Table 30: Tropical Cyclones Annualized Losses, 2006-2016[64]

Type of Storm	NCDC Reports	Annualized Property Loss
Tropical Storm	14	$6,482,920
Hurricane	7	$214,836,200
Total	21	$221,319,120

According to the NCDC Storm Events Database, the property losses due to hurricanes or tropical storms would be about $2.2 million each year.

Overall, all counties in Florida are vulnerable to at least some damage from tropical cyclones. Urban counties in south Florida are particularly vulnerable to damage from storm surge and hurricane force winds due to high populations, many structures and facilities, and the high probability that a tropical cyclone will impact that area.

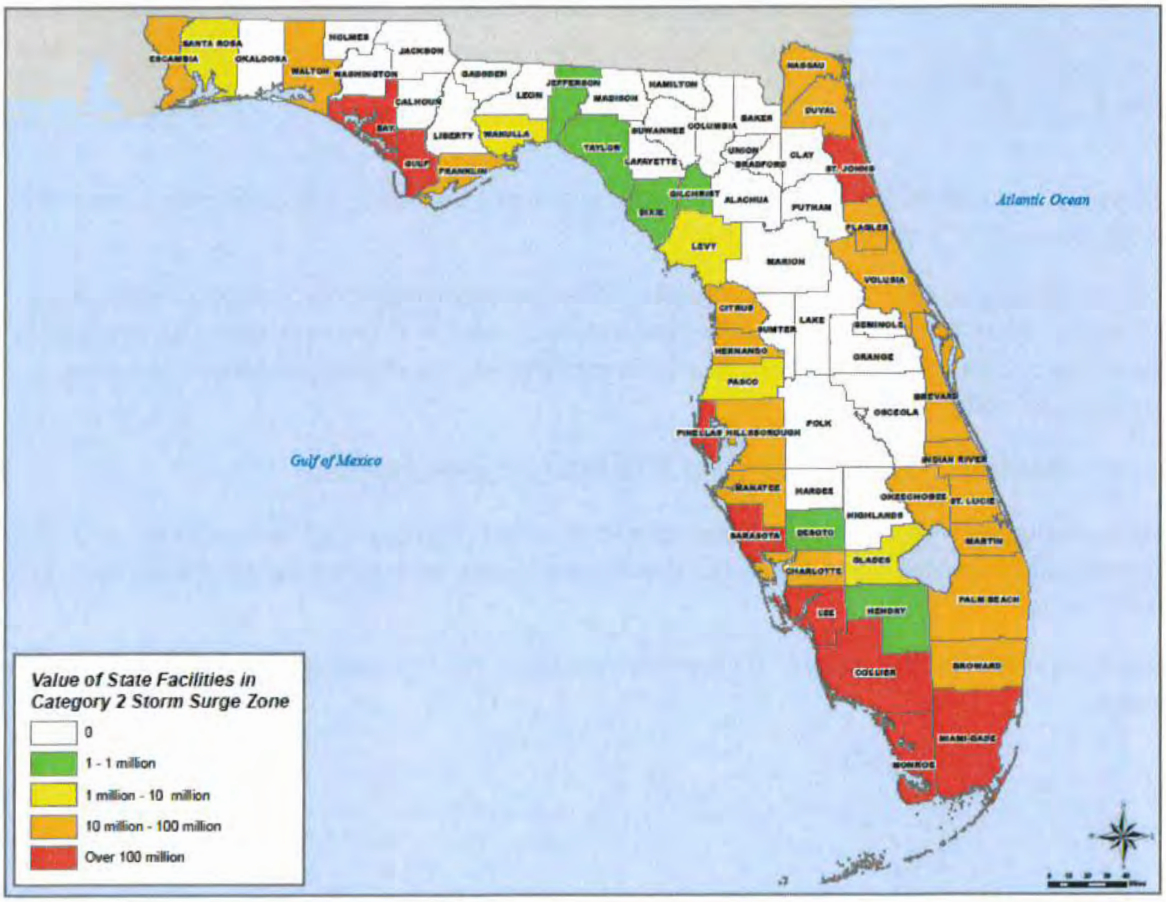
8. Vulnerability Analysis and Loss Estimation, of State Facilities

Since all counties within Florida are vulnerable to the effects of tropical cyclones, all of the 20,231 state-owned facilities and their insured values are vulnerable to potentially damaging storm surge and hurricane force winds.

Below are maps showing value of state-owned facilities at risk to damage from Category 2 and 5 Storm Surge.

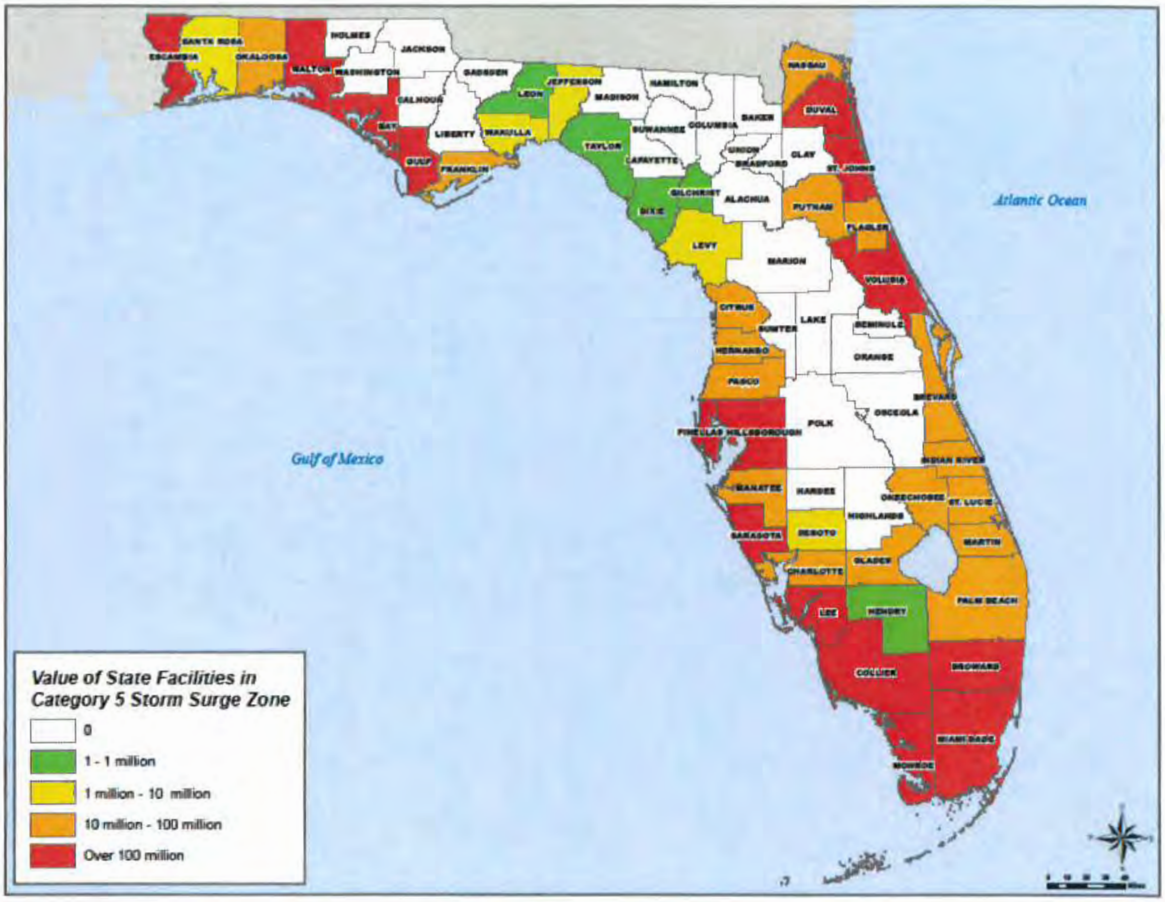
64 https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Hurricane+%28Typhoon%29&eventType=%28Z%29+Tropical+Storm&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2006&endDate_mm=12&endDate_dd=31&endDate_yyyy=2016&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=12%2CFLORIDA

Figure 54: Value of State Facilities in Category 2 Storm Surge Zone



From this map, it is clear to see that south Florida counties, such as Miami-Dade, Monroe, Collier, Lee, Sarasota, and Pinellas and various other counties, namely Bay, Gulf, and St. Johns are estimated to have losses over 100 million dollars due to Category 2 Storm Surge flooding.

Figure 55: Value of State Facilities in Category 5 Storm Surge Zone



This map shows that more counties would have estimated losses over 100 million dollars. These counties include Broward, Miami-Dade, Monroe, Collier, Lee, Sarasota, Pinellas, Hillsborough, Volusia, St. Johns, Duval, Gulf, Bay, Walton, and Escambia.

According to this analysis, $2.2 billion in state-owned facilities are at risk to damage due to Category 2 Storm Surge flooding and $4.9 billion in state-owned facilities are at risk to damage due to Category 5 Storm Surge flooding.

While all state facilities are vulnerable to tropical cyclones, it is clear that there are coastal counties with significant numbers and values of state facilities within category 2 and 5 storm surge zones.

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 13.

<table>
<tr><th colspan="5">TROPICAL CYCLONE</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">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. These storms have been known to transform into tropical storms and even hurricanes. Florida is at risk of experiencing a tropical cyclone due to its tropical climate and vicinity to large bodies of water. There are chances of the effects reaching all parts of the state but, due to high levels of development and concentrated numbers of civilians, the coastlines are vulnerable to greater impacts</td><td rowspan="4">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>Likely</td><td>Likely</td><td>High</td><td>High</td><td>High</td></tr>
</table>

Severe Storm Hazard Profile

1. Severe Storms Description

In this profile, Severe Storms refers to thunderstorms.

Florida is considered the thunderstorm capital of the United States. A thunderstorm forms when moist, unstable air is lifted vertically into the atmosphere. The lifting of this air results in condensation and the release of latent heat. The process to initiate vertical lifting can be caused by:

- Unequal warming of the surface of the Earth;
- Orographic lifting due to topographic obstruction of airflow; or
- Dynamic lifting because of the presence of a frontal zone.

A typical thunderstorm is 15 miles in diameter and lasts an average of 30 minutes. Despite their small size, all thunderstorms are dangerous. Of the estimated 100,000 thunderstorms that occur each year in the United States, about 10 percent are classified as severe.

The three key elements of a thunderstorm are wind, water, and lightning. The National Weather Service (NWS) considers a thunderstorm severe if it produces hail at least one inch in diameter, winds of 58 mph or stronger, or a tornado.

Thunderstorms also vary in type, depending on size and organization. Below are the different types of thunderstorms:[65]

- Ordinary cell thunderstorms only have one cell. These storms may also be referred to as single cell thunderstorms or pulse thunderstorms.
- Multi-cell cluster thunderstorms are organized in clusters of two to four short lived cells.
- Multi-cell line thunderstorms form in a line that extends, sometimes for hundreds of miles and can persist for hours. These are called squall lines and they can be continuous or include contiguous precipitation.
  - Long-lived squall lines are called derechos and can cause severe damage with fast straight line winds.
- Supercell thunderstorms are very dangerous storms with long-lived strong tornadoes and damaging wind, hail, and flash floods.

Lightning

Lightning is a rapid discharge of electricity in the atmosphere between clouds, the air, or the ground. Thunder is the sound of this rapid discharge and can be heard up to 25 miles away. Lightning tends to

[65] http://climatecenter.fsu.edu/topics/thunderstorms

strike tall objects such as trees, but can also strike in an open field. Thunderstorms always include lightning because lightning is what causes the sound of thunder.[66]

Flash Floods

Flash floods are caused by intense large amount of rainfall in a short period. Because of this, flash floods often occur during slow moving thunderstorms. Other factors, such as the topography of the area, the soil conditions, and the ground cover can also affect flash flooding. For example, if the ground is already waterlogged, new rainfall cannot filter into the ground and has no place to go, causing a flood.

As stated in the Flood Hazard Profile, flash flooding is a significant concern because of the rapid onset, the high water velocity, the debris load, and the potential for channel scour. In addition, more than one flood crest may result from a series of fast moving storms. Sudden destruction of structures and the washout of access routes may result in the loss of life. Furthermore, the rapid urbanization within the state of Florida has manifested itself in the form of increased impervious surface areas which leads to less natural drainage and more flash flooding.

Hail

Hail is frozen precipitation that can occur during a thunderstorm. Hail forms when raindrops freeze into balls of ice and usually range in size from 1/4 inch in diameter to 4 1/2 inches in diameter. Damage from hail increases with the size of the hail and can cause damage to vehicles, aircraft, and homes, and can be fatal to people and livestock. However, Florida thunderstorms do not often include hail because the hailstones usually melt before they reach the ground because of the generally warm temperatures in the state.[67]

Straight-line winds

Severe Storms often include strong winds that are called "straight-line" winds and are different than the winds in tornadoes. These damaging winds exceed 50-60 mph and can reach up to 100 mph. Damage from these winds is more common than damage form tornadoes in the continental US. Straight line winds form as a result of outflow from a thunderstorm downdraft.[68]

Tornadoes

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. Tornado wind speed normally ranges from 65 mph to over 200 mph. The maximum winds in tornadoes are often confined to extremely small areas and vary tremendously over very short distances, even within the funnel itself. Additionally, these storms typically travel around 10 to 20 mph, but can move at more than 60 mph. Tornadoes can occur at any time of the year and at any time of day.

[66] http://www.nssl.noaa.gov/education/svrwx101/lightning/
[67] http://www.nssl.noaa.gov/education/svrwx101/hail/
[68] http://www.nssl.noaa.gov/education/svrwx101/wind/

Tornadoes develop under three scenarios: (1) along or ahead of a squall line ahead of an advancing cold front moving from the north; (2) in connection with thunderstorm squall lines during hot, humid weather; and (3) within a tropical cyclone.

The most common, and often the most dangerous, tornadoes come from a supercell thunderstorm. Non-supercell tornadoes form because of spinning air already near the ground, caused by wind shear. These include a gustnado, a whirl of debris with no condensation funnel; a landspout, a narrow condensation funnel that develops while the thunderstorm is still growing; and a waterspout, a landspout that occurs over water.

Florida has two tornado seasons, the spring and summer. The deadly spring season is from February through April, and is characterized by powerful tornadoes associated with squall lines. The summer tornado season runs from June until September and has the highest frequencies of storm generation, with usual intensities of EF0 or EF1 on the Enhanced Fujita Scale. This includes those tornadoes associated with land-falling tropical cyclones.

Tornadoes are measured by their intensity or their wind speed, and their area, using the Enhanced Fujita (EF) Scale. The scale ranges from EF 0, with minor damages from winds ranging 65-85 mph, to EF 5 with severe damages from winds in excess of 200 mph.

Table 31: Enhanced Fujita Scale[69]

EF Number	Estimated 3-second gust (mph)	Typical Damage
0 (Gale)	65-85	Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; damaged sign boards.
1 (Weak)	86-110	Surfaces peeled off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads.
2 (Strong)	111-135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
3 (Severe)	136-165	Roof and some walls torn off well constructed houses; trains overturned; most trees in forests uprooted Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
4 (Devastating)	166-200	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
5 (Incredible)	200+	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.

[69] http://climatecenter.fsu.edu/topics/tornadoes

Advisories

Below are the advisories that the NWS issues regarding flooding hazards:

- Severe Thunderstorm Watch: issued when conditions are favorable for severe thunderstorms to develop.
- Severe Thunderstorm Warning: issued when severe thunderstorms are occurring or are imminent.
- Tornado Watch: issued when conditions are favorable for severe thunderstorms and tornadoes to develop.
- Tornado Warning: issued when a tornado is sighted or imminent.
- Flash Flood Watch: issued when conditions are favorable for a specific hazardous weather event, including flooding, to occur, meaning flooding is possible.
- Flash Flood Warning: issued when a flash flood is imminent or occurring, referring to a sudden violent flood that can take minutes to hours to develop. It is even possible to experience a flash flood in areas not receiving rain.

Causes of Fatalities

All aspects of Severe Storms are life-threatening. NOAA tracks weather related fatalities and lighting itself contributes to the most deaths from thunderstorms in Florida. Other causes include flooding, tornadoes, and winds.[70]

Frequency

This hazard was determined to occur annually, giving it a Frequency ranking of Very Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be High, meaning any deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Medium, meaning significant damage to property occurs.

This hazards *Environment* Magnitude was determined to be Low, meaning little to no damage to the environment occurs.

Potential Effects of Climate Change on Severe Storms and Tornadoes

Higher temperatures and humidity may increase atmospheric instability associated with the generation of severe thunderstorms and tornadoes. However, vertical wind shear could also decrease, resulting in fewer or weaker severe thunderstorms and tornadoes.[71] However, decreases in vertical wind shear are

[70] http://www.nws.noaa.gov/om/hazstats.shtml#

[71] 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.

most likely to occur when convective available potential energy (CAPE) is high in spring and summer months, which could result in more frequent severe storms. Furthermore, days with high CAPE are also likely to occur during times of the year with strong low-level wind shear, increasing the likelihood of the most severe storm events, including tornadoes.[72]

There has been an increase in the number of severe storm and tornado reports over the last 50 years. However, it is believed that this increase is attributed to the technology improvements that allow for better identification and reporting of such storms.

2. Geographic Areas Affected by Severe Storms

Severe Thunderstorms and Tornadoes can occur anywhere throughout the entire state. As the number of structures and the population increases, the probability that a severe storm or tornado will cause property damage or human casualties also increases. Florida experiences more thunderstorms each year than any other state in the US.

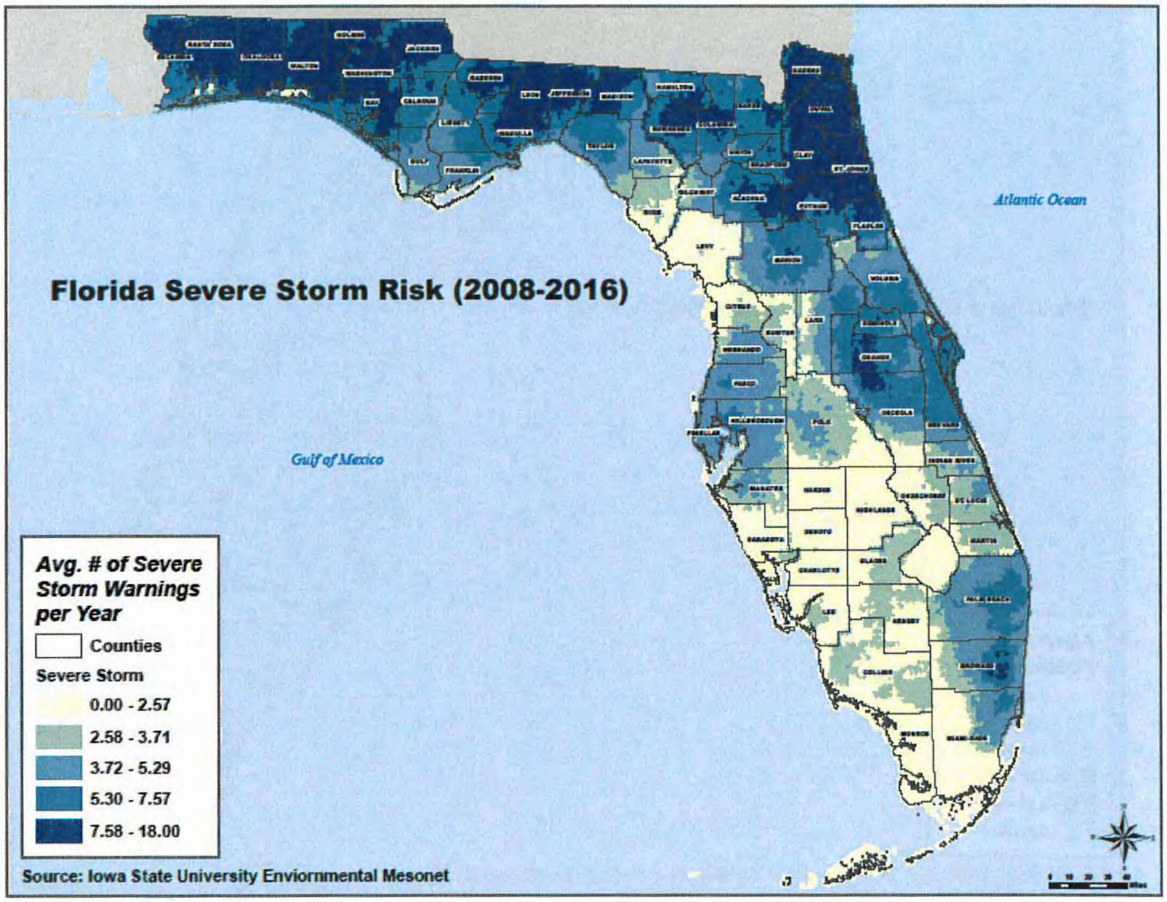
Severe Storm Risk

Below is a depiction of the Severe Storm Risk in Florida, based on the average number of severe storms from 2008 to 2016.

159. https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf., pp. 151-155; National Oceanic and Atmospheric Administration (NOAA) (2013). *Tornadoes, climate variability, and climate change. State of the science fact sheet.* http://nrc.noaa.gov/sites/nrc/Documents/SoS%20Fact%20Sheets/SoS_%20Fact_Sheet_Tornado%20and%20Climate_FINAL_Sept2017.pdf?ver=2017-12-05-115742-360., pp. 1-2. Diffenbaugh, et al. (2013). *Robust increases in severe thunderstorm environments in response to greenhouse forcing.* Proceedings of National Academy of Sciences. doi/10.1073/pnas. 1307758110., http://www.pnas.org/content/110/41/16361.full.

[72] Diffenbaugh et al. (2013), http://www.pnas.org/content/110/41/16361.full., p. 1.

Figure 56: Florida Severe Storm Risk, 2008 – 2016



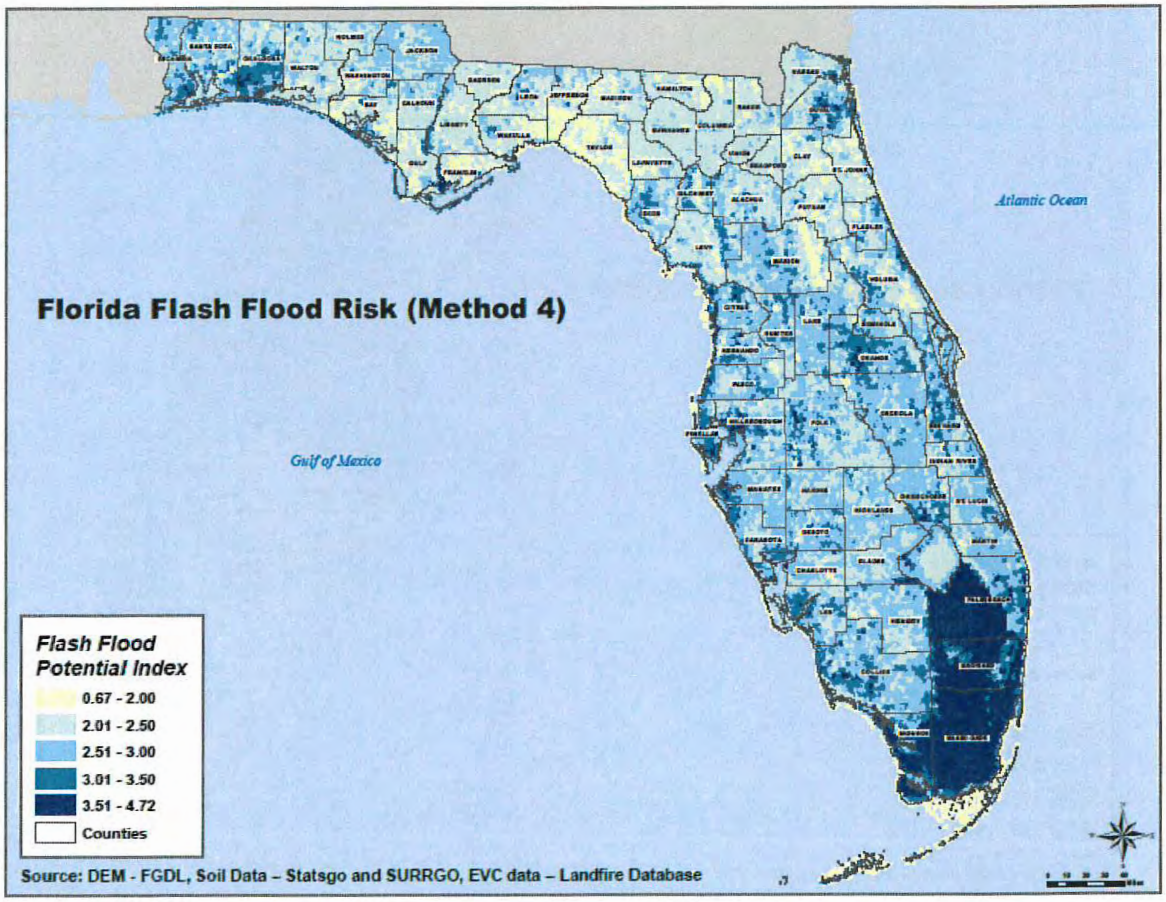
According to the data, north Florida, as well as portions of the state near Orlando and Fort Lauderdale are expected to have between 7.58 and 18 severe storm warnings per year.

Flash Flood

Below is a map depicting the potential for flash flooding to occur.

The map uses an equation called "Method 4" which is (2*M+S+2*LV)/5 where M=Slope, L=land cover/use, S=soil type/texture, and V=vegetation cover/forest density.

Figure 57: Florida Flash Flood Risk

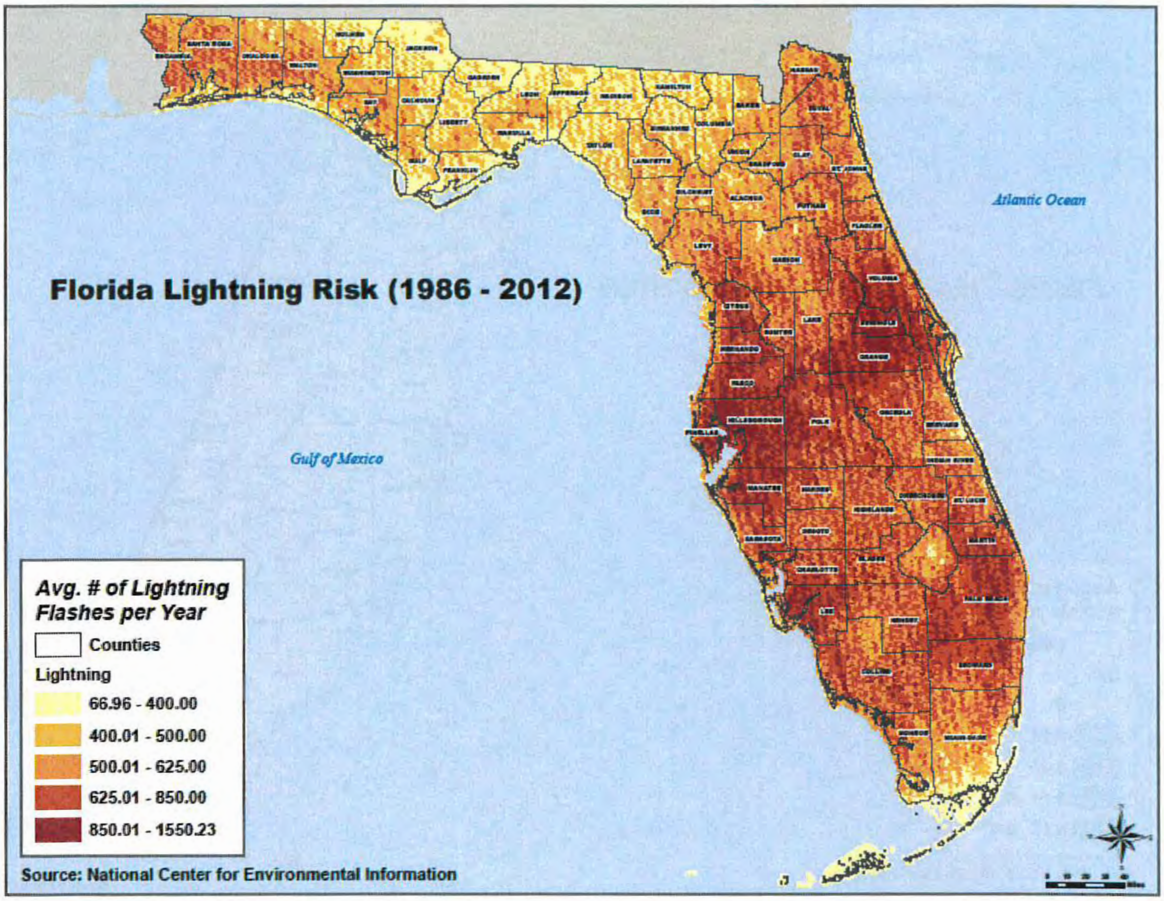


The map shows that most of the state has between 2.01 and 3.50 potential of occurring.

Lightning

Below is a map depicting the average number of lightning flashes per year, based on historical data from 1986 to 2012.

Figure 58: Florida Lightning Risk, 1986 – 2012

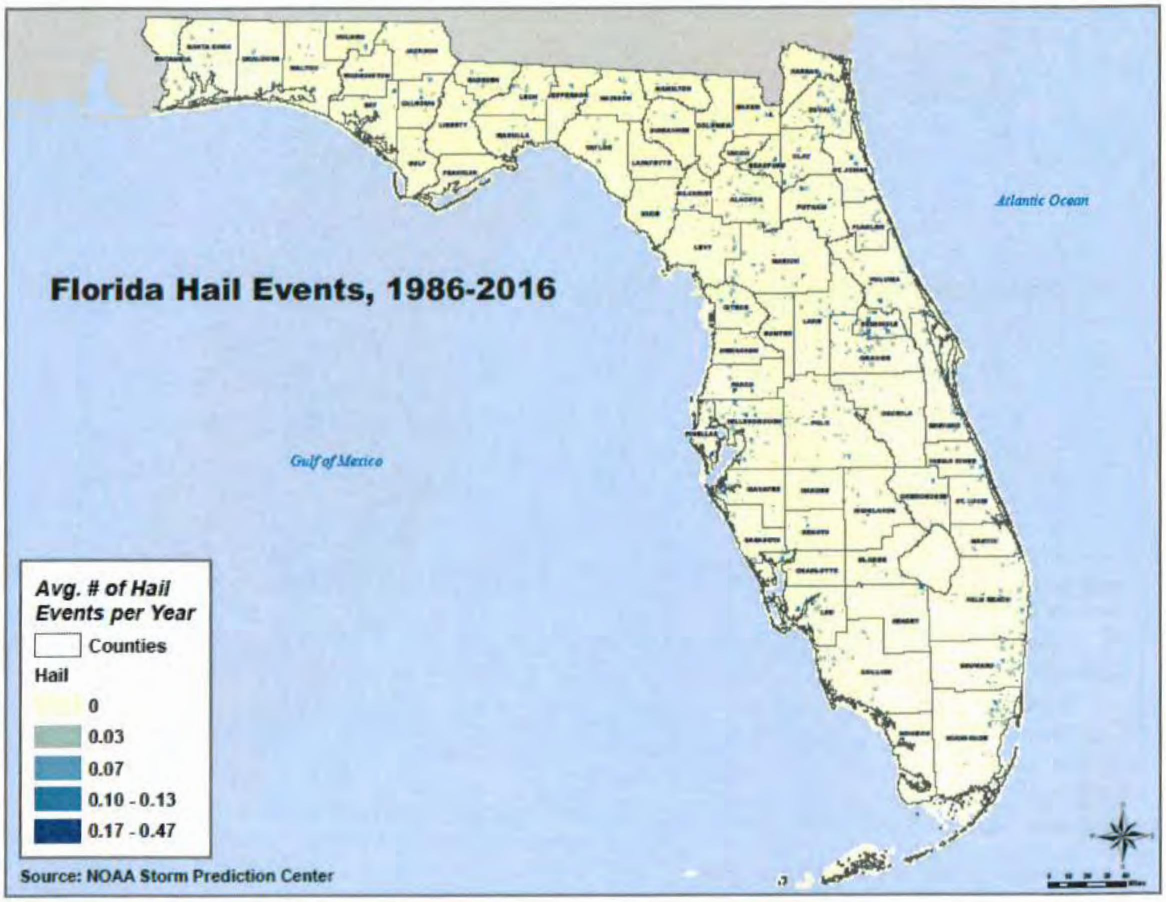


According to the data, central and southern Florida are expected to have between 850 and 1550 lightning flashes per year.

Hail

The map below shows the average number of hail events in Florida, based on historical data from 1986 to 2016.

Figure 59: Florida Hail Events, 1986 – 2016

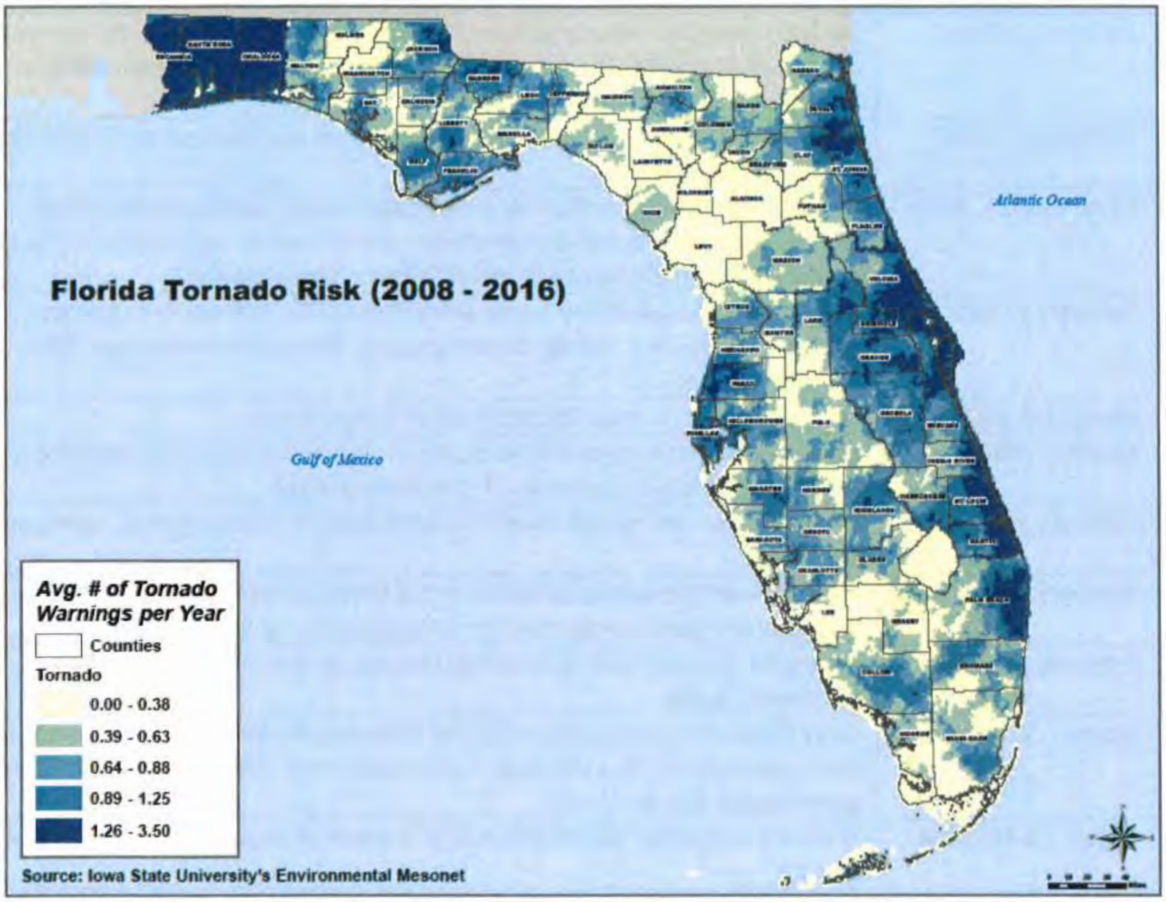


According to the data, hail events are not particularly common. In fact, the highest average number of hail events per year is less than 0.5.

Tornado

Below is a map depicting the average number of tornadoes per year based on historical occurrences of tornadoes from 2008 to 2016.

Figure 60: Florida Tornado Risk, 2008 – 2016



According to the data, the three counties furthest west, Escambia, Santa Rosa, and Okaloosa counties, have a risk of 1 to 3.5 tornado warnings each year. Additionally the east coast of the state is likely to have 1 to 3 tornado warnings each year.

Furthermore, when compared with other states, Florida ranks third in the US for average number of tornado events per year. These rankings are based upon data collected for all states and territories for tornado events between the years 1991 and 2010.[73]

3. Historical Occurrences of Severe Storms

The 2013 update used information from the NCDC storm event database. The database was not used for this update because the filters were for instances of hail, lightning, and high wind, it did not list events that were simply thunderstorms or tornadoes. NWS local data was used to compile a list of previous occurrences of severe storms and tornadoes in Florida.

[73] http://www.srh.noaa.gov/jetstream/tstorms/tornado.html).

Table 32: Florida Historical Occurrences, Severe Storms [74] [75] [76]

Date	Description
January 13, 2006	Several tornadoes developed from supercells that evolved from the remnants of a squall line across the southeastern states, with about a dozen students injured at a damaged school in Santa Rosa County.
October 27, 2006	A waterspout from a thunderstorm came ashore and became an EF 1 tornado in the Apalachicola area.
December 25, 2006	A squall line over the eastern Gulf of Mexico moved rapidly eastward into Florida, spawning severe thunderstorms and tornadoes across Central Florida during the late night and early morning hours Christmas Day.
February 2, 2007	Four tornadoes and severe winds across Central Florida results in twenty-one fatalities, 76 injuries, and significant property damage including over 2,000 damaged homes.
March 1-2, 2007	Several thunderstorms affected much of North Florida.
April 15, 2007	Severe thunderstorms caused widespread tree and property damage across Northeast Florida, including an EF-2 tornado in Baker.
February 13, 2008	Severe storms and tornadoes across South Florida damaged trees, boats, and aircrafts.
February 17-18, 2008	Supercells and tornadoes ahead of a cold front produced widespread damage and several injuries across the Florida Panhandle and Big Bend regions.
February 26, 2008	Severe storms produced widespread tree and power line damage across Northeast Florida.
March 7, 2008	A squall line tracked across the Gulf of Mexico and emerged in northern Florida, with supercells forming within it. Two people were killed and about 50 homes were damaged or destroyed.
August 19-22, 2008	At least 8 tornadoes affected Florida as a result of Tropical Storm Fay making landfall.
Late March to early April 2009	A series of severe thunderstorms, with hail, straight line winds, and record rainfall, affected the Panhandle and the Big Bend regions.
June 29, 2009	Severe storms across the Florida Big Bend region caused power outages and severe damage from falling trees.
January 21-22, 2010	Severe storms and a few weak tornadoes caused widespread tree and property damage in Northeast and East Central Florida.
January 25, 2011	Strong straight lines winds along a squall line produce numerous reports of trees and power lines down, along with minor roof damage across western Central Florida.
March 9, 2011	Over 20 structures were damaged in the western Panhandle associated with a tornado and straight lines winds.
March 31, 2011	Approximately 70 people were trapped in a collapsed building at the Sun 'n' Fun Aviation Fair in Lakeland due to severe winds.

[74] http://www.weather.gov/mob/events
[75] http://www.weather.gov/tae/events
[76] http://www.weather.gov/mfl/events_index

April 5, 2011	A squall line produced widespread tree damage and power outages across North Florida with over a dozen homes with minor damage.
June 23-24, 2012	Several tornadoes across south Florida, which stemmed from Tropical Storm Debby.
April 28 – May 6, 2014	Many severe storms, tornadoes, straight line winds, and flooding caused significant damage across the Panhandle.
October 14, 2014	Several tornadoes and thunderstorm winds along a squall line produced tree and roof damage in the Panhandle and Big Bend regions.
November 17, 2014	A severe weather outbreak took place during the morning hours mainly across the Florida Panhandle and Southwest Georgia. An EF-2 tornado damaged a correctional institute, flipped vehicles, and damaged buildings. Other weak tornadoes damaged mobile homes and sheds. Winds also caused damage across adjacent areas of Northern and Central Florida that afternoon.
April 19-20, 2015	A squall line produced tree damage across North Florida over a two day period. An EF-1 tornado in Marion County damaged 55 homes, 10 of which were uninhabitable. Two additional EF-1 tornadoes were also confirmed in Jackson and Leon counties with tree and home damage.
January 17, 2016	Tornado and straight line wind damage affected South Florida with structural damage.
January 22, 2016	Severe winds caused damage to trees and outdoor furniture, barns, and sheds in the western Panhandle.
February 2, 2016	Severe storms, including an EF 3 tornado, affected Escambia County.
February 16, 2016	Severe winds and tornadoes caused damage to mobile homes, roofs, sheds, pool screens, and outdoor furniture across South Florida.
February 24, 2016	Tornadoes in the western Panhandle caused significant structural damage.
May 17, 2016	Four tornadoes caused damage to warehouses, homes, trees, and mobile homes in St. Lucie and Indian River counties.

There have been 19 major disaster declarations from FEMA for severe storms and tornadoes in Florida.

Table 33: FEMA Major Disaster Declarations in Florida, Severe Storms and Tornadoes[77]

Date	Description
March 23, 1960	DR-97: Severe Weather
May 26, 1973	DR-387: Severe Storms, Flooding
September 26, 1975	DR-484: High Winds, Heavy Rains, Flooding
May 15, 1979	DR-586: Severe Storms, Tornadoes, Flooding
September 29, 1979	DR-607: Severe Storms, Flooding
July 7, 1982	DR-664: Severe Storms, Flooding
March 16 – April 9, 1990	DR-862: Flooding, Severe Storm
June 23 – 30, 1992	DR-952: Flooding, Severe Storm

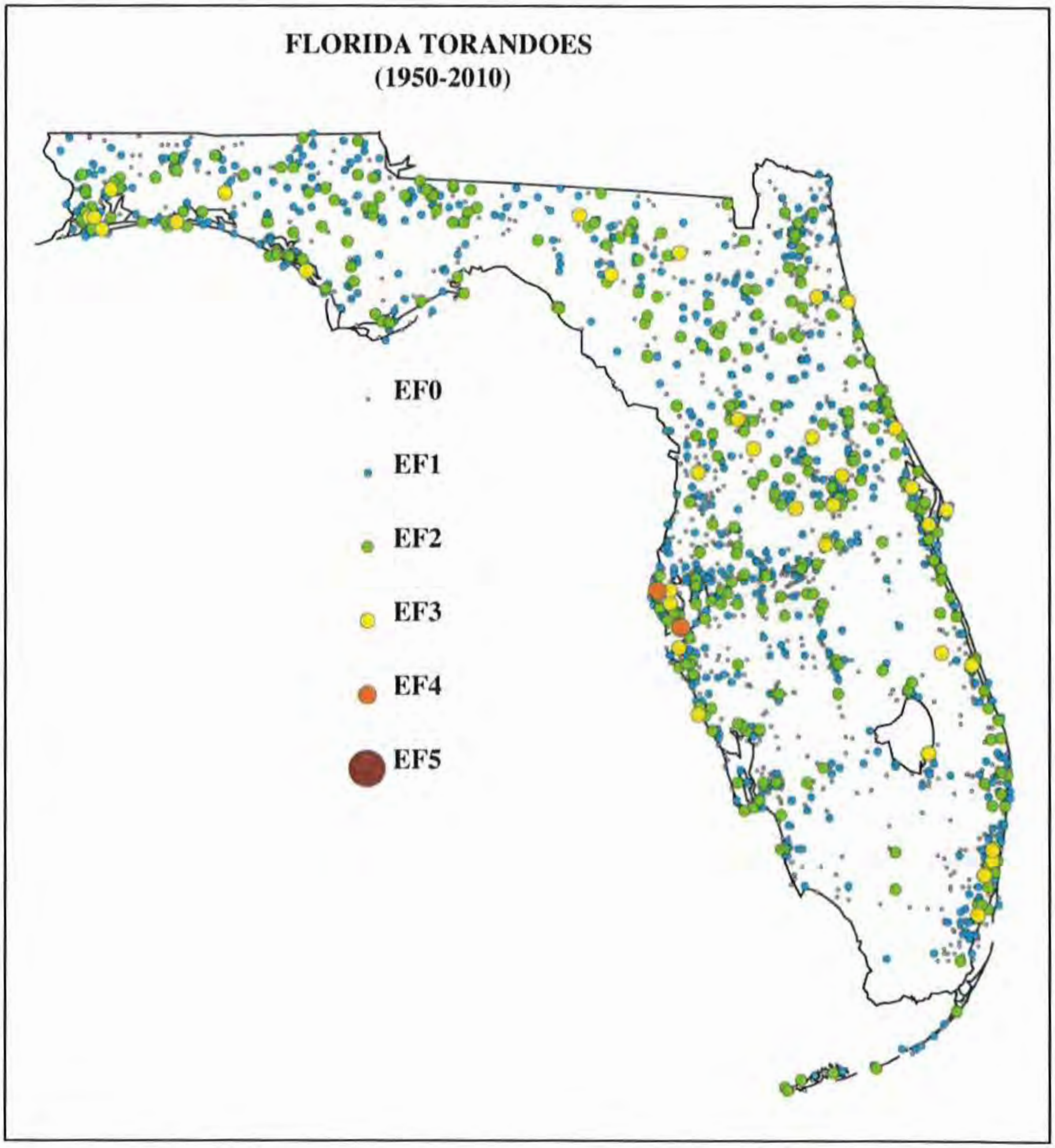
77 https://www.fema.gov/disasters?field_state_tid_selective=47&field_disaster_type_term_tid=7697&field_disaster_declaration_type_value=All&items_per_page=20

October 3 – 4, 1992	DR-1035: Flooding, Severe Storm, Tropical Storm Alberto
October 13 – November 20, 1995	DR-1074: Severe Storm, Flooding
October 7 – 21, 1996	DR-1141: Severe Storms/Flooding
February 2 – 4, 1998	DR-1204: Severe Thunderstorms, Tornadoes, and Flooding
October 3 – 11, 2000	DR-1345: Heavy Rains and Flooding
June 13 – August 22, 2003	DR-1481: Severe Storms and Flooding
February 1 – 2, 2007	DR-1680: Severe Storms and Tornadoes
March 26 – May 5, 2009	DR-1831: Severe Storms, Flooding, Tornadoes, and Straight-line Winds
May 17 – 28, 2009	DR-1840: Severe Storms, Flooding, Tornadoes, and Straight-line Winds
July 2 – 7, 2013	DR-4138: Severe Storms and Flooding
April 28 – May 6, 2014	DR-4177: Severe Storms, Tornadoes, Straight-line Winds, and Flooding

Below is a map showing the occurrences of tornadoes and their EF number in Florida from 1950 until 2010.[78]

[78] Information was available only through 2010.

Figure 61: Florida Tornadoes, 1950 – 2010



From this map, it is possible to understand that lower strength tornadoes, EF-0 through EF-2, are common across the state, while stronger tornadoes like EF-3 and EF-4 are uncommon, but have occurred. According to this data, there has not been an EF-5 tornado in Florida from 1950 to 2010.

While Severe Storms may seem to be lesser threat to life safety than a hurricane, Severe Storms can be fatal. From 2006 to 2016, Severe Storms killed 106 people; 56 people died from lightning strikes, 29 people died from a tornado, 13 people died from wind, and 6 people died from flooding.[79] (It is important to note that the flooding and wind related fatalities could have been from other storms, not only thunderstorms.)

Table 34: Severe Storm Fatalities, Florida, 2006 – 2016[80]

Year	Fatalities by Cause
2006	Lightning: 5
2007	Lightning: 11 Tornado: 21
2008	Lightning: 4 Tornado: 1
2009	Lightning: 5 Wind: 4 Flood: 2
2010	Lightning: 1
2011	Lightning: 1 Wind: 1
2012	Lightning: 5 Tornado: 1 Wind: 2 Flood: 1
2013	Lightning: 4 Tornado: 4 Wind: 1
2014	Lightning: 6 Wind: 1 Flood: 3
2015	Lightning: 5 Wind: 3
2016	Lightning: 9 Tornado: 2 Wind: 1

4. Probability of Future Occurrences of Severe Storms

Based on historical analysis, severe storms and tornadoes will continue to effect Florida. Most of Florida has an average of 80 thunderstorm days each year, with western Florida experiencing an average of 100 each year.[81]

[79] Note that the flooding and wind related fatalities could have been the result of other types of severe weather, such as hurricanes.

[80] http://www.nws.noaa.gov/om/hazstats.shtml#

[81] http://climatecenter.fsu.edu/topics/thunderstorms

The maps in the geographic areas affected section will be referenced here regarding probability of events across the state.

Severe Storms are highly likely in Florida, particularly in the Panhandle, northern, central, and southeast regions of the state. About half the state is likely to have approximately 3 to 18 severe storm warnings each year.

The entire state is likely to experience between approximately 67 and 1550 lightning flashes per year, with central and southern Florida likely to experience the most lightning flashes each year.

The state of Florida is not particularly likely to experience hail events, according to the average (probability) based on historical occurrences.

Tornado

Western Florida and the east coast of the state are likely to experience 1 to 3.5 tornado warnings each year. The central Panhandle region and the Tampa Bay region of Florida are likely to experience at least 1 tornado warning each year. The remaining areas of the state have an average, or probability, or less than 1 warning per year, which means that every few years, those areas are likely to experience a tornado warning.

Furthermore, as shown in the historical occurrences section, most tornadoes in Florida are likely to be of smaller strength, usually between an EF-0 and an EF-2. Additionally, tornadoes are most likely in Florida in the spring and between 4pm and 9pm.

Flash Flood

The map above explains that while most of the state has a Flash Flood Potential Index between 2.01 and 3.50, there are portions of south Florida, mostly near the Everglades, as well as a few other locations around urban coastal areas that have the highest potential index, between 3.51 and 4.72.

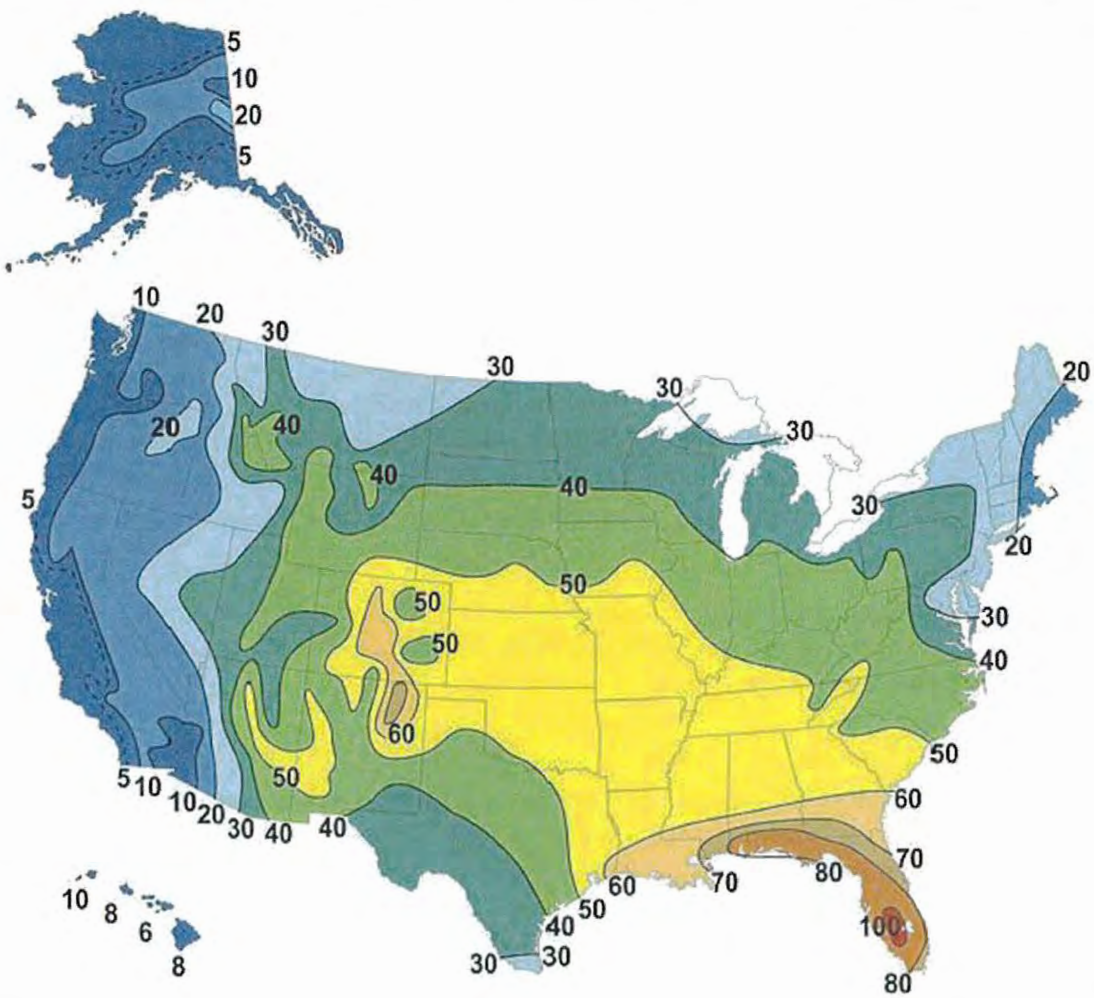
The map below shows the average number of thunderstorm days across the US. Not all storms are severe and any storm that contains thunder, regardless of frequency is classified as a thunderstorm. Given this, it can be impossible to count the number of actual thunderstorms, so the number of days with thunderstorms is counted instead.

Florida being first in the United States for lightning strikes per square mile.[82]

This hazard was determined to occur annually, giving it a Probability of Very Likely.

[82] http://www.nssl.noaa.gov/education/svrwx101/thunderstorms/

Figure 62: Average Number of Thunderstorm Days, United States[83]



5. Severe Storm Impact Analysis

- Public
  - Injury or death from being struck by lightning
  - Injury or death from hail
  - Injury or death from flying debris
  - Injury or death from tornadoes and not having adequate shelter
  - Car accident

[83] http://www.srh.noaa.gov/jetstream/tstorms/tstorms_intro.html

  - Indirect death
  - Survivors guilt if their house wasn't damaged from a severe storm or tornado and many neighbors died
- Responders
  - Responding during a severe storm can be very dangerous because of heavy rains, strong winds, hail, lightning, tornadoes
- Continuity of Operations (including continued delivery of services)
  - Thunderstorms often cause power outages from wind damage to power lines or lightning damage to power stations or other electrical infrastructure
- Property, Facilities, Infrastructure
  - Damage to property, including homes and businesses can occur from strong winds, flooding, or tornadoes. The damage can range from minor roof damage to total structure loss.
  - Damage to critical facilities, such as transformer stations, etc. from fallen trees and limbs, causing a power outage
- Environment
  - Damage to environment, from strong winds, flooding, and tornadoes
  - There may be severe damage to vegetation in localized areas from a tornado
- Economic Condition
  - Power outages cause lost revenue and lost wages for businesses and employees
- Public Confidence in the Jurisdiction's Governance
  - Power outages for extended periods give the appearance that the jurisdiction does not know how to restore power

6. 2018 LMS Integration

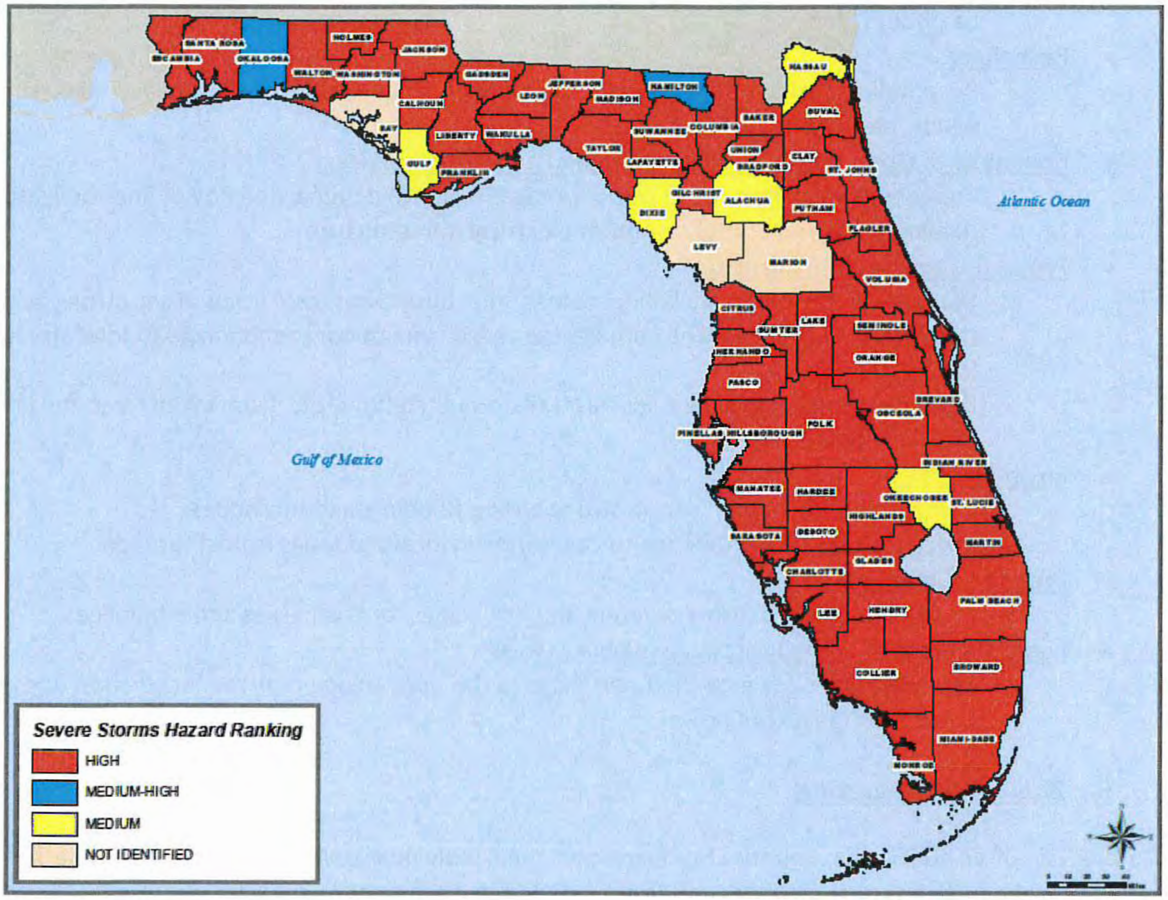
An analysis of all 67 Florida County LMS Plans and their individual severe storm and tornado hazard rankings is shown below. Only three counties did not identify Severe Storms as a Hazard and two counties did not identify Tornadoes as a Hazard.

Severe Storms

Based on the LMS plans, Figure 3.38 displays the jurisdictional rankings for the severe storms hazard. Not all counties have identified severe storms as one of their hazards.

- High-risk Jurisdictions: 57
- Medium-High-risk Jurisdictions: 2
- Medium-risk Jurisdictions: 5
- Low-risk Jurisdictions: 0
- Not identified Jurisdictions: 3

Figure 63: Severe Storm Hazard Rankings by County

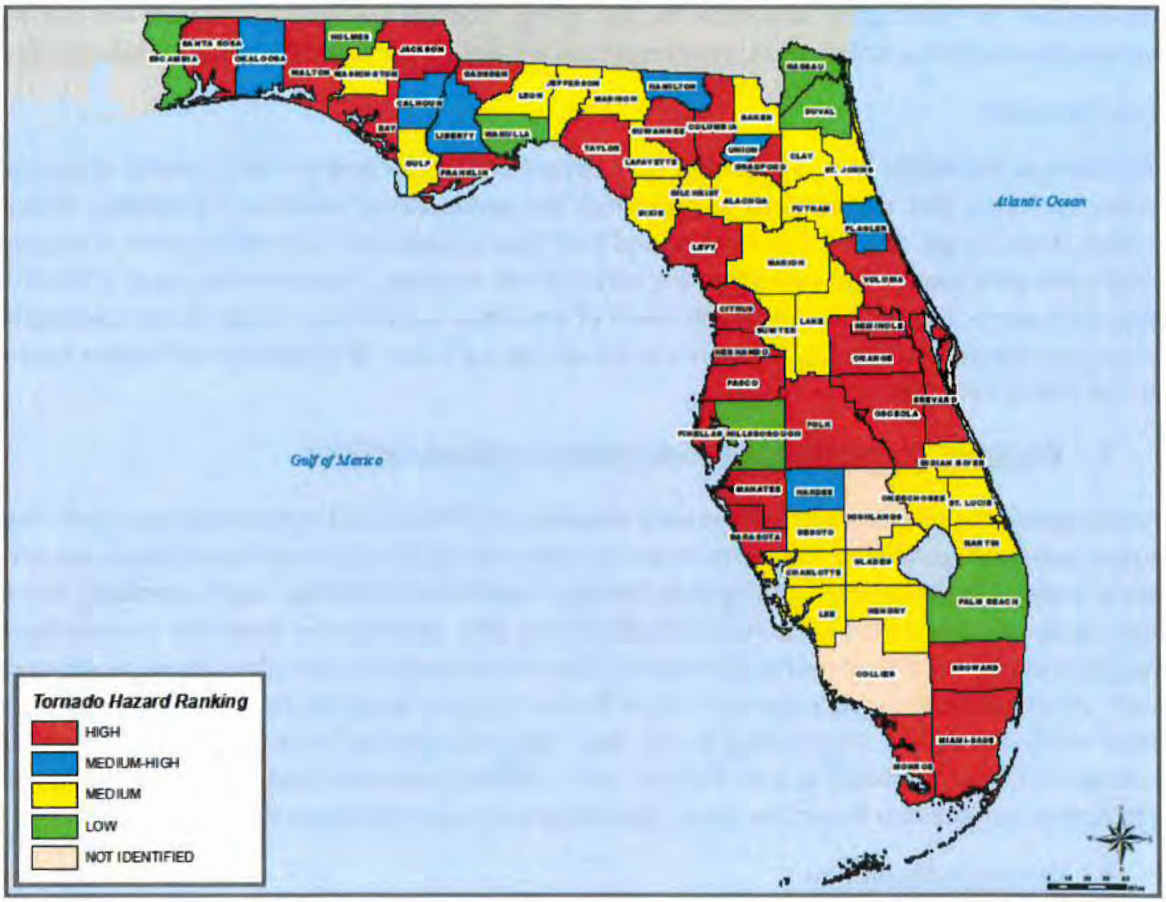


Tornados

Based on the LMS plans, Figure 3.38 displays the jurisdictional rankings for the tornados hazard. Not all counties have identified tornados as one of their hazards.

- High-risk Jurisdictions: 26
- Medium-High-risk Jurisdictions: 7
- Medium-risk Jurisdictions: 25
- Low-risk Jurisdictions: 7
- Not identified Jurisdictions: 2

Figure 64: Tornado Hazard Rankings by County



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

Vulnerability Analysis

According to the HelpFL data, which categorized the state by the average number of severe storm warnings per year, most structures in the state are within the Class 3 areas, meaning they have between 3.72 and 5.29 severe storm warnings per year. Additionally, there are eleven counties with over 300,000 structures in any of the classes, meaning they experience between 0 and 18 severe storm warnings per year. Those counties are Brevard, Broward, Collier, Duval, Hillsborough, Lee, Miami-Dade, Orange, Palm Beach, Pinellas, and Polk.

As explained in the Probability section, the Flash Flood Potential Index shows that there is a high chance of flash flooding in south Florida, as well as a few other locations around the urban coastal areas. Those areas, shaded in dark blue, would be the most vulnerable to flash flooding.

According to the data, counties that are most vulnerable to tornados include those on the east coast, as well as Escambia, Santa Rosa, and Okaloosa. Because hail events are not particularly common in Florida, no counties are particularly vulnerable to hail events. Central and southern Florida are the most vulnerable to lightning strikes, since those areas have the highest number of lightning strikes each year.

Loss Estimation

According to the HelpFL data, 57 counties have between $1 million and $99 billion worth of structures within the areas that are expected to experience any severe storm warnings. Six counties, Broward, Collier, Hillsborough, Miami-Dade, Orange, and Palm Beach, have over $100 billion worth of structures within the areas expected to experience any severe storm warnings. Similarly to the count of structures discussed above, there is over $1 trillion worth of structures in the Class 3 areas alone, meaning they experience between 3.72 and 5.29 severe storm warnings each year. This table can be found in *Appendix E: Risk Assessment Tables.*

8. Vulnerability Analysis and Loss Estimation, of State Facilities

Severe storms can strike anywhere in the state; therefore, all of the 20,231 state facilities and their insured values are equally vulnerable and at risk. However, severe storms do not always impact structures. Severe storm impacts to structures, including state facilities, could include flooding, wind, tornadoes, hail, and lighting. Please refer to the *Flood Hazard Profile* for the 100- and 500-year floodplain vulnerability and loss estimations. Because of the Florida Building Code, and the speed of most winds during severe storms, most structures do not sustain damage. This is because most buildings are built to withstand hurricane force winds and severe storms often do not have high wind speeds. Tornadoes however, may cause damage to structures, including state facilities. Hail is unlikely to cause damage because of the fact that oftentimes, hail does not impact the state. Lightning impacts on structures are minimal.

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 12.

<table>
<tr><th colspan="5">SEVERE STORM</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">The three key elements of a thunderstorm are wind, water, and lightning. The National Weather Service (NWS) considers a thunderstorm severe if it produces hail at least one inch in diameter, winds of 58 mph or stronger, or a tornado. Lightning, Flash Floods, Hail, Straight Line winds, Tornadoes.</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>Medium</td><td>Low</td></tr>
</table>

Wildfire Hazard Profile

1. Wildfire Description

Wildfire, or wildland fire, is a fire that was started by lightning or by humans in an area with vegetation. Wildfires occur in Florida every year and at all times of the year and are part of the natural cycle of Florida's fire-adapted ecosystems. Wildfires can cause major environmental, social, and economic damages because of the possible loss of life, property, wildlife habitats, and timber. Fortunately, many of these fires are quickly suppressed before they can damage or destroy property, homes, and lives.

Causes

Wildfires can be caused by humans or occur naturally. Based on analysis of statistics from 2006 to 2016 in Florida, about 70-80 percent of wildfires are caused by humans, including arson, burning debris, or accidents. Furthermore, 20-30 percent of wildfires are caused by lightning (Florida forest service report). These statistics are similar to nationwide statistics from the National Park Service data.

Wildfire prevention and public awareness campaigns such as Smokey Bear and Firewise Communities have helped to greatly reduce the number of human-caused wildfires in Florida. Other measures used to help reduce the number and severity of wildfires includes NWS advisories, prescribed burns, and county burn bans.

Although wildfires can cause severe damage, there can be benefits from this hazard. Sometimes, burns are "prescribed" by fire managers, meaning they are intentionally lit under carefully controlled conditions. The Florida Forest Service authorizes an average of 2 million acres to be burned each year in these prescribed burns. Benefits of prescribed burns include insect pest control, removal of exotic species, addition of nutrients to the soil for trees and other vegetation, removal of undergrowth to allow sunlight to reach the forest floor, and removal of extra fuel sources so when an un-prescribed burn occurs, there is less fuel for it to grow.[84] [85]

While there are many possible causes of wildfires, all spread in one of three patterns:

- Surface Fires: burn along the forest floor consuming the litter layer and small branches on or near the ground.
- Ground Fires: smolder or creep slowly underground. These fires usually occur during periods of prolonged drought and may burn for weeks or months until sufficient rainfall extinguishes the fire, or it runs out of fuel.
- Crown Fires: spread rapidly by the wind, moving through the tops of the trees.

The type and amount of fuel, as well as its burning qualities and level of moisture, affect wildfire potential and behavior. The continuity of fuels, expressed in both horizontal and vertical components, is also a factor because it expresses the pattern of vegetative growth and open areas. Topography is important

[84] http://www.freshfromflorida.com/Divisions-Offices/Florida-Forest-Service/Wildland-Fire
[85] https://www.nps.gov/fire/wildland-fire/learning-center/fire-in-depth/fire-spread.cfm

because it affects the movement of air (and thus the fire) over the ground surface. The slope and shape of terrain can change the rate of speed at which the fire travels. Temperature, humidity, and wind (both short- and long-term) affect the severity and duration of wildfires.

Environmental short-term loss caused by a wildland fire can include the destruction of wildlife habitat and watersheds. Long-term effects include reduced access to affected recreational areas, destruction of cultural and economic resources and community infrastructure, and vulnerability to flooding due to the destruction of watersheds.

Wildland/Urban Interface Fires

Population movement trends in the U.S. have resulted in rapid development in the outlying fringes of metropolitan areas and in the rural areas with attractive recreational and aesthetic amenities, such as forests. This demographic change is increasing the size of the WUI, defined as the area where structures and other human development meet or intermingle with undeveloped wildland. The WUI creates an environment for fire to move readily between vegetation fuels, such as brush or forests; and structural fuels, such as houses and buildings. Homes and other flammable structures can become fuel for WUI fires. There are three categories of WUI fires:

- Mixed Interface fires: contain structures that are scattered throughout rural areas. Usually, there are isolated homes surrounded by larger or smaller areas of land.
- Occluded Interface fires: are characterized by isolated (either large or small) areas within an urban area. An example may be a city park surrounded by urban homes trying to preserve some contact with a natural setting.
- Class Interface fires: are where homes, especially those crowded onto smaller lots in new subdivisions, press along the wildland vegetation along a broad front. Vast adjacent wildland areas can propagate a massive flame front during a wildfire, and numerous homes are put at risk by a single fire.

The WUI is largely the result of development in areas once considered wildlands where people desire to live in a more natural setting. Natural landscaping, which allows natural vegetation to grow and accumulate near homes, is a hazardous trend and does not mitigate the risk of fire reaching into a homeowner's land. Many subdivision layouts are designed with numerous dead-end streets and cul-de-sacs, creating access issues for firefighting services and equipment. In addition, many of these areas do not have wet hydrants or other sources of water for firefighting.

Advisories

There are three advisories that the NWS can issue for wildfires:[86]

- Fire Weather Watch: indicates weather conditions could result in critical fire weather conditions in the next 72 hours.
- Red Flag Warning: indicates ongoing or imminent critical fire weather in the next 24 hours.

[86] http://www.nws.noaa.gov/om/fire/ww.shtml

- Extreme Fire Behavior: implies that a wildfire is either moving fast, has prolific crowning or spotting, has fire whirls, or has a strong convection column.

Measures

The Florida Forest Service has developed a web-based Geographic Information System (GIS) mapping application called Fire Risk Assessment System (FRAS).[87] FRAS uses wildfire fuel types and densities, environmental conditions, and fire history to produce a Level of Concern (LOC), which is a number on a scale that runs from 1 (low concern) to 9 (high concern), for a given geographic area. This data was compiled in 2011 and used in the Wildfire Annex to the SHMP. As of 2018, this data has not been updated because it would be too costly to update. For more information about this system, please refer to *Appendix G: Wildfire Hazard Mitigation Plan Annex.*

Frequency

This hazard was determined to occur about every 5-10 years, giving it a Frequency ranking of Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be Medium, meaning any injuries, but no deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Medium, meaning significant damage to property occurs.

This hazards Environment Magnitude was determined to be High, meaning significant damage to the environment occurs.

Potential Effects of Climate Change on Wildfire

The increased frequency or intensity of extreme heat or drought events, due to the augmenting of existing fuel flammability, could affect wildfire behavior.[88] Changes in vegetation types could also alter fuel mixtures. Reducing moisture of living vegetation, soils, and decomposing organic matter during drought or extreme heat events is associated with increased incidence of wildfires. Furthermore, changes over time in vegetation types could change the mixture and flammability of fuels. As these transitions occur, wildfire occurrences and severity could increase with the introduction of more flammable vegetation types or decrease with the introduction of more fire resistant species.[89] As the flood hazard profile

[87]http://www.freshfromflorida.com/Divisions-Offices/Florida-Forest-Service/Wildland-Fire/Resources/Fire-Tools-and-Downloads/Florida-s-Wildland-Fire-Risk-Assessment-System-FRAS

[88] Murray et al. (2012). *Case studies*, (https://www.ipcc.ch/pdf/special-reports/srex/SREX-Chap9_FINAL.pdf). In Field et al. (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation; A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, pp. 487-542. https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf., p. 519; Walsh and Wuebbles (2013).; *Our changing climate*. In, *Draft national climate assessment* (pp. 25-103).
http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-fulldraft.pdf

[89] Groffman and Kareiva (2013);
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.431.5893&rep=rep1&type=pdf; Walsh and Wuebbles

discussed that arid areas may become drier and moist areas to become wetter. Florida has weather patterns that lead to both dry and wet periods each year. Climate change may cause one or the other, or both to increase in occurrences and magnitude.

2. Geographic Areas Affected by Wildfire

The land use map below shows that much of Florida is prone to wildfire. Woodlands and timberlands are clearly vulnerable to wildfires. Additionally, droughts increase vulnerability in swamps, wetlands, and agricultural lands. These types of land are vulnerable because they contain materials that are easily combustible fuel.

Figure 65: Florida Land Use[90]

As explained before, the WUI areas of the state have increased. WUI areas are vulnerable to wildfires and can cause significant property damage. The WUI of the US was mapped in 2010, showing WU interface

(2013), https://www.globalchange.gov/sites/globalchange/files/NCAJan11-2013-publicreviewdraft-chap2-climate.pdf

[90] Compiled from Florida Water Management District data.

areas and the intermix areas, as well as areas that were Non-WUI and vegetated, and areas that were Non-Vegetated or Agriculture. The 2010 data and analysis is the most recent of this kind.

Figure 66: Wildland-Urban Interface (WUI) 2010

This map allows visualization of the WU Interface and Intermix. It is clear that between very urban areas, such as the Tampa Bay region or the south east coast, shown in red, and vegetation areas, shown in green, there are areas that is known as WU Interface and Intermix, shown in yellow and orange.

3. Historical Occurrences of Wildfire

The most naturally caused wildland fires typically occur in July due to lightning strikes and coincide with the height of the thunderstorm season. Human-caused fires, such as arson, debris or trash burning, or sparking equipment, can occur any time of year but usually occur during the same season as wildfires. Table 3.37 includes a brief narrative for significant wildfires in the state from 2006 to 2016.

Table 34: Florida Significant Wildfires, 2006-2016

Date	Description
2007	Several wildfires burned across Florida for many weeks. Thick smoke from area wildfires forced officials to close stretches of I-75 and I-10 in northern Florida, among other main roads. The fires burned at least 101,000 acres in Florida. 5 wildfires were authorized to receive the FMAG grant.
2009	There were nearly 3,000 wildfires that burned 136,623 acres in Florida. Much of the activity occurred earlier than usual in the year.
2012	There was a heavy wildfire season with many road closures because of reduced visibility due to smoke. One multi-car accident on I-75 killed 11 people.

Since 1985, FEMA has authorized several Fire Management Assistance Grants (FMAG). The 1999 wildfire season was so severe that in addition to 11 FMAGs being authorized, an Emergency Declaration was made to assist with handling the fires. Below is a list of all the FMAG designations, plus the single major disaster declaration (DR) that Florida has received form FEMA.

Table 35: FEMA Fire Management Authorization Grant Declarations, Florida, 1985 – 2017

Date	Name/Description
May 17, 1985	Perry Fire, Aster Fire, Bonell Fire
May 20, 1985	Tomoka Fire
June 6, 1998	Pine Coast 98 Fire
June 16, 1998	Jacksonville Complex Fire
June 18, 1998	County Line Fire
June 19, 1998	Race Track – Waldo Fire, Waldo Southeast Fire, San Pedro Day Fire, Waccasassa Fire Complex
June 20, 1998	Bunnelle Fire Complex, Suwanee Fire Complex
June 21, 1998	Depot Creek Fire; Caloosahatchee Fire Complex
June 27, 1998	Withlacoochee Fire Complex
June 28, 1998	Orlando Fire Complex
April 13, 1999	Okeechobee Fire Complex, Wacasassa Fire Complex, Florida Fire Complex, Caloosahatchee Fire Complex, Chipola District Fire, Everglades District Fire, Tallahassee Fire District, Suwannee District Fire, Lakeland Fire, Myakka River District Fire
May 14, 1999	Jacksonville District Fire
April 11, 2000	Merritt Fire
May 15, 2000	Flowers – Myakka Fire Complex
May 19, 2000	Withlacoochee District Fire Complex
May 22, 2000	Lakeland District Fire Complex
May 28, 2000	Bunnell District Fire Complex
May 29, 2000	Waccasassa Fire Complex
June 2, 2000	Jacksonville Fire Complex
June 5, 2000	Suwannee Fire Complex
June 9, 2000	Perry Fire Complex

February 17, 2001	Lakeland Fire Complex
February 19, 2001	Okeechobee Fire Complex, Caloosahatchee Fire Complex
April 16, 2001	Orlando Fire Complex
April 17, 2001	Myakka Fire Complex, Everglades Fire Complex
May 14, 2001	Chipola River Fire Complex
May 15, 2001	Escambia Fire Complex
May 23, 2001	Perry Fire Complex
May 15 – June 26, 2006	Volusia Fire Complex
March 25 – 28, 2007	53 Big Pine Fire
May 1, 2007	Deland Fire Complex
May 7, 2007	Suwannee Fire Complex, Black Creek Fire, Caloosahatchee Fire Complex
May 29, 2007	Okeechobee Fire Complex
May 11, 2008	Brevard Fire Complex, Martin County Fire Complex
April 26 – May 31, 2011	Slope Fire
April 20, 2017	30th Avenue Fire
April 21, 2017	Lehigh Acres Fire, Indian Lakes Estate Fire

In addition to these FMAG designations, there has been one major disaster designation for a wildfire in Florida, named the Florida Extreme Fire Hazard, DR-1223, which occurred from May 25 until July 22, 1998.[91]

According to NCDC Storm Events Database, there were 118 reports of wildfires from 2006 until 2016. Some of these reports are regarding the same fire, but in different counties, so the true number is likely lower than 118.[92]

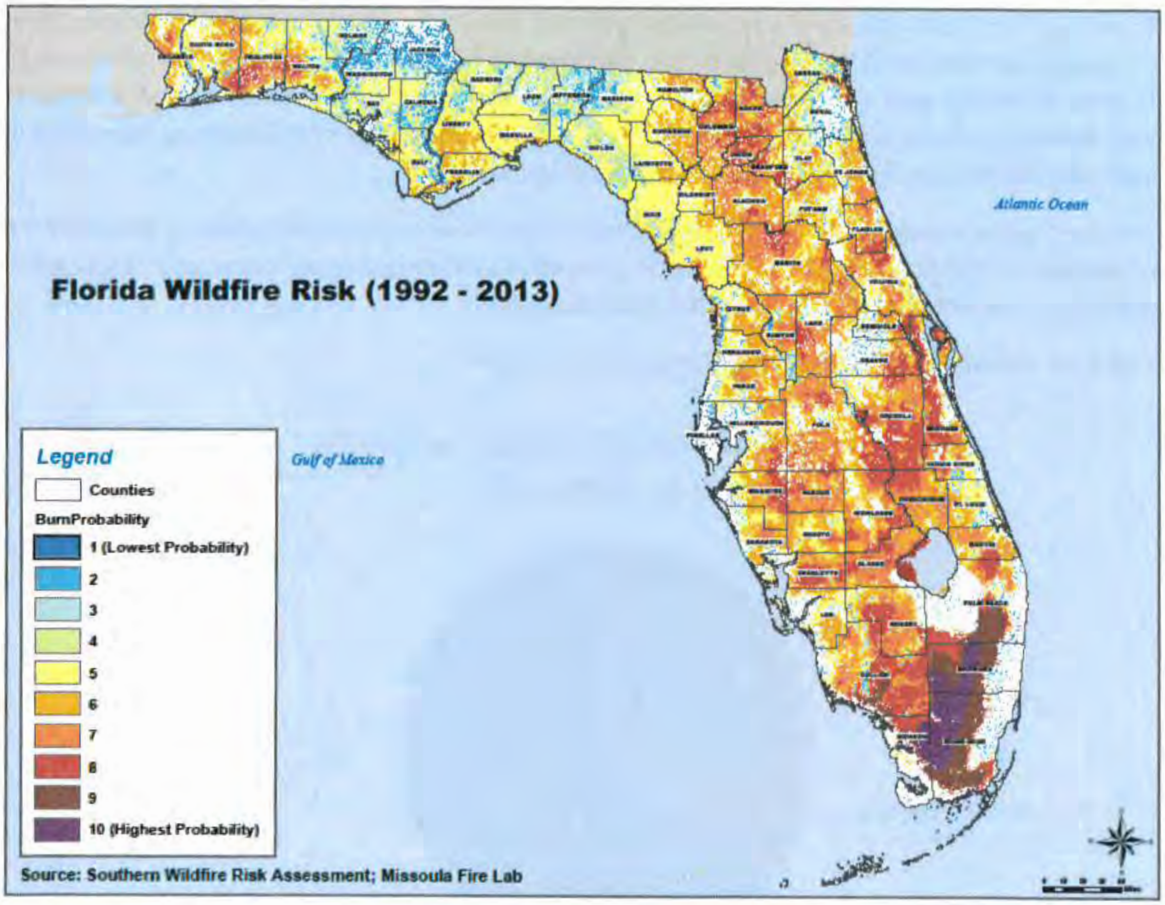
4. Probability of Future Occurrences of Wildfire

Below is a map showing the Burn Probability for Florida, based on historical data from 1992 to 2013.

[91] https://www.fema.gov/disasters?field_state_tid_selective=47&field_disaster_type_term_tid=6845&field_disaster_declaration_type_value=All&items_per_page=20&=GO

[92] https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Wildfire&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2006&endDate_mm=12&endDate_dd=31&endDate_yyyy=2016&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=12%2CFLORIDA

Figure 67: Florida Wildfire Risk, 1992 – 2013[93]



According to this burn probability map, wildfires are likely to occur across most of the state, with a 5 through 10 probability, except for the central Panhandle region and other intermittent areas across the state. Areas in south Florida, in Monroe, Miami-Dade, Broward, and Palm Beach counties are likely to experience wildfires, with a 9 to 10 burn probability.

Florida has a year round fire season with the most active time being April to July, with the largest number of lightning-caused fires occurring in July. The dry months, combined with low humidity and high wind, tend to have the highest number of fires reported. Approximately 80 percent of all wildfires in Florida

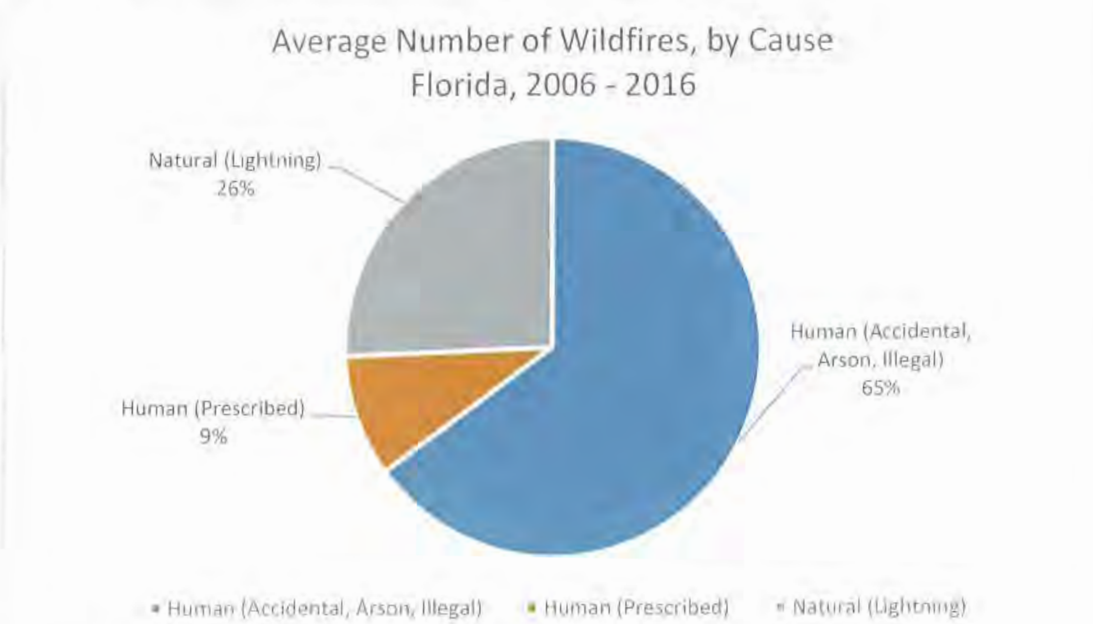
[93] *National burn probability (BP) and conditional fire intensity level (FIL) data were generated for the conterminous United States (US) using a geospatial Fire Simulation (FSim) system developed by the US Forest Service Missoula Fire Sciences Laboratory to estimate probabilistic components of wildfire risk (Finney et al. [2011]). The FSim system includes modules for weather generation, wildfire occurrence, fire growth, and fire suppression. FSim is designed to simulate the occurrence and growth of wildfires under tens of thousands of hypothetical contemporary fire seasons in order to estimate the probability of a given area (i.e., pixel) burning under current landscape conditions and fire management practices. The data presented here represent modeled BP and FIL for the conterminous US at a 270-meter grid spatial resolution.*

occur within one mile of the WUI. According to the map in the geographic section, most counties have a burn probability of at least 6 to 8 and south Florida has a burn probability of 9 to 10.

According to FFS and data about past wildfires, there is an average of 3,171 wildfires each year, burning an average of about 124,117 acres each year. Knowing this information, it is clear that wildfires are likely to occur in Florida each year. Specifically, there was an average of 2,357 human-caused wildfires each year, burning an average of about 70,059 acres per year, and an average of 813 lightning-caused wildfires each year, burning an average of about 54,058 acres per year.[94]

The chart below shows data from FFS and indicates there is an annual probability that approximately 65% of wildfires in Florida will be human caused, 9% of wildfires will be prescribed burns, and 26% of wildfires will occur from natural causes, such as from lightning strikes.

Figure 68: Average Wildfires by Cause, Florida, 2006 – 2016[95]



Furthermore, the chart below shows that there is an annual probability that approximately 124,000 acres will be burned by wildfire in Florida each year. Human caused (accidental, arson, illegal) accounts for about 51% of the wildfires, natural causes, such as lightning strikes, accounts for 43.6%, and Human caused (prescribed) burns cause 9.4% of wildfires each year.

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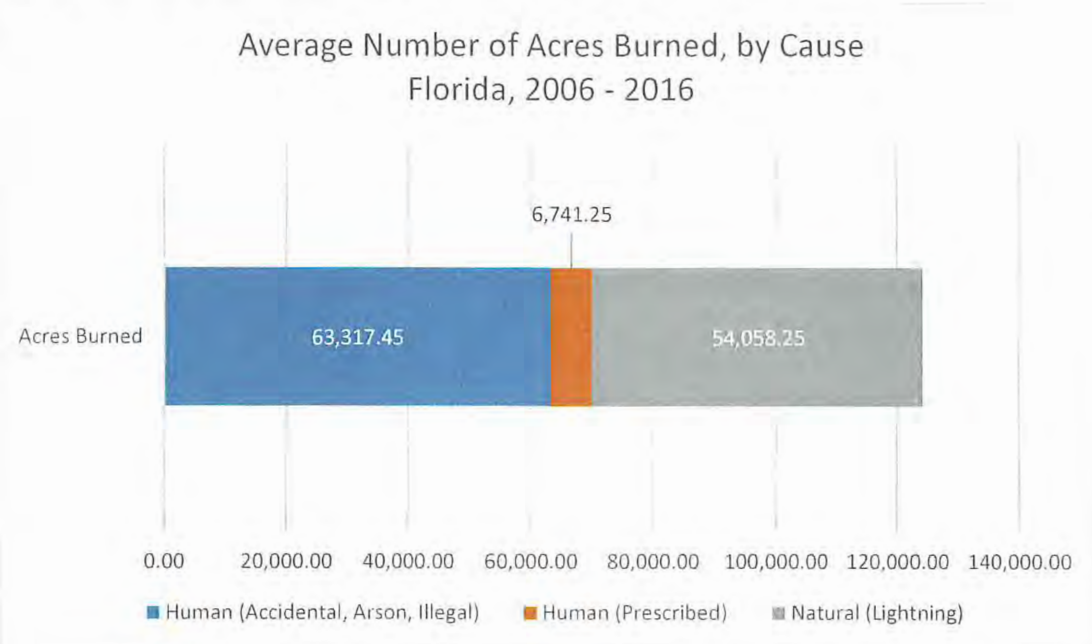
[94] Florida Forest Service Report System, Fire by Causes, Statewide Summary 01/01/2006 through 12/31/2016.
Note: This data is an average of the wildfire occurrences from 2006 to 2016. It is important to note that this data does not include the fires that were managed by other agencies, such as the Department of Defense, US Fish and Wildlife Service, the National Parks Service, and the Bureau of Indian Affairs, all federal or tribal agencies that assist the State of Florida with managing wildfires on non-state owned land.
[95] Florida Forest Service Report System, Fire by Causes, Statewide Summary 01/01/2006 through 12/31/2016

Figure 69: Average Acres Burned by Cause, Florida, 2006 – 2016[96]



According to the NCDC Storm Events Database, there are an average of 12 wildfires each year.[97]

The statewide wildfire hazard mitigation plan provides additional information on wildfires in Florida. Please see *Appendix G: Wildfire Hazard Mitigation Plan Annex* for a copy of the plan.

This hazard was determined to occur about every 5-10 years, giving it a Probability ranking of Likely.

5. Wildfire Impact Analysis

- People
  - Injury or death from fire
  - Injury or death from smoke inhalation
  - Injury or death while evacuating
  - Vehicle accidents due to decreased visibility due to smoke
- Responders
  - Injury or death during wildfire suppression, especially during high wind conditions
  - Injury or death from vehicle accidents due to decreased visibility
  - Injury or death from evacuation and rescue missions
  - Injury or death from smoke inhalation
- Continuity of Operations (including continued delivery of services)

[96] Florida Forest Service Report System, Fire by Causes, Statewide Summary 01/01/2006 through 12/31/2016

[97] https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Wildfire&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2006&endDate_mm=12&endDate_dd=31&endDate_yyyy=2016&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=12%2CFLORIDA

  - Inability to operate businesses if evacuations are ordered, leading to lost wages and revenue
  - Employee absenteeism if employees are evacuated
  - Blocked transportation routes because of decreased visibility
- Property, Facilities, Infrastructure
  - Damage or loss to personal structures and businesses
  - Damage or loss to critical infrastructure such as schools, hospitals, government buildings, utilities, etc.
  - Damage or loss to agricultural crops and timber, which leads to loss of income and loss of revenue
- Environment
  - Damage or loss to large forested areas
  - Damage or loss to habitats
- Economic Condition
  - Closure of businesses if in evacuee area leading to lost wages and revenue
  - Employee absenteeism leading to forced business closure which results in lost wages and lost revenue
  - Damage or loss to agricultural crops and timber, which leads to loss of income and loss of revenue
  - Loss of tourism if wildfires are in popular tourist areas
- Public Confidence in Jurisdiction's Governance
  - Lost confidence if evacuations not ordered, messaged, and coordinated effectively
  - Lost confidence if many deaths from wildfires from those that did not evacuate

6. 2018 LMS Integration

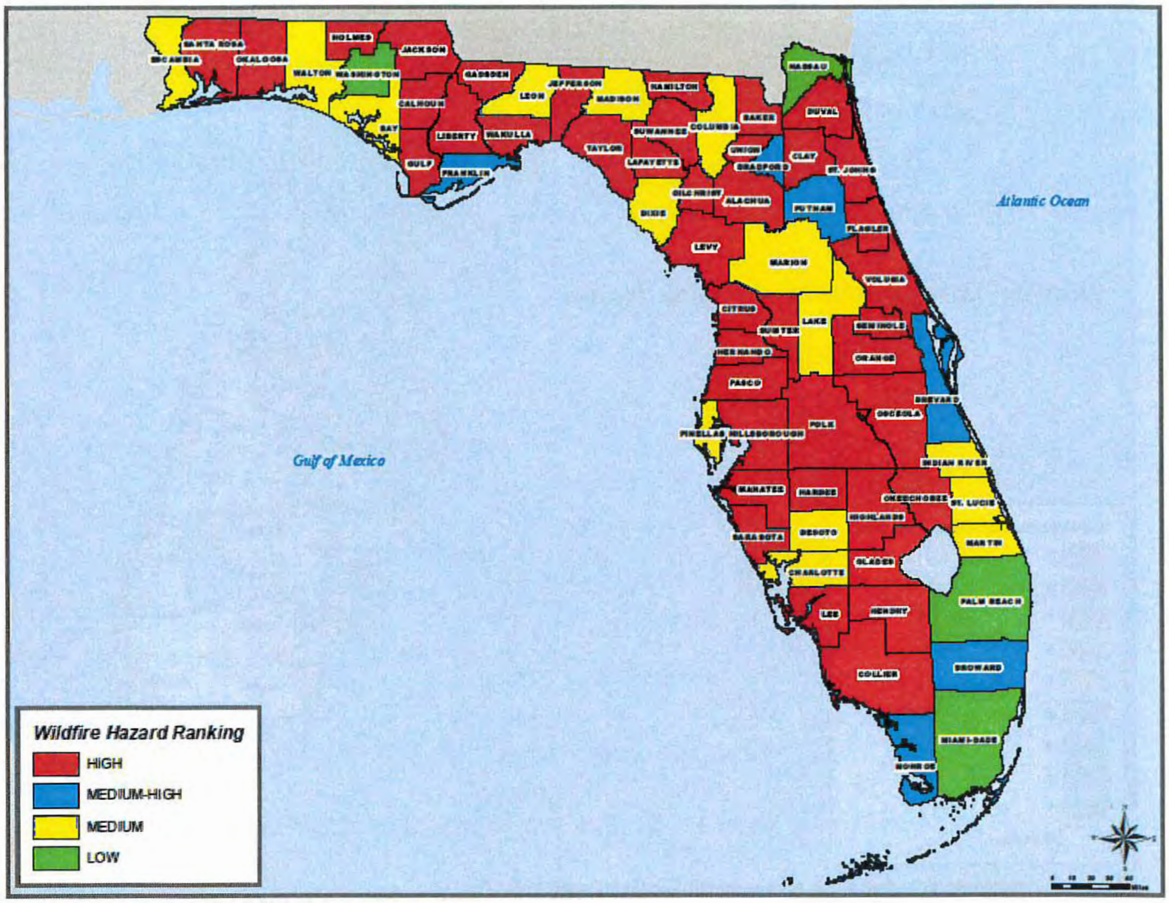
An analysis of all 67 Florida County LMS Plans and their individual wildfire hazard rankings is shown below. All counties identified wildfire as a hazard.

Wildfires

Based on the LMS plans, Figure 3.38 displays the jurisdictional rankings for the wildfire hazard. All counties have identified wildfires as one of their hazards.

- High-risk Jurisdictions: 42
- Medium-High-risk Jurisdictions: 6
- Medium-risk Jurisdictions: 15
- Low-risk Jurisdictions: 4
- Not identified Jurisdictions: 0

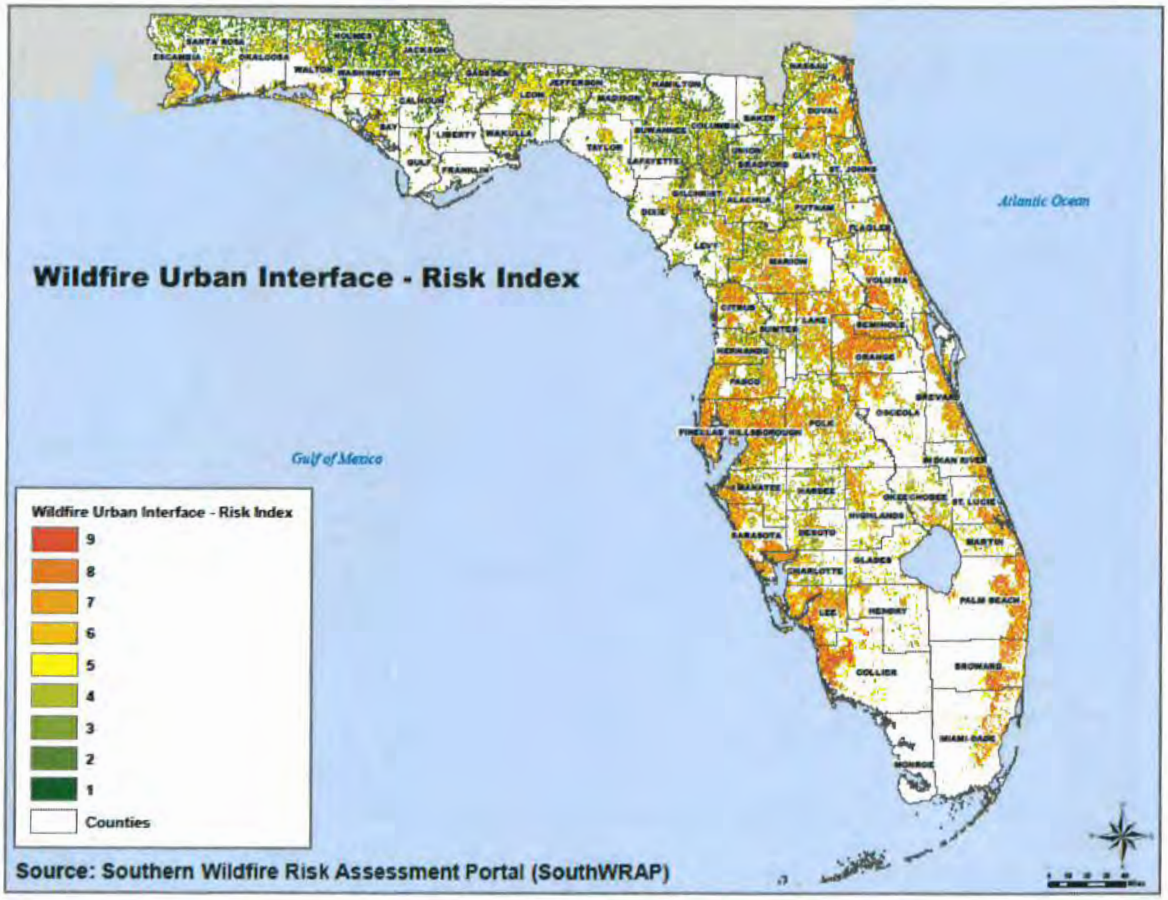
Figure 70: Wildfire Hazard Rankings by County



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

The Burn Probability map above shows that most of the state has a mid-range burn probability, but southern counties, such as Palm Beach, Broward, and Miami-Dade, have the highest burn probability, between 9 and 10.

Figure 71: Wildland Urban Interface Risk Index



This map is similar to the WUI area map above and shows the risk for WUI fires. These maps are similar because they both highlight the WUI areas in the state of Florida. The areas with a high WUI fire risk index are vulnerable because they are highly populated and near forested areas. Coastal areas and the central Florida region have a WUI risk index between 6 and 9.

According to NCDC Storm Events Database, the average (based on data from 2006 to 2016) annual property loss due to wildfires in Florida is $2.81 million.[98]

Table 36: NCDC Wildfires, 2006 – 2016

NCDC Storm Event (hazard)	Average Wildfires per Year	Annualized Property Loss ($Millions)	Annualized Crop Loss ($Millions)
Wildfires	12	2.81	0

[98]https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Wildfire&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2006&endDate_mm=12&endDate_dd=31&endDate_yyyy=2016&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=12%2CFLORIDA

While updated statewide loss estimation information was not possible to obtain, the data in the 2013 Wildfire Mitigation Plan Annex is still a good reference. Additionally, there are examples of how much wildfires can cost. After six weeks of wildfires across 18 counties in northeastern Florida in 1998, the following losses were calculated:[99] [100]

- Commercial timer (softwood) losses: $322 million to $509 million
- Property losses: $10 million to $12 million
- Tourism and trade losses: $140 million

Overall, urban coastal communities, particularly in south Florida, and some parts of central Florida, are vulnerable to wildfires.

8. Vulnerability Analysis and Loss Estimation, of State Facilities

An update of the state facility vulnerability analysis and loss estimation was not possible to obtain in 2017. It can be inferred however, that state facilities in the areas mentioned above, such as the urban coastal communities, are vulnerable to wildfires.

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 11.

[99] Butry and others 2001
[100] https://www.fs.fed.us/openspace/fote/reports/GTR-299.pdf

<table>
<tr><th colspan="5">WILDFIRE</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">Wildfire, or wildland fire, is a fire that was started by lightning or by humans in an area with vegetation. Wildfires occur in Florida every year and at all times of the year and are part of the natural cycle of Florida's fire-adapted ecosystems. Wildfires can cause major environmental, social, and economic damages because of the possible loss of life, property, wildlife habitats, and timber.</td><td rowspan="4">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>Likely</td><td>Likely</td><td>Medium</td><td>Medium</td><td>High</td></tr>
</table>

Coastal Erosion Hazard Profile

1. Coastal Erosion Description

Coastal erosion is the wearing away of land or the removal of beach or dune sediments by wave action, tidal currents, wave currents, or drainage. Waves generated by storms cause coastal erosion, which may take the form of long-term losses of sediment and rocks, or merely in the temporary redistribution of coastal sediments. The study of erosion and sediment redistribution is called "coastal morphodynamics," which can be described also as the dynamic interaction between the shoreline, seabed, and water.

The ability of waves to cause erosion depends on a number of factors, which include:

- Erodibility of the beach, cliff, or rocks;
- Power of the waves to cross the beach;
- Lowering of the beach or shore platform through wave action; and
- Near shore bathymetry.

For example, waves must be strong enough to remove material from the debris lobe for erosion to occur. Additionally, beaches can help dissipate wave energy on the foreshore and can provide a measure of protection to cliffs, rocks, and other harder formations, as well as any area upland.

Below is a table with the majority of the contribution factors to erosion. The factors are organized by first, second, and third orders depending on how the erosion occurs.

Table 37: Erosion Contribution Factors

First Order	Second Order	Third Order
Geological structure and lithology a) Hardness b) Height, etc. c) Fractures/faults d) Wave climate e) Prevailing wave direction f) Sub-aerial climate g) Weathering (frost, etc.) h) Stress relief swelling/ shrinkage i) Water-level change j) Groundwater fluctuations k) Tidal range l) Geomorphology	• Weathering and transport slope processes • Slope hydrology • Vegetation • Cliff foot erosion • Cliff foot sediment accumulation • Resistance of cliff foot sediment to attrition and transport	• Coastal land use • Resource extraction • Coastal management

As beaches are constantly moving, building up here and eroding there, in response to waves, winds, storms, and relative sea level rise, this issue requires long-term analysis and planning. The current beach-erosion problem has many causes, including the following items:

- The desire by many to live near the sea.
- A historically rapid rise in average ocean levels, now estimated to be rising at about 25–30 centimeters per century in much of the United States.
- The gradual sinking of coastal land (since the height of the land and the sea are both changing, the "relative sea level rise" is used to describe the rise of the ocean compared to the height of land in a particular location).
- Efforts to reduce erosion that have proved to be ineffective and instead increased it.

Some erosion changes are slow, inexorable, and usually gradual. However, the changes on a beach can happen overnight, especially during a storm. Even without storms, sediment may be lost to longshore drift (the currents that parallel coastlines), or sediment may be pulled to deeper water and lost to the coastal system. Coastal erosion may also be caused by the construction and maintenance of navigation inlets. There are over 60 inlets across Florida, many of which have been artificially deepened to accommodate commercial and recreational vessels. Jetties are also installed to prevent sediment from filling in these inlets. A consequence of this practice is that the jetties and inlets interrupt the natural flow of sediment along the beach, leading to an accumulation of sediment in the inlet and at jetty on one side of the inlet, and a loss of sediment to beaches on the other side of the inlet. There are many solutions to the major problem of beach erosion, including:

- Beach re-nourishment: Sand is purposefully deposited onto the beaches by humans; however, there is a very high cost associated with the solution.
- Rebuild rivers: Direct rivers back into places with a lack of sediment with the intention that the rivers will push the sediment back into place.
- Breakwaters, sea walls, and groins: While each location has different requirements that drive specific development and construction, these types of structural projects are intended to interfere with erosion. There are however some flaws and issues with these types of projects as they can trap as much sediment as they deposit with down-drift effects.
- Limits on beach development: Limit, restrict, or prohibit development on the impacted beaches.

Florida has 825 miles of sandy beach coastline fronting the Atlantic Ocean, the Gulf of Mexico, and the Straits of Florida. The beaches in Florida serve many critical purposes. For example, the beaches are home to several species of plants and animals that are dependent upon beaches, dunes, and near shore waters for all or part of their lives. In fact, there are over 30 rare species within the state that inhabit the beach and adjacent habitats. These species have adapted to living in the beach's harsh environment of salt spray, shifting and infertile sand, bright sunlight, and storms. Additionally, people visit Florida beaches at very high rates. Tourists and residents visit the beaches and coastal waters to relax, tan, swim, boat, fish, and dive.[101]

[101] http://www.dep.state.fl.us/beaches/

According to the Beach Management Funding Assistance Program (BMFA) within Florida Department of Environmental Protection (FDEP) (formerly the Beach Erosion Control Program), there are many stretches of shoreline that has been critically eroded. Critically eroded shoreline is defined as,

> *"a segment of the shoreline where natural processes or human activity have caused or contributed to erosion and recession of the beach or dune system to such a degree that upland development, recreational interests, wildlife habitat, or important cultural resources are threatened or lost. Critically eroded areas may also include peripheral segments or gaps between identified critically eroded areas which, although they may be stable or slightly erosional now, their inclusion is necessary for continuity of management of the coastal system or for the design integrity of adjacent beach management projects".*

Therefore, critically eroded beaches are those in which there is a threat or loss of one of four specific interests: upland development, recreation, wildlife habitat, or important cultural resources. Non-critically eroded beaches are those in which there may be significant erosion conditions, but there is currently no public or private interest threatened. In Florida, the 2016 Critical Erosion Report from FDEP states there are:

- 411.2 miles of critically eroded beach
- 8.7 miles of critically eroded inlet shoreline
- 93.5 miles of non-critically eroded beach
- 3.2 miles of non-critically eroded inlet shoreline

This is shown below in the map.

Figure 72: Critical Erosion Areas, Florida, 2106[102]

Additionally, there are some areas where the erosion is not significant.

According to FDEP, roughly half of the designated critically eroded beaches are currently managed with restoration efforts such as placement of beach fill material. While these areas are improved from their eroded status, they are kept on the critically eroded list to ensure monitoring and continued eligibility for projects and funding.[103]

Beach Management Funding Assistance (BMFA) Program

The primary vehicle for implementing the beach management planning recommendations is the Florida Beach Erosion Control Program (BECP) within FDEP (formerly the Beach Erosion Control Program), a program established to work in concert with local, state, and federal governmental entities to achieve the protection, preservation, and restoration of the coastal sandy beach resources of the state. Under the program, financial assistance in an amount of up to 50 percent of project costs is available to Florida's

[102] http://www.dep.state.fl.us/beaches/publications/pdf/CriticalErosionReport.pdf
[103] http://www.dep.state.fl.us/beaches/publications/pdf/CriticalErosionReport.pdf

county and municipal governments, community development districts, or special taxing districts for shore protection and preservation activities. Eligible activities include beach restoration and nourishment activities, project design and engineering studies, environmental studies and monitoring, inlet management planning, inlet sediment transfer, dune restoration and protection activities, and other beach erosion prevention-related activities consistent with the adopted Strategic Beach Management Plan.

Frequency

This hazard was determined to occur annually, giving it a Frequency ranking of Very Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be Low, meaning no injuries or deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Medium, meaning significant damage to property occurs.

This hazards Environment Magnitude was determined to be Medium, meaning some damage to the environment occurs.

Potential Effects of Climate Change on Erosion

Both increased rates of global eustatic sea level rise and increased frequency of higher intensity hurricanes may affect coastal erosion. As described in *Section 3.3.1 Flooding*, continued atmospheric warming could increase rates of global eustatic sea level rise. In the absence of offsetting changes in natural sediment supply, sand beaches will erode more rapidly as the rate of sea level rise increases. If the frequency of higher intensity hurricanes does increase (*see section 3.3.2 Tropical Cyclones*), events will occur more often when sand eroded from beaches is transported to depths from which it will not be moved back on shore by swell waves. More frequent category 4 and 5 hurricanes also would increase incidence of dune erosion and over wash where beach sediments are carried landward. These processes can damage structures, but where structures are not present, the over wash process can permit a beach and dune system to migrate landward.[104] Rising sea levels also threaten the survival of coastal wetlands when natural rates of sediment accretion and elevation increase are not fast enough to offset the rising sea.[105] However, wetlands also may be able to migrate landward with adequate sediment influx if there are no physical barriers to their movement.

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[104] *(Gutierrez et al. (2009). Ocean coasts. http://papers.risingsea.net/coastal-sensitivity-to-sea-level-rise-3-ocean-coasts.html; In Titus et al. (Eds.), Coastal sensitivity to sea-level rise: A focus on the mid-Atlantic region. http://downloads.globalchange.gov/sap/sap4-1/sap4-1-final-report-all.pdf.).*

[105] *(Cahoon et al. (2009). Coastal wetland sustainability. http://papers.risingsea.net/coastal-sensitivity-to-sea-level-rise-4-wetland-accretion.html; In Titus et al. (eds.), Coastal sensitivity to sea-level rise: A focus on the mid-Atlantic region.).*

2. Geographic Areas Affected by Coastal Erosion

The Bureau of Beaches and Coastal Systems develops and publishes annually the Critically Eroded Beaches Report. The data from this report is gathered from a set of monitoring locations along the coast throughout the state. Data is collected from each of these stations, and then compiled into a GIS database for modeling and analysis. The continual reporting and analysis is combined with the historical data for detailed records about the status of the state's beaches. Erosion is a constantly changing issue as development continues on the beaches and in the inlets. It can also be instantly changed by a large storm or a hurricane.

The August 2016 Critically Eroded Beaches in Florida Report[106] (*Appendix I*)states that there are 411.2 miles of critically eroded beach and 93.5 miles of non-critically eroded beach. There are also 8.7 miles of critically eroded inlet shoreline and 3.2 miles of non-critically eroded inlet shoreline. The map shown before depicts this information.

3. Historical Occurrences of Coastal Erosion

DEP maintains a database of all the occurrences of erosion in the state with high quality reporting since the inception of the BMFA Program. There are constantly cases of beach erosion throughout the state, and the 2013 revision reflects agreement that each previous occurrence would not be listed in this section.

The disastrous hurricane seasons of 2004–2005 had a severe impact on the state in terms of erosion, and DEP has published a number of reports about the specific details of these events. A number of these events are listed below in Table 38.

Table 38: Florida Significant Erosion Contribution Events[107]

Year	Event
1972	Hurricane Agnes
1975	Hurricane Eloise
1979	Hurricanes David and Frederick
1984	Thanksgiving Day Nor'easter
1982	"no-name" storms
1985	Hurricanes Elena and Kate and Tropical Storms Bob and Juan
1992	Hurricane Andrew
1993	Winter storm
1995	Hurricanes Erin and Opal
1998	Hurricanes Earl and Georges
1999	Hurricanes Floyd and Irene
2004	Hurricanes Charley, Frances, Ivan, and Jeanne,
2005	Hurricanes Dennis, Katrina, Ophelia, Rita, and Wilma,
2008	Tropical Storm Fay and Hurricane Gustav
2012	Hurricane Isaac and Sandy and Tropical Storm Debby

[106] http://www.dep.state.fl.us/beaches/publications/pdf/CriticalErosionReport.pdf
[107] http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/SBMP-Introduction.pdf

Table 39: Historical Beach Erosion Control Program, 2006-2016[108]

Date	Description
2006	Report stated: • 385.2 miles of critical beach erosion, • 96.8 miles of non-critical beach erosion, • 8.6 miles of critical inlet erosion, and • 3.2 miles of non-critical inlet erosion.
2008	Report stated: • 396.4 miles of critical beach erosion, • 95.5 miles of non-critical beach erosion, • 8.9 miles of critical inlet erosion, and • 3.2 miles of non-critical inlet erosion.
2010	Report stated: • 398.6 miles of critical beach erosion, • 95.9 miles of non-critical beach erosion, • 8.6 miles of critical inlet erosion, and • 3.2 miles of non-critical inlet erosion.
2012	Report stated: • 397.9 miles of critical beach erosion, • 96.2 miles of non-critical beach erosion, • 8.7 miles of critical inlet erosion, and • 3.2 miles of non-critical inlet erosion.
2016	Report stated: • 411.2 miles of critical beach erosion, • 93.5 miles of non-critical beach erosion, • 8.7 miles of critical inlet erosion, and • 3.2 miles of non-critical inlet erosion.

4. Probability of Future Occurrences of Coastal Erosion

The beaches of Florida will continue to shift and change over time, especially when faced with the current levels of development. During the 2013 plan revision process, it was agreed that this hazard will continue to affect the state, and there is considerable work being done regularly to mitigate potential damages. DEP maintains an active and on-going program to study this issue and mitigate damages as much as possible. The Mitigate FL Team considers this a high probability hazard, especially in conjunction with hurricanes, winter storms, and coastal flooding, and considering the likelihood of future development in coastal areas. There is a very high probability that this hazard will continue to affect the state in the future. Coastal erosion has occurred in Florida since the start of such record keeping. Additionally, coastal flooding will continue to occur, whether it is due to tropical storms or sea level rise, or both. While it

[108] http://www.dep.state.fl.us/beaches/publications/tech-rpt.htm

would be best to keep areas prone to coastal erosion undeveloped, the Mitigate FL Team recognizes this is unlikely and that future development in coastal areas will increase the probability of coastal erosion affecting developed areas.

This hazard was determined to occur annually, giving it a Probability of Very Likely.

5. Impact Analysis of Coastal Erosion

- Public
  - May lose property
  - May lose sandy beaches, dunes or mangroves, which could lead to storm surge flooding
  - Sandy beaches may have to close
- Responders
  - N/A
- Continuity of Operations (including continued delivery of services)
  - Businesses, critical infrastructure, government buildings, etc. may have operations hindered if erosion leads to damage to the structure
  - Operations may be hindered if roads to the structures are damaged from erosion
  - Continuity of transportation network may be interrupted because of erosion damage to roads
- Property, Facilities, Infrastructure
  - Structures may be damaged when coastal erosion damages the ground
- Environment
  - Coastal areas, marshes, mangroves, sandy beaches etc. may be severely damaged from coastal erosion which is a habitat for many species of plants and animals
  - If large portions of coastal areas and dunes are washed away from coastal erosion, storm surge from the next storm could reach homes, businesses, roads, etc.
- Economic Condition
  - N/A
- Public's Confidence in Jurisdiction's Governance
  - If damage from coastal erosion, such as damage to roads, is not quickly repaired, then the public may be frustrated with the jurisdiction's governance

6. 2018 LMS Integration

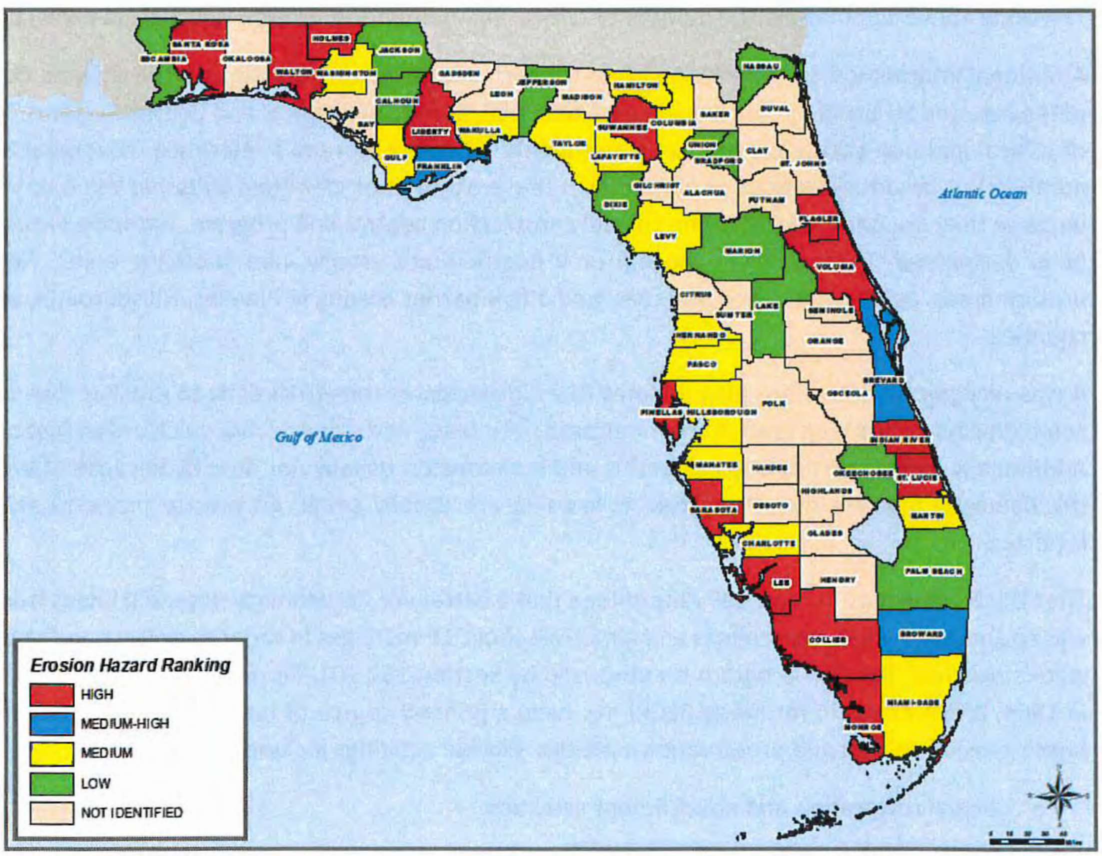
Mitigate FL focused on producing a statewide probability analysis based on estimates provided by all State of Florida LMS plans. The 67 multi-jurisdictional LMS plans provided a solid baseline for the overall state probability analysis. The following pages having the risk assessment information for erosion in the State of Florida.

Erosion

Based on the LMS plans, Figure 73 displays the jurisdictional rankings for the erosion hazard. Not all counties have identified erosion as one of their hazards.

- High-risk Jurisdictions: 14
- Medium-High-risk Jurisdictions: 3
- Medium-risk Jurisdictions: 15
- Low-risk Jurisdictions: 12
- Not identified Jurisdictions: 23

Figure 73: Erosion Hazard Rankings by County



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

In the June 2015 Strategic Beach Management Plan, the critically eroded shorelines were listed by region along with the levels of management. Table 40 lists those values.

Table 40: Florida Critically Eroded Managed Shoreline by Region[109]

Region	Critically Eroded Beaches (miles)	Critically eroded managed beaches (miles)	% of critically eroded beaches that are managed
Northeast Atlantic Coast	56.0	21.6	39
Central Atlantic Coast	82.7	45.3	55
Southeast Atlantic Coast	72.1	45.8	64
Florida Keys	10.2	1.5	15
Panhandle Gulf	84.3	51.9	62
Big Bend Gulf	2.3	0.2	9
Southwest Gulf	102.3	61.1	60
TOTAL	**409.9**	**227.4**	**56**

The table above summarizes the number of critical and non-critical erosion beaches, in miles, by region.

Additional information on the erosion areas for each coastal county fronting on the Atlantic Ocean, Gulf of Mexico, and Straits of Florida is available from FDEP, Bureau of Beaches and Coastal Systems. The listing of critical and non-critical erosion areas are identified by the Bureau's reference movement system (R numbers) or by virtual stations (V numbers). A few areas are not identified by either the R or V numbers because they are not included in the coastal construction control line program, nor have virtual stations been designated. These areas without R or V numbers are usually inlet shoreline areas, Florida Keys erosion areas, coastal bend erosion areas, and a few barrier islands in Pinellas, Hillsborough, and Collier counties.

It was recognized in previous plan updates to estimate losses related directly to erosion. This is because some erosion occurs long term, to be monitored over years, and some occurs quickly after just one storm. Additionally, damage from tropical storms and hurricanes is usually not directly because of erosion and the damages that are directly related to erosion are usually small, on private property and are not reported.

The FDEM, Mitigation FL, and DEP determined that a better way to estimate potential losses from erosion was to analyze the various projects and initiatives that DEP manages in order to protect and revitalize the state's beaches. The DEP program is authorized by Section 161.101, Florida Statutes. Since its inception in 1964, BMFA Program (formerly BECP) has been a primary source of funding to local governments for beach erosion control and preservation activities. Eligible activities include:

- Beach restoration and nourishment activities
- Project design and engineering studies
- Environmental studies and monitoring
- Inlet management planning
- Inlet sand transfer
- Dune restoration and protection activities

[109] http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/SBMP-Introduction.pdf

- Other beach erosion prevention-related activities consistent with the adopted Strategic Beach Management Plan

Below are the appropriations through the program for the last 10 years. This shows that losses from coastal erosion are consistently in the tens of millions of dollars each year.

Table 41: Beach Management Funding Program, Appropriations [110]

Fiscal Year	Allocation
FY 07/08	$47,416,188
FY 08/09	$21,935,695
FY 09/10	$15,000,000
FY 10/11	$16,536,535
FY 11/12	$16,251,074
FY 12/13	$21,863,814
FY 13/14	$37,456,300
FY 14/15	$47,271,537
FY 15/16	$32,106,500
FY 16/17	$32,562,424

8. Vulnerability Analysis and Loss Estimation, of State Facilities

A vulnerability analysis of state facilities to the coastal erosion hazard would not be appropriate. Coastal erosion occurs only in specific locations along the coastline and few, if not none, of the state facilities are located in these coastline areas. Because of this, the vulnerability analysis has shown that state facilities are not vulnerable to coastal erosion. Because the state facilities are not vulnerable to coastal erosion, there will not be a loss estimation of state facilities to coastal erosion.

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 11.

[110] FDEP BMFA grant program

<table>
<tr><th colspan="5">EROSION</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">Coastal erosion is the wearing away of land or the removal of beach or dune sediments by wave action, tidal currents, wave currents, or drainage. Waves generated by storms cause coastal erosion, which may take the form of long-term losses of sediment and rocks, or merely in the temporary redistribution of coastal sediments.</td><td rowspan="4">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>Low</td><td>Medium</td><td>Medium</td></tr>
</table>

Extreme Heat Hazard Profile

1. Extreme Heat Description

Extreme heat is defined as extended period where the temperature and relative humidity combine for a dangerous heat index.[111] Extreme heat events occur across the state each year. This hazard is focused on the effects to the human population, while drought focuses more on environmental interests.

Heat Index

The Heat Index is a measure of how hot the temperature feels when humidity is factored in with the actual temperature. The Heat Index chart is below. The red area indicates extreme danger. The NWS will begin to issue alerts when the heat index is expected to exceed 105-110 degrees Fahrenheit for at least two consecutive days.[112]

Figure 74: Heat Index

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

[111] http://www.nws.noaa.gov/os/heat/index.shtml

[112] http://www.nws.noaa.gov/os/heat/heat_index.shtml

Advisories

The National Weather Service issues the following heat-related advisories:

- Excessive Heat Outlook: issued when the potential exists for an excessive heat event within the next 3-7 days.
- Heat Advisory: issued within 12 hours of extremely dangerous heat conditions.
- Excessive Heat Watch: issued when conditions are favorable for an excessive heat event within the next 24 to 72 hours; this is used when the risk of a heat wave has increased but the timing is still uncertain.
- Excessive Heat Warning: issued within 12 hours of extremely dangerous heat conditions.

Heat Related Illness

Extreme heat can cause death by making it difficult for a body to cool itself. Heat illnesses occur when the body temperature increases too quickly to cool itself or when too much fluid or salt is lost through dehydration or sweating. Older adults, young children, and those who are sick or overweight are more likely to succumb to extreme heat. Below are the different types of heat-related illnesses.[113]

Heat Cramps

Heat Cramps are the first sign of a heat illness and can lead to more serious illnesses. Symptoms of heat cramps include muscular pains and spasms, usually in the legs or abdomen.

Heat Exhaustion

Heat exhaustion follows heat cramps if the body is not able to cool itself. Symptoms include heavy sweating; weakness; cool, pale, clammy skin; a fast and weak pulse; dizziness; nausea or vomiting; and fainting.

Heat Stroke

Heat stroke usually occurs by ignoring the signs of heat exhaustion and is life-threatening. Signs of heat stroke include extremely high body temperature, red skin, changes in consciousness, rapid and weak pulse, rapid shallow breathing, confusion, vomiting, and seizures. This occurs because the body becomes overwhelmed by heat and begins to stop functioning. There are two types of heat stroke, classical and exertional. Classical heat stroke occurs when an individual is unable to maintain thermal equilibrium due to medication, injury, chronic illness, or age. Exertional heat stroke occurs when young and healthy individuals are engaged in strenuous activity in hot and humid weather.

Additionally, other chronic illnesses may become exacerbated by heat-related illnesses. For example, those with cardiovascular disease and other heart conditions may not be able to tolerate the increased cardiac output associated with heat illnesses. People with mental health disorders and certain behavioral disorders, such as substance abuse, are at higher risk for morbidity and mortality during extreme heat

[113] http://www.nws.noaa.gov/om/hazstats.shtml#

events. Those with respiratory diseases and Type I and II diabetes are also at higher risk for morbidity and mortality with increased heat exposure.[114]

Frequency

This hazard was determined to occur annually, giving it a Frequency ranking of Very Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be High, meaning any deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Low, meaning little to no damage to property occurs.

This hazards Environment Magnitude was determined to be Low, meaning little to no damage to the environment occurs.

Potential Effects of Climate Change on Extreme Heat

Average global temperatures are expected to increase anywhere from 4 to 12 degrees Fahrenheit by the end of the 21st century.[115] Average global temperatures move in tandem with extreme temperatures, suggesting that in the future extreme heat events will become more frequent and last longer with an overall warming trend.

According to analysis of 360 U.S. cities and the combination of several climate model projections, Florida will likely see an increase in days when the heat index is above 105 degrees Fahrenheit by 2050. Cities in Florida that are expected to experience these extreme temperatures in 2050, more often than they do now include Fort Meyers, Naples, Punta Gorda, Miami, Lakeland, Tampa, Sarasota, Port St. Lucie, Orlando, Vero Beach, Ocala, Palm Bay, and Gainesville.[116] While it is likely that cycles of cool periods and warm periods will continue in the future, it is believed that the overall long-term trend is projected to be an increase in the number of extreme heat events.

2. Geographic Areas Affected by Extreme Heat

Due to the subtropical climate of Florida, the entire state has historically been vulnerable to extreme heat events. Because of the close proximity of large bodies of water, Florida typically experiences fewer days when the temperature reaches 100 degrees Fahrenheit or greater than many other states. However, the proximity to large bodies of water also increases the humidity, which decreases the body's ability to dissipate the heat. The hottest daytime temperatures tend to occur in the northern and interior areas of the state, away from the moderating influence of the Gulf of Mexico and the Atlantic Ocean.

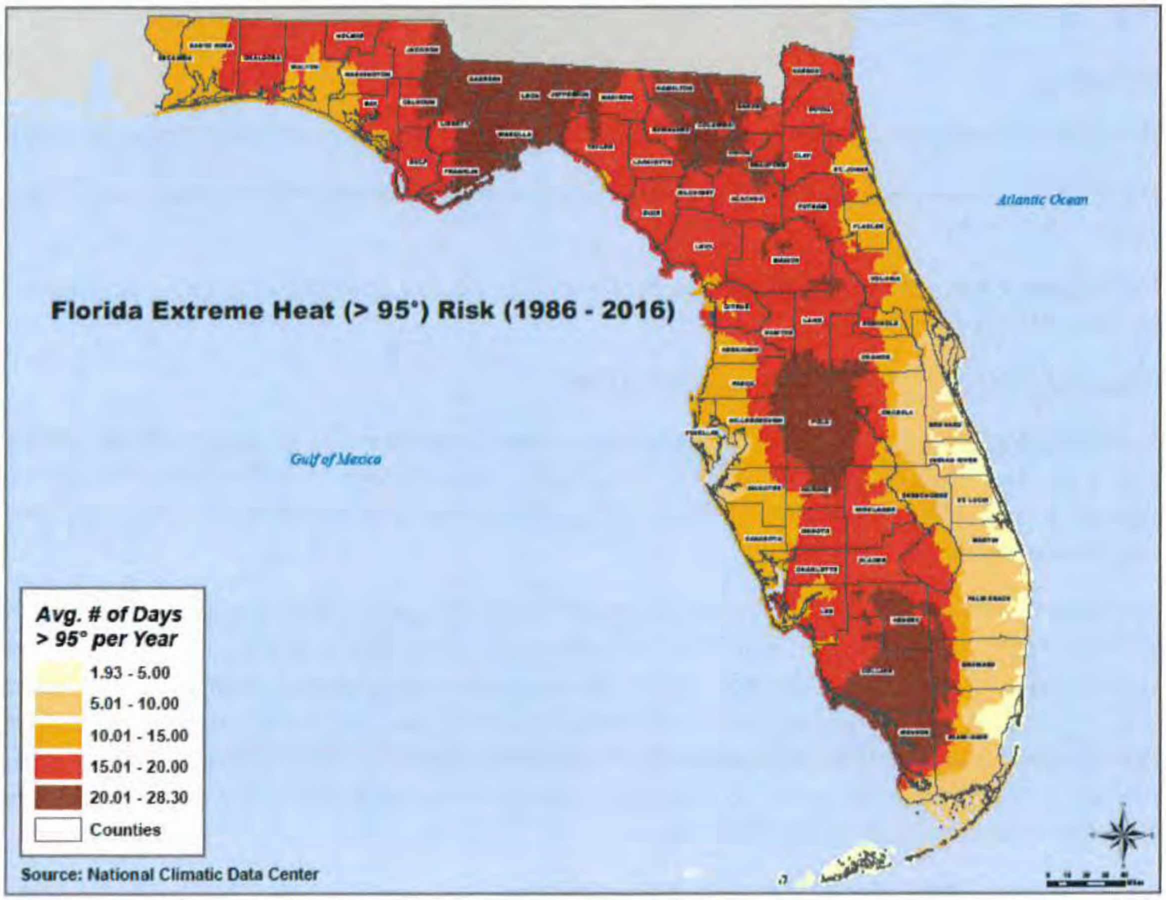
114 http://flbrace.org/images/docs/heat-profile.pdf

115 *(Karl et al. (Eds.). (2009). Global climate change impacts in the United States.* *https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf*

116 *http://www.climatecentral.org/news/sizzling-summers-20515*

Additionally, the expansion of urban development in large cities around the state has increased the magnitude of the urban heat island effect. A heat island occurs when concrete, asphalt, and heat absorbing buildings replace the natural environment.[117]

Figure 75: Florida Extreme Heat (>95 degrees) Risk, 1986 – 2016



The map above shows the average number of days with temperatures above 95 degrees each year. From this map, it is clear that most of Florida experiencing between 10 and 28 days of above 95 degree weather each year.

117 http://flbrace.org/images/docs/heat-profile.pdf

3. Historical Occurrences of Extreme Heat

Florida is known for its high humidity and heat, which combine to affect its population. According to NCEI, there have been 11 extreme heat occurrences since 2007. These extreme heat events sometimes lasted for more than one day and sometimes affected multiple counties.[118]

The table below shows various significant extreme heat incidents from 2006 to 2016.

Table 42: Florida Extreme Heat Occurrences, 2006-2016

Date	Description
August 2008	On August 8, heat advisories were issued in Santa Rosa, Escambia, and Okaloosa Counties for high temperatures and humidities. The heat index values were between 110 and 115 degrees.[119]
July 2010	On July 28, a heat wave began in Florida's panhandle. There were above normal temperatures and high humidity producing a heat index above 110 degrees Fahrenheit in Dixie, Franklin, Jackson, Taylor, Leon, and Bay Counties. Heat index values exceeded 115 degrees in a few locations on occasion.[120]
November 2011	In Mid-November in South Florida, there was unseasonably warm and humid weather, with heat index values in the mid to upper 80 degrees.[121]
July 2016	Seven cities from across Florida reported their hottest July on record.[122]

As stated above, NOAA tracks deaths related to weather events. According to their data, 1 person died from extreme heat in 2006, 2 people died in 2009, and 1 person died in 2010.[123]

Table 43: Significant Events before 2006

Date	Description
June 1998	Several long stretches of record-breaking high temperatures, including in Melbourne, Orlando, and Daytona Beach. Temperatures resulted in 1 death.
July 2000	July was the hottest month that had been recorded in northwest Florida. Several cities had multiple days of 100 degrees or higher, including Pensacola, Milton, and Niceville.[124]

118 https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Heat&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2007&endDate_mm=12&endDate_dd=31&endDate_yyyy=2016&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=12%2CFLORIDA

119 https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=54001

120 https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=253232

121 https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=354723

122 https://weather.com/news/weather/news/record-warm-south-july-2016

123 http://www.nws.noaa.gov/om/hazstats.shtml#

124 https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=348150

4. Probability of Future Occurrences of Extreme Heat

Based on historical analysis, incidents of extreme heat are expected to continue.

Extreme heat can occur throughout the state but typically occurs in the summer between the months of June and September.

As shown in the map above, most of Florida is likely to experience between 10 and 28 days of temperatures above 95 degrees. The panhandle, central Florida, and southwest Florida have the highest number of likely days per year with temperatures above 95 degrees, with between 20 and 28 days.

This hazard was determined to occur annually, giving it a Probability of Very Likely.

5. Extreme Heat Impact Analysis

- Public
  - Injury or death from overexposure, especially to infants, children, the elderly, those who are overweight, those with chronic illnesses, those who take certain medications
- Responders
  - Injury or death from over exertion in heat
- Continuity of Operations (including continued delivery of services)
  - Not likely to impact continuity of operations
- Property, Facilities, Infrastructure
  - Less efficient cooling systems or systems that must run constantly to effectively cool a building
- Environment
  - Faster evaporation
  - Damage to green spaces and agricultural lands
  - Death of plants and animals
- Economic Condition
  - Crop damage or loss
- Public Confidence in Jurisdiction's Governance
  - If people become ill or die from exposure to extreme heat, public may believe the government is not doing all that it can to help those in need, whether or not a cooling shelter was opened

6. 2018 LMS Integration

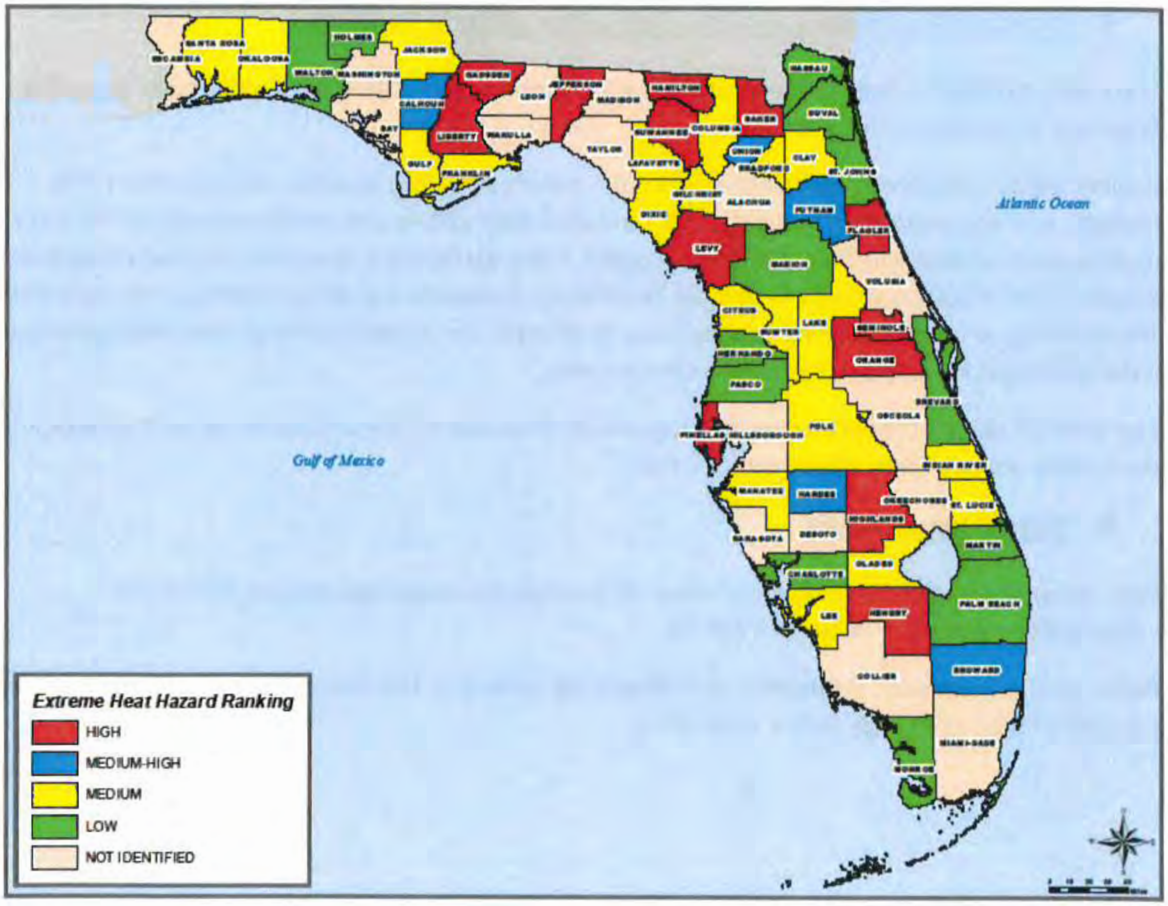
An analysis of all 67 Florida County LMS Plans and their individual Extrema Heat hazard rankings is shown below. Sixteen counties did not profile Extreme Heat as a hazard.

Extreme Heat

Based on the LMS plans, Figure 75 displays the jurisdictional rankings for the extreme heat hazard. Not all counties have identified extreme heat as one of their hazards.

- High-risk Jurisdictions: 13
- Medium-High-risk Jurisdictions: 5
- Medium-risk Jurisdictions: 20
- Low-risk Jurisdictions: 13
- Not identified Jurisdictions: 16

Figure 75: Extreme Heat Hazard Rankings by County



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

The Enhanced SHMP is required to evaluate the vulnerability of jurisdictions and estimate potential losses for each hazard. Below is the Vulnerability analysis and Loss Estimation of the state, by Jurisdiction, to Extreme Heat.

As shown in the map above and explained in the Geographic and Probability sections, most of Florida experiences between 10 and 28 days of temperatures above 95 degrees each year. Counties with the highest number of days with temperatures above 95 degrees, between 20 and 28, are Jackson, Calhoun, Liberty, Gadsden, Leon, Wakulla, Franklin, Jefferson, Madison, Taylor, Hamilton, Suwannee, Columbia, Baker, Union, Bradford, Alachua, Marion, lake, Orange, Polk, Pasco, Hillsborough, Osceola, Hardee, Hendry, Palm Beach, Broward, Collier, Miami-Dade, and Monroe.

The previous version of the plan grouped extreme heat and drought together. The SHMPAT did not conduct loss estimations by jurisdiction on extreme heat and drought in 2004 during the original plan development process. For extreme heat, the 2013 plan update does not include extreme heat-specific estimation by jurisdiction because structures are not vulnerable to extreme heat.

8. Vulnerability Analysis and Loss Estimation, of State Facilities

The Enhanced SHMP is required to evaluate the vulnerability and estimate potential losses regarding the State and its facilities across the state.

A vulnerability analysis on extreme heat was not conducted in 2004; however, in conjunction with drought, one was completed during the 2007 and 2010 plan update and revision process. In the 2013 update, extreme heat was separated from drought. Although facilities themselves are not vulnerable to extreme heat, the areas or regions that the facilities are located in may be susceptible to extreme heat. The efficiency at which a building operates may be affected (i.e. added load to building cooling systems) if the building is in an area vulnerable to extreme heat.

The SHMPAT did not conduct loss estimations on extreme heat for the 2013 plan because state facilities themselves are not vulnerable to extreme heat.

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 11.

EXTREME HEAT					Overall Vulnerability
Overview					
Extreme heat is defined as extended period where the temperature and relative humidity combine for a dangerous heat index.					HIGH
Frequency	Probability	Magnitude			
		Injuries/Deaths	Infrastructure	Environment	
Very Likely	Very Likely	High	Low	Low	

Drought Hazard Profile

1. Drought Description

Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage. While droughts are a normal and recurring feature of our climate, sometimes they can endanger vegetation, animals, and even people. There are several types of droughts, which will be discussed below[125].

- Meteorological droughts are based on the amount of dryness compared to normal for that region.
- Agricultural drought refers to agricultural concerns, such as precipitation shortages and reduced ground water.
- Hydrological drought refers to the hydrological effects from extended periods with precipitation deficits. These droughts take longer to occur than meteorological and agricultural droughts.
- Socioeconomic droughts occur when the demand for an economic good reliant upon water, such as fish, or hydroelectric power, exceeds supply as a result of a weather-related water shortfall.

Many factors of precipitation determine whether the rains will relieve a drought. For example, the timing and effectiveness of the rains. There is also a balance between precipitation and evapotranspiration that must be maintained to avoid a drought. Evapotranspiration is the sum of evaporation and transpiration, which is the release of water from plant leaves. High temperatures, high winds, and low relative humidity are also factors that can intensify a drought.

The agricultural industry is particularly vulnerable to the impacts of a drought because the crops depend on stored soil water and surface water.

Drought Indices and Measurements

One method to interpret drought is the Palmer Drought Severity Index (PDSI), which is based on the supply and demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the Palmer Drought Severity Index (PDSI), shown in Table 44, is to provide measurements of moisture conditions that are standardized so that comparisons using the index can be made between locations and between months.

The PDSI is most effective in determining long-term drought, over a matter of several months, and is not as reliable with short-term forecasts. It uses a 0 as normal, and drought is shown in terms of minus numbers; for example, minus 2 is moderate drought, minus 3 is severe drought, and minus 4 is extreme drought. The advantage of the PDSI is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions.

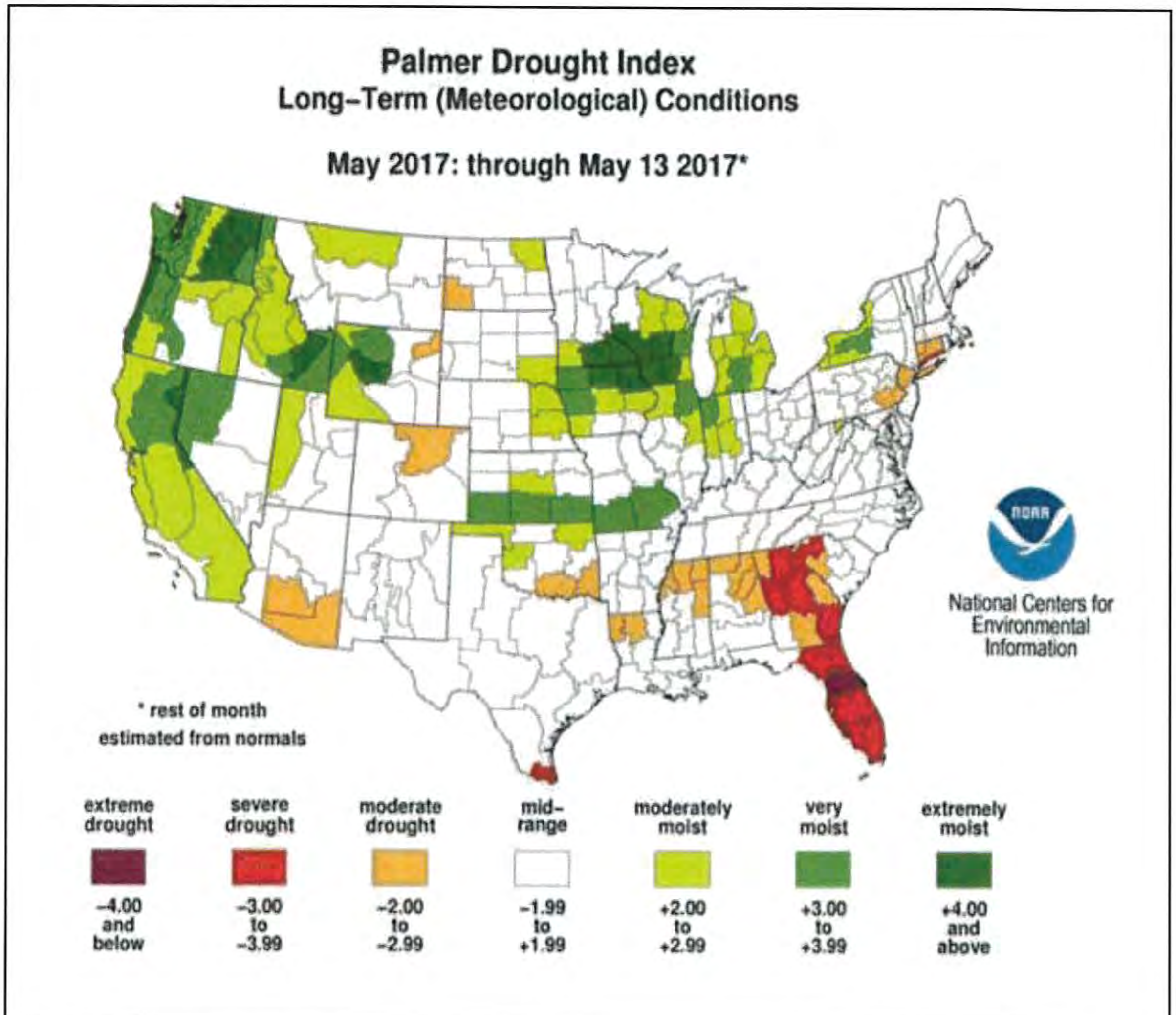
[125] http://www.nws.noaa.gov/os/brochures/climate/DroughtPublic2.pdf

Table 44: Palmer Drought Severity Index[126]

Term	Extreme drought	Severe drought	Moderate drought	Mid-range	Moderately moist	Very moist	Extremely moist
Numerical description	-4.00 and below	-3.00 to -3.99	-2.00 to -2.99	-1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above

Below is an example of the PDSI of the US from May 2017. [127]

Figure 76: Florida PDSI, May 2017



Another method to interpret drought is with the Keetch Byran Drought Index (KBDI). It is a reference scale for estimating the dryness of the soil and duff layers. The index increases for each day without rain and

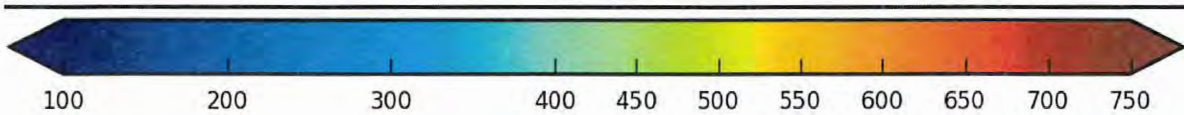
126 https://www.drought.gov/drought/data-maps-tools/current-conditions
127 https://www.ncdc.noaa.gov/temp-and-precip/drought/weekly-palmers/20170513

decreases when it rains and assumes there are 8 inches of saturated soil readily available to vegetation. The scale ranges from 0 (no moisture deficit) to 800.[128]

For different soil types, the depth of soil required to hold 8 inches of moisture varies (loam 30 inches, clay 25 inches, and sand 80 inches). A prolonged drought, meaning a high KBDI, can increase wildfire intensity because more fuel is available for combustion. In addition, the drying of organic material in the soil can lead to increased difficulty in fire suppression.

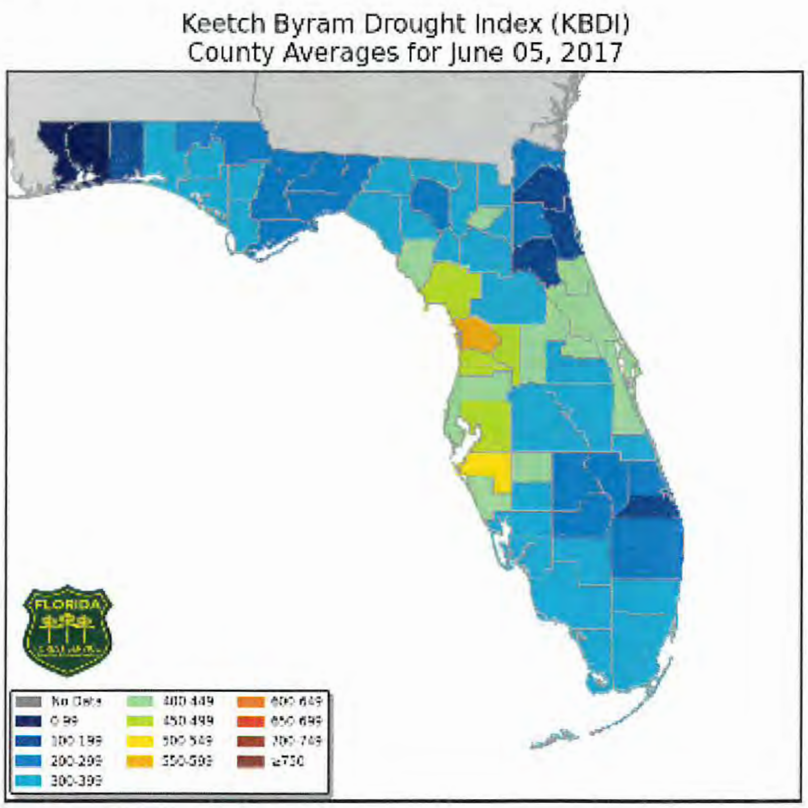
The index rating is displayed below[129].

Figure 77: Keetch Byran Drought Index



Below is an example of the KBDI for Florida from June 5, 2017.

Figure 78: Florida KBDI, June 2017[130]



[128] https://climatecenter.fsu.edu/

[129] http://currentweather.freshfromflorida.com/kbdi_4km.html

[130] http://currentweather.freshfromflorida.com/images/KBDI-countymeans-d0.png

There is also a U.S. Drought Monitor, which focuses on broad drought conditions across the entire United States. In this measurement, drought intensity is classified from D0 Abnormally Dry to D4 Exceptional Drought.

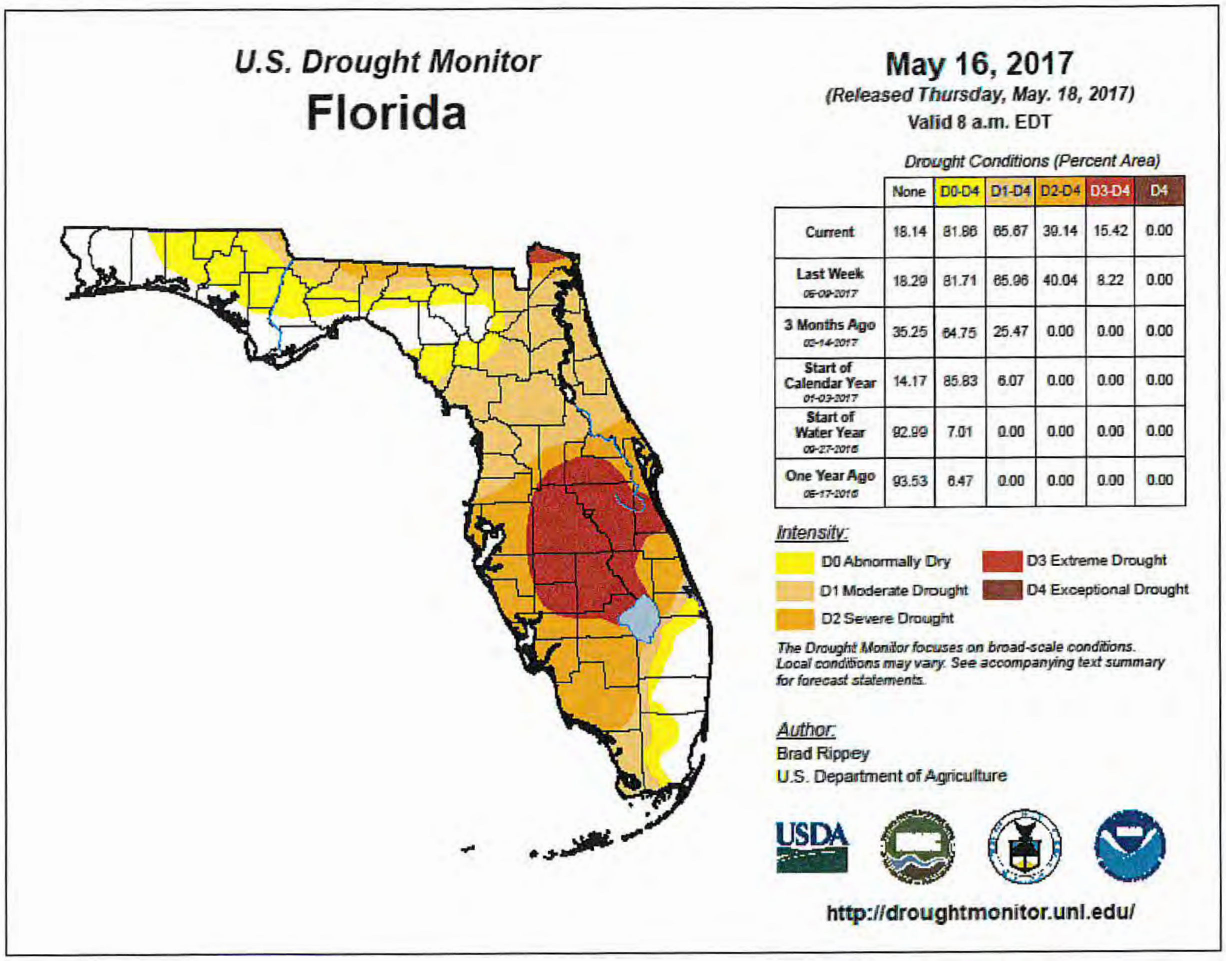
Table 45: United States Drought Monitor[131]

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: • Short-term dryness slows planting and growth of crops or pastures Coming out of drought • Some lingering water deficits • Pastures or crops are not fully recovered
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells are low; some water shortages are developing or imminent • Voluntary water-use restrictions requested
D2	Severe Drought	• Crop of pasture losses are likely • Water shortages are common • Water restrictions are imposed
D3	Extreme Drought	• Major crop or pasture losses • Widespread water shortages or restrictions
D4	Exceptional Drought	• Exceptional and widespread crop or pasture losses • Shortage of water in reservoirs, streams, and wells creating water emergencies

Below is an example of the drought monitor map for Florida from May 30, 2017.

[131] http://droughtmonitor.unl.edu/AboutUs/ClassificationScheme.aspx

Figure 79: Florida U.S. Drought Monitor, May 2017[132]



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	18.14	81.86	65.67	39.14	15.42	0.00
Last Week 05-09-2017	18.29	81.71	65.96	40.04	8.22	0.00
3 Months Ago 02-14-2017	35.25	64.75	25.47	0.00	0.00	0.00
Start of Calendar Year 01-03-2017	14.17	85.83	6.07	0.00	0.00	0.00
Start of Water Year 09-27-2016	92.99	7.01	0.00	0.00	0.00	0.00
One Year Ago 05-17-2016	93.53	6.47	0.00	0.00	0.00	0.00

Frequency

This hazard was determined to occur about every 5-10 years, giving it a Frequency ranking of Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be Low, meaning no injuries or deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Low, meaning little to no damage to property occurs.

This hazards Environment Magnitude was determined to be Medium, meaning some damage to the environment occurs.

132 http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?FL

Potential Effects of Climate Change on Drought

Changes in rates of precipitation, evaporation, and transpiration, may affect the duration and severity of drought events. A warmer climate would impact the hydrological cycle by increasing rates of evaporation leading to a decrease in runoff rates associated with rainfall events. Moreover, increased rates of evapotranspiration would exacerbate current droughts as existing soil moisture and plant moisture would likewise increase moisture in the atmosphere potentially leading to more frequent rainfall events. Regional effects are expected to range widely and are difficult to predict.[133] It is widely believed that an overall warming trend may intensify and prolong droughts as they occur due to increased rates of evapotranspiration associated with higher temperatures.[134]

The Intergovernmental Panel on Climate Change forecasts with medium confidence both an increase in heavy rainfall periods as well as an increase in the duration of relatively dry periods for North America, particularly in the subtropics, such as Florida.[135] South Florida, in particular, may see increased dry and hot periods between heavy rainfall events, exacerbating the risk for drought.[136] However, there is significant uncertainty associated with these projections given the numerous factors that contribute to climatic variability.[137]

As stated in the flood hazard profile, the expected global pattern is for arid areas to become drier, meaning that droughts may occur more frequently and be more severe.

2. Geographic Areas Affected by Drought

The State of Florida experiences cyclical drought on a regular basis. Analyzing past events as well as the current drought conditions has proven that the drought conditions and the severity of drought conditions has been variable over the years, affecting the east, north, south, and central regions randomly and somewhat equally.

[133] *(Walsh and Wuebbles (2013). Our changing climate. In, Draft national climate assessment, pp. 25-103. https://www.globalchange.gov/sites/globalchange/files/NCAJan11-2013-publicreviewdraft-chap2-climate.pdf); p. 113.).*

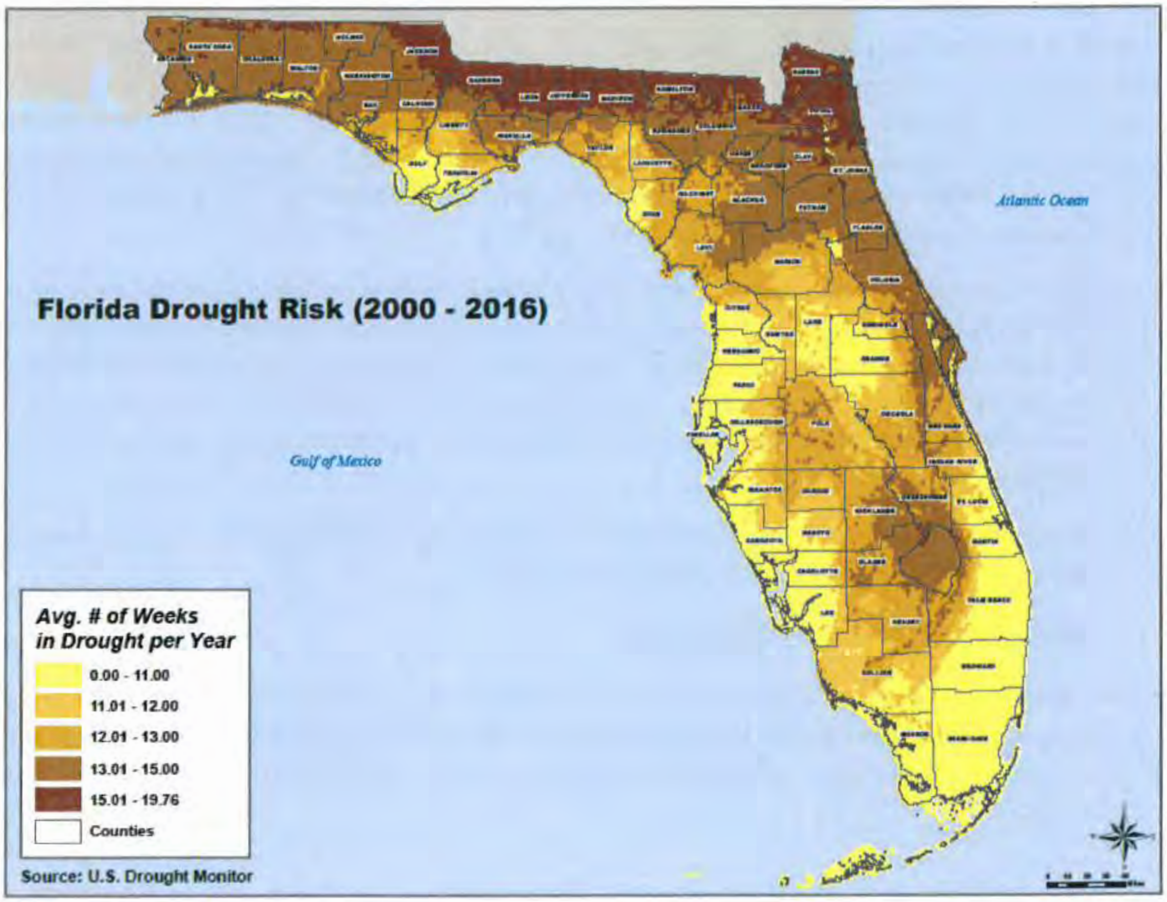
[134] *(Allen et al. (2012). Summary for policymakers. In Field et al. (Eds.), Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, pp. 3-21., https://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf, p. 13).*

[135] *(Seneviratne et al. (2012). Changes in climate extremes and their impacts on the natural physical environment. https://www.ipcc.ch/pdf/special-reports/srex/SREX-Chap3_FINAL.pdf); In Field et al. (Eds.), Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, pp. 109-230. https://www.ipcc.ch/pdf/special-reports/srex/SREX_FD_SPM_final.pdf, pp. 174-175.).*

[136] *(Karl et al. (Eds.) (2009). https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf).*

[137] *(Seager et al. (2009). http://journals.ametsoc.org/doi/full/10.1175/2009JCLI2683.1).*

Figure 80: Florida Drought Risk, 2000 – 2016



The map shows that northern Florida is likely to be impacted by drought. In fact, several counties are likely to experience between 15 and 19 weeks of drought each year, including Jackson, Gadsden, Leon, Jefferson, Madison, Hamilton, Baker, Nassau, Duval, and Clay. Most remaining panhandle counties, as well as a few south central Florida counties are expected to experience between 13 and 15 weeks of drought per year.

3. Historical Occurrences of Drought

Florida experienced a destructive drought from 1998 to 2001 where farm crops were ruined, forest fires burned, and lake levels reached an all-time low. In 2006–2007, rainfall deficits were the largest observed since the mid-1950s, which led to severe wildfires in 2007.

While drought is a common occurrence in Florida, there has never been a Presidential Major Disaster Declaration for drought in the State of Florida. However, there have been disaster declarations for agriculture from the USDA. Agriculture-related disasters are quite common and most counties in the US have been designated as disaster areas at some time since 2012. The disaster designation makes emergency loans and other emergency assistance programs available to producers suffering losses in those counties. As of 2012, a county can be designated as a disaster area when there is a severe drought

(D2) in any area of the county, during the growing season, for 8 consecutive weeks, or a higher intensity (D3+) for any length of time.[138] Below are the drought disaster designations for the state of Florida from 2012 to 2016[139] (earlier data was not available on the USDA website).

- 2012: all counties
- 2013: 42 counties
- 2014: 4 counties
- 2015: 10 counties
- 2016: 11 counties

More specifically, the table below explains various drought events within the last 10 years, from 2006 to 2016.

Table 46: Florida Drought Occurrences, 2006-2016

Date	Description
2006 – 2007	Drought conditions began to develop in 2006 across Florida because of less than average rainfall. In 2007, the drought was so severe it was considered a one in 25-year drought. The drought affected most of the state. The 2007 wildfire season was very active because of the extreme drought classification.[140]
2010 – 2012	Drought conditions began in central Florida in late 2010 and continued into mid-2012. The drought affected most of the state, but the northern central and the Panhandle regions of the state were in "extreme drought" for several months.[141]
2016 – 2017	Drought conditions developed in late 2016 and persisted into mid 2017 leading to several wildfires across the state.[142]

This table shows drought events before 2006, including the worst drought in Florida's recorded history from 1954 to 1956. As well as the severe drought from 1998 to 2001.

Table 47: Drought Occurrences before 2006

Date	Description
1954-1956	The most extreme drought in Florida on record occurred during 1954–1956 when runoff was 8 inches below normal, causing extensive loss of crops and timber. The Panhandle and northern central regions of the state were in a drought for most of 1955 and the almost the entire state was in drought for most of 1956.[143]

[138](https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/2017/emergency_disaster_designation_and_declaration_process_may2017.pdf

[139] https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/disaster-designation-information/index

[140] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/200601-200712

[141] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/201001-201212

[142] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/201601-201704

[143] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/195401-195612

1981-1982	Rainfall deficiencies caused the water levels in Lake Okeechobee reached the lowest levels ever recorded. In mid-1981, the entire state was in moderate or severe drought but most regions were out of drought by the end of the year.[144]
1998-2002	Lower than normal precipitation caused a severe long-term statewide drought in Florida lasting from 1998–2002. Within this timeframe, a severe drought affected southwest Florida from 2000 – 2001. This drought was particularly severe over the 5-year period in the northwest, northeast, and southwest regions of Florida. The drought became so severe that in 2001, the following actions were taken: • Three of Florida's five water management districts imposed mandatory cutbacks, strictly limiting water use. • Several municipalities hiked water-sewer rates, meaning even customers who cut back were paying more. • Restaurants in South Florida were ordered to stop serving water, except to diners who asked.[145]

4. Probability of Future Occurrences of Drought

Based on the previous occurrences of drought conditions in the state, the probability of future drought events occurring over the long term with some frequency remains high. As the state continues to develop with higher populations, higher water demands, and more demands related to agriculture and livestock, these drought conditions and drier trends may begin to have a profound impact on the state and its residents.

According to the Florida Drought Risk map above, most of north Florida is likely to experience between 13 and 20 weeks of drought each year. Central and South Florida, aside from the Lake Okeechobee area, is likely to receive between 0 and 13 weeks of drought each year.

This hazard was determined to occur about every 5-10 years, giving it a Probability ranking of Likely.

5. Drought Impact Analysis

- Public
  - Lack of water or water restrictions for personal use
  - Damage to property, such as grass and other vegetation dying from lack of water
- Responders
  - Lack of water to extinguish fires
- Continuity of Operations (including continued delivery of services)
  - Lack of water or water restrictions may impact the public use of water and wastewater utilities; the public may have to restrict their showering time and other water use in the restroom, restrict their water usage for cooking and drinking, and restrict from watering their gardens or lawns
- Property, Facilities, and Infrastructure
  - Facilities and infrastructure should not be affected by drought

[144] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/198001-198212
[145] https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/199801-200212

  - Property, such as green spaces, gardens, crops, etc. may be damaged from lack of water
- Environment
  - Areas such as green spaces, gardens, and forests may be damaged from drought
- Economic Condition
  - Crop damage or loss from drought can severely impact farmers and the agricultural economy, which can in turn affect the economy of an area if it is dependent upon the sales of the crops, like how Florida relies upon the sales of citrus
  - Employment loss due to lower demand for services such as landscaping, lawn care, car wash, etc.
- Public Confidence in the Jurisdiction's Governance
  - The public may lose confidence in the jurisdiction's governance if there is not a plan in place to deal with lack of water or water restrictions

6. 2018 LMS Integration

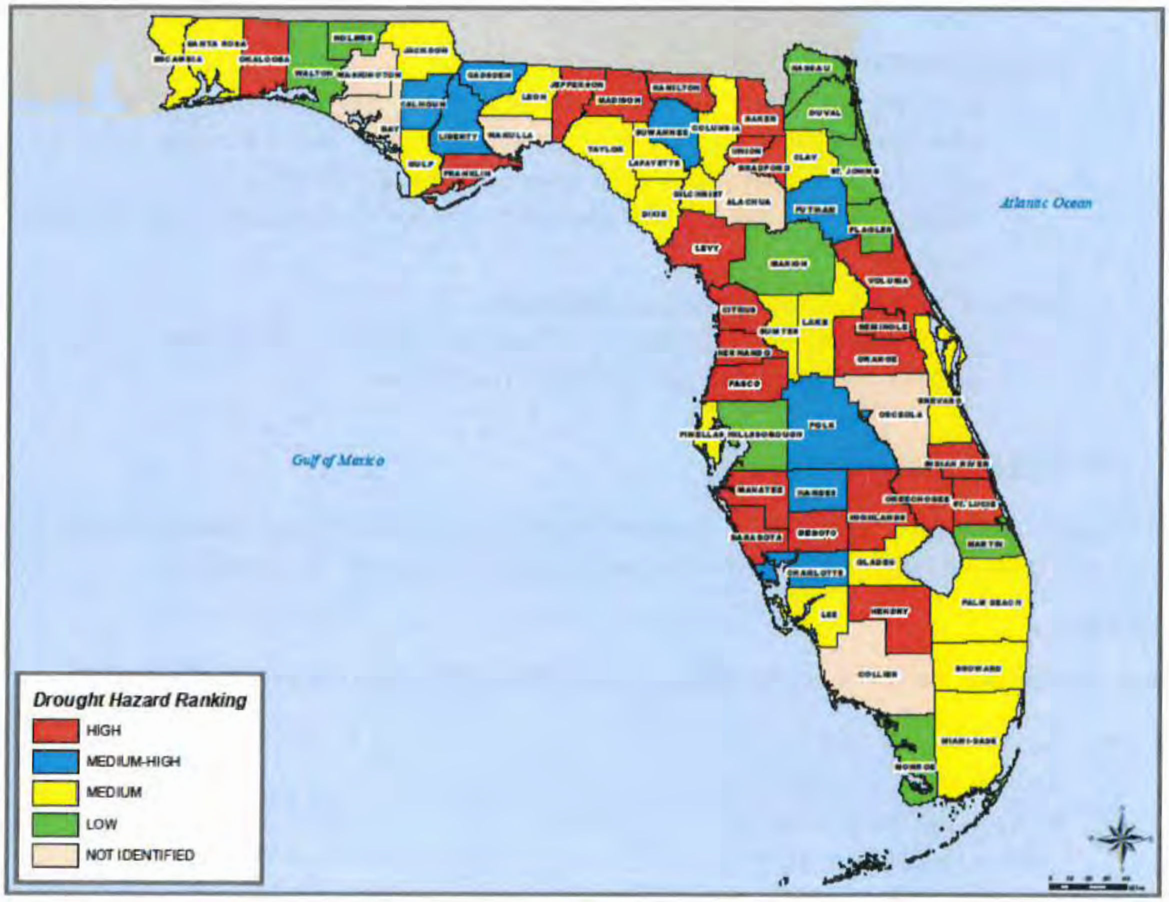
An analysis of all 67 Florida County LMS Plans and their individual drought hazard rankings is shown below. Six counties did not profile drought, while 23 included drought as a high risk hazard.

Drought

Based on the LMS plans, Figure 3.38 displays the jurisdictional rankings for the drought hazard.

- High-risk Jurisdictions: 23
- Medium-High-risk Jurisdictions: 8
- Medium-risk Jurisdictions: 20
- Low-risk Jurisdictions: 10
- Not identified Jurisdictions: 6

Figure 81: Drought Hazard Rankings



7. Vulnerability Analysis and Loss Estimation, by Jurisdiction

The Enhanced SHMP is required to evaluate the vulnerability of jurisdictions and estimate potential losses for each hazard. Below is the Vulnerability analysis and Loss Estimation of the state, by Jurisdiction, to Drought.

Vulnerability

According to the Drought Risk map shown above, as discussed in the Geographic and Probability section, most of north Florida is likely to experience at least 13 weeks of drought each year. Vulnerable counties include Escambia, Santa Rosa, Okaloosa, Walton, Holmes, Washington, Bay, Jackson, Calhoun, Liberty, Gadsden, Wakulla, Leon, Jefferson, Madison, Taylor, Hamilton, Suwannee, Lafayette, Columbia, Baker, Nassau, Duval, Union, Bradford, Clay, St. Johns, Alachua, Putnam, Flagler, Volusia, Marion, and Levy. Other vulnerable counties include Highlands, Okeechobee, Martin, Glades, Palm Beach, and Hendry.

Loss estimation information was unavailable for the 2018 risk assessment update. The 2013 SHMP concluded that several drought impacts would result in losses. For example, the agricultural sector could experience significant economic loss due to crop losses caused by lack of water. Additionally, the lack of water could affect pasturelands and in turn affect livestock. Drought can also increase the likelihood of wildfires and lower water levels in canals and other surface waters which could inhibit the ability to fight fires in rural areas.

During the last several SHMP updates, it was noted that there is a lack of sufficient data to fully estimate losses for drought. It recognized that some droughts are temporary and localized, with minimal or no subsequent losses, and that some have been statewide and prolonged, with extreme financial impact to the state. To collect better data for improved loss estimations during the next plan revision cycle, the team has agreed to work closely with these agencies involved in the state's Drought Action Plan:

- Department of Environmental Protection
- Division of Emergency Management
- Department of Agriculture and Consumer Services
- State Water Management Districts

The entire state continues to be vulnerable to cyclical drought, with the northern portion having a higher overall risk factor. The vulnerability to drought is different from the other vulnerabilities considered in this plan since the majority of the built environment is not vulnerable to this hazard.

The primary vulnerability to drought is the robust agricultural sector of the state. Both short-term drought during critical times in the growth cycle and long-term drought over many years affect the farmers.

Availability of water during drought conditions is controlled largely by the topography, geology, hydrogeology, and hydrology of an area. Because these factors vary considerably by physiographic regions in Florida, drought vulnerability can be generally assessed by physiographic region. Local conditions, such as the availability of a large impoundment for water storage, may affect drought vulnerability on a local scale.

National Climatic Data Center Drought Loss Estimation

Data from the NCDC was not complete. The drought events are listed in the database, however, not all the crop damage and loss information is included in the listings.

8. Vulnerability Analysis and Loss Estimation, of State Facilities

The Enhanced SHMP is required to evaluate the vulnerability and estimate potential losses regarding the State and its facilities across the state. The GIS team used the database of all state facilities and their values to provide the loss estimation data.

Vulnerability

Although facilities themselves are not vulnerable to drought, the areas or regions that the facilities are located in may be susceptible to drought. The efficiency at which a building operates may be affected (i.e., low water pressure) if the building is in a drought-stricken area.

Loss Estimation

The SHMPAT did not conduct loss estimations on drought because the facilities themselves are not vulnerable to drought.

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 Medium, with a score of 8.

<table>
<tr><th colspan="5">DROUGHT</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Overview</th></tr>
<tr><td colspan="5">Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage. While droughts are a normal and recurring feature of our climate, sometimes they can endanger vegetation, animals, and even people.</td><td rowspan="5">MEDIUM</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>Likely</td><td>Likely</td><td>Low</td><td>Low</td><td>Medium</td></tr>
</table>

Geological Event Hazard Profile

1. Geological Event Description

This profile will discuss landslides and sinkholes. In the 2013 update, the SHMP combined sinkholes, landslides and earthquakes. For the 2018 update, Mitigate FL decided to keep landslides and sinkholes together and re-name the profile Geological Events, and create a new hazard named Seismic.

Landslides

Landslides are rock, earth, or debris flows down slopes due to gravity. They can occur on any terrain given the right conditions of soil, moisture, and the angle of slope. Integral to the natural process of the Earth's surface geology, landslides serve to redistribute soil and sediments in a process that can be in abrupt collapses or in slow gradual slides. Also known as mud flows, debris flows, earth failures, and slope failures, landslides can be triggered by rains, floods, earthquakes, and other natural causes as well as human-made causes including grading, terrain cutting and filling, and excessive development.[146]

Because the factors affecting landslides can be geophysical or human-made, they can occur in developed areas, undeveloped areas, or any area where the terrain was altered for roads, houses, utilities, or buildings.

The State of Florida has very low topographic relief, meaning that the state is flat. Because of this, landslides are not a significant natural hazard in Florida.[147] Any risk or vulnerability to people, property, the environment, or operations would be low.

Sinkholes

Sinkholes are landforms created when overburden subsides or collapses into fissures or cavities in underlying carbonate rocks. Florida is underlain by several thousand feet of carbonate rock, limestone, and dolostone, with a variably thick mixture of sands, clays, shells, and other near surface carbonate rock units, called overburden. Those several thousand feet of carbonate rocks are host to one of the world's most productive aquifers, the Floridian aquifer system. Erosional processes, physical and chemical, have created fissures and cavities within the rock. This has created Florida's karst topography, characterized by the presence of sinkholes, swallets, caves, submerged conduits, springs, and disappearing and reappearing streams. Sinkholes are unpredictable, as they can form rapidly, within minutes to hours, or slowly, within months to years.[148]

This profile will focus on the two common types of sinkholes in Florida, cover collapse sinkholes and cover subsidence sinkholes, because of their rate of formation and the risk they pose to human life and property.

[146] https://landslides.usgs.gov/learn/ls101.php

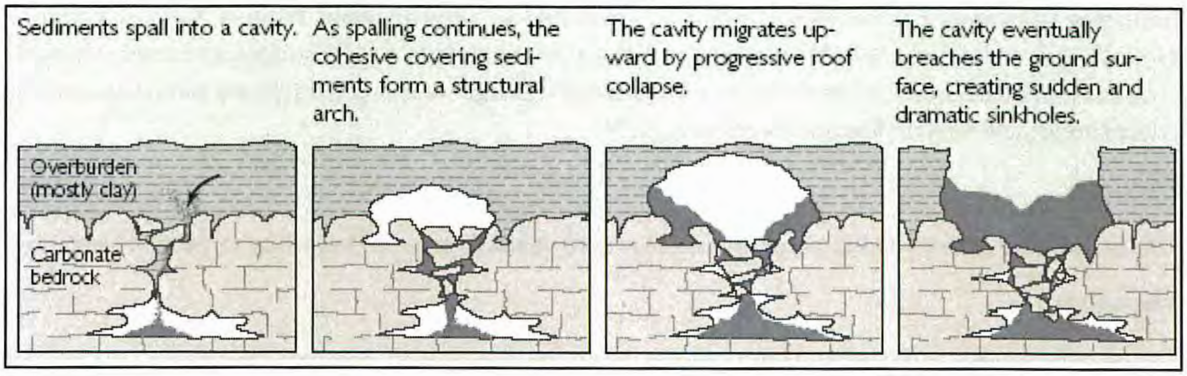
[147] http://www.dep.state.fl.us/geology/geologictopics/hazards/landslides.htm

[148] Florida Department of Environmental Protection Florida Geological Survey. (2017). The favorability of Florida's geology to sinkhole formation. Page 4 – 7.

Cover Collapse Sinkholes

Cover-collapse sinkholes may develop quickly and cause significant damage. These sinkholes develop when the ceiling of an underground cavity can no longer support the overlying weight, resulting in an abrupt collapse of the overburden into the cavity, thereby forming a hole in the land surface.[149] This occurs because over time, surface drainage, erosion, and deposition of materials develop a shallow bowl-shaped depression beneath the surface of the ground.

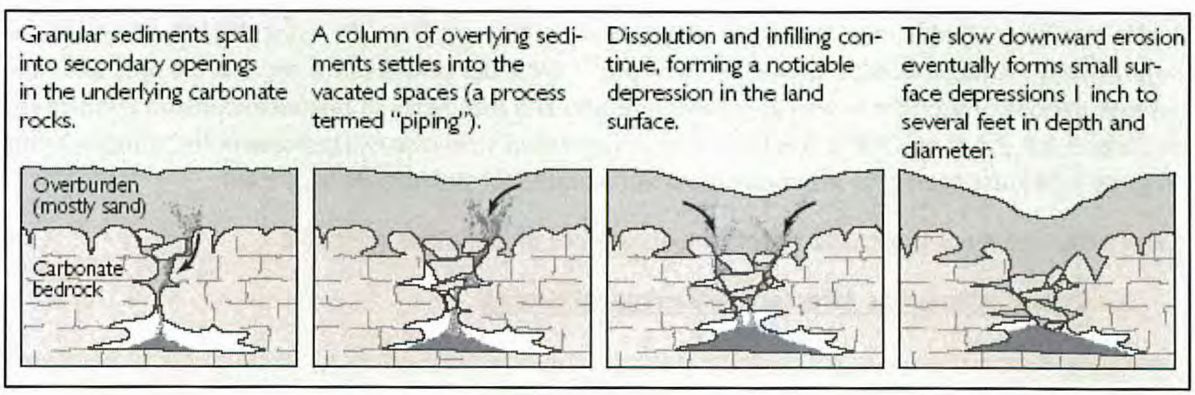
Figure 82: Cover Collapse Sinkholes[150]



Cover Subsidence Sinkholes

Cover-subsidence sinkholes develop more gradually, usually where the sediment is permeable and contains sand. The overburden slowly migrates down into the fissures and cavities in the underlying rock, which results in a depression in the land surface.[151]

Figure 83: Cover Subsidence Sinkholes[152]



[149] Florida Department of Environmental Protection Florida Geological Survey. (2017). *The favorability of Florida's geology to sinkhole formation.* Page 5.

[150] https://water.usgs.gov/edu/sinkholes.html

[151] Florida Department of Environmental Protection Florida Geological Survey. (2017). *The favorability of Florida's geology to sinkhole formation.* Page 4 – 7.

[152] https://water.usgs.gov/edu/sinkholes.html

Triggers

There are several triggers for sinkhole formation. For example, extended periods of drought can lead to sinkholes, especially if a heavy rain event occurs after an extended drought. Heavy rainfall can trigger sinkholes for several reasons. For example, heavy rainfall can add additional weight to overburden sediments above a cavity which could cause a failure of the cavity ceiling. Or heavy rainfall could collect in low lying areas adding to the weight and accelerating infiltration at that location, which could cause failure of a cavity ceilings. Additionally, heavy rainfall could saturate overburden sediments, making them soft, which could weaken the overburden sediments, causing failure of the cavity ceiling (sink report, 10). According to geologists, sinkholes can also be attributed to anthropogenic triggers, such as significant groundwater withdrawal; terraforming, which is the alteration of the earth's surface without realizing the area has thin overburden sediments; some stormwater management practices; heavy infrastructure over critical areas; and well drilling and development.[153]

Frequency

This hazard was determined to occur about every 5-10 years, giving it a Frequency ranking of Likely.

Magnitude

This hazards Injuries and Deaths Magnitude was determined to be High, meaning any deaths are recorded.

This hazards Infrastructure Magnitude was determined to be Medium, meaning significant damage to property occurs.

This hazards Environment Magnitude was determined to be Low, meaning little to no damage to the environment occurs.

Potential Effects of Climate Change on Sinkholes

Incidences of sinkholes increase either after severe storm events with associated flooding and soil saturation or during extended periods of drought.[154] With the potential for more prolonged and more intense periods of drought as well as greater intensity and frequency of rainfall and inland flooding *(see Sections 3.3.1, 3.3.3, and 3.3.5)*, it is likely that incidences of sinkholes will increase in the coming century in areas with karst geology or areas identified as favorable for sinkhole development.

Climate change is not expected to affect the occurrence of landslides in Florida.

2. Geographic Areas Affected by Geological Events

Landslides

Florida has low topographic relief and therefore is not affected by this hazard.

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[153] Florida Department of Environmental Protection Florida Geological Survey. (2017). *The favorability of Florida's geology to sinkhole formation.* Page 11.

[154] Dragoni and Sukhija (2008) *Climate change and groundwater: A short review.* Geological Society, London, Special Publications, 288, 1-12; Hyatt and Jacobs (1996). *Distribution and morphology of sinkholes triggered by flooding following Tropical Storm Alberto at Albany, Georgia, USA.* Geomorphology, 17, 305-316.

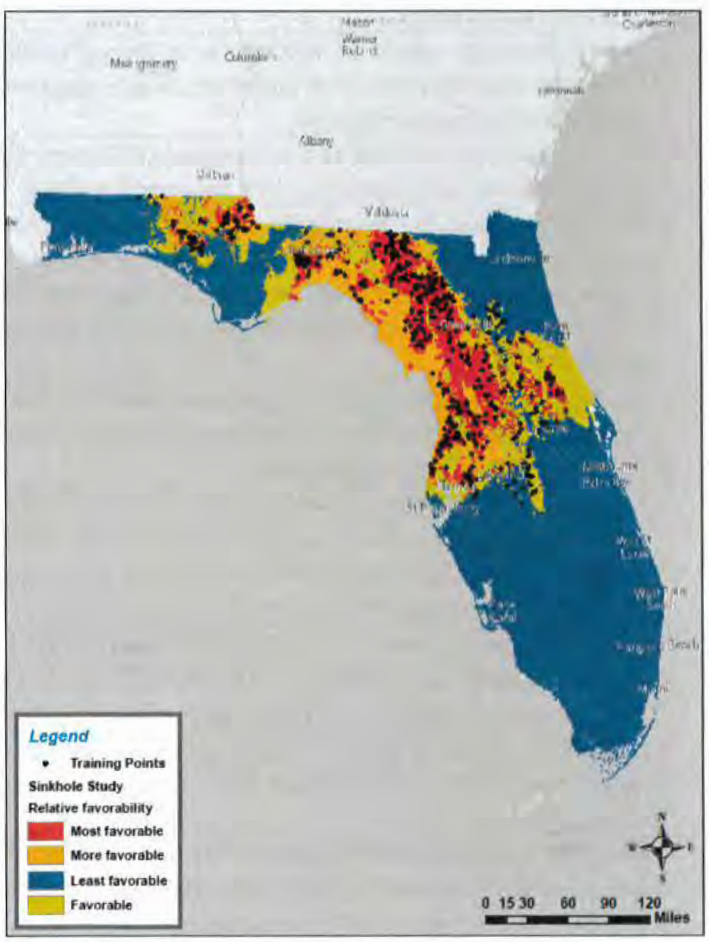
Sinkholes

Sinkholes are common wherever there is limestone terrain, but are rare in the southern part of the state. Central Florida and the Big Bend region have the largest incidence of sinkholes.

A report from FDEP aimed to determine the favorability of Florida's geography to sinkhole development. The results of the study show that 14% of the state is "favorable" to sinkholes, 10% is "more favorable" and 14% is "most favorable" to sinkholes. This was based on several factors, including already existing sinkholes, locations of thin overburden sediments, identification of closed circular topographic features, and locations with a small area between the top of soluble rock and the top of the water table.[155] The report does note however, that the analysis is not accurate or specific enough to determine whether a specific site will develop a sinkhole.

Below is the map from the report.

Figure 84: Favorability of Florida Geology to Sinkhole Formation



[155] Florida Department of Environmental Protection Florida Geological Survey. (2017). *The Favorability of Florida's Geology to Sinkhole Formation.* Page 23 – 24.

The map shows that the Big Bend region of the state, as well as portions of the northern central Panhandle are most favorable to geology that favors sinkhole development.

3. Historical Occurrences of Geological Events

Landslides

There has only been one landslide in Florida in recorded history. In 1948, a landslide occurred on a farm in Gadsden County.[156] No one was injured and no structures were damaged.

Sinkholes

There are several significant historical occurrences of sinkholes, listed below in Table 48.

Table 48: Florida Historical Occurrences, Sinkholes

Date	Event Description
1959	A collapse sinkhole in Keystone Heights, induced by drilling, led to the fatality of a drill hand.
1960	The US-19 bridge over the Anclote River in Tarpon Springs collapsed due to a collapse sinkhole in the river under the bridge supports, leading to one fatality and five people injured.
1967	A young teenage boy died due to a sinkhole in Tampa. It was unknown if the sinkhole formed suddenly or if it previously existed.
May 1981	A roughly circular, but elongated sinkhole formed in Winter Park, Florida, approximately 300 feet by 300 feet in size. The sinkhole swallowed one house, a shed, half of a swimming pool, a vehicle, several large oak trees, and a section of the crossing street, and an estimated four million cubic feet of soil.
September 16, 1999	Lake Jackson in Tallahassee, a nationally known bass fishing lake, experienced a sinkhole that suddenly drained more than half the lake, including water, fish, and alligators.
July 12, 2001	Emergency officials for Hernando County investigated 18 confirmed sinkholes that developed in one day across the area, affecting a 15-16 block residential area and causing extensive damage to one house. One of the largest holes measured between 50 and 100 feet deep.
June 2002	A 150-foot wide sinkhole forced the evacuation of part of a 450-unit apartment building in Orlando, and a Spring Hill woman saw a 40-foot wide hole open in a retention area behind her uninsured home.
June 8, 2009	A sinkhole developed at about 8:45 AM and forced the FDOT to close the northbound outside land of Route 29 near Hollywood, backing up traffic most of the day.
September 15, 2009	Less than 10 feet in width but more than 50 feet deep, this sinkhole was the first of many discovered in High Spring after a torrential downpour. The largest sinkhole measured 75 feet deep and more than a hundred feet across. About a half dozen more are clustered in the same area, with some

[156] http://dep.state.fl.us/geology/geologictopics/hazards/landslides.htm