



Mitigation Assessment Team Report

Hurricane Michael in Florida

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-2077 / February 2020

FEMA

MITIGATION ASSESSMENT TEAM REPORT

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All photographs and figures used in this report were taken by the MAT or developed for this report unless stated otherwise.

Map imagery sources (unless otherwise noted in the report):

- FIRMs (Flood Insurance Rate Maps): FEMA Map Service Center, fema.maps.arcgis.com)
- Aerial imagery: Google Earth Pro, www.google.com/earth/ (used with license, accessed October 2018 through January 2020).

FEMA would also like to thank NOAA for the post-disaster imagery they provided to Google Earth following Hurricane Michael. These images were taken shortly after Hurricane Michael, are included in this report, and provided invaluable data for the desktop analyses conducted by the MAT before, during, and after deployment.

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HURRICANE
MICHAEL
IN FLORIDA

Executive Summary

Hurricane Michael made landfall near Mexico Beach and Tyndall Air Force Base, FL, on October 10, 2018, at 12:30 CDT as a Category 5 hurricane, with maximum sustained winds of 161 miles per hour (mph) and a minimum pressure of 919 millibars (mb). It was the fourth strongest hurricane to make landfall on the continental United States based on wind speed, and the 13th named storm of the 2018 Atlantic Hurricane Season.

After Hurricane Michael made landfall, it continued northeast across the Florida Panhandle, and the maximum winds dropped below the threshold for a Category 3 hurricane before the eye passed into Georgia. Hurricane Michael weakened to a tropical storm over central Georgia and eventually crossed South Carolina, North Carolina, and Virginia before reentering the Atlantic Ocean on the evening of October 12, 2018, as a post-tropical depression.

Hurricane Michael resulted in widespread destruction, injuries and deaths across the southeastern United States from its strong winds, heavy rains, and storm surge (NHC, 2019b). Approximately 375,000 residents in Florida were evacuated from coastal areas. Hurricane Michael caused approximately $25 billion in damages in the United States per the National Oceanic and Atmospheric Administration's (NOAA's) *National Hurricane Center Tropical Cyclone Report Hurricane Michael (AL142018). 7–11 October 2018* (Revision 1 dated May 17, 2019). More than half of these damages were in Florida. A large amount of the total damage cost was to property and infrastructure. However, about $3.3 billion of the damage was agricultural and forestry losses. Most of these losses were in Florida and Georgia.

NOTEWORTHY HURRICANE MICHAEL METRICS

- Hurricane Michael is the fourth strongest hurricane, based on wind speed, to make landfall on the continental United States.
- In only 73 hours, Hurricane Michael developed from a tropical storm with 40 mph winds to a Category 5 hurricane at landfall with 161 mph sustained wind speeds.
- Hurricane Michael's landfall location near Mexico Beach and Tyndall Air Force Base was less than 10 miles from the northwest of the National Hurricane Center's 72-hour forecasted landfall location. The accuracy of this forecast helped state and local officials prepare for the event and encourage evacuation, potentially helping to save countless lives. Approximately 375,000 Florida residents evacuated from coastal areas.

Mitigation Assessment Team Deployment

Approximately 2 weeks after Hurricane Michael struck the Florida coast, the Federal Emergency Management Agency (FEMA) deployed a pre-Mitigation Assessment Team (pre-MAT) (October 22 to 25, 2018) consisting of a small team of subject matter experts (SMEs) to perform a preliminary field assessment of building damage in limited areas in Bay, Calhoun, Franklin, Gulf, Jackson, and Wakulla Counties. The objectives of the pre-MAT included:

- Helping to develop a strategy and determine key logistics for effectively and efficiently deploying the Mitigation Assessment Team (MAT)
- Gaining a situational awareness of the disaster by seeing it first-hand
- Determining the overall impact of the hurricane and developing the proposed scope of the buildings, areas, and topics to be studied by the future MAT
- Determining key people and organizations the future MAT could contact while in the field and the specific Joint Field Office (JFO) setup and reporting requirements
- Observing and recording select perishable data, and comparing preliminary wind speed contours and flood elevations to observed damage
- Determining the skillsets that would be needed for the MAT

Following the pre-MAT, in response to a request for technical support from the JFO in Florida, a MAT consisting of 18 SMEs was deployed from January 6 to 10, 2019, to Bay, Calhoun, Franklin, Gulf, Jackson, and Wakulla Counties. A MAT conducts building performance assessments of buildings and related infrastructure to determine both the causes of damage and results of successful mitigation, and recommends actions that federal, state, and local governments; building officials and floodplain administrators and regulators; the design and construction industry; building code and standard organizations; academia; emergency managers; building owners and operators; or other stakeholders can take to mitigate damage from future natural hazard events. Furthermore, the recommendations resulting from a MAT help FEMA coordinate with agencies and organizations to assess the hazard-resistant provisions of building codes and standards in order to develop long-term strategies to reduce future damage and impacts from flood and wind events, and help improve community resilience. During this deployment, the MAT was able to schedule a helicopter overflight through the Florida JFO to capture important aerial imagery of the impacted area. This imagery enabled an efficient assessment of building performance, particularly of the roof and building envelope systems. The helicopter provided an overview of building damage from a different vantage point and over a wider area much quicker than a MAT could accomplish on the ground, and at closer range than NOAA imagery. Furthermore, the hovering and circling capability of the helicopter around facilities or areas of particular interest helped the MAT in planning, photographic documentation, and development of ensuing conclusions and strategic recommendations for this report.

The Hurricane Michael MAT was deployed 88 days after the storm made landfall, which is outside of the preferred 30- to 45-day window following an event. During the 88 days between Hurricane Michael's landfall and the MAT deployment, some sites and buildings were demolished, and many buildings, roofs, windows, doors, and wall or other systems were already repaired, being repaired, or covered with tarps, preventing detailed observations. The majority of debris was also cleaned up by the time the MAT arrived, which made it more difficult for the MAT to discern between damage and successful building performance, and limited the data pool from which to draw conclusions and make recommendations.

This MAT report provides information that will help communities; businesses; design professionals; code officials; federal, state, and local officials; and other interested stakeholders rebuild and design more robust and resilient buildings, structures, and their associated utility systems. This report describes the MAT's observations during field assessments in Florida and presents conclusions and recommendations based on those observations for improving short-term recovery and long-term disaster resilience from natural hazard events. The recommendations aim to improve community resiliency and minimize loss of life, injuries, and property damage from future natural hazard events like Hurricane Michael.

Summary of Damage Observed by the MAT

Hurricane Michael was both a wind and flood design-level event in some locations. The storm caused widespread damage to residential and commercial buildings and infrastructure. Other long-term damage impacts include the loss of housing, damage to wastewater and potable water infrastructure, damage to critical facilities, and minor to major erosion. The extent of the wind and/or flood damage varied depending on the nature of the building design, siting, and construction.

Flood. Hurricane Michael generated significant storm surge, causing extensive flood damage to residential, commercial, and public buildings and public and private infrastructure. The storm surge in Bay County ranged between 5 and 19 feet above sea level. The maximum reported total rainfall for the storm was approximately 10 to 13 inches.

Coastal construction-related topics assessed by the MAT include the performance of pile foundation systems and coastal protection structures, the role elevation of the lowest structural member plays in the Coastal A Zone and Zone V, and the impact siting decisions make on a structure in the coastal floodplain.

The MAT visited over 100 flood location sites and observed the following:

- Elevating buildings with additional freeboard above the base flood elevation mitigated flood damage.
- The performance of foundations varied depending on construction practices; pile foundation failures occurred in areas subject to wave action in certain locations.
- Improper siting resulted in erosion, scour, and structural damage.
- Stricter enforcement of code and implementation of floodplain management practices that go beyond the minimum requirements is needed to achieve far reaching resilience.

Throughout the area of impact, the MAT observed building damage associated with hydrostatic, buoyant, and/or hydrodynamic forces. These observations included structures that were inadequately fastened and floated off their foundations, structures that were impacted by the flow of water resulting in scour or failure of structural support, and structures that suffered debris impact.

Wind. Hurricane Michael was upgraded by NOAA to a Category 5 hurricane with estimated sustained winds of 161 mph over water when it made landfall near Mexico Beach and Tyndall Air Force Base, FL. Many communities along the track of Hurricane Michael experienced wind speeds that exceeded design level wind speeds based on American Society of Civil Engineers (ASCE) Standard 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (2016), for various risk categories. Bay, Calhoun, Gadsden, Gulf, Jackson, and Liberty Counties all suffered wind speeds in excess of design levels. Furthermore, Hurricane Michael spawned 16 confirmed EF-0 and EF-1 (on the Enhanced Fujita Scale) tornadoes between Florida and Virginia. Only two of these, both EF-1s, were in Florida.

Wind-related topics studied by the MAT included the performance of residential main wind-force resisting systems (MWFRS) and building envelope components such as roof and wall coverings, soffits, windows and doors, and roof ventilation products. MAT observations of residential buildings included significant damage to MWFRS and building envelope systems, with performance varying with the age of construction (although building envelope damage was also widely observed on newer construction). Significant wind-driven rain intrusion occurred through roof coverings, wall coverings, and soffits.

The MAT studied the performance of non-residential structures and critical facilities that had been retrofitted to improve building performance during high-wind events, as well as the performance of commercial buildings and non-retrofitted critical facilities. The MAT assessed the performance of Enhanced Hurricane Protection Areas (EHPAs) designated as shelters by the State of Florida, roof membranes, and the attachment of rooftop equipment. The MAT observed some damage to MWFRS and building envelope systems at several different types of critical facilities and commercial buildings of varying age and size. Non-residential buildings that had been retrofitted to improve building performance in high-wind events also experienced significant damage. The MAT frequently observed that even when retrofitted elements performed well, if other significant non-retrofitted elements of the system failed during a high-wind event, the whole retrofit project was ineffective because the building did not achieve the target performance level intended by the retrofitted system.

MAT Recommendations

The recommendations presented in this report were developed based on the MAT's field observations and informed by the MAT members' expertise. They are directed to design professionals, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners and operators, academia, select industries and associations, local officials, planners, FEMA, and other interested stakeholders. A summary of the recommendations follows.

General recommendations
(Section 6.2)

- FL-1a. The Florida Division of Emergency Management (FDEM) should consider developing/ modifying training on the flood provisions in the Florida Building Code (FBC) and local floodplain management ordinances.

- FL-1b. Building Officials Association of Florida (BOAF) and other stakeholders should consider developing additional training on roles and responsibilities for communities contracting building department services to a private company.
- FL-2a. Local jurisdictions should make building envelope inspections a priority.
- FL-2b. BOAF, Florida Home Builders Association, and other stakeholders should consider developing training and creating a culture of emphasis on building envelope systems.

Flood-related building code, standards, and regulations recommendations

(Section 6.3)

- FL-3a. FEMA should update FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (2010h), and concurrently update FEMA 213, *Answers to Questions about Substantially Damaged Buildings* (2018a), to be consistent with the updated FEMA P-758.
- FL-3b. FEMA should consider expanding/clarifying existing training materials related to Substantial Improvement / Substantial Damage.
- FL-4. Communities should outline clear and consistent responsibilities when contracting with private-sector providers to administer all or part of the community's responsibilities under the FBC.
- FL-5a. FEMA should provide guidance to state and local governments on seeking assistance related to building code and floodplain management ordinance administration and enforcement authorized under Section 1206 of the Disaster Recovery Reform Act of 2018.
- FL-5b. FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through Statewide Mutual Aid Agreement and Emergency Management Assistance Compact.

Wind-related building code, standard, and regulations recommendations

(Section 6.4)

- FL-6. FEMA should work with the American Architectural Manufacturers Association / Window and Door Manufacturers Association / Canadian Standards Association, Insurance Institute for Business & Home Safety, International Code Council (ICC), and other select industry partners to incorporate more comprehensive water intrusion testing requirements that improve overall performance into testing standards.
- FL-7. The wind research engineering community should perform a revised analysis of the ASCE 7 basic wind speed maps for the Florida Panhandle region to include data from Hurricane Michael.
- FL-8a. The FBC should treat all areas within 1 mile inland from the entire Florida coastline as a wind-borne debris region (WBDR).
- FL-8b. The ASCE 7 Wind Load Subcommittee should revise ASCE 7 to lower the basic wind speed trigger in ASCE 7 for requiring glazing to be protected on Risk Category IV buildings in the hurricane-prone region.

- FL-8c. Building owners outside the WBDR but within the hurricane-prone region should consider protecting the glazed openings on their buildings.
- FL-8d. The International Building Code / International Residential Code / FBC should be updated where needed to ensure glazed window, skylight, door, and shutter assemblies have a permanent label that provides traceability to the manufacturer and product.
- FL-8e. The ASCE 7 Wind Load Subcommittee should consider developing commentary on vestibule wind loads.

Flood-related recommendations

(Section 6.5)

- FL-9. Communities should consider more stringent building requirements for development or reconstruction in the unshaded Zone X (area of minimal flood hazard) and shaded Zone X (area of moderate flood hazard).
- FL-10a. Industry groups, interested stakeholders, and/or academia should further evaluate the performance of the concrete pile foundations that failed during Hurricane Michael to determine why they failed.
- FL-10b. FEMA and FDEM should consider providing a code change proposal to the International Codes requiring contractors and/or manufacturers to add length labels or incremental depth markers on vertical piles.
- FL-11a. FEMA and FDEM should consider submitting a code change proposal to the FBC, applying ASCE 24, *Flood Resistant Design and Construction,* Flood Design Class 4 requirements outside the Special Flood Hazard Area (SFHA) in moderate flood hazard areas (shaded Zone X) and to consider flood risk for minimal flood hazard areas (unshaded Zone X).
- FEMA-11b. FEMA should consider developing a change proposal for ASCE 24 requiring consideration of flood risk for essential facilities outside the SFHA in minimal flood hazard areas (unshaded Zone X) and requiring Flood Design Class 4 to apply in moderate flood zones outside of the SFHA.
- FL-12. Local floodplain administrators, design professionals, and building owners should incorporate more freeboard than the minimum required in ASCE 24 based on Flood Design Class whenever possible.
- FL-13a. FEMA should review and update its Event-Based Erosion methodology.
- FL-13b. For parcels that are seaward of Florida’s Coastal Construction Control Line, communities should require—and key stakeholders should encourage—the placement of houses with the maximum distance from the flood source possible within each parcel.
- FL-13c. The Florida Department of Environmental Protection should implement current best practices and consider revising its requirements for erosion vulnerability assessments for new construction in erosion control areas.
- FL-13d. Permitting agencies 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 the water and land sides.

- FL-13e. Communities and building owners should consider acquisition or relocation projects for existing buildings in areas highly vulnerable to erosion.

Wind-related recommendations

(Residential Wind Section 6.6.1)

- FL-14a. Code enforcement authorities having jurisdiction across Florida should make roof covering and underlayment inspections a priority.
- FL-14b. Industry groups should assess the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT
- FL-14c. Contractors and inspectors must ensure roof covering repairs and replacements conform with the FBC as required.
- FL-14d. On buildings built prior to the FBC, before installing a new roof covering, contractors should remove the existing roof covering to evaluate the roof sheathing attachment, and add supplemental fasteners in accordance with the wind mitigation provisions of FBC if the sheathing attachment is found to be deficient.
- FL-14e. FEMA and FDEM should consider supporting current code change proposals to the 7th Edition FBC that provide for improved underlayment systems.
- FL-14f. The Asphalt Roofing Manufacturers Association and National Roofing Contractors Association should consider updating their guidance materials based on observations from the 2017 and 2018 hurricanes.
- FL-15a. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.
- FL-15b. FEMA and FDEM should consider submitting a code change proposal to the FBC requiring soffit inspections, and jurisdictions should prioritize performing soffit inspections.
- FL-15c. The Florida Building Code (FBCR), Residential should be revised to require soffit panels to be labeled to provide traceability to the manufacturer and product.
- FL-15d. Owners should determine whether the soffits attached to their house are “floated,” and, if so, take appropriate mitigating actions.
- FL-16. Industry groups and academia should perform research on commonly used ridge vent products to better determine the causes of ridge vent failure and develop solutions.
- FL-17a. FEMA and FDEM should consider submitting a code change proposal to the FBC requiring exterior wall covering inspections.
- FL-17b. Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue research and investigations of the appropriate pressure equalization factor for vinyl siding.

- FL-17c. The FBC and FBCR should be revised to require vinyl siding be labeled to provide traceability to the manufacturer and product.

(Non-Residential Wind Section 6.6.2)

- FL-18a. Designers and building owners should conduct a comprehensive vulnerability assessment as described in Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* (in FEMA P-2077, 2019d) before beginning a wind retrofit project.
- FL-18b. As appropriate, designers and building owners should consider damage to other buildings from high-wind events as vulnerabilities that should be addressed in their similar undamaged buildings.
- FL-18c. Designers, building owners, and operators of critical facilities should refer to 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* (2007b); and FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010c) for additional guidance and best practices for protecting critical facilities from flooding and high winds.
- FL-19a. Critical facilities that do not meet the FBC requirements for a Risk Category IV building should not be designated as essential facilities to support continuity of operations nor be occupied during a hurricane.
- FL-19b. Owners and authorities having jurisdiction with facilities that present a life-safety threat to occupants during a high-wind event or that need “near absolute protection” or life safety protection should consider designing and constructing a FEMA P-361–compliant safe room or ICC 500–compliant storm shelter for people to take shelter in during a storm.
- FL-19c. FDEM should consider delivering training on FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (2015c), safe room design, construction, and operations and maintenance.
- FL-20. The State of Florida should re-evaluate planning factors and considerations used to estimate hurricane evacuation shelter (HES) “demand in people,” so counties have adequate and more appropriate HES capacity during future hurricanes.
- FL-21a. The State of Florida and FDEM should consider re-evaluating their policies, procedures, and requirements for assessments of existing spaces for use as HES.
- FL-21b. The State of Florida and FDEM should consider re-evaluating EHPA criteria and re-assess safety of existing EHPAs, particularly those designed prior to the 6th Edition FBC (2017).
- FL-22. Critical facility owners and operators should perform a vulnerability assessment of their structures in comparison to the FBC Risk Category IV threshold to determine their risks and vulnerabilities, and a best path forward for mitigating them.
- FL-23a. Designers should properly design rooftop equipment anchorage per the recommendations in Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery

Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions* (in FEMA P-2021, 2018c), and contractors should properly implement the anchorage design to prevent blow-off.

- FL-23b. Copings and edge flashings should comply with ANSI/SPRI/FM 4435/ES-1, *Test Standard for Edge Systems Used with Low Slope Roofing Systems*, to prevent blow-off.
- FL-23c. In high-wind regions, designers should provide an enhanced closure detail for hip and ridge closures on metal panel roofs, and contractors should take special care in properly installing them.
- FL-23d. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.
- FL-23e. To help prevent entry of wind-driven rain into the building, designers should specify weatherstripping for, as well as consider designing vestibules at, exterior doors.
- FL-23f. FEMA Building Science should incorporate best practices for minimizing water infiltration into buildings from wind-driven rain into its relevant publications.
- FL-24a. The task committee for ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*, should consider revising the standard to include the evaluation of the potential for the shutter assembly to unlatch during a storm.
- FL-24b. Existing glazing assemblies that have inadequate wind pressure or wind-driven rain resistance should be replaced with new assemblies rather than being retrofitted with shutters.
- FL-24c. The task committee for ASTM E1886 should add corrosion criteria to the standard to help enable shutters to perform as intended over their useful life.
- FL-24d. The task committee for ASTM E1886 should evaluate the current perpendicular angle specifications for impacting a shutter during testing for its adequacy.
- FL-25a. Designers should specify, and contractors should properly install, standing seam metal panel systems that have been tested in accordance with ASTM E1592, *Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference*.
- FL-25b. Designers should specify, and contractors should install, a roof deck with a secondary roof membrane for critical facilities designed with structural standing seam metal roof panels.
- FL-26. Designers should adequately design, and contractors should properly install, roof systems.
- FL-27. Owners and operators of buildings with unreinforced masonry walls should include the toppling risk of these walls during high-wind events in vulnerability assessments and should mitigate the risk.
- FL-28a. Building owners should have a vulnerability assessment performed for their existing building to ensure brick veneer is properly attached

- FL-28b. Design professionals and contractors should improve installation of brick veneer in high-wind regions for new construction by ensuring it is properly attached.
- FL-29. Designers should consider specifying a more robust wall assembly than Exterior Insulation and Finish System for new critical facilities.
- FL-30. The FBC should provide more specific criteria with restrictions on how, when, and where roof aggregate can be used.

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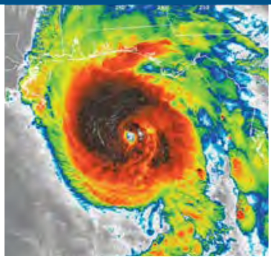
Acronyms and Abbreviations

AAMA	American Architectural Manufacturers Association
AISI	American Iron and Steel Institute
ARA	Applied Research Associates, Inc.
ARMA	Asphalt Roofing Manufacturers Association
ASCE	American Society of Civil Engineers
ASTM	ASTM International
ATC	Applied Technology Council
BFE	base flood elevation
BOAF	Building Officials Association of Florida
BUR	built-up roof
CAC	Community Assistance Contact
CAP-SSSE	Community Assistance Program State Support Services Element
CBRA	Coastal Barrier Resources Act
CBRS	Coastal Barrier Resources System
CCCL	Coastal Construction Control Line
CDT	Central Daylight Time
CFR	Code of Federal Regulations
CMU	concrete masonry unit
COOP	Continuity of Operations Plan
CPCB	Community Planning and Capacity Building
CRS	Community Rating System
CSA	Canadian Standards Association

DFE	design flood elevation
DHS	U.S. Department of Homeland Security
DRRA	Disaster Recovery Reform Act of 2018
DWS	design wind speed
EHPA	Enhanced Hurricane Protection Area
EIFS	Exterior Insulation and Finish System
EMAC	Emergency Management Assistance Compact
EOC	emergency operations center
ESF	Emergency Support Function
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
FDEP	Florida Department of Environmental Protection
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
HES	hurricane evacuation shelter
HQ	Headquarters
HVAC	heating, ventilation, and air conditioning
HVHZ	High-Velocity Hurricane Zone
IBC®	International Building Code
IBHS	Insurance Institute for Business & Home Safety
ICC®	International Code Council
IFAS	Institute of Food and Agricultural Sciences
IMAT	Incident Management Assistance Team
IRC®	International Residential Code

JFO	Joint Field Office
LPS	lightning protection system
MAT	Mitigation Assessment Team
mb	millibars
MBS	Metal Building System
mph	miles per hour
MWFRS	main wind-force resisting systems
NAVD88	North American Vertical Datum of 1988
NDRF	National Disaster Recovery Framework
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRCA	National Roofing Contractors Association
NSSA	National Storm Shelter Association
o.c.	on center
OSB	oriented strand board
PEF	pressure equalization factor
pre-MAT	pre-Mitigation Assessment Team
psf	pounds per square foot
Risk MAP	FEMA Risk Mapping, Assessment, and Planning
RRCC	Regional Response Coordination Center
RSF	Recovery Support Function
RV	recreational vehicle
SESP	Statewide Emergency Shelter Plan
SFHA	Special Flood Hazard Area
SFMO	State Floodplain Management Office
SMAA	Statewide Mutual Aid Agreement
SME	subject matter expert
SPF	sprayed polyurethane foam
TAC	Technical Advisory Committee
USGS	U.S. Geological Survey
URM	unreinforced masonry
VSI	Vinyl Siding Institute
WBDR	wind-borne debris region
WDMA	Window and Door Manufacturers Association



HURRICANE
MICHAEL
IN FLORIDA

CHAPTER 1
Introduction

Hurricane Michael was the most powerful hurricane on record to make landfall on the Florida Panhandle and, based on windspeed, the fourth strongest hurricane to ever make landfall on the continental United States.

Hurricane Michael struck the west coast of Florida near Mexico Beach as a Category 5 hurricane on October 10, 2018, causing significant damage along Florida’s Panhandle, resulting in a presidential disaster declaration (FEMA-4399-DR) on October 11, 2018. 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) to assess the damage in Florida. MATs are composed of national and regional experts in building science and other relevant disciplines who assess building performance after a disaster. These experts then incorporate lessons learned to make recommendations on improving the resilience of new construction and repairs and retrofits of existing buildings.

Soon after Hurricane Michael struck the Florida coast, FEMA deployed a pre-Mitigation Assessment Team (pre-MAT) consisting of a small team of subject matter experts (SMEs) to preliminarily assess building performance in limited areas of Bay, Calhoun, Franklin, Gulf, Jackson, and Wakulla Counties. The pre-MAT, deployed from October 21 to 25, 2019, was sent in advance of the full MAT to:

- Gain situational awareness of the disaster

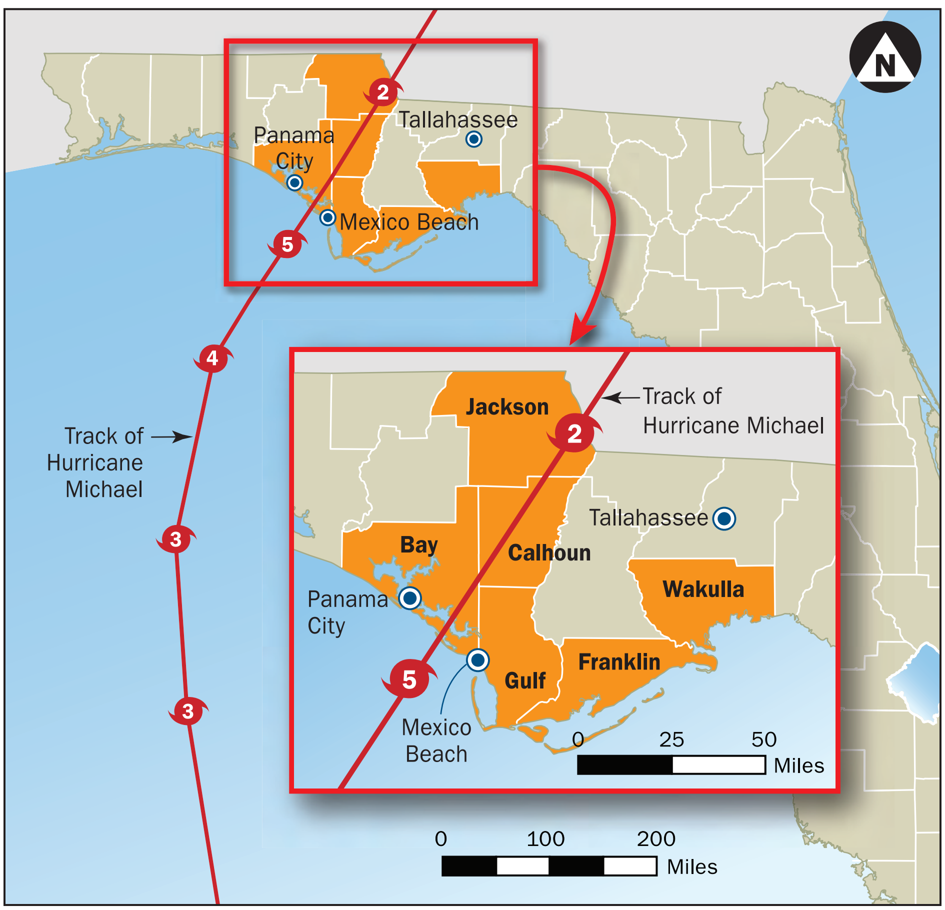
- Observe and record select perishable damage data and compare preliminary wind speed contours and flood elevations to observed damage
- Locate damaged areas that could benefit from further assessment
- Determine the overall impact of the hurricane, scope of buildings and areas to be visited, topics to be studied, and skillsets that would be needed for the larger, follow-on MAT

The full MAT was then deployed from January 6 to 10, 2019, after the technical support for the overall MAT effort was approved and funded by the FEMA Joint Field Office (JFO) in Florida. The MAT visited Bay, Calhoun, Franklin, Gulf, Jackson, and Wakulla Counties as shown in Figure 1-1.

PURPOSE OF A MAT

The primary purpose of a MAT is to improve the building stock's resistance to natural hazards 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, building owners and operators, planners, emergency managers, code officials, and other interested stakeholders in rebuilding and designing more robust and resilient buildings, structures, and associated utility systems. Loss of life, injury, and property damage is reduced in future natural hazard events, thereby improving community resiliency.

Figure 1-1: Counties visited by the MAT



This report describes and summarizes the MAT's observations from its field assessments in Florida after Hurricane Michael and presents conclusions and recommendations based on those observations. The MAT focused on two categories of observations:

- The vulnerability and performance of coastal construction to coastal flooding
- The wind resistance and performance of residential and non-residential structures

In addition to observing overall storm surge flood damage in the four affected coastal counties (Bay, Gulf, Franklin, and Wakulla), the MAT also specifically assessed the following topic areas related to the vulnerability of coastal construction to coastal flooding:

- Comparison of elevated versus non-elevated structures
- Performance of pile foundations
- Considerations for future floodplain management practices

The MAT assessed wind-related performance for both residential and non-residential structures. For residential structures:

- Structural systems / main wind-force resisting systems (MWFRS)
- Building envelope components, such as roof coverings, roof underlayment, soffits, exterior wall coverings, and windows and doors

For non-residential structures:

- Wind retrofit performance at critical facilities that had been retrofitted to improve building performance during high-wind events
- Building performance by building use, including commercial and critical facilities. Critical facilities that were assessed included emergency operations centers (EOCs), hurricane evacuation shelters (HESs) (Enhanced Hurricane Protection Area [EHPA] structures), first responder facilities, hospitals and nursing homes, schools, and other types of critical facilities not usually considered as critical facilities such as courthouses and select local government buildings.

The MAT report also provides conclusions and recommendations that are intended to help guide recovery efforts for hurricane-prone and floodprone communities. It provides strategic recommendations to help improve codes and standards for wind and flood provisions, design and construction guidance to provide more resilient buildings, code enforcement and training outreach recommendations, emergency management recommendations for shelters and safe rooms, and planning on a regional and national scale.

1.1 Organization of Report

This MAT report is divided into six chapters, as described below, and includes three appendices.

- Chapter 1: The Hurricane Michael event and its impact in Florida; the MAT composition; details related to its deployment, mission, and locations visited after Hurricane Michael; and the role of FEMA's Regional Response Coordination Center (RRCC) MAT liaison in response and recovery activities after the event

- Chapter 2: Florida building codes, floodplain management in Florida, and wind provisions of the Florida Building Code (FBC)
- Chapter 3: MAT observations related to the performance of residential and non-residential buildings exposed to storm surge flooding conditions.
- Chapter 4: MAT observations related to the performance of residential buildings exposed to high winds
- Chapter 5: MAT observations related to the performance of non-residential buildings exposed to high winds.
- Chapter 6: The MAT's conclusions and recommendations

In addition, the following appendices are included:

- Appendix A: Acknowledgments
- Appendix B: References
- Appendix C: Recovery Advisories
  - Michael Recovery Advisory 1 – *Successfully Retrofitting Buildings for Wind Resistance*
  - Michael Recovery Advisory 2 – *Best Practices for Minimizing Wind and Water Infiltration Damage*

1.2 Hurricane Michael: The Event

Hurricane Michael, the 13th storm of the 2018 hurricane season for the Atlantic Ocean, formed from a tropical disturbance in the northwest Caribbean Sea, east of the Yucatan Peninsula, on October 6, 2018. Hurricane Michael maintained a rapid intensification along its track toward the Florida Panhandle, increasing from a Category 3 hurricane to a Category 5 hurricane on the Saffir-Simpson Scale (Table 1-1) in the final 18 hours before making landfall (NHC, 2019).

Table 1-1: Saffir-Simpson Hurricane Scale Wind Speeds

Strength	Sustained Wind Speed over Water (mph)[a]	Gust Wind Speed over Water (mph)[b]	Gust Wind Speed over Land (mph)[c]
Category 1	74–95	90–116	81–105
Category 2	96–110	117–134	106–121
Category 3	111–129	135–157	122–142
Category 4	130–156	158–190	143–172
Category 5	157 or higher	>190	>173

[a] 1-minute average wind speed at 33 feet above open water

[b] 3-second gust wind speed at 33 feet above open water

[c] 3-second gust wind speed at 33 feet above open ground in Exposure Category C

mph = miles per hour

SOURCE: ADAPTED FROM SCE 7-16 TABLE C26.5-2

Hurricane Michael made landfall on October 10, 2018, at 12:30 p.m. CDT, between Tyndall Air Force Base and Mexico Beach, FL, with maximum estimated sustained winds over water of 161 miles per hour (mph) and a minimum pressure of 919 millibars (mb) (NHC, 2019b). Hurricane Michael was the fourth strongest hurricane based on windspeed, and the third strongest in terms of lowest pressure, to ever make landfall on the continental United States (Table 1 2).

Table 1-2: Strongest Continental U.S. Hurricane Landfalls

Hurricane	Year	Sustained Wind Speed over Water (mph)[(a)]	Gust Wind Speed over Water (mph)[(b)]	Pressure (mb)
Labor Day	1935	185	225	892
Camille	1969	175	213	900
Andrew	1992	165	201	922
Michael	2018	161	196	918

[(a)] 1-minute average wind speed at 33 feet above open water

[(b)] 3-second gust wind speed at 33 feet above open water

mph = miles per hour

mb = millibars

SOURCE: NHC, 2019a

THE SIGNIFICANCE OF HURRICANE MICHAEL

Within 73 hours, Michael developed from a tropical storm with 40 mph winds to a Category 5 hurricane with sustained winds of 161 mph when it made landfall on the Florida Panhandle; the most powerful hurricane on record to make landfall on the Florida Panhandle.

- Its landfall location between Tyndall Air Force Base and Mexico Beach was less than 10 miles to the northwest of the National Hurricane Center's (NHC's) 72-hour forecasted landfall location.
- In Mexico Beach, FL, the combined effects of storm surge and wind damaged all of the 1,692 buildings located within the city limits, caused major structural damage to 85 percent of the buildings and destroyed 48 percent (809) of the buildings. The hurricane damaged an estimated 2.8 million acres of Florida forest land, an indication of the wind intensity.
- The hurricane caused an estimated $25 billion dollars in damage.

After Hurricane Michael made landfall, it continued northeast across the Florida Panhandle and entered Georgia as a strong Category 2 hurricane. Hurricane Michael weakened to a tropical storm over central Georgia and eventually crossed South Carolina, North Carolina, and Virginia before reentering the Atlantic Ocean on the evening of October 12 as a post-tropical depression (see Figure 1-2).

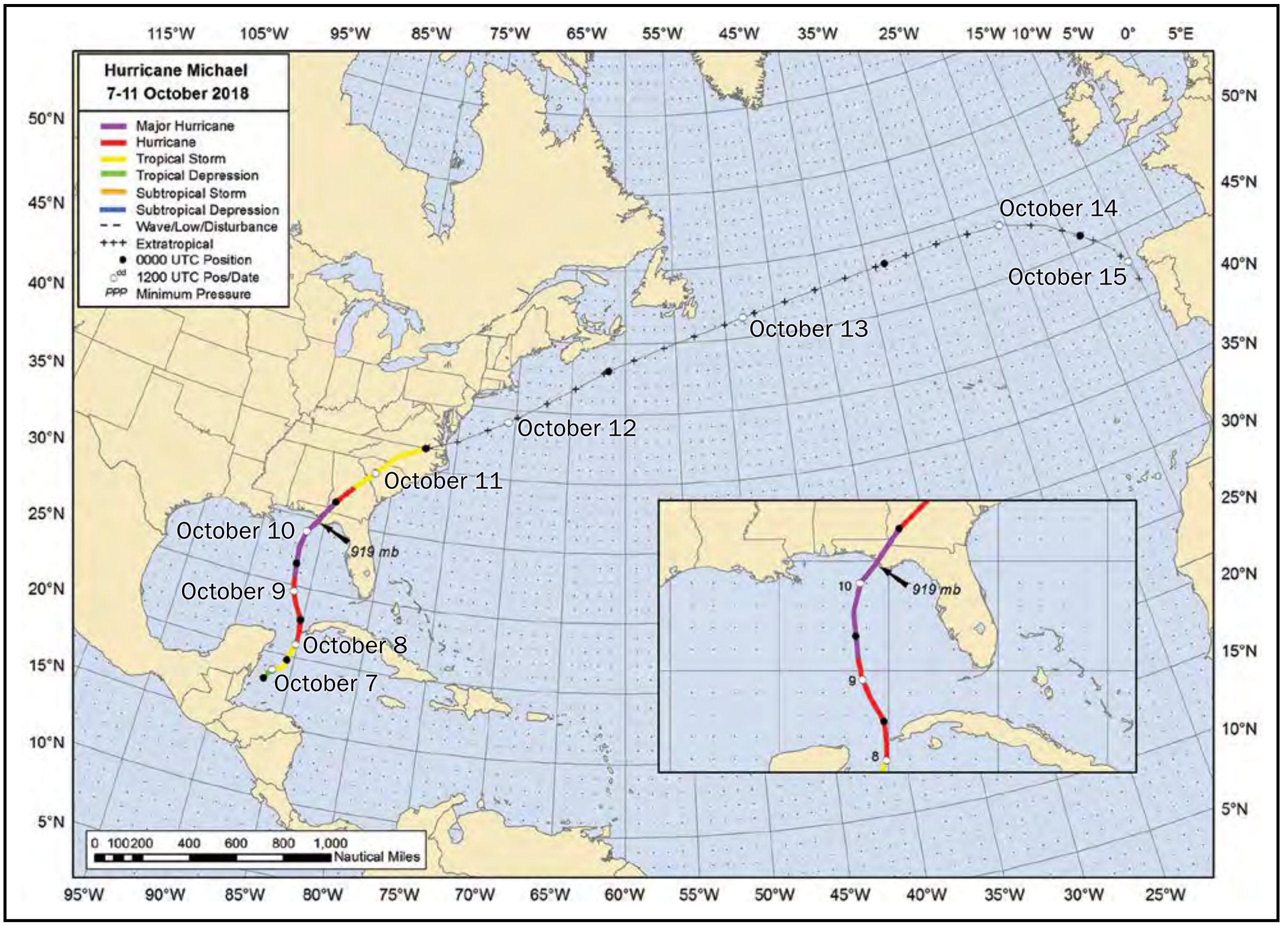


Figure 1-2: Hurricane Michael storm track

SOURCE: NHC, 2019b; FIGURE 1

1.3 Hurricane Michael: The Impact

Hurricane Michael was the first recorded Category 5 hurricane to make landfall on the Florida Panhandle. The extreme winds, storm surge, and heavy rains of the hurricane resulted in widespread destruction, injuries and deaths, directly and indirectly, in the states of Florida, Virginia, North Carolina, and Georgia. The National Oceanic and Atmospheric Administration's (NOAA's) *National Hurricane Center Tropical Cyclone Report Hurricane Michael (AL142018). 7–11 October 2018* (Revision 1 dated May 17, 2019) provides additional detail on the toll of destruction and loss of life. Approximately 375,000 residents in Florida were evacuated from coastal areas.

Wind and water damage caused by Hurricane Michael in the United States totaled approximately $25 billion and includes physical damage to buildings and building contents, personal and business belongings, infrastructure, and agricultural assets, as well as costs related to business interruptions. The estimated damage cost does not include losses related to health care, injury and loss of life, and natural resources (NHC, 2019b).[1]

1 The estimated damage cost is based on a variety of public and private data sources. Additional detail is provided in the National Hurricane Center report on Hurricane Michael (NHC, 2019b).

The damage to buildings, the focus of this report, was caused by the combination of water and wind associated with the hurricane, specifically coastal storm surge flooding, rainfall, wind-driven rain, and high-velocity wind.

1.3.1 Coastal Storm Surge Flooding

Hurricane Michael resulted in significant storm surge inundation on the Florida Panhandle. Figure 1-3 shows the locations and elevations of high-water marks surveyed by the U.S. Geological Survey (USGS) after the event, elevation data from USGS sensor gauges, and elevation data from National Oceanic and Atmospheric Administration (NOAA) tide station data.[2] Three factors led to the unprecedented storm surge depth in the area around Mexico Beach and in western Gulf County:

1) The track of Hurricane Michael, which made landfall just to the northwest of Mexico Beach, resulted in the strongest winds pushing waters from the Gulf of Mexico onto the shore.

2) The shallow depth of the Gulf of Mexico restricted the return flow of storm surge water back into the Gulf.

3) The shape of the Florida Panhandle coastline near Mexico Beach, with the St. Joseph Peninsula and Saint Joseph Bay, impeded return flow water from flowing to the east back into the Gulf of Mexico, causing an increase in surge elevations on land.

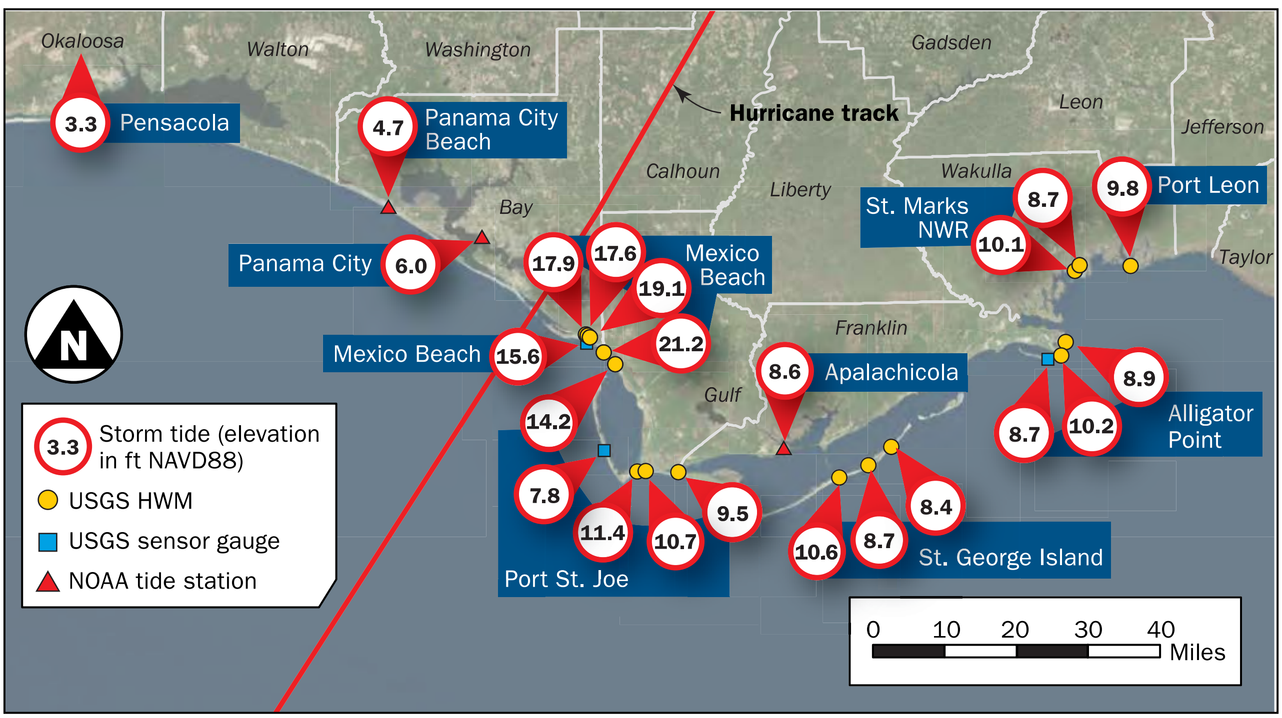


Figure 1-3: Locations of surveyed USGS high water marks for Hurricane Michael

2 Unless otherwise stated, all high water marks in this report refer to data collected by the USGS. They are reported as North American Vertical Datum of 1988 (NAVD88) and available in *Hurricane Michael Post-Storm Beach Conditions and Coastal Impact Report* (FDEP, 2019).

The storm surge brought high waves that caused significant erosion of barrier islands and primary frontal dunes. The barrier islands were breached by storm surge at numerous locations. Figure 1-4 shows an example.

Figure 1-4: Aerial images of the barrier island in T.H. Stone Memorial St. Joseph Peninsula State Park before and after Hurricane Michael showing a breach

The storm surge caused severe flood damage to residential, commercial, and public buildings and infrastructure in areas along the southeast coast of the Florida Panhandle. Hurricane Michael resulted in significant storm surge in Franklin, Gulf, and Wakulla Counties, as well as the eastern portions of Bay County, which includes the City of Mexico Beach. The Florida Department of Environmental Protection (FDEP) conducted a survey in Bay, Gulf, Franklin, and Wakulla Counties of

STORM SURGE TERMINOLOGY

Storm Surge: The abnormal rise of water generated by a storm, over and above the predicted astronomical tide, expressed in terms of height above normal tide levels.

Storm Tide High Water Mark: A mark, represented by a seed line, discoloration, sediment, or debris that indicates the maximum rise of the water above the ground surface, that are surveyed and correlated to a NAVD88 elevation. Note that storm surge high water marks do not always represent the stillwater elevation for an event and can include wave effects.

Storm Tide Stillwater Elevation: The combined water surface elevation rise of storm surge and astronomical tide.

Storm Tide Inundation Depth: Depth of water above the ground surface caused by storm surge.

Wave Runup Elevation: The elevation of the rush of water that extends inland when waves come ashore. It is calculated as the maximum vertical extent above the stillwater level after interfacing with the shoreline or structure.

structures in the Coastal Building Zone[3] indicated that 2,725 structures sustained major structural damage from flooding; in Mexico Beach, FL, 85 percent of the structures sustained major structural damage.

Storm surge across the affected counties varied depending on location. The four counties the most impacted by the storm surge are described below (FDEP, 2019).

Bay County. The storm tide high water marks in Bay County ranged between 4.7 and 19.1 feet North American Vertical Datum of 1988 (NAVD88),[4] according to USGS high water mark surveys. Specifically, storm tide was recorded as follows:

- Panama City: 6.0 feet of storm tide inundation depth
- Tyndall Air Force Base: 4 to 6 feet of storm tide inundation depth
- Mexico Beach: A maximum wave crest elevation of 20.6 feet and a storm tide stillwater elevation of 15.55 feet was measured by USGS gage [see Figure 1-5]) (USGS, 2018)
    - The FEMA Flood Insurance Study report for this location indicates that the 1 percent stillwater elevation is 10.1 feet and the 1 percent wave crest elevation is 15.6 feet.
    - Eastern Bay County: Wave runup elevations of 30 feet were observed by USGS high water mark survey teams

3 Defined in Section 161.54 and 161.55 of the Florida Statutes, the Coastal Building Zone is the land area from the seasonal high-water line landward to a line 1,500 feet landward from the Coastal Construction Control Line (CCCL) as established pursuant to Section 161.053 and for those coastal areas fronting on the Gulf of Mexico, Atlantic Ocean, Florida Bay, or Straits of Florida. The Coastal Building Zone on coastal barrier islands shall be the land area from the seasonal high-water line to a line 5,000 feet landward from the CCCL established pursuant to Section 161.053, or the entire island, whichever is less.

4 All elevations used in this report are NAVD88 unless otherwise specified.

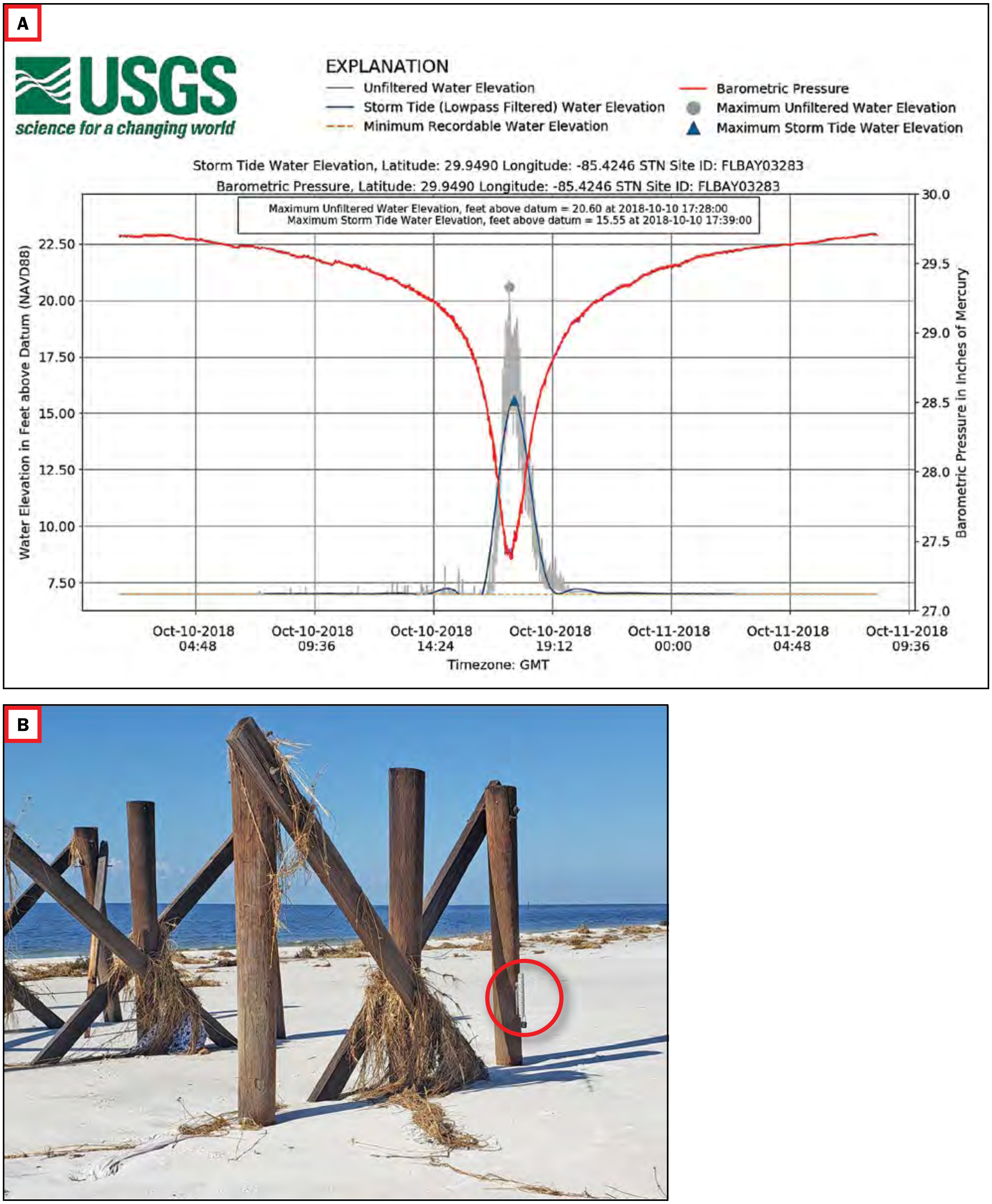


Figure 1-5: (A) Storm tide data for gage attached to the pier in Mexico Beach, FL. (B) Gage location shown attached to pier after Hurricane Michael.

SOURCE: USGS, 2018

Gulf County. The storm tide high water marks in Gulf County ranged between 7.8 and 21.2 feet in elevation according to USGS high water mark surveys. Specifically, storm tide was recorded as follows:

- St. Joseph Peninsula: Storm tide inundation depths were between about 10.7 feet and 11.7 feet
- T.H. Stone Memorial St. Joseph Peninsula State Park: A maximum wave crest elevation of 10.4 feet and a storm tide stillwater elevation of 7.8 feet was measured by USGS gage (USGS, 2019b)
  - The FEMA Flood Insurance Study report for this location indicates that the 1 percent stillwater elevation is 7.6 feet and the 1 percent wave crest elevation is 12 feet.
- Beacon Hill: Storm tide high water marks with elevation of 21.2 feet were measured
- Port St. Joe: Storm tide high water marks with elevations between 10.1 and 12.1 feet were measured
- Western Gulf County: Wave runup elevations of over 30 feet were observed

Franklin and Wakulla Counties. The storm tide high water marks in Franklin and Wakulla Counties ranged in elevation between 8.4 and 10.6 feet according to USGS storm surge high water mark surveys. Since these counties are sparsely populated along the coast, there were limited structures to preserve high water marks. As a result, NOAA created a post-storm model simulation of the storm surge, which indicated a storm tide of approximately 9 feet in Franklin and Wakulla Counties, corroborating with the few storm tide high water marks observed.

RIVERINE FLOODING

The MAT did not visit any areas impacted by riverine flooding. Riverine flooding impacts were not significant, and the MAT's efforts were focused on coastal flooding.

1.3.2 Rainfall

The maximum reported rainfall in Florida was approximately 10 to 13 inches in eastern portions of Washington County and western portions of Jackson County. Rainfall in areas impacted by the outer rain bands of Hurricane Michael varied between 1 and 3 inches, with the areas in the direct path of the eyewall receiving between 6 and 10 inches. As Hurricane Michael continued to the northeast through Georgia, South Carolina, and North Carolina, the rainfall caused isolated flash flooding. Figure 1-6 shows the total estimated rainfall from Hurricane Michael for the Florida Panhandle, southeastern Alabama, and southwestern Georgia.

After Hurricane Michael, the Florida Panhandle received an additional 6 and 9 inches of rain during the months of November and December, in some areas exceeding the rainfall that occurred during Hurricane Michael (The Weather Company, 2018). This additional rain continued to cause damage to contents and interior finishes in thousands of houses in Florida with roofs and exterior envelopes damaged by Hurricane Michael, as thousands of roofs and exterior envelopes were not repaired immediately after the hurricane (Turner, 2019; Schneider, 2019).

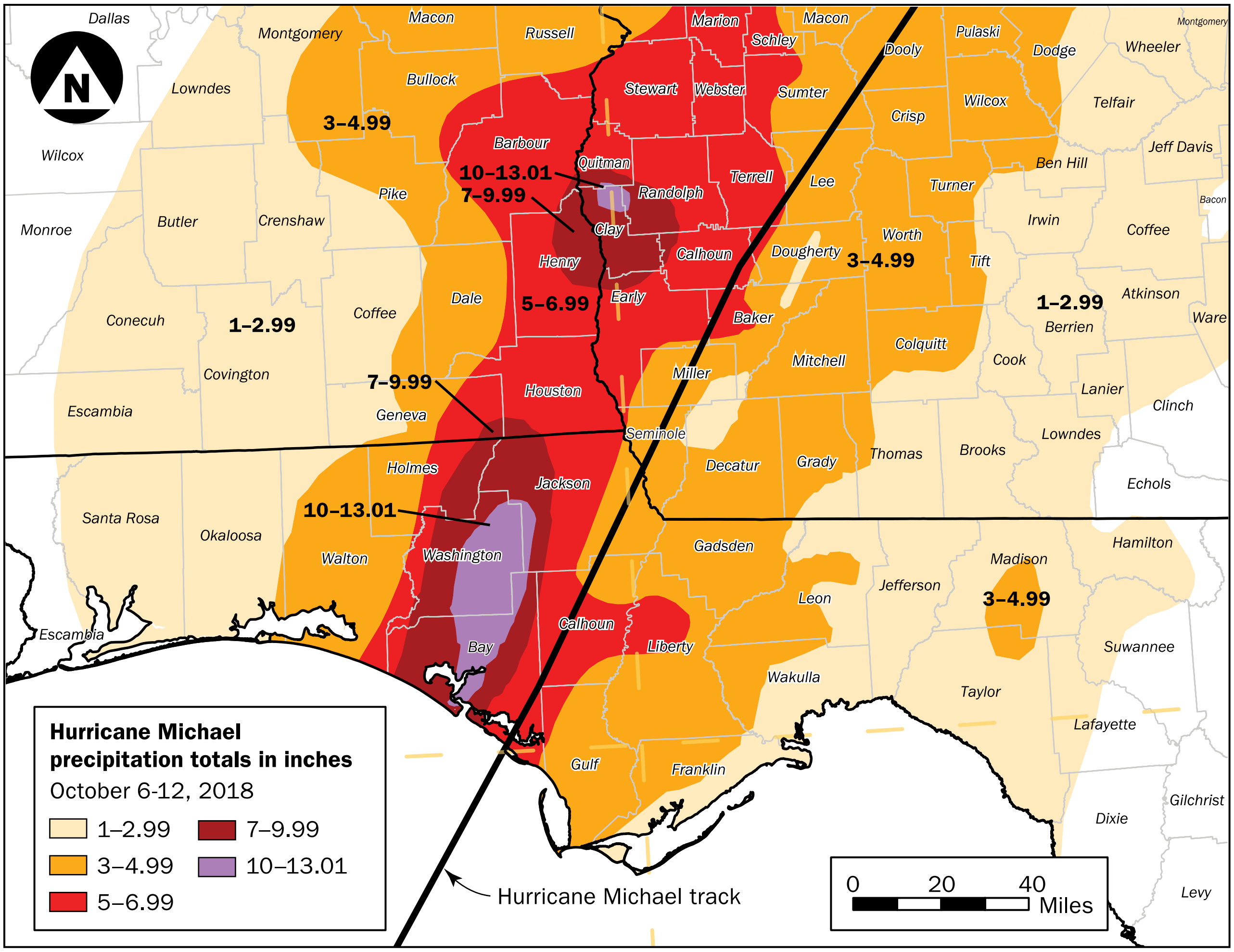


Figure 1-6: Hurricane Michael event rainfall

SOURCE: NHC, 2019b

1.3.3 Wind

Hurricane Michael was a Category 5 hurricane with estimated sustained winds of 161 mph when it made landfall near Mexico Beach and Tyndall Air Force Base. At landfall, Hurricane Michael was approximately 350 miles in diameter, with an eye that was approximately 20 miles in diameter. Its hurricane force winds extended 60 miles from the right side of the track and 40 miles from the left side of the track.

Figure 1-7 compares Hurricane Michael's estimated 3-second gust wind speeds to the basic wind (design) speed from the American Society of Civil Engineers (ASCE) publication *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10) for Risk Category II buildings.[5] Many communities along the track of Hurricane Michael experienced wind speeds that exceeded design level wind speeds. Wind speeds in excess of currently enforced ASCE 7-10 design levels occurred

5 The wind speed contours for ASCE 7-10 Risk Category II buildings match the wind speed contours for ASCE 7-16 Risk Category II buildings.

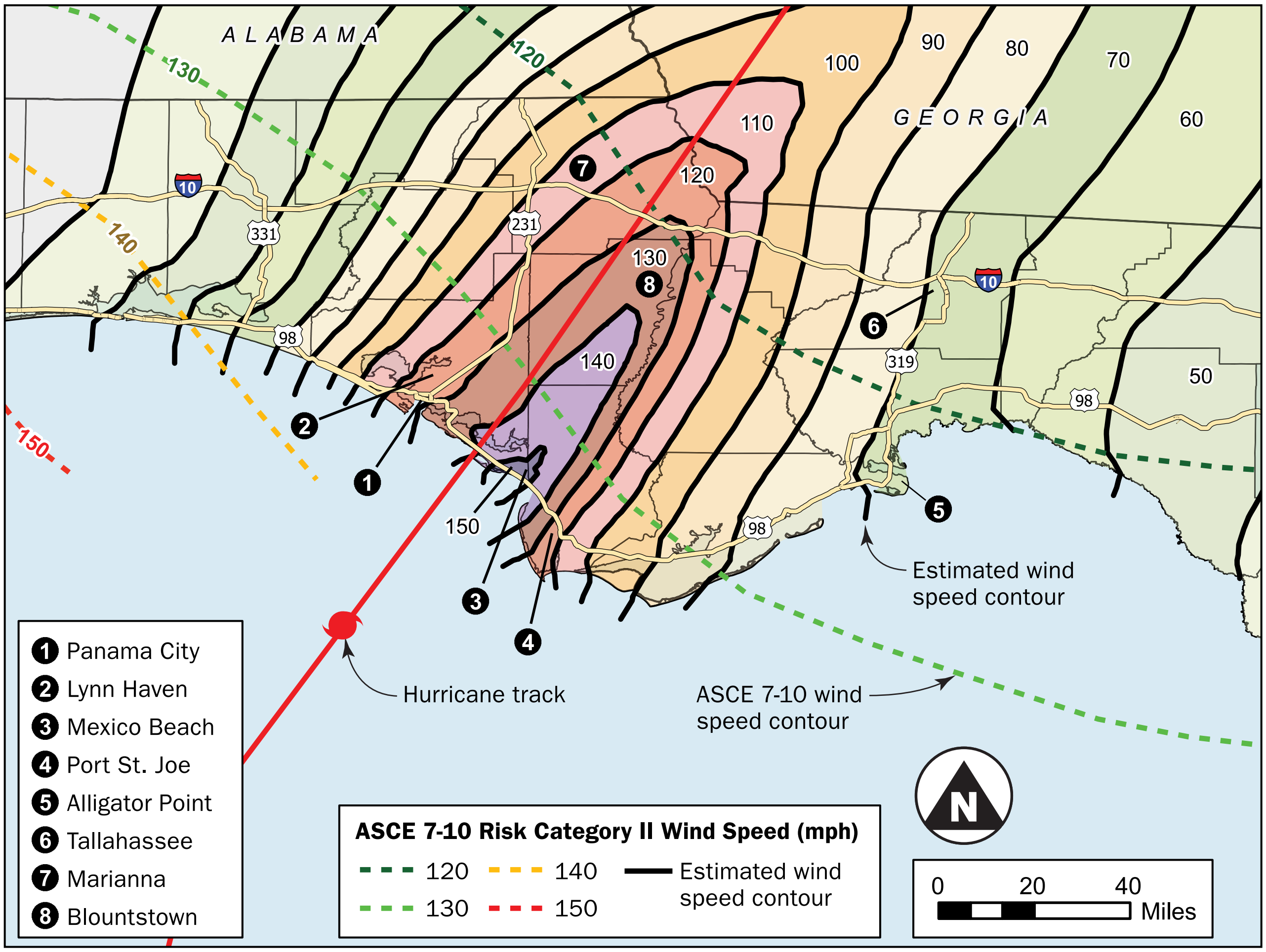


Figure 1-7: Preliminary peak wind swath plot of estimated 3-second gust wind speed in mph at a height of 33 feet above ground, Exposure C (solid lines)

SOURCE: MODIFIED FROM NIST, 2018

in Bay, Calhoun, Gadsden, Gulf, Jackson, and Liberty Counties (see Figure 1-8). In some locations, the wind speeds produced by Hurricane Michael exceeded ASCE 7 Risk Category II wind speeds by more than 10 percent.

The highest wind gust recorded on land was 129 mph at a mobile weather station at Tyndall Air Force Base. This mobile weather station was installed by the University of Florida/Weatherflow in the hours preceding landfall. Shortly after recording the gust of 129 mph, the mobile weather station failed. A wind gust of 102 mph was recorded at the airport in Marianna, FL, near the state line with Georgia; the weather station at the airport remained in operation throughout the event.

Hurricane Michael caused damage to MWFRS and building envelope systems for several different types of critical facilities and commercial buildings of varying age and size. Non-residential buildings that had been retrofitted to improve building performance in high-wind events also sustained damage; most of the observed retrofits were ineffective because a comprehensive vulnerability assessment was not completed at the design/planning phase, leaving gaps that were not understood nor addressed holistically in construction and operations.

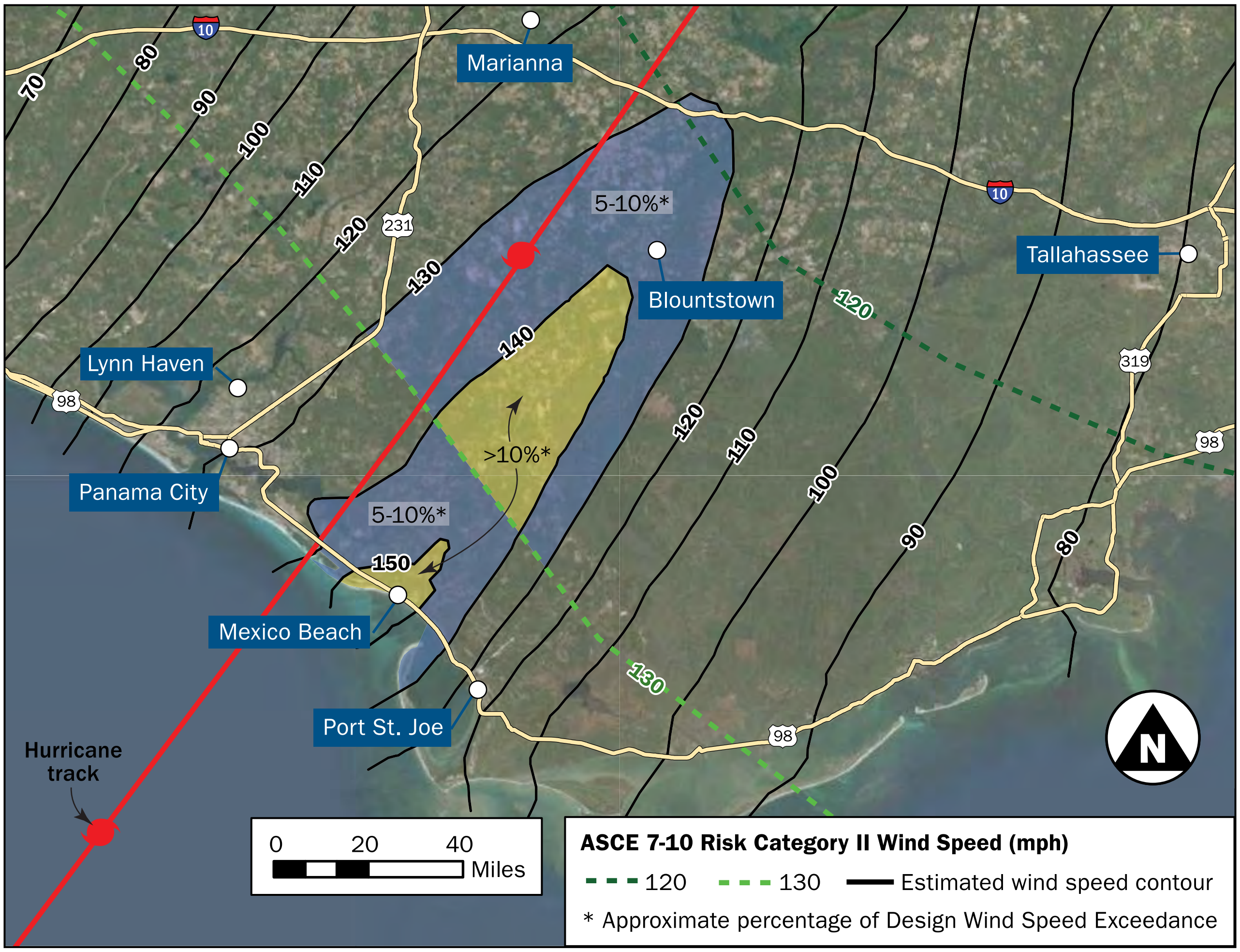


Figure 1-8: Wind swath plot showing approximate percentage of design wind speed exceedances

Hurricane Michael caused significant damage to MWFRS and building envelope systems of residential buildings, with performance varying with the age of construction. Significant wind-driven rain intrusion occurred through roof coverings, wall coverings, and soffits. The heavy rain that occurred in the months after Hurricane Michael further contributed to the damage before repairs could be made.

1.3.4 Tornadoes

Hurricane Michael produced 16 confirmed tornadoes between Florida and Virginia. All of the tornadoes spawned by Hurricane Michael were either EF-0 or EF-1 (on the Enhanced Fujita Scale) and resulted in minor damage to structures but many downed trees. Only two occurred in Florida, in Clay County, and both were an EF-1. The MAT did not visit any areas impacted by tornadoes. The following lists the number of tornadoes associated with Hurricane Michael by state:

- Florida: 2 tornadoes
- Georgia: 3 tornadoes
- South Carolina: 4 tornadoes
- Virginia: 7 tornadoes

1.4 The 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 generally deployed when FEMA believes the findings and recommendations derived from field observations will result in design and construction guidance that will help 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 information such as:

- Magnitude of event
- Potential 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 utility systems
- 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 performance, improving/advancing building codes and standard industry practices or guidance, code enforcement, research needs, closing knowledge gaps, or other topics
- Possibility that the field assessment would reveal pertinent information regarding the effectiveness of certain FEMA grants and key engineering principles and practices that FEMA promotes in published guidance and best practice documents
- Opportunity to:
  - Help in planning, design, and construction of buildings and utilities
  - Encourage code enforcement
  - Strengthen community resilience
  - Enhance capabilities or training for various skillsets or organizations
- Value of providing FEMA guidance in disciplines currently not addressed or information needed to update existing FEMA guidance on select topics as needed

The MAT studies the adequacy of current building codes and floodplain management regulations, local construction requirements, building practices, and building materials in light of the building performance observed after a disaster. Lessons learned from the MAT’s observations are communicated through recovery advisories, fact sheets, and a comprehensive MAT report. Additionally, these lessons learned are incorporated into conference presentations, FEMA training courses, professional meetings, and other outreach venues. All MAT products are made available to communities and the public at large to aid recovery efforts and enhance disaster resilience of buildings and utility systems for both existing buildings and new construction. Conclusions and recommendations from MAT reports are often the basis for FEMA’s building code proposals at code hearings; such code proposals help improve design and construction standards and mitigate damage from hazard events.

1.4.1 Team Composition

The Michael MAT was composed of 18 SMEs drawn from the following four sources:

- FEMA Headquarters (HQ) and Regional office architects, engineers, and specialists
- Florida Division of Emergency Management (FDEM) floodplain management and engineering specialists
- Construction and building code industry specialists
- Design professionals and technical consultants

MAT members included specialists from different areas of interest: architects and structural, civil, coastal, and electrical engineers. The specialists are experts in a variety of pertinent topics, including wind damage-resistant buildings, floodplain management, building codes, construction materials, critical facilities, and housing. The members of the MAT are listed in the front matter of this report.

1.4.2 Involvement of State and Local Agencies

FEMA encouraged the participation of county and local government officials and locally based specialists in the assessment process. Federal, state, and local government officials' involvement was critical and helped improve the MAT's understanding of local construction practices; facilitated communications among governments and the private sector; and improved the state and local understanding of the MAT's observations, conclusions, and recommendations, enabling them to bring about changes in their communities through public outreach efforts spearheaded by the JFO.

The MAT met with local emergency management and government officials in many of the areas visited during the field assessments. These officials gave an overview of the damage in their areas and helped identify and recommend key areas where the MAT should make observations and assessments. The MAT also coordinated with the FEMA JFO that had been established shortly after Hurricane Michael made landfall. Individuals who assisted the MAT with its field operations and report development are listed in the front matter of this report.

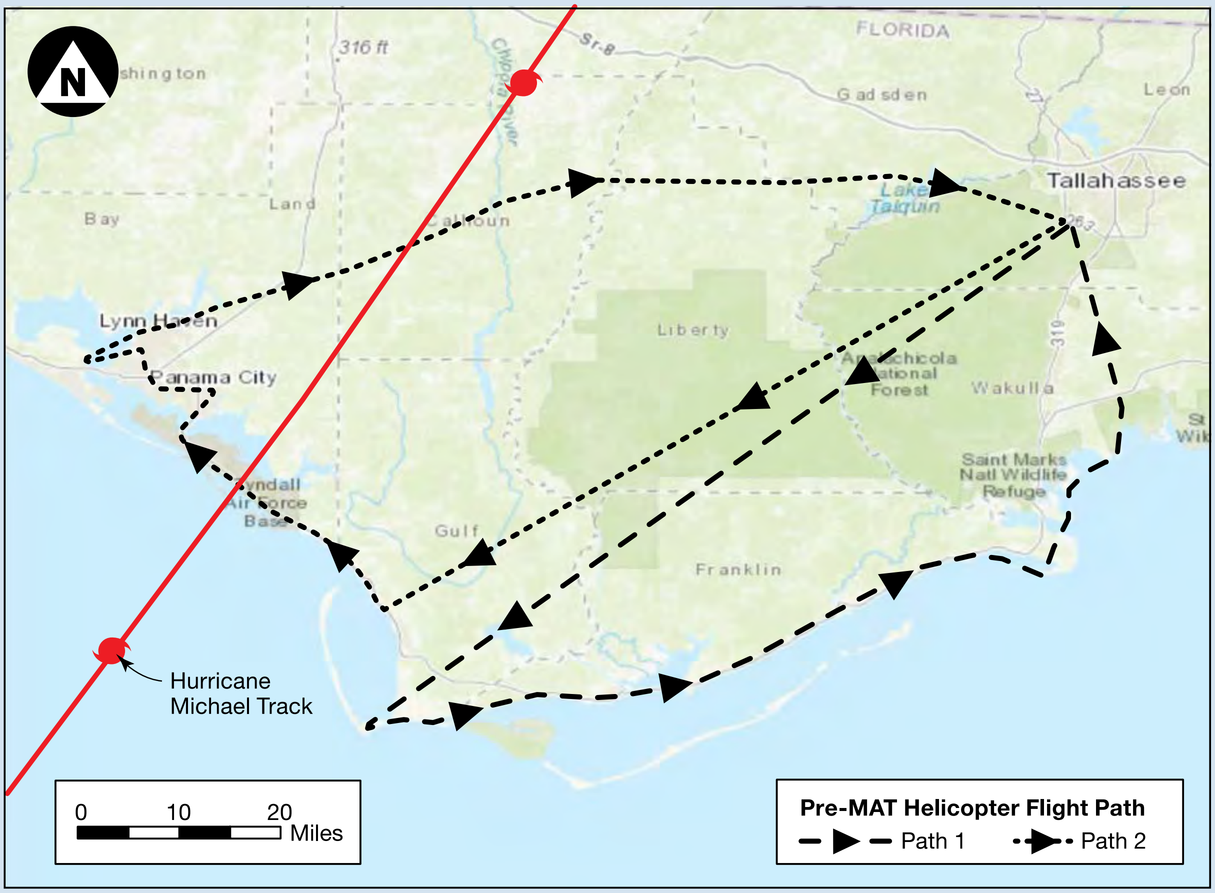
1.4.3 Pre-MAT Deployment and Site Selection

To develop the focus areas for the MAT, FEMA deployed a pre-MAT on October 21, 2018, through October 25, 2018, to the region impacted by Hurricane Michael. The pre-MAT deployed three teams, each composed of three people, consisting of FEMA HQ and Regional personnel and SMEs with a range of expertise. Prior to deploying the pre-MAT, FEMA and pre-MAT members relied on a desktop analysis, news reports of storm damage, social media, NOAA and Civil Air Patrol photographs, and locations of FEMA-funded mitigation projects to identify regions and specific locations for the pre-MAT to visit. Additionally, a helicopter reconnaissance tour was conducted on October 21, 2018, along the west and southern coasts of Florida up to Tallahassee to obtain detailed imagery of specific areas (see textbox for additional detail).

HELICOPTER RECONNAISSANCE

The helicopter reconnaissance tour allowed the pre-MAT to obtain imagery much closer to subject buildings, at a lower altitude and from different angles, giving team members the opportunity to see details of building envelope performance. The flight also enabled the pre-MAT to rapidly assess a large area, thereby identifying the areas with the most damage. The flight took the team inland through the areas impacted by the hurricane to assess areas that were impacted by high wind but not covered by available imagery and, thereby, better determine potential areas and buildings for further study.

The helicopter rapid reconnaissance tour consisted of two separate flights, on the same day, due to weight and fuel limitations, to observe the storm damage and the performance of residential and non-residential buildings, coastal infrastructure, and barrier islands.



Helicopter rapid reconnaissance flight paths

The pre-MAT visited Bay, Franklin, Gulf, and Wakulla Counties to observe storm surge damage and Bay, Calhoun, Franklin, Gulf, and Jackson Counties to observe wind damage. The pre-MAT observations of types and magnitude of damage were used to identify unique conditions and gather information to help the MAT and FEMA Regional and National Leadership develop a deployment strategy for the MAT and identify SMEs. The pre-MAT also provided information on potential logistical concerns, such as road and bridge damage or outages, travel times within the impacted region, key people and organizations the MAT could contact while in the field, and specific JFO setup and reporting requirements. The information gathered by the pre-MAT was used as a base for planning and scheduling the MAT deployment. Using the pre-MAT information, FEMA Leadership, in consultation with the pre-MAT members, determined the focus areas for the MAT (identified at the beginning of this chapter).

1.4.4 Hurricane Michael MAT Deployment and Mission

The Michael MAT was deployed January 6 to 10, 2019, to perform field assessment work in Bay, Calhoun, Franklin, Gulf, Jackson, and Wakulla Counties. Because of the size of the impacted area, the MAT was divided into four specialty groups. Using the information collected by the pre-MAT, each specialty group was deployed to several locations to assess the performance of specific building and facility types. Of the four specialty groups in the MAT, three focused on wind-related damage and one focused on flood-related damage, as follows:

TIMING OF THE MAT DEPLOYMENT

Ideally, a MAT should be deployed within 30 to 45 days of an event to enable collection of perishable data and assess building damage before significant repairs have started in impacted areas. However, in some cases MATs are deployed later than this window due to a variety of logistical, approval, and funding reasons.

- MAT Coastal Group: focused on coastal flood-related damage in Bay, Gulf, Franklin, and Wakulla Counties
- MAT Residential Wind Group: focused on wind-related damage to residential structures in Bay and Gulf Counties
- MAT Non-Residential Wind Group: focused on wind-related damage to non-residential structures in Bay, Calhoun, and Jackson Counties
- MAT Combination Residential/Non-Residential Wind Group: focused on wind-related damage to both residential and non-residential structures in areas of Bay and Gulf Counties that were logistically challenging for the other wind units to cover

The mission of the MAT was to assess the performance of residential and non-residential buildings affected by Hurricane Michael. However, the 3-month delay in deployment after the storm resulted in the loss of perishable damage data. By the time the MAT was able to visit, some sites and buildings had been demolished; many buildings, roofs, windows and doors, and wall or other systems were already repaired or being repaired; and debris fields had been cleaned up. Nevertheless, the MAT was able to obtain significant critical information. In coastal areas, while storm debris had been cleaned up, the damage to the remaining coastal infrastructure allowed the MAT to make determinations about building performance. In other areas, where clean-up and repair had progressed, the MAT was able to determine building performance by observing the sections of buildings that were repaired and attributing those repairs to particular failures and by observing the damage to structures that remained even after the debris had been cleaned up. Additionally, the MAT performed abundant informal interviews with homeowners and managers of critical facilities to understand what happened during the event.

Figure 1-9 through Figure 1-11 depict the approximate locations where the MAT specialty groups assessed building performance. When possible, the MAT interviewed building and facility owners and operators to gain insight into how their buildings and facilities performed during Hurricane Michael. The interviews focused on how buildings and facilities performed during other recent events and how recovery efforts were progressing. Each MAT specialty group assessed successes and failures for its focus area to determine why certain buildings performed better than others and what lessons could be learned from the event.

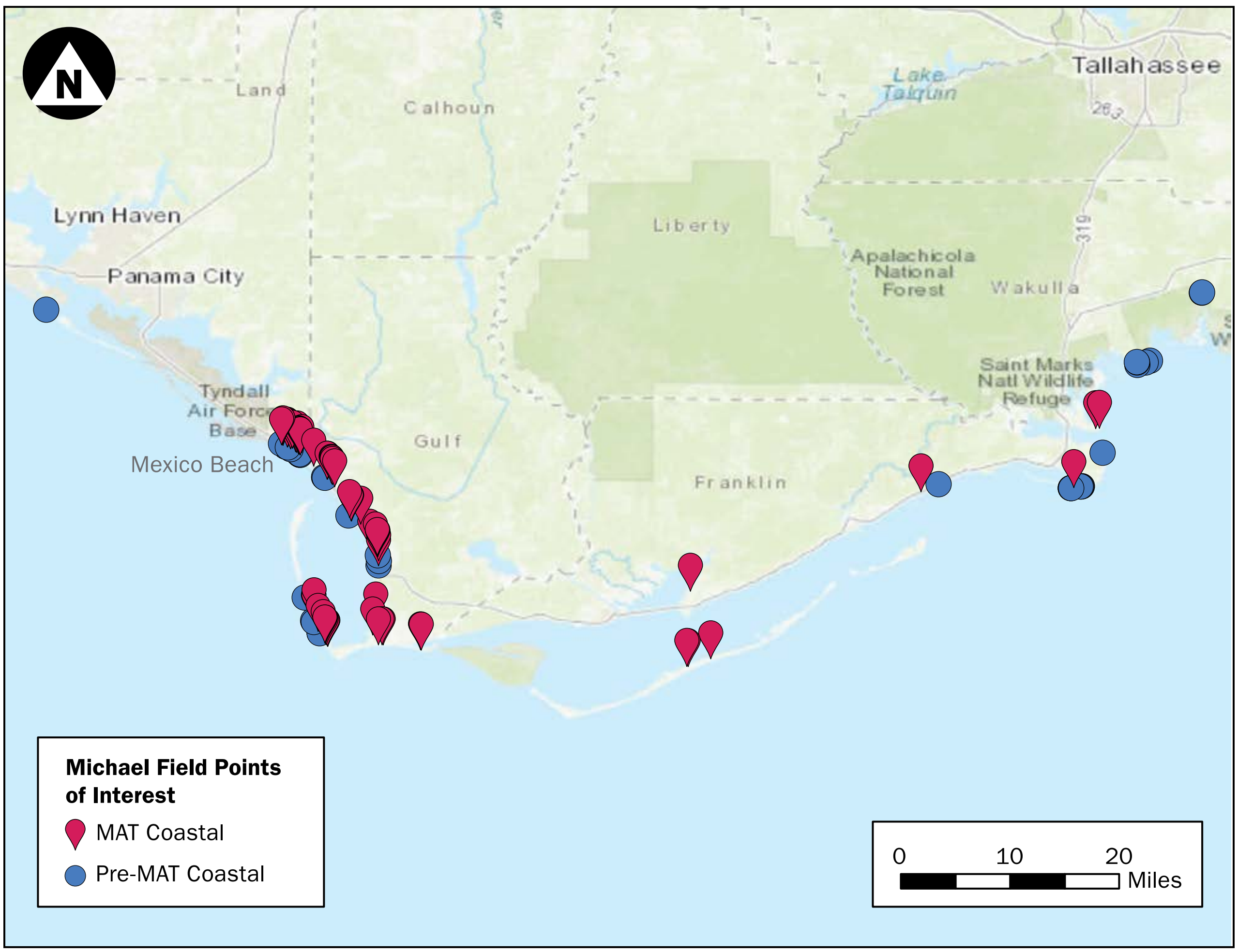


Figure 1-9: Areas of operations for the MAT Coastal Group

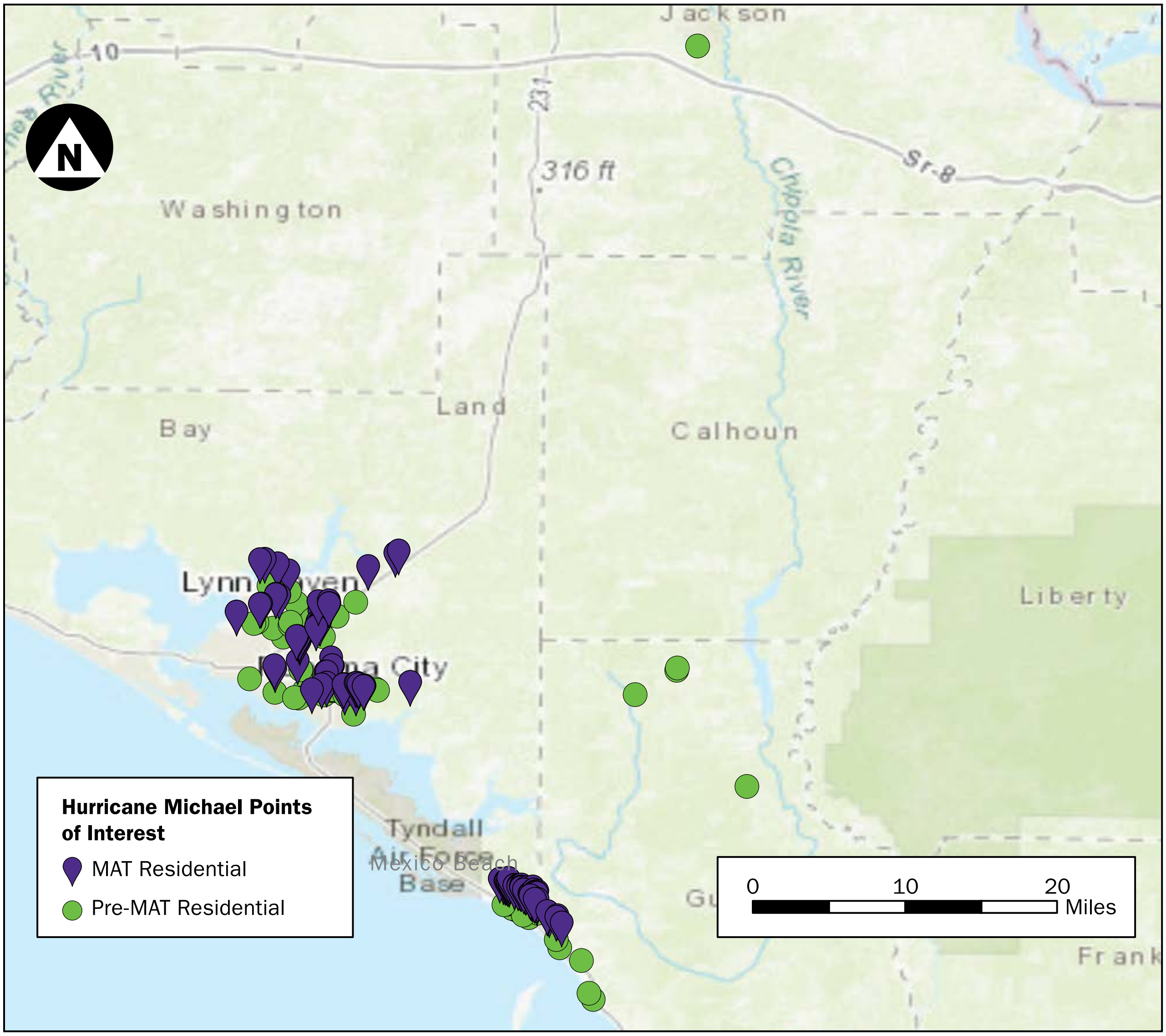


Figure 1-10: Areas of operations for the MAT Residential Wind Group and Combination Residential/Non-Residential Wind Group

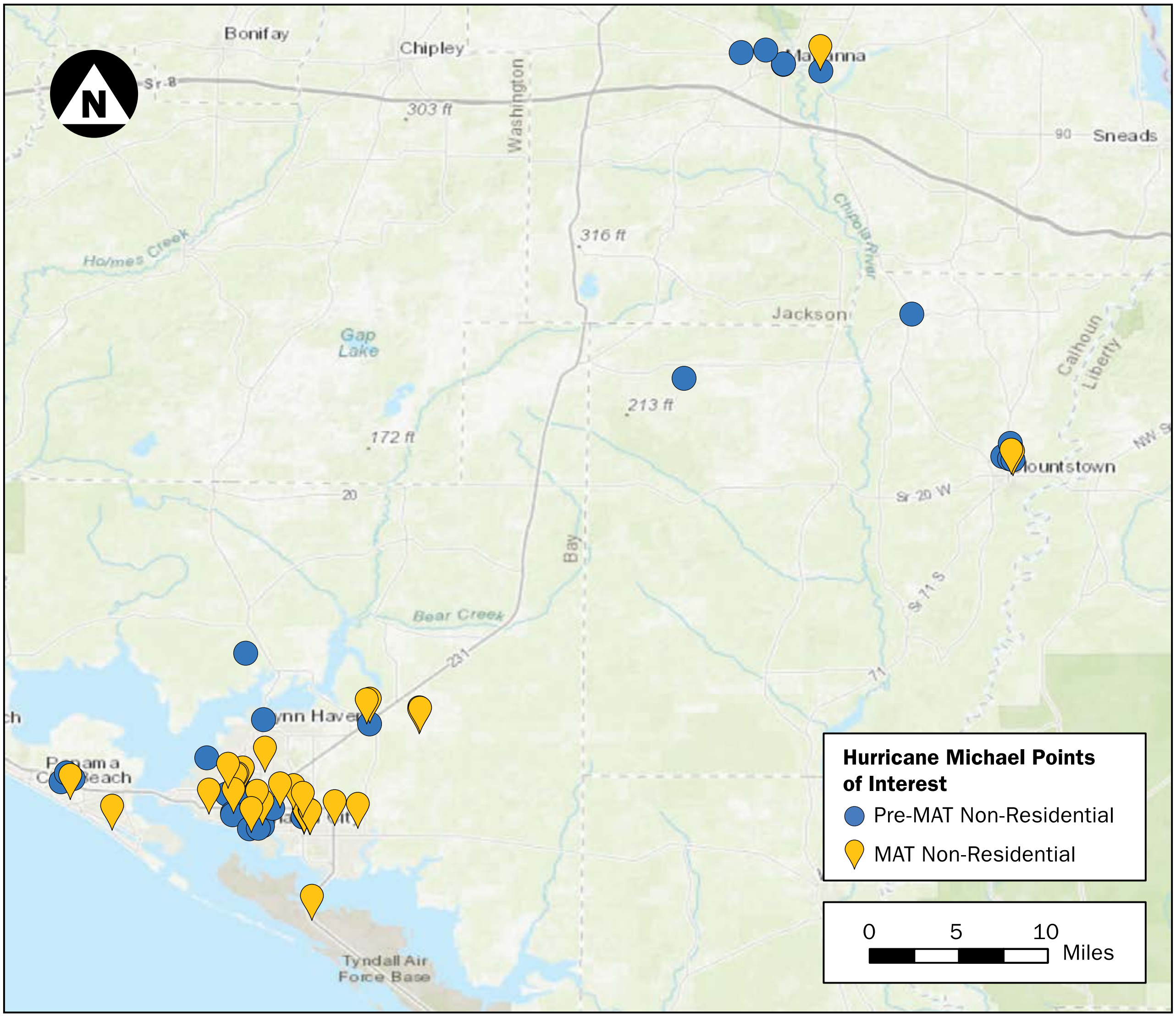


Figure 1-11: Areas of operations for the MAT Non-Residential Wind Group and Combination Residential/Non-Residential Wind Group

1.4.5 Role of Regional Response Coordination Center

FEMA deployed a building science specialist to act as a FEMA MAT liaison at the FEMA Region IV RRCC[6] in Atlanta, GA, from October 10 to 15, 2018. The RRCC does not have a formal position on the roster for a MAT liaison, nor is one needed for most disasters. MAT liaisons to the RRCC are requested by the FEMA MAT to the RRCC leadership and are assigned on a case-by-case basis. The role of the MAT liaison has been effectively performed in the past, such as for the tornado swarm that struck the southeast in 2011 for which a MAT was deployed (refer to FEMA P-908, *Mitigation Assessment Team Report – Spring 2011 Tornadoes: April 25–28 and May 22* [2012]).

6 For more information about RRCCs, refer to the FEMA Fact Sheet, Regional Response Coordination Centers (2015b), at www.fema.gov/media-library/assets/documents/96850.

Role of RRCCs. RRCCs provide response and recovery support to each of the states and tribal governments within its Regional jurisdiction. The RRCC functions as the Regional interface between the states and tribal governments and the FEMA National Response Coordination Center, maintaining situational awareness and executing mission objectives until a JFO opens. The RRCC provides federal support for activities necessitated to respond to a federally declared disaster. Additionally, it coordinates personnel and resource deployments to support disaster operations and prioritizes interagency allocation of resources. The RRCC is an ideal location to coordinate as needed amongst the 15 Emergency Support Functions (ESFs) or organizations that are receiving and coordinating information on response operations, damage occurring, weather updates, and other disaster-related information within the Region and impacted areas.

MAT liaison support. The MAT liaison gathered, assessed, and provided information to the MAT program manager at FEMA HQ, the MAT contractor, and other organizations on MAT conference call updates to help provide situational awareness, improve understanding of key damage and potential trends of interest, and help inform the pre-MAT deployment and overall MAT strategy development. The MAT liaison also relayed key information to the RRCC, such as building codes in effect for the impacted area.

The MAT's strategies, objectives, scope of effort, and geographic areas of coverage were coordinated and developed through progressive draft iterations using knowledge and situational awareness being gained related to the extent of damage being reported to the RRCC. The use of a MAT liaison resulted in contract documents that were better scoped and allowed government cost estimates to be developed. The MAT liaison also initiated coordination with the Incident Management Assistance Team and Mitigation leadership at the Initial Operating Facility before the JFO was activated.

This coordination was instrumental to the functioning of the MAT after Hurricane Michael. One example was the MAT liaison's support arranging a timely helicopter overflight to help the pre-MAT gain better situational awareness of the impacted area and allow photographic documentation of key damage, siting, erosion, and other items to help determine building performance before repairs were initiated. The overflight also aided the overall MAT effort in producing this report with its conclusions and strategic recommendations, preparing two Recovery Advisories, providing training and outreach to improve recovery operations, and supporting mitigation and preparedness into the future.

HURRICANE **MICHAEL** IN FLORIDA

CHAPTER 2

Building Codes, Standards, and Regulations

Building codes that include requirements to address flooding and high winds can help buildings perform better during a disaster event.

This chapter presents an overview of Florida's building codes, the wind and flood provisions in those codes, and floodplain management in Florida. 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 Michael reinforce the value of the wind and flood provisions of the FBC and the importance of trained plan reviewers and inspectors. Observations by the MAT also underscore the critical importance of builders paying attention to details during construction.

Section 2.1 describes the 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; how local jurisdictions can amend the FBC; and options communities have for building department administration.

Section 2.2 highlights recent initiatives of the FDEM to support communities that participate in the National Flood Insurance Program (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. The section also discusses wind, structural, and testing requirements for a special zone called the "High-Velocity Hurricane Zone."

Section 2.4 discusses state emergency shelter operations in Florida. Section 2.4 provides an overview of the structural design provisions of the Public Shelter Design Criteria—also referred to as EHPA provisions—as well as information about meeting these requirements through retrofit of existing spaces.

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 Michael made landfall in the State of Florida, the 6th Edition (2017) 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)

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

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 existing buildings, including historic structures.

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. The Commission is a 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 first step of the development process for the 6th Edition (2017) FBC was to select the base code that would serve as the starting point. The 2015 I-Codes were selected as the base code. 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 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.

Prior to the process used to develop the 6th Edition (2017) FBC, 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 code development process has changed, starting with the 7th Edition (2020) FBC. 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 involves 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 to approve a code change has been reduced from three-fourths of the TAC members present at the meeting to two-thirds.

While the 2017 statutory change also limited the Commission to only approving amendments to the code that are “needed to accommodate the specific needs of this state,” this limitation was eliminated during the 2019 legislative session. 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 2.2.3). The most common technical amendments related to the wind provisions of the code clarify the specific location of the wind speed contours.

STATE FLOODPLAIN MANAGEMENT OFFICE (SFMO) GUIDANCE FOR INTERLOCAL AGREEMENTS

FDEM offers a model interlocal agreement for floodplain management that spells out the duties of the community and the contracting entity, whether another community or a private provider. The model agreements, and a summary of community responsibilities for participation in the NFIP, can be accessed at www.floridadisaster.org/dem/mitigation/floodplain/community-resources/.

2.1.3 Building Department Administration

Florida counties and municipalities are required to have a Building Official to administer and enforce the FBC. Most communities establish building departments and have Building Officials on staff, along with support personnel, to perform all building department functions, including reviewing plans, issuing permits, citing unpermitted construction and violations, and performing construction inspections. The Florida Statute provides municipalities the ability to enter into written interlocal agreements with another community. Communities may also have contracts with private-sector providers to perform all or some of the Building Official responsibilities and the building department functions.

Several communities visited by the MAT use private-sector providers for some or all building department functions. Because the FBC includes requirements for buildings in flood hazard areas, interlocal agreements and contracts do not need to explicitly identify responsibilities related to enforcement of the flood provisions in the FBC. However, agreements and contracts for building department functions typically do not explicitly include the responsibilities of the Floodplain Administrator that are spelled out in local floodplain management regulations. Those regulations, described in Section 2.2.4, are written explicitly to rely on the FBC for buildings and structures in Special Flood Hazard Areas (SFHAs). Gaps in administration may occur when agreements and contracts are silent with respect to floodplain management functions outside of the FBC requirements.

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 (CAVs) 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 Risk Mapping, Assessment, and Planning (Risk MAP) process, and provides training for local officials. The training is conducted primarily through an agreement with the Florida Floodplain Managers Association (FFMA).

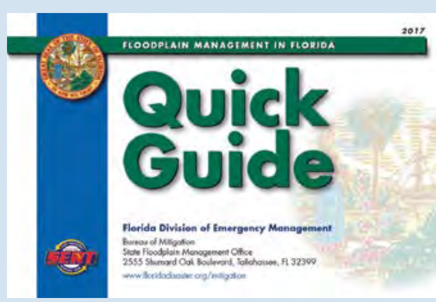
The SFMO also supports communities that participate in the NFIP Community Rating System (CRS), a program that recognizes activities undertaken by communities to reduce flood risk by providing premium discounts to citizens who have NFIP flood insurance policies. As of October 2019, 240 of the 467 Florida NFIP communities participate in the CRS program.

TOOLKITS FOR FLOODPLAIN MANAGERS

After recent hurricanes events, the SFMO produced two resources for floodplain management in Florida.

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

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



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

In May 2018, the SFMO released the *Florida Post-Disaster Toolkit for Floodplain Administrators* (see textbox above). 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 existing buildings is beneficial when owners elect to have certificates prepared as part of obtaining flood insurance policies.

ELEVATION CERTIFICATES

The web applications for submitting Elevation Certificates and accessing submitted documents are available at www.floridadisaster.org/elevation-certificates/.

2.2.1 History of Flood Provisions in the Florida Building Code

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 ICodes 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 considers the flood provisions in the 2015 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 ICodes 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. For the purpose of NFIP participation, FEMA made the same statement about the flood provisions of the 2009 and 2012 I-Codes, which formed the basis of the 2010 FBC and 5th Edition (2014) FBC, respectively.

FLORIDA BUILDING CODE AND THE NFIP

The Florida SFMO compiled excerpts of the flood provisions of the 6th Edition (2017) FBC and a summary of the differences between the 5th and the 6th Editions, online at www.floridadisaster.org/dem/mitigation/floodplain/community-resources.

FDEM refers users to FEMA's *Highlights of ASCE 2414 Flood Resistant Design and Construction* (2015a), online at www.fema.gov/building-code-resources.

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 the 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).

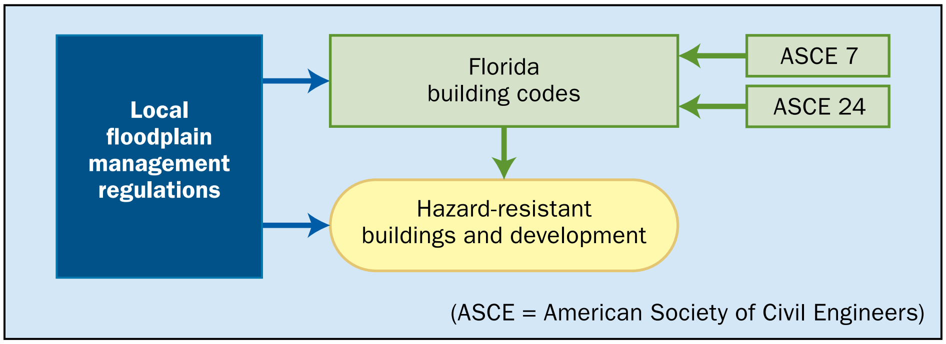


Figure 2-1: FBC and local regulations meet or exceed the NFIP requirements

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 6th Edition (2017) FBC, which was in effect when Hurricane Michael made landfall, contains the following Chapter 1 amendments specific to buildings and structures in flood hazard areas:

- Section 102.7, Relocation of manufactured buildings – Provision added that relocated manufactured buildings (not manufactured housing) shall comply with flood hazard area requirements (e.g., if moved into or within flood hazard areas).
- Section 104.2.1, Determination of substantially improved or substantially damaged existing buildings and structures in flood hazard areas, and Section 104.10.1, [Modifications] Flood hazard areas – 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).
- Section 105.14, [Permits] Permit issued on basis of an affidavit, and Section 107.6.1, [Submittal Documents] Building permits issued on the basis of an affidavit – Provisions added 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, Minimum plan review criteria for buildings – Section added to specify examination of documents, including minimum plan review criteria for "Building" and "Residential." For both, 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 and fuel gas include design flood elevations (DFEs).

- Section 110.3, Required inspections – 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, [Certificate of Occupancy] Certificate issued – New requirement added 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, Variances in Flood Hazard Areas – 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 FBCB Chapter 4, Special Detailed Requirements based on Use and Occupancy, 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:

- Section 449, Hospitals, and Section 450, Nursing Homes – Require, for new construction of hospitals and nursing homes, elevation or dry floodproofing to the base flood elevation (BFE) plus 2 feet or "the height of hurricane Category 3 (Saffir-Simpson scale) surge inundation elevation," whichever is higher. The sections require Substantial Improvements to existing facilities in SFHAs or within a Category 3 surge inundation zone to be designed in compliance with Section 1612, Flood Loads. 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 if the existing building was built in compliance with applicable flood hazard areas requirements, unless otherwise required by Section 1612. For additions to facilities that pre-date the adoption of the code sections or local flood-resistant requirements, the elevation requirements for new facilities must be met, or dry floodproofing may be designed and constructed in accordance with Section 1612.
- Section 453, State Requirements for Educational Facilities – Requires initial and subsequent installation of "public educational 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."
- Table 1612.1, Cross References Defining Flood-Resistant Provisions of the Florida Building Code – Provides a cross-referenced list of all flood-resistant provisions of the FBC.
- Section 1612.3, Establishment of Flood Hazard Areas, and FBCR Table R301.2(1), Climatic and Geographic Design Criteria – 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, Modification of ASCE 24 – Modifies ASCE 24 Table 6-1, Minimum Elevation of Floodproofing – Flood Hazard Areas Other Than Coastal High Hazard Areas, Coastal A Zones, and High Risk Flood Hazard Areas, and Section 6.2.1, Dry Floodproofing Limitations, 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 for specific requirements for buildings and related components in flood hazard areas.
- Section 3109, Structures Seaward of a Coastal Construction Control Line – Contains requirements applicable to most structures located seaward of the Coastal Construction Control Line (CCCL), a line established by Florida Statute. In the 6th Edition (2017) FBCB, this section is completely revised to bring the CCCL 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 CCCL requirements is higher than the BFE shown on Flood Insurance Rate Maps (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 June 2019, 90 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 middle of 2020. 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 must be above the minimum required elevation. More than 40 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).** More than 100 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 100 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 50 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.** Nearly 40 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 (refer to 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 2414 Flood Resistant Design and Construction* (2015a) 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 FIRMs, records retention, and other provisions. FEMA supported this work with technical and financial assistance.

ADOPTION OF FBC-COORDINATED ORDINANCE

As of June 2019, nearly 90 percent of Florida's NFIP communities had adopted local ordinances based on the FBC-coordinated floodplain management ordinance. The remaining communities are expected to make the transition by the middle of 2020.

Final approval of the model ordinance was received in January 2013. A major benefit of the close collaboration with FEMA is that 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 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.

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 June 2019, the most common non-building higher standards are:

- **Manufactured housing restrictions.** Nearly 70 communities have adopted restrictions on the installation of manufactured housing. While some prohibit manufactured housing in SFHAs, most limit the prohibition to the installation of new manufactured housing in Zone V or floodways unless they are in existing manufactured housing parks or subdivisions that were established before the communities joined the NFIP.
- **Compensatory storage.** More than 20 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 6th Edition of the FBC references 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.

There are exceptions specified in the FBC that allow for the use of certain prescriptive high-wind design standards. These prescriptive standards are primarily for one- and two-family dwellings, although ICC 600, *Standard for Residential Construction in High-Wind Regions* (ICC, 2014), is also permitted for applicable Group R2 buildings (apartments, hotels, dormitories, etc.). The prescriptive standards allowed for the FBC for high-wind design 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) (ICC, 2014)
- *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings*, 2007, with Supplement 3, dated 2012 (American Iron and Steel Institute [AISI] S230) (AISI, 2012)

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, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code*. Available at www.fema.gov/media-library/assets/documents/158123.

2.3.1 Wind Loads and Wind Design in the FBC

Section 2.3.1 provides information on the current design wind speeds in the FBC, as well as the wind-borne debris region (WBDR). A history of wind-related changes in the FBC is also provided for reference.

Design Wind Speed Maps in the FBC

The 6th Edition (2017) FBCB and FBCR contain Florida-specific design wind speed maps that 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, including the WBDR, is shown in Figure 2-4. For more information on the WBDR, refer to the following subsection “Wind-Borne Debris Region.”

WIND SPEEDS USED IN MAT REPORT

Chapter 4 of this report provides the estimated wind speeds for sites visited by the MAT, as well as the basic wind speed from ASCE 7-10 for comparison. ASCE 7-10 was chosen for Chapter 4 as it is the version referenced by the current 6th Edition of the FBC.

However, Chapter 5 of this report provides the estimated wind speeds for selected sites visited by the MAT, as well as the basic wind speed from ASCE 7-16 for the location. ASCE 7-16 speeds are used in Chapter 5 because they are the state of the practice even though ASCE 7-10 is referenced in current FBC. Also, ASCE 7-16 provides a new Risk Category IV map, which is not included in ASCE 7-10 or the 6th Edition FBC. This new map would apply to many of the buildings discussed in Chapter 5.

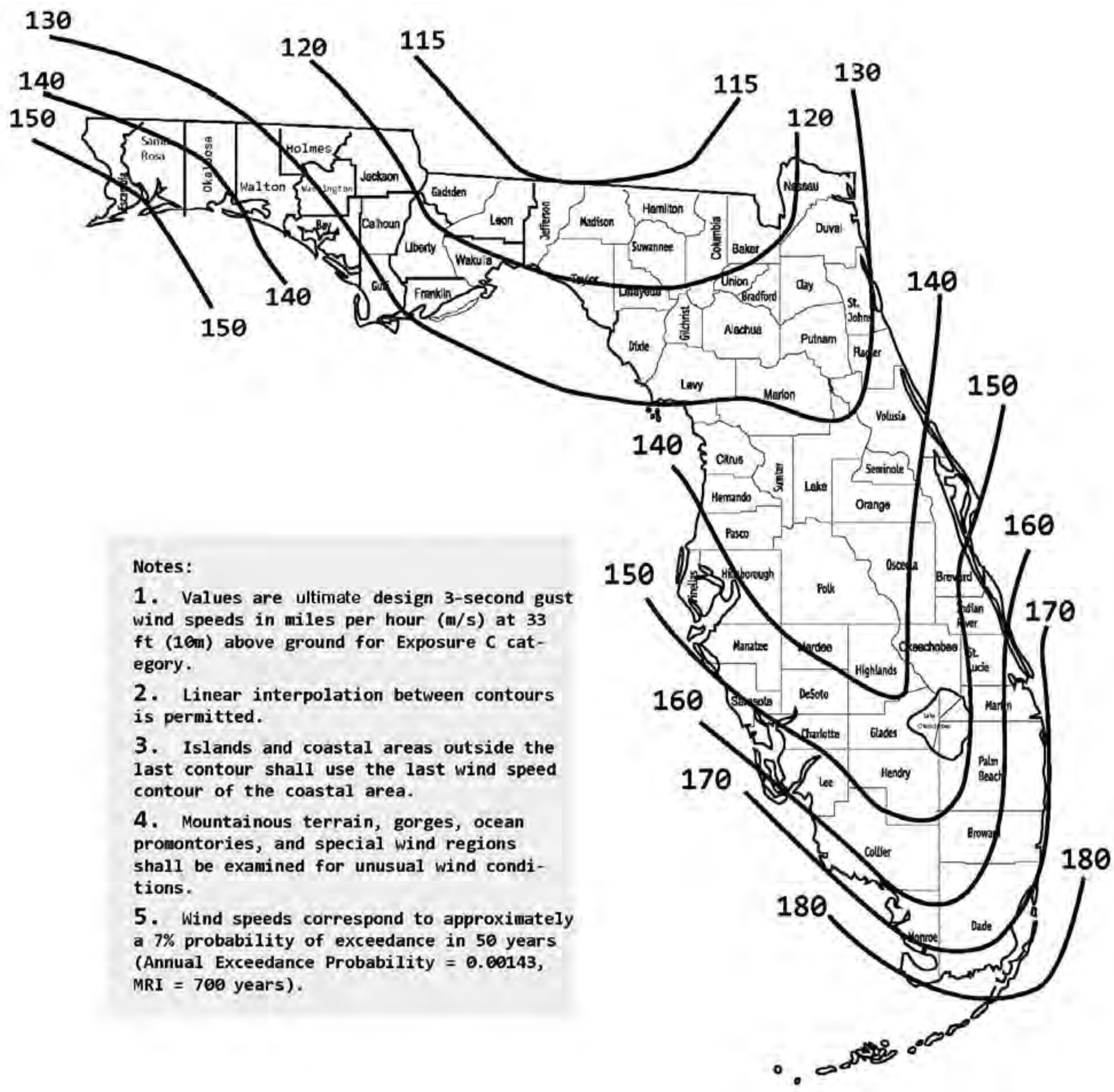


Figure 2-2: Wind speed map for Risk Category II buildings and other structures

SOURCE: 6TH EDITION (2017) FBCB, IMAGE USED WITH PERMISSION FROM ICC

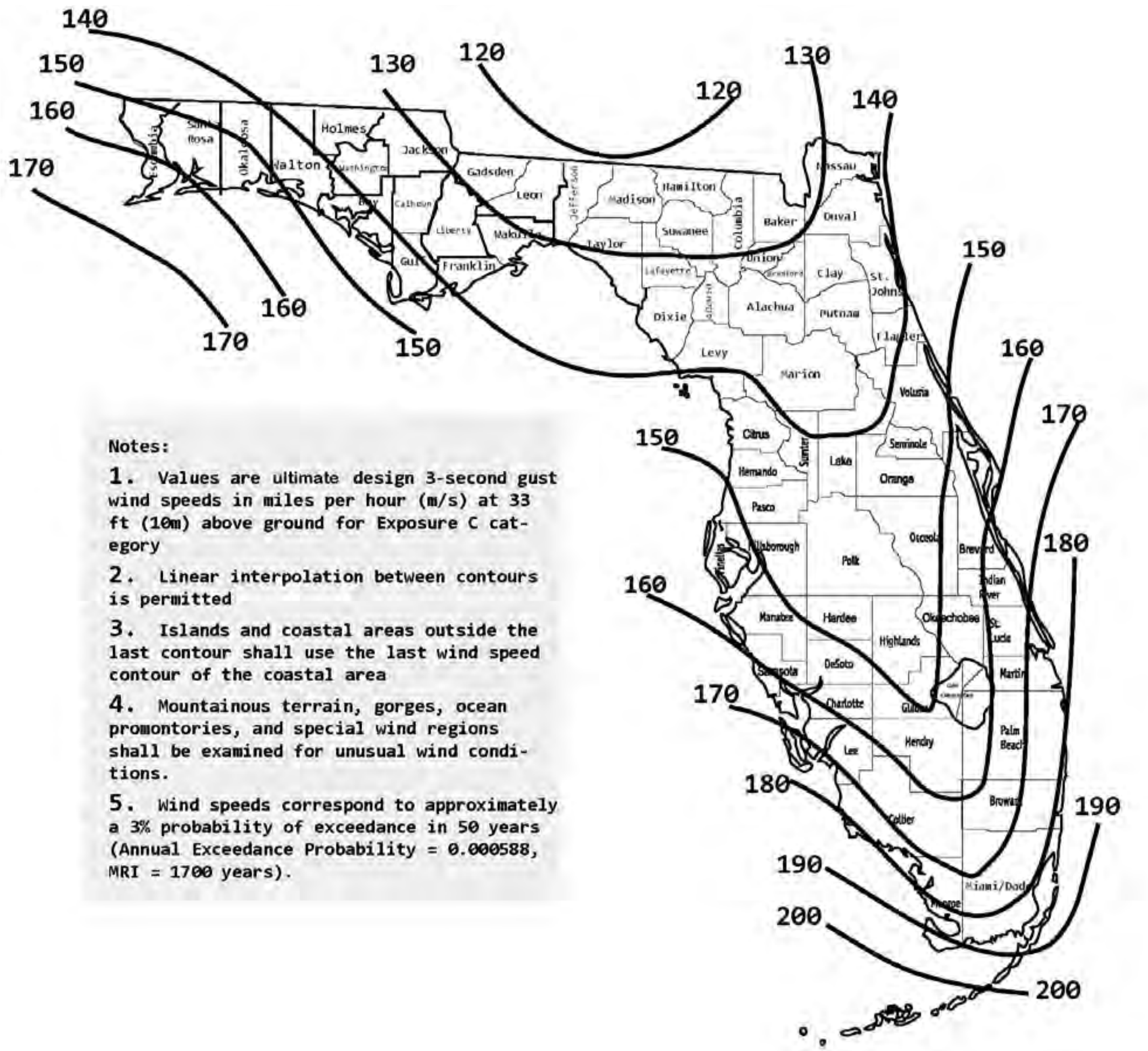


Figure 2-3: Wind speed map for Risk Category III and IV buildings and other structures

SOURCE: 6TH EDITION (2017) FBCB, IMAGE USED WITH PERMISSION FROM ICC

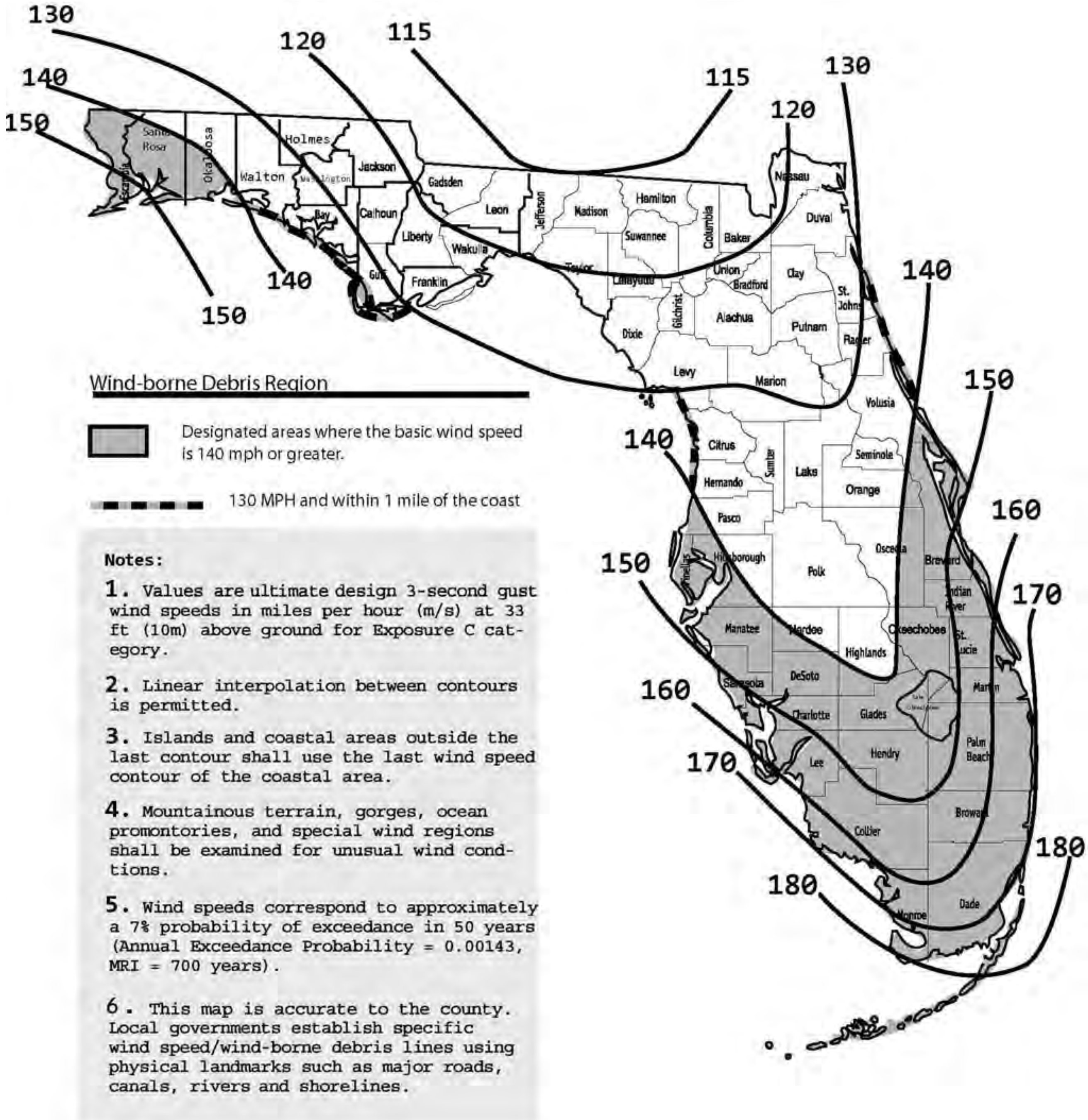


Figure 2-4: Wind speed map and WBDR for FBCR buildings

SOURCE: 6TH EDITION (2017) FBCR, IMAGE USED WITH PERMISSION FROM ICC

Wind-Borne Debris Region

> **DEFINITION: FBC WIND-BORNE DEBRIS REGIONS**
>
> 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.
>
> [SOURCE: CHAPTER 2 OF THE FBCR]
>
> Figure 2-4 shows the wind speed map from the 6th Edition (2017) FBCR with the WBDR shaded.

The 2001 FBC included the WBDR as defined in the 1998 edition of ASCE 7,[7] except in the Florida Panhandle. The Florida Legislature mandated that from the eastern border of Franklin County to the Florida-Alabama line, only buildings within 1 mile of the coast would be subject to wind-borne debris requirements. Hence, Florida's wind-borne debris provisions did not extend as far inland as those in the referenced edition ASCE 7 (i.e., Florida was less conservative with respect to ASCE 7). However, the exception for the Florida Panhandle was removed in the 2007 FBC. In the 6th Edition (2017) FBCB and FBCR, the definition of WBDR is consistent with ASCE 7-10. Figure 2-5 shows a comparison of the WBDR between the 2001 FBC and the 2017 FCBC. The coastal counties visited by the MAT are highlighted. In areas impacted most by Hurricane Michael, the WBDR is essentially the same in the 6th Edition (2017) FBC as it was in the 2001 FBC for Risk Category II buildings, except in Franklin County where only the western tip that is within a mile of the coastal mean high water line is in the WBDR.

7 The WBDR definition in ASCE 7-98 has evolved over time; the definition in the textbox on this page for the WBDR correlates with ASCE 7-10 and ASCE 7-16.

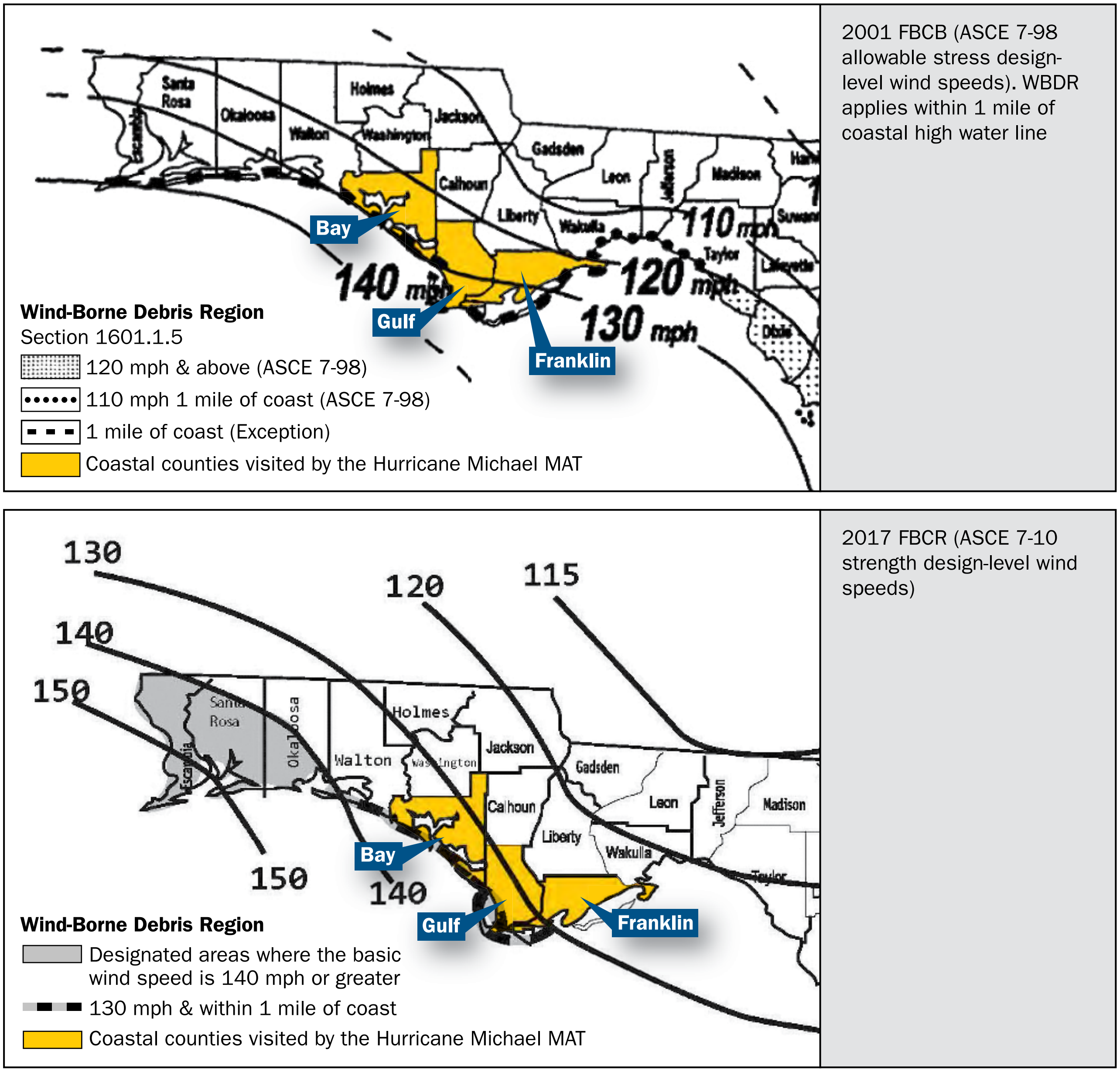


Figure 2-5: Map of Coastal Counties visited by the Hurricane Michael MAT

History of Wind Design-Related Changes in the FBC

For a history of key FBC changes affecting wind design, including information on changes to the mapped wind speeds in ASCE 7-10, refer to Table 2-1.

Table 2-1: Key FBC Changes Affecting Wind Design

Code Edition	Effective Date	Code Basis	ASCE Reference	Changes Affecting Wind Design
2001 FBC	3/2002	Primarily on the 1997 and 1999 Standard Building Code	ASCE 7-98	• The wind-borne debris region (WBDR) in the panhandle area was reduced to apply only within 1 mile of the coast (panhandle exemption) (See Figure 2-5) • Exposure C applied only within 1 mile of the Coastal Construction Control Line (CCCL); Exposure B applied everywhere else • In the WBDR, permitted buildings to be designed as partially enclosed in lieu of protecting glazed openings • Asphalt shingles were required to be tested in accordance with ASTM D3161
2004 FBC	10/1/2005	2003 I-Codes	ASCE 7-02	• Little change to wind design requirements from previous edition • Revised the base code for residential construction (International Residential Code [IRC]) to require high-wind design and construction throughout the state • ASTM D7158 added as additional option for testing asphalt shingles for wind resistance • Included reference to ANSI/SPRI ES-1
2007 FBC	3/1/2009	2006 I-Codes	ASCE 7-05	• The WBDR in the panhandle was revised to be consistent with ASCE 7 because the panhandle exemption was removed • Exposure categories were revised to be consistent with ASCE 7 • In the WBDR, glazed openings were required to be protected from impact, and the option for designing buildings as partially enclosed in lieu of opening protection was removed • New mitigation requirements were added for reroofing on some single-family residential buildings built before the 2001 FBC went into effect • For residential construction, ring shank nails were required for attaching wood roof decking • Improved anchorage requirements for hip and ridge roof tile were added • Design wind loads on soffits were specifically defined • For using wood structural panels used as opening protection, mounting hardware was required to be permanently installed on the building
2010 FBC	3/15/2012	2009 I-Codes	ASCE 7-10	• Due to the update to ASCE 7-10, wind speeds generally decreased throughout the state, and the WBDR decreased in the panhandle area and increased for the southern part of Florida

Table 2-2: Key FBC Changes Affecting Wind Design (continued)

Code Edition	Effective Date	Code Basis	ASCE Reference	Changes Affecting Wind Design
5th Edition (2014) FBC	6/30/2015	2012 I-Codes	ASCE 7-10	• Enhanced underlayment fastening was required for all roof coverings, and thicker underlayment was required for asphalt shingles on steep-sloped roofs
6th Edition (2017) FBC	12/31/2017	2015 I-Codes	ASCE 7-10	• Thicker underlayment required for all steep-sloped roofs • Limited the span of wood structural panels used as opening protection to 44 inches

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 2-2 lists some notable Florida-specific amendments in the 6th Edition (2017) FBC related to wind and water intrusion prevention.

Table 2-2: Notable Florida-Specific Amendments in the FBC for Wind and Water Intrusion

Code	Non-High-Velocity Hurricane Zone	High-Velocity Hurricane Zone

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
	• Applies enhanced roofing underlayment provisions to high-wind areas throughout the entire state
	• Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating
	• Requires that where more than 25% of the total roof area or roof section is repaired, replaced, or recovered in a 12-month period, the entire roof system or section has to be replaced to conform to the requirements of the code
		• 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
		• Requires the entire building envelope to be impact resistant (some deemed-to-comply assemblies are provided)
		• Requires all areas to be designed for Exposure Category C unless Exposure Category D applies
		• Applies enhanced roofing underlayment provisions throughout the HVHZ
		• Requires the use of plywood sheathing; OSB 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
	• Revises exposure category definitions 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
	• Applies enhanced roofing underlayment provisions to high-wind areas throughout the entire state
	• Requires labeling on garage doors, impact-resistant coverings, and windows to include the design wind pressure rating
	• Removes references to the use of staples for wall covering attachment methods
	• Specifically requires most roof coverings to have an uplift resistance in the Product Approval that is equal to or greater than the design uplift pressure
	• Requires that where more than 25% of the total roof area or roof section is repaired, replaced, or recovered in a 12-month period, the entire roof system or section has to be replaced to conform to the requirements of the code
		• 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; OSB = oriented strand board

2.4 State Emergency Shelter Operations in Florida

2.4.1 State Emergency Shelter Mandate

In response to the sheltering challenges posed by Hurricane Andrew (1992), Florida's governor commissioned an evaluation of the state's evacuation and shelter operations. The commission's report, the "Lewis Commission Report" (Florida Governor's Disaster Planning and Response Review Committee, 1993) identified a lack of "adequate and appropriate public shelter space," which led the state legislature to mandate elimination of the hurricane shelter capacity deficit in every region of the state. Subsequently, Florida's Department of Education was charged with developing standards for public shelter design criteria in "consultation with boards, county emergency management offices, and the Division of Emergency Management (DEM)." The resulting Public Shelter Design Criteria were adopted in 1997 and included "structural enhancements, potable water and sanitary requirements, provisions for standby emergency power, and other considerations that improve survivability and shelter management operations."

2.4.2 Enhanced Hurricane Protection Areas in the Florida Building Code

The structural design provisions of the Public Shelter Design Criteria—also referred to as EHPA provisions—have evolved with the FBC. The 1st Edition FBC (2001) included the following provision as cited in Section 6.5 of FEMA 488, *Hurricane Charley in Florida MAT Report (2005):*

> **"(d) Structural Standard for Wind Loads.** At a minimum, EHPAs shall be designed for wind loads in accordance with ASCE 7-98, "Minimum Design Loads for Buildings and Other Structures, Category III (Essential Buildings)." Openings shall withstand the impact of windborne debris missiles in accordance with the impact and cyclic loading criteria per SBC/SSTD 12-99. Based on a research document, "Emergency Shelter Design Criteria for Education Facilities," 1993, by the University of Florida for the DOE, it is highly recommended by the Department that the shelter be designed using the map wind speed plus (40) mph, with an importance factor of 1.0."

FEMA 488 reported on EHPA performance during Hurricane Charley, including one significant structural failure (Section 6.5.1.1), and recommended that 1) the EHPA design wind speed of the 2001 FBC basic wind speed plus 40 mph should be a requirement, not a best practice; and 2) minimum debris impact protection should be per ASTM E 1996 Test Missile E for a 9-pound 2x4 (nominal) missile traveling at 50 mph (instead of 34 mph for all other buildings in the WBDR) (Section 8.2). Note that FEMA 488 preceded the first edition of *ICC/NSSA Standard for the Design and Construction of Storm Shelters* (ICC 500), which was published in 2008.

The 2nd, 3rd, 4th, and 5th Editions of the FBC maintained essentially the same EHPA wind requirements as the 1st Edition (ASTM E1996 and E1886 were added as impact testing alternatives in the 5th Edition). Significantly, the 6th Edition FBC (2017) includes the first reference to ICC 500. Section 453.25.4 (Structural standards for wind loads) now provides: **"At a minimum, EHPA shall be designed for hurricane wind loads in accordance with ICC 500."**

2.4.3 State Emergency Shelter Plan Options: EHPA or Retrofit

In compliance with state statutes, the FDEM prepares and submits the *Statewide Emergency Shelter Plan* (SESP) to the Governor and Cabinet for approval every other year. The plan provides detailed information on the current inventory of HES spaces along with current and projected shelter capacity deficits (or surpluses) for every Florida county. The plan also includes supplemental guidance on implementation of the state's sheltering criteria. The plan's shelter-tracking data and implementation guidance are intended to inform planning decisions by local officials that will ultimately serve to safely eliminate the state's shelter capacity deficit.

According to Section 2.2 of the 2018 SESP, unless specifically exempted by the school board with written concurrence from the state, all new educational facilities (including new buildings on existing campuses) in areas identified with shelter capacity deficits are required to meet the EHPA code provisions so that the facilities can be used during storms as directed by local authorities. However, local authorities can avoid having to meet the EHPA provisions for new school buildings by satisfying the estimated shelter capacity demands by identifying available shelter space in existing buildings. Qualifying existing buildings for state-recognized shelter space requires assessing selected buildings or building areas using the American Red Cross *Standards for Hurricane Evacuation Shelter Selection* (ARC 4496; 2002) – Prescriptive Summary Table (FDEM, 2014). Based on the survey findings, the assessor assigns a qualitative ranking—preferred, less preferred/marginal, or further investigation/mitigation required—to 15 HES criteria categories. Mitigation of any shelter vulnerability may improve the ranking of buildings under consideration. For example, unprotected glazed openings (Category 10 – Fenestration/Window Protection) can be mitigated by retrofitting the opening with hurricane shutters, shields, or impact-resistant glazing, to change the Category 10 ranking from "further investigation/mitigation required" to "preferred." Like the 1st through 5th Editions FBC code recommendations on applying higher wind speeds for design of EHPA, ARC 4496 guidance on the HES selection process is written in non-mandatory language and, therefore, highly subject to interpretation.

Further insight on the balance between HESs designed as EHPAs versus those designated through assessment and mitigation of existing spaces may be found in the FDEM's *2017 Shelter Retrofit Report.* The report outlines its shelter capacity deficit reduction strategy and includes county-specific information gathered on retrofit projects and/or EHPA construction between September 2017 and August 2018. During that time, the FDEM approved approximately half of the 303 shelter retrofit projects submitted by "county emergency management agencies in cooperation with other partner organizations (local American Red Cross chapters and school boards)." In contrast, the report notes that only one new EHPA school was under construction over the same period. The report credits retrofit projects—and the funding that has made them possible—for significantly decreasing the statewide shelter capacity deficit since 1999.

CROSS REFERENCE

Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance,* was developed based on the MAT's observations of critical facilities performance (including HESs) and provides guidance on how to comprehensively assess building vulnerabilities to hurricane high winds. FEMA P-2062, *Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities* (2019c) is a newly released resource that also provides comprehensive guidance on performing vulnerability assessments for critical facilities.

HURRICANE
MICHAEL
IN FLORIDA

CHAPTER 3
Coastal Flood-Related Observations

Storm surge from Hurricane Michael's strong winds and low pressure caused severe flooding along much of the Florida Panhandle.

One area of emphasis for the MAT was the performance of residential and non-residential buildings affected by coastal flooding. This chapter describes the MAT's observations, which focused on the following:

- General flood observations by county (Section 3.1)
- Comparison of elevated and non-elevated structures (Section 3.2)
- Performance of concrete and wooden pile foundations (Section 3.3)
- Observations pertaining to floodplain management practices (Section 3.4)

The pre-MAT performed a cursory review of flood damage to structures at approximately 44 sites across Bay, Gulf, Franklin, and Wakulla Counties in October 2018. The MAT conducted more detailed evaluations of flood conditions and flood damage in January 2019 at the same geographic areas that the pre-MAT visited. In total, the coastal group visited 113 sites. The general vicinity of locations visited by the pre-MAT and MAT are shown in Figure 1-1 in Chapter 1.

> **FLOOD DAMAGE**
>
> The primary source of flood damage in areas visited was from storm surge. Flooding from heavy rainfall during the storm did not cause significant inundation damage in the coastal areas visited by the MAT. However, since the MAT visited months after the storm, it observed damage most likely related to precipitation events subsequent to the hurricane, such as water infiltration into structures with damaged roofs and exterior envelopes and other drainage problems related to clogged ditches and canals.

The MAT observed varying levels of coastal flood-related damage from storm surge and waves throughout the four counties assessed for coastal flood damage. Overall, building elevation was a primary predictor of building performance in the areas visited by the MAT; this observation has been frequently documented in previous FEMA MAT reports as well as by other research groups. Another significant building performance issue identified by the MAT was pile foundation failures in areas subject to wave action. While limited to certain locations visited by the MAT, this observation is relatively unique to Hurricane Michael because this is the first time it has been noted since the Hurricane Katrina MAT. Additionally, the damage observed by the MAT after Hurricane Michael demonstrates that stricter enforcement of code and implementation of floodplain management practices that go beyond the minimum requirements is needed to achieve far reaching resilience, as recommended in numerous previous MAT reports.

The characteristics of this storm, the causes for differing levels of storm surge, the measured water surface elevations, and flood depths throughout the area visited by the MAT are described in Chapter 1. Site-specific conditions such as beach width, natural features (i.e., dunes, barrier sandspits, embankments), and manmade topographical features (i.e., roads, ditches, culverts) can have localized impacts on the extent and severity of flood damage. Such conditions are described in this chapter, as relevant.

3.1 General Observations by County

This section describes general site conditions encountered by the MAT in the four counties assessed for coastal flood-related damage: Bay, Gulf, Franklin, and Wakulla Counties.

3.1.1 Bay County

Both wind and flood caused considerable damage to the easternmost portion of Bay County where Hurricane Michael made landfall (wind damage is described in Chapters 4 and 5). Hurricane Michael flood levels often exceeded the BFE in Bay County by several feet. Mexico Beach suffered the worst coastal flooding in the impacted area. Panama City, Panama City Beach, and other Bay County communities also received coastal flooding, though based on measured USGS high water marks, inundation in these communities was not as severe as flooding in Mexico Beach (see Figure 1-3 for USGS high water marks). Although examples are provided from Panama City Beach and the City of Callaway, the MAT observations and assessments focused on Mexico Beach located approximately 30 miles southeast of Panama City Beach, which was catastrophically damaged by Hurricane Michael.

3.1.1.1 Panama City Beach and City of Callaway

The following examples in these two communities were selected to illustrate the difference in damages incurred of elevated versus non-elevated houses. The construction demonstrated in these two examples are typical for this area.

Panama City Beach. Figure 3-1 is an example of a single-family house built in 2018 elevated on a stem wall (backfilled) foundation that did not incur any flood damage. Based on floodplain management requirements at the time of construction and an Elevation Certificate for a recently constructed residence nearby, the house was elevated approximately 1 foot above the BFE. Houses built at grade in the surrounding neighborhood with a similar ground elevation, but not elevated, experienced 1 to 2 feet of flooding according to the homeowners. For example, one residential property built in 1972 located two parcels from the house in Figure 3-1 had approximately 1 foot of floodwater on the lowest floor. A nearby residence built at-grade had over $75,000 of flood-related damages. Flood-related damages were determined using insurance payment data for Hurricane Michael.

City of Callaway. Figure 3-2 is a representative single-family dwelling in the City of Callaway, built in 1997. The building is located in Zone AE; it had approximately 2 feet of flooding according to the homeowners, resulting in approximately $60,000 in flood-related damages. Based on a homeowner interview, the flood insurance policy for the house was rated based on the house being built to the current BFE. An Elevation Certificate was not available for this house, nor did the flood insurance policy include a reported difference between the BFE and the lowest floor with which the MAT could deduce the elevation of the house.

This house was constructed in 2018 1 foot above BFE and had no damage.
A nearby residence built at-grade had over $75,000 of flood-related damage.

Figure 3-1: No visible damage to elevated house constructed in 2018 (Panama City Beach; Zone AE)

This house was constructed in 1997 and at-grade. The bottom photograph shows its proximity to its flooding source.

Figure 3-2: Representative at-grade single-family house, constructed in 1997, was flooded with 2 feet of water (Callaway; Zone AE)

3.1.1.2 Mexico Beach

Most structures were destroyed in areas of Mexico Beach seaward of US Highway 98, from the western portion of the community along the canal to 25th Street, especially those that were constructed as slab-on-grade. Overall observations in this area demonstrated that storms can be stronger than modeled, resulting in catastrophic building damage. When storms occur that are stronger than anticipated, building performance indicated the importance of a proper foundation (there was a clear difference in building performance between structures with an open versus closed foundation) and elevating above minimum requirements (the higher the lowest horizontal structural member of the lowest floor, the better the building performed). It is critical for homeowners building in coastal areas to understand that flood conditions do not always match what is modeled (in several cases Zone X construction experienced coastal high hazard waves and flood loads). Although the FIRM may reflect reduced flood risk for insurance rating purposes, the residual risk associated with siting buildings in floodprone areas, including potential storm surge, should be incorporated into design and construction.

The ocean-fronting portion of this section of Mexico Beach is mapped as a Zone VE 16 to Zone AE 10, with the SFHA extending to approximately the second row of structures from the shoreline. Figure 3-3 shows the 2009 effective SFHA in Mexico Beach between Canal Parkway and 21st Street. At the Mexico Beach Pier, which is along 37th Street, a USGS temporary water surface

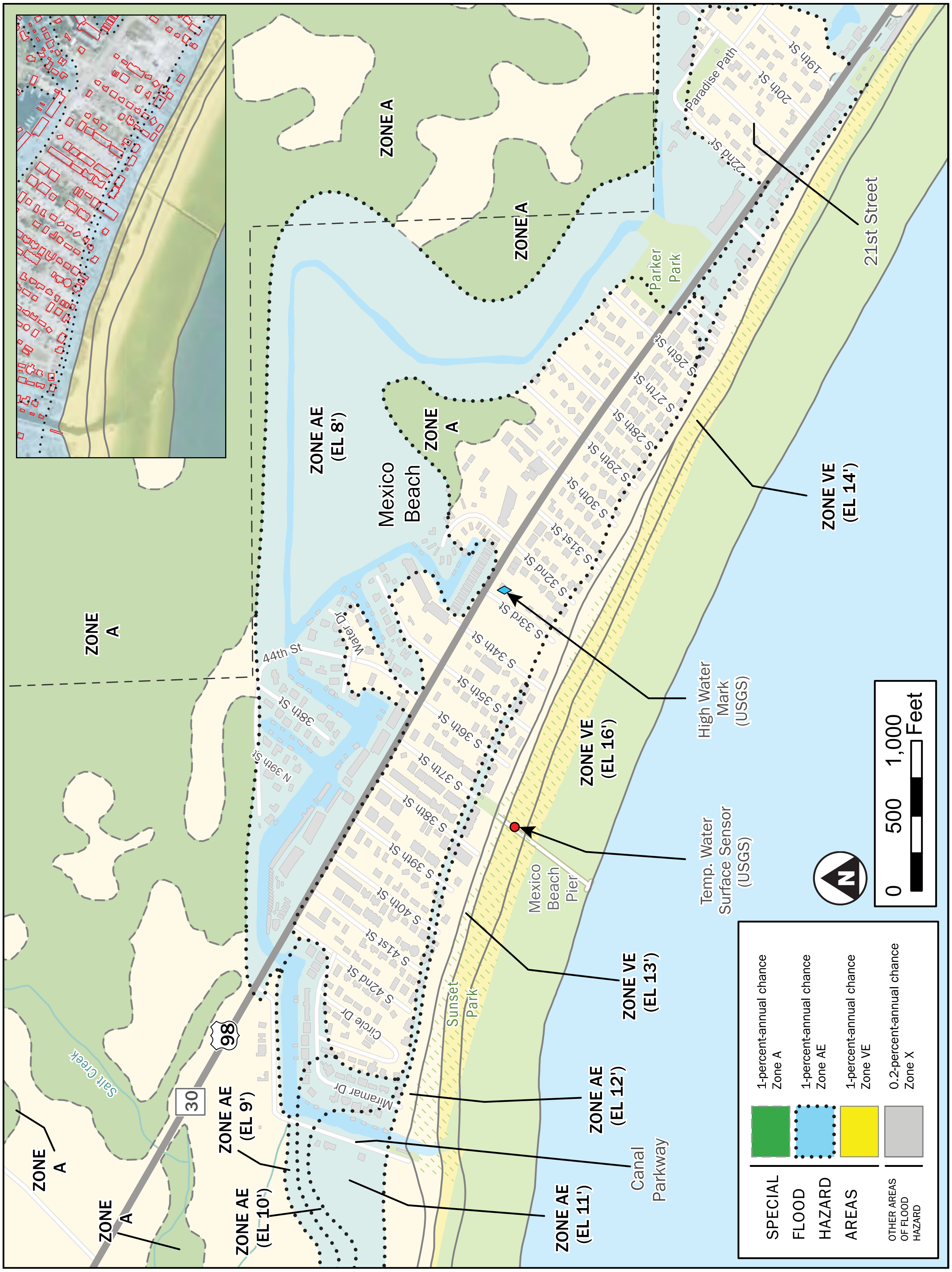


Figure 3-3: FIRM for Mexico Beach; inset shows building footprints relative to the SFHA

sensor measured a storm surge elevation of 15.6 feet NAVD88. According to the FDEP, the storm surge elevation at this point was comparable to a 280-year recurrence interval (FDEP, 2019). Nearby high water marks surveyed after the storm indicated water surface elevations were as high as 19 feet NAVD88 in certain areas (USGS, 2019a).

The MAT's review of aerial imagery indicated a previously healthy beach and dune system at this location prior to Hurricane Michael. During the hurricane, a significant portion of the beach and dune system was removed by wave action and erosion, allowing greater inundation and penetration of wave action of the area.

At the time the MAT visited Mexico Beach, homeowners were in the process of removing debris. The MAT was often not able to determine whether debris or damage sustained to the houses was because of the storm or because of demolition and clean-up efforts that were in progress. Many structures in this community were impacted by both flood and wind, and differentiating the cause of damage based on the timing of site visits and ongoing repairs was generally difficult. Where buildings were subjected to flooding, storm surge damaged the foundations and lower portions of the buildings, while the hurricane-force wind damaged the remainder of the building and most building envelopes.

Observations in inland areas of Mexico Beach, including those to Mexico Beach facilities, revealed that many buildings in the unshaded Zone X (area of minimal flood hazard) experienced just as much damage as those in the SFHA. The damage reinforced previous MAT observations that although areas in Zone X may have a lower probability of flooding and are not required to be regulated under the NFIP, there is a residual risk as the flood hazard does not stop at the extent of the SFHA. In various storm scenarios (i.e., greater than 1-percent-annual-chance event), the exposure to damage may not drastically differ. Shaded Zone X is also referred to as an "area of moderate flood hazard" and unshaded Zone X as "area of minimal flood hazard," meaning a flood hazard still exists as opposed to the hazard being eliminated at the extent of the regulated floodplain. Based on damage observed in and out of the regulated floodplain, in certain circumstances (limited elevation difference, lack of natural terrain features to provide protection, etc.), where siting, design, and construction practices addressed this residual risk, buildings were less damaged.

SHADED VERSUS UNSHADED ZONE X

FEMA established the shaded and unshaded Zone X to differentiate flood risk in areas for which federal flood insurance requirements do not apply.

Shaded Zone X. Areas having between a 0.2 percent and 1 percent annual chance of flooding. Properties in shaded Zone X are considered to be in areas of moderate flood hazard.

Unshaded Zone X. Areas with less than 0.2 percent annual chance of flooding. Properties in unshaded Zone X are considered to be in areas of minimal flood hazard.

Between Canal Parkway and 12th Street. Many structures that remained standing after the storm in the area between Canal Parkway and 12th Street were elevated at or above the BFE on piles (refer to Section 3.3 for observations related to pile performance).

Figure 3-4 and Figure 3-5 are representative examples of elevated single-family houses that were not completely destroyed in Mexico Beach. Although the foundations and a majority of the structures survived the hurricane, the extensive flood damage made the houses uninhabitable while repairs and, in some cases, replacement were underway.

This house was built in 1997. The left photograph shows the side that faced the Gulf of Mexico. The right photograph shows the side facing the street.

Figure 3-4: Representative single-family house elevated on wood piles that remained after the hurricane (Mexico Beach; Zone AE)

The structure on the left was built in 2016 and is located in Zone X. The structure on the right was built in 2002, also in Zone X, but is located closer to the ocean.

Figure 3-5: Representative adjacent single-family dwellings elevated on concrete piles that survived the hurricane (Mexico Beach; unshaded Zone X)

Figure 3-6 is representative of damage along 36th Street. Figure 3-7 is a slab-on-grade house, not commonly seen in this area, that was not completely destroyed by surge (most slab-on-grade houses could only be identified by their slab). However, the flood loads significantly damaged the single-story structure, and the uninhabitable house had to be demolished.

Figure 3-6: Representative damage along 36th Street (Mexico Beach; unshaded Zone X)

SOURCE: NATIONAL SCIENCE FOUNDATION STRUCTURAL EXTREME EVENTS RECONNAISSANCE NETWORK

Remnant of slab (foreground) compared to elevated structures (background). Photograph was taken through a clearing from the remaining slab of a non-elevated structure.

Figure 3-7: Slab-on-grade single-family dwelling along 33rd Street built in 2018 (Mexico Beach; unshaded Zone X)

The house was built in 2018. [A] shows the side that faced the Gulf of Mexico. [B] shows the impact of wave and water loads on the back wall of the house.

Inland areas of Mexico Beach. Some inland areas of Mexico Beach, north of US Highway 98 in the neighborhoods near the Mexico Beach City Hall, are adjacent to ditches and canals. These areas experienced inundation of approximately 1 to 7 feet above grade based on USGS high water marks. The MAT observed the following:

- Slab-on-grade structures generally did not perform well because of flood loads and debris impact on the buildings.
- Many structures that were recently constructed (post-FIRM) remained standing but had evidence of flooding as interior finishes (such as gypsum board panels) were being replaced at the time the MAT visited.

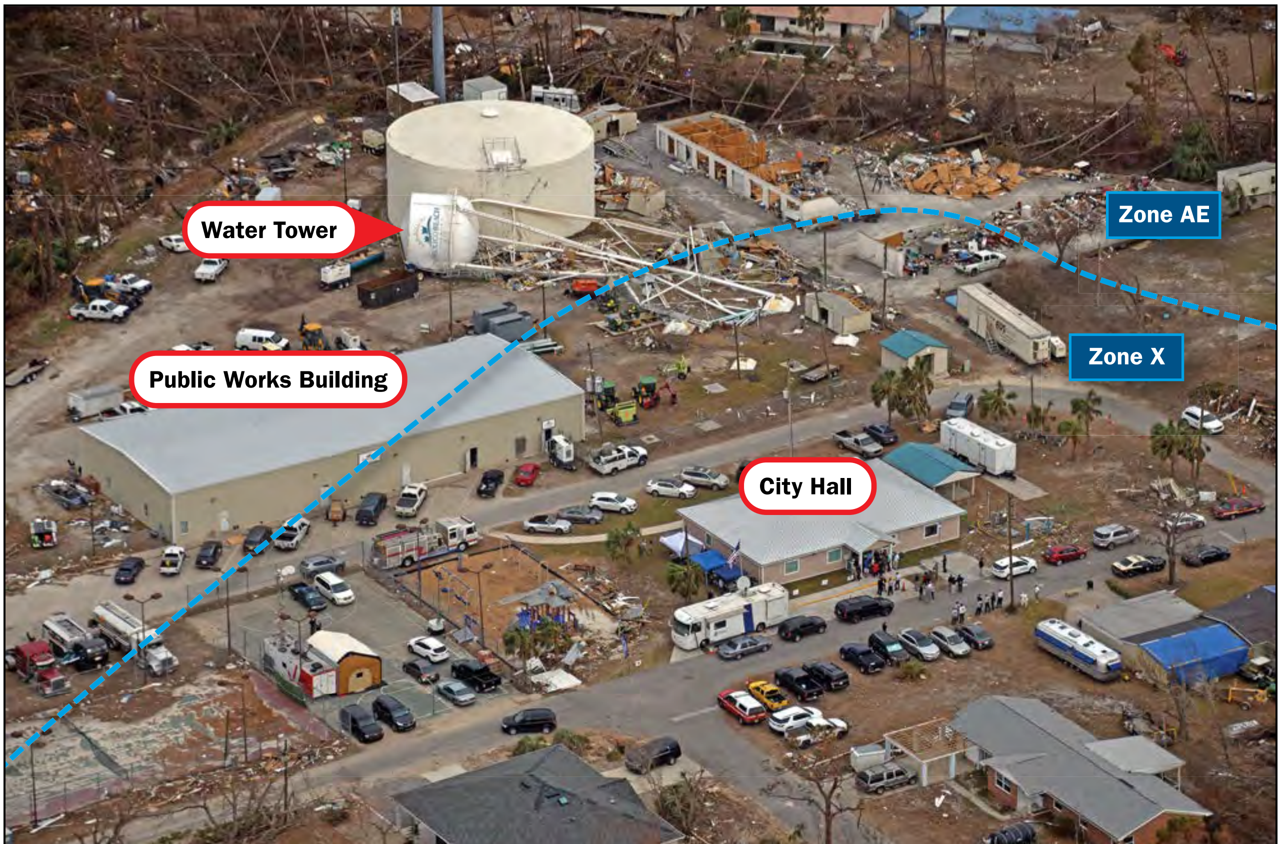
- At-grade structures were susceptible to impact from debris of adjacent structures. As such, even those at-grade structures that were constructed with adequate hydrostatic equalization measures were subject to failure due to debris impact from adjacent structures.
- Fasteners that connected structures to stem wall, pier, and, in some cases, pile foundations, were frequently inadequate and failed. Where foundation connections failed (or were non-existent), the structures broke free and floated a distance, at times striking a neighboring building or a tree (Figure 3-8). Most older construction lacked a load path through the foundation; although newer construction had a load path to resist uplift from wind, in some cases the connections were insufficient for buoyancy loads, which were likely not considered because the houses were outside the SFHA.

Figure 3-8: Single-family dwelling along Kim Kove that floated off its foundation (Mexico Beach; unshaded Zone X)

This house was built in 1976 with a crawlspace underneath. It detached from its foundation and floated approximately 40 feet before striking a tree. Standing concrete masonry unit (CMU) blocks visible in the photograph are located at the original footprint (yellow box).

Mexico Beach Public Works Building and City Hall. The difference in damage to the Mexico Beach City Hall and the adjacent Public Works building (Figure 3-9) demonstrates the effect building elevation can have on building performance.

The Public Works building is located within the SFHA and approximately 100 feet from the nearest drainage ditch, which was a conveyance channel for floodwater. The building was damaged by approximately 18 inches of floodwater. The building was repaired by the time the MAT visited. The adjacent Mexico Beach City Hall and other structures on city property were slightly higher and not within the SFHA; while these structures still experienced flood damage during the event, it was less than the Public Works building. The City Hall, located 300 feet from the drainage ditch, experienced minor flood damage from approximately 6 inches of water. The City Hall building also had minimal interior water infiltration damage (wind-driven rain), primarily around windows and doors. The facility was in use when the MAT visited, and according to staff interviews, it remained opened after the hurricane while repairs were made.



The Public Works building, along with older unreinforced masonry storage buildings on the city property, was damaged by flooding. The City Hall had only minor damage from flooding. Also visible in the photograph are the effects of high winds: the toppled Mexico Beach water tower, snapped trees, and damaged roofs.

Figure 3-9: Mexico Beach City Hall (unshaded Zone X) and Public Works Facility (Zone AE)

Mexico Beach Fire and Police Stations. The MAT visited two critical facilities that were damaged: the Mexico Beach fire and police stations. Both buildings were located outside of the SFHA within unshaded Zone X. The fire station was built in the 1970s and expanded over the years to include three bays with a second story. The fire station had extensive flood and wind damage. The police station, constructed in 2014, was lifted from its pier foundation by flood loads during Hurricane Michael (Figure 3-10 shows aerial imagery taken before the MAT visited). The fire station was still standing when the MAT visited and when the photograph was taken, but the police station has since been demolished.

In addition to damage to the fire and police stations, other buildings in the immediate vicinity had widespread damage from flood and wind: flooding caused the dislocation of buildings washed off of their foundations and wind caused roof deck and covering loss and structural damage to older buildings.

The fire station [A] had interior damage due to water infiltration and flooding, but also had wind envelope damage. The police station [B] was lifted from its foundation and eventually demolished due to the extent of damage.

Figure 3-10: Mexico Beach fire station [A] and police station [B] were heavily damaged by flood and wind (Mexico Beach; unshaded Zone X)

3.1.2 Gulf County

In Gulf County, flood levels generally reached about 2 to 3 feet above the BFE. The MAT visited the areas of Beacon Hill, Port St. Joe, and Cape San Blas on St. Joseph Peninsula (Figure 3-11). The MAT found trends that mirrored those in Bay County, including:

- Several pre-FIRM at-grade buildings floated off of their foundation because of an inadequate load path (see Figure 3-12 in the Beacon Hill neighborhood).
- Structures both inside and beyond the SFHA were damaged by floodwater, especially those that were minimally elevated.
- Structures within low-lying areas, mapped in Zone A as well as in adjacent Zone X (shaded and unshaded), were damaged by floodwater.
- A significant portion of the beach and dune system was removed by wave action and erosion during the hurricane, allowing greater inundation and wave penetration of the area.

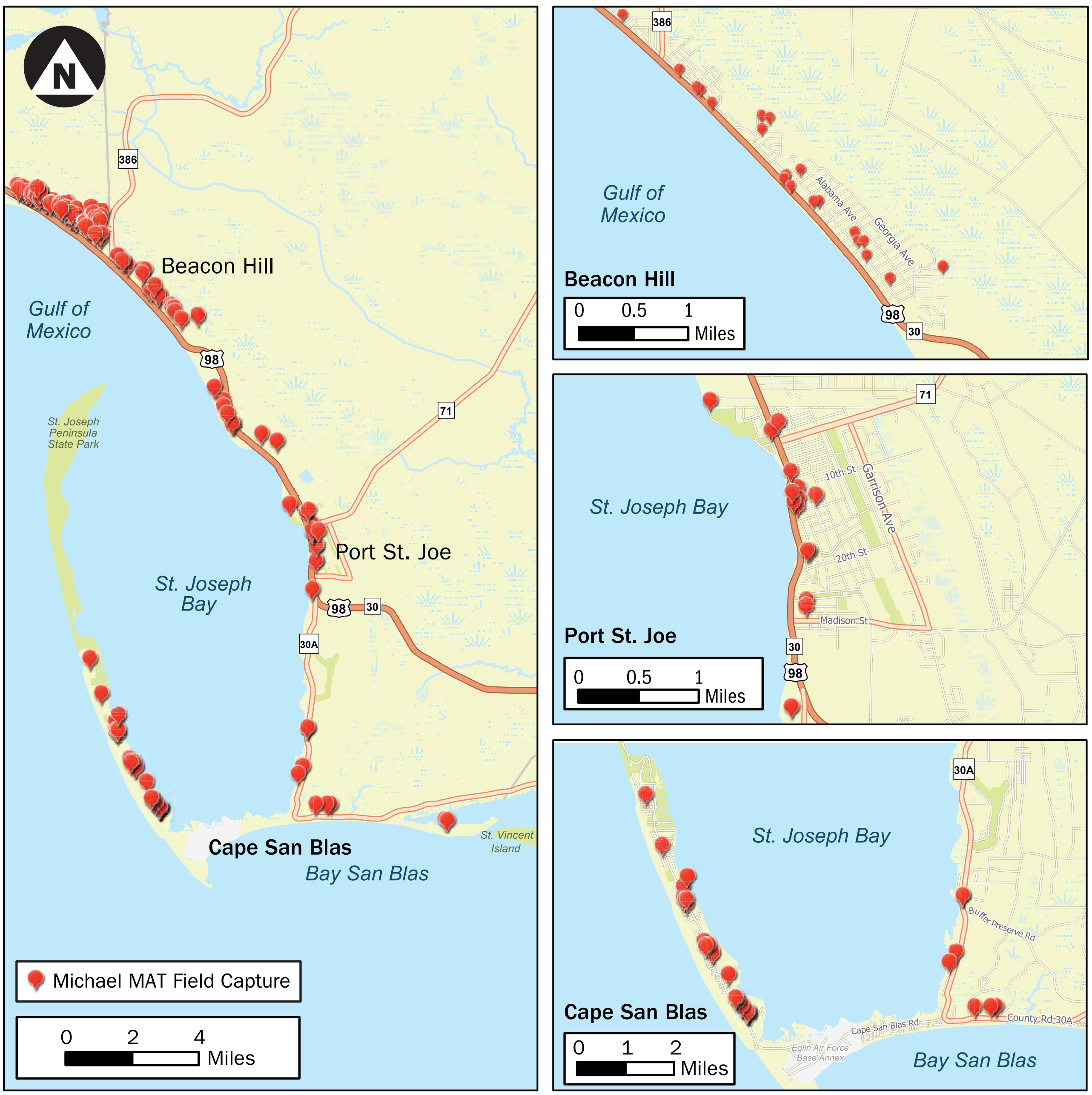


Figure 3-11: Map of Gulf County and MAT field visit locations

3.1.2.1 Beacon Hill

The MAT visited a small residential neighborhood known as Beacon Hill in Gulf County, located south of Mexico Beach and north of Port St. Joe. This community experienced flooding ranging from 1 to 6 feet above grade based on USGS high water marks. In Beacon Hill, there is only one row of structures seaward of US Highway 98, and most of those structures were damaged or destroyed. Structures located inland of US Highway 98 were also significantly damaged, especially those in low-lying areas. Many houses in the Beacon Hill neighborhood were constructed at-grade or minimally elevated on masonry foundation walls.

According to homeowners in the inland neighborhoods, water levels rose very rapidly. When the MAT visited this area, the recovery effort had progressed. Figure 3-12 is an example of a house that floated because the load path was insufficient to resist the flood loads. Nearby, a homeowner of a house of similar size and construction was in the process of elevating their building by approximately 10 feet and installing a foundation for pier supports (see Figure 3-13).

Figure 3-12: Single-family house (built in 2008) located inland of US Highway 98 that was washed off its foundation (Beacon Hill; shaded Zone X)

In the foreground is former foundation with metal straps (red arrows). The home detached and floated approximately 80 feet across the street before striking a neighboring structure (yellow arrow).

Figure 3-13: Single-family house located inland of US Highway 98 undergoing elevation during rebuilding (Beacon Hill; shaded Zone X)

3.1.2.2 Port St. Joe

The MAT visited the neighborhood within the SFHA south of Costin Boulevard and east of Constitution Drive in Port St. Joe, which is predominantly designated as Zone A. Port St. Joe is protected by a natural barrier spit directly west of the city (refer also to Section 3.1.2.3) that limits fetch for wind-driven waves. Based on the USGS high water marks and measurements in the field, the water depth was 1 to 6 feet above grade in this area, exceeding the BFE by 1 to 5 feet depending on the location.

Along Constitution Drive, post-FIRM construction houses were elevated, and some had breakaway walls. While recovery and repairs were underway when the MAT visited, there was only limited or no damage evident in the elevated houses, but considerably more damage to those built at-grade. The MAT also observed structures that had experienced major flood damage that were either completely demolished by the time the MAT visited or had been left open to the elements, exacerbating the water infiltration and water intrusion. Newer construction built to higher elevation requirements (approximately 3 to 5 feet above grade in most cases) had considerably less damage than houses that were built at or closer to grade. Figure 3-14 shows a newer elevated house and an older construction non-elevated house approximately 600 feet apart on Constitution Drive.

Figure 3-14: Comparison of houses built 50 years apart (Building A was built in 2006 as an elevated house and Building B in 1956, renovated in 2000) along Constitution Drive (Port St. Joe; Zone AE)

[A] Elevated single-family house with no apparent floodwater damage

[B] Non-elevated single-family house damaged during Hurricane Michael and left unprotected from subsequent rainfall

Farther inland of Constitution Drive, most houses were constructed on slabs or minimally elevated on piers of 1 to 3 feet above grade. As a result, most houses had 4 to 5 feet of water from the storm. Figure 3-15 and Figure 3-16, both located in Zone AE at the same BFE, highlight the effect of elevation as it relates to flood damage:

- Figure 3-15 is a representative at-grade, single-family house along Palm Boulevard built in 1977. Based on known elevations for existing adjacent houses, the first floor elevation was likely at the BFE (approximately 1 to 2 ft above grade) and had approximately $150,000 in flood damages based on preliminary flood insurance claims data.

Figure 3-15: Representative single-family house (built in 1997) along Palm Boulevard with a high water mark (red dashed line) of 60 inches above grade (Port St. Joe; Zone AE)

- Figure 3-16 is a rare (for this flood zone area) elevated single-family house built in 2007 in the vicinity of Palm Boulevard, with its lowest horizontal structural member of the lowest floor around 8 feet above grade. This house had less than $10,000 in flood damages based on preliminary flood insurance claims data.

This structure was built in 2007 and elevated on piles.

Figure 3-16: Newer single-family house in the vicinity of Palm Boulevard (Port St. Joe; Zone AE)

3.1.2.3 Barrier Spit / Cape San Blas

The MAT visited locations along the barrier spit, located west of Port St. Joe. The northern portion of the barrier spit is primarily a wilderness preserve and the southern portion is where Cape San Blas is located. Wave action and erosion during Hurricane Michael caused a 900-foot-wide breach of the peninsula in the state park north of Cape San Blas (see Figure 1-4 in Chapter 1 for an aerial image).

Many Cape San Blas houses on the ocean side of the barrier spit are elevated on open pile foundations and these houses experienced minimal damage from the hurricane. The western shore of Cape San Blas has the highest erosion rate on the Florida Gulf Coast (approximately 40 feet per year) (FDEP, 2019), and the MAT observed major beach and dune erosion along the peninsula. Erosion that occurred during Hurricane Michael caused approximately 8 feet of beach lowering at a recently constructed house along the western shore of Cape San Blas (Figure 3-17).

Figure 3-17: Newer (post-2017 construction) single-family house with significant erosion (more than 8 feet) at foundation (Cape San Blas; Zone VE)

Concrete pile foundation that withstood over 8 feet of erosion. The yellow arrow shows the approximate pre-storm beach elevation.

3.1.3 Franklin County

Flood levels were near the BFE in many locations in Franklin County. The MAT visited two areas in Franklin County: Apalachicola and St. George Island. Flooding was not as severe in these two geographic areas compared to Mexico Beach. By the time the MAT visited these neighborhoods, only a few houses had debris that had not yet been cleaned up and there were far fewer contractors completing repairs, which was indicative of less widespread damage.

3.1.3.1 Apalachicola

Most buildings in Apalachicola were only somewhat damaged during Hurricane Michael by floodwaters as the area is sheltered from significant wave action by St. George Island. Portions of the downtown are located within the SFHA, but most areas are located in Zone X. Along the low-lying marsh or park areas in town, USGS high water marks and a temporary sensor indicated a water depth of about 1 to 3 feet that quickly receded after the storm passed. Windshield assessments indicated that damage was less than that observed in Port St. Joe. The MAT did not document building performance throughout the Apalachicola area as there was less severe or limited damage when compared to other areas the MAT visited.

3.1.3.2 St. George Island

St. George Island is a barrier island to the south of Apalachicola. Aside from very localized ridges and regions along the barrier spit, the majority of St. George Island is located within the SFHA.

The MAT visited a pre-FIRM house on St. George Island that is located along the shoreline of Apalachicola Bay (Figure 3-18). The MAT visited this property because it had a remote camera placed on a pole outside that captured live video during Hurricane Michael, which the homeowner posted to social media during the storm. The video showed the level of inundation and waves passing through the house during the storm. Although the video stills are blurry, the video was a unique opportunity to observe both the wave interaction with the building during an event over time and the destructive impact of bayside flooding.

Figure 3-18: View of the damage of the wall perpendicular to the direction of waves at pre-FIRM house built in 1966. Inset shows damage to the bay-facing façade (red arrow indicates close-up of wave damage on the building). (St. George Island; Zone VE)

The house is currently mapped in Zone VE but was constructed in 1966 well before Zone V construction requirements existed. Based on the video footage, this area likely did not experience Coastal High Hazard Area/Zone VE wave conditions (3 feet or greater). Based on the video footage filmed during Hurricane Michael, the house and surrounding area likely experienced Coastal A Zone conditions with breaking wave heights of 1.5 to 3 feet. The flood loads and structural damage caused by the moderate wave action observed reinforce previous MAT recommendations and current ASCE 24 requirements that design and construction practices follow Zone VE requirements in Coastal A Zones.

The pre-FIRM, single-family house incurred approximately $150,000 in estimated flood damages based on preliminary flood insurance claims information from the owner. At the time the MAT visited, the homeowner indicated that she was planning on submitting documentation to her insurance agent to access NFIP Increased Cost of Compliance to help pay to elevate the house.

3.1.4 Wakulla County

The counties farthest east in the area visited by the MAT experienced water levels between 1 and 6 feet above ground. Flood levels were near the BFE in many locations in Wakulla County. The pre-MAT visited St. Marks and Shell Point in Wakulla County and observed high water marks consistent with the USGS surveyed observations. Similar to Franklin County, flooding impacts were less severe in Wakulla County than in other counties closer to landfall. Generally, Wakulla County is rural with state parks and wildlife refuges. Because of the relative lack of building damage observed by the pre-MAT in October 2018, the MAT prioritized other much more heavily damaged areas throughout the impacted area during its site visits conducted in January 2019. The MAT visited Shell Point in Wakulla County.

3.1.4.1 Shell Point

Based on pre-MAT observations, floodwater reached at least 3.5 feet above grade in Shell Point. The left image in Figure 3-19 shows an elevated residence where the highwater mark is visible on the garage.

The right image in Figure 3-19 shows a breakaway wall at the residence that was partially detached, leaving shredded building material. This breakaway wall may have been subjected to design flood depth conditions as it was partially detached, but evidence of moderate wave action that would have caused this type of force and damage on the breakaway wall was absent during the field assessment. Instead, evidence pointed to floodwater that rose and quickly receded. Thus, the breakaway wall did not perform as intended. From a design standpoint, the best practice of incorporating flood vents or openings would have allowed hydrostatic pressure on both sides of the wall to equalize. The 3.5 feet of water depth at the residence would have been enough to push the wall inward, but not fully detach.

To perform as intended, breakaway walls must break away cleanly so as to avoid damaging the elevated building when they break away. If the wall remains attached to the building instead of breaking cleanly via the building material, there is potential for continued damage from debris to the building and the foundation. In this instance, it is unclear whether the shredded building materials prevented the wall from detaching or was there for another reason.

The red dashed line shows a high water mark approximately 3.5 feet above ground (left image). Image on the right shows a partially detached breakaway wall.

Figure 3-19: Single-family house (built in 2008) that experienced minimal flooding. The building is elevated, and breakaway walls became partially detached during the event. (Shell Point; Zone VE)

ENCLOSURES AND BREAKAWAY WALLS

Designers and owners should realize that: (1) enclosures and items within them are likely to be damaged even during minor flood events; (2) enclosures, and most items within them, are not covered by the NFIP flood insurance and damage can result in significant costs to the building owner; and (3) even the presence of properly constructed breakaway wall enclosures can increase NFIP flood insurance premiums for the entire building (the premium rate will increase as the enclosed area increases).

Including enclosures in a building design can have significant cost implications. Although the NFIP does not require the installation of flood openings in breakaway walls in Zone V areas, FEMA recommends, as a best practice, openings be provided to allow for the balance of hydrostatic pressure (FEMA, 2009a). A number of state and local governments do require flood openings in Zone V, as does ASCE 24-14. Refer to Technical Bulletin #9, *Design and Construction Guidance for Breakaway Walls* (FEMA, 2008).

3.2 Comparison of Lowest Floor Elevation across Structures

The most common predictor of whether a building was damaged by flooding during Hurricane Michael was its lowest floor elevation relative to the flood level during the event. Structures with lowest floors at or below the flood level were inundated, floated, or heavily damaged from wave action. Hurricane Michael flood levels often exceeded the BFE in Bay County, with Mexico Beach experiencing the greatest inundation levels (refer to Section 1.3.1 for discussion of flood depths and water surface elevations). Across the impacted area, structures constructed to include freeboard above the BFE experienced less flood damage than those that were not, and pre-FIRM and at-grade structures sustained the most severe flood damage.

The MAT visited structures located in Zone VE, Zone AE, and outside the SFHA and observed similar performance across the impacted area: elevated structures had less flood damage than those that were not elevated. A few examples from Mexico Beach and Port St. Joe that illustrate the effect of elevation on building damage are provided in the sections that follow.

FREEBOARD

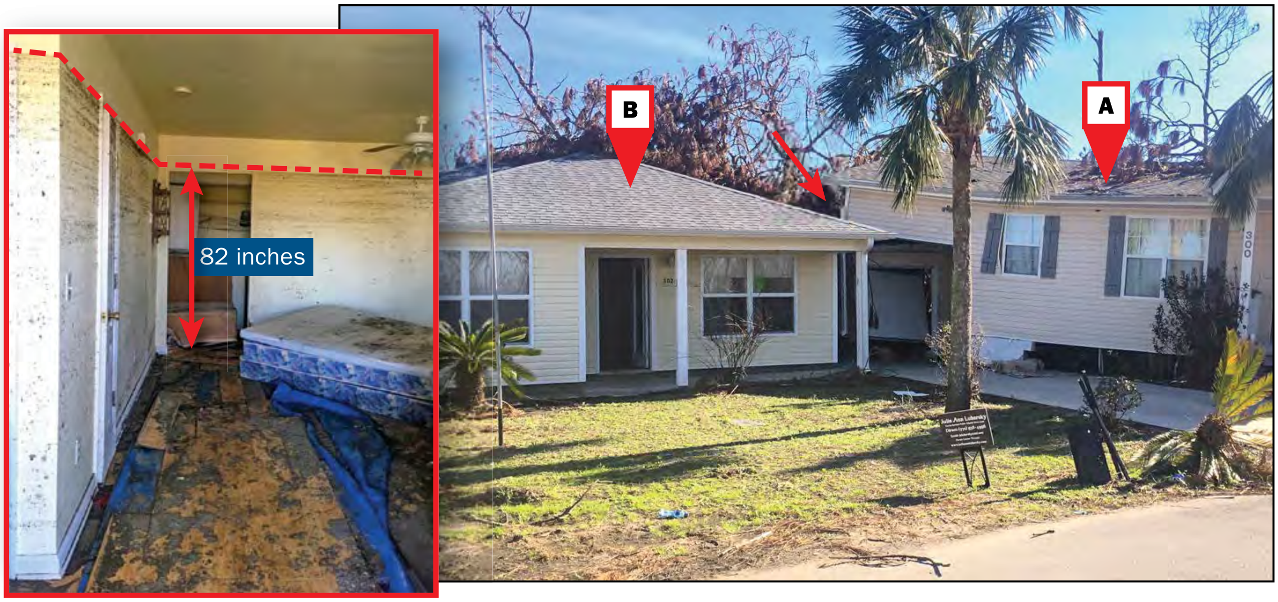
Freeboard is a factor of safety usually expressed in feet above a flood level for purposes of floodplain management. Although not required by NFIP standards, the latest building code requires communities to adopt at least a 1 foot freeboard requirement. Many Florida communities have enforced at least 1 foot of freeboard above the BFE for many years. With the adoption of the 5th Edition FBC, all communities enforce a minimum of the BFE + 1 foot.

3.2.1 Resistance to Buoyancy Load (Flotation)

The MAT visited eight structures built on a crawlspace foundation that did not resist the buoyant loads and floated off their foundations. Figure 3-20 illustrates the significance of elevation as it relates to flood damage. The three structures shown in the figure are located in an unshaded Zone X, so they were not required to be built to a regulated elevation, and are adjacent to an unnumbered Zone A. Building A floated off its foundation and into Building B, most likely due to an inadequate load path, while Building C (with the exception of a damaged enclosure) did not appear to have any flood-related damage, likely because the lowest floor was elevated above the flood elevation. Although there were high water mark stains visible in Building A, there was no reference line on Building C. Elevating Building C helped to avoid damage, while minor elevation without consideration for buoyancy loads resulted in flotation of Building A.

Figure 3-21 is a close up of the foundation of Building A (as shown in Figure 3-20). The MAT noted several potential issues that may have led to the floatation:

- No metal strapping, which would be typical for this type of construction, was observed.
- The concrete masonry unit (CMU) stem wall foundation had little evidence of steel reinforcement and had remnants of grout.



[A] This single-family house (built in 1986) in Mexico Beach floated off its foundation and into the neighboring structure **[B]** (red arrow).

[B] Slab-on-grade house, built in 2003, is located just beyond Zone A and was significantly flooded. Inset shows interior of house. Red line shows the high water mark.

[C] This single-family house (built in 2003), located across the street from **[A]** and **[B]**, was proactively elevated multiple feet to accommodate storage and parking and to improve the resilience of this residence to future flooding. Observed flood damage was minimal.

Figure 3-20: Examples of effects of elevation related to flood damage (Mexico Beach; unshaded Zone X)

Figure 3-21: Foundation of Building A shown in Figure 3-20 (Mexico Beach; unshaded Zone X)

3.2.2 Elevated Residences

Figure 3-22 shows post-storm aerial imagery of a beach front residential community in Mexico Beach that was heavily damaged during Hurricane Michael. The inset photograph shows an elevated house built in 2012 in an unshaded Zone X. This structure was the only residence for several blocks in each direction that survived the hurricane. The walls of the structure’s at-grade first-floor enclosure suffered significant damage perpendicular to the flood path and erosion was observed around the piles and slab; otherwise, the house, with its lowest floor above the high water mark, withstood the flood loads experienced during Hurricane Michael. There was damage to the exterior on the second story (loss of soffits and other envelope damage) due to high winds that resulted in interior wind-driven rain damage. Other houses near the canal were standing when the MAT visited but had visible structural damage.

This single-family house (built in 2012) in Mexico Beach was elevated to approximately 11 feet above grade, or at the BFE (red dashed line), and was one of the few houses in this neighborhood that survived.

As shown in the post-storm aerial imagery, most of the other houses in the area (built in the 1960s to 1980s) were slab-on-grade construction or had one- to two-block concrete masonry foundations, and were destroyed by Hurricane Michael. The yellow outline shows houses that survived Hurricane Michael, but were damaged.

Figure 3-22: Post-storm aerial image of a beach front residential community in Mexico Beach that was heavily damaged by both wind and flood during Hurricane Michael (Mexico Beach; Zone VE, Zone AE, and unshaded Zone X)

3.2.3 Freeboard in New Construction

Figure 3-23 shows a street view in Port St. Joe of four residential buildings, built to the BFE, that are situated next to a non-residential building that was built to 2 feet above the BFE. During Hurricane Michael, the four residential buildings were flooded to approximately 2 feet (with approximately $30,000 in flood damages per house based on preliminary flood insurance claim estimations), but the non-residential structure was not flooded.

Figure 3-23: Comparison of non-residential building built to above the BFE to residential buildings built to the BFE (Port St. Joe; Zone AE)

3.2.4 Freeboard in Building Additions

Figure 3-24 shows the First United Methodist Church in Port St. Joe, which is in a Zone AE10. The original church building experienced extensive inundation damage with more than 5 feet of water throughout as well as additional damage from sewage backup into the building because the outgoing pipe was missing a backflow prevention device (resulting in additional restoration costs and time). The addition at the back of the original pre-FIRM church building was built more than 5 feet higher than the original church building and experienced only minor flooding (less than 6 inches). When the MAT visited several months after Hurricane Michael, the addition was being used, but the original church facilities were still being repaired. An Elevation Certificate was not available for the addition; however, based on information gathered during the site visit interview, the addition may have been built 1 foot above the BFE. The church staff specifically recall having to navigate all the floodplain management requirements for the addition as it was considered new construction/Substantial Improvement. The staff seemed appreciative of the requirements based on how the new building performed and only wished they had built it even higher.

Before Hurricane Michael, the facility manager of this church in Port St. Joe had invested in a project to move the air conditioning units to the roof and to construct an addition (red square and inset) to be used as a community room. The floor of the addition was built more than 5 feet higher than the original church building. While the addition experienced some flooding (less than 6 inches), the damage was primarily limited to flooring. When the MAT visited, the addition was being used for most community functions, while the original church facilities were in the process of being repaired.

Figure 3-24: First United Methodist Church main building compared to the newer addition (Port St. Joe)

3.2.5 Elevation on Concrete Pile with Breakaway Wall

Figure 3-25 shows the administrative building for a recreational vehicle (RV) resort along State Route 30 in Port St. Joe. This elevated, non-residential building has an open concrete foundation with an enclosure consisting of breakaway walls. The administrative building had minimal flood damage as the flood inundation levels reached the bottom of the lowest horizontal structural member, it experienced very limited to no water infiltration through the window and doors, and the breakaway walls in the enclosure performed as intended. About 50 to 75 campers are typically onsite, and all but one were evacuated (the one camper was destroyed). The administrative building was back in operation by mid-December, with power restoration being a critical factor in the building being fully operational.

Figure 3-25: Administrative building elevated on a concrete pile foundation (Port St. Joe; Zone VE)

This elevated, non-residential building built in 2016 with an open concrete pile foundation and breakaway walls had minimal flood damage. During an interview with the property owners, the MAT learned that the breakaway walls broke away as intended, and floodwater reached the beam supporting the administrative building/clubhouse but did not enter the first floor. The enclosures were used for storage and restrooms. The damage to the enclosure did not cause any damage to the first floor (NOTE: Restrooms below the BFE are not compliant with the NFIP for new construction).

3.3 Performance of Concrete and Wooden Pile Foundations

Concrete pile foundations are commonplace in Florida coastal communities. The MAT visited multiple structures with pre-cast concrete piles that failed during Hurricane Michael. Remnants of piles observed by the MAT exhibited rotational failure as a result of scour and undermining, fracture of the concrete, and bending of the reinforcing steel. The MAT assessed 67 sites with concrete and wooden piles across the Florida Panhandle, of which eight had failed. In most cases, the MAT did not have sufficient information to determine the cause of the failures. The following subsections describe the MAT's observations of concrete and wooden piles that failed. A combination of factors and deficiencies could have contributed to these failures, as outlined in the textbox "Possible – Failure Mechanisms for Piles."

POSSIBLE FAILURE MECHANISMS FOR PILES

The following are potential failure mechanisms for the piles of structures subject to flood loads:

Undermining of slab. Improperly designed concrete piles can fail due to instability or loss of lateral restraint if the piles rely on concrete slabs for their lateral support. The concrete slabs can be undermined or destroyed. (NOTE: A concrete slab structurally attached to a pile system may be considered the lowest horizontal structural member, which can be an NFIP regulatory violation, where NFIP compliance is required, and can result in much higher annual flood insurance premiums. Although a concrete slab may serve as the floor of a ground-level enclosure [usable only for parking, storage, or building access], the slab must be independent of the building foundation.)

Insufficient number and size of grade beams. The number and size of grade beams to provide fixity to the foundation system may be insufficient.

Erosion and scour. Piles may be incapable of resisting applicable uplift and lateral loads when the structure is undermined by erosion and scour. Piles may also fail if not designed to adequately address the weight of grade beams and the loads imposed by forces acting on them after erosion and scour occur.

Insufficient material strength. Materials and reinforcement used in pile construction may not be strong enough to adequately counter wave, debris impact, and other applicable loads in a coastal high hazard environment.

Inadequate embedment depth. Pile embedment depth may be inadequate to resist applicable loads without rotation.

Inadequate spacing and size. Pile spacing and size may be inadequate to resist applicable loads.

Inadequate connections. Pile-to-floor beam connections may be inadequate to resist applicable loads.

Wind loads. Lateral or uplift wind loads on the structure may cause structural failure of the piles.

Alterations. Repair, reinforcement, or retrofitting of existing piles may be inadequate to resist applicable loads.

3.3.1 Concrete Pile Performance

The MAT observed instances of concrete piles that failed and some that survived. In Mexico Beach along US Highway 98, the concrete piles of many structures failed completely. Figure 3-26 shows two examples of failed piles. The majority of the residences with failed piles were located on Gulf-front property, seaward of US Highway 98. Although the structures, which were located in Zone X, need not adhere to stricter codes, the designers could have considered the proximity to the ocean and eroding dunes and built to a higher standard.

Based on the paint line visible on the remnant concrete piles shown in the left photograph of Figure 3-26, the failure appears to have likely occurred at the connection to the concrete slab. The right photograph in Figure 3-26 shows a building located two lots west of the building in the left photograph. The MAT observed stress fractures in these piles from lateral loads, possibly from surge, wave, wind or debris loads. In both cases shown in Figure 3-26, the buildings may have rotated landward, thereby stressing the piles. Both cases show a final failure location that occurred at approximately the elevation of the concrete slab, which itself was undermined by flood effects and failed.

The two broken columns in the background failed along the paint line (yellow arrows) that was most likely associated with the location of a concrete slab. The pile closest to the water did not fail (red arrow).

Red arrows indicate lateral cracks (stress fractures) on the gulf-fronting pile, possibly from surge or waves.

Figure 3-26: Examples of failed reinforced concrete piles along US Highway 98 (Mexico Beach)

There were several locations throughout the area visited by the MAT where concrete piles survived Hurricane Michael but were heavily damaged. In an area of Mexico Beach, the concrete piles (shown in Figure 3-27) supporting the deck and building of a single-family dwelling remained in place, though the MAT observed lateral displacement of the beam spanning between the pile pairs. This residence, which is in a Zone AE12, received extensive flood and wave damage to the lowest floor, and also suffered erosion as a result of the emergency power crews striking a water line while driving new poles. The breakaway walls and decking were not attached when the MAT visited; the MAT was not able to determine whether these elements failed during the hurricane or were removed by the homeowner.

The Cape San Blas area of Franklin County sustained significant erosion (in excess of 8 feet in some areas) and wave attack, yet concrete piles and structures remained standing (see Figure 3-17). The pile performance is considered successful because the structure and piles were standing with no observed failure, displacement, or fracture.

These concrete piles, which support a deck and residence, remained standing, resisting extensive flood and wave damage. Inset shows lateral displacement of the pile beam (red circle).

Figure 3-27: Residence along 24th Street with concrete piles that remain standing (Mexico Beach; Zone AE)

3.3.2 Wooden Pile Performance

In Cape San Blas, the MAT team visited a site of 16 condominium units across four structures built in 1986 on wooden piles. The condominium complexes were located in a Zone VE. The wooden piles failed during the event, resulting in structural damage and eventual demolition of the entire condominium building (Figure 3-28). At some point prior to Hurricane Michael, the foundation system had been modified and retrofitted to extend the depth of embedment of the piles; as shown in Figure 3-28, a round steel pipe was driven alongside the existing wooden piles and attached via a connection system. The MAT observed a contractor clearing debris from the remaining structure from the beach. Many factors could have contributed to the failure of the wooden piles, as outlined in the textbox “Possible Failure Mechanisms for Piles.”

Figure 3-28: Fractured wooden pile attached to retrofitted steel pipe foundation connection (Cape San Blas; Zone VE)

A 16-unit condomium structure had to be demolished when these retrofitted wooden piles failed during Hurricane Michael. Based on discussions with private owners of neighboring structures, previous erosion events had resulted in the need to reinforce and extend the embedment depth of the piles. Instead of installing or developing a new open foundation, the existing foundation system was retrofitted by driving round steel pipes next to the existing wooden piles and then connecting them to the piles.

3.4 Observations Pertaining to Floodplain Management Practices

The damage caused by Hurricane Michael highlights the need to enact higher standards and floodplain management regulations to better prepare communities for future disasters. Communities and developers can minimize damage to areas vulnerable to natural disasters by requiring construction to build above the minimum standard (i.e., vertically) and to use siting best practices as well as carefully evaluating and siting structures in locations that will be less vulnerable to flooding (i.e., laterally).

Structures that are located relatively near and outside of the SFHA (particularly those in Zone X) should be elevated at least 1 foot above the adjacent grade or the crown of nearby streets. Federal, state, and local regulations define where development is permissible. Adopting higher standards and considering certain reasonable construction best practices as requirements, as well as siting shoreline development with

BUILDING DAMAGE OUTSIDE OF THE FEMA FLOODPLAIN

Many of the buildings that were completely destroyed or significantly damaged during Hurricane Michael were located in areas mapped by the NFIP as shaded Zone X (area of moderate flood hazard) or unshaded Zone X (area of minimal flood hazard).

a conservative setback, are some prudent tactics that can effectively mitigate flood damage to vulnerable structures and minimize destabilization of natural resources.

Communities may wish to consider the lessons learned from Hurricane Michael based on the following review of insurance claims data, which demonstrates the importance for elevation (vertical extent) considerations outside of the SFHA (Section 3.4.1, Flood Damage Data Analysis and Trends) and examples that help demonstrate the relationship of building damage to proximity (lateral extent) to water (Section 3.4.2, Importance of Siting to Potential Damage).

REBUILDING DECISIONS AFTER A DISASTER

An important aspect of a community's preparation in advance of a natural disaster or reconstruction after a disaster is careful consideration of the amount of time it takes to change local code and planning requirements. Typically, code changes and planning regulations take a relatively long time to enact, so are best accomplished before a disaster. Communities may wish to establish a process (before a disaster strikes) that allows code adoption changes related to expedited recovery to occur immediately after a storm hits. FEMA Building Science publications offer best practices for code adoption and are available at www.fema.gov/building-science-publications.

Implementing Better Building Codes

The MAT observed structures that were recently elevated or were in the process of being elevated after the storm. The MAT interviewed homeowners performing the elevations about their experiences before, during and after the storm, as well as town officials to determine how elevation decisions were being. Town officials indicated there was often uncertainty about how best to implement stricter post-storm rebuilding requirements when elevating damaged structures and for new construction during recovery.

At the time the MAT visited Mexico Beach, the city had instituted a building permit moratorium while a decision regarding the appropriate DFE was being made. **After the MAT's visit, the city passed an ordinance to use a DFE of 1.5 feet above the 0.2-percent-annual-chance flood elevation**.

As discussed in Technical Fact Sheet No. 1.6, "Designing for Flood Levels Above the BFE" (in FEMA P-499, 2010d) and Hurricane Sandy Recovery Advisory 5, Designing for Flood Levels Above the BFE After Hurricane Sandy (2013), the cost of adding freeboard when a house is constructed is modest, especially when compared to the benefits from elevating structures, which can include reduced building damage during flood events, reduced flood insurance premiums, reduced period of time in which building occupants are displaced, reduced job loss, and increased retention of the tax base. The MAT observed the costs of not adding freeboard in communities across the impacted area—homeowners with buildings that were at or below flood level were not able to return to their house and were often seen living in temporary housing (RVs or campers) beside their house while cleaning up. Some businesses were still in the process of recovery months after the storm, and many restaurants in the area resorted to using mobile trucks to serve customers.

3.4.1 Flood Damage Data Analysis and Trends

As described in Section 3.1, the MAT observed flood damage in Bay and Gulf Counties to be considerably greater than damage in Franklin and Wakulla Counties. Communities can use damage data from specific events or the FEMA historical claims data to shape future floodplain management and building code decisions. For this report, the MAT looked at historical, nationwide NFIP insurance claims and compared them to Hurricane Michael insurance claims from 2018. Elevation of structures in flood hazard zones (Zones V, A, and X) is dictated by applicable building codes and requirements. Using insurance claim data categorized by flood hazard zones, the MAT parsed flood damage to look for trends relative to structures that were not required to be elevated above the BFE (such as Zone A and X). The MAT found that a structure's elevation was a key driver of that structure's performance.

Based on the review of NFIP claims data, the MAT concluded that building above the minimum requirement by including freeboard across all vulnerable and floodprone areas, especially those designated as Zone A and Zone X, would help mitigate future damage. Using historical flood elevations, flood extents, and flood damage data, communities can make more informed decisions during the rebuilding and recovery process. Such data can be useful to help inform stakeholders and private homeowners of the vulnerabilities of living and working within the floodplain. Those affected by Hurricane Michael will not forget the impacts. For new homeowners or businesses, reminders of the impact of the storm either through public outreach, communication, or the availability of data during property transactions, helps to drive the point home that these areas remain vulnerable to flooding.

3.4.1.1 NFIP Claims Data Overview

Information on the more than 2 million NFIP claim transactions over the history of the NFIP were released by FEMA in June 2019. Within this comprehensive nationwide dataset, the average NFIP flood insurance claim (inflated to 2019 dollars) was approximately $40,450 in Zone V, $42,800 in Zone A, and $40,800 in Zone X. These are national averages of claims over 40 years of data in all 50 states using a history of flood impacts.

The MAT reviewed recent insurance payments following Hurricane Michael to compare to the nationwide dataset to measure the severity of damage. Table 3-1 summarizes NFIP insurance claims in the four counties visited by the MAT. The data show:

- ***Hurricane Michael damage was similar to nationwide averages.*** The 3,300 flood damage claims related to Hurricane Michael are consistent with national averages over the 40-year history of the nationwide dataset. Hurricane Michael was therefore typical, on a countywide scale, in having average flood damages in the $20,000 to $50,000 range.
- ***Hurricane Michael Zone X damage was greater in Zone X than Zone A or Zone V.*** The average damages were higher in Zone X ($53,562), outside the designated SFHA, compared to Zones A and V ($47,930 and $23,763, respectively), within the SFHA. Using the NFIP claims as a proxy for damages, the data show that damage outside of the SFHA was higher than inside of the SFHA. The data from Hurricane Michael contrasts with the nationwide dataset: areas in Zone X affected by Hurricane Michael incurred more damage and were at risk. There are currently no NFIP requirements, nor are there flood-related provisions in model building codes

and standards, for typical Zone X structures, unless a structure (i.e., critical or essential facility) is specifically regulated to the 500-year event. In order to reduce or prevent flood damage to structures in floodprone Zone X areas, prudent minimum requirements should be implemented to improve building resilience.

- ***Hurricane Michael flooding surpassed the effective SFHA.*** The higher claim average in Zone X indicates that flooding from Hurricane Michael surpassed the effective SFHA. The FIRMs are developed based on accepted science and engineering, but the flood zones only represent the 1-percent-annual-chance event. The flood zones on a map do not delineate what will or will not flood during a real event. Houses constructed outside of the SFHA or within certain flood zones (and therefore not subject to certain construction standards) can be just as susceptible to flooding events but are not as resistant to flood loads because of weaker or non-existent flood resistant construction standards.

Table 3-1: Summary of Flood Damage Claims by County from Hurricane Michael

County[(a)]	Zone V	Zone A	Zone X
	Number of Claims within Flood Zone		
Bay[(b)]	49	745	849
Gulf	165	397	203
Franklin	445	207	30
Wakulla	144	52	3
Total Number	**803**	**1,401**	**1,085**
	Average Claim Amount by Flood Zone		
Bay[(b)]	$7,855	$36,073	$53,033
Gulf	$39,571	$87,320	$62,093
Franklin	$16,460	$18,534	$13,760
Wakulla	$33,634	$34,099	$24,072
Average Michael Claim by Zone[(c)]	**$23,763**	**$47,930**	**$53,562**
National Average Claim by Zone[(d)]	$40,450	$42,800	$40,800

(a) The counties are presented in order from west to east.

(b) Note that there are only 49 structures in Zone V in Bay County that incurred damage. Due to the topographical features of Bay County, including the eroded beach/dune complex and the crest of US Highway 98, Bay County has a limited Zone V spatial extent. This explains why there are fewer Zone V claims compared to Zones A and X.

(c) Average claim per county includes building and contents damage for claims that were closed with payment. Data accessed December 2018.

(d) Average claim was derived from over 40 years' worth of FIMA NFIP redacted nationwide claims data (FEMA, 2019b).

3.4.1.2 NFIP Claims Data by Community

To analyze detailed patterns of flood damage, the MAT summarized claims data by communities visited with the greatest number of NFIP claims from Hurricane Michael (see Table 3-2). The five communities with the greatest number of claims were Port St. Joe, Panama City, Mexico Beach, St. George's Island, and Lynn Haven. As shown by shading in Table 3-4, Port St. Joe had the highest total number of claims, Mexico Beach had the highest number of Zone X claims, Panama City had the highest number of Zone A claims, and St. George Island had the highest number of Zone V claims.

While it may be expected that Zone V, associated with the highest flood risk, would receive the most damage and have the highest number of claims, the data indicate that the greatest number of claims were for damage that occurred in Zone A, followed by Zone X, with the fewest number of claims for damage that occurred in Zone V.

Table 3-2: Number of NFIP Claims for Top Five Communities by Flood Zone

Community	Zone V	Zone A	Zone X	Total Number of Claims
Port St. Joe (Bay & Gulf County)	165	382	197	744
Panama City (Bay County)	23	403	277	703
St. George Island (Franklin County)	277	132	13	422
Mexico Beach (Bay County)	0	129	290	419
Lynn Haven (Bay County)	9	107	186	302
Total Number	**474**	**1,153**	**963**	**2,590**

To further analyze detailed patterns of flood damage, the MAT summarized average claim amount data for the communities identified above as having the greatest number of NFIP claims from Hurricane Michael. Total NFIP claim amounts as of March 2019 for each of the five communities are reported as estimates that include both building and contents (see Table 3-3). The nationwide average claim data by flood zone is shown for comparison.

The highest average claims in Port St. Joe, Panama City, and St. George Island were from damage that occurred in Zone A. Mexico Beach and Lynn Haven had slightly higher average claims from damage that occurred in Zone X, though similar in magnitude to those that occurred in Zone A.

Table 3-3: Average NFIP Claim Amount of Top Five Communities by Flood Zone

Community	Zone V	Zone A	Zone X	Average Claim
Port St. Joe (Bay & Gulf County)	$39,571	$88,418	$63,884	$71,089
Panama City (Bay County)	$8,773	$20,510	$13,752	$17,463
Mexico Beach (Bay County)	$0	$125,707	$125,893	$125,836
St. George Island (Franklin County)	$9,655	$10,329	$8,279	$9,824
Lynn Haven (Bay County)	$13,967	$17,492	$20,988	$19,540
Average Michael Claim by Zone[(a)]	**$20,108**	**$53,333**	**$59,102**	**$49,397**
National Average Claim by Zone[(b)]	$40,450	$42,800	$40,800	$40,503

(a) Average claim per county includes building and contents damage for claims that were closed with payment. Data accessed December 2018.

(b) Average claim was derived from over 40 years' worth of FIMA NFIP redacted nationwide claims data (FEMA, 2019b).

In summary, the greatest number of NFIP claims were for damage that occurred in Zone A, followed by Zone X and the highest average claim amounts were for damage that occurred in Zone X, followed by Zone A. These data suggest a need to consider enacting stricter codes and standards and floodplain management regulations, especially within Zone A, such as building or elevating structures above the minimum requirements in Zone A. Furthermore, consideration should be given to developing prudent requirements and enforcing them in appropriate areas beyond the SFHA in Zone X, which will help minimize future flood damage. Communities can use this type of data analysis, in combination with specific local details of historical flood damage and insurance claims, to strengthen floodplain management and development decision-making.

While this type of community level analysis can reveal trends, it does not capture the complete picture. For example, these data do not show:

- Structures that were destroyed or damaged by high winds
- Structures where flood insurance claims were not filed
- The number of structures in the flood zone compared to the number of claims in the flood zone, which is very dependent on how many structures are originally sited within the flood zone.

Age of building stock, construction of non-compliant enclosures, and general enforcement of floodplain regulations are some variables not included in this particular analysis that could influence these observed trends.

3.4.1.3 Community-Specific NFIP Claims Data

The following narrative provides community-specific considerations for the NFIP data analysis as it relates to Mexico Beach, Port St. Joe, Lynn Haven, Panama City, and St. George Island (in order of average claim amount from highest to lowest). In each case, the community claims data is compared to the countywide and nationwide data.

Mexico Beach. Table 3-4 shows a comparison of the number of claims and average claim amount by flood zone in Mexico Beach with county and national data, as available.

Table 3-4: Mexico Beach - Comparison of NFIP Data to Countywide and Nationwide Datasets

Flood Zone	Mexico Beach	Bay County	Nation
	Number of Claims within Flood Zone		
Zone V/VE	0	49	n/a
Zone A/AE	129	745	n/a
Zone X	290	849	n/a
	Average Claim Amount by Flood Zone		
Zone V/VE	$0	$7,855	$40,450
Zone A/AE	$125,707	$36,073	$42,800
Zone X	$125,893	$53,033	$40,800

n/a = not available

A review of the NFIP data for Mexico Beach shows that:

- This community had the fourth highest number of claims filed (419 total) and the highest average claim amount relative to the other top five communities; Mexico Beach is where Hurricane Michael made landfall. The number of claims in Zone X (290) was more than double the number in Zone A (129).
- There were no claims in Zone V, which is attributed to the limited extent of Zone V in Mexico Beach given the local topographic features.
- Zone A average claim amounts were only marginally lower than the average claim in Zone X. Zone A and Zone X average claims in Mexico Beach were significantly higher than the Bay County average claim and three times the national average, confirming that this community was most affected by the storm.

The NFIP claim amount data for Mexico Beach reflect flood extents that were greater than the 1-percent-annual-chance flood, and which caused significant damage to many structures outside of the SFHA.

Port St. Joe. Table 3-5 shows a comparison of the number of claims and average claim amount by flood zone in Port St. Joe with county and national data, as available.

Table 3-5: Port St. Joe - Comparison of NFIP Data to Countywide and Nationwide Datasets

Flood Zone	Port St. Joe	Gulf County	Nation
	Number of Claims within Flood Zone		
Zone V/VE	165	165	n/a
Zone A/AE	382	397	n/a
Zone X	197	203	n/a
	Average Claim Amount by Flood Zone		
Zone V/VE	$39,571	$39,571	$40,450
Zone A/AE	$88,418	$87,320	$42,800
Zone X	$63,884	$33,634	$40,800

n/a = not available

A review of the NFIP data for Port St. Joe shows that:

- This community had the highest number of claims filed (744 total) and the second highest average claim amount compared to the other top five communities, even though Mexico Beach is where Hurricane Michael made landfall.
- Zone V average claim amounts in Port St. Joe were roughly equal to the Gulf County average claim amount and were similar to the nationwide average. The average claim amounts in Zones A and X in Port St. Joe exceeded the nationwide average claims for Zones A and X by 1.5 to 2 times.

While one might expect claims damage amounts would increase with hazard risk, so that structures in Zone V would have more damage than Zone A or in Zone X, this was not the case in Port St. Joe.

Lynn Haven. Table 3-6 shows a comparison of the number of claims and average claim amount by flood zone in Lynn Haven with county and national data, as available.

Table 3-6: Lynn Haven - Comparison of NFIP Data to Countywide and Nationwide Datasets

Flood Zone	Lynn Haven	Bay County	Nation
	Number of Claims within Flood Zone		
Zone V/VE	9	49	n/a
Zone A/AE	107	745	n/a
Zone X	186	849	n/a
	Average Claim Amount by Flood Zone		
Zone V/VE	$13,967	$7,855	$40,450
Zone A/AE	$17,492	$36,073	$42,800
Zone X	$20,988	$53,033	$40,800

n/a = not available

A review of the NFIP data for Lynn Haven shows that:

- This community had the fifth highest number of claims filed (302 total) and the third highest average claim amount relative to the other top five communities. This community is similar to Panama City in that there was a small number of claims in Zone V, likely due to the limited extent of Zone V in this area, but many more claims in Zone A and X.
- The average claims in Lynn Haven were similar to the average claims in Panama City (see Table 3-3 or Table 3-7). Zone V claims in Lynn Haven were greater than the Bay County average, but less than the national average. Zone A and X claims in Lynn Haven were less than the Bay County average and the national average.

The NFIP claim amount data for Lynn Haven demonstrates that many buildings incurred only minor or moderate flood damage as compared to other parts of Bay County. This community is located to the north of Panama City and more inland than Mexico Beach.

Panama City. Table 3-7 shows a comparison of the number of claims and average claim amount by flood zone in Panama City with county and national data, as available.

Table 3-7: Panama City - Comparison of NFIP Data to Countywide and Nationwide Datasets

Flood Zone	Panama City	Bay County	Nation
	Number of Claims within Flood Zone		
Zone V/VE	23	49	n/a
Zone A/AE	403	745	n/a
Zone X	277	849	n/a
	Average Claim Amount by Flood Zone		
Zone V/VE	$8,773	$7,855	$40,450
Zone A/AE	$20,510	$36,073	$42,800
Zone X	$13,752	$53,033	$40,800

n/a = not available

A review of the NFIP data for Panama City shows that:

- This community had the second highest number of claims filed (703 total) and the fourth highest average claim amount compared to the other top five communities.
- The average claim for all three flood zones was less than or near $20,000, well below the national average for each zone. Zone V claim amounts in Panama City were similar to those in the Bay County average claim, but Zone A and Zone X claims were significantly less.

Similar to Lynn Haven, many buildings incurred only minor or moderate flood damage as compared to other parts of Bay County. This could be because the storm surge effects of Hurricane Michael were not as severe in Panama City due to the inland location of the community.

St. George Island. Table 3-8 shows a comparison of the number of claims and average claim amount by flood zone in St. George Island with county and national data, as available.

Table 3-8: St. George Island - Comparison of NFIP Data to Countywide and Nationwide Datasets

Flood Zone	St. George Island	Franklin County	Nation
	Number of Claims within Flood Zone		
Zone V/VE	227	445	n/a
Zone A/AE	132	207	n/a
Zone X	13	30	n/a
	Average Claim Amount by Flood Zone		
Zone V/VE	$9,655	$16,460	$40,450
Zone A/AE	$10,329	$18,534	$42,800
Zone X	$8,279	$13,760	$40,800

n/a = not available

A review of the NFIP data for St. George Island shows that:

- This community had the third highest number of claims filed (422 total) and the lowest average claim amount relative to the other top five communities. This community had the highest number of claims filed in Zone V (277) compared to other top five communities.
- Despite having the highest number of claims in Zone V and a high overall number of claims, similar to Panama City, the average claim of less than or equal to $10,000 was less than Franklin County and much less than the national average.

St. George is part of the barrier spit complex located southeast of Apalachicola. This community is almost entirely covered by the SFHA with a large section of the community facing the open ocean in Zone V.

3.4.2 Importance of Siting to Potential Damage

An important consideration in floodplain management regulation is siting requirements for development relative to the water's edge. Structures located closer to the shoreline are more exposed to wave impacts such was wave runup, scour, short-term and long-term erosion, debris impact, and storm surge, and thus also flood damage. Local, state, and federal requirements are used to help control development in vulnerable areas.

FEMA GUIDANCE FOR SITING STRUCTURES

FEMA guidance and recommendations for siting structures within a parcel are presented in Chapter 4 of FEMA P-55, *Coastal Construction Manual* (2011).

FEMA guidance, described in FEMA P-55 (see textbox), clearly states that developers need to evaluate and understand hazards and vulnerability of structures within the coastal zone. Other federal regulatory programs, such as the Coastal Barrier Resources Act (CBRA), are set to preserve coastal areas, open land, and vulnerable shorelines by limiting federal investment and discouraging development. FEMA guidance also provides insight on development of raw land, notably that developers should not rely on engineering solutions to correct poor planning decisions.

From a state perspective, one of the measures to regulate structures and activities in the coastal zone along the shoreline is the State of Florida's CCCL program. The CCCL marks the landward limit of areas where special siting and design considerations are necessary to protect the beach-dune system, proposed and existing structures, and adjacent properties, as well as to preserve public beach access. It is not a setback line but rather defines the landward limit of the FDEP's jurisdiction. These data are readily available to the public using a web mapper, are required to be documented on a CCCL permit, and can be used by private developers or landowners to take hazards into account. Some structures were constructed before the CCCL was put in place. Available information, such as the CCCL and federal guidelines, should be used to characterize the hazard and likelihood of it occurring, as well as long-term trends.

COASTAL BARRIER RESOURCES ACT

The CBRA and subsequent amendments designated relatively undeveloped coastal barriers along the Atlantic, Gulf of Mexico, Great Lakes, U.S. Virgin Islands, and Puerto Rico coasts as part of the John H. Chafee Coastal Barrier Resources System (CBRS).

Additional information about CBRS regulations and areas included in the CBRA is available at www.fws.gov/CBRA/. Any building within a CBRS area that is constructed or Substantially Improved after October 1, 1983, or the date of designation for areas added to the system in 1991, is not eligible for federal flood insurance or other federal financial assistance. The same restriction applies to Substantially Damaged buildings in a CBRS area that are repaired or renovated after those dates. However, all buildings within the CBRS must still comply with the NFIP siting, design, and construction requirements in their communities.

3.4.2.1 Building Siting Within Parcel Boundaries

The importance of the location of the building within a building lot and relative to the shoreline is illustrated in a case study of a building along the shoreline in Port St. Joe (Indian Peninsula). Figure 3-29 shows a structure (green circle) sited too close to the shoreline. Note the relatively narrow parcel boundaries, which typically evolve over time with land acquisition, real estate transactions, and eventually development, and the division of parcels along Indian Pass Road. The case study structure is located at the midpoint of the parcel and is in front of the vegetated dune area. Other structures are set back farther on their respective parcels.

Figure 3-30 shows two aerial images of the same location along Indian Pass Road, one taken in 2015 and the other in 2018. The structures visible in both aerial images are located within Zone VE 11. Structures in this aerial are seaward of the CCCL. In the same neighborhood, there are structures that are set back farther from the shoreline.

Image A in Figure 3-30 shows a historical aerial photograph taken on October 16, 2015. The case study structure, the most seaward building, was constructed in 1991; the building slightly to the west was constructed in 1999. In 2015, the case study structure was over 250 feet from the water's edge. Image B in Figure 3-30 is the same area along Indian Pass Road taken during the NOAA post-Hurricane Michael overflights on October 11, 2018. Buildings constructed after the 2015 image was taken are visible, sited seaward of the CCCL.

Figure 3-29: Parcel outlines along Indian Pass Road showing the location of the structure relative to the parcel extent. The red circle indicates the approximate location of a building (Indian Peninsula).

FEMA GUIDANCE FOR CONSIDERING EROSION

FEMA guidance and recommendations for evaluating hazards are presented in Section 3.3 of FEMA P-55, *Coastal Construction Manual* (2011). Proper planning, siting, and design of coastal residential buildings require: (1) a basic understanding of shoreline erosion processes, (2) erosion rate information from the community, State, or other sources, (3) appreciation for the uncertainty associated with the prediction of future shoreline positions, and (4) knowledge that siting a building immediately landward of a regulatory coastal setback line does not guarantee the building will be safe from erosion.

The CCM recommends siting coastal residential structures based on the larger of the published erosion rate, or 1 foot per year.

Imagery from October 16, 2015 [A], and October 11, 2018 [B]. The distance of the home in the red circle from the water's edge in 2015 is was more than 250 feet from the water's edge, whereas in 2018, this distance was less than 150 feet (Indian Peninsula).

Figure 3-30: Location of houses relative to the shoreline in area along Indian Pass Road

Post-storm imagery indicates that floodwater flowed beneath and beyond the case study building (as evidenced by the darker coloration of sand). The MAT visited this area and observed that the case study structure (red circle) received damage at ground level with broken lateral bracing perpendicular to the flow path and damage to utilities. The case study structure sustained over $36,000 in flood damages from the event. Neighboring structures and those set back farther from the water's edge within their respective parcel had no reported damage. Figure 3-30 also shows the damage to the vegetated dune, which has clearly eroded significantly since 2015.

3.4.2.2 Development Proximity to Shoreline

As described in Section 3.1, buildings located at or near the shoreline were severely damaged by Hurricane Michael across the four counties visited by the MAT. Two case studies illustrate building at and near the shoreline, one in Mexico Beach and the other in Cape San Blas.

Mexico Beach. Figure 3-31 shows the location of the CCCL in Mexico Beach before Hurricane Michael. The CCCL was established in Bay County in 1974 and updated in 1995 after Hurricane Opal and revised again in 1997. One-third of the residential structures seaward of the 1997 CCCL in Figure 3-31 were constructed prior to the establishment of the CCCL in Bay County.

COASTAL CONSTRUCTION CONTROL LINE REQUIREMENTS

Chapter 62B-33 of the Florida Administrative Code provides the design and siting requirements for structures seaward of the CCCL.

Chapter 62B-33.024 requires builders to use a 30-year erosion projection for siting structures. The rule provides guidance for developing the shoreline change rates for natural beaches; for beaches where coastal armoring is present; for beaches adjacent to or in the vicinity of inlets without jetty structures; and for beaches with established beach nourishment or restoration projects.

The CCCL can be accessed from the FDEP website at: floridadep.gov/rcp/coastal-construction-control-line/content/locate-coastal-construction-control-line-cccl.

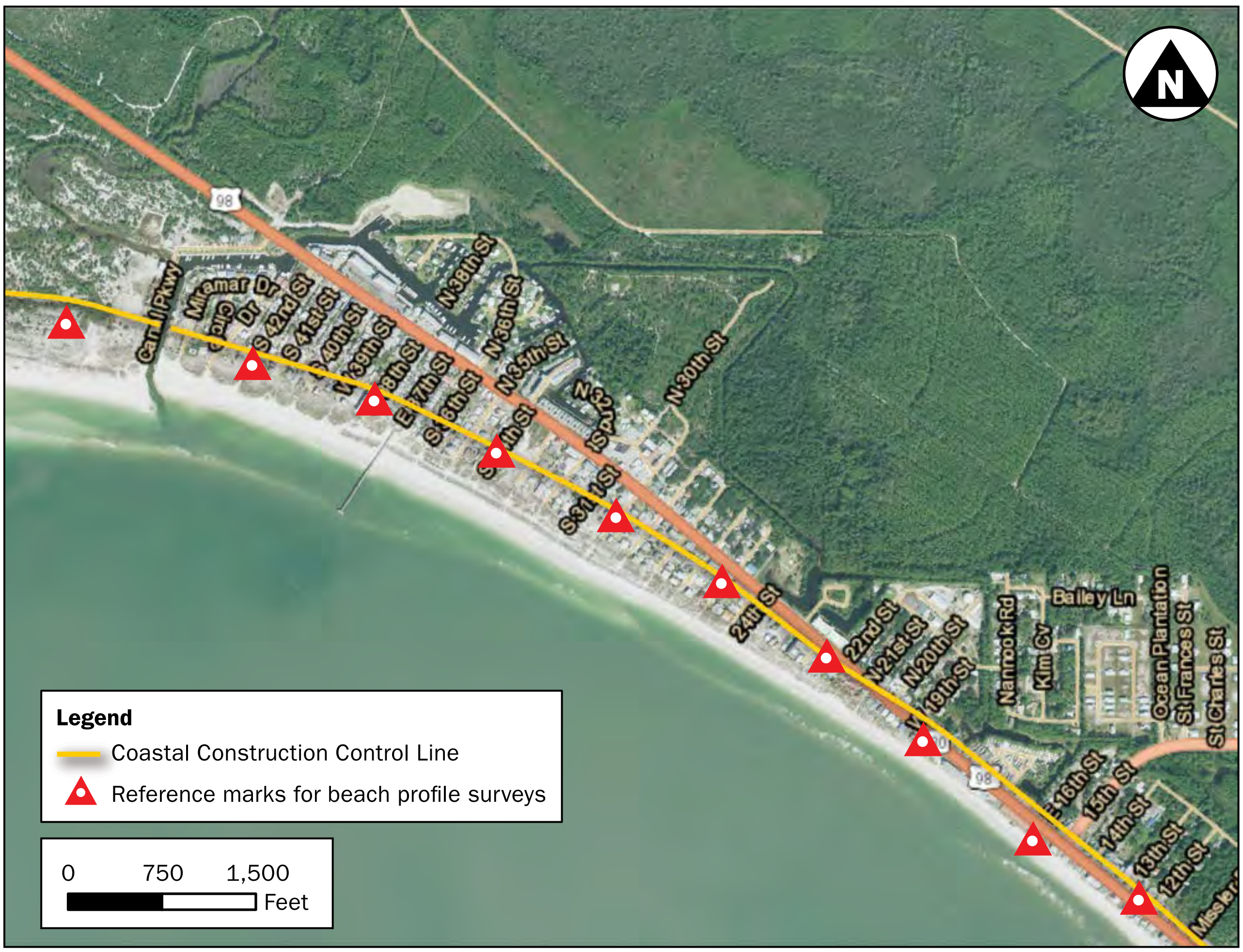


Figure 3-31: Aerial imagery showing CCCL in Mexico Beach before Hurricane Michael

Damage to Mexico Beach was extensive and is described in Section 3.1.1.2. Structures were sited too close to the shoreline and long-term erosion trends were not accounted for. Many pre-FIRM structures and infrastructure were built close to the shoreline and were destroyed by Hurricane Michael. This area is highly susceptible to future damage. Prudent decisions about rebuilding more resiliently should be made.

Cape San Blas. Figure 3-32 shows the location of the CCCL in the Cape San Blas area before Hurricane Michael. Similar to Mexico Beach and clearly visible in the aerial image, much development was present between the CCCL and the shoreline before the storm. The CCCL was first established in Gulf County in 1975 and re-established in 1986 and 2010. A dozen

> **COMMUNITY ACTION**
>
> Community governments, in conjunction with private landowners, should determine the suitability of redevelopment in highly vulnerable areas given the high winds, storm surge, and waves that occurred during Hurricane Michael. Using the CCCL as a guideline, communities should consider rezoning to limit development, and developers should consider exceeding siting requirements and incorporating best practices.

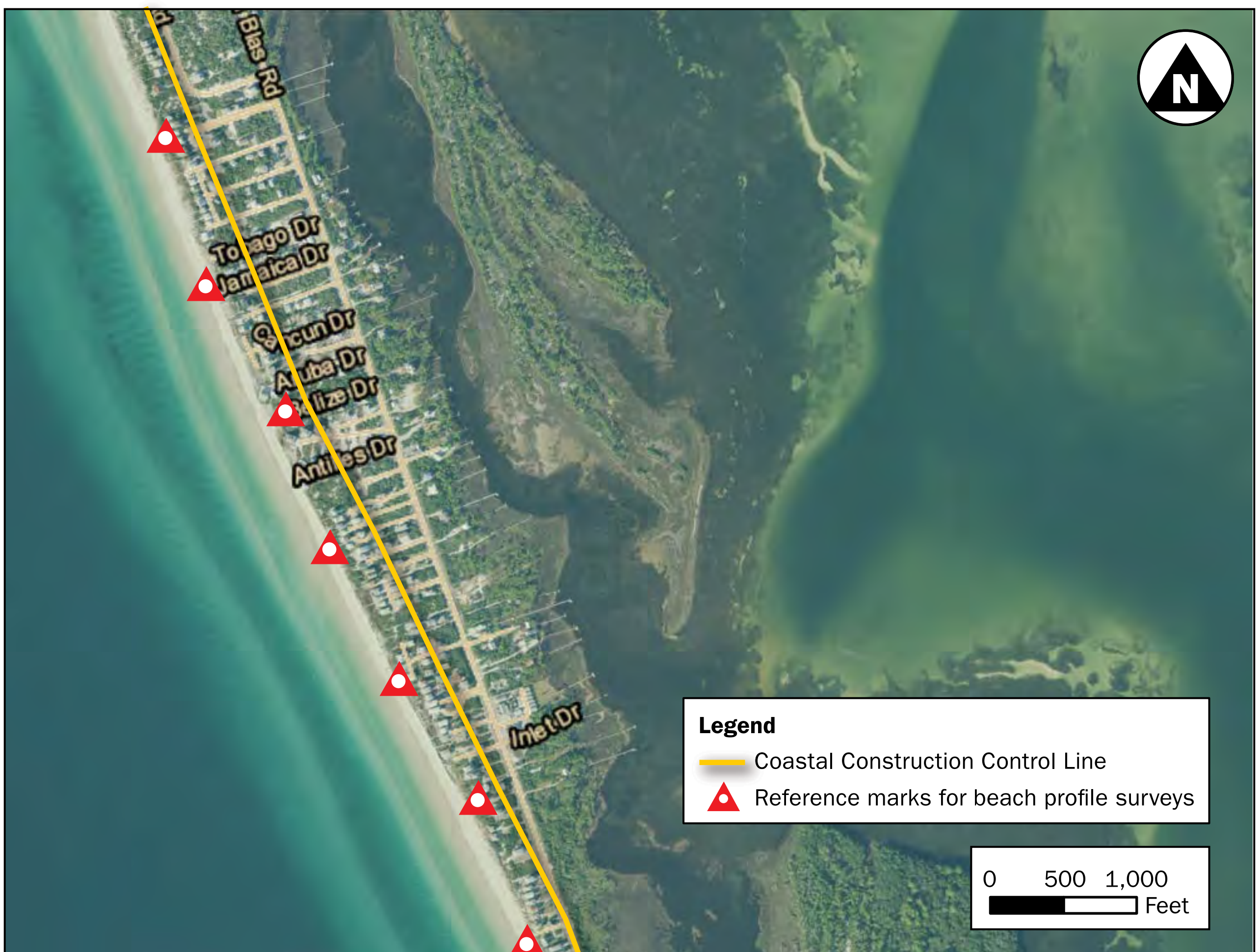


Figure 3-32: Aerial imagery showing CCCL in Cape San Blas before Hurricane Michael

residential structures seaward of the CCCL were constructed prior to the establishment of the 2010 CCCL in Bay County (post-1974) (see Figure 3-32).

There was major erosion of beaches and dunes in the Cape San Blas area, as described in Section 3.1.2.3. The west shoreline of Cape San Blas is susceptible to wave attack and listed by FDEP as critically eroded. This area is currently a large barrier spit that is entirely within a U.S. Fish and Wildlife Service CBRS area. The southern end of the barrier spit is developed, while the northern end is a state park and aquatic preserve. It experienced an inlet breach during Hurricane Michael (see Figure 1-4). The MAT observed scour and erosion of structures and pile foundations seaward of the CCCL along the developed portions of the spit and identified (based on erosion around structure piles) 8 feet in beach lowering near the southern breach. The State of Florida has already designated this area as vulnerable to significant erosion hazards, such as scour, erosion, and overwash.

COMMUNITY ACTION

Enforcement of certain construction practices or reconsidering where development may occur with respect to the CCCL will help better preserve natural features like dunes and beaches that are at risk of destabilization as well as mitigate future damage to structures.

HURRICANE
MICHAEL
IN FLORIDA

CHAPTER 4
Wind-Related Observations: Residential

The MAT evaluated the wind-related performance of newer residential buildings in the path of Hurricane Michael.

Using a desktop analysis, the MAT identified the locations of residential buildings that were built after the effective date of the 1st Edition of the FBC (March 2002) (referred to as “Post-FBC” throughout this chapter) and in the path of Hurricane Michael. With this data, the team targeted areas for evaluation where the estimated wind speeds were near or above design levels (specifically areas concentrated near Mexico Beach and Panama City). Neighborhoods and houses that were built after March 2012 (effective date of the 2010 FBC) were given priority. The team visited 127 sites and often documented the performance of multiple buildings at each site. The locations visited by the MAT are shown on Figure 1-10 of Chapter 1. The MAT focused its evaluation on one- and two-family dwellings, although the team also evaluated the performance of some multi-family buildings (apartments and condominiums).

Hurricane Michael’s estimated wind speeds exceeded the basic (design) wind speeds required by the FBC and ASCE Standard 7, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7) in some areas in and around the hurricane’s landfall, particularly in the Mexico Beach area. Refer to Chapter 1 for a detailed discussion of Hurricane Michael and wind speeds.

In general, failures of structural systems such as the MWFRSs of post-FBC buildings were rare in the areas the MAT visited, even in areas with the highest estimated wind speeds. However, wind-induced failures of building envelope components, such as roof coverings, wall coverings, and soffits, were widespread and observed, to some degree, on almost every building the MAT assessed. Damage to glazed openings was observed on many buildings, but was sporadic and typically limited to one or two glazed openings in any given building. Overall, the MAT's assessments of buildings impacted by Hurricane Michael and other recent hurricanes show that structural systems of buildings built to modern building codes are performing well. As performance of structural systems has improved, the vulnerability of the building envelope has become increasingly apparent.

This chapter describes the MAT's observations of the performance of structural systems of post-FBC residential buildings compared to pre-FBC residential buildings (Section 4.1) and the performance of building envelope elements (Section 4.2). Each photograph caption in this chapter includes the estimated wind speed for the location shown in the photograph during Hurricane Michael and the design wind speed for comparison. While this chapter uses wind speeds to compare event conditions and design requirements, other factors also affect wind pressures and damage to buildings (site location, internal pressures, wind-borne debris, etc.). Nevertheless, wind speed provides a useful and convenient basis for comparing event conditions with design requirements.

Each photograph caption also shows the year the building was built in addition to the wind speeds. The year built is provided to offer some context with respect to the wind provisions in the FBC that were in effect when the building was permitted for construction. Having knowledge of the wind-specific requirements in the various editions of the FBC and the year built provides a good baseline from which to evaluate and compare damage observed to relevant code requirements. Buildings built prior to March 2012 (effective date of the 2010 FBC) were likely designed to wind speeds different from those shown because of changes in the 2010 FBC and ASCE 7-10 mapped design wind speeds. Refer to Table 2-1 in Chapter 2 for a history of key FBC changes affecting wind design, including information on changes to the mapped wind speeds in ASCE 7-10 and the 2010 FBC.

ESTIMATED WIND SPEEDS/ DESIGN WIND SPEEDS

Estimated wind speeds were developed by Applied Research Associates (ARA).

Design wind speeds were determined from ASCE 7-10 (referred to as basic wind speeds), which is referenced in the current edition of the FBC (6th Edition [2017]), using the Hazards by Location website (hazards.atcouncil.org) developed by the Applied Technology Council (ATC). Design wind speeds are 3-second peak gust wind speeds for Risk Category II buildings.

4.1 Structural Systems / Main Wind-Force Resisting Systems

In Mexico Beach, older buildings (pre-FBC) sustained significant structural damage, and many were completely destroyed. However, post-FBC buildings performed much better than pre-FBC buildings, particularly in their resistance to wind loads. In some cases, though, failures were observed in post-FBC buildings. The MAT was able to draw general conclusions as to the cause of failure for some of the post-FBC buildings assessed, but access issues and/or significant damage often restricted determinations on others. For buildings that were catastrophically damaged, such as was commonly observed in Mexico Beach, it was often difficult to determine the exact cause (wind or coastal storm surge/flood). Many of the older buildings had slab-on-grade foundations, but many were also elevated to some degree. Buildings with slab-on-grade foundations would have been extremely susceptible to failure due to storm surge. However, given that the wind speeds from Hurricane Michael around Mexico Beach were severe and the estimated wind speeds were approximately 15 percent above the design level for this area, many of the failures were likely due to a combination of wind and surge. Refer to Chapter 3 for observations related to coastal surge and flood damage.

MAIN WIND-FORCE RESISTING SYSTEM

ASCE 7 defines the MWFRS as an assemblage of structural elements assigned to provide support and stability for the overall structure. Examples of MWFRS elements in typical residential structures include exterior walls (shear walls); wood roof decking (roof diaphragms); and structural connections between foundations, floors, walls, and the roof (metal uplift connectors).

4.1.1 Structural Performance of Pre-FBC and Post-FBC Buildings

The structural performance of pre-FBC buildings was notably inferior compared to post-FBC buildings. Although many of the post-FBC buildings were exposed to wind loads exceeding the design level and to considerable amounts of wind-borne debris, most performed well structurally. Three neighborhoods with both pre-FBC and post-FBC houses offer examples of the difference in performance.

Example 1 – Mexico Beach: The contrast in building performance is illustrated by four houses located near each other, as indicated on an aerial photograph (Figure 4-1). Examples of post-FBC performance are shown in Figure 4-2 and Figure 4-3. Figure 4-2 shows an elevated post-FBC house that had severe envelope damage, but did not appear to have any damage to its MWFRS even though the building was subjected to wind speeds that exceeded the design wind speed. Similarly, Figure 4-3 shows another elevated post-FBC building (built in 2017) that had little structural damage (likely due to surge) and very little envelope damage.

In contrast, an adjacent house constructed pre-FBC suffered significantly more structural damage (Figure 4-4). Figure 4-5 shows a nearby post-FBC house (built in 2017) with some wall covering and soffit damage, but no apparent structural damage.

Location of houses shown in Figures 4-2 to 4-5. The surrounding construction was mostly older than 1980.

[A] Figure 4-3 (post-FBC, built in 2017) [B] Figure 4-2 (post-FBC, built in 2010)

[C] Figure 4-4 (pre-FBC, built in 1984) [D] Figure 4-5 (post-FBC, built in 2017)

Figure 4-1: Spatial relationship of houses in Figure 4-2 through Figure 4-5 (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

SOURCE: ESRI TOOL SCREEN CAPTURE

This elevated two-story, wood-frame, post-FBC house (built in 2010) was near the beach in Mexico Beach. While the building clearly suffered severe envelope damage (including siding loss, roof covering loss, and breach of impact-resistant glazing), elements of the MWFRS did not appear to suffer any major damage. The inset shows a breach of what is likely impact-resistant glazing, indicating the severity of the wind and wind-borne debris experienced at this location.

Figure 4-2: Post-FBC house (built in 2010) with severe envelope damage, but no obvious MWFRS damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Figure 4-3:
Post-FBC house (built in 2017) with minimal damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

This house had only a small amount of damage, which was most likely due to coastal storm surge, and very little envelope damage.

Figure 4-4:
Pre-FBC house (built in 1984) with severe structural damage (Mexico Beach)

The damage to this building was likely due to a combination of wind and coastal storm surge.

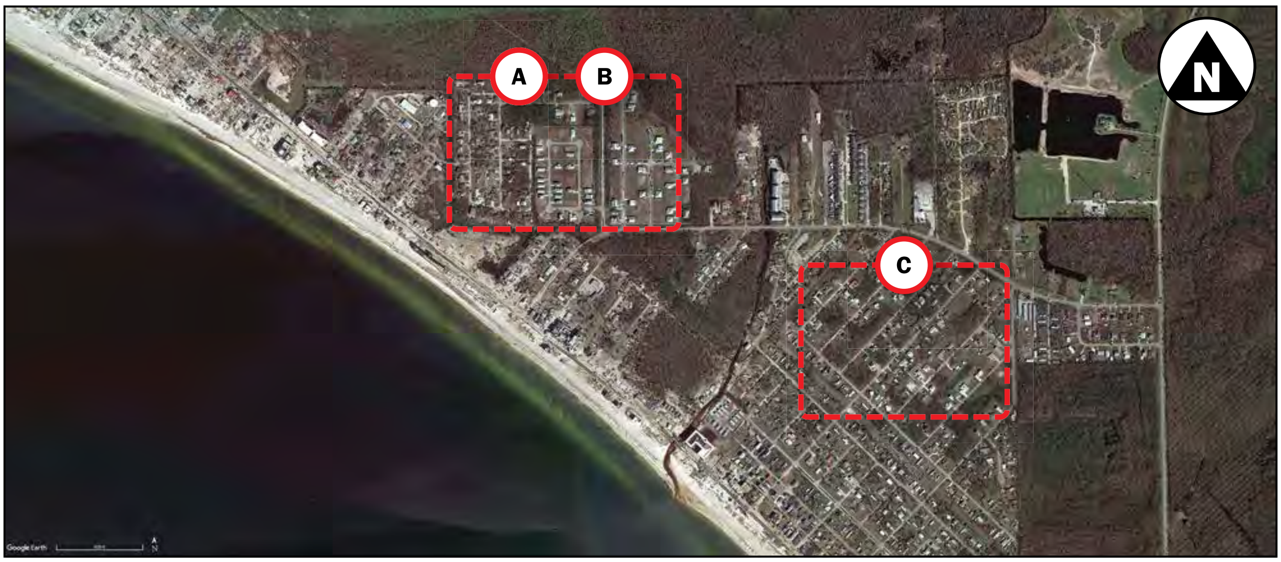
Figure 4-5: Post-FBC house (built in 2017) with no apparent structural damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

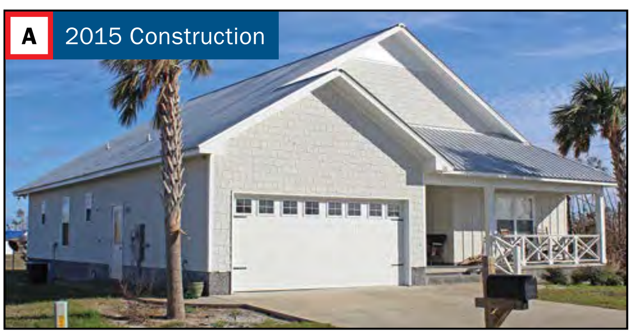
Example 2 – Mexico Beach: Houses in another neighborhood in Mexico Beach show another example of the performance of post-FBC buildings compared to pre-FBC buildings (Figure 4-6). The post-FBC house built in 2011 (Building [A] in the figure) had asphalt shingle failure on the south slope, but no other damage was observed. In contrast, Buildings [B], [C], and [D], all pre-FBC, sustained significant wind damage.

Building [A], built in 2011, had asphalt shingle failure on the south slope but no other damage was observed.

Figure 4-6: Building [A] is a post-FBC house (built in 2011) located near three pre-FBC houses [B, C, and D]. Building [A] is also shown in Figure 3-14 (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Example 3 – Mexico Beach: The MAT assessed several post-FBC buildings north of US Highway 98 in Mexico Beach. Although the wind speed from Hurricane Michael in these areas was estimated to be 150 mph, many buildings appeared to have suffered minimal to no wind-related damage. The houses in Figure 4-7 are approximately ½ mile from the beach. The owner of the post-2017 construction shown in Figure 4-7 said there was approximately 5 inches of water inside the building due to flooding, but no indication of water intrusion due to wind-driven rain. Several houses suffered siding failure (mostly fiber cement siding in this area), and a few had partial roof covering failure. However, many appeared to have sustained no damage at all.





Located approximately ½ mile from the coast in Mexico Beach, the houses in this area appeared mostly undamaged (Buildings [A] and [C]); though some siding and roof covering damage was observed (Building [B]).

Figure 4-7: These post-FBC houses (built between 2011 and after 2017) located about ½ mile from the beach all performed well (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

4.1.2 Structural Failures of Post-FBC Buildings

Although the MAT observed a few structural failures at post-FBC houses, they were generally isolated. The following are three examples observed by the MAT.

Example 4 – Mexico Beach: The house shown in Figure 4-8 sustained a significant gable failure. Given its location (Exposure D) and unique roof framing, this building could not have been built to any of the prescriptive high-wind standards referenced in the FBC. It would have been required to be designed by a registered design professional.

Although the MAT could not determine the exact cause of failure, a couple of issues likely contributed to the failure of this gable end wall. The gable end wall was particularly tall and likely needed bracing in locations other than at the interface with the wall below. The blue dashed rectangles in the figure show where additional support was likely intended. However, there was no evidence of any metal straps/clips at these points to resist the outward or suction forces on the gable end wall. The end wall framing was turned flatwise, which is a weaker orientation for the framing. Additionally, the outlookers appeared to not have been adequately connected to the end truss. Where the outlookers are still attached to the roof decking, two or three nails through the outlookers are visible. However, several of the notches in the end truss/framing on the right side of the gable showed no sign of fastener penetration, indicating that there was no connection at that joint (yellow rectangle). The lack of a connection at the outlooker would make the gable end wall susceptible to failure at that location.

Figure 4-8: Post-FBC house (built in 2016) with significant gable end failure (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Blue dashed outlines show where connectors were missing at points of support for the gable end wall. The yellow outline shows lack of connection at the outlooker to the end truss in some cases.

Example 5 – Mexico Beach: The Mexico Beach house shown in Figure 4-9 had severe structural damage. The damage to this building was too severe to draw any conclusions about what caused the structural failures. This house is approximately 325 feet from the Gulf of Mexico in open terrain with limited obstructions.

Figure 4-9: Post-FBC house (built in 2012) with significant structural damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

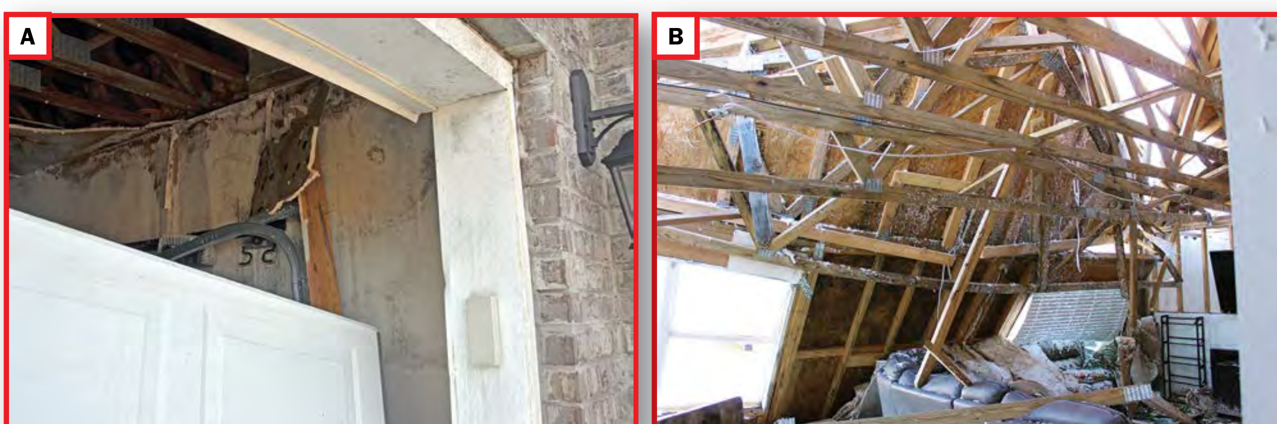
Example 6 – Mexico Beach: The house shown in Figure 4-10 was built in 2017. The south face of this particular building suffered severe damage to the roof and walls. Based on the MAT's observations, the south face of the building likely had an overhanging porch, as shown in the picture of the north face of the building (which was not severely damaged). The south porch, being the windward face and exposed to a combination of wind loads on the roof and underneath the porch overhang (in addition to possible wind-borne debris), is likely where failure initiated. The failure of the porch may have created a breach in the envelope, allowing wind to enter the interior of the building, resulting in high internal pressures and significant structural damage to the south end of the building.

Figure 4-10: Post-FBC house (built in 2012) with significant structural damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Example 7 – Panama City: The house shown in Figure 4-11 was one of a few post-FBC houses assessed in the Panama City area that suffered significant structural damage. It was built in 2016, and the homeowners were home during the storm. The homeowner described the series of events that unfolded, which included the failure of gypsum board on the wall adjacent to the garage, failure of the sectional (garage) door, failure of a window on the first floor, and failure of the gable end area on the second floor (not necessarily in chronological order). The MAT was not able to make a definitive determination about the initial or primary cause of failure, but it likely was a combination of failure of the sectional (garage) door and breaching of the first- and/or second-story window. These events enabled wind to enter the interior of the house, creating high internal pressures, which contributed to the failure of the second-story gable end wall. The back door also blew out.

The vertical framing supporting the sectional (garage) door track failed as shown in Figure 4-11. While it was difficult to make a definitive determination about the gable end given the degree of destruction, the MAT could not find evidence of appropriate bracing of the gable end wall that failed. As previously indicated, numerous glazed openings were also breached. Although the glazed openings did not appear to be impact-resistant, this house is not located in a WBDR (see Section 2.3.1 of this report for a discussion on the WBDR).

Figure 4-11: Post-FBC house (built in 2016) with significant structural damage (EWS = 127 mph, DWS = 133 mph) (Panama City)



4.2 Building Envelope

> **PROTECTING BUILDING ENVELOPE COMPONENTS IS CRITICAL**
>
> While newer houses may have improved outcomes after hurricane events, an insurance closed-claims study for residential properties conducted following Hurricane Charley in 2004 found that interior losses and additional living expenses were 27 percent of the total loss costs (Brown, T.M. et. al., 2015). Additional living expenses include the costs for renting an apartment or staying in a hotel while repairs are made.

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. Reducing damage to envelope components is critical because such damage can result in significant water intrusion and damage to interior components such as gypsum board wall coverings, floor coverings (carpet), and other furnishings (mattresses, furniture, etc.).

The MAT observed many instances where it was clear that houses had experienced water intrusion and resulting interior damage, as evidenced by water-damaged interior components piled outside the house. Such debris piles were common, particularly throughout the Panama City area, even when the houses appeared to have suffered only minor exterior damage from the storm. One such example is shown in Figure 4-12. Another example that demonstrates the importance of building envelope components is illustrated by the house in Figure 4-13, which had so much water intrusion damage that the building was declared unsafe.

When the MAT visited this house, it appeared to have recently had a new roof installed. NOAA post-storm imagery indicates that this area suffered significant roof covering loss. Clearly, this house suffered severe water intrusion as evidenced by the debris pile at the curb. Although the MAT could not be certain of the source of the water intrusion, the loss of the asphalt shingle roof covering was likely a contributor to the interior damage.

Figure 4-12: Post-FBC house (built in 2016) that experienced water intrusion (EWS = 127 mph, DWS = 133 mph) (Panama City)

While this relatively new house shown in [A] appeared from the road to have performed relatively successfully, it suffered significant water intrusion. The house suffered roof covering loss near the ridge, some soffit damage, and damage to one glazed opening [B]. The MAT could not determine whether the damage was due to wind-borne debris or wind pressure. The interior finishes and furnishings were mostly removed [C], and the building was declared unsafe.

Figure 4-13: Post-FBC house (built after 2017) with significant water intrusion (EWS = 125 mph, DWS = 134 mph) (Panama City)

The most commonly observed damaged elements of the building envelope in the areas visited by the MAT after Hurricane Michael were roof coverings, soffits, and exterior wall coverings. Damage to windows and doors, including impact protection systems, and garage doors was also often noted, but was generally scattered. The MAT focused its visits to assess primarily post-FBC houses and observations for each of these building elements are presented in the following subsections.

FLORIDA PRODUCT APPROVAL

The State of Florida requires building envelope products to be approved through its Product Approval system.

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 be approved for compliance with the structural requirements of the FBC:

- 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 by 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, refer to 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.

4.2.1 Roof Coverings

In the Panama City area, asphalt shingles were by far the predominant roof covering on post-FBC residential buildings. In Mexico Beach and Port St. Joe, metal panel roof coverings appeared to be the more common type of roof covering. The use of concrete or clay roof tile was limited in all areas visited by the MAT.

The performance of roof coverings on post-FBC houses was generally very poor for all areas assessed. It was difficult to make specific observations related to performance issues for several reasons. Primarily, most damaged roofs were covered with tarps to prevent further water infiltration after the storm (see Figure 4-14: Aerial perspective of roof covering damage in the Panama City area). Additionally, many roofs had already been recovered/repaired at the time the MAT assessments took place. The information in this section highlights trends the MAT discerned using the data available.

Figure 4-14: Aerial perspective of roof covering damage in the Panama City area

The blue temporary roof tarps show the extent of roof covering damage in the Panama City area.

4.2.1.1 Asphalt Shingles

Asphalt shingle loss on post-FBC houses was widespread and observed at the majority of sites visited by the MAT. Damage to asphalt shingle roofs was observed on both relatively new construction (post-2017) and houses that were 10 to 15 years old. Trends and analytics were difficult to establish because most damaged roofs were protected with temporary tarps, and ongoing recovering/repair work was underway at many sites. Additionally, the amount of damage for a given area was often inconsistent. For example, in some developments visited, the amount of damage to asphalt shingles varied depending on which side of the street the building was located.

Figure 4-15 depicts a clear example of these inconsistencies. In this picture, asphalt shingles on the houses built in 2016 appeared to perform better than the adjacent houses built between 2012 and 2014 (exposed roof decking). However, the MAT visited several sites where asphalt shingles on newer houses performed worse than those on older houses. The MAT could not make any correlations between age of the asphalt shingles and performance.

Construction dates of the houses to the left of the red line ranged from 2012 to 2014. The houses to the right of the red line were built in 2016.

Figure 4-15: Aerial view of post-FBC houses (built 2012–2016) showing performance of asphalt shingles (EWS = 127 mph, DWS = 133 mph) (Panama City)

SOURCE: ESRI TOOL SCREEN CAPTURE

Hip and ridge shingle performance. Failure of hip and ridge shingles was prevalent. Failure of ridge shingles often included failure of ridge vents, which resulted in significant water intrusion according to homeowners. A new roof covering had recently been installed on the house in Figure 4-16. The homeowner said the roof covering mostly stayed intact except for the shingles at the ridge and the ridge vent. No other envelope components were observed to have failed. Observations from the road would indicate that the house fared reasonably well during the storm. However, according to

Figure 4-16: Post-FBC house (built in 2012) with interior damage due to loss of ridge shingles and ridge vent (EWS = 128 mph, DWS = 133 mph) (Panama City)

the homeowner, significant water intrusion occurred, causing the collapse of ceilings in multiple rooms.

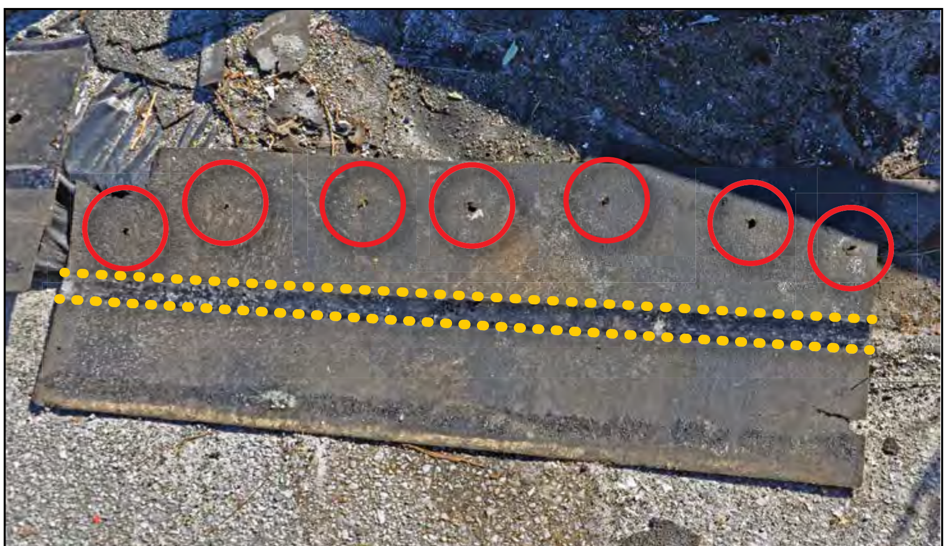
Ridge vent performance. The MAT evaluated ridge vents in debris piles, but could not determine whether the vents failed because of high winds or were removed as part of a roof replacement. Some ridge vents the MAT examined may not have been sufficiently fastened. Others had far more fasteners than the manufacturer would have specified and in some cases appeared to be fastened with relatively large nails. It is possible that using too many or too large fasteners could cause them to "punch out" the back side of oriented strand board (OSB) roof decking, resulting in reduced withdrawal resistance. Another possibility is that the fasteners for the ridge vents were not long enough to penetrate through the roof sheathing.

The MAT was given the opportunity go inside and document the interior water intrusion in the house shown in Figure 4-16. This house had recently had the roof replaced and a new ridge vent installed. The MAT observed the ridge vent and sheathing from the inside of the house and could not find definitive evidence that the ridge vent fasteners adequately penetrated the roof sheathing.

Evaluation of asphalt shingles in debris piles. As previously noted, the specific cause of failure of asphalt shingles for most houses that the MAT visited could not be determined. However, there was asphalt shingle debris observed at nearly every site visited. Although it was usually unclear if the shingle debris was due to storm damage or if the shingles were removed during a roof replacement, a couple of trends were noticed by evaluating the old asphalt shingles in the debris piles, related to fasteners and roofing cement.

First, the Michael MAT noted, as did the Hurricane Irma in Florida MAT report, incorrect location of fasteners in asphalt shingles was commonly observed either on damaged roofs or asphalt shingles in debris piles. Figure 4-17 depicts an asphalt shingle retrieved from a debris pile indicating fasteners were installed well above the recommended location.

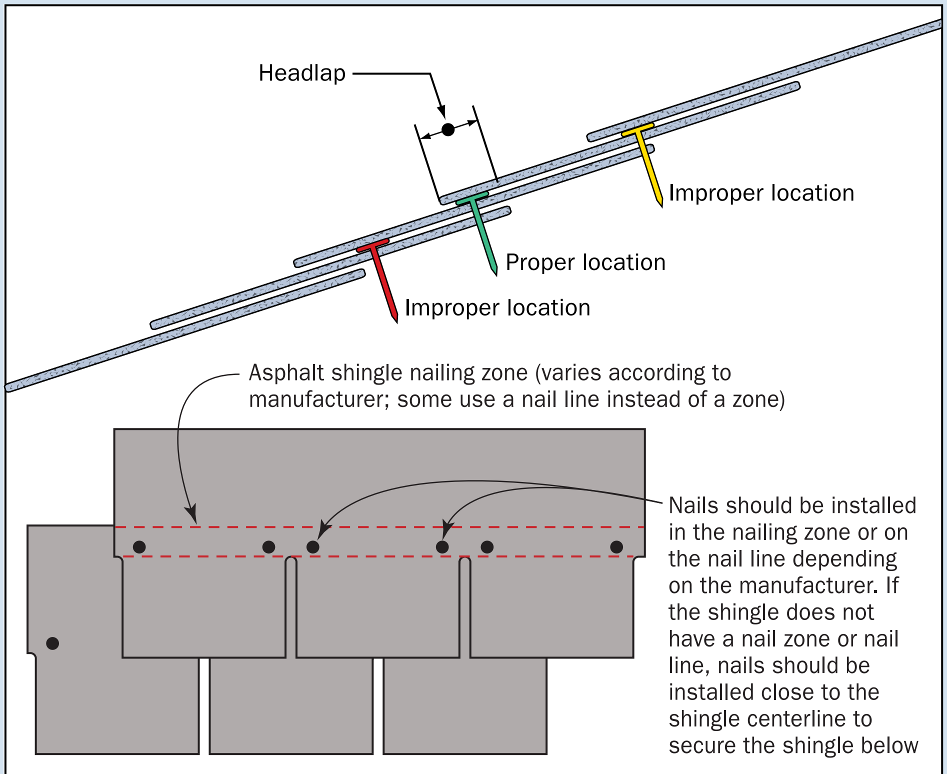
Figure 4-17: Incorrect location of fasteners in asphalt shingle



Red circles show where fasteners were driven through the shingle. Yellow dotted lines show the approximate location of where fasteners should have been placed.

GUIDANCE: PROPER LOCATION FOR ASPHALT SHINGLE FASTENERS

Asphalt shingle fasteners should be installed on the nail line or in the nail zone, as specified by the manufacturer. If the shingle does not have a nail line or nail zones, nails should be installed such that they also secure the shingle underneath as shown in the image below.



When properly located, the nail engages the underlying shingle in the headlap area (center nail).

From FEMA Hurricane Michael in Florida Recovery Advisory 2 Figure 2 Modified from the *Asphalt Roofing Residential Manual: Design and Application Methods* (ARMA, 2014).

ROOFING CEMENT ON HIP AND RIDGE SHINGLES

Although the use of roofing cement on hip and ridge shingles is not required in the FBC unless required by the Product Approval, FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010e), and FEMA P-55, *Costal Construction Manual* (2011), both recommend the use of roofing cement when installing hip and ridge shingles. (Refer to Technical Fact Sheet No. 7.3, "Asphalt Shingle Roofing for High-Wind Regions" [in FEMA P-499, 2010a], and Section 11.5.1 in FEMA P-55.)

The second trend observed from evaluating debris piles is related to hip and ridge shingles. Most hip and ridge shingles that were observed in debris piles lacked evidence of roofing cement. Figure 4-18 shows a residential building in Panama City with mostly hip and ridge asphalt shingle damage.

Figure 4-18: Post-FBC (2015) house with hip and ridge asphalt shingle damage (EWS = 132 mph, DWS = 134 mph) (Panama City)

4.2.1.2 Metal Panel Roof Systems

While asphalt shingles were the predominant roof covering type in the Panama City area, metal panel roof systems were more widely used on post-FBC houses in the Mexico Beach area.

Metal panel roof systems in Mexico Beach were primarily the standing seam type with concealed clips. Metal panel roof systems observed in the Panama City area were primarily the through-fastened (exposed fastener heads) type. Examples of standing seam and through-fastened metal roof systems are shown in Figure 4-19.

Metal panel roof systems on post-FBC houses performed reasonably well overall in the areas visited by the MAT. There were some instances of damage to metal panel roof systems observed. Figure 4-20 and Figure 4-21 show post-FBC houses (both built in 2006) with metal roof panel damage. It is worth noting that most of the metal panel roof damage observed was in areas where the estimated wind speeds were above the design level wind speed.

Figure 4-19: Typical metal panel roof systems

Figure 4-20: Post-FBC house (built in 2006) with metal roof panel damage (EWS = 138 mph, DWS = 130 mph) (Port St. Joe)

Figure 4-21: Post-FBC house (built in 2006) with metal roof panel damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

4.2.1.3 Concrete or Clay Roof Tile

The use of concrete or clay roof tile was not widely observed on post-FBC houses in the area impacted by Hurricane Michael. The few tile roofs the MAT observed appeared to perform relatively well with minor damage.

FBC REQUIREMENTS FOR ROOF REPLACEMENT

Mitigation triggers for roof repair and replacement in the FBC are addressed in detail in Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement* in the 6th Edition (2017) Florida Building Code (2018f).

4.2.1.4 Roof Re-Covers (Roof-Overs) and FBC Mitigation Requirements

When a roof covering on a site-built, pre-FBC single-family dwelling is removed and replaced, the FBC requires certain mitigation techniques be performed. Most notably, if the existing roof sheathing nailing does not meet certain criteria, the FBC requires roof sheathing to be re-nailed. These provisions are addressed in detail in Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (2018f). However, this mitigation criterion does not apply to roof re-covers (a roof re-cover is the process of installing a new roof covering over an existing roof covering and is often referred to as a “roof-over”).

Although observing the performance of roof re-covers was not a primary objective, the MAT did observe a couple of severe roof sheathing failures where pre-FBC buildings with asphalt shingles were re-covered with metal roof panels. As previously mentioned, the FBC does not require re-nailing of the roof deck where metal roof panels are installed over an existing asphalt shingle roof. However, if the asphalt shingles are removed, the roof sheathing nailing has to be evaluated and re-nailed if found to be deficient.

Figure 4-22 shows a pre-FBC multi-family complex where asphalt shingle roofs were re-covered with metal roof panels. Figure 4-23 shows a pre-FBC single-family dwelling where an asphalt shingle roof was re-covered with metal roof panels. It is possible that these houses would have performed better if the roof sheathing had been re-nailed.

Note that the actual design wind speed for the buildings in Figure 4-22 and Figure 4-23 is unknown as they were built in 1987 and 1975, respectively. The design wind speed from the current FBC and ASCE 7 is provided to give a general perspective of the design criteria in this area.

Figure 4-22:
Pre-FBC multi-family house (built in 1987) with asphalt shingle roofs re-covered with metal roof panels; aerial view shows the scope of damage in the vicinity of the house (EWS = 134 mph, DWS = 133 mph) (Panama City)

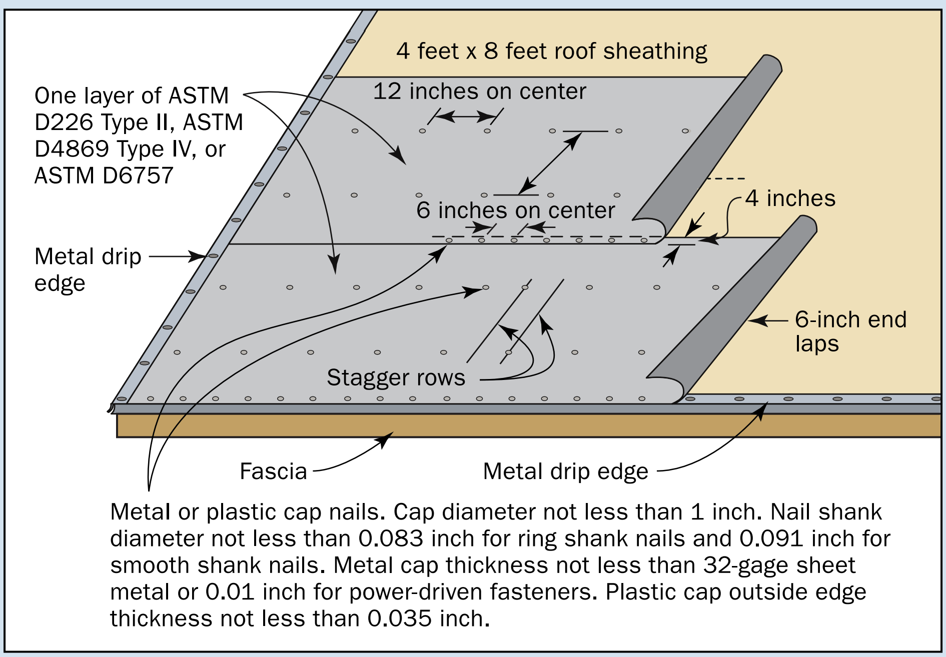
Figure 4-23:
Pre-FBC single-family house (built in 1975) with asphalt shingle roof re-covered with metal roof panels (EWS = 127 mph, DWS = 133 mph) (Panama City)

4.2.1.5 Roof Underlayment

The MAT observed many buildings undergoing roof replacement during their assessment. At many of the job sites visited, new underlayment installation was not being fastened as required by code. Roof underlayment can be used as a secondary method for preventing water infiltration where the primary roof covering fails due to wind; studies and tests have validated the effectiveness of certain underlayment installations. As a result, the FBC requires enhanced attachment of traditional underlayment products such as felt, and also recognizes more robust underlayment such as the self-adhered modified bitumen products (in the IBC and IRC, enhanced underlayment is required only where the design wind speed is 140 mph and greater). Refer to the textbox for additional information on underlayment requirements. A couple of examples of improper attachment of underlayment observed by the MAT are shown in Figure 4-24 and Figure 4-25.

GUIDANCE: FBC REQUIREMENTS FOR INSTALLING ROOFING FELT UNDERLAYMENT

For roof slopes of 4:12 and greater, the FBC requires that felt used as an underlayment to be in accordance with ASTM D226 Type II or ASTM D4869 Types III or IV. The felt underlayment must be fastened with cap nails at 6 inches on center (o.c.) at side laps and have two staggered rows at 12 inches o.c. in the field of the sheet. Synthetic underlayment is permitted if it is approved as an alternate to ASTM D226 Type II and is fastened as required for felt underlayment. The specific installation requirements for this method are shown below.



From FEMA Hurricane Irma in Florida Recovery Advisory 3

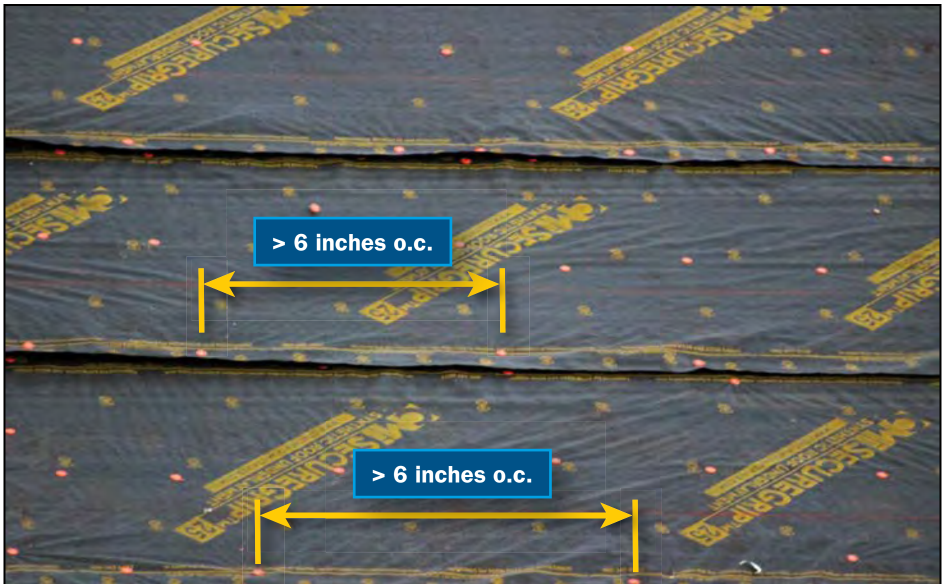


Figure 4-24: Pre-FBC house (built in 1986) roof replacement using synthetic underlayment (EWS = 123 mph, DWS = 134 mph) (Lynn Haven)

Yellow arrows show spacing of underlayment at side laps, which exceeds the maximum spacing of 6 inches. Also note the field of the underlayment sheet only has a single line of fasteners at varied spacing instead of the two required staggered rows.

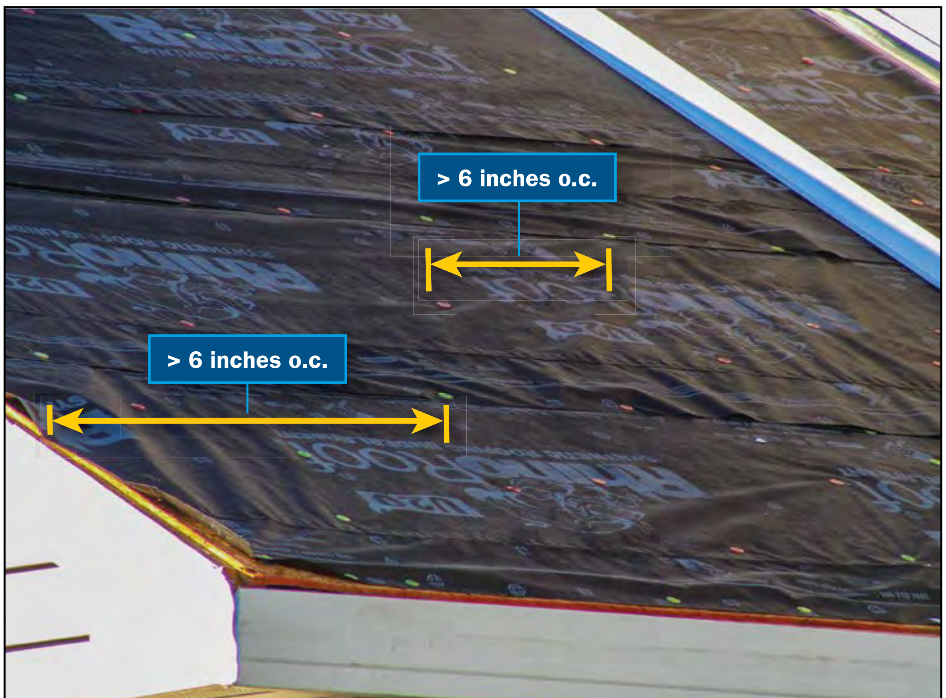


Figure 4-25: Post-FBC house (built in 1986) roof replacement using synthetic underlayment (EWS = 129 mph, DWS = 132 mph) (Panama City)

Yellow arrows show the fastener spacing on the side laps, which exceeds the maximum spacing of 6 inches. Also note the field of the underlayment sheet only has a single line of fasteners for most sheets at varied spacing instead of the two required staggered rows.

Sealed Roof Decks

Water intrusion through the roof deck can be substantially mitigated using underlayment products to create a "sealed roof deck." Sealed roof decks have been tested and shown to be effective in significantly reducing water intrusion through the roof deck when the primary roof covering is lost or damaged due to wind loads. A sealed roof deck is required by Insurance Institute for Business & Home Safety (IBHS) to receive a FORTIFIED Roof™ designation.[1]

SEALED ROOF DECK SUCCESS

This house was successfully protected by a sealed roof deck during Hurricane Michael after wind-borne debris punctured the metal roof covering.

Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (2019a), discusses detailed options to create a sealed roof deck.

4.2.2 Soffits

The performance of roof eave and rake soffit assemblies, particularly vinyl soffits, was poor across all areas visited by the MAT. Since the hurricanes of 2004, failed soffits have been identified as a common likely source of water intrusion. The Hurricane Irma MAT report also noted the poor performance of soffits in the Florida Keys. Vinyl was by far the most common soffit material in the areas assessed, and the MAT observed soffit failure on post-FBC houses at most sites visited.

IMPROVING SOFFIT PERFORMANCE

FEMA Hurricane Irma in Florida Recovery Advisory 2, *Soffit Installation in Florida* (2018g) includes recommendations for improving soffit performance.

4.2.2.1 Soffit Installation

The MAT could not determine if soffit installations complied with their Product Approvals because the products were not labeled. However, there are installation techniques that are critical to successful wind performance of soffits that the MAT assessed in the field.

A common practice is to "float" one or both ends of the soffit panels in channels that are attached near the fascia and the wall. Although this method of installing vinyl soffit may be the most convenient, it offers very little wind resistance.

1 FORTIFIED is a national standard for resilient construction based on scientific research and real-world testing by IBHS. More information is available at fortifiedhome.org.

In high-wind areas, vinyl soffit panels have to be fastened at both ends to framing, the fascia board, and/or a nailing strip to meet the required design wind pressures in these areas. Fastening the vinyl soffit panel at both ends, as shown in Figure 4-26, is one of the key installation criteria for successful performance under wind loading. While soffit framing methods may differ from those shown in Figure 4-26, the soffit panel should be fastened at both ends and the span of the soffit panel should not exceed 12 inches. Where the span of the eave or rake exceeds 12 inches, additional nailing strips should be provided. The maximum span of 12 inches is recommended by the Vinyl Siding Institute (VSI) and IBHS, and is also a requirement in a code change currently moving through development of the IRC and the FBC.

> **FLORIDA PRODUCT APPROVAL – SOFFITS**
>
> In the State of Florida, soffits are required to have a Florida Product Approval (see textbox "Florida Product Approval" at front of Section 4.2). However, based on discussions with code officials throughout the state, soffit assemblies are rarely inspected to confirm the product complies with its Product Approval.

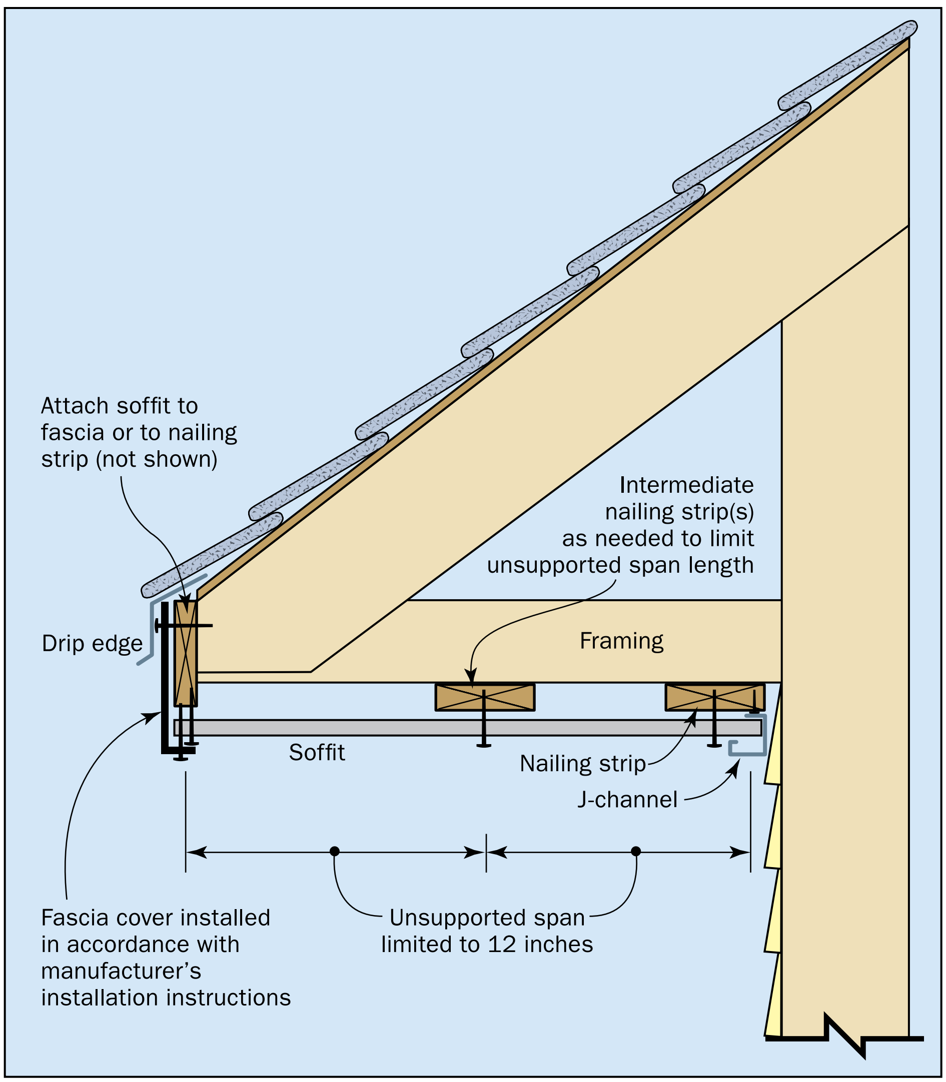


Figure 4-26: Recommended vinyl soffit installation

4.2.2.2 Examples of Soffit Failures

Lack of nailing strip/framing. The lack of a nailing strip/framing at the exterior wall on which to attach the end of the vinyl soffit panel likely contributed to the failure of the soffit assembly in Figure 4-27. Without a nailing strip, the end of the vinyl soffit panel cannot be secured at the wall, and it simply “floats” in the vinyl channel. This installation method and vulnerability was widely observed throughout the areas visited by the MAT.

Figure 4-27: Post-FBC house (built after 2017) with vinyl soffit damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Soffit attachment issues. At some sites, the MAT was able to document the presence of nailing strips or framing at the wall where soffit assemblies failed. However, whether the soffit was attached at the end adjacent to the wall could not be verified. Figure 4-28 is one example of several observations of soffit assembly failure where a nailing strip could be seen at the adjacent wall, but evidence of attachment of the end of the soffit panel to the nailing strip could not be verified.

The red outline shows a nailing strip that was used to attach the J-channel, but attachment of the soffit panel at that end could not be verified.

Figure 4-28: Post-FBC house (built in 2006) with vinyl soffit damage (EWS = 131 mph, DWS = 134 mph) (Panama City)

Fastening of soffit panels varied as well. The MAT observed some soffit panels that were attached with staples. While the FBCR has eliminated the use of staples as an approved fastener, many of the Product Approvals for vinyl soffit panels permit the use of staples. The *Vinyl Siding Installation Manual* (VSI, 2017), as well as Florida's Product Approvals, require soffit panels to be fastened through the nail hem. Figure 4-29, Figure 4-30, and Figure 4-31 show vinyl soffits that were not installed properly.

Red circles indicate where the vinyl soffit panel was attached at the midpoint of the panel instead of at the nail hem. Yellow dashed line circles indicate where the vinyl soffit panel should have been attached.

Figure 4-29: Post-FBC house (built in 2015) with vinyl soffit damage (EWS = 128 mph, DWS = 133 mph) (Panama City)

Red circle shows where nail hem failed at staple connection.

Figure 4-30: Post-FBC house (built in 2016) with vinyl soffit damage (EWS = 128 mph, DWS = 133 mph) (Panama City)

Red circles show staples fastened through the edge of the soffit panel instead of through the nail hem. The yellow circle shows where the soffit should have been fastened through the nail hem.

Figure 4-31: Post-FBC house (built after 2017) with vinyl soffit damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

4.2.3 Exterior Wall Coverings

The MAT observed widespread damage to exterior wall coverings throughout the areas it visited. The predominant types of wall covering used in the Panama City area were vinyl siding and brick veneer, while in Mexico Beach and Port St. Joe, fiber-cement siding was more commonly used than vinyl siding or brick veneer.

Damage to vinyl siding on post-FBC houses was particularly prevalent and damage to fiber-cement siding was observed at many sites. Brick veneer damage on post-FBC houses was very limited and for that reason is not described in this report.

In the State of Florida, exterior wall coverings (as well as other envelope components) are required to have Product Approval (see textbox called "Florida Product Approval" at front of Section 4.2). However, based on discussions with code officials throughout the state, exterior wall coverings are rarely inspected to confirm the product complies with its Product Approval.

The discussion in this section is limited to MAT observations of damage to residential buildings at the sites visited. Because many buildings were undergoing repair work at the time of the MAT visit, assessment of undamaged building envelope components was often an unreliable indicator of success or failure.

4.2.3.1 Vinyl Siding

The performance of vinyl siding in high winds hinges particularly on the selection of an appropriate high-wind rated product and proper installation. The lack of a proper starter strip, utility trim under windows, and proper fastening techniques can significantly and adversely affect the siding's performance to wind loading. The location of vinyl siding failures on houses observed by the MAT after Hurricane Michael varied, but was particularly prevalent on walls between closely spaced houses in dense developments (possibly due to a channeling effect between buildings that increased wind speed). An example is shown in Figure 4-32.

Additionally, siding is required to have a design wind pressure rating that equals or exceeds the required design wind pressure specified in ASCE 7 (or the FBCR or IRC as applicable) (see textbox).

VINYL SIDING PRESSURE EQUALIZATION FACTOR

Vinyl siding is required to be certified and labeled as conforming to ASTM D3679, *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding*. The 6th Edition (2017) FBC refers to the 2011 edition of ASTM D3679, and the 5th Edition (2014) FBC refers to the 2009 edition of ASTM D3679. For determining the design wind pressure rating of vinyl siding, ASTM D3679 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). Previous editions of ASTM D3679 permitted 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 wind 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 wind pressure rating (D_p) of 60 pounds per square foot (psf), that product met a test pressure (P_t) of 32.4 psf (60 psf x 0.36 x 1.5).

The 2017 edition of ASTM D3679 increased the PEF to 0.5. Therefore, in the example above, a vinyl siding product with a D_p of 60 psf will have met a test pressure of 45 psf. While the PEF of 0.5 currently recognized in the latest edition of ASTM D3679 produces a significant increase in required test pressure when compared to the former PEF of 0.36, wind tunnel research (refer to the IBHS report *Wind Loads on Components of Multi-Layered Wall Systems with Air-Permeable Cladding* [2012]) on vinyl siding clad structures has indicated that the PEF for vinyl siding is as high as 0.8 or 60 percent larger than the currently recognized value of 0.5.

The vinyl siding between these closely spaced houses was damaged, possibly due to increased wind speeds being channeled between the buildings.

Figure 4-32: Post-FBC house (built in 2015) with vinyl siding damage (EWS = 135 mph, DWS = 134 mph) (Panama City)

The MAT could not determine the cause of vinyl siding failure on most houses it visited because of limited access at many sites and a lack of product labeling. However, the MAT did observe several instances of vinyl siding damage where installation issues likely contributed.

Improper installation. The MAT identified several instances of improper installation involving vinyl siding installed with staples. Figure 4-33 shows an example of vinyl siding fastened to the wall with staples. While the wind performance of vinyl siding installed with staples can be debated, this installation did not comply with the *Vinyl Siding Installation Manual*. Where staples are used to attach vinyl siding, the *Vinyl Siding Installation Manual* requires the staples to be wide enough in the crown to allow free movement of the siding (approximately 1/32 inch away from the nailing hem). The staples in Figure 4-33 are fastened through the top of the nail hem, and even if they were installed over the top of the nail hem, they do not appear to be wide enough. This installation method would clearly compromise the vinyl siding's performance in resisting wind loads.

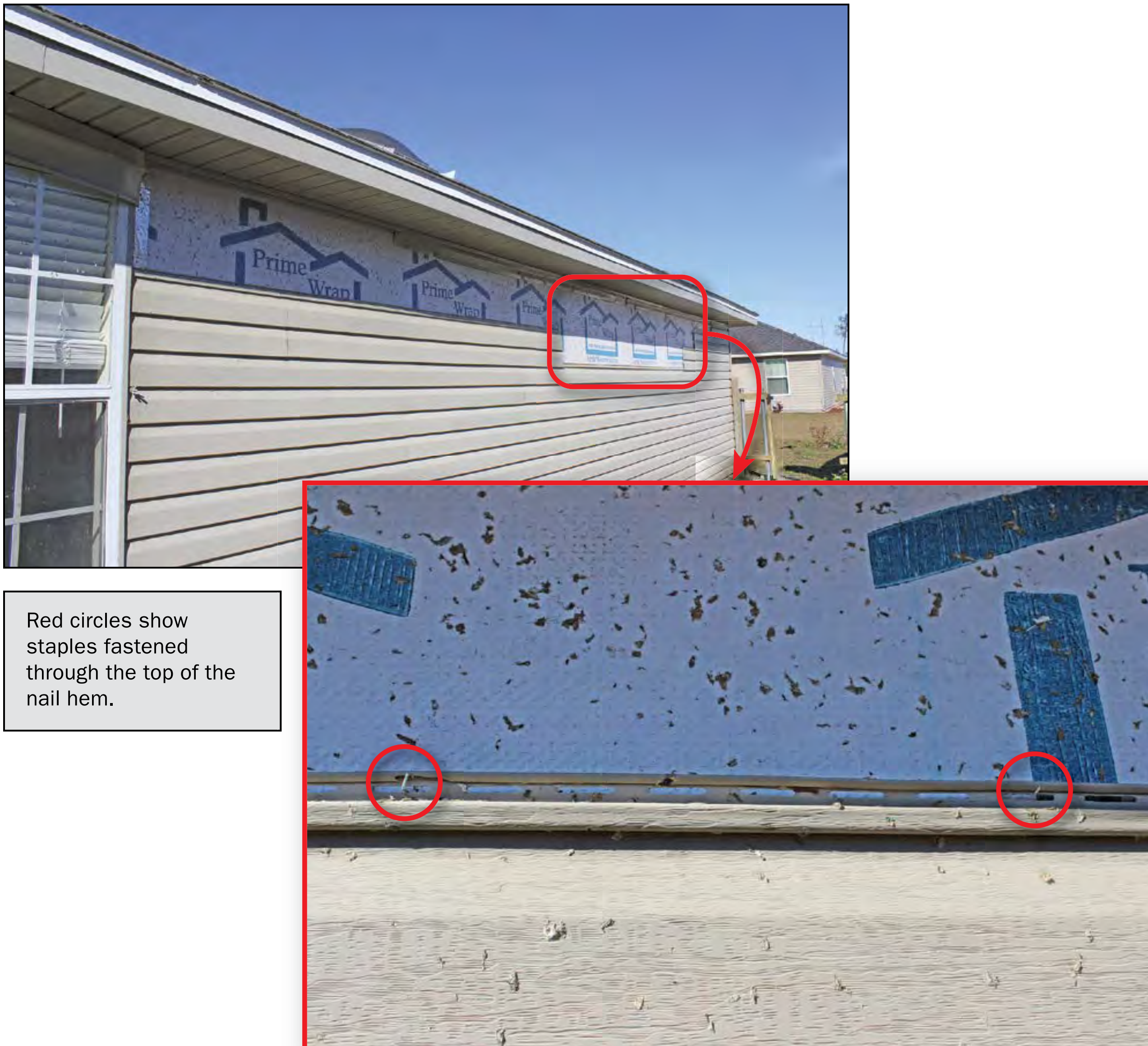


Figure 4-33: Post-FBC house (built in 2008) with vinyl siding damage (EWS = 128 mph, DWS = 134 mph) (Panama City)

Improper starter strip. The MAT also observed issues where vinyl siding lacked a proper manufacturer-specified starter strip and/or utility trim under windows. An example of an improper starter strip is shown in Figure 4-34. A proper starter strip specified by the manufacturer will be matched to the lock design of the siding and is usually the same color as the siding. If the starter strip is not matched to the lock design of the siding, the siding is vulnerable at the bottom course and can result in progressive loss of the siding. Notably, the house in Figure 4-34 is in an area where the estimated wind speed was about 15 percent greater than the design wind speed.

Red rectangle indicates improper starter strip.

Figure 4-34: Post-FBC house (built in 2002) with vinyl siding damage (EWS = 150 mph, DWS = 130 mph) (Panama City)

4.2.3.2 Fiber-Cement Siding

Fiber-cement siding was more commonly observed as an exterior wall covering in Mexico Beach and Port St. Joe than in the Panama City area. Although numerous failures of fiber-cement siding were observed at sites visited, the MAT was not able to determine the cause of failure due to limited access at many sites and a lack of product labeling. On some houses, the MAT observed fastener pull-out failure. At other sites, failure of the fiber-cement siding around the fastener head was observed. Most of the fiber-cement siding the MAT assessed was installed using the concealed fastening (sometimes referred to as blind fastening) method. The concealed fastening method hides the fasteners by overlapping successive siding pieces.

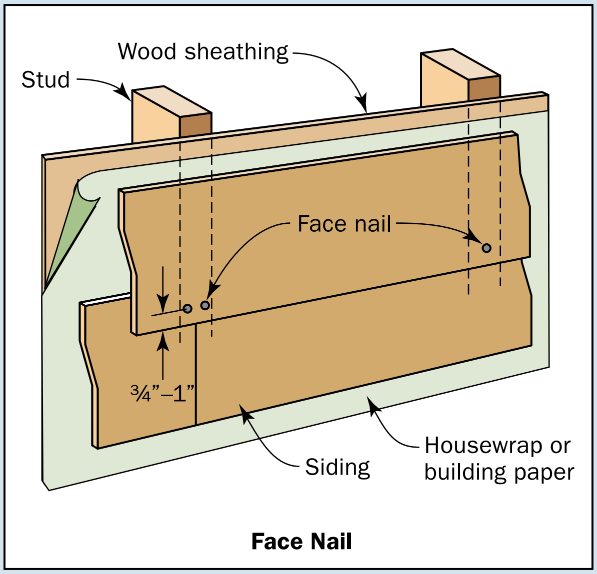
The following discussion shows some of fiber-cement siding failures observed by the MAT:

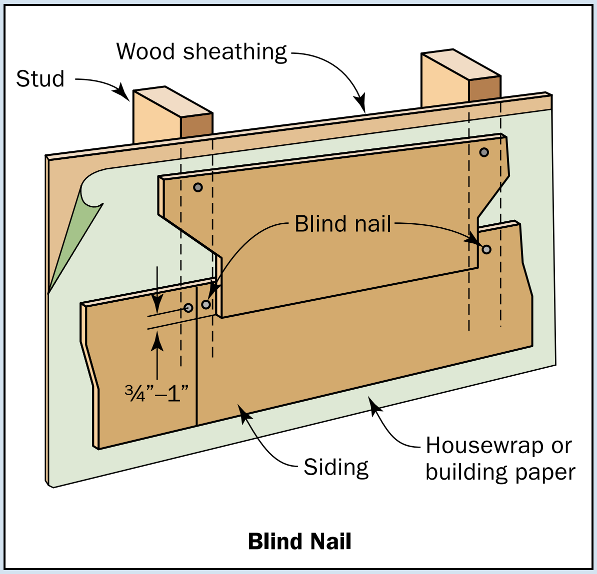
- Figure 4-35 is an example of a residential building in Panama City that suffered extensive fiber-cement siding failure. Fiber-cement siding failure in this development was common, and the MAT noted ongoing repair work on buildings in this area. While the estimated wind speed for this site was less than the design wind speed, these houses were adjacent to a very large area of open terrain with scattered obstructions (Exposure C condition).
- The house in Figure 4-36 experienced significant fiber-cement siding damage, particularly in the gable wall area. The inset shows the location of the fasteners. Although the siding appears to be well fastened into plywood wall sheathing, some of the fasteners appear to have missed the wall stud framing as the joints in the plywood sheathing indicate where wall studs are located. This poor installation could have contributed to the poor performance of the siding.

FIBER-CEMENT SIDING INSTALLATION

As with other wall coverings, fiber-cement siding is required to have Product Approval in Florida. While installation methods can vary depending on the product, fiber-cement siding is typically installed with 6d common or 11-gauge 2½-inch roofing nails at every stud. The manufacturer's installation instructions in the Product Approval typically specify a maximum stud spacing.

While the code and manufacturer Product Approvals permit the use of the concealed nailing method for the specified design pressures, face-nailing of fiber-cement siding would improve wind resistance. An example of recommended face-nailing of fiber-cement is shown below.





Typical examples of blind and face-nailing of fiber-cement siding

SOURCE: FIGURES 10 AND 11 OF FEMA P-499 TECHNICAL FACT SHEET NO. 5.3

Figure 4-35: Post-FBC house (built after 2017) with fiber-cement siding damage (EWS = 125 mph, DWS = 134 mph) (Panama City)

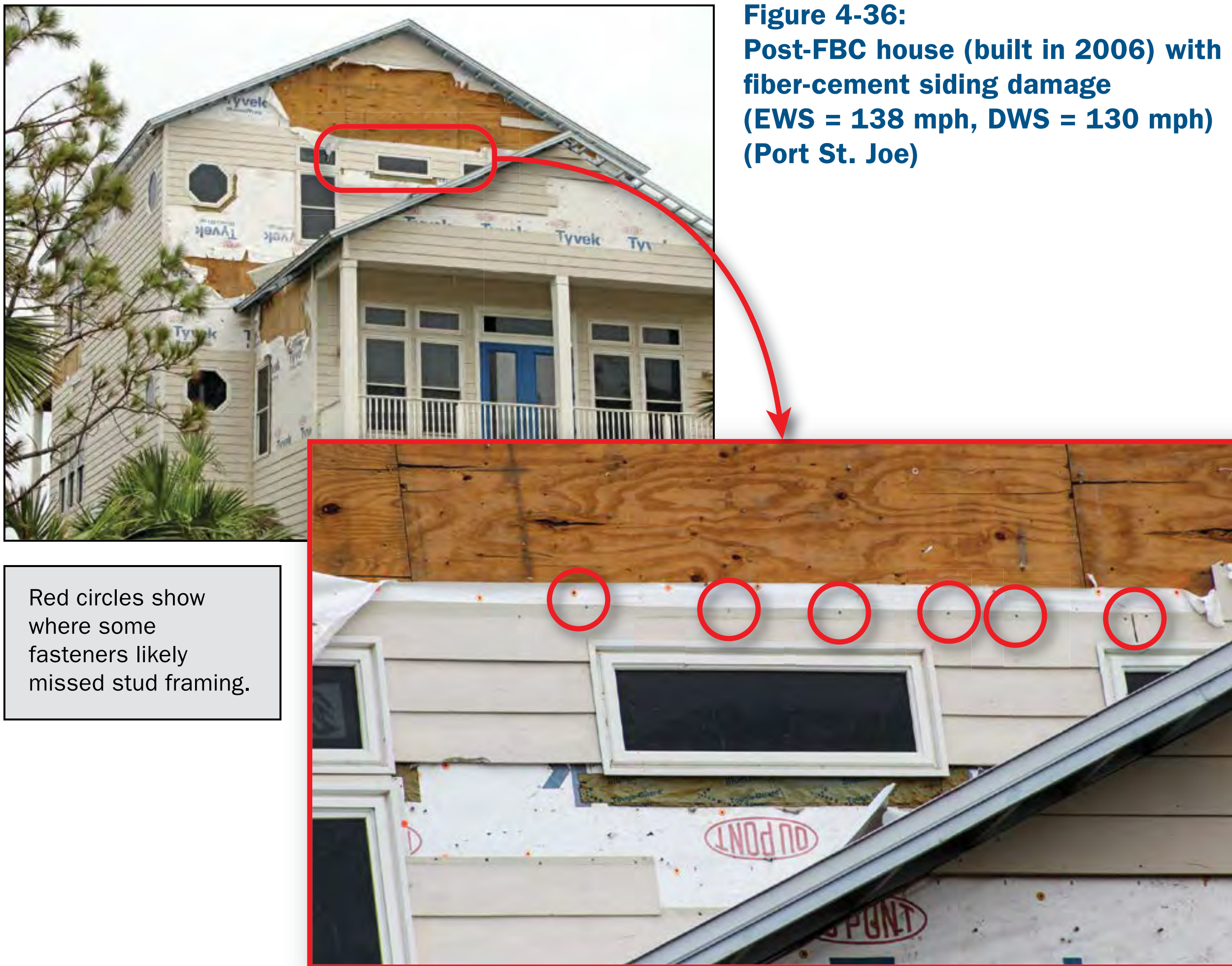


Figure 4-36:
Post-FBC house (built in 2006) with fiber-cement siding damage (EWS = 138 mph, DWS = 130 mph) (Port St. Joe)

- Figure 4-37 shows siding failure due to head pull-through or failure of the siding around the fastener head. Increasing the number of fasteners would put less load in each fastener, which would reduce the potential for head pull-through or failure of the siding around the fastener head. Increasing the head size would also reduce the potential for head pull-through.

Blue dashed circles in the inset photograph show head pull-through failure (numerous examples in the photograph).

Figure 4-37: Post-FBC house (built after 2017) with fiber-cement siding damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

4.2.4 Windows and Doors

Damage to glazed openings (windows and doors with glass), exterior entry doors, and sectional (garage) doors on post-FBC houses was generally scattered throughout the areas visited by the MAT. In many cases, the damage had been covered with plywood/OSB or a fabric material so the MAT was unable to determine the extent of the damage or whether the damage was due to wind-borne debris or wind pressures. Additionally, the MAT could not determine with certainty that any of the glazed openings evaluated were impact-resistant products; closer product inspection and research would have been required to make that determination.

Many of the homeowners interviewed throughout the area visited by the MAT described water intrusion through windows and entry doors during the storm. However, the MAT could not independently document evidence of this.

4.2.4.1 Glazed Openings

Mexico Beach. In Mexico Beach, particularly near the shore, damage to glazed openings was observed on several post-FBC houses. However, on the north side of US Highway 98, away from the shore, glazed opening damage to post-FBC houses was less common and limited. Given the date of construction and concurrent FBCR requirements of some of the buildings, much of the glazed opening damage observed in the Mexico Beach area was likely impact-resistant glazing.

The MAT observed several instances where the outer pane of a glazed assembly was damaged or broken, but the inner pane remained intact. A double-glazed window is not a definitive indicator of an impact-resistant assembly. However, the MAT did document damage in Mexico Beach that was likely impact-resistant glazing.

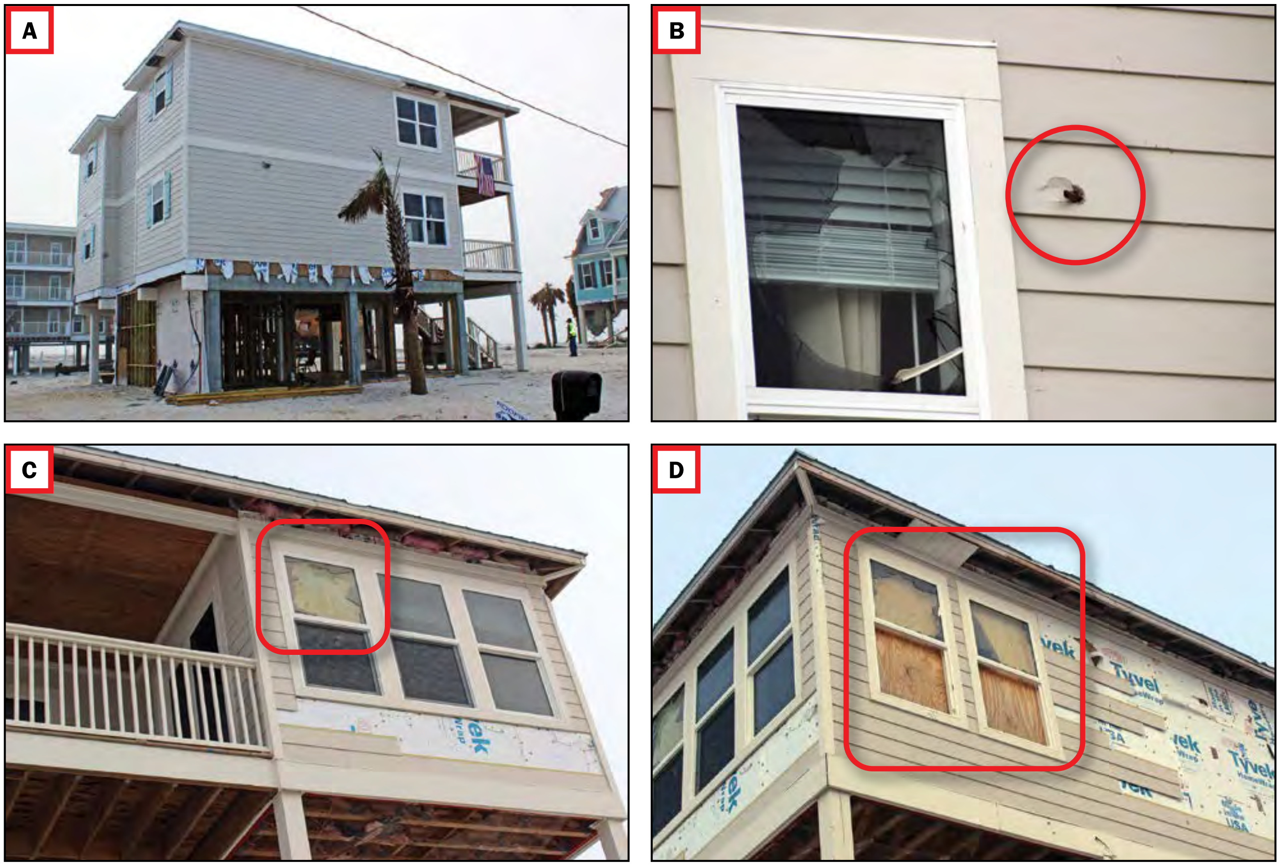
GLAZED OPENINGS IN WIND-BORNE DEBRIS REGIONS

The FBC requires all glazed openings in the WBDR to be protected from wind-borne debris. Buildings can be protected from wind-borne debris using impact-resistant glazing, impact protective devices (shutters), or wood structural panels (if they are installed as required in the FBCR).

> Section R301.2.1.2 of the FCBR requires that exterior glazed openings are protected in the WBDR. Glazed opening protection for windborne debris must meet 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. Any garage door glazed opening protection must meet the requirements of an approved impact-resisting standard or ANSI/DASMA 115.

While the actual location of the WBDR has varied in the different editions of the FBC, in the areas most impacted by Hurricane Michael, it essentially applies to the same area in the current (6th) Edition (2017) as it did in the first edition (2001). Refer to Section 2.3.1 for additional discussion of the WBDR.

An example of damaged glazed openings is shown in Figure 4-38. The house in Figure 4-38 was exposed to some of the highest estimated wind speeds from Hurricane Michael in addition to wind-borne debris. Despite having estimated wind speeds well above the design wind speed for this location, the building performed reasonably well. Because this house was built in 2017 or later, the FBC (5th Edition [2014] or 6th Edition [2017]) requires glazed openings to be protected from wind-borne debris. While the MAT could not determine with certainty that the glazed openings in this building were impact-resistant, considering the date of construction and breakage similarities on one of the assemblies, these glazed openings were likely impact-resistant. For double pane impact-resistant windows, the preferred design has the laminated impact-resistant product as the inner lite.



In images [B], [C]. and [D], the outer upper sash layer of the double-glazed assembly is broken. In [C], the inner layer is also cracked and displays the classic "spider-web" appearance that occurs when an impact-resistant assembly is struck and broken by debris. Also noteworthy is that the bottom sashes in [D] are gone and plywood is installed over the opening from the inside. It is unclear what happened to the lower sashes on these windows. A close inspection of the photograph shows no sign of damage to the frame. The lower sashes appear to have been knocked out due to wind pressure or debris.

Figure 4-38: Post-FBC house (built after 2017) with glazed opening damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Another example is shown in Figure 4-39. This house is a few blocks east of the building in Figure 4-38. The glazed openings that failed in this photograph were also probably impact-resistant, as evidenced by the broken pieces of glass being held together by an interlayer that was likely impact-resistant.

Panama City. Typical damage to glazed openings observed by the MAT in the Panama City area is shown in Figure 4-40 through Figure 4-42. Similar to other areas visited by the MAT, damage to glazed openings was generally scattered and limited to one or two glazed openings.

Located a few blocks east of the building in Figure 4-38. Note the broken pieces of glass being held together by an interlayer that was likely impact-resistant.

Figure 4-39: Post-FBC house (built in 2010) with glazed opening damage (EWS = 150 mph, DWS = 130 mph) (Mexico Beach)

Figure 4-40: Post-FBC house (built in 2005) with glazed opening damage (EWS = 128 mph, DWS = 133 mph) (Panama City)

Figure 4-41: Post-FBC house (built after 2017) with glazed opening damage (EWS = 134 mph, DWS = 135 mph) (Panama City)

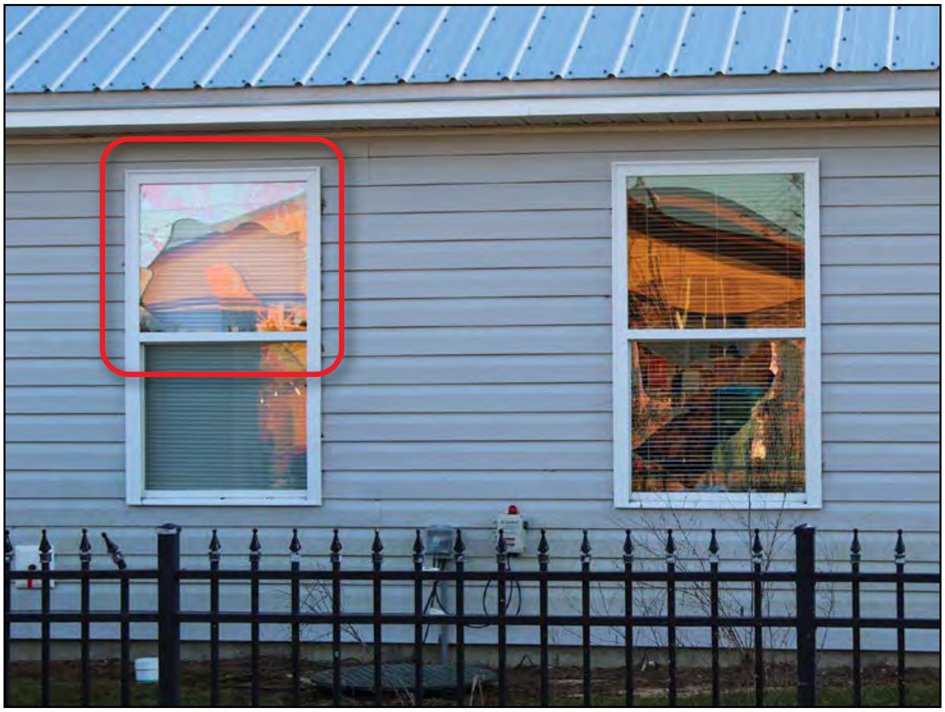


Figure 4-42: Post-FBC house (built in 2012) with glazed opening damage (EWS = 150 mph, DWS = 126 mph) (Panama City)

According to the homeowner, the glazed opening damage at this building was caused by an asphalt shingle. No other glazed opening was damaged on this building.

Impact-Protective Devices. The use of impact-protective devices such as shutters did not appear to be widespread throughout the areas visited by the MAT. At the time of the MAT visit, many types of shutters would likely have been taken down, making their use difficult to determine. However, there are certain features on buildings that would suggest that shutters were installed or were intended to be installed to protect the glazed openings (the MAT saw very few instances of mechanically operated devices such as roll-down or accordion shutters). The FBC requires permanent anchorage to be installed on the building where impact-resistant shutters, including wood structural panels, are used to protect glazed opening. Therefore, the presence of small posts or anchors around an opening indicate that some type of impact protective device is intended to protect the glazed opening. The MAT observed evidence of fabric-type shutters in a post-2017 development in Port St. Joe and a few houses with awning-type shutters.

4.2.4.2 Sectional (Garage) Doors

Damage to sectional (garage) doors on post-FBC houses varied across the area visited by the MAT. The MAT observed both good and poor performance of sectional (garage) doors on post-FBC houses. However, the number of failures observed were present at only a small percentage of the houses documented, so no further observations are included herein.

HURRICANE
MICHAEL
IN FLORIDA

CHAPTER 5
Wind-Related Observations: Non-Residential

Hurricane Michael significantly affected many commercial and critical facilities, totally destroying some of them and severely interrupting the operations of many others.

This chapter describes the MAT's observations of the wind performance of non-residential buildings. Section 5.1 describes the performance of buildings that had been retrofitted for the purpose of improving wind performance. Section 5.2 discusses performance by building use. Non-residential buildings include commercial, critical, and government facilities that may or may not be deemed critical. The MAT assessed all of these building types. The described facilities were selected to document lessons learned related to both good and poor performance. Some of these facilities were selected as representative of various performance issues, while other facilities were selected because of their unique attributes. In addition to describing the performance of each facility, the functional loss and any known operational issues are described. The locations of the non-residential facilities visited by the MAT are shown on Figure 5-1.

All of the observed critical facilities experienced winds that were below or near current basic (design) wind speeds (see Figure 5-1). Building damage resulted in occupant injuries and put many other occupants at risk of injury. Building damage also placed additional burdens on response and recovery personnel as they endeavored to assist their communities after the event.

CRITICAL FACILITIES

Critical facilities are vitally important to communities that have been struck by hurricanes. Schools are needed to provide educational continuity, and they are often used as HESs and/or recovery operations. Hospitals and other healthcare facilities are needed to treat injuries and provide routine ongoing care to the community. Police and fire stations and EOCs are needed to manage their normal missions, along with response and recovery operations after an event.

ASCE: Critical facilities are Category III and IV buildings as defined in the 2016 edition of ASCE Standard 7. Category III and IV buildings include, but are not limited to, hospitals and other medical facilities, fire and police stations, primary communications facilities, EOCs, schools, shelters, and power stations and other facilities required in an emergency.

FEMA: FEMA considers critical facilities as those buildings that are essential for the delivery of vital services or protection of a community (FEMA 2007a).

5.1 Wind Retrofit Performance

The Hurricane Michael MAT observed the performance of 19 buildings that had been retrofitted for the purpose of improving wind performance. Most of the buildings highlighted in this section received FEMA funding to execute wind retrofit projects under the agency's Hazard Mitigation Assistance grant programs; the project completion dates ranged from the early 2000s to the early 2010s.

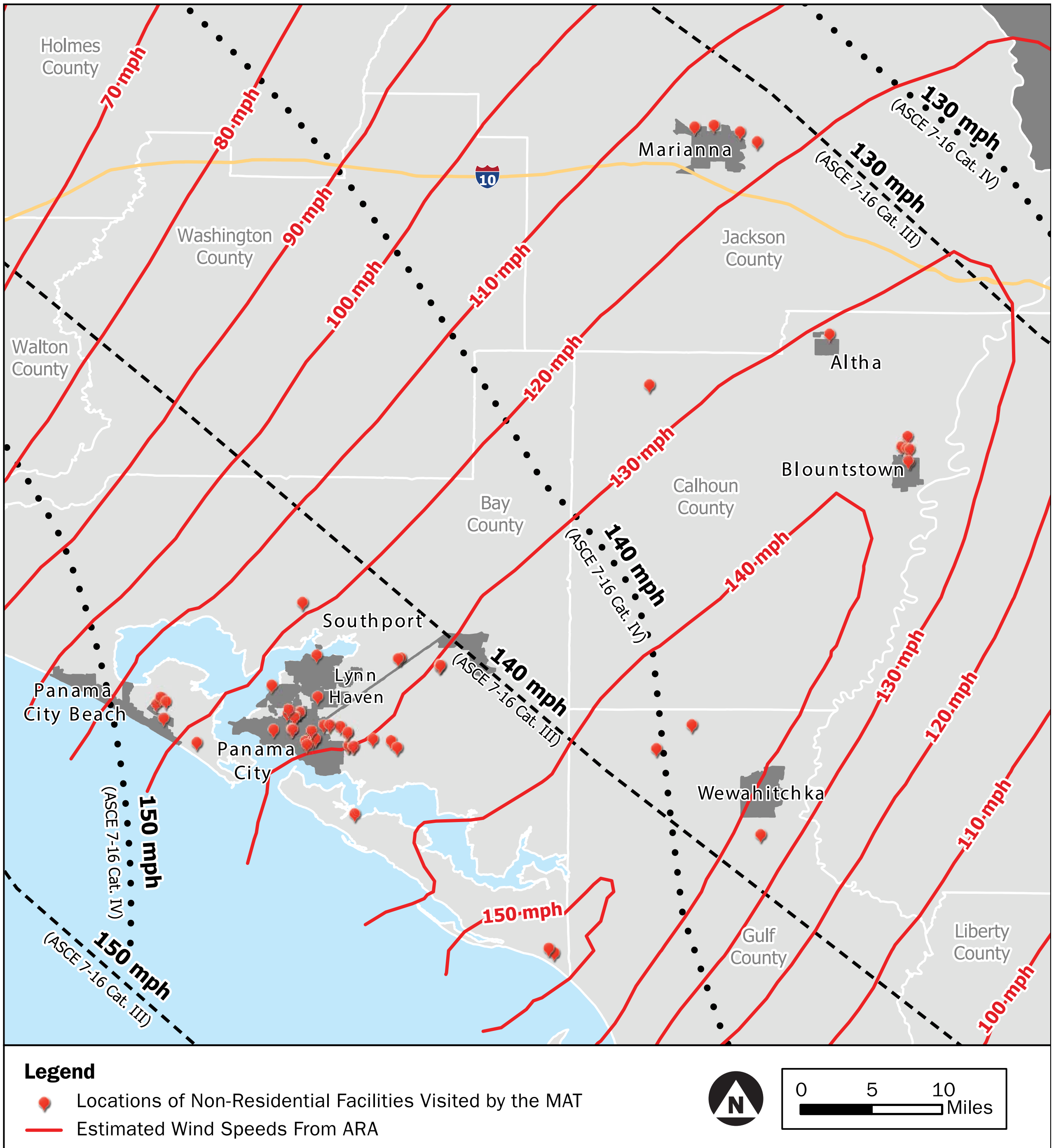
Most of the retrofit projects were ultimately ineffective at limiting significant damage to the building or its contents. Substantial building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the funded wind retrofit project. The examples demonstrate that even when individual retrofitted elements perform well, for the retrofits as a whole to be effective in avoiding significant building damage and occupancy disruption, all significant wind vulnerabilities of a building need to be mitigated. Additional information is provided in Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* (see textbox). Had the first step of the process outlined in the advisory—performing a comprehensive wind vulnerability assessment—been taken for the buildings described in this section, more comprehensive retrofits would likely have been made and building damage would have been avoided or substantially reduced.

BUILDING WIND RETROFITS

Wind retrofits consist of voluntary mitigation actions taken on existing buildings. For a building retrofit to be effective, the building needs to achieve the performance level selected by the building owner or operator (the target performance level) and be commensurate with the magnitude of the wind event for which the retrofit was designed.

HURRICANE MICHAEL IN FLORIDA RECOVERY ADVISORY 1

Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* (Appendix C of this report), provides examples of ineffective wind retrofits and presents a five-step process for considering and executing successful wind retrofits.



The red contours indicate estimated wind speeds from Applied Research Associates, Inc. (ARA)/FEMA Geospatial Working Group (2018). The ASCE 7-16 basic wind speeds for Risk Category III and IV are shown; for Risk Category II see Figure 1-8.

Figure 5-1: Location of non-residential facilities visited by the MAT and estimated wind speeds from ARA/FEMA Geospatial Working Group (2018)

5.1.1 Panama City Police Department

Facility Description and Wind Retrofit Project. The one-story Panama City police facility opened in 1978. It had a steel roof deck over steel joists with 13 rooftop heating, ventilation, and air conditioning (HVAC) units. The adhered fleece-backed, single-ply roof membrane was installed in 2014. The building was reroofed in December 2018.

The building was retrofitted with permanently mounted polycarbonate shutters over the windows and roll-down storm shutters at the doors (Figure 5-2). The roll-down shutters had a label indicating that the shutters had been tested in accordance with various standards, including ASTM E1886, using the large missile. However, the label did not indicate whether test missile D or E was used. The polycarbonate shutters were not labeled.

PANAMA CITY POLICE DEPARTMENT SITE CONDITIONS

Estimated wind speed = 127 mph

Location = Exposure B, with adjacent open patches to the northwest, north, and northeast

ASCE 7-16 basic wind speed = 146 mph (Risk Category IV)

Wind Damage Observations. The pre-MAT visited the facility 14 days after hurricane landfall. Figure 5-3 is an aerial view of the Panama City police facility shortly after Hurricane Michael.

Figure 5-2: Panama City police facility window and main door shutters (red and green arrows) (Panama City, FL)

The polycarbonate shutters appeared to be well attached. Attachment included use of angles at ends of the panels (yellow dotted arrow in inset).

The blue arrow indicates one of the 13 HVAC units. The inset [A] indicates the adjacent U.S. Army Reserve building. The yellow double arrows indicate where the insulation boards debonded from the mopping asphalt and initiated roof membrane lifting and peeling. Board debonding from mopping asphalt is indicative of a workmanship deficiency. The red dashed arrows indicate progressive failure, wherein the roof membrane peeled from the insulation boards. The primary wind direction was from the west.

Figure 5-3: Aerial view of the Panama City Police Department (blue arrow) and adjacent U.S. Army Reserve Building (Panama City, FL)

Retrofit observations. No wind damage to the retrofitted window shutters and roll-down storm shutters was observed by the MAT, but the MAT did not observe any shutters that were impacted by wind-borne debris (not all shutters were checked for debris impact). The rear door shutter was inoperable and, therefore, was not lowered prior to the storm. Although the glazed doors were not struck by wind-borne debris, there was water infiltration into the building at this door.

OVERALL EFFECTIVENESS OF RETROFIT PROJECT

The shutter retrofit project was ineffective at limiting significant damage to the building and its contents. Significant building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the retrofit.

Other damage observations. Other damage, unrelated to the retrofit project, was also observed by the MAT. There was significant wind damage to the rooftop equipment. Some of the HVAC units blew off their curbs (Figure 5-4 and Figure 5-5), which resulted in extensive water entry (Figure 5-6) and rupture of gas lines serving the units. The roof membrane was punctured in several areas by wind-blown debris, and water that got underneath the roof membrane adversely affected the integrity of the membrane's attachment. Much of the debris was likely from failed HVAC units, blown-off HVAC unit access panels, and condensate drain lines. A walkway canopy was also blown off (Figure 5-7). Roof drains were clogged by debris.

RECOMMENDATIONS FOR ROOFTOP EQUIPMENT ATTACHMENT

Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions* (2018c) provides recommendations for attaching various types of rooftop equipment. The recommendations address buildings in the planning stage, existing rooftop equipment, preparations prior to hurricane landfall, and post-hurricane landfall assessment.

The red dotted arrows indicate blown-off HVAC units. The blue dashed arrow indicates vegetation debris at a roof drain. The debris was likely deposited on the roof during the storm. The inset shows one of the exhaust fans. The yellow arrow shows the brackets that attach the lower portion of the cowling to the fan base. Screws and clips, which attach the upper cowling to the lower cowling, are indicated by the green arrow.

Figure 5-4: A portion of the roof of the Panama City police facility (Panama City, FL)

Although exhaust fans or fan cowlings are often blown off, that did not occur at this facility even though far fewer screws were used to attach the fan to the curb than recommended in FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings* (2007a). The fans at this facility had brackets that attached the lower portion of the cowling to the fan base (yellow arrow on the inset of Figure 5-4). Screws and clips attached the upper cowling to the lower cowling (green arrow).

Figure 5-5: One of the blown-off HVAC units at the Panama City police facility roof (Panama City, FL)

The HVAC unit in the foreground was not fastened to the curb and blew off (green dotted arrow). Lack of unit attachment is very easy to detect during a wind vulnerability assessment. When inadequate or lack of attachment is found, it is very inexpensive to add fasteners. The red arrow indicates a missing access panel. The inset shows a roof membrane tear (a putty knife is shown for scale).

Figure 5-6: Interior views below an HVAC unit blow-off (Panama City, FL)

Plywood was placed over a curb opening where an HVAC unit blew off (red arrow). Rain infiltration at open curbs resulted in about 1 inch of standing water in the building. The inset shows where wetted ceiling boards had collapsed.

Figure 5-7: Damaged walkway canopy (Panama City, FL)

Some of the canopy debris (red arrow) landed on the roof. The red X shows the original location of the canopy.

Operations During Event and Functional Loss. In light of the wind retrofit that had been installed, the building was thought to have adequate wind resistance and was not evacuated prior to landfall. There were approximately 73 occupants (including family members) during the hurricane. The building also housed Panama City's EOC.

In addition to the building damage described in the previous section, Hurricane Michael caused significant disruption to facility operations, including communications, power, and water and sewage function in this critical facility:

- Communication capabilities were disrupted following Hurricane Michael, as telephones and internet were down. Because of the majority of the radio towers going down, only one police radio channel remained operational and it was only marginally functional.
- The electrical conductors that powered the rooftop HVAC units were ruptured when the units blew away. Soon after municipal power was lost, the generator began to automatically provide emergency power.
  - Although those in the building observed electrical arcing at the ruptured conductors, they had more pressing issues to deal with at the time. Consequently, those circuits were not de-energized until natural gas was discovered to be escaping at the ruptured gas lines a few days later. Fortunately, a gas-fed rooftop fire was not started.
  - Although the generator restored power for some functions after the storm, air conditioning was not restored. The loud fans used to circulate air and cool down the facility made it even more difficult to communicate using the single remaining radio channel.
- Portable toilets were not received until 2 days after the hurricane. At the time of the MAT's visit, the building was still dependent on portable toilet facilities.

Because of the significant damage that occurred at the facility, a portable office building was brought in after the storm to help with continuity of operations for the police station. It was used from November 2018 through June 2019. Even with its functional deficiencies, this building continued to be used as the city's EOC.

The building and contents damage cost approximately $1.8 million. The repairs were completed in August 2019.

5.1.2 University of Florida Institute of Food and Agricultural Sciences Bay County Extension

Facility Description and Wind Retrofit Project. The wood-frame University of Florida Institute of Food and Agricultural Sciences (IFAS) building located in Panama City was built in 1987.

In 2014, the building was retrofitted with laminated glass window and door assemblies. Project records indicate the new assemblies were designed to resist 160 mph winds. The sloped roofs had standing seam metal panels, and the low-slope roof had a single-ply membrane. The exterior wall covering was an Exterior Insulation and Finish System (EIFS).

UNIVERSITY OF FLORIDA IFAS BUILDING SITE CONDITIONS

Estimated wind speed = 128 mph

Location = Exposure B

ASCE 7-16 basic wind speed = 134 mph (Risk Category II)

Wind Damage Observations. The MAT visited the facility on January 8, 2019, 92 days after the hurricane landfall. Damage is shown in Figure 5-8, an aerial view of the University of Florida IFAS facility shortly after the hurricane and in Figure 5-9 is a view at the time of the MAT visit.

Figure 5-8: Aerial view of the University of Florida IFAS Bay County Extension (Panama City, FL)

One of the HVAC units blew off its curb (red arrow), allowing rain to enter the building.

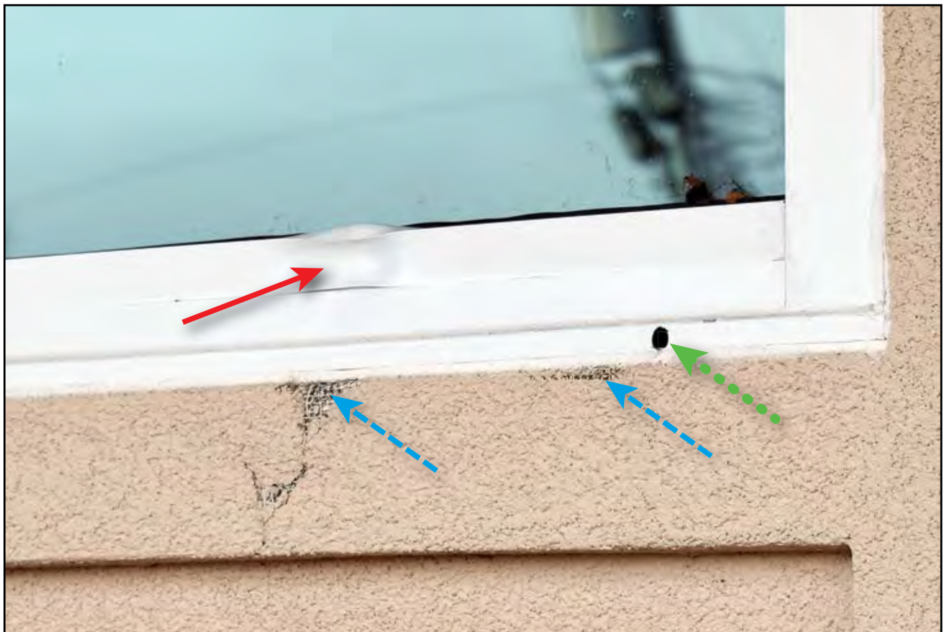
Figure 5-9: Front of the University of Florida IFAS facility (Panama City, FL)

The red arrow indicates the HVAC unit that blew off the curb (the unit had been placed back onto the curb). The coping was blown off the front and part of two sides (green dotted arrows).

Retrofit observations. One of the retrofitted window frames was struck by wind-borne debris (Figure 5-10). The other window and door assemblies did not appear to be struck by debris. However, water infiltration was reported at the front doors and windows.

OVERALL EFFECTIVENESS OF RETROFIT PROJECT

The window and door retrofit project was ineffective at limiting significant damage to the building and its contents. Significant building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the retrofit.



The blue dashed arrows indicate exposed EIFS mesh. It was unclear whether the synthetic stucco was dislodged during the storm, or it was a pre-existing condition. The green dotted arrow indicates a weep hole.

Figure 5-10: IFAS facility window frame that was struck by wind-borne debris (red arrow) (Panama City, FL)

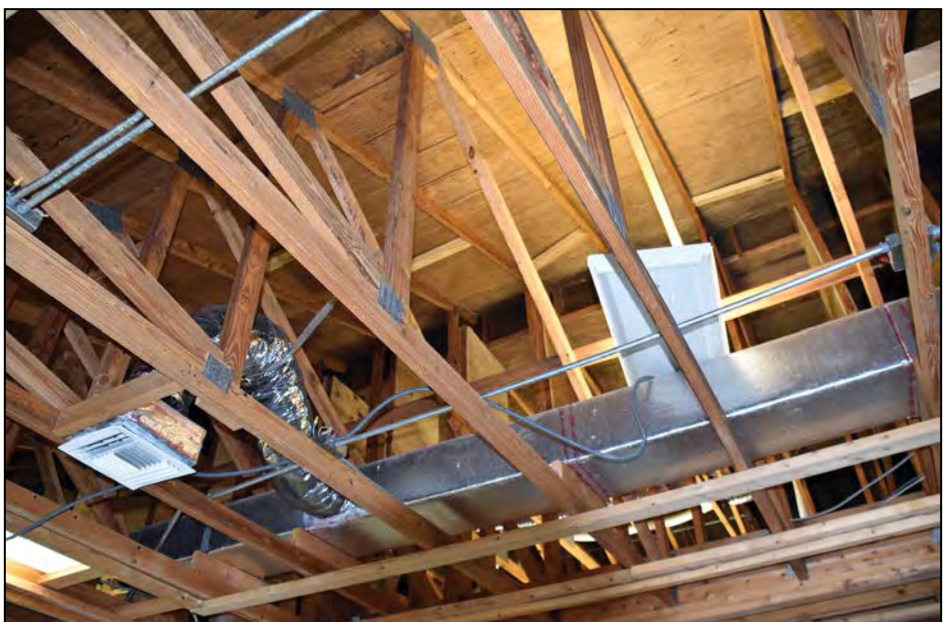
Other damage observations. Other damage, unrelated to the retrofit project, was observed by the MAT, including damage that resulted from HVAC unit blow-off, coping damage, interior water intrusion, and soffit panel blow-off.

An HVAC unit was blown off (Figure 5-11) and the roof membrane was punctured. The roof membrane punctures were likely caused by the HVAC unit and coping blowing off. At the time of the MAT visit, some of the punctures had been repaired, but at least one puncture was still open (inset at Figure 5-11). Water entry at the open curb and membrane punctures wetted and collapsed the gypsum board ceiling below the low-slope roof (Figure 5-12).

Figure 5-11: Low-slope roof of the IFAS facility (Panama City, FL)

The red arrow indicates the HVAC unit that had blown off the curb (the unit was subsequently placed back onto the curb). The yellow double arrows indicate where the coping was blown off. The blue dashed arrow indicates an emergency repair at a membrane puncture. The inset shows a roof membrane tear (a putty knife is shown in the tear for scale). Small punctures such as these can be difficult to find.

Figure 5-12: The area below the low-slope roof of the IFAS facility (Panama City, FL)



Roof leakage wetted and collapsed the gypsum board ceiling.

Coping blew off during the storm. Figure 5-13 shows how the coping was attached. The inner leg was attached with exposed screws and the outer leg was attached to an L-shaped cleat. The cleat was only attached at the horizontal leg, which provided only limited moment resistance for the vertical leg. This type of cleat and method of attachment was found to provide poor performance during Hurricane Andrew (1992). Suction pressure on the vertical flange of the coping results in outward rotation of the coping flange and cleat that can result in the coping detaching from the cleat (see textbox "Recommended Cleat Fastener Placement" for recommended fastener placement to avoid disengagement). The coping did not appear to comply with ANSI/SPRI/FM 4435/ES-1.[8]

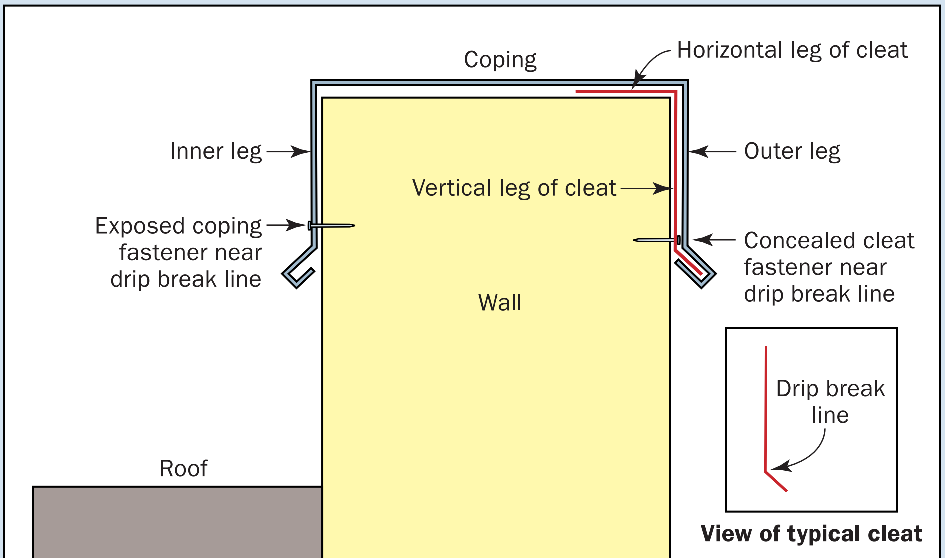
Figure 5-13: A parapet where the coping and some of the cleat blew off (Panama City, FL)

The cleat was only attached at the horizontal flange (green dotted arrow). The cleat fasteners should have been near the break line (red line). The blue dashed arrow indicates exposed screws at the inner leg of a portion of the coping that did not blow off.

8 ANSI/SPRI ES-1 has been referenced in the IBC since the 2003 edition. FM 4435, included in the current Test Standard title, was not part of the title in 2003.

RECOMMENDED CLEAT FASTENER PLACEMENT

Cleat fasteners should be placed as close as possible to the drip break line, thus reducing the potential for the coping to disengage from the cleat due to cleat deformation.



Note: Cleats typically are not L-shaped (i.e., no horizontal flange). The inset shows a typical cleat. A horizontal flange is sometimes provided to facilitate cleat alignment during installation.

Interior Water Intrusion. Water leakage wetted and collapsed the gypsum board ceiling below a portion of the sloped roof (Figure 5-14 and Figure 5-15). Based on the MAT observations, the source of the leakage was judged to have been wind-driven rain that entered the building at the hip because the closure was ineffective (see figure in textbox titled "Recommended Roof Hip and Ridge Closure" for an enhanced closure detail).

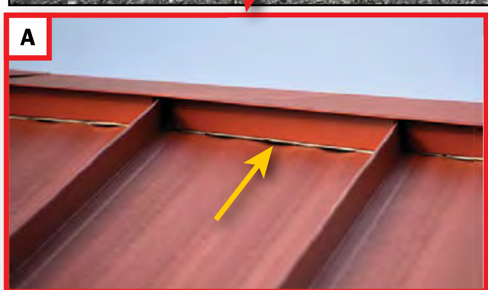


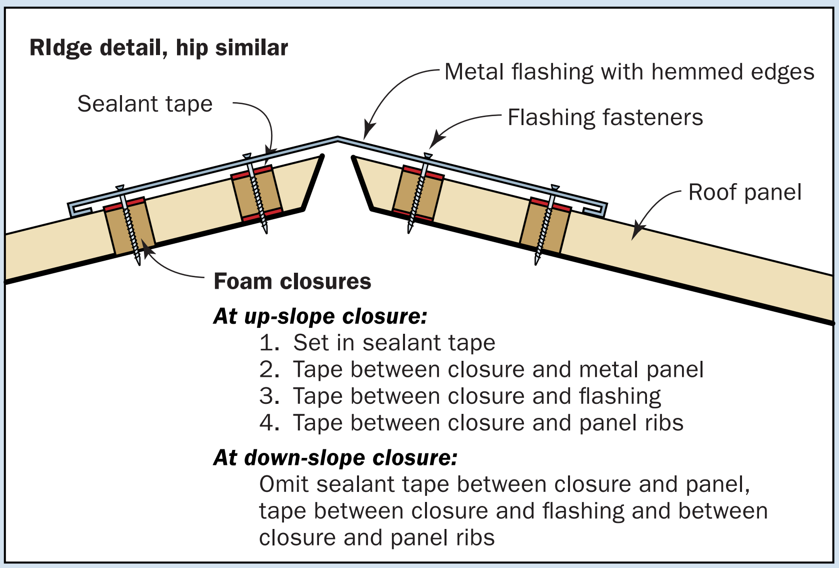
Figure 5-14: The gypsum board ceiling at this corner office was wetted and collapsed, as shown in Figure 5-15 (Panama City, FL)

Wind-driven rain could drive through the gaps between the closure and roof panel pan (yellow arrow) **[A]**. Without a secondary closure, rain driving past this closure could leak into the building. The green dotted arrow indicates a strip of gravel adjacent to the wall **[B]**. When coupled with a perforated drainage pipe, this can effectively control rain that spills over a gutter during deluge or wind-driven rains.

Figure 5-15: The gypsum board ceiling collapsed below this sloped roof; debris had been removed by the time the MAT arrived (Panama City, FL)

RECOMMENDED ROOF HIP AND RIDGE CLOSURE

In high-wind regions, it is important to use at least two rows of closures at hips and ridges to prevent entry of wind-driven rain. All edges of the inner closure should be set in sealant or sealant tape. At the outer closure, sealant should be at the top and edges of the closure. The juncture between this closure and the pan of the roof panel is left unsealed to allow water that may be blown past the outer closure at sealant discontinuities to drain.



Soffit Blow-Off. Several soffit panels were also blown away (Figure 5-16), thereby exposing the attic space to entrance of wind-driven rain.

RECOMMENDED SOFFIT DESIGN AND CONSTRUCTION

Refer to FEMA Fact Sheet 7.5, *Minimizing Water Intrusion Through Roof Vents in High-Wind Regions* (in FEMA P-499, 2010f).

Figure 5-16: One of the damaged soffit panels (Panama City, FL)

Operations During Event and Functional Loss. The building was not occupied during the hurricane. Electrical power, water, sewer, and natural gas were disrupted following Hurricane Michael. It took approximately 2 weeks for power, water, and sewer to be restored. At the time of the MAT visit, landline telephone service had not been restored.

IFAS operations were temporarily moved to the county library because of the extent of interior water damage that occurred during the hurricane. Additional significant water damage occurred during a rain event 2 weeks after the hurricane. At the time of the MAT visit, staff had reoccupied the building, but portions of it were still unusable.

Reroofing of the low-slope roof started in June 2019. The target date for reopening the building is July 8, 2019.

5.1.3 Tom P. Haney Technical Center

Facility Description and Wind Retrofit. The Tom P. Haney Technical Center, located in Panama City, is

TOM HANEY TECHNICAL CENTER SITE CONDITIONS

Estimated wind speed = 126 mph

Location = Exposure B, with adjacent open patches to the west, northwest, and east

ASCE 7-16 basic wind speed = 143 mph (Risk Category III)

a complex of several buildings (see Figure 5-17). The first phase of the facility opened in 1968. Subsequent phases were opened in 1970, 1972, 1974, and 1979. The Tom P. Haney Technical Center provides career technical education and adult general education operating under the auspices of the Bay District Schools.

In 2004, the building was reroofed. As part of the reroofing project, some of the roofs on the main building were converted to a steep slope by installing sloped steel framing over the existing single-ply roof. A structural standing seam metal roof was attached to the new framing.

A wind retrofit after 1998 added permanently mounted screen shutters at most of the windows.

OVERALL EFFECTIVENESS OF RETROFIT PROJECT

The retrofit grant application stated that the shutters would allow the building to provide community sheltering after a hurricane. The shutter retrofit project was ineffective at limiting significant damage to the building and its contents. Significant building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the retrofit. The hurricane damage prevented the school from being opened as a post-hurricane recovery shelter; thus, the retrofit project failed to meet its intended purpose.

The red lines and arrow indicate where the single-ply roof membranes blew off. The yellow double arrow indicates the steep-slope conversion. The area within the yellow rectangle is a separate upper level roof. The green dashed rectangle indicates where roof panels blew off (Figure 5-21). The blue dotted arrows indicate where standing seams opened up (Figure 5-23).

Figure 5-17: Aerial view of the Tom P. Haney Technical Center (Panama City, FL)

Wind Damage Observations. The MAT visited the facility on January 8, 2019 (92 days after hurricane landfall). Damage is shown in Figure 5-17, an aerial view of the facility shortly after the hurricane and in Figure 5-18, a view at the time of the MAT visit.

Retrofit observations. The MAT did not observe any retrofitted shutters that were struck by windborne debris, but not all of the shutters were checked for debris impact. One window assembly was blown into a room and caused occupant injuries. The MAT determined that the issue was not with the shutter itself, but rather that the window assembly behind the shutter had inadequate wind pressure resistance; a description of this failed window assembly damage is presented in Hurricane Michael in Florida Recovery Advisory 1 (Appendix C of this report).

General guidance on shutter retrofits is also presented in this advisory (see Appendix C of this report).

In addition to the window assembly failure, several shutters unlatched during the hurricane. The shutters were hinged to allow them to be opened to clean the windows (Figure 5-19). Figure 5-20 shows a shutter hinge that was likely damaged when the shutter unlatched during the storm. At least one window was broken where a shutter unlatched (Figure 5-18).

Other damage observations. Other damage, unrelated to the shutter retrofit project, was observed by the MAT.

- There was widespread significant roof covering damage (see Figure 5-17). Several of the steep-slope conversion roof panels blew off the east side of the main building (Figure 5-21). Figure 5-22 is a view of the attic space below the area where the roof panels were blown off. Metal framing was installed over the previous low-slope roof, and the old roof

The red arrows indicate the steep-slope conversion. The green dotted arrows indicate where standing seams opened up (Figure 5-23). The yellow double arrows indicate a blown-off gutter, broken glazing, and a damaged screen shutter frame.

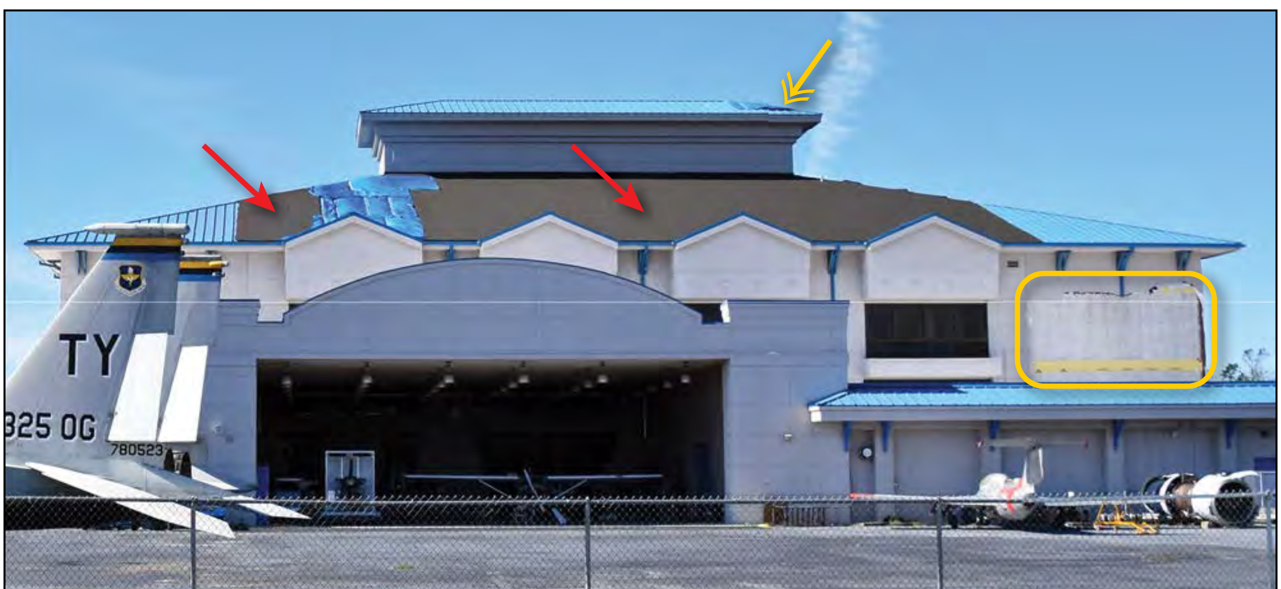
Figure 5-18: The campus (Panama City, FL)

Red circles indicate the latching mechanism.

Figure 5-19: A shutter in the unlatched position (Panama City, FL)

This damage likely occurred when the shutter unlatched during the storm.

Figure 5-20: A damaged shutter hinge (Panama City, FL)



The black area (red arrows) is where emergency roof repairs were made. The yellow double arrow indicates a tarped area. The yellow outlined area indicates where stucco blew off.

Figure 5-21: East elevation of the main building (Panama City, FL)

The red arrow indicates OSB and 2xs that were installed over the purlins to provide a substrate for the emergency roof covering. The yellow double arrow indicates metal panels. The blue dashed arrow indicates a vapor retarder that was underneath fiberglass insulation. Wetted fiberglass insulation was hanging from the framing and lying on the old roof. The inset shows a hole through a roof panel; the roof was still taking on rainwater 92 days after the storm.

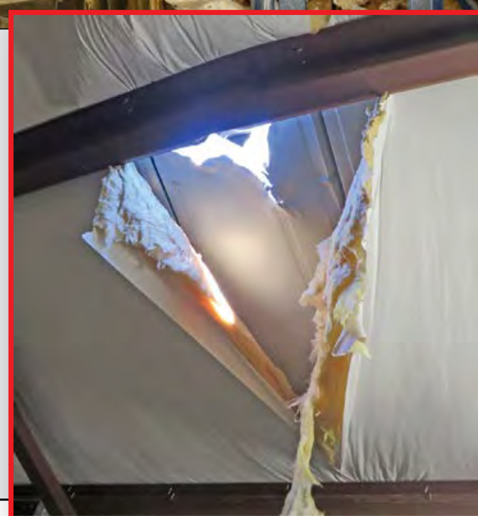


Figure 5-22: Attic space below the damaged area shown in Figure 5-21 (Panama City, FL)

membrane served as a secondary membrane after the panels blew off. Some water leaked into the second floor, but much of the rain was intercepted by the old roof. The MAT observed a few other buildings that experienced blow-offs of structural standing seam metal roofs that were attached to framing. Figure 5-23 shows a portion of the west elevation of the main building where roof panel seams opened up.

- Rooftop equipment (including the lightning protection system [LPS] conductors) was blown off at areas where the roof membrane was not damaged.
- Gutters, downspouts, and exterior wall coverings were damaged.
- It was reported that wind-driven rain infiltrated about 25 windows that were protected by shutters (see textbox). Most of the leakage occurred at operable windows, but some fixed glazing units also leaked.
- Glazing was damaged where not retrofitted with shutters (Figure 5-24).
- Wind-driven water entered the main building at the main entry doors.

Operations During Event and Functional Loss. There were 43 occupants (staff caretakers and family members) during the hurricane. In addition to the building damage described in the previous section, the emergency generator system failed during the storm.

This facility was planned to be used as a post-hurricane recovery shelter, but because of significant damage during the hurricane, it was not opened for that purpose. A portion of the facility opened on November 5, 2018 (26 days after hurricane landfall).

STANDING SEAM METAL ROOF ASSEMBLIES

With standing seam metal roof assemblies attached to framing, if the roof panels blow off, wind-borne debris and rain are free to enter the building.

For structural metal roofs, FEMA P-424 recommends that a roof deck be specified, rather than attaching the panels directly to purlins as is commonly done with metal building systems. Then, over the deck, a secondary roof membrane should be placed, followed by the metal panels. With this assembly if the panels blow off, the secondary membrane provides leakage protection and the deck provides wind-borne debris protection. FEMA P-424 provides further guidance on this type of assembly.

AVOIDING RAIN INFILTRATION AT DOORS

For recommendations regarding rain infiltration at doors, refer to Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 4, *Design Installation and Retrofit of Doors Windows and Shutters* (in FEMA P-2021, 2018d).

At the lower roof, the panels remained on the roof, but a few of the seams opened up. In the opened condition, the panels were very susceptible to progressive failure, and they were no longer watertight.

Figure 5-23: Open roof panel seams (red arrows) (Panama City, FL)

Figure 5-24: Broken unprotected glazing (Panama City, FL)

5.2 Building Performance by Building Use

This section presents performance observations of some of the non-residential buildings visited by the Hurricane Michael MAT, organized by building use:

- 5.2.1 Commercial
- 5.2.2 Critical Facilities – Emergency Operations Centers
- 5.2.3 Critical Facilities – Hurricane Evacuation Shelters
- 5.2.4 Critical Facilities – First Responder Facilities
- 5.2.5 Critical Facilities – Hospitals and Nursing Homes
- 5.2.6 Critical Facilities – Schools
- 5.2.7 Critical Facilities – Other Types of Buildings

5.2.1 Commercial

The MAT's non-residential observations focused on critical facilities; however, a few commercial buildings were also visited. In the context of this section, commercial buildings include retail, office, hotel, and condominium buildings. Although being operational during and/or after a storm is far more important for critical facilities, it is also important for many commercial buildings to be operational within a few days of hurricane landfall to provide goods and services (such as building materials and food) to the community and to provide places of employment. Several MWFRS failures were observed during the MAT's helicopter and vehicular reconnaissance. However, MWFRS failures mostly occurred at buildings constructed prior to 2000, when codes, standards, design, and construction practices did not adequately address wind issues. A notable exception was damage observed at the Dollar General (Section 5.2.1.1). Building envelope failures were commonly observed, even at relatively new buildings.

The MAT conducted an assessment of the Dollar General building (Section 5.2.1.1), but only a cursory review of other buildings (Sections 5.2.1.2 to 5.2.1.6). The MAT's wind damage observations are presented and, in those cases where the observations support a general building performance observation, a short discussion is included. The case studies are presented in order of building element damage (roof, rooftop equipment, glazing, wall), not occupancy type.

5.2.1.1 Dollar General

Facility Description. The Dollar General opened for business in 2015. It was a Metal Building System (MBS, formerly known as a "pre-engineered metal building") with structural standing seam metal roof panels, exposed metal panels at two walls, and fiber cement siding/masonry veneer over metal panels at the other two walls.

According to contract drawings reviewed by the MAT, the 2010 Edition of the FBC was applicable to the design of the building. The drawings specified a basic wind speed of 140 mph (ultimate), Exposure C. The drawings

DOLLAR GENERAL SITE CONDITIONS

Estimated wind speed = 132 mph

Location = Exposure B, with adjacent open patches to the west and north of the building

ASCE 7-16 basic wind speed = 134 mph (Risk Category II)

included a table that provided component and cladding design pressures. The drawings that were provided to the MAT did not include the MBS drawings.

Wind Damage Observations. The MAT visited the Dollar General building on January 7, 2019 (91 days after hurricane landfall) (see Figure 5-25). The building experienced a partial collapse. The failure was predominantly in the first windward bay. The end wall main frame collapsed, and the purlins in the first bay buckled, which resulted in roof panel blow-off. This type of metal panel roof system does not provide any significant resistance to lateral loads (i.e., it is not a diaphragm).

Figure 5-25: North end wall and the east side wall of the Dollar General building (Panama City, FL)

This structural failure is noteworthy because the basic wind speed and exposure parameters given in the contract drawings are more conservative than the criteria given in the 2016 edition of ASCE 7. It is apparent that the collapse was due to a significant MBS design or installation error. Without the drawings for the MBS, the MAT was unable to evaluate the adequacy of the design. A glass storefront system was in the wall that collapsed. A security fence prohibited the MAT from getting close enough to the storefront to determine whether it failed before or after the main frame began to fail. If the storefront failed first, partially enclosed conditions would have occurred, which would have resulted in increased pressures on the MWFRS. However, such a load increase should not have resulted in failure of a properly designed and constructed MBS because of the load factor, especially considering the conservative basic wind speed and exposure that was specified on the contract drawings.

Much of the fiber cement siding blew off (Figure 5-26 and Figure 5-27). The siding was inadequately attached; however, blow-off was likely initiated by the frame collapse. A portion of the masonry veneer collapsed, likely also initiated by the frame collapse. Most of the fasteners that attached the masonry ties to the building pulled out of the masonry.

Figure 5-26: Siding and masonry veneer failure of the Dollar General building (Panama City, FL)

Figure 5-27: Close-up of the siding attachment for the Dollar General building (Panama City, FL)

The siding was blind nailed at 24 inches on center; several nails were too close to the edge of the siding (red arrows). Fact Sheet 5.3, *Siding Installation in High-Wind Regions* (in FEMA P-499, 2010) recommends face nailing instead of blind nailing where the allowable stress design wind speed is 100 mph or greater (this equates to an ultimate speed of 126 mph).

5.2.1.2 Shopping Center

Wind Damage Observations. There was considerable damage to the older construction of the shopping center shown in Figure 5-28. The newer portion shown at the bottom of Figure 5-28 had limited damage and was operational at the time of the observation (12 days after hurricane landfall). Figure 5-29 shows a close-up of the shopping center roof.

SHOPPING CENTER SITE CONDITIONS

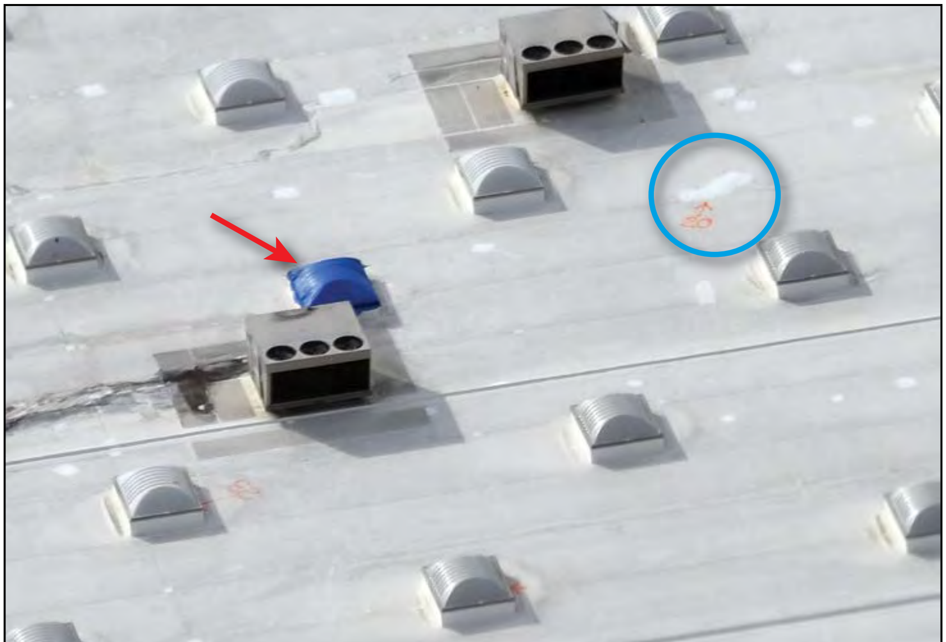
Estimated wind speed = 125 mph

Location = Exposure B, with adjacent open patches to the north of the shopping center

ASCE 7-16 basic wind speed = 135 mph (Risk Category II)

The red oval indicates where the roof structure collapsed. The red arrows indicate where HVAC units blew off. The yellow double arrows indicate where an EIFS blew off the studs. The green dotted arrows indicate where the roof membrane blew off. The white triple arrows indicate where the decking blew off of the two roofs. The blue dashed arrow indicates coping damage. The portion of the shopping center shown at the bottom of the figure has a large number of skylights. Three of the skylights were damaged. See Figure 5-30 for a close-up of this roof.

Figure 5-28: A portion of the shopping center, looking west (Panama City, FL)



The blue area is a tarped skylight (red arrow). Repairs appear to have been made to roof membrane punctures (circled in blue).

Figure 5-29: Close-up of the single-ply membrane roof of the shopping center shown in Figure 5-28 (Panama City, FL)

5.2.1.3 Condominium No. 1

Wind Damage Observations. This condominium experienced significant interior water damage due to blow-off of low-slope and steep-slope roof coverings. Figure 5-30 shows the condominium 12 days after hurricane landfall. The building was constructed in 2007.

CONDOMINIUM NO. 1 SITE CONDITIONS

Estimated wind speed = 150 mph

Location = Exposure D

ASCE 7-16 basic wind speed = 134 mph (Risk Category II)

At one of the low-slope roofs shown in Figure 5-30, the primary failure plane was separation of the facer from the polyisocyanurate roof insulation as a result of roof membrane lifting and peeling. The coping all around this roof area was blown off; failure of the coping likely initiated the membrane blow-off.

At the other two low-slope roofs, the primary failure plane was between the foam ribbon adhesive and the top insulation board (Figure 5-31). While the copings also blew off of these areas, the roof membrane failures were likely initiated by lifting of the top insulation board because of inadequate adhesion.

Figure 5-30: Condominium roof covering damage (Mexico Beach, FL)

The red arrows indicate exposed roof sheathing, where the synthetic underlayment and architectural metal roof panels blew off. The panels were attached with concealed clips. The green dotted arrows indicate where the adhered single-ply membrane blew off. The yellow oval indicates the area where the primary failure plane was the separation of the facer from the polyisocyanurate roof insulation as a result of roof membrane lifting and peeling. The coping all around this roof area was blown off; this failure likely initiated the membrane blow-off.

Discussion. Foam ribbon adhesive has been the predominant method to adhere insulation boards for several years. It can be an effective attachment method, but damage investigations by others have shown inadequate adhesion in many cases. Attachment problems can be related to adhesive material deficiencies; however, application deficiencies are typically the root cause of inadequate adhesion. To ensure adequate adhesion is achieved, test cuts must be taken or field uplift testing must be performed.

Figure 5-31: Close-up of the largest low-slope roof shown in Figure 5-30 (Mexico Beach, FL)

The black serpentine lines (red arrow) indicate the foam ribbon adhesive. The ribbons at the perimeter uplift zone are too far apart. The red circled area is where the adhesive had a poor bond to its substrate. The green dotted arrow indicates top insulation boards that remained attached to the adhesive. The blue material around the edges of the roof is emergency protection where the coping blew off. The yellow double arrows indicate exposed roof sheathing where the underlayment and metal panels blew off.

5.2.1.4 Bay County Tax Collector Office

Wind Damage Observations. The Bay County Tax Collector's office, an example of an older commercial building, experienced significant interior water damage due to roof membrane blow-off. The building had been reroofed with an adhered single-ply membrane over polyisocyanurate roof insulation that was mechanically attached to a wood plank deck. The failure was initiated by lifting of the roof deck. Figure 5-32 shows the roof of the building 12 days after hurricane landfall.

BAY COUNTY TAX COLLECTOR OFFICE SITE CONDITIONS

Estimated wind speed = 124 mph

Location = Exposure B

ASCE 7-16 basic wind speed = 134 mph (Risk Category II)

Discussion. This blow-off demonstrates the importance of evaluating the adequacy of roof deck attachment as part of a reroofing project. Portions of the roof membrane were poorly adhered; this failure highlights the importance of quality control and quality assurance during roof system application.

RISK CATEGORY FOR GOVERNMENT BUILDINGS

Government buildings that are essential to a community should be considered by the owner as critical facilities, and hence for wind loads, designed as Risk Category III or IV buildings. Examples of such buildings are given in Section 5.2.6. Other government buildings may be appropriately designed as Risk Category II. The MAT judged that the tax collector building was considered to be Risk Category II when the reroofing project was designed.

Figure 5-32: Roof damage initiated by lifting of the roof deck at the Bay County Tax Collector office building (Lynn Haven, FL)

The yellow arrow indicates the blown-off roof deck. The red arrow indicates where the membrane was well adhered to the insulation facer (the facer separated from the insulation). The grey area in the vicinity of the red dashed outline is the underside of the roof membrane; the membrane was superficially adhered in this area.

5.2.1.5 Condominium No. 2

Wind Damage Observations. Condominium No. 2, constructed in 2005, experienced damage to rooftop equipment when two of the four exhaust fans blew off their curbs, causing the LPS conductor to detach from the roof membrane. However, there was no apparent roof membrane damage, though the roof membrane may have been punctured by the detached LPS. Figure 5-33 shows the condominium 12 days after hurricane landfall.

CONDOMINIUM NO. 2 SITE CONDITIONS

Estimated wind speed = 121 mph

Location = Exposure D

ASCE 7-16 basic wind speed = 135 mph (Risk Category II)

Two rooftop exhaust fans blew off (red arrows). The blue dashed arrow indicates a detached LPS conductor. The green dotted arrow indicates walkway pads. Pads are often blown off, but these pads stayed in place. An adjacent twin building did not have any apparent wind damage.

Figure 5-33: Successful wind uplift resistance of a single-ply membrane for a condominium building (Panama City, FL)

5.2.1.6 Bank

Wind Damage Observations. This bank building, constructed in 1989, has eight sides, five of which were exposed to windward winds. Figure 5-34 is a view of a bank shortly after the hurricane. The building did not have protected glazing. Most of the windows and spandrel glazing were broken on the windward facades (Figure 5-35). Based on MAT observations, the damage was judged to have been primarily initiated by wind-borne debris from nearby residential buildings.

BANK SITE CONDITIONS

Estimated wind speed = 126 mph

Location = Exposure B, with open patches adjacent to all sides of the building

ASCE 7-16 basic wind speed = 135 mph (Risk Category II)

Some glazing was also broken on the leeward sides of the building (Figure 5-35 and Figure 5-36). Some of the leeward damage was caused by air pressure that exceeded the resistance of the window assembly. Other leeward damage appeared to have been caused by wind-borne debris striking the interior side of the glazing after the windward glazing was breached.

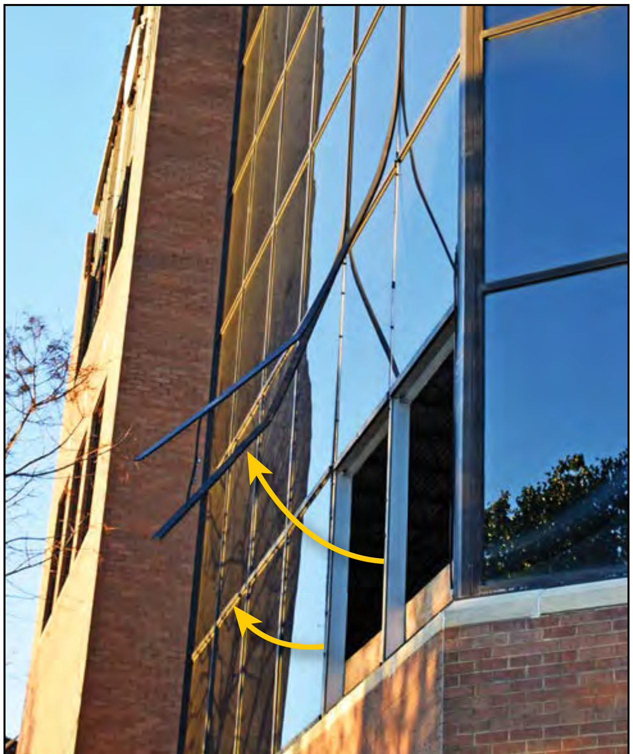
Discussion. In the counties struck by Hurricane Michael, buildings constructed prior to the adoption of the 2001 FBC were not required to have protected glazing. Refer to Section 2.3.1 for a discussion of the FBC wind-borne debris provisions. As illustrated by the unprotected glazing damage shown in Figure 5-35 and glazing damage observed at several other Risk Category II buildings, a portion of the boundary of the current Florida Panhandle WBDR does not adequately address the threat that wind-borne debris posed to unprotected glazing.

Figure 5-34: Aerial view of bank and adjacent residential buildings (Panama City, FL)

The red lines indicate façades that had extensive glazing damage. The red arrow indicates the primary wind direction. The yellow double arrows indicate the façades shown in Figure 5-35. The blue dashed arrow indicates the façade shown in Figure 5-36.

Figure 5-35: Broken glazing on the bank shown in Figure 5-34 (photograph taken 15 days after hurricane landfall) (Panama City, FL)

The red line indicates a windward façade. The yellow line indicates a leeward façade. The yellow dotted arrow indicates glazing that failed by over-pressurization. It was unclear whether other glazing on this façade and the façade indicated by the blue line failed due to over-pressurization or wind-borne debris. The right portion of the façade indicated by the blue line appeared to have been subject to windward wind. Plywood had been installed for temporary protection after the storm.



The yellow arrows indicate pressure plates that detached from the mullions, thereby allowing the glazing to blow away.

Figure 5-36: Two windows on a leeward facade of the bank shown in Figure 5-34 that failed due to over-pressurization (photograph taken 93 days after hurricane landfall) (Panama City, FL)

5.2.1.7 Office Building

Wind Damage Observations. The office shown in Figure 5-37 had stucco-surfaced, unreinforced CMU exterior walls that collapsed during Hurricane Michael. Figure 5-37 was taken 15 days after hurricane landfall.

OFFICE BUILDING SITE CONDITIONS

Estimated wind speed = 129 mph

Location = Exposure B, with an adjacent open patch to the northeast

ASCE 7-16 basic wind speed = 135 mph (Risk Category II)

Discussion. Exposed CMU and stucco-surfaced CMU walls may be perceived as having high wind resistance. However, when unreinforced, this type of wall can topple and present a significant life-safety risk. For buildings that will be occupied during a hurricane, it is important to predetermine if there are unreinforced walls that could topple onto occupants or if toppled walls could result in roof collapse in occupied areas. If either condition exists, the vulnerability should be mitigated, or the area should not be occupied during a hurricane.

Figure 5-37: Collapsed unreinforced CMU walls at an office building (Panama City, FL)

An unreinforced CMU wall toppled into the parking area. Previous MATs have observed unreinforced CMU walls that have fallen inward.

5.2.2 Critical Facilities – Emergency Operations Centers

EOCs need to manage their normal mission, along with response and recovery operations after an event. EOCs are where activities for the coordination of information and resources to support incident management (on-scene operations) normally take place. The command and response personnel must remain on duty, in full readiness for action before, during, and in the aftermath of a disaster. In addition to personnel and resources, EOCs house the information and communications systems that provide feedback to the emergency managers to help them make decisions about efficient and effective deployment of resources. They also relay information to local residents, storm shelters, media, and other first responders, while providing continuity of government and other operations. The loss of or significant damage to an EOC can severely affect the overall response and recovery in the area. For these reasons, good hurricane performance of these facilities is of utmost importance.

5.2.2.1 Bay County Emergency Operations Center and Gulf Coast State College Public Safety Building

Facility Description. The Bay County EOC and Gulf Coast State College Public Safety building opened in 2010. Figure 5-38 is a view of the facility at the time of the pre-MAT visit on October 25, 2018 (15 days after hurricane landfall). According to contract drawings reviewed by the MAT, design wind loads were determined from the 2004 FBC, with 2005 and 2006 supplements. The building's wind design criteria exceeded the criteria given in the FBC.

- The FBC basic wind speed was 130 mph (allowable stress design) for this location, but the building owner required the building to be designed for 220 mph, using an importance factor of 1.0.[9]

9 The ASCE 7-16 basic wind speed is much less than the speed used for the design of this building.

Figure 5-38: Front of the EOC (Southport, FL)

- The Exposure Category per the FBC is B for this location, but the building owner required the building to be designed for Exposure C.

According to the contract drawings, the roof deck consisted of 2 inches of normal-weight concrete over an 18-gauge steel deck welded to steel joists. The exterior walls are fully grouted 12-inch CMU with a #7 rebar at 48 inches on center (o.c.) and ladder reinforcing at 16 inches o.c. There was additional vertical reinforcing at corners and openings. The building had no rooftop mechanical equipment. The condensers were protected by CMU walls and a metal grate over the top of the walls.

The main entry doors were protected with roll-down storm shutters (Figure 5-39) and the windows were protected with permanently mounted screen shutters (Figure 5-40).

The contract drawings do not address the roof system, doors, and windows. The MAT was unable to obtain the contract specifications and submittals needed to evaluate the wind, wind-borne debris, and wind-driven rain resistance of these items.

Wind Damage Observations. There was no apparent wind damage to the Bay County EOC and Gulf Coast State College Public Safety building.

STEEL DECK ATTACHMENT

Numerous storm damage investigations have documented steel deck blow-offs that were caused by poor quality arc spot welds. FEMA 543 recommends that screw attachments be specified because screws are more reliable and much less susceptible to workmanship problems.

BAY COUNTY EOC SITE CONDITIONS

Estimated wind speed = 119 mph

Location = Exposure B, with an open patch to the northeast

ASCE 7-16 basic wind speed = 146 mph (Risk Category IV)

Figure 5-39: The main entry doors were protected with roll-down storm shutters (Southport, FL)

Figure 5-40: The windows were protected with permanently mounted screen shutters (Southport, FL)

Operations During Event and Functional Loss. Although the building did not experience wind damage, many operational issues presented significant challenges to EOC operations, including the following.

- ***Occupancy.*** There were approximately 150 occupants during the hurricane.

  Soon after the hurricane, many organizations and personnel began arriving at the EOC. It essentially became a staging area for those who did not know where else to go first. Approximately 5,000 people came to the EOC at its peak in a single day. The large influx of people put demands on the facility services, overwhelming their water, sewer, toilet and garbage collection capabilities, while also far exceeding the amount of available parking spaces. This parking issue was exacerbated by power lines that fell across the parking lot.

- ***Water and sewer.*** Municipal water and sewer were lost. The facility had a well that was on emergency power. However, the well's output was insufficient to serve the number of people at the facility.
- ***Power.*** Municipal power was lost. The facility had two generators. One generator could handle the emergency circuits. One transfer switch failed, and one generator failed causing about half the building to momentarily lose power.
- ***Toilets.*** The building had an inadequate number of toilets. The number of toilets for the EOC was not based on the increased occupant load that occurred after the hurricane.
- ***Garbage collection.*** The garbage collection was inadequate. Overflowing refuse containers near entrances attracted wasps, which presented problems.
- ***Communication.*** Communication problems were significant. Fiber communications were lost. Initially, runners were used, but runners were slowed by roads blocked by trees and by very congested traffic. AT&T's FirstNet system (a public safety communications platform dedicated to first responders) was flown in a day or two after the storm. Cell phones were also flown in, but it was difficult to have a call last longer than about 2 minutes without being dropped.

  The college that shared the building with the EOC had an IT person at the building. With this employee's knowledge of the facility and workarounds to the downed systems, some communications were restored.
- ***Radio.*** The public radio system is housed in the EOC building. It sends an emergency broadcast during a major event. The radio was able to broadcast other radio stations but could not receive transmissions from other stations.

5.2.2.2 Jackson County Emergency Operations Center

Facility Description. The Jackson County EOC opened in 2008. It had metal wall panels that were attached with exposed fasteners. Figure 5-41 is an aerial view of the Jackson County EOC facility shortly after the hurricane. Figure 5-42 is a view at the time of the MAT visit on January 10, 2019 (94 days after hurricane landfall).

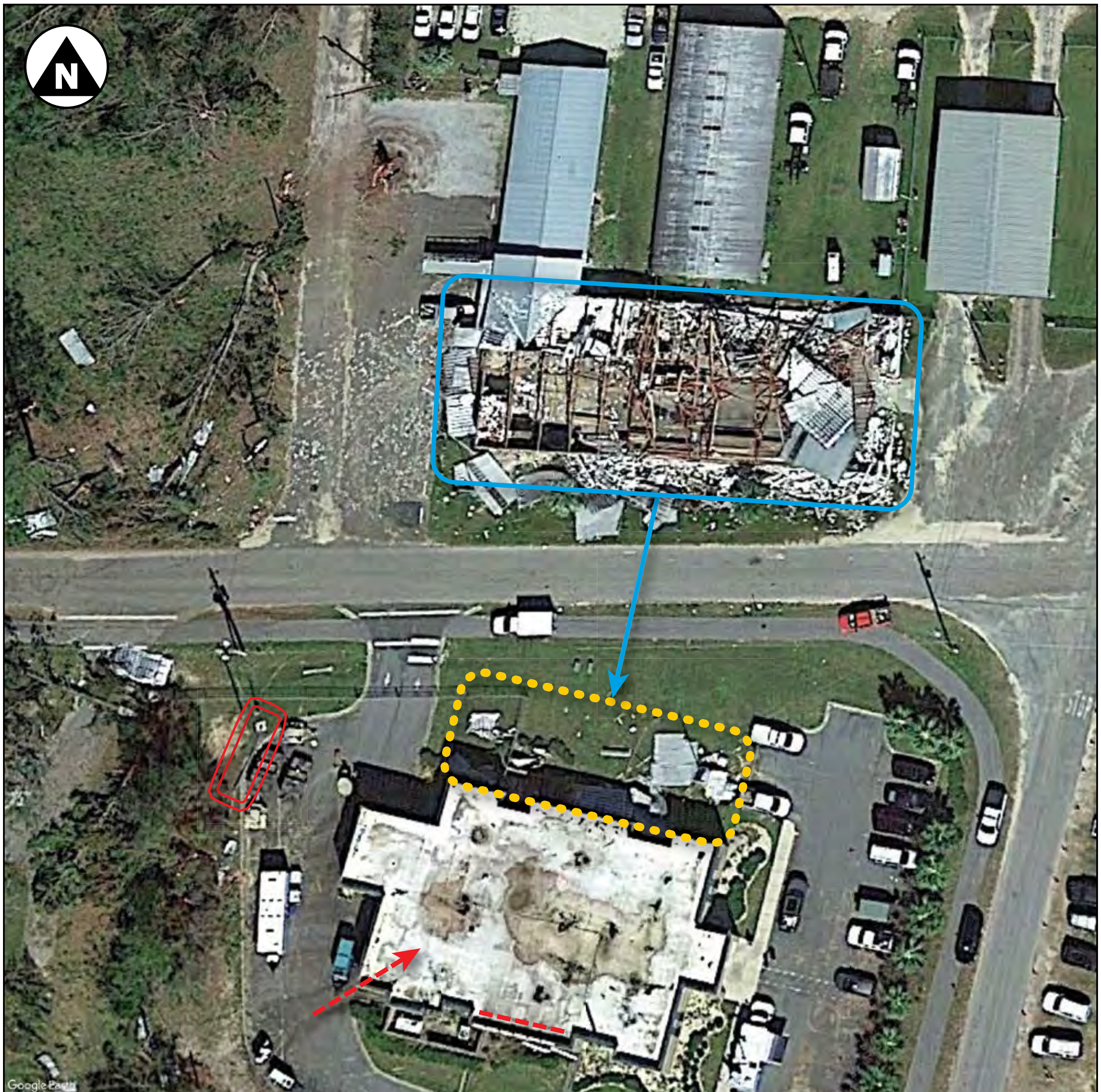
Approximately a year after the building was constructed, it was retrofitted with permanently mounted screen shutters.

JACKSON COUNTY EOC SITE CONDITIONS

Estimated wind speed = 117 mph

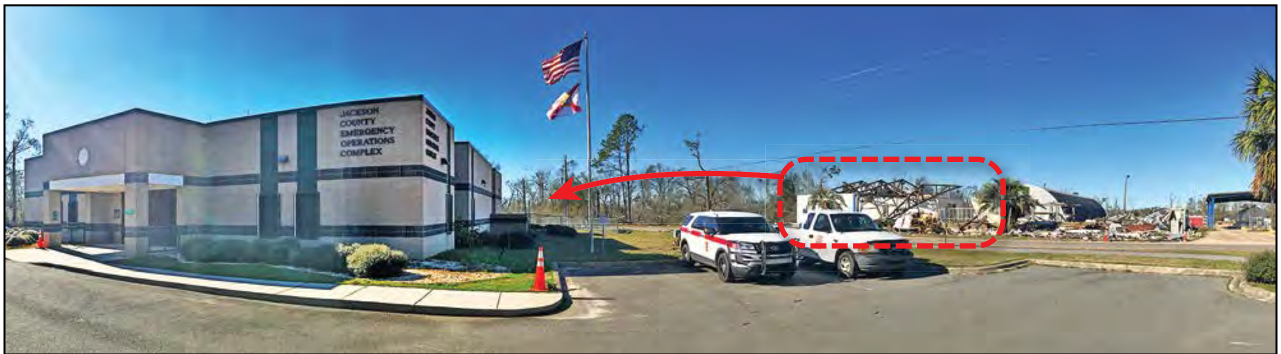
Location = Exposure B, with an open patch to the north

ASCE 7-16 basic wind speed = 133 mph (Risk Category IV)



The roof and wall of the EOC were impacted by debris from a nearby building (blue solid outline). Debris that landed on the ground near the EOC is within the yellow dotted outline. The red dashed line indicates where coping blew off. The red double outline indicates the communications antenna.

Figure 5-41: Aerial view of the Jackson County EOC (red arrow) (Marianna, FL)



The red arrow indicates the debris flight path.

Figure 5-42: The EOC (left) and the building that generated the wind-borne debris (red dotted outline) (Marianna, FL)

Wind Damage Observations. The wind-borne debris (from the building in Figure 5-42) that struck the EOC marred and dented some of the metal wall panels and coping (Figure 5-43), and also damaged the roof membrane (Figure 5-44) and a grade-mounted condenser. However, the debris impact did not result in wall panel or coping blow-off. Blow-off would have been more likely if the panels had been attached with concealed clips.

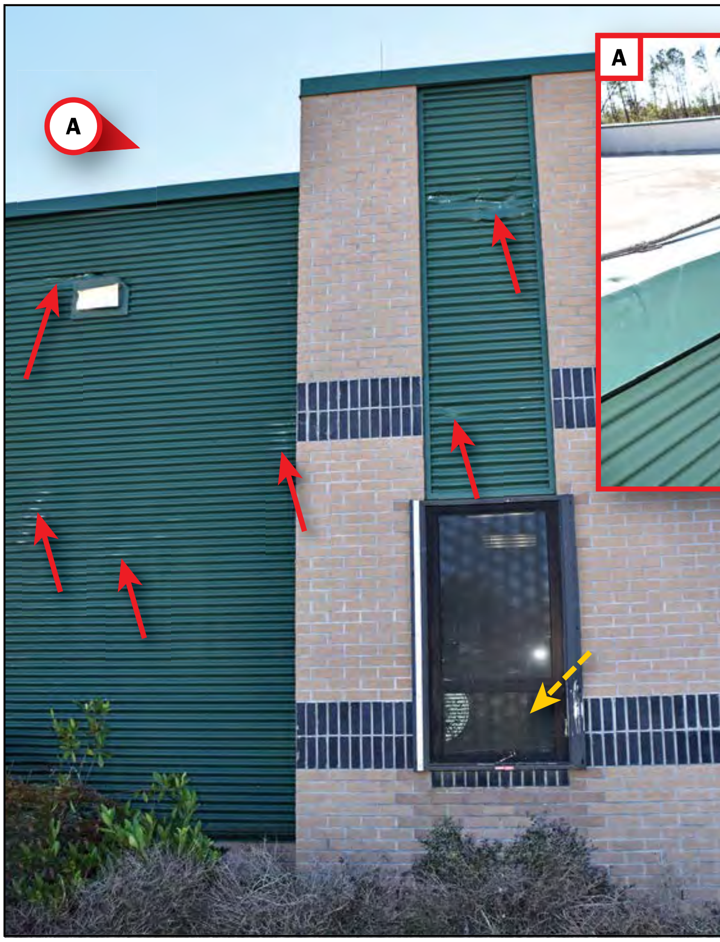
Debris also punctured the single-ply membrane in several locations resulting in minor interior water leakage. Apparently, the roof system had a secondary membrane (which is recommended in FEMA 543), or the roof deck acted as secondary membrane. Water leakage also occurred at windows. The MAT was unable to obtain the contract documents, specifications, and submittals needed to evaluate the building's wind and wind-driven rain resistance.

WIND-BORNE DEBRIS REGION AND RISK CATEGORIES

In the 2005 edition of ASCE 7, the extent of the WBDR is the same for Risk Categories II, III, and IV. However, in the 2010 edition, the region extends farther inland for some Category III buildings and all Category IV buildings. Even with the more conservative 2010 criteria, this site is not within the WBDR.

FEMA 543 recommends protected glazing when the basic wind speed is above 110 mph (allowable stress design). Had the design of this building followed the recommendation in FEMA 543, protected glazing would have been part of the original design.

The coping blew off a portion of the south parapet (see Figure 5-45 for location and Figure 5-46 for a close-up). The blow-off was caused by a significant workmanship error. Screws were not installed at the inner leg of the coping clips.



The dashed yellow arrow shows the shutter that was impacted by debris. The red arrows indicate where the metal wall panels were struck by debris. Inset **[A]** shows a close-up of wall and coping damage.

The LPS conductor clips were adhered to the coping; some of the clips detached from the coping. At other connectors, the conductor deformed the prongs and pulled away from the connector. FEMA 543 recommends that mechanically attached loop connectors be used at the inside leg of the coping. This type of connector is more reliable than pronged connectors set in adhesive.

Figure 5-43: The shutter (yellow dashed arrow) and metal wall panels (red arrows) that were struck by wind-borne debris (Marianna, FL)

Figure 5-44: Jackson County EOC roof (Marianna, FL)

The bright white spots are patches that were made where the roof membrane was punctured by wind-borne debris. The red dashed outline indicates the building that shed the debris.

Discussion/Guidance. The workmanship error illustrates the importance of diligent quality control and the need for quality assurance during roof application. It is important for coping to remain intact because coping blow-off often results in roof membrane lifting and peeling. Also, coping that becomes wind-borne debris can puncture roof membranes and cause other types of damage. A wind vulnerability assessment has the potential of detecting inadequately attached copings (such as those shown at Figure 5-45 and Figure 5-46) and edge flashings. By detecting vulnerable building components/systems, corrective action can be taken before they are damaged by a storm. Refer to FEMA P-2062, *Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities* (2019c).

At least one of the retrofitted shutters was struck by wind-borne debris during Hurricane Michael (Figure 5-43). The building is not in the ASCE 7 or FBC WBDR, so it was not required to have protected glazing. However, considering the critical nature of this facility and the weak nearby building, the shutter retrofit was prudent.

The coping blew off because the inner legs of the coping clips (red arrow) were not attached.

Figure 5-45: Where the coping blew off the Jackson County EOC roof (Marianna, FL)

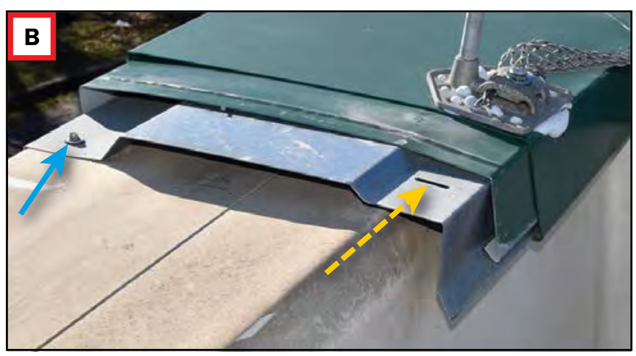


Figure 5-46: One of the lifted coping clips at the Jackson County EOC roof (Marianna, FL)

The clips were intended to be attached with four screws, two at each leg.

[A] Screws were not installed at the inner leg.

[B] A clip and coping still in place. The blue arrow indicates a screw at the outer leg. The yellow dashed arrow indicates a slot for the inner leg screw. The nailer did not cover the entire width of the parapet.

The communications antenna, which had a hinged base, was placed on the ground prior to the storm to avoid it being struck by wind-borne debris (see Figure 5-47). The antenna was damaged by a falling tree during the storm.

Discussion/Guidance. To avoid tree-fall damage, FEMA 543 recommends that trees with trunks larger than 6 inches in diameter not be within laydown distance of a critical facility. Similar laydown guidance is applicable to communications towers.

Figure 5-47: The lowered antenna that was struck by a falling tree (Marianna, FL)

Operations During Event and Functional Loss. There were approximately 70 to 80 occupants in the building during the hurricane. Although the building remained functional after the storm, the following operational issues occurred:

- ***Power.*** Municipal power was lost during the storm and was restored 16 days later. The EOC's emergency generator could not provide power because of a control panel problem, so a portable generator was brought to the site.
- ***Water and sewer.*** Municipal water and sewer remained operational during and after the storm.
- ***Communications.*** In addition to EOC communications, this EOC provides dispatch services for the county sheriff's department. The telephone landline was operational for a while, but service was interrupted after the storm. The wireless network also went out of service. The EOC had a ham radio, which enabled communications with the state through Jacksonville.

LESSON LEARNED

Because of security issues, the EOC personnel recommended to the MAT that the EOC be a standalone facility to prevent people from coming to the facility for unrelated services.

- ***Security.*** This building also houses other county services. During and after the storm, many people came to the building to access the other services, which compromised the security of the EOC.

5.2.3 Critical Facilities – Hurricane Evacuation Shelters

FLORIDA STATE EMERGENCY SHELTER PLAN

Refer to Section 2.4 for more information on Florida's long-established SESP, including the criteria for designating new and existing building areas as HESs. Florida's criteria for HESs differs from FEMA criteria for hurricane safe rooms and ICC 500 criteria for hurricane storm shelters.

In response to past hurricane damage, Florida developed the SESP (FDEM, 2018), which identifies HESs. The SESP is updated every other year to guide local emergency planning and "to provide advisory assistance to school districts contemplating construction of educational facilities and the need to provide public shelter space within those facilities."

The MAT is not aware of any FEMA P-361 safe rooms (compliant to FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* [2015c]), or ICC 500 storm shelters (compliant with ICC 500, Standard for the Design and Construction of Storm Shelters) open to the public in the area impacted by Hurricane Michael. However, numerous HESs were occupied and tested by the event; refer to Table 5-2 for more information on safe rooms and select shelter types. The MAT visited four HESs designated in the SESP for general use during Hurricane Michael, two in Calhoun County and two in Bay County. All of the shelters visited were located on school campuses. The MAT assessed the performance of the four identified HESs to document how these critical facilities performed during the hurricane to provide feedback to the State of Florida and local emergency managers who make decisions on opening and using shelters during storm events.

Two of the HESs visited by the MAT were constructed to meet FBC EHPA provisions (Blountstown and Altha in Calhoun County) and the other two were identified through evaluation and had been retrofitted to serve as HESs (Rutherford and Merrit in Bay County)[10] (FDEM, 2018; Table 6-1). Shelter demand varied at the different locations, from less than capacity in Calhoun County sites to significantly over capacity at Rutherford High School. According to the 2018 SESP (Table 3-1[1]), Bay and Calhoun Counties currently have general population shelter capacity surpluses of 9,485 and 1,977 (people spaces), respectively, and therefore under current state law, neither county is required to meet EHPA criteria when installing new school buildings.

All four of the shelters assessed by the MAT suffered roof damage and/or wind driven rain infiltration, but levels of damage and damage effects on occupants varied significantly. Table 5-1 summarizes the MAT's observations and Sections 5.2.3.1 through 5.2.3.4 describe the MAT's observations in detail.

10 Per Table 6-1 of the 2018 SESP, 5.6 percent of Bay County HES spaces were built to EHPA criteria and 35.3 percent of Calhoun County spaces were built to EHPA criteria; the remainder in each county were identified through evaluation (and as-needed mitigation) of existing buildings.

Table 5-1: Summary of Data Collected from School HES Buildings

School (County)	Shelter Buildings(1)	Determination Mode		Capacity/ Portions Occupied	HES Damage Severity
		EHPA	Retrofit		
Blountstown High School (Calhoun County)	• Gym • Dining hall • Classrooms in Building Nos. 5, 7, 8	X		• Under • Building Nos. 4 & 8	**Severe:** Building Nos. 2 & 7 roof damage results in HES exposure, significant infiltration **Moderate to minor:** Roof damage to all other shelter areas
Altha Public School (Calhoun County)	• Dining • Gym	X		• Under • Dining	**Minor:** Dining hall infiltrated with water from windows and doors **Moderate to severe:** Gym roof damage results in significant infiltration
Rutherford High School (Bay County)	• Halls/media center • Dining		X	• • Over • None(2)	**Severe:** Lost roof deck over Media Center result in HES exposure; flooded 1st floor causing evacuation **Moderate:** Dining roof damage results in significant infiltration
Merritt-Brown Middle School (Bay County)	• First floor of Building No. 4		X	• N/A (not opened) (3)	**Moderate to severe:** Building No. 4 roof damage results in significant infiltration

(1) For locations of buildings numbers, refer to detailed descriptions in Sections 5.2.3.1 to 5.2.3.4

(2) First floor corridors of buildings not designated as HESs were used.

(3) School was not opened during event because of concerns that a nearby pump station would fail during the hurricane.

Table 5-2: Shelter Terminology and Comparison

Safe Room	A hardened structure specifically designed to meet FEMA criteria and provide life-safety protection in extreme wind events, including tornadoes and hurricanes. To be considered a safe room, the structure must be designed and constructed to the guidelines specified in FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (2015c). Safe rooms constructed with FEMA grant funds are required to adhere to FEMA Recommended Criteria described at the beginning of FEMA P-361 Part B chapters as well as the corresponding ICC 500 requirements (FEMA, 2015c).
Storm Shelter	A building, structure, or portion(s) thereof, constructed in accordance with Standard ICC 500, *Standard for the Design and Construction of Storm Shelters,* and designated for use during a severe wind storm event such as a hurricane or tornado (FEMA, 2015c).
Florida Evacuation Shelter	A safe congregate care facility that provides services and is utilized for populations displaced by an emergency or disaster incident. An evacuation shelter may be located either inside (risk shelter) or outside (host shelter) of the disaster impact area and is typically operational for a period not to exceed 72 hours. Typically, these capacities are determined based on 20 square feet per person (FDEM, 2018).
Risk Shelter	Facilities designated as risk shelters may be located within the hazard risk zone (i.e., lie in the forecast path and associated error cone of an approaching hurricane or severe storm). Construction of these facilities meets established minimum safety requirements considered for least-risk decision-making for the community (FDEM, 2018).
Host Shelter	A facility that is safe and provides services, and is located outside of a hazard risk zone (FDEM, 2018).

In comparison, only ICC 500-compliant storm shelters and FEMA-compliant safe rooms are designed to provide life-safety protection during tornadoes and hurricanes. The storm type—tornado, hurricane, or combined—chosen for the individual facility dictates storm-specific design criteria. For example, hurricane storm shelters and safe rooms must be designed for longer duration occupancy than tornado shelters and must be sited and elevated to mitigate hurricane-specific flood hazards. Although many Florida HES non-structural criteria (e.g., flood hazard siting/minimum lowest floor elevation, minimum occupant space, sanitation) equal those of ICC 500 and FEMA, structural criteria for existing evacuation shelters are lower and vary significantly from shelter to shelter. Even with the improved structural criteria for EHPAs under the 6th Edition FBC (2017) as described in Section 2.4.2, safe rooms and storm shelters still require substantially higher criteria for opening protection.

5.2.3.1 Blountstown High School

Facility Description. Blountstown High School (Calhoun County) opened in 2011. The construction type for all nine campus buildings is MBS with structural standing seam roof panels with fiberglass blanket insulation and vapor retarder. Figure 5-48 is an aerial photograph of the campus 12 days after the hurricane; refer to discussion of "operations during event and functional loss" for information about the occupancy of the HES areas.

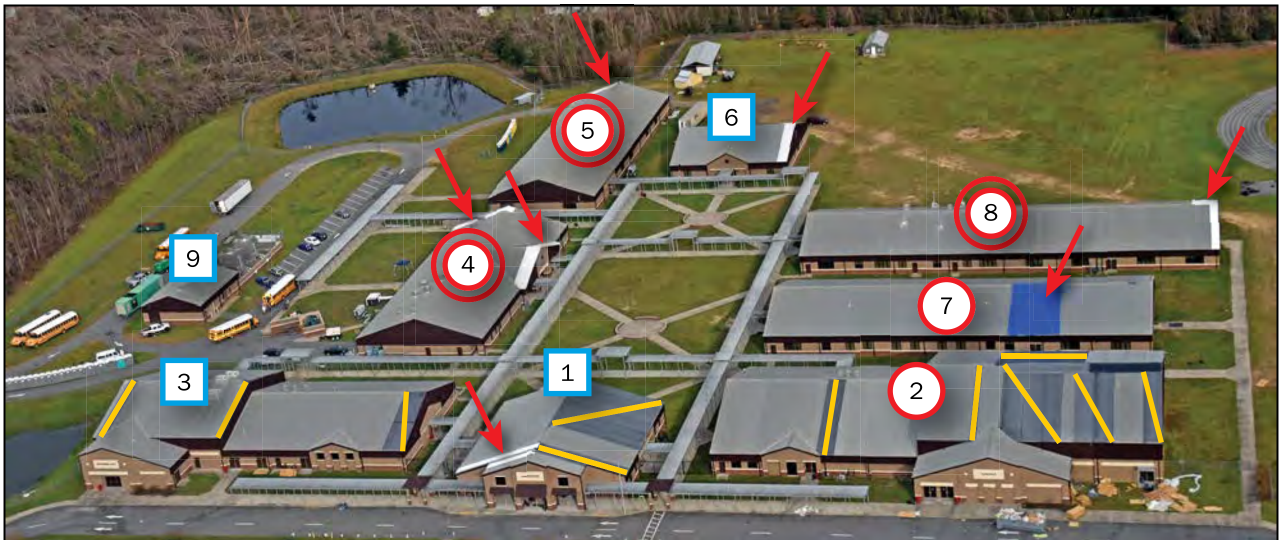
Wind Damage Observations. Every building at this school campus experienced roof covering damage except for the emergency generator building. The MAT's visit focused on observations of Building Nos. 2, 4, 5, 7, and 8. Overall, the roof panel failures resulted in extensive interior water damage. Some metal wall panels were also damaged. There was no apparent damage to the small amount of rooftop equipment present at the campus.

BLOUNTSTOWN HIGH SCHOOL SITE CONDITIONS

Estimated wind speed = 136 mph

Location = Exposure B, with adjacent open patches all around the campus

ASCE 7-16 basic wind speed = 133 mph (Risk Category III)



Legend:

1 = Administration
2 = Gym
3 = Auditorium
4 = Dining hall
5 = Classrooms
6 = Vocational
7 = Classrooms
8 = Classrooms
9 = Emergency generator

Numbers in red circles indicate designated HES. Double circles indicate buildings occupied during the hurricane.

Emergency roof repairs are indicated by the white and blue areas at the red arrows and the dark areas at the yellow lines.

Figure 5-48: Aerial view of the Blountstown High School (Blountstown, FL) TLS 512

Buildings Nos. 2 and 7 were the most heavily damaged. Damage to these buildings included:

- Blown-off roof panels on Building No. 7. Negative pressure (uplift) from high winds during the storm caused roof panel to structural framing member connections to fail. With no roof deck between the roof panels and the framing members, rain and debris freely entered the building (see Figure 5-49).
- Infiltration at ridge/roof panel interface. Fiberglass insulation was visible along several of the roof ridges (see Figure 5-50). Both HESs and non-HES buildings were affected. Suction from high winds pulled the insulation from underneath the panels, indicating that ridge closures had not been sealed to the roof panels. The breach created between the ridge flashing and roof panels allowed wind-driven rain to drive past the closures and wet the insulation.

The MAT also observed water infiltration damage to Building No. 1, which caused the ceiling boards to collapse. Figure 5-51 shows the interior of a corridor in Building No. 1 (repairs had been made by the time the MAT visited 13 days after the event).

The MAT was unable to obtain contract drawings, specifications, and submittals needed to evaluate the building's wind, wind-borne debris, and wind-driven rain resistance.

Operations During Event and Functional Loss. According to interviews with school staff, at the time of the storm, approximately 250 people took shelter at the facility. As a result, only Building No. 4 (dining hall, general occupants), Building No. 8 (classrooms, general occupants), and Building No. 5 (classrooms, occupants with pets) were used to shelter during the storm.

The roof panels blew off this building, exposing would-be occupants to the elements and allowing the ceiling boards to become wetted and collapse. A blue tarp is visible placed over the damaged roof.

Figure 5-49: Building No. 7 area designated as a HES, and constructed to meet EHPA provisions, was damaged during Hurricane Michael; the building was not occupied during the event (Blountstown, FL)

Wind-driven rain infiltrated the building where breaches developed between the ridge flashing and roof panels. The red arrow indicates the ridge flashing. The green dotted arrow indicates a closure. The yellow double arrow indicates an unsealed gap between the closure and metal roof panel.

Figure 5-50: Roof of Building No. 3, while not designated as HES, similar damage was evident along ridges of HESs including Building No. 2. Pulled-out fiberglass insulation can be seen coming through the unsealed gap between the closure and metal roof panel. (Blountstown, FL)

BLOUNTSTOWN HIGH SCHOOL SESP 2018

Designated areas for use as HES:

- Building No. 2 = gym
- Building No. 4 = dining
- Building Nos. 5, 7, and 8 = all classrooms

Capacity: 1,892 people total

- Building No. 2 = 657
- Building No. 4 = 172
- Building No. 5 = 131
- Building No. 7 = 459
- Building No. 8 = 473

Mode of determination: HESs intended to meet EHPA provisions

Figure 5-51: Corridor in Building No. 1 area, which was damaged during Hurricane Michael (Blountstown, FL)

Interior of Building 1 in which wetted ceiling boards collapsed and then were cut and removed.

The other EHPAs—Building No. 2 (gym) and Building No. 7 (classrooms)—were not occupied by the general public, which was fortunate considering the level of roof damage to each.

Blountstown High School reopened to students on November 2, 2018, approximately 3 weeks after the hurricane. The site also accommodated first and second graders from Blountstown Elementary School, which was closed for repairs. All campus buildings were functional (as of the preparation of this report) but still awaiting permanent repairs.

5.2.3.2 Altha Public School

Facility Description. Altha Public School (K–12, Calhoun County) opened in 2017.

Figure 5-52 is an aerial photograph of the campus shortly after the hurricane and shows the locations of both buildings the MAT visited.

Wind Damage Observations. The MAT's visit focused on the dining hall and gym of the school campus.

There was no apparent damage to the building envelope of the dining hall area. However, a significant

ALTHA PUBLIC SCHOOL SITE CONDITIONS

Estimated wind speed = 131 mph

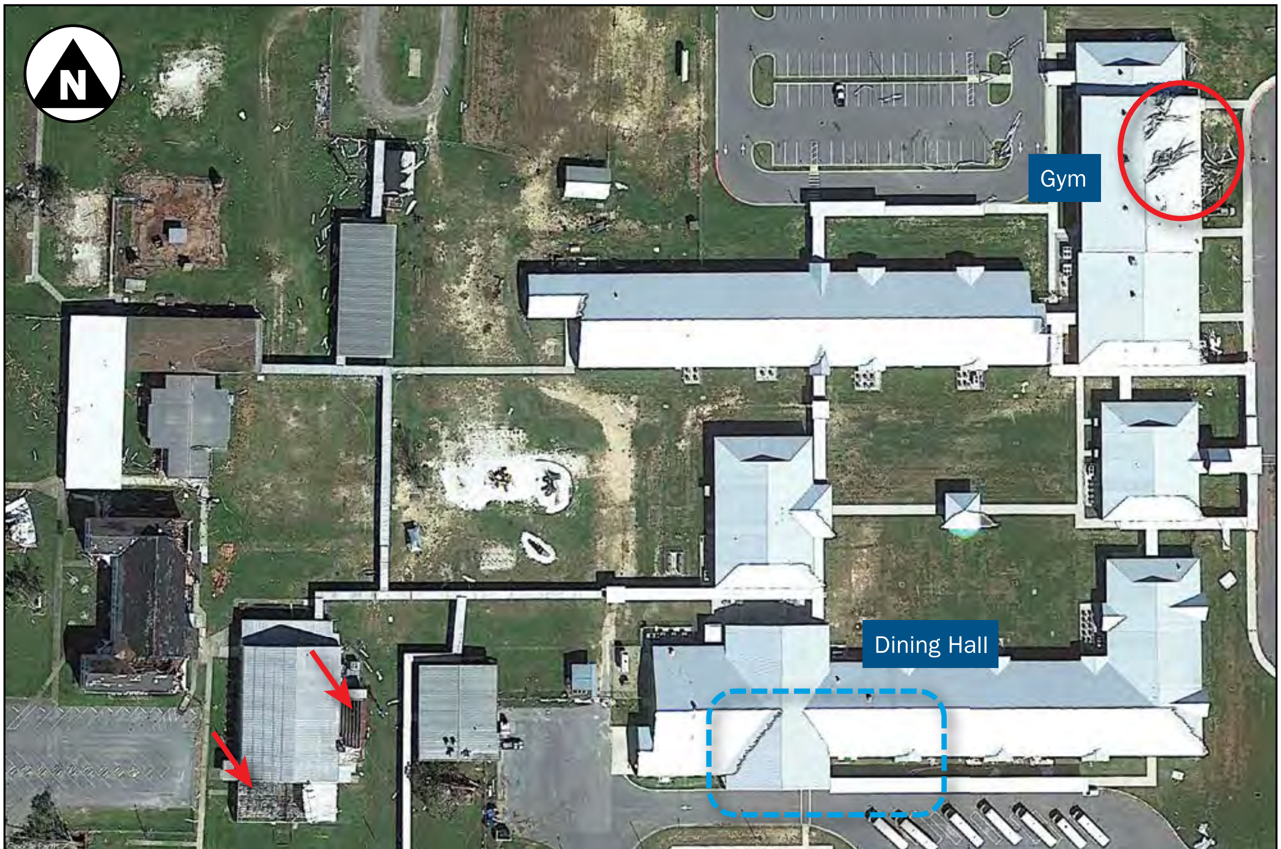
Location = Exposure B, with adjacent open patches to the north and east, and an open patch to the west

ASCE 7-16 basic wind speed = 133 mph (Risk Category III)

amount of wind-driven rain entered at the exterior doors and some of the windows also leaked (Figure 5-53).

At the gym, portions of the metal roof and wall panels, LPS conductors, and rooftop mechanical equipment were blown off (Figure 5-54), resulting in interior water intrusion.

The MAT was unable to obtain contract drawings, specifications, and submittals needed to evaluate the building's wind, wind-borne debris, and wind-driven rain resistance.



The gym and dining hall are EHPAs and used for shelter during the storm. Metal roof panels blew off the gym (red oval). The blue dashed outline indicates the dining hall shown in Figure 5-54. The red arrows indicate roof damage at older buildings.

Figure 5-52: Aerial view of the Altha Public School taken shortly after the hurricane (Altha, FL)

ALTHA PUBLIC SCHOOL SESP 2018

Designated areas for use as HES:
- Building No. 600 = gym
- Building No. 300 = dining hall

Capacity: 1,014 people total
- Building No. 600 = 702
- Building No. 300 = 312

Mode of determination: HESs intended to meet EHPA provisions

Figure 5-53: Portion of the Altha public school that was used as a shelter (Altha, FL)

The blue dashed arrow indicates the dining hall and multipurpose room. The inset shows that the pair of doors had a sweep, rather than an automatic door bottom. Note the absence of an astragal (weatherstripping) at the meeting stile.

Figure 5-54: Altha Public School gym (Altha, FL)

The red arrow indicates a displaced LPS conductor. The blue dashed arrow indicates emergency roof repairs. The green dotted arrow indicates where metal wall panels blew off. The panels were attached with concealed clips, rather than the more reliable exposed fasteners.

Operations During Event and Functional Loss. According to interviews with school staff, approximately 200 people took shelter at the facility at the time of the storm. Because of the below-capacity turnout, only the dining hall was used to shelter the general public.

The dining hall performed well and did not experience functional loss, though some water intrusion occurred around windows and exterior doors (described above). The gym was significantly damaged but was unoccupied.

Altha Public School reopened to students on November 2, 2018. All campus buildings were functional (as of the preparation of this report), but still awaiting permanent repairs.

5.2.3.3 Rutherford High School

RUTHERFORD HIGH SCHOOL SITE CONDITIONS

Estimated wind speed = 129 mph

Location = Exposure B, with an open patch adjacent to the east side of the school

ASCE 7-16 basic wind speed = 144 mph (Risk Category III)

Facility Description. Rutherford High School (Bay County) opened in 1961. Several campus buildings were subsequently added including Building No. 2 (1986) and Building No. 13 (1995). Areas of those two buildings were assessed and retrofitted with permanently mounted screen shutters to serve as HESs.

Based on MAT observations, buildings on the school campus had roof construction as follows:

- Building No. 2 had a steel roof deck welded to steel joists and structural standing seam trapezoidal metal panels
- Building No. 13 had a steel roof deck welded to steel joists and a single-ply membrane roof covering
- Building No. 1 had pre-cast concrete single-tee roof panels
- Building Nos. 4 through 8, 11, and, 12 (all classrooms) had pre-cast double-tee panels
- Building Nos. 3 and 9 had single-ply membrane roofs
- All other buildings on the campus had roofs with structural standing seam trapezoidal metal panels

Figure 5-55 is an aerial photograph of the campus shortly after the hurricane; refer to the discussion within this section on "operations during event and functional loss" for information about the occupancy of the HES areas.

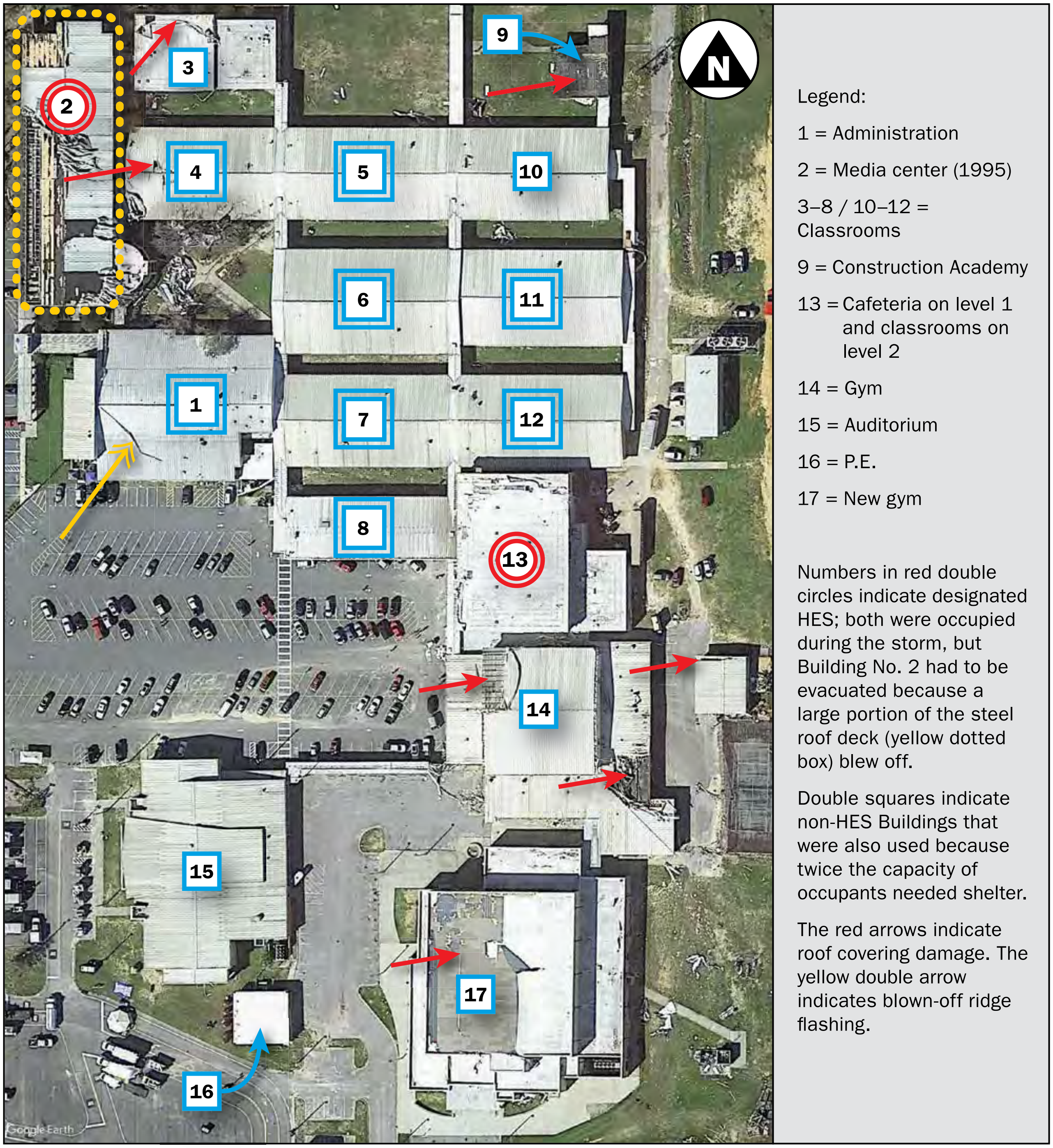
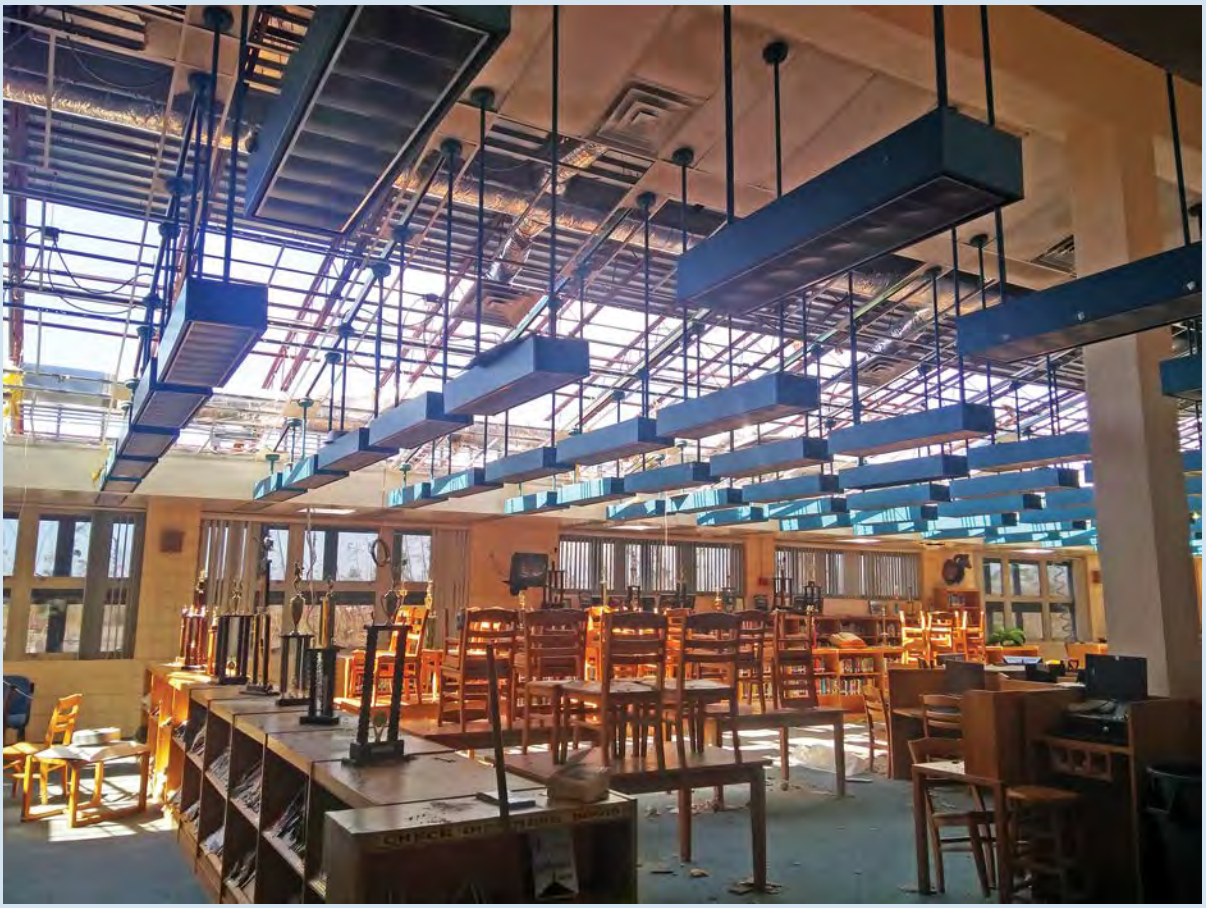


Figure 5-55: Aerial view of the Rutherford High School (Panama City, FL)

OVERALL EFFECTIVENESS OF RETROFIT PROJECT

The shutter retrofit project at Rutherford High School was ineffective at limiting significant damage to the buildings and their contents. Significant building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the retrofit. Specifically, while the screen shutters prevented wind-borne debris from penetrating the window and door openings, much of the roof deck above the Media Room—a designated HES—was blown off. For guidance on wind retrofit projects, refer to Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* (see Appendix C).



Wind Damage Observations. Overall, the campus was heavily damaged during Hurricane Michael. Roof system damage was most prevalent, but wall cladding, soffits, gutters, and screen shutters were also damaged.

Performance of Roof Decks and Coverings. The MAT's visit focused on HESs, which were located in Building Nos. 2 and 13, though it visited other buildings on the campus. Both Building No. 2 and No. 13 had roof damage.

- Most notable, a large portion of the steel roof deck at Building No. 2 was blown off, leaving the second story Media Room exposed to wind-borne debris and allowing rain to flood the first floor areas below as shown in the textbox photograph above, which was taken immediately after the storm. Wind-borne roof deck and/or metal roof panels from this building struck Building No. 4 (Figure 5-56).

- Building No. 13 suffered roof covering damage (Figure 5-57) that allowed a significant amount of rain to enter the building. Water reportedly reached the first floor.

Figure 5-56: Roof damage at Building No. 4 (Panama City, FL)

The red arrows indicate fascia and gutter damage at Building No. 2. The red outline indicates a composite roof insulation board (OSB/polyisocyanurate) that was blown from Building No. 2. The metal roof panel clips were attached to the OSB. The blue dashed arrows indicate detached LPS conductors. The black areas are emergency roof patches; some or all of the Building No. 4 roof damage was likely caused by wind-borne debris from Building No. 2. The yellow double arrow indicates the retrofitted screen shutters.

Figure 5-57: Missing soffit panel (inside blue outline) and screen shutters (inside red outlines) on floor 2 of Building No. 13 (a designated HES) (Panama City, FL)

Figure 5-58 is a view of a portion of the school campus showing damage at three large roof areas. Elsewhere on campus, rooftop fan cowlings and other rooftop equipment (including LPS conductors) were blown off along with gutters, soffits, fascia, and ridge flashings.

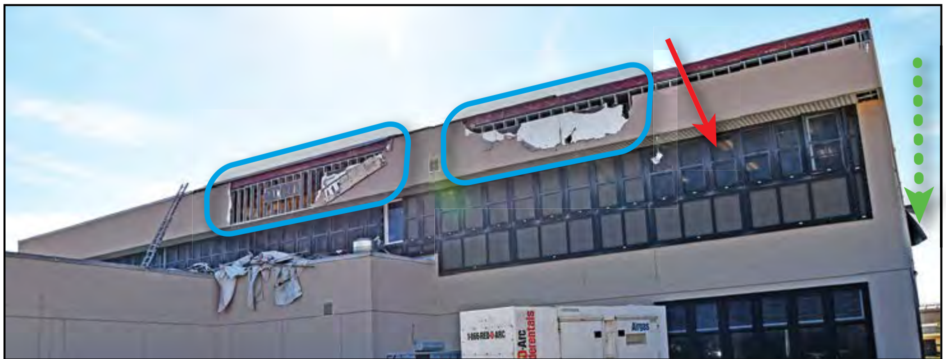
Performance of Permanently Mounted Screen Shutters. The MAT assessed the school's retrofitted permanently mounted screen shutters. The MAT saw shutters by two different manufacturers on the campus. One type of shutter had a label that provided the name of the manufacturer, but the label did not indicate that it was a tested assembly. The other type had a label that indicated it was a tested assembly, but it did not indicate the test missile level.

Although not every shutter onsite was checked, the MAT did not observe evidence of damage by wind-borne debris on any screen shutters that were still in place. However, the MAT noted two missing screen shutters on the second floor of Building No. 13 as shown in Figure 5-57. Staff stated that the screens were in place prior to the storm; they suspect the screens were damaged during the event by building cladding (see wall section above windows in Figure 5-59) that peeled off multiple buildings and damaged campus building envelopes as shown in Figure 5-57.

Figure 5-58: Building Nos. 13, 14, and 17 (looking north) (Panama City, FL)

The red arrow indicates a single-ply membrane at Building No. 13; it replaced the single-ply membrane that was blown off. The yellow double arrows indicate emergency roof patches at damaged metal roof panels at Building No. 14. The blue dashed arrows indicate suction-induced window frame failures at the corner zones. The green dotted arrow indicates a new single-ply membrane on the lower roof of Building No. 17; it was part of the reroofing work that replaced the single-ply membrane that was blown off the upper roof. The red outline indicates portable classroom buildings that were brought in after the storm.

Figure 5-59: Damage at Building No. 13 (Panama City, FL)



The red arrow indicates the retrofitted screen shutters. The green dotted arrow indicates blown-off roof membrane. The blue outlines indicate damaged EIFS. Typically, the gypsum board detached from the studs. At the white area in the right outlined area, the synthetic stucco detached from the molded expanded polystyrene insulation.

Operations During Event and Functional Loss. According to staff interviewed, Rutherford High School opened to shelter the general public on October 9, the day before landfall. While the designated capacity of the school shelter areas was 789 (FDEM, 2018), 1,142 members of the community showed up and registered for shelter by the time the buildings were secured. Significantly over capacity and needing to close off unsecured building areas, school staff opened the first floor hallways of several non-designated buildings and locked the stairwells of all occupied buildings, including Building Nos. 2 and 13, to protect unsecured areas. In the end, Building Nos. 2 and 13 (both designated as HESs) were occupied during Hurricane Michael although Building No. 2 was evacuated mid-storm as described below. Portions of Building Nos. 1, 4 through 9, 11, and 12 (not designated as HESs) were also used as general population shelter areas.

In retrospect, the decision to close off the second floor of Building No. 2 protected occupants who would have been exposed when the roof blew off. After rain from the exposed second story Media Room in Building No. 2 began pouring through light fixtures and inundating the first floor below, shelter staff decided to evacuate Building No. 2 and relocate people to Building No. 13 (designated as a HES) and hallways of other buildings. Building No. 2 occupants were guided between two rows of National Guard personnel who acted to shield them from the elements and wind-borne debris. While no serious injuries were reported, failure of the Building No. 2 roof assembly endangered staff and the general public who sought shelter in the HES.

RUTHERFORD HIGH SCHOOL SESP 2018

Designated areas for use as HES:

- Building No. 2 = classrooms/hallways, (floor 1) and media center (floor 2)
- Building No. 13 = cafeteria (floor 1) and classrooms (floor 2)

Mode of determination: Existing buildings that were assessed and mitigated to qualify

Capacity: 789 people total

- Building No. 2 = 237
- Building No. 13 = 552

High demand for sheltering space across Bay County appears to have resulted in some sites, such as Northside Elementary, serving as shelter space for the general public during Hurricane Michael even though it is not listed as an HES in the 2018 SESP.

Despite roof covering, cladding, and screen shutter losses described in the "Wind Damage Observations" section, the cafeteria of Building No. 13 provided the greatest capacity for general population sheltering and served as the hub for shelter operations.

In addition to failing to provide safe shelter for the general public during the storm, Building No. 2 remains closed for repairs.

5.2.3.4 Merritt Brown Middle School

Facility Description. Merritt Brown Middle School (Bay County) opened in 1988. Building No. 4, the only designated HES (floor 1 only), had a single-ply roof system over steel roof deck that was welded to steel joists. Figure 5-60 is an aerial photograph of the campus shortly after the hurricane.

The school was retrofitted with permanently mounted screen shutters (Figure 5-61) sometime after 1998.

MERRITT BROWN MIDDLE SCHOOL SITE CONDITIONS

Estimated wind speed = 128 mph

Location = Exposure B, with adjacent open patches to the north and east

ASCE 7-16 basic wind speed = 142 mph (Risk Category III)

Wind Damage Observations. Merritt Brown Middle School was heavily damaged during Hurricane Michael. Damage is shown in Figure 5-60, an aerial photograph of the campus shortly after the hurricane. Roof damage was most prevalent and occurred across all campus buildings. The MAT only had access to Building No. 4 and the gym where remediation was underway to dry out areas inundated from rain infiltration that occurred during and after the hurricane.

As shown in Figure 5-60, the steel roof deck blew off at least four different buildings and there was widespread roof membrane blow-off. Remaining roof membranes showed evidence of puncture by wind-borne debris (Figure 5-62). These failures resulted in extensive interior water damage (Figure 5-63). Gutters were also blown off.

The MAT did not observe any of the retrofitted screen shutters that were impacted by wind-borne debris. However, not all shutters were checked for debris impact. Similar to many of the retrofit projects described in Section 5.1, the shutter retrofit project at this school was ineffective at limiting significant damage to the buildings and their contents. Significant building damage and occupancy disruption occurred because not all significant wind vulnerabilities were addressed by the retrofit.

Operations During Event and Functional Loss. According to interviews with Bay County school system personnel, Merritt Brown Middle School was intended to be used as a public shelter during the storm but was excluded over concerns related to a nearby lift station. The school was therefore not occupied by the general public during Hurricane Michael; had it been designated for use, occupants of the HES area would likely have been exposed to prolonged inundation.

Merritt Brown Middle School was closed at the time of the MAT visit and not anticipated to be opened to students

MERRITT BROWN MIDDLE SCHOOL SESP 2018

Designated areas for use as HES:

- Building No. 4 = classrooms (floor 1)

Mode of determination: Existing buildings that were assessed and mitigated to qualify

Capacity: 877 people total

during the remainder of the 2018–2019 school year because of the significant repairs needed at the school. Students have been reassigned to surrounding Bay County campuses.

The red arrows indicate where steel deck blew off. The yellow double arrows indicate damaged mechanically attached single-ply membranes. The single-ply membranes at Building No. 4 and the multipurpose room were adhered. The first floor of Building No. 4 was the designated shelter area.

Figure 5-60: Aerial view of the Merritt Brown Middle School (Panama City, FL)

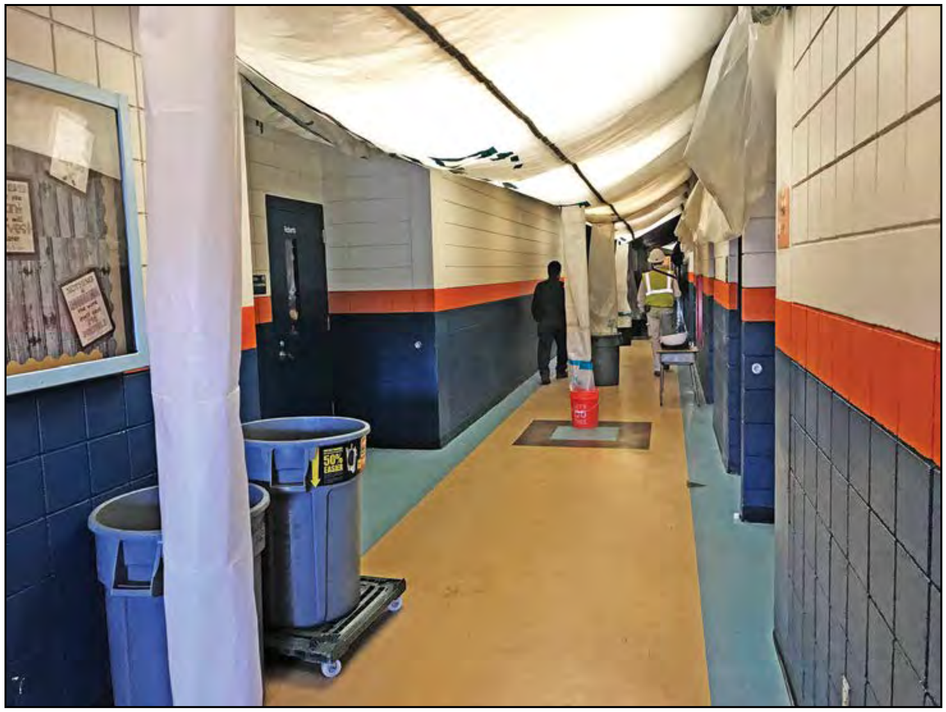
The windows were protected by screen shutters (red arrow). The blue area is a temporary tarp.

Figure 5-61: Roof and side of Building No. 4 (designated HES) (Panama City, FL)

The small black areas are emergency patches at roof membrane punctures. Because this membrane was mechanically attached, water could readily spread laterally until it reached an insulation board joint, where it could then migrate toward the building's interior unless intercepted by a secondary roof membrane. When the membrane is adhered, if a puncture or tear occurs somewhere other than at a board joint (which is likely), water is inhibited from migrating towards the interior.

Figure 5-62: Wind-borne debris damage, looking east (Panama City, FL)

Figure 5-63: A second floor corridor in Building No. 4 located below the roof shown in Figure 5-61 (Panama City, FL)



5.2.4 Critical Facilities – First Responder Facilities

Police and fire rescue facilities are critical to disaster response because an interruption in their operations may prevent rescue operations, evacuation and other assistance, or general maintenance of law and order, which can have serious consequences for the community. In addition to the discussion below, refer to Section 5.2.4 for a wind retrofitted police station; Hurricane Michael in Florida Recovery Advisory 1 for a wind retrofitted fire station (see Appendix C); and Chapter 3 for a fire station and a police station that was impacted by wind and flooding.

5.2.4.1 Lynn Haven Police Administration

Facility Description. A portion of the Lynn Haven Police Administration building collapsed. The collapsed portion was originally an A-frame church that opened in 1974. It had wood plank decking over laminated beams and unreinforced CMU walls with brick veneer. The portion of the building with the low-slope roof that did not collapse had a steel roof deck over steel joists.

LYNN HAVEN POLICE ADMINISTRATION SITE CONDITIONS

Estimated wind speed = 124 mph

Location = Exposure B

ASCE 7-16 basic wind speed = 146 mph (Risk Category IV)

Wind Damage Observations. The portion of the building that was an A-frame collapsed during Hurricane Michael. Prior to its collapse, HVAC units on the adjacent low-slope roof blew off and windows were broken. Figure 5-64 is an aerial view of the facility at the time of the pre-MAT on October 22, 2018 (12 days after hurricane landfall). Figure 5-65 is a close-up of the building.

The red arrows indicate where HVAC units blew off the building with the low-slope roof. The red rectangle indicates the collapsed A-frame.

Figure 5-64: Aerial view of the Lynn Haven Police Administration building (Lynn Haven, FL)

Figure 5-65: Collapsed A-frame and building with the low-slope roof (green arrow) (Lynn Haven, FL)

Figure 5-66 and Figure 5-67 illustrate brick veneer attachment problems.

Discussion/Guidance. Performing a wind vulnerability assessment of brick veneer can be important at facilities where bricks could collapse on people seeking shelter during a storm. FEMA Fact Sheet 5.4, *Attachment of Brick Veneer in High-Wind Regions* (in FEMA P-499, 2010b) provides brick veneer attachment design and construction guidance.

Figure 5-68 is a view of the corridor between the low-slope and A-frame portions of the building. This illustrates the potential harm to people in buildings that collapse.

Figure 5-66: Collapsed brick veneer, CMU, and roof structure (Lynn Haven, FL)

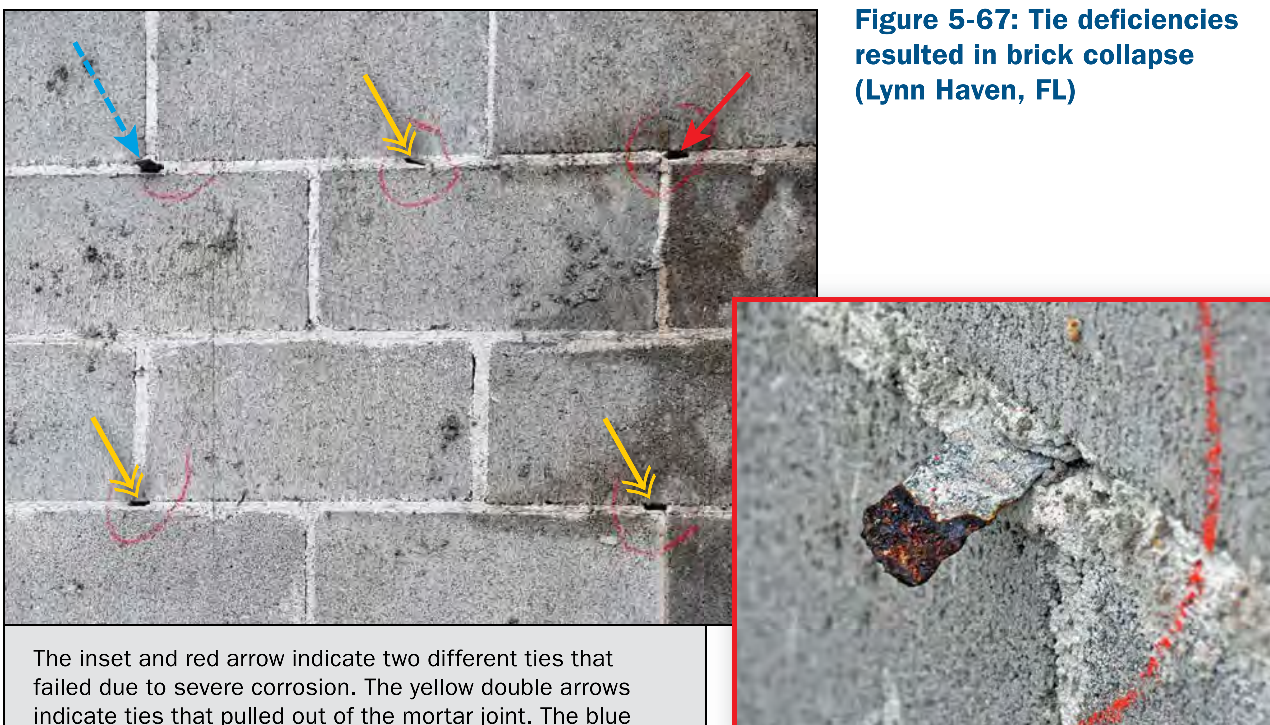


Figure 5-67: Tie deficiencies resulted in brick collapse (Lynn Haven, FL)

The inset and red arrow indicate two different ties that failed due to severe corrosion. The yellow double arrows indicate ties that pulled out of the mortar joint. The blue dashed arrow indicates a tie that failed in tension (the tie was well embedded in the CMU and brick mortar joints). Note the significant difference in tie failure modes within a small area of the wall.

Figure 5-68: The end of the corridor was open to the sky (Lynn Haven, FL)

The red arrow indicates an A-frame beam that penetrated an interior partition.

Operations During Event and Functional Loss. The building was not evacuated prior to landfall because key staff believed the building would be safe, based on the views of lay people.[11] There were approximately 65 to 75 occupants (including city officials and family members) in the building at the time of the hurricane. Children and pets were in the A-frame building prior to it collapsing. As the storm progressed, there were concerns about the safety of the A-frame building, so all occupants were moved to a corner office and hallway in the building with the low-slope roof.

Collapse of the A-frame building and entry of water from the roof openings and broken windows at the building with the low-slope roof resulted in loss of facility functions. The building was

11 Hurricane Michael in Florida Recovery Advisory 1 recommends that a wind vulnerability assessment be performed by a qualified team of architects and engineers for buildings that need to be operational during or immediately after a hurricane to provide or assist with response and recovery efforts.

demolished after the hurricane. The insurer estimated $1.9 million dollars for the building damage and $400,000 for building contents. Operations were moved into portable office buildings behind the nearby public library.

Discussion/Guidance. The failures at this building illustrate the importance of performing a wind vulnerability assessment for buildings that will be occupied during a hurricane. If significant vulnerabilities exist, they should be mitigated, or the vulnerable area(s) should not be occupied during a hurricane, as discussed in Hurricane Michael in Florida Recovery Advisory 1.

5.2.5 Critical Facilities – Hospitals and Nursing Homes

The MAT visited five hospitals, one emergency clinic, and two nursing homes. Three of the hospitals are discussed in detail in the subsections that follow, with a fourth briefly discussed in the textbox below.

GULF COAST REGIONAL MEDICAL CENTER, PANAMA CITY

The Gulf Coast Regional Medical Center opened in 1977. It is licensed for 227 beds. It has the region's only Level III Neonatal Intensive Care Unit. At the time of the hurricane, there were nearly 600 people in the hospital, including 150 patients, family members, and people seeking shelter.

The roof system on an adjacent three-story medical office building blew off, which resulted in extensive water damage throughout that building. Wind-borne roof debris from the office building broke several hospital windows. Some of the hospital windows were protected by polycarbonate shutters, but most of the windows were not protected. A few of the hospital's bituminous cap sheet membrane roofs were damaged. Municipal water and sewer service were interrupted. An on-site well was damaged and not operational for a couple of days.

Except for the emergency room, evacuation of the hospital commenced the day after hurricane landfall. During the evacuation, there was loss of communication with the police department, the EOC, and incoming helicopters.

A phased reopening started on November 8 (29 days after hurricane landfall). On January 7 (91 days after hurricane landfall) the hospital had 100 percent of pre-storm capability.

5.2.5.1 Bay Medical Sacred Heart Health System

Facility Description. The Bay Medical Sacred Heart Health System facility opened in 1949. The campus includes several buildings built over the past five decades. The latest addition opened in 2010. It was a Level 2 trauma center with 323 beds, and the only trauma center between Pensacola and Tallahassee. The 2010 addition had protected glazing. A few of the windows and glazed doors on some of the older buildings on the campus were retrofitted with permanently mounted screen shutters or accordion shutters.

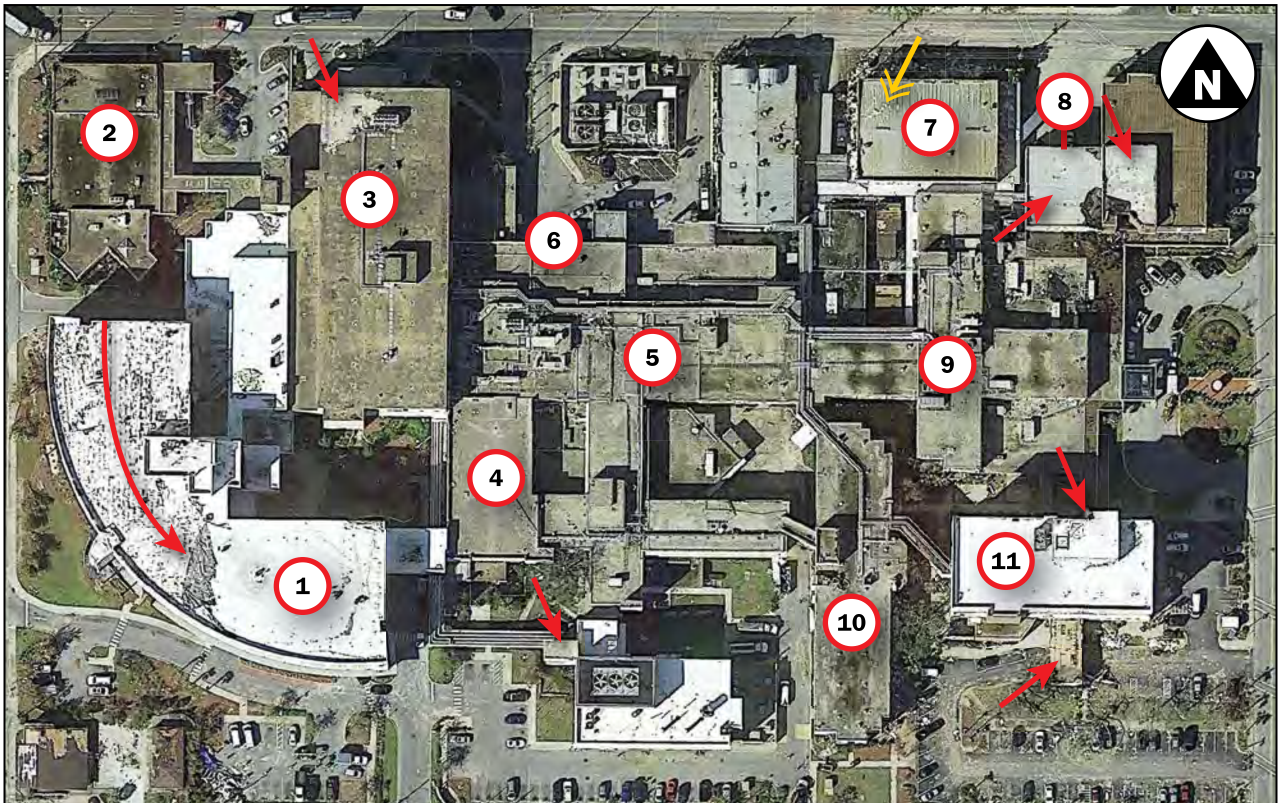
BAY MEDICAL SITE CONDITIONS

Estimated wind speed = 130 mph

Location = Exposure B, with an open patch (bayou) to the east

ASCE 7-16 basic wind speed = 147 mph (Risk Category IV)

Wind Damage Observations. The pre-MAT visited the facility on October 22, 2018 (12 days after hurricane landfall). The campus shown in Figure 5-69, an aerial view of the facility shortly after Hurricane Michael that highlights some of the damage. An overview of the wind damage is shown in Figure 5-70, an aerial view of the facility at the time of the pre-MAT on October 22, 2018. The MAT did not observe any of the retrofitted shutters that were impacted by wind-borne debris, though the MAT did not check all the shutters for debris impact.

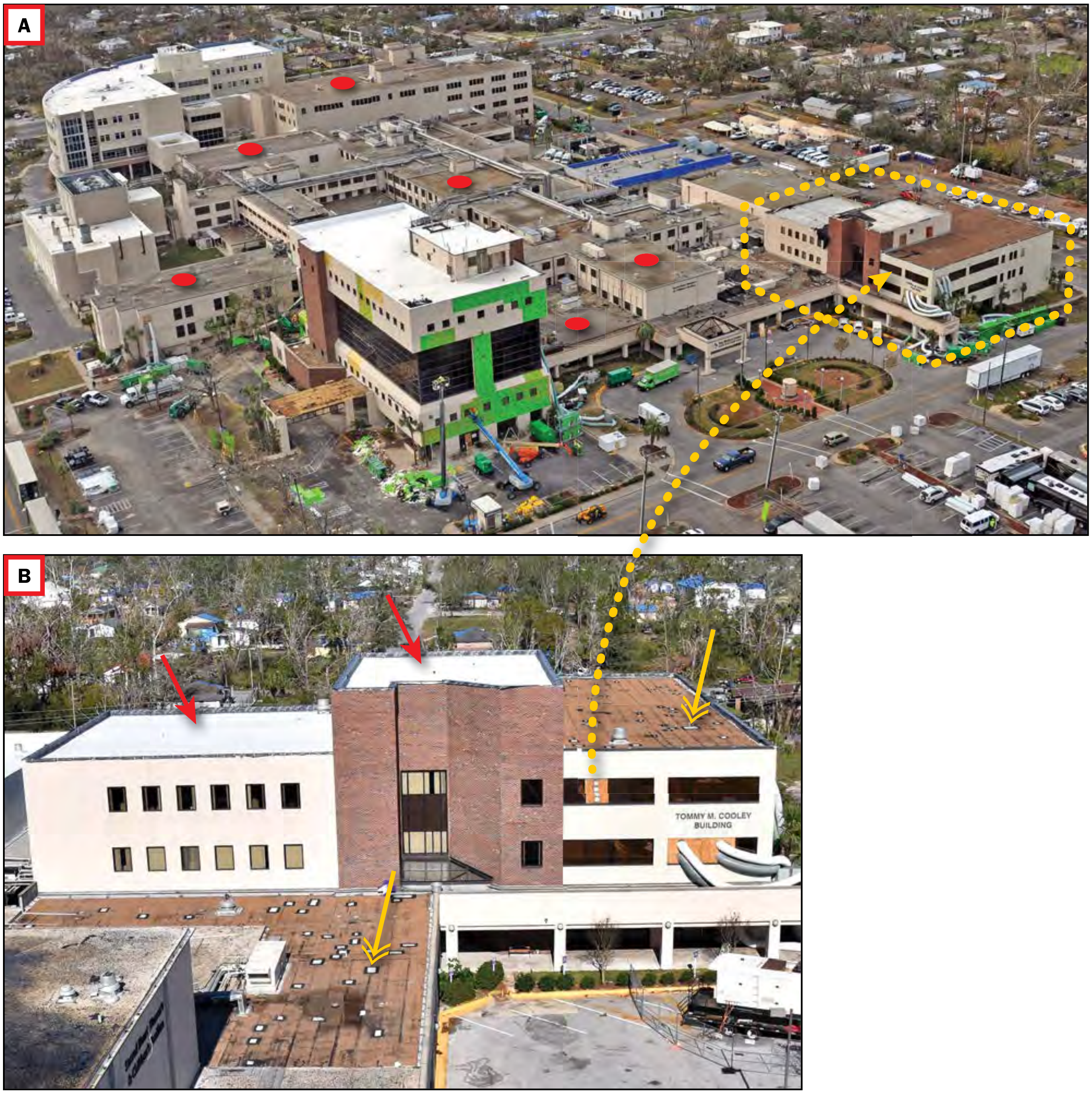


Legend:

1 = Patient Care Tower (2010)
2 = Outpatient
3 = Emergency, Heart and Vascular
4 = Cancer Center
5 = Select Specialty
6 = Admissions
7 = Classrooms
8 = Administration
9 = Women and Children's Pavilion
10 = Laboratory and Convent Hospice
11 = Medical Office Building

The red arrows indicate areas where the roof membranes blew off.
The yellow double arrow indicates damaged metal roof panels.

Figure 5-69: Aerial view of the Bay Medical Sacred Heart Health System Hospital (Panama City, FL)



[A] The red dots indicate aggregate surface built-up roofs (BURs), which were a major source of wind-borne debris. The yellow outline indicates the Administration Building No. 8, which is shown in photo B.

[B] The red arrows indicate where roof membranes blew off. The yellow double arrows point to white temporary patches where the roofs were punctured by wind-borne debris. The roof coverings that blew off and those that were patched were bituminous cap sheet membranes. The base sheet of coverings that blew off were mechanically attached to lightweight insulating concrete.

Figure 5-70: Overview of wind damage at the Bay Medical Sacred Heart campus (Panama City, FL)

The MAT observed damage at Building No. 1, the Patient Care Tower built in 2010, as well other buildings on the campus, described below.

Building No. 1, Patient Care Tower (2010). Figure 5-71 through Figure 5-79 show the five-story 2010 Patient Care Tower (which included the intensive care unit). As shown in Figure 5-69, more than half of the single-ply roof membrane blew off. Several ceiling boards at the fifth floor were wetted by roof leakage and collapsed. However, there was not widespread interior water damage under the area where the roof membrane blew off. Apparently, there was a concrete topping over the steel deck, which limited the amount of leakage into the building. In addition to Figure 5-70, Figure 5-71 through Figure 5-73 show various types of roof and rooftop equipment damage. Figure 5-74 through Figure 5-76 show glazing damage. Figure 5-77 and Figure 5-78 show EIFS damage. Figure 5-79 shows soffit damage.

The MAT collected a sample of aggregate from the roof that was the primary source of aggregate that struck the Patient Care Tower (2010) for laboratory analysis of gradation and density. The 4.676 pound sample was analyzed by Intertek PSI. The aggregate had a specific gravity of 2.61,[12] and the gradation met the sieve requirement in ASTM D1863 for Size Number 67 (3/4 inch to number 4 [4.75 mm]). The gradation complies with the requirement in the FBC. The FBC requires a minimum of 4 pounds of aggregate per square foot, with a 50 percent minimum embedment in the flood coat, which has been the roofing industry's practice for many decades. It appeared that the total aggregate coverage and embedment generally complied with the FBC.

Figure 5-71: Damaged base flashing, Building No. 1, Patient Care Tower (2010) (Panama City, FL)

The base flashing blew off the parapet in the area where the roof membrane blew off. The portion of the parapet shown above was in an area where the membrane did not blow off. The base flashing had detached from the substrate. The base flashing was also torn by wind-borne debris (a putty knife is shown in the tear for scale). FEMA 577 recommends and provides design guidance for placing metal panels on furring strips over the base flashing to protect it from wind-borne debris and subsequent leakage.

12 The 2.61 specific gravity of the sample is similar to the 2.7 specific gravity that was used in Design of Rooftops Against Gravel Blow-Off (Kind and Wardlaw, 1976).

ROOF AGGREGATE IN HURRICANE-PRONE REGIONS

Numerous wind damage investigations have documented glazing broken by wind-borne roof aggregate, and subsequent interior wind pressure and water damage. The 2006 edition of the IBC added a provision that prohibited roof aggregate in hurricane-prone regions. The provision pertains to new buildings and reroofing projects. Neither the IBC nor the International Existing Building Code requires replacement of aggregate surface roofs.

The FBC still allows installation of aggregate surface roofs.

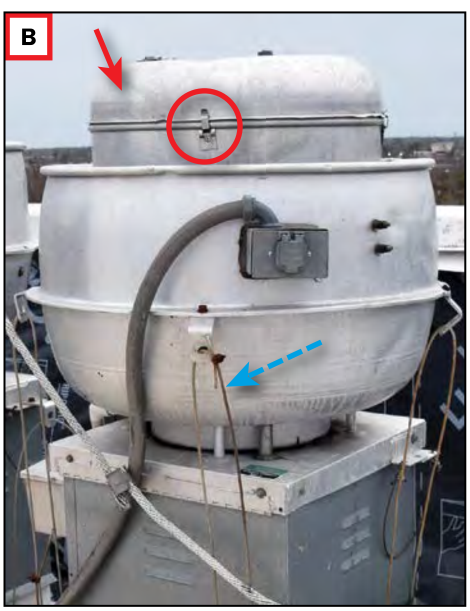


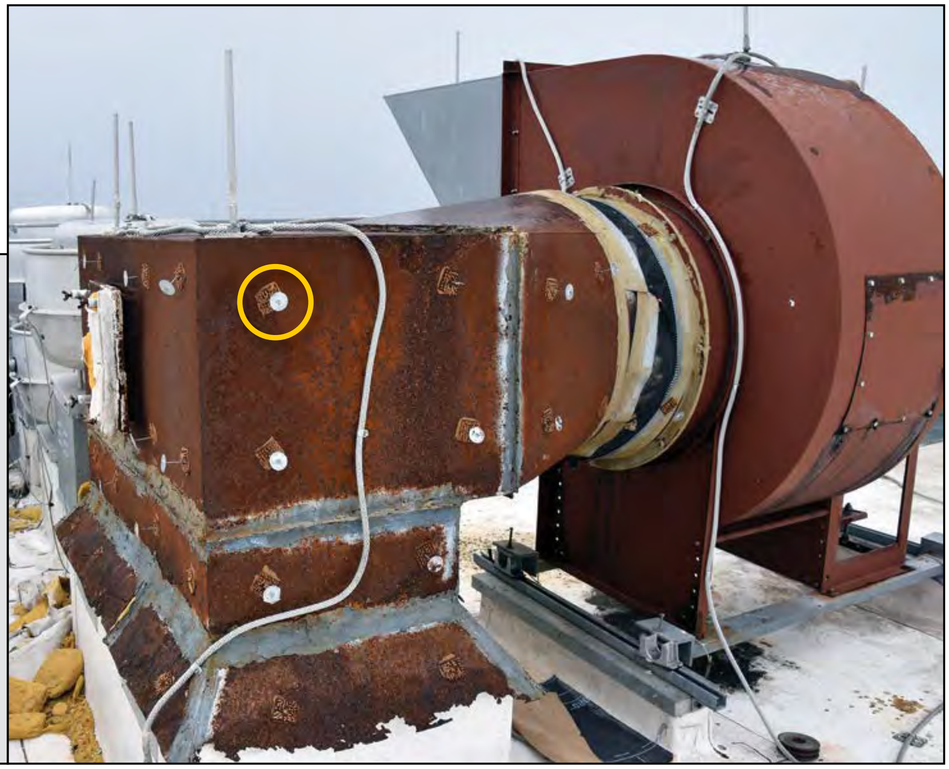
Figure 5-72: A portion of the roof that was not blown off Building No. 1, Patient Care Tower, showing damage to rooftop equipment (2010) (Panama City, FL)

[A] The fan in the foreground was struck by wind-borne debris. The top portion of the cowling on this fan and the one beyond were blown off. The top cowlings were attached to the lower portion of the cowling (see B, red circle) with a snap clip. Loss of the cowling in the foreground was likely caused by debris impact. However, loss of the cowling beyond was likely caused by the clip unlatching. The blue arrow indicates detached base flashing. The fan's disconnect switch bracket was not anchored to the roof deck. The green dotted arrow indicates a detached LPS conductor.

[B] A fan with the top cowling (red arrow) in place. The blue dashed arrow indicates a cable that anchored the outer cowling to the curb (similar to a connection shown in FEMA 577).

Figure 5-73: Insulation was blown off rooftop ductwork, Building No. 1, Patient Care Tower (2010) (Panama City, FL)

The insulation was attached with stickpins that had washers (yellow circle).
There were four failure modes: the base plate debonded from the duct, the pin failed in tension, the washer pulled off the pin, and the insulation pulled over the washer. Wind-borne stickpin and insulation debris can damage other building components and clog roof drains.



The dark roofs are aggregate surface BURs; they do not have parapets. Most of the outer panes (tempered glass) of the windows in the windward walls of the tower were broken by wind-borne roof aggregate (red arrows). Some of the small blunt fragments of the tempered glass fell on lower single-ply membrane roofs (blue dashed arrow). The impacted roofs were not punctured. Had annealed or heat-strengthened glass been used in lieu of tempered glass, shards would have been generated, which would have likely punctured the roof membranes. The red dashed outline indicates where the EIFS gypsum board substrate blew off the studs (see Figure 5-78 for repair work). The green dotted arrow indicates a temporary repair where the roof membrane blew off. Brick veneer collapsed from walls on the other side of the penthouse indicated by the yellow arrow (see Figure 5-80).

Figure 5-74: Damage at the windward walls of Building No. 1, Patient Care Tower (2010) (Panama City, FL)

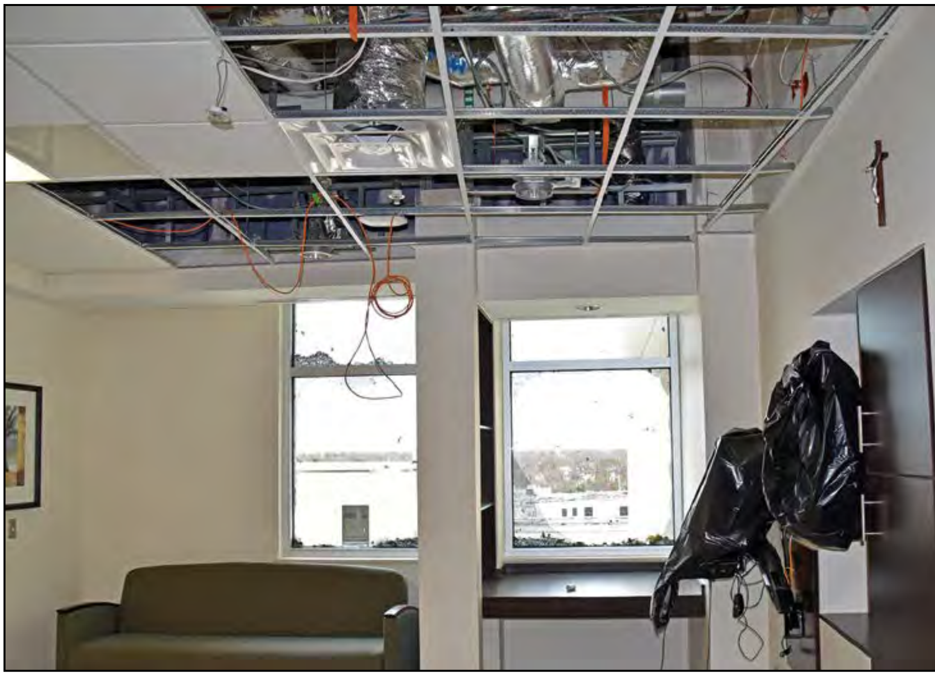


Figure 5-75: View within a fifth floor patient room in Building No. 1, Patient Care Tower (2010) (Panama City, FL)

All four of the tempered glass outer panes in this room were broken by wind-borne roof aggregate. The inner laminated glass panes were not broken; these panes prevented the entry of wind and wind-driven rain, although some window leakage was reported. Wetted ceiling boards had collapsed.

Figure 5-76: Damaged lobby widows in Building No. 1, Patient Care Tower (2010) (Panama City, FL)

All of the outer tempered glass panes shown in this figure were broken by wind-borne aggregate from one of the roofs shown in Figure 5-74. Several of the laminated glass inner panes were also broken, but the polymer interlayer prevented the entry of wind and wind-driven rain.

Figure 5-77: Repairing the damaged EIFS shown in Figure 5-74, Building No. 1, Patient Care Tower (2010) (Panama City, FL)

The Patient Care Tower's wall assembly consisted of synthetic stucco, rigid insulation, metal studs, and gypsum board (one layer over the exterior face of the metal studs and another layer on the inner face of the metal studs). This type of wall assembly is insufficient to resist wind-borne debris that has high momentum, and numerous wind damage investigations have documented poor wind performance. FEMA 577 does not recommend this type of wall assembly for hospitals located in hurricane-prone regions.

The red boxes indicate where wind-borne debris damaged the EIFS. These impacts were on the leeward side of the tower. They illustrate that debris can strike multiple stories above grade.

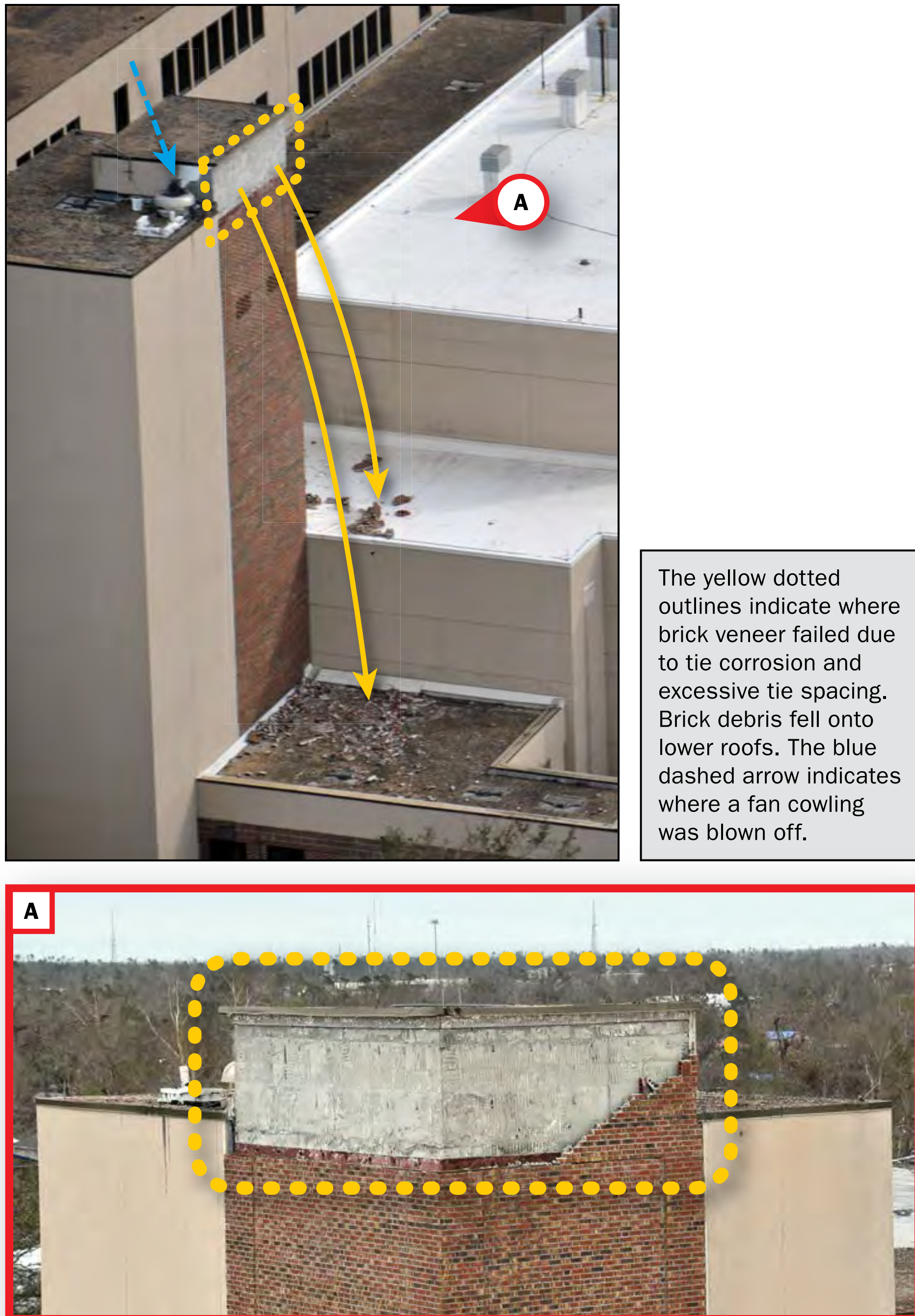
Figure 5-78: Wind-borne debris wall damage at Building No. 1, Patient Care Tower (2010) (Panama City, FL)

Other buildings on campus. In addition to damage observed at the Patient Care Tower, the MAT observed damage at other locations on the campus. The damage included:

- Brick veneer (Figure 5-80)
- Glazing damage (Figure 5-81, Figure 5-82, Figure 5-85, Figure 5-86)
- EIFS damage (Figure 5-81, Figure 5-85, Figure 5-86)
- Stucco damage (Figure 5-82)
- Shutter corrosion (Figure 5-83)
- Coping and flashing blow-off (Figure 5-84)
- Roof damage (Figure 5-70, Figure 5-82, Figure 5-85)

Figure 5-79: Damaged soffit panels at Building No. 1, Patient Care Tower (2010) (Panama City, FL)

Figure 5-80: Brick veneer blow-off. See Figure 5-74 for location. (Panama City, FL)



The yellow dotted outlines indicate where brick veneer failed due to tie corrosion and excessive tie spacing. Brick debris fell onto lower roofs. The blue dashed arrow indicates where a fan cowling was blown off.

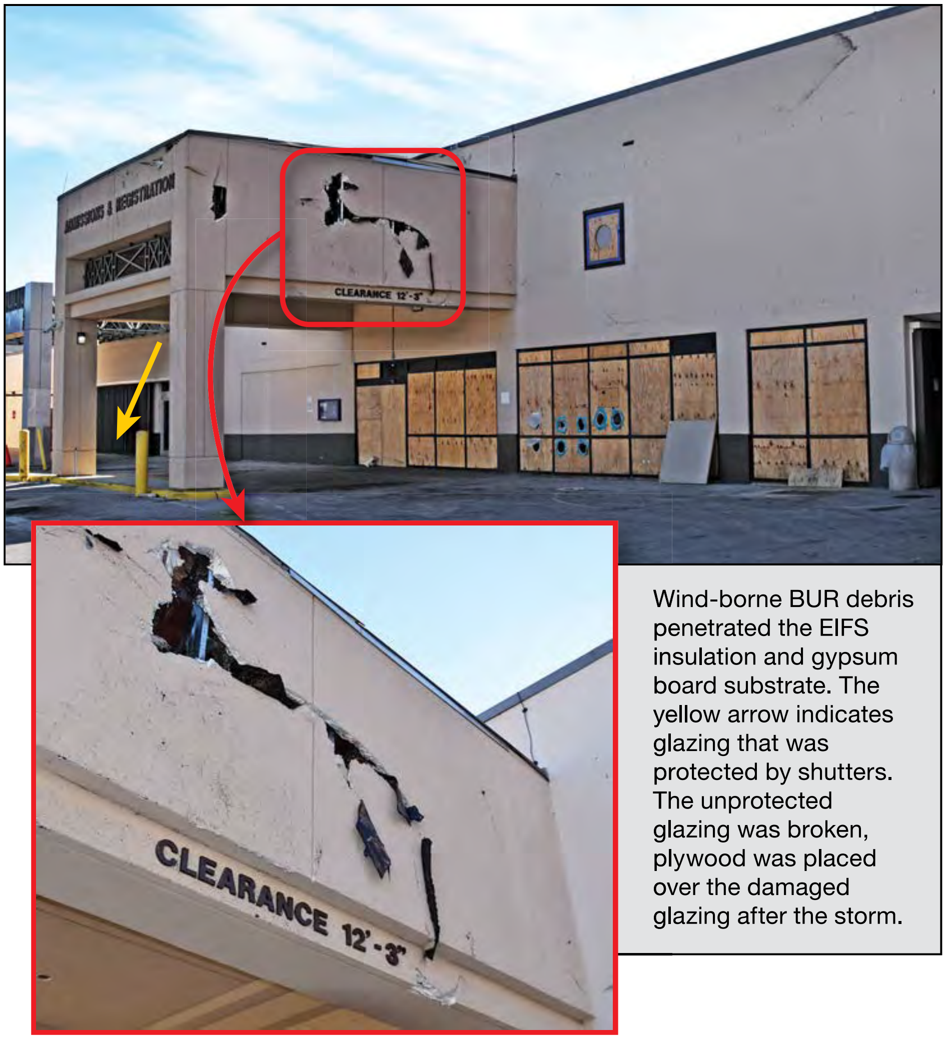


Figure 5-81: Broken glazing and damaged EIFS at Building No. 1, Admissions (Panama City, FL)

Wind-borne BUR debris penetrated the EIFS insulation and gypsum board substrate. The yellow arrow indicates glazing that was protected by shutters. The unprotected glazing was broken, plywood was placed over the damaged glazing after the storm.

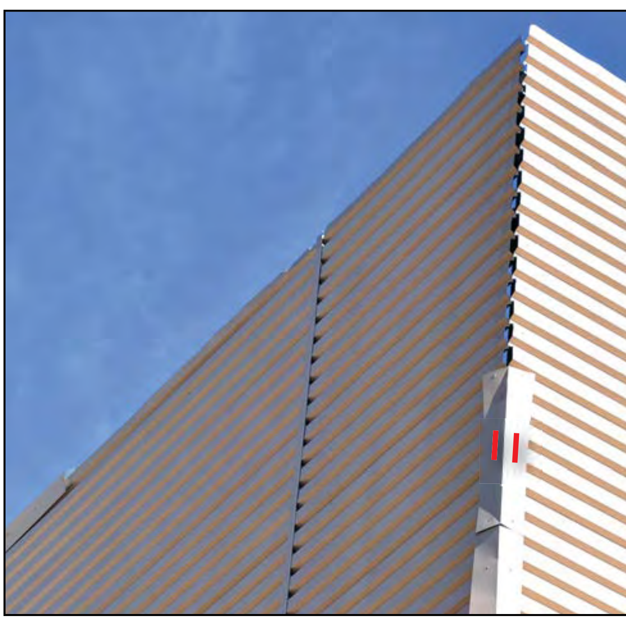
The yellow double arrows indicate CMU. The red arrows indicate stucco. The blue dashed arrows indicate metal roof panel seams that opened up and allowed the fiberglass insulation to blow out.

Figure 5-82: Damaged stucco and glazing at Building No. 7, Classrooms (Panama City, FL)

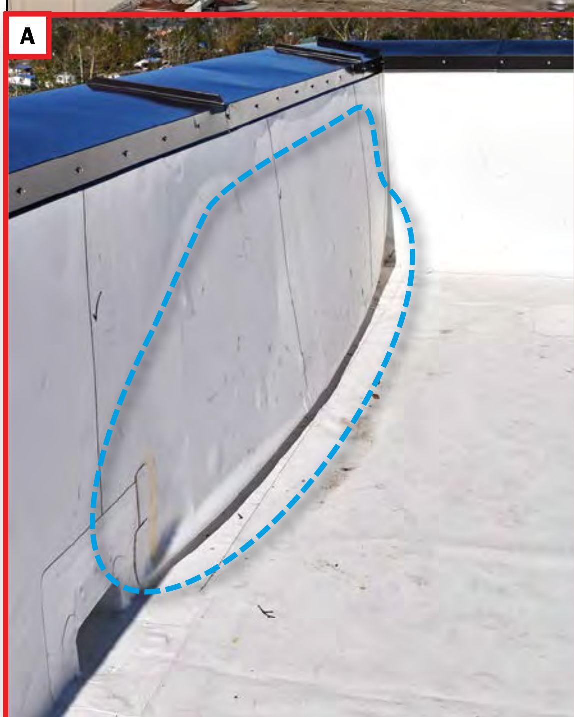
Figure 5-83: Permanently mounted screen shutters at Building No. 9, Women's and Children's Pavilion (Panama City, FL)

A portion of a screen was severely corroded; it was no longer capable of protecting the glazing.

Figure 5-84: Coping and corner flashing blow-off at a metal screen wall (Panama City, FL)



The corner flashing was attached with a single row of screws on each flange (red lines). The screws were near the center of the flanges, which allowed the edge of the flashing to lift. Wind-borne copings and flashings can puncture roof membranes and may injure people coming to a hospital during a storm.



[A] At the red circle, EIFS insulation and some gypsum board adjacent to the coping blew off. The inset shows the back side of the parapet in this area. The base flashing remained adhered to the sheathing, but the sheathing detached from the metal studs (blue dashed outline). The blue arrows indicate other areas where EIFS gypsum board blew off. The green and yellow patches are where EIFS repairs are underway.

[B] At the green circle, the nailer lifted and caused progressive lifting and peeling of the roof membrane. The nailer was part of the original construction but its attachment was apparently not checked when the building was reroofed.

Several windows on the west facade were broken; likely by wind-borne roof aggregate. The yellow double arrow indicates a detached LPS conductor.

Figure 5-85: Damage at the roof, west and south facades of Building No. 9, Medical Office Building (Panama City, FL)

Several windows on the north façade were broken, likely by wind-borne roof aggregate. The green and yellow areas are where EIFS repairs are underway. The inset shows one of the upper floors of this building after water-damaged ceiling boards and gypsum wall board were removed.

The red arrow indicates broken skylight glazing likely caused by wind-borne BUR debris from Building No. 8, Administration.

Figure 5-86: Damage at the north and east facades of Building No. 9, Medical Office Building (Panama City, FL)

Operations During Event and Functional Loss. About 1,500 people occupied the hospital campus during the hurricane, including family members and pets. It was reported that the emergency room was “inundated” by people seeking shelter. No occupants were injured during the storm. When the outer panes of the 2010 Patient Care Tower started to break, there was concern about the safety of about 40 patients (post-heart surgery patients, critically ill septic patients, and respiratory patients on ventilators). Those patients were moved to rooms without exterior windows on lower floors.

The day after hurricane landfall, evacuation (including about 200 patients) of the entire facility commenced, except for the emergency room.

Municipal electrical power was interrupted for 9 days after hurricane landfall. During this time, power was provided by several generators. Municipal water service was interrupted for 4 or 5 days. In the interim, water was provided by an on-site well and tanker trucks. Lack of water initially prevented the flushing of toilets.

At the time of the pre-MAT visit, the first floor lobby of Building No. 1, Patient Care Tower (2010) was operational. The first phase of reopening began on January 2, 2019, with 75 patient beds, eight operating rooms, and five cardiac catherization labs. More than 600 employees were laid off in February 2019 and in March, it was announced that obstetrical services were being eliminated because of limited space options in the first phase of reconstruction. The rebuilding project is estimated to cost $47 million.

5.2.5.2 Encompass Health Rehabilitation Hospital of Panama City

Facility Description. The Encompass Health Rehabilitation Hospital was built in 1997. It has 75 beds. All or a portion of the facility was reroofed in 2015.The building was retrofitted with laminated glass window and door assemblies.

Wind Damage Observations. The MAT visited the facility on January 7, 2019 (91 days after hurricane landfall). Damage is shown in Figure 5-87, an aerial view of the facility from shortly after Hurricane Michael.

The standing seam metal panels were blown off most of the west side of the gym (Figure 5-87 and Figure 5-88), which resulted in extensive interior water damage. Installation of a new roof system on one of the wings was underway at the time of the MAT visit. Reroofing of this area was apparently needed because of the amount of rain that got underneath the roof membrane at punctures caused by wind-borne debris. Coping blew off the entry canopy and a rooftop HVAC unit reportedly blew off the roof.

The MAT did not observe any window or door assemblies, including those that had been retrofitted, that were impacted by wind-borne debris, but the MAT did not check all of them for debris impact. Some of the retrofitted window assemblies leaked. There were problems with the glass sliding automatic entrances (doors). The doors reportedly

ENCOMPASS HEALTH REHABILITATION HOSPITAL SITE CONDITIONS

Estimated wind speed = 127 mph

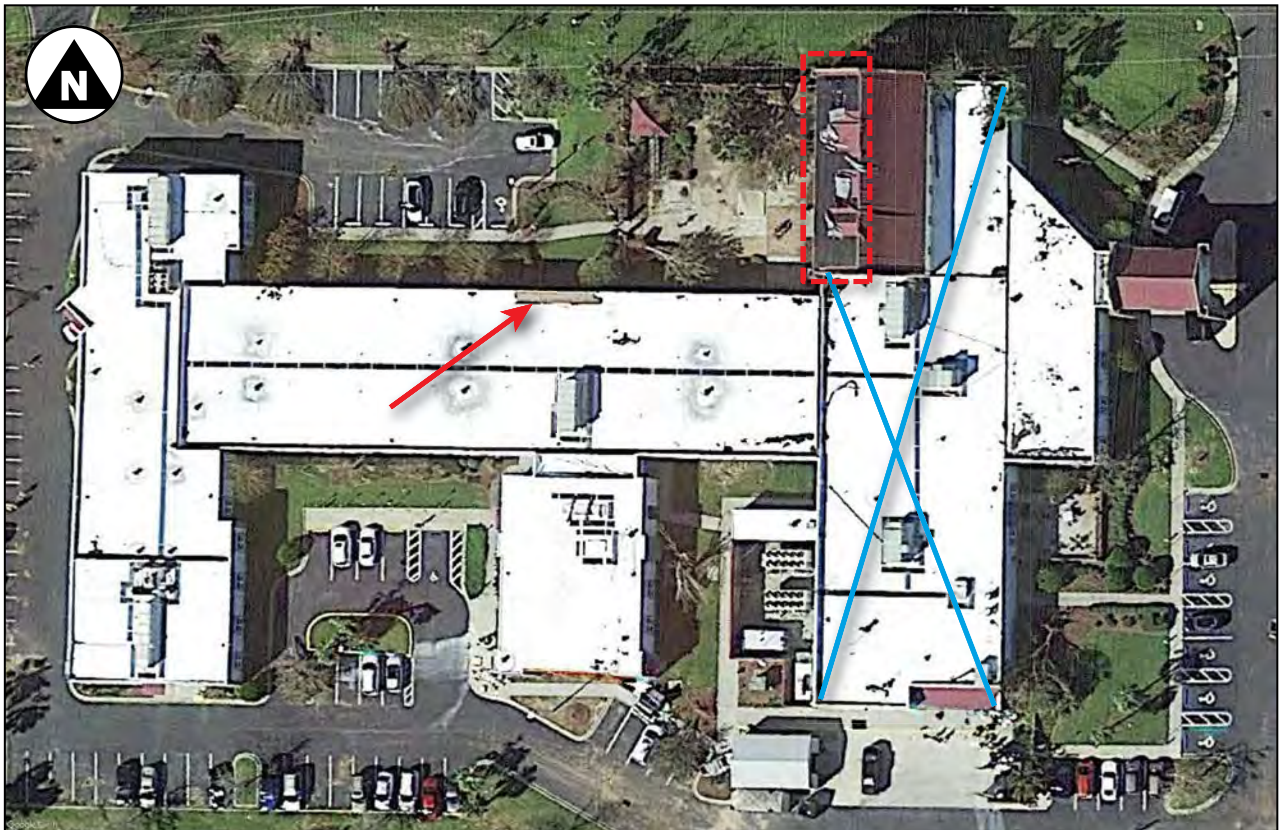
Location = Exposure B

ASCE 7-16 basic wind speed = 147 mph (Risk Category IV)

GLASS SLIDING AUTOMATIC ENTRANCES

Assemblies are now available to cope with challenges presented by hurricanes:

- To prevent the door from opening automatically when wind-borne debris blows past the door, the door can be placed in a manual mode. In this mode, the door is locked to resist positive and negative air pressure.
- To accommodate emergency egress when in the manual/locked mode, the door is equipped with panic release hardware.
- To accommodate wind-borne debris, door and sidelite assemblies are available that have passed testing with the ASTM D1996 test missile E.



The red dashed rectangle indicates where the metal roof panels blew off the gym. Installation of a new roof system at the area shown by the blue X was underway at the time of the MAT visit. The red arrow indicates parapet base flashing damage shown in Figure 5-88.

Figure 5-87: Aerial view of Encompass Health Rehabilitation Hospital (Panama City, FL)

The yellow area is an emergency roof repair over the gym. The red outline indicates emergency repair at damaged parapet base flashing. The black areas are emergency repairs at roof membrane punctures.

Figure 5-88: Roof damage at the Encompass Health Rehabilitation Hospital (Panama City, FL)

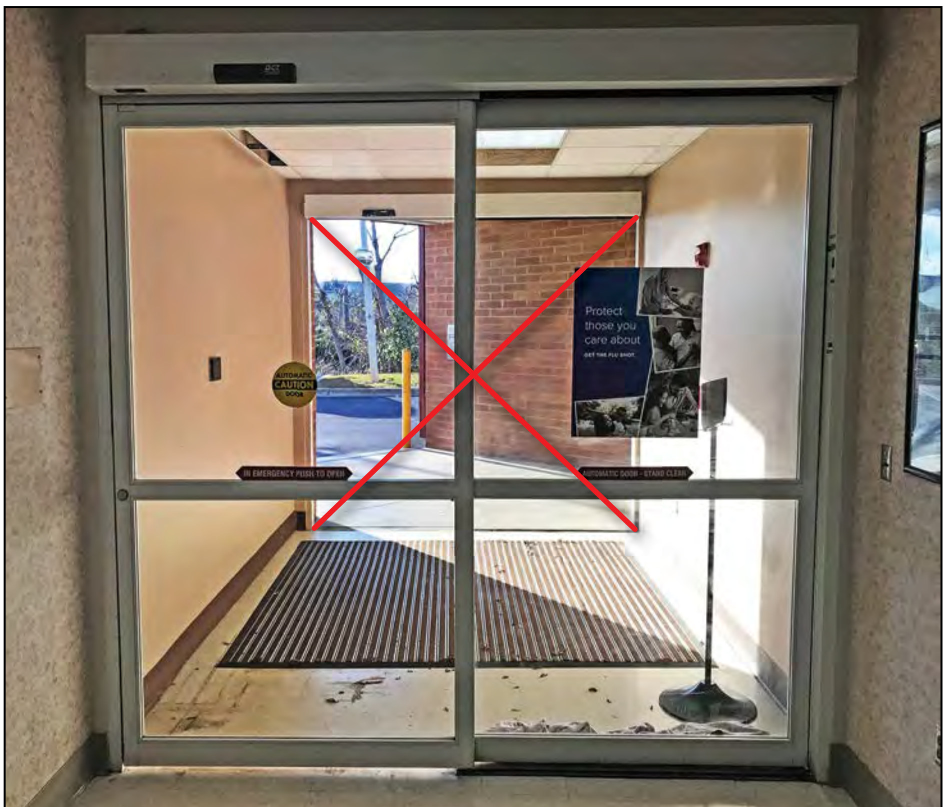
opened during the storm; facility maintenance staff attributed the openings to wind pressures that exceeded pressure that is required to manually open the door during panic egress. Also, at both entrances, the outer door and sidelite blew away (Figure 5-89 and Figure 5-90). Hospital staff braced the interior door and sidelite at the main entry.

Operations During Event and Functional Loss. The Encompass Health Rehabilitation Hospital housed 53 patients during the hurricane. The hospital was shut down after hurricane landfall. Municipal water and sewer were interrupted for 3 to 4 weeks. Municipal power was also interrupted, but the hospital's generator provided power. The hospital reopened on November 19, 2018 (40 days after hurricane landfall).

LOBBY VESTIBULE WIND LOADS

ASCE 7-16 does not provide wind load criteria for the ceiling/roof of a lobby, the interior walls of the lobby, and the inner door and sidelite in the event that the exterior door is breached. Breaching of the exterior door would lead to increased pressure within the vestibule. To avoid free entry of wind and rain into the interior of a building in the event of exterior door failure, the interior vestibule envelope could be designed for the same pressures as the exterior wall and door.

Figure 5-89: West entry door failure (Panama City, FL)



The exterior glass sliding automatic door and sidelite were blown away (red X). The interior door and sidelite remained in place and prevented free entry of wind and rain into the interior of the hospital. Although the interior walls of the lobby were exposed to increased air pressure after the door failure, they apparently were not over-stressed.

Figure 5-90: East (main) entry door failure (Panama City, FL)

As at the west entry, the exterior glass sliding automatic door and sidelite at the east entry were blown away (red X). The interior door and sidelite remained in place and prevented free entry of wind and rain into the interior of the hospital. Although the interior walls of the lobby were exposed to increased air pressure after the door failure, they apparently were not over-stressed.

5.2.5.3 Jackson Hospital

Facility Description. Jackson Hospital is a 100-bed hospital that opened in 1979.

Wind Damage Observations. The Jackson Hospital had some minor damage to rooftop equipment, wind-driven rain infiltration, and fallen trees. Figure 5-91 is a view at the time of the pre-MAT visit on October 25, 2018 (15 days after hurricane landfall). Damage to the building is shown in Figure 5-92 and Figure 5-93. Figure 5-94 shows a fan supported by vibration isolators on an equipment stand.

JACKSON HOSPITAL SITE CONDITIONS

Estimated wind speed = 115 mph

Location = Exposure B

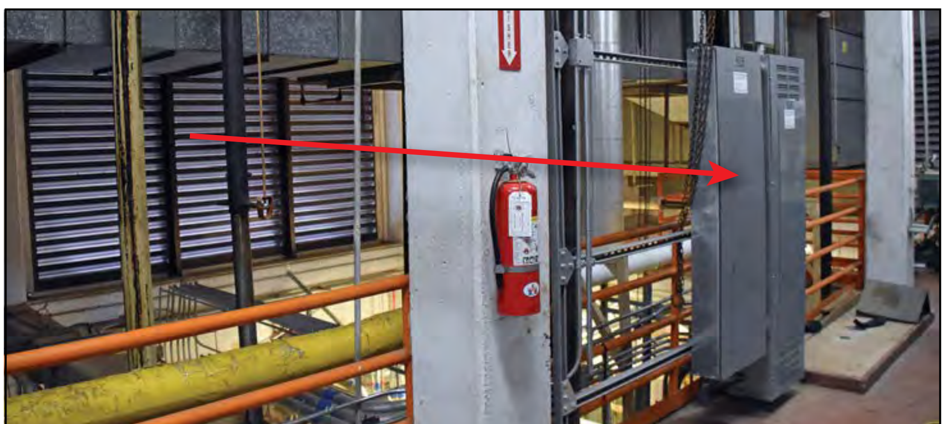
ASCE 7-16 basic wind speed = 133 mph (Risk Category IV)

Figure 5-91: Jackson Hospital (Marianna, FL)

Figure 5-92: Rooftop equipment damage at the tower roof (Marianna, FL)

The cowling at the left fan lifted, but did not blow off. The adjacent fan blew away.

Figure 5-93: Wind-driven rain infiltration at a mechanical equipment room (Marianna, FL)



Although the estimated wind speed was only 115 mph, rain was driven several feet past the louvers and wetted the electrical panels, which caused the circuit breakers to trip. The panels were dried with a hair dryer and the breakers reset.

Figure 5-94: Cable tie-down for equipment mounted on vibration isolators (Marianna, FL)

The vibration isolators provided lateral resistance but no uplift resistance. Cable tie-downs had been installed to provide uplift resistance beyond that provided by the dead load of the equipment. FEMA 577 recommends such an attachment enhancement.

Several large trees were within lay-down distance of the roads on the hospital campus (Figure 5-95). Many trees fell during the hurricane, but most of them did not fall onto the road.

Figure 5-95: Downed trees along a Jackson Hospital campus road (Marianna, FL)

BEST PRACTICE: TREES

FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (2007b), recommends for hospitals that poles, towers, and trees with trunks larger than 6 inches be located away from primary site access roads so that they do not block access to, or hit, the facility if toppled.

In contrast to the relatively small amount of damage that occurred at Jackson Hospital, a two-story medical office building adjacent to the hospital experienced rooftop equipment and roof membrane damage that resulted in significant water infiltration at both floors.

Operations During Event and Functional Loss. The hospital was occupied during the hurricane. The minor wind damage and water infiltration had limited impact on operations during and after the hurricane. However, municipal water service was interrupted. The hospital did not have an on-site well or water storage tank, so it had to be evacuated because of lack of water for fire sprinklers.

The hospital had installed two additional emergency generators prior to the hurricane to augment the original generator. One generator was dedicated to serving the emergency circuits, another was dedicated serving air conditioning equipment, and the third generator served the normal power circuits. Hence, if municipal power had been interrupted, there was sufficient emergency power to energize all circuits. The generators were configured so that if the generator serving the emergency circuits or the air conditioning equipment failed, the generator serving the normal circuits could drop those circuits and replace the failed generator.

BEST PRACTICE: BACK-UP WATER SUPPLY

FEMA 577 (2007b) recommends that hospitals in hurricane-prone regions have an on-site well or water storage tank to cope with interruption of municipal water service.

BEST PRACTICE: EMERGENCY GENERATORS

FEMA P-1019, Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability (2014) describes methods to keep critical facilities operational during power outages.

5.2.6 Critical Facilities – Schools

The MAT visited 11 schools and observed a few others from the helicopter reconnaissance conducted during the pre-MAT. Section 5.1.3 provides information about a school that had an unsuccessful wind retrofit; that school was not used as a shelter. Some of the schools that were used as shelters are discussed in Section 5.2.3. This section describes another school that was not used as a shelter, Tyndall Elementary School.

5.2.6.1 Tyndall Elementary School

Facility Description. Tyndall Elementary School is part of the Bay District School System and is located just outside of Tyndall Air Force Base. Original construction dates back to 1952; newer buildings have been added since. The latest, Building #8, an MBS, was constructed in 2000.

According to information shared by school staff, 798 students were enrolled before Hurricane Michael, but attendance had dwindled to approximately 200 students by early 2019, primarily as a result of post-storm relocation of families stationed at the base.

TYNDALL ELEMENTARY SCHOOL SITE CONDITIONS

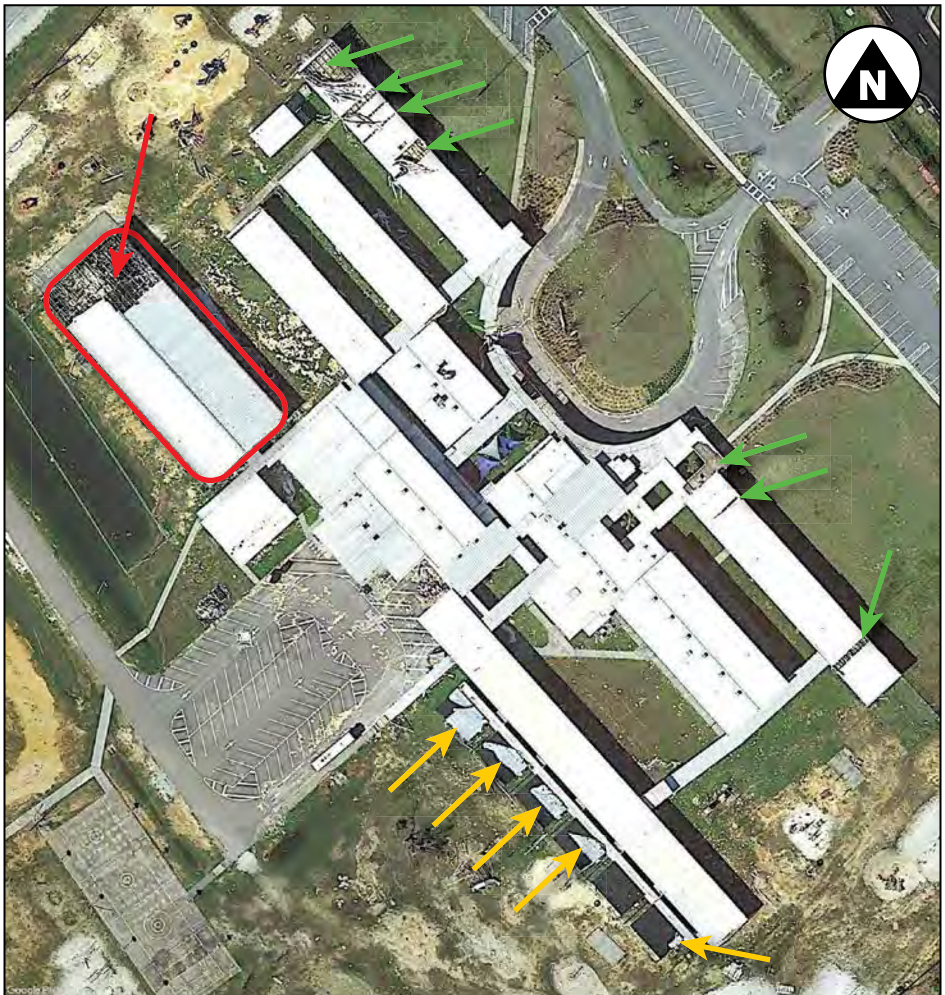
Estimated wind speed = 135 mph

Location = Exposure B, with adjacent open patches all around the campus

ASCE 7-16 basic wind speed = 145 mph (Risk Category III)

Wind Damage Observations. The MAT visited the school on January 9, 2019 (93 days after hurricane landfall). Damage is shown in Figure 5-96, an aerial view of the facility shortly after Hurricane Michael and in Figure 5-97, a view of the facility at the time of the MAT.

Figure 5-96: Aerial view of Tyndall Elementary School Building No. 8 (Panama City, FL)



Aerial view of Tyndall Elementary School shortly after Hurricane Michael. The MBS with the roof and end wall failure (red arrow) is indicated by the red box. The green arrows indicate roof covering blow-off. The yellow arrows indicate roof covering blow-off at portable classroom buildings.

Figure 5-97: Tyndall Elementary School with damaged roof area (blue tarps) on the right end of photograph (shown in inset) (Panama City, FL)

Building No. 8 had a failed end wall and several structural standing seam trapezoidal metal roof panels were blown off (Figure 5-98). This type of metal panel system does not provide any significant resistance to lateral loads (i.e., it is not a diaphragm). To resist lateral loads parallel to the ridge, cable x-bracing was provided (Figure 5-99). The roof panels between the failed end wall and first main frame were blown off, as were the panels between the first and second main frames. At the time of the MAT visit, missing metal panels had been temporarily replaced with plywood, as indicated in Figure 5-100 and Figure 5-101. Some metal wall panels on the end wall were also blown off.

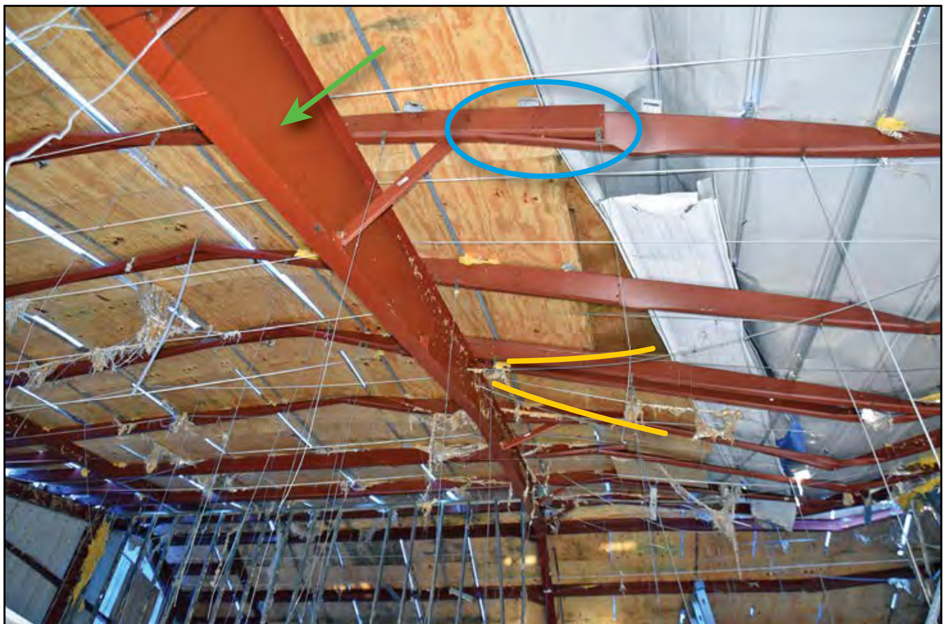
Figure 5-99 illustrates structural roof damage on either side of the first main frame where purlins buckled.

Figure 5-100 and Figure 5-101 are interior views of the damaged end wall, which was observed to be out of plumb.

The MAT was unable to obtain the contract drawings, specifications, and submittals needed to evaluate Building No. 8's wind resistance. Without the drawings, it is not possible to determine whether the ceiling, duct, and piping loads hung off the purlin were accounted for. Hanging these loads off the purlin lips can distort the geometry of the purlin and adversely affect wind resistance if not addressed by system design. Also, without the drawings it is not possible to determine whether the purlin overlap shown in Figure 5-99 and other structural details complied with the design. It is also unclear what design loads were used for this building. Accordingly, it is not possible to determine whether the end wall failure was due to a design or installation deficiency(s).

Operations During Event. The school was not occupied during the storm.

Figure 5-98: Blue tarps cover portions of the failed end wall and damaged roof areas of Building No. 8 (Panama City, FL)



The northwest end bay is to the left of the main frame indicated by the green arrow. The yellow lines indicate cable x-bracing. The purlin overlap (blue oval) may not have been installed with the proper number of bolts.

Figure 5-99: Structural roof damage at Building No. 8 (Panama City, FL)

Figure 5-100: Interior view of the damaged northwest end bay of Building No. 8 (Panama City, FL)

Figure 5-101: Interior view of damaged end wall of Building No. 8 (Panama City, FL)

Yellow arrows indicate twisted end wall girts between columns. The metal cladding between girts has deformed under pressure.

5.2.7 Critical Facilities – Other Types of Buildings

This section addresses types of critical facilities that are not EOCs, shelters, first responder, hospitals, nursing homes, or schools. Facilities in this section are government buildings that are not thought of as critical. Depending upon the type of services that are provided in local, state, or federal government buildings, they could be designed as Risk Category II, III, or IV.

The following Bay County facilities would prudently be designed as Risk Category III because of their importance to the community.

5.2.7.1 Bay County Administration

BAY COUNTY ADMINISTRATION SITE CONDITIONS

Estimated wind speed = 128 mph

Location = Exposure B, with adjacent open patches to the west, east, and southeast, and an open patch to the north.

ASCE 7-16 basic wind speed = 144 mph (Risk Category III)

Facility Description. The Bay County Administration building opened in approximately 2009. It had structural standing seam metal roof panels over steel deck over steel joists. According to interviews with staff, the building serves as a multi-function complex for county services.

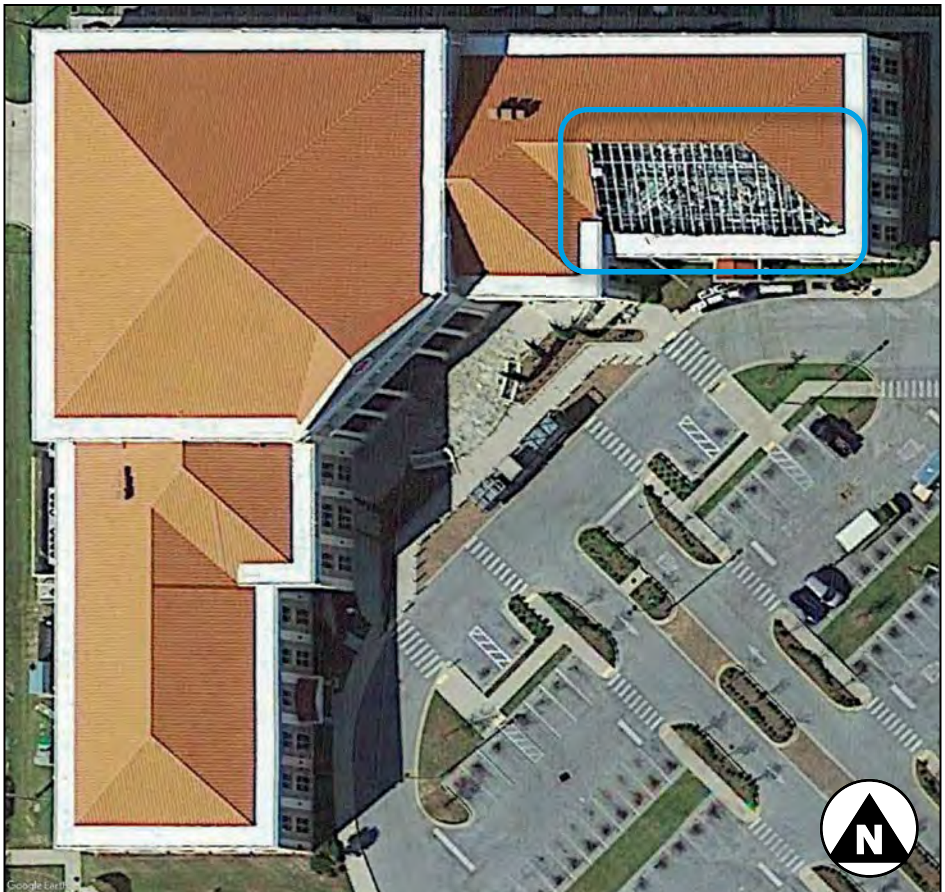
Wind Damage Observations. The pre-MAT visited the facility on October 25, 2018 (15 days after hurricane landfall). Figure 5-102 is an aerial view of the facility shortly after Hurricane Michael and Figure 5-103 is a view at the time of the pre-MAT visit.

A portion of the steel roof deck blew off during the hurricane, which allowed rain and debris to freely enter the building. Figure 5-104 is a view of the attic space after an emergency roof had been installed. The deck was screwed to cold-formed steel roof trusses. In some undamaged and damaged areas, the deck was screwed to the truss at each bottom flange (Figure 5-105 and Figure 5-106). However, along one of the trusses in the damaged area, several screws had not been installed (Figure 5-107). Based on these observations, it appeared the lack of several contiguous fasteners in one or more localized areas caused the deck blow-off. The deck blow-off did not damage the trusses that were observed by the MAT.

In addition to the roof deck damage, a metal exit door blew outward. It had been replaced at the time of the MAT visit. The door failure resulted in water damage in the auditorium and hallway to the door.

Operations During Event and Functional Loss. There were three or four occupants in the Bay County Administration building during the hurricane, but it was not operational during the storm. In addition to water that entered the building where the roof deck blew off, some fire sprinklers discharged water (the activation was not caused by fire). The building was closed to the public for 3 weeks after Hurricane Michael.

Figure 5-102: Aerial view of the Bay County Administration facility (Panama City, FL)



The steel roof deck and metal roof panels blew off at the area indicated by the blue rectangle.

An emergency roof covering had been installed where the roof deck blew off (red outline).

Figure 5-103: Front of the Bay County Administration facility (Panama City, FL)

OSB was placed over the trusses after the storm to support an emergency roof covering. Prior to placing the OSB, the offices below were open to the sky.

Figure 5-104: Attic space where the roof deck blew off (Panama City, FL)

In this area, each bottom flange (rib) of the deck was screwed to the truss.

Figure 5-105: An area near the deck blow-off (Panama City, FL)

In this area, it was apparent that the deck screws pulled out of the truss. Each bottom flange was screwed to the truss in this area. Pull-out of these screws was likely a progressive failure, with failure beginning at an area with insufficient deck attachment, such as shown at Figure 5-107.

Figure 5-106: An area where the deck blew off (Panama City, FL)

Figure 5-107: A boundary of the deck blow-off (Panama City, FL)

The red arrows indicate screws that were added after the blow-off to secure the temporary 2x4s. The yellow double arrow indicates the only screw in this area between the steel deck and the truss.

5.2.7.2 Bay County Courthouse

Facility Description. The Bay County Courthouse building includes a historic building that is approximately 100 years old with an adjoining addition that was opened in 2016.

Wind Damage Observations. The MAT visited the Courthouse on January 9, 2019 (93 days after hurricane landfall). Damage is shown in Figure 5-108, an aerial view of the facility taken shortly after Hurricane Michael and Figure 5-109, a view at the time of the MAT visit.

The building addition had soffit, brick veneer, downspout and gutter blow-off (Figure 5-110); ridge and hip flashing deficiencies (Figure 5-111 and Figure 5-112); and roof membrane damage (Figure 5-108, Figure 5-113, and Figure 5-115). The historic building had metal roof panel blow-off (Figure 5-108, Figure 5-114, and Figure 5-115) and brick damage (Figure 5-114 and Figure 5-115).

BAY COUNTY COURTHOUSE SITE CONDITIONS

Estimated wind speed = 128 mph

Location = Exposure B, with open patches adjacent to the northeast, east, and south, and open patches to the south and southeast.

ASCE 7-16 basic wind speed = 144 mph (Risk Category III)

While the large rooftop HVAC unit shown in Figure 5-116 did not fail, the MAT observed attachment concerns.

Functional Loss. Permanent roof repairs commenced in June 2019, for a cost of $1,377,127. This work is estimated to take 6 months. The interior repair work is estimated to cost $477,000 and is expected to be completed by April 2020.

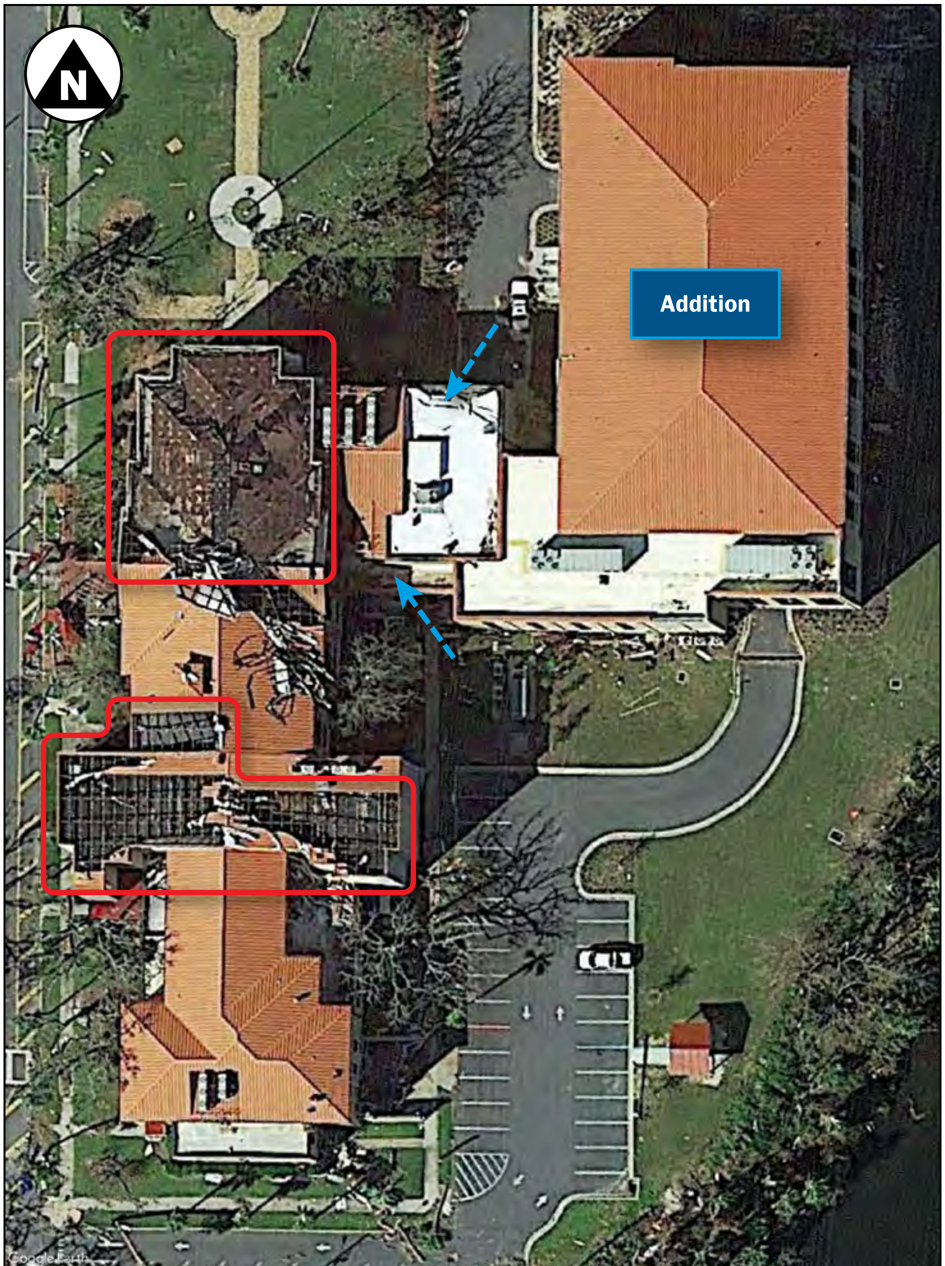
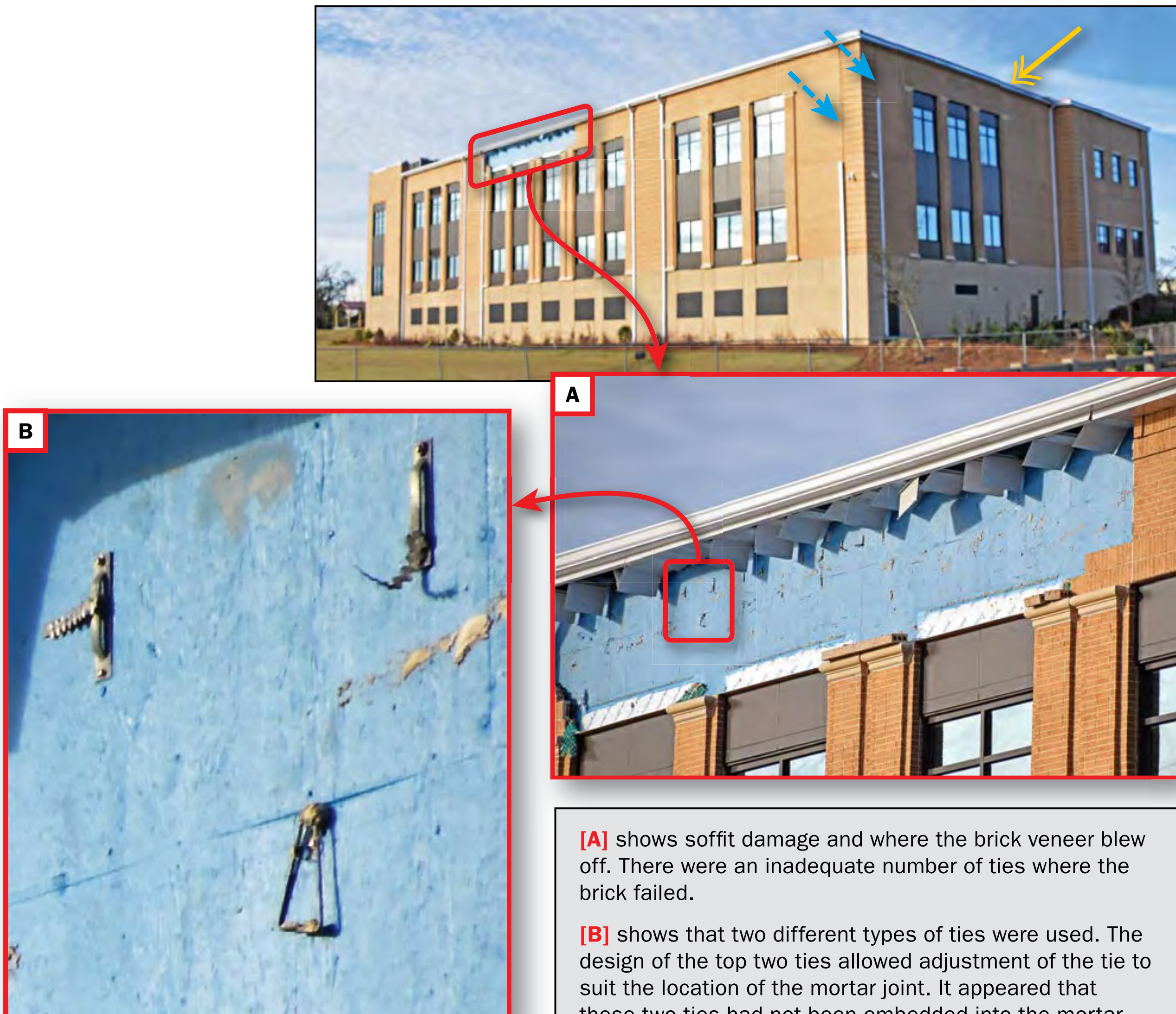


Figure 5-108: Aerial view of the Bay County Courthouse (Panama City, FL)

The red outlines indicate areas where the structural standing seam roof panels blew off the historic building. The blue dotted arrows indicate roof membrane damage (refer also to Figures 5-113 and 5-115).

The addition is at the left and the historic building is at the right.

Figure 5-109: Bay County Courthouse complex (Panama City, FL)



[A] shows soffit damage and where the brick veneer blew off. There were an inadequate number of ties where the brick failed.

[B] shows that two different types of ties were used. The design of the top two ties allowed adjustment of the tie to suit the location of the mortar joint. It appeared that these two ties had not been embedded into the mortar. The yellow double arrow indicates where a portion of the gutter blew off. The blue dashed arrows indicate where portions of the downspout blew off.

Figure 5-110: Bay County Courthouse addition (Panama City, FL)

The ridge flashing was inadequately attached. There was only a single row of rivets on either side of the ridgeline. The rivets were 16 inches apart where the ridge flashing lifted. The spacing is too far apart. Screws provide more reliable flashing attachment. The lifted flashing was no longer able to prevent entrance of wind-driven rain.

Figure 5-111: Ridge flashing at the Bay County Courthouse addition (Panama City, FL)

It appeared that only one foam closure was installed on either side of the hipline. Sealant was placed between the metal panel and foam closure (yellow double arrow). However, as shown by the putty knife, the sealant did not provide a continuous barrier to wind-driven rain, which is important if only one closure is installed. In a high-wind region, it is prudent to install two closures (see figure in textbox titled “Recommended Roof Hip and Ridge Closure” in Section 5.1.2).

Figure 5-112: Hip flashing at the Bay County Courthouse addition (Panama City, FL)

Figure 5-113: Roof membrane punctured by wind-borne debris at the Bay County Courthouse addition (Panama City, FL)

This mechanically attached single-ply membrane was punctured by wind-borne debris. Emergency repairs were performed with sprayed polyurethane foam (SPF). SPF is a fast, effective way to perform emergency repairs. This illustrates the amount of debris that can be generated during a hurricane. It appeared that the debris source was the metal roof panels from the historic building (see Figure 5-108).

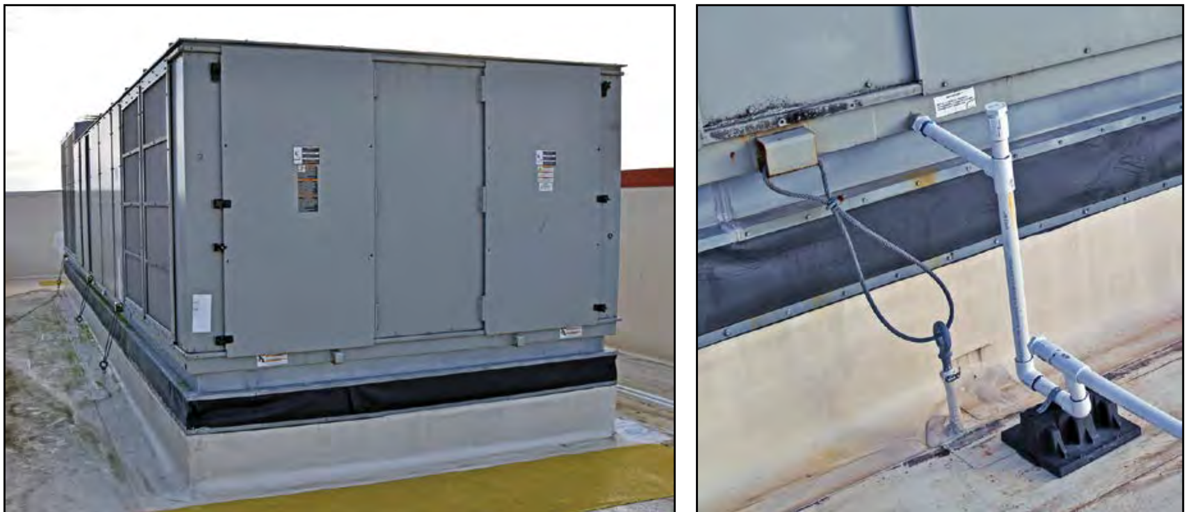
The blue dashed arrow indicates an emergency roof membrane where metal roof panels blew off. The inset indicates an area where roof panels were blown off; the emergency membrane had not been installed. The white areas in the inset are emergency SPF repairs. The SPF had been coated, which is not necessary for an emergency repair. The yellow dotted outline indicates the area shown in Figure 5-115.

Figure 5-114: Roof covering damage at the Bay County Courthouse and addition (Panama City, FL)

[A] Stone coping was blown off (yellow double arrow). SPF had been applied along parapet base flashing and at numerous punctures on this mechanically attached single-ply membrane. The red outlined area shows the location of photo [B].

[B] Shows the open brick joints and the missing brick (blue dashed arrow).

Figure 5-115: Roof and wall damage at the Bay County Courthouse (Panama City, FL)



This unit had three cable tie-downs on each side. The three tie-downs on the left side of the unit were taut and the unit did not shift.

The tie-downs on the right side were not taut. When tie-downs are not taut, units can lift and shift off of their curb.

Figure 5-116: Attachment of an HVAC unit on the Bay County Courthouse addition

CHAPTER 6
Conclusions and Recommendations

The conclusions and recommendations are intended to help reduce future damage and impacts from flood and wind events similar to Hurricane Michael.

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

The recommendations are intended to assist FEMA, the State of Florida, communities, designers, contractors, building officials, facility managers, floodplain administrators, regulators, emergency managers, building owners, academia, select industries and associations, local officials, various agencies and organizations, and individuals in the reconstruction process. The recommendations will also help FEMA coordinate with agencies and organizations to help assess hazard-resistant provisions of building codes and standards, improve planning, outreach, training, design and construction among many other efforts, to ultimately minimize future injuries, reduce damage and enhance community resilience.

The organization of Chapter 6 is shown in Table 6-1.

Table 6-1: Chapter Organization

Section	Description
6.1	Overview of the conclusions and recommendations based on the MAT's observations
6.2	General conclusions and recommendations related to floodplain management, inspections, and training
6.3	Flood-related conclusions and recommendations correlated to building codes, standards, and regulations
6.4	Wind-related conclusions and recommendations correlated to building codes, standards, and regulations
6.5	Flood-related building performance conclusions and recommendations
6.6	Wind-related building performance conclusions and recommendations, with the residential focus presented in Section 6.6.1 and the non-residential focus presented in Section 6.6.2
6.7	Crosswalk matrix, in tabular format, of the MAT's observations (with section number), conclusions and recommendations, and the pertinent action office / Recovery Support Function (RSF)

6.1 Overview of Conclusions and Recommendations

The conclusions in the sections that follow are drawn from the MAT observations discussed in previous chapters. Each conclusion sets up a list of specific recommendations. The recommendations are presented as guidance to the many stakeholders listed in the introduction to this chapter and those who are involved with the design, construction, and maintenance of the built environment in the state, as well as other regions impacted by hurricanes. 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.

The following overall conclusions provide a snapshot of the overarching themes that form the basis of the more specific conclusions and recommendations presented herein:

- 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. However, codes and standards are minimum requirements, and there is room for improvement given the degree of damage still being observed. The use of best practices, especially with respect to water intrusion, would further mitigate that damage. Furthermore, building codes must be properly enforced and implemented to perform 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. Elevation, as well as proper siting, matters.
- Wind-related damage was observed for both pre- and post-FBC buildings. Although structural damage observations were almost exclusively limited to pre-FBC residential buildings (with only a few exceptions), 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.

- Best practices can be implemented to help further protect buildings from wind- and flood-related damage. Vulnerability assessments should be performed for critical facilities (at a minimum), and recommended mitigation actions following these assessments should be implemented as efficiently as possible to protect a building as a whole.
- A retrofit to protect a single building element is typically not effective in protecting the entire building.

APPLYING RESIDENTIAL BUILDING RECOMMENDATIONS TO NON-RESIDENTIAL BUILDINGS

Different components of and themes from the recommendations presented for residential buildings can be adapted and applied to non-residential buildings, and vice-versa. The MAT recommends a registered design professional be consulted for specific applications. Questions can also be directed to the FEMA Building Science Helpline at FEMA-Buildingsciencehelp@fema.dhs.gov regarding if specific recommendations from Section 6.4 can be pertinent to non-residential buildings.

6.2 General Conclusions and Recommendations

Conclusion FL-1

Floodplain management requirements were inconsistently enforced.

The MAT observed numerous inconsistencies in local floodplain management regulation enforcement, as well as non-compliance, across the sites visited.

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 Building Officials Association of Florida (BOAF), should develop training on the flood provisions in the FBC and local floodplain management ordinances, specifically about building enclosures, with emphasis on the use of flood damage-resistant materials below the required lowest floor elevation as well as a local official's role in Substantial Damage determinations. This training should be for builders, developers, floodplain administrators, building officials, plan reviewers, and building inspectors.

Recommendation FL-1b. BOAF and other stakeholders should consider developing additional training on roles and responsibilities for communities contracting building department services to a private company.

BOAF and other stakeholders should consider developing a job aid or guidance along with additional training that addresses the roles and responsibilities of a building department in the post-disaster environment. In particular, the training should emphasize who performs post-disaster safety evaluations of buildings as well as Substantial Damage determinations for buildings in the regulated floodplain, especially when day-to-day building department services are contracted out by a community. Finally, the training should include information regarding Statewide Mutual Aid Agreements (SMAAs) and encourage building departments to conduct pre-event evaluations of post-disaster needs and communicate with appropriate parties about coordinating resources.

Conclusion FL-2

In-progress inspections of building envelope components throughout Florida were inconsistently performed.

Discussions with local code enforcement personnel in Florida exposed inconsistencies with respect to inspections of building envelope components such as roof coverings, underlayment, wall coverings, and soffits.

Recommendation FL-2a. Local jurisdictions should make building envelope inspections a priority.

Although the FBC requires roof coverings to be inspected, in practice, very few jurisdictions perform in-progress roof covering inspections because of timing, liability, and other factors. Very few, if any, jurisdictions perform in-progress wall covering and soffit inspections.

Recommendation FL-2b. BOAF, FHBA, and other stakeholders should consider developing training and creating a culture of emphasis on building envelope systems.

BOAF, Florida Home Builders Association (FHBA), and other stakeholders should consider developing training and creating a culture of emphasis on the use of appropriate building envelope products that have been designed and tested for high-wind locations. This topic could be addressed in conjunction with continuing education courses on the building code. Best practices for minimizing water infiltration from wind-driven rain should be covered.

6.3 Flood-Related Building Codes, Standards, and Regulations Conclusions and Recommendations

Conclusion FL-3

Officials in most communities visited by the MAT did not have a clear understanding of Substantial Improvement / Substantial Damage requirements and the process for making Substantial Improvement / Substantial Damage determinations.

The FBC flood provisions apply to new construction, Substantial Improvement, and repair of Substantial Damage. Although FBC Chapter 1, Scope and Administration, does not explicitly provide criteria for making Substantial Improvement / Substantial Damage determinations, local floodplain management regulations do include a section on these determinations and direct coordination with the Building Official. Some communities affected by Hurricane Michael amended the FBC for cumulative Substantial Improvement or amended the Substantial Damage definition to include repetitive flood loss.

Recommendation #FL-3a. FEMA should update FEMA P-758 and concurrently update FEMA 213 to be consistent with the updated FEMA P-758.

FEMA P-758, *Substantial Improvement/ Substantial Damage Desk Reference* (2010h) should be updated. Updates should include lessons learned, recommended guidance and clarifications provided by FEMA since it was published in 2010, and guidance on developing local Substantial Improvement / Substantial Damage procedures. At the same time, FEMA 213, *Answers to Questions about Substantially Improved/Substantially*

Damaged Buildings (2018a) should be updated to be consistent with the updated FEMA P-758. Outreach material should be developed as part of the publication updates. The updates should include roles and responsibilities for executing the inspections (e.g., floodplain administrator, building official, any private contractors, mutual aid, state, federal).

Recommendation #FL-3b. FEMA should consider expanding/clarifying 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 stakeholders or entities related to Substantial Improvement / Substantial Damage. The materials should incorporate lessons learned after Hurricane Michael and other recent flood events. The materials should include a practical step-by-step lesson in cost estimating and market values and making Substantial Improvement / Substantial Damage determinations. Information to help develop local Substantial Improvement / Substantial Damage procedures should also be included. For example, roles and responsibilities for executing inspections should be defined. The training should have 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-4

Some communities visited by the MAT use the services of private companies for some or all building department operations but do not include administration of local floodplain management regulations, which can create gaps in administration of requirements for flood hazard areas.

Community officials advised that private service provider contracts typically are limited to administration of the FBC, and do not include administration of floodplain management regulations. Local floodplain management regulations are written to work with the FBC and include administrative responsibilities and requirements for development other than buildings.

Recommendation #FL-4. Communities should outline clear and consistent responsibilities when contracting with private-sector providers to administer all or part of the community's responsibilities under the FBC.

In particular, the contracts should be clear about whether the assigned responsibilities include administering the community's floodplain management regulations. Special attention should be paid to post-disaster inspections and permitting and making Substantial Damage determinations. When floodplain management responsibilities are not contracted out, those responsibilities must be carried out by the community if it is an NFIP participating community.

Conclusion FL-5

Numerous local government departments do not appear to be adequately coordinating to enforce floodplain regulations and flood provisions of the FBC in a post-disaster environment, due in part to the number of permit applications submitted and limited staff capacity.

Some jurisdictions did not have coordination between floodplain management offices and building departments with respect to inspecting damaged buildings for life-safety, conducting Substantial

Damage determinations, verifying Substantial Improvement projects, reviewing permit applications for repairs, and enforcing FBC requirements during the post-disaster recovery period. Because a large number of permit applications were submitted in a short time after the event, some communities did not have adequate time or resources to coordinate or properly perform their duties.

Recommendation #FL-5a. FEMA should provide guidance to state and local governments on seeking assistance related to building code and floodplain management ordinance administration and enforcement authorized under Section 1206 of the DRRA.

With the passing of Section 1206 of the Disaster Recovery Reform Act of 2018 (DRRA), policies and procedures are needed to help state and local governments seek financial assistance for building code and floodplain management enforcement. This should help communities better plan for post-disaster enforcement, including establishment of pre-event mutual aid agreements.

Recommendation #FL-5b. FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through SMAA and EMAC.

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 interstate Emergency Management Assistance Compact (EMAC). 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 BOAF and FFMA to develop strategies under their SMAA and should recruit professional assistance to support communities in need. FDEM should also consider training designers 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.

6.4 Wind-Related Building Codes, Standards, and Regulations Conclusions and Recommendations

Conclusion FL-6

Testing standards for door and window assemblies did not appear to adequately help prevent water infiltration.

In multiple locations, the MAT observed broken laminated glass or undamaged doors that remained in the frame but allowed water infiltration; the leakage may have been related to installation deficiencies. Although the products observed were tested for the region in which they were installed, the damage indicates the performance measures in current testing requirements may not adequately address water infiltration, especially with respect to limiting infiltration of wind-driven rain.

Recommendation #FL-6. FEMA should work with AAMA/WDMA/CSA, IBHS, ASTM, ICC, and other select industry partners to incorporate more comprehensive water intrusion testing requirements that improve overall performance into testing standards.

Using damage observations made after Hurricane Harvey and Hurricane Michael, the FEMA Building Science Branch should collaborate with American Architectural Manufacturers Association (AAMA) / Window and Door Manufacturers Association (WDMA) / Canadian Standards Association (CSA), IBHS, ASTM, ICC, and other select industry partners to identify trends in damage (e.g., interior finishes subject to water intrusion/wind-driven rain) that are potentially a result of inadequate testing requirements and work to incorporate water infiltration testing after impact. For example, ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*, the standard for glazing protection systems impacted by test missiles and exposed to cyclic pressure differentials, does not consider water leakage after debris impact, nor does it consider debris impact to the framing around the opening. The current testing standard evaluates missile impacts to the glazing, but the framing around the glazing is not impacted during testing.

Conclusion FL-7

The basic wind speeds for the Florida Panhandle may not accurately reflect the appropriate wind hazard for the region.

Hurricane Michael produced wind speeds above design levels in certain areas of the Florida Panhandle.

Recommendation #FL-7. The wind engineering research community should perform a revised analysis of the ASCE 7 basic wind speed maps for the Florida Panhandle region to include data from Hurricane Michael.

The wind research engineering community should perform a revised analysis of the ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures,* basic wind speed maps for the Florida Panhandle region to include data from Hurricane Michael. This study can then be submitted to the ASCE 7 Wind Load Committee so that it can provide its determination of whether the current wind design requirements for the Florida Panhandle are reflective of the hazard for that region given recent events.

Conclusion FL-8

Damage to glazing is not limited to within the 1-mile area of the coast, and can occur much farther inland.

Given the timing of the MAT, much of the observed glazed opening damage had been covered by plywood or tarps to prevent further water infiltration. However, although the MAT could not verify much of the glazed opening damage was explicitly attributable to wind-borne debris, it is highly likely that wind-borne debris was a significant contributor in many instances.

Recommendation #FL-8a. The FBC should treat all areas within 1 mile inland from the entire Florida coastline as a WBDR.

The MAT observed that buildings experienced damage from wind-borne debris within 1 mile of the coast, which leads to further damage from wind pressures and wind-driven rain. Currently, only Risk Category III healthcare facilities and Risk Category IV buildings have all areas within 1 mile inland from the Florida coastline defined as a WBDR.

Recommendation #FL-8b. The ASCE 7 Wind Load Task Committee should revise ASCE 7 to lower the basic wind speed trigger in ASCE 7 for requiring glazing to be protected on Risk Category IV buildings in the hurricane-prone region.
Given the critical functions of Risk Category IV buildings, the Wind Task Committee should lower the basic wind speed trigger in ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures,* for requiring protected glazing on Risk Category IV buildings. The MAT observed costly damage, degraded capabilities, and increased recovery repair time to Risk Category IV buildings as a result of breached glazing. Currently, the existing trigger depends on the location of the Risk Category IV building. The hurricane-prone region is defined by ASCE 7-16, where the basic wind speed for Risk Category II buildings is greater than 115 mph along the Atlantic coast and Gulf of Mexico coast (as well as Hawaii, Puerto Rico, Guam, U.S. Virgin Islands, and American Samoa). Glazed openings in Risk Category II, III, or IV buildings located in hurricane-prone regions shall be protected as specified in Section 26.12.3 of ASCE 7-16.

Recommendation #FL-8c. Building owners outside the WBDR but within the hurricane-prone 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, but outside of the WBDR, 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 they are unwilling to tolerate risks associated with debris impacts due to design windspeeds.

Recommendation #FL-8d. The IBC/IRC/FBC should be updated where needed to ensure glazed window, skylight, door, and shutter assemblies have a permanent label that provides traceability to the manufacturer and product.
The manufacturer and product label will help users determine the design pressure rating, as well as the test method and test missiles that were used to evaluate the assembly. This will help with enforcement of the use of proper assemblies in the WBDR, as well as post-storm damage assessments for adequacy. Protected glazing and shutter assemblies observed by the MAT often did not have labels indicating whether they were tested assemblies. Also, while some products had labels, they did not indicate the test method and/or the test missile utilized. The IRC already requires shutters to have a permanent label. The IBC will likely do the same in the 2021 edition, as a similar code change is moving through the process and was approved by the Code Development Committee. The FBC requires shutters to be labeled and requires glazed openings to have a permanent label that provides traceability to the manufacturer and product. However, the IBC/IRC/FBC should update their requirements so that permanent labels for glazed window, skylight, door, and shutter assemblies are included in their respective provisions.

Recommendation #FL-8e. The ASCE 7 Wind Load Subcommittee should consider developing commentary on vestibule wind loads.
Currently, ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures,* does not address wind loads on the ceiling/roof, interior walls, or the interior

doors of a vestibule. In the event that the exterior door or envelope is breached, the vestibule is subjected to increased pressure. The commentary in ASCE 7 should advise that to avoid free entry of wind and rain into the interior of a building in the event of exterior door failure, the interior vestibule envelope could be designed for the same pressures as the exterior wall and door.

6.5 Flood-Related Conclusions and Recommendations

Conclusion FL-9

Many houses in the unshaded Zone X (area of minimal flood hazard) experienced just as much damage as those in the SFHA (in this case, Zone AE).

Based on NFIP claims data, the average flood insurance claim in Mexico Beach was higher outside (approximately $110,000) the SFHA than within (approximately $95,000) the SFHA. Across the four coastal counties visited by the MAT, the average claim inside the SFHA was approximately $40,000 compared to $50,000 outside.

Recommendation #FL-9. Communities should consider more stringent building requirements for development or reconstruction in the unshaded Zone X (area of minimal flood hazard) and shaded Zone X (area of moderate flood hazard).

Although the minimal and moderate flood hazard areas may have a lower probability of flooding, there is a residual risk as the flood hazard does not stop at the extent of the SFHA and the exposure to damage does not change. Following Hurricane Harvey, the City of Houston and Harris County now regulate based on the 500-year floodplain, in addition to having a DFE that exceeds the 0.2-percent-annual-chance (or 500-year) flood elevation.

Conclusion FL-10

Multiple concrete pile foundations, some with unknown pile embedment depth, suffered rotational failure.

The MAT observed numerous concrete piles that failed from rotational forces. When assessing the piles, the MAT observed no labels or markers that could help determine embedment lengths or help building officials in their assessments.

Recommendation #FL-10a. Industry groups, interested stakeholders, and/or academia should further evaluate the performance of the concrete pile foundations that failed during Hurricane Michael to determine why they failed.

The MAT observed instances where scour and erosion exceeded the ability of the pile/column foundation to remain vertical. There were also some instances where lateral loads and bending moments appeared to exceed the material properties of the foundation piles/columns, causing them to crack and break. Industry groups and interested parties (e.g., FEMA Building Science Branch, DHS Science and Technology Directorate, the National Institute of Standards and Technology's Disaster and Failure Studies Program, National Science Foundation, NOAA Sea Grant, IBHS, ASCE, and FBC), as well as academia, should consider collaborating to determine the cause of the observed failures, whether by undersized piles, improperly embedded piles, insufficient lateral bracing, defective manufacturing, or some other cause. The analysis should also evaluate material properties versus flood load foundation calculations, such as the flood loads methodology presented in ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures,* and FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations* (2009b).

Recommendation #FL-10b. FEMA and FDEM should consider providing a code change proposal to the I-Codes requiring contractors and/or manufacturers to add length labels or incremental depth markers on vertical piles.

These labels would help in construction management, quality control, code enforcement, and as post-disaster or damage assessments to quickly determine the embedment length and/or depth or failure mode. In addition, added emphasis should be placed on the requirement for inspections and certified inspection reports to be submitted to the local Building Official by a registered design professional where special conditions exist as authorized by the FBC.

Conclusion FL-11

Flood damage can occur to critical facilities outside the SFHA.

In particular, the MAT observed flood damage to a relatively new critical facility, which likely could have been avoided had the facility been evaluated for vulnerabilities to flooding in excess of the base flood, with corrective actions (i.e., additional freeboard) taken to address those vulnerabilities.

Recommendation #FL-11a. FEMA and FDEM should consider submitting a code change proposal to the FBC, applying ASCE 24 Flood Design Class 4 requirements outside the SFHA in moderate flood hazard areas (shaded Zone X) and to consider flood risk for minimal flood hazard areas (unshaded Zone X).

ASCE 24, *Flood Resistant Design and Construction*, and most model building code and floodplain management ordinance requirements only apply to buildings within the SFHA. Given the frequent need for critical facilities to continue operations during, or immediately after, flood events, communities and other developers should be required to evaluate flood hazards when planning, constructing, and renovating Flood Design Class 4 (essential facilities) outside the SFHA. When located in moderate flood hazard areas (shaded Zone X), essential facilities should be designed in accordance with ASCE 24. When located in minimal flood hazard areas (unshaded Zone X), communities and other developers should be encouraged to examine proximity to flood hazard areas and incorporate flood risk reduction measures where appropriate.

Recommendation #FL-11b. FEMA should consider developing a change proposal for ASCE 24 requiring consideration of flood risk for essential facilities outside the SFHA in minimal flood hazard areas (unshaded Zone X) and requiring Flood Design Class 4 to apply in moderate flood zones outside the SFHA (shaded Zone X).

Currently, ASCE 24, *Flood Resistant Design and Construction,* and most model building code and floodplain management ordinance requirements only apply to buildings within the SFHA. Given the frequent need for critical facilities to continue operations during, or immediately after, an event, communities should be required to evaluate the flood hazard when constructing or renovating essential facilities outside the SFHA. FEMA should consider developing code change proposals implementing flood risk reduction measures in minimal flood hazard areas when appropriate, and requiring Flood Design Class 4 be applied in moderate flood hazard areas.

Conclusion FL-12

Non-elevated or insufficiently elevated buildings sustained damage from inundation and/or wave effects (inside and outside the SFHA).

NFIP insurance claims data for the four coastal counties visited by the MAT indicate there were over 4,000 claims (about 66 percent within the SFHA and 33 percent outside the SFHA) with an average building damage claim of approximately $42,700. A clear indicator of building performance was that buildings elevated on strong foundations above the flood levels experienced during Hurricane Michael sustained little or no flood damage. The average non-elevated building claim was over $47,700 and average elevated building claim was under $36,400; pre-FIRM rated properties had an average claim above $57,200 and post-FIRM properties had an average claim under $36,400. Those rated at or below the BFE had an average claim of $58,500; those rated based on being elevated above the BFE had an average claim of $32,800.

Recommendation #FL-12. Local floodplain administrators, designers, and building owners should incorporate more freeboard than the minimum required in ASCE 24 based on Flood Design Class whenever possible.

Communities already require new buildings, those determined to have incurred Substantial Damage, and those that will undergo Substantial Improvement to be elevated in accordance with the FBC (based on the I-Codes) and ASCE 24, *Flood Resistant Design and Construction,* which exceed the NFIP minimum elevation requirements. The FBC, by reference to ASCE 24, allows communities to establish a DFE that exceeds the elevation requirements in the standard. In some communities, Hurricane Michael inundation levels rose higher than the minimum requirements established in the FBC (by reference to ASCE 24). Hurricane Sandy MAT Recovery Advisory 5, *Designing for Flood Levels Above the BFE* (in FEMA P-942, 2013), provides numerous factors that are not included in Flood Insurance Studies and FIRMs. Given that the requirements in the FBC and ASCE 24 can, and have been exceeded, in previous storm events, communities should consider adopting elevation requirements that exceed ASCE 24 (i.e., more than the minimum code requirements) for improved resilience. In addition, communities should consider elevating buildings to appropriate requirements for properties in the shaded Zone X (area of moderate flood hazard) as well as the unshaded Zone X (area of minimal flood hazard) where it is prudent to reduce flood risk.

Conclusion FL-13

Numerous buildings sited on erodible shorelines subject to storm flood loads experienced damage, and many erosion control structures performed poorly.

The MAT observed numerous instances of erosion leading to foundation or structural damage to buildings and erosion control structure failures (bulkheads, seawalls, etc.) on open coast and estuarine shorelines, in many cases under less than base flood conditions. Numerous bulkheads observed by the MAT were too close to the structures they were intended to protect and were ineffective. Bulkheads and other erosion control structures often may not provide the level of protection expected by an owner or intended by the designer.

Recommendation #FL-13a. FEMA should review and update its Event-Based Erosion methodology.

FEMA should review and update the methodology used to estimate dune erosion. FEMA should also improve existing siting and foundation design guidance for coastal dune and bluff areas. In consultation with the FDEP and other coastal states, FEMA should evaluate siting criteria and consider recommending revisions to Chapter 3, *High Risk Flood Hazard Areas*, of ASCE 24, *Flood Resistant Design and Construction,* on how best to consider erosion in design and construction.

Recommendation #FL-13b. For parcels that are seaward of Florida's CCCL, communities should require—and key stakeholders should encourage—the placement of houses with the maximum distance from the flood source possible within each parcel.

Key stakeholders, such as builders, designers, and property owners, should minimize highly vulnerable siting by funding, designing, and building houses with the maximum distance from the flood source allowable by the parcel for sites seaward of Florida's CCCL. Structures are too often being built with minimum distances from the shoreline for aesthetics or views. This leaves them in vulnerable locations as short- (storm-induced) and long-term erosion can, over decades, increase their susceptibility to flood damage within the parcel.

Recommendation #FL-13c. FDEP should implement current best practices and consider revising its requirements for erosion vulnerability assessments for new construction in erosion control areas.

Currently, FDEP provides guidelines for estimating the 30-year erosion projection, which is required for coastal construction permitting. In addition, FDEP Coastal Management Program's *Florida Adaptation Planning Guidebook* (2018) provides best practices related to exposure and sensitivity analysis along with adaptation strategies to reduce the negative impacts of sea level rise and climate change. Designers should be required to estimate flood depths and engineering loads for new construction based on long-term erosion assessments, including analysis that are based on the adverse impacts of sea level rise and climate change. In addition, erosion control measures, such as a nature-based buffer, should be considered as requirements to help reduce the projected impacts based on the assumptions made in the erosion vulnerability assessment.

Recommendation FL-13d. Permitting agencies 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 the water and land sides.

Permitting agencies (e.g., FDEP, Water Management Districts, local governments) should review public materials, emphasize the importance of evaluating existing bulkheads before relying on them for protection, and encourage communities to avoid siting buildings too close to bulkheads and seawalls. In addition, the best practices related to exposure and sensitivity analyses along with adaptation strategies to reduce the adverse impacts of sea level rise and climate change outlined in the FDEP Coastal Management Program's *Florida Adaptation Planning Guidebook* (2018) should be highly encouraged (and eventually required). Buildings situated adjacent to erosion control structures should have their foundations designed to accommodate likely or expected failure of the erosion control structures.

Recommendation FL-13e. Communities and building owners should consider acquisition or relocation projects for existing buildings in areas highly vulnerable to erosion.
Implementing acquisitions or relocations of buildings that are highly vulnerable to erosion would reduce the risk to these buildings as well as eliminate the need for infrastructure (roads, utilities, etc.) to service buildings in these areas. Both communities and building owners benefit from improved resilience by taking these actions.

6.6 Wind-Related Conclusions and Recommendations

This section includes all of the wind-related building performance conclusions and recommendations from the MAT assessments related to both residential (Section 6.6.1) and non-residential buildings (Section 6.6.2).

6.6.1 Residential Wind

Conclusion FL-14

The roof coverings for many residential buildings appeared to have inadequate resistance to wind loads; the loss of the primary roof covering contributed to significant water infiltration in many buildings.
Similar to historical and Hurricane Irma in Florida observations, widespread damage to asphalt shingles was observed on post-FBC residential buildings. The MAT was not always able to determine the reason(s) for this damage. In addition, observations of roof replacements indicated underlayment was not being installed as required by the FBC. Multiple MAT observations revealed contractors were not repairing roof coverings and installing replacements in conformance to the FBC requirements.

Recommendation #FL-14a. Code enforcement authorities having jurisdiction across Florida should make roof covering and underlayment inspections a priority.
Although roof coverings are required to be inspected by the FBC, because of a range of issues that include liability and timing, they typically are not inspected. Installation issues were observed at many sites.

Recommendation #FL-14b. Industry groups should assess the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.
Installation issues of asphalt shingles were observed at many sites. More research should be considered by industry groups (e.g., manufacturers, insurers, builders) and academia to explain why post-FBC asphalt shingle damage was observed to be widespread. In particular, this research should focus on areas where wind speeds were below design level. The research should attempt to determine whether these failures were the result of design, installation, testing, inspection, manufacturing, or other issues.

Recommendation #FL-14c. Contractors and inspectors must ensure roof covering repairs and replacements conform with the FBC as required.

When more than 25 percent of the total roof area or roof section has to be repaired, provisions of the FBC must be met. Designers, contractors, and inspectors should ensure roof covering repairs and replacements meet FBC requirements. Refer to Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (in FEMA P-2023, 2018f) for additional guidance.

Recommendation #FL-14d. On buildings built prior to the FBC, before installing a new roof covering, contractors should remove the existing roof covering to evaluate the roof sheathing attachment, and add supplemental fasteners in accordance with the wind mitigation provisions of FBC if the sheathing attachment is found to be deficient.

Currently, an evaluation of the roof deck attachment on pre-FBC buildings is only required where the existing roof covering is removed and replaced. The FBC permits some roof coverings to be installed over existing roof coverings provided there is not more than one layer of the existing roof covering. The MAT observed a couple instances of severe roof sheathing failures where pre-FBC buildings with asphalt shingles were recovered with metal roof panels. Therefore, it is recommended that contractors remove the existing layer of roof covering, evaluate the roof sheathing attachment, and add supplemental fasteners as needed when installing a new roof covering.

Recommendation #FL-14e. FEMA and FDEM should consider supporting current code change proposals to the 7th Edition FBC that provide for improved underlayment systems.

One such proposal was submitted by IBHS, which requires the use of underlayment systems that also function as a sealed roof deck. A secondary roof sealing strategy using underlayment products can significantly reduce water infiltration through the roof when the primary roof covering is blown off. Water infiltration can saturate attic insulation and collapse ceilings, allow water seepage into exterior and interior wall systems, damage interior finishes and furnishings, and lead to algae and mold growth. Refer to Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (in FEMA P-2077, 2019a) for additional guidance.

Recommendation #FL-14f. ARMA and NRCA should consider updating their guidance materials based on observations from the 2017 and 2018 hurricanes.

In particular, the Asphalt Roofing Manufacturers Association (ARMA) and the National Roofing Contractors Association (NRCA) should address/add emphasis to nailing and use of asphalt roof cement at rakes, eaves, and hips/ridges in high-wind regions as part of the next update, among other potential items. Refer to Hurricane Harvey in Texas Recovery Advisory 2, Asphalt Shingle Roofing for High-Wind Regions (in FEMA P-2022, 2018b) for additional guidance.

Conclusion FL-15

Improper installation of soffits led to inadequate resistance to wind pressures.

Widespread loss of soffits was observed in residential construction, and wind-driven rain infiltrated many areas where soffits were displaced or lost.

Recommendation #FL-15a. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.

Hurricane Irma in Florida Recovery Advisory 2, *Soffit Installation in Florida* (in FEMA P-2023, 2018g), provides soffit installation guidance and resources to meet or exceed minimum provisions of the FBC. Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (in FEMA P-2077, 2019a) provides additional guidance and resources.

Recommendation #FL-15b. FEMA and FDEM should consider submitting a code change proposal to the FBC requiring soffit inspections, and jurisdictions should prioritize performing soffit inspections.

Soffit inspections will help to ensure compliant products are used and soffits are securely attached.

Recommendation #FL-15c. The FBCR should be revised to require soffit panels to be labeled to provide traceability to the manufacturer and product.

Section 1709.10.2 of the FBCB requires soffit panels to have a label that provides traceability back to the manufacturer at least every 4 feet o.c. The FBCR does not contain a similar requirement. Soffit failure was widespread throughout all areas visited by the MAT. Because of a lack of labeling, the MAT could not determine whether the products had the appropriate design wind pressure rating.

Recommendation #FL-15d. Owners should determine whether the soffits attached to their house are "floated," and, if so, take appropriate mitigating actions.

Property owners should ensure both ends of the vinyl soffit panel are securely fastened to framing or a nailing strip; do not float (leave unattached) vinyl soffit panels in channels, as this installation method offers poor wind resistance. The unsupported span of vinyl soffit panel should be limited to 12 inches. Refer to Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* (in FEMA P-2077, 2019d), for more detail regarding proper installation of vinyl soffits for high-winds.

Conclusion FL-16

The failure of ridge vents contributed to significant water infiltration at many sites.

The loss of ridge vents can expose large openings in the roof deck to water infiltration. Water infiltration can cause extensive interior damage, contribute to the growth of mold and mildew, and result in degraded building function or downtime until repairs are made.

Recommendation #FL-16. Industry groups and academia should perform research on commonly used ridge vent products to better determine the causes of ridge vent failure and develop solutions.

More research should be considered by industry groups (e.g., manufacturers, insurance organizations—IBHS, builders, trade associations—NRCA) to determine why ridge vent failure was observed to be widespread and whether these failures were the result of design, installation, testing (including for wind-driven rain infiltration), inspection, manufacturing, or other issues. Information to help improve the performance of ridge vents in high-wind areas can be found in Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (in FEMA P-2077, 2019a).

Conclusion FL-17

There was evidence of widespread failure of exterior wall coverings throughout all areas assessed, particularly vinyl siding and fiber cement.

In addition to the poor performance of vinyl siding in many areas, numerous installation issues were observed for all types of wall coverings. Although the failure of fiber cement siding was observed on many houses, the failure of vinyl siding on post-FBC residential buildings was widespread. Failures were observed in areas where wind speeds were at or below design levels.

Recommendation #FL-17a. FEMA and FDEM should consider submitting a code change proposal to the FBC requiring exterior wall covering inspections.

Inspections will help ensure compliant installation and use of proper materials. Most MAT-observed wall covering failures demonstrated one or more examples of non-compliant installation, which can be mitigated through proper installation, or afterwards through identification during field inspections. Common examples of wall cladding failures for vinyl siding include missing utility trim and missing starter strips. Existing guidance, resources, and best practices for exterior wall coverings can be found in Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (in FEMA P-2077, 2019a), as well as Technical Fact Sheet 5.3, “Siding Installation in High Wind Regions” (in FEMA P-499, 2010g).

Recommendation #FL-17b. Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue research and investigations of the appropriate PEF for vinyl siding.

The MAT observed widespread failure of vinyl siding throughout all areas visited by the MAT. Failure was observed in areas where wind speeds were above and below design level; better performance would have been expected. 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 pressure equalization factor (PEF) for vinyl siding. Some research facilities are currently investigating.

Recommendation #FL-17c. The FBC and FBCR should be revised to require vinyl siding be labeled to provide traceability to the manufacturer and product.

Vinyl siding failure was also observed where installation issues could not be found. Given the lack of labeling, the MAT could not determine whether the products had the appropriate design wind pressure rating. Labeling of vinyl siding material should be required by the FBC and FBCR to provide traceability to the manufacturer and product.

6.6.2 Non-residential Wind

Conclusion FL-18

The majority of wind retrofits observed by the MAT failed to address all significant wind vulnerabilities.
The MAT observed widespread damage to retrofitted buildings, sometimes significant damage, from Hurricane Michael. The majority of wind retrofits observed only addressed a single component of the building. By not retrofitting all significant vulnerabilities, the building was still vulnerable to wind, even when the single retrofitted component worked as intended. Building operations were severely impacted by the loss of municipal power, municipal water and/or sewer, and other utilities needed for continuing operations.

Recommendation #FL-18a. Designers and building owners should conduct a comprehensive vulnerability assessment as described in Hurricane Michael in Florida Recovery Advisory 1 before beginning a wind retrofit project.
Before repairing wind-damaged buildings or retrofitting a building to be more wind resistant, all relevant building elements should be assessed for vulnerability to high-wind events (refer to Hurricane Michael in Florida Recovery Advisory 1, *Successfully Retrofitting Buildings for Wind Resistance* [in FEMA P-2077, 2019d]), even those that were not damaged. If undamaged elements are determined to have significant vulnerabilities, they should be mitigated as part of the repair work to avoid future damage. Even when retrofitted elements perform well, if other non-retrofitted elements fail during a high-wind event, the whole retrofit project may be ineffective because the building did not achieve the target performance level intended by the retrofit. Designers should check all connections and elements along a retrofit element's load path for all retrofit projects. A retrofit project's scope of work should include the analysis, design, and/or strengthening of all elements and connections along each retrofit element's load path.

Recommendation #FL-18b. As appropriate, designers and building owners should consider damage to other buildings from high-wind events as vulnerabilities that should be addressed in their similar undamaged buildings.
The MAT observed several cases where lessons learned could be applied to buildings outside of the areas impacted by Hurricane Michael to help mitigate future damage. If a building impacted by a high-wind event is similar to another building outside of the area impacted by the event, the building owner should consider proactively addressing the vulnerabilities revealed by the damaged building.

Recommendation #FL-18c. Designers, building owners, and operators of critical facilities should refer to FEMA 543, FEMA 577, and FEMA P-424 for additional guidance and best practices for protecting critical facilities from flooding and high winds.
Together, these three FEMA Risk Management Series publications provide building professionals and decisionmakers with information and guidelines for implementing a variety of mitigation measures to reduce the vulnerability to damage and disruption of operations during severe flooding and high-wind events, as well as other types of natural disasters.

- FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007a) provides building professionals and decisionmakers for critical facilities with information and guidelines for implementing a variety of mitigation measures to reduce the vulnerability to damage and disruption of operations during severe flooding and high-wind events.
- FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (2007b) provides information on the variety of vulnerabilities faced by hospitals exposed to earthquakes, flooding, and high-winds risks, as well as the best ways to mitigate the risk of damage and disruption of hospital operations caused by these events. The information presented in this publication provides an exhaustive review of mitigation measures and design solutions that can improve the safety of hospitals in natural hazard events.
- FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010c) provides guidance for the protection of school buildings from natural disasters: earthquakes, floods, and high winds. Its intended audience is designers and school officials involved in the technical and financial decisions of school construction, repair, and renovations.

Conclusion FL-19

Many critical facilities that had significant wind vulnerabilities were occupied during Hurricane Michael with no safe room or storm shelter.

The criteria for a safe rooms and storm shelters are provided in FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (2015c), and the ICC/National Storm Shelter Association (NSSA) *Standard for the Design and Construction of Storm Shelters* (ICC 500). The MAT observed numerous critical facilities with significant wind vulnerabilities, but did not observe nearby FEMA P-361–compliant safe rooms or ICC 500–compliant storm shelters that could have been used or occupied during the event. Numerous critical facility occupants interviewed during MAT site visits anticipated a Category II hurricane to make landfall, not the Category V hurricane that actually occurred. Once a commitment was made to shelter in place, a time came at which it was no longer possible to evacuate. Most staff interviewed that had sheltered in place at a critical facility during the hurricane wished they had evacuated.

Recommendation #FL-19a. Critical facilities that do not meet the FBC requirements for a Risk Category IV building should not be designated as essential facilities to support continuity of operations nor be occupied during a hurricane.

As part of routine updates to Continuity of Operations Plans (COOPs), communities and government agencies should conduct a thorough vulnerability assessment of facilities they plan to operate from during a flood or high-wind event. Facilities that do meet the FBC requirements for a Risk Category IV building should not be considered for this use. While most COOP processes identify the best available facility to maintain continuity of operations, including planning triggers when the facilities should not be utilized, vulnerability assessments should include criteria to ensure occupied facilities meet or exceed current FBC risk Category IV requirements.

Recommendation #FL-19b. Owners and authorities having jurisdiction with facilities that present a life-safety threat to occupants during a high-wind event or that need "near absolute protection" or life safety protection should consider designing and constructing a FEMA P-361–compliant safe room or ICC 500–compliant storm shelter for people to take shelter in during a storm.

Owners of critical facilities with portions that remain staffed, or otherwise occupied, during high-wind events should consider providing near-absolute protection. Examples include but are not limited to critical emergency operations and healthcare facilities. FEMA has several funding vehicles for safe rooms; information on FEMA safe room grants is available at www.fema.gov/safe-room-funding.

Recommendation FL-19c. FDEM should consider delivering training on FEMA P-361 safe room design, construction, and operations and maintenance.

FDEM, in conjunction with FEMA, FFMA, and BOAF, should develop and provide a webinar on residential and community safe room design and construction, including FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (2015c). This training should be directed to builders, developers, building officials, plan reviewers, building inspectors, and building owners and operators.

Conclusion FL-20

Anticipated demand for hurricane shelter space and actual demand differed significantly.

There were significant inconsistencies between the number of people seeking refuge in Florida's HESs during Hurricane Michael and the "shelter demand in people" estimates in the 2018 SESP (FDEM, 2018) for Bay and Calhoun Counties.

Recommendation #FL-20. The State of Florida and FDEM should re-evaluate planning factors and considerations used to estimate HES "demand in people," so counties have adequate and more appropriate HES capacity during future hurricanes.

The 2018 SESP indicates Bay County's General Population Shelters currently have capacity for 15,928 occupants, but only need space for 6,443 (surplus of 9,485). Yet Rutherford High School and other Bay County HESs significantly exceeded capacity, which resulted in occupation of non-HES areas. Conversely, the 2018 SESP indicates a similar surplus ratio for less densely populated Calhoun County, where HESs observed by the MAT were sparsely populated during Michael.

Conclusion FL-21

The HESs observed by the MAT demonstrated significant vulnerabilities to high-wind hazards.

The Bay County HESs, which the County identified through assessment and mitigation of existing spaces, incurred significant damage during Hurricane Michael and exposed shelter occupants to hurricane hazards. The Calhoun County HESs, which were designed to meet earlier EHPA criteria, incurred significant damage as well. Based on damage observations, roof systems of both types of HES are particularly vulnerable to high winds.

Recommendation #FL-21a. The State of Florida and FDEM should consider re-evaluating their policies, procedures, and requirements for assessments of existing spaces for use as HES.

The State of Florida and FDEM should consider requiring more robust and holistic vulnerability assessments for future HESs that are designated through assessment and mitigation of existing spaces. Further, consideration should be given to reassessing existing HES areas that were designated through assessment and mitigation to identify and retrofit their vulnerabilities or explore incentivizing local authorities to replace the more vulnerable existing HESs with new EHPAs, or better yet, storm shelters or safe rooms.

Recommendation #FL-21b. The State of Florida and FDEM should consider re-evaluating EHPA criteria and re-assess safety of existing EHPAs, particularly those designed prior to the 6th Edition FBC (2017).

While new EHPAs are required by the 6th Edition FBC (2017) to be designed and constructed in accordance with the hurricane wind load provisions of ICC 500, structural criteria for EHPA as designed and constructed prior to 6th Edition FBC (2017) were less stringent and non-mandatory. The State of Florida and FDEM should consider reassessing existing EHPAs that were designed and constructed prior to the 6th Edition FBC (2017) to identify and retrofit their vulnerabilities or explore incentivizing local authorities to replace the more vulnerable aging EHPAs with new EHPAs, or better yet, storm shelters or safe rooms.

Conclusion #FL-22

Many facilities used as critical (essential) facilities in the Florida Panhandle did not meet FBC Risk Category IV criteria (requirements), leaving people and property vulnerable to high-wind events.

The FEMA MAT observed numerous critical facilities that were older buildings and highly vulnerable to damage from high-wind events. The FBC requirements only apply to new facilities or those triggered for compliance by the codes. As such, many older facilities being used for Risk Category IV essential facility functions do not have to comply with the FBC Risk Category IV requirements if they have not been triggered. However, critical facilities, along with their occupants and the critical functions performed there, would remain highly vulnerable to hazard loads (i.e., wind, wind-borne debris, etc.) they are subject to, if not designed for them.

Recommendation #FL-22. Critical facility owners and operators should perform a vulnerability assessment of their buildings in comparison to the FBC Risk Category IV threshold to determine their risks and vulnerabilities, and a best path forward for mitigating them.

Risks and vulnerabilities identified through the vulnerability assessment to the Risk Category IV threshold can then be addressed by a) retrofits to the building to comply with FBC Category IV criteria (requirements) even if it is not a mandatory trigger, b) planning to construct a new facility complying with FBC Risk Category IV requirements, c) moving to another facility that complies with FBC Risk Category IV requirements, or d) constructing a FEMA P-361–compliant safe room or ICC 500–compliant storm shelter that can be used by essential personnel remaining behind for life safety protection during a major storm event (see Recommendation #FL-19b above).

Conclusion FL-23

Buildings throughout the impacted area were found to be vulnerable to wind-driven rain and water infiltration.

The MAT observed wind-driven rain and water infiltration at many buildings. These vulnerabilities can lead to extensive damage and disruption of normal building operations.

Recommendation #FL-23a. Designers should properly design rooftop equipment anchorage per the recommendations in Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2 and contractors should properly implement the anchorage design to prevent blow-off.

Blown-off equipment can result in extensive damage and lack of continuity of operations, and also typically results in water infiltration through the resulting penetrations in the building envelope. Implementation of the recommendations in Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions* (in FEMA P-2021, 2018c), will enhance the wind performance of rooftop equipment.

Recommendation #FL-23b. Copings and edge flashings should comply with ANSI/SPRI/FM 4435/ES-1 to prevent blow-off.

The MAT observed many coping and edge flashing blow-offs. Blown-off copings and edge flashing can result in roof membrane lifting and peeling, and they can puncture roof coverings and cause other damage or injuries. Copings and edge flashings that comply with ES-1, *Test Standard for Edge Systems Used with Low Slope Roofing Systems*, and that are properly installed are expected to provide reliable wind performance.

Recommendation #FL-23c. In high-wind regions, designers should provide an enhanced closure detail for hip and ridge closures on metal panel roofs, and contractors should take special care in properly installing them.

Wind-driven rain can enter a building at the hip or ridge of a metal roof, saturating the ceiling below. In high-wind regions, it is important to use at least two rows of closures at hips and ridges to prevent entry of wind-driven rain. All edges of the inner closure should be set in sealant or sealant tape. At the outer closure, sealant should be at the top and edges of the closure. The juncture between this closure and the pan of the roof panel should be left unsealed to allow drainage of water that may be blown past the outer closure at sealant discontinuities. Refer to the "Standing Seam Metal Roof Assemblies" textbox in Section 5.1.2 of this Report for a closure detail.

Recommendation #FL-23d. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.

Designers and contractors should adapt the guidance in Hurricane Irma in Florida Recovery Advisory 2, *Soffit Installation in Florida* (in FEMA P-2023, 2018g), Hurricane Michael in Florida Recovery Advisory 2, *Best Practices for Minimizing Wind and Water Infiltration Damage* (in FEMA P-2077, 2019a), and Technical Fact Sheet 7.5, "Minimizing Water Intrusion through Roof Vents in High-Wind Regions" (in FEMA P-499, 2010f) to non-residential applications to help prevent soffit blow-off.

Recommendation #FL-23e. To help prevent entry of wind-driven rain into the building, designers should specify weatherstripping for, as well as consider designing vestibules at, exterior doors.

Weatherstripping is necessary to avoid wind-driven rain penetration. A variety of weatherstripping products are commercially available. Vestibules can also be useful for preventing wind-driven rain that gets past exterior doors from getting beyond the vestibule. FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010c), provides weatherstripping and vestibule guidance.

Recommendation #FL-23f. FEMA Building Science should incorporate best practices for minimizing water infiltration into buildings from wind-driven rain into its relevant publications.

Best practices for minimizing infiltration of wind-driven rain into buildings, such as those identified in Recommendations #FL-23a, #FL-23b, #FL-23c, #FL-23d, and #FL-23e should be incorporated into appropriate FEMA Building Science publications. Publications should include FEMA P-55, *Coastal Construction Manual* (2011), FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010e), and FEMA's Risk Management Series publications, among others.

Conclusion FL-24

Permanently mounted screen shutters installed with incompatible glazing assemblies and those with significant corrosion did not perform as intended and some came unlatched.

The MAT observed multiple failure modes of permanently mounted screen shutter systems. Failure of these systems leaves glazing vulnerable to wind-borne debris. When this glazing is breached, internal pressurization of the impacted building, water infiltration from wind-driven rain, and occupant injury can result. When properly designed, installed, and maintained, permanently mounted screen shutters, as well as other types of tested shutter assemblies, help protect glazing from wind-borne debris.

Recommendation #FL-24a. The task committee for ASTM E1886 should consider revising the standard to include the evaluation of the potential for the shutter assembly to unlatch during a storm.

The testing in ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials,* should be revised to include evaluation of the potential for a shutter assembly to unlatch during a storm.

Recommendation #FL-24b. Existing glazing assemblies that have inadequate wind pressure or wind-driven rain resistance should be replaced with new assemblies rather than being retrofitted with shutters.

Although shutter systems are tested for wind-borne debris resistance, they cannot be relied upon to prevent weaker glazing assemblies from failing as a result of air pressure, nor to prevent the entrance of wind-driven rain.

Recommendation #FL-24c. The task committee for ASTM E1886 should add corrosion criteria to the standard to help enable shutters to perform as intended over their useful life.

Over time, corrosion can weaken the components of shutters. This weakening can result in failure of the shutter to provide wind-borne debris protection. ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials,* should include corrosion criteria.

Recommendation #FL-24d. The task committee for ASTM E1886 should evaluate the current perpendicular angle specifications for impacting a shutter during testing for its adequacy.

The current ASTM E1886, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials,* specifies impacting shutters within 5 degrees perpendicular to them, but does not evaluate shutter performance when a test missile hits them at different angles. The MAT observed shutter assembly damage caused by the angular impact of wind-borne debris and recommends testing for a wider range of angles.

Conclusion FL-25

Structural standing seam metal panel roofs can blow off if not properly specified or installed.

When panels blow off, if there is no secondary roof membrane, rain directly enters the interior of the building through the breach. The MAT observed numerous cases where the panels blew off, and a few cases where remained on the roof, but a few of the seams opened up; the damaged panels were very susceptible to progressive failure and were no longer watertight.

Recommendation #FL-25a. Designers should specify, and contractors should properly install, standing seam metal panel systems that have been tested in accordance with ASTM E1592.

ASTM E1592, *Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference*, is recognized as the best available laboratory method to evaluate the wind uplift performance of metal panels and their attachment to the substrate.

Recommendation #FL-25b. Designers should specify, and contractors should install, a roof deck with a secondary roof membrane for critical facilities designed with structural standing seam metal roof panels.

In the case of metal panel blow-off, or opening of seams, a secondary roof membrane would avoid wind-driven rain entry, thus allowing critical facilities to maintain operations during and/or following an event.

Conclusion FL-26

Numerous membrane roofs were found to have inadequate wind resistance and/or were vulnerable to being punctured by wind-borne debris.

Failure of membrane roof systems were found by the MAT to result in the entry of wind-driven rain, which in some cases caused loss of continuity of operations and extensive damage to building interiors. Special attention to design, installation, and maintenance of membrane roof systems is necessary to avoid interior water damage.

Recommendation #FL-26. Designers should adequately design, and contractors should properly install, roof systems.

Section 3.4.3.4 of FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings* (2007a), provides guidance and recommendations on roof systems for critical facilities in hurricane-prone regions, including special design provisions to address wind-borne debris. Additional guidance on wind performance of roof systems (including inspection and testing during construction) is provided by ASCE's *Prestandard for Performance-Based Wind Design* (2019). The guidance in these publications, as well as FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010c), is applicable to all non-residential buildings in hurricane-prone regions.

Conclusion FL-27

URM walls are highly susceptible to collapse during high winds.

Exterior CMU and stucco-surfaced CMU walls may be perceived as having a high wind resistance. However, as often observed by the MAT, these types of unreinforced masonry (URM) walls are highly susceptible to toppling over during high-wind events, causing damage to the facility and anything below the failed wall; fatalities can also result from such collapse.

Recommendation #FL-27. Owners and operators of buildings with URM walls should include the toppling risk of these walls during high-wind events in vulnerability assessments and should mitigate the risk.

Buildings with URM walls that could topple onto occupants or result in roof collapse should be identified, as these buildings should not be occupied during a high-wind event. Ideally, this vulnerability should be permanently mitigated. Building occupants should also be made aware of the hazard through their building emergency operations plan, which should be exercised annually.

Conclusion FL-28

Brick veneer can fail if not properly installed or best practices are not employed in high-wind regions.

The common issues observed were randomly spaced brick ties and tie corrosion.

Recommendation #FL-28a. Building owners should have a vulnerability assessment performed for their existing building to ensure brick veneer is properly attached.

Model codes prior to 1995 permitted brick veneer in any location, with no wind speed restrictions. For existing buildings with brick veneer, a vulnerability assessment should be performed by a registered design professional who can make recommendations to improve the brick veneer's resistance to high winds, if needed.

Recommendation #FL-28b. Designers and contractors should improve installation of brick veneer in high-wind regions for new construction by ensuring it is properly attached.

Current building requirements and referenced standards, including TMS 402/602, *Building Code Requirements and Specification for Masonry Structures* (2016) (formerly the ACI 530), provide design and construction guidance for the installation of brick veneer. Technical Fact Sheet 5.4, "Attachment of Brick Veneer in High-Wind Regions" (in FEMA P-499, 2010b), provides additional guidance on properly attaching brick veneer in high-wind regions. Designers and contractors should place more emphasis on proper construction of brick veneer wall systems to limit potential damage.

Conclusion FL-29

The blow-off of EIFS, which was a common observation, can lead to additional damage throughout the buildings, especially due to water infiltration.

The Hurricane Michael MAT, as well as previous MATs, frequently observed EIFS blow-off during high-wind events.

Recommendation #FL-29. Designers should consider specifying a more robust wall assembly than EIFS for new critical facilities.

Although EIFSs are designed to provide continuous insulation while having aesthetic flexibility, they continue to be observed by MATs as a commonly damaged wall covering system. Given their essential functions, critical facilities' designers should consider specifying a more robust wall assembly to help minimize loss of operations and costly repairs following a high-wind event.

Conclusion FL-30

Roof aggregate can cause glazing damage to other floors on existing buildings or to nearby buildings.

The MAT observed incidents of blown-off roof aggregate causing glazing damage to other floors of the same building as well as adjacent buildings. This is a frequent observation made by previous MATs.

Recommendation #FL-30. The FBC should provide more specific criteria with restrictions on how, when, and where roof aggregate can be used.

Aggregate roof surfacing provides a ready source of wind-borne debris that can damage unprotected glazing in high wind. The 2003 through 2018 editions of the IBC prohibit the use of aggregate roof surfacing in hurricane-prone regions. This is a stark contrast to the FBC, which permits roof aggregate. Chapter 15, Roof Assemblies and Rooftop Structures, of the FBC includes some requirements for roof aggregate, including size and percent embedded. However, additional criteria should be incorporated to prevent aggregate blow-off or to specify that roof aggregate is prohibited.

6.7 Crosswalk/Matrix of Conclusions and Recommendations with MAT Observations

Table 6-2 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 "Action Offices" when appropriate, as well as RSFs for recommendations provided in this report to assist Florida or other agencies or organizations with accelerating the process of recovery, redevelopment, and revitalization. The "Action Offices" identified in the table are "key stakeholders" for implementing specific recommendations, but are not intended to be all inclusive. While there are primary, secondary, and tertiary stakeholders for each of these recommendations, the table only provides the primary and FEMA RSF stakeholders as written in the summary recommendation statement. Many local organizations and stakeholders, although not listed for a given recommendation, are critical to championing and implementing the recommendation in their states and communities. Examples include FDEM, local officials (emergency managers, floodplain administrators, building code officials, ASFPM chapters), and other professional groups.

NATIONAL DISASTER RECOVERY FRAMEWORK AND RECOVERY SUPPORT FUNCTIONS

FEMA developed the National Disaster Recovery Framework (NDRF) to create a common platform and forum by which the whole community builds, sustains, and coordinates delivery of recovery capabilities. FEMA's *National Disaster Recovery Framework: Second Edition* (2016) 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 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 online at www.fema.gov/recovery-support-functions).

Recovery Support Functions

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

Table 6-2: Summary of Conclusions and Recommendations

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 2 (Section 2.2) and General Field Observation	**FL-1** Floodplain management requirements were inconsistently enforced.	**FL-1a.** FDEM should consider developing/ modifying training on the flood provisions in the FBC and local floodplain management ordinances.	FDEM, CPCB
		FL-1b. BOAF and other stakeholders should consider developing additional training on roles and responsibilities for communities contracting building department services to a private company.	BOAF, CPCB
Chapter 4 (Section 4.2) and General Field Observation	**FL-2** In-progress inspections of building envelope components throughout Florida were inconsistently performed.	**FL-2a.** Local jurisdictions should make building envelope inspections a priority.	Local jurisdictions, CPCB, Housing
		FL-2b. BOAF, FHBA, and other stakeholders should consider developing training and creating a culture of emphasis on building envelope systems.	BOAF, FHBA, CPCB, Housing
Chapter 2 (Section 2.2), Chapter 3 (Section 3.4), General Field Observation	**FL-3** Officials in most communities visited by the MAT did not have a clear understanding of Substantial Improvement / Substantial Damage requirements and the process for making Substantial Improvement / Substantial Damage determinations.	**FL-3a.** FEMA should update FEMA P-758 and concurrently update FEMA 213 to be consistent with the updated FEMA P-758.	FEMA, CPCB
		FL-3b. FEMA should consider expanding/ clarifying existing training materials related to Substantial Improvement / Substantial Damage.	FEMA, CPCB
Chapter 2 (Section 2.2) and General Field Observation	**FL-4** Some communities visited by the MAT use the services of private companies for some or all building department operations but do not include administration of local floodplain management regulations, which can create gaps in administration of requirements for flood hazard areas.	**FL-4.** Communities should outline clear and consistent responsibilities when contracting with private-sector providers to administer all or part of the community's responsibilities under the FBC.	Communities, CPCB
Chapter 2 (Section 2.2) and General Field Observation	**FL-5** Numerous local government departments do not appear to be adequately coordinating to enforce floodplain regulations and flood provisions of the FBC in a post-disaster environment, due in part to the number of permit applications submitted and limited staff capacity.	**FL-5a.** FEMA should provide guidance to state and local governments on seeking assistance related to building code and floodplain management ordinance administration and enforcement authorized under Section 1206 of the DRRA.	FEMA, CPCB
		FL-5b. FDEM should continue to encourage pre-event evaluation of post-disaster needs and inform appropriate parties about assessing resources through SMAA and EMAC.	FDEM, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 2 (Section 2.3) and Chapter 4 (Section 4.2)	**FL-6** Testing standards for door and window assemblies did not appear to adequately help prevent water infiltration.	**FL-6.** FEMA should work with AAMA/ WDMA/CSA, IBHS, ASTM, ICC®, and other select industry partners to incorporate more comprehensive water intrusion testing requirements that improve overall performance into testing standards.	FEMA, AAMA/ WDMA/CSA, IBHS, ASTM, ICC, CPCB, Housing
Chapter 2 (Section 2.3), Chapter 4, and Chapter 5	**FL-7** The basic wind speeds for the Florida Panhandle may not accurately reflect the appropriate wind hazard for the region.	**FL-7.** The wind engineering research community should perform a revised analysis of the ASCE 7 basic wind speed maps for the Florida Panhandle region to include data from Hurricane Michael.	Wind engineering research community, CPCB, Housing
Chapter 2 (Section 2.3), Chapter 4, and Chapter 5	**FL-8** Damage to glazing is not limited to within the 1-mile area of the coast, and can occur much farther inland.	**FL-8a.** The FBC should treat all areas within 1 mile inland from the entire Florida coastline as a WBDR.	FBC, CPCB, Housing
		FL-8b. The ASCE 7 Wind Load Task Committee should revise ASCE 7 to lower the basic wind speed trigger in ASCE 7 for requiring glazing to be protected on Risk Category IV buildings in the hurricane-prone region.	ASCE 7 Wind Load Task Committee, CPCB, Housing
		FL-8c. Building owners outside the WBDR but within the hurricane-prone region should consider protecting the glazed openings on their buildings.	Building owners outside the WBDR, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-8d. The IBC/IRC/FBC should be updated where needed to ensure glazed window, skylight, door, and shutter assemblies have a permanent label that provides traceability to the manufacturer and product.	IBC/IRC/FBC proponents, CPCB, Housing
		FL-8e. The ASCE 7 Wind Load Subcommittee should consider developing commentary on vestibule wind loads.	ASCE 7 Wind Load Subcommittee, CPCB
Chapter 3 (Section 3.1, Section 3.2, and Section 3.4)	**FL-9** Many houses in the unshaded Zone X (area of minimal flood hazard) experienced just as much damage as those in the SFHA (in this case, Zone AE).	**FL-9.** Communities should consider more stringent building requirements for development or reconstruction in the unshaded Zone X (area of minimal flood hazard) and shaded Zone X (area of moderate flood hazard).	Communities, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 3 (Section 3.3)	**FL-10** Multiple concrete pile foundations, some with unknown pile embedment depth, suffered rotational failure.	**FL-10a.** Industry groups, interested stakeholders, and/or academia should further evaluate the performance of the concrete pile foundations that failed during Hurricane Michael to determine why they failed.	Academia and concrete pile industry groups, CPCB
		FL-10b. FEMA and FDEM should consider providing a code change proposal to the International Codes requiring contractors and/or manufacturers to add length labels or incremental depth markers on vertical piles.	FEMA, FDEM, CPCB
Chapter 3 (Section 3.4)	**FL-11** Flood damage can occur to critical facilities outside the SFHA.	**FL-11a.** FEMA and FDEM should consider submitting a code change proposal to the FBC, applying ASCE 24 Flood Design Class 4 requirements outside the SFHA in moderate flood hazard areas (shaded Zone X) and to consider flood risk for minimal flood hazard areas (unshaded Zone X).	FEMA, FDEM, CPCB, Infrastructure
		FL-11b. FEMA should consider developing a change proposal for ASCE 24 requiring consideration of flood risk for essential facilities outside the SFHA in minimal flood hazard areas (unshaded Zone X) and requiring Flood Design Class 4 to apply in moderate flood zones outside of the SFHA.	FEMA, CPCB, Infrastructure
Chapter 3 (Section 3.2)	**FL-12** Non-elevated or insufficiently elevated buildings sustained damage from inundation and/or wave effects (inside and outside the SFHA).	**FL-12.** Local floodplain administrators, designers, and building owners should incorporate more freeboard than the minimum required in ASCE 24 based on Flood Design Class whenever possible.	Local floodplain administrators, designers, building owners, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 3 (Section 3.4)	**FL-13** Numerous buildings sited on erodible shorelines subject to storm flood loads experienced damage, and many erosion control structures performed poorly.	**FL-13a.** FEMA should review and update its Event-Based Erosion methodology.	FEMA, CPCB, Natural and Cultural Resources
		FL-13b. For parcels that are seaward of Florida's CCCL, communities should require—and key stakeholders should encourage—the placement of houses with the maximum distance from the flood source possible within each parcel.	Communities, designers, developers, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-13c. FDEP should implement current best practices and consider revising its requirements for erosion vulnerability assessments for new construction in erosion control areas.	FDEP, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-13d. Permitting agencies 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 the water and land sides.	Permitting agencies, CPCB, Housing, Infrastructure, Natural and Cultural Resources
		FL-13e. Communities and building owners should consider acquisition or relocation projects for existing buildings in areas highly vulnerable to erosion.	Communities and building owners, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 4 (Section 4.2)	**FL-14** The roof coverings for many residential buildings appeared to have inadequate resistance to wind loads; the loss of the primary roof covering contributed to significant water infiltration in many buildings.	**FL-14a.** Code enforcement authorities having jurisdiction across Florida should make roof covering and underlayment inspections a priority.	Code enforcement authorities, CPCB, Housing
		FL-14b. Industry groups should assess the causes for the widespread asphalt shingle roof covering loss that was observed by the MAT.	Asphalt shingle-related industry groups, CPCB, Housing
		FL-14c. Contractors and inspectors must ensure roof covering repairs and replacements conform with the FBC as required.	Roof contractors and inspectors, CPCB, Housing
		FL-14d. On buildings built prior to the FBC, before installing a new roof covering, contractors should remove the existing roof covering to evaluate the roof sheathing attachment, and add supplemental fasteners in accordance with the wind mitigation provisions of FBC if the sheathing attachment is found to be deficient.	Roof contractors, CPCB, Economic, Housing
		FL-14e. FEMA and FDEM should consider supporting current code change proposals to the 7th Edition FBC that provide for improved underlayment systems.	FEMA, FDEM, CPCB, Housing
		FL-14f. ARMA and NRCA should consider updating their guidance materials based on observations from the 2017 and 2018 hurricanes.	ARMA, NRCA, CPCB
Chapter 4 (Section 4.2)	**FL-15** Improper installation of soffits led to inadequate resistance to wind pressures.	**FL-15a.** Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.	Designers, contractors, inspectors, CPCB
		FL-15b. FEMA and FDEM should consider submitting a code change proposal to the FBC requiring soffit inspections, and jurisdictions should prioritize performing soffit inspections.	FEMA, FDEM, CPCB, Housing
		FL-15c. The FBCR should be revised to require soffit panels to be labeled to provide traceability to the manufacturer and product.	FBC, CPCB, Housing
		FL-15d. Owners should determine whether the soffits attached to their house are “floated,” and, if so, take appropriate mitigating actions.	Homeowners, CPCB, Economic, Housing
Chapter 4 (Section 4.2)	**FL-16** The failure of ridge vents contributed to significant water infiltration at many sites.	**FL-16.** Industry groups and academia should perform research on commonly used ridge vent products to better determine the causes of ridge vent failure and develop solutions.	Ridge vent industry groups and academia, CPCB, Economic, Housing

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 4 (Section 4.2) (continued)	**FL-17** There was evidence of widespread failure of exterior wall coverings throughout all areas assessed, particularly vinyl siding and fiber cement.	**FL-17a.** FEMA and FDEM should consider submitting a code change proposal to the FBC requiring exterior wall covering inspections.	FEMA, FDEM, CPCB, Housing
		FL-17b. Vinyl siding manufacturers, insurance organizations, and other stakeholders should continue research and investigations of the appropriate PEF for vinyl siding.	Vinyl siding manufacturers, insurance organizations, CPCB, Housing
		FL-17c. The FBC and FBCR should be revised to require vinyl siding be labeled to provide traceability to the manufacturer and product.	FBC, CPCB, Housing
Chapter 5 (Section 5.1)	**FL-18** The majority of wind retrofits observed by the MAT failed to address all significant wind vulnerabilities.	**FL-18a.** Designers and building owners should conduct a comprehensive vulnerability assessment as described in Hurricane Michael in Florida Recovery Advisory 1 before beginning a wind retrofit project.	Designers and building owners, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-18b. As appropriate, designers and building owners should consider damage to other buildings from high-wind events as vulnerabilities that should be addressed in their similar undamaged buildings.	Designers and building owners, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-18c. Designers, building owners, and operators of critical facilities should refer to FEMA 543, FEMA 577, and FEMA P-424 for additional guidance and best practices for protecting critical facilities from flooding and high winds.	Designers, building owners and operators of critical facilities, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
Chapter 5 (Section 5.2)	**FL-19** Many critical facilities that had significant wind vulnerabilities were occupied during Hurricane Michael with no safe room or storm shelter.	**FL-19a.** Critical facilities that do not meet the FBC requirements for a Risk Category IV building should not be designated as essential facilities to support continuity of operations nor be occupied during a hurricane.	Critical facility owners, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 5 (Section 5.2) (continued)	**FL-19** (continued)	**FL-19b.** Owners and authorities having jurisdiction with facilities that present a life-safety threat to occupants during a high-wind event or that need "near absolute protection" or life safety protection should consider designing and constructing a FEMA P-361–compliant safe room or ICC 500–compliant storm shelter for people to take shelter in during a storm.	Building owners and operators, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-19c. FDEM should consider delivering training on FEMA P-361 safe room design, construction, and operations and maintenance.	FDEM, CPCB
Chapter 5 (Section 5.2)	**FL-20** Anticipated demand for hurricane shelter space and actual demand differed significantly.	**FL-20.** The State of Florida and FDEM should re-evaluate planning factors and considerations used to estimate HES "demand in people," so counties have adequate and more appropriate HES capacity during future hurricanes.	The State of Florida and FDEM, CPCB, Health and Social Services
Chapter 2 (Section 2.4) and Chapter 5 (Section 5.2)	**FL-21** The HESs observed by the MAT demonstrated significant vulnerabilities to high-wind hazards.	**FL-21a.** The State of Florida and FDEM should consider re-evaluating their policies, procedures, and requirements for assessments of existing spaces for use as HES.	The State of Florida and FDEM, CPCB, Health and Social Services
		FL-21b. The State of Florida and FDEM should consider re-evaluating EHPA criteria and re-assess safety of existing EHPAs, particularly those designed prior to the 6th Edition FBC (2017).	The State of Florida and FDEM, CPCB, Health and Social Services
Chapter 5 (Section 5.2)	**FL-22** Many facilities used as critical (essential) facilities in the Florida Panhandle did not meet FBC Risk Category IV criteria (requirements), leaving people and property vulnerable to high-wind events.	**FL-22.** Critical facility owners and operators should perform a vulnerability assessment of their buildings in comparison to the FBC Risk Category IV threshold to determine their risks and vulnerabilities, and a best path forward for mitigating them.	Critical facility owners and operators, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 5 (Section 5.1 and Section 5.2)	**FL-23** Buildings throughout the impacted area were found to be vulnerable to wind-driven rain and water infiltration.	**FL-23a.** Designers should properly design rooftop equipment anchorage per the recommendations in Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 2 and contractors should properly implement the anchorage design to prevent blow-off.	Designers and contractors, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-23b. Copings and edge flashings should comply with ANSI/SPRI/FM 4435/ES-1 to prevent blow-off.	Designers and contractors, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-23c. In high-wind regions, designers should provide an enhanced closure detail for hip and ridge closures on metal panel roofs, and contractors should take special care in properly installing them.	Designers, CPCB, Economic
		FL-23d. Designers, contractors, and inspectors should place more emphasis on proper soffit installation to limit wind-driven rain.	Designers, contractors, inspectors, CPCB, Economic
		FL-23e. To help prevent entry of wind-driven rain into the building, designers should specify weatherstripping for, as well as consider designing vestibules at, exterior doors.	Designers, CPCB, Economic Health and Social Services
		FL-23f. FEMA Building Science should incorporate best practices for minimizing water infiltration into buildings from wind-driven rain into its relevant publications.	FEMA, CPCB, Economic

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 5 (Section 5.1 and Section 5.2) (continued)	**FL-24** Permanently mounted screen shutters installed with incompatible glazing assemblies and those with significant corrosion did not perform as intended and some came unlatched.	**FL-24a.** The task committee for ASTM E1886 should consider revising the standard to include the evaluation of the potential for the shutter assembly to unlatch during a storm.	ASTM E1886 Task Committee, CPCB
		FL-24b. Existing glazing assemblies that have inadequate wind pressure or wind-driven rain resistance should be replaced with new assemblies rather than being retrofitted with shutters.	Designers and contractors, CPCB, Economic, Health and Social Services, Housing, Infrastructure, Natural and Cultural Resources
		FL-24c. The task committee for ASTM E1886 should add corrosion criteria to the standard to help enable shutters to perform as intended over their useful life.	ASTM E1886 Task Committee, CPCB
		FL-24d. The task committee for ASTM E1886 should evaluate the current perpendicular angle specifications for impacting a shutter during testing for its adequacy.	ASTM E1886 Task Committee, CPCB
Chapter 5 (Section 5.1 and Section 5.2)	**FL-25** Structural standing seam metal panel roofs can blow off if not properly specified or installed.	**FL-25a.** Designers should specify, and contractors should properly install, standing seam metal panel systems that have been tested in accordance with ASTM E1592.	Designers and contractors, CPCB, Economic
		FL-25b. Designers should specify, and contractors should install, a roof deck with a secondary roof membrane for critical facilities designed with structural standing seam metal roof panels.	Designers and contractors, CPCB, Economic, Health and Social Services, Infrastructure, Natural and Cultural Resources
Chapter 5 (Section 5.1 and Section 5.2)	**FL-26** Numerous membrane roofs were found to have inadequate wind resistance and/or were vulnerable to being punctured by wind-borne debris.	**FL-26.** Designers should adequately design, and contractors should properly install, roof systems.	Designers and contractors, CPCB, Economic, Housing, Health and Social Services
Chapter 5 (Section 5.2)	**FL-27** URM walls are highly susceptible to collapse during high winds.	**FL-27.** Owners and operators of buildings with URM walls should include the toppling risk of these walls during high-wind events in vulnerability assessments and should mitigate the risk.	URM building owners and operators, CPCB, Economic, Housing, Health and Social Services, Infrastructure, Natural and Cultural Resources

Table 6-2: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Action Office/ Recovery Support Function
Chapter 5 (Section 5.2) (continued)	**FL-28** Brick veneer can fail if not properly installed or best practices are not employed in high-wind regions.	**FL-28a.** Building owners should have a vulnerability assessment performed for their existing building to ensure brick veneer is properly attached	Building owners, CPCB, Economic, Housing, Health and Social Services, Infrastructure, Natural and Cultural Resources
		FL-28b. Designers and contractors should improve installation of brick veneer in high-wind regions for new construction by ensuring it is properly attached.	Designers and contractors, CPCB, Housing, Health and Social Services
Chapter 5 (Section 5.1 and Section 5.2)	**FL-29** The blow-off of EIFS, which was a common observation, can lead to additional damage throughout the buildings, especially due to water infiltration.	**FL-29.** Designers should consider specifying a more robust wall assembly than EIFS for new critical facilities.	Designers, CPCB, Economic, Health and Social Services, Infrastructure
Chapter 5 (Section 5.2)	**FL-30** Roof aggregate can cause glazing damage to other floors on existing buildings or to nearby buildings.	**FL-30.** The FBC should provide more specific criteria with restrictions on how, when, and where roof aggregate can be used.	FBC, CPCB, Health and Social Services

AAMA = American Architectural Manufacturers Association
ANSI = American National Standards Institute
ARMA = Asphalt Roofing Manufacturers Association
ASCE = American Society of Civil Engineers
ASTM = ASTM International
BOAF = Building Officials Association of Florida
CCCL = Coastal Construction Control Line
CPCB = Community Planning and Capacity Building
CSA = Canadian Standards Association
DRRA = Disaster Recovery Reform Act of 2018
EHPA = Enhanced Hurricane Protection Area
EIFS = Exterior Insulation and Finish System
EMAC = Emergency Management Assistance Compact
FBC = Florida Building Code
FBCR = Florida Building Code, Residential
FDEM = Florida Division of Emergency Management
FEMA = Federal Emergency Management Agency
FHBA = Florida Home Builders Association
FM = FM Approvals
HES = Hurricane Evacuation Shelter
IBHS = Insurance Institute for Business & Home Safety
IBC = International Building Code
ICC = International Code Council
IRC = International Residential Code
MAT = Mitigation Assessment Team
NRCA = National Roofing Contractors Association
PEF = pressure equalization factor
SFHA = Special Flood Hazard Area
SMAA = Statewide Mutual Aid Agreement
SPRI = Single Ply Roofing Industry
URM = unreinforced masonry
WBDR = wind-borne debris region
WDMA = Window and Door Manufacturers Association

Appendix A

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Appendix B
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Appendix C

Recovery Advisories

RA1: *Successfully Retrofitting Buildings for Wind Resistance*

RA2: *Best Practices for Minimizing Wind and Water Infiltration Damage*

These advisories are also available online at https://www.fema.gov/media-library/assets/documents/180337.

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