Mitigation Assessment Team Report

Hurricane Irma in Florida

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-2023 / December 2018

FEMA

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Big Pine Key, FL
FEMA / J.T. BLATTY, 2017

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HURRICANE IRMA IN FLORIDA

Executive Summary

Hurricane Irma struck Florida's coast on September 10, 2017, as a low Category 4 storm and caused building damage across the entire affected area.

Hurricane Irma made landfall on the East Coast of the United States at Cudjoe Key, FL, with maximum winds near 130 miles per hour (mph) and a minimum pressure of 931 millibars (mb) (NOAA NHC, 2018). Later that day, Hurricane Irma made a second landfall on Marco Island as a low Category 3 hurricane with maximum sustained winds of 115 mph and a central pressure of 936 mb before tracking up the Florida Peninsula and into Georgia on September 11 (NOAA NWS, 2017). Sustained hurricane force winds (i.e., 74 mph or greater) were reported along much of the east coast of Florida, from Jacksonville to Miami. The Naples Municipal Airport reported a wind gust of 142 mph. In addition to the long periods of heavy rain and strong winds, storm surge caused flooding along the Florida coast, particularly on the east side of the State in the Jacksonville area (NOAA NHC, 2018; NOAA NWS, 2017).

NOTEWORTHY STORM METRICS

- One of the strongest hurricanes ever observed in the open Atlantic Ocean
- One of only five hurricanes with measured sustained winds of 185 miles per hour (mph) or higher
- Maintained 185 mph sustained wind speed for 37 hours, the longest period for any tropical cyclone

Hurricane Irma resulted in one of the largest evacuations (approximately 6.5 million people) and most extensively used sheltering operations for the State of Florida (Florida House of Representatives, 2018). Presidential disaster declarations were issued for Florida, Georgia, Puerto Rico, and the U.S. Virgin Islands following the storm (FEMA, 2018c). Hurricane Irma caused damage to buildings across the entire affected area, as well as widespread power outages and interruptions in utility service.

Mitigation Assessment Team Deployment and Observations

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the Federal Emergency Management Agency (FEMA) deployed a pre-Mitigation Assessment Team (pre-MAT) to perform a preliminary field assessment of building damage in limited areas of Collier, Lee, Miami-Dade, and Monroe Counties. This pre-MAT was a small team sent in advance of the larger MAT to quickly observe and record select perishable damage data; locate damaged areas requiring further assessment; and determine the overall impact of the hurricane, scope of buildings and areas to be visited, and skillsets that would be needed for the larger, follow-on MAT. Following the pre-MAT, in response to a request for technical support from the Joint Field Office (JFO) in Florida, FEMA deployed the full MAT in December 2017 to assess the performance of buildings in Florida. A MAT conducts forensic engineering analyses of buildings and related infrastructure to determine causes of damage and success, and recommends actions that Federal, State, and local governments; the design and construction industry; and building code and standards organizations can take to mitigate damage from future natural hazard events.

The MAT deployed to Florida assessed the performance of municipal buildings, coastal residential properties, and public facilities. The MAT focused on structures in Lee, Collier, Miami-Dade, and Monroe Counties.

Summary of Damage Observed by the MAT

Although Hurricane Irma was neither a flood nor wind design-level event, the storm caused widespread damage to residential and commercial buildings and infrastructure. Other long-term damage impacts include the loss of housing in the Florida Keys, damage to wastewater and potable water infrastructure, and minor to major erosion at different locations along the coastline. The extent of the wind and/or flood damage varied depending on the nature of the building design and construction. Chapters 3 and 4, as well as Chapter 5, provide additional insight into why a below design-level event caused the damage that it did.

Flood. The storm caused moderate flooding and erosion in South Florida but was not considered a storm surge design event (i.e., exceedance of the 1-percent-annual-chance flood elevations was only observed where the combination of storm surge and rainfall caused severe flooding). Buildings in low-lying areas were damaged from inundation.

Although inundation alone was a significant source of damage, some of the more dramatic structural failures observed were a result of the added force of wave action and scour. The extent of flood damage to buildings varied with the depth of floodwater, the amount of energy in the water (waves, velocity), and the nature of building design and construction (old versus new, at-grade versus elevated, manufactured housing [MH] units / recreational vehicle versus site-built/modular). Some of the structures destroyed by the storm were MH units located in the floodplain. Very few of these houses were elevated to the base flood elevation. Buildings constructed at or near grade were subject to deeper and more damaging flooding from either storm surge or rainfall-induced flooding.

The MAT also spoke with building owners, operators, and managers of dry floodproofed non-residential buildings to understand the performance of dry floodproofing systems.

In addition, the MAT visited 15 public restroom buildings and sites on or near the shoreline in public parks in Lee, Collier, Monroe, and St. Johns Counties. For those restrooms damaged by flooding, iii the degree of damage ranged from complete destruction, to some structural damage, to damage to doors and fixtures only. The degree of damage depended on both flood conditions and building characteristics.

Wind. The MAT focused primarily on one- and two-family dwellings, but also assessed some multi-family dwellings (apartments and condominiums) and MH units. Estimated wind speeds from Hurricane Irma in Florida did not approach the design wind speeds required in the last six editions of the Florida Building Code (FBC).

Buildings designed and constructed to comply with the FBC met expectations by performing well structurally. Though not widespread, wind-induced structural damage to main wind-force resisting systems was observed in older (pre-FBC) residential construction and included roof failure and loss of exterior walls. Wind damage to roof structures appeared to have been generally initiated through loss of roof covering or breaching of the attic envelope. Framed walls of residential structures collapsed where significant portions of the roof and ceiling diaphragm were destroyed by wind.

Many buildings sustained wind-induced failures of building envelope components, connections, and systems that allowed wind-driven rain to penetrate into the interior, resulting in costly damage. While structural damage observations from Hurricane Irma winds were almost exclusively limited to pre-FBC residential buildings, envelope damage was commonly observed on both older and newer construction. The most frequently observed damage affected roof coverings, soffits, exterior wall coverings, glazed openings, and garage doors.

Most observed damage to MH units was initiated by wind acting on improperly attached appurtenances. When carports and covered porches broke away from MH units, they left openings at failed connections in the remaining roof or wall that allowed rain to enter the MH unit envelopes.

MAT Recommendations

The recommendations presented in this report are made based on the MAT's field observations. They are directed to design professionals, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners, academia, select industries and associations, and local officials, as well as FEMA.

General recommendations. The Florida Division of Emergency Management (FDEM), the Building Officials Association of Florida (BOAF), Florida Home Builders Association (FHBA), and/or other stakeholders should consider developing additional training opportunities regarding contemporary flood- and wind-related design and construction issues. The FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform building officials and local officials responsible for floodplain management about accessing resources to aid recovery through the Statewide Mutual Aid Agreement. FDEM should also consider training design professionals to assist with inspections. Furthermore, FEMA should develop a timely and effective means to deliver the Adjuster Preliminary Damage Assessment data submitted by National Flood Insurance Program (NFIP) claims adjusters to States and communities.

Building codes and floodplain management ordinances. Permitting agencies (e.g., Florida Department of Environmental Protection [DEP], Water Management Districts, local government) should evaluate permitting criteria and performance requirements for new or replacement bulkheads with respect to design conditions, including the effects of saturated backfill, wave forces, overtopping, and erosion on both water and land sides. Recommendations related to FEMA reviewing and updating its event-based erosion methodology. FDEM should expand its technical assistance for Community Rating System (CRS) communities are also provided. The Florida Department of Highway Safety and Motor Vehicles should update its Florida statutes for MH unit installation to reference the most recent edition of FEMA P-85, *Protecting Manufactured Homes from Floods and Other Hazards* (2009c), and consider incorporating additional wind- and flood-resistant construction provisions with particular emphasis on anchoring.

Flood-related building performance. Because dry floodproofing measures were found to fail under less than design flood conditions, the MAT recommends that building owners, design professionals, and local floodplain administrators follow the guidance in Florida MAT Recovery Advisory 1, *Dry Floodproofing: Operational Considerations* (2018d), and Texas MAT Recovery Advisory 1, *Dry Floodproofing: Planning and Design Considerations* (2018e), related to dry floodproofing methods and procedures. These methods and procedures were developed based on observations during and after the two storms. Facility managers should develop an emergency operations plan that outlines how to prepare the building when severe weather is expected. Facility managers should also routinely re-evaluate dry floodproofing designs and plans after deployment of their systems or training exercises, as well as instill a culture of preparedness.

Wind-related building performance. Because building envelope failures were observed on post-FBC residential structures following a below design-level wind event, industry groups should investigate the causes. In particular, the causes for the observed widespread asphalt shingle roof covering loss and the appropriate pressure equalization factor for vinyl siding should be investigated. Industry groups and/or academia should also study debris impacts to protective systems from the 2017 (and future) hurricanes to determine whether the current wind speed triggers for the wind-borne debris region (WBDR) are appropriate as defined in the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Building owners outside of the WBDR, in the hurricane-prone region, should consider protecting the glazed openings on their buildings. Contractors and inspectors should ensure roof covering repairs and replacements are in conformance with FBC requirements. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain from entering building envelopes and damaging building interiors. The FBC should require soffit and wall cladding inspections. Furthermore, as a best practice, MH appurtenances should be built as standalone units without structural connection to the MH unit.

FEMA technical publications and guidance. The FEMA Building Science Branch should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities*. FEMA should include lessons learned from the 2017 hurricane season in finishing this publication. FEMA should also consider updating or producing a supplement for its key hurricane and Risk Management Series technical guidance publications to include lessons learned from the 2017 hurricane season and to reflect updates to current building codes since the publications' latest releases. FEMA should update FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010) to incorporate new lessons learned and recommended guidance and clarifications since it was published in 2010. At the same time FEMA 213, *Answers to Questions about Substantially Damaged Buildings,* should be updated to be consistent with the updated FEMA P-758. FEMA should consider expanding existing training materials on Substantial Improvement/Substantial Damage for distribution to NFIP State Coordinators and other entities. Finally, dry floodproofing guidance should be updated and a comprehensive recommendation for dry floodproofing design, limitations, testing, and maintenance and operations requirements should be developed for inclusion in ASCE 24, *Flood Resistant Design and Construction.*

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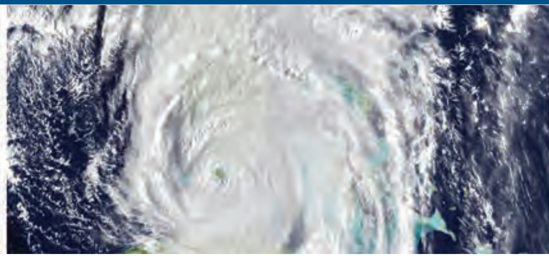
Acronyms and Abbreviations

AAMA	American Architectural Manufacturers Association
ACE	Accumulated Cyclone Energy
ACI	American Concrete Industry
ADCIRC	Advanced Circulation
AISI	American Iron and Steel Institute
ASCE	American Society of Civil Engineers
ASD	allowable stress design
ATC	Applied Technology Council
BCIS	Building Code Information System
BFE	base flood elevation
BOAF	Building Officials Association of Florida
CAC	Community Assistance Contact
CAP-SSSE	Community Assistance Program State Support Services Element
CAV	Community Assistance Visits
CERA	Coastal Emergency Risks Assessment
CFR	Code of Federal Regulations
CPCB	Community Planning and Capacity Building
CRS	Community Rating System
DBPR	Department of Business and Professional Regulation
DEP	Department of Environmental Protection (Florida)
DFE	design flood elevation
DHS	U.S. Department of Homeland Security
EDT	Eastern Daylight Time
EDWS	estimated design wind speed
EOP	emergency operations plan
EWS	estimated wind speed
FBC	Florida Building Code
FBCA	Florida Building Code, Accessibility
FBCB	Florida Building Code, Building
FBCEB	Florida Building Code, Existing Building
FBCEC	Florida Building Code, Energy Conservation
FBCFG	Florida Building Code, Fuel Gas
FBCM	Florida Building Code, Mechanical
FBCP	Florida Building Code, Plumbing
FBCR	Florida Building Code, Residential
FDEM	Florida Division of Emergency Management
FEMA	Federal Emergency Management Agency

FFMA	Florida Floodplain Managers Association
FHBA	Florida Home Builders Association
FIMA	Federal Insurance and Mitigation Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurances Study
HUD	U.S. Department of Housing and Urban Development
HVHZ	High-Velocity Hurricane Zone
IBC®	International Building Code
ICC®	International Code Council
IRC®	International Residential Code
JFO	Joint Field Office
MAT	Mitigation Assessment Team
MEP	mechanical, electrical, and plumbing
MH	manufactured housing
mph	miles per hour
MWFRS	main wind-force resisting systems
NAVD88	North American Vertical Datum of 1988
NCEI	National Center for Environmental Information
NDRF	National Disaster Recovery Framework
NFIP	National Flood Insurance Program
NGVD29	National Geodetic Vertical Datum of 1929
NHC	National Hurricane Center
NHRAP	Natural Hazard Risk Assessment Program
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWS	National Weather Service
PEF	pressure equalization factor
Risk MAP	FEMA Risk Mapping, Assessment, and Planning
RRCC	Regional Response Coordination Center
RSF	Recovery Support Function
SFHA	Special Flood Hazard Area
SFMO	State Floodplain Management Office
SMAA	Statewide Mutual Aid Agreement
SWAN	Simulating Waves Nearshore
TAC	Technical Advisory Committees
TAS	Testing Application Standards
USGS	U.S. Geological Survey
WBDR	windborne debris region



HURRICANE
IRMA
IN FLORIDA

1 Introduction

Hurricane Irma was one of the strongest hurricanes ever observed in the open Atlantic Ocean and caused 92 fatalities in five States (NOAA NHC, 2018).

On September 10, 2017, Hurricane Irma made landfall on the East Coast of the United States. As part of the response to the disaster, the Federal Insurance and Mitigation Administration (FIMA) of the U.S. Department of Homeland Security's (DHS's) Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) composed of national and regional building science and other types of experts to assess the damage in Florida.

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the MAT performed a preliminary field assessment of building damage in limited areas in Collier, Lee, Miami-Dade, and Monroe Counties. This pre-MAT was a small team sent in advance tasked to quickly observe and record select perishable damage data; locate damaged areas requiring further assessment; and determine overall impact of the hurricane, scope of buildings and areas to be visited, and skillsets that would be needed for a larger, follow-on MAT. The MAT was then deployed from December 10 to 16, 2017 to Collier, Lee, Miami-Dade, and Monroe Counties. Investigative field work to evaluate erosion impacts in St. Johns County was conducted on February 14 and 15, 2018. Its mission was to assess the performance of buildings affected by Hurricane Irma and their associated utility systems.

The primary purpose of a MAT is to improve the natural hazard resistance of buildings by evaluating the key causes of building damage, failure, and success, and developing strategic recommendations for improving short-term recovery and long-term disaster resilience to future natural hazard events. The MAT report provides information that will help communities, businesses, design professionals, and other interested stakeholders to rebuild and design more robust and resilient buildings, structures, and their associated utility systems, thereby minimizing loss of life and injuries, and reducing property damage resulting from future natural hazard events. This report describes the MAT's observations during field assessments in Florida and presents conclusions and recommendations based on those observations.

This MAT report focuses on several construction and floodplain management issues observed after Hurricane Irma that were not observed in former MAT damage assessments or that were addressed in lesser detail in those MAT reports. These issues include, but are not limited to:

- The lack of planning and operations associated with deploying active dry floodproofing systems
- The effect of preferential scour pathways
- Damage to structures due to improperly secured fastening of breakaway walls
- Damage to asphalt shingles, vinyl soffits, and vinyl siding from wind and wind-borne debris

1.1 Organization of the Report

This MAT report is divided into five chapters and three appendices. This chapter describes Hurricane Irma, regional preparedness activities and the MAT background and process. Chapter 2 discusses building codes, standards, and regulations in effect in Florida. Chapter 3 describes MAT observations related to the performance of residential and non-residential buildings under flood conditions. Chapter 4 describes MAT observations related to damage sustained by residential and non-residential buildings from high winds and evaluates the effect building codes have had on building performance for those buildings exposed to high winds. Chapter 5 presents the MAT's conclusions and recommendations and is intended to help guide reconstruction for flood- and hurricane-prone communities. In addition, the report includes the following appendices:

- Appendix A: Acknowledgements
- Appendix B: Glossary
- Appendix C: Links to Recovery Advisories for Hurricane Irma in Florida
    - Recovery Advisory 1 (2018d), *Dry Floodproofing: Operational Considerations*
    - Recovery Advisory 2 (2018h), *Soffit Installation in Florida*
    - Recovery Advisory 3 (2018f), *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) of the Florida Building Code*

1.2 Hurricane Irma: The Event

Irma began as a weak wave of low pressure accompanied by disorganized showers and thunderstorms that emerged off the West African coast on August 27. Tropical Storm Irma formed in the far eastern Atlantic Ocean, just west of the Cape Verde Islands, on the morning of August 30. Over the next 30 hours, the storm intensified into a major hurricane with highest sustained winds of 115 miles per hour (mph), a Category 3 storm on the Saffir-Simpson Hurricane Wind Scale. The storm became a Category 5 hurricane on September 5, with maximum sustained winds of 185 mph, and was located north of the islands of Puerto Rico and Hispaniola. This made Hurricane Irma one of the strongest observed hurricanes in the open Atlantic Ocean. Table 1-1 shows a comparison of Hurricane Irma's wind speeds with other major Atlantic hurricanes.

THE SIGNIFICANCE OF HURRICANE IRMA

- Hurricane Irma became a Category 5 hurricane on September 5, 2017. Hurricane Irma's 185 mph winds were the strongest 1-minute maximum sustained winds recorded for an Atlantic hurricane outside of the Gulf of Mexico and the Caribbean.
- Hurricane Irma maintained an intensity of 185 mph for 37 hours—the longest any cyclone on record has maintained that intensity—breaking the old record of 24 hours set by Typhoon Haiyan in 2013.
- As a measure of the storm's intensity, the Accumulated Cyclone Energy (ACE) index of 67.5 generated by Irma was the second highest in the satellite era (since 1966) for an Atlantic hurricane, trailing only Hurricane Ivan (2004), which had an ACE index of 70.4.
- As Hurricane Irma hit Florida, tropical storm force winds extended outward up to 400 miles from the center.
- Approximately 6.5 million residents in Florida were evacuated from coastal areas.

SOURCES: NOAA NWS, 2017; KLOTZBACH AND BELL, 2017

Table 1-1: Comparison of Hurricane Irma Wind Speed to Other Major Atlantic Hurricanes

Year	Hurricane	Maximum Sustained Winds (mph)
1992	**Andrew**	173
2004	**Ivan**	167
2005	**Katrina**	173
2005	**Wilma**	184
2017	**Irma**	185

SOURCES: NOAA, N.D.; NOAA NHC, 2004; NOAA NHC, 2005; NOAA NHC, 2006; NOAA NCEI, 2018b

The storm weakened to a Category 4 on September 8 and then re-intensified while crossing the open waters of the Straits of Florida. On September 10 at 9:10 a.m. EDT, Hurricane Irma made landfall on Cudjoe Key, FL, as a Category 4 storm with maximum sustained winds near 130 mph and a minimum pressure of 931 millibars (mb) (NOAA NHC, 2018). Later that day, Hurricane Irma made a second landfall near Marco Island as a Category 3 hurricane with maximum sustained winds of 115 mph and a central pressure of 940 mb before tracking up the Floridian Peninsula (Figure 1-1) and into Georgia on September 11 (NOAA NWS, 2017). Sustained hurricane force wind (i.e., 74 mph or greater) extended well inland over the southern Florida peninsula. The Marco Island Police Department reported a wind gust of 130 mph, and a wind gust of 142 mph was reported at the Naples Municipal Airport (NOAA NWS, 2017; NOAA NHC, 2018).

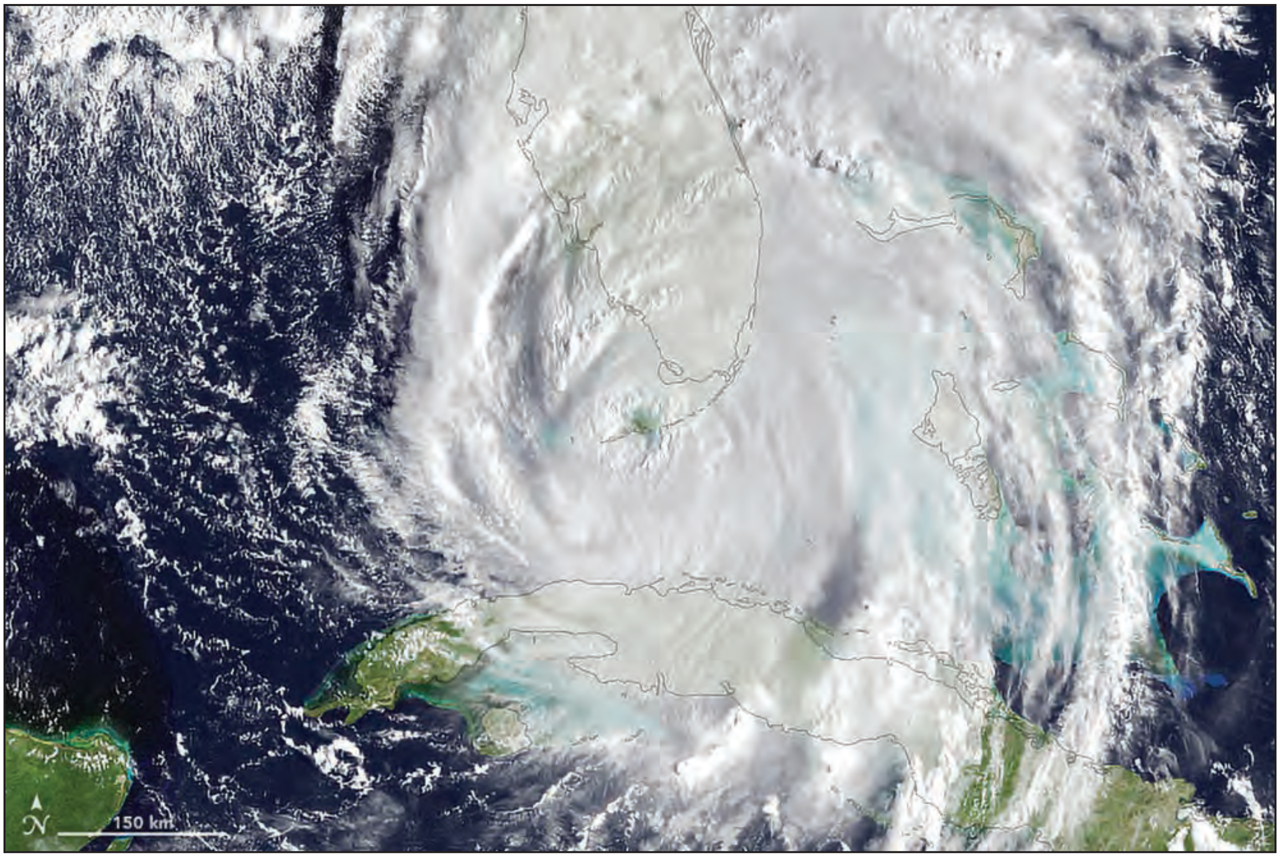
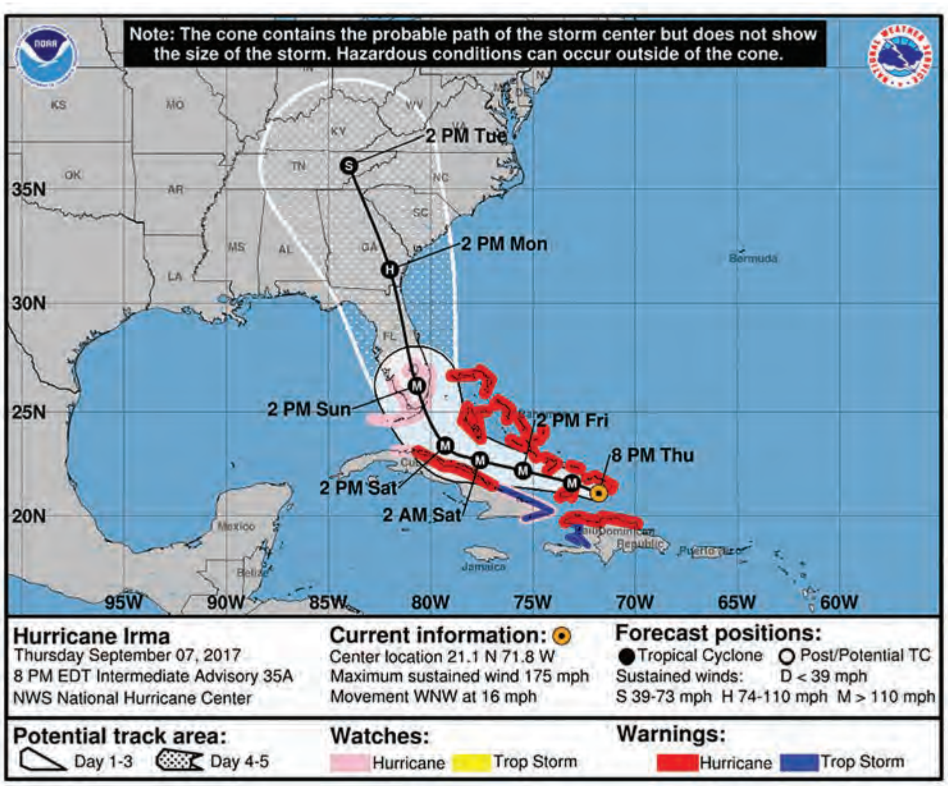


Figure 1-1: Composite satellite image from the GOES-13 weather satellite of landfall near the Florida Keys (left) on September 10, 2017 8:15 AM
SOURCE: NASA, 2017

As Hurricane Irma hit Florida, tropical storm force winds extended up to 400 miles from the center, and hurricane force winds extended outward 80 miles. Figure 1-2 shows the cone of the probable track that was forecast on Thursday, September 7, enveloping the entire State of Florida, and the most likely arrival time of tropical storm force winds on Sunday, September 10. In addition to the long periods of heavy rain and strong winds, storm surge flooding also pummeled the coasts well away from the storm center. In the Jacksonville area, strong and persistent onshore winds blew for days before Irma's center made its closest approach.

The National Oceanic and Atmospheric Administration (NOAA) measures the power of hurricanes using the estimated maximum sustained surface wind velocity for each 6-hour period of their existence. This measurement, the ACE, was 67.5 for Hurricane Irma, which is the second most powerful storm in the satellite era (since 1966) (Klotzbach and Bell, 2017). Irma's power was the result of the duration of sustained hurricane force winds as the storm approached the U.S. coast. As it approached southern Florida, the storm weakened to a Category 3 hurricane. For a detailed discussion of the timeline and formation history of Hurricane Irma, see the NOAA National Hurricane Center's (NHC's) Hurricane Irma Tropical Cyclone Report (NOAA NHC, 2018).



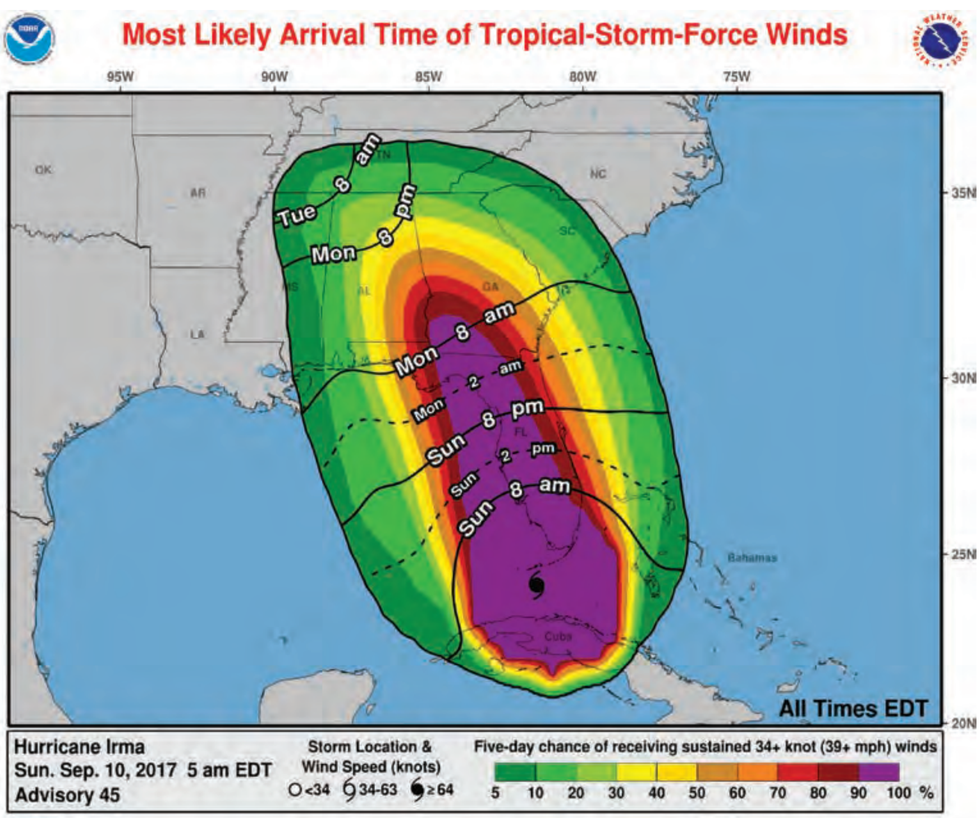


Figure 1-2: Hurricane Irma cone of probable track forecast on Thursday, September 7 (upper) and most likely arrival of tropical storm force winds on Sunday, September 10 (lower)

SOURCE: NOAA NHC, 2017A AND 2017B

1.2.1 Storm Surge Flooding

Hurricane Irma was the first major (Category 3 or higher) hurricane to make landfall in South Florida since Hurricane Wilma of 2005, bringing with it high winds and predicted storm surge inundation. Figure 1-3 to Figure 1-6 show the locations of high water marks surveyed by the U.S. Geological Survey (USGS) after the event. Significant flooding occurred where the combination of storm surge and riverine flooding from rainfall-runoff overflowed streams and riverbanks and related infrastructure in the City of Jacksonville (Note: the MAT did not visit this area). This phenomenon probably occurred in locations where rivers flow into tidal areas that experienced storm surge, although the timing of the runoff and storm surge peaks seldom coincide (NOAA NHC, 2018).

To characterize the storm surge flooding from Hurricane Irma, two datasets from FEMA's Flood Map Service Center[1] were queried and compared: tide gage data at locations in South Florida and the 10-, 2-, 1-, and 0.1-percent-annual-chance stillwater elevations from the counties' Flood Insurance Studies (FISs). The results of this comparison are reported in Table 1-2.

The FISs for Lee, Collier, Miami-Dade, and Monroe County are currently in the process of being updated. The revised Flood Insurance Rate Maps (FIRMs) are estimated to be completed in 2019–2021. Thus, the effective FISs (circa 2009–2012) were used to determine the annual percent chance stillwater elevations. Although the effective studies are dated 2009–2012, the storm surge elevations are based on studies from the 1970–1980 timeframe. As reported at these five gages, Hurricane Irma was below the 1-percent-annual-chance event (or 100-year flood).

1-PERCENT-ANNUAL-CHANCE EVENT

FEMA FIRMs delineate flood hazard areas and zone designations (e.g., Zone VE, Zone AE) that reflect the nature of the flood conditions expected during the base flood. The base flood is the flood that has a 1 percent annual chance of occurrence (frequently referred to as the 100-year flood). FIRMs show the base flood elevation, or BFE. The area designated as subject to inundation from the 1-percent-annual-chance flood is called the Special Flood Hazard Area (SFHA).

Locations within the SFHA can be exposed to flooding at a greater frequency (i.e., more often) than the 1-percent-annual chance event. The water surface elevation at these locations may be less than the BFE, but may still cause minor damage. Subsurface areas and infrastructure at ground level are subject to flooding at a water surface elevation below the BFE.

1 The FEMA Flood Map Service Center can be accessed here: msc.fema.gov/portal/home.

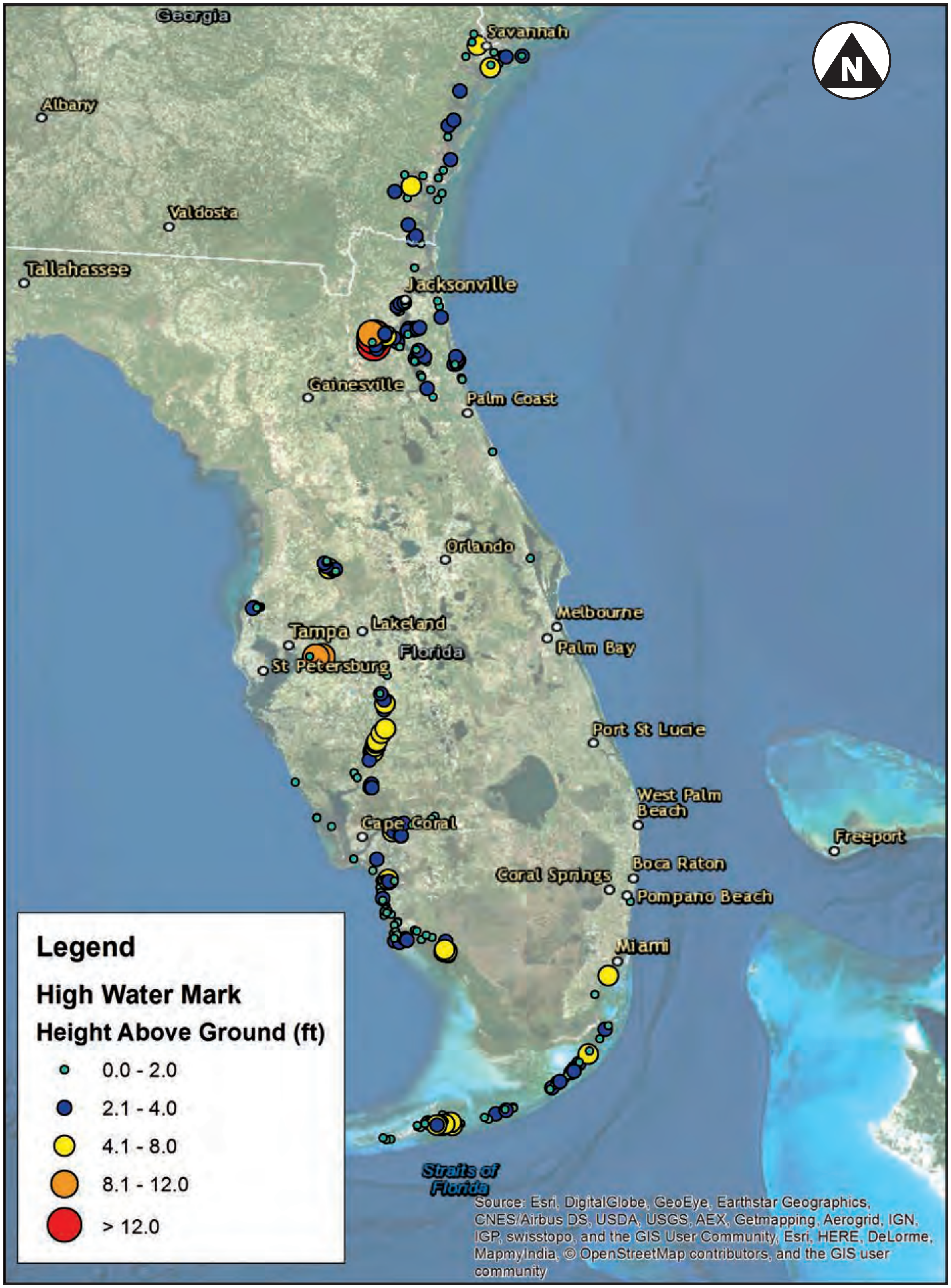


Figure 1-3: Surveyed locations of Hurricane Irma's high water marks

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

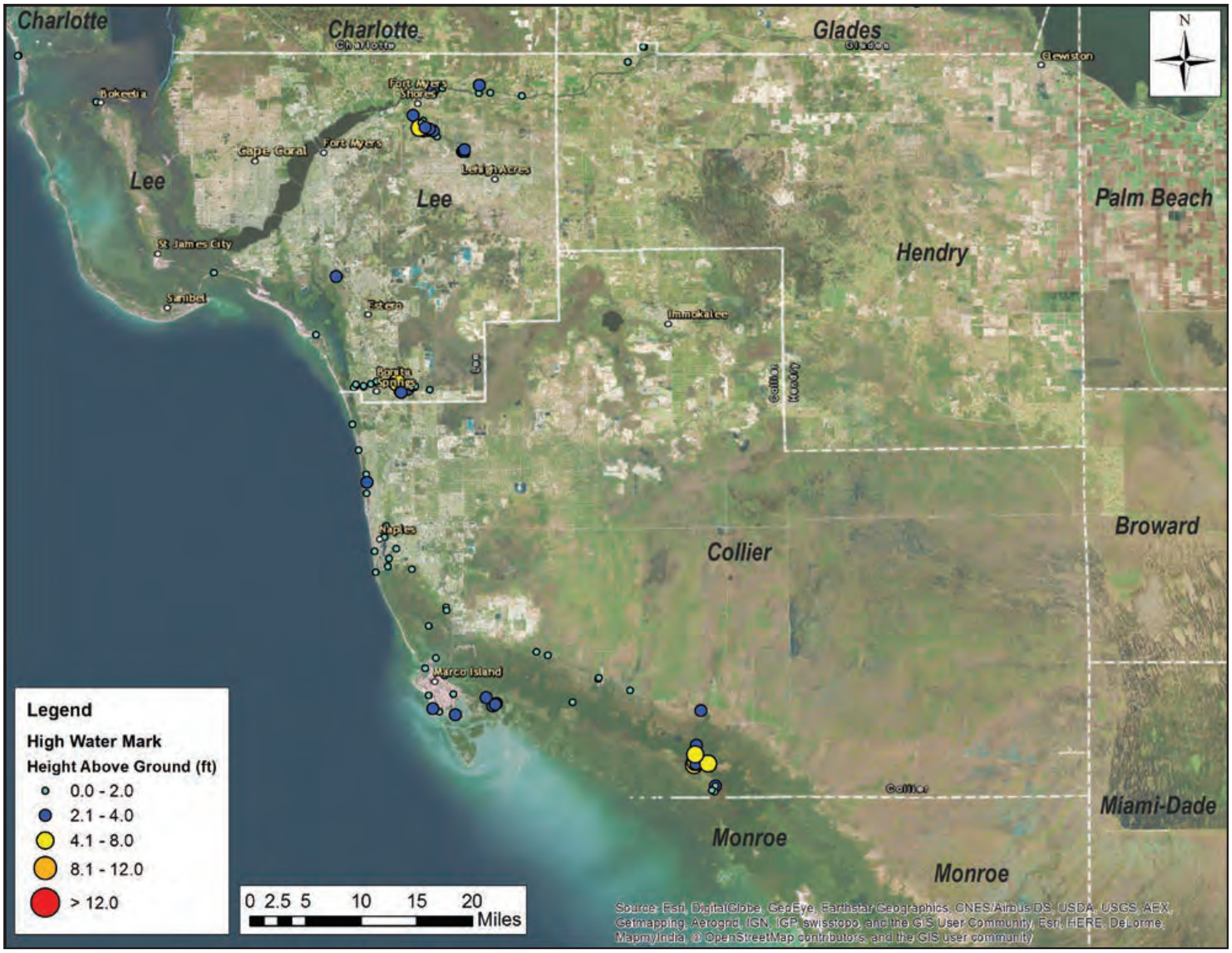


Figure 1-4: Surveyed locations of Hurricane Irma's high water marks in Lee and Collier Counties

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

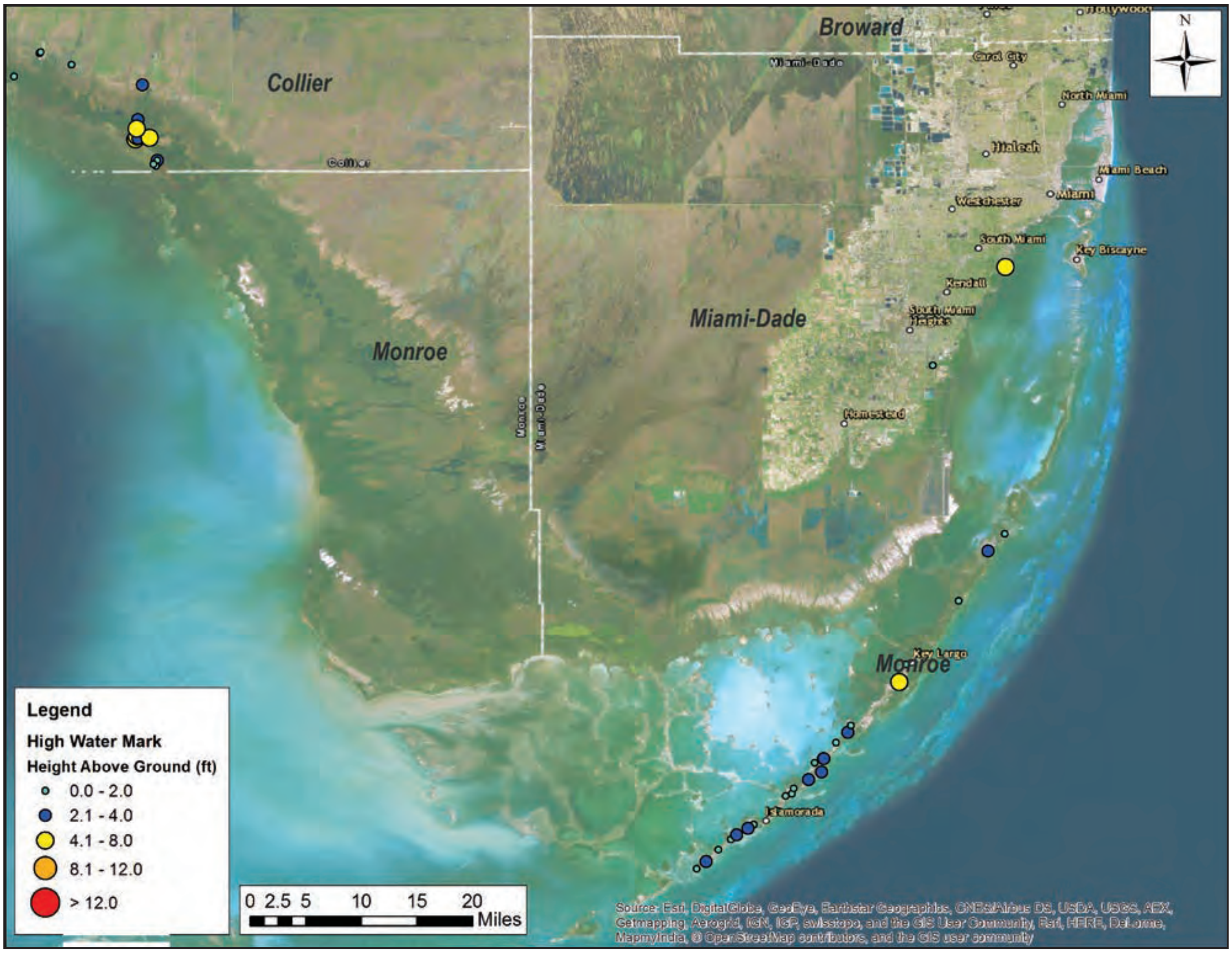


Figure 1-5: Surveyed locations of Hurricane Irma's high water marks in Miami-Dade County
SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

The combined effect of storm surge and tide produced maximum inundation levels between 5 and 8 feet above ground level for small portions of the Lower Florida Keys from Cudjoe Key eastward to Big Pine Key and Bahia Honda Key. Several high water marks of at least 4 feet above ground level were also surveyed by USGS in this area, with the highest mark being 5.45 feet above ground level on Little Torch Key (NOAA NHC, 2018).

In Collier County at Chokoloskee, inundation levels were as high as 6 to 8 feet near the waterfront. Inland areas of the island had inundation levels of 3 to 5 feet. At the Everglades National Park Gulf Visitor Center in Everglades City, the USGS measured a high water mark greater than 5 feet above ground. Flooding in other areas in Everglades City ranged from 2 feet to a maximum of 6 feet of inundation. Marco Island had up to 3 feet of inundation above ground (NOAA NWS, 2017). Strong offshore winds initially blew away from the coast causing water to recede along the southwestern coast of Florida. As the center of the storm moved past this area, the winds shifted onshore, and the water level at the NOAA tide gage at Naples increased by 6 feet within the first hour and 9 feet in 3 hours (NOAA NHC, 2018).

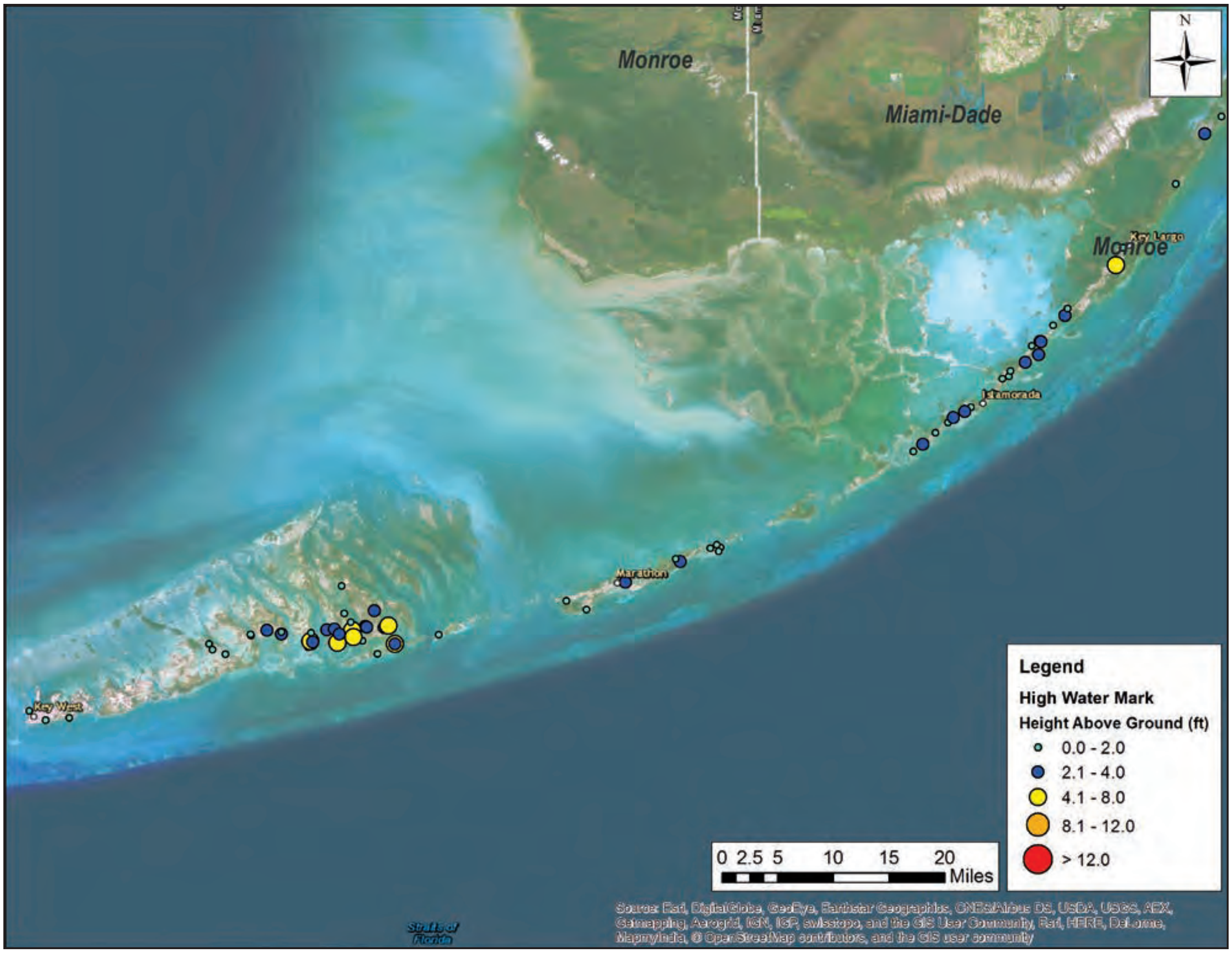


Figure 1-6: Surveyed locations of Hurricane Irma's high water marks in Monroe County

SOURCE: HIGH WATER MARK DATA IS FROM USGS, 2017

In Miami-Dade County along the shoreline of Biscayne Bay, the USGS measured 4 to 6 feet of inundation, with the highest estimated depth of more than 5 feet in Matheson Hammock Park. Downtown Miami was flooded, likely due to the combination of rainfall and runoff, wave overwash, and backflow through the city's drainage system (NOAA NHC, 2018). Inundation depths were shallower in the communities north of downtown Miami. In Broward County, the highest inundation was 2 to 3 feet from Ft. Lauderdale Beach southward. In Palm Beach County, inundation was not significant (NOAA NWS, 2017).

The combined effect of storm surge and the tide produced maximum inundation levels of 1 to 2 feet above ground level along the west coast of Florida north of Charlotte Harbor to Apalachee Bay. Similar to what occurred near Naples, offshore winds on the northern side of Irma's circulation initially caused water levels to recede below normal levels along much of the west coast of Florida, including Tampa Bay. In Tampa Bay at St. Petersburg, the water level was 5 feet below normal (NOAA NWS, 2017).

Table 1-2: Water Surface Elevations and Estimated Return Periods in South Florida Counties

County	NOAA ID	NOAA Station Name	Maximum Water Surface Elevation (feet NAVD88)	Estimated Return Period[(a)]	Annual-Chance Stillwater Elevation (feet NAVD88)			
					10% (10-Year)	2% (50-Year)	1% (100-Year)	0.2% (500-Year)
Lee	8725520	Fort Myers, Caloosahatchee River, FL	3.33	10 year	3.3[(b)]	N/A[(b)]	7.0[(b)]	8.1[(b)]
Collier	8725110	Naples, Gulf of Mexico, FL	4.60	<20 year	3.9[(c)]	7.3[(c)]	8.4[(c)]	10.4[(c)]
Miami-Dade	8723214	Virginia Key, Biscayne Bay, FL	3.84	<10 year	4.3[(d)]	5.6[(d)]	6.2[(d)]	7.2[(d)]
Monroe	8723970	Vaca Key, Florida Bay, FL	2.14	<10 year	3.2[(e)]	5.4[(e)]	6.3[(e)]	7.6[(e)]
Monroe	8724580	Key West, FL	2.64	<20 year	1.9[(e)]	4.2[(e)]	5.5[(e)]	6.0[(e)]

NAVD88 = North American Vertical Datum of 1988; NGVD29 = National Geodetic Vertical Datum of 1929; NOAA = National Oceanic and Atmospheric Administration

(a) Prior to Hurricane Irma, FEMA initiated a coastal flood risk study for the South Florida Study Area (Broward, Miami-Dade, Monroe, and Palm Beach Counties) and the Southwest Florida Study Area (Charlotte, Collier, Desoto, Hendry, Lee, and Sarasota Counties). Hurricane Irma impacted the coast in the middle of the coastal flood mapping update process.

(b) The Lee County FIS is preliminary (dated February 2018). The stillwater values do not include wave setup.

(c) The effective Collier County FIS (dated May 2012) is in the process of being updated by the Southwest Florida Study. The return period results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup.

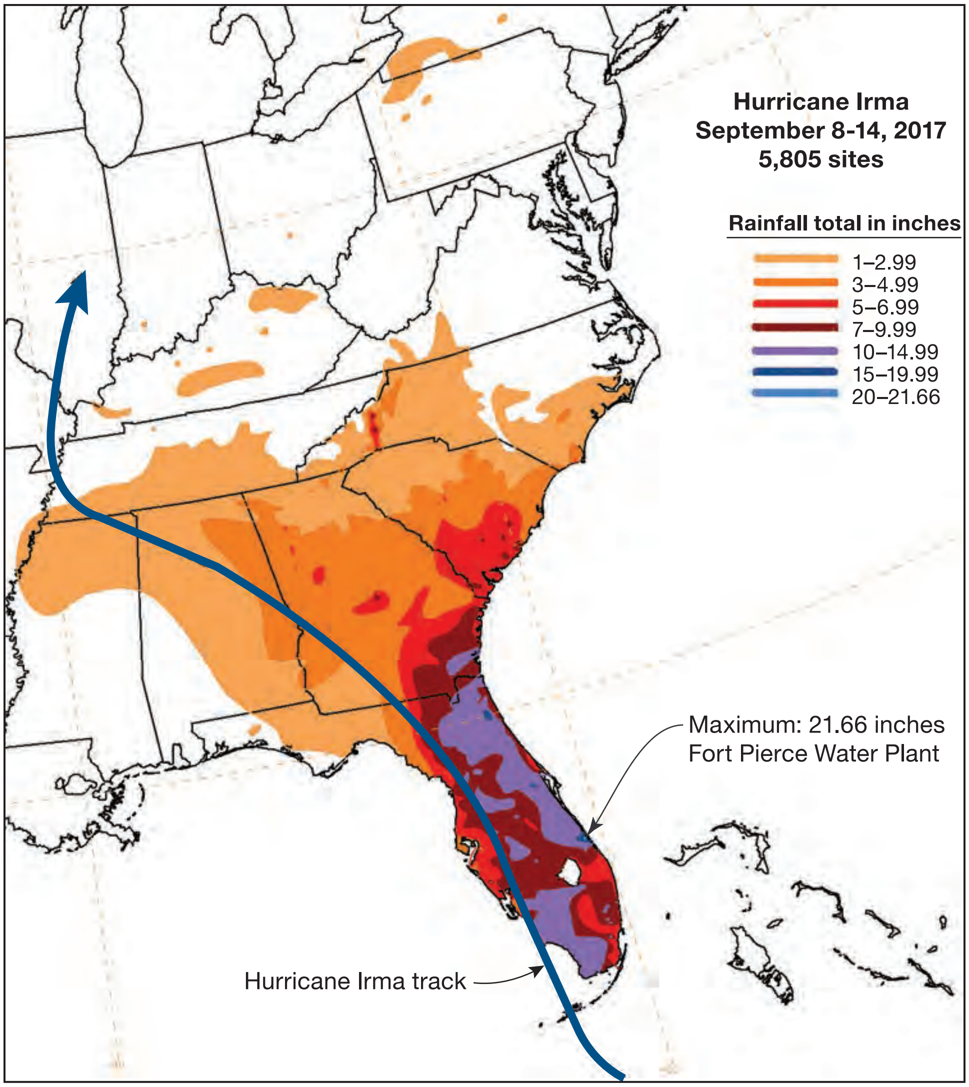
(d) The effective Miami-Dade County FIS (dated September 2009) is in the process of being updated by the South Florida Study. The results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup. The stillwater values were converted from NGVD29 to NAVD88.

(e) The effective Monroe County FIS (dated February 2005) is in the process of being updated by the South Florida Study. The results herein are only to provide a comparison and will be superseded once the new study is released (2019–2021). The stillwater values do not include wave setup. The stillwater values were converted from NGVD29 to NAVD88.

1.2.2 Rainfall

Rainfall totals of 10 to 15 inches were common for Hurricane Irma across the peninsula and the Florida Keys. The maximum reported total rainfall for the storm was near the Fort Pierce Water Plant in St. Lucie County, where 21.66 inches of rain was measured between September 9 and 12. Most rivers in northern Florida were flooded, and major or record flood stages were reported at rivers in Alachua, Bradford, Clay, Duval, Flagler, Marion, Nassau, Putnam, and St. Johns Counties (Note: the MAT did not visit riverine areas in these counties). The St. Johns River set record flood stages at many locations in Duval County, causing major flooding in the Jacksonville metropolitan area (NOAA NHC, 2018). Figure 1-7 shows the total estimated rainfall from Hurricane Irma for the southeastern United States.

Figure 1-7: Map of rainfall totals associated with Hurricane Irma (or its remnants)
SOURCE: NOAA NCEP, 2017



1.2.3 Wind

On September 10 at 9:10 a.m. EDT, Hurricane Irma made landfall on Cudjoe Key, FL, as a Category 4 storm with maximum sustained winds near 130 mph. Later that day as Hurricane Irma approached the mainland, sustained Category 3 winds of 111 to 115 mph were confined to a small area of the eye that touched Marco Island, FL, and a small part of the immediate coastline of Collier County. Sustained Category 2 winds (96 to 110 mph) occurred in portions of the Naples area. The highest wind gust recorded on land in South Florida was 142 mph at a monitoring site at the Naples Municipal Airport (ID: NPLMP). The maximum sustained wind speed on Marco Island was recorded at 112 mph (NOAA NWS, 2017).

Many locations in Broward and Miami-Dade Counties reported sustained winds below hurricane force (between 50 and 73 mph). Isolated locations (immediate coastal areas of Broward and Miami-Dade Counties within 1 mile of the coast and southern Miami-Dade) may have experienced sustained winds that reached the low end of Category 1 hurricane strength (around 75 mph). Wind gusts in Broward, Miami-Dade, and Palm Beach Counties likely peaked in the 80 to 100 mph range (see Figure 1-8). For comparison, the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* basic wind speeds[2] for Risk Category II building design are shown on the right (ASCE 7-10).

ASCE 7 RISK CATEGORIES

The ASCE classifies buildings as Risk Category I, II, III, or IV depending on the risk posed to human life if the structure were to fail. Almost all residential buildings fall into Category II. Category II includes buildings that do not fall into Category I (those that pose a low risk to human life in the event of failure), Category III (those that pose substantial risk to human life in the event of failure), or Category IV (those designated as essential facilities, which pose substantial hazard to the community in the event of failure).

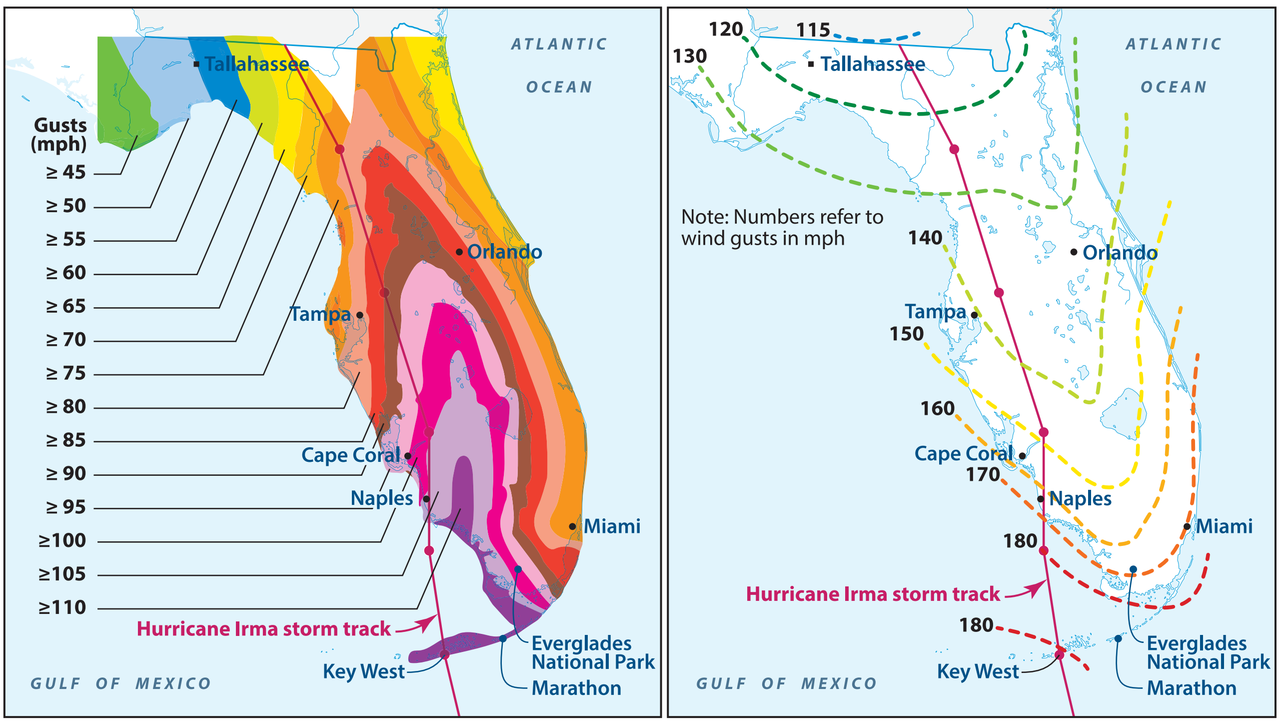


Figure 1-8: Comparison of gusts experienced during Hurricane Irma (left) with ASCE 7-10 design 3-second wind gusts (right)

SOURCES: LEFT MAP MODIFIED FROM ARA/FEMA GEOSPATIAL WORKING GROUP, 2017. RIGHT MAP MODIFIED FROM ASCE, 2010

2 Basic wind speed is defined as the 3-second gust speed at 33 feet (10 meters) above the ground in Exposure Category C.

1.2.4 Tornadoes

Hurricane Irma produced 25 confirmed tornadoes, 21 of which occurred in Florida. There were three EF-2 (on the Enhanced Fujita Scale[3]), 15 EF-1, and 7 EF-0 tornadoes (NOAA NHC, 2018). The majority of the tornadoes developed along the east coast of central and northern Florida. The tornado in Miami-Dade County struck near Homestead Motor Speedway. In Broward County, two of the tornadoes were EF-1 and the other was EF-0. One of the EF-1 tornadoes occurred 4 miles west of Miramar along 172nd Avenue between Memorial Hospital and Miramar Regional Park, where sections of trees were ripped apart. The other EF-1 tornado formed 4 miles west-northwest of Miramar in the Chapel Trail Neighborhood near NW 196th Avenue, north of Pines Boulevard. Several trees were ripped apart in a localized area, with some damage to roof tiles and screened-in patios. The damage pattern suggested rotation from a tornado vortex. The EF-0 tornado briefly touched down near Oakland Park (NOAA NWS, 2017).

1.3 Hurricane Irma: The Impact

The Tropical Cyclone Report for Hurricane Irma published by NOAA's NHC on May 30, 2018, indicates that Hurricane Irma was directly responsible for 47 fatalities across the Caribbean Islands and the southeastern United States as a result of strong winds, heavy rains, and high surf. In the United States, 10 direct fatalities were reported and an additional 82 indirect fatalities occurred, 77 of which were in Florida. These include the fatalities of elderly residents in a nursing home when the facility lost power to its central air conditioning, causing the facility to become overheated. Hundreds more were injured as a result of the storm (NOAA NHC, 2018). Approximately 6.5 million residents in Florida were evacuated from coastal areas (Florida House of Representatives, 2018).

NOAA's National Center for Environmental Information (NCEI) estimates that wind and water damage caused by Irma in the United States totaled approximately $50.5 billion (NOAA NCEI, 2018a). This estimate is based on a variety of public and private data sources, including FEMA, the Insurance Services Office, the U.S. Department of Agriculture, the Energy Information Administration, the U.S. Army Corps of Engineers, and State and other agencies. The data sources provide key pieces of information that capture the total, direct costs (both insured and uninsured) of weather and climate events. The estimated costs were adjusted for inflation and reported in dollars in terms of damages avoided had the event not taken place. The damage costs incorporate estimates based on physical damage to residential, commercial, and government or municipal buildings; material assets within a building; time element losses such as business interruption; vehicles and boats; offshore energy platforms; public infrastructure such as roads, bridges, and buildings; and agricultural assets such as crops, livestock, and timber. Insured loss data were scaled up to account for uninsured and underinsured losses. This is specific by peril, geography, and asset class. In addition, the estimated damage costs do not include losses related to health care, injury and loss of life, and natural capital.

In the Florida Keys, more than 1,300 boats were damaged or destroyed (NOAA NHC, 2018). Other long-term damage impacts include the loss of housing in the Florida Keys, damage to wastewater and potable water infrastructure, and minor to major erosion at different locations along the coastline. In addition, the estimate of Hurricane Irma's impact on Florida's agriculture industry is $2.5 billion

3 For more information about the Enhanced Fujita scale, refer to www.spc.noaa.gov/faq/tornado/ef-scale.html.

in total losses (Florida House of Representatives, 2018). The insurance industry estimated $8.6 billion in insured losses (Florida Office of Insurance Regulation, 2018).

For a detailed discussion on the assessment of the storm's impact on beach and dune erosion and structural damage to coastal regions of Florida, refer to the Florida Department of Environmental Protection's report titled, *Hurricane Irma Post-Storm Beach Conditions and Coastal Impact in Florida Report* (Florida DEP, 2018).

1.4 Regional Preparedness Actions

On September 4, Florida Governor Rick Scott declared a state of emergency for Florida and placed 100 members of the Florida National Guard on duty to assist in preparations. According to a report prepared for the Florida House of Representatives (2018), all 7,000 National Guard troops were ordered to be on duty by September 8. State and local emergency management officials advised residents to stock their hurricane kits. Governor Scott suspended tolls on all toll roads in the State starting at 5:00 p.m. on September 5. All State offices in Florida were closed on September 8. Schools and colleges were closed in 44 of the State's 67 counties before Governor Scott ordered all State colleges, universities, schools, and offices to be closed from September 8 to 11.

Fifty-four of Florida's 67 counties issued both voluntary and mandatory evacuation orders to a record 6.8 million people. Nearly 700 shelters were opened throughout the State, housing a record 190,000 people. A record 6.5 million people evacuated, all while the State Emergency Operations Center and local emergency management officials adjusted to 10 different scenarios over the course of Irma's track (Florida House of Representatives, 2018).

1.5 FEMA Mitigation Assessment Team

FEMA conducts building performance studies after unique or nationally significant disasters to better understand how natural and manmade events affect the built environment. A MAT is deployed when FEMA believes the findings and recommendations derived from field observations will result in design and construction guidance that will improve the disaster resistance of the built environment in the affected State or region and will be of national significance to other disaster-prone regions. FEMA bases its decision to deploy a MAT on preliminary information, such as:

- Magnitude of event
- Type and severity of damage in the affected areas
- Pre-storm site conditions in the impacted areas, such as the presence of older housing, newer housing, non-residential and critical facility stock, and building utility infrastructure
- Potential value of study results to the recovery effort
- Strategic lessons that can be learned and applied, potentially on a national level, related to improving building codes, standards, industry practices or guidance, code enforcement, research needs, knowledge gaps, or others
- Possibility of the field assessment gathering and analyzing pertinent information regarding the effectiveness of (1) certain FEMA grants and (2) key engineering principles and practices that FEMA promotes in published guidance and best practice documents

- Value of providing FEMA guidance in discipline topics currently not addressed or updating existing FEMA guidance on select topics as needed

The MAT studies the adequacy of current building codes and floodplain management regulations, local practices, and building materials in light of the damage observed after a disaster. Lessons learned from the MAT's observations are communicated through recovery advisories, fact sheets, and a comprehensive MAT report, all of which are made available to communities and the general public to aid their rebuilding efforts and enhance the disaster resistance of building improvements and new construction.

1.5.1 Hurricane Irma MAT

Twelve days after Hurricane Irma struck the Florida coast (September 22–25, 2017), the pre-MAT performed a preliminary field assessment of building damage in limited areas in Collier, Lee, Miami-Dade, and Monroe Counties. The full Irma MAT was deployed on December 10, 2017, to the areas initially surveilled by the pre-MAT and completed its field assessment work in February 2018. The MAT's mission was to assess the performance of residential and non-residential buildings affected by Hurricane Irma in Florida. To assess the effectiveness of flood and wind mitigation efforts previously undertaken, the MAT evaluated buildings that had previously undergone mitigation to improve their resistance to hurricane conditions (either wind or flood), as well as residential and non-residential buildings that had not been mitigated. The MAT focused on buildings located in the area of Hurricane Irma's landfall in Collier, Lee, Miami-Dade, and Monroe Counties.

1.5.2 Team Composition

The Irma MAT was composed of 17 subject matter experts, including:

- FEMA Headquarters and Regional office staff
- A representative from the State of Florida Division of Emergency Management (FDEM) Floodplain Management Office
- Building code, construction, and manufacturing industry staff from the Asphalt Roofing Manufacturers Association and PGT Industries
- Design professionals and technical consultants

Team members have backgrounds in structural, civil, and coastal engineering; floodplain management and mapping; building codes; critical facility protection; flood and wind damage-resistant materials; and urban floodproofing. The members of the MAT are listed in the front matter of this report.

1.5.3 Methodology

The Hurricane Irma MAT was divided into two specialty units: Flood and Wind. The Flood Unit focused on flood damage related to inundation, scour, and wave forces, as well as the performance of dry floodproofing and facility planning. The Wind Unit focused on wind-related damage and roof and soffit performance. Each unit visited several locations in Florida to assess the performance of different building and facility types.

Involvement of State and Local Agencies

FEMA encouraged State, county, and local government officials and locally based experts to participate in the assessment process. Their involvement was critical and helped improve the MAT's understanding of local construction and enforcement practices; encouraged the MAT to develop recommendations that were both economically and technically feasible for the communities involved; facilitated communications among Federal, State, and local governments and the private sector; and improved the State and local understanding of the MAT's observations, conclusions, and recommendations, which should enable them to bring about changes in their communities.

The MAT members met with local emergency management and government officials in many of the areas they visited. The officials gave an overview of the damage in their area and helped identify key sites to visit. The MAT also coordinated with the FEMA Joint Field Offices (JFOs) that had been set up in the area shortly after Hurricane Irma. Individuals who assisted the MAT in its field operations and report development are listed in Appendix A.

Pre-MAT Deployment and Site Selection

The pre-MAT was deployed shortly after Hurricane Irma's landfall and was tasked to quickly observe and record select perishable damage data, locate damaged areas requiring further assessment, and help determine the size and scope of areas and buildings to be visited, as well as the skillsets that would be needed for a larger follow-on MAT. The pre-MAT conducted ground surveillance in the areas shown in Figure 1-9. The members of the pre-MAT developed a list of select locations and specific building sites they considered important for the MAT to observe to better understand performance, vulnerabilities, and gaps or strengths in building planning, design, construction, enforcement, or other practices.

FEMA, State and local government agencies, and the MAT members also identified additional potential sites for the MAT to visit. To produce the final site list, the MAT assessed whether data were sufficient to evaluate building damage at each site. Specifically, the availability of the following data sources was considered for each site:

- Wind field maps, wind contour maps, and grids showing flood depths and extents produced by the FEMA Natural Hazard Risk Assessment Program (NHRAP)
- Water surface elevation data compiled from USGS, recorded high water marks, and surge sensor data
- Data on FEMA Hazard Mitigation Assistance grant projects
- Claims from the FEMA National Flood Insurance Program (NFIP)
- Data from the effective FEMA National Flood Hazard Layer and preliminary/ongoing FEMA Risk Mapping, Assessment, and Planning (Risk MAP) coastal studies in South Florida
- Damage information received from the FEMA Regional Response Coordination Center (RRCC) and JFO through Federal, State, and local governments and academic and private sector sources from which buildings of interest were selected
- Orthophotographs and data from NOAA and the Civil Air Patrol

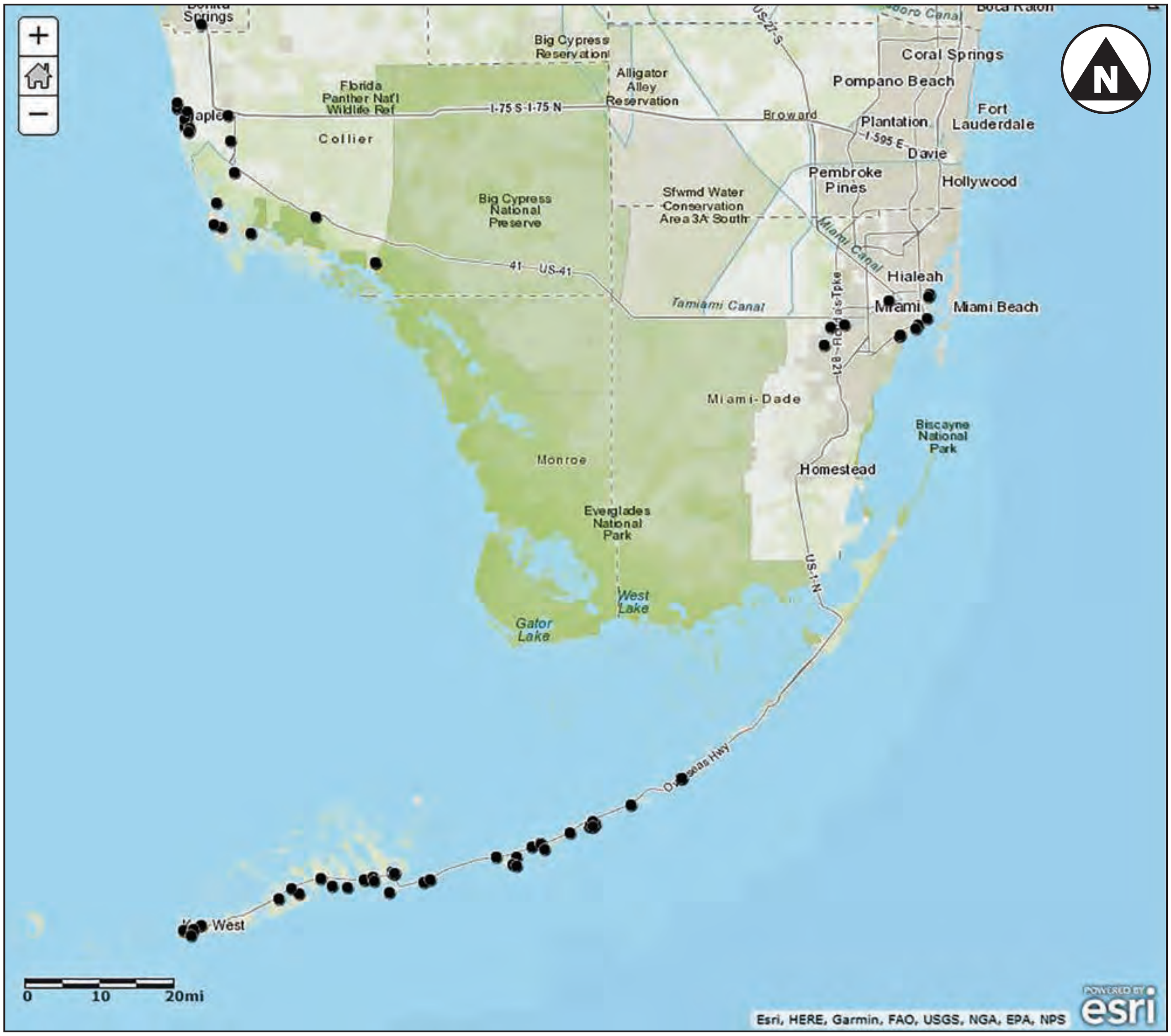


Figure 1-9: Field locations visited by the pre-MAT

- Data from the Fulcrum Community Data National Science Foundation (NSF) Rapid Response Research for the 2017 hurricanes[4]
- Estimates of storm surge and wave heights from the Coastal Emergency Risks Assessment's (CERA's) Advanced Circulation (ADCIRC) Storm Surge and Simulating Waves Nearshore (SWAN) models webcast[5]
- Press/social media stories and photographs of post-disaster damage

4 Fulcrum Community is a crowdsourced data collection solution for qualified humanitarian projects. For the 2017 disaster season, the NSF funded teams from universities across the United States and coordinated a response with the objective of collecting perishable data on the performance of U.S. civil infrastructure. The data collected are accessible here: web.fulcrumapp.com/communities/nsf-rapid.

5 The CERA group delivers storm surge and wave predictions for impending or active tropical cyclones in the United States. Based on the ADCIRC model, the CERA web mapping application provides an easy-to-use interactive web interface, which is accessible here: nc-cera.renci.org.

Based on the results of the pre-MAT, buildings were selected as examples of wind or flood effects for the full MAT damage assessment. The buildings selected for damage assessment included residential, non-residential, and mixed-use low-rise buildings; mid- and high-rise buildings; critical facilities and key assets; and public facilities, specifically public restrooms. Buildings were located in both coastal and riverine floodplains, as well as in urban areas, as described in the section that follows.

Field Deployment

Two MAT units were deployed on December 10, 2017, for 1 week. The 3-month delay in deployment after the storm resulted in the loss of perishable damage data (some sites and buildings were demolished; many buildings, roofs, windows and doors, and wall or other systems were already repaired or being repaired; and debris fields were cleaned up by the time the MAT arrived). When speaking with individuals about specific buildings, some were hesitant to discuss damage repairs affecting insurance claims.

To assess the performance of specific building and facility types, the MAT Flood and Wind units visited different locations depending on the type of damage—wind or flood—that occurred during Hurricane Irma. Both units conducted site visits and recorded observations along the coast of Florida at the locations shown in Figure 1-10.

The locations were based on those previously visited by the pre-MAT and on FEMA, State, and local input. For specific locations, outreach was conducted before and during the MAT deployment via telephone and email with site visit representatives to coordinate access. Some attempts were successful, while others were not. If a site of interest was identified in a conversation with the local contact, the contact was included as part of the field reconnaissance team.

When possible, building or facility owners were interviewed to gain insight into how well their buildings and facilities withstood Hurricane Irma and how their recovery efforts were progressing. The MAT spent considerable time assessing partially damaged buildings to determine why certain buildings performed better than others. The MAT members documented any observed best practices.

Figure 1-10: Field locations visited by the MAT Wind and Flood Units after Hurricane Irma. The inset map shows the locations of field visits in St. Johns County to evaluate erosion impacts.

HURRICANE
IRMA
IN FLORIDA

2 Building Codes, Standards, and Regulations

Building codes that include requirements to address flooding and high winds can help buildings resist damage.

This chapter presents an overview of Florida's building codes, the wind and flood provisions in those codes, and floodplain management in Florida. Section 2.1 describes the Florida Building Code (FBC), the process used by the Florida Building Commission to adopt and modify the International Codes® (I-Codes®), the model codes on which the FBC is based, and how local jurisdictions can amend the FBC.

Section 2.2 highlights recent initiatives of the Florida Division of Emergency Management (FDEM) to support communities that participate in the NFIP and summarizes the history of flood provisions in the FBC. Florida-specific amendments to the flood provisions of the I-Codes are described, including requirements specific to hospitals, nursing homes, and public education relocatable units. This section also lists the most common local amendments to the flood provisions in the FBC adopted by many Florida communities to incorporate higher and more restrictive standards. Section 2.3 summarizes the wind requirements in the FBC, including Florida-specific amendments for wind and water intrusion. Section 2.4 discusses Florida manufactured housing (MH) installation standards.

FEMA, the State of Florida, and others have documented how buildings are better able to resist damage from high winds and flooding when designed and constructed in compliance with building codes that contain requirements to address those hazards. As with other post-disaster MAT reports, observations after Hurricane Irma reinforce the value of the wind and flood provisions of the FBC, and the importance of trained plan reviewers and inspectors. Observations also identify the critical importance of builders paying attention to details during construction.

2.1 Building Codes in Florida

The FBC is part of the Florida Administrative Code adopted through Rulemaking as governed by Chapter 120 of the Florida Statutes. The adoption of the FBC by the Florida Building Commission as a Rule is mandated by the Florida Legislature (the code is not adopted statutorily). Local jurisdictions are required to enforce the FBC, but do not need to adopt it locally.

When Hurricane Irma made landfall in the State of Florida, the 5th Edition (2014) FBC was in effect. The 6th Edition (2017) FBC was adopted on June 13, 2017 through Rulemaking with an effective date of December 31, 2017. The term "Florida Building Code" refers to all of the codes administered by the Florida Building Commission, which include:

- Florida Building Code, Building (FBCB)
- Florida Building Code, Residential (FBCR)
- Florida Building Code, Existing Building (FBCEB)
- Florida Building Code, Mechanical (FBCM)
- Florida Building Code, Plumbing (FBCP)
- Florida Building Code, Energy Conservation (FBCEC)
- Florida Building Code, Accessibility (FBCA)
- Florida Building Code, Fuel Gas (FBCFG)
- Florida Building Code, Test Protocols (High-Velocity Hurricane Zone [HVHZ] Test Protocols)

SCOPE OF THE FLORIDA BUILDING CODE

For new construction, the FBCB applies to all buildings and structures except detached one- and two-family dwellings and townhouses not more than three stories above grade plane, which are within the scope of the FBCR. One- and two-family dwellings and townhouses outside the scope of the FBCR are required to comply with the FBCB. The FBCEB applies to the repair, alteration, change of occupancy, addition to, and relocation of buildings, including historic structures.

The 5th Edition (2014) FBC is based on the 2012 Edition of the applicable I-Codes published by the International Code Council (ICC). The 6th Edition (2017) FBC is based on the applicable 2015 I-Codes. The base codes are revised by Florida-specific amendments through Florida's code development process to create the FBC.

2.1.1 Florida Building Commission

The FBC is maintained and updated by the Florida Building Commission with administrative support and technical assistance from the Florida Department of Business and Professional Regulation (DBPR). The Commission is a 27-member stakeholder group that strives for consensus decisions on changes and updates to the FBC. Although the FBC is required to be updated every 3 years, the Commission may revise the code annually to incorporate Declaratory Statements (interpretations), clarifications, and standard updates.

Code Development Process

The development processes for the 5th Edition (2014) and 6th Edition (2017) FBC were essentially the same. The first step was to select the base code that would serve as the starting point. The 2015 I-Codes were selected as the base code for the 6th Edition (2017) FBC. For each update, all Florida-specific amendments expire except for the minimum requirements for State agencies (schools, nursing homes, swimming pools, etc.), statutory requirements, and the provisions of the HVHZ. The public is invited to propose code changes (Florida-specific amendments) to the base codes through the online Building Code Information System (BCIS) portal. Before the Florida Building Commission reviews the proposed code changes, they are first reviewed by Technical Advisory Committees (TACs). Eleven TACs review the proposed changes to the base code and make recommendations to the Florida Building Commission.

Previously, for a proposed code change to be recommended for approval by a TAC, three-fourths of the TAC members in attendance were required to be in support of the change. The recommendations of the TAC were then forwarded to the Florida Building Commission; incorporating the code change in the next edition of the FBC required three-fourths of the Commission members present to support the proposal. Once the code development process was completed, the Rulemaking process began, and the updated FBC became effective at a predetermined date.

However, as a result of 2017 changes to Section 553.73 of the Florida Statutes, the process for developing the 7th Edition (2020) FBC will change rather significantly. The Commission must use the 6th Edition (2017) FBC as the base code or starting point. The first phase of the process requires the Commission and TACs to review the 2018 I-Codes to examine changes from the 2015 I-Codes and determine whether to incorporate those changes into the 7th Edition (2020) FBC. The second phase will involve the TACs and Commission reviewing proposals submitted by the public to determine whether to incorporate those changes into the 7th Edition (2020) FBC. Additionally, the threshold for a TAC recommendation of approval of a code change has been reduced from three-fourths of the TAC members present at the meeting to two-thirds.

The 2017 statutory change also limits the Commission to only approving amendments to the code that are “needed to accommodate the specific needs of this state.” The statute further specifies that, at a minimum, the Commission must “adopt any updates to such codes or any other code necessary to maintain eligibility for federal funding and discounts from the National Flood Insurance Program, the Federal Emergency Management Agency, and the United States Department of Housing and Urban Development.” Any amendments or modifications made to the FBC will be carried forward until the next edition of the FBC.

The statute also prohibits any weakening of the wind resistance or prevention of water intrusion requirements in the FBC, including those contained in referenced standards, though this is not part of the 2017 changes.

2.1.2 Local Amendments

Local jurisdictions in Florida are permitted to amend the FBC provided such amendments do not weaken the code. Amendments must be submitted to the Florida Building Commission, which makes them available online. As part of the triennial code development process, the Commission reviews local amendments for consideration and inclusion in the FBC. However, the Commission does not have authority to approve or disapprove local amendments.

Local amendments expire with the effective date of each new edition of the codes, which means communities must re-adopt local amendments every 3 years. There are several other limitations on local technical amendments, but they can be challenged. As a result, there are very few local technical amendments of the code except for those related to flood, which, by statute, do not expire (refer to Section 2.3.3). The most common technical amendments related to the wind provisions of the code clarify the specific location of the wind speed contours.

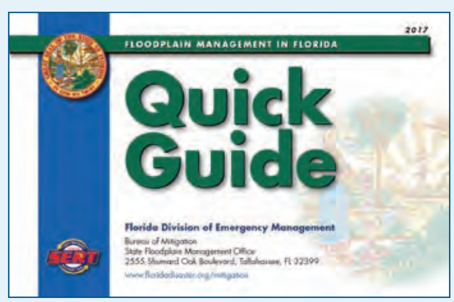
2.2 Floodplain Management in Florida

Communities that participate in the NFIP agree to adopt and enforce floodplain management regulations that meet or exceed the minimum requirements of the NFIP (44 CFR Parts 59 and 60). The State Floodplain Management Office (SFMO) of the FDEM is designated by the Governor as the NFIP State Coordinating Agency. In this capacity, the SFMO serves as a liaison between Florida's 467 NFIP communities and FEMA, helping communities implement sound land use development in floodplain areas to promote public health and safety, minimize loss of life, and reduce economic losses caused by flooding. Communities achieve those objectives by enforcing local floodplain management ordinances and the flood provisions of the FBC.

Supported by FEMA Community Assistance Program State Support Services Element (CAP-SSSE) funding, the SFMO conducts Community Assistance Visits (CAV) and Community Assistance Contact (CAC) interviews, provides one-on-one assistance for ordinance development and amendments, offers general technical assistance to Florida communities, supports FEMA's Map Modernization and Risk MAP processes, and provides training for local officials. The training is

QUICK GUIDE FOR FLOODPLAIN MANAGEMENT

The SFMO produced an illustrated overview of floodplain management for non-technical local staff and refresher for floodplain administrators. The guide is useful for informing elected officials, appointed citizen boards, and the public.



The Quick Guide is available online at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

conducted primarily through an agreement with the Florida Floodplain Managers Association (FFMA).

The SFMO also supports communities that participate in the NFIP Community Rating System (CRS), a program that recognizes activities undertaken by communities to reduce flood risk by providing premium discounts to citizens who have NFIP flood insurance policies. As of April 2018, 236 of the 467 Florida NFIP communities are in the CRS. Charged by FDEM leadership in early 2015 to increase participation in the CRS, the SFMO worked with FEMA to develop an initiative to visit more than 200 communities. Depending on the results and resolution of any identified concerns, the reports produced for each community can be used by FEMA to qualify communities for the CRS.

A central element of the initiative was development of "Seven Performance Measures" that, in effect, form a recommitment to the NFIP. The measures include conducting annual inspections of Special Flood Hazard Areas (SFHAs), having permit procedures and checklists in place, having procedures for making Substantial Improvement/Substantial Damage determinations, and communicating with utility companies and service providers regarding equipment and tank requirements. As of mid-2018, 26 of the visited communities have received FEMA approval for CRS entry. Other benefits of the initiative include increased awareness of the SFMO's availability to provide technical support and acceleration of communities transitioning to floodplain management ordinances written explicitly to rely on the flood provisions of the FBC (refer to Section 2.2.4).

In May 2018, the SFMO released the *Florida Post-Disaster Toolkit for Floodplain Administrators* (see text box on the right). The toolkit describes six key actions, including planning ahead to communicate, assessing post-disaster needs, documenting high water marks, making Substantial Improvement/Substantial Damage determinations, understanding the NFIP claims and Increased Cost of Compliance coverage, and identifying post-disaster and mitigation funding assistance.

To facilitate insurance company access to elevation certificates, in the 2016 legislative session, the Governor signed a bill amending Section 472.0366 of the Florida Statutes to require professionals authorized to prepare land surveys to submit elevation certificates to FDEM using the form developed by FEMA. Communities report that having access to elevation certificates for buildings is beneficial when owners elect to have certificates prepared as part of obtaining flood insurance policies.

TOOLKIT FOR FLOODPLAIN MANAGERS

The toolkit is available online at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

ELEVATION CERTIFICATES

The web application for submitting elevation certificates and accessing submitted documents is available at www.floridadisaster.org/elevation-certificates.

2.2.1 History of Flood Provisions in the Florida Building Code

> **FLORIDA BUILDING CODE AND THE NFIP**
>
> The Florida SFMO compiles excerpts of the flood provisions of the 6th Edition FBC and a summary of the differences between the 6th Edition and the 5th Edition, online at www.floridadisaster.org/dem/mitigation/floodplain.
>
> FDEM refers users to FEMA's *Highlights of ASCE 24-14 Flood Resistant Design and Construction* (2015), online at www.fema.gov/building-code-resources.

The flood provisions in the FBC are based on the flood provisions in the I-Codes, which in turn are related to the floodplain management regulations of the NFIP. Since 1998, FEMA has participated in the code development process for the I-Codes. Every 3 years, the family of I-Codes is modified through a formal, public consensus process. Starting with the 2010 FBC, the flood provisions in the I-Codes are retained as the Florida Building Commission undertakes the code development process every 3 years.

FEMA deems the flood provisions in the 2018, 2015, 2012, and 2009 I-Codes to meet or exceed the minimum NFIP requirements for buildings and structures. Because the 6th Edition (2017) FBC is based on the 2015 I-Codes and the Florida Building Commission has not weakened any flood provision below the NFIP minimums, the flood provisions of the 6th Edition (2017) FBC also meet or exceed the minimum NFIP requirements for buildings and structures. In conjunction with floodplain management ordinances, Florida communities rely on the FBC to fulfill the requirements for participation in the NFIP. FEMA makes the same statement about the flood provisions of the 2012 and 2009 I-Codes, which formed the basis of the 2010 FBC and 5th Edition (2014) FBC, respectively.

In 2007 and 2008, with technical and funding support from FEMA Headquarters and FEMA Region IV, FDEM made a commitment to re-establish the NFIP State Coordinating Agency function and build capacity to become a premier State partner in floodplain management. In mid-2008, FDEM asked the Florida Building Commission to appoint a flood standards workgroup to develop recommendations for integrating the flood damage-resistant provisions in the I-Codes into the FBC. In mid-2009, the Commission adopted the workgroup recommendations. As a result, the 2010 FBC included those provisions, with some Florida-specific amendments.

Many Florida communities, through local floodplain management regulations, have adopted and enforced provisions that exceed the NFIP minimum requirements for buildings. However, as dictated by Florida Statutes, only the FBC governs the design and construction of buildings. Thus, to address the potential for conflict and challenge to locally adopted higher standards, the SFMO developed a companion model ordinance written explicitly to rely on the FBC for design and construction of buildings in SFHAs. The ordinance, described in Section 2.2.4, includes administrative provisions and requirements for development other than buildings within the scope of the FBC. Together, the FBC and the model ordinance meet or exceed the NFIP requirements (Figure 2-1).

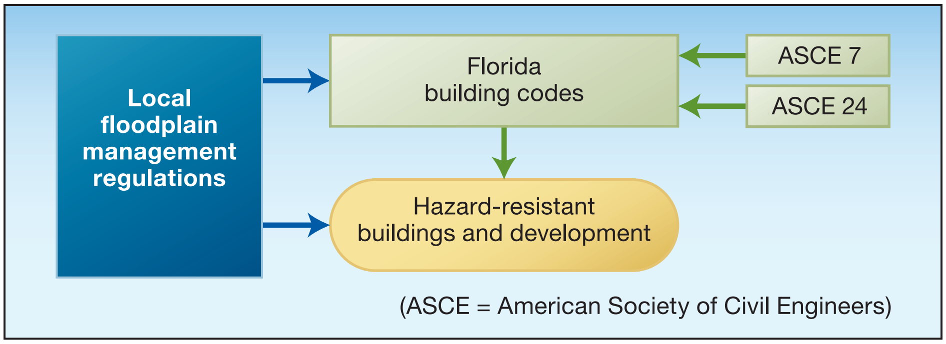


Figure 2-1:
FBC and local regulations meet or exceed the NFIP requirements

2.2.2 Flood Provisions in the Florida Building Code

International Building Code (IBC) Chapter 1, Administration, forms the basis for Chapter 1 of the FBC, which is used to administer all volumes in the FBC family of codes. For each triennial code development cycle, the Florida Building Commission makes numerous amendments to tailor Chapter 1 of the IBC according to statutory requirements and State-specific needs. The 5th Edition (2014) FBC, which was in effect when Hurricane Irma made landfall, and the 6th Edition (2017) FBC, effective December 31, 2017, contain the following Chapter 1 amendments specific to buildings and structures in flood hazard areas:

- Section 102.7 adds a provision that relocated manufactured buildings (not manufactured housing) shall comply with flood hazard area requirements (e.g., if moved into or within flood hazard areas).

- Sections 104.2.1 and 104.10.1 are not retained. Local floodplain management regulations incorporate equivalent provisions for Substantial Improvement and Substantial Damage determinations and requests for modification of flood provisions (refer to Section 2.2.4 of this report).

- Sections 105.14 and 107.6.1 add provisions to restrict the building official's authority to issue permits based on affidavits by stating it does not extend to flood load and flood resistance requirements. This limitation is necessary because of the NFIP requirement that communities review development for compliance.

- Section 107.3.5 adds a section to specify examination of documents, including minimum plan review criteria for "Building" and "Residential." These review criteria include flood hazard area requirements, lowest floor elevations, enclosures, and flood damage-resistant materials. Plan review criteria for mechanical, electrical, and plumbing (MEP) and fuel gas include design flood elevations (DFE).

- Section 110.3 replaces the I-Code section for inspections. It requires two inspections specific to flood hazard areas: a foundation inspection and a final inspection. As part of the foundation inspection, elevation certification must be submitted upon placement of the lowest floor and prior to further vertical construction. As part of the final inspection, final certification of the lowest floor elevation must be submitted.

- Section 111.2 adds a new requirement that certificates of occupancy for buildings in flood hazard areas must include a statement that documentation of the as-built lowest floor elevation has been provided and is retained in the community's records.

- Section 117 refers to local floodplain management ordinances for procedures when requests for variances to the flood provisions (Section 1612 or R322) are requested. This section does not apply to Section 3109, Coastal Construction Control Line.

Through the triennial code development process, the Florida Building Commission considers Florida-specific amendments, including several sections in Chapter 4 that outline requirements for specific occupancies. Provisions in those sections are considered "agency amendments" and are carried forward from edition to edition. Specific to flood hazard areas, agency amendments include:

- Sections 449 and 450 require, for new construction and Substantial Improvements of hospitals and nursing homes, elevation or dry floodproofing to the higher of the base flood elevation (BFE) plus 2 feet or "the height of hurricane Category 3 (Saffir-Simpson scale) surge inundation elevation." The sections also specify that for all additions, patient support areas, including food service, and patient support utilities for the additions shall be at or above the elevation of the existing building, unless otherwise required by Section 1612.

- Section 454 requires initial and subsequent installation of public education relocatable units to comply with floodplain standards, including setting the "finished floor" 12 inches above the BFE and anchoring the units to resist "buoyant forces."

- Section 1612.3 and Table R301.2(1) specify the establishment of flood hazard areas, which is accomplished by local floodplain management ordinances that adopt flood hazard maps and supporting data.

- Section 1612.4.1 modifies ASCE 24 Table 6-1 and Section 6.2.1 to permit dry floodproofing of non-residential buildings located in Coastal A Zones provided "wave loads and the potential for erosion and local scour are accounted for in the design." The FBC references ASCE 24, *Flood Resistant Design and Construction*, for specific requirements for buildings and related components in flood hazard areas.

- Section 3109 contains requirements applicable to most structures located seaward of the Coastal Construction Control Line, a line established by Florida Statute. In the 6th Edition (2017) FBC, this section is completely revised to bring the Coastal Construction Control Line requirements more in line with the Section 1612 requirements for Coastal High Hazard Areas (Zone V), while retaining certain requirements of statute and declaration statements (interpretations) issued by the Commission. At many locations around Florida's coast, the "100-year storm elevation" used in the Coastal Construction Control Line requirements is higher than the BFE shown on FIRMs.

2.2.3 Local Amendments to the Flood Provisions of the FBC

A statutory provision was added in 2010 specifically for local amendments to the FBC flood provisions. Under three circumstances, these amendments do not expire every 3 years as other local amendments do (refer to Section 2.1.2): (1) if they are locally adopted before July 1, 2010; (2) if the higher standard is freeboard; and (3) if the higher standard is adopted for the purpose of participating in the NFIP CRS.

As of mid-2018, 80 percent of Florida's NFIP communities had adopted FBC-coordinated floodplain management regulations (refer to Section 2.2.4), with the remainder expected to do so by the end of 2019. The SFMO maintains a database of the most common locally adopted higher standards. The most common higher standards that affect the design and construction of buildings in flood hazard areas include:

SFMO INSTRUCTIONS FOR HIGHER STANDARDS

The SFMO provides instructions for local adoption of common higher standards, including local technical amendments to the flood provisions of the FBC. The instructions can be accessed at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

- **Additional elevation (freeboard).** Freeboard specifies how high lowest floors and dry floodproofing are above the minimum required elevation. More than 30 communities have adopted freeboard of 2 or 3 feet above the BFE, more than 10 have adopted 1.5 feet above the BFE, and many have adopted a minimum elevation above the crown of the road (typically 12 to 18 inches). Prior to the 6th Edition FBCR, which now requires a minimum BFE plus 1 foot, nearly 125 communities had individually adopted 1 foot of freeboard.

- **Enclosure limits (prohibition, size limits, access, no partitions).** Eighty communities have adopted some form of enclosure limits. A small number prohibit walls (other than insect screening or lattice). Some communities limit the size to less than 299 square feet (primarily in Zone V), while many others limit the size and number of doors and do not allow partitions (except crawlspace if required for fire safety).

- **Cumulative Substantial Improvement.** More than 80 communities have adopted requirements to accumulate costs of improvements and repairs over specific periods of time. The most common period of time is 5 years, followed by 10 years, 2 years, and life of structures. Shorter periods are typically selected when the objective is to discourage deliberate phasing of improvements that, if taken together, would trigger the Substantial Improvement requirement to bring structures into compliance with the flood provisions.

- **Repetitive flood loss.** About 40 communities modified the definition of "Substantial Damage" to include repetitive flood damage, such that the term includes "flood-related damage sustained by a structure on two separate occasions during a 10-year period for which the cost of repairs at the time of each such flood event, on average, equals or exceeds 25 percent of the market value of the structure before the damage occurred." Thus, buildings that are determined to be substantially damaged by repetitive flooding must be brought into compliance with the flood requirements of the FBC. Owners of those buildings, if covered by NFIP flood insurance policies, may qualify for Increased Cost of Compliance claims that pay up to $30,000 toward the cost of bringing the buildings into compliance.

- **Critical facilities.** More than 30 communities have adopted some form of regulation pertaining to critical facilities. A common amendment is to define critical facilities to include Flood Design Class 3 and 4 structures (see ASCE 24-14 for the Flood Design Class descriptions). Many have adopted higher elevation requirements, which may now be superseded by the Flood Design

Class 4 requirement that specifies lowest floors and dry floodproofing be at or above the BFE plus 2 feet or the 500-year flood elevation (elevation of the 0.2-percent-annual-chance flood), whichever is higher. A number of communities do not permit critical facilities in all or part of the SFHA or have adopted language requiring alternative locations to be considered.

FLOOD DESIGN CLASS

FEMA's *Highlights of ASCE 24-14 Flood Resistant Design and Construction* (2015) includes Table 1-1, "Flood Design Class of Buildings and Structures," available online at www.fema.gov/building-code-resources.

2.2.4 Floodplain Management Ordinances Coordinated with the FBC

In 2009, concurrent with the work of the Florida Building Commission's flood standards workgroup, FDEM began developing a model floodplain management ordinance written explicitly to rely on the FBC for NFIP-consistent requirements for buildings and structures. The ordinance contains administrative provisions, duties and responsibilities of the Floodplain Administrator, provisions for determining BFEs and floodways when not specified on Flood Insurance Rate Maps (FIRMs), records retention, and other provisions. FEMA supported this work with technical and financial assistance. Final approval of the model ordinance was received in January 2013. A major benefit of the close collaboration with FEMA is the FEMA Region IV office relies on FDEM's recommendations for approval when communities are required to demonstrate that their ordinances comply with the NFIP as part of the flood map revision process.

The FBC-coordinated model ordinance is intended to be administered by the community Floodplain Administrator and Building Official and contains direct links with the FBC as follows:

- **Buildings, structures, and facilities that are exempt from the FBC**. The NFIP requires communities to regulate all development. Thus, the scope of the ordinance specifically includes such buildings and structures and requires conformance with the flood load and flood-resistant provisions of ASCE 24. The Floodplain Administrator is responsible for inspecting these buildings and structures.
- **Substantial Improvement and Substantial Damage determinations**. The Floodplain Administrator and Building Official coordinate on these determinations, which are spelled out in the ordinance. In addition, the ordinance defines "market value."
- **Variances**. Restrictions on variances and conditions and issues that must be examined when considering requests for variances are specified. FBC Section 117 refers to local ordinances when variances to the flood provisions of the FBC are requested.

ADOPTION OF FBC-COORDINATED ORDINANCE

As of mid-2018, more than 80 percent of Florida's NFIP communities have adopted local ordinances based on the FBC-coordinated floodplain management ordinance. The remaining communities are expected to make the transition by the end of 2019.

FDEM anticipated a significant level of effort to work with the 467 NFIP-participating communities in Florida to transition to the FBC-coordinated ordinance. To meet the demand and facilitate adoption, the agency procured professional services to review draft ordinances and work with communities to incorporate community-specific amendments and higher standards. Considerable attention was paid to preparing higher standards that affect the design of buildings in the format required for local technical amendments of the FBC (refer to Section 2.2.3).

The SFMO database of higher standards adopted by communities includes common higher standards that do not affect the design and construction of buildings in flood hazard areas. As of mid-2018, the most common non-building higher standards:

- **Manufactured home restrictions.** Nearly 50 communities adopt restrictions on the installation of manufactured homes. While some prohibit manufactured homes in SFHAs, most limit the prohibition to the installation of new manufactured homes in Zone V or floodways unless they are in existing manufactured home parks or subdivisions that were established before the communities joined the NFIP.
- **Compensatory storage.** More than 15 communities have adopted some form of compensatory storage, most commonly requiring excavation of a volume equivalent to the volume of fill brought into flood hazard areas. Some require analyses to demonstrate compensation is hydraulically equivalent.

2.3 Wind Provisions of the Florida Building Code

The design of buildings for wind loads in the State of Florida is governed primarily by the FBCB, FBCR, and FBCEB. The 5th and 6th Editions of the FBC reference the 2010 Edition of ASCE Standard 7, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10). However, the FBCB, FBCR, and FBCEB also contain numerous Florida-specific, wind-related amendments that exceed the minimum criteria in the I-Codes.

The FBC also contains separate wind, structural, and testing requirements for a special zone called the "High-Velocity Hurricane Zone." The HVHZ, specifically defined as Miami-Dade and Broward Counties, was created for the inaugural version of the FBC (2001) as a way to maintain certain wind-related provisions from the South Florida Building Code. The wind criteria applicable in the HVHZ have historically been more stringent than the criteria applied in the rest of the State. However, more recent versions of the code have been minimizing the differences.

WIND REQUIREMENTS FOR EXISTING BUILDINGS

The FBCEB contains several mitigation "triggers" for roof repairs and reroofing. These triggers and mandated mitigation of existing buildings are discussed in Hurricane Irma in Florida Recovery Advisory No. 3 (see Appendix C).

2.3.1 Wind Loads and Wind Design in the FBC

The wind load and wind design requirements of the 5th Edition (2014) and the 6th Edition (2017) FBCB and FBCR are similar. Both editions reference ASCE 7-10, and the definition of wind-borne debris regions, protection of glazed openings, and classification of exposure categories are also consistent with ASCE 7. Exceptions permit the use of certain prescriptive high-wind design standards primarily for one- and two-family dwellings, although ICC 600 is permitted for Group R2 buildings (apartments, hotels, dormitories, etc.). These prescriptive standards include:

- *Wood-Frame Construction Manual for One- and Two-Family Dwellings*, American Wood Council, 2015
- *Standard for Residential Construction in High-Wind Regions* (ICC 600), International Code Council, 2014
- *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings, 2007, with Supplement 3, dated 2012* (AISI S230), 2012

Florida-specific design wind speed maps are contained in the 6th Edition (2017) FBCB and FBCR; the maps are consistent with ASCE 7-10. The wind speed maps for Risk Category II, III, and IV buildings (FBCB) are shown in Figure 2-2 and Figure 2-3, and the wind speed map in the FBCR is shown in Figure 2-4.

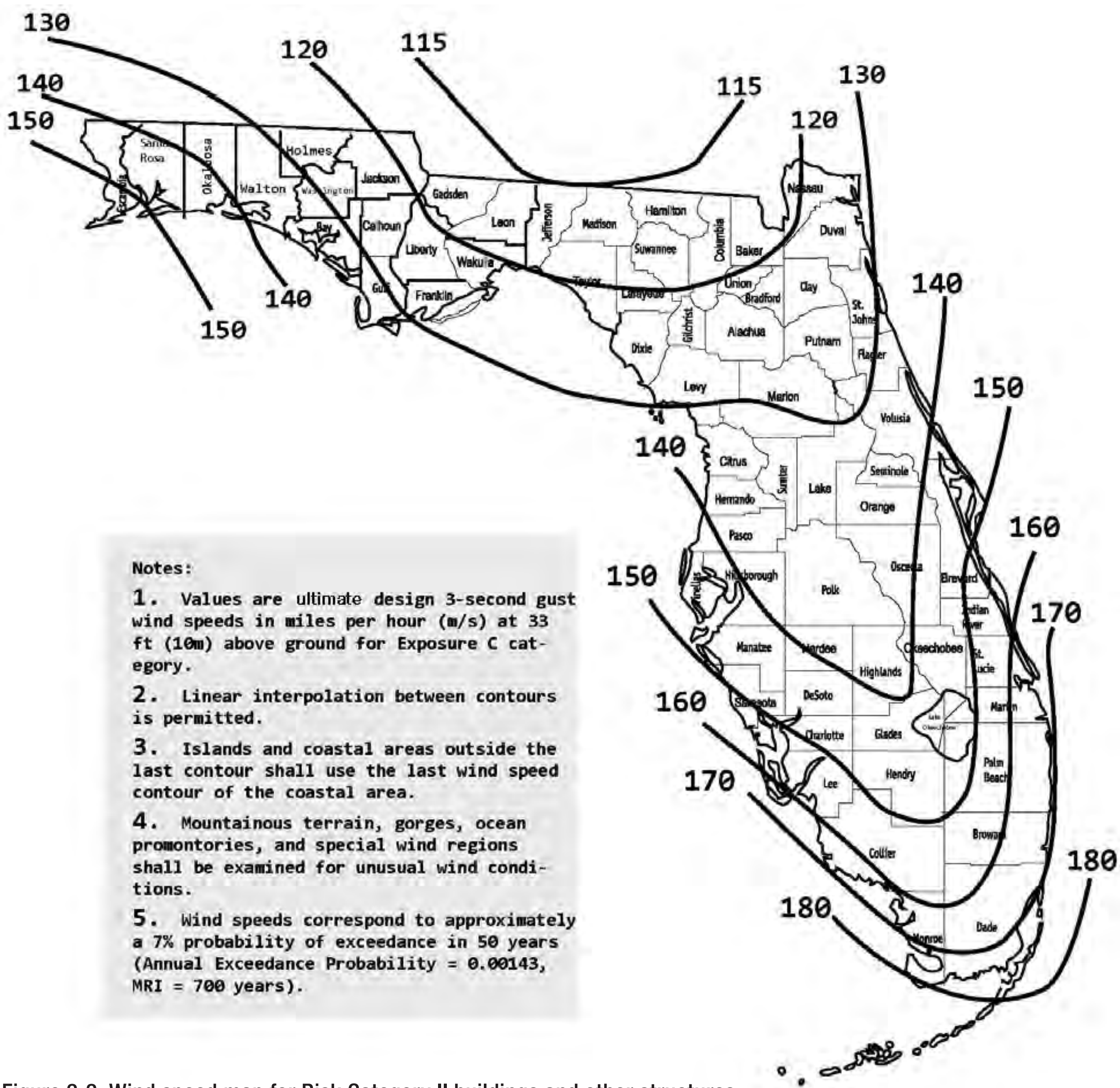


Figure 2-2: Wind speed map for Risk Category II buildings and other structures

SOURCE: 6TH EDITION [2017] FBCB

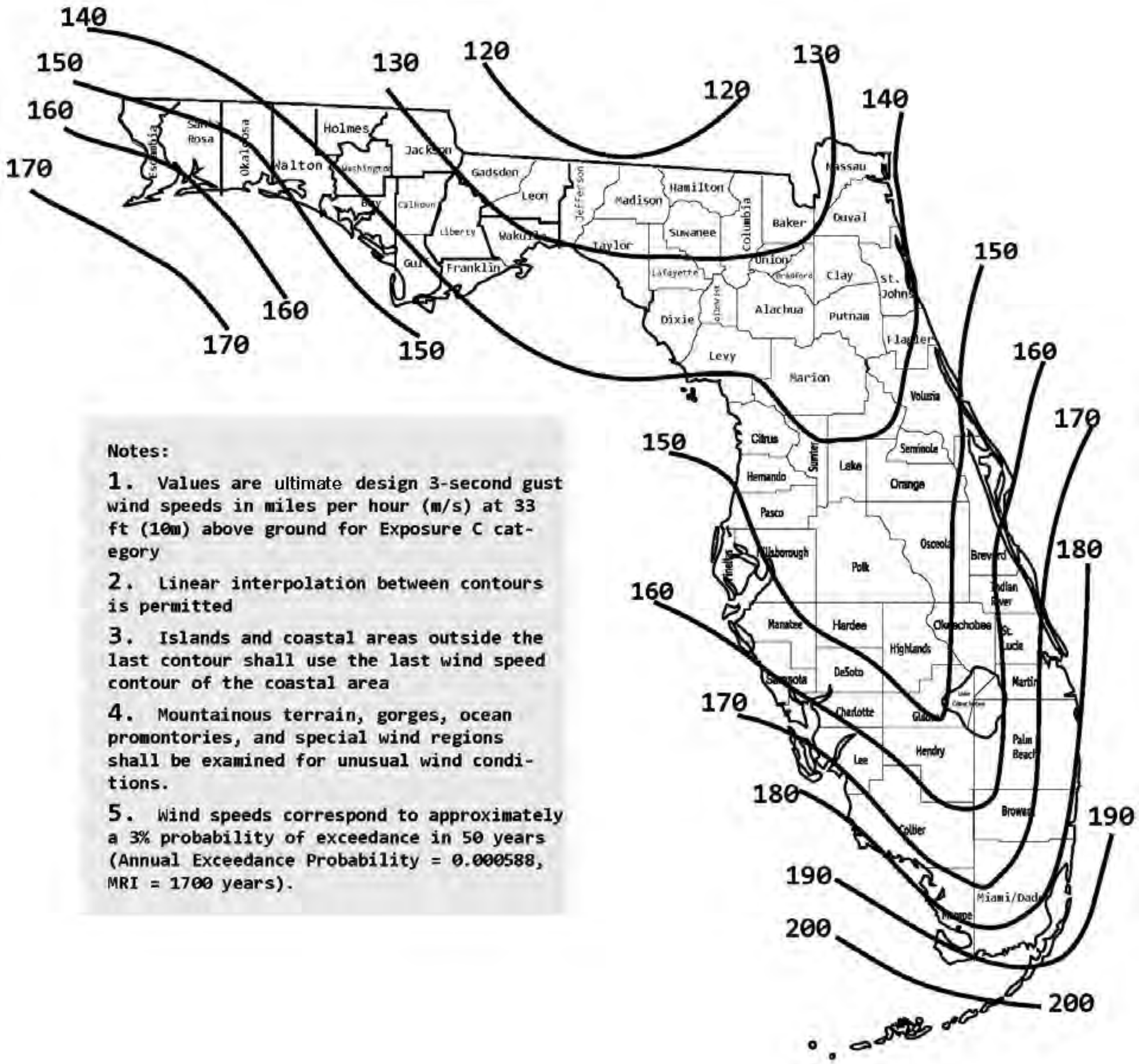


Figure 2-3: Wind speed map for Risk Category III and IV buildings and other structures
SOURCE: 6TH EDITION [2017] FBCB

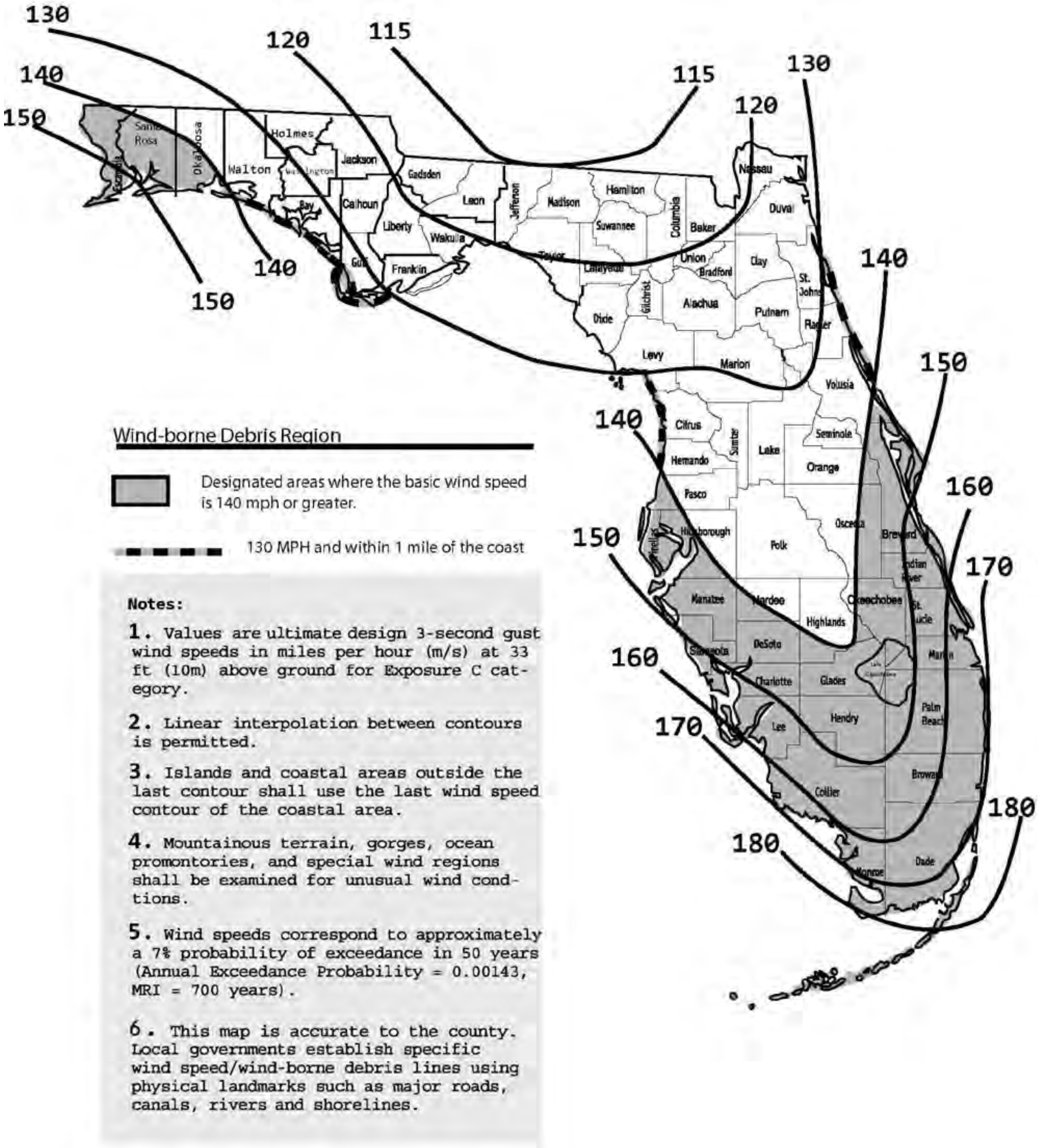


Figure 2-4: Wind speed map for FBCR buildings

SOURCE: 6TH EDITION [2017] FBCR

2.3.2 Florida-Specific Amendments for Wind and Water Intrusion

As previously stated, the FBC contains numerous Florida-specific amendments related to wind and water intrusion, including the requirements in the HVHZ that exceed the minimum requirements in the 2015 I-Codes. Table 2-1 lists some notable Florida-specific amendments related to wind and water intrusion prevention.

Table 2-1: Notable Florida-Specific Amendments for Wind and Water Intrusion

	Non-HVHZ	HVHZ
6th Edition (2017) FBCB	• Specifically requires soffits to be designed for wall component and cladding loads • Limits the span of wood structural panels used for opening protection to 44 inches • Enhanced roofing underlayment provisions for high-wind areas apply throughout the entire State • Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating	• Requires all buildings to be designed for wind loads; prescriptive high-wind standards are not permitted • Requires a single wind speed to be used for each county – Miami-Dade County – Risk Category II = 175 mph – Risk Categories III and IV = 186 mph – Broward County – Risk Category II = 170 mph – Risk Categories III and IV = 180 mph • The entire building envelope is required to be impact resistant (some deemed-to-comply assemblies are provided) • All areas are required to be designed for Exposure Category C unless Exposure Category D applies • Enhanced roofing underlayment provisions apply throughout • Requires the use of plywood sheathing; oriented strand board is not permitted
6th Edition (2017) FBCR	• Establishes the entire State as requiring wind design – Prescriptive high-wind standards are permitted – Prescriptive construction provisions in the 2015 IRC are not permitted • Exposure category definitions have been revised to be consistent with ASCE 7 • Specifically requires soffits to be designed for wall component and cladding loads • Limits the span of wood structural panels used for opening protection to 44 inches • Enhanced roofing underlayment provisions for high-wind areas apply throughout the entire State • Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating • References to the use of staples for wall covering attachment methods have been removed	• Refers to the HVHZ provisions in the FBCB

ASCE = American Society of Civil Engineers; FBCB = Florida Building Code, Building; FBCR = Florida Building Code, Residential; HVHZ = High-Velocity Hurricane Zone; IRC = International Residential Code; mph = miles per hour

2.4 Florida Manufactured Housing Installation Standards

The Florida Department of Highway Safety and Motor Vehicles has jurisdiction over the installation of MH units. Requirements for installation, setup, tie-downs, and anchoring foundations, with specific provisions related to wind loads, are contained in Chapter 15C of the Florida Administrative Code. With respect to installation in floodprone areas, the regulations refer to and incorporate by reference the 1985 edition of FEMA 85, *Manufactured Home Installation in Flood Hazard Areas*.

MANUFACTURED HOMES CONSTRUCTION

The Manufactured Home Construction and Safety Standards, 24 CFR Part 3280, developed by the U.S. Department of Housing and Urban Development, cover the design and construction of manufactured homes.

HURRICANE
IRMA
IN FLORIDA

3 Flood-Related Observations

The Irma MAT made general flood-related observations as well as examined specific building performance issues.

This chapter describes the MAT's observations, which focused on the following:

- General flood damage
- Performance of dry floodproofing measures
- Performance of public restrooms in coastal flood hazard areas

MAT OBSERVATIONS

Deployments

Pre-MAT: September 22 to 25, 2017
MAT: December 10 to 15, 2017
MAT: February 14 to 15, 2018

Locations

- Southwest Florida (Fort Myers to Marco Island to Everglades City)
- Southeast Florida (Miami and Miami Beach)
- The Florida Keys (Tavernier to Key West)
- St. Johns County (Vilano Beach and South Ponte Vedra Beach)

The Irma MAT deployed on three occasions: September 2017 (pre-MAT), December 2017, and February 2018; see text box for additional information. The pre-MAT performed a cursory review of flood damage to buildings at approximately 150 locations in the Florida Keys, Southwest Florida, and Southeast

Florida. For the second deployment, the MAT conducted more detailed evaluations of flood conditions and flood damage to buildings in the same geographic areas of the pre-MAT visit, at approximately 25 general damage sites, 25 floodproofing sites, and 15 public restroom sites. For, the third deployment, the MAT visited approximately 20 general damage sites and one public restroom site in St. Johns County, FL.

Figure 3-1 shows locations for selected September 2017 observations, and Figure 3-2 shows selected locations of flood-related observations made during the December 2017 and February 2018 deployments.

Hurricane Irma was a large storm that traveled northward over the entire Florida peninsula. It resulted in storm surge and heavy rain in many areas not visited by the MAT. However, the MAT observations included in this chapter capture the type and range of effects produced by Hurricane Irma.

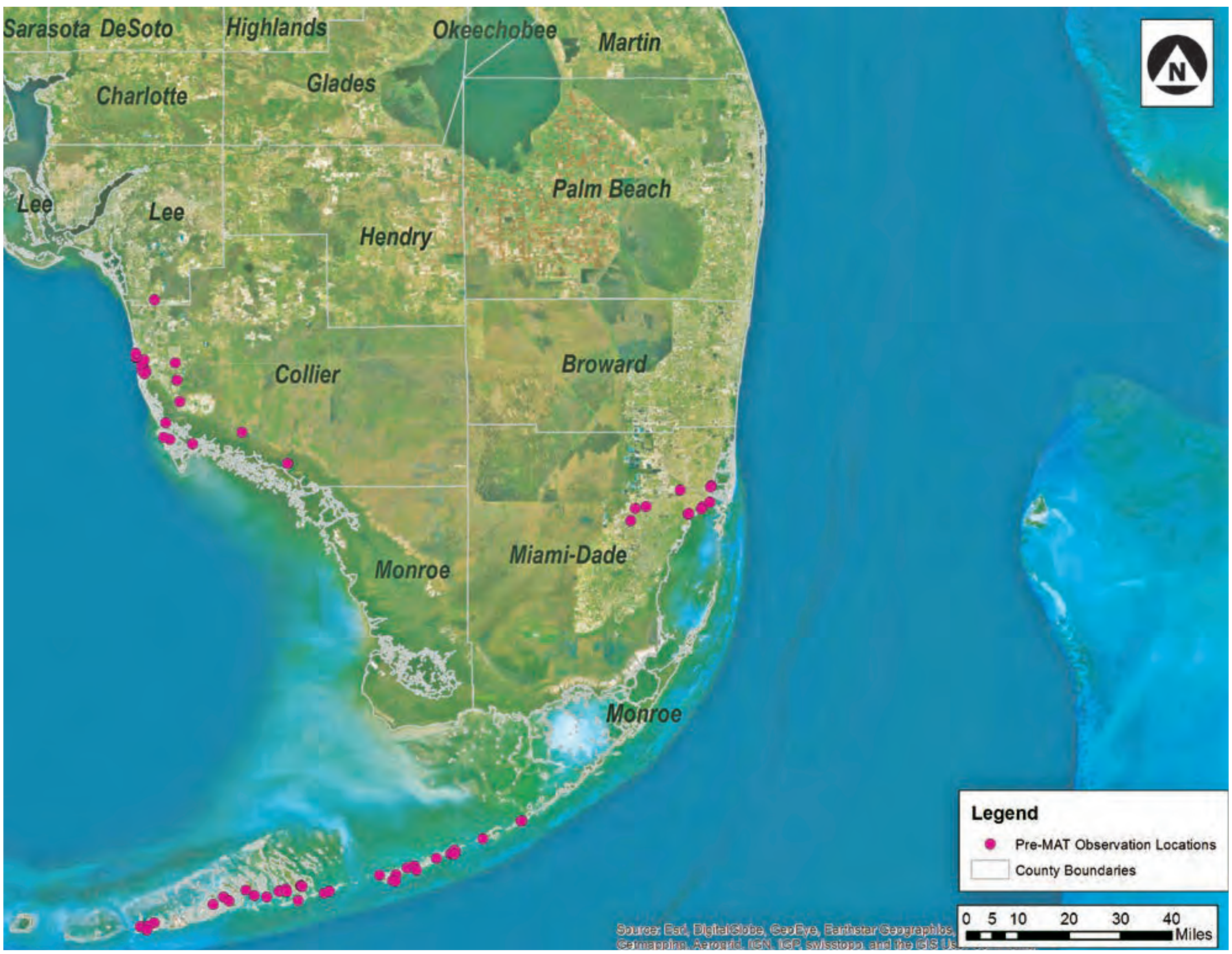


Figure 3-1: Locations of selected September 22–25, 2017 (pre-MAT) observations for Hurricane Irma

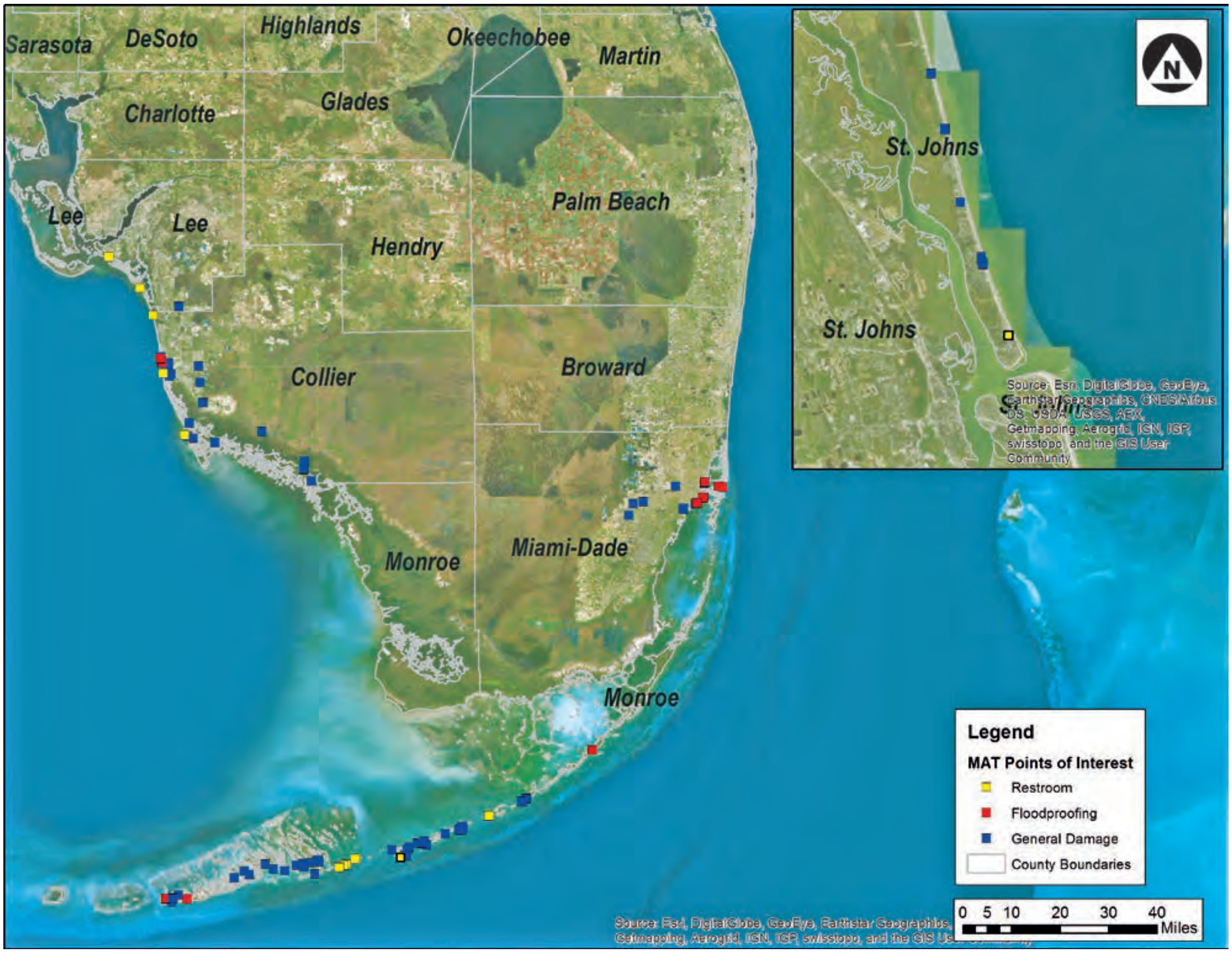


Figure 3-2: Locations of selected December 10–15, 2017 and February 14–15, 2018 (MAT) observations for Hurricane Irma

3.1 General Flood Damage Observations

The Irma MAT, like other post-Hurricane MATs, planned for and made general observations of building performance under a variety of flood conditions. Observations of building performance under a variety of flood conditions are summarized in this section. The MAT observed many cases of erosion and scour, along with variable performance of erosion control structures. Sections 3.1.1 and 3.1.2 summarize observations made related to these topics.

The extent of flood damage to buildings observed by the MAT varied with the depth of floodwater, the amount of energy in the water column (waves, velocity), and type of building design and construction (old versus new, at-grade versus elevated, MH unit/recreational vehicle versus site-built/modular). Buildings constructed at or near grade were subject to deeper and more damaging flooding. This applied to buildings subject to storm surge and to buildings subject to rainfall-induced flooding.

Figure 3-3 shows how flood damage varied along one street on Big Pine Key. Figure 3-4 shows long-duration flooding in the Bonita Springs area. Figure 3-5 and Figure 3-6 show damage to adjacent elevated and non-elevated homes on the Atlantic Ocean shoreline of Big Pine Key.

House near shoreline and subject to wave action/ high water velocity was washed off its foundation and destroyed.

Inundation, water velocity, and debris damage to buildings situated farther from the shoreline.

Inundation, water velocity, and debris damage to buildings situated farther from the shoreline.

Minor enclosure damage to newer, elevated house situated away from the shoreline.

Figure 3-3: Typical range in flood damage observed along Avenue D, in order along the street as indicated (Big Pine Key, FL)

Figure 3-4: Long-duration flooding in the Bonita Springs area (Lee County, FL)

View looking north across Bonita Beach Road SE on September 15, 2017 (photograph courtesy of Civil Air Patrol).

Part of Bonita Springs still flooded on September 23, 2017, nearly 2 weeks after Irma.

Figure 3-5:
Elevated house with unreinforced masonry breakaway walls that performed as intended (Big Pine Key, FL)

Figure 3-6:
House constructed at grade where the masonry walls parallel to the shoreline were destroyed; this house was near the house shown in Figure 3-5 (Big Pine Key, FL)

Performance of breakaway walls below elevated buildings varied. Some walls broke away cleanly without damaging the main structure (see Figure 3-7), while others did not. Of those that did not break away cleanly, some appeared to cause no damage to the structure (see Figure 3-8), while others appeared to cause damage to the columns to which they were attached (see Figure 3-9).

Figure 3-7:
Example of a breakaway wall that was reported by a local code official to have performed as intended (Lower Matecumbe Key, FL)

Figure 3-8:
Example of partial failure of breakaway wall, with no associated damage to main structure observed (Cudjoe Key, FL)

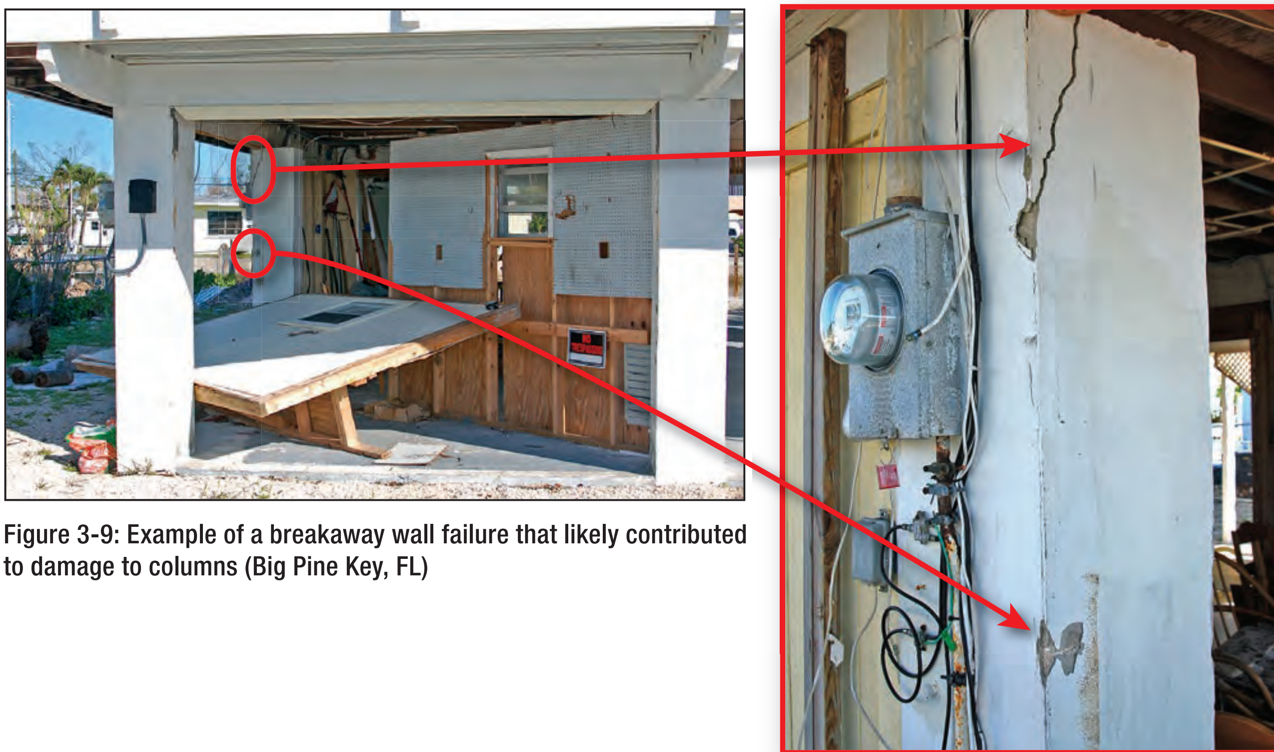


Figure 3-9: Example of a breakaway wall failure that likely contributed to damage to columns (Big Pine Key, FL)

The MAT observed considerable debris that had washed around and into buildings in the Florida Keys. Debris was composed of building materials and furnishings from damaged and destroyed buildings, displaced sheds, automobiles, boats, and recreational vehicles, as illustrated in Figure 3-10 through Figure 3-13.

Figure 3-10: Building debris and recreational vehicles washed into a canal on 61st Street Ocean (Marathon, FL)

Figure 3-11:
Boat and small debris that washed across a canal and onto houses
(Big Pine Key, FL)

Note the wind damage to the elevated portion of the house.

Figure 3-12:
Car and debris that washed into a house
(Big Pine Key, FL)

Figure 3-13: Shed that washed across Highway US 1 (Grassy Key, FL)

3.1.1 Erosion and Scour

The MAT observed a few instances of erosion and scour in Monroe County and widespread dune and bluff erosion in St. Johns County. In both counties, buildings with deep foundations performed better than buildings with shallow foundations.

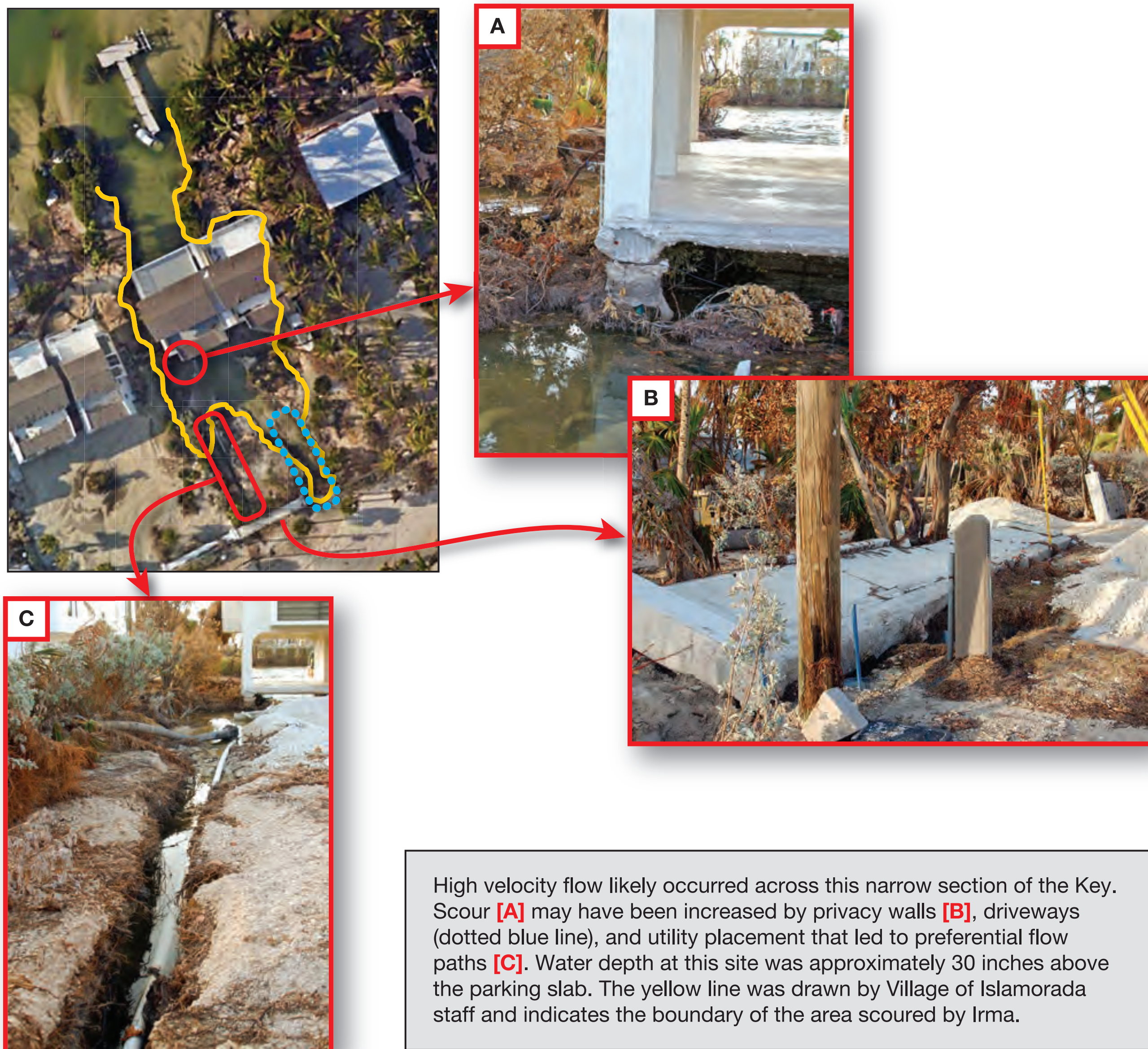
Monroe County

The Monroe County erosion the MAT observed was likely due to a combination of waves and high-velocity flow across low-lying areas along the Atlantic shoreline of the Florida Keys. In some cases, the flow could have been affected by development practices that channeled or confined flow (e.g., privacy walls, driveways, utility installations), which contributed to the erosion (see Figure 3-14).

> **EROSION AND SCOUR**
>
> **Erosion:** Loss of soil over a large area.
>
> **Scour:** Localized loss of soil due to interaction of flow and building components.

Most building foundations constructed in the last few decades in the Florida Keys are reinforced concrete piles that are augered into the soil and underlying rock. These foundations were resistant to scour and erosion (see Figure 3-14, Figure 3-15, and Figure 3-16).

The MAT observed one instance of building collapse in the Florida Keys (Figure 3-17). The building was a two-story multi-family structure elevated on an open concrete column foundation, with ground-level parking below (this building is 600 feet from the undermined building shown in Figure 3-14).

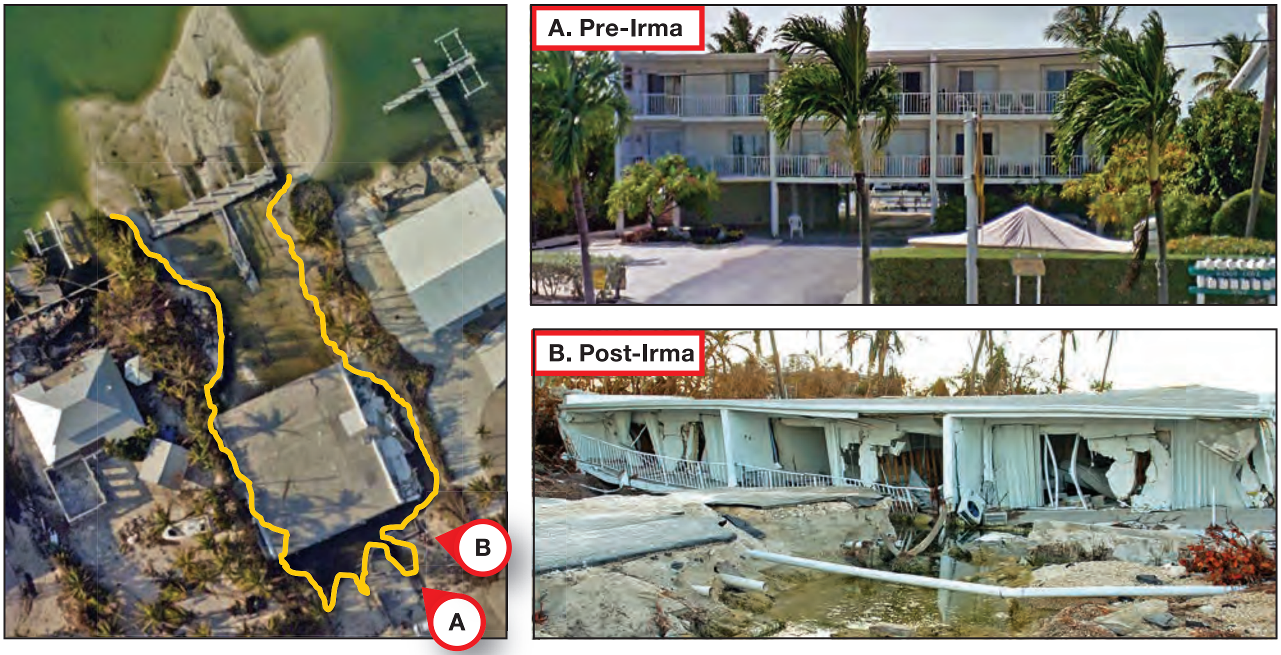


High velocity flow likely occurred across this narrow section of the Key. Scour **[A]** may have been increased by privacy walls **[B]**, driveways (dotted blue line), and utility placement that led to preferential flow paths **[C]**. Water depth at this site was approximately 30 inches above the parking slab. The yellow line was drawn by Village of Islamorada staff and indicates the boundary of the area scoured by Irma.

Figure 3-14: Scour near and around building foundation (Lower Matecumbe Key, FL)

Figure 3-15:
Scour was likely due to waves and high-velocity flow at this house on Long Beach Drive (same house is shown in Figure 3-6) (Big Pine Key, FL)

Figure 3-16:
Erosion was likely due to wave attack around the foundation of this house on Sombrero Beach Road (Marathon, FL)



The yellow line in the aerial image was drawn by Village of Islamorada staff and indicates the boundary of the area scoured by Irma. The MAT did not determine whether scour contributed to the collapse.

Figure 3-17: Collapsed building (Lower Matecumbe Key, FL)

St. Johns County

Erosion observed by the MAT in St. Johns County was a result of storm surge and waves attacking oceanfront dunes and bluffs. The same shoreline was also battered by storm surge and waves during Hurricane Matthew (2016) and various northeast storms before and after Irma.

Many undermined buildings were on deep pile foundations and survived the erosion (Figure 3-18 and Figure 3-19), but many were rendered uninhabitable pending repairs to buildings and utilities (and in some cases, replacement of soil). Some houses were on shallow foundations and collapsed (Figure 3-20).

Figure 3-18: Undermined house on deep piles that survived erosion (Vilano Beach, FL)

Figure 3-19: Undermined houses constructed on top of the dune (Vilano Beach, FL)

These houses survived the undermining, even though approximately 10 to 15 feet of dune height was lost beneath the houses. The pilings farther seaward are for a seawall under construction at the time of the MAT visit (February 2018).

Figure 3-20: Collapsed house on shallow foundation that was undermined by erosion induced by Hurricane Irma (Vilano Beach, FL)

SOURCE: UPPER PHOTOGRAPH COURTESY OF CIVIL AIR PATROL (SEPTEMBER 20, 2017); LOWER PHOTOGRAPH COURTESY OF ST. JOHNS COUNTY (SEPTEMBER 12, 2017).

Figure 3-21 through Figure 3-26 illustrate dune erosion that occurred at selected FIS transect locations during Hurricane Matthew and Hurricane Irma.[1] The "preliminary transect" lines represent pre-Matthew ground elevations. The "preliminary modeled" lines represent the FIS estimation of dune erosion during a base flood. In some cases, Hurricane Matthew erosion was greater than Hurricane Irma erosion, while in others Hurricane Irma erosion was greater. In some cases, the modeled erosion understated actual erosion, while in others it overstated actual erosion. This information indicates high longshore variability in dune erosion may occur in any given storm. It also demonstrates that building foundations in high dune areas may sustain 5 to 10 feet or more of vertical erosion during a severe storm event.

1 Post-Matthew and pre-Irma beach nourishment was implemented in some locations, and the profiles in Figure 3 22 through Figure 3 26 reflect this. Details on volumes and locations of nourishment are unknown.

Figure 3-21:
Locations of FIS transects 28–39, where comparative beach and dune profiles are shown in Figure 3-22 through Figure 3-26 (R-numbers are survey monuments established by the State of Florida)

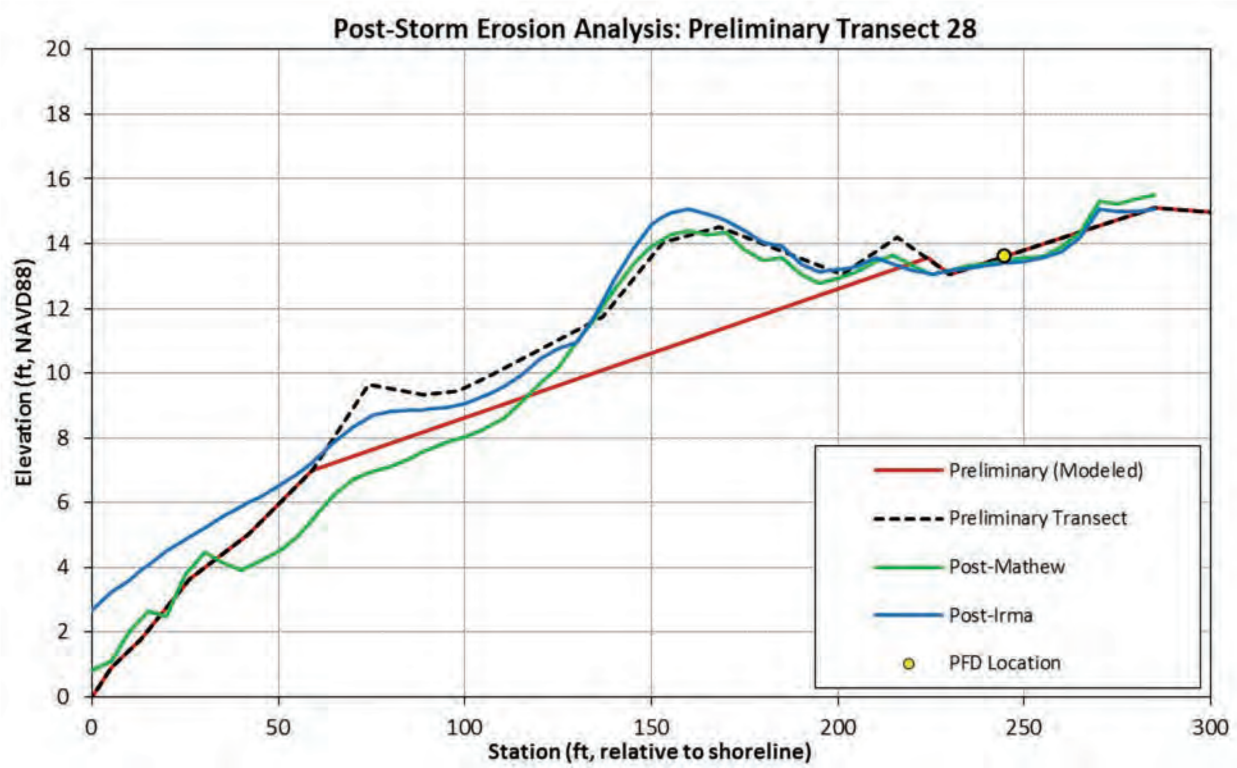


Figure 3-22: Beach and dune profiles at Transect 28

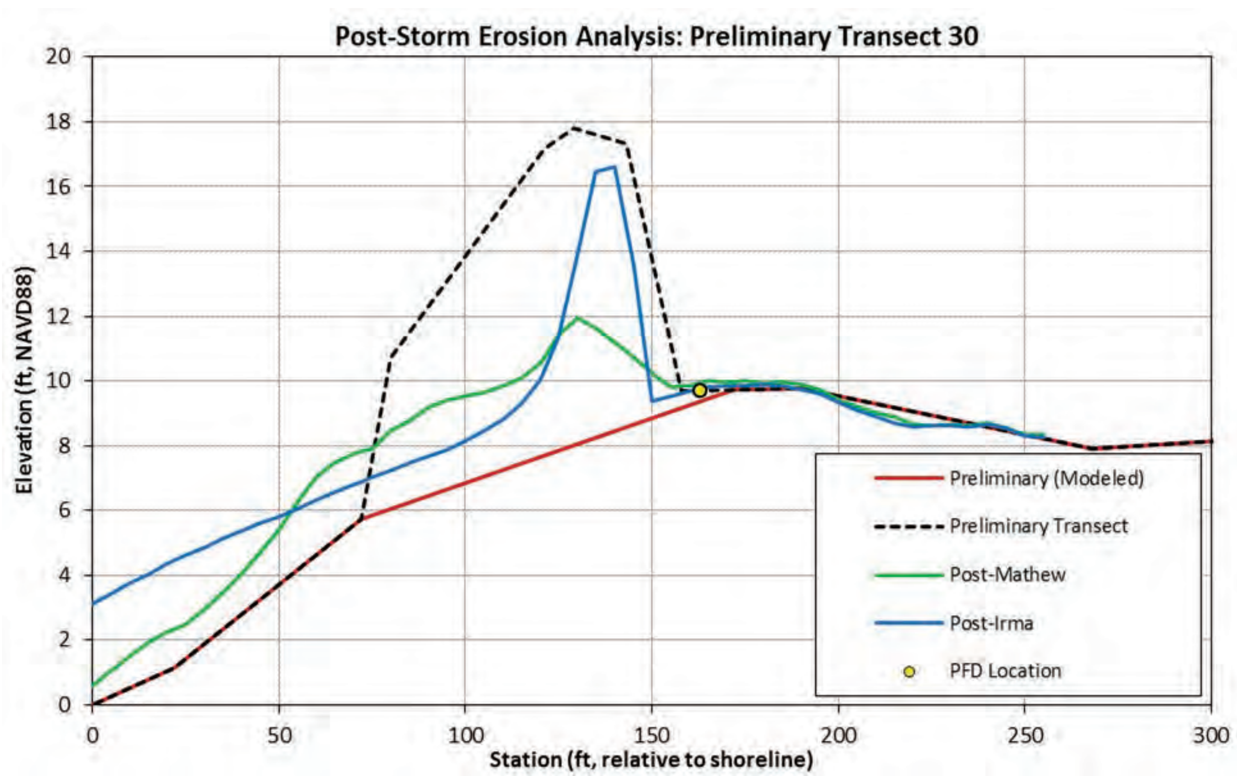


Figure 3-23: Beach and dune profiles at Transect 30

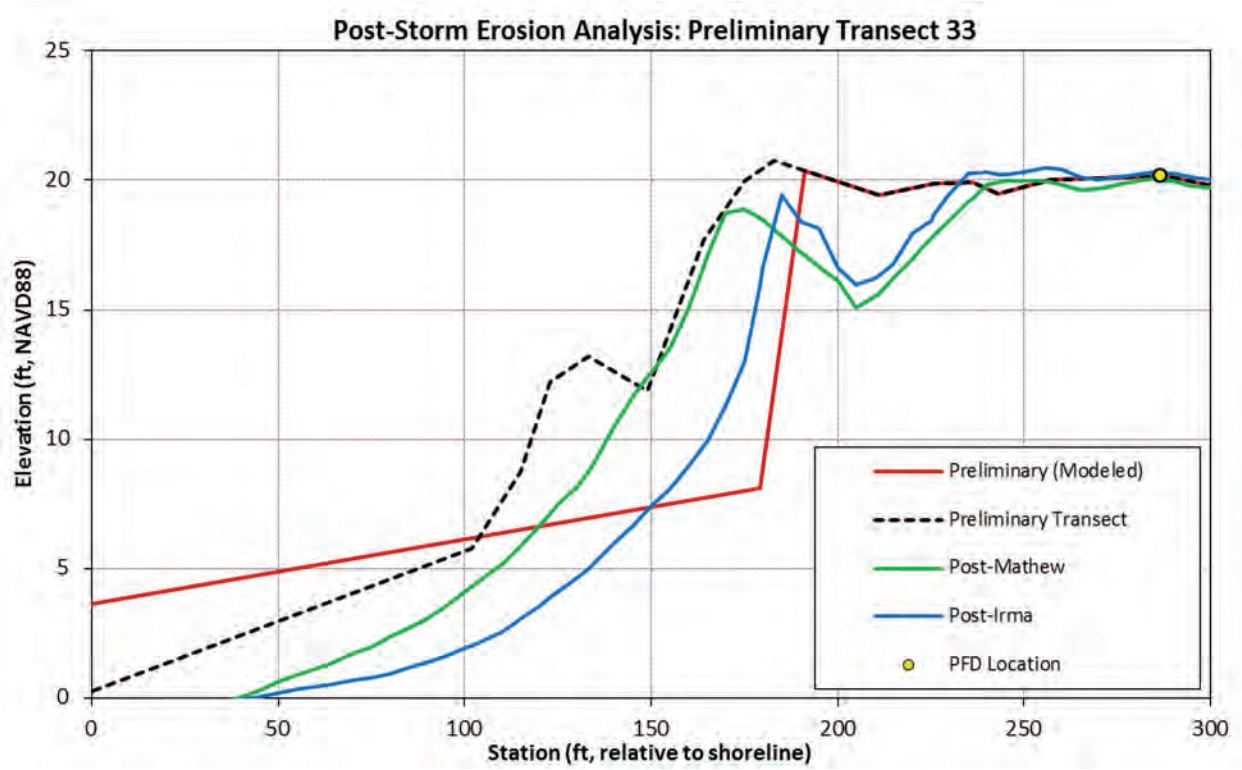


Figure 3-24: Beach and dune profiles at Transect 33

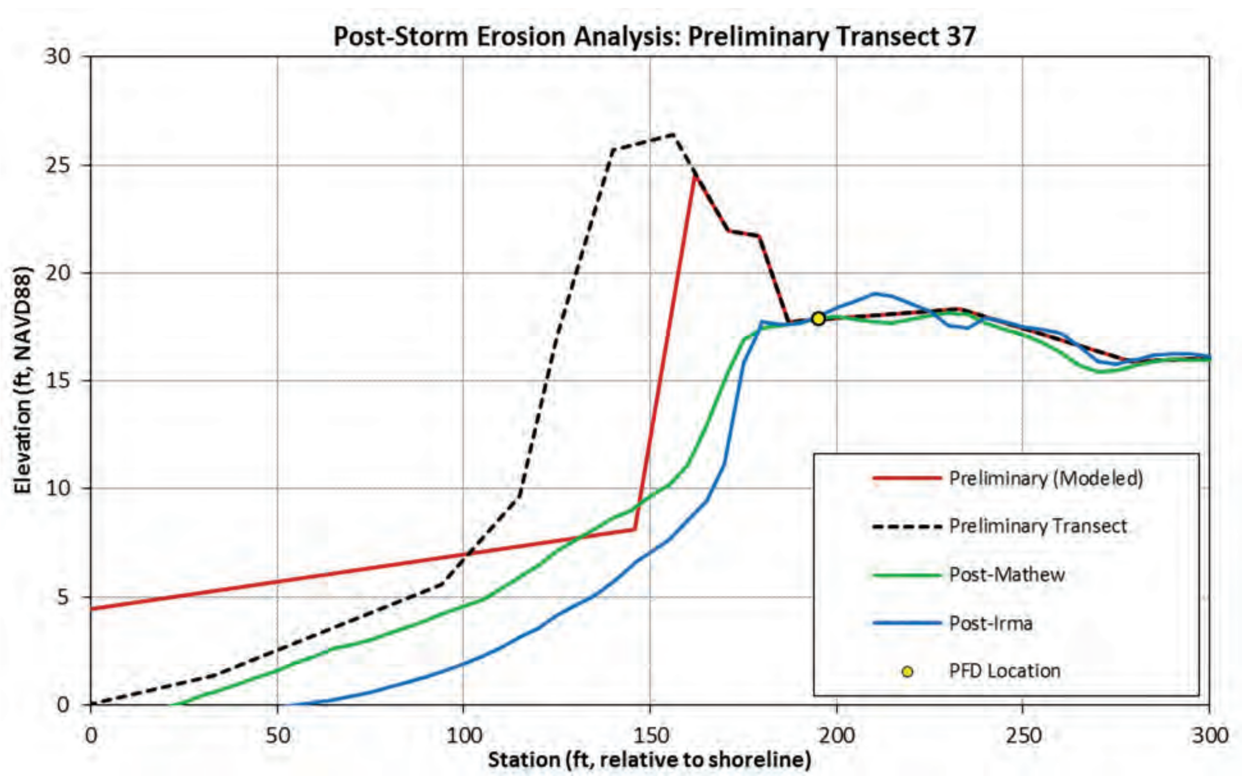


Figure 3-25: Beach and dune profiles at Transect 37

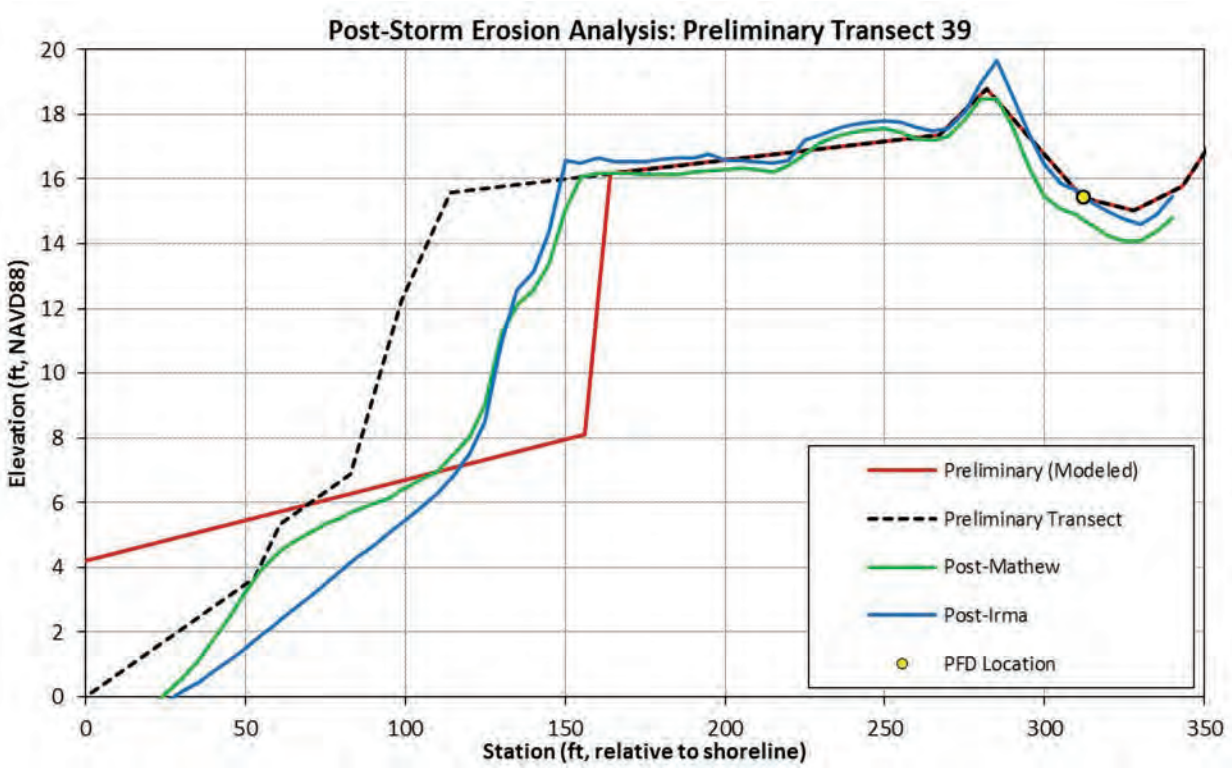


Figure 3-26: Beach and dune profiles at Transect 39

3.1.2 Erosion Control Structures

The pre-MAT and MAT observed many erosion control structures during field visits in canal, bay, and estuarine areas (Southwest Florida, Southeast Florida, and the Florida Keys) and along the oceanfront (St. Johns County). Many of these structures survived Hurricane Irma and protected land behind them, but some showed signs of damage or failure.

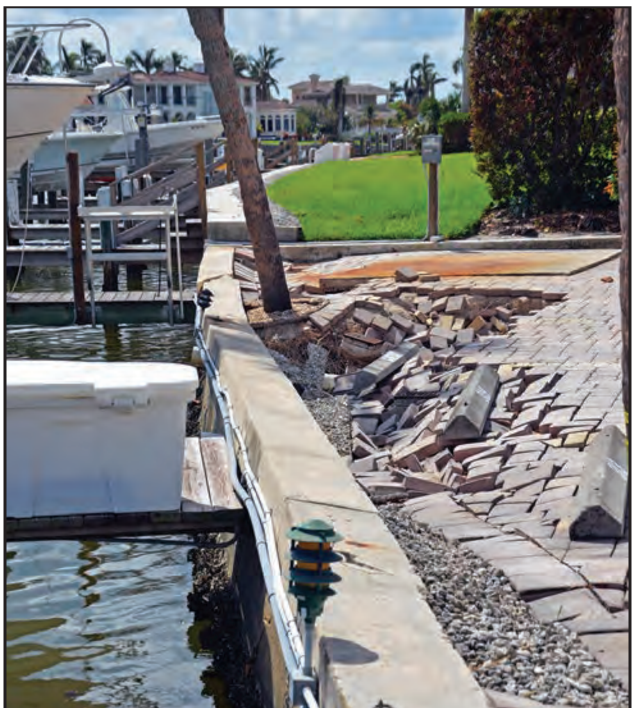
Numerous instances of canal or estuarine bulkhead failures were observed in Southwest and Southeast Florida. Failures were typically associated with saturated soil behind bulkheads exerting loads that exceeded the capacity of anchor systems or insufficient embedment of the bulkhead into the ground. Anchor system failure likely caused the top of the bulkhead to rotate toward the water, as shown in Figure 3-27. Failures of bulkheads that were insufficiently embedded into the ground likely resulted in the toe of the bulkheads moving toward the water, as shown in Figure 3-28.

Similar anchor system and toe embedment failures have occurred for decades during periods of heavy rain when backfill becomes heavily saturated, and the failures observed after Hurricane Irma are not new or different. The canal and estuarine bulkhead failures that the MAT observed did not lead to undermining and failure of buildings, but bulkhead failures could be a concern where buildings are located close to bulkheads or where bulkheads are constructed close to buildings.

Figure 3-27:
Failure of bulkhead (anchor system) (Naples, FL)

The failure of this bulkhead likely originated at its anchor system. This type of failure allows the top of a bulkhead to rotate toward the water.

Figure 3-28:
Bulkhead toe failure (insufficient embedment) (Naples, FL)



The failure of this bulkhead was likely due to insufficient embedment of the bulkhead toe into the ground. This type of failure allows the bottom of a bulkhead to rotate toward the water.

Oceanfront bulkheads that were supposed to prevent loss of soil under buildings did not always perform as intended to protect the buildings. Some oceanfront bulkhead failures were observed in St. Johns County, and such failures exposed the foundations and septic systems of homes to undermining. Homes on very deep foundations withstood the loss of soil, while homes on shallow foundations did not. Figure 3-29 shows one such bulkhead failure and the resulting collapse of a building with a shallow foundation.

ADDITIONAL INFORMATION

Additional information pertaining to dry floodproofing for areas affected by Hurricanes Irma and Harvey in 2017 can be found in the following recovery advisories:

- *Dry Floodproofing: Operational Considerations* (Hurricane Irma in Florida, Recovery Advisory 1, 2018d)
- *Dry Floodproofing: Planning and Design Considerations* (Hurricane Harvey in Texas, Recovery Advisory 1, 2018e)

Figure 3-29: House on a shallow foundation that collapsed after it was undermined following failure of the bulkhead during Hurricane Irma (St. Johns County, FL)

3.2 Performance of Dry Floodproofing Measures

The MAT was tasked with evaluating how dry floodproofing systems had performed during Hurricane Irma. Approximately 25 sites with dry floodproofing systems were investigated. Not all of the systems were deployed prior to Irma, and only some of those deployed were "tested" by Irma (i.e., in many cases, the flood level did not reach the flood barrier or closure). In cases where floodproofing was tested by floodwater, most buildings sustained at least minor flooding, and some sustained more serious flooding.

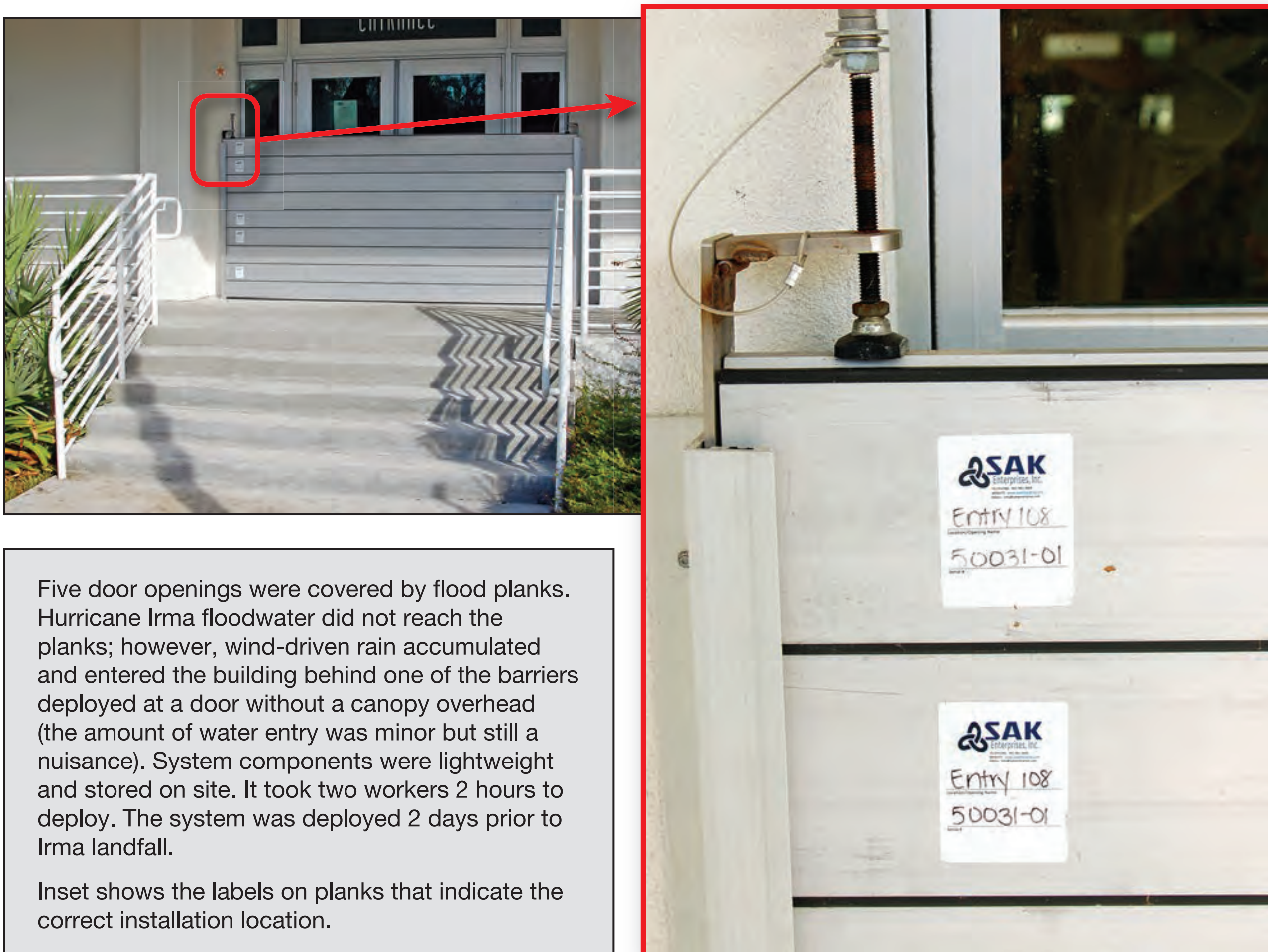
Evaluations of dry floodproofing performance were sometimes hampered by a reluctance of building owners and managers to discuss their dry floodproofing. Based on discussions, this reluctance appears to be related to concerns that comments made to the FEMA MAT might somehow affect the floodproofing credit for their NFIP flood insurance policy. However, the MAT was able to obtain enough information to make general observations about dry floodproofing performance, owner/manager understanding of dry floodproofing requirements, deployment successes and failures, implementation issues, and availability and scope of floodproofing plans. One designer interviewed by the MAT indicated that he specifies dry floodproofing on all his projects, but his two main worries are gasket degradation and the time required to deploy dry floodproofing systems.

Based on interviews conducted by the MAT, building managers and owners understand dry floodproofing concepts and understand that floodproofing can lead to NFIP flood insurance premium credit, but may not appreciate the importance of design and deployment details necessary to achieve successful floodproofing systems. In many cases, deployment is handled by contractors, so owners and managers may not understand installation and maintenance procedures, and they may not conduct annual testing.

Finally, there appears to be a need for guidance on maintaining and deploying dry floodproofing systems, as well as on developing emergency operations and maintenance plans that meet the requirements of Chapter 6 of ASCE 24 (the standard referenced by the FBC and specified by FEMA Form 086-0-34, *NFIP Floodproofing Certificate for Non-Residential Structures*).

3.2.1 Failure Modes

Some dry floodproofing systems were not subject to flooding, but still sustained some minor water accumulation behind them due to rainwater between the floodproofing system and the building face (see Figure 3-30). In one case, significant flooding infiltrated a building as a result of building envelope failure that allowed large quantities of rainwater to enter and become trapped behind the floodproofing system.



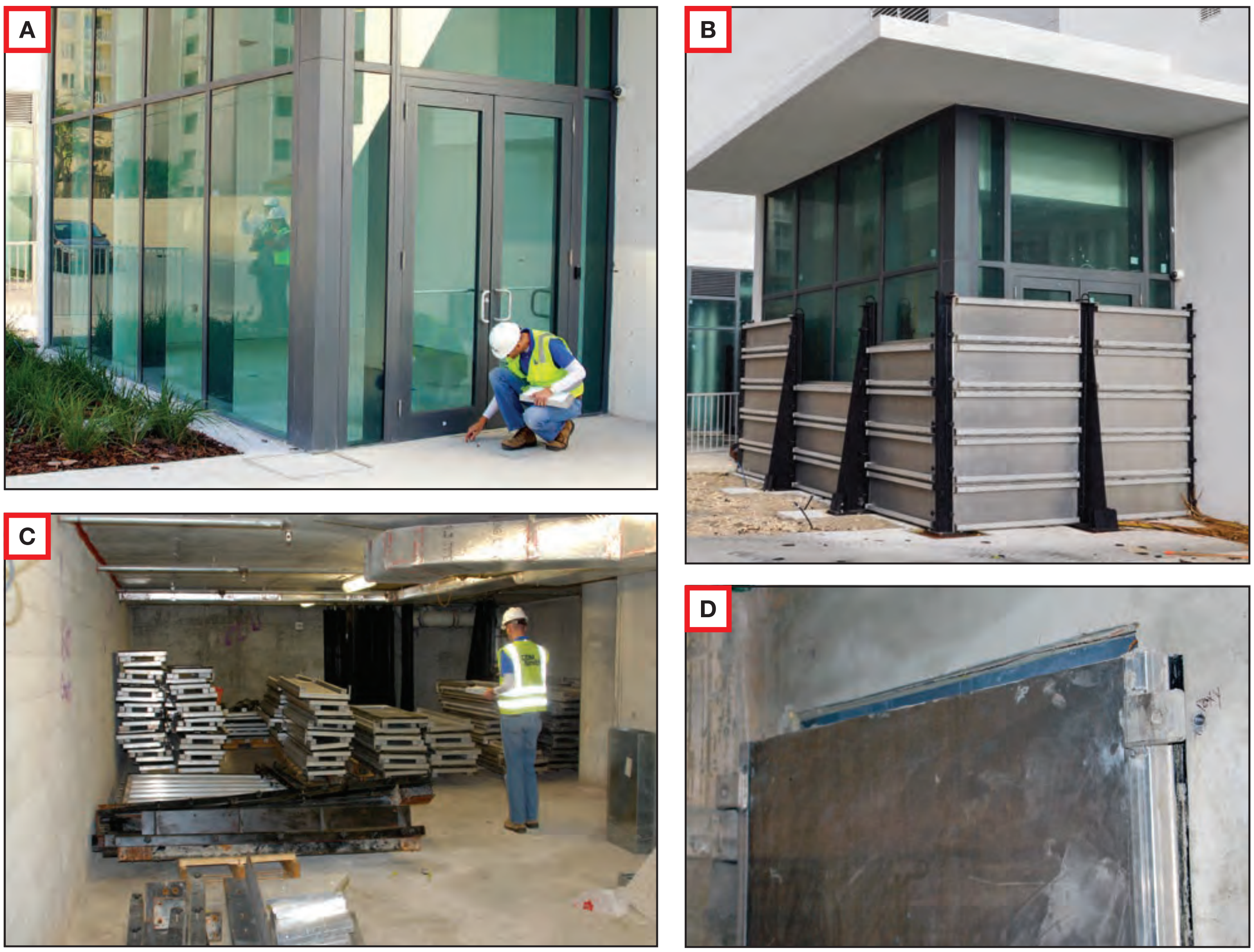
Five door openings were covered by flood planks. Hurricane Irma floodwater did not reach the planks; however, wind-driven rain accumulated and entered the building behind one of the barriers deployed at a door without a canopy overhead (the amount of water entry was minor but still a nuisance). System components were lightweight and stored on site. It took two workers 2 hours to deploy. The system was deployed 2 days prior to Irma landfall.

Inset shows the labels on planks that indicate the correct installation location.

Figure 3-30: Flood plank system deployed at utility company building (Key West, FL)

Of those dry floodproofing systems that were deployed and tested, a few worked as intended (see Figure 3-31), but most were reported to have leaked (minor quantities of water) or failed (major quantities of water; see Figure 3-32). Failure modes described by those responsible for implementing floodproofing or observed by the MAT at many floodproofing locations included lack of gaskets, failure of gaskets due to physical damage or degradation over time, gasket compression during storage, and leaking valves (air gasket systems).

More significant floodproofing failures were likely associated with human intervention aspects of floodproofing (installation and maintenance). In one case, a contractor failed to properly install the complete floodproofing system, allowing floodwater to enter the building through the unprotected area.



The doors without **[A]** and with **[B]** the floodproofing system deployed. The system took 10 workers with heavy equipment 2 full days to install prior to Hurricane Irma.

[C] shows the panel and post storage room.

[D] shows a gap at the top of a doorway flood shield.

Figure 3-31: A high-rise residential building under construction was successfully protected by a dry floodproofing method that used flood panels and doors; the floodproofing was installed by the building contractor (Miami, FL)

[A] Mechanical flood door at one building entrance.

[B] Air gasket on aquarium glass door (some air gaskets deflated).

[C] Penetration through wall that may have allowed water entry due to improper seal.

[D] and **[E]** Flood panels for windows that were stored outside near the windows.

Figure 3-32: Floodproofing system components at a historic building (top); parts of the system failed and approximately 3 feet of flooding infiltrated part of the building (Miami, FL)

3.2.2 Implementation Considerations

One of the MAT's concerns is the time necessary to implement some of the observed dry floodproofing systems. While some systems can be (and were) deployed in 2 hours or less by just two workers (see Figure 3-30), other complex systems likely required many workers using material handling equipment to lift and position heavy flood posts and panels over 2 or more days (see Figure 3-31). Small panels and planks are relatively easy to handle and install and do not require equipment. Single, large, heavy panels require more workers and equipment to install and can be difficult to lift, hold, align, and secure. As one architect interviewed by the MAT said, "simpler is better" when it comes to floodproofing systems.

Lengthy deployment times not only increase the likelihood of flooding when systems are installed, but they leave insufficient time to install the dry floodproofing measure before rapid-onset, intense rainfall events ("rain bombs").

The MAT observed that flood protection components often were not stored in a secure and dedicated location. If components are not stored securely in a designated area, they can be misplaced or stolen. In many cases, the storage arrangements did not facilitate component inventory, making it hard to identify missing parts.

3.2.3 Operations and Maintenance Plans

The MAT obtained written plans for deployment of dry floodproofing systems for some floodproofed sites, but for other sites, plans either were not obtained or may not exist. Plans that were reviewed varied in scope and complexity, and some did not include all necessary information for successful installations. The required installation knowledge may reside with current staff, but staff members change over time, and institutional floodproofing knowledge may be lost if it is not documented.

3.3 Performance of Public Restrooms

The MAT visited 15 public restroom buildings and sites on or near the shoreline in public parks in Lee, Collier, Monroe, and St. Johns Counties.

The restrooms visited were of varying ages and construction and were subject to a variety of flood conditions during Hurricane Irma, depending on building location and elevation. Some restrooms were likely exposed to Zone V conditions during Irma (wave heights of 3 feet or higher), while others were likely exposed to shallow flooding and small waves (or no waves).

Table 3-1 summarizes the MAT restroom observations.

Table 3-1: Summary of Public Restrooms Visited

Site Identifier	Name/Location	MAT Observations
1	**Bunche Beach Preserve** (Lee County)	• Zone VE[a] • Intact and in use, December 2017 • Elevated on masonry foundation walls • Owner reported possible shallow flooding in grade-level enclosure • See Figure 3-33
2	**Lovers Key State Park** (Lee County)	• Zone VE[a] • Intact and in use, December 2017 • Timber pile foundation • Owner reported shallow flooding in enclosure below building • See Figure 3-34
3	**Barefoot Beach Preserve County Park** (Collier County)	• Zone VE[a] • Intact and in use, December 2017 • Timber pile foundation • Flooding was likely shallow and passed beneath building • There may have been wind damage to building • See Figure 3-35
4	**City of Naples Pier – two buildings** (Naples)	• Zone VE[a] • Intact and in use, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • See Figure 3-36
5	**Tigertail Beach Park** (Marco Island)	• Zone AE[a] • Intact and in use, December 2017 • Timber pile foundation • Flooding was likely shallow and passed beneath elevated building • See Figure 3-37
6	**Tigertail Beach Park** (Marco Island)	• Zone AE[a] • Intact and in use, December 2017 • At-grade building • Likely shallow flooding inside restroom building • See Figure 3-38
7	**Sombrero Beach City Park** (Marathon)	• Zone AE[a] • Intact and closed, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • See Figure 3-39
8	**Sombrero Beach City Park** (Marathon)	• Zone AE[a] • Intact and closed, December 2017 • Concrete pile foundation • Flooding was likely shallow and passed beneath building • Construction identical to site 7; see Figure 3-39
9	**Long Key State Park** (Monroe County)	• Zone AE[a] • Damaged by flood, September 2017 • At-grade masonry building • Building demolished by owner and site cleared between September 2017 and December 2017 • See Figure 3-40

(a) Flood zone at time of Hurricane Irma, not necessarily at time of restroom construction.

(continued on page 3-28)

Table 3-1: Summary of Public Restrooms Visited (concluded)

Site Identifier	Name/Location	MAT Observations
10	**Long Key State Park** (Monroe County)	• Zone AE[(a)] • Intact and closed (park closed), December 2017 • Concrete column foundation • Flooding was likely shallow and passed beneath building • See Figure 3-41
11	**Bahia Honda State Park, Sandspur Day Use** (Monroe County)	• Zone AE[(a)] • Washed away by Hurricane Irma, September 2017
12	**Bahia Honda State Park, Sandspur Camping Restroom** (Monroe County)	• Zone AE[(a)] • Intact and closed (park closed), December 2017 • Elevated on high masonry foundation walls with louvers • Flooding in enclosure below elevated building was approximately 5 feet deep (approximately 1 foot below floor of restroom) • See Figure 3-42
13	**Bahia Honda State Park, Loggerhead Restroom** (Monroe County)	• Zone AE[(a)] • Damaged by wind and closed (park closed), September 2017 • Wood frame building elevated on timber pile foundation • Building demolished by owner between September 2017 and December 2017 • Replaced with temporary (mobile) toilet building • See Figure 3-43
14	**Veterans Memorial Park** (Monroe County)	• Zone AE[(a)] • Damaged by flood, September 2017 • At-grade masonry building • See Figure 3-44
15	**Surfside Park, Vilano Beach** (St. Johns County)	• Zone VE[(a)] • Intact and functional, February 2018 • Wood frame, at-grade building (walls do not extend to slab) • See Figure 3-45

(a) Flood zone at time of Hurricane Irma, not necessarily at time of restroom construction.

For those restrooms damaged by flooding, the degree of damage ranged from complete destruction, to some structural damage, to damage to doors and fixtures only. The degree of damage depended on both flood conditions (flood depth, flood velocity, wave conditions) and building characteristics (floor elevation, robustness of construction, features allowing flow-through). Figure 3-33 through Figure 3-45 show the restrooms that the MAT observed (site numbering refers to Table 3-1). For the following observations, see Table 3-1.

- One restroom was destroyed by Hurricane Irma and nothing remained to evaluate (Bahia Honda State Park – Sandspur Day Use, Site 11). This restroom was likely exposed to Zone V conditions.
- Two restrooms were heavily damaged and observed by the pre-MAT in September 2017, but were demolished by the Florida Division of Recreation and Parks before the December 2017 return visit to the sites (Long Key, Site 9; Bahia Honda – Loggerhead, Site 13). The Long Key restroom was likely exposed to Zone V conditions.
- One flooded restroom that did not sustain structural damage, Veterans Memorial Park (Site 14), was likely subject to Zone V flood conditions.

- Two restrooms were at grade and were flooded (Tigertail, Site 6; Veterans, Site 14). The Tigertail restroom was far from the shoreline, sheltered by 200 feet of dense vegetation, and subject to storm surge only. The Veterans restroom was close to the shoreline and subject to storm surge and wave action.
- One restroom was constructed with at-grade enclosures and partial-height walls (Surfside Park, Site 15). Whether the floor slab was flooded as a result of Hurricane Irma is unclear, but if it was, the flood depth would have been shallow (inches).
- Three restrooms were elevated above the Hurricane Irma flood level and had ground-level enclosures that were or may have been flooded (Bunche Beach Preserve, Site 1; Lovers Key, Site 2; and Bahia Honda, Site 12).
- Six restrooms were elevated above the Hurricane Irma flood level and had no ground-level enclosure (Barefoot Beach, Site 3; City of Naples Pier, Site 4; Tigertail, Site 5; Sombrero Beach, Sites 7 and 8; and Long Key, Site 10).

Figure 3-33: Elevated restrooms with ground-level enclosure. Bunche Beach Preserve restroom (Site 1; Lee County), where the degree of flooding in the enclosure, if any, would have been shallow.

Figure 3-34:
Elevated restrooms with ground-level enclosure. Lovers Key State Park restroom (Site 2; Lee County) enclosure sustained shallow flooding but no damage during Hurricane Irma.

Figure 3-35:
Elevated restroom at Barefoot Beach Preserve County Park (Site 3; Collier County)

[A] Photo taken from land side

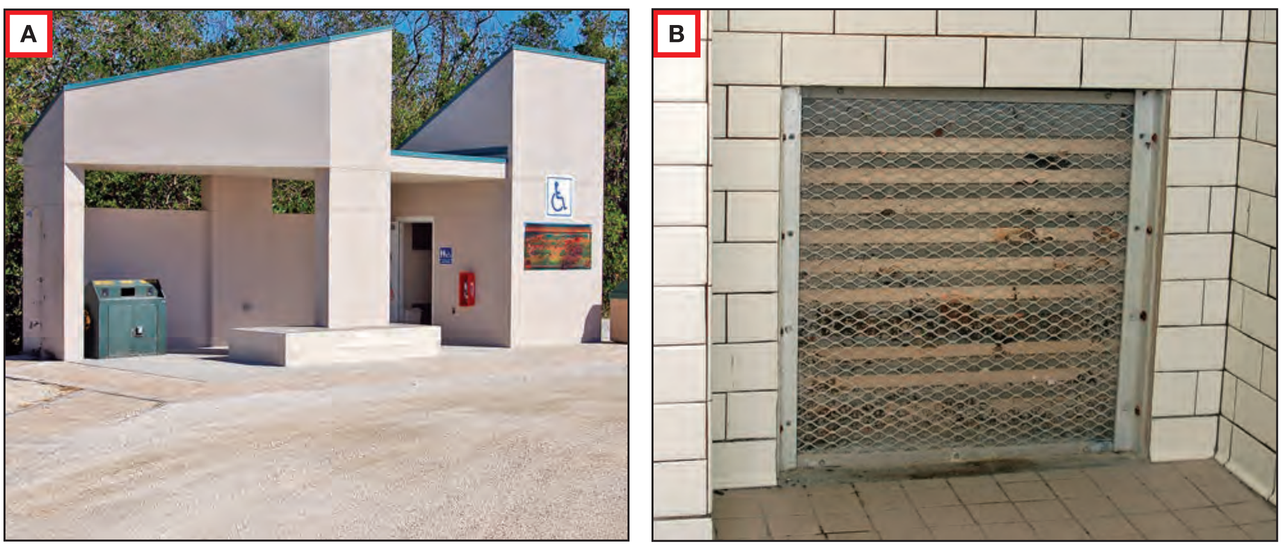
[B] Photo taken from beach

[C] Finished floor is below BFE but restroom walls are wet floodproofed to 1 foot above BFE

[D] Flood openings have been installed

Figure 3-36: Elevated restrooms (Site 4; City of Naples Pier)

Figure 3-37:
Elevated restroom at Tigertail Beach Park (Site 5; Marco Island, Collier County)



[A] Restroom at Tigertail Beach, Marco Island. The estimated flood depth was 1 to 2 feet, and stormwater and surge from Hurricane Irma carried enough velocity to drive parking lot gravel around the restroom.

[B] Flood debris in a vent

Figure 3-38: Grade-level restrooms at Marco Island (Site 6; Collier County)

Figure 3-39:
Elevated restrooms at Sombrero Beach Park without ground-level enclosure and that sustained no flood damage during Hurricane Irma
(Site 7; Marathon)

Figure 3-40:
Elevated Long Key State Park restroom without ground-level enclosure and that sustained no flood damage during Hurricane Irma
(Site 9; Monroe County)

The bottom photos show damage to fixtures, partitions, and walls that was likely caused by waves and high-velocity flow. The restroom was demolished between the pre-MAT and MAT visits.

Figure 3-41: Restroom in Long Key State Park that sustained structural flood damage (Site 10; Monroe County)

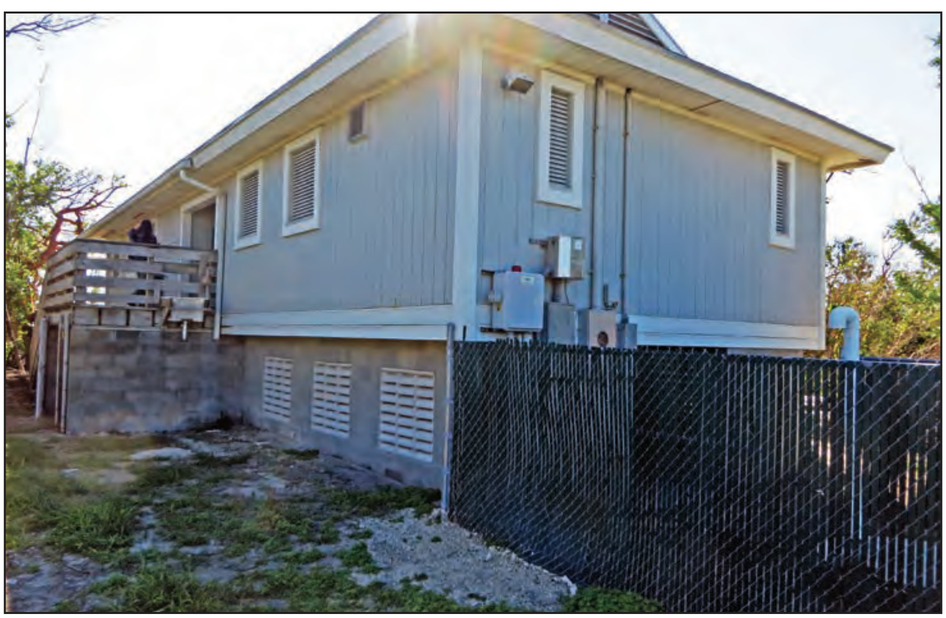


Figure 3-42: Elevated restroom with ground-level enclosure at Bahia Honda State Park, Sandspur Campground; Hurricane Irma flood depth in enclosure was 5 feet (Site 12; Monroe County)

Figure 3-43: Elevated restroom at Bahia Honda State Park, Loggerhead (Site 13; Monroe County)

The elevated restroom sustained wind damage.

The same site after building demolition, showing temporary mobile restroom building installed for public use (photo taken in December 2017).

[A] Rear of restroom showing debris trapped inside vent—debris level was approximately 7 feet above grade and would have accounted for stillwater plus sloshing waves trapped inside restrooms

[B] Wave splash against seaward restroom wall likely damaged soffit

[C] Exterior door damaged by waves

[D] Wave crests were likely just below the shelter soffit and lifted the roof deck off

Figure 3-44: Grade-level Veterans Memorial Park restroom that was likely exposed to Zone V conditions (Site 14; Monroe County)

Exterior and interior photos of a restroom building at Surfside Park, St. Johns County. The wood frame outer walls do not extend to the floor slab (red arrows), and gable ends are open, allowing light and air to enter the restrooms. There is no electric service to the restrooms. The building likely sustained no flood damage during Irma.

Figure 3-45: Grade-level Vilano Beach Surfside Park restrooms (Site 15; St. Johns County)

4 Wind-Related Observations

The MAT Wind team assessed one- and two-family dwellings in the vicinity of the first and second Florida landfall locations.

Building assessments also included some multi-family dwellings (apartments and condominiums) and MH units and also covered Key West eastward to Duck Key and throughout Collier County, as well as the Miami area.

Estimated wind speeds from Hurricane Irma did not approach the design wind speeds required by the last six editions of the FBC. Each photograph caption in this chapter includes both the estimated wind speed for the photograph location during the storm and estimated design wind speed for comparison. Estimated event wind speeds were taken from Applied Research Associates data, and ASCE 7-10 design wind speeds, which are referenced in the current edition of the FBC, were taken from the Applied Technology Council (ATC) Hazards by Location website.[1] Wind speeds provided are 3-second peak gust for Risk Category II buildings. Wind speed is not the only factor for determining wind pressures or levels of damage; however, wind speeds provide a good basis for comparing event conditions and design requirements. In addition to high wind pressures, damage to buildings may be caused by wind-borne debris. However, wind speeds were used to more easily compare event conditions and design requirements.

1 The ATC Hazards by Location website is available at hazards.atcouncil.org/.

In addition to estimated wind speed and estimated design wind speed in each photograph caption, the text describing each figure identifies the year the building was constructed. The date built is provided to offer some context with respect to the wind provisions that were in effect when the building was permitted for construction. The estimated design wind speed may not be correlated with the wind requirements of the codes that were in effect when the building was built. Further, damaged components shown in the photographs may have been replaced since the original date of construction. Where the property appraisal databases indicated that work permits were issued after the original date of construction, the date of the permitted work is noted for damaged components identified in the photographs.

Although failures of the main wind-force resisting systems (MWFRSs) were observed in some buildings, as described in Section 4.1, most buildings designed and constructed to comply with the FBC performed well structurally. However, many of these same buildings sustained wind-induced failures of building envelope components that allowed wind-driven rain to penetrate, resulting in costly damage, as described in Section 4.2.

Section 4.3 describes performance assessments of MH units and includes observations on anchorage (tie-downs) and damage resulting from failure of attached appurtenances.

4.1 Main Wind-Force Resisting System Performance

The MWFRS is defined in ASCE 7-10 as an assemblage of structural elements assigned to provide support and stability for the overall structure. Examples of MWFRS elements include shear walls, roof diaphragms, and structural frames. Wind-induced structural damage to MWFRS was not widespread and, where observed, mostly occurred in older (pre-FBC) buildings. Damage observations did include roof failure and loss of exterior walls.

4.1.1 Roof Failure

Wind damage to roof structures was often found to have initiated through loss of the roof covering or breaching of the attic envelope, though the cause of the initial failure cannot always be determined after the event. Once wind enters a building, failures can progress to other components and connections along numerous load paths.

Figure 4-1 shows an elevated, single-story, wood-framed house (built in 1988) that lost nearly all its roof sheathing, most likely due to withdrawal of the roof decking-to-framing fasteners. Numerous roof truss top chords located near the roof ridge were also damaged or missing, but roof framing adjacent to the front wall and the roof-to-front wall connections remained intact (see bottom photo in Figure 4-1). The roof truss bottom chords remained in place, providing lateral support that prevented wall collapse.

Another example of roof damage on a pre-FBC dwelling (built in 1923) in Miami is shown in Figure 4-2, where large sections of roof were picked up by Irma's winds and dropped onto the neighboring house. As shown in the red circle, where connected, the conventional wood frame roof and bond beam separated from the masonry wall.

Figure 4-1:
House with structural damage to roof system (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The close-up shows severed truss upper top chords (blue circles) and intact connection of lower top chord and top of wall (yellow circles).

Figure 4-2:
Residence where a roof-to-wall connection failed (EWS = 78 mph; EDWS = 169 mph) (Miami)

The failed connection resulted in large sections of roof being blown atop an adjacent structure. The red circle shows a portion of the bond beam attached to the displaced roof section.

4.1.2 Wall Failure

Framed walls of residential structures collapsed where significant portions of the roof and ceiling diaphragm were destroyed by wind and the lateral support for the walls was compromised.

Figure 4-3 shows the south end of an elevated one-story, wood-framed residence (built in 1986) on Cudjoe Key where roof-to-wall connections failed to prevent large portions of the conventionally framed roof from lifting away. The rafters separated from the connectors, which are visible along the top of the wall everywhere the roof is missing. The MAT could not determine why the connection failed; the connectors may not have been adequate to resist uplift forces associated with Irma's winds on Cudjoe Key, or they may not have been installed according to the manufacturer's instructions. Pre-damage images show the north end of the house had a screened porch; all that remains of the porch is shown on Figure 4-4 and Figure 4-5, where the remaining post and header are visible along the right side of Figure 4-4 and left side of Figure 4-5. An exterior wall section adjacent to the screened porch also collapsed and is also shown in the images. One possible scenario is that the overhang portion of the screened porch began failing and created a breach in the envelope, allowing wind to enter the interior of the building and create high internal pressures.

Another example of wall failure was observed on Ramrod Key, as shown in Figure 4-6. The two-story, wood-framed residence (built in 1990) lost roof trusses above the east-facing (ocean-facing) second floor area; two exterior walls were lost from the room below the missing roof trusses, and the adjacent deck floor collapsed onto the porch floor below.

Figure 4-3: South end of east-facing wall; the south end of the roof remained in place (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

One section of the north-facing exterior wall (painted orange, indicated with the red arrow) adjacent to screened porch remained in place. Same house as Figure 4-3.

Figure 4-4:
North end of east-facing wall where the roof was (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

The screened porch and portion of the exterior wall, which is painted orange and indicated with the red arrow, remained standing. There is a missing wall section between it and the west-facing exterior wall. Same house as Figure 4-3.

Figure 4-5:
Remainder of the screened porch and exterior wall (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

Figure 4-6:
House with roof structure loss and collapse of the second floor exterior wall and adjacent deck (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

4.2 Envelope

Although MAT observations of structural damage from Hurricane Irma winds were almost exclusively limited to pre-FBC (prior to March 1, 2002, the date the first edition FBC went into effect) residential buildings, the MAT observed envelope damage on both older and newer construction. The building envelope includes exterior doors, windows, skylights, exterior wall coverings, soffits, roof systems, and attic vents. In buildings elevated on open foundations, the floor is also considered a part of the envelope. The most frequently damaged elements of these envelope systems observed by the MAT were roof coverings, soffits, and exterior wall coverings. While less frequent, damage to glazed openings, impact-protection systems, and garage doors was also noted.

4.2.1 Roof Coverings

MAT wind observations of roof covering loss are grouped according to common material types present in South Florida: asphalt shingles, tile, and metal. In many cases, the reason for the damage could not be determined because damaged roofs were under repair or covered by tarps.

4.2.1.1 Asphalt Shingles

Asphalt shingle loss was observed to be widespread, especially in the Florida Keys. Asphalt shingle failure was observed on both older dwellings and those built after adoption of the FBC.

The roof of the Big Coppitt Key house (built in 2005) shown in Figure 4-7 and Figure 4-8 was mostly hidden under a tarp, but the uncovered slope reveals shingle loss near the eaves and ridge. Figure 4-9 shows another post-FBC dwelling (built in 2007) with significant asphalt shingle loss that was observed in Marathon.

Figure 4-7:
The MAT could not observe much of the asphalt roof damage on this house because it was covered by a tarp (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

Figure 4-8:
Asphalt shingle loss shown inside yellow ovals for house shown in Figure 4-7 (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

Figure 4-9:
House with asphalt shingle loss as evidenced by tarp (EWS = 120 mph; EDWS = 180 mph) (Marathon)

Asphalt shingle loss was limited on the Sugarloaf Key house (built in 1997) shown in Figure 4-10, but the pattern of loss near the ridge remains evident in the inset photo where shingle-to-roof deck nails remain in place. The Figure 4-10 inset photo indicates the shingles were likely installed incorrectly, because the shingle-to-roof deck nails were positioned too close to the top edge of the shingle. As shown in Figure 4-11, asphalt shingle nails in high-wind regions should be positioned close to the centerline of the shingle to secure the shingle underneath and decrease the moment arm of the uniform wind pressure acting on the shingle.

Figure 4-10:
Residence that lost shingles near the ridge (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

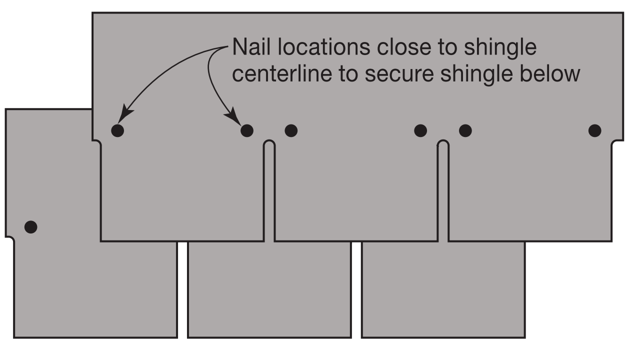


Figure 4-11:
Recommended asphalt shingle nail locations for high wind regions

As the MAT anticipated, older asphalt shingle roofs on pre-FBC dwellings were more vulnerable to wind damage than newer roofs on post-FBC buildings. Figure 4-12 shows a typical example from Marco Island (built in 1971) where asphalt shingle loss is visible near the main ridge and between the hips above the garage.

Figure 4-12:
House with shingle loss near main ridge and between roof hips (yellow oval) (EWS = 109 mph; EDWS = 170 mph) (Marco Island)

4.2.1.2 Roof Tile

Based on MAT observations, damage to roof tile was limited and generally minor. However, the MAT observed failure of several older, pre-FBC roofs with mortar-set roof tiles as described below. The Cudjoe Key house (built in 1989), shown in Figure 4-13, lost a significant number of tiles, particularly at the hips and garage ridge. The Florida's Association of Roofing Professionals / Tile Roofing Institute (FRSA/TRI) *Florida High Wind Concrete and Clay Roof Tile Installation Manual*, Fifth Edition (2012) (FRSA/TRI Manual) requires mortar-set hip and ridge tiles to be fully embedded in mortar. The hip tiles shown in 4-13 were not fully embedded in mortar.

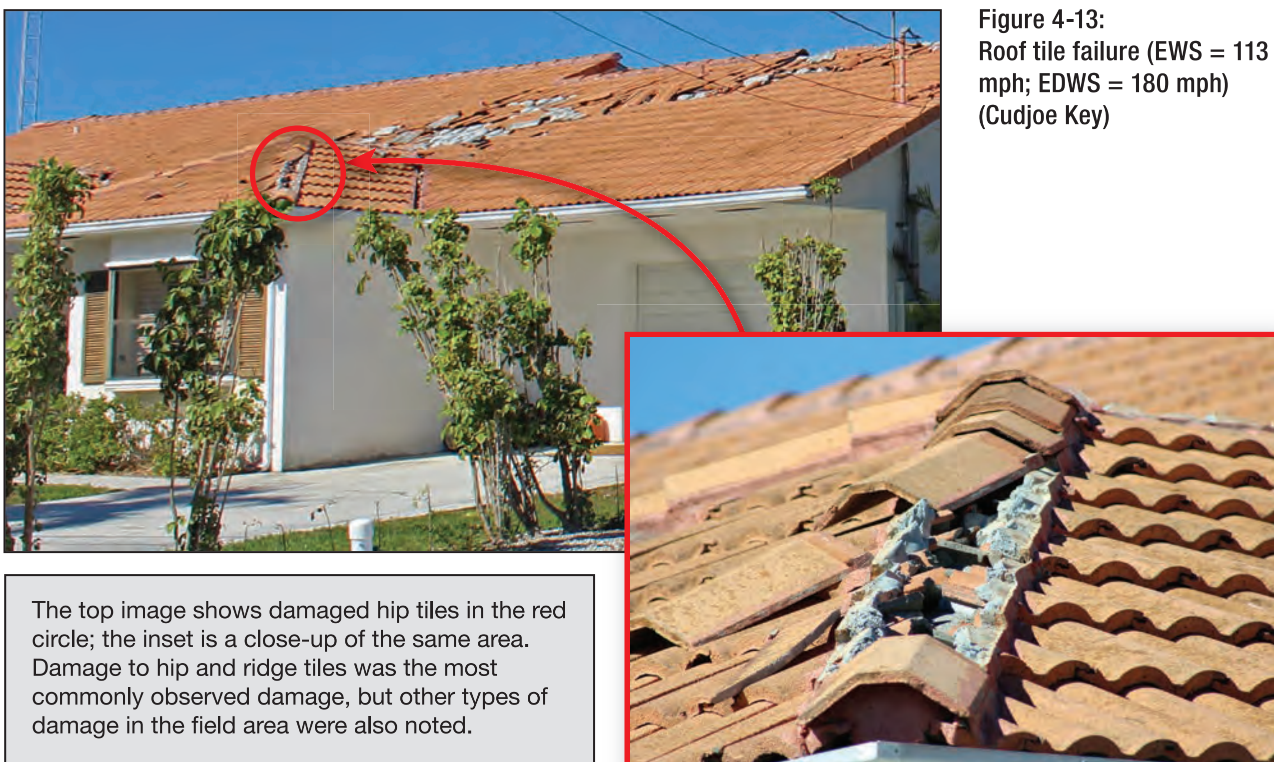


Figure 4-13:
Roof tile failure (EWS = 113 mph; EDWS = 180 mph) (Cudjoe Key)

The top image shows damaged hip tiles in the red circle; the inset is a close-up of the same area. Damage to hip and ridge tiles was the most commonly observed damage, but other types of damage in the field area were also noted.

Similar damage was observed along the front eaves, ridge, and area along and adjacent to the left hip over the front porch of the roof on the Duck Key house (built in 1984) shown in Figure 4-14. Although no measurements could be taken, the first course of tile appears to project too far over the eave. The FRSA/TRI Manual specifies that tiles must overhang the eave at least ¾ inch but not more than 2 inches. Additionally, the first course near the eave does not appear to be set in mortar, as the first row of mortar patties are beyond the first course of tile.

Inset shows close-up of mortar-set roof tile loss around ridge and between left hip and front porch eaves.

Figure 4-14:
House lost roof tiles across most of its front eaves (red arrows) (EWS = 111 mph; EDWS = 180 mph) (Duck Key)

4.2.1.3 Metal Roof Systems

Residential metal roof systems performed well overall, with a few isolated instances of damage. The damage to metal roof systems that the MAT observed was generally limited to roof edges. For example, the metal fascia cover separated from the fascia board along the front- and side-facing gables of the Sugarloaf Key house (built in 2003) shown in Figure 4-15. The metal roof trim directly above the missing fascia covers had also peeled back, but the edge of the metal roof system itself appeared to be intact where visible along the right side of the front-facing gable.

The metal roof system damage shown in Figure 4-16 appears to be limited to the hip caps of the Sugarloaf Key residence (built in 1992). Monroe County property appraisal data indicate that the roof was installed in 1999.

Figure 4-15: House with separated metal roof trim and missing fascia cover (red ovals) along gable end. (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

Damaged hip cover components are shown from both visible hips (red oval and circle). Yellow arrows indicate exposed sections of hip joint.

Figure 4-16: House with damaged metal roof system (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

4.2.2 Soffits

The MAT observed widespread damage to soffits in the Florida Keys, particularly vinyl soffits. MAT wind observations of soffit loss are grouped according to common material types present in South Florida: vinyl and metal (aluminum and steel).

In some cases, vinyl soffit failure was also associated with fascia cover loss. While further study is needed, the loss of the fascia cover could have resulted in more wind exposure on the edges of soffits, affecting their performance. Information on soffit installation in Florida is available in Florida Recovery Advisory 2, *Soffit Installation in Florida* (2018h) (Appendix C).

4.2.2.1 Vinyl

Vinyl soffit panel assemblies were the most common soffit variety observed by the MAT. Wind damage to vinyl soffit assemblies was widespread, especially in the Florida Keys.

The Summerland Key dwelling (built in 2008) in Figure 4-17 shows an example of soffit failure associated with fascia cover loss. Interrelated fascia cover/soffit damage was also observed in a house built in 2001 on Little Torch Key, shown in Figure 4-18.

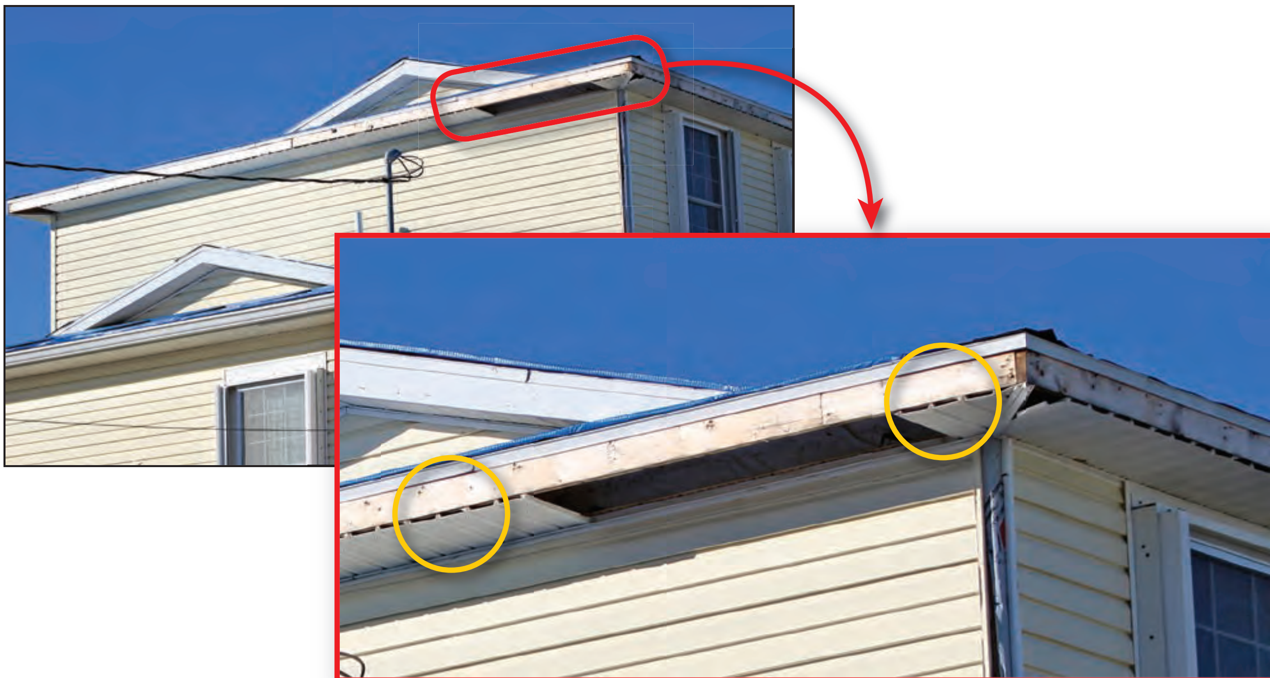


Figure 4-17: House that lost its vinyl soffit panel (EWS = 113 mph; EDWS = 180 mph) (Summerland Key)

The inset shows how the ends of the adjacent remaining panels are exposed where the fascia cover has pulled away, allowing wind to enter the closed soffit (yellow circles) and increase outward pressure, facilitating soffit blow-out.

Not all observed vinyl soffit damage was associated with fascia cover loss. The Sugarloaf Key house in Figure 4-19 (built in 1995) lost its vinyl soffit in several areas; the red outline shows where the soffit panel was stripped from the assembly's J-channel, which remains attached along the exterior wall. The soffit appears to have been attached to only a single nailing strip across the midpoint of the framing above.

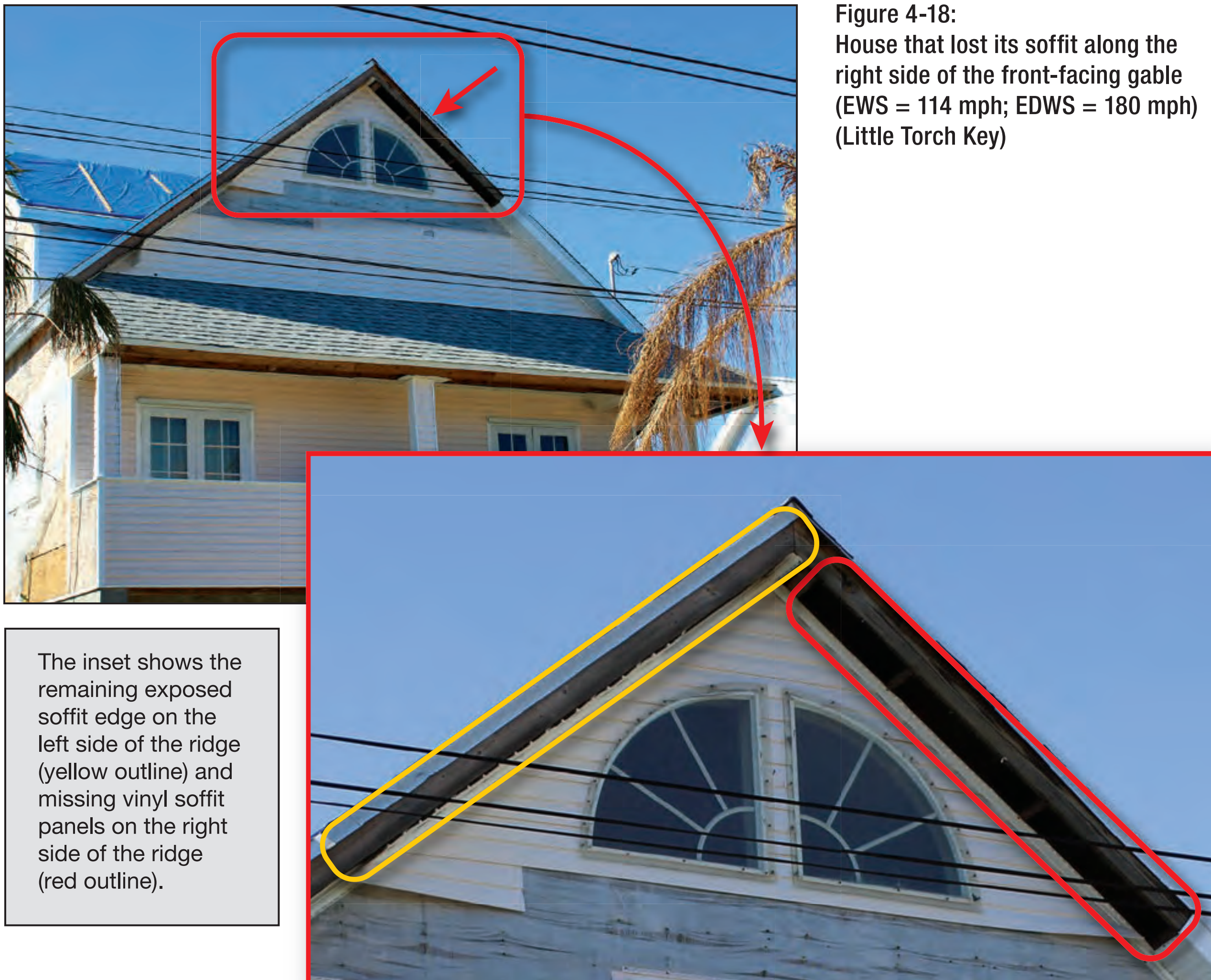


Figure 4-18:
House that lost its soffit along the right side of the front-facing gable (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

The inset shows the remaining exposed soffit edge on the left side of the ridge (yellow outline) and missing vinyl soffit panels on the right side of the ridge (red outline).

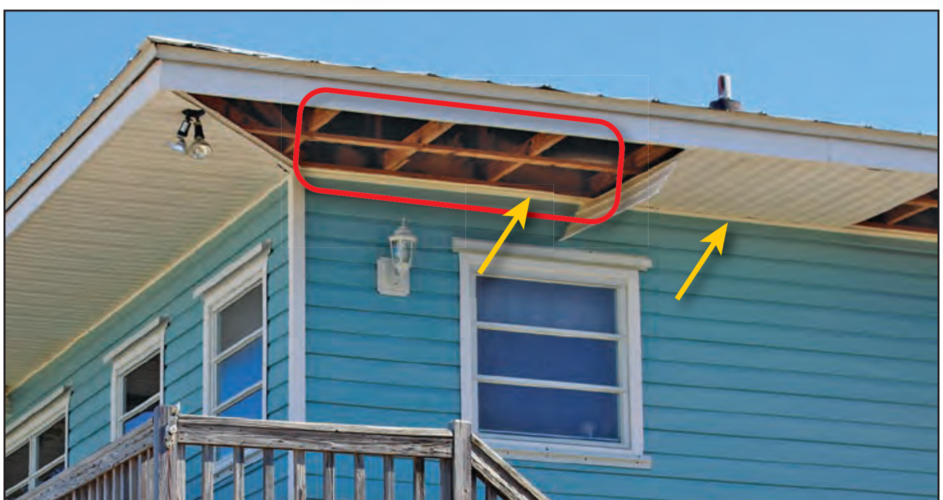


Figure 4-19:
House with vinyl soffit damage not caused by fascia loss (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The red outline shows where the soffit panel was stripped from the assembly's J-channel, which remains attached (yellow arrows).

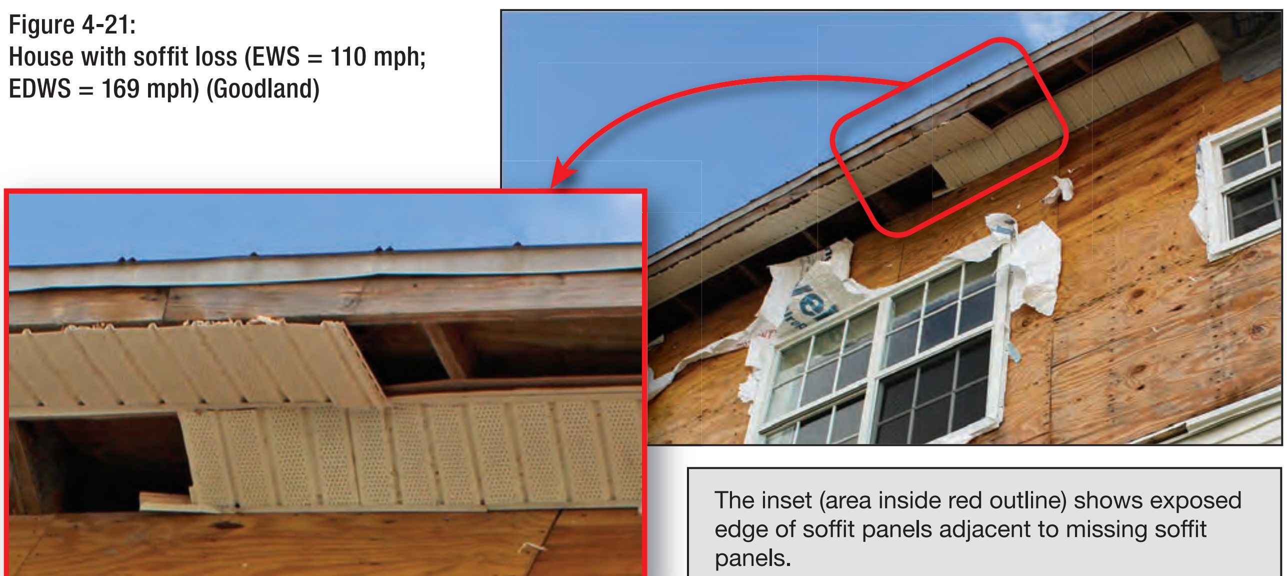
Figure 4-20 shows similar soffit panel attachment and loss on a Sugarloaf Key dwelling (built in 1999). The wider eaves included a second nailing strip to attach the vinyl soffit panels, but the attachment did not prove adequate for wind pressures experienced during Hurricane Irma.

The MAT also observed post-FBC construction with vinyl soffit damage outside the Florida Keys, as demonstrated by a house in Goodland (Collier County) as shown in Figure 4-21. The dwelling (built in 2005) is part of a development described in detail in the text box "Vinyl Siding/Soffit Failure Example" in Section 4.2.3 and is another example of soffit failure associated with fascia cover loss. Although the missing fascia cover played a role by elevating wind pressures within the closed soffit system shown in Figure 4-21, the unconventional installation provided inadequate support for the soffit panels. The two parallel runs of soffit appear to be joined at the eave's midpoint with back-to-back J-channels. With no nailing strip along the exterior wall, the inside edge of the soffit system could only be attached directly to framing at 24 inches on center.

Figure 4-20: Dwelling with similar soffit panel attachment and loss as shown in Figure 4-19 (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

The wider eaves on this dwelling (in comparison to Figure 4-19) included a second nailing strip (red arrows), though the attachment did not resist the wind loads.

Figure 4-21: House with soffit loss (EWS = 110 mph; EDWS = 169 mph) (Goodland)



The inset (area inside red outline) shows exposed edge of soffit panels adjacent to missing soffit panels.

4.2.2.2 Metal

Metal soffit assemblies were not as common as vinyl soffit assemblies in areas visited by the MAT. However, the MAT did observe wind damage to metal soffits in the Florida Keys and Collier County.

Figure 4-22 shows metal soffit panel loss along the corner of a Ramrod Key front porch (house built in 2005). The remains of the soffit attachment, which were fastened directly to the nailing strip along the outside edge and held in place by a channel above the porch opening, are indicated by the red arrow. Similar to the damage pattern noted in the previous discussion on vinyl soffits, some metal soffit panels were missing; an example is shown in Figure 4-23, where soffits were missing below the Big Pine Key house's (house built in 1989) screened porch gable end outlooker rafters, directly below an area where the fascia cover had blown away (compare with Figure 4-17).

The red arrow shows direct attachment of soffit to framing along the outside edge of eaves only; panels are secured by a channel only above the porch opening.

Figure 4-22: Metal soffit loss on house (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

Figure 4-23: House with metal soffit loss below missing fascia cover (EWS = 114 mph; EDWS = 180 mph) (Big Pine Key)

ROOF VENTILATION/SOFFIT VENTS

Refer to Section R806 of the 6th Edition (2017) Florida Building Code, Residential (FBCR) for roof ventilation requirements. To avoid water entry at soffit vents, options include eliminating soffit vents and providing an alternate method for roof ventilation, or designing for an unvented attic. For additional guidance on mitigating water intrusion through attic vents and strengthening soffits, refer to Technical Fact Sheet No. 7.5, "Minimizing Water Intrusion through Roof Vents in High-Wind Regions" in FEMA P-499, *Homebuilder's Guide to Coastal Construction* (2010).

In Naples, the MAT observed two apartment buildings with metal soffit panel loss patterns similar to the single-family Florida Keys dwellings shown above. On the left side of Figure 4-24, metal fascia covering can still be seen hanging from the eaves near the corner of the hip-roofed building (built in 1983). Soffit panels remain in place toward the center of the building, but are missing closer to the corner. The right side image of Figure 4-24 shows the adjacent side of the building where fascia covering is completely gone along with most of the metal soffit panels. On a nearby Naples apartment building (built in 1980), metal soffit panels were lost below the front porch gable end outlooker rafters. As shown in Figure 4-25, no damage is apparent along the adjacent fascia of the building.

Dangling fascia cover (red outline) is shown adjacent to missing metal soffit panels near the corner of a Naples apartment building (yellow outline indicates intact soffit panels).

Missing metal soffit panels are shown below damaged fascia; located on the other side of the corner shown in left image.

Figure 4-24: Apartment building with metal soffit panel loss (EWS = 104 mph; EDWS = 166 mph) (Naples)

Figure 4-25: Metal soffit panel loss apartment gable end overhang (EWS = 104 mph; EDWS = 166 mph) (Naples)

4.2.3 Exterior Wall Coverings

The MAT observed exterior wall covering damage and loss resulting from Hurricane Irma winds. Aside from a few isolated instances of damage to wood siding, most of the exterior wall covering damage observed by the MAT was to vinyl siding. Damage to vinyl siding was widespread in the Florida Keys, but was also observed in Collier County. In most cases, the Irma MAT could not determine the design pressure rating of the failed vinyl siding. However, most of the observations indicated that the vinyl siding did not appear to be "high-wind" siding. The vinyl siding text box on the next page describes a failed vinyl siding installation that did not appear to be rated for South Florida application. The subsequent high wind-rated vinyl siding text box describes differences between vinyl siding rated for high-wind regions and standard vinyl siding.

For a few other sites, such as the Sugarloaf Key house shown in Figure 4-26, the MAT was able to record product identification numbers that allowed them to compare product-specific wind ratings to the FBC requirements. The house (built in 2014) lost siding along its back; based on the product identification shown in the inset, the MAT determined that the product had a negative design wind pressure rating of –74 psf (refer to Section 4.2.3.2). This vinyl siding product had a rolled-over nail hem, which is characteristic of higher-rated vinyl siding. Using the Risk Category II design wind speed of 180 mph, Exposure Category D, an effective wind area of 10 square feet for Zone 5 (corner zone), enclosed building classification, and an approximate mean roof height of 20 feet, the required design pressures (ASD) are +54 psf and –72 psf. Therefore, based on the required design pressure, the design pressure rating, and the estimated wind speeds at this site, the vinyl siding, if installed properly, should have resisted wind pressures sustained during Hurricane Irma. The State of Florida also requires building envelope products to be approved as described in the text box on the next page.

VINYL SIDING/SOFFIT FAILURE EXAMPLE

The MAT visited a subdivision of 24 elevated single-family dwellings in Goodland that sustained significant damage to vinyl siding and soffit assemblies on nearly all houses. Typical construction featured combinations of masonry and wood-framed exterior walls with a wood-framed roof.

Maximum estimated 3-second gusts for Goodland during Irma were estimated to be 110 mph. The design wind speed for this site is approximately 169 mph, so vinyl siding and soffit assemblies rated for the site-specific conditions and installed per manufacturer's instructions should not have failed. According to Collier County Property Appraisal information, the houses were all built between 2005 and 2006, when the 2004 FBC was in effect statewide.

The top left photo shows typical siding damage in the area. The bottom left photo shows where siding was attached with staples to masonry wall furring strips at 16 inches on center. Additionally, there is no evidence of utility trim in the J-channel above, which would have been needed to secure the trimmed top course. Similarly, it does not appear that starter strips were used at the bottom of the first (lowest) course of siding, nor at the division between first and second floor siding sections. The photo on the right shows an aerial view of the neighborhood for perspective.

HIGH WIND-RATED VINYL SIDING VS. STANDARD VINYL SIDING

Much of the failed vinyl siding that the Irma MAT observed in Florida did not appear to be rated for high-wind regions. Technical Fact Sheet 5.3, “Siding Installation in High-Wind Regions,” in FEMA P-499, *Homebuilders Guide to Coastal Construction* (2010), includes guidance on vinyl siding installation. The left-side graphic below from Technical Fact Sheet 5.3 demonstrates the basic differences between vinyl siding rated for high-wind regions and standard vinyl siding. The right-side image is siding from one of the damaged houses in Goodland described in the previous text box. Note how the detached siding has a standard (single) hem and locking area depicted in left image (rather than the high-wind siding required by the FBC in this area).

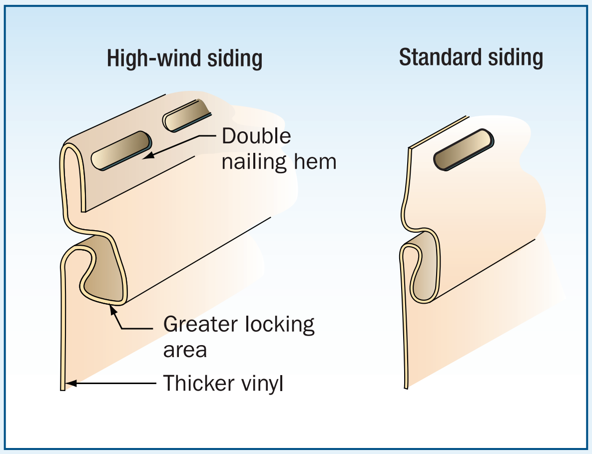


Figure 4-26:
Vinyl siding lost along the back of a house (EWS = 113 mph; EDWS = 180 mph) (Sugarloaf Key)

FLORIDA-PRODUCT APPROVAL

Rule 61G20-3 of the Florida Administrative Code applies to products and systems that compose the building envelope and structural frame. The rule requires the following products to have product approval for compliance with the structural requirements of the Florida Building Code:

- Panel walls (subcategories include soffits and siding)
- Exterior doors
- Roofing products
- Skylights
- Windows
- Shutters
- Structural components
- Impact protective systems

Products may be approved using either the optional statewide product approval system or local product approval. Regardless of the method used, products have to be evaluated for compliance (evaluation report, certification, test report, etc.), be validated for compliance with the evaluation, and approved by the Florida Building Commission. For additional information on product approval in the State of Florida, see Rule 61G20-3 of the Florida Administrative Code or the Building Code Information System at www.floridabuilding.org administered by the Florida Department of Business and Professional Regulation. A database of products approved using the statewide product approval system can be found under the "Product Approval" tab at www.floridabuilding.org.

The Marathon Key house (built in 2009) shown in Figure 4-27 lost siding across a significant portion of one gable end wall; based on the product identification shown in the inset, the MAT determined that the product had a design wind pressure rating of –55 psf (refer to Section 4.2.3.2). Using the Risk Category II design wind speed of 180 mph, Exposure Category D, an effective wind area of 10 square feet for Zone 5 (corner zone), enclosed building classification, and approximate mean roof height of 25 feet, the required design pressures are +56 psf and –75 psf. While the design pressure rating is about 27 percent less than the required design pressure, considering the estimated wind speeds at this site, the siding should have resisted wind pressures experienced during Hurricane Irma if it was properly installed. There is no evidence of utility trim under the window, which left the siding vulnerable at that location.

The red oval on left image shows the area magnified in the inset.

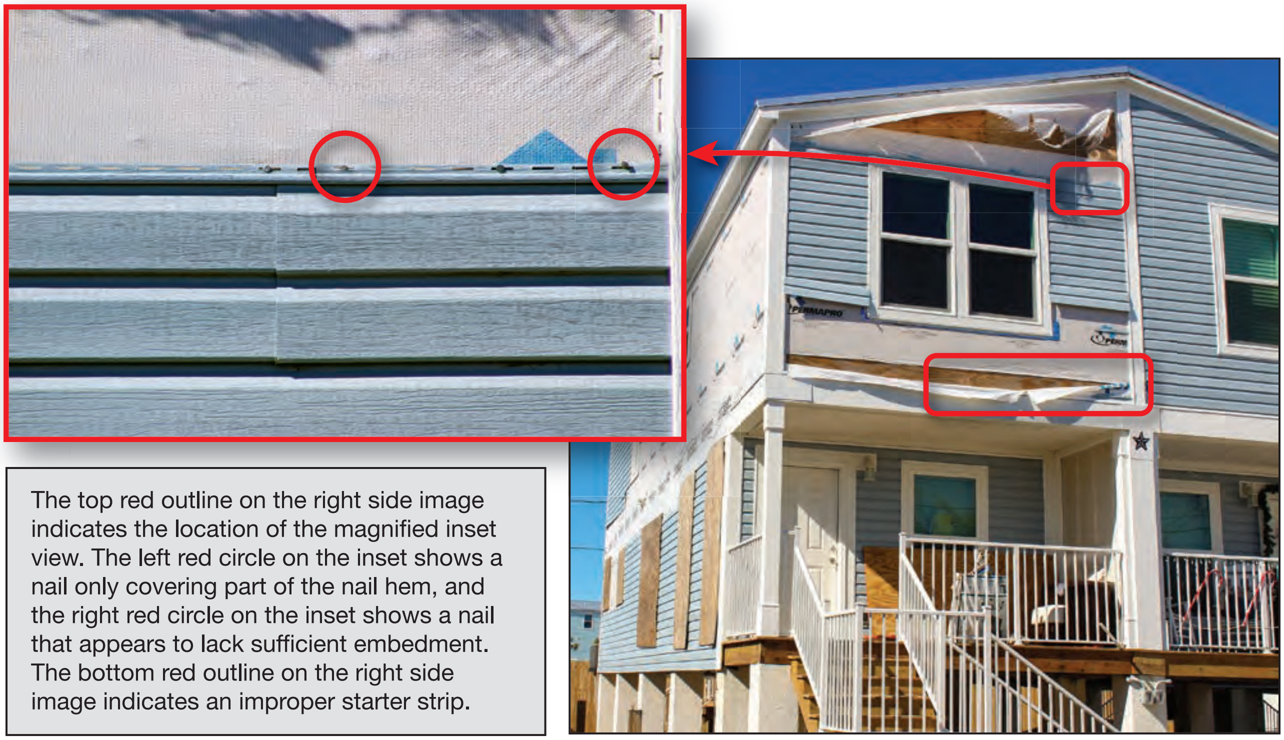
**Figure 4-27:
House that lost vinyl siding on its gable end wall (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)**

4.2.3.1 Vinyl Siding Installation Issues

In addition to concerns about the use of vinyl siding with inadequate pressure ratings, the MAT observed several instances of vinyl siding wind damage on buildings that may have been due to installation issues. Figure 4-28 shows a Marathon Key duplex building (built 2017) with vinyl siding loss across the front and left exterior walls. The Vinyl Sinding Institute's 2015 *Vinyl Siding Installation Manual* recommends that the head of the fastener not be driven tightly against the nail hem to allow for expansion.[2] A clearance of 1/32 inch is recommended between the nail head and nail hem. The clearance shown in Figure 4-28 appears to exceed 1/32 inch. Further, vinyl siding loss above the front-facing wall above the front porch may have been initiated where a J-channel was installed instead of the manufacturer's specified starter strip.

The houses in Figure 4-29 (built in 2000), Figure 4-30 (built in 1977), and Figure 4-31 (built in 2000) show representative installation issues where vinyl siding failed. The house in Figure 4-29 was permitted to have its vinyl siding replaced in 2015, with work completed in 2016. The Little Torch Key house in Figure 4-31 was permitted to repair damage to its vinyl siding due to Hurricane Wilma in 2006, with the work completed the same year.

2 The Vinyl Siding Institute's 2018 *Vinyl Siding Installation Manual* makes this same recommendation.



The top red outline on the right side image indicates the location of the magnified inset view. The left red circle on the inset shows a nail only covering part of the nail hem, and the right red circle on the inset shows a nail that appears to lack sufficient embedment. The bottom red outline on the right side image indicates an improper starter strip.

Figure 4-28: Duplex where vinyl siding above the front porch did not comply with manufacturer's installation instructions (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

Figure 4-29: House appeared to lack utility trim under the windows, as shown in the red outline (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

Figure 4-30:
House that lacked a proper starter strip, as shown in the red outline (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Figure 4-31:
House with irregular fastener pattern and apparent lack of a proper starter strip (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

4.2.3.2 Vinyl Siding Design Pressure Ratings and the Pressure Equalization Factor

Vinyl siding is required to be certified and labeled as conforming to ASTM D 3679, *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding*. The 6th Edition (2017) FBC refers to the 2011 edition of ASTM D 3679, and the 5th Edition (2014) refers to the 2009 edition of ASTM D 3679. For determining the design wind pressure rating of vinyl siding, ASTM D 3679 permits test pressures to be adjusted to account for pressure equalization across the vinyl siding due to leakage paths (gaps). Pressure equalization refers to the reduction in net wind forces across cladding layers caused by external pressures being transferred to an interior air space. Pressure equalization of vinyl siding is accounted for by using a pressure equalization factor (PEF). ASTM D 3679 permits the PEF for vinyl siding to be taken as 0.36, which has the net effect of reducing the required test pressure to 36 percent of the design pressure rating of the vinyl siding times a Factor of Safety of 1.5. To clarify, the applicable equation is shown below:

$$P_t = D_p \text{ x PEF x } 1.5$$

Where:

P_t = test pressure

D_p = design pressure rating of vinyl siding

PEF = Pressure Equalization Factor, 0.36

1.5 = Factor of Safety

For example, if a vinyl siding product had a design pressure rating (D_p) of 60 psf, that product was tested to a pressure of 32.4 psf (60 psf x 0.36 x 1.5).

Recent research (refer to the Insurance Institute for Business & Home Safety report *Wind Loads on Components of Multi-Layered Wall Systems with Air-Permeable Cladding* [2012]) has indicated that the PEF for vinyl siding should be higher. As a result, the 2017 edition of ASTM D 3679 increases the PEF to 0.5. Therefore, in the example above, the test pressure in ASTM D 3679-17 for a vinyl siding product with a design pressure rating (D_p) of 60 psf will be 45 psf. Debate continues about whether the PEF should be even higher than 0.5.

4.2.4 Glazed Openings and Opening Protection Systems

All sites that the MAT visited are located within the FBC's Wind-Borne Debris Region (WBDR) (see text box "FBC Wind-Borne Debris Region"). These sites have been included in the WBDR since the first edition of the FBC went into effect. The FBCR requires protection of all exterior glazed openings in the WBDR with products meeting the Large Missile Test of ASTM E 1886 and ASTM E 1996, Testing Application Standards (TAS) 201, 202, and 203 (HVHZ Test Protocols), AAMA 506, or ANSI/DASMA 115 (garage doors). The FBCR also provides a prescriptive solution for wood structural panels to serve as opening protection with limitations (the prescriptive solution for wood structural panels is not permitted in the HVHZ). While there are several limitations when using wood structural panels as opening protection, key limitations include:

- They must be a minimum of 7/16 inch thick
- Their span is limited to 44 inches
- Permanent corrosion-resistant attachment hardware must be provided, and anchors must be permanently installed on the building

The MAT observed the impact-resistant glazing and covering damage described in the following subsections.

FBC WIND-BORNE DEBRIS REGION

Wind-Borne Debris Regions are defined in Chapter 2 of the FBCR as follows:

> **Wind-Borne Debris Region.** Areas within *hurricane-prone regions* located in accordance with one of the following:
>
> - Within 1 mile (1.61 km) of the coastal mean high water line where the ultimate design wind speed, V_{ult}, is 130 mph (58 m/s) or greater.
> - In areas where the ultimate design wind speed, V_{ult}, is 140 mph (63.6 m/s) or greater; or Hawaii.

See Figure 2-4 of this MAT report for the Wind-Borne Debris Region for FBCR buildings.

The following excerpt from the FBCR applies to exterior glazed openings in the WBDR:

> **R301.2.1.2 Protection of openings.** Exterior glazed openings in buildings located in windborne debris regions shall be protected from wind-borne debris. Glazed opening protection for windborne debris shall meet the requirements of the Large Missile Test of ASTM E1996 and ASTM E1886 as modified in Section 301.2.1.2.1, TAS 201, 202 and 203, or AAMA 506, as applicable. Garage door glazed opening protection for windborne debris shall meet the requirements of an *approved* impact-resisting standard or ANSI/DASMA 115.

4.2.4.1 Impact-Resistant Glazing

The MAT observed damage to at least three double-paned glazed openings along one side of the Ramrod Key house (built in 2017) shown in Figure 4-32. However, the damaged openings appear to have resisted penetration, because in each case the inner panes were intact. The MAT could not determine with certainty that the glazed openings in Figure 4-32 were impact-resistant products without closer product inspection and research. But given the date of construction and concurrent FBCR requirements, the openings were likely protected with impact-resistant glazing to comply with building code requirements.

Figure 4-32: Residence with two windows where the outer panes were broken (see red arrows) but the inner panes stayed intact (EWS = 113 mph; EDWS = 180 mph) (Ramrod Key)

The MAT visited the Little Torch Key house shown in Figure 4-33 and Figure 4-34 (built in 1985) to observe extensive wind-borne debris damage. The dwelling was struck repeatedly by construction materials blown from a nearby structure that was destroyed during Hurricane Irma. Figure 4-33 shows where the impact-resistant glazing did not prevent a wind-borne, 12-foot-long, 2x10 rafter from penetrating the interior of the house. This missile in particular is more massive than the D test missile (9-pound, 2x4 lumber) required by ASTM E1996. According to the homeowners, after penetrating the French door side light panel, the missile still had enough energy to reach and damage a television on the other side of the room. A second piece of wind-borne lumber penetrated the frame of an upper floor door unit on the same (east-facing) side of the house (see Figure 4-34).

Figure 4-33: House damaged by wind-borne debris (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

The right image shows east-facing, first floor door that was penetrated by a 12-foot-long, 2x10 rafter (indicated by the red outline). The left image is a close-up of damage to impact-resistant glazing that failed to resist the impact of a large rafter.

Figure 4-34: Wind-borne driven missile damaged second floor door at the same house as shown in Figure 4-33 (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Red arrow indicates a piece of lumber that was driven partially through an east-facing second floor door frame.

4.2.4.2 Impact-Resistant Coverings

In addition to damaged impact-resistant glazing, the MAT observed some damage to impact-resistant covering systems. The shutter and shutter system frame on the Little Torch Key dwelling (built in 2008) shown in Figure 4-35 was significantly damaged when struck by wind-borne debris. Also, note the damage to the railing in the foreground of Figure 4-35.

Figure 4-35: House with impact-resistant shutter system damaged by wind-borne debris; opening was covered at the time the MAT visited (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

Another example of damage to impact-resistant covering systems is shown in Figure 4-36, where a portion of the system's frame supporting the left end of the corrugated metal shutter is missing (see yellow outline). Shutters were still in place on the elevated first floor of the Goodland residence (built in 2005), but the damaged frame (see right image of Figure 4-36) rendered the glazed opening beneath it vulnerable to impact, as the metal shutter peeled toward the right side support.

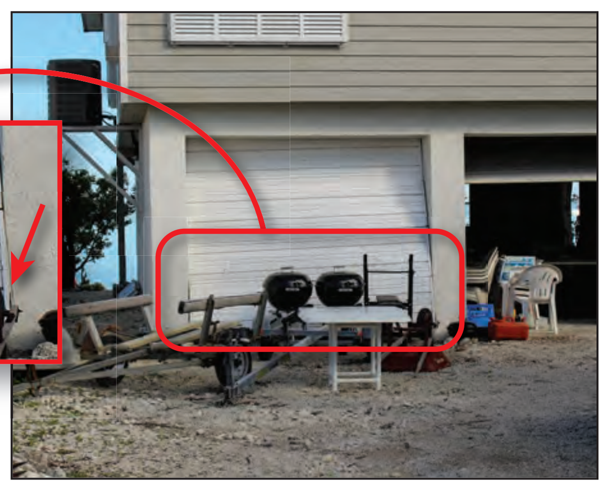
Shutters are shown in place over first-floor glazed openings (red arrows).

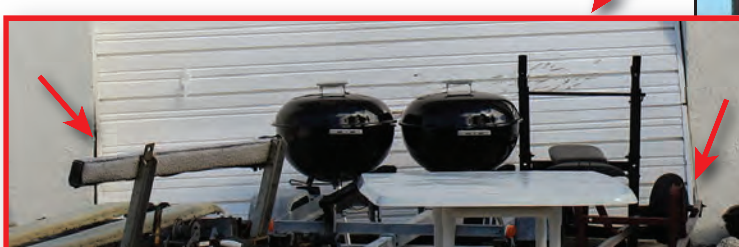
A close-up of a shutter above the air conditioning unit platform where the upper left frame is missing (yellow outline).

Figure 4-36: House with corrugated metal shutters (EWS = 110 mph; EDWS = 169 mph) (Goodland)

4.2.5 Garage Doors

The MAT observed a few instances of garage door failure on older, pre-FBC dwellings in the wake of Hurricane Irma. The failure mode for each was generally buckling near the base and failure at the track, as shown in Figure 4-37 and Figure 4-38. Both single-car overhead garage doors on the Little Torch Key house (built in 1980) shown in Figure 4-37 were damaged, but the right side opening could not be assessed in its partially open position. The left side door appears to have been pulled away from the track (evidenced by the greatest deflection present at the base of the door) by outward-acting negative wind pressure. A similar example of a single-width overhead garage door that buckled and pulled away from its track at the base is shown in Figure 4-38 for a Duck Key house (built in 1985).





The base of the door deflected outward beyond the exterior wall in the lower corners (red arrows).

Figure 4-37: Damaged overhead garage doors (EWS = 114 mph; EDWS = 180 mph) (Little Torch Key)

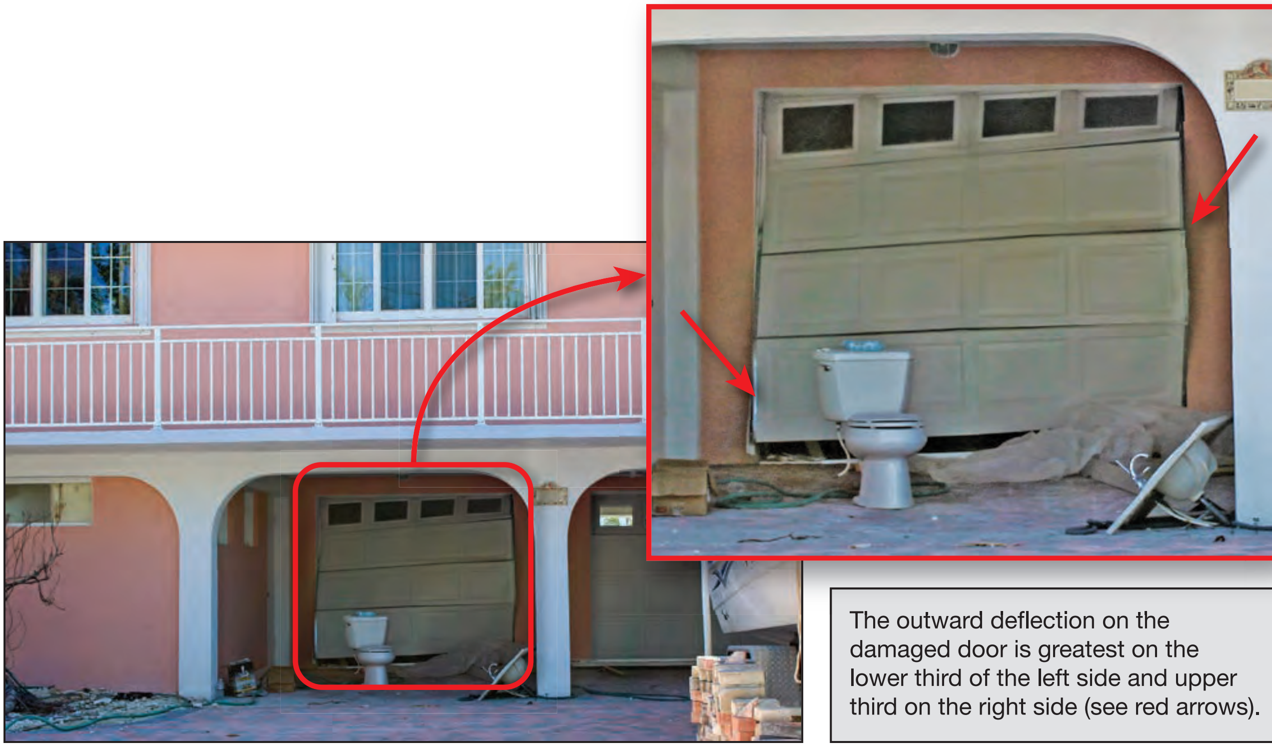


Figure 4-38: Damaged overhead garage door on a house (EWS = 111 mph; EDWS = 180 mph) (Duck Key)

4.3 Manufactured Housing Units

The MAT observed MH units in Collier County and the Florida Keys. Although some examples of MH anchorage techniques used in the Florida Keys are included below, inland observations from Collier County are primarily discussed because many installations in the Florida Keys were destroyed by storm surge. In Collier County, many more MH units than site-built houses were destroyed by Hurricane Irma's winds. Collier County building officials shared district-specific damage assessment information indicating that in three districts, 45 MH units were destroyed, while only three single-family dwellings and one multi-family dwelling were destroyed. Almost all destroyed units were inland of Irma's storm surge and were therefore destroyed by wind effects.

Date built and/or date manufactured information was not as readily available for the MH units as it was for site-built dwellings, which made it difficult for the MAT to determine the applicable construction criteria for observed units. When MH units were included on property appraisal websites maintained by counties and municipalities, the date listed was the date that units were installed in the referenced location, and not the date they were constructed in the factory. The date of manufacture should be included on identification plates required by the Department of Housing and Urban Development (HUD) as of June 15, 1976. However, the only observed MH units with HUD identification plates were newly installed to replace units destroyed by Irma, so the age of damaged and destroyed MH units is largely unknown.[3] Absent HUD tags could have been destroyed, removed, or located inside the MH units where the MAT did not have access.

3 For the purposes of this report, the MH units presented in this section were likely built after June 15, 1976, and are therefore referred to as MH units and are not differentiated as "Early Code" MH units (built after June 15, 1976 but before July 13, 1994) or "New" MH units (built July 13, 1994 to present).

4.3.1 Anchoring

New MH units installed after Irma and observed by the MAT appeared to be anchored much more consistently than older installations. Figure 4-39 and Figure 4-40 show two examples of post-Irma anchorage. Note both units' metal anchor straps are tight, aligned at the top and bottom, spaced 3 feet or less on center, and attached to the base of the wall. One exception to post-Irma anchorage consistency is shown in Figure 4-41, where straps are misaligned from top to bottom.

Figure 4-39: Anchorage on a new MH unit installation (EWS = 105 mph; EDWS = 164 mph) (Collier County)

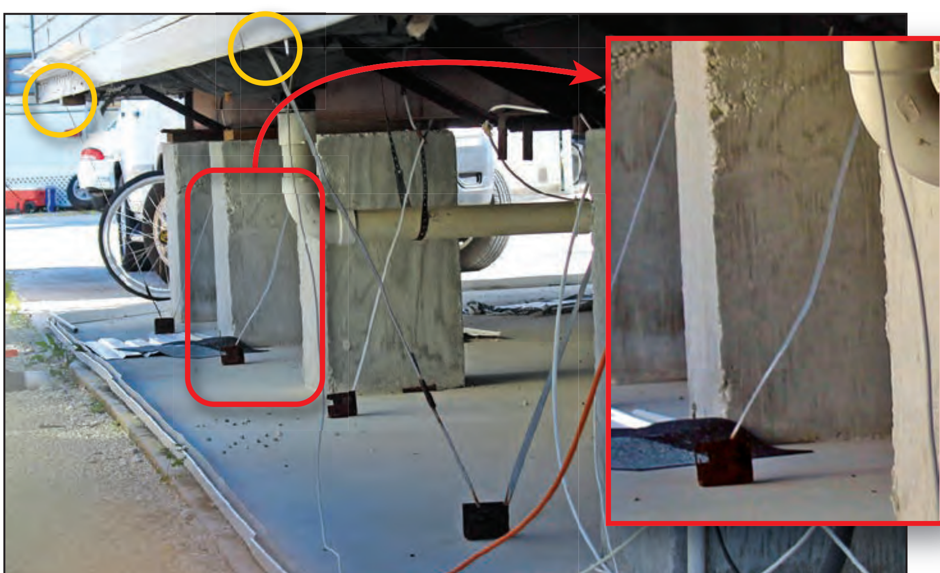
Yellow arrows show the consistent anchorage pattern and the red arrows show cross bracing behind piers.

Figure 4-40: Consistent anchorage pattern observed on a new MH unit installation (EWS = 105 mph; EDWS = 164 mph) (Collier County)

Figure 4-41:
New MH unit installation with misaligned anchor strap installation (red outline) was otherwise anchored consistently with other post-Irma examples (EWS = 105 mph; EDWS = 164 mph) (Collier County)

Aside from the newly installed units described above, the MAT observed significant variation across MH installations with respect to the spacing of anchors and where they were connected to the unit. Loose anchor straps were also commonplace. Without adequate tension, the anchor straps are ineffective at resisting the lateral and uplift effects of high wind.

Figure 4-42 shows a unit in Big Coppitt Key that illustrates typical anchorage variations observed in older installations. The unit anchors are spaced at approximately 3 feet on center, but only every third strap is attached to the base of the exterior wall, and one of the anchors is not tight (see figure caption and inset). Another example from Marathon Key shows all straps spaced at approximately 3 feet on center and attached to the exterior wall base, but with a visibly loose anchor strap (see Figure 4-43).



Yellow circles show where straps are attached to the base of the unit wall.
The inset shows close-up of loose strap inside red outline.

Figure 4-42:
MH unit installation where only the first and fourth straps are attached to the exterior wall base (EWS = 111 mph; EDWS = 180 mph) (Big Coppitt Key)

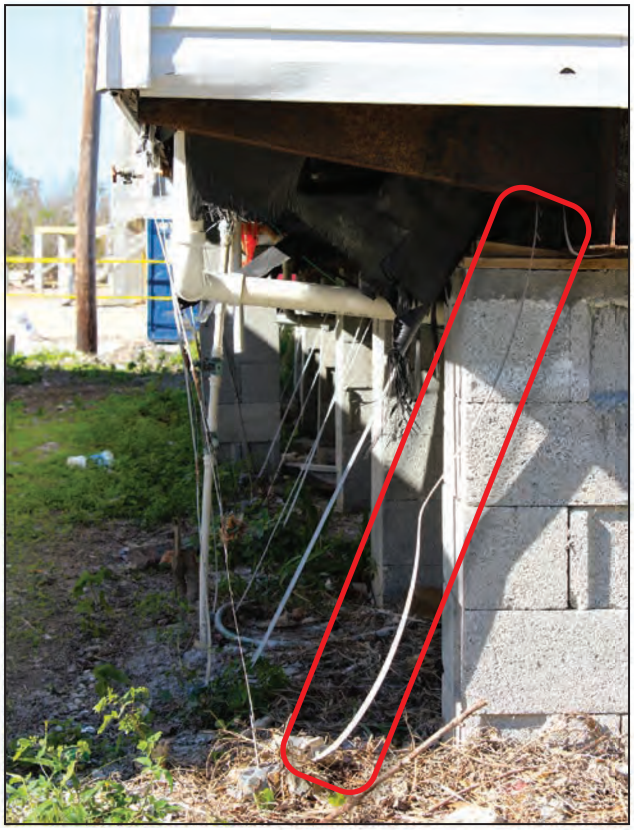


Figure 4-43:
MH unit installation with straps spaced at approximately 3 feet on center and attached to the exterior wall base, but with loose anchor strap shown in red outline (EWS = 120 mph; EDWS = 180 mph) (Marathon Key)

4.3.2 Other Observations

Carports, decks, porches, and awnings are often attached after the MH unit has been installed. Chapter 15C of the Florida Administrative Code requires that additions "shall be free-standing and self-supporting with only the flashing attached to the main unit unless the added unit has been designed to be married to the existing unit (15C-2.0081)."

As observed in the Hurricane Charley MAT report (FEMA, 2005: Section 7.4), and in FEMA Recovery Advisories 4 and 5 for the 2007 tornado outbreak in central Florida, "Understanding and Improving Performance of Older Manufactured Homes During High-Wind Events" (2007d), and "Understanding and Improving Performance of New Manufactured Homes During High-Wind Events" (2007c), respectively, wind damage to MH units is frequently initiated when improperly attached appurtenances are blown off or damaged. Specifically, when carports and covered porches—which are particularly vulnerable to wind loads—break away from the MH unit, they leave openings at failed connections in the remaining roof and/or wall that allow rain to enter the MH unit envelope. In some cases, damage progresses from the initial point of failure. The MAT observations confirm this progressive failure pattern occurred in Florida during Hurricane Irma.

The following examples of MH unit damage initiated by improperly attached appurtenances were observed during the Hurricane Irma MAT site visits (before damage was cleared away) and are representative of many more failures. In the MH unit shown in Figure 4-44, loss of vinyl siding across the top and left end of the exterior wall was initiated by loss of the screened porch. The red tag on the front-facing window of the Everglades City installation means that the damage resulted in condemnation by local officials. Furthermore, the unit appears to be half of a double-wide MH unit, as evidenced by the exposed wall section (inside yellow oval) where there is no sheathing and no insulation in the exposed stud bays. The lack of wood structural sheathing on the wall may have contributed to the loss of the vinyl siding. Figure 4-45 shows another example of Collier County MH unit damage initiated by an attached screened porch, where the top of a wall opened up along the entire length of the unit and the adjacent roof section peeled back. Figure 4-46 shows a unit from the same neighborhood where the top of a wall was stripped away by the (formerly) connected carport. This MH unit also received a red tag from local officials.)

A remnant of the porch is shown in the red outline, and the red tag indicating condemnation by local officials is shown in the blue circle. The yellow oval shows missing sheathing and insulation characteristic of interior walls.

Figure 4-44:
This MH unit sustained exterior wall damage that was initiated by the loss of the attached screened porch (EWS = 115 mph; EDWS = 164 mph) (Everglades City)

The screened porch (remnants shown with blue arrows) opened the top of an exterior wall (red outline) and peeled back the adjacent roof section (red arrows) when the porch was lost to high winds.

Figure 4-45:
MH unit that was damaged when its screened porch was lost to high winds (EWS = 105 mph; EDWS = 166 mph) (Collier County)

Figure 4-46:
MH unit where carport detached from the unit, opening the building envelope across the top of a wall (EWS = 105 mph; EDWS = 166 mph) (Collier County)

The inset is a close-up of the area inside the red outline, and the red tag indicating condemnation by local officials is shown in the yellow circle.



HURRICANE
IRMA
IN FLORIDA

5 Recommendations and Conclusions

The conclusions and recommendations are intended to help reduce future damage and impacts from flood and wind events such as Hurricane Irma.

The conclusions and recommendations presented in this report are based on the MAT's observations in the areas studied; evaluations of relevant codes, standards, and regulations; and meetings with local officials, facility representatives, design professionals, and contractors.

The recommendations are intended to assist the State of Florida, communities, design professionals, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners, academia, select industries and associations, local officials, and individuals in the reconstruction process, and to help reduce future damage and impacts from flood and wind events such as Hurricane Irma. The recommendations will also help FEMA assess the adequacy of building codes and standards as they relate to dry floodproofing and floodplain management requirements and determine whether changes are needed or additional guidance is required to reduce hurricane damage.

Section 5.1 is a summary of the conclusions and recommendations based on the MAT's observations. Section 5.2 discusses general conclusions and recommendations. Section 5.3 discusses conclusions and recommendations related to building codes, standards, and regulations. Section 5.4 includes flood-related building performance conclusions and recommendations. Section 5.5 includes wind-related building performance conclusions and recommendations. Section 5.6 provides conclusions and recommendations on FEMA Technical Publications and Guidance. Section 5.7 provides a summary of the conclusions and recommendations in a tabular format.

5.1 Overview of Conclusions and Recommendations

The recommendations are presented as guidance to the State of Florida and those who are involved with the design, construction, and maintenance of the built environment in the State. The entities involved in the reconstruction and mitigation efforts should consider these recommendations in conjunction with their existing priorities and resources when determining how they can or will be implemented.

Overall, newer construction generally sustained much less damage than older construction, so the requirements incorporated in the FBC, along with floodplain management regulations, appear to be working as intended. The extent of flood damage to buildings varied with the depth of floodwater, the amount of energy in the water (waves, velocity), and the nature of building design and construction (old versus new, at-grade versus elevated, MH units/recreational vehicles versus site-built/modular). Although inundation alone was a significant source of damage, some of the more dramatic structural failures observed were a result of wave action and scour. Wind-related damage was observed for both pre- and post-FBC buildings. While structural damage observations were almost exclusively limited to pre-FBC residential buildings, envelope damage was commonly observed on both older and newer construction. This envelope damage allowed wind-driven rain to penetrate to the interior, resulting in costly damage.

The MAT Conclusions and Recommendations are prioritized within each subsection as those that may be most important to implement by the State, community, or interested party. Specifically, recommendations of note from each section include:

Recommendation FL-1a (Section 5.2). FDEM should develop/modify training on the flood provisions in the FBC and local floodplain management ordinances.

Recommendation FL-4a (Section 5.3). Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.

Recommendation FL-7 (Section 5.4). Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).

Recommendation FL-9a (Section 5.5). Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.

Recommendation FL-14a (Section 5.6). FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities.*

5.2 General Conclusions and Recommendations

Conclusion FL-1

Building codes and floodplain management requirements were inconsistently enforced. The MAT observed inconsistencies in local code enforcement, as well as noncompliance by builders, throughout the sites visited (e.g., improper load path and not requiring or using products that are on the approved and tested list). Some observed damage is associated with use of non-flood damage-resistant materials.

Recommendation FL-1a. **FDEM should consider developing/modifying training on the flood provisions in the FBC and local floodplain management ordinances.** FDEM, in conjunction with FFMA and the Building Officials Association of Florida (BOAF), should develop a webinar on the flood provisions in the FBC and local floodplain management ordinances, specifically about enclosures, with emphasis on the use of flood damage-resistant materials below the required floor elevation. This training should be for builders, developers, floodplain administrators, building officials, plan reviewers, and building inspectors.

Recommendation FL-1b. **BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on building envelope components.** BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on the use of appropriate building envelope products that have been designed or tested for high wind locations. This topic could be addressed in conjunction with continuing education courses on the building code.

Conclusion FL-2

Building officials expressed concerns about having adequate resources. Some building officials did not feel they had adequate resources to properly inspect damaged buildings for life-safety, conduct Substantial Damage determinations, verify Substantial Improvement projects, review permit applications for repairs, and enforce FBC requirements during the post-disaster recovery period when extensive numbers of work projects are proposed in a short time.

Recommendation FL-2. **FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through the Statewide Mutual Aid Agreement (SMAA).** FDEM should inform building officials and local officials responsible for floodplain management about accessing resources to aid recovery through the SMAA signed by all Florida counties, or the inter-state Emergency Aid Compact. Although the agreement may be accessed at any time, when events are declared major disasters, some costs of aid provided under the agreement may be eligible for reimbursement by FEMA. FDEM should encourage the BOAF and the Florida Floodplain Managers Association (FFMA) to develop strategies under their SMAA and FDEM to recruit professional assistance to support communities in need. FDEM should also consider training design professionals to assist with inspections. The Florida Post-Disaster Toolkit for Floodplain Administrators should be distributed to all communities. FDEM should also continue to encourage pre-event evaluation of post-disaster needs.

Conclusion FL-3

The State and communities did not receive (or did not receive in a timely manner) data on buildings that appeared to have incurred Substantial Damage. When buildings appeared to have incurred Substantial Damage, the State and communities either did not receive requested data submitted by NFIP claims adjusters, or did not receive the information in a timely manner.

Recommendation FL-3. **FEMA should develop an effective and timely means to deliver the Adjuster Preliminary Damage Assessment data.** When NFIP claims adjusters identify claims that, based on available data, appear to have incurred Substantial Damage, the adjusters submit data using FEMA Form 086-0-20, *Adjuster Preliminary Damage Assessment* (2018a). The form indicates FEMA and communities can use the data to identify potentially Substantially Damaged buildings. FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010e) (Section 7.4.1), describes using the data for screening purposes only, especially after flood events that damage large numbers of buildings. FEMA should develop an effective and timely means to deliver data submitted by NFIP claims adjusters to States and communities.

5.3 Building Codes, Standards, and Regulations

Conclusion FL-4

The MAT observed damaged buildings that illustrate the problems associated with siting buildings on erodible shorelines. The Florida DEP report (*Hurricane Irma Post-Storm Beach Conditions and Coastal Impact in Florida* [2018]) identified numerous examples of dune/bluff erosion and building damage in these areas. Foundation design in these areas is particularly challenging. The MAT also observed numerous instances of erosion and damage to buildings and many areas where erosion control structures (bulkheads, seawalls, etc.) failed on open coast and estuarine shorelines, in many cases under less than base flood conditions. Bulkheads and other erosion control structures may not offer the intended level of protection.

Recommendation FL-4a. **Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.** Permitting agencies (e.g., Florida DEP, Water Management Districts, local government) should review public materials, emphasize the importance of evaluating existing bulkheads before relying on them for protection, and encourage communities to avoid siting buildings close to bulkheads. Permitting criteria and performance requirements for new or replacement bulkheads should be evaluated with respect to design conditions, including the effects of saturated backfill, wave forces, overtopping, and erosion on both water and land sides.

Recommendation FL-4b. FEMA should review and update their event-based erosion methodology. FEMA should review and update the methodology used to estimate dune and bluff erosion. FEMA should also improve existing siting and foundation design guidance for coastal dune and bluff areas in FEMA P-55, *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas* (2011, 4th Edition), FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010b), and other publications. In consultation with the Florida DEP and other coastal States, FEMA should evaluate siting criteria and consider recommending revisions to ASCE 24 Chapter 3 on how best to consider erosion in design and construction.

Conclusion FL-5

FDEM documented the successful completion of its multi-year CRS initiative. During the initiative, which extended into post-Irma recovery, FDEM visited and offered technical assistance to more than 200 communities with emphasis on eligibility for the CRS.

Recommendation FL-5. FDEM should expand its technical assistance for CRS communities. FDEM should review activities undertaken by CRS communities and higher standards adopted in floodplain management ordinances by CRS communities to identify activities and standards not widely employed. Future technical assistance for CRS communities should focus on encouraging consideration of those activities and standards, such as performing stormwater master plan studies; establishing compensatory storage requirements; identifying BFEs in Approximate Zone A; conducting public outreach for design professionals, surveyors, and mappers; and adopting the construction industry Coastal A Zone requirements in the FBC.

Conclusion FL-6

Florida's installation requirements for MH units do not reference the current edition of FEMA 85. Florida's installation requirements for MH units reference the 1985 edition of FEMA 85, *Protecting Manufactured Homes from Floods and Other Hazards*. The current edition, FEMA P-85, was published in 2009 and includes updated guidance for installation to address resistance to both flood and wind conditions. The 2009 edition includes some pre-engineered foundation specifications that minimize the need for site-specific engineered solutions for many locations.

Recommendation FL-6. The Florida Department of Highway Safety and Motor Vehicles should reference the most recent edition of FEMA P-85. The Florida Department of Highway Safety and Motor Vehicles should update Chapter 15C, Florida Statues (Manufactured home installation) to reference the most recent edition of FEMA P-85 (the 2009 edition, or "as revised by FEMA") in Chapter 15C. The State agency should also consider incorporating additional wind- and flood-resistant construction provisions with particular emphasis on anchoring, as well as develop a training unit for manufactured home installers, with specific focus on requirements for wind resistance and installation in SFHAs. This training should be designed to satisfy continuing education requirements for manufactured home installers.

5.4 Flood-Related Building Performance

Conclusion FL-7

Dry floodproofing measures often failed under less than design flood conditions. The MAT visited approximately 25 dry floodproofed sites following Hurricane Irma and identified several lessons to be learned from dry floodproofing failures under less than design flood conditions. The MAT also identified best practices from successfully implemented dry floodproofing measures.

Recommendation FL-7. **Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).** Texas Recovery Advisory 1, *Dry Floodproofing: Planning and Design Considerations* (2018e), and Florida Recovery Advisory 1, *Dry Floodproofing: Operational Considerations* (2018d), have guidance related to dry floodproofing methods and procedures developed based on observations made during and after Hurricanes Irma and Harvey. The MAT observations illustrate that designing and implementing dry floodproofing for buildings is complicated. Therefore, guidance based on recent events should be incorporated into the design and implementation of new and existing dry floodproofing. Specific considerations from the Recovery Advisories include:

- Conduct a thorough vulnerability assessment, including a survey of all potential water entry points, as part of the design process.
- Incorporate freeboard into the design flood elevation based on the building use.
- Treat flood barriers like fire wall assemblies—label them and minimize modifications and penetrations.
- Evaluate utility components and penetrations through walls and floors as potential water entry points.
- Install check valves in floor drain systems and require ejector systems with check valves/ backflow preventers for stormwater and sanitary sewers.
- Provide waterstops at the seals in foundation walls and floor slabs where those spaces are intended to remain dry and are located below the design flood elevation.

Conclusion FL-8

Dry floodproofed buildings where building managers had instilled a culture of preparedness sustained less damage than other dry floodproofed buildings. The scope and detail of operations, maintenance, and testing plans was an indicator of the dry floodproofing system performance.

Recommendation FL-8a. **Facility managers should develop an emergency operations plan (EOP) for severe weather.** An EOP that outlines how to prepare the building when severe weather events are expected should be developed by facility managers. Each dry floodproofed facility should have an EOP with action items or an implementation checklist based on a timeline keyed to official severe weather warnings and watches. ASCE 24 Chapter 6 contains requirements for and discussion of EOPs.

Recommendation FL-8b. Facility managers should routinely re-evaluate dry floodproofing designs and plans as required by codes and standards. After each deployment of a dry floodproofing system, including training exercises, the overall design of dry floodproofing systems and EOPs for severe weather should be revisited to resolve any deficiencies identified while systems were being tested, installed, or subjected to floodwater. ASCE 24 Chapter 6 requires periodic practice of installing shields as well as testing of sump pumps and other drainage measures.

Recommendation FL-8c. Facility managers should take reasonable measures to instill a culture of preparedness. Facility managers should conduct annual training exercises during which dry floodproofing measures are installed, taking note of the time to install each portion of the system and the total time to install the entire dry floodproofing system. The commentary in ASCE 24 indicates persons responsible for installing or implementing the measures must be familiar with the procedures and equipment. Therefore, training exercises should include building maintenance and engineering staff along with other building staff that may be needed to install dry floodproofing systems with little warning time. Maintenance of dry floodproofing system components should be conducted annually, as well as during training exercises and following deployment for a flood event. To ensure system functionality, periodic maintenance should include checking gaskets and seals, installation hardware and fasteners, and the condition of building elements to which dry floodproofing components will be attached. Consider creating a video recording of manual dry floodproofing installations, especially the complex steps, so the video can be referenced later if untrained staff are required to assist.

5.5 Wind-Related Building Performance

Conclusion FL-9

The MAT observed evidence of inadequate resistance to wind loads for roof coverings of residential buildings. In particular, the MAT observed widespread damage to asphalt roof coverings on post-FBC residential structures; the reason(s) for this damage was not determined by the MAT.

Recommendation FL-9a. Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT. More research needs to be done by industry groups (e.g., manufacturers, insurances, builders) to explain why post-FBC asphalt shingle damage was observed to be widespread following a below design-level event and whether these failures were the result of design, installation, testing, inspection, or other issues. Appropriate mitigating actions should then be taken.

Recommendation FL-9b. Contractors and inspectors must ensure roof covering repairs and replacements are in conformance with FBC requirements. When more than 25 percent of the total roof area or roof section has to be repaired, provisions of the FBC must be met. Contractors and inspectors should ensure roof covering repairs and replacements meet FBC requirements. Refer to Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (2018f) for additional guidance.

Conclusion FL-10

The MAT observed evidence of inadequate resistance to wind pressures and improper installation of soffits on residential buildings. Widespread loss of soffits was observed in residential construction, and wind-driven rain infiltrated some areas where soffits were displaced or lost.

Recommendation FL-10a. **Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.** Proper soffit installation should be emphasized by designers, contractors, and inspectors in order to limit wind-driven rain from entering building envelopes and damaging building interiors. Florida Recovery Advisory 2, *Soffit Installation in Florida* (2018h), provides soffit installation guidance and resources to meet or exceed minimum provisions of the FBC.

Recommendation FL-10b. **The FBC should require soffit inspections.** Soffit inspections will help to ensure compliant products are used and the soffit is securely attached.

Conclusion FL-11

The MAT observed evidence of inadequate resistance to wind pressures for certain wall coverings of residential buildings. In particular, failure of vinyl siding on post-FBC residential structures was widespread. Instances of improper installation and concerns about appropriate design pressure ratings are addressed in Chapter 4 and were probable factors in the damage observed.

Recommendation FL-11a. **Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding.** The MAT's observations of the amount of damage to vinyl siding and its unique sensitivity to proper installation suggests vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding. Considering that maximum peak gusts in the Florida Keys were approximately 120 mph (well below the design wind speed), better performance would have been expected.

Recommendation FL-11b. **The FBC should require wall cladding inspections.** Most MAT-observed wall cladding failures demonstrated one or more examples of non-compliant installation, which can be mitigated through field inspections. Common examples of wall cladding failures for vinyl siding include missing utility trim and starter strips.

Conclusion FL-12

The MAT observed evidence of wind-borne debris, but very few instances of glazed openings being breached. ASCE 7-required protection of windows and glazed doors in the wind-borne debris region appears to have been widely applied. However, the few instances of observed damage to protected glazed openings occurred in areas where estimated wind speeds during Hurricane Irma were well below the 130 mph wind-borne debris trigger for which ASCE 7 requires glazed opening protection. This suggests that wind-borne debris was generated at wind speeds well below the 130 mph trigger.

Recommendation FL-12a. **Industry groups and/or academia should study debris generation and strikes to protective systems during hurricanes to determine whether the wind speed triggers for the ASCE 7 wind-borne debris region are appropriate.** Industry groups and/or academia should study debris generation and associated debris strikes to protective systems from the 2017 hurricane, as well as for future storms, to determine whether the current wind speed triggers for the wind-borne debris region as defined in ASCE 7 are appropriate. Data collected and analyzed during the study can be used to make recommendations on ASCE 7-required protection of windows and glazed doors.

Recommendation FL-12b. **Building owners outside the wind-borne debris region should consider protecting the glazed openings on their buildings.** Although not required by codes and standards, owners of buildings in the hurricane-prone region should consider protecting glazed window systems and doors with rated opening protection systems (i.e., storm shutters) or retrofitting the building with impact-resistant glazing when located anywhere in the hurricane-prone region.

Conclusion FL-13

Failures of appurtenance attachments to MH units increase the units' vulnerability to wind and rain damage. Wind damage to MH units is frequently initiated when improperly attached appurtenances (such as carports and screened porches) are blown off or damaged leaving openings at failed connections that allow rain to enter the MH unit envelope. In some cases, damage progresses from the initial point of failure. This damage increases the unit's vulnerability to wind and rain damage.

Recommendation FL-13. **As a best practice, MH appurtenances should be built as stand-alone units without structural connection to the MH unit.** If the appurtenance is not free-standing and is connected to the manufactured home for structural support, plans should be prepared that clearly detail the connection between the unit and the structure being attached. The design and construction should be approved, permitted, and inspected by building officials.

5.6 FEMA Technical Publications and Guidance

Conclusion FL-14

Select FEMA Building Science technical guidance publications are becoming increasingly incongruent with current building codes and do not include lessons learned from recent MATs. The Building Science Branch at FEMA Headquarters develops and maintains over 200 publications and resources that provide technical guidance on how to assess risk; identify vulnerabilities; better understand the NFIP and the regulatory environment with respect to building codes and standards; and provide best practices and mitigation measures that can be taken to reduce vulnerabilities to flood, wind, and seismic hazards. Some of the FEMA Building Science technical guidance publications do not reflect advanced requirements in current building codes nor do they include new lessons learned from recent MAT reports.

The 2017 hurricane season brought landfalling hurricanes on the island territories and the continental United States. There are many valuable and important damage observations and lessons learned from this and other events, and the observed damage might have been avoided if the guidance from these documents had been incorporated at different building locations. However, while the approaches and theories in these publications are still accurate, many of the building codes have been updated in the last 8 to 10 years and may impact the current approaches outlined in these documents.

Recommendation FL-14a. **FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities.*** FEMA's Building Science Branch has been developing guidance to assess wind vulnerabilities of critical facilities. FEMA should include lessons learned from the 2017 hurricane season in finishing this publication, which would greatly benefit many stakeholders in the U.S.

Recommendation FL-14b. **FEMA should update select FEMA Building Science publications that affect coastal construction.** The FEMA Building Science Branch should consider updating or producing a supplement for its key hurricane technical guidance publications to include lessons learned from the 2017 hurricane season and to reflect updates to building codes since the publications' latest releases. These publications might include, but are not necessarily limited to, the following:

- FEMA P-55, *Coastal Construction Manual* (2011)
- FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010d)
- FEMA P-762, *Local Officials Guide for Coastal Construction* (2009b)
- FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (2010f)

Recommendation FL-14c. **FEMA should update the FEMA Risk Management Series guidance publications for natural hazards.** The FEMA Building Science Branch, working with other FEMA and DHS entities, should consider updating or producing a supplement to select technical documents from the FEMA Natural Hazard Risk Management Series to include lessons learned from the 2017 hurricane season and to reflect updates to building codes since the publications' latest releases. These publications might include, but are not limited to, the following:

- FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010a)
- FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007a)
- FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings* (2007b)

Conclusion FL-15

Many communities have difficulty implementing the Substantial Improvement/Substantial Damage requirements, especially after major disasters. Many buildings damaged by flooding were designed and built before communities joined the NFIP and began regulating development in SFHAs. Enforcing the NFIP and FBC requirements to bring Substantially Improved and Substantially Damaged buildings into compliance continues to be one of the more difficult challenges for floodplain administrators and building officials.

Recommendation FL-15a. **FEMA should update FEMA P-758; at the same time, FEMA 213 should be updated to be consistent with the updated FEMA P-758.** FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010e) should be updated. Updates should include lessons learned, and recommended guidance and clairifcations since it was published in 2010. At the same time, FEMA 213, *Answers to Questions about Substantially Improved/Substantially Damaged Buildings* (2018b) should be updated to be consistent with the updated FEMA P-758. Outreach material should be developed as part of the publication updates.

Recommendation FL-15b. **FEMA should consider expanding existing training materials related to Substantial Improvement/Substantial Damage.** FEMA should consider developing a webinar format training for distribution to NFIP State Coordinators and other entities related to Substantial Improvement/Substantial Damage. The materials should incorporate lessons learned after Hurricane Irma and other recent flood events and should include a unit focused on the local official's role in helping insured property owners satisfy requirements to qualify for Increased Cost of Compliance claims and in issuing permits for mitigation measures eligible for use of those claim payments.

Conclusion FL-16

Future dry floodproofing design and construction can benefit from observed failures and successes. The MAT visited about 25 dry floodproofed sites following Hurricane Irma and observed several lessons learned from dry floodproofing failures under less than design flood conditions, as well as best practices from successes.

Recommendation FL-16a. **FEMA should update dry floodproofing guidance.** Based on the varying performance of dry floodproofing measures observed, FEMA should revise existing dry floodproofing guidance to include data and observations from recent events. In particular, FEMA Technical Bulletin 3, *Non-Residential Floodproofing—Requirements and Certification* (1993), should be updated to improve guidance on planning, design and construction, and emergency operations, as well as maintenance planning requirements. Specific points of emphasis include:

- For new construction, recommend using ACI 350 for designing concrete that will be constructed below the required dry floodproofing elevation (ACI 350 concrete design reduces the crack width in concrete and increases the fineness of the concrete matrix to reduce concrete permeability rates).

- Consider limiting the amount of openings below the required dry floodproofing elevation, i.e., the portion of the building envelope that is not permanently substantially impermeable. As a result, the amount of temporary protective measures would be limited to the length of the perimeter required for egress (pedestrian and vehicular).

FEMA should also consider updating FEMA P-936, *Floodproofing for Non-Residential Buildings* (2013a), with relevant lessons learned from the 2017 hurricane season as well.

Recommendation FL-16b. **FEMA should evaluate existing dry floodproofing guidance and post-flood investigations to develop a recommendation for inclusion in ASCE 24.** FEMA should review recommendations, fact sheets, and recovery advisories related to dry floodproofing included in other MAT reports to develop a comprehensive recommendation for dry floodproofing design, limitations, testing, and maintenance and operations requirements for consideration by the ASCE 24 committee charged with revising Chapter 6, "Dry Floodproofing and Wet Floodproofing."

5.7 Summary of Conclusions and Recommendations

Table 5-1 is a matrix listing the conclusions and recommendations cross-referenced to the sections of the report that describe the supporting observations. The recommendations provided in the table have also been cross-referenced to Recovery Support Functions (RSFs) supported by FEMA through the National Disaster Recovery Framework (NDRF). FEMA developed the RSFs with the objective of facilitating the identification, coordination, and delivery of Federal assistance needed to supplement recovery resources and efforts by local, State, tribal, and territorial governments, as well as private and nonprofit sectors. The MAT has identified RSFs for the recommendations provided in this report to assist Florida with accelerating the process of recovery, redevelopment, and revitalization.

NATIONAL DISASTER RECOVERY FRAMEWORK AND RECOVERY SUPPORT FUNCTIONS

FEMA has developed the NDRF to create a common platform and forum for how the whole community builds, sustains, and coordinates delivery of recovery capabilities. FEMA guidance states:

> Resilient and sustainable recovery encompasses more than the restoration of a community's physical structures to pre-disaster conditions. The primary value of the NDRF is its emphasis on preparing for recovery in advance of disaster. The ability of a community to accelerate the recovery process begins with its efforts in pre-disaster preparedness, including coordinating with whole community partners, mitigating risks, incorporating continuity planning, identifying resources, and developing capacity to effectively manage the recovery process, and through collaborative and inclusive planning processes. Collaboration across the whole community provides an opportunity to integrate mitigation, resilience, and sustainability into the community's short- and long-term recovery goals.

The RSFs compose the coordinating structure for key functional areas of assistance in the NDRF. Their purpose is to support local governments by facilitating problem solving, improving access to resources and by fostering coordination among State and Federal agencies, nongovernmental partners, and stakeholders.

The list of RSFs and the leading coordinating agencies is presented below (and available on line at www.fema.gov/recovery-support-functions):

- Community Planning and Capacity Building (CPCB) RSF (U.S. Department of Homeland Security/FEMA)
- Economic RSF (U.S. Department of Commerce)
- Health and Social Services RSF (U.S. Department of Health and Human Services)
- Housing RSF (U.S. Department of Housing and Urban Development)
- Infrastructure Systems RSF (U.S. Army Corps of Engineers)
- Natural and Cultural RSF (U.S. Department of the Interior)

Table 5-1: Summary of Conclusions and Recommendations

Observations	Conclusions	Recommendations	Recovery Support Function
General MAT Field Observation	**FL-1** Building codes and floodplain management requirements were inconsistently enforced.	**FL-1a.** FDEM should develop/modify training on the flood provisions in the FBC and local floodplain management ordinances.	CPCB, Economic
		FL-1b. BOAF, FHBA, and other stakeholders should consider developing additional training and placing additional emphasis on building envelope components.	CPCB, Economic
	FL-2 Building officials expressed concerns about having adequate resources.	**FL-2.** FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through the SMAA.	CPCB, Economic, Housing
	FL-3 The State and communities did not receive (or did not receive in a timely manner) data on buildings that appeared to have incurred Substantial Damage.	**FL-3**. FEMA should develop an effective and timely means to deliver the Adjuster Preliminary Damage Assessment data.	CPCB, Economic, Housing
Chapter 3 (Section 3.1)	**FL-4** The MAT observed damaged buildings that illustrate the problems associated with siting buildings on erodible shorelines.	**FL-4a.** Permitting agencies should evaluate permitting criteria and performance requirements for new or replacement bulkheads.	CPCB, Economic, Housing, Infrastructure
		FL-4b. FEMA should review and update their event-based erosion methodology.	CPCB, Economic, Housing, Infrastructure
Chapter 2 (Section 2.3)	**FL-5** FDEM documented the successful completion of its multi-year CRS initiative.	**FL-5**. FDEM should expand its technical assistance for CRS communities.	CPCB, Economic, Housing
Chapter 2 (Section 2.4) and Chapter 4 (Section 4.3)	**FL-6** Florida's installation requirements for MH units do not reference the current edition of FEMA 85.	**FL-6**. The Florida Department of Highway Safety and Motor Vehicles should reference the most recent edition of FEMA P-85.	CPCB, Economic, Housing

Table 5-1: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Recovery Support Function
Chapter 3 (Section 3.2)	**FL-7** Dry floodproofing measures often failed under less than design flood conditions.	**FL-7.** Local floodplain administrators, design professionals, and building owners should follow the guidance in FEMA's Texas Recovery Advisory 1 (2018e) and Florida Recovery Advisory 1 (2018d).	CPCB, Economic
	FL-8 Dry floodproofed buildings where building managers had instilled a culture of preparedness sustained less damage than other dry floodproofed buildings.	**FL-8a.** Facility managers should develop an EOP for severe weather.	CPCB, Health and Social Services, Economic
		FL-8b. Facility managers should routinely re-evaluate dry floodproofing designs and plans as required by codes and standards.	CPCB, Health and Social Services, Economic
		FL-8c. Facility managers should take reasonable measures to instill a culture of preparedness.	CPCB, Health and Social Services, Economic
Chapter 4 (Section 4.2.1)	**FL-9** The MAT observed evidence of inadequate resistance to wind loads for roof coverings of residential buildings.	**FL-9a.** Industry groups should investigate the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.	Housing, Economic
		FL-9b. Contractors and inspectors must ensure roof covering repairs and replacements are in conformance with FBC requirements.	Housing, Health and Social Services, Economic
Chapter 4 (Section 4.2.2)	**FL-10** The MAT observed evidence of inadequate resistance to wind pressures and improper installation of soffits on residential buildings.	**FL-10a.** Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.	Housing, CPCB, Economic
		FL-10b. The FBC should require soffit inspections.	Housing, CPCB, Economic
Chapter 4 (Section 4.2.3)	**FL-11** The MAT observed evidence of inadequate resistance to wind pressures for certain wall coverings of residential buildings.	**FL-11a**. Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue investigations of the appropriate PEF for vinyl siding.	Housing, Economic
		FL-11b. The FBC should require wall cladding inspections.	Housing, CPCB, Economic

Table 5-1: Summary of Conclusions and Recommendations (concluded)

Observations	Conclusions	Recommendations	Recovery Support Function
Chapter 4 (Section 4.2.4)	**FL-12** The MAT observed evidence of wind-borne debris, but very few instances of glazed openings being breached.	**FL-12a**. Industry groups and/or academia should study debris generation and strikes to protective systems during hurricanes to determine whether the wind speed triggers for the ASCE 7 wind-borne debris region are appropriate.	Housing, CPCB, Economic
		FL-12b. Building owners outside the wind-borne debris region should consider protecting the glazed openings on their buildings.	Housing, CPCB, Economic
Chapter 4 (Section 4.3)	**FL-13** Failures of appurtenance attachments to MH units increase the units' vulnerability to wind and rain damage.	**FL-13.** As a best practice, MH appurtenances should be built as stand-alone units without structural connection to the MH unit.	Housing, Economic
General MAT Field Observation	**FL-14** Select FEMA Building Science technical guidance publications are becoming increasingly incongruent with current building codes and do not include lessons learned from recent MATs.	**FL-14a.** FEMA should complete *Guidelines for Wind Vulnerability Assessments for Critical Facilities*.	CPCB, Health and Social Services, Economic
		FL-14b. FEMA should update select FEMA Building Science publications that affect coastal construction.	Housing, CPCB, Economic
		FL-14c. FEMA should update the FEMA Risk Management Series guidance publications for natural hazards.	Housing, CPCB, Health and Social Services, Economic
	FL-15 Many communities have difficulty implementing the Substantial Improvement/Substantial Damage requirements, especially after major disasters.	**FL-15a.** FEMA should update FEMA P-758; at the same time, FEMA 213 should be updated to be consistent with the updated FEMA P-758.	Housing, CPCB, Economic
General MAT Field Observation		**FL-15b**. FEMA should consider expanding existing training materials related to Substantial Improvement/Substantial Damage.	CPCB, Economic
Chapter 3 (Section 3.2)	**FL-16** Future dry floodproofing design and construction can benefit from observed failures and successes.	**FL-16a.** FEMA should update dry floodproofing guidance.	CPCB, Economic
		FL-16b. FEMA should evaluate existing dry floodproofing guidance and post-flood investigations to develop a recommendation for inclusion in ASCE 24.	CPCB, Economic

ASCE = American Society of Civil Engineers
BOAF = Building Officials Association of Florida
CPCB = Community Planning and Capacity Building
CRS = Community Rating System (NFIP)
EOP = emergency operations plan
FBC = Florida Building Code
FDEM = Florida Division of Emergency Management
FEMA = Federal Emergency Management Agency
FHBA = Florida Home Builders Association
MAT = Mitigation Assessment Team
MH = manufactured housing
PEF = pressure equalization factor
SMAA = Statewide Mutual Aid Agreement

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Appendix C: Recovery Advisories

Dry Floodproofing: Operational Considerations

FEMA

HURRICANE IRMA IN FLORIDA *Recovery Advisory 1, May 2018*

Purpose and Intended Audience

The purpose of this advisory is to provide guidance on how to effectively implement dry floodproofing mitigation measures for non-residential structures. This Recovery Advisory incorporates observations made by the Federal Emergency Management Agency (FEMA) Mitigation Assessment Teams (MATs) in Texas and Florida after Hurricanes Harvey and Irma. It describes best practices and lessons learned about planning, preparation, and operations of dry floodproofing systems that can make facilities more resistant to disruption in future flood events. The information in this advisory is directed toward existing and new, non-residential facilities.

The guidance in this advisory, along with other FEMA publications related to dry floodproofing, should be used by building owners and design professionals to take action to limit the interruption of building services and flood damage to buildings. It will also be useful to communities and building owners preparing designs and proposals for FEMA Section 404 Hazard Mitigation grants and hazard mitigation elements included in recovery funding available through FEMA Section 406 Public Assistance.

The primary audience for this advisory includes building owners, operators, and managers; installers; and contractors, but may also be helpful for architects, engineers, various planners, as well as local government and building code officials involved with building planning, design, enforcement, operations, or maintenance. It will also be useful to communities and building owners preparing designs and proposals for FEMA hazard mitigation funding.

FEMA Public Assistance Program Funding for Dry Floodproofing Projects

In addition to funding for repair and recovery projects, FEMA Public Assistance (PA) Program funding may be available for cost-effective hazard mitigation measures that increase resilience, such as dry floodproofing projects. For more information, refer to Chapter 2 Section VII.C., “Hazard Mitigation” of FEMA’s *Public Assistance Program and Policy Guide* (2018).

Key Issues

- Some dry floodproofing systems were not regularly tested or properly maintained. When the systems were installed prior to the storm, several systems did not provide the intended level of protection.
- Some facilities lacked formal or written documentation on who, how, when, and where to deploy floodproofing systems, which resulted in time and energy wasted on a disorderly or partial deployment prior to the event.

This Recovery Advisory Addresses

- Observations related to dry floodproofing system operations
- Operations, maintenance, and testing plans for dry floodproofing systems
- Deployment considerations for active dry floodproofing
- Floodproofing considerations for a facility Emergency Operations Plan

A companion advisory, titled *Dry Floodproofing: Planning and Design Considerations* (Hurricane Harvey in Texas, TX-RA1, 2018), describes observations of system failures; flood vulnerability assessments; and planning and design considerations for dry floodproofing.

Observations Related to Dry Floodproofing System Operations

The floodwaters of Hurricanes Harvey and Irma tested passive and active dry floodproofing systems. Dry floodproofing involves using passive and active measures to seal a structure or area so floodwater cannot enter (see text box).

With the uncertainty surrounding the tracks of both storms and amount of flooding predicted from rainfall and storm surge, the planning, preparation, and installation of dry floodproofing systems was a timing and logistical challenge.

After Hurricanes Harvey and Irma, the MATs deployed by FEMA to evaluate building performance observed some best practices that enhanced response, such as the use of passive floodproofing systems that operated automatically with the rise of floodwater. However, the MATs observed other active measures that created significant challenges, such as systems that required a sizeable crew with heavy and specialized equipment to mobilize over a period of several days in advance of the storm to properly install the system.

The damage observed by the MATs illustrate that planning for dry floodproofing deployment is inconsistent, installation of dry floodproofing is not always effective, and even when installed, the level of effectiveness of the operation and implementation of dry floodproofing systems is variable.

Dry Floodproofing Systems

Active: Dry floodproofing systems that require human intervention to deploy the physical barrier and are effective only if there is enough warning time to mobilize the labor and equipment necessary to implement them and safely evacuate.

Passive: Dry floodproofing systems that do not require human intervention to deploy the physical barrier.

The image below (from Delaware, 2007) shows an example of an active dry floodproofing barrier installed at a commercial property.

Key Terminology

Flood Barrier: The physical barrier, composed of opening protection, floor slab, and wall system, that separates floodwater from the dry floodproofed portion of the building.

Opening Protection: A cover, shield, or door that covers a window, doorway, loading dock access, or other opening in a building wall or floor. Sometimes called a "closure device."

Floodwall: A constructed barrier of flood damage-resistant materials to keep water away from or out of a specific area. Floodwalls surround a building and are typically offset from the exterior walls of the building; some floodwalls can be integrated into the building envelope. Floodwalls are considered a component of the overall flood barrier.

Flood Entry Point: Any opening, joint, gap, crack, low point, or other location through or over which floodwater can enter.

Operations, Maintenance, and Testing Plans for Dry Floodproofing Systems

Both the American Society of Civil Engineers, *Standard for Flood Resistant Design and Construction* (ASCE 2014), and the National Flood Insurance Policy (NFIP) guidelines require that the operations, maintenance, and testing[1] plan of a dry floodproofing system be developed during the design of the system and regularly updated throughout the life of the building.

The procedures described in the operations, maintenance, and testing plan should be conducted annually and considered part of the long-term approach to maintaining the effectiveness of the building's flood protection system. The floodproofing components at installation locations should be inspected to evaluate system performance following any flood event and after any construction or demolition project in the building's vicinity. Periodic deployment drills (at least annually) should also be specified in the operations, maintenance, and testing plan. FEMA recommends that the operations, maintenance, and testing plan include the following items:

- A decision tree identifying responsible parties, a sequence and timeline by which various components will be installed, including identified triggers or benchmarks to initiate procedures
- A list of personnel, equipment, and supplies needed to deploy all system components
- A map of the equipment storage location and component deployment locations
- A record of the manufacturer or designer and their contact information for expediting replacement parts and support as needed
- A copy of the NFIP Floodproofing Certificate

In addition to the above-described elements of the operations, maintenance, and testing plan, the following should be considered. These are based on MAT observations of damage and interviews with building owners and managers after Hurricanes Harvey and Irma.

Size and weight. Consider the size and weight of individual dry floodproofing panels when choosing or designing a system and the openings they will cover

1 The terms "testing" and "exercising" are used interchangeably in this advisory although they may have different definitions for design professionals and emergency managers. Regular evaluation of how the dry floodproofing system performs (under practice and design flood conditions) can improve a facility's response to disruption in future flood events.

Applicable Codes

ASCE 24 (Section 6.2.3) describes implementation requirements and restrictions for dry floodproofing new buildings and when Substantial Improvements are made to existing buildings. Owners who want to dry floodproof existing buildings may also benefit from following the guidelines in this standard.

NFIP Floodproofing Certificate

The requirements of the NFIP Floodproofing Certificate are described in FEMA P-936 (1993) and should be understood before starting design. The NFIP Floodproofing Certificate requires compliance with ASCE 24 and is both a design and construction certification. Professional engineers and architects should read the Floodproofing Certificate in its entirety and the applicable sections of ASCE 24, FEMA P-936, and Technical Bulletin 3, "Non-Residential Floodproofing" (FEMA 1993), prior to signing it.

Responsible Parties

Deployment of dry floodproofing systems is a shared responsibility of the building owner or manager, installer (i.e., contracted or on-site staff), and possibly building occupants.

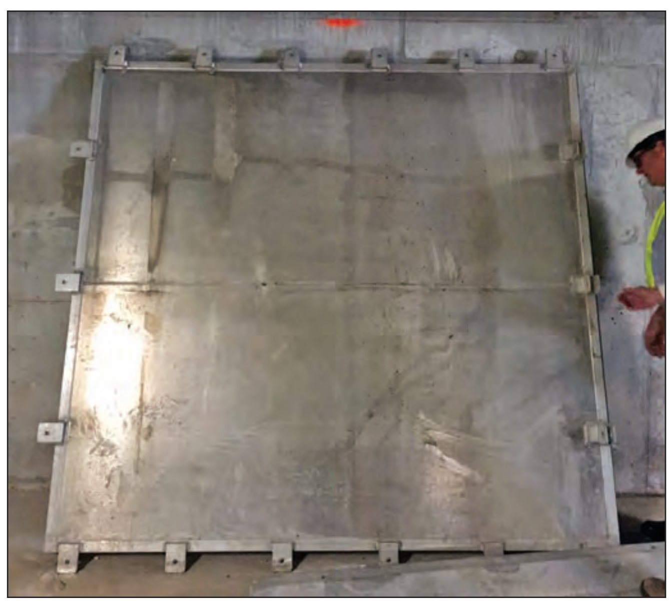

Figure 1: Large (6 feet high x 6 feet wide) metal flood panel requiring special equipment for installation

(Figure 1). If there are difficulties in installing large panels, consider approaches to improve the installation process. This may entail replacing the panel type with a passive floodproofing component or with a component that is easier to install.

System manufacturer. Flood protection systems should come from a reputable manufacturer and be consistent with a testing standard such as ANSI/FM 2510 that includes performance standards for hydrostatic test strength, system leakage, corrosion, and resistance to impact, wear, abrasion, tear, and puncture.

Storage. Determine an appropriate storage location for the dry floodproofing components, supplies, and equipment. Ensure the location is not open to the elements, as ultraviolet radiation and temperature extremes degrade rubber seals, gaskets, and component identification labels (Figure 2). Ensure this location is secure to prevent theft and vandalism, but is also accessible and labeled for the installer in case of deployment. On-site storage of floodproofing components is preferable. A separate location should be provided for spare parts.

All parts should be clearly labelled with permanent marker and a unique identification label that signifies its location when installed.

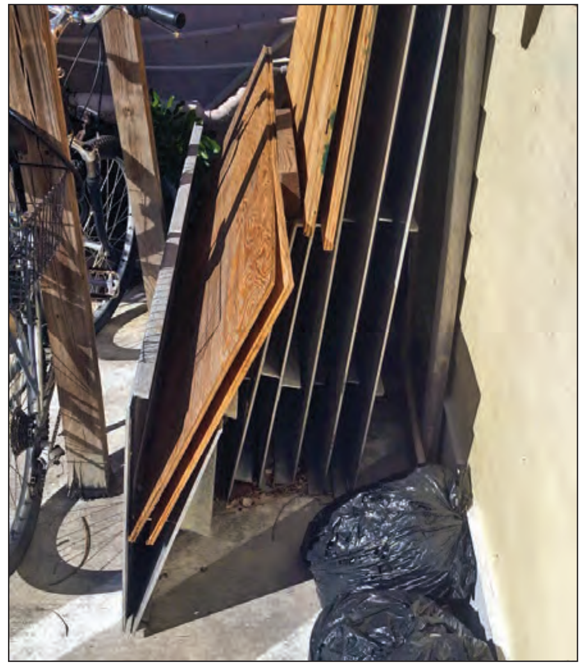

Figure 2: Flood panels (metal) and window shutters (plywood) were stored together outside a building. Panels and rubber gaskets were exposed to the elements; this storage practice is not recommended.

In-house versus contract staff. Assess the pros and cons of using contracted installers versus in-house staff. Ensure sufficient, trained staff will be available to implement the system prior to a flood event. Some dry floodproofing systems are installed by hired contractors who may be responsible for deploying systems at many sites across a city or region. Contract laborers may be limited in availability and timing in the days before an event.

Deployment drills. Conduct a deployment drill of the floodproofing system annually, or more frequently, as prescribed by the operations, maintenance, and testing plan, including testing all valves, sump pumps, power generators, and other drainage measures. An important task is to ensure that all valves or other drainage measures are clear of debris.

Figure 3: Torn gasket on metal flood panel after panel was removed. Gasket must be replaced before the next deployment.

During drills and tests, building operators should record the number of workers, the equipment needed, and the time it takes to install part or all of the system, and any perceived system deficiencies should be identified. Ensure that any staff member who may be called upon to install specific floodproofing measures participates in drills and is familiar with and able to implement the floodproofing system. Ensure that the deployment drill considers egress requirements for personnel who remain inside the building.

Regular inspection. Regularly inspect and maintain shields, doors, gates, pumps, equipment, gaskets, seals, brackets, panels, hardware, etc., and replace immediately if needed, to ensure system performance (Figure 3). Use the equipment list in the operations, maintenance, and testing plan to perform an annual accounting of all component and installation equipment.

Perform a building-wide inspection of all areas below the design flood elevation to check for penetrations in walls, floors, and ceilings, which are common sources of leakage during flood events. If not properly designed with seals able to withstand hydrostatic loads for their given locations, such penetrations can negate flood protection benefits afforded by any floodproofing systems.

Penetrations Below Design Flood Elevation

If any pipes, conduits, or ducts that penetrate below the design flood elevation cannot resist flood loads, a mitigation solution should be immediately identified and implemented. Refer to Hurricane Harvey Recovery Advisory TX-RA1 for more information about penetrations.

Wet-testing. Perform wet-testing of the floodproofing system every 5 years or after gasket replacement.

Water leak detection system. Install a water leak detection system behind the dry floodproofing system to allow remote monitoring to determine when passive systems are deployed and whether measures are performing as expected.

Provide labels. To discourage unnecessary penetrations, consider labeling the walls and slabs of a dry floodproofed area, including any flood barriers that are part of a building design (e.g., foundation walls) with "Dry Floodproofed: No Penetrations Below This Level;" the sign should indicate the design flood elevation on the wall (Figure 4). For any existing penetrations that are sealed with watertight components or assemblies, consider a similar marking or designation.

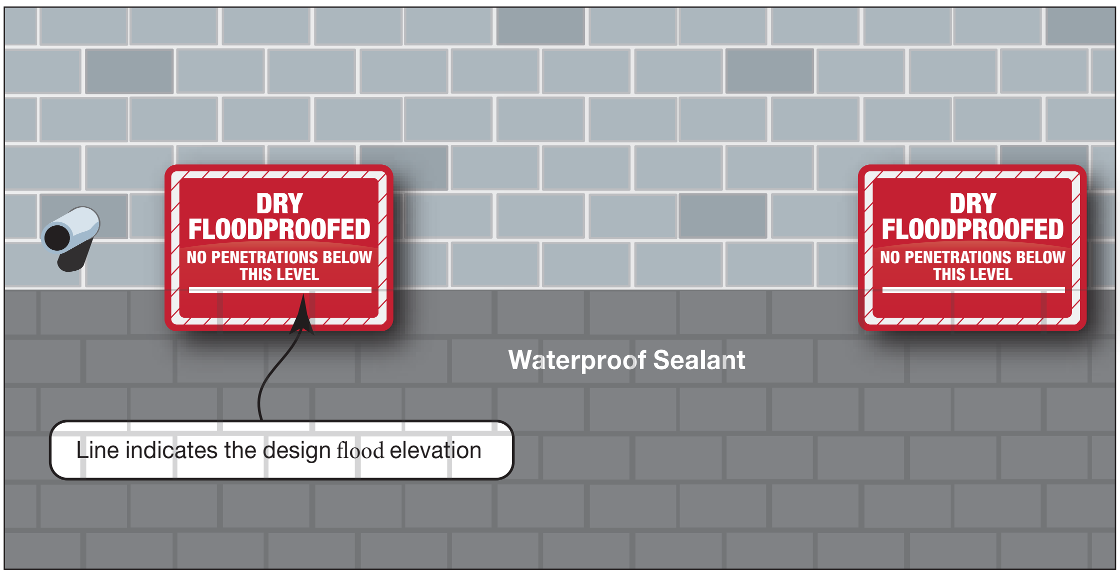

Figure 4: Example signage on a dry floodproofed wall spaced appropriately to maintain awareness

Deployment Considerations for Active Dry Floodproofing

Dry floodproofing measures should be activated once specifically identified triggers or benchmarks occur per the facility Emergency Operations Plan (refer to the following section). The following list includes common considerations to help building owners and operators effectively deploy their active dry floodproofing systems.

- Ensure that the appropriate building operations staff, installer, or municipality officials, if required, have copies of the operations, maintenance, and testing plan and the facility Emergency Operations Plan.
- Deploy all components specified by the operations, maintenance, and testing plan.
- Deploy in the order and at the locations specified in the operations, maintenance, and testing plan. Consider prioritizing locations that are more vulnerable or critical.
- Ensure that the dry floodproofing systems are installed correctly. Failure to install and tighten bolts, or repair/replace gaskets and seals as needed, can lead to leaks or floodproofing system failure.

- Verify that the system components required to install the dry floodproofing systems are stored together, as outlined in the operations, maintenance, and testing plan, with a separate area for spare parts (Figure 5).
- For individual flood components, verify that each component has retained its marking with its unique identification label that signifies its location when installed (Figure 6). Stickers and ink have a tendency to degrade over time, potentially leaving installers unsure of the proper sequence or location of the panels. Some manufacturers make flood panels with installation directions directly on the panel rather than in a separate document.

Figure 5: Enclosed storage space for multiple flood panels, stanchions, and hardware

- The map showing where the dry floodproofing components will be installed should be reviewed and made available, as needed.
- If the flood panel requires a gasket to be inflated with air to ensure a watertight seal, provide redundant methods to maintain inflation, such as a portable air tank or pump (Figure 7).

Figure 6: Installed flood panels. Each flood panel has a unique ID number. Also note the tightener bracket at top.

Figure 7: Flood gate with an air tank and a hand pump as a redundancy measure to inflate gaskets

Floodproofing Considerations for a Facility Emergency Operations Plan

Floodproofing considerations should be included in the facility's Emergency Operations Plan regardless of the size, scope, and complexity of the building(s). The scope and complexity of the floodproofing system and dry floodproofing measures will dictate the level of detail, phasing, and sequencing specified in the Emergency Operations Plan. It will also affect the equipment needed, number of personnel and time needed to install the system, maintenance requirements, appropriate training and exercising, and other issues. Flood-related considerations should address the process and timeline leading up to and during deployment, specific storm conditions that trigger deployment of floodproofing measures, and whether and how the system will be operated during the storm event. Specific additional emergency procedures should be developed for events larger than the design event.

> **Hurricane Irma Floodproofing Example**
>
> A building manager stated that a contractor had installed parts of the dry floodproofing system at one entrance of a building, but had not installed the required components at another building entrance. The result was that the first floor of the building flooded.

Pertinent information from the floodproofing system's operations, maintenance, and testing plan should be included in the floodproofing portion of the facility Emergency Operations Plan, as well as deployment considerations for active dry floodproofing measures (see previous subsections). Refer to Table 1 for details to evaluate when preparing the facility Emergency Operations Plan.

Building owners and operators should review and update the floodproofing portions of their facility Emergency Operations Plan on an annual basis (e.g., after hurricane or rainy season), and after each time the facility's floodproofing system is deployed. Pertinent information related to storm observations, system performance, damage to the floodproofing system, or any perceived system weaknesses or deficiencies should be recorded in both the facility Emergency Operations Plan and the operations, maintenance, and testing plan.

The building owners and operators should ensure that the facility Emergency Operations Plan and operations, maintenance, and testing plan are accessible to appropriate building operations staff, installer, or municipality, if required, and are forwarded as part of any workplace transition to maintain institutional continuity.

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan

Considerations	Details to Evaluate
Standby Power	• How long will emergency generators supply power for the sump pump system and other building systems without an off-site fuel delivery? • Will emergency generators be accessible during the flood event and equipped to operate during a flood event? • Will fuel delivery be hindered by the implemented dry floodproofing? • Are redundancy measures such as backup connections to other generators needed?
Prior to Event	• Who makes the decision to initiate mobilization and deployment of the floodproofing system? When will it occur based on warning time and expected flood conditions? • Is the facility Emergency Operations Plan permanently posted in at least two conspicuous locations? • What staff or contractors will be needed (e.g., maintenance staff, building engineer, contractors, installers) to retrieve and install active dry floodproofing components? • How many days prior to an event will personnel be mobilized? • How will personnel, equipment, and components be staged or phased? • Where are the storage location(s) and deployment location(s) of all necessary equipment? • How long will it take to deploy or activate the floodproofing system? • What is the system's design flood elevation? What is the expected flood depth?

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan (concluded)

Considerations	Details to Evaluate
Evacuation*	• Under what conditions will the building be evacuated? • Who will make the decision to evacuate the building in advance of or during a flood event? • Which points are designated as egresses or emergency openings and are they clearly marked? • Does the means of egress allow the floodproofing measures to remain in place? • How does the facility Emergency Operations Plan account for building evacuation timing and sequencing?
Building Occupancy During Event*	• Will the building be occupied during a flood event? If yes, then by whom (e.g., maintenance staff, employees, tenants)? What will their role be, if any, in deploying and operating the dry floodproofing system? • What will the occupants require in the event of an emergency (e.g., food, water, shelter)? How will supplies be stockpiled and how will operations continue during the event? • Will implemented dry floodproofing measures disrupt operations?
After the Event	• What staff or contractors will be needed for cleanup, debris management, removal of floodproofing equipment, and inspection of floodproofing equipment performance? • How long will it take to resume normal operations?

* FEMA recommends evacuating a building before a flood event whenever possible. Building owners and operators should evacuate in accordance with state and local government orders or notices. For unique situations that may require critical personnel to remain behind, advanced coordination and planning should occur with the local government so that emergency and government personnel can plan accordingly for their jurisdictional emergency operations plan.

References and Resources

References

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FEMA (Federal Emergency Management Agency). 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93. https://www.fema.gov/media-library/assets/documents/3473.

FEMA 2013. *Floodproofing Non-Residential Structures.* FEMA P-936. https://www.fema.gov/media-library/assets/documents/34270.

Resources

ASCE. 2016. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-16.

ASFPM (Association of State Floodplain Managers). n.d. "National Flood Barrier Testing & Certification Program." http://www.nationalfloodbarrier.org.

FEMA. 2017. *Protecting Building Utility Systems from Flood Damage.* FEMA P-348. https://www.fema.gov/media-library/assets/documents/3729.

Risk Management Series publications listed below are available at https://www.fema.gov/security-risk-management-series-publications.

- FEMA. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds.* FEMA P-543.

- FEMA. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds.* FEMA P-577.
- FEMA. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds.* FEMA P-424.

Technical Bulletins listed below are available at https://www.fema.gov/media-library/collections/4.

- FEMA. 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93.
- FEMA. 1993. *Wet Floodproofing Requirements.* Technical Bulletin 7-93.
- FEMA. 2008. *Flood Damage-Resistant Materials Requirements.* Technical Bulletin 2.

Recovery Advisories for Hurricane Sandy listed below are available at https://www.fema.gov/media-library/assets/documents/30966.

- FEMA. 2013. *Reducing Flood Effects in Critical Facilities.* Hurricane Sandy RA2.
- FEMA. 2013. *Reducing Interruptions to Mid- and High-Rise Buildings During Floods.* Hurricane Sandy RA4.
- FEMA. 2013. *Designing for Flood Levels Above the BFE After Hurricane Sandy.* Hurricane Sandy RA5.

Recovery Advisories from the 2016 Fall Flooding in Iowa listed below are available at https://www.fema.gov/media-library/assets/documents/130555.

- FEMA. 2017. *Flood Protection for Critical and Essential Facilities.* 2016 Fall Flooding in Iowa RA3.
- FEMA. 2017. *Flood Protection and Elevation of Building Utilities.* 2016 Fall Flooding in Iowa RA4.
- FEMA. 2017. *Flood Protection for Backup and Emergency Power Fuel Systems.* 2016 Fall Flooding in Iowa RA5.

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions-building-science.

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Soffit Installation in Florida

HURRICANE IRMA IN FLORIDA

Recovery Advisory 2, May 2018

Purpose and Intended Audience

This Recovery Advisory provides soffit installation guidance and resources to meet or exceed minimum provisions of the 6th Edition (2017) Florida Building Code, Residential (FBCR). The primary audience for this advisory includes contractors and homeowners, but may also be helpful for building officials and design professionals.

Key Issues

- Wind-damaged soffits allowed wind-driven rain to enter building envelopes, resulting in costly damage to building interiors.
- While some water was blown into attics through soffit vents, the amount of water intrusion increased dramatically when the soffit material was missing (Figure 1).
- Need for clarification of how to meet the 6th Edition (2017) FBCR soffit installation criteria.

This Recovery Advisory Addresses

- Soffit design wind loads and installation in the Florida Building Code
- Installing the soffit

Soffit Design Wind Loads and Installation in the Florida Building Code

Compliance with the 6th Edition (2017) of the Florida Building Code (FBC) is required throughout the state for building permits issued after December 31, 2017, including projects to repair and rebuild Hurricane Irma damage. One- and two-family dwellings are covered under the scope of the FBCR. Soffit provisions in the 6th Edition (2017) of FBCR were updated from the previous (5th) edition as follows:

1. In the 6th Edition (2017) FBCR Component and Cladding Load Table R301.2(2), design wind pressures are tabulated as Allowable Stress Design (ASD)-level values. The 5th Edition (2014) FBCR tabulated strength design-level

Florida Building Code and International Code Council Codes

The 2015 International Residential Code (IRC) serves as the base code for the 6th Edition (2017) FBCR. Florida-specific amendments are added through the state's established code development process. The Florida Building Codes can be viewed for free through the "Public Access" option on the ICC website: https://codes.iccsafe.org/public/collections/FL.

Figure 1: Vinyl soffit damage on a home in Sugarloaf Key

Soffit Vents

Refer to the 6th Edition (2017) of FBCR Section R806 for roof venting provisions. To avoid water entry at soffit vents, options include eliminating soffit vents and providing an alternate method for air to enter the attic, or designing for an unvented attic. Another approach is to place filter fabric (like that used for heating, ventilation, or air conditioning system filters) above the vent openings; however, such an approach needs to be custom designed. For additional guidance on mitigating water intrusion through attic vents and strengthening undamaged soffits, refer to Technical Fact Sheet No. 7.5, "Minimizing Water Intrusion Through Roof Vents in High-Wind Regions" in FEMA P-499, *Homebuilder's Guide to Coastal Construction* (FEMA 2010).

wind pressures and included a note that permitted the values to be multiplied by 0.6 for ASD. Since component and cladding products are rated using ASD wind pressures, the 6th Edition table values should be easier to use than the previous edition's.

2. The effective wind area for soffit design pressures is specified as 10 square feet. The clarification simplifies soffit load determination. Unlike Table R301.2(2) in the FBCR, Table 1 on page 3 of this advisory is further simplified for soffit applications and only includes design pressures for effective wind areas of 10 square feet.

Installing the Soffit

Meeting the 6th Edition (2017) FBCR soffit installation criteria requires determining (1) the site- and location-specific wind loads that soffits must resist, and (2) which soffit assemblies are rated and approved to meet the wind load demand, and how the chosen soffit assembly must be installed to perform as designed.

> **FBCR Soffit Installation Provision**
>
> The following Chapter 7 (Wall Covering) provisions specifically address soffit installation:
>
> **R703.1.2.1 Wind resistance of soffits:** Soffits and their attachments shall be capable of resisting wind loads specified in Tables R301.2(2) and R301.2(3) for walls using an effective wind area of 10 square feet.
>
> **R703.11.1.4 Vinyl soffit panels:** Soffit panels shall be individually fastened to a supporting component such as a nailing strip, fascia or subfascia component or as specified by the manufacturer's instructions.
>
> Source: 6th Edition (2017) FBCR

Step 1: Determine the Wind Loads

Follow the steps below to find minimum soffit wind loads (pressures) in accordance with the 2017 FBCR.

1. Determine location- and site-specific factors that affect the soffit wind pressures.

   a. **Design wind speed:** Find location-specific design wind speeds in Figure R301.2(4) of the 6th Edition (2017) FBCR. Wind speeds for specific addresses and latitude/longitude can be found at http://windspeed.atcouncil.org or https://asce7hazardtool.online/. For one- and two-family dwellings, select wind speeds given for ASCE 7-10, Risk Category II.

   b. **Exposure category:** Check with your local building official to determine site-specific exposure category (B, C, or D) in accordance with the 6th Edition (2017) FBCR Section 301.2.1.4.3. Keep in mind that exposure category can vary within individual neighborhoods because it is related to the terrain that surrounds the building.

   c. **Mean roof height:** Determine the mean roof height (MRH) in accordance with the 6th Edition (2017) FBCR Section R202 definition: "The average of the roof eave height and the height to the highest point on the roof surface, except that eave height shall be used for a roof angle of less than or equal to 10 degrees." Refer to Figure 2 for clarification.

2. Using the site-specific wind speed determined in Step 1a, find the Zone 4 and Zone 5 pressures using Table 1.

   Zone 5 wind pressures apply to soffit surfaces within 4 feet of wall corners, and Zone 4 wind pressures apply to all other areas. The selected soffit system must resist the building's highest (Zone 5) wind pressures, so calculating Zone 4 pressures will not be necessary for many assemblies (refer to Figure R301.2(7)).

3. Modify the wind pressure(s) for the specific wind zone, as determined in Step 2, for factors determined in Steps 1b and 1c.

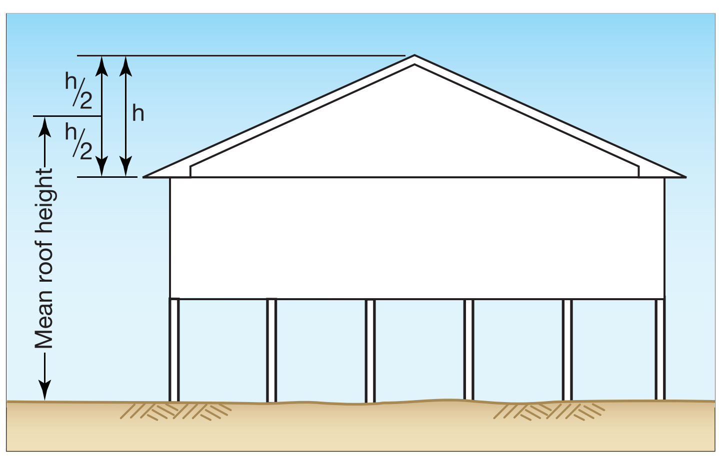

Figure 2: Illustration showing how to determine the MRH

To do this, multiply wind pressure values by the coefficients in Table 2 as needed to adjust for exposure categories other than B and MRHs other than 30 feet. For MRHs between those given in Table 2, use the value assigned to the higher MRH or interpolate between the higher and lower values.

4. Select a soffit system rated to resist Zone 5 pressures determined in Step 3.

   In some cases, such as the prescriptive wood structural panel soffit, the soffit attachment schedule may be reduced for (lesser) Zone 4 pressures where soffit sections are 4 feet or more from building corners. Follow material-specific guidance in Step 2 of this advisory to ensure compliant application.

Table 1: Soffit Positive and Negative Pressures (Pounds per Square Foot) for Zones 4 and 5 with MRH=30 feet, Exposure B

	115 mph	120 mph	130 mph	140 mph	150 mph	160 mph	170 mph	180 mph
Zone 4	-15.0	-16.0	-19.0	-22.0	-26.0	-30.0	-33.0	-37.9
	14.3	15.5	18.2	21.2	24.3	27.7	31.2	35.0
Zone 5	14.3	-20.0	-24.0	-28.0	-32.0	-37.0	-41.0	-46.8
	-19.0	15.5	18.2	21.2	24.3	27.7	31.2	35.0

Source: Table R301.2(2) in the FBCR, abbreviated to address Florida-specific wind speeds and wall zones only; available at https://codes.iccsafe.org/public/collections/FL.

Table 2: Height and Exposure Adjustment Coefficients for Soffit Pressure

Mean Roof Height (feet)	Exposure B	Exposure C	Exposure D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

Source: Table R301.2(3) in the FBCR available at https://codes.iccsafe.org/public/collections/FL.

Step 2: Material-Specific Soffit Installation

Whether or not a soffit installation is code-compliant depends on both the material and product. In Florida, manufactured soffit products must be approved as described in the text box titled "Florida Product Approval" because they are part of the building envelope and included under the "panel walls" product category. As such, selecting manufactured soffit products with up-to-date Florida product approval is the first required step for most soffit installations. Alternately, wood structural panel soffits may be assembled and installed on site to resist the wind pressures determined in Step 1 using the prescriptive approach described at the end of this section.

Soffit system support and corrosion resistance. Regardless of whether the chosen soffit system is manufactured or assembled prescriptively using wood structural panels, soffit system support and the corrosion resistance of the soffit fasteners must be addressed. Section 802 of the 6th Edition (2017) FBCR and Section 3.5 of the 2015 Edition Wood Frame Construction Manual provides requirements for ceiling joists, rafter overhangs, rake overhangs, and outlookers that support soffit systems. Section R703.3.2 of the 6th Edition (2017) FBCR requires corrosion-resistant wall covering fasteners in accordance with manufacturer's installation instructions. Refer to Note 1 of Table 3 for guidance on corrosion protection specific to wood structural panel soffits.

Florida Product Approval

Rule 61G20-3 of the Florida Administrative Code applies to products and systems that comprise the building envelope and structural frame. The rule requires the following products to have product approval for compliance with the structural requirements of the Florida Building Code:

- Panel walls
- Exterior doors
- Roofing products
- Skylights
- Windows
- Shutters
- Structural components
- Impact protective systems

Products may be approved using either the optional statewide product approval system or local product approval. Regardless of the method used, products have to be evaluated for compliance (evaluation report, certification, test report, etc.), be validated for compliance with the evaluation, and approved by the Florida Building Commission. For additional information on product approval in the State of Florida, see Rule 61G20-3 of the Florida Administrative Code or the Building Code Information System at http://www.floridabuilding.org administered by the Florida Department of Business and Professional Regulation. A database of products approved using the statewide product approval system can be found under the "Product Approval" tab at http://www.floridabuilding.org.

Navigating the Florida Approval Website to Find Approved Products for Your Location

1. Link to the main page: http://www.floridabuilding.org
2. Select the "Product Approval" option from the left margin
3. From the Product Approval menu, select "Find a Product or Application"
4. From the "Category" pull-down options, select "Panel Walls"
5. From the "Subcategory" pull-down options, select "Soffits"
6. For "Application Status," select "Approved"
7. If in Broward or Miami-Dade Counties, select "Yes" from "Approved for use in HVHZ"
8. Click on "Search"
9. Select any given listing to determine allowable "Design Pressure" and installation instructions

In some cases, allowable design pressures are shown in "Summary of Products" at the bottom of the page. In other cases, it is necessary to open the Evaluation Report(s) or Installation Instructions linked in the right column of "Summary" for design pressures.

Since fastener vulnerability to corrosion varies with location, check with your local building official for any specific requirements or guidelines. For further recommendations on corrosion-resistant connectors, see Table 1 in the National Flood Insurance Program Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas* (FEMA 1996).

Manufactured soffit systems. Since February 2018, the Florida Product Approval website has listed approved soffit assemblies for vinyl, metal (aluminum and steel), fiber cement, and engineered wood assemblies.

To find the rated design pressures approved for each product, refer to the evaluation report and/or the installation instructions linked at the bottom of each product page. Only soffit panels that have been rated to meet or exceed the wind pressures determined for the specific location and site should be installed. See the text box for Florida Product Approval website navigation tips.

When selecting soffit systems from the Florida Product Approval website that meet the wind pressure loading for your building, note that individual product installation instructions vary with respect to the information and level of detail provided. Review the installation instructions on the Florida Product Approval website for any prospective product prior to purchasing while considering the following:

- When determining soffit pressure resistance from the evaluation report or installation instructions, select "Allowable Design Load," not "Ultimate Load." If needed, Ultimate Loads can be converted to Allowable Design Loads by multiplying values by 0.6.
- Check whether the installation instructions have sufficient detail needed to install and inspect the soffits. In cases where blocking or substrate size and/or attachment to framing indicates "by others" or "per project requirements," the details will need to be specified and sealed by a professional engineer licensed in Florida for site-specific loads.
- Ensure that the installation instructions include all referenced details needed for the chosen design pressure application.

Wood structural panel, closed soffit. As an alternative to manufactured soffit systems, wood structural panel soffits may be prescriptively installed to resist the location- and site-specific wind pressures determined in Step 1.

Where the design pressure is 30 pounds per square foot (psf) or less, wood structural panel soffits should be a minimum of 3/8 inch in thickness and fastened to framing or nailing strips with a minimum of 6d box nails (2-inch x 0.099-inch x 0.266-inch head diameter [flat head]) spaced not more than 6 inches on center at panel edges and 12 inches on center at intermediate supports.

For design pressures greater than 30 psf, refer to Table 3 for modified panel thickness, fastener type, size, and spacing. See Figure 3 for a detail of a wood structural panel, closed soffit.

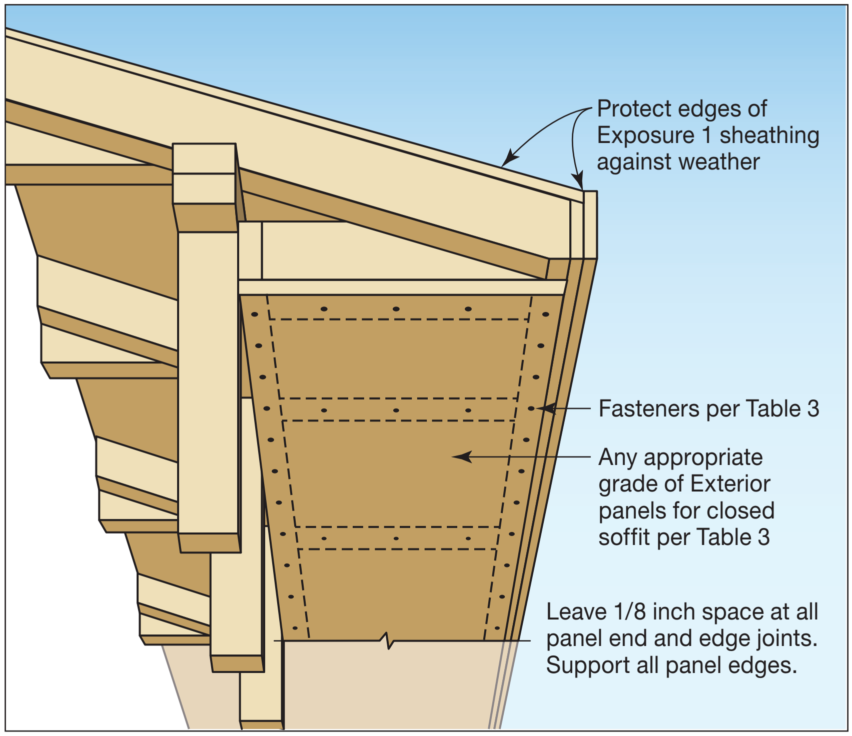

Figure 3: Detail of wood structural panel, closed soffit

Wood Structural Panel Sheathing

Wood structural panel sheathing is manufactured with span ratings of 12/0, 16/0, 20/0, 24/0, 24/16, 32/16, 40/20, and 48/24, in performance categories ranging from 5/16 to 3/4, and in two bond classifications: Exterior and Exposure 1.

Span ratings appear as two numbers separated by a slash, such as 32/16, 48/24, etc. The left-hand number denotes the maximum recommended spacing of supports when the panel is used for roof sheathing with the strength axis of the panel across three or more supports (two or more spans). The right-hand number denotes the maximum recommended spacing of supports when the panel is used for subflooring with the strength axis of the panel across three or more supports (two or more spans). A panel marked 32/16, for example, may be used for roof decking over supports up to 32 inches on center or for subflooring over supports up to 16 inches on center.

Source: APA, http://www.wooduniversity.org/glossary

Table 3: Installation Information for Wood Structural Panel, Closed Soffit

Maximum Design Pressure (- or + psf)	Minimum Nominal Panel Thickness (inch)	Nail Type and Size (inch)	Fastener Spacing along Supports (inch)	
			Galvanized Steel	Stainless Steel
40	3/8	6d box (2 x 0.099 x 0.266 head diameter)	6	4
50	3/8	6d box (2 x 0.099 x 0.266 head diameter)	4	4
		8d common (2½ x 0.131 x 0.281 head diameter)	6	6
60	3/8	6d box (2 x 0.099 x 0.266 head diameter)	4	3
		8d common (2½ x 0.131 x 0.281 head diameter)	6	4
70	7/16	8d common (2½ x 0.131 x 0.281 head diameter)	4	4
		10d box (3 x 0.128 x 0.312 head diameter)	6	4
80	7/16	8d common (2½ x 0.131 x 0.281 head diameter)	4	4
		10d box (3 x 0.128 x 0.312 head diameter)	6	4
90	15/32	8d common (2½ x 0.131 x 0.281 head diameter)	4	3
		10d common (3 x 0.148 x 0.312 head diameter)	6	4

Notes:

1: Fastener spacing for galvanized steel nails can be larger than for stainless steel nails of the same diameter and length because galvanized steel nails have better withdrawal resistance from wood. Hot-dip galvanized steel nails or stainless steel nails are recommended in coastal areas.

2: Maximum spacing of soffit framing members = 24 inches; tabulated values assume minimum two-span continuous condition.

3: Only exterior panels should be used for closed soffits. To achieve pressure values shown in Table 3, panels must be installed with strong axis across supports. A 3/8-inch, 7/16-inch, and 15/32-inch minimum nominal panel thickness is associated with minimum panel span ratings (e.g., panel grade) of 24/0, 24/16, and 32/16, respectively.

4: Tabulated nail spacing assumes sheathing is attached to soffit framing members with a specific gravity of at least 0.42, which includes the following species combinations: spruce-pine-fir, hem-fir, Douglas-fir-larch, and southern pine.

Source: Table adapted from data available in *National Design Specifications for Wood Construction* (AWC 2015) and *Special Design Provisions for Wind & Seismic* (AWC 2015).

References and Useful Links

References

ASCE (American Society of Civil Engineers). 2010. ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*.

AWC (American Wood Council). 2015. *National Design Specifications for Wood Construction*. http://www.awc.org/pdf/codes-standards/publications/nds/AWC-NDS2015-ViewOnly-1603.pdf?_sm_au_=iVV06qrjPvPZPnZj.

AWC. 2015. *Special Design Provisions for Wind & Seismic*. http://www.awc.org/pdf/codes-standards/publications/sdpws/AWC-SDPWS2015-ViewOnly-1508.pdf.

AWC. 2015. *Wood Frame Construction Manual for One- and Two-Family Dwellings*. http://www.awc.org/pdf/codes-standards/publications/wfcm/AWC-WFCM2015-ViewOnly-1510.pdf.

FEMA (Federal Emergency Management Agency). 1996. Technical Bulletin 8, *Corrosion Protection of Metal Connectors in Coastal Areas.* https://www.fema.gov/media-library/assets/documents/3509.

FEMA. 2010. *Home Builder's Guide to Coastal Construction.* FEMA P-499. https://www.fema.gov/media-library/assets/documents/6131.

Useful Links

"Florida Building Codes." Florida Department of Business & Professional Regulation (DBPR). Link: https://www.floridabuilding.org/bc/bc_default.aspx.

"APA Glossary." WoodUniversity.Org. Link: https://www.wooduniversity.org/glossary.

"APA Help Desk." WoodUniversity.Org. Link: https://www.apawood.org/help.

"Hazards by Location." Applied Technology Council. Link: https://hazards.atcouncil.org/.

"ASCE 7 Hazard Tool." American Society of Civil Engineers (ASCE). Link: https://asce7hazardtool.online/.

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions-building-science.

If you have any additional questions on FEMA Building Science Publications, contact the helpline at FEMA-Buildingsciencehelp@fema.dhs.gov or 866-927-2104.

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Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code

FEMA

HURRICANE IRMA IN FLORIDA *Recovery Advisory 3, May 2018*

Purpose and Intended Audience

This Recovery Advisory provides guidance on wind mitigation triggers for roof repairs and replacement in the 6th Edition (2017) Florida Building Code (FBC). The information in this advisory is particularly pertinent to repairs and rebuilding in areas of Florida recovering from Hurricane Irma. However, this information applies generally throughout Florida. The primary audience for this advisory includes building owners, operators, and managers; design professionals; building officials; contractors; and municipal building and planning officials.

The guidance in this advisory should be incorporated or referenced to help in the development of repair scopes of work and/or hazard mitigation proposals for FEMA Section 406 Public Assistance grants or used by designers and various stakeholders for other projects. Relevant guidelines and codes are listed in the text boxes to the right.

Key Issues

- Damage requiring reroofing or roof repairs to withstand future events
- Need for clarification of the applicability of the 25% Rule in the FBC for reconstruction
- Need for clarification of mitigation actions required when a roof covering is replaced or repaired in Florida

This Recovery Advisory Addresses

- Roof repairs
- Residential wind mitigation
- Commercial wind mitigation

Roof Repairs

Building codes have historically required reroofing to meet the same requirements as new construction but permitted repairs to be made using like materials, provided no dangerous or unsafe condition was created by using such materials. However, as a result of the damage caused by the hurricanes of 2004, the FBC adopted several wind mitigation measures that apply when roofs are replaced or repaired. These provisions recognize that with the roof covering removed, upgrades and improvements to the resistance of the roof assembly (underlayment, roof decking, roof-to-wall connections) to wind loads and water penetration are more easily performed.

FEMA Public Assistance Program and Policy Guide

See Section VII, "Permanent Work Eligibility" in FEMA's Public Assistance Program and Policy Guide (FEMA 2018).

Florida Building Code

- Florida Building Code, Building (FBCB)
- Florida Building Code, Residential (FBCR)
- Florida Building Code, Existing Building (FBCEB)

Florida Building Code Definitions

High-Velocity Hurricane Zones (HVHZ): The HVHZ consists of Broward and Dade Counties.

Reroofing: The process of recovering or replacing an existing roof covering.

Roof Repair: Reconstruction or renewal of any part of an existing roof for the purposes of its maintenance.

Roof Replacement: The process of removing the existing roof covering, repairing any damaged substrate, and installing a new roof covering.

Source: 6th Edition (2017) FBC

FBC 25% Rule. The FBC limits how much of an existing roof can be repaired within a specific period of time before triggering the requirement to comply with the latest code, often referred to as the "25% Rule." The 25% Rule has applied to construction in South Florida as far back as the 1957 South Florida Building Code. In the 2001 and 2004 FBC, the 25% Rule only applied to buildings within a High-Velocity Hurricane Zone (HVHZ). In the 2007 FBC, the rule was modified slightly and adopted to be applicable to the rest of Florida. The applicability of the 25% Rule has differed somewhat for buildings within and outside the HVHZ, with changes made between the 5th Edition (2014) and 6th Edition (2017), as described below.

5th Edition (2014) FBC. The 5th Edition (2014) versions of the rule are as follows:

- Areas outside the HVHZ: "Not more than 25 percent of the total roof area or roof section of any existing building or structure shall be repaired, replaced or recovered in any 12-month period unless the entire roofing system or roof section **conforms** to requirements of this code" (Section 708.1.1, FBCEB 2014).
- Areas within the HVHZ: "Not more than 25 percent of the total roof area or roof section of any existing building or structure shall be repaired, replaced or recovered in any 12-month period unless the entire existing roofing system or roof section **is replaced to conform** to requirements of this code" (Section 1521.4, FBCB 2014).

The distinction is that for areas outside the HVHZ, if more than 25 percent of the total roof area or roof section had to be repaired, replaced, or recovered in any 12-month period, the remainder of the roof only had to be replaced if it did not conform to the requirement of the current code. For areas in the HVHZ, if more than 25 percent of the total roof area or roof section had to be repaired, replaced, or recovered in any 12-month period, the remainder of the roof or roof section had to be replaced to conform to the requirements of the code, regardless of whether it complied with the current code.

6th Edition (2017) FBC. In the 6th Edition (2017) FBC, the 25% Rule was revised for areas outside the HVHZ to make it consistent with how it is applied in the HVHZ. Therefore, if more than 25 percent of the total roof area or roof section has to be replaced or recovered in any 12-month period, the 6th Edition (2017) FBC requires the remainder of the roof or roof section to be replaced to conform to the requirements of the code, regardless of whether it complies with the current code (see FBCR Section R908.1.1, FBCB Sections 1511.1 and 1521.4, and FBCEB Section 706.1.1).

Roof Sections: If a building roof contains multiple levels or is divided by, for example, parapet walls or expansion joints, each area is considered an individual roof section when applying the 25% Rule. Therefore, in accordance with the 6th Edition (2017) of the FBC, if more than 25 percent of the total roof area or roof section of a building has to be repaired or replaced, the entire roof or roof section has to be replaced to conform to the requirements of the code. Figures 1 and 2 show examples of roof sections on two different buildings.

Florida Building Code Definitions

Roof Section: A separation or division of a roof area by existing joints, parapet walls, flashing (excluding valleys), difference of elevation (excluding hips and ridges), roof type, or legal description, not including the roof area required for a proper tie-off with an existing system.

Source: 6th Edition (2017) FBC

Figure 1: Example of residential building with two roof sections

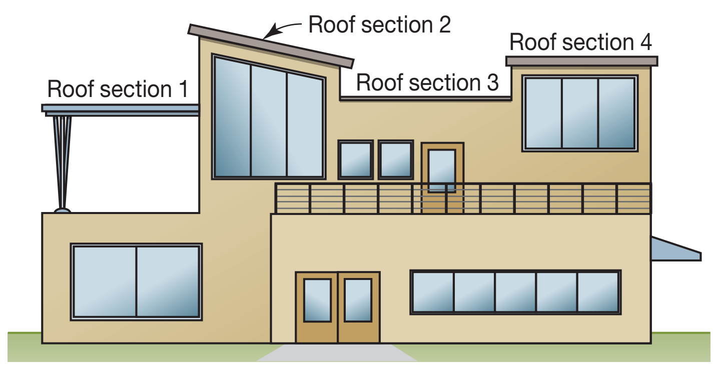

Figure 2: Example of non-residential building with four roof sections

Residential Wind Mitigation

When a roof covering system on a single-family dwelling is removed and replaced, the 6th Edition (2017) FBCR requires the following components to be investigated and subsequent measures to be taken if deficiencies are found:

- **Roof deck attachment** – Several options are provided for improving the roof deck attachment.
- **Enhanced underlayment (secondary water barriers)** – Since the underlayment requirements for new construction have been improved, the secondary water barrier requirements now simply reference the applicable underlayment table for new construction.
- **Roof-to-wall connections** – Improvements to roof-to-wall connections are covered in Section R908.8.

As indicated in the text box titled "FBCR Wind Mitigation Requirements," single-family residential structures permitted subject to the Florida Building Code are exempt from the residential wind mitigation requirements. The phrase "permitted subject to the Florida Building Code" means a building permitted to any version of the Florida Building Code (2001, 2004, 2007, 2010, 5th Edition [2014], or 6th Edition [2017]).

Additionally, the FBCR and FBCEB permit the investigation of the roof decking and any mitigation measures taken to be performed by a roofing contractor.

FBCR Wind Mitigation Requirements

R908.7: When a roof covering on an existing site-built single-family residential structure is removed and replaced, the following procedures shall be permitted to be performed by the roofing contractor:

- Roof-decking attachment shall be as required by Section R908.7.1.
- A secondary water barrier shall be provided as required by Section R908.7.2.

Exception: Single-family residential structures permitted subject to the Florida Building Code are not required to comply with this section.

Source: 6th Edition (2017) FBCR

Roof Deck Attachment

An evaluation of the existing roof deck fastening is required to determine if mitigation is required. If the existing connections are found to be insufficient, specific supplemental fasteners are required at specific spacings. Supplemental fasteners must be ASTM F1667 RSRS-01 ring shank nails with the minimum dimensions specified in the FBCEB and FBCR. The number and minimum spacing of supplemental fasteners depend on the spacing of the existing fasteners as specified in Table R908.7.1.2 of the FBCR and shown in Table 1. Figure 3 is an illustration of a roof decking showing where supplemental fasteners are required and the required spacing.

Table 1: Supplemental Fasteners at Panel Edges and Intermediate Framing (FBCR)

Existing Fasteners	Existing Spacing	V_{asd} 110 mph or Less Supplemental Fastener Spacing Shall Be No Greater Than	V_{asd} Greater Than 110 mph Supplemental Fastener Spacing Shall Be No Greater Than
Staples or 6d	Any	6 inches on center [b]	6 inches on center [b]
8d clipped head, round head, smooth or ring shank	6 inches on center or less	None necessary	None necessary
8d clipped head, round head, smooth or ring shank	Greater than 6 inches on center	6 inches on center [a]	6 inches on center [a]

a. Maximum spacing determined based on existing fasteners and supplemental fasteners.

b. Maximum spacing determined based on supplemental fasteners only.

Note: V_{asd} (nominal wind speed per FBC) shall be determined in accordance with Section 1609.3.1 of the Florida Building Code, Building or Section R301.2.1.3 of the Florida Building Code, Residential.

Source: Table R908.7.1.2 in the FBCR, modified slightly to define terms, available at https://www.floridabuilding.org

Florida Building Code Wind Speeds

Wind Speed, V_{ult}: Ultimate design wind speeds. V_{ult} is determined from the wind speed maps.

Wind Speed, V_{asd}: Nominal design wind speeds. V_{asd} is determined by multiplying V_{ult} by $\sqrt{0.6}$.

Source: 6th Edition (2017) FBC

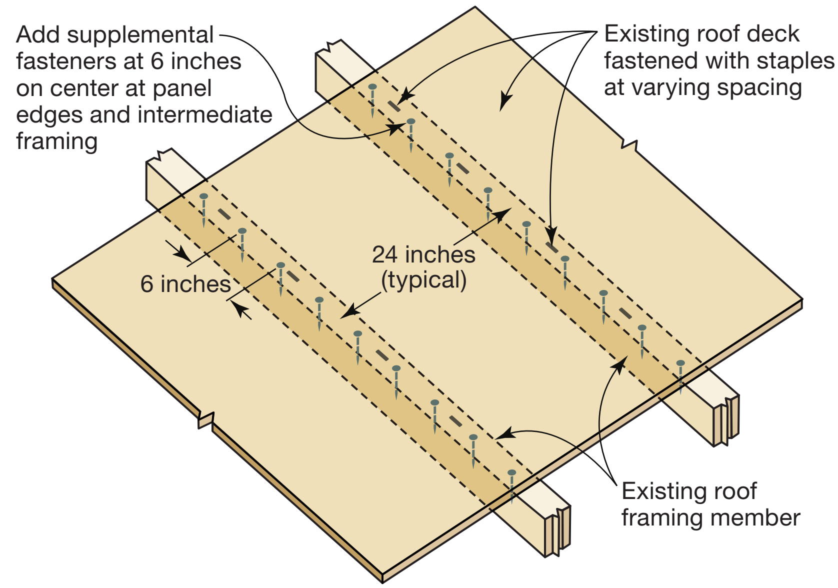

Figure 3: Example of roof decking showing placement and spacing of supplemental roof deck fasteners

Secondary Water Barriers

Criteria for the required secondary water barrier are addressed in Section R908.7.2 of the FBCR. Provisions for areas within and outside the HVHZ are provided separately; while the requirements for within and outside the HVHZ are generally similar, there are subtle differences. Additionally, the requirements also differ slightly depending on the type of roof covering being installed. Table 2 summarizes what qualifies as a secondary water barrier for asphalt shingle roofs that are removed and replaced in the HVHZ and outside the HVHZ.

Table 2: Summary of Secondary Water Barrier Options for Asphalt Shingle Roofs

Roof Slope	Material	Details
Within High-Velocity Hurricane Zones		
2:12 and greater	Approved asphalt impregnated 30# felt underlayment or approved synthetic underlayment (ASTM D226 Type II or ASTM D4869 Type IV)	• Single layer with 4-inch side lap • 6-inch end laps • Metal cap nails with a cap diameter of not less than 1-5/8 inches but no more than 2 inches and thickness of 32-gage sheet metal • Nails are required to be minimum 12 gauge, annular ring shank nails having not less than 20 rings per inch, heads not less than 3/8 inch (9.5 mm) in diameter, and lengths sufficient to penetrate the thickness of plywood panel or wood plank decking not less than 3/16 inch (4.8 mm), or to penetrate into a 1-inch (25 mm) or greater thickness of lumber not less than 1 inch • Fasteners to be in a grid pattern of 12 inches between laps • Fasteners at side and end laps at 6 inches on center
	ASTM D1970	• Apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified in the FBC for the HVHZ over the entire roof deck Note: In the HVHZ, if the self-adhering membrane is to be applied over the entire roof, it must be applied over a mechanically fastened anchor sheet (using one of the underlayment materials and attachment methods described in the row above).

Table 2: Summary of Secondary Water Barrier Options for Asphalt Shingle Roofs (concluded)

Roof Slope	Material	Details
Outside High-Velocity Hurricane Zones		
2:12 to less than 4:12	ASTM D226 Types I or II ASTM D4869 Types II, III, or IV ASTM D6757	• Double layer with 19-inch side lap for all types • 6-inch end laps offset 6 feet • Metal or plastic cap nails with a cap diameter of not less than 1 inch and thickness of 32-gage sheet metal • One row of fasteners in the field of the sheet at 12 inches on center • Fasteners at side and end laps at 6 inches on center
	ASTM D1970	• Apply self-adhering membrane over the entire roof • Alternatively, apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified above over the entire roof deck
4:12 and greater	ASTM D226 Type II ASTM D4869 Type IV ASTM D6757	• Single layer with 4-inch side lap for all types • 6-inch end laps offset 6 feet • Metal or plastic cap nails with a cap diameter of not less than 1 inch and thickness of 32-gage sheet metal • Two staggered rows of fasteners in the field of the sheet with a maximum fastener spacing of 12 inches on center • Fasteners at side and end laps at 6 inches on center
	ASTM D1970	• Apply self-adhering membrane over the entire roof • Alternatively, apply 4-inch-wide self-adhering strips over joints in roof sheathing with one of the underlayment installation methods and types identified above over the entire roof deck

Source: Compiled from Sections R908.7 and 2 and Table R905.1.1 of the 6th Edition (2017) FBCR and Sections 1517.5.1, 1517.5.2, 1518.2, 1518.3, and 1518.4 of the 6th Edition (2017) FBCB.

For areas outside the HVHZ, Section R905.1.1 of the FBCR permits the use of a reinforced synthetic underlayment that is approved as an alternative to underlayment complying with ASTM D226 Type II. In addition, a minimum tear strength of 20 pounds in accordance with ASTM D1970 or ASTM D4533 is permitted as an alternative outside the HVHZ. This underlayment is required to be installed and attached in accordance with the requirements for the applicable roof covering and slope, except metal cap nails are required where the ultimate design wind speed, V_{ult}, equals or exceeds 150 mph. In the HVHZ, a synthetic underlayment installed with tin tabs is permitted in accordance with Sections 1518.2, 1518.3, and 1518.4 of the FBCB.

Figures 4 through 8 illustrate some of the secondary water barrier methods that are summarized in Table 2.

Roof-to-Wall Connections

Improvements to roof-to-wall connections are covered in Section R908.8 of the FBCR and only apply to buildings located in the wind-borne debris region with an insured value of $300,000 or more, or if uninsured, have a just valuation for purposes of ad valorem taxation of $300,000 or more. The code requires roof-to-wall connections to be retrofitted only up to a 15 percent increase in the cost of reroofing. As with roof deck attachments and secondary water barriers, single-family residential structures permitted subject to the Florida Building Code are exempted from these requirements.

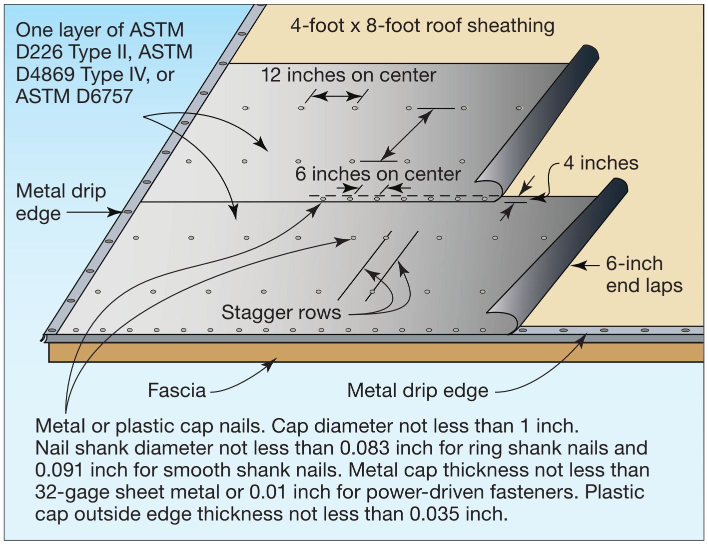

Figure 4: Example 1 – Outside the HVHZ

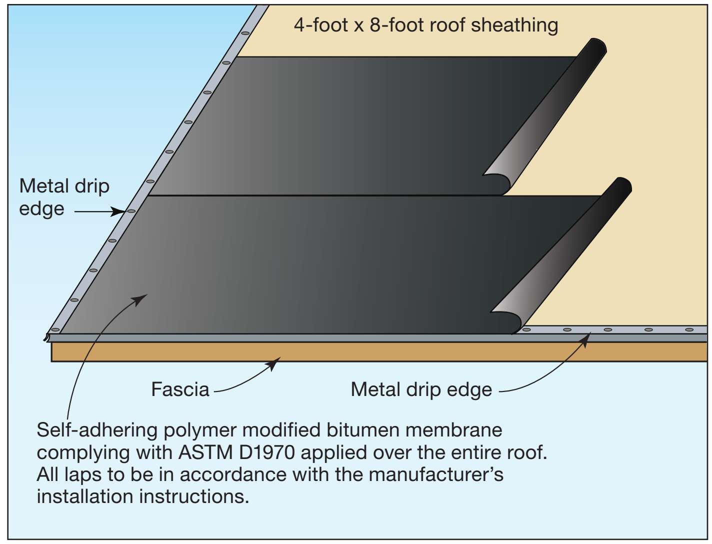

Figure 5: Example 2 – Outside the HVHZ

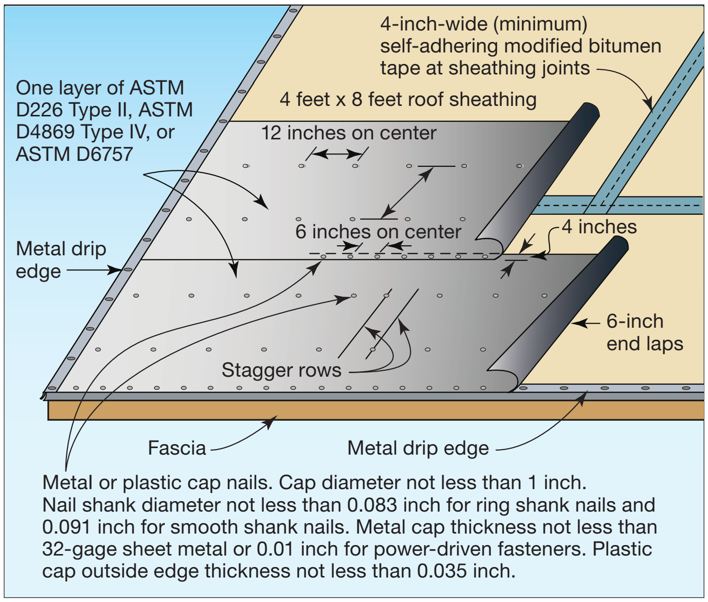

Figure 6: Example 3 – Outside the HVHZ

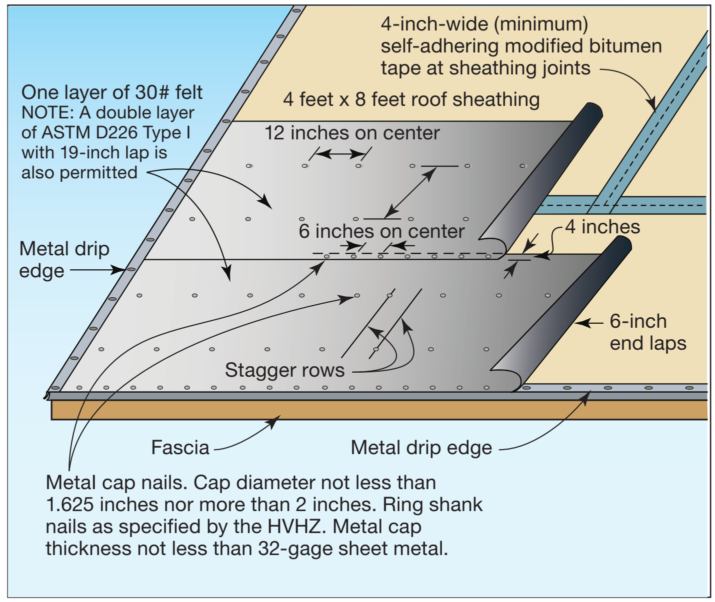

Figure 7: Example 1 – Within the HVHZ

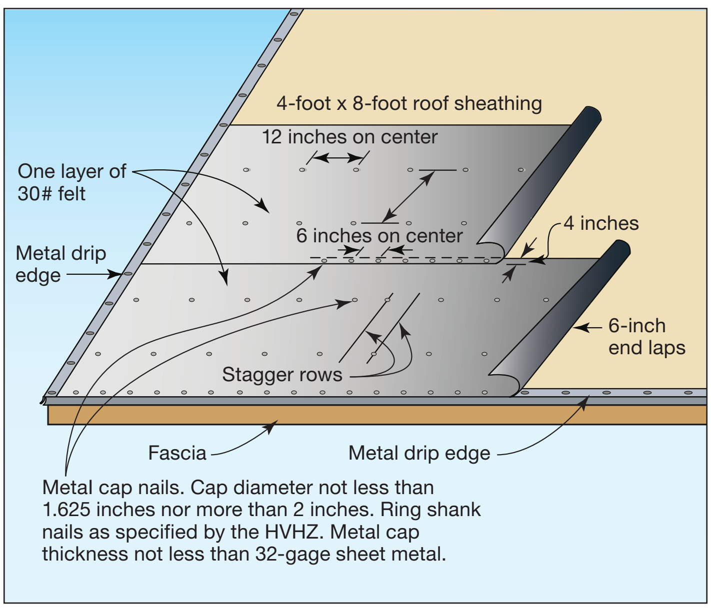

Figure 8: Example 2 – Within the HVHZ

The FBCR and FBCEB codes provide prescriptive solutions for various roof configurations and wall types. They also address the most vulnerable locations by prioritizing mandated roof-to-wall retrofit expenditures.

Commercial Wind Mitigation

While the wind mitigation provisions for commercial buildings are not as encompassing as those for single-family dwellings, the FBCEB requires certain roof components to be evaluated and potentially improved when the roof covering is replaced.

Section 707.3.2 of the FBCEB requires an evaluation of the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections when roofing materials are removed from more than 50 percent of the roof diaphragm or section. If the diaphragm and the connections specified are not capable of resisting 75 percent of the wind loads specified in the FBCB, they are required to be replaced or strengthened to meet those loads (refer to the text box titled "Roof Diaphragms Resisting Wind Loads").

The 6th Edition (2017) FBCEB includes new exceptions to Section 707.3.2 shown in the text box. They are intended to apply to buildings that have been designed for wind loads that are comparable to modern wind load standards. The American Society of Civil Engineers (ASCE) *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-88) and the 1991 Standard Building Code (SBCCI 1991) specified component and cladding loads comparable to the loads in modern codes and standards. When an evaluation is performed by a registered design professional confirming that the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections are in compliance with ASCE 7-88 or the 1991 Standard Building Code, the strengthening or replacing of these components is not required.

Florida Building Code, Existing Building – Roof Diaphragms Resisting Wind Loads

707.3.2 Roof diaphragms resisting wind loads in high-wind regions. Where roofing materials are removed from more than 50 percent of the roof diaphragm or section of a building located where the ultimate design wind speed, V_{ult}, determined in accordance with Figure 1609.3(1) of the Florida Building Code, Building, is greater than 115 mph (51 m/s), as defined in Section 1609 (the High-Velocity Hurricane Zone shall comply with Section 1620) of the Florida Building Code, Building, roof diaphragms, connections of the roof diaphragm to roof framing members, and roof-to-wall connections shall be evaluated for the wind loads specified in the Florida Building Code, Building, including wind uplift. If the diaphragms and connections in their current condition are not capable of resisting at least 75 percent of those wind loads, they shall be replaced or strengthened in accordance with the loads specified in the Florida Building Code, Building.

Exceptions:

1. This section does not apply to buildings permitted subject to the Florida Building Code.
2. This section does not apply to buildings permitted subject to the 1991 Standard Building Code or later edition, or designed to the wind loading requirements of ASCE 7-88 or later editions, where an evaluation is performed by a registered design professional to confirm the roof diaphragm, connections of the roof diaphragm to roof framing members, and roof-to-wall connections are in compliance with the wind loading requirements of either of these standards or later editions.
3. Buildings with steel or concrete moment resisting frames shall only be required to have the roof diaphragm panels and diaphragm connections to framing members evaluated for wind uplift.
4. This section does not apply to site built single family dwellings. Site-built single-family dwellings shall comply with Sections 706.7 and 706.8.
5. This section does not apply to buildings permitted within the HVHZ after January 1, 1994, subject to the 1994 South Florida Building Code, or later editions, or where the building's wind design is based on the wind loading requirements of ASCE 7-88 or later editions.

Source: 6th Edition (2017) FBCEB

Similar to the mitigation provisions for residential construction, Section 707.3.2 does not apply to buildings permitted subject to the Florida Building Code. In addition, the provisions do not apply to site-built single-family dwellings, as those structures are addressed in Section R908.7 of the FBCR (also covered in Section 706.7 of the FBCEB).

Buildings with moment-resisting frames do not have roof-to-wall connections and are therefore only required to have roof diaphragm panels and diaphragm connections to framing members evaluated for wind uplift.

References and Resources

References

ASCE (American Society of Civil Engineers). 1988. *Minimum Design Loads for Buildings and Other Structures.* ASCE Standard ASCE 7-88.

ASTM (American Society for Testing and Materials). 2009. *Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing.* D226 / D226M-09.

ASTM. 2015. *Specification for Self-Adhering Polymer Modified Bitumen Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.* D1970 / D1970M-15.

ASTM. 2015. *Specification for Driven Fasteners, Nails, Spikes, and Staples.* F1667-15.

ASTM. 2015. *Standard Test Method for Trapezoid Tearing Strength of Geotextiles.* D4533 / D4533M-15.

ASTM. 2016. *Specification for Asphalt-Saturated Organic Felt Underlayment Used in Steep Slope Roofing.* D4869 / D4869M-16a.

ASTM. 2016. *Standard Specification for Inorganic Underlayment for Use with Steep Slope Roofing Products.* D6757-2016.

FBC (Florida Building Code). 2017. “Florida Department of Business & Professional Regulation” Web page. https://www.floridabuilding.org/bc/bc_default.aspx. Codes are available from ICC at https://codes.iccsafe.org/public/collections/Florida.

FEMA (Federal Emergency Management Agency). 2018. *Public Assistance Program and Policy Guide.* FP-104-009-2. https://www.fema.gov/media-library/assets/documents/111781.

SBCCI (Southern Building Code Congress International). 1991. *Standard Building Code.*

Resources

FEMA (Federal Emergency Management Agency). 2009. *Local Officials Guide for Coastal Construction.* FEMA P-762. https://www.fema.gov/media-library/assets/documents/16036.

FEMA. 2010. *Home Builder’s Guide to Coastal Construction.* FEMA P-499. https://www.fema.gov/media-library/assets/documents/6131.

FEMA. 2010. *Wind Retrofit Guide for Residential Buildings.* FEMA P-804. https://www.fema.gov/media-library/assets/documents/21082.

FEMA. 2011. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th Edition.* FEMA P-55. https://www.fema.gov/media-library/assets/documents/3293.

Useful Links

FBC (Florida Building Code), multiple years and editions, can be obtained from ICC at https://codes.iccsafe.org/public/collections/Florida.

Insurance Institute for Business & Home Safety (IBHS) Fortified Home Standards and Technical Bulletins. https://disastersafety.org/fortified/resources/.

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions-building-science.

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