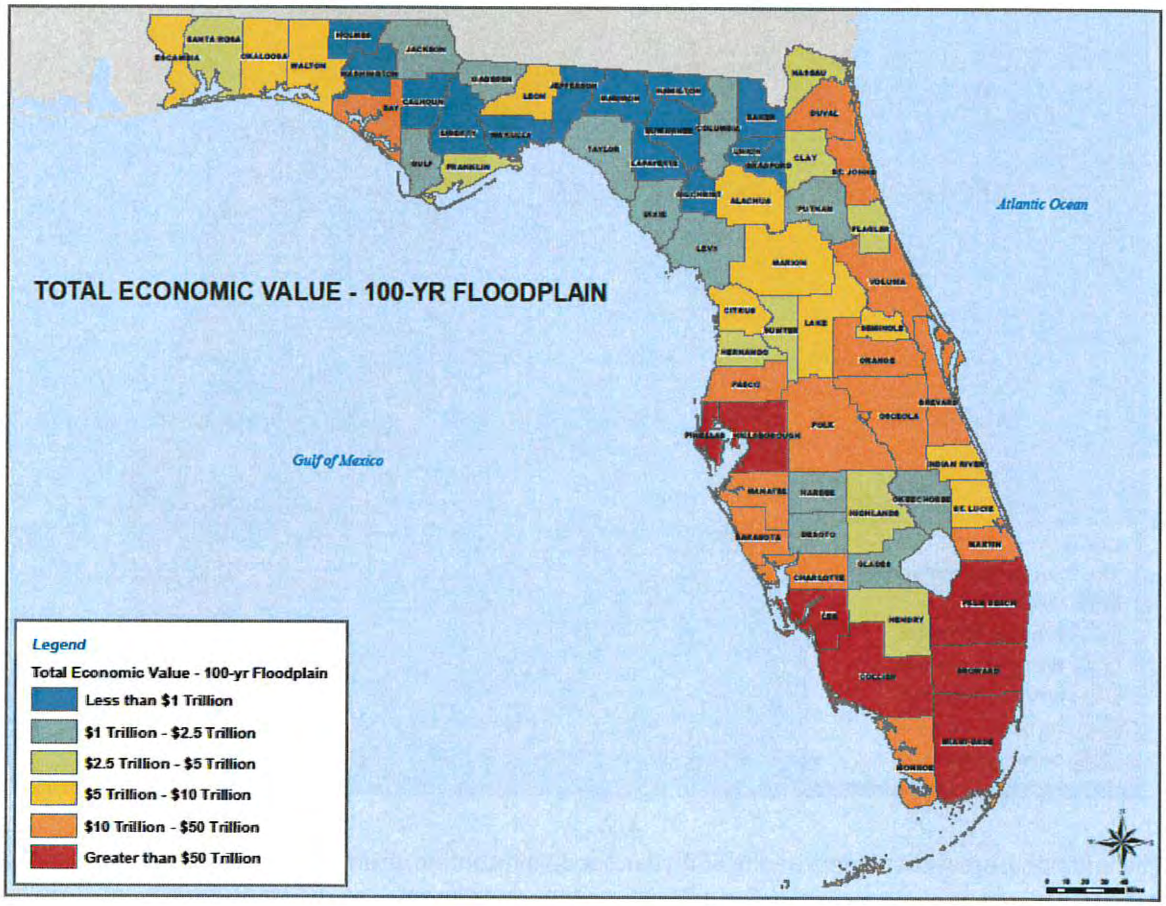
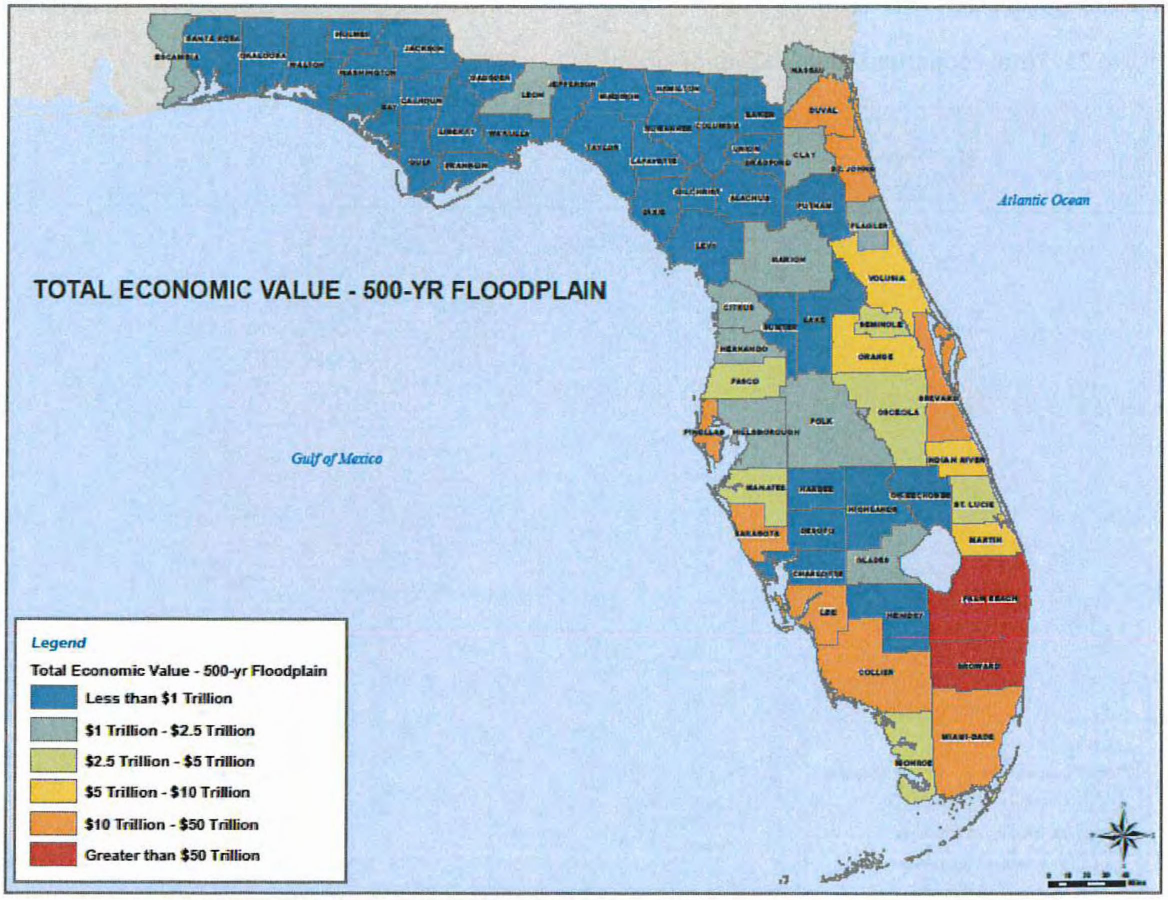
Structures included in a separate analysis include residential buildings, commercial buildings, medical buildings, educational buildings, and governmental buildings per parcel data from coastal and riverine flooding (Figure 23).

Figure 21: Total Economic Value 100-year Floodplain



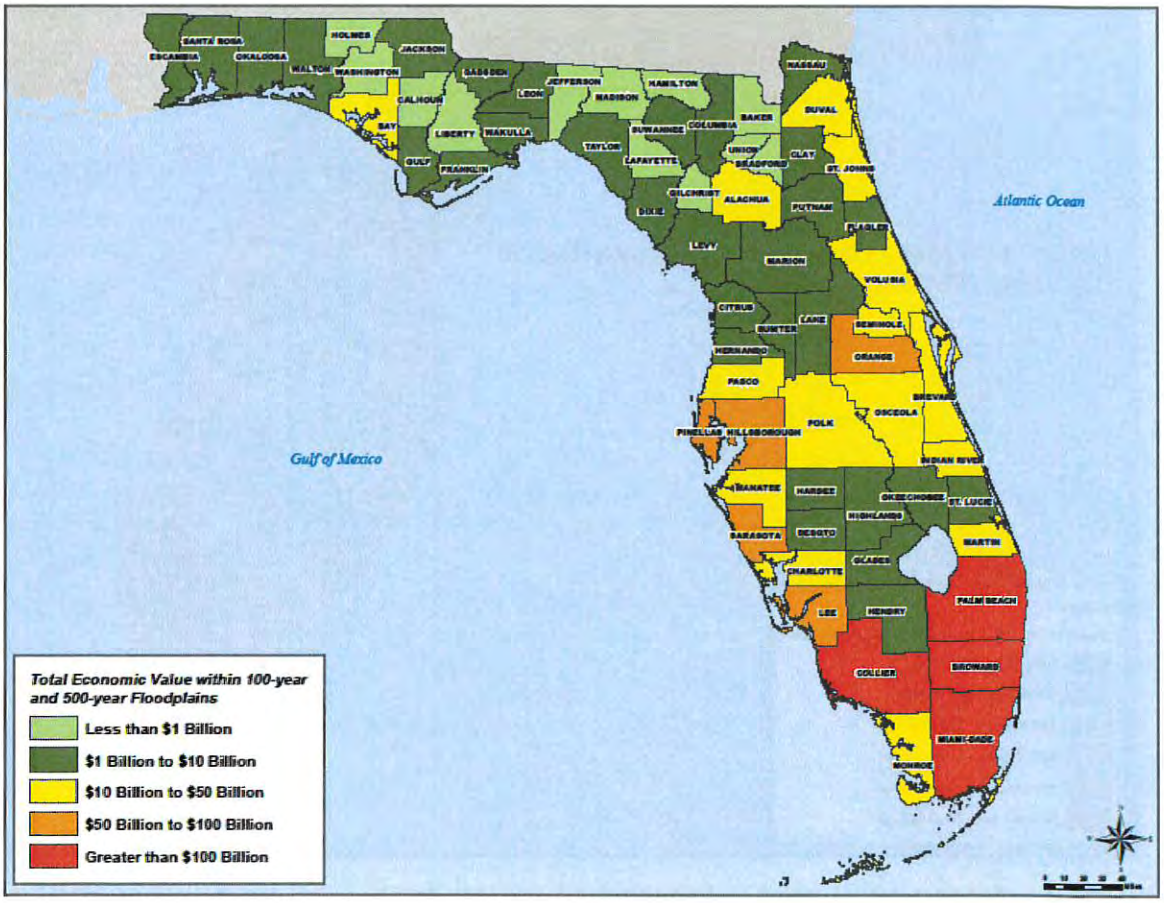
From this map, it is clear that there are many structures, worth trillions of dollars, located within the 100-year floodplain. Counties with over $50 trillion include Miami-Dade, Broward, Palm Beach, Collier, Lee, Hillsborough, and Pinellas.

Figure 22: Total Economic value 500-year Floodplain



The additional areas that comprise the 500-year floodplain contain structures worth trillions more dollars. Palm Beach and Broward counties both have an additional $50 trillion in structures at risk.

Figure 23: Total Economic Value within 100-year and 500-year Floodplains

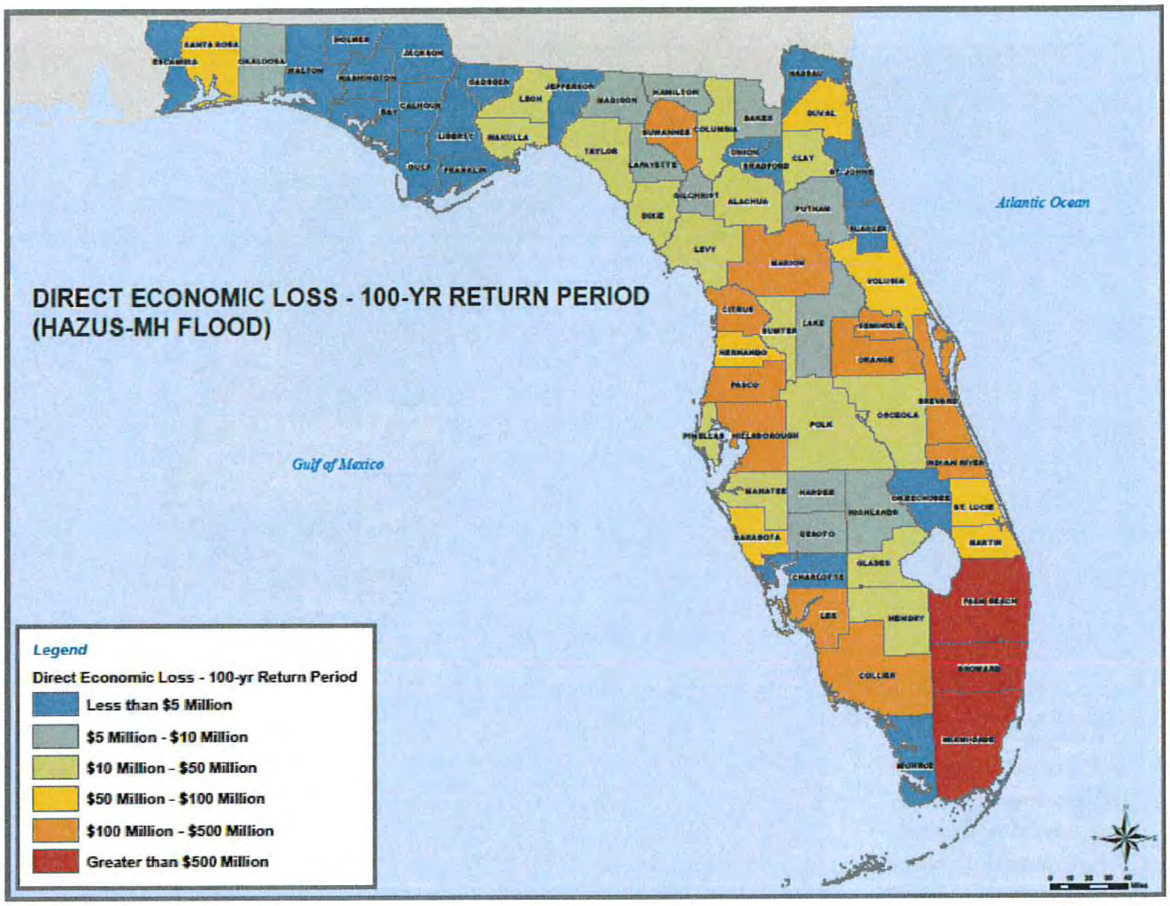


According to the data, there are four counties, Broward, Collier, Miami-Dade, and Palm Beach, which have over $100 billion worth of structures within 100-year floodplains. Data from the tables in *Appendix E: Risk Assessment Tables* show that there are six counties with over 100,000 structures within the 100-year floodplain, Broward, Hillsborough, Lee, Miami-Dade, Palm Beach, and Pinellas. When the 100-year and 500-year floodplains are added together, two more counties, Collier and Sarasota, have over 100,000 structures within the 500-year floodplain.

From this data it is clear that south Florida is highly vulnerable. Additionally, several urban coastal counties are also highly vulnerable.

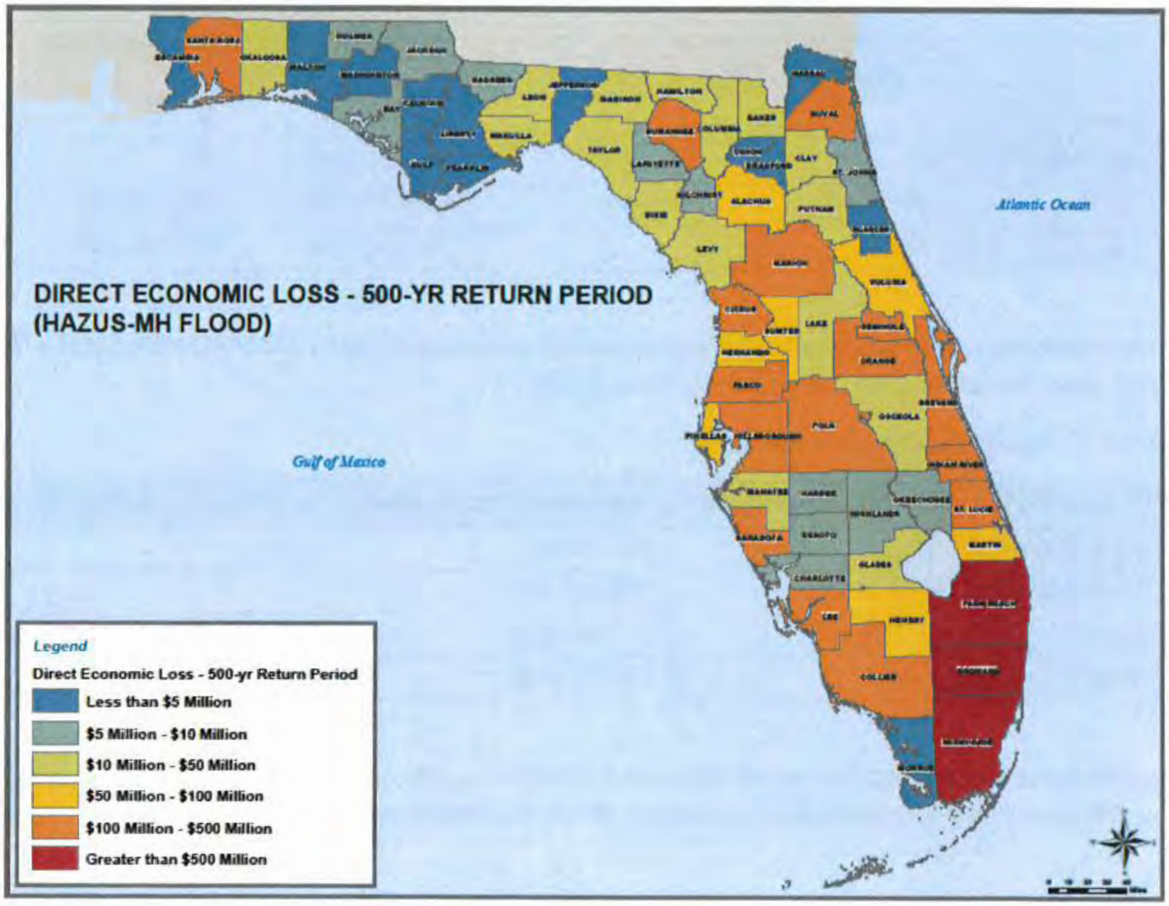
Below are figures showing the direct economic losses expected due to a 100-year and 500-year flood event. Direct economic losses were calculated in HAZUS-MH by taking the general building stock (Residential, Commercial, Industrial, etc.) that intersected a given Census Block and applied damage curves within the model based on the depth of flood inundation from the model's derived 100-year and 500-year return periods that were generated based on a Digital Elevation Model and calculated reaches within a County. The data for these figures can be found in *Appendix E: Risk Assessment Tables*.

Figure 24: Direct Economic Loss 100-year Return Period



According to data from HAZUS, three counties would experience more than $500 million in direct economic losses due to a 100-year flood. Eleven counties would experience between $100 million and $500 million in direct economic losses, including Suwannee, Marion, Citrus, Pasco, Hillsborough, Seminole, Orange, Brevard, Indian River, Lee, and Collier counties. Tables detailing this information are available in *Appendix E: Risk Assessment Tables*.

Figure 25: Direct Economic Loss 500-year Return Period



Similarly to the HAZUS data for a 100-year flood, a 500-year flood would result in over $500 million in direct economic losses in Palm Beach, Broward, and Miami-Dade counties. Fifteen counties would experience between $100 million and $500 million in direct economic losses due to a 500-year flood, including Santa Rosa, Suwannee, Duval, Marion, Citrus, Pasco, Hillsborough, Polk, Seminole, Orange, Brevard, Indian River, St. Lucie, Sarasota, Lee, and Collier counties. Tables detailing this information are available in *Appendix E: Risk Assessment Tables*.

Coastal Flooding

Please refer to the Tropical Cyclone Profile for vulnerability and loss estimates by jurisdiction due to coastal flooding and storm surge.

Historical Losses

The NCDC Storm Event Database information, presented in the Probability section above, also contained property and crop damage dollar amounts, which is shown in the table below. This information, combined with values of structures in hazard areas and with projected losses from HAZUS-MH can provide a more complete analysis than using only one data source.

Table 21: Flood Events in Florida, by Type, (2012-2016)[38] [39]

Type of Event	Number of Events	Deaths	Injuries	Property Damage	Crop Damage
Coastal Flood	48	0	0	$46,072,000	$0
Flash Flood	81	3	0	$198,702,000	$0
Flood	98	1	0	$186,731,000	$39,265,000
Total	227	4	0	$431,505,000	$39,265,000

The information can be analyzed to provide the average amount of property and crop damage that is likely each year. This information is shown in the chart below.

Table 22: Flood Event Losses (2012-2016)[40] [41]

Type of Flood	Average per Year	Annualized Property Loss	Annualized Crop Loss
Coastal Flood	9.6	$9,214,400	$0
Flash Flood	16.2	$39,740,400	$0
Flood	19.6	$37,346,200	$7,853,000
Total	45.4	$86,301,000	$7,853,000

According to the analysis, Florida is historically vulnerable to over $86 million in property damages and nearly $8 million in crop damages from roughly 45 flood events each year.

8. Vulnerability Analysis and Loss Estimation of State Facilities

The table below shows the number of state facilities that are located within the 100-year and 500-year floodplains, based on the state facility database and the HelpFL inland flood data.

Table 23: Inland Flood Count of State Facilities

Inland Flood Count of State Facilities		
County	100-Year	500-Year

[38] http://www.ncdc.noaa.gov/stormevents/listevents.jsp?beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2008&endDate_mm=12&endDate_dd=31&endDate_yyyy=2011&county=ALL&eventType=Coastal+Flood&statefips=12%2CFLORIDA

[39] Note: multiple reports that occurred on the same day were considered one event.

[40] http://www.ncdc.noaa.gov/stormevents/listevents.jsp?beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2008&endDate_mm=12&endDate_dd=31&endDate_yyyy=2011&county=ALL&eventType=Coastal+Flood&statefips=12%2CFLORIDA

[41] Note: multiple reports that occurred on the same day were counted as one event.

Alachua	66	0
Baker	0	0
Bay	54	8
Bradford	3	0
Brevard	24	12
Broward	161	168
Calhoun	0	0
Charlotte	66	0
Citrus	93	19
Clay	5	0
Collier	151	9
Columbia	14	9
Desoto	17	4
Dixie	1	0
Duval	48	11
Escambia	63	13
Flagler	31	21
Franklin	186	8
Gadsden	6	0
Gilchrist	9	0
Glades	15	26
Gulf	150	0
Hamilton	29	7
Hardee	8	1
Hendry	11	2
Hernando	4	23
Highlands	23	0
Hillsborough	59	0
Holmes	6	4
Indian River	72	14
Jackson	14	0
Jefferson	9	0
Lafayette	27	3
Lake	14	1
Lee	177	45
Leon	42	8
Levy	36	2
Liberty	0	0
Madison	9	0
Manatee	20	1
Marion	57	2
Martin	17	0
Miami-Dade	685	13

Monroe	223	14
Nassau	26	18
Okaloosa	1	0
Okeechobee	61	45
Orange	12	0
Osceola	30	2
Palm Beach	203	42
Pasco	42	1
Pinellas	147	16
Polk	179	0
Putnam	21	0
Santa Rosa	36	3
Sarasota	72	71
Seminole	0	0
St. Johns	161	31
St. Lucie	60	20
Sumter	13	1
Suwannee	59	19
Taylor	8	0
Union	0	0
Volusia	36	8
Wakulla	36	2
Walton	24	0
Washington	11	0

According to data there are nearly 4,000 state facilities in the 100-year floodplain and over 700 additional state facilities in further 500-year floodplain.

There are eleven counties with over 100 state facilities in the 100-year floodplain. They include Broward, Collier, Franklin, Gulf, Lee, Miami-Dade, Monroe, Palm Beach, Pinellas, Polk, and St. Johns. Miami-Dade County has the most, with almost 700 state facilities in the 100-year floodplain. Broward County is the only county with an additional 100 or more state facilities in the 500-year floodplain.

Please refer to the Tropical Cyclone Profile for vulnerability and loss estimations of state facilities due to coastal flooding and storm surge.

9. Overall Vulnerability

Each category was given a number and when all 5 categories are added together, the overall vulnerability is a number between 5 and 15.

Based on the Frequency, Probability, and Magnitude summary, the Overall Vulnerability of this hazard was determined to be High, with a score of 15.

<table>
<tr><th colspan="5">FLOOD</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">A flood or flooding refers to the general or temporary conditions of partial or complete inundation of normally dry land areas from the overflow of inland or tidal water and of surface water runoff from any source. While many people underestimate the severity of floods, loss of life and property from flooding are real threats in Florida. Florida experiences several different kinds of floods due to the effects of severe thunderstorms, hurricanes, seasonal rains and other weather-related events.</td><td rowspan="5">HIGH</td></tr>
<tr><th rowspan="2">Frequency</th><th rowspan="2">Probability</th><th colspan="3">Magnitude</th></tr>
<tr><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Very Likely</td><td>Very Likely</td><td>High</td><td>High</td><td>High</td></tr>
</table>

Tropical Cyclone Hazard Profile

1. Tropical Cyclone Description

A tropical cyclone is a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation. Tropical cyclones rotate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere and have an average diameter of 200 to 400 miles across. These storms form when a developing center of low pressure moves over warm water and the pressure drops (measured in millibars or inches of Mercury) in the center of the storm. As the pressure drops, the system becomes better organized and the winds begin to rotate around the low pressure, pulling in the warm and moist ocean air. This is what causes the wind and rain associated with a tropical cyclone. If all of the conditions are favorable (warm ocean water and favorable high altitude winds), the system could build to a point where it has winds in excess of 155 miles per hour and could become catastrophic if it makes landfall in populated areas. Tropical cyclones act as a safety valve that limits the build-up of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole ward latitudes. As the storm system rotates faster, an eye forms in the center. Higher pressure air from above flows down into the eye.

Tropical cyclones occasionally strengthen to become tropical storms or hurricanes. The following are descriptions of the four general levels of development for tropical cyclones:

- Tropical depression: The formative stages of a tropical cyclone in which the maximum sustained (1-min mean) surface wind is < 38 mph.
- Tropical storm: A warm core tropical cyclone in which the maximum sustained surface wind (1-min mean) ranges from 39–73 mph.
- Hurricane: A warm core tropical cyclone in which the maximum sustained surface wind (1-min mean) is at least 74 mph.
- Major Hurricane: A warm core tropical cyclone in which the maximum sustained surface wind (1-min mean) is at least 111 mph.

Hurricanes are further ranked by wind speed from Category 1 to 5, with 5 being catastrophic. The Saffir-Simpson Hurricane Wind Scale is shown in Table 24 below.

Table 24: Saffir-Simpson Hurricane Wind Scale[42]

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74-95 mph	**Very dangerous winds will produce some damage:** Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.

[42] http://www.nhc.noaa.gov/aboutsshws.php

2	96-110 mph	**Extremely dangerous winds will cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph	**Devastating damage will occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes
4 (major)	130-156 mph	**Catastrophic damage will occur:** Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157 mph or higher	**Catastrophic damage will occur:** A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Advisories

Below are the advisories and thresholds that the National Hurricane Center (NHC) can issue during Tropical Cyclone events.[43]

- Tropical Storm
  - Tropical Storm Watch: issued when sustained winds of 39 to 73 mph are possible in the specified area within 48 hours in association with a tropical cyclone. These watches are issued 48 hours in advance of the anticipated onset of tropical storm force winds because preparedness activities become difficult and unsafe once winds reach tropical storm force.
  - Tropical Storm Warning: issued when sustained winds of 39 to 73 mph are expected in the specified area within 36 hours in association with a tropical cyclone. These warnings are issued 36 hours in advance of the anticipated onset of tropical storm force winds because preparedness activities become difficult and unsafe once winds reach tropical storm force.
  - Potential Tropical Storm: until 2017, the National Hurricane Center was only able to issue warnings when a storm was already formed. This is a problem because sometimes forecasting is certain enough to know that a disturbance will turn into a storm closer to landfall, but by the time a warning is sent out when a storm is close to land, it will be too late for protective actions. To remedy this issue, the NHC will now have the option to issue Potential Tropical

[43] http://www.nhc.noaa.gov/aboutgloss.shtml

Cyclone Warnings for areas of disturbance that are expected to develop into a tropical storm or hurricane and impact land within 48 hours.

- Hurricane
  - Hurricane Watch: issued when 74 mph winds or higher are possible in the specified area within 48 hours in association with a tropical cyclone. Because preparedness activities become difficult once winds reach tropical storm force, the hurricane watch is issued 48 hours in advance of the anticipated onset of tropical storm force winds
  - Hurricane Warning: issued when 74 mph winds or higher are expected in the specified area within 36 hours in association with a tropical cyclone. Because preparedness activities become difficult once winds reach tropical storm force, the hurricane warning is issued 36 hours in advance of the anticipated onset of tropical storm force winds
- Storm Surge
  - Storm Surge Watch: issued when there is the possibility of life-threatening inundation from rising water moving inland from the shoreline in the specified area, generally within 48 hours, in association with an ongoing or potential tropical cyclone.
  - Storm Surge Warning: issued when the danger of life-threatening inundation from rising water moving inland from the shoreline in the specified area, generally within 36 hours, in association with an ongoing or potential tropical cyclone.
  - Storm Surge Watches and Warnings may be issued earlier based on timing forecasts and may be issued for locations adjacent to expected life-threatening inundation areas.

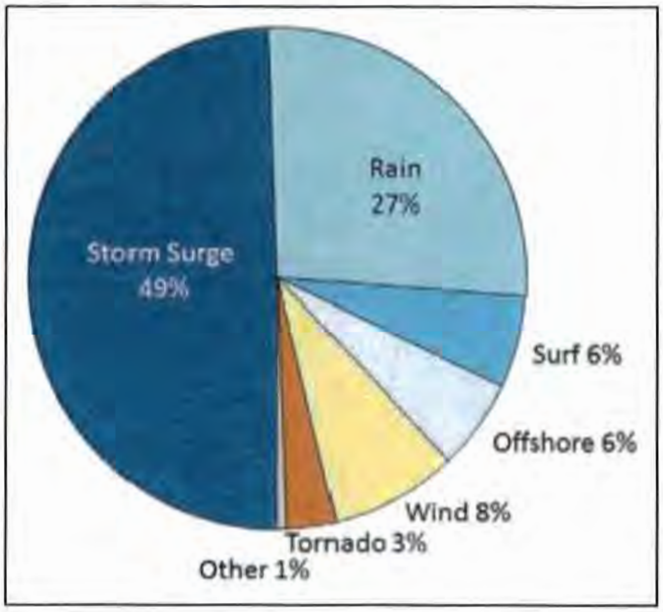
Causes of Fatalities in Tropical Cyclone Storms

There are two categories of causes of fatalities in tropical storms or hurricanes, direct and indirect. A direct death means that the fatality is attributable to forces of the storm, such as water or wind. An indirect death means that the fatality resulted from actions before, during, and after the storm.

In a study from the National Hurricane Center, from 1963 to 2012, there are an average of 40 to 50 direct deaths from tropical storms or hurricanes each year. According to the study, 90% of the deaths are due to water, either storm surge, freshwater flooding, or rainfall. Of course, there is a large storm-to-storm and year-to-year variability associated with that average. It was also determined that while 1 in every 5 tropical cyclones cause death in the US, two thirds of direct deaths from tropical cyclones were from just six specific storms.[44]

[44] http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00074.1

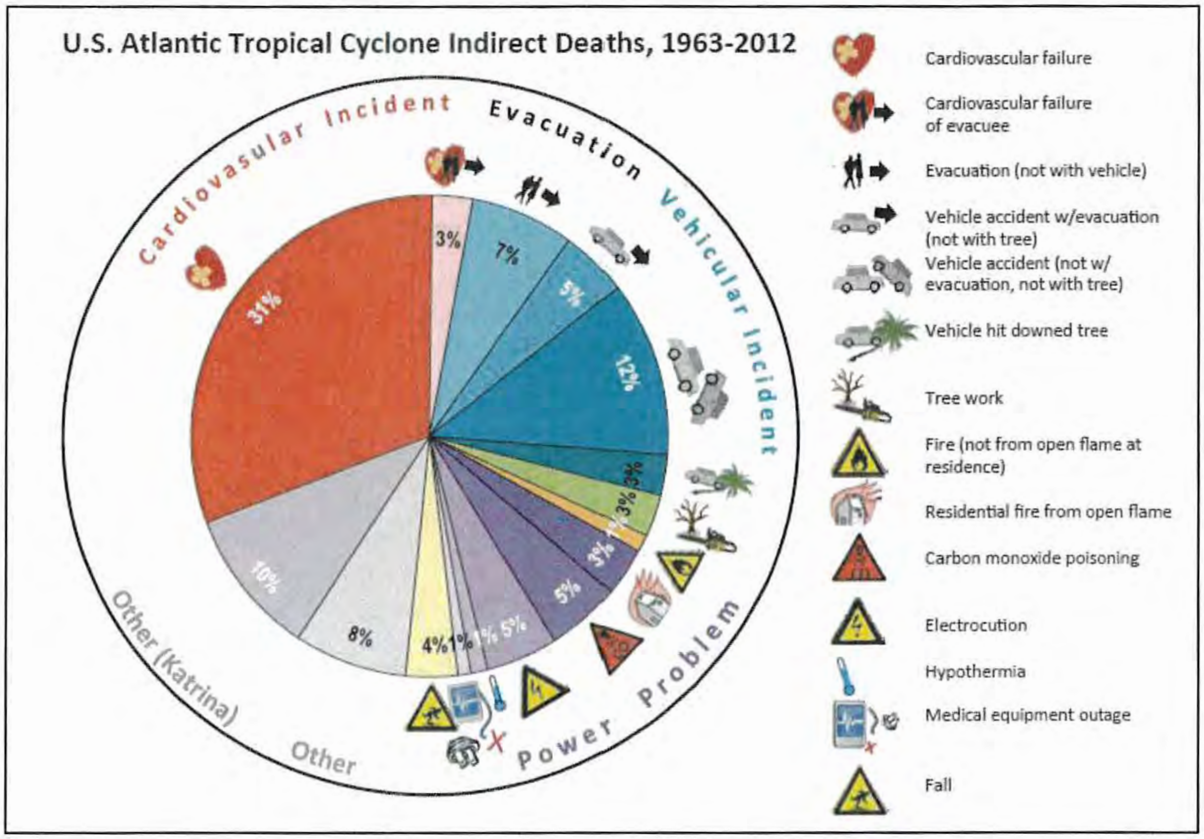
Figure 26: Deaths in the United States Directly Attributable to Atlantic Tropical Cyclones, 1963-2012.[45]



The study also examined indirect deaths and found that there are an average of 30 to 40 indirect fatalities from tropical storms or hurricanes each year. Additionally, those over age 70 were found to be 8 times as likely to be victims, than those under age 21. The study found four primary contributing factors to indirect deaths, some of which occur in combination. The leading cause of indirect deaths is cardiovascular complications; in fact, one third of all indirect deaths are attributed to cardiovascular complications. The next factor is complications during evacuations, either during the evacuation or when the victim reaches the destination. Vehicle accidents are also a contributing factor to indirect deaths. Examples of vehicle accidents include hydroplaning, traffic lights out, and downed trees. Finally, indirect deaths are sometimes caused by power related complications, such as the improper use of generators leading to carbon monoxide poisoning or structure fires; electrocutions; and losing power to life sustaining medical equipment.[46]

[45] http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00042.1
[46] http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00042.1

Figure 27: United States Atlantic Tropical Cyclone Indirect Deaths, 1963-2012[47]

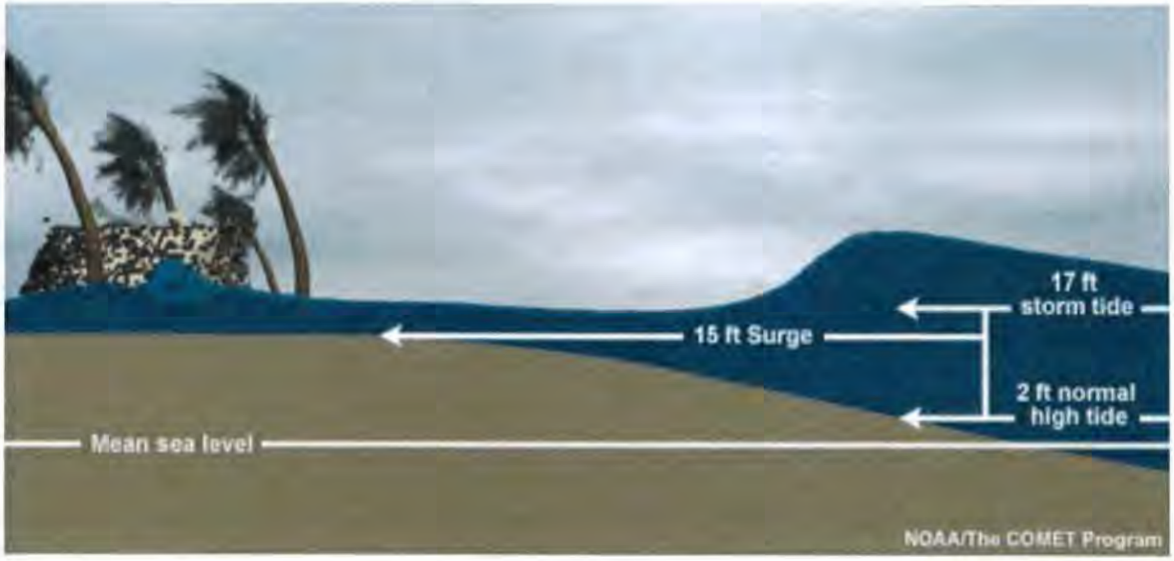


Storm Surge

Storm surge is perhaps the most dangerous aspect of a hurricane. It is a phenomenon that occurs when the winds and forward motion associated with a tropical cyclone pile water up in front, as it moves toward shore. Below is a diagram to demonstrate storm surge.[48]

[47] http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-15-00042.1
[48] http://www.nws.noaa.gov/om/hurricane/resources/surge_intro.pdf

Figure 28: Storm Surge Explanation



Storm surge heights are dependent upon the configuration of the continental shelf (narrow or wide) and the depth of the ocean bottom (bathymetry). In 2010, the National Hurricane Center separated storm surge from the Saffir-Simpson Hurricane Wind Scale because it did not accurately describe storm surge. For example, a Category 1 hurricane could have devastating storm surge, while a Category 5 hurricane could have minimal storm surge. Along most of the Atlantic coast of Florida, a narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water in close proximity to the shoreline, tends to produce a lower surge but higher and more powerful storm waves. The Gulf Coast of Florida has a long, gently sloping shelf and shallow water depths, leading to higher surge but smaller waves. South Miami-Dade County is somewhat of an exception to these general rules due to Biscayne Bay, which has a wide shelf and shallow depth. In this instance, a hurricane has a larger area to "pile up" water in advance of its landfall. Nowhere is the threat of storm surge more prevalent than in the Apalachee Bay Region, where storm surge can reach several feet above ground.

The National Hurricane Center forecasts storm surge using the SLOSH model, which stands for Sea, Lake, and Overland Surges from Hurricanes. The model is accurate to within 20 percent. The inputs include the central pressure of a tropical cyclone, storm size, the forward motion, its track, and maximum sustained winds. Local topography, bay and river orientation, depth of the sea bottom, astronomical tides, as well as other physical features are taken into account in a predefined grid referred to as a "SLOSH basin." Overlapping basins are defined for the southern and eastern coastlines of the continental U.S.

The final output from the SLOSH model run will display the Maximum Envelope of Water, or MEOW, that occurred at each location. To allow for track or forecast uncertainties, usually several model runs with varying input parameters are generated to create a map of MOMs, or Maximum of Maximums. For hurricane evacuation studies, a family of storms with representative tracks for the region with varying intensity, eye diameter, and speed are modeled to produce worst-case water heights for any tropical cyclone occurrence. The results of these studies are typically generated from several thousand SLOSH runs.[49]

Tornadoes

Tornadoes are a significant threat during tropical cyclones and have been associated with the majority that have affected Florida. Tornadoes tend to develop on the leading northwest edge relative to the forward motion (or on the right-front quadrant) of hurricanes, within thunderstorms and rain bands away from the center. The majority of tornadoes that occur with hurricanes are relatively weak and short-lived. In recent years, much of the wind damage in hurricanes attributed to tornadoes has, in reality been the result of down bursts, which are strong downdrafts causing damaging winds on or near the ground. For more information regarding tornadoes, please see the Severe Storms Hazard Profile.

High Winds

Tropical Cyclones can produce very strong and destructive winds that can persist for great distance in area and duration even after landfall. Hurricane force winds are extremely dangerous and can cause severe damage and debris. This debris, including signs, pieces of structures not properly secured, and shallow rooted trees, is often then carried by the high winds and can cause further damage.

Rainfall

Tropical Cyclones are capable of producing widespread and heavy rains, which can result in life-threatening and damaging floods. This flooding is actually the biggest threat from tropical cyclones for people who live inland. The rainfall can cause flash flooding and flooding on rivers and streams that can persist for several days after the storm. Rainfall amounts are related to the speed and size of tropical cyclones, not the intensity. This is because a slower moving and larger tropical cyclone has a longer and larger capacity to produce more rainfall.

Rip Currents

The strong winds associated with tropical cyclones can cause rip currents, which are a significant drowning threat to coastal residents and beach goers. Rip currents are channeled currents of water flowing away from shore and can easily pull strong swimmers into the open water. These rip currents can occur at large distances from the storm.

The National Weather Service produces Rip Current Outlooks to alert beach goers to the risk of rip currents at a particular beach. There are three levels of outlooks:[50]

- Low Risk: The risk for rip currents is low; however, life-threatening rip currents often occur in the vicinity of jetties, reefs, and piers.
- Moderate Risk: Life threatening rip currents are possible in the surf zone.
- High Risk: Life threatening rip currents are likely in the surf zone.

[49] http://www.nhc.noaa.gov/surge/slosh.php
[50] http://www.nws.noaa.gov/os/hurricane/resources/TropicalCyclones11.pdf

Potential Effects of Climate Change on Tropical Cyclones

A warmer atmosphere could influence two of the factors that affect the generation and strength of tropical cyclones: (1) increased thermal energy resulting from higher sea surface temperatures (SST), and (2) increased vertical wind shear.[51] These effects are likely to counteract each other to some degree. The exact role of increasing SST remains to be determined: tropical cyclone intensity, as measured by power dissipation indices[52] may increase directly as a function of SST, or intensity may be a function of the difference between SST in the cyclone development region and mean global tropical SST.[53] Vertical wind shear disturbs the structure of a tropical cyclone and, therefore, increased shear can lead to system weakening *(Grossman and Morgan (2011), p. 547.)*. Tropical cyclone intensity is one of the principal determinants of storm surge height; thus, the net effects of climate change on tropical cyclone intensity will also affect the magnitude of coastal flooding associated with these storms. Tropical cyclone tracks and consequently, the number of systems that make landfall in Florida, could be influenced by atmospheric steering currents and climate phenomena such as the El Niño-Southern Oscillation, North Atlantic Oscillation, Atlantic Meridional Mode, and Madden-Julian Oscillation.[54] As stated in the flood hazard profile, higher rainfall intensity is likely as atmospheric moisture increases.[55]

2. Geographic Areas Affected by Tropical Cyclones

The entire State of Florida is subject to the effects of tropical cyclones, but some areas are much more vulnerable than others. This is due to its large areas of coastal shorelines on the Atlantic and Gulf Coast. The average diameter of hurricane force winds averages 100 miles, and tropical storm force winds extend out 300–400 miles;[56] while at the same time no point within Florida is more than 70 miles from the Atlantic Ocean/Gulf of Mexico. Maps throughout this section illustrate that all parts of Florida are and can be impacted by hurricanes at different levels over time. Tropical cyclones are random in distribution, so there is no specific region of Florida that is more at risk than another. However, the coastal areas are more vulnerable to the effects that a tropical cyclone can produce due to their urban development, location, and the storm surge that can occur.

[51] Grinsted et al. (2013). *Projected Atlantic hurricane surge threat from rising temperatures. Proceedings of the National Academy of Sciences,* 110(14), 5369, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3619316/; (Grossman and Morgan (2011). *Tropical cyclones, climate change, and scientific uncertainty: What do we know, what does it mean, and what should be done?* Climatic Change, 108, 547.

[52] Power dissipation indices are "an aggregate compound of tropical cyclone frequency, duration, and intensity that measures total energy consumption by tropical cyclones," Seneviratne et al., 2012, p. 159. https://www.ipcc.ch/pdf/special-reports/srex/SREX-Chap3_FINAL.pdf

[53] Seneviratne et al. (2012). *Changes in climate extremes and their impacts on the natural physical environment.* In Field et al. (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation,* p. 159. https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

[54] Kossin et al. (2010). *A globally consistent reanalysis of hurricane variability and trends.* Geophysical Research Letters, 34, 4. doi: 10.1029/2006GL028836.

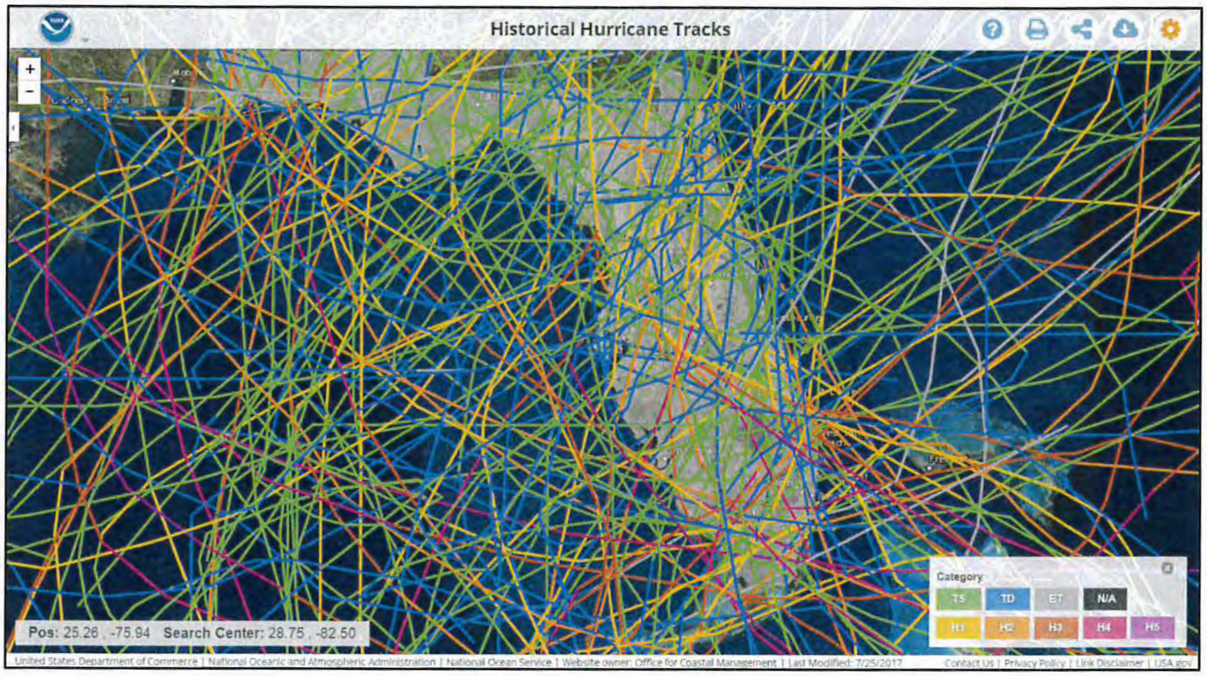
[55] Knutson et al. (2010). *Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions.* Nature Geoscience,1(6), 161.

[56] http://www.hurricanescience.org/science/science/hurricanestructure/

As seen in the image below, tropical cyclones are random and affect all of Florida.

The image below depicts all the tropical cyclones to affect Florida from 1916 to 2016. This graphic shows that all areas of Florida can be affected by tropical cyclones.[57]

Figure 29: Historical Tropical Cyclone Tracks, Florida, 1916 to 2016



[57] https://coast.noaa.gov/hurricanes/

Figure 30: Coastal Flood Depth, Category 2 Hurricane

This map shows that the Big Bend coastal region, the southwest coast and a small portion of the northeast coast of Florida are susceptible to coastal flooding due to a Category 2 Hurricane.

Figure 31: Coastal Flood Depth, Category 5 Hurricane

This map shows that the entire west coast of Florida, along with the upper half of the eastern coast and the Florida Keys are susceptible to coastal flooding due to a Category 5 Hurricane.

3. Historical Occurrences of Tropical Cyclones

The table below lists the hurricanes and tropical storms that affected the state from 2006 to 2016.

Table 25: Significant Tropical Cyclone Occurrences, 2006-2016

Name	Date
Tropical Storm Fay	August 18–23, 2008
Hurricane Ike	September 7, 2008
Hurricane Gustav	October 27, 2008
Tropical Storm Beryl	May 28–30, 2012
Tropical Storm Debby	June 24–25, 2012
Hurricane Isaac	August 25-27, 2012

Tropical Storm Erika	August 28, 2012
Tropical Storm Colin	June 6-7, 2016
Hurricane Hermine	August 31-September 2, 2016
Hurricane Matthew	October 3-6, 2016

Table 26: Significant Tropical Cyclones before 2006[58]

Date	Information
1921	Storm surge and abnormally high tides caused damage along much of the Florida west coast, from Pasco County southward. Several areas in Tampa were inundated with water. Strong winds damaged trees and structures. The agricultural industry suffered a significant loss. There were 4 deaths in Florida attributed to the storm.
1926	The eye of the Category 4 hurricane passed directly over Miami, there was 10 feet of storm surge in Miami Beach and the barrier islands. There were several deaths, many of which are attributed to the misunderstanding of hurricanes and that the calm was the eye of the storm, not the end of the storm. Damages were estimated to be over $1.2 billion in current US dollars.[59]
Okeechobee Hurricane, September 16–17, 1928	A Category 4 Hurricane made landfall near Palm Beach and the center of the hurricane passed near Lake Okeechobee causing lake waters to flood the surrounding areas. There were hundreds of deaths, perhaps as many as 2,500. Damage throughout the region was estimated to be between $25 million and $150 million in Florida.
Labor Day Hurricane, August 31–September 8, 1935	The Labor Day Hurricane hit Florida, mostly in the Florida Keys, and is considered to be one of the most severe hurricanes ever recorded in Florida. There were hundreds of deaths and the Keys Islands were cut off from the mainland for three days. Damage was estimated to be nearly $6 million.
1945 Miami	A Category 4 Hurricane hit Key Largo, Miami, and Homestead. Most of Homestead was destroyed.
Palm Beach 1949	A strong Category 4 Hurricane made landfall in West Palm Beach and moved inland over the northern part of Lake Okeechobee. This hurricane caused extensive damage across most of the east coast of Florida.
1950 – Easy; King	Hurricane Easy impacted northwest Florida and produced severe rainfall and high waves. Hurricane King hit Miami as a Category 4 hurricane, causing millions of dollars (1950 US dollars) of damage.

58 https://www.fema.gov/disasters?field_state_tid_selective=47&field_disaster_type_term_tid=6840&field_disaster_declaration_type_value=All&items_per_page=20&=GO

59 http://www.nhc.noaa.gov/outreach/history/#miami26

Hurricane Andrew, August 24, 1992	Hurricane Andrew hit south Florida as a Category 5 storm. While there were less than 100 deaths, hundreds of thousands of homes were destroyed or severely damaged. Additionally, Hurricane Andrew caused an estimated \$26.5 billion in damages. The US military also deployed nearly 22,000 troops to aid in the recovery efforts.
Hurricane Earl, August 31–September 3, 1998	Hurricane Earl made landfall near Panama City, Florida as a Category 1 hurricane. There were very high storm surges in the Big Bend area of Florida, well away from the center of the hurricane. Hurricane Earl caused 2 deaths and an estimated \$79 million in damages.
2004 Hurricane Season	There were several tropical cyclones to affect Florida in the 2004 hurricane season, including: • Tropical Storm Bonnie, which made landfall in panhandle of Florida; • Hurricane Charley, which made landfall as a Category 4 on the southwestern coast of Florida; • Hurricane Frances, which affected Florida east coast as a Category 2 hurricane; • Hurricane Jeanne, which made landfall in central Florida east coast as a Category 3 hurricane. The season led to over \$3.6 billion in federal assistance
2005 Hurricane Season	The most active Atlantic Hurricane season in recorded history had several tropical cyclones that affected Florida, including: • Tropical Storm Arlene, which made landfall on the Florida panhandle; • Hurricane Dennis, which went through the western panhandle; • Hurricane Katrina, which caused significant effects in the Florida panhandle; • Hurricane Rita, which caused storm surge in the Florida keys; • Tropical Storm Tammy, which made landfall along the northeastern Florida coast; and • Hurricane Wilma, which affected southern Florida. These storms led to over \$2.25 billion in federal assistance

Table 27: FEMA Major Disaster Declarations in Florida, 1960 – 2016[60]

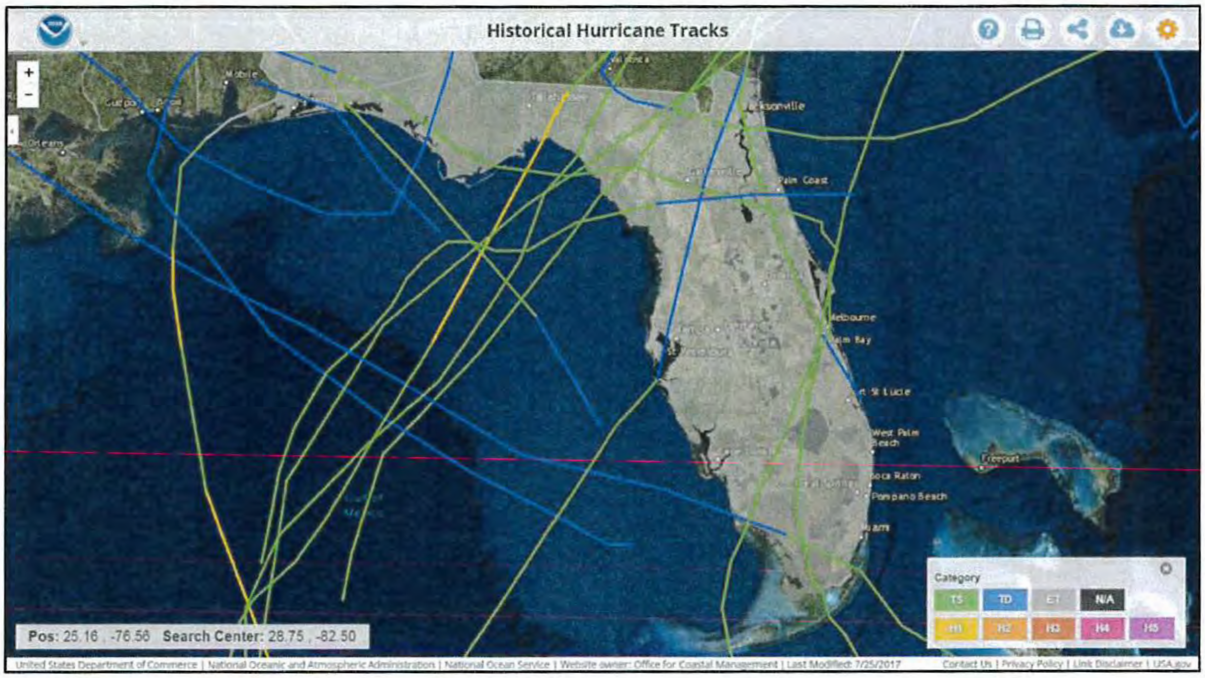
Date	Description
September 12, 1960	DR-106: Hurricane Donna
September 8, 1964	DR-175: Hurricane Cleo
September 10, 1964	DR-176: Hurricane Dora
September 14, 1965	DR-209: Hurricane Betsy
November 7, 1968	DR-252: Hurricane Gladys
June 23, 1972	DR-337: Tropical Storm Agnes
September 13, 1979	DR-600: Hurricane Frederic

60 https://www.fema.gov/disasters?field_state_tid_selective=47&field_disaster_type_term_tid=6840&field_disaster_declaration_type_value=DR&items_per_page=20

August 29 - September 2, 1985	DR-743: Hurricane Elena
November 21 – 22, 1985	DR-756: Hurricane Kate
August 24 – 25, 1992	DR-955: Hurricane Andrew
July 2 – 29, 1994	DR-1035: Tropical Storm Alberto
August 2 – 3, 1995	DR-1062: Hurricane Erin
October 4 – 11, 1995	DR-1069: Hurricane Opal
September 3, 1998	DR-1241: Hurricane Earl
September 25 – October 2, 1998	DR-1249: Hurricane Georges
November 4 – 5, 1998	DR-1259: Tropical Storm Mitch
September 13 -25, 1999	DR-1300: Hurricane Floyd
October 14 – 24, 1999	DR-1306: Hurricane Irene
September 21 – October 4, 2000	DR-1344: Tropical Storm Helene
June 11 – 15, 2001	DR-1381: Tropical Storm Allison
September 13 – 21, 2001	DR-1393: Tropical Storm Gabrielle
August 11 – 30, 2004	DR-1539: Hurricane Charley and Tropical Storm Bonnie
September 3 – October 8, 2004	DR-1545: Hurricane Frances
September 13 – November 17, 2004	DR-1551: Hurricane Ivan
September 24 – November 17, 2004	DR-1531: Hurricane Jeanne
July 7 – 20, 2005	DR-1595: Hurricane Dennis
August 24 – September 6, 2005	DR-1602: Hurricane Katrina
October 23 – November 18, 2005	DR-1609: Hurricane Wilma
August 18 – September 12, 2008	DR-1785: Tropical Storm Fay
August 31 – September 7, 2008	DR-1806: Hurricane Gustav
June 23 – July 26, 2012	DR-4068: Tropical Storm Debby
August 27 – 29, 2012	DR-4084: Hurricane Isaac
August 31 – September 11, 2016	DR-4280: Hurricane Hermine
October 3 – 19, 2016	DR-4283: Hurricane Matthew

The figure below shows all the tracks of tropical cyclones that affected Florida from 2006 to 2016.

Figure 32: Tropical Cyclone Tracks, Florida, 2006 to 2016[61]



NOAA tracks all weather related fatalities in the US. According to their data, there were nine deaths in Florida from 2006 to 2016 due to tropical cyclones:[62]

- 2008: 3 deaths
- 2009: 1 death
- 2012: 3 deaths
- 2016: 2 deaths

There were also 13 deaths attributed to wind from 2006 to 2016 in Florida:[63]

- 2009: 4 deaths
- 2011: 1 death
- 2012: 2 deaths
- 2013: 1 death
- 2014: 1 death
- 2015: 3 deaths
- 2016: 1 death

[61] https://coast.noaa.gov/hurricanes/
[62] http://www.nws.noaa.gov/om/hazstats.shtml#
[63] http://www.nws.noaa.gov/om/hazstats.shtml#

Furthermore, six deaths were attributed to floods in Florida from 2006 to 2016.

4. Probability of Future Tropical Cyclones

Since tropical cyclones are random in distribution, it is impossible to forecast whether Florida will experience a tropical cyclone. However, because of the high frequency of tropical cyclones that have affected Florida in the past, it is reasonable to assume that Florida will experience tropical cyclones again in the future.

The following maps show the probability that areas in Florida will receive Tropical Storm through Hurricane force winds within the specified return period.

Figure 33: Hurricane Winds Probabilistic Scenario, 10-Year Return Period

This map is showing that it is likely that every 10 years, the areas shaded in darker green will experience at least one Tropical Storm and the areas shaded in lighter green will experience at least one Category 1 Hurricane.

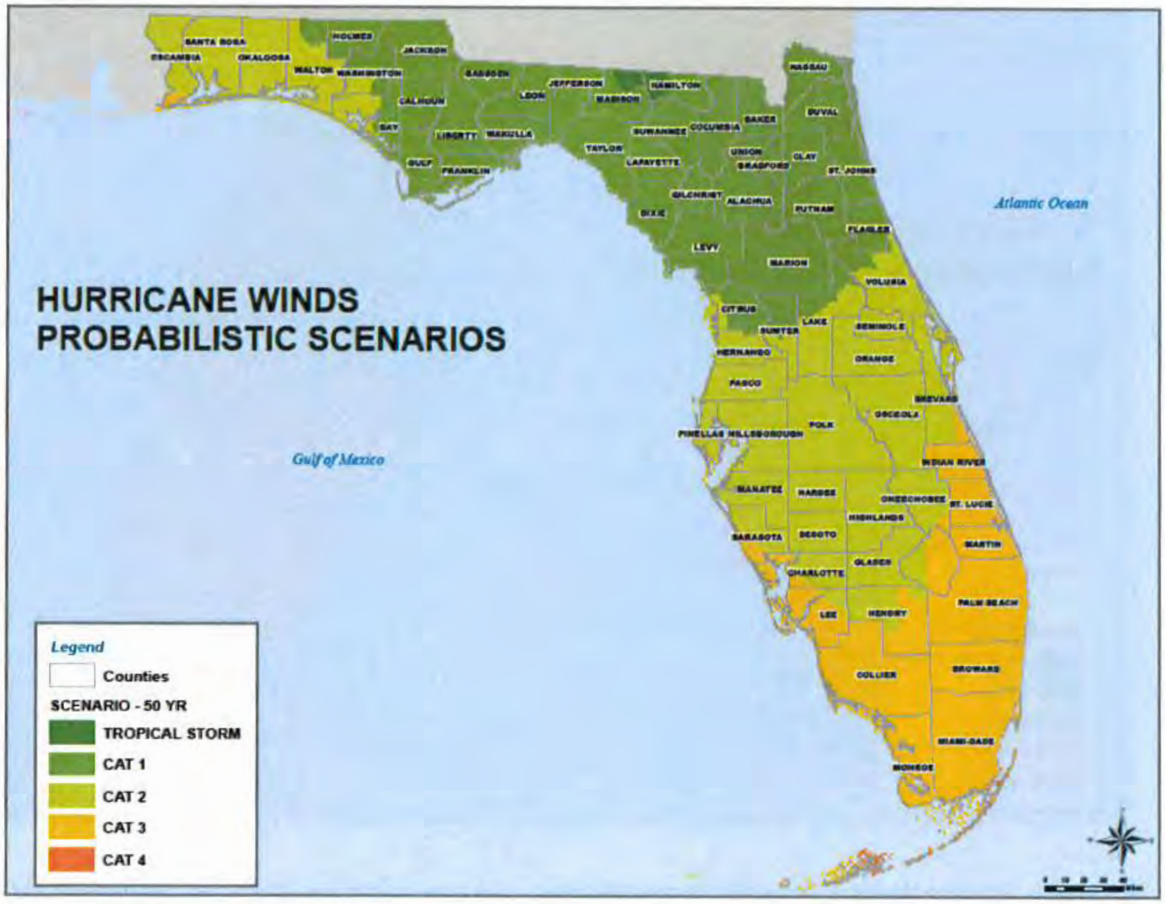
Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 10-year return period scenario, there are fifty-two counties with less than 1,000 structures likely to be damaged and fifteen counties with 1,000 to 100,000 structures likely to be damaged. There are twenty-four counties with zero to one million dollars of structural damage likely. Another thirty counties have between one million and 100 million dollars of structural damage likely. There are nine counties with between 100 million and 1 billion dollars of structural damage likely and four counties with over 1 billion dollars of structural damage likely.

Figure 34: Hurricane Winds Probabilistic Scenario, 20-Year Return Period

This map is showing that it is likely that every 20 years, the areas shaded in darker green will experience at least one Tropical Storm; the areas shaded in lighter green will experience at least one Category 1 Hurricane; and the areas shaded in yellow-green will experience at least one Category 2 Hurricane.

Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 20-year return period scenario, there are thirty six counties with less than 1,000 structures likely to be damaged, twenty-nine counties with between 1,000 and 100,000 structures likely to be damaged, and two counties with over 100,000 structures likely to be damaged. Only nine counties have between 100,000 and one million dollars of structural damage likely. There are thirty-one counties with between one million and 100 million dollars of structural damage likely and twenty-three counties with between 100 million and one billion dollars of structural damage likely. There are four counties with over one billion dollars of structural damage likely.

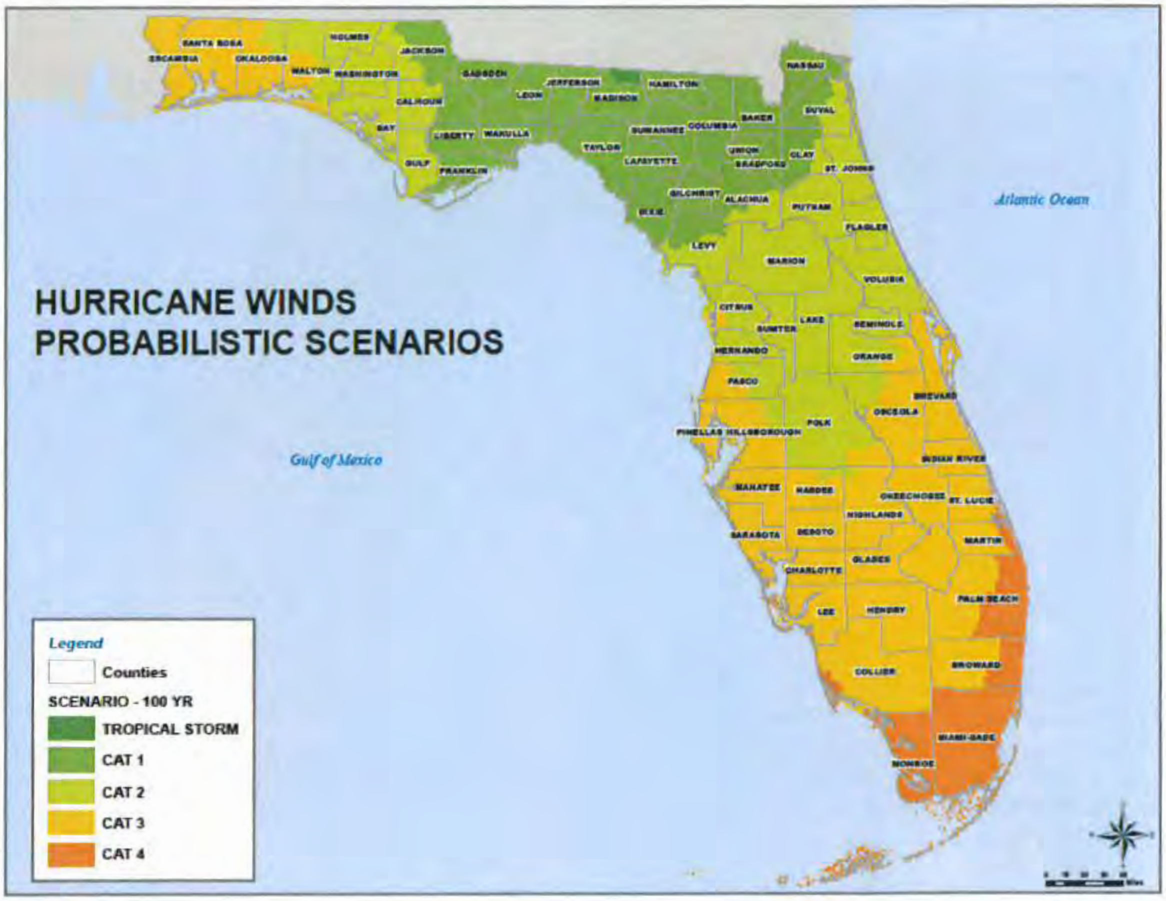
Figure 35: Hurricane Winds Probabilistic Scenario, 50-Year Return Period



This map is showing that it is likely that every 50 years, the areas shaded in green will experience at least one Tropical Storm; the areas shaded in lighter green will experience at least one Category 1 Hurricane; the areas shaded in yellow-green will experience at least one Category 2 Hurricane; the areas in yellow-orange will experience at least one Category 3 Hurricane; and areas shaded in orange will experience at least one Category 4 Hurricane.

Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* There are twenty-four counties with less than 1,000 structures likely to be damaged and thirty-nine counties with between 1,000 and 100,000 structures likely to be damaged. Only four counties have over 100,000 structures likely to be damaged. There are twenty-eight counties with between one million and 100 million dollars of structural damage likely; twenty-two counties with between 100 million and one billion dollars of structural damage likely; and seventeen counties with between one billion and 100 billion dollars of structural damage likely.

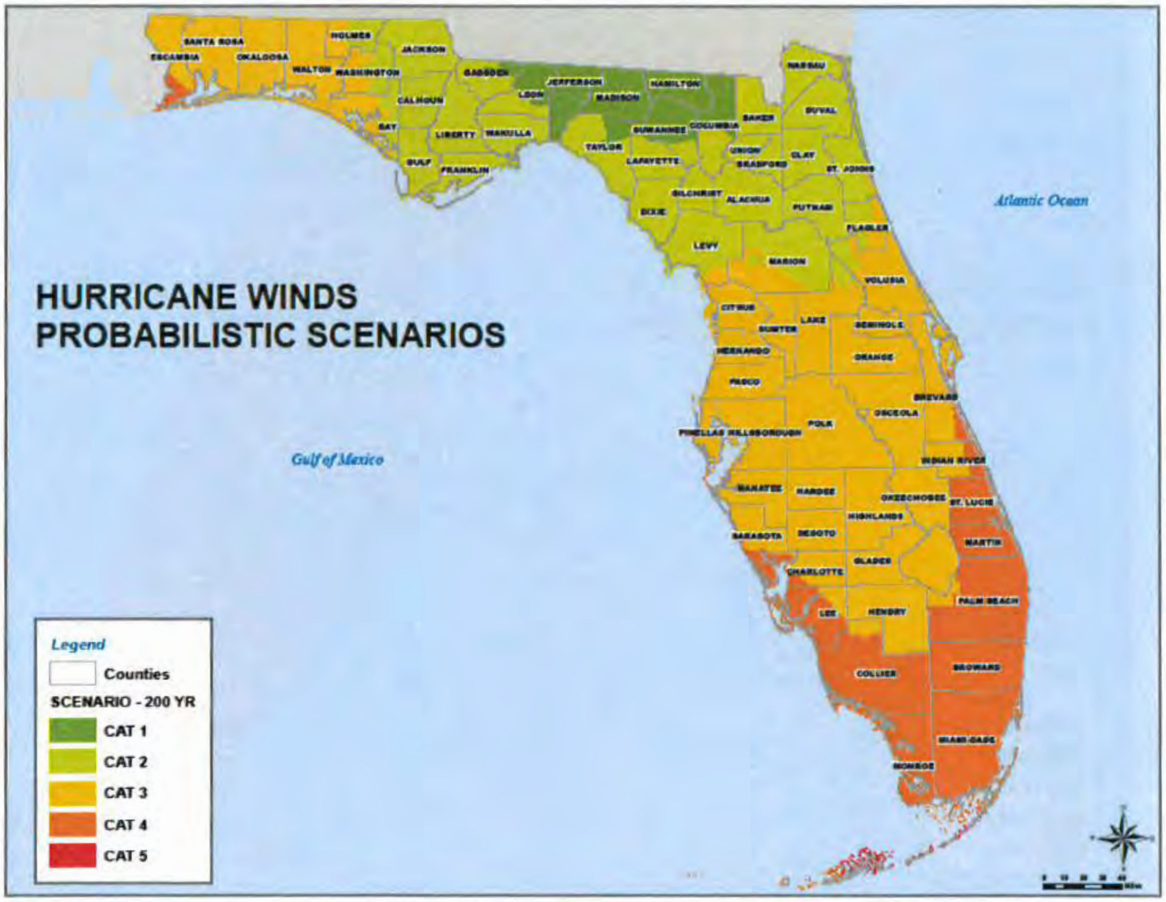
Figure 36: Hurricane Winds Probabilistic Scenario, 100-Year Return Period



This map is showing that it is likely that every 100 years, the area shaded in green will experience at least one Tropical Storm; the areas shaded lighter green will experience at least one Category 1 Hurricane; the areas shaded yellow-green will experience at least one Category 2 Hurricane; the areas shaded yellow-orange will experience at least one Category 3 Hurricane; and the area shaded orange will experience at least one Category 4 Hurricane.

Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 100-year return period scenario, there are seventeen counties with less than 1,000 structures likely to be damaged, forty one counties with between 1,000 and 100,000 structures likely to be damaged, and nine counties with over 100,000 structures likely to be damaged. There are twenty-five counties with between one million and 100 million dollars of structural damage likely; eighteen counties with between 100 million and 1 billion dollars of structural damage likely, and twenty-four counties with between one billion and 100 billion dollars of structural damage likely.

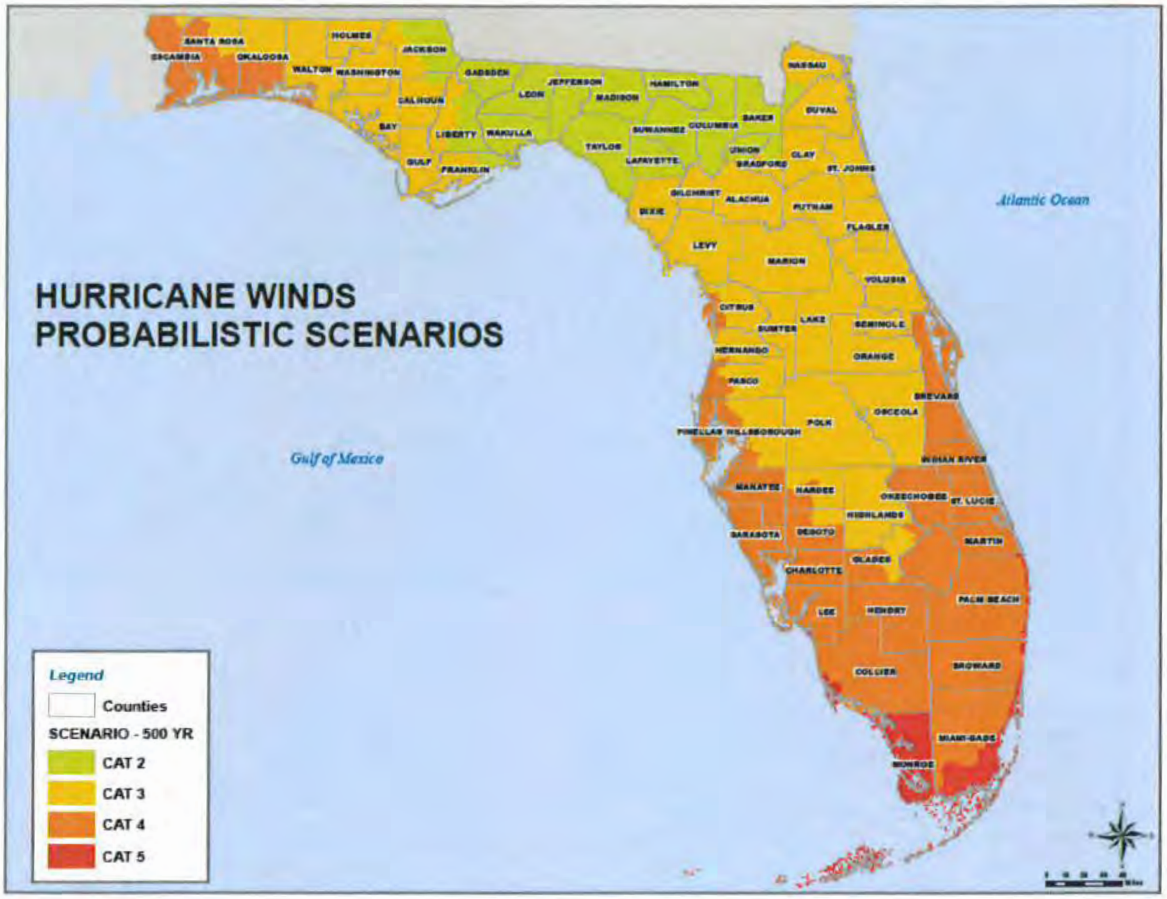
Figure 37: Hurricane Winds Probabilistic Scenario, 200-Year Return Period



This map is showing that it is likely that every 200 years, the area shaded in green will experience at least one Category 1 Hurricane; the areas shaded in yellow-green will experience at least one Category 2 Hurricane; the areas shaded in yellow-orange will experience at least one Category 3 Hurricane; the areas shaded in orange will experience at least one Category 4 Hurricane; and the areas shaded in red (in the Florida Keys) will experience at least one Category 5 Hurricane.

Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 200-year return period scenario, there are eight counties with less than 1,000 structures likely to be damaged, 45 counties with between 1,000 and 100,000 structures likely to be damaged, and fourteen counties with more than 100,000 structures likely to be damaged. There are twenty-one counties with between one million and 100 million dollars of structural damage likely, fifteen counties with between 100 million and one billion dollars of structural damage likely, thirty counties with between one billion and 100 billion dollars of structural damage likely, and one county with over 100 billion dollars of structural damage likely.

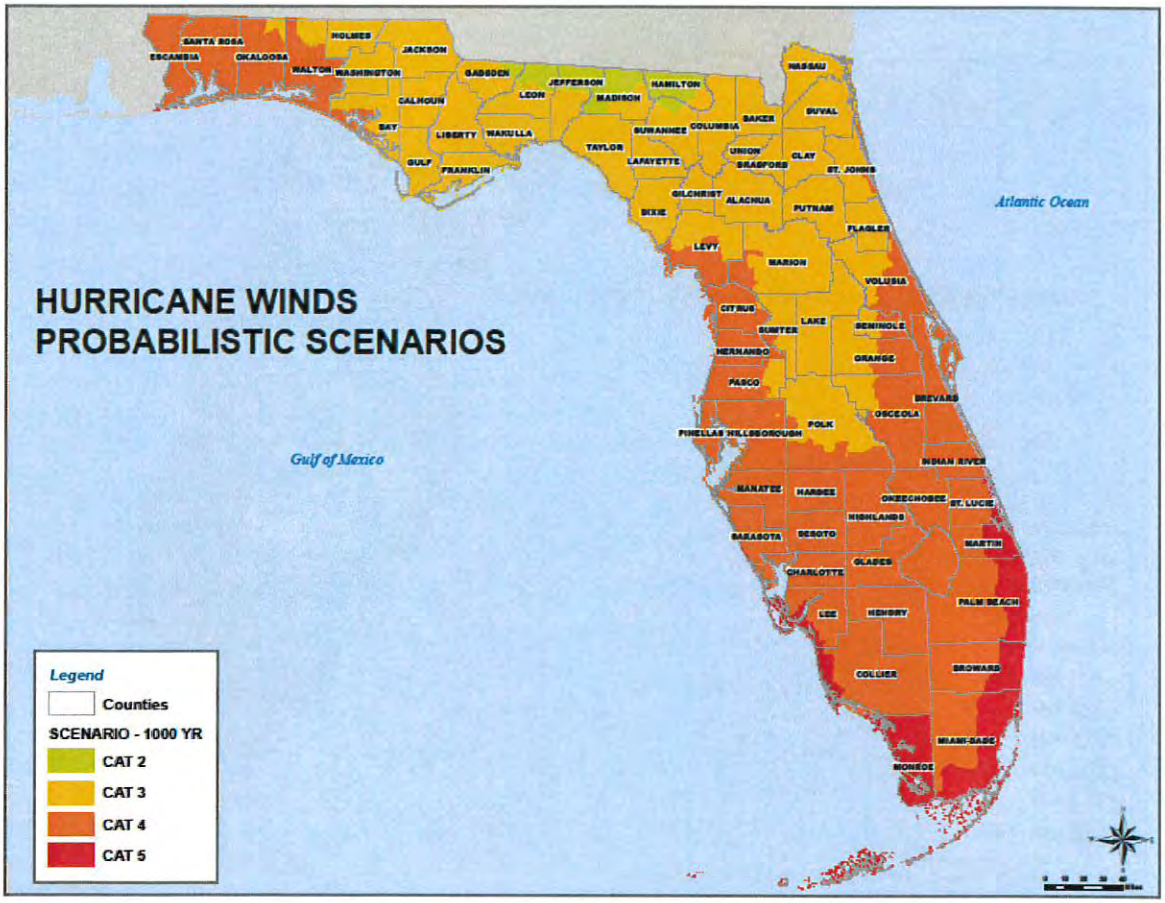
Figure 38: Hurricane Winds Probabilistic Scenario, 500-Year Return Period



This map is showing that it is likely that every 500 years, the areas shaded in yellow-green will experience at least one Category 2 Hurricane; the areas shaded in yellow-orange will experience at least one Category 3 Hurricane; the areas shaded in orange will experience at least one Category 4 Hurricane; and the areas shaded in red will experience at least one Category 5 Hurricane.

Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 500-year return period scenario, there are four counties with less than 1,000 structures likely to be damaged, forty six counties with between 1,000 and 100,000 structures likely to be damaged, and seventeen counties with more than 100,000 structures likely to be damaged. Sixteen counties would have between one million and 100 million dollars of structural damage likely and another sixteen counties have between 100 million and 1 billion dollars of structural damage likely. Thirty-three counties would have between one billion and 100 billion dollars of structural damage likely and two counties would have over 100 billion dollars of structural damage likely.

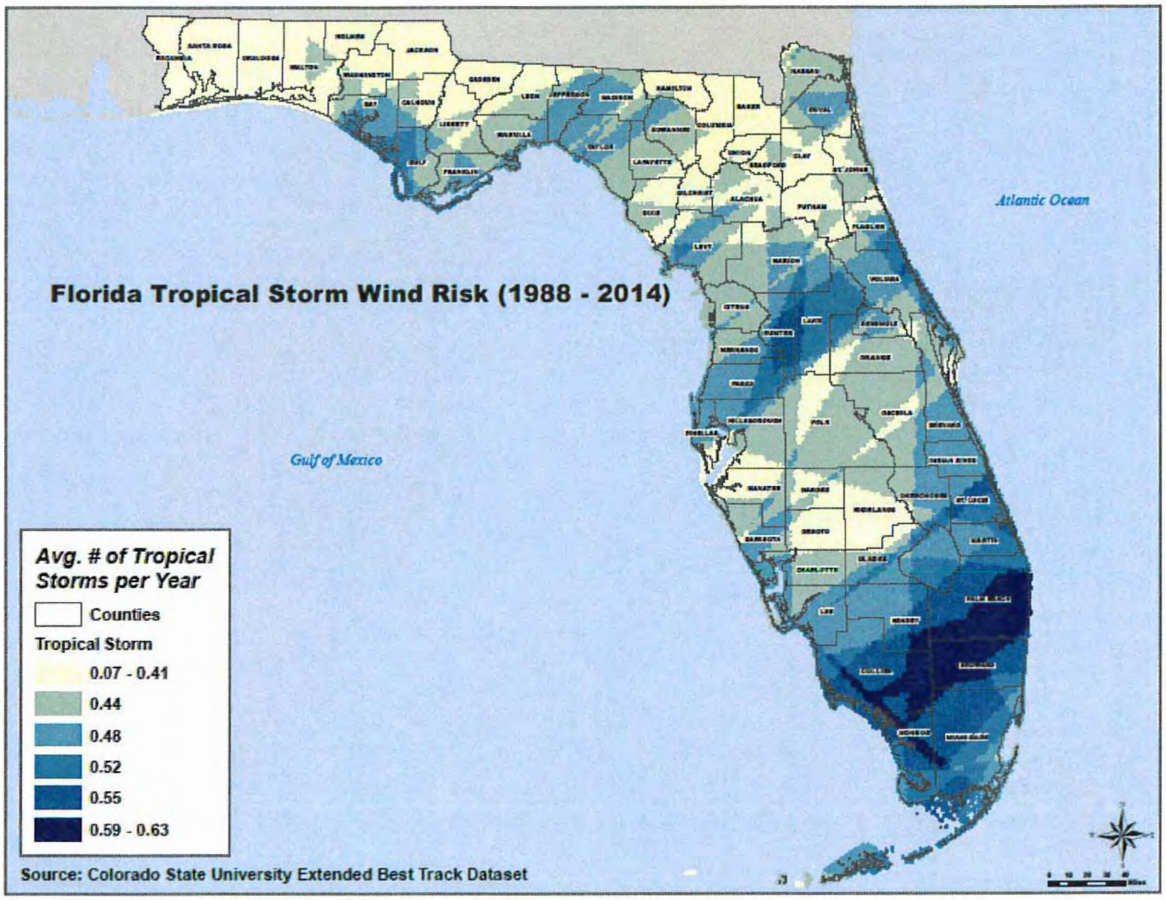
Figure 39: Hurricane Winds Probabilistic Scenario, 1000-Year Return Period



This map is showing that it is likely that every 1,000 years, the areas shaded yellow-green will experience at least one Category 2 Hurricane; the areas shaded in yellow-orange will experience at least one Category 3 Hurricane; the areas shaded orange will experience at least one Category 4 Hurricane; and the areas shaded in red will experience at least one Category 5 Hurricane.

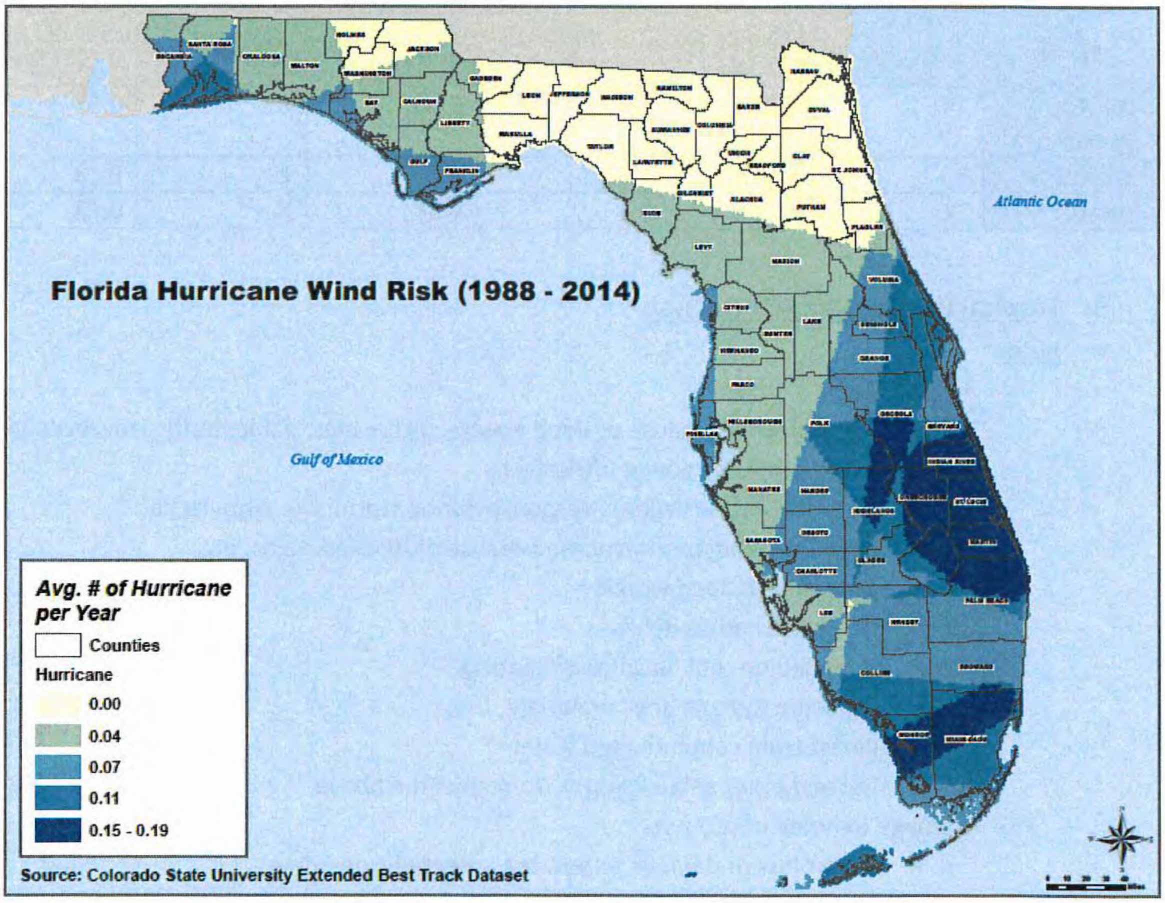
Tables with the Count and Value of structures within the shaded areas can be found in *Appendix E: Risk Assessment Tables.* For this 1,000-year return period scenario, there are forty-eight counties with less than 100,000 structures likely to be damaged and nineteen counties with over 100,000 structures likely to be damaged. There are nine counties with between one million and 100 million dollars of structural damage likely; eighteen counties with between 100 million and one billion dollars of structural damage likely; thirty-seven counties with between one billion and 100 billion dollars of structural damage likely; and three counties with over 100 billion dollars of structural damage likely.

Figure 40: Tropical Storm Wind Risk, Florida, 1988 – 2014



According to this data, south Florida is likely to experience between .48 and .63 tropical storms each year.

Figure 41: Hurricane Wind Risk, Florida, 1988 – 2014



According to this data, the western Panhandle and the peninsula of Florida are likely to experience between .04 and .19 hurricanes each year.

NCDC Average Number of Events

According to data from the NCDC Storm Event Database, and data from 2006 to 2016, Florida experiences an average of 1.27 tropical storms and .64 hurricanes each year. The data also included injury and death information and shows that it is likely that there will be .36 injuries and .73 deaths each year due to tropical storms and hurricanes.

Table 28: NCDC Tropical Storms and Hurricanes, Florida, 2006 – 2016

Type of Storm	NCDC Report	Average Events per year	Injuries	Average Injuries per year	Deaths	Average Deaths per year
Tropical Storm	14	1.27	4	0.36	6	0.55
Hurricane	7	0.64	0	0	2	0.18
Total	21	1.91	4	0.36	8	0.73

5. Tropical Cyclones Impact Analysis

- Public
  - Injury/death
    - Car accidents because of flood waters, high winds, panic, traffic jams because of evacuations, no power after storm
    - Not receiving emergency response during storm, like ambulance
    - Delayed emergency response because of blocked roads, etc.
    - Drowning in flood waters
    - Hit or crushed by debris
    - Stranded on roof because of flooding
    - Exposure to hazardous materials
    - Illness from contaminated water
    - Pet and other animal deaths from all of the above
  - Damage to home or property
    - Power loss or damage to power connections on home
    - Mold damage causing the need for expensive mold remediation actions
    - Cost to replace damaged and destroyed items, such as furniture, flooring, etc.
    - Cost and labor to repair damaged homes and other structures to make the house inhabitable
    - If the property was uninsured, the cost falls upon the property owner
    - Hotel room fees or having to live in a shelter until damage is repaired or home is replaced
    - Damaged or washed-away vehicles
    - Lost wages because no way to get to work if roads are blocked or if car was damaged in storm or if employer experienced damage
    - Possible forced to evacuate
      - Cost to travel
      - Cost to stay at hotel
      - Loss of wages if out of town
      - Loss of food if you can't go back to get it
  - Power outage

        - Cost of generators and gas to run the generators
            - Risk of accidental fire or carbon monoxide poisoning is high
        - Loss of food in refrigerator and freezer
        - Difficulties travelling anywhere because of outages at traffic lights
        - Cost of purchasing disaster supplies such as flashlights
        - Hotel room fees or having to live in a shelter until power is restored
        - Lost wages because employer is experiencing power outage
    - Emotional or psychological toll of surviving
        - If a friend or family member dies in storm individual may feel great sense of guilt or stress
        - If major damage occurs for an individual, they will likely experience stress and anxiety dealing with evacuating, staying in shelters, working to get insurance payments, working to get government assistance, etc.
        - Being forced to leave or forfeit a pet in an unsafe area during or after a tropical cyclone
- <u>Responders</u>
    - Injury/death
        - Responding during tropical storms is unsafe
        - Responding immediately after tropical storms is unsafe because of debris, unstable transportation infrastructure, unstable structures
        - Rescuing people from unstable buildings or by boat
        - Exposure to hazardous materials
    - Stress caused by severity of tasks such as rescuing people
    - Feelings of guilt for not being able to save people
    - Witnessing gruesome scenes of injured or dead
- <u>Continuity of Operations (including continued delivery of services)</u>
    - Loss of revenue if businesses cannot operate during or after event
    - Loss of wages if your employer's organization is damaged or destroyed and you cannot work
    - Utility failures such as electric or gas may prevent businesses from opening even if there is no damage
    - Utility failures may impede or prevent government offices from continuing daily services
    - Severe damage and interruption to transportation systems and infrastructure like roads and bridges; communication systems; power; water; wastewater; etc.
- <u>Property, Facilities, Infrastructure</u>
    - Damaged or destroyed property, such as homes and other buildings
        - Roofing is particularly susceptible to damage from high winds
        - The first floor of many buildings, plus all the items on that floor, are susceptible to severe damage from flooding
    - Cost of repairing damage to property such as buildings

   - Cost of replacing items damaged such as furniture on the first floor of a flooded home
   - Crop damage or loss
   - Damage to transportation infrastructure, like a road being washed out or a bridge collapsing and/or closure of major transportation networks
   - Inability to get clean water
   - Inability to control wastewater
   - Release of hazardous materials
- Environment
   - Beach and dune erosion
   - Downed trees
   - Eroded river banks
   - Release of hazardous materials can contaminate or damage the environment
   - Loss or damage to habitat for animals because of flooding or high winds
   - Crop damage or loss
   - Event generated marine debris impacting waterway navigation and submerged wetland habitats
- Economic Condition
   - Damaged and destroyed businesses leading to long-term closures and possibly permanent closures
   - Delayed re-opening of businesses because of utility issues, road blockages, etc.
   - Crop damage or loss from flooding and high winds
   - Absenteeism from work
   - Loss of tourism because of eroded beaches or damaged attractions
- Public Confidence in Jurisdiction's Governance
   - Evacuations not ordered in time lead to decrease in public confidence
   - Shelters not opened or having little information
   - Warnings not communicated effectively
   - Communicating too much
   - Over exaggeration of possible storm impacts, especially if the storm doesn't have expected impacts

6. 2018 LMS Integration of Tropical Cyclones

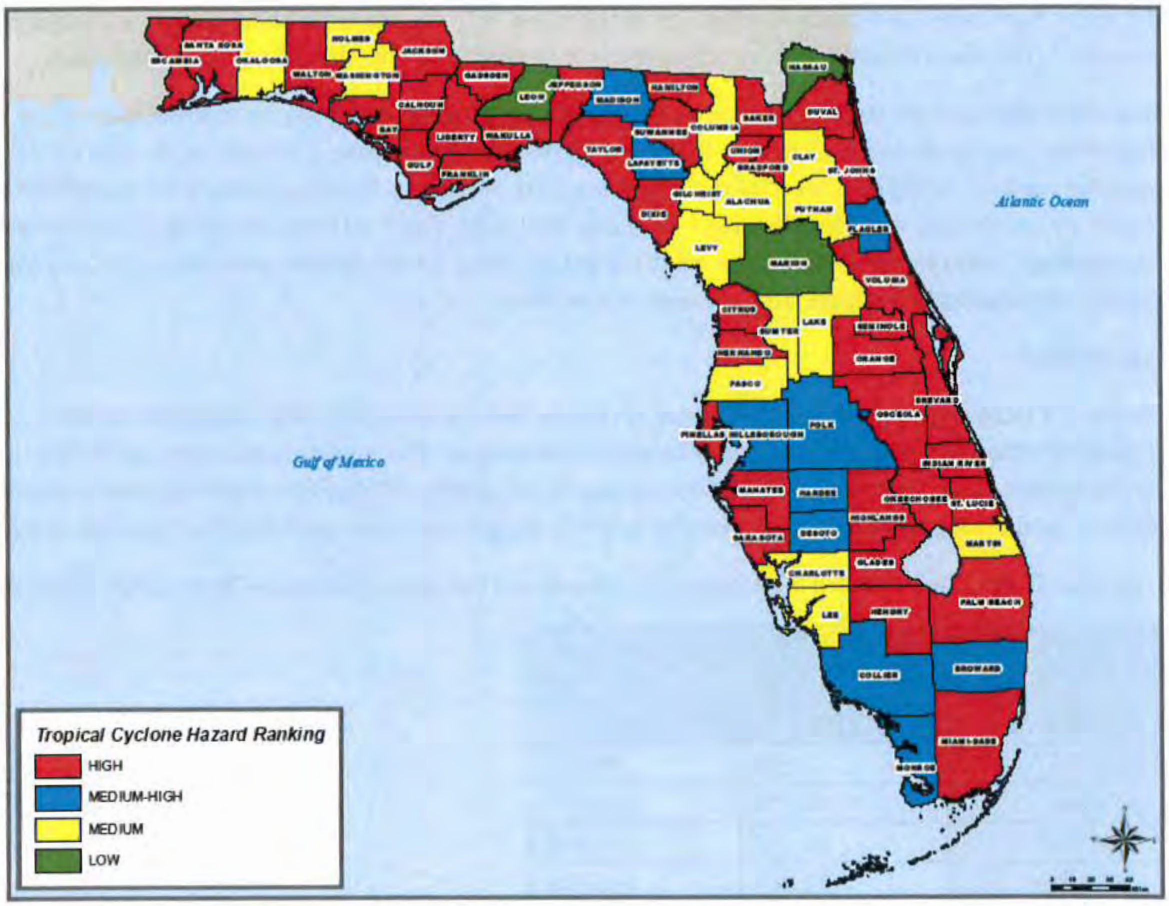
An analysis of all 67 Florida County LMS Plans and their individual tropical cyclone hazard rankings is shown below. All counties identified tropical cyclones (or something similar such as tropical storms or hurricanes) as a hazard.

Tropical Cyclones/ Hurricanes

Based on the LMS plans, Figure 3.38 displays the jurisdictional rankings for the tropical cyclone/hurricane hazard. All counties have identified tropical cyclones/hurricanes as one of their hazards.

- High-risk Jurisdictions: 39
- Medium-High-risk Jurisdictions: 10
- Medium-risk Jurisdictions: 15
- Low-risk Jurisdictions: 3
- Not identified Jurisdictions: 0

Figure 42: Tropical Cyclones Hazard Rankings by County



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

Due to Florida's geographic location, the entire state is vulnerable to damage from tropical cyclones. The southern tip of the peninsula and the Florida Keys are especially vulnerable due to exposure and the high population.

As the population of Florida increases, so too does the number of those who have not experienced the impact of a tropical cyclone or major hurricane. Approximately 33 percent of the total state population lives within 20 miles of the coast. The proximity of the Atlantic Ocean or the Gulf of Mexico, coupled with the generally low coastal elevations and the fact that 75 percent of the state's population resides in the 35 coastal counties, makes Florida very vulnerable to tropical cyclones.

Of the state's 67 counties, 35 have coastlines bordering either the Atlantic Ocean or the Gulf of Mexico. These counties comprise approximately 1,350 miles of general coastline. When considering the intricacies of the Florida coastline, with bays, inlets, and waterways, there is over 8000 miles of coastline.

Between 1906 and 2016, 28 major (Category 3 or higher) hurricanes affected the state. In that timeframe, 68 major hurricanes have made landfall within the state, with the majority being Category 1 hurricanes. Generally, the lower intensity hurricanes have made landfall in the northwest portion of the state.

The vulnerability of the state to hurricanes varies with the progression of the hurricane season. Early and late in the season (June and October), the region of maximum hurricane activity is in the Gulf of Mexico and the western Caribbean. Most of those systems that move into Florida approach the state from the south or southwest, entering the keys or along the west coast. Mid-season (August and most of September), tropical cyclones develop off the coast of Africa. These systems are known as Cape Verde Storms and approach the state from the east or southeast.

Storm Surge

Below is a table showing the population that resides in the areas that would be impacted by storm surge coastal flooding due to a Category 2 and Category 5 Hurricane. This analysis was based on the Sea, Lake and Overland Surge from Hurricanes (SLOSH) maps, flood depth grids from the State Regional Evacuation Studies, and census block data. Counties not at risk to storm surge have been omitted from the analysis.

Table 29: Coastal Flood Hazard in Category 2 Hurricane and Category 5 Hurricane Storm Surge, Population

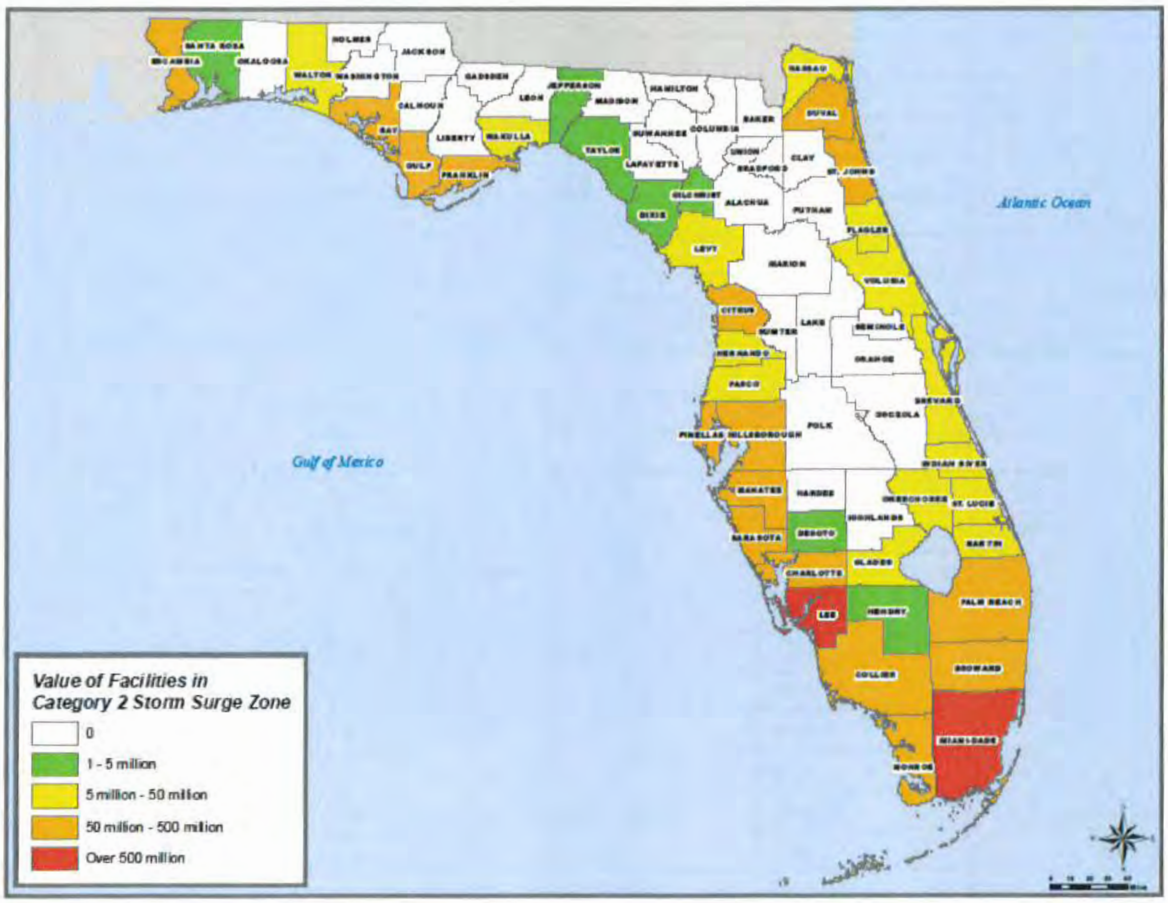
Population in Coastal Flood Hazard (storm surge)		
COUNTY	CATEGORY 2	CATEGORY 5
Bay	7,105	30,851
Brevard	17,178	144,575
Broward	29,157	204,988
Charlotte	99,047	154,345
Citrus	26,647	36,122
Clay	10,838	42,009
Collier	141,908	292,653
DeSoto	536	4,645
Dixie	1,679	7,267
Duval	55,063	295,720
Escambia	6,982	34,849
Flagler	16,095	30,936
Franklin	2,396	10,614
Gilchrist	132	1,246

Glades	1,236	6,435
Gulf	1,163	7,206
Hendry	2,009	4,312
Hernando	4,386	39,364
Highlands	14	60
Hillsborough	186,769	471,028
Indian River	12,841	33,620
Jefferson	1	241
Lafayette	0	27
Lee	297,359	547,803
Leon	0	5,855
Levy	3,452	6,791
Liberty	7	44
Manatee	57,253	234,414
Marion	0	75
Martin	9,355	50,238
Miami-Dade	272,382	1,454,072
Monroe	56,294	65,930
Nassau	12,929	41,801
Okaloosa	2,963	36,353
Okeechobee	2,456	3,305
Palm Beach	11,499	71,894
Pasco	66,804	192,971
Pinellas	280,349	569,882
Putnam	3,665	7,421
St. Johns	52,035	105,614
St. Lucie	6,564	27,085
Santa Rosa	5,364	26,038
Sarasota	58,315	257,964
Taylor	1,499	6,922
Volusia	59,082	198,437
Wakulla	3,950	26,840
Walton	1,318	12,060
Washington	3	39
TOTAL	1,888,079	5,802,961

According to this data, there are five counties with over 100,000 people living in the storm surge zone of a Category 2 Hurricane. These counties are Collier, Hillsborough, Lee, Miami-Dade, and Pinellas. Furthermore, there are fourteen counties with over 100,000 people living in the storm surge zone of a Category 5 hurricane. These counties are Brevard, Broward, Charlotte, Collier, Duval, Hillsborough, Lee, Manatee, Miami-Dade, Pasco, Pinellas, St. Johns, Sarasota, and Volusia. Notably, Miami-Dade County has the highest population in the Category 5 storm surge zone, with 1.4 million people.

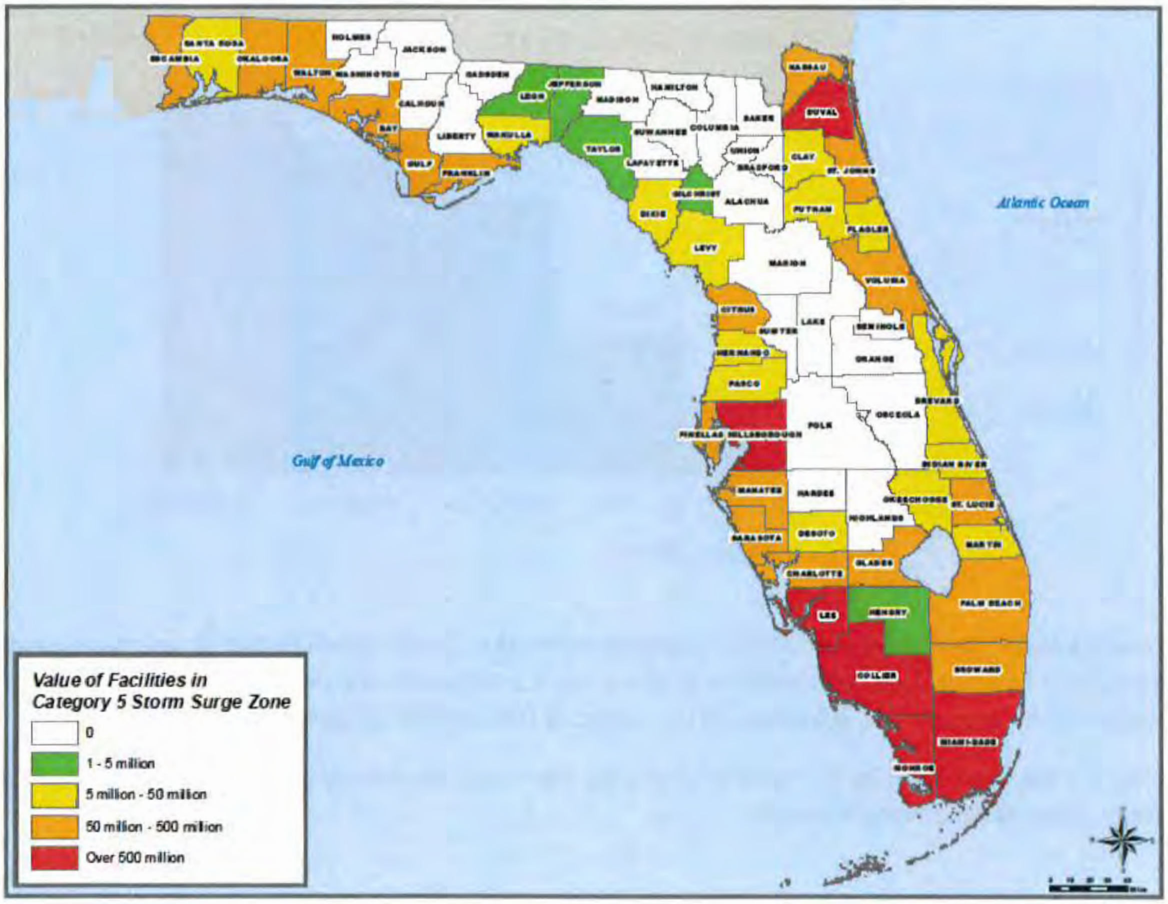
Below are maps showing the total number and total value of county facilities in the storm surge zones of a Category 2 and Category 5 hurricane. Tables detailing this data can also be found in *Appendix E: Risk Assessment Tables.*

Figure 43: Value of Facilities in Category 2 Storm Surge Zone



According to this data, Lee and Miami-Dade counties would have over $500 million of facilities in the storm surge zone for a Category 2 hurricane.

Figure 44: Value of Facilities in Category 5 Storm Surge Zone



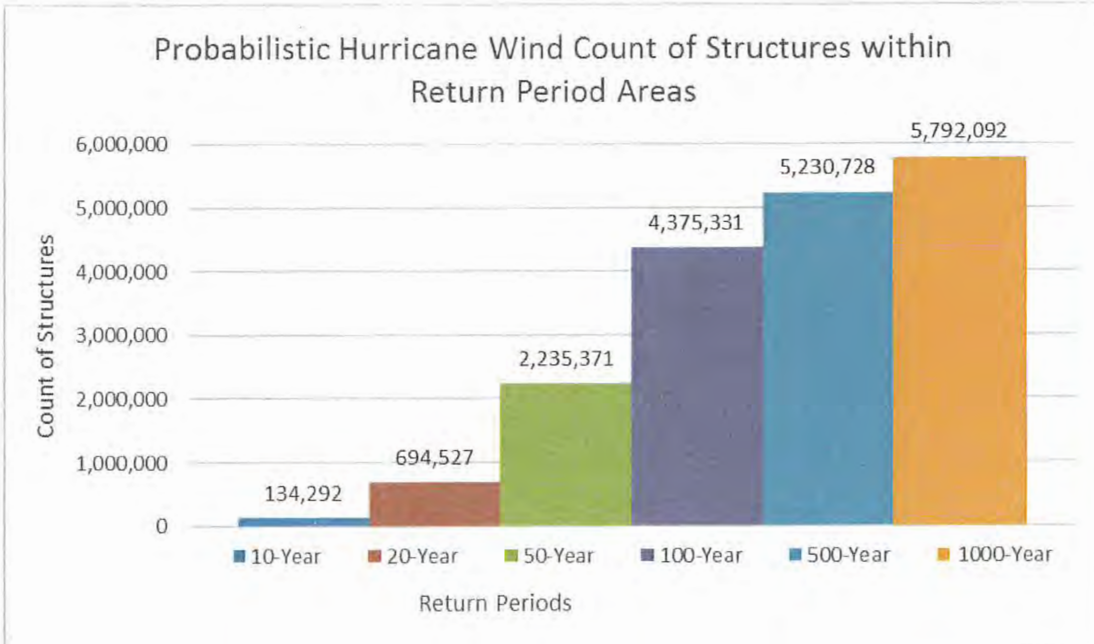
There are more counties with facilities in the Category 5 storm surge zone and the value of those facilities are much higher than the value of those in the Category 2 storm surge zone. There are six counties with over $500 million worth of facilities in the Category 5 storm surge zone. Notably, Lee and Miami-Dade counties each have over $1 billion worth of facilities within the Category 5 storm surge zone.

Wind

The vulnerability to Hurricane Winds is shown above in the Probability section. This analysis also depicts the areas that would be vulnerable to hurricane winds for various return periods. The Loss Estimation, by Jurisdiction, is shown in the bar chart below and is referencing those maps shown in the Probability section.

The loss estimation discussion below is based on tables that can be found in *Appendix E: Risk Assessment Tables.* Those tables include the information below, separated by county.

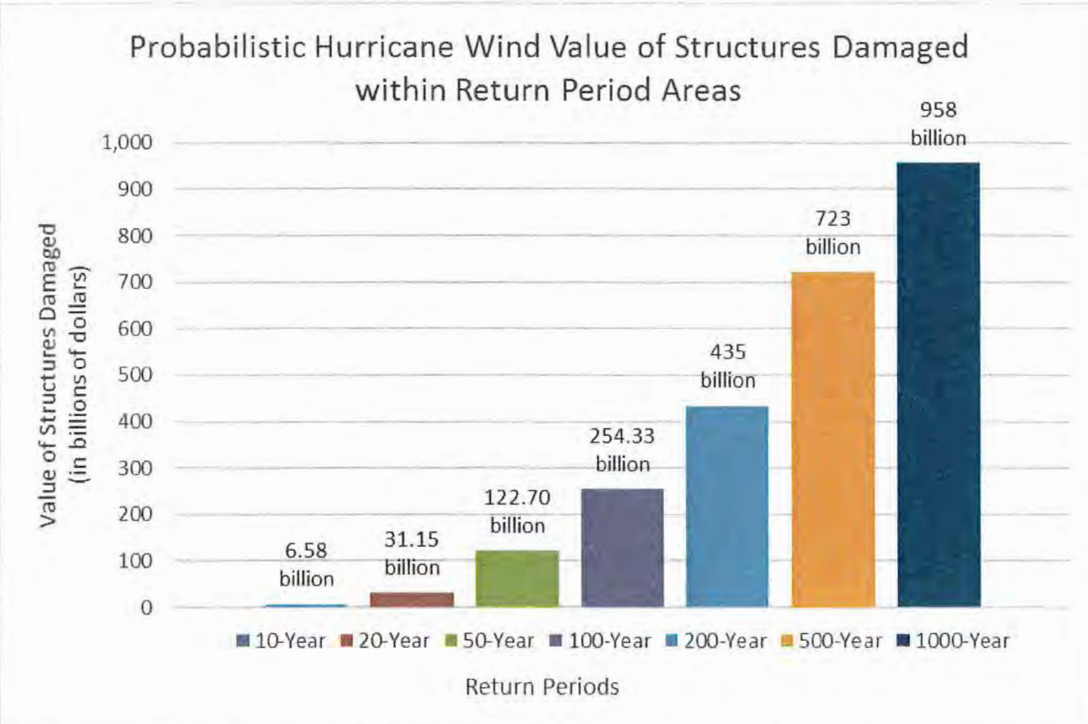
Figure 45: Probabilistic Hurricane Wind Count of Structures, Return Period Areas



According to the data, there are 134,292 structures within the 10-year return period for hurricane winds. The 50-year return period data shows that there are 2.2 million structures in that area, a significant increase from the structures vulnerable to the hurricane winds in the 10-year return period scenario.

Below is a bar chart showing the value of structures that would be damaged due to hurricane winds, in specific areas based on return periods.

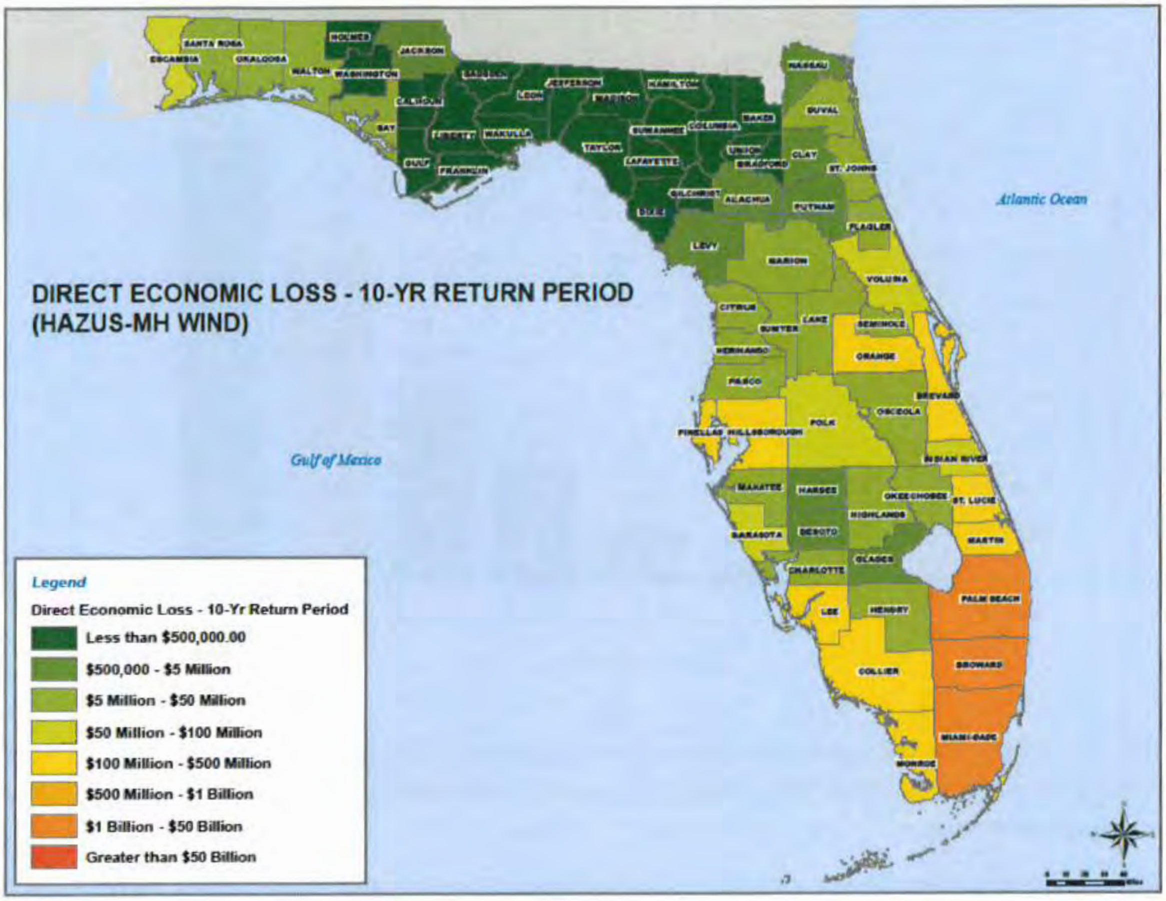
Figure 46: Probabilistic Hurricane Wind Value of Structures Damaged, Return Period Areas



This shows that while the value of structures that would be damaged from hurricane winds in the 10-year return period area is $6.58 billion that number increases exponentially to $958 billion in the 1000-year return period area.

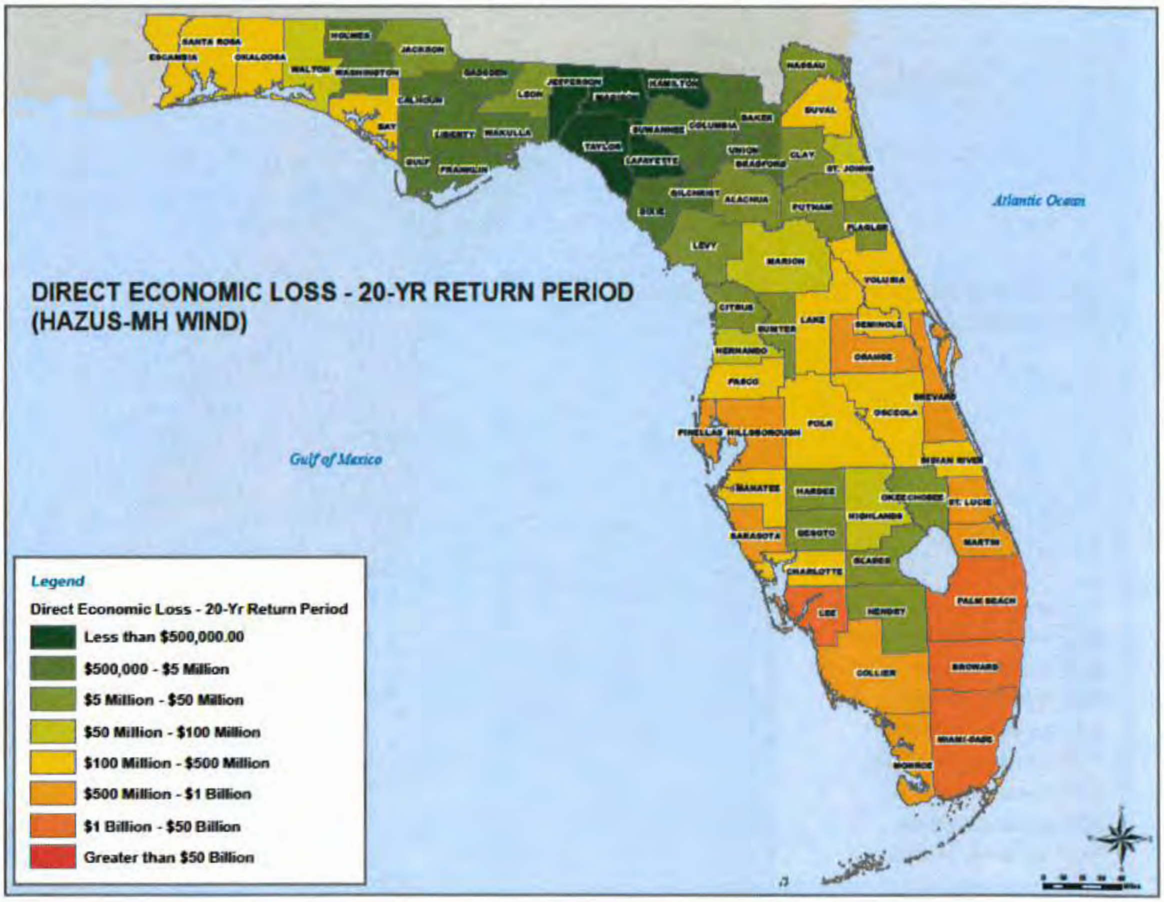
The maps below reflect the Economic Loss for Buildings by County and Return Period derived from the HAZUS-MH Wind model. Direct Economic Loss refers to a value from HAZUS-MH, which is the sum of the capital stock losses and the income losses. The capital stock losses include the cost building damage, the cost contents damage, and the inventory loss. The income losses include the cost of relocation, the capital related loss value, the wages lost, and the rental income lost. Tables detailing this data can be found in *Appendix E: Risk Assessment Tables*.

Figure 47: Direct Economic Loss, 10-Year Return Period



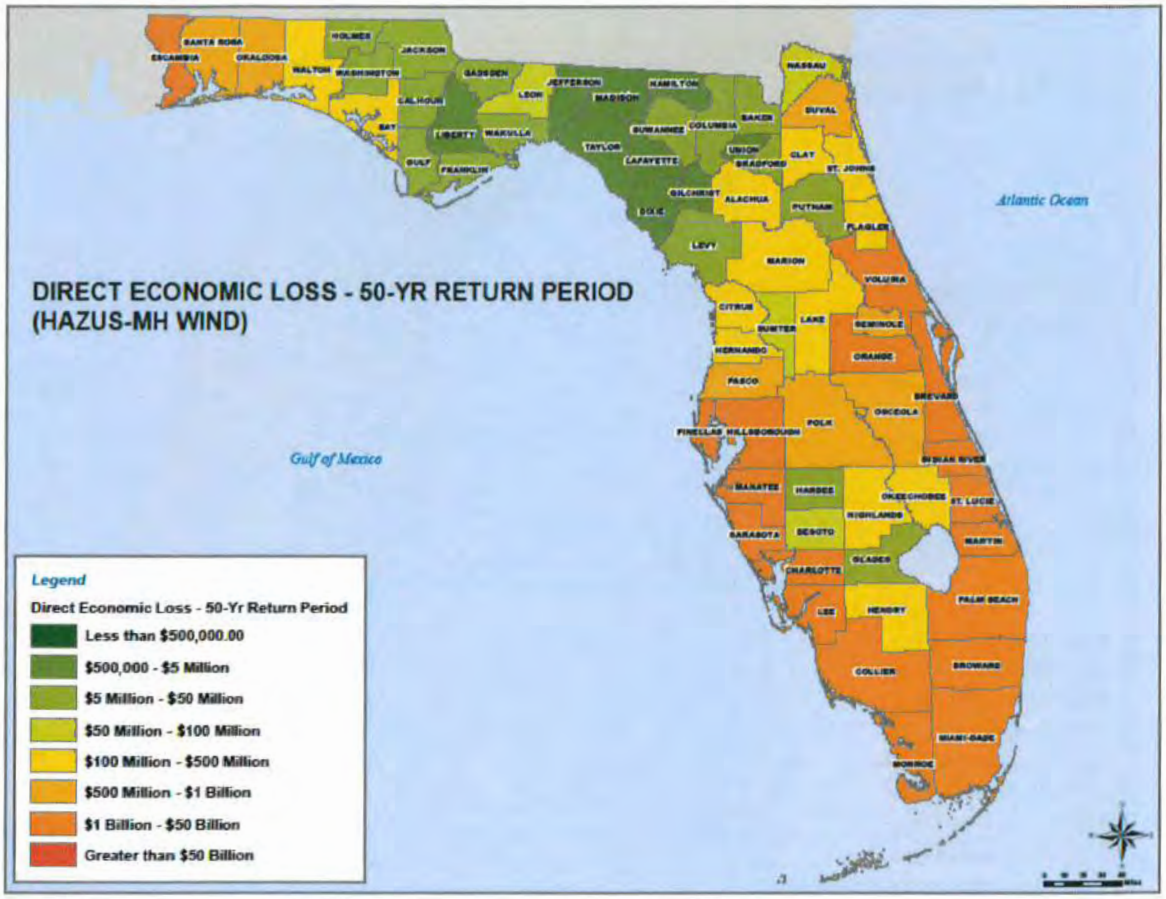
According to the HAZUS-MH data, there are three counties, Palm Beach, Broward, and Miami-Dade, which would sustain between $500 million and $1 billion worth of damage due to tropical storm and Category 1 winds in the 10-year return period (see map above). Most counties in the state would sustain less than $50 million in damages in this return period scenario.

Figure 48: Direct Economic Loss, 20-Year Return Period



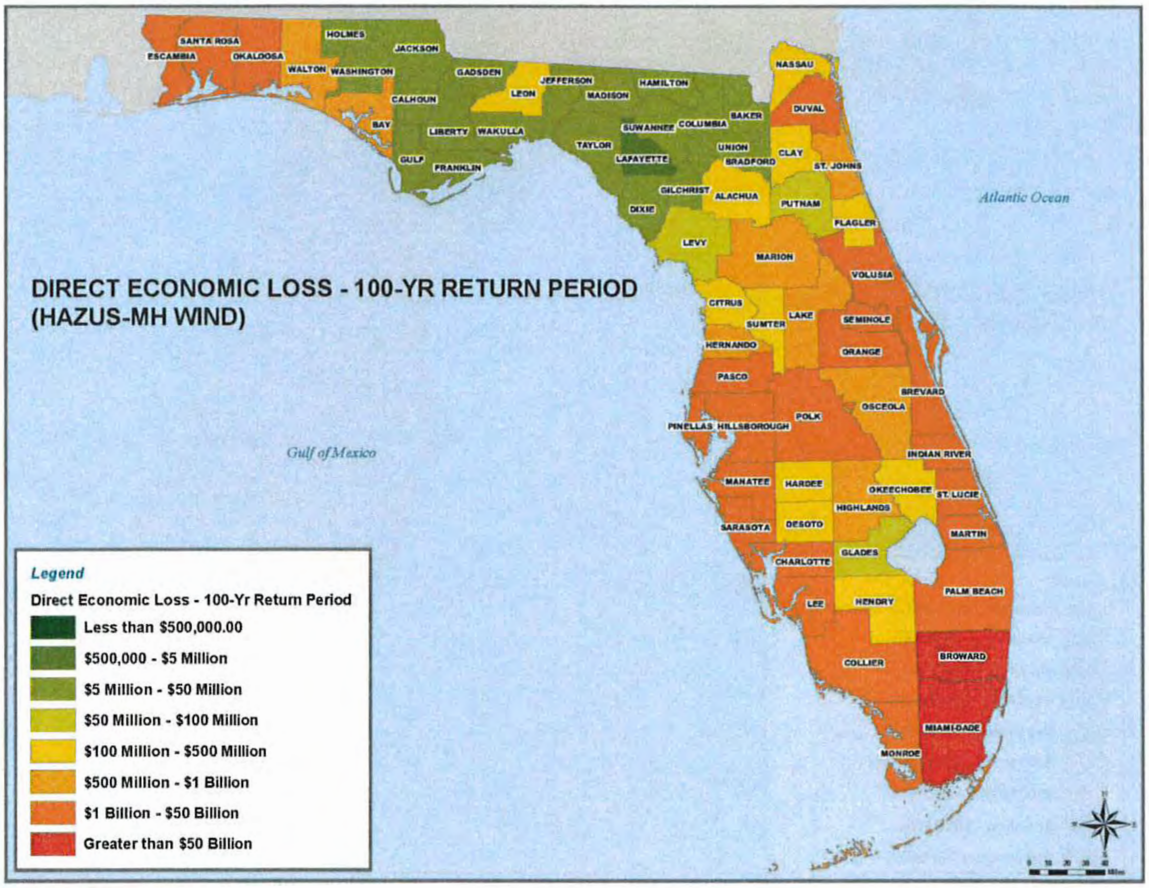
According to HAZUS-MH, there are four counties, Palm Beach, Broward, Miami-Dade, and Lee, which would sustain between $1 billion and $50 billion of damage due to tropical storm and Category 1 and 2 winds, as shown in the probabilistic wind 20-year return period map above. Several more counties would experience higher damage amounts, such as some of the western Florida and central Florida counties that would experience between $100 million and $500 million in damages.

Figure 49: Direct Economic Loss, 50-Year Return Period



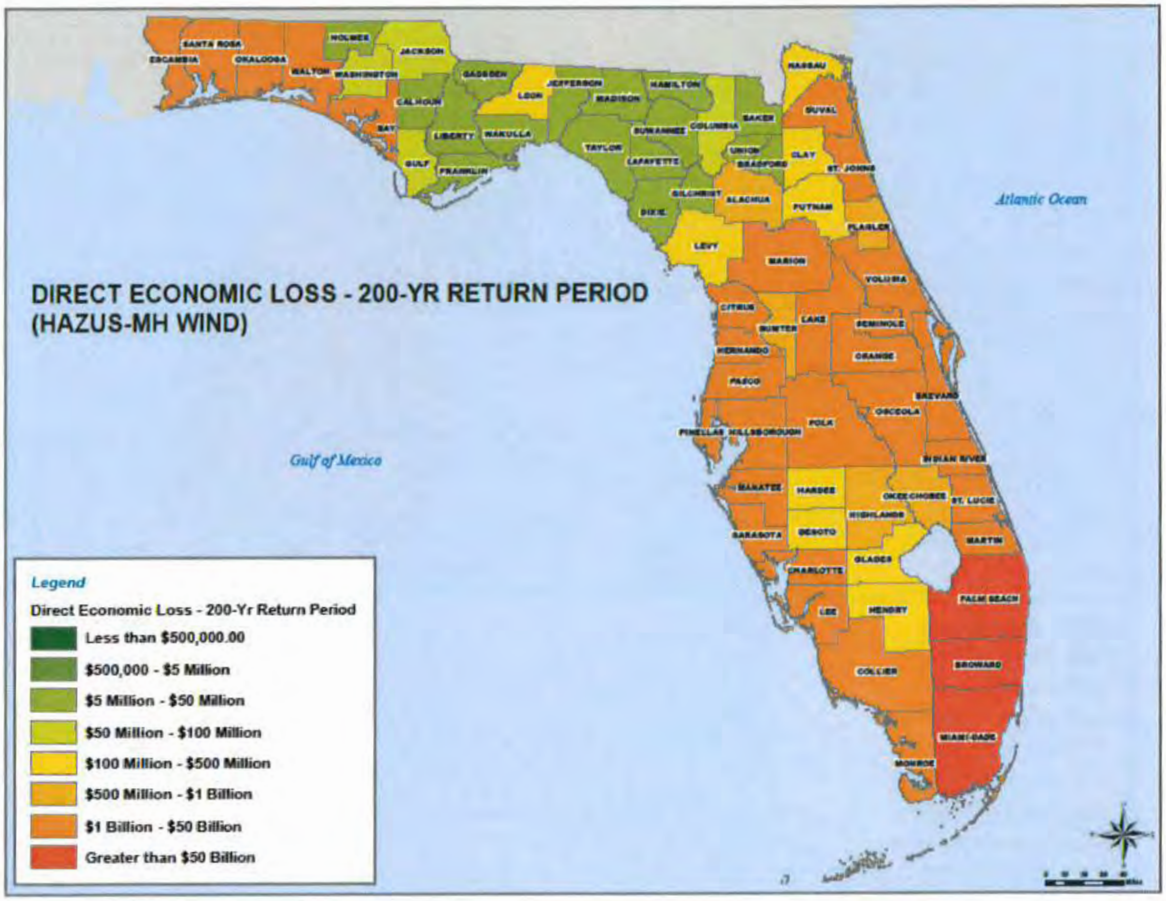
This map shows that in the 50-year return period, with between tropical storm winds and Category 4 winds likely, there would be significantly more damage likely. Most peninsula coastal counties would experience between $1 billion and $50 billion in damages.

Figure 50: Direct Economic Loss, 100-Year Return Period



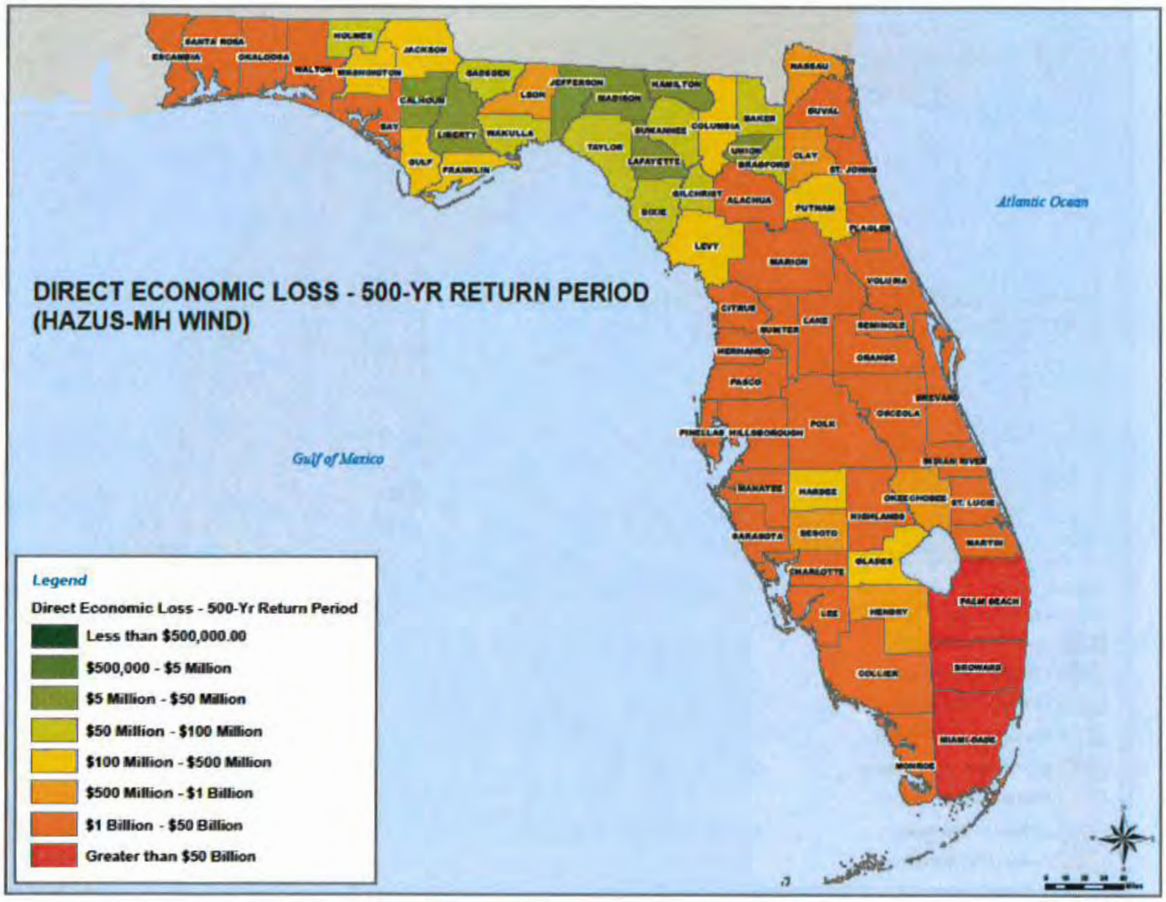
The 100-year return period for probabilistic wind shows that winds between tropical storm and Category 4 would be expected, but stronger winds would affect more areas of the state than in the 50-year return period. This map shows that a significant portion of the state would sustain between $1 billion and $50 billion of damages. Broward and Miami-Dade counties would experience the most damage, over $50 billion.

Figure 51: Direct Economic Loss, 200-Year Return Period



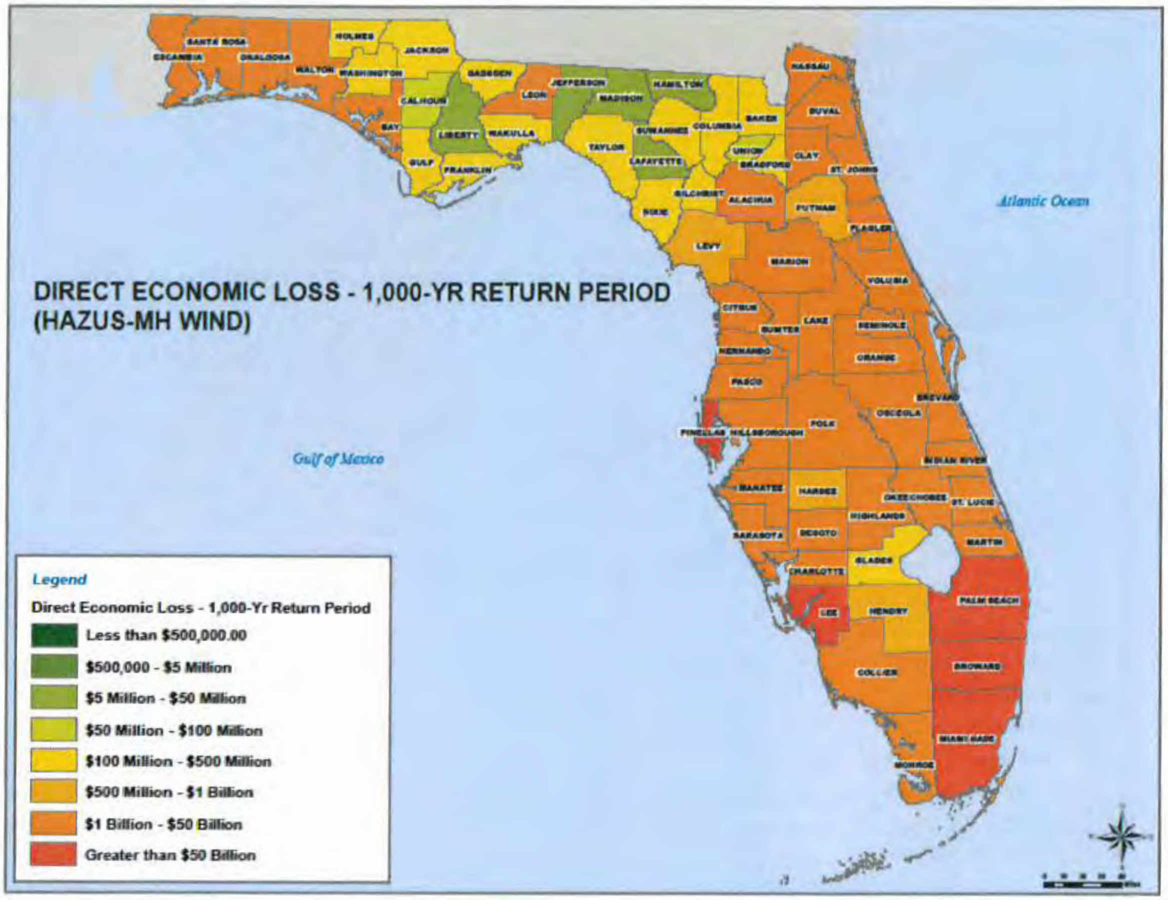
The 200-year return period winds would likely be between Category 1 and Category 5. Again, there is an increase in the number of counties that would sustain between $1 billion and $50 billion in damages and there are three counties, Palm Beach, Broward, and Miami-Dade, that would sustain over $50 billion in damages.

Figure 52: Direct Economic Loss, 500-Year Return Period



More counties would reach between $1 billion and $50 billion in damages due to most of the state experiencing Category 3 and 4 winds in the 500-year return period scenario. Again, Palm Beach, Broward, and Miami-Dade counties would sustain over $50 billion in damages.

Figure 53: Direct Economic Loss, 1000-Year Return Period



In the 1000-year return period, most of the state would experience Category 3 and 4 winds, with portions of coastal south Florida experiencing Category 5 winds. Therefore, most of the state would experience between $1 billion and $50 billion in damages, with Palm Beach, Broward, Miami-Dade, and Lee counties experiencing more than $50 billion in damages.

Data from the NCDC provides details about the historical hurricanes and tropical storms that have affected the state. The table below shows a breakdown of the types of tropical cyclones and associated annualized losses that have occurred in Florida from 2006 to 2016. There is also information in this table about the number of injuries and deaths from tropical cyclones in Florida.