and shorebird nesting habitat. To the south, 3.8 miles of beach (R132-R152) along Conch Island and Anastasia Island through St. Augustine Beach are critically eroded, threatening development and recreational interests. Much of this area has a rock revetment, and inlet channel maintenance dredging disposal is being conducted. Beach restoration has been conducted in this area. The southern tip of Anastasia Island (R193.5-R196) has 0.5 mile of non-critical erosion north of Matanzas Inlet within the Fort Matanzas National Monument. The southern 2.4 miles of St. Johns County beaches (R197-R209) are critically eroded between Matanzas Inlet and the Flagler County line. The northern portion threatens State Road A1A and private development. Although the State Road A1A roadbed has been abandoned along the southern segment, wildlife habitat within the Matanzas River lagoon is being threatened with continued storm surge overwash and breaches. This area was recently restored by excavating overwash sediments from the river.

Storm Effects and Erosion Conditions

The storm tides of Hurricane Irma in St. Johns County generally ranged between 6 to 7 feet above sea level. The USGS measured a storm tide in southern St. Johns County near Matanzas Inlet to be +7.6 feet

NAVD. The St. Johns County coast was substantially impacted by Hurricane Matthew in October 2016, and again by Hurricane Irma with major beach and dune erosion (condition IV). During the 11 months between Hurricanes Matthew and Irma, some emergency public and private fill placements along the toe of the eroded dune had taken place, along with some minor natural beach recovery. Table 4 provides the countywide erosion volumes in cubic yards, dune bluff recession and shoreline recession. The erosion volumes were obtained from pre-storm and post-storm LIDAR flown by the USACE, and represent volumes lost above mean high water.

Table 4. *St. Johns County Erosion Volumes, Beach and Dune Recession.*

Location	DEP Monuments	Volume Change above MHW (cy)	Average Dune Recession at the 9-foot Contour (feet)	Average Shoreline Change (feet)
Ponte Vedra	R1 - R46	-472,997	-22.3	-24.3
Guana Tolomato Matanzas National Estuarine Research Reserve	R46 - R67	-104,907	-27.9	-11.6
South Ponte Vedra	R67 - R101	-117,251	-11.7	-19.5
Vilano	R101 - R122	-113,927	-12.8	-20.1
Anastasia Island State Park	R123 - R141	-134,261	-4.4	-37.7
St. Augustine	R141 - R196	-559,466	-6.0	-59.7
Summer Haven	R197 - R209	-16,108	NA	15.1
Countywide	**R1 - R209**	**-1,518,917**	**-12.9**	**-30.5**

Irma's impact along the northern coast of St. John's County (R1-R118) north of St. Augustine Inlet was particularly severe, resulting in 115 buildings being left in imminent danger of incurring damage from another major storm (see Figure 9 and Figure 10). Example profiles of the major beach and dune erosion are shown in Figure 11 at R28 in Ponte Vedra and in Figure 12 at R94 in South Ponte Vedra adjacent to three destroyed single-family dwellings. South of St. Augustine Inlet, major beach and dune erosion (condition IV) was sustained along Anastasia Island State Park (R123-R140). Along the developed segment of Anastasia Island (R140-R193), including St. Augustine Beach, Crescent Beach and Matanzas Shores, the island sustained moderate to major beach and dune erosion (condition III to IV). Major beach and dune erosion is shown in Figure 13 at R142 in St. Augustine Beach adjacent the St. Augustine Beach

Fishing Pier. Major beach and dune erosion (condition IV) was also sustained along Matanzas Inlet National Monument (R194-R196) at the south end of Anastasia Island.

South of Matanzas Inlet (R197-R209), the beach community of Summer Haven sustained major beach and dune erosion (condition IV). Hurricane Matthew's impact on Summer Haven in October 2016 was the most severe since Hurricane Dora in 1964, resulting in part of the granite boulder revetment and old State Road A1A being destroyed along with eight houses between R197 and R200. Hurricane Matthew also caused a major tidal breach across the barrier beach and entire coastal barrier near R204, which needed to be closed in an emergency project after the storm. After Hurricane Matthew, a previously planned and authorized beach and river restoration project began, which involved excavating overwash sand from the Matanzas River and constructing a barrier dune and nourished beach berm for roughly 5,000 feet between R200 and R205. Irma caused little damage to the revetment and old A1A between R197 and R200; however, roughly 90 percent of the fill from the beach and river restoration project appears to have been lost from the fill template between R200 and R205. Part of this material was transported seaward and part of the placement material was spread back into the river as overwash deposits. Low depressions in the barrier existed after Irma's passage prompting emergency remedial fill placement to prevent a tidal breach from developing like the breach caused by Hurricane Matthew. Figure 14 shows post-Matthew and post-Irma profile changes at R203.

Storm Damage

Hurricane Irma caused roughly twice the coastal building damage in St. Johns County as was sustained during Hurricane Matthew. Matthew caused major structural damage to 86 major structures, whereas, Irma caused major damage to 171 major structures, including 15 that were destroyed. Ten single-family dwellings were destroyed by the storm surge, waves and erosion in Ponte Vedra, South Ponte Vedra and Vilano Beach, and one single-family dwelling and four multi-family dwellings were destroyed by winds in southern Anastasia Island (Figure 15 and Figure 16). Conversely, less than half the armoring damage was sustained from Irma as compared to Matthew. Matthew damaged or destroyed 7,690 feet of seawalls and revetments, whereas Irma damaged or destroyed 3,470 feet of seawalls and revetments (Figure 17). Some walls of lesser design strength were destroyed, and some walls were compromised when their return walls were flanked. Wall age was not an issue as most of the walls in northern St. Johns County are less than 5 years old. Another major factor affected southern Anastasia Island at Matanzas Shores at a residential development that was well planned and reasonably well designed for the coastal environment. A tornado or suite of tornadoes made landfall in a major rain band causing severe damage that resulted in

four condominium buildings being destroyed and five condominium buildings, eight single-family dwellings and a storage building sustaining major damage (Figure 18).



Figure 9. *Major dune erosion threatening structure at R30, Ponte Vedra.*



Figure 10. *Major dune erosion threatening structure at R27.6, Ponte Vedra.*

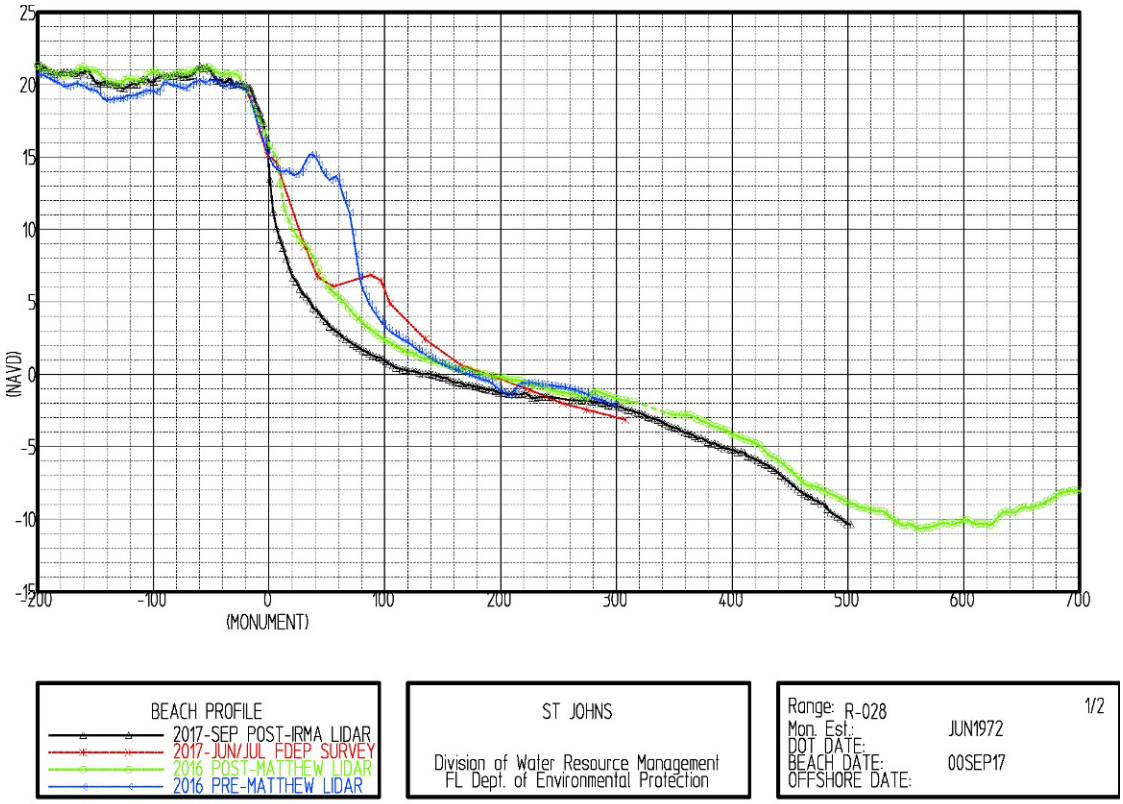


Figure 11*. Profiles showing major beach and dune erosion at R28, Ponte Vedra.*

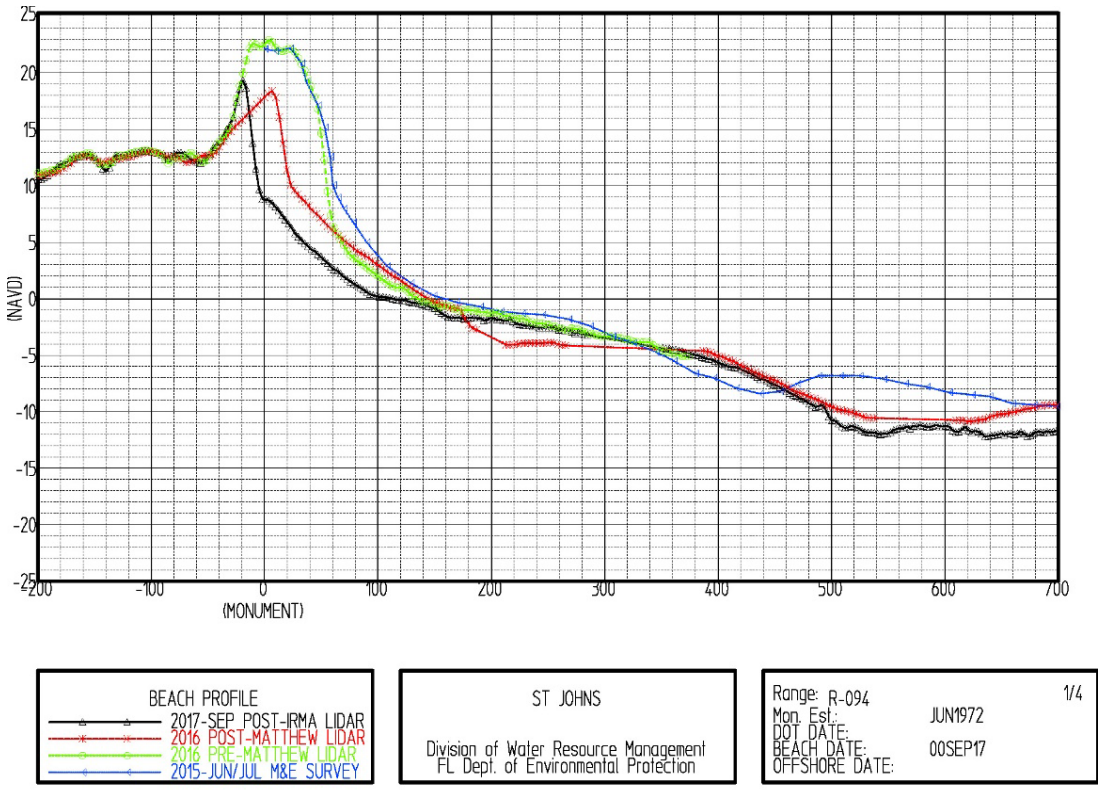


Figure 12. *Major beach and dune erosion at R94, South Ponte Vedra.*

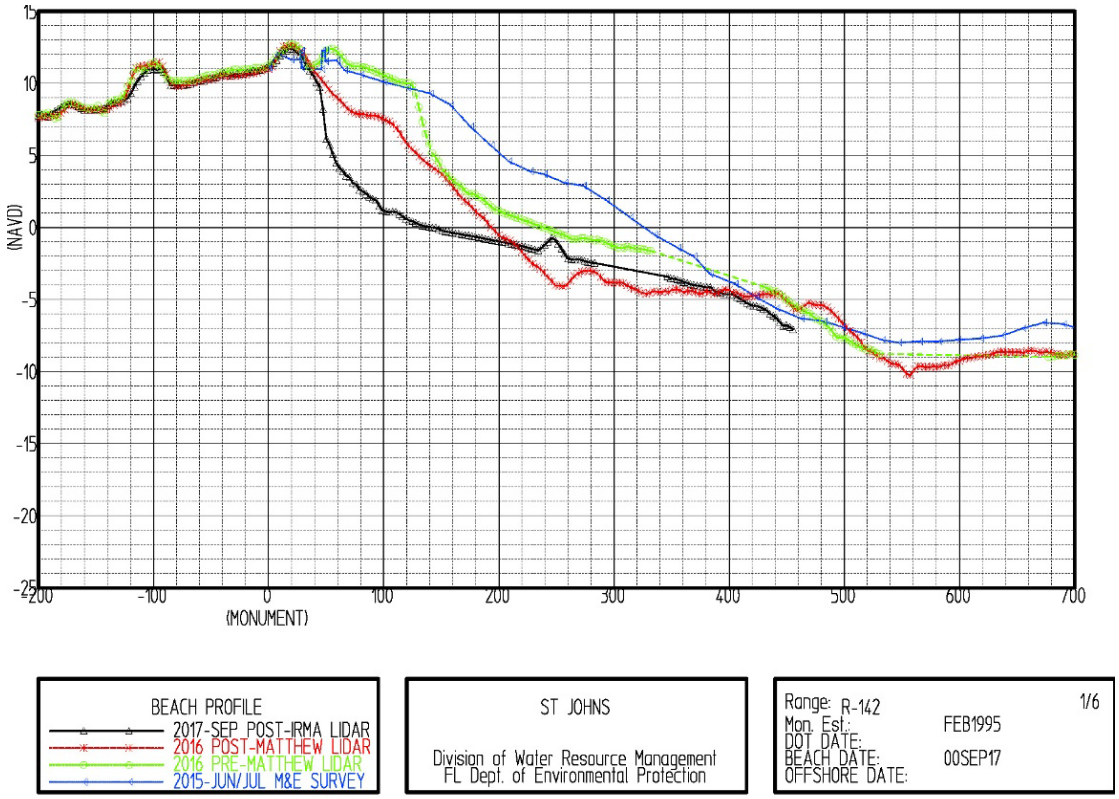


Figure 13. *Major beach and dune erosion at R142 adjacent to the St. Augustine Pier.*

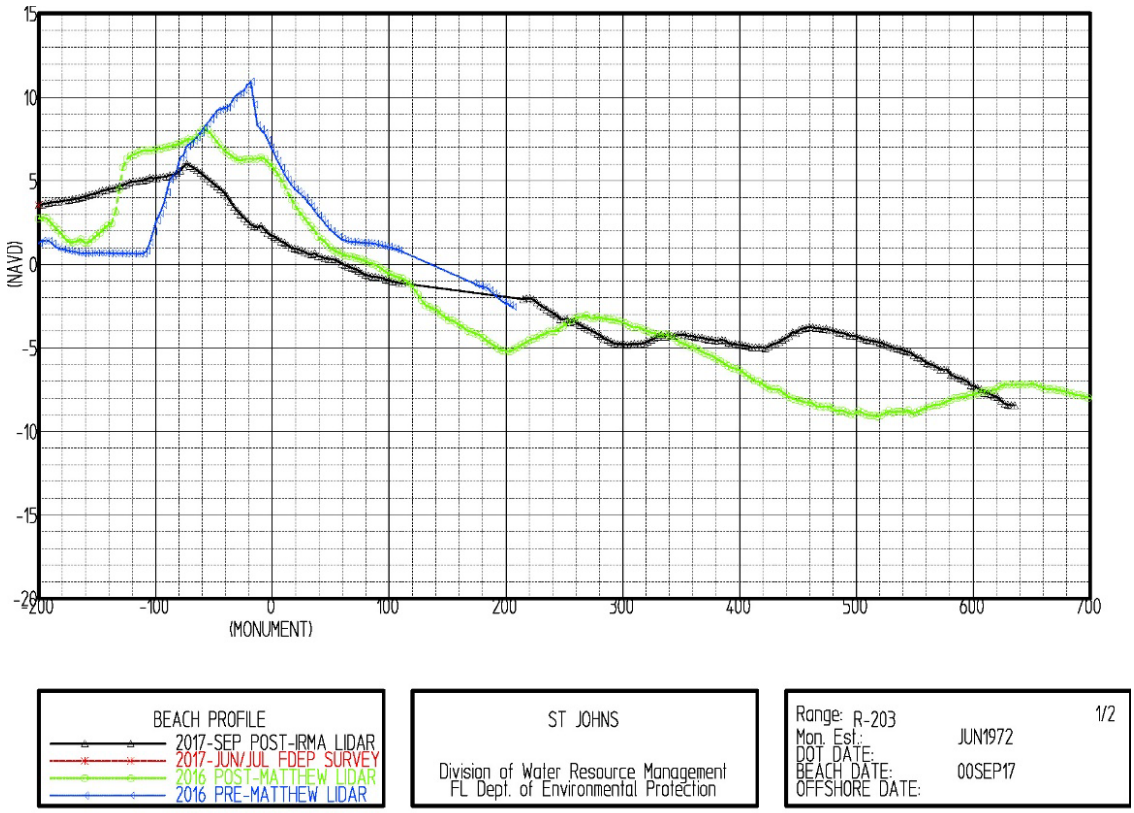


Figure 14. *Major beach erosion and overwash in the Matanzas River at Summer Haven.*



Figure 15. *Single-family dwelling destroyed at R110, Vilano Beach.*



Figure 16. *Single-family dwelling destroyed near R94, South Ponte Vedra.*



Figure 17. *Seawall failure and single-family dwelling destroyed at R89.4, South Ponte Vedra.*



Figure 18. *One of four condominiums destroyed by rain band tornado, Matanzas Shores, R192.4.*

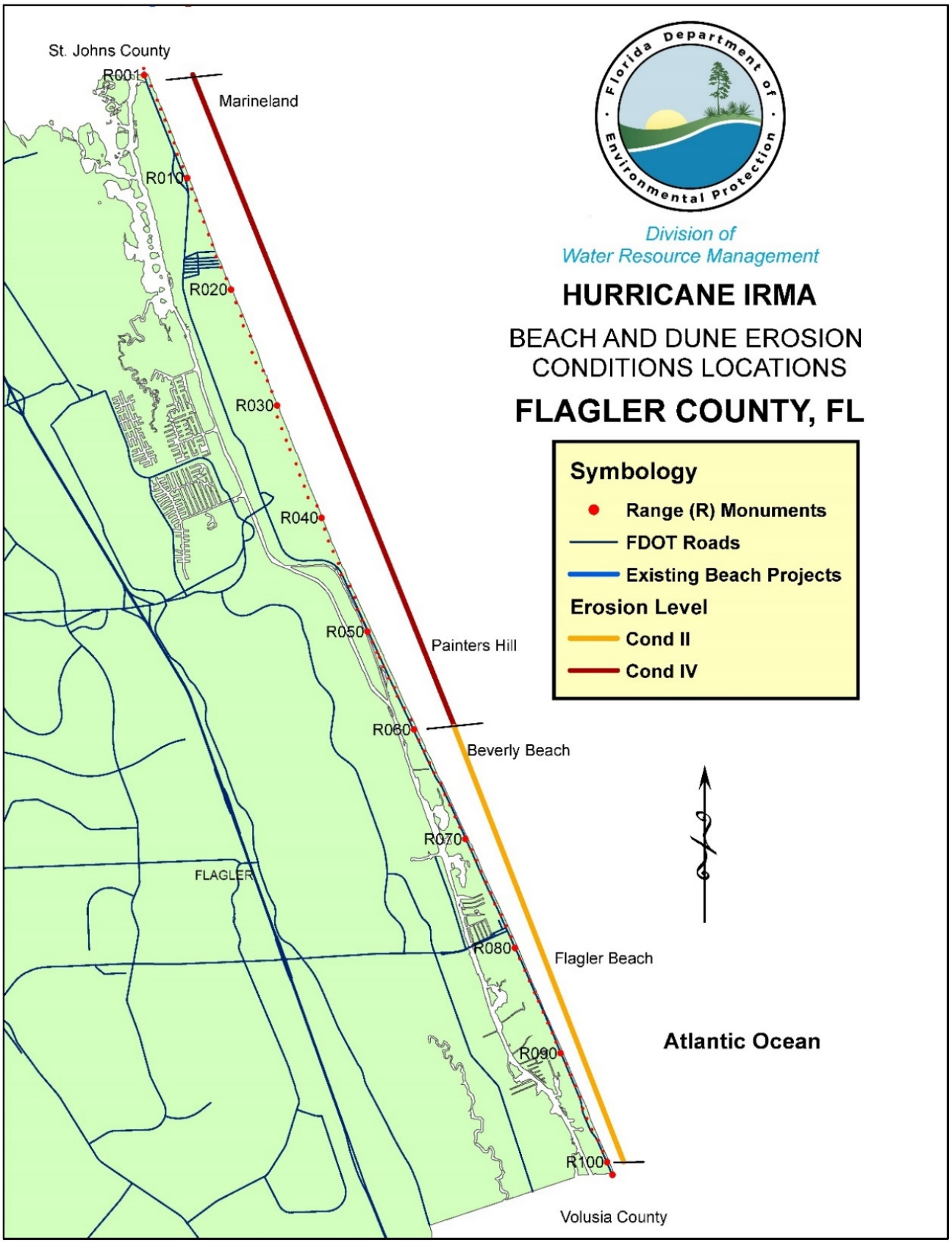


Figure 19. *Flagler County beach and dune erosion conditions from Hurricane Irma.*

Flagler County

The Atlantic Ocean fronting beaches of Flagler County that extend for 18.1 miles between St. Johns County and Volusia County include the following communities and major parks: Marineland, Washington Oaks State Park, Palm Coast, Hammock Dunes, Painters Hill, Beverly Beach, Flagler Beach, and Gamble Rogers State Park (see Figure 19 above). There are no inlets in Flagler County.

The net direction of longshore transport along the Flagler County coast is generally to the south. The northern Flagler County coast is characterized by moderate to high wave energy and relatively narrow, steep beaches fronted by exposed Anastasia rock formations. The beach sediments of Flagler County are unique because of the presence of orange-colored, coquina shell fragments mixed with the quartz sand. The dune ridge along Washington Oaks State Park (R11-R16) is very low due to the smaller fraction of fine grained silicate sediment that would facilitate the natural development of dunes through aeolian sediment transport. To the south, with less rock exposure and a greater percentage of silicate sediment on the beach berm, a higher dune ridge exists.

There are five critically eroded areas (6.5 miles) in Flagler County. Erosion at the northern 0.6 mile of beach (R1-R4) is threatening development and recreational interests at Marineland. This area has a rock revetment and coquina rock groins. Following storm damage by Hurricane Floyd in 1999, the revetment was restored, and a new revetment constructed to the south at a more landward alignment with dune restoration. Following the impact of Hurricane Matthew, a 1.1-mile segment of Painters Hill (R50-R57) is critically eroded threatening development. A 0.9-mile segment of erosion at the north Flagler Beach city limits (R65.2-R70) and 3.3 miles of erosion along southern Flagler Beach (R76-R94.8) threatens State Road AIA. Much of this southern area has a rock revetment. Following the impact of Hurricane Matthew, the southernmost 0.6 mile of Flagler Beach was added as critically eroded threatening State Road A1A between R98 and the south county line.

Storm Effects and Erosion Conditions

The storm tides of Hurricane Irma in Flagler County generally ranged between 6 to 7 feet above sea level. The USGS measured a storm tide in southern St. Johns County just north of the county line near Matanzas Inlet to be +7.6 feet NAVD. The Flagler County coast was substantially impacted by Hurricane Matthew in October 2016, with major beach and dune erosion (condition IV), and only minor natural recovery of the beach berm had taken place during the 11 months before Hurricane Irma; however, between Matthew and Irma, dune restoration was conducted along a portion of “The Hammocks” development and emergency fill placements occurred along Flagler Beach. Table 5 provides the countywide erosion

volumes in cubic yards, dune bluff recession and shoreline recession. The erosion volumes were obtained from pre-storm and post-storm lidar flown by the USACE, and represent volumes lost above mean high water elevations.

Table 5. *Flagler County Erosion Volumes, Beach and Dune Recession.*

Location	DEP Monuments	Volume Change above MHW (cy)	Average Dune Recession at the 8-foot Contour (feet)	Average Shoreline Change (feet)
North Flagler	R1 - R60	-132,723	-11.0	-9.1
South Flagler	R60 - R100	-103,808	-5.2	-13.9
Countywide	**R1 - R100**	**-236,531**	**-8.7**	**-11.0**

Irma's impact along the northern coast of Flagler County (R1-R60) north of Beverly Beach was particularly severe, resulting in 33 buildings being left in imminent danger from incurring damage from another major storm (Figure 20). During Matthew, storm surge and waves overtopped the dunes and caused inland flooding along most of northern Flagler County, and a major dune breach occurred at Washington Oaks State Park. This breach was filled in and a barrier dune was constructed along the park shore to prevent further overtopping. However, Hurricane Irma eroded all the constructed dune, and caused another dune breach to occur at the same location (Figure 21). In Figure 22, the effects of Matthew, the assisted recovery after Matthew, and the effects of Irma are seen immediately north of the breach site at Washington Oaks State Park are shown. Figure 23 shows the dune erosion from Matthew and Irma in Painters Hill immediately adjacent to five threatened single-family dwellings. South of Beverly Beach, including Flagler Beach, the beach and dune erosion from Irma was not as severe as following Matthew. Minor beach and dune erosion was sustained along southern Flagler County (R60-R100) between Beverly Beach and Gamble Rogers State Park, which added to the major beach and dune erosion from Hurricane Matthew particularly in northern Flagler Beach.

Storm Damage

Hurricane Irma caused roughly three times the coastal building damage in Flagler County as was sustained during Hurricane Matthew. Matthew caused major structural damage to 21 major structures, whereas, Irma caused major damage to 78 major structures. Conversely, Matthew destroyed 8,286 feet of coastal armoring, including a 1.5-mile boulder rock revetment in Flagler Beach, whereas, Irma only damaged 160 feet of two walls in northern Flagler County. None of the revetment fronting State Road A1A was damaged by Irma. Likewise, Matthew destroyed or damaged 3,350 feet of State Road A1A, but Irma caused no further road damage.



Figure 20. *Single-family dwellings threatened along Painters Hill near R55.*



Figure 21. *Dune breach by storm surge of Irma, Washington Oaks State Park, R14.5.*

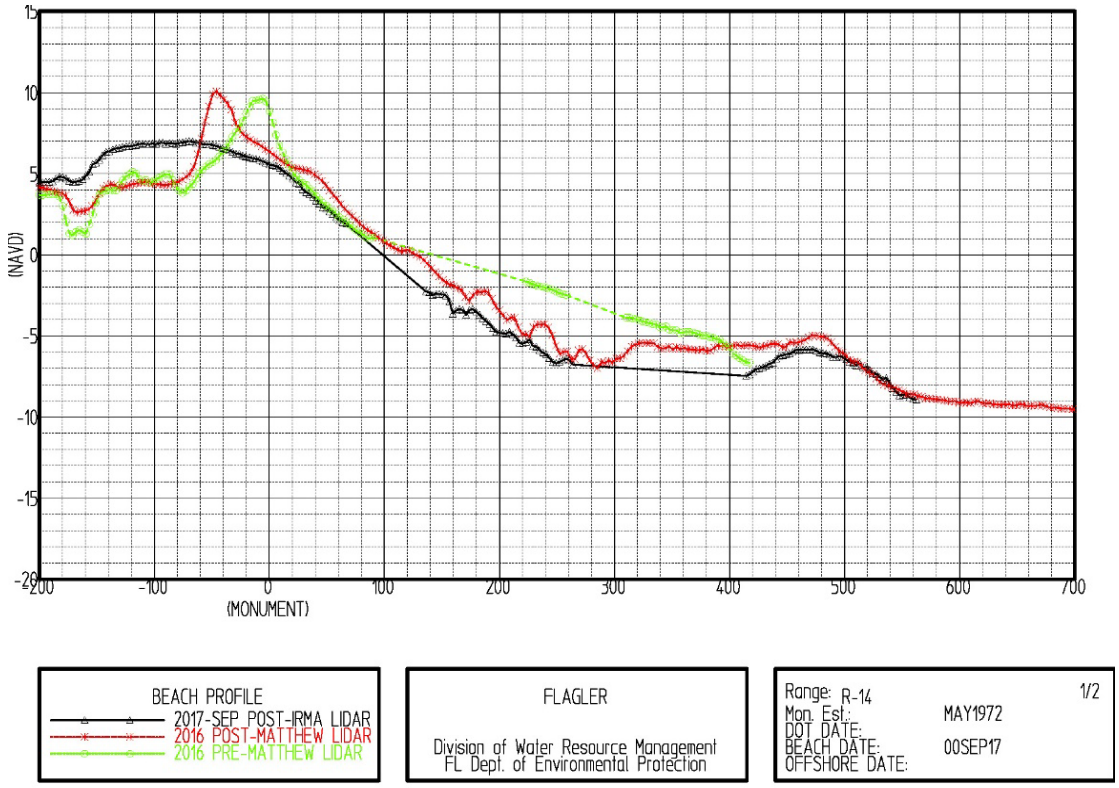


Figure 22. *Beach and dune erosion with overwash at R14, Washington Oaks State Park.*

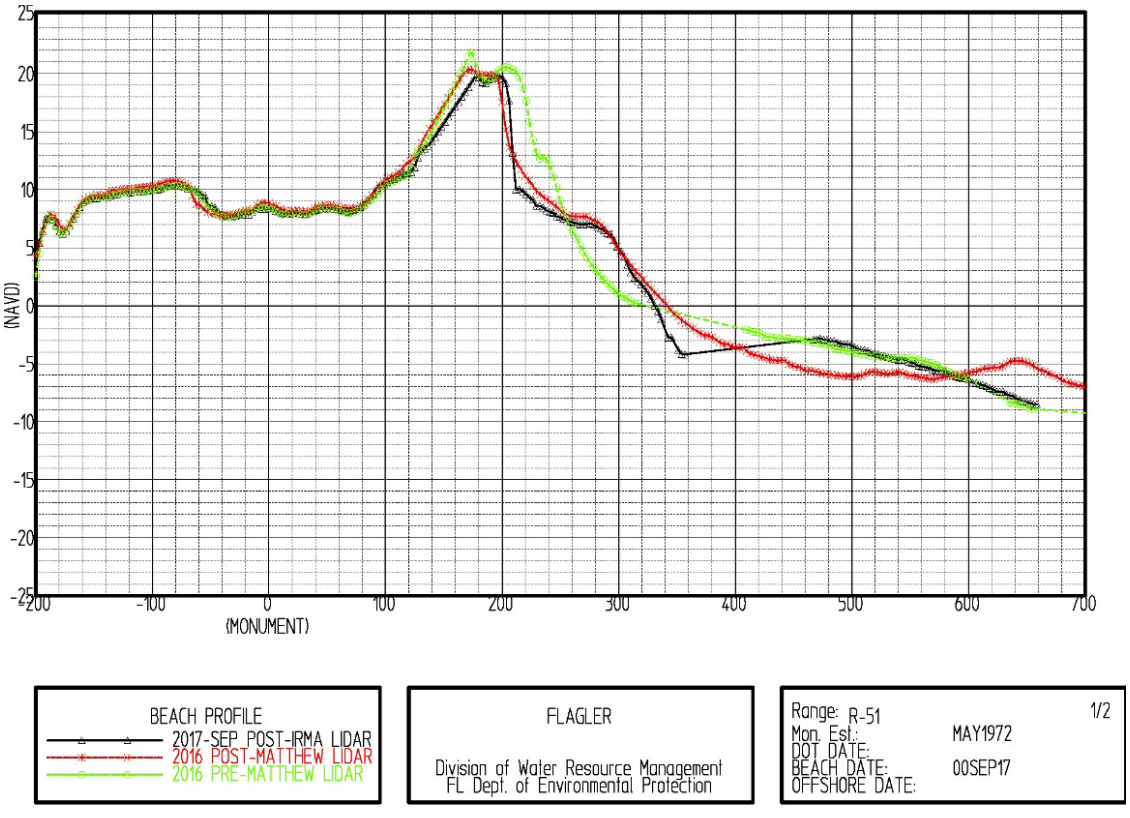


Figure 23. *Profiles of beach and dune erosion at R51, Painters Hill.*

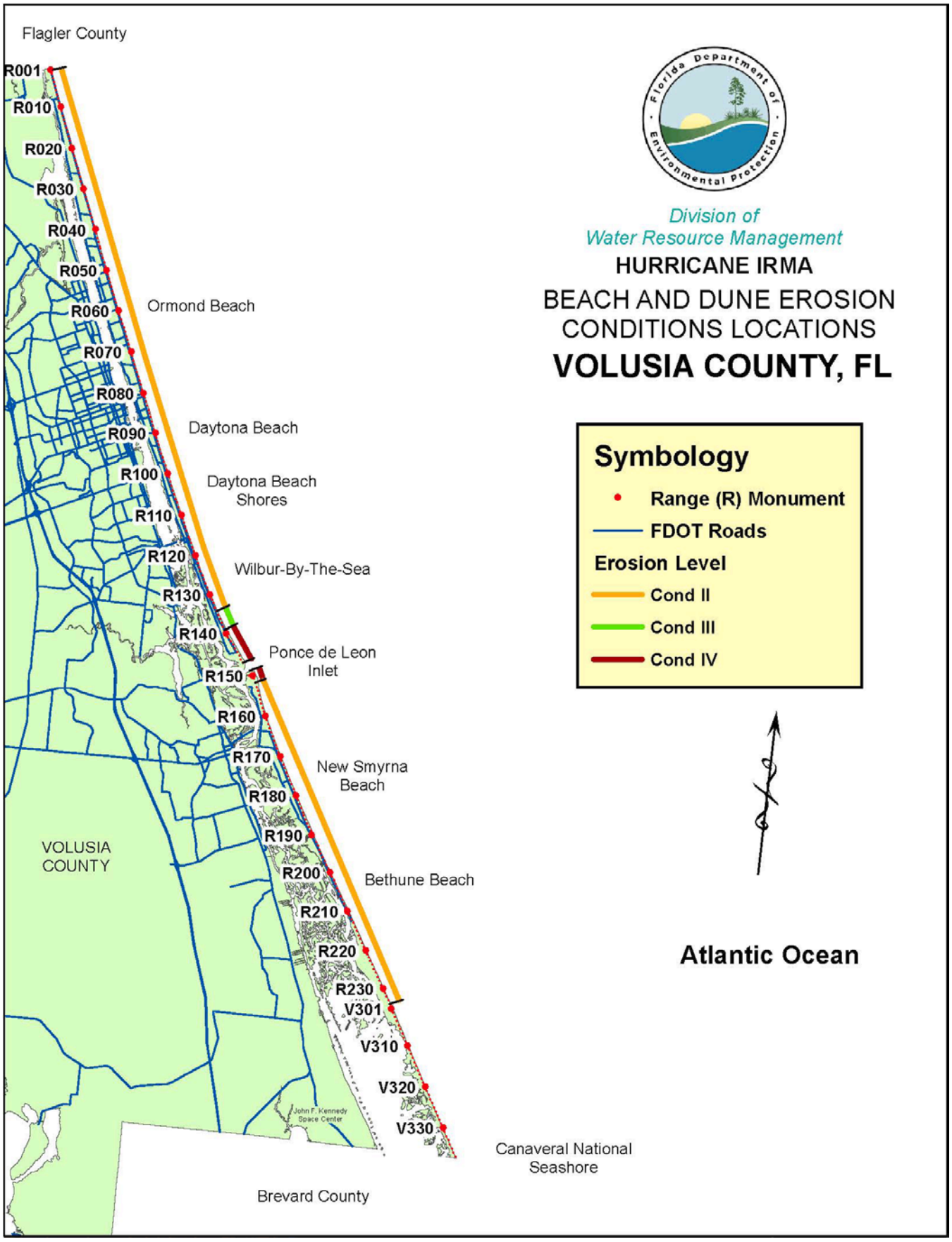


Figure 24. *Volusia County beach and dune erosion conditions from Hurricane Irma.*

Volusia County

Volusia County, the southernmost of the five northeast Florida coastal counties, extends for 48.8 miles between Flagler and Brevard counties. Volusia County includes the following barrier beach communities and major parks: North Peninsula State Park, Ormond-by-the-Sea, Ormond Beach, Daytona Beach, Daytona Beach Shores, Wilbur-by-the-Sea, Town of Ponce Inlet, Ponce de Leon Inlet County Park, New Smyrna Beach, Bethune Beach and Canaveral National Seashore (see Figure 24 above). Ponce de Leon Inlet between the north and south peninsulas of Volusia County has a federal navigation project, which experienced significant shoaling due to Hurricane Irma.

There are three critically eroded beach areas (21.0 miles), one non-critically eroded beach area (1.1 miles), and one critically eroded inlet shoreline area (0.6 mile) in Volusia County. Following the impact of Hurricane Matthew, a 1.6-mile segment (R24-R33) of northern Volusia County is critically eroded threatening State Road A1A. An 11.0-mile segment of beach (R57-R118) along Ormond Beach, Daytona Beach and Daytona Beach Shores is critically eroded, threatening development and recreational interests, as well as sea turtle nesting areas where the dry sand beach has become very narrow. Most of this segment is armored with seawalls. The north shoreline (0.6-mile) of Ponce de Leon Inlet is critically eroded and threatens recreational interests at the county park. The 8.4 miles of beaches (R160.8-R207.8) south of Ponce de Leon Inlet within New Smyrna Beach and Bethune Beach are critically eroded. Threatened are private development and recreational interests, as well as sea turtle nesting habitat. Much of New Smyrna Beach is armored with seawalls and much of Bethune Beach is protected by a boulder rock revetment. The New Smyrna Beach area has received inlet sand transfer material from maintenance dredging of the federal navigation channel within Ponce de Leon Inlet and additional material from maintenance dredging of the Atlantic Intracoastal Waterway. A 1.1-mile segment of the Canaveral National Seashore (R207.8-R214) south of Bethune Beach is also non-critically eroded without any threatened interests at this time.

Storm Effects and Erosion Conditions

The storm tides of Hurricane Irma in Volusia County generally ranged between 6-7 feet above sea level. The USGS measured a storm tide in northern Volusia County to be +6.7 feet NAVD and in southern Volusia County to be +6.2 feet NAVD (Figure 4**)**. The Volusia County coast was substantially impacted by Hurricane Matthew in October 2016 with major beach and dune erosion (condition IV); however, substantial natural recovery of the beach and dunes had taken place after Matthew. This substantial recovery during the 11 months prior to Irma's impact made a positive difference in the beach conditions following the impact of Irma. Table 6 provides the countywide erosion volumes in cubic yards, dune bluff

recession and shoreline recession. The erosion volumes were obtained from pre-storm and post-storm LIDAR flown by the USACE, and represent volumes lost above mean high water elevations.

Table 6. *Volusia County Erosion Volumes, Beach and Dune Recession.*

Location	DEP Monuments	Volume Change above MHW (cy)	Average Dune Recession at the 7-foot Contour (feet)	Average Shoreline Change (feet)
North Peninsula	R0 - R39	-125,546	-6.9	-16.9
Daytona	R39 - R148	-544,108	-3.2	-44.6
New Smyrna	R149 - R208	-292,117	0.5	-42.8
Canaveral National Seashore	R208 - R234	21,474	5.0	-2.8
Countywide	**R0 - R234**	**-940,297**	**-1.9**	**-34.7**

Irma's impact along most of the northern peninsula of Volusia County (R1-R135) was minor beach and dune erosion (condition II). Closer to Ponce de Leon Inlet, the conditions transitioned from moderate beach and dune erosion (condition III) between R135 and R139 to major beach and dune erosion (condition IV) between R139 and R148 at the north jetty (Figure 25).

Immediately south of Ponce de Leon Inlet was 0.5 mile of major beach and dune erosion (condition IV) between R149 and R151.5. The northward littoral transport of sand from the beaches south of the south jetty carried a substantial quantity of overwash sediment into Ponce de Leon Inlet (Figure 26), during Matthew and even more significantly in Irma. The remainder of the south peninsula of Volusia County sustained only minor beach and dune erosion (condition II) between R152 and R202 at Bethune Beach. Minor beach and dune erosion (condition II) continued southward along Cape Canaveral National Seashore (R208-R234).

Storm Damage

Hurricane Irma caused slightly more coastal building damage in Volusia County than was sustained during Hurricane Matthew. Matthew caused major structural damage to 75 major structures, whereas, Irma caused major damage to 106 major structures. Conversely, Matthew destroyed 3,820 feet of coastal armoring, whereas, Irma only damaged 100 feet of one rock revetment in Volusia County. Much of the major damage due to Irma in Volusia County was due to winds (Figure 27). At Ponce de Leon Inlet, 225 feet of major damage was sustained on the granite boulder mound north jetty (Figure 28). The damage location was adjacent to the beach at the shoreward end of the structure. The boardwalk providing access to the jetty was also substantially damaged.



Figure 25. *Major beach and dune erosion near R143, Town of Ponce Inlet.*



Figure 26. *South jetty breach and overwash into Ponce de Leon Inlet (looking northwest), R149.*



Figure 27. *Wind damage to condominium at R40, Ormond Beach.*



Figure 28. *Major damage to north jetty and boardwalk at Ponce de Leon Inlet, R148.*

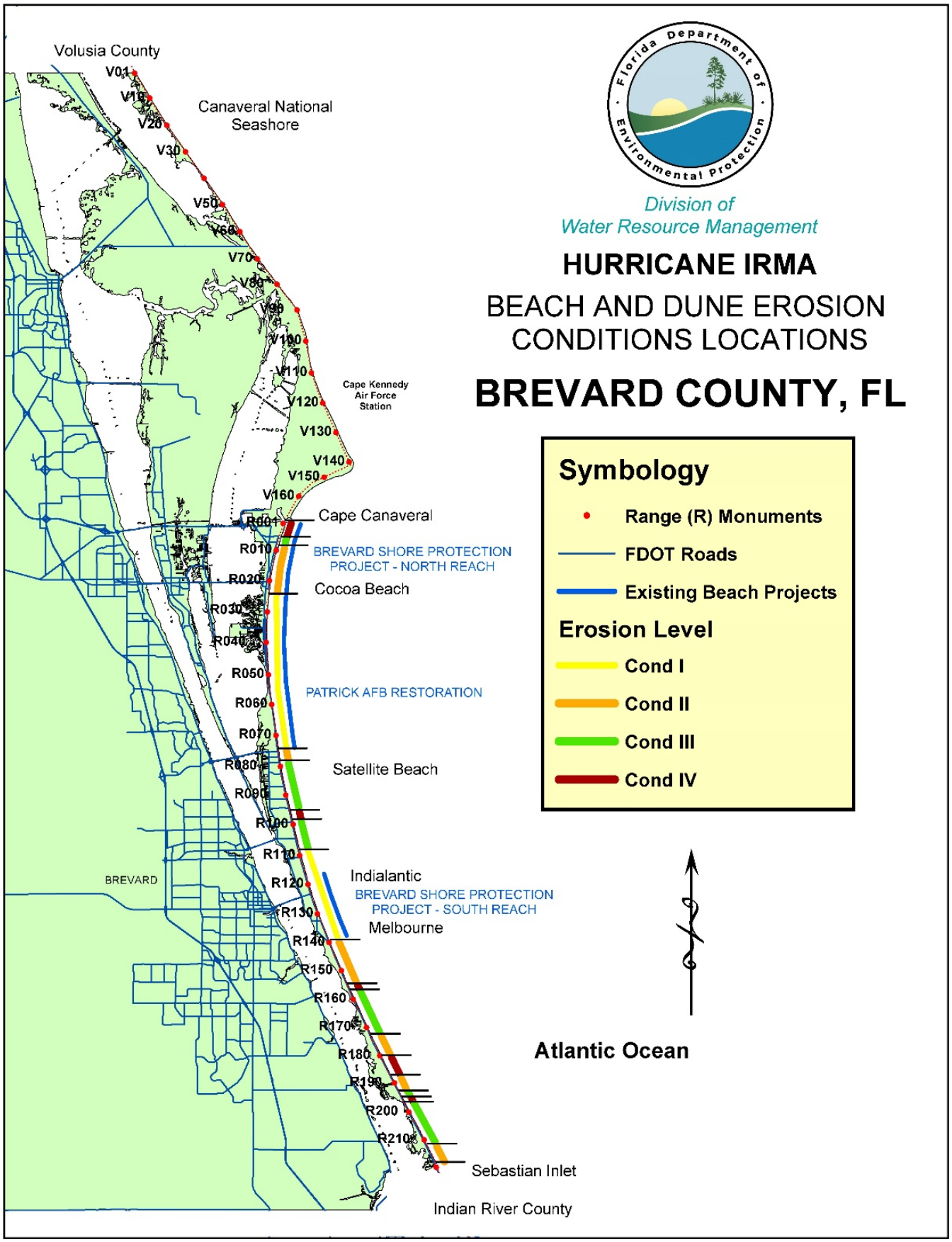


Figure 29. *Brevard County beach and dune erosion conditions from Hurricane Irma.*

Brevard County

The longest of the central Atlantic coast counties, Brevard County extends for 71.6 miles between Volusia and Indian River counties (see Figure 29 above). Coastal Brevard County includes the following communities and parks: Canaveral National Seashore, Kennedy Space Center, Cape Canaveral Air Force Station, Port Canaveral Jetty Park, City of Cape Canaveral, Cocoa Beach, Patrick Air Force Base, Satellite Beach, Indian Harbour Beach, Melbourne, Indialantic, Melbourne Beach, Melbourne Shores, Floridana Beach, Archie Carr National Wildlife Refuge, and Sebastian Inlet State Park. Port Canaveral Inlet between Cape Canaveral Air Force Station and the City of Cape Canaveral has a federal navigation project, which likely experienced significant shoaling due to Hurricane Irma; however, the port reopened to vessel traffic two weeks after Hurricane Irma, indicating shoaling had not disrupted the inlet's navigability as it did following Hurricane Frances in 2004. Continued shoaling was also apparent at Sebastian Inlet at the southern end of the county.

The net direction of longshore transport along the Brevard County coast is generally to the south. Most of the Brevard County coast is characterized by moderate to high wave energy and relatively narrow, steep beaches, except along the two federal shore protection projects at Canaveral-Cocoa Beach (North Reach) and Indialantic-Melbourne Beach (South Reach), where the beaches are substantially wider with a more dynamic dune field.

There are two critically eroded areas (41.2 miles) and two non-critically eroded areas (12.1 miles) in Brevard County. Two areas along the Canaveral National Seashore (V320-V365 and V417-V436) are non-critically eroded. Both areas are located north of Cape Canaveral. A 4.7-mile segment along Kennedy Space Center (V365-V390) is critically eroded, threatening manned spacecraft facilities, launch pads, Phillips Parkway and buried infrastructure. From Port Canaveral Inlet extending 36.5 miles to the south is a long coastal segment (R1-R202) designated as critically eroded. Threatened are development, recreational interests and wildlife habitat. Beach restoration projects have been conducted in the City of Cape Canaveral, Cocoa Beach, Patrick Air Force Base, Indialantic and Melbourne Beach. Local dune restoration projects have been conducted along various shoreline segments in south Brevard County.

Storm Effects and Erosion Conditions

The storm tide of Hurricane Irma in Brevard County generally ranged between 5 to 6 feet above sea level. The USGS measured a storm tide in Port Canaveral to be +5.1 feet NAVD (Figure 4). Wave uprush likely exceeded this measured storm tide by two or more feet along Brevard County beaches, as was observed by the dune erosion conditions after Irma as well as from on-site observations made during the offshore

passage of Hurricane Maria on September 23 and 24. The Brevard County coast was substantially impacted by Hurricane Matthew in October 2016, with major beach and dune erosion (condition IV). Some natural beach recovery had taken place during the 11 months between Hurricanes Matthew and Irma, and Brevard County conducted maintenance nourishment of existing dune restoration projects along much of the south Brevard beaches where, after Matthew, at least 65 buildings were threatened from structural damage due to erosion from future storm conditions.

Beach conditions along the northern half of Brevard County north of Port Canaveral were not assessed. Immediately south of Port Canaveral Inlet (R1-R5), major beach and dune erosion (condition IV) was sustained during Hurricane Irma (Figure 30). Brevard County staff measured as much as approximately 40 feet of dune recession in this area. Throughout the remainder of the North Reach of the federal shore protection project (R5-R55), minor beach and dune erosion prevailed (condition I to II). Beach profile surveys from the dunes seaward to a wading depth were obtained and analyzed by Olsen Associates, Inc., for the entire 9.7 miles of the North Reach project (R1-R55). This data indicated an average of -12.8 cubic yards per linear foot of the upper beach profile was eroded and transported seaward, for a total upper beach volume loss within the project of -658,700 cubic yards of sand. Future monitoring surveys will determine how much sand returns to the upper beach and how much is lost from the seaward limits of the project.

Along the beach restoration project at Patrick Air Force Base (R56-R75), minor beach erosion (condition I) was observed. The Mid-Reach of the federal shore protection project (R75.4-R118.3) has not yet been constructed for Satellite Beach and Indian Harbour Beach; however, substantial dune restoration has been conducted by Brevard County, and generally moderate beach and dune erosion (condition III) was sustained with some minor and some major dune erosion in isolated segments. In Indian Harbour Beach, a historic hot spot of erosion along Shell Street (R97-R99) sustained major beach and dune erosion (condition IV) (Figure 31). Brevard County staff has calculated the volume losses from the dune restoration projects in this area to be -32,000 cubic yards.

Along the South Reach of the federal shore protection project in Indialantic and Melbourne Beach, conditions varied between minor beach erosion (condition I) and minor beach and dune erosion (condition II). Beach profile surveys from the dunes seaward to a wading depth were obtained and analyzed by Olsen Associates, Inc., for the entire 3.9 miles of the South Reach project (R118-R139). This data indicated an average of -14.5 cubic yards per linear foot of the upper beach profile was eroded and transported seaward, for a total upper beach volume loss within the project of -296,124 cubic yards of sand. Future monitoring

surveys will determine how much sand returns to the upper beach and how much is lost from the seaward limits of the project. Along the south Brevard County beaches (R140-R213), where substantial natural recovery and dune restoration by Brevard County had taken place following Hurricane Matthew, the beach conditions varied after Irma from minor beach and dune erosion (condition II) to major beach and dune erosion (condition IV), (Figure 32). Brevard County staff has calculated the volume losses from the dune restoration projects in this area to be -79,000 cubic yards (not counting the beach erosion seaward of the restored dunes). At the south end of the county along Sebastian Inlet State Park, minor beach and dune erosion (condition II) was sustained.

Storm Damage

Hurricane Irma caused substantially more coastal building damage in Brevard County than was sustained during Hurricane Matthew. Matthew caused major damage to three major structures, whereas, Irma caused major damage to 217 major structures. Damage to coastal buildings in Brevard County has only been exceeded by Hurricane Frances (256 buildings) and Hurricane Jeanne (346 buildings) in 2004. It is noteworthy that while Frances and Jeanne damaged buildings in Brevard County by the storm surge, waves, erosion and wind loads, Irma only caused major building damage by its wind loads. Also, multiple tornadoes were sighted, and pockets of damage clearly suggest tornadoes were carried cross-shore in the major rain bands of Irma.

At the north end of Indialantic, tornado damage was observed where the entire roof of a condominium building was blown off, with a major section being transported over 600 feet across State Road A1A and over another building before landing on a single-family dwelling (Figure 33). A total of 12 buildings, including six single-family dwellings, two condominium buildings, two commercial buildings, and a motel were damaged along an east-west path of tornado damage. Another tornado was most likely the cause of damage to a beach-front high-rise hotel in Cocoa Beach, where major damage to the second, third, fourth and fifth floors were observed (Figure 34). Severe wind damage, which may not have been due to tornadoes, was also sustained at beach front condominium buildings, where entire roofs blew off. These buildings were located adjacent to the Pineda Causeway south of Patrick Air Force Base and at Fifth Avenue in Melbourne Beach. Storm surge and wave damage were observed at Jetty Park at Port Canaveral Inlet, where 850 feet of the inner railing of the fishing pier was destroyed along the segment parallel to the south jetty. Major damage was also sustained to a 50-foot pier segment normal to the jetty where the concrete deck slabs were separated (Figure 34).



Figure 30. *Major dune erosion at Jetty Park near R1, Port Canaveral.*



Figure 31. *Major dune erosion at Shell Street, Indian Harbour Beach, R97.*



Figure 32. *Major dune erosion near R196, south Brevard County.*



Figure 33. *Condominium roof section blown across State Road A1A onto single-family dwelling by tornado at R122, Indialantic.*



Figure 34. *Hotel severely damaged by an apparent tornado at R26, Cocoa Beach.*



Figure 35. *Jetty Park fishing pier damage where concrete deck slabs were separated, R1.*

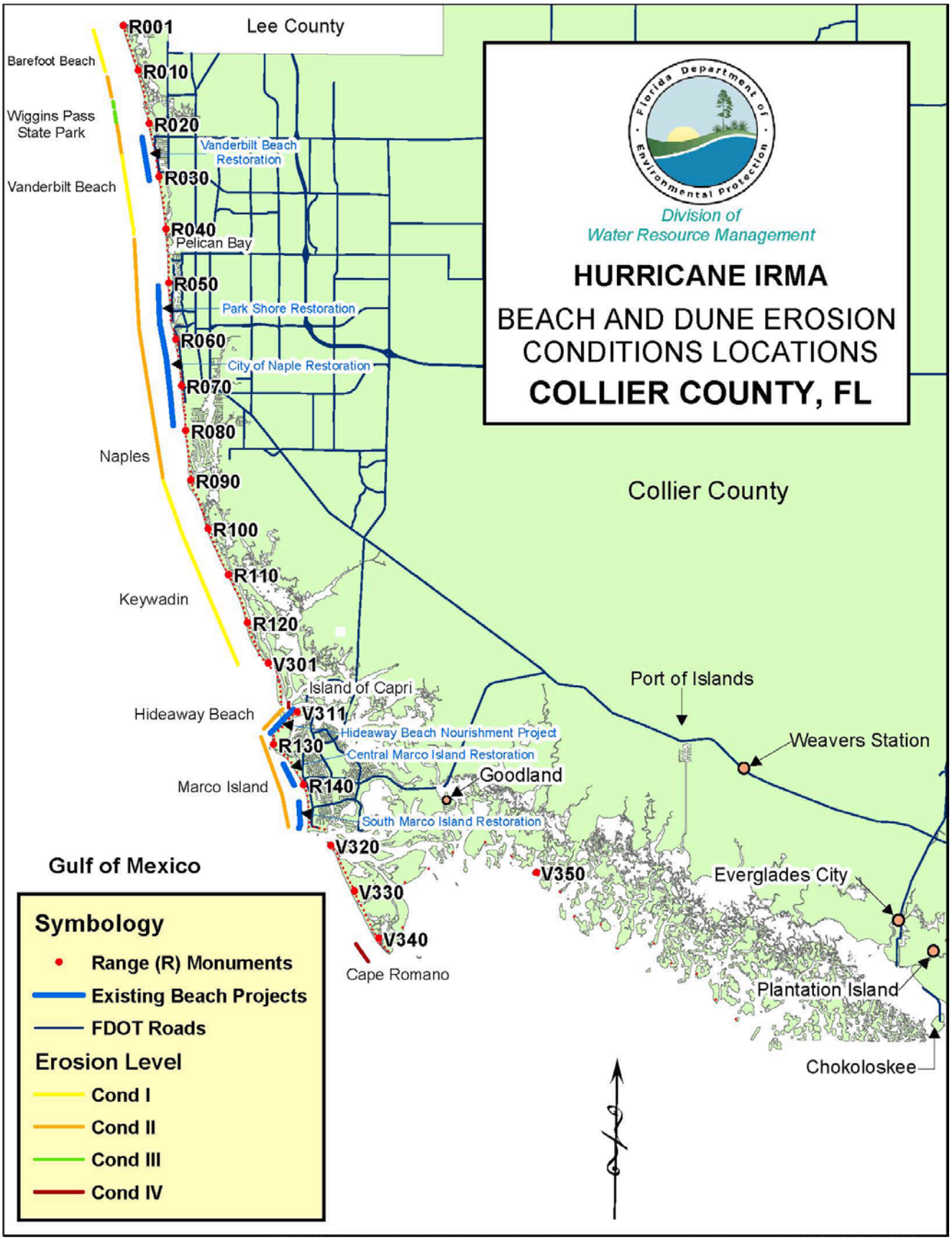


Figure 36. *Collier County beach and dune erosion conditions from Hurricane Irma.*

Collier County

Collier County is located on Florida's southwest coast fronting the Gulf of Mexico (see Figure 36 above), and has 34.1 miles of beaches extending southward from Lee County to the southwest tip of Cape Romano. Scattered small beaches also exist intermittently east-southeast of Cape Romano within the Ten Thousand Islands region. Coastal Collier County includes the following beach communities and major parks: Lowdermilk Park, Barefoot Beach County Park, Delnor-Wiggins Pass State Park, Vanderbilt Beach, Park Shore, Naples, Keewaydin Island, Sea Oat Island, Isle of Capris, Hideaway Beach, Marco Island, Kice Island, Morgan Island, Cape Romano, Goodland, Port of Islands, Weavers Station, Everglades City, Plantation Key and Chokoloskee. The net direction of longshore transport along the Collier County coast is generally to the south with some drift reversals in the vicinity of inlets.

Prior to the 2017 hurricane season, there were eight critically eroded beach areas (14.8 miles), three non-critically eroded beach areas (5.1 miles), and one critically eroded inlet shoreline area (0.8 mile) in Collier County. In northern Collier County, a 0.4-mile segment of critical erosion exists north of Wiggins Pass threatening sea turtle and gopher tortoise habitat. A 1.6-mile beach segment (R22.3-R30.5) is critically eroded threatening development interests in Vanderbilt Beach. This area is substantially armored with seawalls and has a beach restoration project. The City of Naples has two segments that are critically eroded, threatening development interests north and south of Doctors Pass. North of Doctors Pass (R45-R57.5) is a 2.4-mile critically eroded segment with the northern 1.1 mile included for the design integrity of the beach restoration project. Between Doctors Pass and Gordon Pass (R57.8-R89) is a 5.6-mile critically eroded segment. Most of Naples is armored with bulkheads, seawalls and revetments, and these two critically eroded segments have a continuous beach restoration project.

South of Gordon Pass (R90-R111) is a 3.9-mile stretch that is non-critically eroded along the northern half of Keewaydin Island. Between Little Marco Pass and Capri Pass, Sea Oat Island has 0.9 mile of beach that is non-critically eroded. Marco Island has three areas that are critically eroded, threatening development interests. Along Hideaway Beach, the north shore of Marco Island (H3-H11) fronting on Big Marco Pass has 0.8 mile of inlet shoreline that is critically eroded. The central gulf beach of Marco Island (R134.5R139) has 0.8 mile that is critically eroded, and the southern stretch of beach (R143-R148) has 0.9 mile that is critically eroded. All three critically eroded areas on Marco Island have beach restoration projects, and the northern segment also has a rock groin field along Hideaway Beach. Erosion on the two southern barrier islands in Collier County has progressed into the backshore mangrove forest resulting in the loss of beach wildlife habitat. Following Hurricane Wilma in 2005, a 1.6-mile segment of Kice Island

(V23-V31.4) is critically eroded. South of Morgan Pass, Morgan Island has a 1.5-mile segment (V33.8-V41.8) that is critically eroded, and a 0.3-mile segment (V41.8-V43.5) that is non-critically eroded.

Storm Effects and Erosion Conditions

Hurricane Irma made landfall at 3:35 p.m. on September 10, with the geographic center of the eye crossing Marco Island on a northerly track. Irma's Category Three intensity winds and storm tide primarily impacted the Ten Thousand Islands region of Collier County. A wind gust of 130 mph was reported on Marco Island, and a peak gust of 142 mph was reported at the Naples Municipal Airport. The highest storm tide for Irma in Collier County, and probably in Florida, was measured in the Ten Thousand Islands region at Everglades City to be +8.78 feet NAVD. On the weak side, or western side of the eye, the highest storm tide was measured on the southern end of Marco Island to be +6.6 feet NAVD. Further northwest at Naples, a measured peak water level was obtained at the Naples Fishing Pier to be +4.7 feet NAVD (see Figure 5).

Table 7 provides the countywide erosion volumes in cubic yards and shoreline recession. LIDAR data was collected by the USACE for the Collier County coast in response to Hurricane Irma in September 2017. Topographic LIDAR data was also collected in Collier County in June 2015. For much of the county, conventional surveys were taken at DEP monuments throughout 2016 and 2017. For each monument, the latest survey taken prior to Hurricane Irma was used as the pre-Irma profile to compare with the 2017 post-Irma LIDAR data. These pre-Irma surveys have a date range from June 2015 to February 2017. Because there was no survey data for the North Marco Island nourishment area (R136-R138) taken after the fill placement in July 2016 and preceding Hurricane Irma, these profiles were removed from the computations.

Table 7. *Collier County erosion volumes and shoreline change.*

Location	DEP Monuments	Volume Change above MHW (cy)	Average Shoreline Change (feet)
North Collier	R1 - R41	-60,610	-6.1
Naples	R42 - R89	-47,561	-2.9
Keewaydin	R90 - R127A	-24,931	-10.7
Marco Island	R128 - R148	-54,911	-31.8
Countywide	**R1 - R148**	**-188,013**	**-9.4**

Erosion conditions along the shorelines of the Ten Thousand Islands were not assessed. Irma caused major beach and dune erosion (condition IV) at Cape Romano. Along Marco Island (R128-R148), the beach is wide and flat with a low-profile dune fronting the upland. Aptim Environmental and Infrastructure, Inc.,

surveyed the South Marco Island project from R139 to the southern tip of Marco Island, and found that the worst erosion area stretched from R147 southward for a total loss of material above the depth of closure to be -13,864 cubic yards (Aptim, 2017). The northern end of Marco Island sustained significant erosion, resulting in mangroves being stranded by shoreline recession (Figure 37). Hideaway Beach, which is stabilized by a T-groin field on the north shore of Marco Island, sustained minor beach and dune erosion (condition II) (Figure 38). Minor beach erosion (condition I) was sustained along Keewaydin Island (R90-R127). Along Naples' beaches (R42-R89) and Vanderbilt Beach (R23-R35), minor beach and dune erosion (condition II) was sustained. At Wiggins Pass State Park, minor to major beach and dune erosion (condition II to IV) was sustained, with the erosion becoming more severe within 2,000 feet of Wiggins Pass (Figure 39). North of Wiggins Pass along Barefoot Beach County Park, minor to major beach and dune erosion (condition II to IV) was sustained, with the erosion becoming more severe nearest to the inlet (Figure 40). Major erosion was also sustained along both the northern and southern shorelines of Wiggins Pass. Substantial shoaling is apparent at Wiggins Pass as erosion off the adjacent beaches have developed large spits of sand on both sides of the entrance.

Storm Damage

Other than the Florida Keys, the worst coastal building damage was experienced in five small coastal communities east-southeast of Marco Island. NOAA aerial photography permitted an inventory of the major damage to these communities. The major damage in these communities was due to the storm surge, waves and high winds. Chokoloskee sustained major damage to 30 buildings, including at least three that were destroyed. Plantation Key sustained major damage to 43 buildings, including at least seven that were destroyed. Everglades City sustained major damage to 57 buildings, including at least eight that were destroyed. Port of Islands sustained major damage to 14 buildings, and Goodland sustained major damage to 68 buildings, including seven that were destroyed.

There were no major structures on Marco Island destroyed; however, three multi-family dwellings along South Collier Boulevard (each a high-rise condominium building) sustained major roof damage due to the hurricane force winds. At the southern end of Marco Island fronting on Caxambas Pass and the Gulf of Mexico, 3,000 feet of boulder lime-rock revetment sustained minor damage (level II damage) (Figure 41). Numerous large armor stone boulders were displaced landward over the seawall cap. Landward of the seawall, many small apron rocks with an approximate average diameter of 1 foot were scattered landward across the upland. Fronting this revetment, at the southern end of the Marco Island beach, a 200-foot boulder mound terminal groin sustained minor damage consisting of displaced boulders. Offshore from the terminal groin, three detached boulder mound breakwaters sustained minor damage consisting of

displaced boulders. At the north end of Marco Island along Hideaway Beach, five of the boulder mound T-groins sustained minor damage consisting of displaced boulders. To the east of Hideaway Beach at the Ville de Marco West complex, 250 feet of concrete seawall was destroyed (level IV damage) and a condominium building was undermined (Figure 42). Another condominium building on the Isle of Capri across Big Marco Pass from Marco Island sustained major roof damage. Along the 7 miles of shoreline on Keewaydin Island north of Marco Island, three single-family dwellings sustained major roof damage. Most of the damage along the coast of the City of Naples was due to the storm surge and waves, with a little wind damage. One single-family dwelling, one parking garage and one multi-family dwelling sustained major wind damage. The multi-family dwelling also sustained understructure damage to three units from the storm surge. Three ocean outfall pipes and the Naples Fishing Pier also sustained major damage due to the storm waves. In southern Naples, four timber groins also sustained major damage due to the storm waves, and a 125-foot-long vertical concrete seawall sustained minor damage (level II damage).



Figure 37. *North Marco Island erosion near R132.*



Figure 38. *T-groin field along Hideaway Beach near V313.*



Figure 39. *Major beach and dune erosion near R17 south of Wiggins Pass looking south.*



Figure 40. *Major beach and dune erosion near R15 north of Wiggins Pass looking south.*



Figure 41. *South Marco Island revetment damage near R148.*



Figure 42. *Seawall destroyed and condominium undermined in Big Marco Pass near V310.*

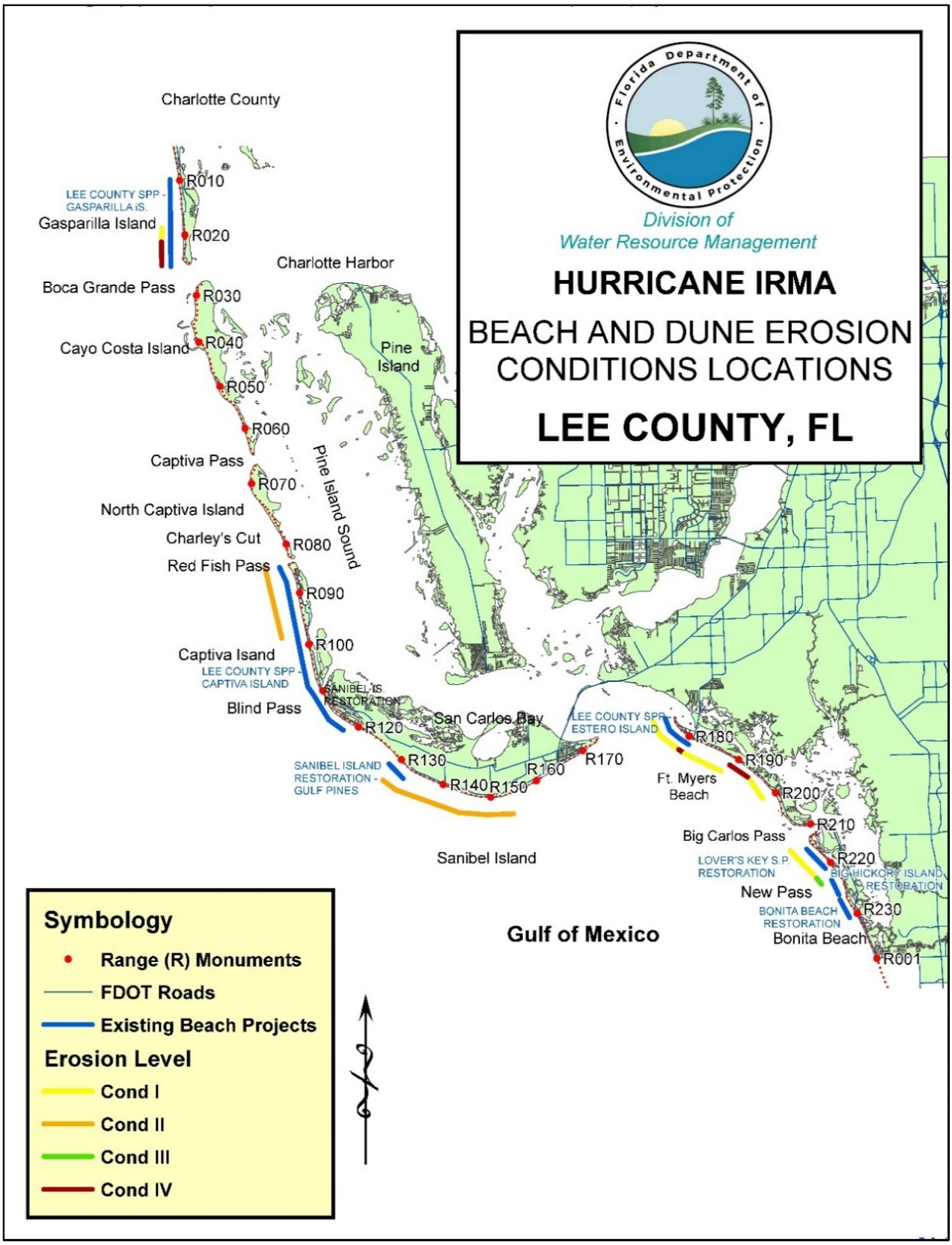


Figure 43. *Lee County beach and dune erosion conditions from Hurricane Irma.*

Lee County

Lee County is located on Florida's southwestern coast fronting the Gulf of Mexico (see Figure 43 above), and has 47.3 miles of beaches extending southward from Charlotte County to Collier County. The coast of Lee County includes most of Gasparilla Island, Cayo Costa Island, North Captiva Island, Captiva Island, Sanibel Island, Estero Island, Lovers Key, Big Hickory Island, and Bonita Beach on Little Hickory Island. Lee County has eight coastal inlets, including Boca Grande Pass, Captiva Pass, Redfish Pass, Blind Pass, San Carlos Bay Entrance, Big Carlos Pass, New Pass and Big Hickory Pass.

There are 11 critically eroded beach areas (22.4 miles), four non-critically eroded beach areas (5.3 miles), three critically eroded inlet shoreline areas (0.6 mile), and two non-critically eroded inlet shoreline areas (0.4 mile) in Lee County. The southern 4.0 miles of Gasparilla Island (R7-R26.7) is critically eroded threatening development and recreational interests in the town of Boca Grande and the Gasparilla Island State Park. Much of this area has bulkheads, and inlet sand transfer has been conducted using Boca Grande Pass dredge material. The northern shoreline of Boca Grande Pass within the Gasparilla Island State Park (0.2 mile) is also critically eroded.

Three areas on Cayo Costa Island are non-critically eroded. The northern segment (R27-R33) extends for 1.1 miles, the central segment (R46-R52) extends for 1.2 miles, and the southern segment (R60-R65) extends for 1.0 mile. All of North Captiva Island is either critically or non-critically eroded: the northern shore fronting on Captiva Pass (R66, east 1,000 feet) has critical inlet shoreline erosion, threatening development interests; the northern 1.0-mile of gulf beach (R66-R71) is critically eroded, threatening development interests; and from R71 through R78 is 2.0 miles of non-critical erosion. The southern 0.8 mile of North Captiva Island extending into Redfish Pass (R79-R82.3) is critically eroded, threatening development and wildlife habitat. All of Captiva Island is critically eroded. The inlet shore fronting Redfish Pass (R83-R84) has 0.2 mile of critically eroded inlet shoreline. This shoreline has a rock revetment with a terminal groin. The 5 miles of Gulf beach from R84 through R109 is critically eroded. This entire island segment is a beach restoration project.

Northern Sanibel Island from R109 to R118 is critically eroded, extending 1.7 miles south of Blind Pass where the road, development, recreation and wildlife habitat are threatened. Part of this segment received nourishment from the Captiva Island beach restoration project. Another segment (R129-R133) on northern Sanibel Island has 0.9 mile that is critically eroded, threatening development interests. This segment in the neighborhoods of Gulf Shores and Gulf Pines has a beach restoration project.

Fort Myers Beach on Estero Island from R175 (-0.4) to R200 has 5.0 miles that is critically eroded, threatening development and recreational interests. This entire segment is a beach restoration project. A 0.8-mile southern segment of Estero Island (R203-R207) is also critically eroded along the Little Estero Island Critical Wildlife Area. The northern shore of Lovers Key (R211-R213) fronting on Big Carlos Pass has 0.3 mile that is non-critically eroded. Most of the Gulf beach extending from R214 to R222 has 1.5 miles that is critically eroded, threatening recreational interests and wildlife habitat in Lovers Key State Park. A beach restoration project was constructed in 2004 and nourished again in 2014. The southern shore of Lovers Key (R222) fronting on New Pass also has 0.1 mile of non-critically eroded inlet shoreline.

Between New Pass and Big Hickory Pass, Big Hickory Island (R222.7-R225.9) has 0.8 mile that is critically eroded where wildlife habitat and recreation has been lost. South of Big Hickory Pass, Little Hickory Island (R226-R230) has 0.9 mile of critically eroded beach threatening development interests in Bonita Beach. This area has a beach restoration project with bulkheads and two terminal groins at the northern end.

Storm Effects and Erosion Conditions

Coastal Lee County sustained greater impacts from Hurricane Irma than the southwestern Florida counties to the north, but generally less than Collier County to the south. Most of Gasparilla Island sustained no observable erosion (R1-R17) or minor beach erosion (R18-R21). However, at Gasparilla Island State Park (R22-R26), major beach and dune erosion was sustained (condition IV) (Figure 44). Beach conditions are not currently available for the unbridged barrier islands of Cayo Costa Island (R27-R65) and North Captiva Island (R66-R83).

Most of Captiva Island (R84-R98) and the central third of Sanibel Island (R131-R154) sustained minor beach and dune erosion (condition II) (Figure 45 and Figure 46). Along Estero Island (R182-R199), generally minor beach erosion (condition I) was observed with the exception of a couple of properties adjacent to coastal armoring (Figure 47 and Figure 48). Likewise, minor beach erosion (condition I) was observed along Lovers Key (R213-R221) (Figure 49), except for a small segment at the southern end (R221-R222) where moderate beach and dune erosion was observed. Beach conditions are not currently available for Big Hickory Island. No erosion was observed along Bonita Beach at the southern end of Lee County.

Storm Damage

Six major structures in coastal Lee County sustained major damage, including one single-family dwelling, two multi-family dwellings and three non-habitable major structures. Two bathhouses at Lovers Key State Park sustained major wind damage to their roofs when their skylights were blown out. One of these bathhouses on the beach near R219 had additional interior rain damage. A parking garage structure collapsed in Fort Myers Beach on Estero Island (Figure 49). In addition, approximately 30 feet of boulder rock revetment was damaged (level II damage) at Gasparilla State Park.



Figure 44. *Erosion and damage to dune walkovers at the southern end of Gasparilla Island State Park, R26.*



Figure 45. *Captiva Island in South Seas Plantation development, R88.*



Figure 46. *Erosion at the southern end of Sanibel Island near R131.*



Figure 47. *Erosion at Fort Myers Beach near R194.*



Figure 48. *Erosion south of the Fort Myers Beach Pier near R180.*



Figure 49. *Minor erosion at the northern end of Lovers Key near R213.*



Figure 50. *Collapsed parking garage structure at Fort Myers Beach near R201.*

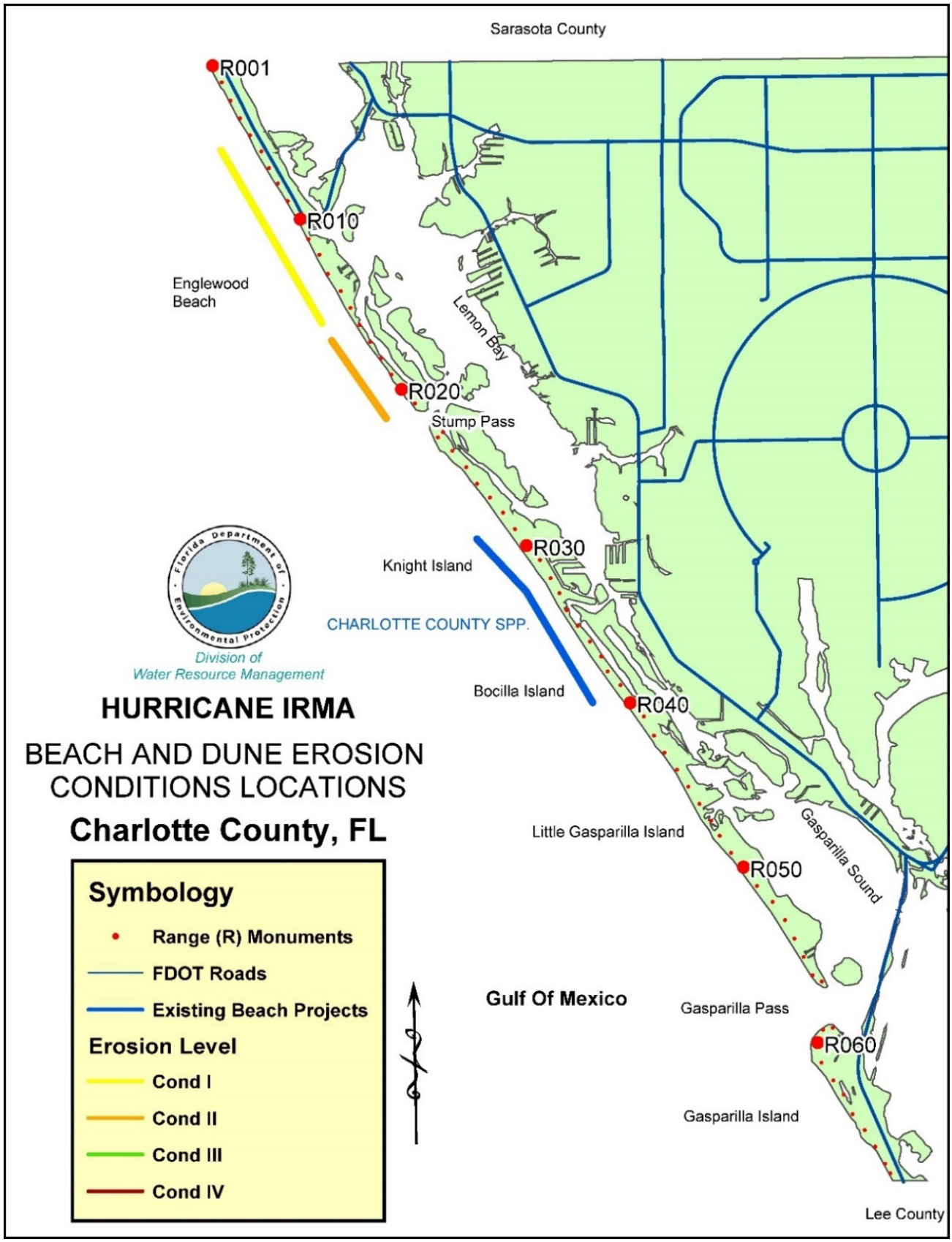


Figure 51. *Charlotte County beach and dune erosion conditions from Hurricane Irma.*

Charlotte County

Charlotte County is located on Florida's southwestern coast fronting the Gulf of Mexico (see Figure 51 above), and has 12.2 miles of beaches extending southward from Sarasota County to Lee County. The coast of Charlotte County includes the southern half of Manasota Key, the Knight Island-Bocilla Island-Little Gasparilla Island barrier complex, and the northern 1.5 miles of Gasparilla Island. There are two natural inlets in Charlotte County: Stump Pass between Manasota Key and Knight Island, and Gasparilla Pass between Little Gasparilla Island and Gasparilla Island. Coastal Charlotte County includes the beach community of Englewood Beach and Stump Pass State Park.

There are three critically eroded areas (6.5 miles) and one critically eroded inlet shoreline (0.1 mile) in Charlotte County. The northern 3.8 miles of Charlotte County (R1-R21.2) along southern Manasota Key including Englewood Beach and Stump Pass State Park are critically eroded, threatening private development and public recreational interests. A few retaining walls and bulkheads exist north of Stump Pass State Park. The park is periodically nourished with Stump Pass maintenance dredge material. The south inlet shoreline of Stump Pass (0.1 mile) is critically eroded, threatening residential development on Knight Island. Along Knight Island and Bocilla Island (R28-R40.5) are 2.3 miles of critically eroded beach threatening private development. Beach restoration of this area has been conducted with Stump Pass dredge material. South of Little Gasparilla Pass, which is closed, is a 0.4-mile segment of critically eroded beach on Little Gasparilla Island. This erosion threatens private development.

Storm Effects and Erosion Conditions

Charlotte County beaches were not significantly impacted by Hurricane Irma. The highest winds were directed substantially offshore until the storm's passage. Along nearly 3 miles of Manasota Key, minor beach erosion (condition I) was observed (R1-R15). The southern mile of Manasota Key (R16-R21) sustained minor beach and dune erosion (condition II) (Figure 51). Beach conditions are not currently available for the unbridged Knight Island-Bocilla Island-Little Gasparilla Island barrier complex (R22-R57). The northern end of Gasparilla Island within Charlotte County (R58-R68) sustained minor beach erosion (condition I).

Storm Damage

On Little Gasparilla Island, an older pile-supported single-family dwelling near R49 that was located on the active beach and into the foreshore seaward of mean high water was destroyed (Figure 53).



Figure 52. *Beach and dune erosion at Stump Pass State Park near R16.*



Figure 53. *Comparative NOAA aerial photos showing the dwelling on Little Gasparilla Island destroyed near R49 (Source: National Assessment of Coastal Change Hazards, St. Petersburg Coastal and Marine Science Center, USGS).*



Figure 54. *Sarasota County beach and dune erosion conditions from Hurricane Irma.*

Sarasota County

Sarasota County is located on Florida's southwestern coast fronting the Gulf of Mexico (see Figure 54 above), and has 34.7 miles of beaches extending southward from Manatee County to Charlotte County. The coast of Sarasota County includes the southern half of Longboat Key, Lido Key, Siesta Key, Casey Key, a mainland segment along Venice, and a northern segment of Manasota Key. Sarasota County has three inlets: New Pass between Longboat Key and Lido Key, Big Sarasota Pass between Lido Key and Siesta Key, and Venice Inlet between Casey and the City of Venice. Coastal Sarasota County includes the following beach communities: Town of Longboat Key, Lido Beach, City of Sarasota and City of Venice.

There are eight designated critically eroded beach areas (24.2 miles), one non-critically eroded beach area (0.7 mile), and two critically eroded inlet shoreline areas (1.1 miles) in Sarasota County. The southern half of Longboat Key (R1-R29) between Manatee County and New Pass has 5.4 miles of critically eroded beach that has threatened development interests in the Town of Longboat Key. This area has a beach restoration project, and terminal groins exist at New Pass. The northern end of Lido Key fronting on New Pass is a critically eroded inlet shoreline area (R31, east 1,500 feet) for 0.3 mile. Nearly all of Lido Key (R31-R44.5) has critically eroded beach that has threatened private development and recreational interests along 2.4 miles. Beach restoration has been conducted along the island and maintenance dredging material has been obtained from the federal navigation channel at New Pass. The south shoreline of Big Sarasota Pass (R44A-R45) is critically eroded along 0.8 mile of Siesta Key. The threatened private properties along this inlet shoreline have bulkheads and rock revetments. At the northern end of Siesta Key south of Sarasota Point (R46-R48.4) is a critically eroded beach area that threatens private development and Beach Road. This 0.4-mile erosion area has rock revetments. Along the southern half of Siesta Key south of the Point of Rocks headland is a 2.4-mile long critically eroded beach area (R64-R77) that threatens private development. Some rock revetments exist in this area, and a beach restoration project has been constructed. Along the northern half of Casey Key (R81-R100.3) is a 3.7-mile long critically eroded beach area that threatens private development and the Casey Key Road. Much of this erosion area has rock revetments. Extending 5.1 miles south of Venice Inlet is a critically eroded beach segment (R116-R143) that has threatened development and recreational interests along the City of Venice, and to the south along a sewage treatment plant, Harbor Drive and Caspersen Beach. This area has a beach restoration project, and numerous concrete bulkheads exist at the northern end of the City of Venice. To the south is a 0.7-mile segment of non-critical erosion (R143-R146.5) and a 0.3-mile segment of critical erosion (R146.5-R148.3) threatening private development. The southern end of Sarasota County (R160-R183.7) is

critically eroded for 4.5 miles along Manasota Key, threatening private development and Manasota Key Road. Some rock revetments have been constructed in this area.

Storm Effects and Erosion Conditions

Sarasota County beaches were not significantly impacted by Hurricane Irma. The highest winds were directed substantially offshore until the storm's passage. Where erosion was observed along the county beaches, it was generally minor beach and dune erosion (condition II) along small discreet segments of beach. There was no discernable erosion along southern Longboat Key (R1-R37), Siesta Key (R45-R75), or portions of Casey Key (R92-R99), Venice (R108-R114), or Manasota Key (R176-R183, except at R182). Moderate beach and dune erosion (condition III) was observed at the southern end of Lido Key (R43-R44), and major beach and dune erosion was observed near the north end of Manasota Key (R138-R149).

Storm Damage

A small segment of beach erosion was observed near the south end of Manasota Key (R175-R176) where more than 100 feet of the Manasota Key Road sustained major damage (Figure 55). Another small segment of erosion was observed further south at R182, where a single-family dwelling is threatened (Figure 56).



Figure 55. *Dune erosion that damaged Manasota Key Road near R175.*



Figure 56. *Dune erosion that threatened a residence near R182.*

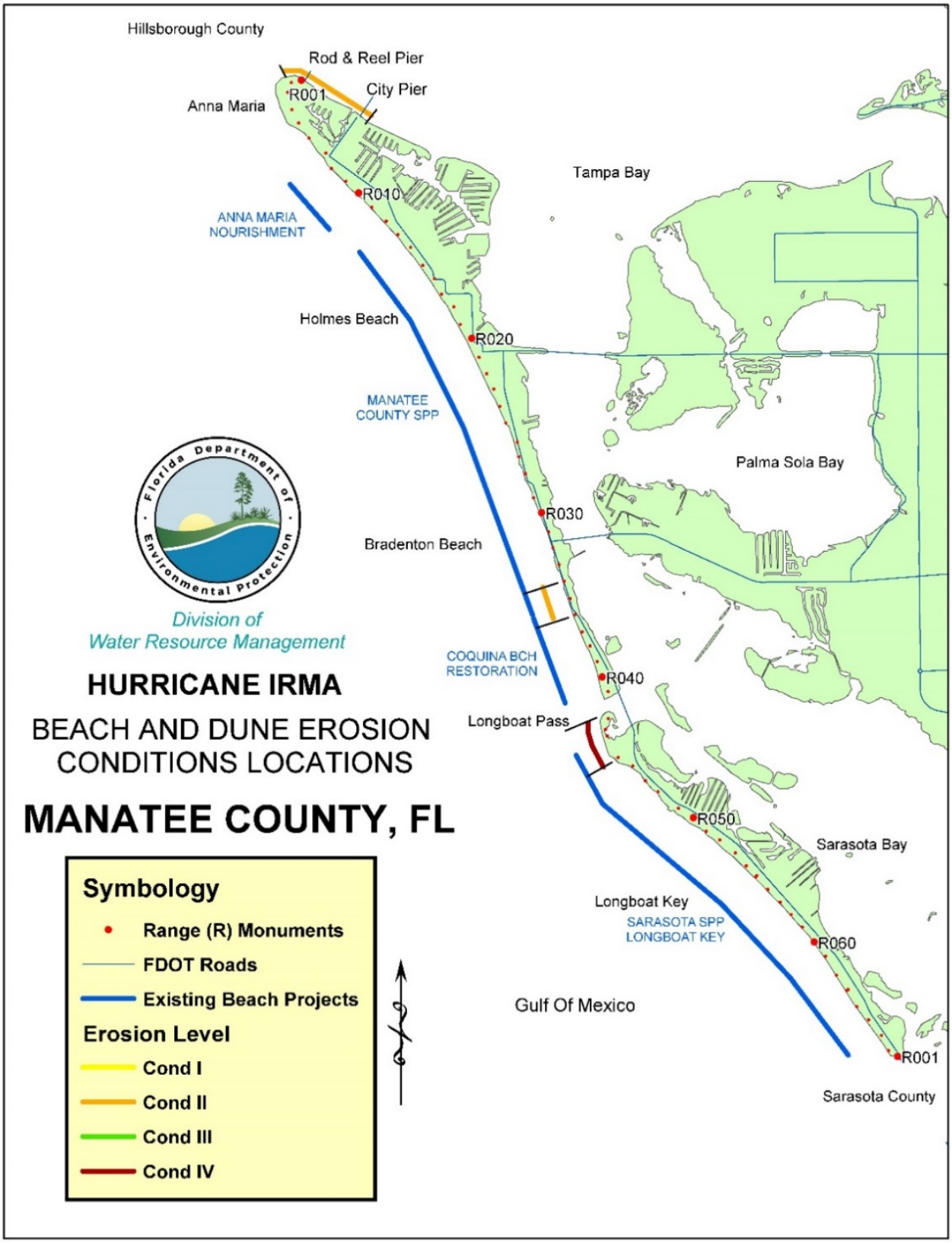


Figure 57. *Manatee County beach and dune erosion conditions from Hurricane Irma.*

Manatee County

Manatee County is located on Florida's southwestern coast fronting the Gulf of Mexico (see Figure 57 above), and has 12.3 miles of beaches extending southward from Tampa Bay to Sarasota County. The coast of Manatee County includes all of Anna Maria Island and the northern half of Longboat Key. Coastal Manatee County includes the following beach communities and major parks: City of Anna Maria, Holmes Beach, Bradenton Beach, Coquina Beach Park, Cortez Beach Park, and the Town of Longboat Key. All of Manatee County is critically eroded. The full-length of Anna Maria Island between the Rod and Reel Pier and Longboat Pass (R41.3) has 7.9 miles of critically eroded beach that has threatened development and recreational interests. This barrier island has a federal beach restoration project, and numerous bulkheads and revetments exist along the road and in front of private development. A groin field and terminal groin exist at the island's southern end. Between Longboat Pass and Sarasota County, the northern half of Longboat Key (R42-R67.3) has 4.8 miles of critically eroded beach that has threatened development and recreational interests. This barrier island has a beach restoration project, and numerous concrete bulkheads exist along the north end fronting the private development.

Storm Effects and Erosion Conditions

Manatee County had three areas of erosion along its coastline from Hurricane Irma. The northern end of Anna Maria Island between R2 and the City Pier sustained minor beach and dune erosion (condition II) due to the northeasterly winds of Irma and wave action across Tampa Bay (Figure 58). Minor beach and dune erosion (condition II) occurred at Coquina Beach (R35) at the southern end of Anna Maria Island. Major beach and dune erosion (condition IV) occurred on Greer Island at the northern end of Longboat Key (R43-R45) (Figure 59).

Storm Damage

Major structural damage occurred to the City of Anna Maria Island's Pier from storm surge, wind and wave damage, with parts of the roof beams exposed.



Figure 58. *Beach erosion at the northern end of Anna Maria Island between R2 and City Pier.*



Figure 59. *The northern end of Longboat Key had severe erosion between R43 and R45.*

V. The Impact of Hurricane Irma on the Carbonate Beaches of the Florida Keys

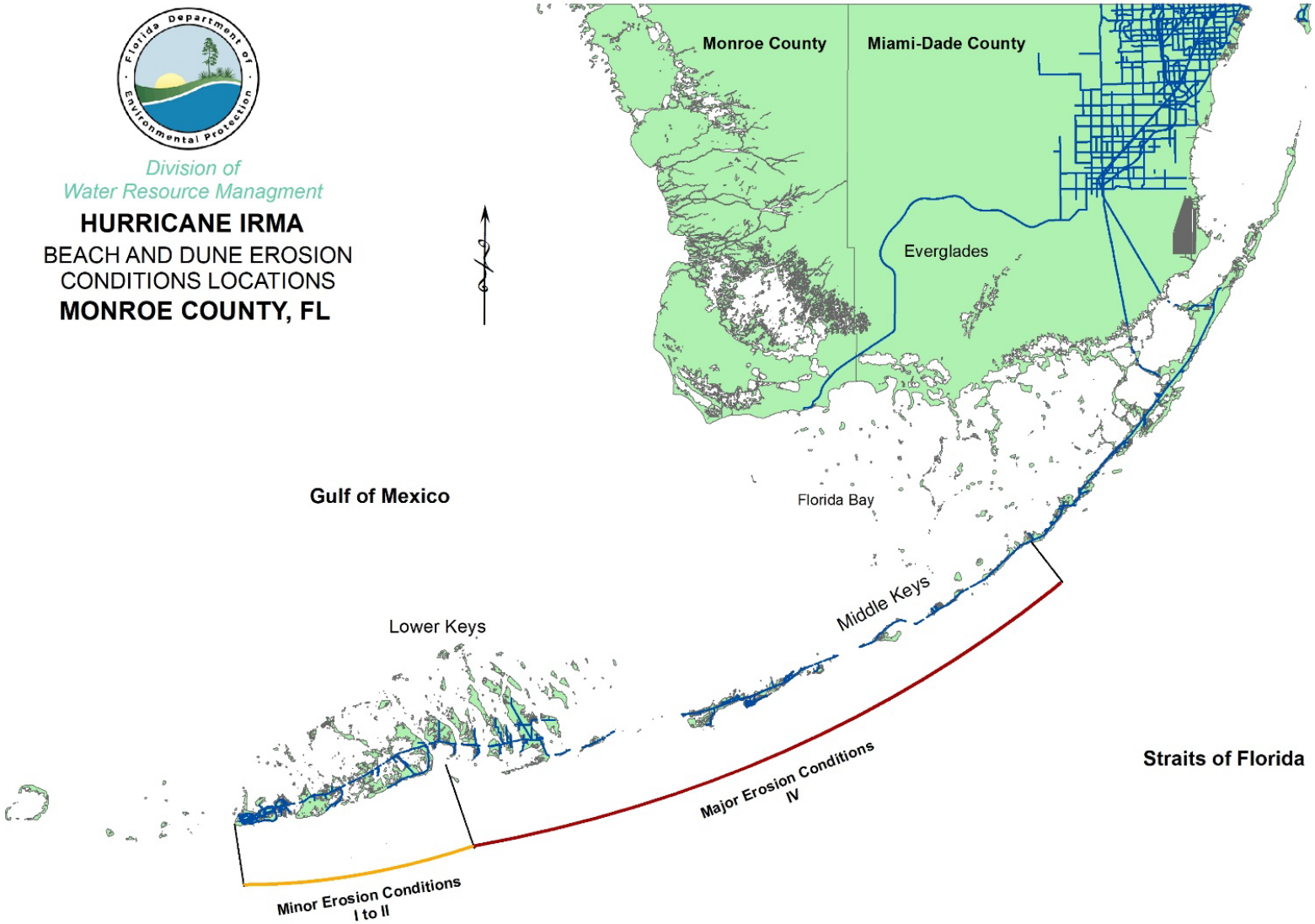


Figure 60. *Monroe County beach and dune erosion conditions from Hurricane Irma.*

Monroe County – Florida Keys

On September 10, 2017, Hurricane Irma strengthened to a Category Four hurricane with maximum sustained winds of 133 mph over the Florida Straits. The eye of Irma passed over the Florida Keys with official landfall on Cudjoe Key at 9:10 a.m. To the west in the weak quadrant of the eye, a National Ocean Service station in Key West measured sustained winds of 71 mph with a gust of 90 mph. The National Weather Service in Key West reported a gust of 91 mph. The eye of Irma moved away from the Keys in the late morning. A 75-mph sustained wind and 87-mph gust was reported at the NDBC C-MAN station at Fowey Rocks, adjacent to Biscayne Bay far to the east of the eye. Reliable wind data in the hard-hit areas of the lower and middle Keys are lacking.

There are no natural beaches in the upper Keys northeast of the Matecumbe Keys (Clark, 1990). All the carbonate sand beaches of the Florida Keys to the east of Cudjoe Key sustained major beach and dune erosion (see Figure 60 above). Those beaches to the west of where the eye passed sustained only minor erosion. Likewise, the islands within the hurricane's eye and to the east sustained the highest storm tide, waves and wind, which caused the most severe damages to development and infrastructure. The county and municipal building departments of Monroe County collectively determined that 1,179 buildings were destroyed. The Department's EHG damage assessment team also logged damage to 8,725 feet of coastal armoring fronting the Straits of Florida.

Given the lack of natural beaches and the generally light wind damage in the upper Keys, the Department's EHG damage assessment team spent little time assessing conditions northeast of the Matecumbe Keys. Figure 61 shows the middle Keys, including the islands and beaches assessed by the EHG damage assessment team. Specifically, the following middle Keys beaches were assessed: Sea Oats Beach on Lower Matecumbe Key; Anne's Beach on Lower Matecumbe Key; Long Key State Park and private beaches at the western end of Long Key; Grassy Key; Curry Hammock State Park on Little Crawl Key; Coco Plum Beach; Key Colony Beach; Sombrero Beach on Vaca Key; and Tingler Island. Following the discussion of the middle Keys, Figure 76 shows the lower Keys, including the islands and beaches assessed by the Department's EHG damage assessment team. Specifically, the following lower Keys beaches were assessed: Little Duck Key; Missouri Key; Ohio Key; Bahia Honda State Park on Bahia Honda Key; Spanish Harbor Keys; Long Beach on Big Pine Key; Newfound Harbor Keys; Sugarloaf Beach on Sugarloaf Key; Geiger Key; Boca Chica Beach on Boca Chica Key; and the Key West beaches. Figure 95 shows the Key West beaches assessed.

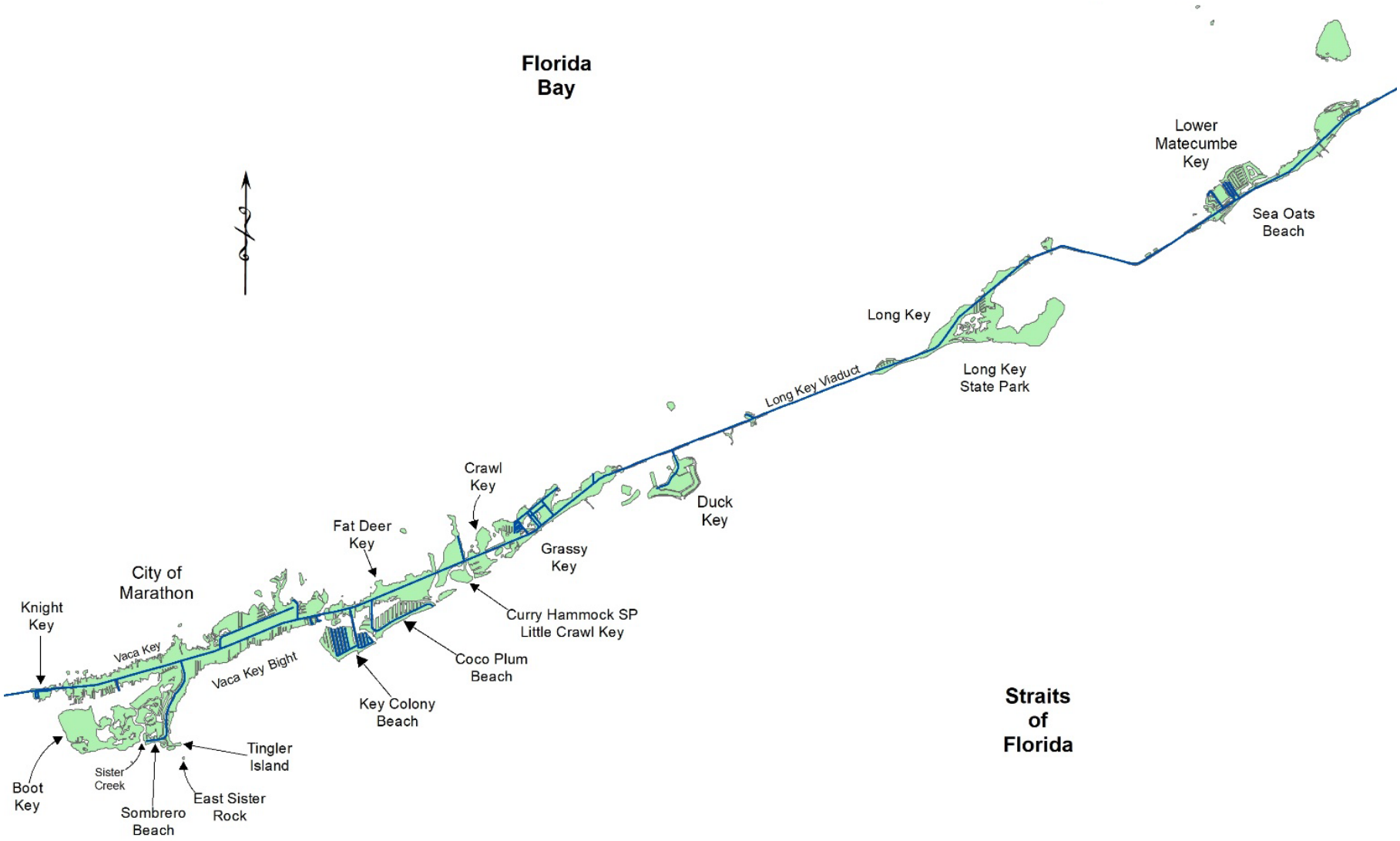


Figure 61. *Middle Keys from Lower Matecumbe Key to the City of Marathon.*

Lower Matecumbe Key

The 4.5-mile long Lower Matecumbe Key, including the community of Islamorada, has approximately 2.8 miles of sand beaches with a width varying between approximately 25 to 50 feet. Along western Lower Matecumbe Key is the 7,000-foot long Sea Oats Beach. The eastern 4,100 feet of Sea Oats Beach fronts on U.S. Highway 1, and 3,700 feet of this public beach segment is designated critically eroded. The western approximately 2,900 feet of Sea Oats Beach fronts private properties consisting of about 30 single-family homes along Sunset Drive. The general trend of net longshore transport along Sea Oats Beach is to the southwest (Clark, 1990), and the beach is anchored by a 350-foot long terminal groin at its western end. Hurricane Irma caused severe erosion along all of Sea Oats Beach, destroying what dune system existed before the storm. Within the right of way along U.S. Highway 1, the Florida Department of Transportation had constructed a dune system with a core of armoring consisting of a concrete block mattress and a concrete slab. These armoring structures were substantially destroyed (level IV damage), along with the dune system (Figure 62). The western end terminal groin sustained minor damage (level II damage). West of Sea Oats Beach and the Calusa Cove Marina is a sandy shoreline of predominantly mangrove. Intermittent sandy beach segments along 2,500 feet of this shoreline is called Anne's Beach. Erosion substantially removed the beach along this segment. All the elevated wooden walkways through the mangrove and along the pocket beaches were destroyed. Throughout Lower Matecumbe Key, widespread wind damage and flooding was sustained by development and infrastructure. Interior water marks observed in a residence at the west end of Sunset Drive appear to reach +9 feet.



Figure 62. *Sea Oats Beach fronting U.S. Highway 1, Lower Matecumbe Key.*

Long Key

The 4.2-mile long island of Long Key has predominantly coarse-grained sand beaches. The eastern approximately 14,000 feet has mostly pocket beaches along a predominantly mangrove shoreline. Along the western 8,500 feet of the island is continuous beach averaging 25 feet in width. Of this beach segment, 5,700 feet are within the Long Key State Park and the western 2,800 feet front private development consisting of 14 single-family residences and five multi-family buildings. One mile of the state park beach is designated critically eroded. Hurricane Irma inflicted severe erosion and overwash along the entire beach front, as well as minor damage (level II damage) to 700 feet of boulder mound limerock revetment (Figure 63).



Figure 63*. The park road in Long Key State Park with overwash of revetment boulders.*

Following the storm, much of the overwash sand throughout Long Key State Park was scraped into piles for the reconstruction of the campsites and nourishment of the beaches (Figure 64). All of the 60 beach front camp sites and one of the three bathhouses in the park were destroyed. In addition, approximately 4,100 feet of state park road was damaged. The private development at the western end of Long Key west of the state park sustained wind and flooding damage and three major structures were destroyed. The Long Key east bridge abutment was also severely eroded on its southern side.



Figure 64. *Staged overwash material in Long Key State Park.*

Grassy Key

On the 3.0-mile long island of Grassy Key, longshore transport is generally toward the west. A mangrove shoreline exists at the eastern end of Grassy Key due to the sheltering effect of the islands to the southeast. This sheltering from southeastern waves has also led to an eastward longshore transport reversal from the DEP virtual monument V-361 at Guava Road to the east. Approximately 1,500 feet east of Guava Road is the Guerrero property, on which exists a boat channel, dock, shore-normal breakwater and two groins, all extending seaward from the shoreline. To the east of the Guerrero property there are at least 2,000 feet of severe erosion (condition IV). Between the boat channel and the western groin, which had supported an artificially nourished beach, the beach was completely lost. To the west of the western groin, along the adjacent property, a 500-foot segment of beach accreted. A significant volume of material from the offshore sand shoal was transported as overwash across private properties. The USGS measured a storm tide on Grassy Key of +7.1 feet NAVD. At least one single-family residence was destroyed by the storm surge (Figure 65) along with 10 other major structures. Other development sustained wind and flooding damages.



Figure 65. *Single-family dwelling destroyed on Grassy Key.*

Little Crawl Key

Little Crawl Key has a 1,500-foot beach that varies from 25 to 50 feet wide, which is within Curry Hammock State Park. This is the site of a truck-hauled beach restoration project constructed in 2008, with additional dune nourishment in 2011. The beach project was constructed with silicate sand, which has blended with the native calcium carbonate sediments on-site. Hurricane Irma inflicted major beach and dune erosion (condition IV) along the eastern approximately 400 feet of the beach, and moderate beach and dune erosion (condition III) along the western 1,100 feet of the beach. The erosion along the eastern stretch of beach has undermined two of the four pavilion structures (Figure 66).



***Figure 66**. Undermined pavilion at Curry Hammock State Park.*

Coco Plum Beach

Coco Plum Beach, located along and seaward of Fat Deer Key, has 7,500 feet of fine grained sand beach averaging 25 feet wide. The eastern 0.6 mile of beach is currently designated as non-critical erosion. At the eastern end of the beach is a terminal rock groin and at the western end are two rock groins. The net sediment transport direction is to the southwest, as seen by the severe erosion west of the eastern terminal groin and the accretion at the western groins. Hurricane Irma severely eroded approximately 3,500 feet of the eastern end of Coco Plum Beach (condition IV). Much of this beach segment has been lost through overwash into the mangrove lagoon landward of the beach (Figure 67). Sea turtle nesting has now been lost along this segment. The 1,250 feet of beach to the west of the severely eroded segment, which is part of a Monroe County park, sustained minor beach and dune erosion (condition II). This segment had previously been nourished with sand that was trucked in by Monroe County.



Figure 67. *Overwash of beach sediments off Coco Plum Beach (to the right of the image) into a lagoon (to the left of image).*

The western 2,500 feet of Coco Plum Beach is developed with a mix of single-family and multi-family dwellings. About 1,600 feet of this segment is designated critically eroded. Hurricane Irma only caused minor beach erosion (condition I) in this area; however, this area sustained flooding and wind damage. Two swimming pools were damaged and two rock revetments (400 feet) sustained minor damage (level II damage) (Figure 68). One building sustained major structural damage due to the storm surge and waves, and many others sustained major roof damage due to the winds.



Figure 68. *Damaged revetment and undermined pool at Coco Plum Beach.*

Key Colony Beach

West of Coco Plum Beach is Key Colony Beach, which is developed and incorporated as the City of Key Colony Beach. This 4,550-foot-long private beach averages 50 feet wide, and is stabilized by 15 limerock groins, which were constructed in 1958. The longshore transport direction is normally to the southwest; however, there is likely little movement of sediment along the beach between the groins. Hurricane Irma inflicted major beach erosion (condition IV), as well as substantial flooding and structural damage along these beaches (Figure 69). Along the beach front, 11 multi-family buildings and one nonhabitable major structure sustained first floor structural damage, and had their foundations undermined (Figure 70). All of the 11 multi-family buildings sustained major flood damage. One multi-family building had understructure damage (Figure 70) and six other major structures were destroyed. Throughout Key Colony was major roof damage and severe flood damage. In addition, there was major damage (level III damage) or total destruction (level IV damage) to 875 feet of concrete seawalls, plus major damage (level III damage) to a boulder mound groin.



Figure 69. *Major beach erosion, Key Colony Beach.*



Figure 70. *Building damage, Key Colony Beach.*



Figure 71. *Major damage to shorefront development, Key Colony Beach.*

Vaca Key – Marathon

The eastern half of the 5.5-mile long Vaca Key is protected by bulkheads and riprap, and a western shoreline segment fronting Vaca Key Bight is predominantly a mangrove shoreline. Erosion was sustained in these areas, along with severe flooding and structural damage from the storm tide and wind throughout much of Marathon. As neighborhoods cleaned up from the storm, large debris piles were generated (Figure 72).



Figure 72. *Debris piles throughout City of Marathon.*

Vaca Key – Sombrero Beach

The southern extension of Vaca Key includes small sandy beaches. Along Sombrero Beach Village are 800 feet of private beach fronting Sister Creek to the west. All the beaches seaward of the seawalls along this stretch have now disappeared due to erosion. Fronting the Straits of Florida and Sister Creek is the Monroe County Park at Sombrero Beach. This fine-grained sandy beach is 1,600 feet long and sheltered from east to southeast wave activity. The eastward transport of beach sediment off Sombrero Beach and into the adjoining canal to the east has contributed to the critical erosion conditions (Clark, 1990). The entire park and facilities sustained major damage from the storm tide flooding as seen in comparative NOAA aerial photos (Figure 73).

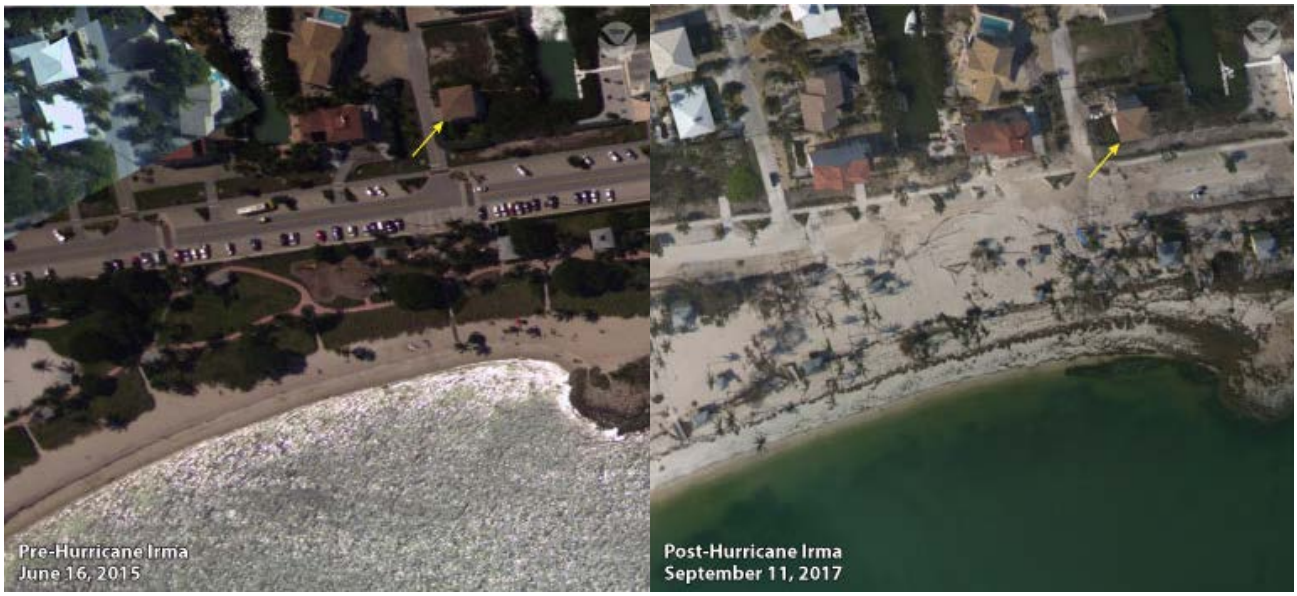


Figure 73. *Sombrero Beach, Monroe County Park, impacted by the storm surge causing substantial overwash and park damage (Source: National Assessment of Coastal Change Hazards, St. Petersburg Coastal and Marine Science Center, USGS).*

All the beach access walkways, fences and dunes were destroyed (Figure 74). Four single-family dwellings to the immediate east of the park were effectively destroyed with structural damage and severe flood damage. The storm surge overwash from the public beach caused accretion at the western end of the park fronting Sister Creek, where a boulder revetment was buried in the sand and a park dock was destroyed.



Figure 74. *Damaged walkway and dunes, Sombrero Beach.*

Tingler Island

To the southeast of Sombrero Beach and at the southern tip of Vaca Key is the small Tingler Island. The Tingler Island shoreline, which is substantially armored with seawalls and revetments, sustained severe erosion along its southern shoreline fronting the Straits of Florida (Figure 75). On this shoreline, a swimming pool was destroyed, and a single-family dwelling was undermined and sustained major damage. Many single-family dwellings on Tingler Island were severely flooded or sustained major roof damage due to the wind.



Figure 75. *Tingler Island shoreline and structural damage, including a swimming pool.*



Figure 76. *Lower Keys from Little Duck Key to the City of Key West.*

Little Duck Key, Missouri Key and Ohio Key

At the western end of the Seven-Mile Bridge are the three small islands of Little Duck Key, Missouri Key and Ohio Key (Figure 76). Little Duck Key has a 25-foot-wide, 825-foot-long public beach park, which is maintained by Monroe County. This beach is designated critically eroded. Missouri Key at its western end has a couple of narrow 500-foot-long pocket beaches. The larger Ohio Key has 1,600 feet of narrow beach along the eastern half of its shoreline and mangrove on the western half. These islands sustained major beach and dune erosion, extensive flooding and wind damage. On Little Duck Key, the Monroe County park was substantially destroyed (Figure 77). Sand overwash covered the parking area, the entrance road was destroyed, and the pavilions and bathrooms were substantially damaged.



Figure 77. *Monroe County park damages on Little Duck Key.*

On Missouri Key, the beach has effectively disappeared due to the loss of beach sediments being transported offshore. The beach along Ohio Key rolled over into the lagoon by the overwash process during Irma's storm tide of approximately +8 feet NAVD (Figure 78). North of U.S. Highway 1, numerous trailers were substantially damaged or destroyed by the storm surge flooding or the wind (Figure 79).



Figure 78. *Ohio Key beach rolled over into lagoon by overwash.*



Figure 79. *Trailer damage, Ohio Key Campgrounds.*

Bahia Honda Key

The most significant carbonate beaches and dunes of the lower Keys are on Bahia Honda Key, and are part of the Bahia Honda State Park. The island has 11,900 feet of beach south of U.S. Highway 1 fronting the Straits of Florida, and another 800 feet of beach north of the highway fronting the Gulf of Mexico. Bahia Honda State Park contained the most significantly impacted beaches in the Florida Keys. The USGS obtained an interior mud line measurement of the storm tide within a park office of +8.04 feet NAVD. Between the current U.S. Highway 1 bridge and the old Flagler bridge is a 600-foot-long recreational beach, called Calusa Beach, that is designated critically eroded (Figure 80). Six of the beach pavilions had to be removed due to the erosion conditions.



Figure 80. *Calusa Beach erosion, Bahia Honda State Park (Picnic tables replace lost pavilions after the storm).*

The western 3,500 feet of park beach fronting the Straits of Florida is also designated critically eroded. Comparing pre- and post-Irma vertical aerial photography, the largest shoreline recession was observed to be -50 feet, located about 500 feet from the western end at the old bridge (Figure 81). A bathhouse building was also destroyed at this location. In addition, about 800 feet of road was destroyed, which was part of the old roadbed adjacent the old U.S. Highway 1 bridge approach. Another larger, two-building bathhouse complex was destroyed approximately 1,000 feet from the western end.



Figure 81. *Severe beach erosion and road destroyed at west end of Bahia Honda Key.*

Loggerhead Beach, on the southern side of Bahia Honda Key, extends along the Straits of Florida near the bridge approach. All the infrastructure for Loggerhead Beach was destroyed, including a 400-foot-long asphalt parking lot, two beach access walkways, a wooden accessibility ramp, and 400 feet of rock revetment (Figure 82).



Figure 82. *Revetment, access walkways, parking lot and all infrastructure for Loggerhead Beach was destroyed.*

To the east along the park road, approximately 2,000 feet of rock revetment sustained minor to major damage (level II to III damage), and 340 feet of paved road were damaged in two segments (Figure 83).



Figure 83. *Bahia Honda State Park road and revetment damage.*

The eastern 7,400 feet of beach on Bahia Honda Key, known as Sandspur Beach, is a fine-grained carbonate beach that averages 60 feet in width, fronting prominent vegetated barrier dunes. Except for periodic hurricane impacts, most of this stretch of beach has been stable. Hurricane Irma inflicted major beach and dune erosion (condition IV) along Sandspur Beach and substantially destroyed the park's infrastructure. Comparing pre- and post-Irma NOAA aerial photography, as much as approximately -75 feet of shoreline recession was observed within Sandspur Beach, particularly between the campsites and the day-use parking lots (Figure 84). About 1,000 feet of road and all the campsites were destroyed or severely damaged (Figure 85). In the high use public beach access area, two 500-foot-long asphalt parking lots were destroyed, and approximately 1,500 feet of park road was damaged (Figure 86). Three beach pavilions, a large bathhouse, and seven beach access walkways were also destroyed adjacent to the parking lots (Figure 87, Figure 88 and Figure 89). In addition, at the far eastern end of Bahia Honda Key, a state park maintenance building was destroyed. Along with the beach erosion and damage to park structures and infrastructure, Irma caused extensive damage to native vegetation across the island.



Figure 84. *Comparative NOAA aerial photos of the Bahia Honda State Park campgrounds adjacent to Sandspur Beach (Source: National Assessment of Coastal Change Hazards, St. Petersburg Coastal and Marine Science Center, USGS).*



Figure 85. *Destroyed road and campsites, Bahia Honda State Park.*



Figure 86. *Sandspur Beach parking lot destroyed.*



Figure 87. *Middle beach pavilion and parking lot destroyed, Sandspur Beach.*



Figure 88. *Bathhouse structure totally destroyed, Sandspur Beach.*



Figure 89. *Eastern pavilion structure and parking lot destroyed, Sandspur Beach.*

Spanish Harbor Keys

West of Bahia Honda Key and east of Big Pine Key lie the relatively small Spanish Harbor Keys. Four segments of vertical seawalls exist along the predominantly rock shoreline fronting the Straits of Florida. The most significant perched sandy beaches exist within the Edward B. Knight Scout Reservation, which is also known as Camp Sawyer. Severe erosion occurred at the southwestern point of the island. Four major buildings and approximately 1,000 feet of road were destroyed within the campgrounds.

Big Pine Key

The easternmost lower Keys island fronting the Florida Straits is Big Pine Key. Much of the Florida Straits shoreline of Big Pine Key is a coarse-grained sand, perched beach, and prominent dune known as Long Beach (Clark, 1990). A 1.0-mile length has been designated non-critically eroded.

Big Pine Key may have been within the eye wall of Irma, as the flood damage was extensive throughout the island south of U.S. Highway 1 and wind damage was significant across the entire island. At the eastern end of the island is a large recreational vehicle park where roughly 70 campers and trailers were destroyed or severely damaged by storm surge. At this location, from a seed line on an interior wall of the Big Pine Key Fishing Lodge, the USGS measured a storm tide of +6.875 feet NAVD.

Major beach and dune erosion (condition IV) was sustained along Long Beach (Figure 90). The USGS measured a storm tide of +7.723 feet NAVD inside a dwelling on Long Beach. Damage to development was severe, as four single-family dwellings and six other major structures were destroyed, two single-family dwellings sustained major structural damage to their first floor, and another sustained major structural damage to its second floor (Figure 91, Figure 92 and Figure 93). Many other dwellings sustained understructure damage from the storm surge, and major roof damage due to wind loads. Approximately 400 feet of Long Beach Road was damaged.



Figure 90. *Major erosion and structural damage along Long Beach, Big Pine Key.*



Figure 91. *Single-family dwelling destroyed, Long Beach, Big Pine Key.*



Figure 92. *Dwelling and dock destroyed, Long Beach, Big Pine Key.*



Figure 93. *Single-family dwelling destroyed, Long Beach, Big Pine Key.*

Newfound Harbor Keys

To the west of Big Pine Key are the Newfound Harbor Keys. The easternmost island is developed with single-family dwellings; however, access to the island is by boat as there are no connecting bridges. As determined from post-Irma aerial photography provided by the NOAA, major beach erosion (condition IV) was sustained along this island. Ten single-family dwellings were destroyed or sustained major structural damage, and 10 other major structures were destroyed. The middle island is undeveloped and sustained major beach erosion (condition IV), with substantial overwash occurring. The small western island, Munson Key, is heavily developed with about 20 major habitable structures that sustained severe flooding damage.

Little Torch Key, Ramrod Key, Summerland Key and Cudjoe Key

These four major islands of the lower Keys generally front the Straits of Florida and are located west of Big Pine Key and east of Sugarloaf Key. They are connected by U.S. Highway 1 and are substantially developed. No beaches exist on these islands, which have both natural rocky mangrove shorelines and armored shorelines generally associated with finger canal development. The eye of Hurricane Irma passed over Cudjoe Key, and significant wind and flooding damages were sustained on these islands. Many single-family dwellings sustained major roof damage, understructure damages and major flooding damage. The following peak storm tide elevations were measured by the USGS on these islands:

Little Torch Key	+6.786 feet NAVD
Ramrod Key	+6.641 feet NAVD
Summerland Key	+6.675 feet NAVD
Cudjoe Key	+6.473 feet NAVD

Sugarloaf Key

In the geographic center of the lower Keys lies the island of Sugarloaf Key. The privately-owned Straits of Florida shoreline of Sugarloaf Key is predominantly a mangrove shoreline; however, Sugarloaf Beach comprises 3,000 feet of sandy beach. Like Long Beach of Big Pine Key, Sugarloaf Beach is a narrow, severely eroded, perched beach fronting a prominent barrier dune. As generally observed along the beaches west of where the eye of Irma crossed the Florida Keys, minor beach and dune erosion (condition II) was sustained along Sugarloaf Beach. Although no storm surge data was obtained along Sugarloaf Beach, data obtained at other locations on Sugarloaf Key indicate the storm surge was likely between +3.5 and +4 feet NAVD. Although flooding was not as severe as on the islands to the east, wind damage was still significant, with many single-family dwellings sustaining major roof damage as well as understructure

damage from the flooding. Along U.S. Highway 1, three mobile homes and six campers were observed to be destroyed.

Big Coppitt Key, Geiger Key and Boca Chica Key

In the western lower Keys, the three islands of Big Coppitt Key, Geiger Key and Boca Chica Key are connected by Boca Chica Road and bridges. U.S. Highway 1 crosses the extensively developed Big Coppitt Key, where many single-family dwellings sustained major roof damage, understructure damage, and major flooding damage from Hurricane Irma. South of Big Coppitt Key is Geiger Key, which is likewise extensively developed. On Geiger Key, four single-family dwellings were destroyed, and many others sustained major roof damage, understructure damage and major flooding damage. No major damage was observed to the seawalls on these islands. West of Geiger Key, the large island of Boca Chica Key is mostly within federal ownership as part of the U.S. Naval Air Station. Half of Boca Chica Key's shoreline is a natural mangrove shoreline, and half is a narrow severely eroded coarse-grained sandy shoreline. The beaches were significantly wider prior to the hurricanes of 1944 and 1948, which inflicted severe erosion throughout the area (Clark, 1990). Following Hurricane Georges in 1998, 1.3 miles of Boca Chica Key was designated critically eroded. Due to its location to the west of the eye of Hurricane Irma, only minor beach and dune erosion (condition II) was sustained along Boca Chica Beach (Figure 94), which is a Monroe County park.



Figure 94. *Minor beach and dune erosion, Boca Chica Key.*

Key West



Figure 95. *Key West beaches, aerial 2017 (Source: ESRI images).*

The westernmost three islands of the lower Keys fronting the Straits of Florida are Stock Island, Cow Key and Key West. Key West lies 14 to 17 miles west of Cudjoe Key, where the eye of Hurricane Irma crossed the lower Keys (Figure 95). A National Ocean Service weather station in Key West measured sustained winds of 71 mph, with a gust to 90 mph. The National Weather Service in Key West reported a gust to 91 mph. Light wind damage was generally observed from Stock Island through Key West. The exception was observed along North Roosevelt Boulevard where three major structures, including a five-story hotel, bank and commercial garage, had their roofs blow off by what could have been a downburst. The USGS obtained six high water measurements on Key West from the eastern to the western end of the island, ranging from +2.735 to +3.371 feet NAVD. The average high water elevation measured was +2.9 feet NAVD, which resulted in little flood damage in Key West.

There are three designated critically eroded beach areas on the island of Key West, including 2.8 miles of shoreline fronting the Straits of Florida, plus 0.3 mile on the southwest point of the island at Fort Zachary Taylor State Park and a small pocket beach on the northwest point at the northern end of Simonton Street. The net annual longshore sediment transport direction along the south shoreline of Key West is to the west (Clark, 1990). There is little littoral material entering the area from the east because past erosion from storms, coupled with seawall construction in 1926, caused the loss of the beach. The seawall fronting South Roosevelt Boulevard now defines the shoreline for over a mile of the easternmost stretch of Key West's southern shoreline. Over 4,000 feet of this wall were destroyed in the hurricane of 1944, and another 400 feet were destroyed in five separate sections during Hurricane Georges in 1998 (Clark, 1998). There was no discernable damage to the seawall by Hurricane Irma.

To the west is the 3,300-foot segment of shoreline named George Smathers Beach, which was originally restored in 1960 and included the construction of four boulder mound limerock groins (200 to 300 feet long) and beach restoration with 30,000 cubic yards of crushed limerock fine-grained sediment. George Smathers Beach was subject to erosion from several storms, and was first nourished with oolitic aragonite material from the Bahamas in 1989 and again with quartz sand trucked in from South Florida in 2000. Minor beach erosion (condition I) was sustained during Hurricane Irma (Figure 96). Surveys by the City of Key West measured a sand volume loss of -1,630 cubic yards (Atkins, 2017).

West of George Smathers Beach, at the end of Bertha Street, 35 feet of concrete seawall with sloping concrete revetment and concrete boardwalk sustained major damage (level III damage) (Figure 97). Another 60 feet of concrete seawall cap sustained minor damage (level II damage). West of Bertha Street, the 480-foot shoreline fronting the 1800 Atlantic Condominiums completely lost the beach seaward of its

rock revetment, which sustained minor damage (level II damage). To the west is a city park along Berg and Kitsos Beach, which experienced minor beach and dune erosion (condition II) to one of the last segments of natural beach on Key West (Figure 98). West of Berg and Kitsos Beach are private properties with seawalls and little to no beach remaining. To the west of these private properties is a 660-foot city park called Rest Beach. A wide beach prior to the hurricane of 1944, Rest Beach was adversely affected by the White Street Pier construction in the mid-1960s. Rest Beach sustained minor beach and dune erosion (condition II) during Hurricane Irma (Figure 99). Sidewalks and beach access walkways were destroyed.

West of Rest Beach and the White Street Pier is a 1,250-foot segment of Monroe County park known as the Clarence S. Higgs Memorial Beach. Although the gardens within West Martello Tower sustained wind damage, the seawall and revetment along the tower and the eastern segment of Higgs Beach sustained no discernable damage. The unarmored western segment of Higgs Beach experienced minor erosion and needs additional sand (Figure 100).

West of Higgs Beach, the Rainbow Pier was damaged and the 950-foot long perched beach adjacent the Casa Marina Hotel sustained minor erosion and needs additional sand. Between the Casa Marina Hotel and the Reach Hotel to the west is a street-end beach called Dog Beach, where pet owners can access the beach with their pets on a leash. Both Dog Beach and the 300-foot-long Reach Hotel Beach sustained minor beach erosion (condition I). The seaward end of the pier at the Reach Hotel was also damaged. At the southern end of Duval Street is another pocket beach owned by the City of Key West known as South Beach. Minor beach erosion (condition I) was sustained during Irma at South Beach, which is now in need of additional sand.

On the southwestern tip of Key West is an area that was built by dredge spoil from the ship channel dredging project of the 1950s. The fill site surrounds the 150-year old Fort Zachary Taylor and includes a 1,500-foot recreational beach within the Zachary Taylor State Park. This beach sustained minor beach and dune erosion (condition II) (Figure 101). In addition, two of the four nearshore boulder mound breakwaters appear to have sustained minor damage (level II damage) (Figure 102). On the northwestern shoreline of Key West at the northern end of Simonton Street is another street-end pocket beach that sustained minor beach erosion (condition I).

Many other islands with beaches are located west of Key West. Cumulatively, the outer islands nearest Key West have over 2.6 miles of calcareous sand beaches. Further westward, 18 miles from Key West and part of the Florida Keys National Marine Sanctuary managed by the Florida Department of

Environmental Protection are the Marquesas Keys, with a cumulative length of nearly 4.5 miles of calcareous sand beaches. The most remote beaches of Florida are those of the Dry Tortugas or Tortugas Keys, which are located 65 to 70 miles west of Key West. All six islands of this group have beaches that cumulatively measure 4.5 miles in length. Although the beaches on these islands west of Key West were not individually assessed following Hurricane Irma, given the greater distance in the lee of the hurricane's eye, there was most likely only minor beach erosion conditions.



Figure 96. *George Smathers Beach, Key West.*



Figure 97. *Bertha Street end seawall damage, Key West.*



Figure 98. *Berg and Kitsos Beach, Key West.*



Figure 99. *Rest Beach, Key West.*



Figure 100. *Clarence Higgs Beach, Key West.*



Figure 101. *Minor beach and dune erosion, Fort Zachary Taylor State Park.*



Figure 102. *Fort Zachary Taylor State Park beach and breakwaters, aerial September 2017 (Source: ESRI.com).*

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