

The Impact of Hurricane Floyd & Hurricane Irene on the Florida East Coast 1999



Post-Storm Report No. BCS-00-01



*Ralph R. Clark
Florida Department of Environmental Protection
Bureau of Beaches and Coastal Systems
April 2000*

STORM SUMMARIES

Hurricane Floyd

Hurricane Floyd formed in the eastern north Atlantic as a tropical wave that moved off the African coast on September 2nd (figure 1). After traveling westward several days, the eighth tropical depression of the season became organized on September 7th and was upgraded to Tropical Storm Floyd on September 8th and then to Hurricane Floyd on September 10th when it was about 200 miles from the Leeward Islands. On September 11th, Floyd slowed, turned to the northwest and avoided the northeast Caribbean. A turn westward coincided with strengthening, and from September 12 to 13 Floyd strengthened to an intense category four hurricane on the Saffir-Simpson Hurricane Classification Scale.

Floyd passed just northeast of San Salvador and the Cat Islands in the Bahamas late on September 13 but grazed Eleuthera Island on September 14 in the morning and turned northwest moving over Abaco Island in the afternoon where there was slight weakening from its peak intensity. Floyd finally veered from its track toward Florida moving northwest then north paralleling the coast. Hurricane Floyd's eye came within 95 nautical miles off Cape Canaveral on September 15 before heading north toward the Carolina's where it made landfall with 10-foot storm tides as a category two hurricane near Cape Fear on September 16.

The Tropical Prediction Center reports maximum intensity winds of 135 knots (155 miles per hour) on September 13th when Floyd was located in the Atlantic east of the Bahamas. Peak wind gusts were measured in Florida at Daytona Beach (69 mph), the Melbourne Airport (68 mph), and Patrick Air Force Base (65 mph). Maximum sustained winds were measured in Florida at Patrick Air Force Base (56 mph), Melbourne Airport (52 mph), and Jacksonville Airport (46 mph). When the eye of Floyd passed nearest Cape Canaveral on September 15, the NOAA buoy located 120 nautical miles to the east measured a maximum sustained wind of 83 mph (figure 2) and a peak wind gust of 106 mph (figure 3). More important for the beach erosion conditions along the northeast coast of Florida, the same offshore buoy also measured peak wave heights of over 50 feet (figure 4).

Although Hurricane Floyd did not make landfall in Florida, and only strong tropical storm conditions were experienced in northeast Florida, the coast took its worst pounding in fifteen years since the 1984 Thanksgiving northeaster. Storm tides were generally only five to six feet along the coast, but the wave conditions experienced were those generated by a major hurricane. The along-shore pass extended the time frame of wave energy influence and that subjected Florida's beaches to severe erosion conditions. Half of the major structures damaged along coast were fishing piers which were subjected to the extreme wave forces.

The estimated total damages in the United States alone have exceeded 3 billion dollars with some estimates as high as 5 or 6 billion dollars. Most of the flood damage occurred in North Carolina from storm water flooding due to the extreme rainfall of 15 to 20 inches, however, South Carolina, Virginia, Maryland, Delaware, New Jersey, Pennsylvania, New York, Massachusetts, and Connecticut also had severe storm water flooding. The Tropical Prediction Center also reported 56 American lives lost, which were the most U.S. casualties outside of Puerto Rico since Hurricane Agnes in 1972. The Federal Emergency Management Agency (FEMA) also reported over 2 million coastal residents were evacuated for Floyd making it the largest peace time evacuation in American history.

Hurricane Irene

Hurricane Irene evolved as a low pressure area over the southwestern Caribbean Sea during the period October 8-12 (figure 5). By morning of October 13th, the low pressure had become the thirteenth tropical depression of 1999 and was Tropical Storm Irene by noon the same day. Over the next 24 hours, Irene moved northerly on a track, which brought it over Isla de Pinos off the south coast of western Cuba at noon on October 14th. During the remainder of the day Irene crossed over western Cuba on a north-northeast storm track.

Once over the warm waters of the Florida Straits Irene intensified to hurricane strength and made landfall with the eye crossing Key West during the morning of October 15. Hurricane force winds raked the lower and middle keys as Irene made landfall as a minimal category one hurricane. During the afternoon, Irene tracked to the northeast across Florida Bay and made another landfall at Cape Sable. The northeastward track across south Florida brought torrential rains of a foot to a foot and a half, which flooded agricultural and residential areas of western Dade, Broward, and Palm Beach Counties.

The eye of Hurricane Irene exited the southeast coast of Florida at Jupiter in northern Palm Beach County late that evening. As it emerged back over the warm Gulf Stream waters, hurricane force winds started battering the coastal counties to the north (e.g., Martin, St. Lucie, Indian River, Brevard, and Volusia Counties). Irene continued to track northward on October 16 and 17 along the Florida east coast while gradually moving further offshore into the Atlantic and north toward the Carolinas where it brushed the Outer Banks and then became an extratropical storm in the North Atlantic.

The Federal Emergency Management Agency (FEMA), the Red Cross, and the Florida Department of Agriculture, estimated property damage and agricultural losses in Florida of around 0.8 billion dollars. There were also eight deaths attributed to Irene in south Florida.

NASSAU COUNTY

Hurricane Floyd

Countywide, Nassau County experienced generally minor beach and dune erosion (Condition II) along Amelia Island during Hurricane Floyd with the exception of the south end, which sustained severe erosion. At St. Marys River Entrance, Fort Clinch sustained no apparent major damage and the fishing pier at the jetty was undamaged. Beach nourishment was underway south of the inlet and minor beach erosion (Condition I) appeared to be sustained along the state park shoreline (R9-R13); however, it would be difficult to quantify the offshore sand loss given the work was still in progress. The dredge pipe along the beach may also have prevented some wave uprush from reaching the vegetated dune area.

South along the City of Fernandina Beach generally minor beach and dune erosion (Condition II) was sustained. Along Ocean Avenue (R16-R20) the revetment and road were overtopped and numerous dwellings were flooded at ground level but no structural damage was reported or apparent. A substantial quantity of sand covered the road and street ends prompting a major poststorm scraping operation to restore the original road grades. Minor beach and dune erosion (Condition II) continued south along South Fletcher Avenue (R20-R33) and numerous overwashes caused significant street flooding. A major overwash deposit of sand in the road occurred between R25 and R27.

The south end of Fernandina Beach (R33-R47) sustained only minor beach erosion (Condition I). The private fishing pier at R39 sustained no apparent major structural damage. Continuing south through the county stretch of Amelia Island including American Beach (R57-R59) and the beach restoration area (R60-R75), generally only Condition I erosion was sustained. In the state park south of the groin field (R76-R80), Condition IV erosion was sustained. While this area suffers from continued erosion stress, severe erosion was sustained from the storm tides and wave conditions from Floyd.

Hurricane Irene

Little additional erosion was experienced along Amelia Island during Irene's offshore pass. Both storms had a similar location relative to Nassau County, but Floyd was substantially stronger. Additional critical erosion was experienced at the island's south end (R76-R80).

DUVAL COUNTY

Hurricane Floyd

Variable erosion conditions were experienced throughout Duval County from Hurricane Floyd, making generalizations difficult. While much of the county fared well along Atlantic Beach and Jacksonville Beach, Little Talbot Island may have sustained its worst erosion event in 35 years since Hurricane Dora in 1964.

South of Amelia Island, the Nassau Sound ebb tidal delta is accumulating large volumes of sand eroded off Amelia Island, Big Talbot Island, and Little Talbot Island. The Nassau Sound shoreline along Big Talbot Island sustained continued major beach and dune erosion (Condition IV) during the storm tides of Floyd. Numerous mature oak trees continue to be undermined and lost within the Big Talbot Island State Park. However, the rate of bluff retreat is unknown and a shoreline monitoring program needs to be implemented.

The north end of Little Talbot Island has continued to accrete northward into Nassau Sound. This may be contributing to the erosion stress on the south end of Amelia Island. Along northern Little Talbot Island (R3-R12) moderate beach and dune erosion was sustained (Condition III). The southern half of Little Talbot Island varied from R12-R14 (Condition II), R14-R18 (Condition III), to R18-R21 (Condition II). Generally, most of the Atlantic Ocean front of Little Talbot Island sustained moderate beach and dune erosion (Condition III) making it perhaps the worst erosion event since Hurricane Dora in 1964.

The south end of Little Talbot Island (R21-R25) is a designated critical erosion area which suffers continued severe erosion stress due to the northward migration of Fort George Inlet. Hurricane Floyd caused Condition IV erosion in this area with an estimated dune retreat between 25 and 30 feet (B. Nelson).

South of Fort George Inlet, along Wards Bank, only minor beach and dune erosion (Condition II) was sustained. Immediately south of the St. Johns River Entrance (V501-R31) there was no significant erosion apparent. Minor beach and dune erosion occurred near R32 and moderate beach and dune erosion (Condition III) was sustained between R33-R35 within Kathryn Abby Hanna Park. Throughout the remainder of Duval County (R36-R80) the erosion varied from Condition I to Condition II. Some street end and beach ramp flooding occurred along Neptune Beach, Atlantic Beach, and Jacksonville Beach. The only reportable major damage occurred at the Jacksonville Beach fishing pier (R69) where the end 140 feet was destroyed and another 75 feet was substantially damaged.

Hurricane Irene

With the exception of additional erosion at the south end of Little Talbot Island, Irene had little additional influence on the beach conditions in Duval County.

ST. JOHNS COUNTY

Hurricane Floyd

During the offshore pass of Hurricane Floyd, St. Johns County experienced its worst erosion event in 15 years since the Thanksgiving, 1984 northeaster. Generally the northern half of the county, particularly through Guano State Park, escaped any major erosion. However, Ponte Vedra at the north end, Vilano Beach (north of St. Augustine Inlet), Conch Island (Anastasia State Park), Anastasia Island (St. Augustine Beach to Matanzas Inlet), and Summer Haven, all sustained moderate to major beach and dune erosion. Most structural damages were limited to beach access walkways, beach vehicle ramps, and some concrete retaining walls. But a couple roofs sustained major damage in the less than hurricane force winds and there was some revetment damage.

The northern mile of St. Johns County (R1-R5) sustained little impact, but much of Ponte Vedra between R6 and R23, roughly three miles, sustained moderate beach and dune erosion (Condition III). Southward between R23 and R34 at Mickler Landing minor beach and dune erosion was sustained. The ends of many beach access walkways were damaged throughout northern St. Johns County. The coast south of Mickler Landing through the Guano River State Park (R34-R67) shows general stability and sustained only Condition I erosion.

Erosion became more apparent in South Ponte Vedra south of R67. Roof damage was sustained near R80 and minor flooding occurred at four single-family dwellings between R80.5-R81.5. Damage in this area was particularly light in comparison to that which occurred in 1964 during the direct hit by Hurricane Dora which destroyed a number of dwellings along a very sparsely populated beach at that time.

In the four to five miles north of St. Augustine Inlet more erosion was apparent. The stretch near Usinas Beach between R95-R98 sustained Condition III erosion. Between R115 and R116 the vegetation line retreated about 50 feet as the vegetated storm berm was leveled out and beach sand was even transported landward into the depression in front of the remnant dune ridge. In the designated critical erosion area (R110-R117) Condition III to IV erosion was sustained. State road AIA is threatened between R115 and R116. At R117 there was over 100 feet of recession of the vegetation line. Generally through Vilano Beach (R117-R121) Condition IV erosion prevailed as 100 foot recession in the vegetation line was typical. The Vilano Beach access park lost over 100 feet of vegetation and sustained flooding and sand overwash into the parking lot. In contrast, inside St. Augustine Inlet substantial flooding was incurred on Porpoise Point. Massive accretion occurred at R122 where the beach has buried the north jetty with sand being transported into the inlet.

South of St. Augustine Inlet, Condition IV erosion was sustained along the entire length of Conch Island and northern Anastasia Island (R126-R141). A substantial quantity of sand had just been pumped onto the beaches of Conch Island (R126-R134) for dune restoration; however, the flooding and erosion from Floyd was severe throughout.

Between R134.5-R137, the dune system was a complete loss with extensive sand washovers dominating. Salt Run at R137 was flowing during the storm tides, and the park road a half-mile inland and west of Salt Run was flooded. Between R137 and R138 only two eroded dunes remain (photo 1). Between R138 and R139 is an extensive washover area which the Corps of Engineers had to close with a beach scraping project. The State Park's beach ramp was damaged and the parking area was flooded. Between the beach ramp near R139 and the south end of the park at Pope Road (R141), severe erosion and dune breaches were sustained and substantial peat deposits became exposed on the beach. State Road A1A is being threatened between R140 and R141 and the beach access stairs were destroyed at R141.

From Pope Road (R141) to 3rd Street South (R145.5), the City of St. Augustine Beach is armored by revetments and seawalls. The shore-parallel spur groin at R141 sustained extensive damage as much rock was dislodged and rolled off the structure. The seaward 200 feet by 75 feet of the parking area at the end of Pope Road behind the revetment was destroyed and substantial revetment damage was sustained for about 150 feet as much rock was displaced during wave overtopping. The adjacent Howard Johnson's Hotel had first floor flooding and two segments of concrete block wall were destroyed for 35 feet and 75 feet. The St. Augustine Beach concrete fishing pier appeared to have sustained no major structural damage; however, a 30-foot concrete wall north of the pier and a 150-foot concrete wall south of the pier were destroyed.

Numerous beach access stairs throughout St. Augustine Beach were damaged. At 16th Street between R142 and R143 the upland property yards were substantially eroded behind the revetment and decks were damaged and destroyed. Significant upland property erosion behind the revetment also occurred south of R145. Immediately south of the revetments (R146-R147) Condition III erosion prevailed. Also, 30 feet off the end of a concrete block wall was destroyed north of R146, and 200 feet north of R147 another 50 feet of concrete block retaining wall was destroyed.

Along most of Anastasia Island beaches between St. Augustine Beach and Crescent Beach (R147-R174) Condition III erosion prevailed with localized Condition IV erosion (photo 2). This erosion was definitely the worst sustained by these beaches and dunes since the Thanksgiving, 1984 northeaster. At Crescent Beach, roof damage was sustained by one motel building (R174). South from Crescent Beach (R174-R192) the beaches and dunes sustained Condition III to IV erosion. Consistent with the severe erosion sustained on the south ends of Amelia Island and Little Talbot Island, the south end of Anastasia Island also sustained severe erosion. From R192 through R196, in the Fort Matanzas National Monument, Condition IV erosion occurred. Adjacent the beach vehicle ramp (R194) the vertical dune erosion escarpment reached at least 10 feet and at least 50 feet of the wooden public beach access walkway (R195) was destroyed (photo 3).

South of the Matanzas Inlet bridge at R197, some accretion was apparent and a deck was damaged. The Summerhaven revetment held up well and protected the old section of State Road A1A. To the south between R200-R202, as has occurred during numerous

storms, there was substantial storm surge overtopping into the Matanzas River lagoon through several breaches. From 400 feet south of R203 to R205 is a 1600-foot long breach. From R205 to R208+300 feet old State Road A1A was buried with sand inhibiting access to numerous single-family dwellings. Faring no better, the paved stretch of State Road A1A to the Flagler County line (200 feet south of R208 to 200 feet south of R209) was breached by the storm surge for 1000 feet and buried with sand. Condition IV erosion prevailed along this south stretch of Summerhaven where the dune system was completely destroyed by erosion.

Hurricane Irene

Overall, there was additional beach and dune erosion caused by Hurricane Irene's offshore pass. The erosion from Irene was not as severe individually as the erosion from Floyd, but the additional erosion has made the beach conditions more critical than ever. From Ponte Vedra through Vilano Beach, the conditions were not much worse than after Floyd; however, the south half of the county experienced additional severe erosion.

Anastasia State Park along Conch Island sustained more beach and dune erosion. The additional erosion at the end of Pope Road (R141) threatens State Road A1A. However, south of the St. Augustine revetment at 3rd Street (R146), the conditions were no worse than after Floyd. Southward along Anastasia Island through Crescent Beach, additional dune erosion was sustained as little recovery had taken place after Floyd. Dune erosion conditions have become most severe at the Fort Matanzas National Monument (R194-R196) (photo 4). South of Matanzas Inlet, the erosion conditions did not appear to be much worse after Irene, although additional storm tide overtopping occurred south of R200 through R206.

FLAGLER COUNTY

Hurricane Floyd

Like St. Johns County, Flagler County sustained its worst coastal storm impact in 15 years since the Thanksgiving, 1984 northeaster. Hurricane Floyd may have even caused worst erosion damage than the 1984 storm. There was substantial armoring damage as over 4225 feet of rock revetment was destroyed or substantially damaged at both Marineland and Flagler Beach.

Marineland at the north end of the county was particularly hard hit. A 75-foot segment of rock revetment was destroyed at R1, and 200 to 300 feet south of R1 a 100-foot segment of revetment was destroyed along with a concrete deck and recreation facilities on the upland property. The large Marineland sign also blew over at R1. The revetment along the entire reach of Marineland (R1-R3) was substantially impacted; however, the only other failures were at the south end where 50 feet of revetment was destroyed 250 feet north of R3, another 50 feet was lost immediately south of R3, and another 50 feet was destroyed located 300 feet south of R2. The five rock groins at Marineland were also substantially impacted.

The coast south of Marineland (R3-R16) has exposed Anastasia rock formation. From R3 through R14 moderate dune erosion was sustained leaving exposed a lot more rock than before the storm. Only minor beach and dune erosion was apparent between R14 and R17, which includes Washington Oaks State Park and Marineland Acres in an area, which is normally very stable. To the south however, from R17 through R24, Condition III erosion was predominant. The erosion lessened somewhat from R24-R49, varying from Condition I to II. At R49 there was substantial damage to the county park's handicap ramp and beach access walkway.

Central Flagler County erosion conditions continued to vary, with R49-R58 incurring predominately Condition III erosion and R58 to R60 incurring predominately Condition II erosion. Between R60 and the Beverly Beach Campgrounds seawall, which starts 300 feet north of R61, moderate dune erosion threatens several structures. Although the wall had no apparent damage, there was substantial dune erosion for about 100 feet south of the wall. Otherwise the stretch from R62 to R67 sustained only minor beach and dune erosion north of Flagler Beach.

Northern Flagler Beach (R67-R79) is not armored and Condition II to III erosion prevailed. At R79 the Flagler Beach fishing pier had about 75 feet off its end destroyed. Condition III erosion prevailed south of the pier (R79-R86) through the armored stretch of Flagler Beach. North of 9th Street and north of 10th Street between R80 and R81 about 50 feet of revetment was destroyed at each location. Commencing at 150 feet north of R81 south of 10th Street and continuing to 150 feet north of R84 north of 16th Street approximately 2950 feet of revetment was destroyed or substantially damaged. Starting 100 feet south of R84 and extending generally between 16th and 17th Streets is 500 feet of

destroyed revetment behind which erosion encroached upon the State Road A1A shoulder and prompted emergency filling by the Department of Transportation. North and south of 18th Street is another 300 feet of substantially damaged revetment and the south end of the revetment is damaged for 50 feet north of 19th Street. In all, 3900 feet of the A1A revetment was destroyed or substantially damaged in Flagler Beach.

Immediately south of 19th Street (R87-R89) major dune erosion was sustained where no revetment existed (photo 5). This Condition IV erosion threatens A1A. To the south erosion conditions lessened from Condition III between R89-R91 to Condition II between R91-R94. The south end of the county between R95 and R100 including the State Park varied between Condition II and III erosion.

Hurricane Irene

Generally, Flagler County escaped the level of damage sustained during Hurricane Floyd when Irene passed offshore. Additional erosion was sustained to the beach but little additional dune loss was sustained. At Marineland, the beach conditions were no worse; however, the large Marineland “arch” sign and the roof of the spectator seating area over the porpoise tank sustained wind damage.

At Beverly Beach, the campgrounds had placed fill after Floyd to the south of the wall (R62) but lost half of the fill during Irene. Flagler Beach sustained additional beach erosion, which dramatically lowered the beach profile (photo 6). About three fourths of the fill placed by the Department of Transportation between 16th and 17th Streets was lost. Beach/dune conditions remain very critical along Flagler Beach, which also experienced light wind damage to mostly roofs, signs, and fences.

VOLUSIA COUNTY

Hurricane Floyd

During the offshore pass of Hurricane Floyd, Volusia County sustained its worst erosion event in 15 years. Most of the northern half of the county (R1-R128) sustained at least moderate beach and dune erosion (Condition III) while the southern half (R128-R213) sustained major beach and dune erosion (Condition IV). The southern 10 miles within the Cape Canaveral National Seashore sustained minor to moderate beach and dune erosion. Over 50 of the estimated 120 public beach access walkway structures sustained damage to railing, decking or support beams and piles. Most of the seawalls and revetments in the county sustained no damage.

Along the northern 7 miles of the county (R1-R39) the usually stable north peninsula sustained minor to moderate beach and dune erosion. Numerous beach access walkways had their seaward ends damaged. The north county lifeguard station (R39) sustained structural damage to its first floor level. To the south along the generally stable coarse grained coquina sand beaches of Ormond by the Sea and northern Ormond Beach (R40-R56) generally only minor beach and dune erosion was sustained (Condition II). Condition III erosion was sustained in one localized area between R49 and R50.

The beach sediments change to predominately fine silicate sand from Granada Avenue (R57) to Ponce de Leon Inlet (R148). The 200 feet of public park north of Granada Avenue sustained moderate to major beach and dune erosion. Along the remainder of Ormond Beach (R57-R66) Condition III erosion prevailed. The designated critical erosion area extends from R57 through R77 in Daytona Beach, however, all of Daytona Beach (R67-R93) sustained Condition III erosion during Floyd.

Along with numerous beach access stairs being damaged, a couple of concrete block walls were destroyed in Daytona Beach. A large roof section was blown off Our Lady of Lourdes Catholic School in Daytona Beach. The Seaview Avenue beach ramp was damaged near R73. A 25-foot segment of concrete block wall was destroyed at the Seabreeze Motel 250 feet south of R76 and another 25 feet of wall was collapsed on the Seabreeze recreational center public beach access walkway (300 feet south of R76). The most significant damage however was to the Main Street fishing pier (near R84). The seaward 300 feet of the pier was destroyed during the height of the storm wave conditions and the pier debris was scattered for 12.3 miles south to the Ponce de Leon Inlet north jetty.

Condition III erosion prevailed throughout Daytona Beach Shores (R93-R120) to the south of Dayton Beach. Along with beach stairs and walkway ends damaged, several concrete block walls were also destroyed. At the Old Salty's Motel (400 feet north of R94) 75 feet of concrete block wall was destroyed. Two other 75-foot segments of concrete block walls were also destroyed at 200 feet north of R98 and 200 feet south of

R102. Another 65-foot segment of wall was destroyed at R120. Located near R118, the Sun glow Fishing Pier had some decking damage but none of the major structural damage of the Daytona Beach pier; however, the Sun glow Pier is considerably shorter and does not extend as far seaward as the destruction sustained on the Daytona Beach pier.

South of Daytona Beach Shores, Condition III erosion generally prevailed through Wilbur by the Sea (R120-R128). Some localized major beach and dune erosion was sustained at R126. Erosion conditions worsened to the south as the Town of Ponce Inlet (R128-R145) generally suffered Condition IV erosion. However, conditions have not returned to critical in this area as had once prevailed during the 70's and 80's. Substantial fill had been placed and the area was stabilized by the closure of the north jetty weir.

At Ponce de Leon Inlet, the jetties appeared to have rocks dislodged but they are still structurally functional. There was some pier deck railing damage on the jetty fishing pier. Inlet shoreline erosion was severe and threatens the Lighthouse Point Park's parking area. In contrast, the first mile of beach south of the inlet (R150-R155) appeared to only have very minor erosion. This transitioned to Condition II erosion between R155 and R158 and Condition III between R158 and R159.

Most of New Smyrna Beach from R160 to Bethune Beach and into the Cape Canaveral National Seashore to R213 suffered major beach and dune erosion (Condition IV). Numerous walkway ends were damaged and entire dune areas were removed below dune overwalks. Armoring generally fared well as no significant damage appeared to be sustained by any of the walls in New Smyrna Beach or the coquina rock revetments in Bethune Beach. Roof damage was sustained at the Coronado Condominium near R162 and a few single family dwellings were being undermined at R161. Some of the roof was also blown off Our Lady Star of the Sea Catholic Church. However, the worse damage occurred in Bethune Beach near R201 where a 400 foot section of North Atlantic Avenue was destroyed (photo 7). About 2000 feet of a new dune restoration project (R200-R202) was destroyed seaward of the road. At a gap in the revetment south of 7th Street (250 feet south of R204), the storm tide and wave uprush breached the dune and inundated the road with sand.

The northern mile within the Cape Canaveral National Seashore (R208-R213) is part of a designated noncritical erosion area and sustained Condition IV erosion. The southern approximately four miles of National Seashore within Volusia County sustained only minor to moderate beach and dune erosion as conditions started improving to the south.

Hurricane Irene

As Hurricane Irene exited the coast south of Cape Canaveral and headed offshore, its intensity increased. Of the northeast Florida counties, Volusia was closest to the higher velocity wind field. Already severely eroded by Floyd, Volusia sustained additional erosion leaving the famous tourist beaches in a very critical condition.

At Ormond Beach, there was more beach and dune erosion, which left the beach undriveable at high tide. There was also scattered wind damage with many single-family dwelling roofs losing roofing materials. Many fences and commercial signs were blown down including a large billboard being toppled at R39. In addition, gas station signs and convenience store awnings were blown out.

In Daytona Beach, conditions are still very critical. More beach erosion was sustained and there was scattered light wind damage throughout the area. Daytona Beach Shores also had scattered light wind damage. Conditions in the designated critical erosion area are very serious. There was more erosion in the seawalled area and the normal high tide is now at the wall. In the unarmored areas there was more dune erosion (photo 8). More beach and dune erosion was also sustained throughout Wilbur by the Sea and the Town of Ponce Inlet. At Ponce de Leon Inlet the designated critical inlet shoreline sustained additional erosion.

South of Ponce de Leon Inlet, New Smyrna Beach sustained additional severe erosion. Conditions are very critical along North Atlantic Avenue (R161-R162) where at least three single-family dwellings are in danger and one dwelling had its parking slab undermined and destroyed. One building in New Smyrna Beach had its roof blown off and at R165 a swimming pool was being undermined.

Further south in Bethune Beach, the erosion conditions were not much worse than after Floyd. Many single-family dwellings had roofing damage and a screened porch roof blew off at R197.

BREVARD COUNTY

Hurricane Floyd

The historic erosion problem areas in Brevard County continued to be the worst eroded sites from Hurricane Floyd, which brushed closest to the eastward projecting Cape Canaveral. Overall most of the county's coast sustained minor beach and dune erosion (Condition II), but localized problem areas sustained moderate to major beach and dune erosion (Condition III to IV). Numerous beach access walkway ends were damaged throughout the county and approximately 600 feet of armoring were damaged.

The northern one third of the county includes Canaveral National Seashore and Cape Canaveral. The erosion varied from relatively minor erosion just south of Volusia County to moderate and major beach and dune erosion along the Playalinda beaches. At Playalinda nine beach access walkways sustained major damage and seven received minor impacts. Further south, the north shore of the cape (V117-V136) had extensive overwashes. The south shore of the cape extending to Canaveral Inlet sustained generally only Condition II erosion in the lee of the storm's wind and wave action.

At Canaveral Inlet the north jetty had a substantial quantity of sand washed over into the inlet channel. A geotube groin north of the jetty was also substantially damaged. On the south side, the Canaveral Inlet pier and south jetty had no apparent damage. Jetty Park and the beaches extending south (R1-R4) had only minor erosion (Condition I).

Throughout all of the City of Canaveral and most of Cocoa Beach, Condition II erosion prevailed. Throughout this region (R4-R53) numerous beach access walkways had their seaward ends damaged. The Canaveral Pier near R16 sustained no apparent structural damage. Two revetments were damaged, including a 100-foot segment near R33 and a 250-foot segment located 200 to 450 feet south of R43. The end of 12th Street, with the Sunshine Villas to the north and Pelican Landing to the south, sustained major erosion into the upland prompting the emergency placement of 400 cubic yards of sand fill. At other isolated gaps in armoring between R44 and R49 there were moderate to severe erosion conditions into the upland.

The central Brevard County coast between R53 and R84 is Patrick Air Force Base, which sustained generally minor beach and dune erosion (Condition II). South of the concrete wall at R53 through R54 were extensive overwash deposits. Condition II to III erosion generally prevailed between R53 and R56. At a beach access park about 500 feet south of R58, fifty feet of parking area pavement was damaged and the entire dune restoration was lost beneath a wooden elevated boardwalk. At two particularly critical sites, at R60 (Condition IV erosion) and R61-R62 (Condition III erosion), A1A is being threatened.

Minor beach and dune erosion (Condition II) also prevailed throughout Satellite Beach (R85-R97). 500 feet north of R88 there was minor revetment damage at the northeast corner of the Buccaneer Condominium property. Many beach access walkways had their seaward projecting stairs damaged. From R93 at Pelican Beach Park, Condition II

erosion trended into Condition III erosion from R94 to R95 where single-family dwellings are threatened. Conditions worsened to the south at R97 along Shell Street where four single-family dwellings and a swimming pool were imminently threatened prompting the emergency placement of over 2000 cubic yards of orange sand fill. 700 feet south of R97, 150 feet of revetment was substantially damaged.

Indian Harbour Beach Park (R99) to the Eau Gallie Causeway (R105) sustained minor beach and dune erosion (Condition II). To the south continued Condition II erosion until Paradise Beach Park (R110-R111.5) where moderate beach and dune erosion (Condition III) was sustained and the handicap access ramp (R111) was destroyed. South into Indianalantic continued Condition II erosion. 300 feet north of R122, erosion threatens a street and adjacent pool. Minor beach and dune erosion prevailed between R123-R126 along the Indianalantic boardwalk and this Condition II erosion continued south through Indianalantic except for a few localized dune erosion problems, which posed no threat to residences.

Melbourne Beach sustained generally minor beach and dune erosion (Condition II) in the north (R133-R135) through the historic erosion problem area during the 1970's. This worsened dramatically into major beach and dune erosion (Condition IV) from R135.5 through R137. The northern six of eight buildings of the Breakers Condominium are in imminent danger from the erosion conditions (photo 9). To the south the erosion ameliorated to Condition II along Spessard Holland Park (R138).

The south Brevard County area generally sustained Condition II erosion except at isolated problem sites such as Sea Grape Manor at R162 where 100 feet of revetment was damaged and the bluff erosion threatens the building. At the Sebastian Inlet State Recreation Area, the beach north of the inlet sustained Condition III erosion from about R217 to R218.5 but this is generally an area of accretion and no facilities are threatened. The seaward 50 feet of the north jetty pier was structurally damaged and numerous deck grates blew out. The end of the jetty sustained some rock displacement.

Hurricane Irene

As Hurricane Irene exited the southeast coast of Florida, the eye reformed over open Atlantic waters off Ft. Pierce and Vero Beach. The storm strengthened and convection intensified bringing strong winds and battering storm waves to the coast of Brevard County. Unlike during Hurricane Floyd when the greater impact was felt north of Cape Canaveral, Irene's greater impact was experienced south of the cape. Countywide, major damage was assessed to 17 single-family dwellings, 15 mobile homes, and 5 commercial buildings. Minor damage was also assessed to 1,074 single-family dwellings, 445 mobile homes, and 555 commercial buildings.

As Irene angled away from the Florida coast on a northerly track, the central east coast of Florida experienced hurricane force winds from the north. Cape Canaveral and the Canaveral Shoals provided some protection to the coast between Canaveral Inlet (R1) and Satellite Beach (R110). But from Indian Harbor Beach south to just north of Sebastian

Inlet, south Brevard County suffered its worst storm event in 20 years since Hurricane David in 1979.

In the north, the beaches of Canaveral were no worse off than after Floyd, as the cape and shoals provided substantial protection from the storm waves. Cocoa Beach had some additional beach erosion. Some of the 400 cubic yards of fill placed at the end of 12th Street in front of the Pelican Landing was lost and most of the material placed at Sunshine Villas was lost. Additional erosion affected the worst gaps in coastal armoring between 13th and 14th Streets and at the end of 18th Street.

Along Patrick Air Force Base and throughout Satellite Beach there was more beach erosion from Irene added to the erosion from Floyd. At the south end of Satellite Beach adjacent Shell Street (R97) much of the fill placed after Floyd was eroded. To the south along Indian Harbour Beach (R98-R105) more beach erosion was sustained. Generally, south of the Eau Gallie Causeway at R105 the beach erosion conditions worsened dramatically southward through the county.

South Brevard County sustained a greater impact during Irene than during Floyd. Throughout Melbourne (R105-R120), Irene inflicted more beach and additional dune erosion than Floyd did. Beach rock of the Anastasia formation became exposed near R116. There was also widespread roofing damage to single-family dwellings, condominiums and commercial buildings. The roof blew off one apartment building damaging 13 units. In Indialantic, Condition II erosion prevailed after Hurricane Floyd, but after Irene Condition III erosion prevailed.

Likewise in Melbourne Beach, from R129-R134, Floyd inflicted minor beach and dune erosion (Condition II), but Irene caused Condition III erosion. In this area a roof blew off the north two units of a condominium at 4th Avenue. From R135 through R137.5, Condition IV erosion prevailed. The combined impact of Floyd and Irene has inflicted severe erosion threatening the eight buildings of the Breakers Condominium (photo 10).

From Spessard Holland Park (R138) to Sebastian Inlet (R218), Condition II erosion prevailed after Floyd. After Irene, Condition III erosion prevailed. A single-family dwelling and restaurant at R147 are now in imminent danger. At R162, of the 800 cubic yards of fill placed at Sea Grape Manor after Floyd, about 200 cubic yards were lost during Irene. Throughout Melbourne Shores was widespread roofing damage. A single-family dwelling near R185 sustained wave damage to its east side and the dwelling is now in imminent danger. In Floridana, at a single-family dwelling at R196 a swimming pool was undermined and in imminent danger and a viewing deck had collapsed. Additionally a concrete wall to the north collapsed. Erosion continued unabated southward to just north of Sebastian Inlet, where conditions were not as bad as after Floyd. No apparent additional damage was sustained by the pier and jetties; however, there was additional erosion on the inlet's north shoreline damaging a parking area.

INDIAN RIVER COUNTY

Hurricane Floyd

Indian River County was the southernmost county in Florida to be significantly impacted by Hurricane Floyd. Most of the county's coast sustained moderate to major beach and dune erosion. Two major structures were substantially damaged and numerous beach access walkway ends were damaged throughout the county.

South of Sebastian Inlet at the north end of the county between R1 and R7 only minor beach and dune erosion (Condition II) was sustained in an area recently nourished with inlet sand transfer material. From R8 to R12, immediately north and south of the McClarty State Treasure Museum, moderate beach and dune erosion (Condition III) was sustained. On the back side of the coastal barrier, the Indian River lagoon shoreline sustained severe erosion causing damage to the State Road A1A road shoulders between R8 and R13.

Ambersand Beach experienced major beach and dune erosion (Condition IV) in a historic problem area between R12 and R13. Previously, two single-family dwellings had to be removed after Hurricane Erin in 1995, the last severe storm to affect the area. During Floyd, another single-family dwelling located approximately 500 feet south of R12 was substantially damaged by the storm surge and erosion, which prompted emergency foundation repairs to prevent its collapse (photo 11). Two other dwellings were imminently threatened by erosion. At R13 was a substantial washover deposit of sand at the site where one of the dwellings had been removed in 1995. Throughout the remainder of Ambersand Beach, R13 to R15 had Condition III erosion and R15 to R18 experienced Condition II erosion.

The north county coast between Ambersand Beach and Wabasso Beach was generally hard hit with moderate to major beach and dune erosion prevailing from R19 to R40. Condition IV erosion was sustained at the county parks at Treasure Shores (R25) and Golden Sands (R32) as well as along the Sanderling Subdivision (R33-R34) where several houses were left threatened by future storms.

Along the coastal segment between R37 and R45, north and south of Wabasso Beach Park (R40), major dune erosion (Condition IV) prevailed. The Summerplace Subdivision (R38-R40) is substantially armored with a steel sheet pile wall, but houses in the gap between walls and to the north were all left threatened by future storms (photo 12). At Wabasso Beach Park south of the wall, the entire dune fill placed in the spring was lost to erosion and the 300-foot elevated wooden boardwalk was substantially damaged prompting emergency repairs.

The coastal reach between R45 and R57 sustained moderate beach and dune erosion (Condition III) and between R57 and R73 sustained minor beach and dune erosion (Condition II). At the north end of Vero Beach was localized major dune erosion

(Condition IV) between R74.5 and R75.5. The outer 400 feet of the 600-foot long fishing pier (R75) at the Sea Quay Condominiums was destroyed.

Most of Vero Beach (R76-R82) experienced minor to moderate beach and dune erosion; however, at Humiston Park (R83) the storm tides eroded the entire dune fill landward of the concrete boardwalk. South Vero Beach between R83 and R85 also sustained major beach and dune erosion (Condition IV). North of Riomar (R86) moderate erosion tapered to minor beach and dune erosion (Condition II) which prevailed through South Beach (R90) and continued south around the cove to R100.

The designated critical erosion area of south Indian River County has experienced severe erosion problems in recent years. During Floyd, Condition IV erosion prevailed between R102 and R107, threatening numerous single-family dwellings. The remainder of the county (R107-R119) experienced minor to moderate beach and dune erosion.

Hurricane Irene

Following Hurricane Floyd, emergency dune restoration activity was conducted at different areas in Indian River County. The county brought in sand fill from an upland borrow area to restore the dune at Treasure Shores (R25), Golden Sands (R31-R32) and Wabasso Park (R40). Private interests brought in sand at other locations and also conducted beach scraping projects at four locations: Ambersand Beach (R12-R15), Sanderling (R33-R34), Summerplace (R38), and Anglers Cove to Porpoise Point (R103-R106).

Hurricane Irene exited southeast Florida and reformed just off Vero Beach. As the hurricane reintensified, scattered wind damage was sustained throughout the county. Generally the north end of the county fared better with regard to erosion than the southern half of the county. The scraping project worked well at Ambersand Beach (R12-R15) and provided sufficient protection from the storm tides and wave uprush of Irene. Roughly only about one quarter of the project's berm was eroded back into the beach system and none of the threatened dwellings were damaged by the storm surge or erosion. There was scattered wind damage and one roof sustained major damage.

At the Treasure Shores Park (R25) the county had placed about 3000 cubic yards of sand for dune restoration and lost roughly half of the material into the beach system. An unknown quantity of fill was placed at private properties near R28 and about one half was also eroded into the beach. The county also placed about 3000 cubic yards of fill for dune restoration at the Golden Sands Park (R31-R32) and lost at least three fourths of it to the beach system. Some additional dune erosion was sustained outside these project areas along with substantial beach profile lowering. The scraping projects at the Sanderling Subdivision (R33-R34) and Summerplace (R38) also worked to protect the upland properties against further erosion. About half of the scraped material at Sanderling was eroded and about one fourth of the scraped material at Summerplace was eroded back into the beach system.

At Wabasso Beach Park, the county had completed the post-Floyd repairs to the boardwalk and was beginning to haul in fill for dune restoration when Irene passed through and eroded most of the new material. Disney Resort to the south also lost most of the material they had trucked in to the beach. Throughout the central county coast dramatic beach profile lowering of about 6 feet vertically prevailed, but only about one to two feet of dune erosion was sustained. An entry building at Johns Island also sustained major wind damage.

Vero Beach had more beach erosion throughout due to Irene. Humiston Park (R83) had more dune erosion back to the parking slab. Vero Beach also sustained scattered wind damage. At the Bay Island Club on Ocean Drive, a five-story condominium lost the northern half of its roof. In the Barefoot Bay Subdivision, three roofs were lost on homes, and at the Moorings a roof was lost on a parking garage.

In south Indian River County, the scraping project between Anglers Cove and Porpoise Point Subdivisions (R103-R106) lost most all the sand scraped up, but the project did work to provide needed protection from the storm. The beach profile lowered about six feet but there was little additional erosion into the upland properties. One property did lose 50 feet of wood retaining wall on its north return wall and 15 feet of concrete slab. The concrete bulkhead and house were substantially undermined and both the wall and dwelling are in imminent danger. Another property's north return wall was also flanked and material was lost.

ST. LUCIE COUNTY

Hurricane Floyd

St. Lucie County sustained only a relatively minor fringe impact from Hurricane Floyd. Along the northern half of the county's coast (R1-R44) minor beach erosion (Condition I) to minor beach and dune erosion (Condition II) prevailed. Along the southern half of the coast (R46-R115) Condition II erosion prevailed. Had it not been for a subsequent major storm occurring so soon after Floyd, the beach conditions would probably have experienced complete recovery within at least the next year. Localized Condition III erosion (moderate beach and dune erosion) was sustained at R45, immediately south of the Ft. Pierce Beach restoration project.

Hurricane Irene

The center of the eye of Hurricane Irene exited the Florida east coast over St. Lucie County making this county's coast closest to the maximum wind field not counting the landfall in Monroe County. St. Lucie County estimated about six million dollars in damages throughout the county with scattered wind, rain and flooding damage. One single-family dwelling east of A1A on Hutchinson Island lost a roof and two walls to the wind, and a mobile home on Nettles Island was totally destroyed by the wind.

The erosion along the coast of St. Lucie County was the worse sustained in 20 years since Hurricane David made a similar brushing exit in September, 1979. The northern end of the county sustained only Condition II erosion to Ft. Pierce Inlet. Avalon Park, Martins Restaurant (R10), Pepper Park (R24), and Fort Pierce Inlet State Recreation Area (R32), all sustained only minor beach and dune erosion. Following Hurricane Irene and partly due to the overload on the system, the sewage treatment plant inside Ft. Pierce Inlet had a 36-inch pipe rupture, releasing eight million gallons of raw untreated sewage into the Indian River Lagoon and the inlet. The sewage plume passed out the inlet into the Atlantic Ocean and extended about four miles north and south forcing the closure of all beaches in Indian River, St. Lucie, and Martin Counties.

There was no apparent storm damage to the north and south jetties of Ft. Pierce Inlet, but there was substantial erosion along the causeway leading out to Ft. Pierce Beach. The recently completed beach restoration project had significant erosion along its length, which will necessitate follow-up monitoring surveys. There was no erosion escarpment to the beach project after Hurricane Floyd, but Irene left a two to three-foot vertical cut along the beach. Near R38 sand was washed and blown into the parking area of the county park, which had to be scraped out by bulldozers.

Immediately south of the project between R45 and R47 severe erosion (Condition IV) was sustained. The Ocean Village development south of the beach restoration project has very critical erosion, which threatens the development. At R45 the Ocean Village Clubhouse also had its roof damaged by the wind. Further south at John Brooks Park (R49) moderate beach and dune erosion (Condition III) was sustained.

Southward along Hutchinson Island (R50-R87) severe erosion prevailed throughout this undeveloped stretch of coast. Near R77 at Blind Creek Beach, many Australian pines were toppled to the severe erosion conditions (photo 13). Throughout the region large overwash deposits prevailed. Most of the remainder of St. Lucie County along the developed stretch of coast (R88-R115) sustained moderate beach and dune erosion (Condition III) (photo 14).

MARTIN COUNTY

Hurricane Floyd

Martin County sustained only a relatively minor fringe impact from Hurricane Floyd. Generally only minor beach and dune erosion (Condition II) prevailed throughout Martin County. The exception was the Bathtub Reef area at R35 where moderate beach and dune erosion (Condition III) occurred and a 15-foot concrete block wall was destroyed.

Hurricane Irene

Hurricane Irene inflicted a much greater impact on Martin County than Hurricane Floyd which probably set the stage for damage with its initial erosion. Martin County reported a total of \$5.2 million in damages of which \$3.4 million was attributed to the erosion of Jupiter Island beach restoration project.

The north Martin County beach restoration project was eroded between R1 and R23. It appeared that Condition II erosion prevailed except between R19 and R19.5 at Little Ocean Club and Place and the northern portion of Suntide Condominium where Condition III was sustained. This area was always an erosion hotspot prior to beach restoration and apparently continues to still be an area of accelerated erosion losses.

South of the project at R26, major dune erosion (Condition IV) was sustained (photo 15). Between R27 and R29 is predominantly the exposed ironshore formation where the beach is perched experiencing only minor erosion. This narrow stretch of Hutchinson Island near the House of Refuge experienced some overtopping of the wave uprush.

At the south end of the ironshore exposure the Bathtub Reef extends southward and offshore. To the north of R34 Condition II erosion prevailed, but between R34 and R36 Condition IV erosion was sustained. The properties of two single-family dwellings and the Bathtub Reef County Park are being damaged as the erosion conditions have become the worst ever sustained in this area (photo 16). The beach conditions here are subject to dramatic fluctuations of accretion and erosion depending on the availability of sand transported over the reef from the northeast and held by southeast swell during the spring and summer. Further south along Sailfish Point erosion conditions lessened to Condition III between R36 and R38 and minor erosion southward to St. Lucie Inlet.

South of St. Lucie Inlet minor to moderate beach and dune erosion (Condition II to III) prevailed along northern Jupiter Island (R45-R82) including the Pecks Lake area (R61-R67) within the Hobe Sound National Wildlife Refuge. Along the Town of Jupiter Island generally Condition I to II erosion prevailed. In the area of R110 to R111 the beach has eroded back to the existing walls. Scattered light wind damage was sustained and one house had major roof damage.

PALM BEACH COUNTY

Hurricane Floyd

Much of Palm Beach County was spared a major impact from Hurricane Floyd given its storm track further north and the sheltering effect of the Bahamas Banks. Countywide minor beach erosion (Condition I) to minor beach and dune erosion (Condition II) prevailed; however, there were several hotspots of moderate to major erosion and damage.

North of Jupiter Inlet along Tequesta and Jupiter Inlet Colony (R1-R12) minor beach erosion (Condition I) prevailed. There was some sand overtopping into Jupiter Inlet at the north jetty and some jetty walkway railing was lost. To the south within Jupiter Inlet Park (R14-R15) moderate beach and dune erosion (Condition III) was sustained and walkovers were damaged south of the park. Further south at the Radnor Park (R24-R26) moderate dune erosion was sustained leaving a 2 to 8-foot scarp.

In the Juno Beach area, between R26 and R52, minor beach and dune erosion prevailed. To the south in McArthur State Park moderate dune erosion conditions existed at R52-R53, R55-R56, and R58-R59. The remainder of Singer Island experienced only minor beach erosion. Likewise most of Palm Beach experienced only minor erosion to the beaches with the exception of minor dune erosion along the midtown project area.

In Gulfstream adjacent Sea Lane there was major dune erosion between R167 and R168, leaving a 15-foot vertical erosion escarpment. A 25-foot ornamental wall was destroyed and a deck and walkway damaged at 3051 Ocean Boulevard.

In the southern part of Palm Beach County, the restored beaches of Ocean Ridge and Delray Beach had only minor beach erosion. The beaches of Boca Raton sustained minor beach and dune erosion (Condition II) which left 2 to 3-foot scarps in the dune at Red Reef Park and South Beach.

Hurricane Irene

While Palm Beach claimed over \$100 million in damages from Irene's trek northward across the county, most of the damage was to agriculture losses resulting from the storm water flooding. While most of the beach and dune erosion impact was minor there were several hotspots of moderate to major erosion. In addition several areas experienced wind damage.

Northern Palm Beach County along south Jupiter Island sustained Condition II erosion except in Coral Cove Park between R4 and R5 where moderate dune erosion (Condition III) was sustained. South of Jupiter Inlet severe beach and dune erosion continued between R14 and R15.5 causing the loss of many mature sea grape plants and damaging beach access walkways (photo 17). To the south along northern Singer Island, including Carlin Park, Jupiter, and Juno Beach to John D. McArthur State Park the erosion varied

from Condition I to II. South of McArthur Park moderate beach and dune erosion (Condition III) was sustained between R61 and R63.

In the Town of Palm Beach the midtown project area experienced more minor beach and dune erosion (Condition II). However, in the southern part of the town from Phipps Ocean Park to Lake Worth (R118-R127) sustained moderate beach and dune erosion (Condition III). To the south of the Lake Worth Pier between R128 to R133 relatively stable conditions prevailed with no erosion problems. At Lantana Park (R137) some minor beach and dune erosion (Condition II) was sustained but little erosion was experienced southward along Manalapan to South Lake Worth Inlet.

South of South Lake Worth Inlet, the recent beach restoration project fared well with only minor beach erosion (Condition I). However, at Boynton Beach Oceanfront Park (R156-R157) Condition III erosion was sustained and many trees were blown down causing damage throughout the park. More wind damage was seen in the mobile home community of Briny Breezes (R165). Seaward of the coastal construction control line but landward of Old Ocean Boulevard, one mobile home had its roof blown off and two others had major roof damage.

South of the Briny Breezes groin in the community of Gulfstream, the severe dune erosion (Condition IV) continued adjacent Sea Lane (R167-R168) leaving a 15-foot vertical scarp (photo 18). A deck and walkway were damaged at the Gulfstream Manor. The beach restoration projects to the south from Delray Beach through Boca Raton fared well with only minor beach erosion.

BROWARD COUNTY

Hurricane Floyd

Much of the wave energy generated by Hurricane Floyd was dissipated by the Bahamas Banks and did not substantially impact Broward County or the coast to the south. The beaches of Deerfield Beach, Hillsboro Beach, Pompano Beach, and Lauderdale by the Sea fared reasonably well. However in Ft. Lauderdale, between R52 and R74, erosion from the earlier Hurricane Dennis as well as Floyd has had a cumulative effect in making the beach narrower than before the storms. Storm tides from both storms caused sand to overwash onto State Road A1A.

South of Port Everglades, the chronically eroding beaches of John U. Lloyd State Recreation Area sustained more erosion varying from Condition II to III. To the south the beaches of Dania, Hollywood, and Hallandale fared generally well.

Hurricane Irene

Hurricane Irene crossed the western reaches of Broward County on its northward track through south Florida. Beach erosion from Irene was generally no greater than that caused by Hurricane Floyd throughout the county. In Ft. Lauderdale along State Road A1A, sand had been removed from the road and street ends after Dennis and Floyd and returned to the beach in the placement of mounds. These mounds were not eroded by Irene.

Some additional erosion was sustained south of Port Everglades along John U. Lloyd State Recreation Area. Of note, following Hurricane Floyd there was still a remnant fillet beach against the south jetty in front of the Nova University seawall. Hurricane Irene substantially eroded this remnant fillet of beach.

In northern Hollywood along Surf Road between R101 and R102 all the streets were flooded back to State Road A1A and covered with sand. Approximately five inches of overwash sand had to be removed from Surf Road and put back on the beach.

DADE COUNTY

Dade County fared the best of all the east coast counties during the hurricanes. The Dade County shoreline was substantially sheltered by the Bahamas Banks as well as by the Palm Beach coastal protrusion against the effects of Hurricane Floyd. Hurricane Irene generally bypassed west of the beaches tracking northward over western Dade County

Golden Beach was in great shape after the storms while Sunnyside, Haulover Beach, Bal Harbour, and Surfside fared very well. Miami Beach generally fared well, although at a chronic erosion spot near R45 south of 65th Street, Condition II erosion was sustained. On Virginia Key, north of R84 fared well, but south of R84, more chronic erosion caused a few small Australian pines to be undermined and knocked down. Key Biscayne and the south Dade County islands fared well.

MONROE COUNTY

Hurricane Irene

During the morning of October 15, 1999, the center of Hurricane Irene passed over Key West bringing hurricane force winds over the middle and lower keys. The eye of the hurricane took a northeastward track across Florida Bay and made landfall again over Cape Sable during the afternoon before returning to a more northerly track across south Florida and exiting the coast of southeast Florida over Jupiter. The lower and middle keys were still recovering from the landfall of Hurricane Georges, a category three hurricane, in 1998, which had been their worst storm in 35 years since Hurricane Betsy in 1965. Hurricane Irene made landfall as a category one hurricane with a peak wind gust of 103 mph measured on Big Pine Key. Peak storm tides were measured to be +3.25 feet at both Key West and Vaca Key (near Marathon) in Florida Bay. Relatively light wind damage occurred throughout the middle to lower keys in contrast to Hurricane Georges' widespread damage where 1566 buildings were destroyed or sustained major damage in the keys.

Beach erosion through the lower keys was relatively light; however, the middle keys sustained a more significant impact during Irene though generally less than during Hurricane Georges. An interesting difference between the erosion of Irene and Georges was due to the track taken by each storm and the direction of the dominant storm wave attack. While Georges emerged off eastern Cuba and tracked northwest across the Florida Straits, Irene emerged off western Cuba and tracked north-northeast to the keys before turning even further northeastward before landfall at Cape Sable. Typically along the west to east trending shorelines of the keys fronting on the Florida Straits the wave energy of Georges transported beach sediment westward and the waves of Irene transported beach sediment eastward. In beach areas such as Coco Plum and Key Colony Beach where groins exist, leeside erosion conditions from Irene were dramatically opposite of those found after Georges.

Conditions along the Matecumbe Keys were significantly better after Irene than following Hurricane Georges a year earlier; however, there was substantial flooding and minor beach erosion. At Anne's Beach in Caloosa Cove there was minor beach erosion and damage to the public walkway. Conditions were more severe on the 4.2-mile long island of Long Key at the Long Key State Park. Although there was less structural damage in the State Park than during Georges, Irene caused what appeared to be more severe beach erosion while destroying most of the waterfront camping areas (photo 19). Many trees, which survived Georges, were lost to Irene. On Little Crawl Key nearby, the Curry Hammocks State Park had severe erosion of its eastern segment of beach. The lost recreation beach has made this erosion critical.

South of Fat Deer Key, Coco Plum Beach has 7,500 feet (1.4 miles) of fine grained sand beach varying in width from 25 to 50 feet. The eastern 0.9-mile of beach is currently designated as noncritical erosion. During Hurricane Georges the east end of the beach

sustained moderate erosion along with additional road damage. A rock revetment was subsequently built at the end of the road. During Irene additional moderate erosion was sustained at the eastern beach area and now the revetment is at the shoreline. To the west extensive tree damage was sustained previously during Georges, and some additional but lesser tree damage was sustained during Irene. Along most of the public beach Irene caused Condition II erosion. West of the public beach minor beach erosion (Condition I) was sustained at the Coco Plum Club. To the west at the Coco Plum Beach and Tennis Club, Condition II erosion was sustained. Due to the eastward sediment transport caused by Irene the four single-family residences at the west end of Coco Plum Beach sustained the most erosion which ranged from moderate (Condition III) to severe (Condition IV) at the western property adjacent the west end groin.

To the west of Coco Plum Beach is Key Colony Beach, which is substantially developed and is incorporated as the City of Key Colony Beach. This 4550-foot long private beach averages 50 feet wide and is stabilized by 15 limerock groins, which were constructed in 1958. In 1998, Hurricane Georges inflicted substantial flooding and structural damage along these beaches along with minor to moderate beach erosion. A number of piers were destroyed or severely damaged during Georges and many of them were subsequently rebuilt. Due to the erosion conditions this area was added to the state's critical erosion list in October, 1998. During Hurricane Irene, additional minor to moderate beach erosion was sustained. Flooding and structural damages were relatively light in comparison to during Hurricane Georges. Irene damaged the west shore revetment at the Key Colony Point, collapsed a tiki hut at The Cay, damaged 75 feet of wall at the Key Colony Beach Motel, damaged 25 feet of groin and a large wooden deck at Ocean Beach Club and 25 feet of pier at the Tortuga Beach Club. At the Key Colony Point at the extreme west end of Key Colony Beach, the entire beach was lost to the southwest storm wave attack. The Key Colony Point was left without any beach and is extremely susceptible to damage by future wave attack (photo 20).

The east half of the 5.5-mile long Vaca Key shoreline (Marathon) is protected by bulkheads and riprap, and a shoreline segment fronting Vaca Key Bight is predominantly a mangrove shoreline. Minor flooding and no significant erosion was incurred throughout most of Marathon. However, west of the southern tip of Vaca Key is the Monroe County Park at Sombrero Beach, a 1600-foot long fine-grained sand beach. During Hurricane Georges in 1998 the entire park and facilities sustained major damage from the storm tide flooding. Sand was transported inland across the park burying nearly all the existing ground vegetation. To mitigate this reoccurrence the county constructed a low profile berm vegetated with sea oats between the beach and inland grassed area. This vegetated berm prevented substantial inundation of sand to the inland area during Hurricane Irene, although, there were numerous small breaches with washover deposits (photo 21). Generally Condition II erosion was sustained along Sombrero Beach during Irene.

West of the Seven-Mile Bridge the narrow beaches of Little Duck Key, Missouri Key, and Ohio Key had only minor erosion. To the west, Bahia Honda Key had erosion throughout the state park. The 12,700 feet of carbonate beaches and dunes of Bahia

Honda State Park are the most significant of the lower keys. Hurricane Georges in 1998 had a devastating impact causing major beach and dune erosion and damage to the park roads, access walkways, bathhouse, restrooms, camp sites, and other facilities. The 600-foot long public beach (Caloosa Beach) between the US Highway 1 bridge and the old Flagler Bridge is a designated critical erosion area. Both Hurricane Georges in 1998, and Irene in 1999, caused similar moderate beach erosion along Caloosa Beach. The erosion from Irene has undermined and threatened the picnic shelters (photo 22).

The western 3,500 feet of beach fronting directly on the Straits of Florida is also a designated critical erosion area. Hurricane Georges caused major beach and dune erosion and severe damage along this entire stretch of shoreline including the public beach area (Loggerhead Beach) at the west end. Substantial beach and dune restoration and recovery had taken place only to be impacted once again by Hurricane Irene. Moderate beach and dune erosion (Condition III) was sustained along the west end adjacent the bathhouses during Irene. To the east along Loggerhead Beach, the beach and dunes had Condition II erosion which caused substantial impact to the sea oats. Further east, the armored segment of park road had some additional damage to the revetment and some stones were transported landward into the road. Erosion also threatened the bridge approaches as well as the bridge over the tidal creek connecting the large intertidal lagoon.

The eastern 7,400 feet of beach of Bahia Honda Key is known as Sandspur Beach. Prior to Hurricane Georges there were prominent vegetated barrier dunes and a beach width averaging 60 feet. But Georges had a devastating impact throughout Sandspur Beach. The camping sites, parking area, restrooms, bathhouse, and beach access walkways were all destroyed and major beach and dune erosion (Condition IV) was sustained. An additional 1.4 miles of shoreline was added to the existing designated critical erosion area. Following Georges, major recovery efforts were made at Sandspur Beach, which included rebuilding a new bathhouse/restroom facility, beach access walkways, and vegetated dune system in front of the parking area. Irene's impact was not as severe as Georges' was; however, much of the new vegetated dune system and sea oats were lost and one large beach access walkway was destroyed. Irene caused generally moderate beach and dune erosion (Condition III) throughout the area.

Minor erosion and flooding occurred along the lower keys of Big Pine Key, Sugarloaf Key, Shark Key, Big Coppitt Key, and Geiger Key. West of Geiger Key, the large island of Boca Chica Key (which is mostly federal land) had minor beach erosion and only about a two-foot storm tide. One dwelling on Boca Chica Key had its roof blown off.

Minor erosion continued along Key West beaches to the west of Boca Chica Key. Along South Roosevelt Boulevard Hurricane Georges destroyed about 400 feet of seawall and road in five separate sections of damage. These sections were subsequently repaired or rebuilt, however, Irene destroyed about 250 feet, and all within the same previously damaged sections. Unfortunately the concrete wall thickness of the repaired sections was much less than the original wall thickness and would not withstand breaking wave loads (photo 23).

To the west is the 3,300-foot segment of public beach park named George Smathers Beach, which was originally constructed in 1960 and consisted of the construction of four limestone rock groins and beach restoration. In 1998, Hurricane Georges inflicted moderate beach and dune erosion throughout Smathers Beach as the storm tides transported sand across Roosevelt Boulevard as well as offshore. The City of Key West removed sand from the road and spread it back on the beach and subsequently constructed a raised sand berm, which was to be vegetated as a barrier dune. Hurricane Irene caused minor to moderate erosion of the beach and the newly constructed berm. Some sand was transported once again onto the road although it was much less than occurred during Georges.

There was only very minor wind damage throughout Key West during Irene, which was a category one hurricane. In contrast there was major wind damage the year before during Georges, a much stronger category three hurricane. Most of the damage from Irene was confined to the waterfront on the Straits of Florida, whereas, Georges caused damage across the entire island. West of Smathers Beach, the end of Bertha Street sustained minor damage from Irene. The private beaches to the west had additional erosion, but Georges removed most of the sand in this area between Smathers Beach and Rest Beach.

Rest Beach, the 660-foot stretch of beach owned by the City of Key West sustained moderate erosion to its beach and newly constructed sand berm project during Irene (photo 24). At the Monroe County public beach (Clarence Higgs Beach) to the west of Rest Beach, minor erosion occurred throughout. Between Rest Beach and Higgs Beach, sand was scoured out behind the wall at Martello Tower. West of Higgs Beach minor erosion was also sustained at the Casa Marina Hotel's 950-foot long beach, the Reach Hotel's 300-foot long beach, and the 300-foot long South Beach.

On the southwest tip of Key West is the Fort Zachary Taylor State Historical Site. Fort Taylor has a history of severe erosion conditions; however, over the past ten years three breakwaters and a terminal groin have been constructed to slow down the erosion processes. Hurricane Georges inflicted major beach and dune erosion along this beach leaving an eight to nine-foot vertical escarpment along the dune line between the west breakwater and the terminal groin. Hurricane Irene caused additional moderate erosion to the dune line and beach, and nourishment is critically needed to cover the coarse limerock gravel, which currently dominates the beach sediment. Extending north from the terminal groin along the ship channel shoreline the rock revetment experienced some minor damage, and several washouts of the embankment occurred, which prompted emergency refilling.

The distal islands west of Key West were fortunate to be situated in the lee of the eye of Hurricane Irene. Only minor beach erosion was sustained on Woman Key, Ballast Key, Boca Grande Key, or the Marquesas Keys. The Tortugas Keys located 65 to 70 miles west of Key West were spared any significant impact from Irene.

REFERENCES

Avila, Lixion A. (1999). *Hurricane Irene, 13 – 19 October 1999*, Preliminary Report, National Hurricane Center.

Clark, R. R. (1998). *The Impact of Hurricane Georges on the Carbonate Beaches of the Florida Keys*, Florida Office of Beaches and Coastal Systems, Post Storm Report.

Pasch, R. J., T. B. Kimberlain, and S. R. Stewart (1999). *Hurricane Floyd, 7–17 September 1999*, Preliminary Report, National Hurricane Center.

Presnell (1999). *Post-Hurricane Report: Hurricane Irene*, National Weather Service, Key West, Florida.

Hurricane Floyd and Hurricane Irene (1999) Report Photos:



Photo 1. Dune erosion at Salt Run, northern Anastasia Island.



Photo 2. Dune erosion between St. Augustine Beach and Crescent Beach.



Photo 3. Ft. Matanzas National Monument beach and dune erosion and deck damage.



Photo 4. Ft. Matanzas continued dune erosion from Irene.



Photo 5. Floyd's erosion threatens State Road A1A in Flagler Beach south of 19th Street.



Photo 6. Irene caused additional profile lowering in Flagler Beach.



Photo 7. North Atlantic Avenue segment destroyed by Floyd in Bethune Beach.



Photo 8. Irene caused additional beach and dune erosion in Daytona Beach Shores.



Photo 9. Floyd's erosion at the Breakers Condominium, Melbourne Beach.



Photo 10. Additional erosion from Irene beginning to undermine threatened buildings.



Photo 11. Ambersand Beach dwelling damaged by Floyd.



Photo 12. Summerplace Subdivision dwelling threatened by Floyd's erosion.



Photo 13. Severe erosion during Irene at Blind Creek Beach.

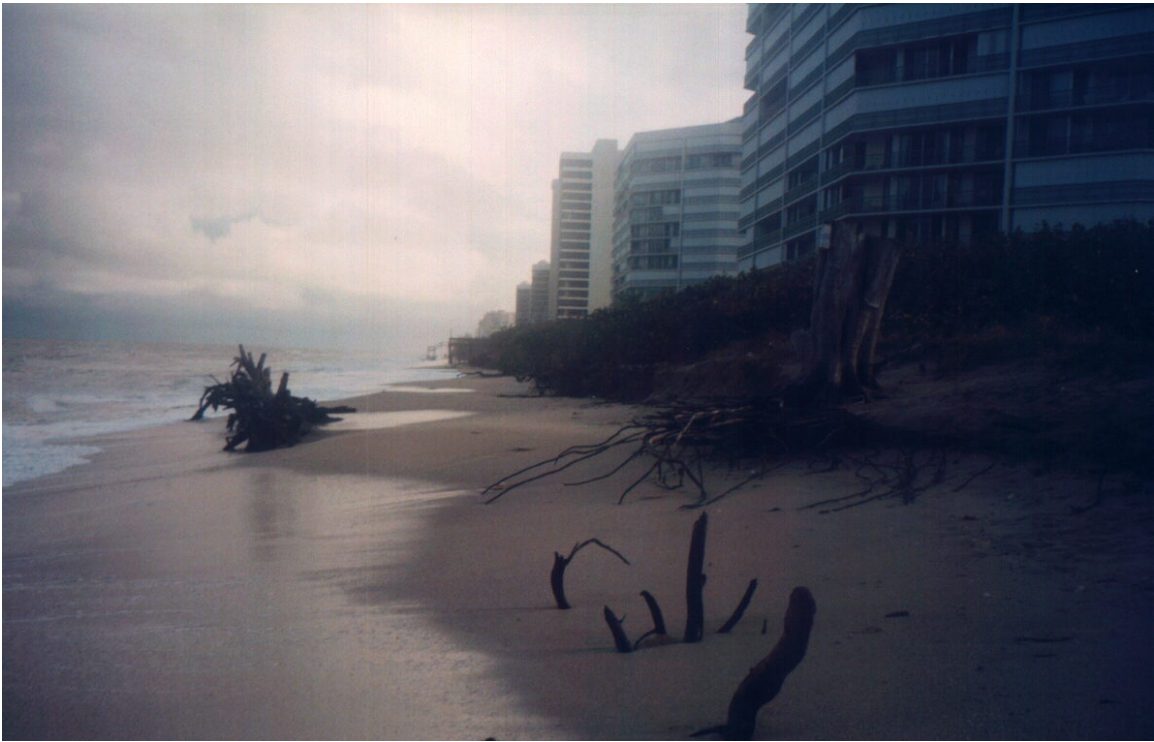


Photo 14. Moderate beach and dune erosion in southern St. Lucie County.



Photo 15. Irene caused major dune erosion on south Hutchinson Island (R26).



Photo 16. Severe erosion at Bathtub Reef, south Hutchinson Island (R34-R36).



Photo 17. Severe beach and dune erosion south of Jupiter Inlet (R14-R15.5).



Photo 18. Severe dune erosion near Sea Lane in Gulfstream (R167-R168).



Photo 19. Irene inflicted severe damage at Long Key State Park.



Photo 20. Key Colony Point in Key Colony Beach lost all beach to Irene's erosion.



Photo 21. Small breaches with washover deposits on Sombrero Beach, Vaca Key.



Photo 22. Erosion threatens picnic shelters on Caloosa Beach, Bahia Honda State Park.



Photo 23. Irene destroyed seawalled segments of South Roosevelt Boulevard, Key West.



Photo 24. Moderate beach and dune erosion at Rest Beach, Key West.