Hurricane Milton
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PRELIMINARY VIRTUAL RECONNAISSANCE REPORT (PVRR)

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PREFACE

The National Science Foundation (NSF) awarded an EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network (see https://www.steer.network for more details). StEER was renewed through a second award (CMMI 2103550) to further enhance its operational model and develop new capabilities for more efficient and impactful post-event reconnaissance. StEER builds societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities. StEER achieves this vision by: (1) deepening structural engineers' capacity for post-event reconnaissance by promoting community-driven standards, best practices, and training, as well as their understanding of the effect of natural hazards on society; (2) coordination leveraging its distributed network of members and partners for early, efficient and impactful responses to disasters; and (3) collaboration that broadly engages communities of research, practice and policy to accelerate learning from disasters.

Under the banner of the Natural Hazards Engineering Research Infrastructure (NHERI) CONVERGE node, StEER works closely with the wider Extreme Events consortium to promote interdisciplinary disaster reconnaissance and research. The consortium includes the Geotechnical Extreme Events Reconnaissance (GEER) Association and the networks for Interdisciplinary Science and Engineering Extreme Events Research (ISEEER), Nearshore Extreme Event Reconnaissance (NEER), Operations and Systems Engineering Extreme Events Research (OSEEER), Social Science Extreme Events Research (SSEER), Sustainable Material Management Extreme Events Reconnaissance (SUMMEER), and Public Health Extreme Events Research (PHEER), as well as the NHERI RAPID facility, the NHERI Network Coordination Office (NCO), and NHERI DesignSafe CI, curation home for all StEER products.

While the StEER network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Southeast Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER is currently expanding its network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as the cross-cutting area of Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI)**, University of Notre Dame, serves as StEER Director responsible for overseeing the design and operationalization of the network and representing StEER in the NHERI Converge Leadership Corps.
- **Khalid Mosalam (co-PI)**, University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI)**, University of Florida, serves as StEER Associate Director for Wind Hazards, serving as primary liaison to the Wind Engineering community.
- **Mohammad S. Alam (co-PI)**, University of Hawai'i at Manoa, serves as StEER Associate Director for Coastal Hazards, serving as a primary liaison to the coastal engineering community.
- **David Roueche (co-PI)**, Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data suitable for re-use by the community.

This core leadership team works closely with StEER's Program Manager and Data Librarians in event responses, in consultation with its Advisory Boards for Coastal, Seismic and Wind Hazards.

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remuneration directly related to the publication of this research document.

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Reference to PVRR Analyses, Discussions or Recommendations

Reference to the analyses, discussions or recommendations within this report should be cited using the full citation information and DOI from DesignSafe (these are available at https://www.steer.network/responses).

Citing Images from this PVRR

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ACKNOWLEDGMENTS

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A number of VAST members contributed to the corresponding Media Repository, published under a separate DOI (Kameshwar, et al., 2024). Their photographic evidence and analysis was vital to the production of this report:

- Sabarethinam Kameshwar, Louisiana State University
- Amalesh Jana, Montana State University
- Hongtao Dang, Washington State University
- Mariantonieta Gutierrez Soto, Penn State
- Ahmed Abdelhady, University of Michigan
- Amy Diekmann, University of West Florida
- Ian Robertson, University of Hawai'i at Manoa
- Julide Yuzbasi, Cukurova University
- Kate Ancona, University of Notre Dame

Special thanks also go to Keegan Wolohan for coordination of this virtual response.

The sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated. StEER recognizes the efforts of the DesignSafe CI team who continuously supported and responded to StEER's emerging needs.

For a full listing of all StEER products (briefings, reports and datasets) please visit the StEER website: https://www.steer.network/responses

COMMON TERMS & ACRONYMS

Acronym	General Terms	Brief Description

--	DesignSafe	Data Repository
--	DesignSafe-CI	Academic Organization within NHERI
ASCE	American Society of Civil Engineers	Professional Organization
ASTM	American Society for Testing and Materials (now ASTM International)	Standards Body
ATC	Applied Technology Council	Professional Organization
BOCA	Building Officials and Code Administrators	Code Body
CC-BY	Creative Commons Attribution License	Code/Standard
CESMD	Center for Engineering Strong Motion Data	Governmental Agency
CI	Cyberinfrastructure	Research Asset
CLPE	Critical Load Path Elements	StEER Term
CMU	Concrete Masonry Unit	Building Material
CPIC	Center for Public Interest Communication	Research Support Organization within University of Florida to study, test and apply strategic communication for social change
CWA	Central Weather Administration	Taiwan Governmental Agency
DBE	Design Basis Earthquake	Design Terminology
DEQC	Data Enrichment and Quality Control	StEER Term
DOI	Digital Object Identifier	Common Term
EARR	Early Access Reconnaissance Report	StEER Term
EERI	Earthquake Engineering Research Institute	Professional Organization
EEFIT	Earthquake Engineering Field Investigation Team	Professional Organization
EF	Enhanced Fujita Scale	Hazard Intensity Scale
EF	Equipment Facility	Academic Organization within NHERI
EIFS	Exterior Insulation Finish System	Building Component
FAA	Federal Aviation Administration	Governmental Agency
FAQ	Frequently Asked Questions	Common Term
FAST	Field Assessment Structural Team	StEER Term
FEMA	Federal Emergency Management Agency	Governmental Agency
FIRM	Flood Insurance Rate Maps	Regulatory Product
GEER	Geotechnical Extreme Events Reconnaissance	Academic Organization within

		NHERI
GPS	Global Positioning System	Measurement Technology
GSA	Government Services Administration	Governmental Agency
HVAC	Heating, ventilation and air conditioning	Building System
HWM	High Water Mark	Intensity Measure
IBC	International Building Code	Code/Standard
ICC	International Code Council	Code Body
IRC	International Residential Code	Code/Standard
ISEEER	Interdisciplinary Science and Engineering Extreme Events Research	Academic Organization within NHERI
LiDAR	Light Detection and Ranging	Measurement Technology
MCE	Maximum Considered Earthquake	Design Terminology
ME&P	Mechanical, electrical and plumbing	Building System
MMI	Modified Mercalli Intensity	Hazard Intensity Scale
NBC	National Building Code	Code/Standard
NEER	Nearshore Extreme Event Reconnaissance	Academic Organization within NHERI
NFIP	National Flood Insurance Program	Government Program
NHERI	Natural Hazards Engineering Research Infrastructure	Academic Organization within NHERI
NIST	National Institute of Standards and Technology	Governmental Agency
NOAA	National Oceanic and Atmospheric Administration	Governmental Agency
NSF	National Science Foundation	Governmental Agency
NWS	National Weather Service	Governmental Agency
OSB	Oriented strand board	Construction Material
OSEEER	Operations and Systems Engineering Extreme Events Research	Academic Organization within NHERI
PEER	Pacific Earthquake Engineering Research center	Academic Organization (Earthquakes)
PGA	Peak Ground Acceleration	Intensity Measure
PHEER	Public Health Extreme Events Research	Academic Organization within NHERI
PVRR	Preliminary Virtual Reconnaissance Report	StEER Term

QC	Quality Control	Oversight process
RAPID	RAPID Grant	Funding Mechanism
RAPID-EF	RAPID Experimental Facility	Academic Organization within NHERI
RC	Reinforced Concrete	Building Material
SAR	Search and Rescue	Standard Hazards Terminology
SGI	Special Government Interest	FAA Process
SLP	Surface-Level Panoramas	Measurement Technology
SMS	Short Message Service	Communication Modality
SPC	Storm Prediction Center	Governmental Agency
SSEER	Social Science Extreme Events Research	Academic Organization within NHERI
StEER	Structural Extreme Events Reconnaissance network	Academic Organization within NHERI
SUMMEER	SUstainable Material Management Extreme Events Reconnaissance	Academic Organization within NHERI
TAS	Testing Application Standard	Technical Standard
UAS/V	Unmanned Aerial Survey/System/Vehicle	Measurement Technology
USD	US Dollar	Standard Currency
USGS	United States Geological Survey	Governmental Agency
VAST	Virtual Assessment Structural Team	StEER Term
WS	Windshield Survey	Measurement Technology

EXECUTIVE SUMMARY

Hurricane Milton was the fastest Atlantic storm to intensify from a tropical depression to a Category 5 hurricane, with maximum sustained winds increasing from 35 mph to 160 mph in just over 48 hours. During this period, it became the fifth most intense recorded hurricane in the Atlantic Basin in terms of central pressure, just behind Hurricane Rita (2005), and only the sixth storm in the Atlantic to have a central pressure below 900 mb. Despite the potential to be a catastrophic storm, Hurricane Milton weakened substantially, making landfall as a Category 3 storm on October 9, 2024 near Siesta Key, Florida with estimated maximum sustained winds of 120 mph. Hurricane-force winds extended up to 35 miles, with peak gusts reaching 112 mph in some regions, though these winds were well below the design wind speeds in the affected areas. Storm surges exceeded 9 feet in some areas, while some inland regions experienced over 18 inches of rainfall, resulting in compound flooding particularly in areas with high water tables. Notably, 46 tornadoes were reported across Florida as Milton cut across the state, with the most destructive rated EF-3, causing fatalities and widespread structural damage.

The storm's impact on the built environment was observed across residential, commercial, and critical infrastructure. Damage to residential construction was driven by storm surge along the Gulf coast, particularly in Sarasota and neighboring areas, inland flooding in a swath cross-cutting the state from Tampa to Daytona Beach, and tornado-wind damage on the Atlantic coast of Florida. Critical infrastructure, such as power lines, transportation networks, and telecommunication systems faced extensive disruption, with a number of roadways damaged by flood conditions and 3.4 million customers losing power.

In response, StEER activated a Level 1 response, forming a Virtual Assessment Structural Team (VAST) on October 10, 2024 to generate this Preliminary Virtual Reconnaissance Report (PVRR). The PVRR: (1) overviews Hurricane Milton, particularly relating to hurricane winds, tornadoes, flooding, and storm surge impacts on the built environment; (2) establishes the regulatory environment and construction practices in the affected area; (3) synthesizes preliminary reports of damage to buildings, infrastructure, and critical facilities; and (4) provides recommendations for continued study of this event by StEER and the wider engineering reconnaissance community, particularly related to the performance of construction designed for hurricanes during tornadoes and the performance of flood control measures under compound flooding.

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1. Introduction

Hurricane Milton was a remarkable storm: the fastest Atlantic storm to intensify from a tropical depression to a Category 5 hurricane, with maximum sustained winds increasing from 35 mph to 160 mph in just over 48 hours. During this period, it became the fifth most intense recorded hurricane in the Atlantic Basin in terms of central pressure, just behind Hurricane Rita (2005), and only the sixth storm in the Atlantic to have a central pressure below 900 mb (Lang, 2024). Despite the potential to be a catastrophic storm, Hurricane Milton weakened substantially, making landfall as only Category 3 storm on October 9, 2024 near Siesta Key, Florida. Despite weakening, the hurricane still induced high winds, flooding, and tornadoes, damaging buildings, critical infrastructure, and coastal protective systems, as documented by this report.

1.1. Societal Impact

The state of Florida bore the brunt of the storm's impacts, with 34 out of 51 counties affected and initial estimates of damage to crops and infrastructure ranged from $1.5 to $2.5 billion (FDACS, 2024), with total economic losses estimated at $34.3 billion (NCEI, 2024). Schools and healthcare facilities faced significant challenges due to disruption of essential services, such as power and transportation.

1.2. Loss of Life and Injuries

Thirty-five confirmed fatalities (32 in Florida) were attributed to Milton as of October 21, 2024 (NCEI, 2024). Many of these deaths resulted from tree falls and accidents that occurred during recovery operations. In Florida's St. Lucie County, an EF3 tornado spawned by the storm destroyed numerous homes and killed 6 people living in mobile/manufactured homes, becoming the deadliest tornado to strike Florida since 2007.

1.3. Official Response

The official response to Hurricane Milton involved coordinated efforts from state, local, and federal officials, as well as significant support from humanitarian organizations. In the days leading up to the storm, the National Hurricane Center (NHC) issued hurricane warnings and watches for much of Florida's Gulf Coast, with particular emphasis on the Siesta Key area where the storm eventually made landfall. Governor Ron DeSantis declared a state of emergency across 46 counties, activating the Florida National Guard and prepositioning resources to support emergency response. Local governments implemented mandatory evacuations in low-lying and flood-prone areas. Coastal counties like Sarasota and Pinellas were particularly proactive, providing transportation for vulnerable populations. More than 500,000 people were evacuated in Hillsborough and Pinellas Counties (Chavez & Garcia, 2024). Despite these efforts, some residents remained in their homes, contributing to challenges post-landfall. The Southwest Florida Water Management District proactively lowered water levels on all canals and reservoirs ahead of the storm (SFWMD, 2024).

Federal agencies, including FEMA, deployed disaster response teams and set up Disaster Recovery Centers (DRCs) in the hardest-hit regions to assist with applications for aid and temporary housing (Disaster Assistance, 2024). FEMA has approved $349 million in funding to support communities under a major disaster declaration in Florida (FEMA, 2024a). The American Red Cross and other non-governmental organizations offered critical support, such as operating shelters, distributing food and water, and providing mental health services for storm survivors (Red Cross, 2024).

These efforts were complemented by utility companies mobilizing thousands of workers to restore power to over 3 million customers left in the dark (Bridges, 2024). More than 50,000 utility workers from across 42 states, Canada, and the District of Columbia pre-positioned before Hurricane Milton made landfall (DOE, 2024). However, logistical challenges like flooded roads and debris slowed recovery operations in certain areas.

1.4. Report Scope

StEER activated a Level 1 response to evaluate this event, forming a Virtual Assessment Structural Team (VAST) on October 10, 2024, based on the event having the strong potential to generate new knowledge, evidenced by achieving more than 50% of the response activation criteria (see Table 1.1). The official response page was then instituted at the StEER website. The VAST was charged with the production of the primary product of StEER's Level 1 response to this event: this **Preliminary Virtual Reconnaissance Report (PVRR),** intended to:

1. provide an overview of Hurricane Milton, particularly relating to hurricane winds, tornadoes, flooding, and storm surge/wave impacts on the built environment,
2. overview the regulatory environment and construction practices in the affected area,
3. synthesize preliminary reports of damage to buildings, infrastructure, and critical facilities,
4. provide recommendations for continued study of this event by StEER and the wider engineering reconnaissance community.

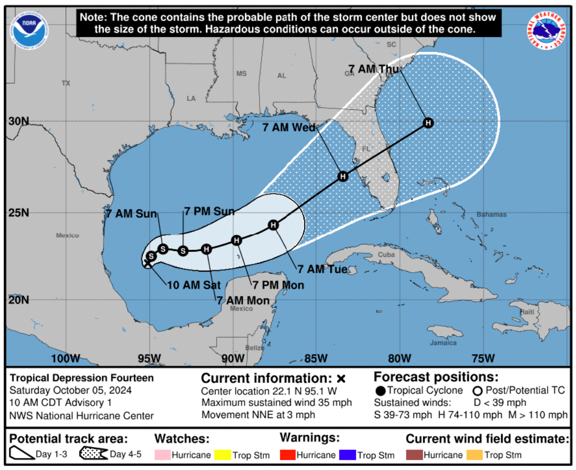
Table 1.1. Summary of Level 1 Activation Criteria

Hazard	Exposure	Feasibility
• Category 3+ hurricane at landfall • Impacts regions already impacted by Helene in 2024 and Ian in 2022 • Notable joint/compounding wind and surge hazards	• High population density in landfall region • Communities previously recovered from Hurricane Ian (2022) • Many modern buildings affected by direct impacts from surge and hurricane/tornado winds • Diversity of infrastructure classes impacted including critical facilities • Relatively high density of surge and wind measurements in the landfall region	• Many StEER members should be interested in this event • High levels of media coverage

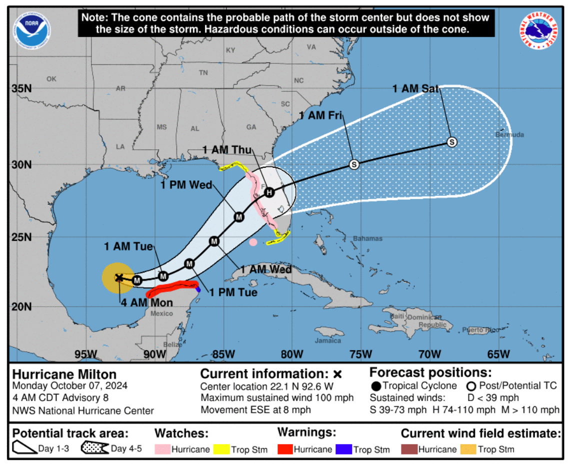
2. Hazard Characteristics

2.1. Meteorological Background

Hurricane Milton formed as a tropical depression over the southwestern Gulf of Mexico and started being tracked by the NHC as a Potential Tropical Cyclone Fourteen on October 5, 2024 (Fig. 2.1a). In the Atlantic Basin, it is quite rare for a hurricane to develop in the Gulf and then move eastward as Milton did (News Center Main, 2024; US News, 2024). Hurricane Milton continued to intensify and was upgraded to a Category 2 Hurricane with maximum sustained winds of 100 mph; the NHC issued Storm Surge and Hurricane Watches for portions of the west coast of the Florida Peninsula on October 7, 2024 (Fig. 2.1b). Later that day, Hurricane Milton underwent rapid intensification and was upgraded to a Category 5 hurricane with maximum sustained winds of 180 mph.



(a)



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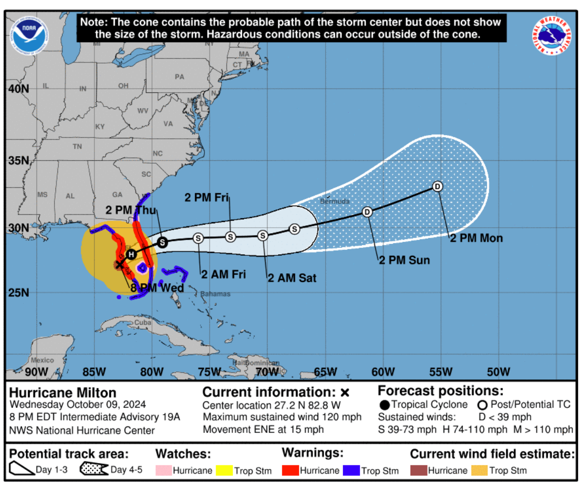

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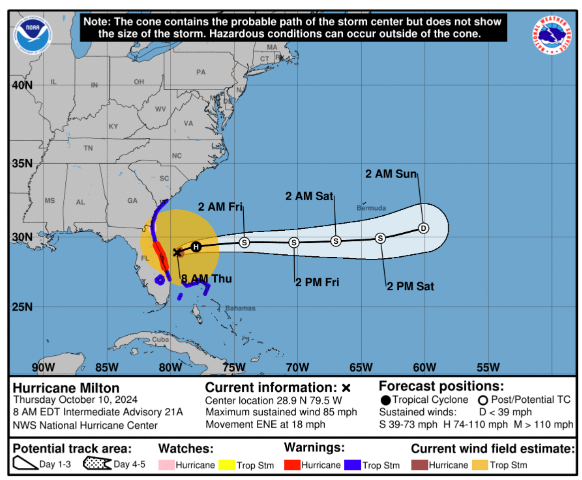
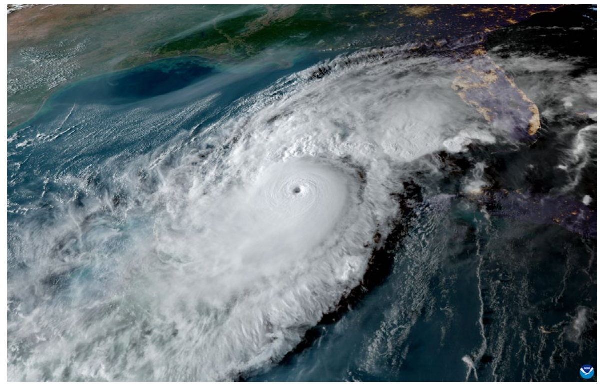


(d)

Figure 2.1. Progression of forecast graphics from the NHC between October 05-10, 2024 (Source: NHC Milton Graphic Archive)

The NHC issued a Hurricane Warning for the west coast of Florida, anticipating high winds, heavy rainfall and destructive surge of 10 ft or greater (NHC, 2024). At this stage, Hurricane Milton was one of the most intense hurricanes ever recorded in the Atlantic basin (Thiem, 2024). On October 8, 2024, due to increasing wind shear, Hurricane Milton began losing intensity and was downgraded to Category 4 storm with maximum sustained winds of 150 mph. The storm weakened further as it made landfall on Wednesday, October 9, 2024, as a Category 3 hurricane near Siesta Key, with maximum sustained winds of 120 mph (NESDIS, 2024) (Fig. 2.1c). The hurricane maintained its intensity as it traversed the state, entering the Atlantic Ocean near Cape Canaveral shortly after 4:00 am EDT on October 11 (Fig. 2.1d). Figure 2.2a shows the track of Hurricane Milton, with satellite imagery of the hurricane on October 8, 2024 as it approached the Gulf Coast of Florida (Fig. 2.2b).



(a) (b)

Figure 2.2. (a) Hurricane Milton Tracks (Source: NOAA Hurricane Tracker); (b) Hurricane Milton Eyes Florida (Source: NOAA GOES East Satellite)

2.2. Wind Field

Figure 2.3 shows the extent of the wind field along the track as Milton made landfall, and Figure 2.4 depicts the design wind speeds for ASCE 7-22, focusing on Risk Category II structures (associated with a 700-year mean recurrence interval) across Florida. The figure also shows the estimated 3-second peak gusts for Hurricane Milton, at 10 m (33 ft) above flat, open terrain by NIST/ARA (NIST, 2024). Notably, Hurricane Milton's peak overland winds fell well below the thresholds established by current building codes in Florida, as discussed in Section 3. The highest gust recorded at St. Petersburg Whitted Airport (from the KSPG ASOS station; 3-second peak gusts at 10 m height in open terrain) was 112 mph (NIST, 2024). Based on ASCE 7-22, this wind speed corresponds to a return period of approximately 65 years, far less than the specified return periods for design wind speeds in Florida. For example, the design wind speed for risk category II structures (most buildings) near the St. Petersburg Whitted Airport is 146 mph, corresponding to a 700-year return period.

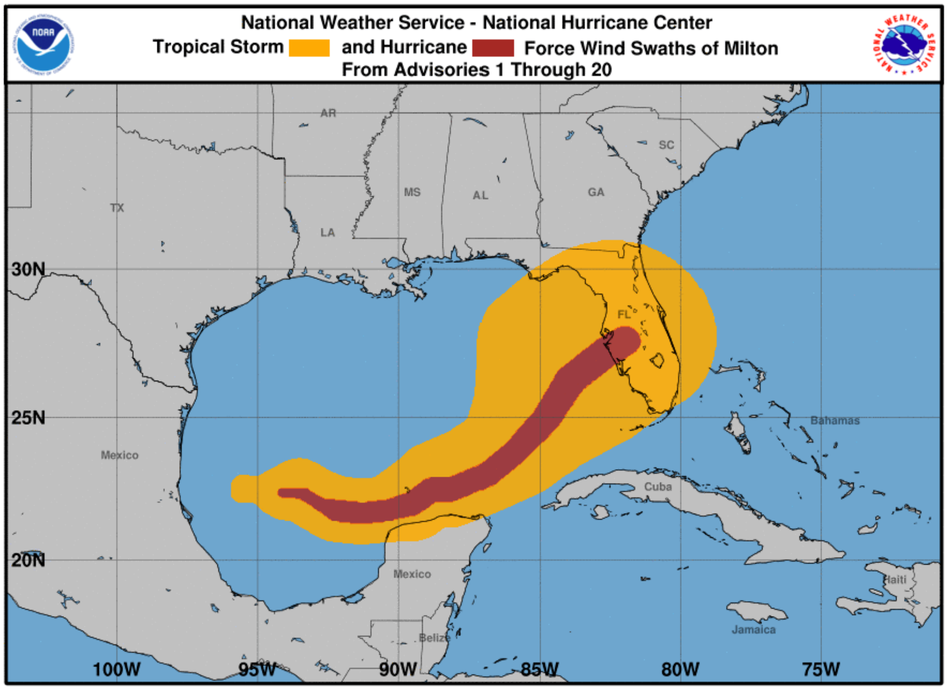


Figure 2.3. Overview of the wind field of Hurricane Milton that shows the extents of the hurricane force winds and tropical storm force winds as provided by the NHC (Source: NHC, 2024)

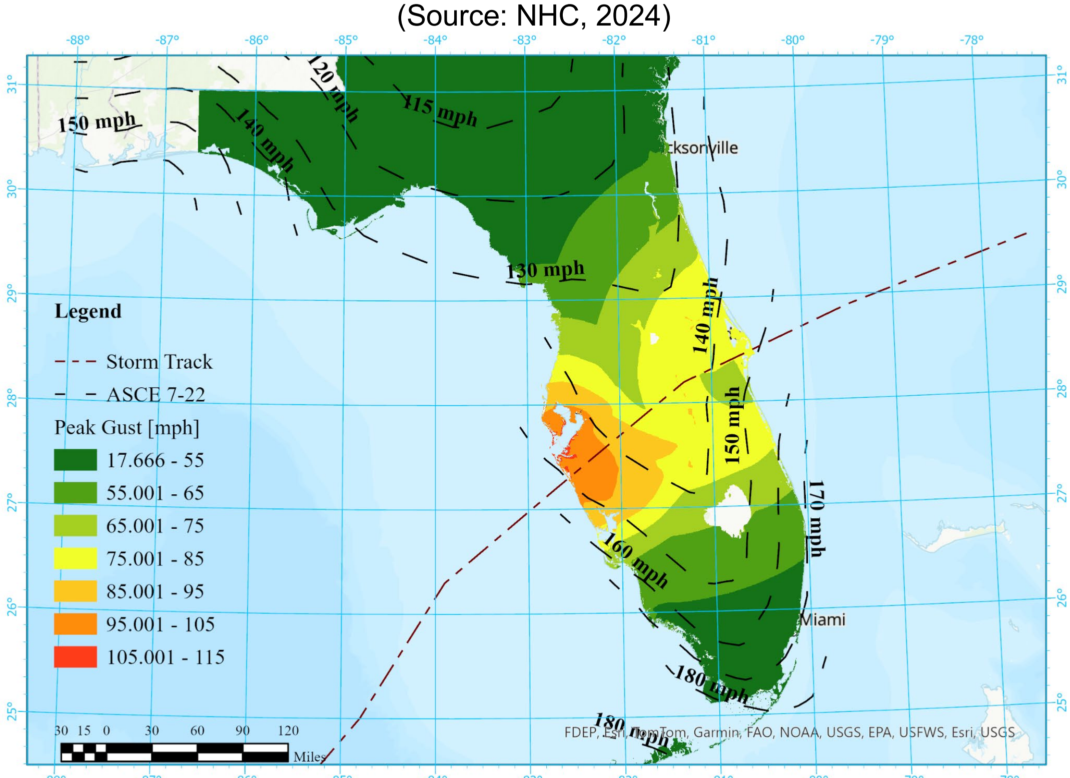


Figure 2.4. Design wind speeds in Florida for ASCE 7-22 Risk Category II buildings and estimated wind field maps produced by NIST/ARA (Source: FEMA, 2024b).

2.3. Storm Surge and Coastal Flooding

Hurricane Milton's largest storm surges were observed between Siesta Key and Fort Myers Beach, FL. Figure 2.5 illustrates the predicted water height (storm surge + tide) above Mean Sea Level (MSL) generated by ADCIRC for the Coastal Emergency Risks Assessment (CERA) under NHC Advisory #19, near the time of the storm's landfall. The ADCIRC results suggest that Hurricane Milton caused a maximum inundation depth of more than 9 ft (2.75 m) above MSL in Siesta Key, and about 6 ft (1.8 m) above MSL in Fort Myers Beach. A reverse storm surge of up to 15 feet (4.57m) was observed in the Tampa region (Peltz, 2024).

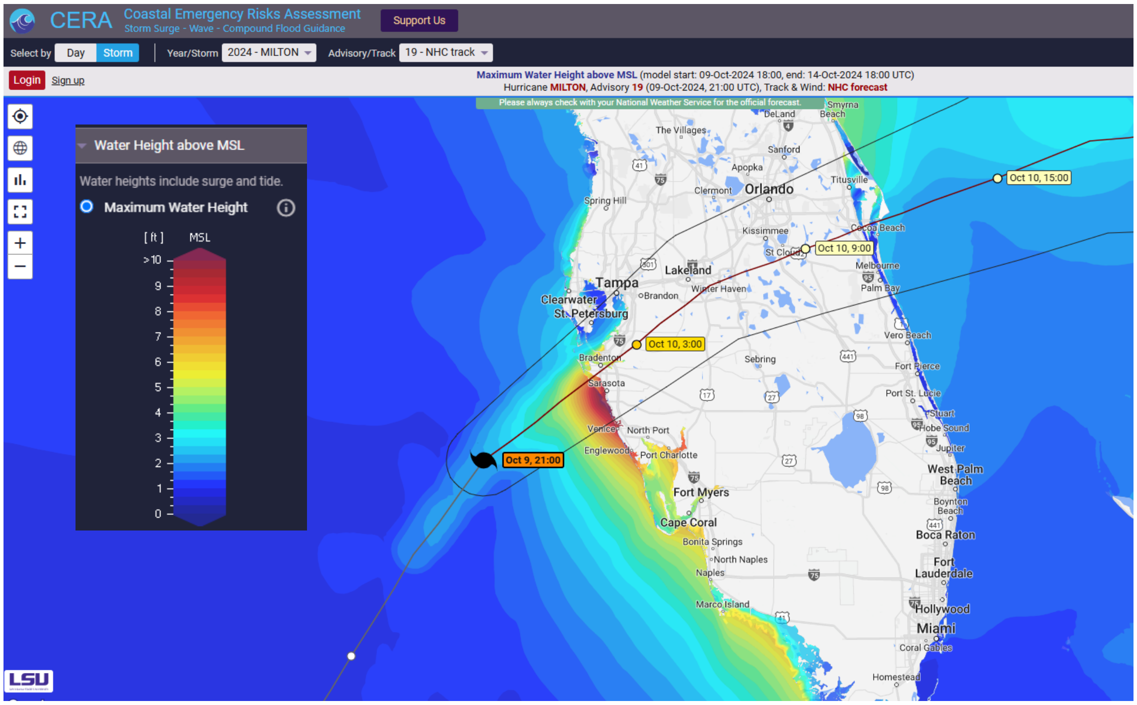


Figure 2.5. Maximum water height (tide + storm surge), in ft, referenced to Mean Sea Level (MSL) generated by CERA for NHC Advisory #19 (Source: CERA)

Figure 2.6 shows the water level for Hurricane Milton measured at NOAA stations along the east coast of Florida, including Clearwater Beach, Fort Myers, Naples Bay, and Vaca Key (NOAA, 2024) with corresponding storm return periods from the Coastal Hazards System (CHS, 2024). As shown in Figure 2.6, the surge height induced significant flooding: about 1.5 m above NVD88 in Fort Myers (60-year return period) and exceeding 1.5 m in Naples Bay (40-year return period). The storm surge in Clearwater Beach, near Tampa, resulted in minor flooding (reached less than 1.0 m), less than half that was observed in Hurricane Helene just one week prior (NOAA, 2024).

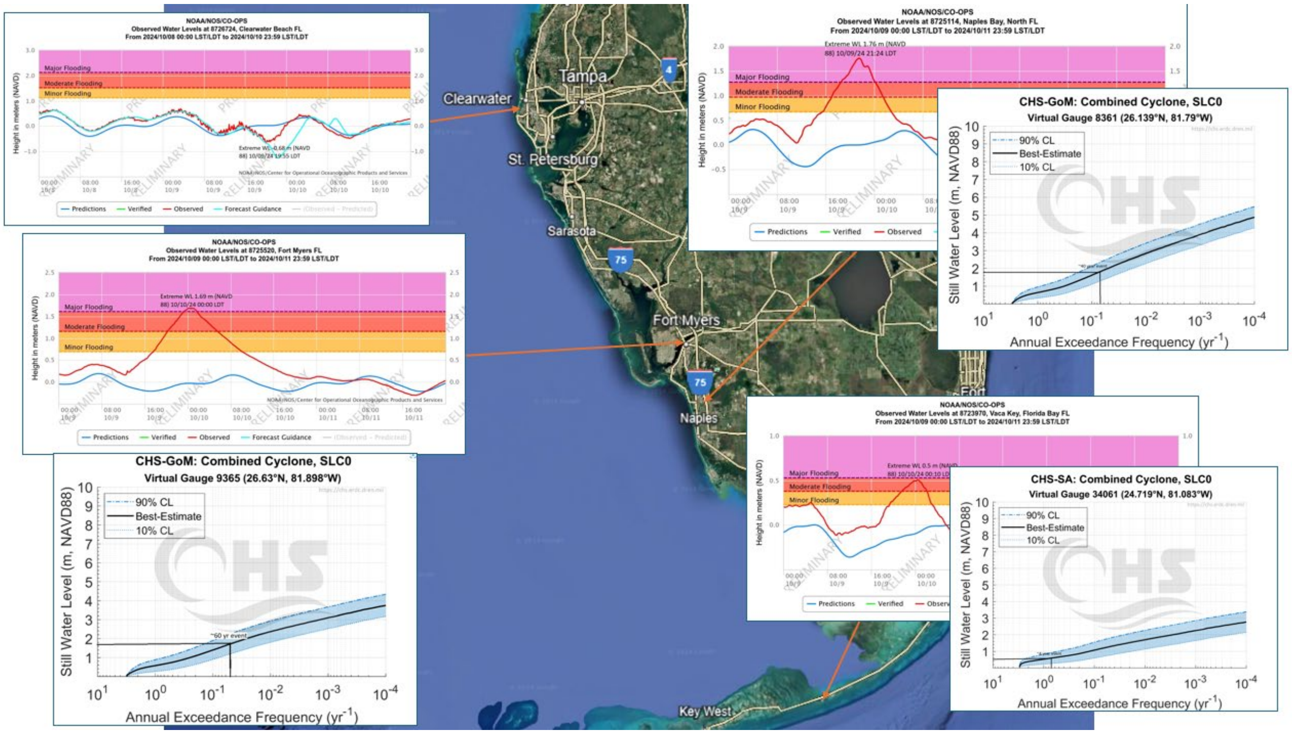


Figure 2.6. Water levels measured at NOAA stations during Hurricane Milton: 8726724 Clearwater Beach; 8725520 Fort Myers FL; 8725114 Naples Bay; 8723970 Vaca Key. Predicted (blue curves) and preliminary observed (red curves) in meters relative to NVD88, along with thresholds for minor, moderate, and major flooding. Corresponding annual exceedance probabilities displayed for each station (NOAA, 2024; CHS, 2024).

2.4. Rainfall and Inland Flooding

Hurricane Milton produced significant rainfall totals across Florida, leading to flash flooding and other impacts in various regions as shown in Table 2.1 (Powell, 2024). The hardest-hit area was Gibsonia 7.6 N, Polk County, which recorded up to 18.75 inches (47.6 cm) of rain (Powell, 2024). The intense rainfall occurred over a 24- to 48-hour period as Milton made landfall and moved inland (Fig. 2.7).

Table 2.1. Locations in Florida with the highest 24-hour rainfall totals during Hurricane Milton

No	Location	Total Rainfall (inches)
1	Gibsonia 7.6 N	18.75
2	St. Petersburg Albert Whitted AP	18.54
3	McKay Creek at Largo	16.87
4	Daytona Beach Shores 1.8 SSE	15.8
5	Lake Helen 0.9 S	15.37

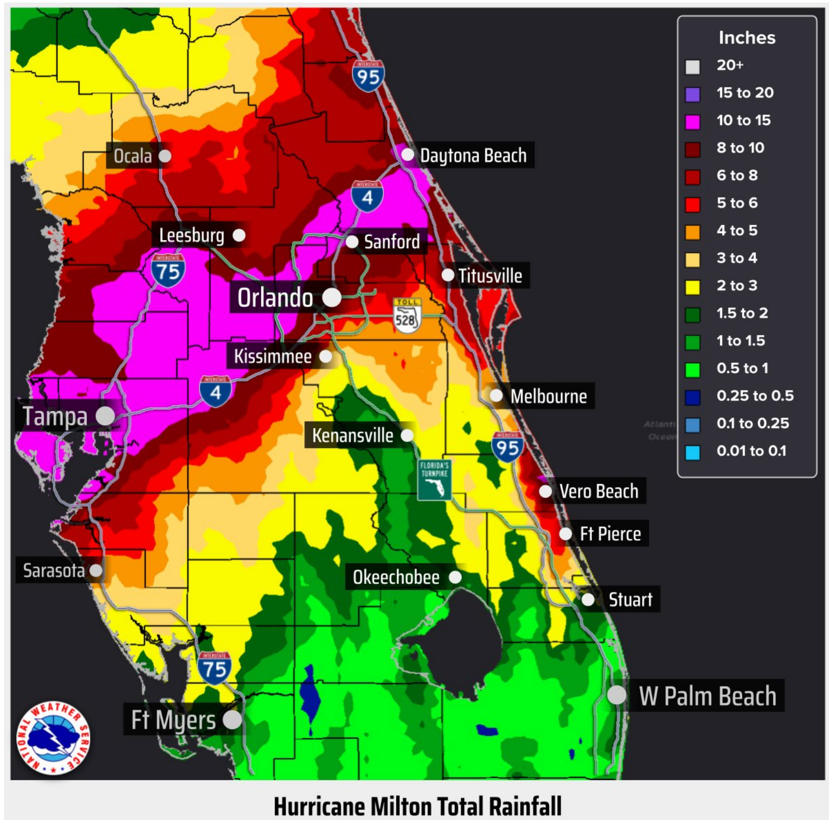


Figure 2.7. Hurricane Milton total rainfall (Source: NWS, 2024).

2.5. Tornadoes

On October 9, 2024, National Weather Service (NWS) offices issued 126 Tornado Warnings across Central and South Florida associated with Hurricane Milton (Erdman, 2024). East-central Florida experienced significant impacts, with at least 46 confirmed tornadoes, ranging from EF0 to EF3 on the Enhanced Fujita (EF) Scale (NWS, 2024). Figure 2.8 illustrates the confirmed tornado tracks over East Central Florida on October 9, whose characteristics are reported in the Appendix. The strongest tornado, rated EF3, affected the Fort Pierce, Spanish Lakes, and Vero Beach communities, with estimated peak winds of 155 mph, a path length of 21.2 miles, and a maximum width of 500 yards, resulting in six fatalities (NWS, 2024).

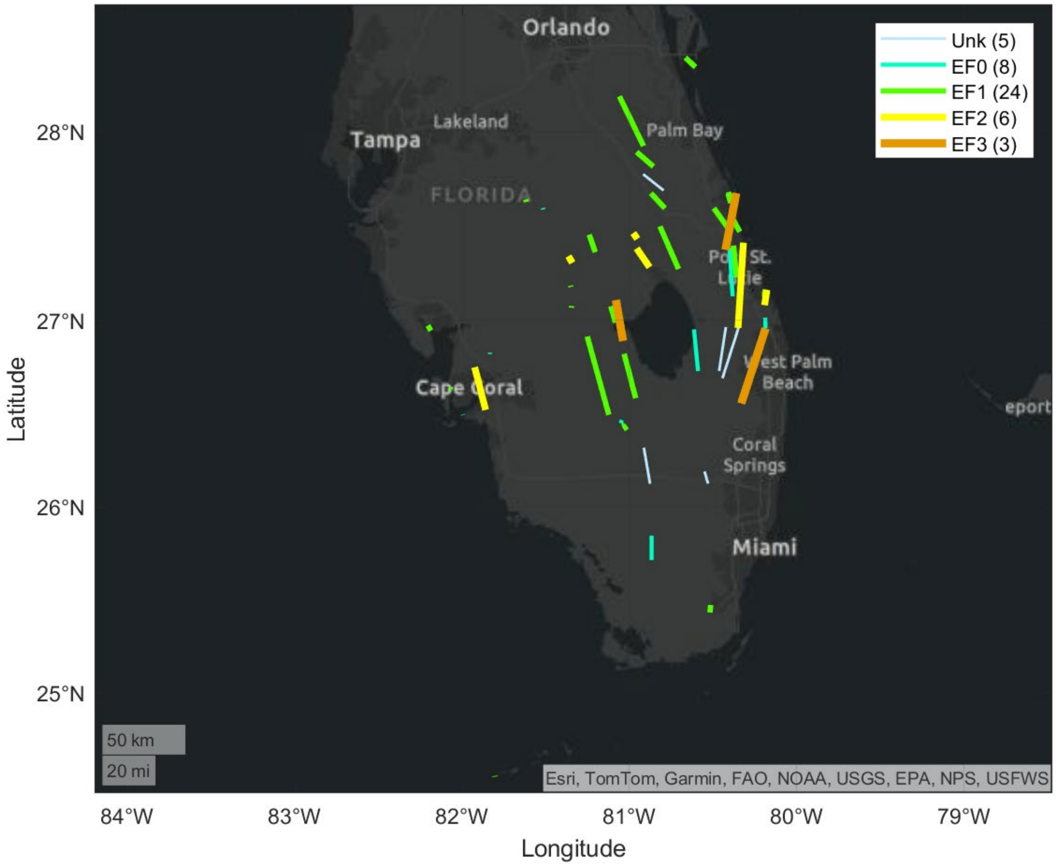


Figure 2.8. Confirmed tornado tracks over East Central Florida (Data Source: NWS, 2024).

3. Local Codes and Construction Practices

Florida's local building codes and construction practices have evolved significantly, particularly following the devastation caused by Hurricane Andrew in 1992, which resulted in over 65 fatalities and caused $27 billion in damage (Blake et al., 2011). At that time, Florida had numerous local building codes, many of which lacked the strict regulations needed to withstand hurricane-force winds, leaving structures highly vulnerable. In response, the state introduced the South Florida Building Code in 1994, and later adopted the Florida Building Code (FBC) in 2002. The FBC, based on the 2000 International Building Code (IBC) and International Residential Code (IRC), was established as a statewide standard to enhance building resilience, particularly in hurricane-prone regions. FBC wind load calculations primarily reference ASCE 7.

The 2004 hurricane season, which brought four major hurricanes—Charley, Frances, Ivan, and Jeanne—to Florida, further underscored the importance of strong building codes across the state. The collective impact of these storms, which caused billions in damages and revealed widespread structural vulnerabilities, prompted additional updates to the FBC. The season exposed weaknesses in roofing systems, water intrusion protections, and wind-borne debris defenses, even in inland areas previously considered less at risk. As a result, the FBC was strengthened to include enhanced roofing attachment standards, expanded wind-borne debris regions to the panhandle area, and stricter regulations for both coastal and inland zones (Dixon, 2009). These updates ensured that buildings across Florida were better equipped to withstand the intense wind, rain, and storm surge associated with hurricanes.

The FBC now includes a High-Velocity Hurricane Zone (HVHZ) with specific provisions for Broward County, Miami-Dade County, and the Florida Keys, mandating stronger construction standards like impact-resistant windows, reinforced roofs, and hurricane straps. As a result, Florida's building codes are now regarded as some of the most effective in the U.S., as rated by FEMA and the Institute for Business and Home Safety (IBHS) (FEMA, 2023; IBHS, 2024).

3.1 Mobile and Manufactured Homes

In Florida, mobile/manufactured homes are regulated by both federal and state building codes to ensure safety, particularly in hurricane-prone areas. The primary code governing the construction of manufactured homes nationwide is the Manufactured Home Construction and Safety Standards established by the U.S. Department of Housing and Urban Development (HUD). This code preempts local building codes and sets requirements for design, construction, strength, and energy efficiency. Since Florida is prone to hurricanes, homes in the state must meet the stricter HUD standards for Wind Zones II and III, which apply to high-wind regions. The wind speed requirements for Wind Zones II and III are fastest-mile wind speeds of 100 mph and 110 mph, which convert to 3-sec gusts of 116 mph and 126 mph, respectively. However, the standard also provides net main wind force resisting system (MWFRS) pressures of 39 psf and 47 psf, which are equivalent to 138 mph and 150 mph 3-second gusts per ASCE 7-16 guidelines with $K_z = K_d = G = 0.85$ and a net C_p of 1.3 (0.8 for windward wall and 0.5 for leeward wall).

In addition to federal standards, Florida's Administrative Code (Chapter 15C-1) outlines specific rules for the installation, tie-downs, and anchoring systems for mobile/manufactured homes. These regulations are critical for ensuring that homes remain secure during high winds, reducing the risk of overturning or displacement.

3.2 Coastal Regulations

The Coastal Construction Control Line (CCCL) Program is a vital aspect of Florida's coastal management efforts, aimed at safeguarding the state's beaches and dunes while balancing private property rights (Florida Department of Environmental Protection, n.d.). Initiated by the Florida Legislature, the CCCL Program addresses the potential risks posed by poorly sited and designed structures that could lead to beach erosion, dune destabilization, and damage to upland properties. The CCCL locations are determined based on coastal engineering models, survey and bathymetric data, and scientific principles that assess the landward extent of the damaging effects of a 100-year storm event. This establishes a jurisdictional area where stricter siting and design criteria are enforced, particularly for construction activities in more vulnerable seaward zones that experience greater forcing during storm events. Additionally, coastal construction regulations extend to sandy "pocket beaches" in Florida's Big Bend region and the Florida Keys.

To minimize the damaging impact on the natural functioning of the beach and dune system, major structures such as single or multi-family residences, parking garages, or commercial facilities should be placed on piles. Elevating the structure in this manner ensures that the bottom of the lowest horizontal structural member is at or above the design breaking wave crest. This design minimizes the resistance to coastal floodwaters, allowing for free flow during storm events, thus further protecting both the coastal environment and upland properties. Additionally, the use of slab on-grade foundations and extensive impervious surfaces is restricted in favor of pervious or semi-pervious materials, allowing for proper water drainage and minimizing runoff, to promote vegetation growth and preserve natural dune dynamics. Currently, CCCLs are established in 25 coastal counties across Florida, and they can be re-evaluated and adjusted in response to significant changes in shoreline conditions due to erosion or major storms (Florida Department of Environmental Protection, n.d.).

4. Building Performance

This section summarizes building performance observed in publicly reported data. Tables 4.1 and 4.2 provide a synthesis of the typical performance of buildings in this event, respectively organized by occupancy and geography. The observed damage exhibited a bi-modal geographical distribution, with the first cluster concentrated near the landfall region with the strongest storm surge and hurricane-force winds. A second cluster of damage emerged on the east side of the state in Martin and Saint Lucie Counties where tornadoes were more prevalent (Fig. 4.1). The subsections that follow present notable case studies. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe (Kameshwar, et al., 2024), to access a richer collection of georeferenced visual evidence cataloged by occupancy.

Table 4.1. Summary of Building Performance by Occupancy

Single-Family Residential Buildings	Widespread damage, primarily non-structural, was observed in areas around Sarasota due to wind and surge. Tornado-induced damages were reported all the way from Fort Myers to Port St. Lucie.
Multi-Family Residential Buildings	Flooding was reported, though structural damage appeared limited; a rare case of structural failure was observed on an island in Tampa Bay.
Commercial Buildings	Damage to glass facades, loss of roof cover, structural roof damage were reported; most notable: roof failure of Tropicana Field Stadium.
Healthcare/Medical Facilities	Instances of water intrusion damage in a few hospitals.
Schools	Isolated damage to schools in Pasco and Martin Counties, another in Clearwater; damages included severe loss of roof cover and underlying structural damage.
Government Facilities	No notable damage reported.
Mobile/Manufactured Homes	Widespread damage to mobile homes due to storm surge, inland flooding, hurricane winds, and tornadoes; included frequent structural roof and wall failures, particularly in coastal areas and among homes built before the 1990s; flooding also observed.
Critical Facilities	Damage to the St. Lucie County sheriff’s building housing patrol vehicles and Albert Whitted Airport in St. Petersburg.
Historical Buildings	Rod and Reel Pier (historical commercial building) damaged during Helene and washed away during Milton.
Religious Institutions	Damage to church in Fort Pierce; wind damage to irregularly shaped roof of Lakewood Park Church.

Table 4.2. Summary of Building Performance by Geography	
Sarasota and neighboring areas	Damage from storm surge, wave, and hurricane winds, though less widespread compared to Hurricane Helene. Flooding caused structural failures and building collapses, particularly in coastal regions and on outlying islands. Roof failures and tree fall damage were also observed in residential and commercial buildings.
Lee county and neighboring areas	A few incidences of tornado -induced damage reported along with water intrusion into some schools.
Areas near Martin and St. Lucie counties	Widespread tornado damage was reported in these areas due to multiple tornado outbreaks.
Orlando metropolitan area, St. Lucie County, Martin County, and Palm Beach County	Non-structural roof and facade damage was commonly observed due to strong winds/tornadoes, with isolated severe structural damage. Pre-manufactured metal buildings and mobile homes were particularly vulnerable. Limited damage by flooding.

Figure 4.1. Damaged residential buildings in the Spanish Lakes community impacted by an EF3 tornado with variable levels of structural and roof damage (Source: Miguel J. Rodriguez Carrillo).

4.1. Tropicana Field Stadium

Figure 4.2b shows an aerial view of the damage to the roof of the Tropicana Field Stadium in St. Petersburg, FL aligned with an aerial view of the pre-damaged structure (Figure 4.2a). While the frame supporting the roof is intact, the majority of the tension membrane fabric roof was shredded. Media reports based on a city-sponsored inspection report suggest that there was no major structural damage (Anderson, 2024), although the ring beam was damaged in some areas. The maximum wind speed at the nearby Albert Whitted Airport in St. Petersburg was reported to be 101 mph. The stadium was constructed between 1986 to 1990 and was recently renovated in 2014. The renovations did not focus on the roof. As per the *Minimum Design Loads for Buildings and Other Structures*, ANSI A58.1-1982, which might have been used to design the roof, the design wind speed for the St. Petersburg area was 100 mph, which would have been used in tandem with load factor of 1.3, which would suggest the roof membrane should have been designed for the wind speeds observed during Hurricane Milton. Moreover, the stadium was not in close proximity to reported tornado warnings and tornado outbreaks (Washington Post, 2024). Therefore, further investigations are needed to determine the cause of membrane failure.

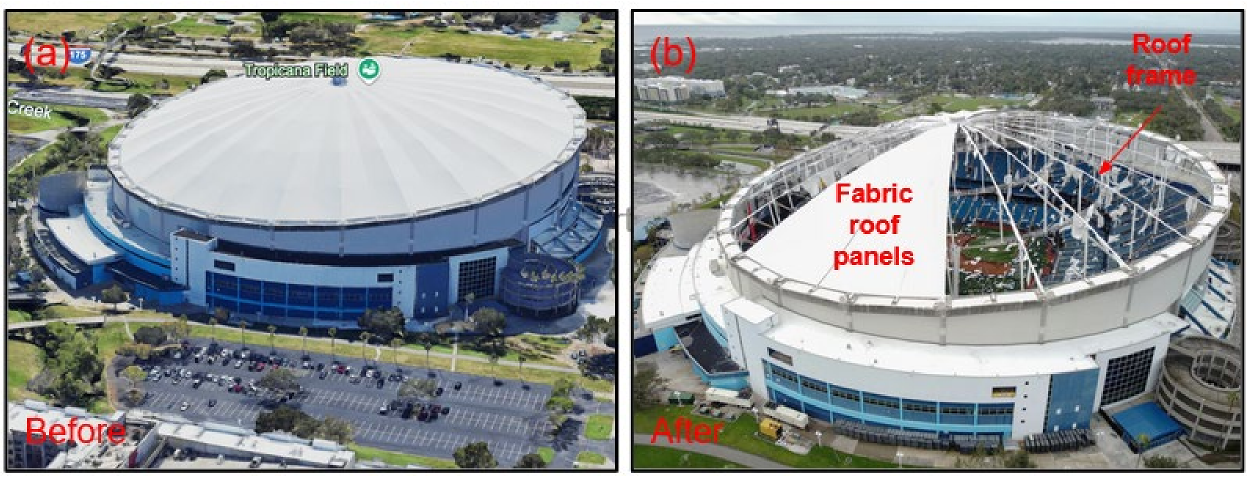


Figure 4.2. (a) Tropicana Field Stadium before Hurricane Milton (Source: Google Earth) (b) Damage to Tropicana Field Stadium roof located in St. Petersburg, FL (Source: Bryan R. Smith/Agence France-Presse/Getty Images).

4.2. Tornado-Induced Damages in SE Florida

Widespread damage was reported from tornadoes in Martin, St. Lucie, and West Palm Beach Counties, with more isolated damage from tornadoes in other counties as well. Per the ASCE 7-16 basic wind speed maps, design wind speeds in the three counties with the highest impacts vary between 150 and 170 mph. The two strongest tornadoes that impacted these counties were rated EF3, with maximum wind speeds estimated by the National Weather Service to be 155 mph for the Spanish Lakes tornado and 140 mph for the Palm Beach Gardens tornado. The damage indicator used by the NWS to rate the 155 mph tornado was a 1.1M square foot distribution warehouse constructed in 2023, which had a basic design wind speed of 160 mph. Tornadoes tend to produce higher wind loads for a given wind speed than straight line wind events, which could explain the observed damage. Wind speed estimates based on the EF Scale also have high uncertainty associated with them, and local peak wind speeds may have been higher than estimated. Regardless, the available evidence at present suggests that the tornado wind speeds throughout southeast Florida were below design wind speed levels in contemporary codes.

Multiple potential tornado-damaged building case studies were observed. One example is the failure of the St. Lucie County Sheriff's building, an open metal building used to store and shelter emergency vehicles. While the failure of a canopy structure may not typically be deemed critical, this failure damaged critical contents: emergency vehicles, vital in the recovery following a major hurricane. The Sheriff's building (Fig. 4.3) was in close proximity to two tornadoes (one EF-1 and another EF-0) with maximum estimated wind speeds up to 90 mph (NWS, 2024). Currently, St. Lucie County has adopted the 2023 Florida Building Code (8th edition), which uses 2021 IBC and IRC. The 2021 IBC uses ASCE 7-16, which has a design wind speed of 150 mph for Risk Category I structures in areas around St. Lucie County. Using analysis of historical satellite images, it was determined that the building was constructed between 1995 and 1999. While the building code at the time of construction is unknown, the design wind speed (50-yr return period) for this area as per ASCE 7-93 was approximately 100 mph, warranting further investigation into the cause of this failure.

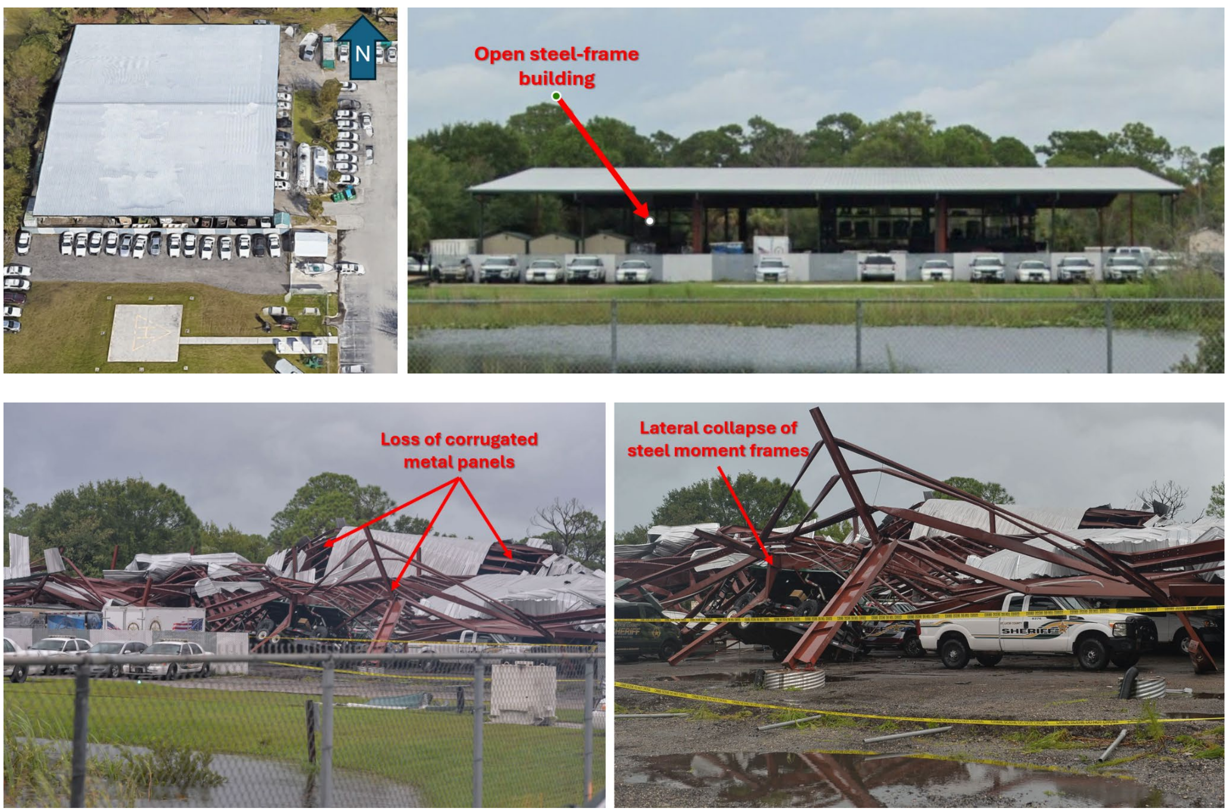


Figure 4.3. Damage to St. Lucie County Sheriff's vehicle storage facility: top shows aerial and street view perspectives of the pre-storm condition; bottom shows complete facility collapse. The comparison between original view and the photo shot after hurricane shows complete collapse of steel frame, trapping emergency vehicles within (Sources: Top left: Google Earth 3D Satellite View, Top Right: Google Streetview, Bottom images: Eric Hasert/TCPALM).

Another notable case study was the Spanish Lakes community, which was struck by an EF3 tornado, causing six (6) fatalities. The community consisted of a mix of modern site-built homes adjacent to older mobile/manufactured homes (Fig. 4.4). A review of aerial imagery confirmed that no site-built homes suffered any observable structural damage, while dozens of mobile/manufactured homes were dislodged from their foundations and/or completely destroyed. It is believed that all fatalities at this site occurred in mobile/manufactured homes.

Figure 4.4. Tornado damage path through the Spanish Lakes community near Ft. Pierce. Approximate year of construction is provided in the annotations, with green highlights representing that for site-built homes and white for mobile/manufactured homes (Source: NY Times, with annotations by the StEER VAST).

4.3. Damage to glass facades

Figure 4.5 shows several buildings with glass facades sustaining damage during this hurricane. The building in the middle of the top panel is the Sarasota Private Trust Company building in Sarasota. The aerial images of the buildings surrounding this building do not show that adjacent buildings had gravel covered roofs or other debris sources. The concentration of shattered glass panels with otherwise enacted assemblies near the building corner suggests that strong edge pressures were the likely cause. By contrast, the building in the bottom right in Figure 4.5, the Sarasota Retina Institute, has entire window assemblies missing along two faces of the building, well away from the building corners. Aerial images of the surrounding buildings similarly show lack of obvious debris sources, possibly suggesting the assembly attachments may have failed either due to insufficient capacity or possible degradation over time.

Figure 4.5. Shattered glass panels at Sarasota Private Trust Company (top) and dislodged window panes at Sarasota Retina Institute (Sources: Top left and middle Mike Lang, top right, bottom left, and bottom right: Derek Gilliam).

4.4. Melbourne Orlando International Airport

A 30-by-40-foot section of skylight at the Melbourne Orlando International Airport collapsed onto the terminal floor due to intense winds generated by Hurricane Milton, as illustrated in Figure 4.6. There is no visible damage to any of the skylight panels (those that remained in place and those that fell to the ground); their boundaries show no visible failure of attachments. It is possible that the panels, which are modular, were unseated due to fluctuations under the wind experienced wind pressures, possibly bowing sufficiently out of plane to eventually become unseated. Despite the large opening created by the collapse, dry conditions during the event minimized water intrusion into the building. As shown in the aerial view (Fig. 4.7), the skylight is located in the terminal's central atrium area. While the airport underwent major renovations and expansions in 2017 and 2021, it is unclear whether the skylight was updated during these projects. Fortunately, the failure occurred around 2 a.m. on October 10, 2024, when the terminal was closed, fortunately preventing injuries. Nonetheless, the failure of these roof panels in such a high-traffic atrium warrants further investigation given its life-safety implications.

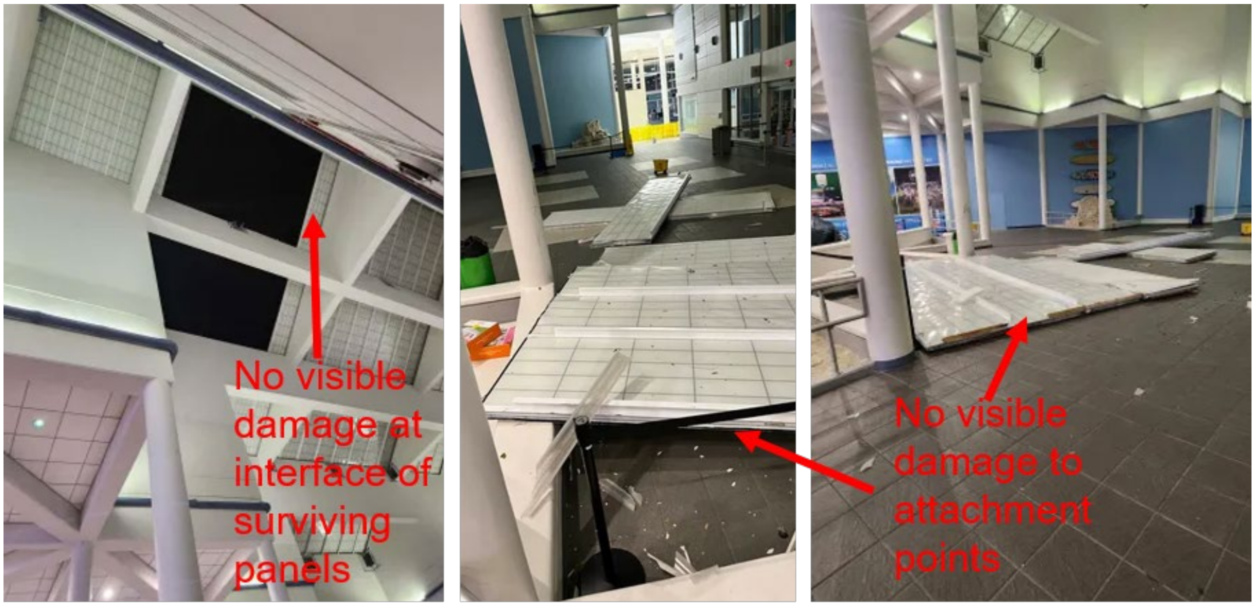


Figure 4.6. Skylight failures at Melbourne Orlando International Airport where entire skylight panels were apparently unseated under wind gusts. No visible damage to the panels or their attachments is apparent (Source: [Jennifer Sangalang/USA TODAY NETWORK]).

Figure 4.7. Aerial exterior view of the Melbourne Orlando International Terminal. The skylight that failed due to wind is circled in red (Source: Google Earth).

4.5. Storm Surge Impacts to Mobile Homes

Hurricane Milton caused extensive damage at Shady Haven Mobile Home Park in Englewood, Florida, primarily due to storm surge. As noted in Figure 2.5, this area experienced approximately 7 feet of storm surge above MSL. Figure 4.8 depicts two mobile homes in the community. The home on the left was displaced inland by 12 feet. The home on the right, in addition to being displaced from its base, also sustained severe damage to its façade, interiors, and wood structure due to storm surge and potential transported debris. Figure 4.8 provides visual references based on typical dimensions of typical mobile homes.

Figure 4.8. Destruction of mobile homes in Shady Haven Mobile Home Park in Englewood, FL, caused by storm surge: (left) mobile home displaced 12 feet from foundation; (right) mobile home also displaced from its foundation with severe wall damage from storm surge (Source: [Mike Lang/Sarasota Herald-Tribune]).

4.6.Elevated House on Concrete Piles Overturned By Flooding

A yellow elevated house located on the barrier island of Bradenton Beach, near Tampa Bay, experienced a failure of its elevated foundation. As shown in Figure 4.9, the concrete piles supporting the structure rotated rigidly at their bases, causing the elevated foundation to fail. Exposed footings in Figure 4.9 suggest the piles were fairly shallow. The fairly good condition of the surviving property in the left image of Figure 4.9 does not suggest a storm surge sufficient to cause a failure of the yellow elevated home. A photograph taken after Hurricane Helene and before Hurricane Milton shows that the house on the left side of the failed yellow home had already been completely removed before Hurricane Milton, ruling out the possibility that the elevated house was rammed by the adjacent lower-elevation home. However, it remains possible that other objects, such as vehicles, boats or other debris, could have impacted the piles and instigated the failure.

Figure 4.9. Overturned yellow elevated house on concrete piles on the barrier island of Bradenton Beach near Tampa Bay (Source: Rebecca Blackwell/AP).

5. Infrastructure Performance

Tables 5.1 and 5.2 provide a synthesis of the typical performance of other infrastructure classes in this event, respectively organized by class and geography. The subsections that follow present notable case studies. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe (Kameshwar, et al., 2024), to access a richer collection of georeferenced visual evidence cataloged by infrastructure class. Interested readers may also consult the Outage/Restoration Database, curated with this report in DesignSafe, for a chronology of disruption/outage/restoration data for power, telecommunications, and transportation networks.

Table 5.1. Summary of Performance by Infrastructure Class	
Power and Telecommunications Infrastructure	Peak power outage: 3,365,661 customers; by 11 AM EDT on October 16, 2024, 98% of the outages had been restored (DOE, 2024). Peak telecom outage: 1,273,354 wireline and cable users and 12.3% of cell sites (FCC, 2024); by October 14, 2024, 2.2% of cell sites were and 411,360 wireline and cable users were still affected.
Airports	Greater Tampa Bay and Orlando areas airports affected by flooded runways and damage to boarding gates; Sarasota-Bradenton International Airport: metal hangar collapsed and interior flooding.
Roads & Bridges	Typical road washouts and flooding issues; roads blocked by debris and fallen trees with minor roadway damage.
Other Lifelines	Wastewater impacts at Palm Bay (at least five sewage spills), one significant spill reported in Titusville, along with several smaller sewage leaks across the county (Waymer, 2024).
Port Facilities	Port Tampa Bay experienced minor building impacts and no significant damage to the docks; damage confined to piers and seawalls. SeaPort Manatee lost 10 out of 13 on-site warehouses, sustained damage to 3 of 10 port-owned docking facilities; widespread damage to port offices (FDOT, 2024).
Agricultural	Damage to crops and infrastructure attributed to heavy rainfall and high winds (Plume, 2024).

Table 5.2. Summary of Infrastructure Performance by Geography	
Greater Tampa Bay Area	Roads flooding and wash outs; damaged boarding gates, flooded interiors, and roof damage at airport; Port Tampa Bay minor building and pier damage; SeaPort Manatee experienced severe damage; extensive power outages.

Highland County	86.48% of customers lost power (FCC, 2024); solar power plant severely damaged by hurricane-induced tornado.
Greater Orlando Area	Notable power outages; minor gate and roof damage at airport; flooding on area roads; flooding of croplands.
Orlando metropolitan area, St. Lucie County, Martin County, and Palm Beach County	Comparatively lesser power outages; flooding and obstruction of area roads; wastewater pipeline spill in Palm Beach.

5.1. Power Outages & Restoration

Hurricane Milton resulted in widespread power outages in Tampa Bay and nearby counties like Sarasota and Manatee, leaving approximately 3.4 million people without electricity at its peak. Power infrastructure impacts were reported throughout central Florida, including key urban areas like Orlando and Canaveral; power restoration was gradual (Fig. 5.1) and hampered by disruption of fuel supplies due to the closure of major ports such as Tampa and Manatee. By October 16, less than 69,000 customers were still affected, with nearly 98% of the outages resolved.

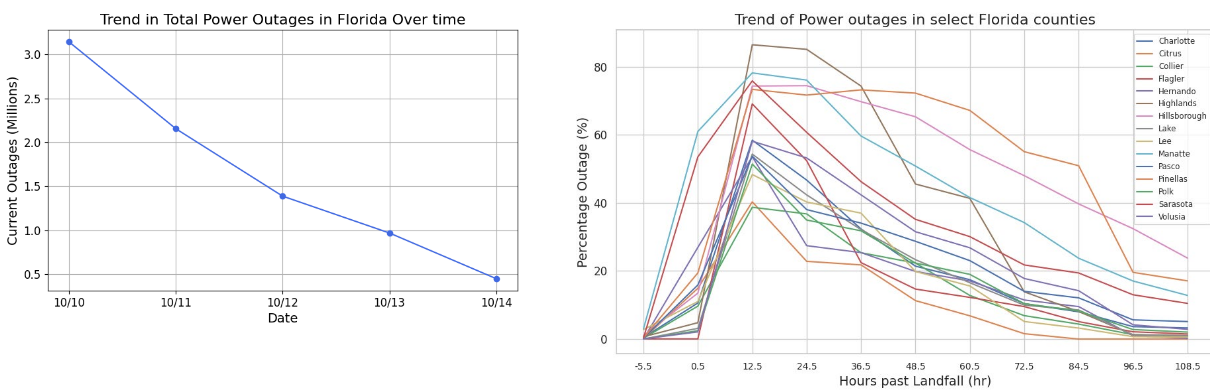


Figure 5.1. Power outage rates in Florida up to Oct. 14 (left), with outage data by county (Source for left images: Department of Energy, Office of Cybersecurity, Energy Security, and Emergency Response, Source for right image: FPFC, 2024).

An EF-2 tornado spawned by Hurricane Milton struck Duke Energy's Lake Placid Solar Power Plant in Highlands County, Florida, on October 9, 2024. Although much of the facility was left intact, the western quadrant of the plant suffered the most severe destruction, with solar panels torn from their single-axis trackers and scattered across the site (Fig. 5.2).

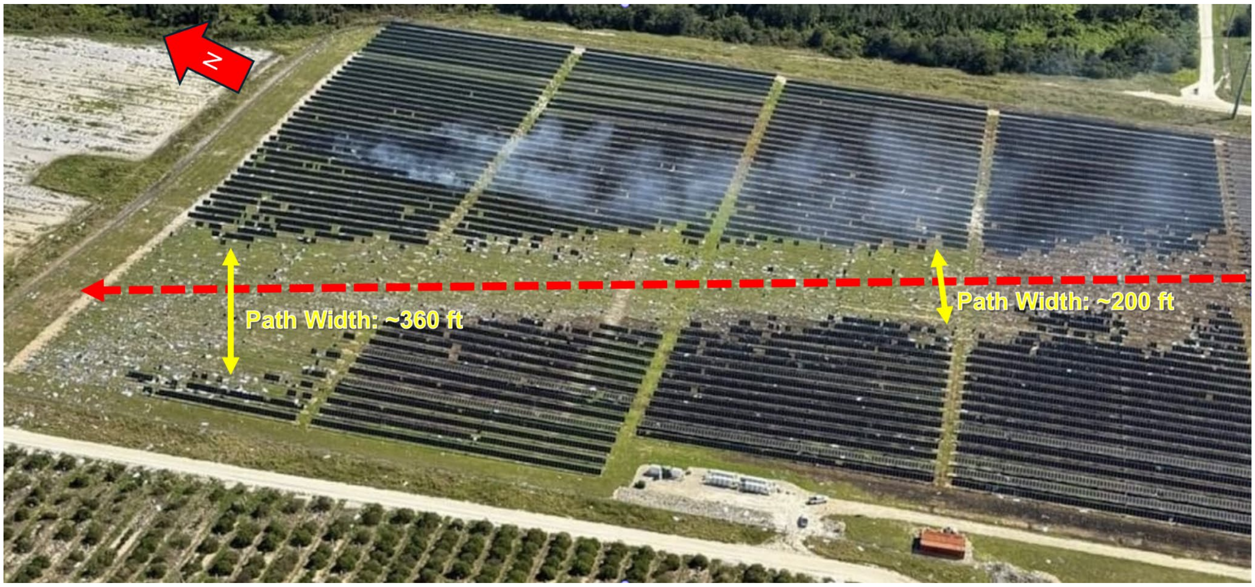


Figure 5.2. Tornado damage to the Lake Placid Solar Power Plant in Highlands County, FL (GPS: 27.333993, -81.360365). The tornado path and direction are indicated by the red dashed arrow. The tornado damage width was between 200-360 ft as it passed through the solar farm (Source: Duke Energy).

5.2. Transportation Disruptions & Restoration

In coastal areas like Tampa and Punta Gorda, storm surge and heavy rainfall led to widespread flooding. In Central Florida, heavy rainfall and flooding were the primary causes of road infrastructure damage. According to the Florida Department of Transportation, both the Florida Turnpike FL-91 (FDOT Turnpike, 2024) and US 17-92 (FDOT Central Florida, 2024) experienced severe damage due to erosion caused by floodwaters. See Section 6 for discussion of damage at US 17-92 and other roadways due to inland flooding.

5.3. Telecommunication

Telecommunication system impacts were most significant in the Tampa Bay metro area. According to the Federal Communications Commission (FCC), cell service outages improved substantially, dropping from 12.3% on October 10, 2024 to around 2.2% by October 14, 2024 (Fig. 5.4). Similarly, the total number of wireline and cable users affected in Florida decreased from approximately 1,273,354 to around 411,360 users during the same period (Fig. 5.4).

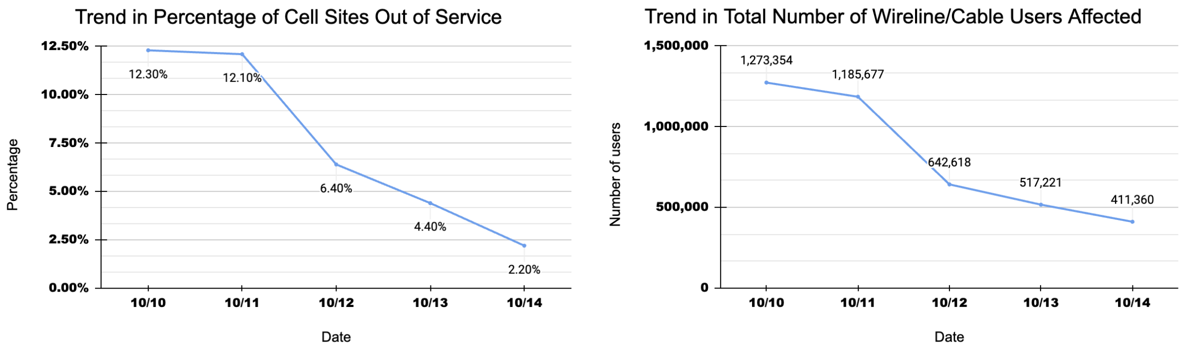


Figure 5.4. Percentage of cell sites out of service (left) and total number of wireline/cable users affected in the landfall region by date (right) (Source: FCC, 2024).

6. Geotechnical Performance

Milton-affected regions in Florida experienced severe soil erosion due to heavy rainfall, leading to road failures. The Media Repository, curated with this report in DesignSafe (Kameshwar, et al., 2024), provides a wide cross section of geotechnical failures observed in Hurricane Milton, an example of which is shown in Figure 6.1 associated with heavy rain conditions in Mt. Dora. Sinkhole formations were reported in Hillsborough County and Polk County; the example in Figure 6.1 on Willow Wisp Drive in Polk County, was deep enough to consume a pick up trick and resulted in structural damage to a neighboring home (Bowen, 2024).

Figure 6.1. Example of geotechnical failures in Hurricane Milton (left) collapse of Wolf Branch Road at Niles Road in Mt. Dora adjacent to body of water receiving outflow; (right) sinkhole between two residences in Polk County, swallowing a pick up truck and leading to partial collapse of garage (Source left: Daily Commercial; Source right: Bowen, 2024).

7. Coastal Protection & Flood Control System Performance

Storm surge impacts were mainly observed on the barrier islands, where storm surge caused extensive damage to the ground floor of on-grade properties and adjacent seawalls in Manasota Key (Oberholtz, 2024) (Fig. 7.1). Minor seawall damage was also reported in downtown St.

Petersburg. Storm surge also overwhelmed the seawall in Boca Grande, depositing 2 feet of water and 4 feet of sand on North Beach Road, obstructing access to local businesses (Wheelen, 2024). On Captiva Island, storm surge and sand overwash exceeded levels in Hurricane Helene, but not Hurricane Ian in 2022 (Southwest Florida Conservation Council, 2024).

Figure 7.1. Seawall failure associated with storm surge in Manasota Key; depth of storm surge evident from loss of ground floor unit cladding and contents suggesting storm surge to full height of ground floor (Source: Mike Lang/Sarasota Herald Tribune).

However, groundwater flooding, overwhelming inland canals in urban estuaries, was likely a primary driver of total damages associated with this event. Aquifers in western Florida are extremely shallow, with depths to groundwater averaging 0-10 feet throughout Hurricane Milton's impact area. Thus, even after typical rainfall events, extensive freshwater flows are still observed in canal systems across all urban estuaries surrounding the Caloosahatchee River, Charlotte Harbor, Manatee River, and Tampa Bay. These base flows represent groundwater flowing out of the terrestrial system into the ocean and increase in response to heavy rains and storm surges. As groundwater moves slowly, groundwater flooding may begin significantly after the storm passes and may persist significantly longer, even in the absence of significant storm surge. For example, the neighborhood of Clearwater in Tampa was inundated by 6 feet of freshwater due to saturated drainage systems, despite the reverse storm surge (Fig. 7.2). Thus, while pluvial and fluvial mechanism dominated flooding in the immediate aftermath of the storm, groundwater flooding led to persistence of floodwaters well after the hurricane passed (Hollis 2024). In the case of Milton, canal and stormwater systems remained overwhelmed for weeks (Lewis, 2024) (Fig. 7.2).

Figure 7.2. Estimated 3 feet of groundwater flooding in the Clearwater neighborhood in Tampa (left); over 3 feet of sustained groundwater flooding in Ridge Manor (Sources: left: Hollis, 2024; right: FOX 13).

It has long been recognized that the legacy of channelization in Florida's coastal estuaries leads to increased flood risk during tropical cyclones, and as estuaries continue to be developed to accommodate a rapidly growing population, southwest Florida is increasingly finding its flood control infrastructure to be inadequate against tropical cyclones (Phillbrick & Wu, 2022). Punta Gorda, which was directly hit by Milton, has been designated as America's most flood prone city by the risk assessment company First Street, with 97% of properties currently at risk of flooding. Tampa ranks thirteenth, with 44.6% of properties currently at risk of flooding, and 71.8% of properties projected to be at risk of flooding by 2050 (First Street Foundation, n.d.). As a result, nature-based solutions are broadly recognized as critical components of Florida's coastal flood control infrastructure at the city, county, water district, and federal level. As an example, the Green Swamp was saved from development by way of designation as an Area of Critical Environmental Concern. The Green Swamp was exposed to 16 inches of precipitation during Hurricane Milton. The most severe flooding impacts of Milton were observed by communities along the Withlacoochee River, which is one of four rivers that drain the Green Swamp, where floodwaters continued to rise five days after Milton's landfall (SFWMD, 2024).

8. Recommended Response Strategy

Based on the information gathered by this Preliminary Virtual Reconnaissance Report (PVRR), StEER offers the following recommendations for future study.

TOPIC 1: PERFORMANCE OF HURRICANE-RESISTANT CONSTRUCTION IN TORNADOES

Given the higher design wind speeds and resistance requirements in hurricane-prone regions, any time tornadoes strike coastal construction designed to such standards, the research community has an opportunity to evaluate if hurricane-resistant construction can deliver increased resistance to tornado demands. StEER members have investigated such questions using a sampling of structures affected by the Arabi, LA tornado, which were located in a hurricane-prone region with ultimate design wind speeds in the range of 145-160 mph (Roueche, et al., 2024). The tornadoes spawned following Hurricane Milton provide another opportunity to systematically study performance of buildings designed to different design wind speeds to determine if those designed as hurricane-resistant construction can more effectively resist tornado demands and are thus worthy of promotion in inland areas with high tornado risk. Such an investigation should identify comparative structures subjected to the same tornado intensity but with differences in age (governing code edition) and design wind speed (based on code edition and/or proximity to coastline).

Beyond this systematic investigation, in-depth evaluation of case studies presented in this report is also warranted. For example, Tropicana Field Stadium in St. Petersburg, FL is an engineered structure that sustained severe damage to its roof system despite being an assumed Risk Category III structure in a windborne debris zone subject to a design wind speed of 153 mph. Further evaluation of the load demands, material integrity, and damage mechanisms observed in that structure is warranted. Similarly the solar array at Duke Energy's Lake Placid Solar Power Plant in Highlands County, Florida can provide an opportunity to evaluate assumedly identical panel assemblies designed for hurricane-force winds across a gradient of wind speeds associated with a passing EF-1 tornado.

TOPIC 2: PERFORMANCE OF FLOOD CONTROL MEASURES UNDER COMPOUND FLOODING

Flood control infrastructure, which is designed to handle either flash flooding, riverine flooding, or coastal flooding, is not parameterized to handle compound flooding observed in Milton. The passage of the hurricane over regions with shallow groundwater table, resulted in increased levels of baseflow in natural and engineered channels that amplify compound flooding. As the majority of flood control infrastructure in Milton’s impact area was designed and constructed before a direct hit of a major hurricane had been observed in the meteorological record, flood control systems were unlikely to be designed to withstand precipitation totals observed in recent storms. This storm can serve as a case study to evaluate the demand levels assumed in the design of the region’s flood control systems and how these may need to be revisited in light of evolving hurricane risk and the enhanced likelihood of compound flooding. Furthermore, given the Green Swamp contributed to attenuation of peak flows associated with record-breaking rainfall, quantifying the extent to which this natural flood control entity reduced the peak flood depth and extent along the Withlacoochee River would be valuable.

This event did not satisfy the majority of escalation criteria (see summary in Table 8.1), so **StEER’s response to this event will remain at Level 1 with no activation of a Field Assessment Structural Team (FAST).** As a result, this PVRR represents the extent of StEER’s official response. However, StEER did coordinate with other groups responding to this event as part of a study requested by the Florida Building Commission, whose assessments used the Fulcrum app to document tornado impacts from Milton. Beyond this, StEER will continue to encourage consideration of the above recommendations. Should these or other ongoing efforts reveal new information that would satisfy additional escalation criteria, StEER may re-evaluate its decision and deploy a FAST.

Table 8.1. Summary of Escalation Criteria Satisfied

Hazard	Exposure	Feasibility
(None satisfied)	• Potential for prolonged downtime and recovery (due to compound flooding)	• Availability/interest of members in the impacted region • Driving access to affected areas

Appendix: Confirmed Tornado Characteristics

Table A.1. NWS confirmed tornadoes associated with Hurricane Milton (Source: NWS Damage Assessment Toolkit).

#	NWS Event Name	Rating	Est. Peak Wind (mph)	Path Length (miles)	Max Width (yds)	Injuries/ Deaths
1	I75East	EF1	95	0.3	50	0 / 0
2	SR80W	EF1	90	2.9	100	0 / 0
3	Miccosukee	EF0	80	9	0	0 / 0
4	SR80E	EFU	0	13.5	0	0 / 0
5	Blue Cypress	EFU	0	4.7	0	0 / 0
6	Avon Park Tornado	EF1	95	17	0	0 / 0
7	SR41	EF1	110	29.9	0	0 / 0
8	BelleGlade	EF0	74	15.4	0	0 / 0
9	CR833N	EF1	110	6.2	0	0 / 0
10	Port St. Lucie West	EF0	80	0.2	33	0 / 0
11	South Martin	EF1	105	0.9	100	0 / 0
12	Babcock Area Tornado	EF2	132	16.6	500	0 / 0
13	Jonathan Harbour Tornado	EF1	105	6.8	500	0 / 0
14	Venus Tornado	EF1	94	2.6	450	0 / 0
15	Wild Island - Lorida Tornado	EF0	85	0.5	25	0 / 0
16	Cocoa Beach	EF2	115	8.5	250	2 / 0
17	Pine Creek	EF0	0	18.1	0	0 / 0
18	Stuart #1	EF1	110	17.1	300	0 / 0
19	LakeportWest	EF2	130	2.9	300	1 / 0
20	CR833S	EF0	60	1.3	0	0 / 0
21	KEY-MILTON1	EF1	102	1.3	0	0 / 0
22	Clewiston	EF1	107	1.7	0	0 / 0
23	Ortona	EF3	140	15.2	250	3 / 0
24	TripsMid	EF2	115	2.6	100	0 / 0
25	S Holopaw	EF1	105	0.6	100	0 / 0
26	Port St. Lucie Central	EF1	105	0.5	0	0 / 0
27	Fort Pierce	EF0	85	0.6	75	0 / 0
28	Archbold Tornado	EF1	90	7.9	100	0 / 0
29	Matlacha Tornado	EFU	0	16.3	0	0 / 0
30	St. Lucie Indrio	EF1	104	1	40	0 / 0
31	Vero Beach #1	EFU	-99	9.9	0	0 / 0

32	Vero Beach #2	EF1	90	11.7	200	0 / 0
33	El Jobean Tornado	EF1	90	8.5	100	0 / 0
34	Escape Ranch	EF1	95	8.1	150	0 / 0
35	Bereah Tornado	EF1	100	21.1	100	0 / 0
36	Fort Drum	EF1	95	4.1	0	0 / 0
37	FLCity	EF1	105	2.7	250	1 / 0
38	Lake Placid Tornado	EF1	100	3.4	100	0 / 0
39	Dixie Acres	EF1	95	6.9	150	0 / 0
40	Rucks Dairy	EFU	0	19.6	0	0 / 0
41	Stuart #2	EF3	140	29.1	457	7 / 0
42	Palm City and Port St. Lucie	EF3	155	21.2	500	Unk / 6
43	Fort Myers Tornado	EF2	125	31.6	-99	0 / 0
44	Spanish Lakes	EF0	80	3.9	150	0 / 0
45	LakeportEast	EF2	120	5.7	400	1 / 0
46	PalmBeachGardens	EF1	95	5.2	250	0 / 0

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