Warren County- Southern part of unincorporated Warren County would impact agricultural fields

City of Marthasville- Bridges and roads would be impacted due to dam failure.

Village of Innsbrook has lots of lakes and therefore any breach would impact the area.

School District of Washington which serves part of Warren County doesn't have school buildings in the planning area. Due the geography and location of major roads, dam breach is a concern. In addition, the Washington Regional Airport and MO 47 / MO 94 highways are vulnerable to closure and erosion during dam failure.

Problem Statement

Areas at risk in Warren County are very limited and for the most part concentrated around the Village of Innsbrook and the City of Marthasville which are the only areas with a concentration of structures in the inundation area. It will be helpful for residents near the high hazard dams to get familiarized with the dam's Emergency Action Plan (EAP) and work closely with County EOP & participate in dam emergency exercises.

3.4.4 Earthquakes

Hazard Profile

Hazard Description

An earthquake is a sudden motion or trembling that is caused by a release of energy accumulated within or along the edge of the earth's tectonic plates. Earthquakes occur primarily along fault zones and tears in the earth's crust. Along these faults and tears in the crust, stresses can build until one side of the fault slips, generating compressive and shear energy that produces the shaking and damage to the built environment. Heaviest damage generally occurs nearest the earthquake epicenter, which is that point on the earth's surface directly above the point of fault movement. The composition of geologic materials between these points is a major factor in transmitting the energy to buildings and other structures on the earth's surface.

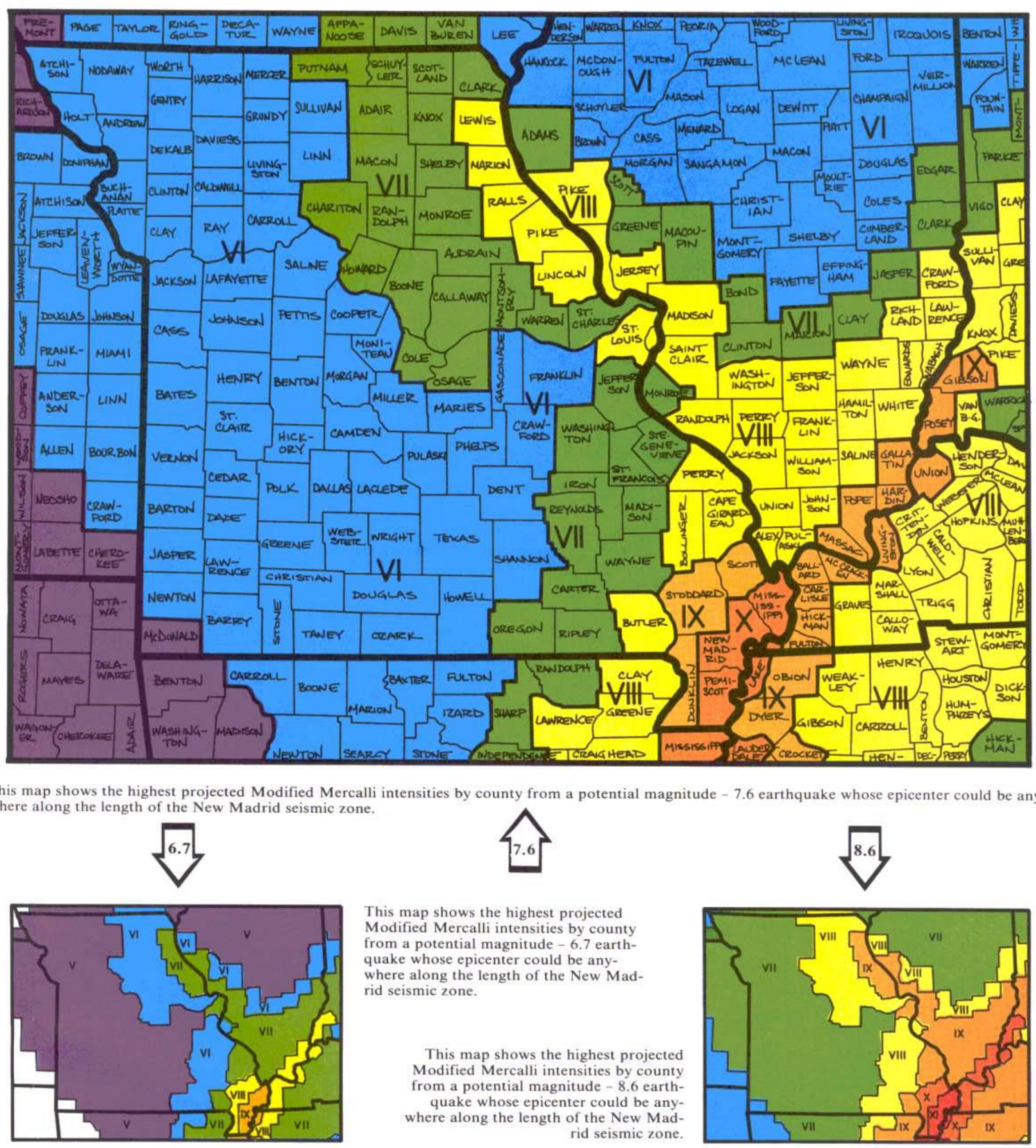
Eight earthquake seismic zones are located in the central United States, two of which are located in Missouri. The most active zone is the New Madrid Seismic Zone, which is also the most active seismic area in the United States east of the Rocky Mountains according to the U.S. Geological Survey. The New Madrid Zone is by some measures as high a risk for tremors as seismic zones in California. It runs from northern Arkansas through southeast Missouri and western Tennessee and Kentucky to the Illinois side of the Ohio River Valley. During the winter of 1811-1812 three earthquakes estimated to have been magnitude 7.5 or greater were centered in the New Madrid fault in the Bootheel region of southeast Missouri. Thousands of aftershocks continued for years.

Significant earthquakes, each about magnitude 6, occurred in 1843 near Marked Tree, Arkansas, and on October 31, 1895 near Charleston, Missouri. In November 1968 a magnitude 5.5 earthquake centered in southeastern Illinois caused moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. The quake was felt in areas that include all or portions of 23 states. Other earthquakes have occurred throughout southeastern parts of Missouri. Smaller, but still destructive earthquakes are even more likely, according to the Missouri Seismic Safety Commission.

Geographic Location

Of the potential earthquake risk zones, the New Madrid Fault Zone is the most likely to impact Warren County. The following figure illustrates the highest projected Modified Mercalli intensities by county from a potential magnitude 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid Seismic Zone.

Figure 3.9. Impact Zones for Earthquake Along the New Madrid Fault



This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 6.7 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 8.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

Source: https://sema.dps.mo.gov/docs/EQ_Map.pdf

Fortunately for Warren County, it lies within Category VII, meaning the effects of a New Madrid quake should be relatively minor.

Figure 3.10. Projected Earthquake Intensities

MODIFIED MERCALLI INTENSITY SCALE

I People do not feel any Earth movement.

II A few people might notice movement.

III Many people indoors feel movement. Hanging objects swing.

IV Most people indoors feel movement. Dishes, windows, and doors rattle. Walls and frames of structures creak. Liquids in open vessels are slightly disturbed. Parked cars rock.

V Almost everyone feels movement. Most people are awakened. Doors swing open or closed. Dishes are broken. Pictures on the wall move. Windows crack in some cases. Small objects move or are turned over. Liquids might spill out of open containers.

VI Everyone feels movement. Poorly built buildings are damaged slightly. Considerable quantities of dishes and glassware, and some windows are broken. People have trouble walking. Pictures fall off walls. Objects fall from shelves. Plaster in walls might crack. Some furniture is overturned. Small bells in churches, chapels and schools ring.

VII People have difficulty standing. Considerable damage in poorly built or badly designed buildings, adobe houses, old walls, spires and others. Damage is slight to moderate in well-built buildings. Numerous windows are broken. Weak chimneys break at roof lines. Cornices from towers and high buildings fall. Loose bricks fall from buildings. Heavy furniture is overturned and damaged. Some sand and gravel stream banks cave in.

VIII Drivers have trouble steering. Poorly built structures suffer severe damage. Ordinary substantial buildings partially collapse. Damage slight in structures especially built to withstand earthquakes. Tree branches break. Houses not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Temporary or permanent changes in springs and wells. Sand and mud is ejected in small amounts.

IX Most buildings suffer damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks conspicuously. Reservoirs suffer severe damage.

X Well-built wooden structures are severely damaged and some destroyed. Most masonry and frame structures are destroyed, including their foundations. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, and lakes. Railroad tracks are bent slightly. Cracks are opened in cement pavements and asphalt road surfaces.

XI Few if any masonry structures remain standing. Large, well-built bridges are destroyed. Wood frame structures are severely damaged, especially near epicenters. Buried pipelines are rendered completely useless. Railroad tracks are badly bent. Water mixed with sand, and mud is ejected in large amounts.

XII Damage is total, and nearly all works of construction are damaged greatly or destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move. Lakes are dammed, waterfalls formed and rivers are deflected.

Intensity is a numerical index describing the effects of an earthquake on the surface of the Earth, on man, and on structures built by man. The intensities shown in these maps are the highest likely under the most adverse geologic conditions. There will actually be a range in intensities within any small area such as a town or county, with the highest intensity generally occurring at only a few sites. Earthquakes of all three magnitudes represented in these maps occurred during the 1811 - 1812 "New Madrid earthquakes." The isoseismal patterns shown here, however, were simulated based on actual patterns of somewhat smaller but damaging earthquakes that occurred in the New Madrid seismic zone in 1843 and 1895.

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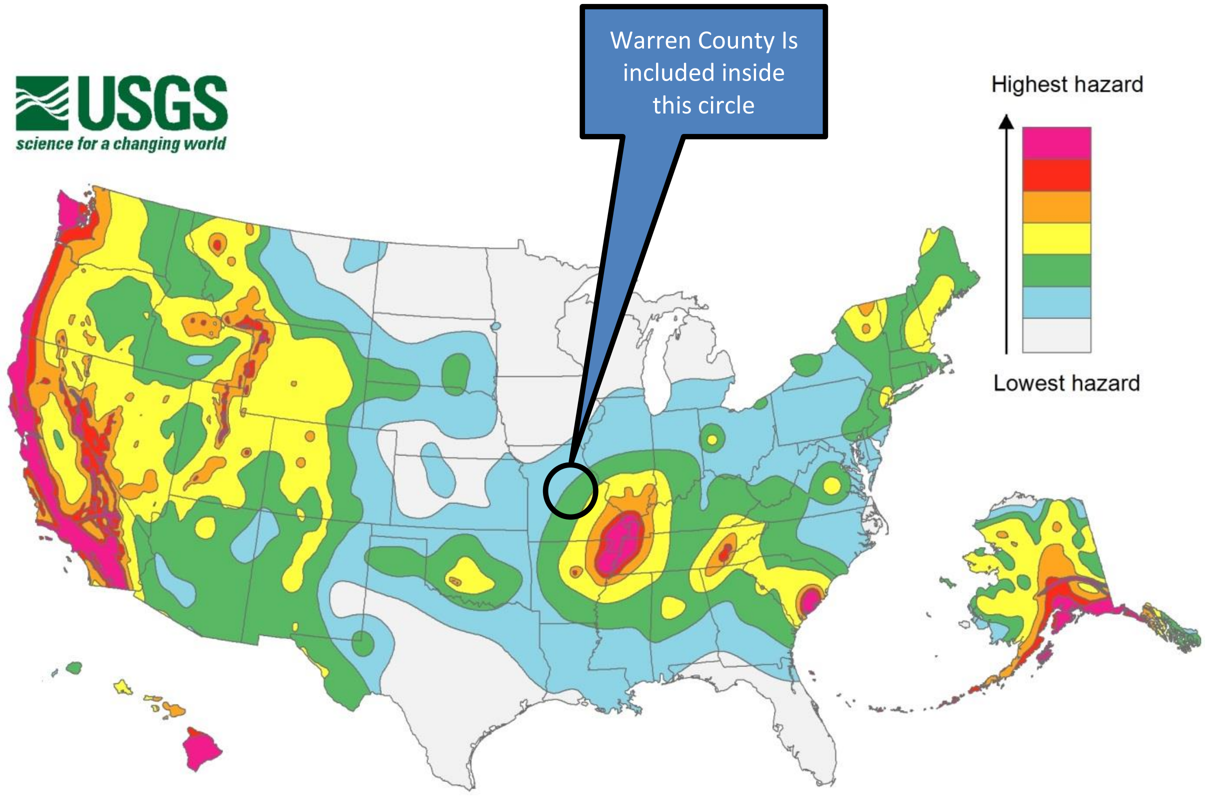
The following figure shows seismicity in the United States. Warren County is located within the small blue ring on the map.

Figure 3.11. United States Seismic Hazard Map



Source: United States Geological Survey at
https://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg

Strength/Magnitude/Extent

The extent or severity of earthquakes is generally measured in two ways: 1) the Richter Magnitude Scale is a measure of earthquake magnitude; and 2) the Modified Mercalli Intensity Scale is a measure of earthquake severity. The two scales are defined as follows.

Richter Magnitude Scale

The Richter Magnitude Scale was developed in 1935 as a device to compare the size of earthquakes. The magnitude of an earthquake is measured using a logarithm of the maximum extent of waves recorded by seismographs. Adjustments are made to reflect the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, comparing a 5.3 and a 6.3 earthquake shows that the 6.3 quake is ten times bigger in magnitude. Each whole number increase in magnitude represents a tenfold increase in measured amplitude because of the logarithm. Each whole number step in the magnitude scale represents a release of approximately 31 times more energy.

Modified Mercalli Intensity Scale

The intensity of an earthquake is measured by the effect of the earthquake on the earth's surface. The intensity scale is based on the responses to the quake, such as people awakening, movement of furniture, damage to chimneys, etc. The intensity scale currently used in the United States is the Modified Mercalli (MM) Intensity Scale. It was developed in 1931 and is composed of 12 increasing levels of intensity. They range from imperceptible shaking to catastrophic destruction, and each of the twelve levels is denoted by a Roman numeral. The scale does not have a mathematical basis, but is based on observed effects. Its use gives the laymen a more meaningful idea of the severity.

Previous Occurrences

According to Homefacts.com, there have been no recorded earthquakes in Warren County since 1931. In addition, the University of Memphis Center for Earthquake Research and Information shows no recent quakes within 100 miles of Warren County nor any record of earthquake damage.

Probability of Future Occurrence

There have been no earthquakes recorded in Warren for 85 years thereby the probability of an earthquake occurring in Warren County as 0 in any given year. Homefacts.com calculates the probability of a magnitude 5.0 or greater earthquake within the next 50 years at .74%

The two-percent probability of exceedance in 50 years map of peak ground acceleration (PGA) found at: https://earthquake.usgs.gov/hazards/hazmaps/conterminous/index.php#2014 shows peak ground acceleration as .1% of standard gravity. This indicates a low risk of an earthquake.

Changing Future Conditions Considerations

Chapter 3, Section 3.3.1., page 3-202 of the 2018 State Plan states, "Scientists are beginning to believe there may be a connection between changing climate conditions and earthquakes. Changing ice caps and sea-level redistribute weight over fault lines, which could potentially have an influence on earthquake occurrences. However, no studies quantify the relationship to a high level of detail, so recent earthquakes should not be linked to climate change.

Vulnerability

Vulnerability Overview

The 2018 State Plan, Chapter 3, Section 3.3.4, State Vulnerability Overview, annualized loss for Warren County as $210,000, with per capita loss at $6,500.

Missouri is the third largest market for earthquake insurance among the states, exceeded only by California and Washington. A study by the U.S. Geological Survey estimates the probability of a magnitude 7.5 or greater earthquake in the New Madrid zone over the next 50 years is 7-10 percent. The probability of an earthquake exceeding magnitude 6 over the same period is 25-40 percent. A joint assessment by the Mid-America Earthquake Center of the University of Illinois and the Federal Emergency Management Agency predicts the New Madrid event could constitute the highest total economic loss of any natural disaster in U.S. history. Earthquake coverage is not included on most homeowners' insurance policies. It must be purchased as separate coverage, called an "endorsement." This type of insurance requires that the earthquake is the direct cause of damage to the property. Natural disasters can, in many instances, trigger other events that may also damage property. One example is earthquakes causing bodies of water to produce waves, resulting in flooding.

Earthquake insurance usually features two high deductibles: Rather than a dollar amount, it's a percentage of the cost of rebuilding the home and a separate deductible for the home's contents. Deductibles of 10-15 percent are common. For example, with a 15 percent deductible, the owner of a $200,000 home could expect to pay up to $30,000 in deductibles for damage to the dwelling before receiving any benefit from their earthquake insurance policy.

The material used to build the home can also determine premiums or whether your home is even insurable. For instance, rates may be cheaper for wood-frame homes, which withstand tremors better than homes made of masonry such as brick and stone. Single-story homes may also receive better rates as they tend to sustain less damage from an earthquake. Age of the home can also affect premiums. Some insurers will not offer earthquake insurance for masonry homes.

Potential Losses to Existing Development

The Hazus building inventory counts are based on the 2010 census data adjusted to 2014 numbers using the Dun & Bradstreet Business Population Report. Inventory values reflect 2014 valuations, based on RSMeans (a supplier of construction cost information) replacement costs. Population counts are 2010 estimates from the U.S. Census Bureau.

Impact of Previous and Future Development

Future development is not expected to increase the risk other than contributing to the overall exposure of what could become damaged as a result of an event.

Hazard Summary by Jurisdiction

Earthquake intensity is not likely to vary greatly throughout the planning area so the risk will be the same throughout. Damages could differ if there are structural variations in the planning area built-environment; however, each community has roughly the same built-environment.

Problem Statement

Warren County is at low probability of suffering an earthquake with only superficial damage forecast. It will be helpful for the communities that don’t have building codes to adopt them and the ones that have building codes to update if needed to incorporate potential damages to future development.

3.4.5 Drought

Hazard Profile

Hazard Description

Drought is generally defined as a condition of moisture levels significantly below normal for an extended period of time over a large area that adversely affects plants, animal life, and humans. A drought period can last for months, years, or even decades. There are four types of drought conditions relevant to Missouri, according to the State Plan, which are as follows.

- Meteorological drought is defined in terms of the basis of the degree of dryness (in comparison to some “normal” or average amount) and the duration of the dry period. A meteorological drought must be considered as region-specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.

- Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (e.g., streamflow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and ground water and reservoir levels. As a result, these impacts also are out of phase with impacts in other economic sectors.

- Agricultural drought focus is on soil moisture deficiencies, differences between actual and potential evaporation, reduced ground water or reservoir levels, etc. Plant demand for water depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.

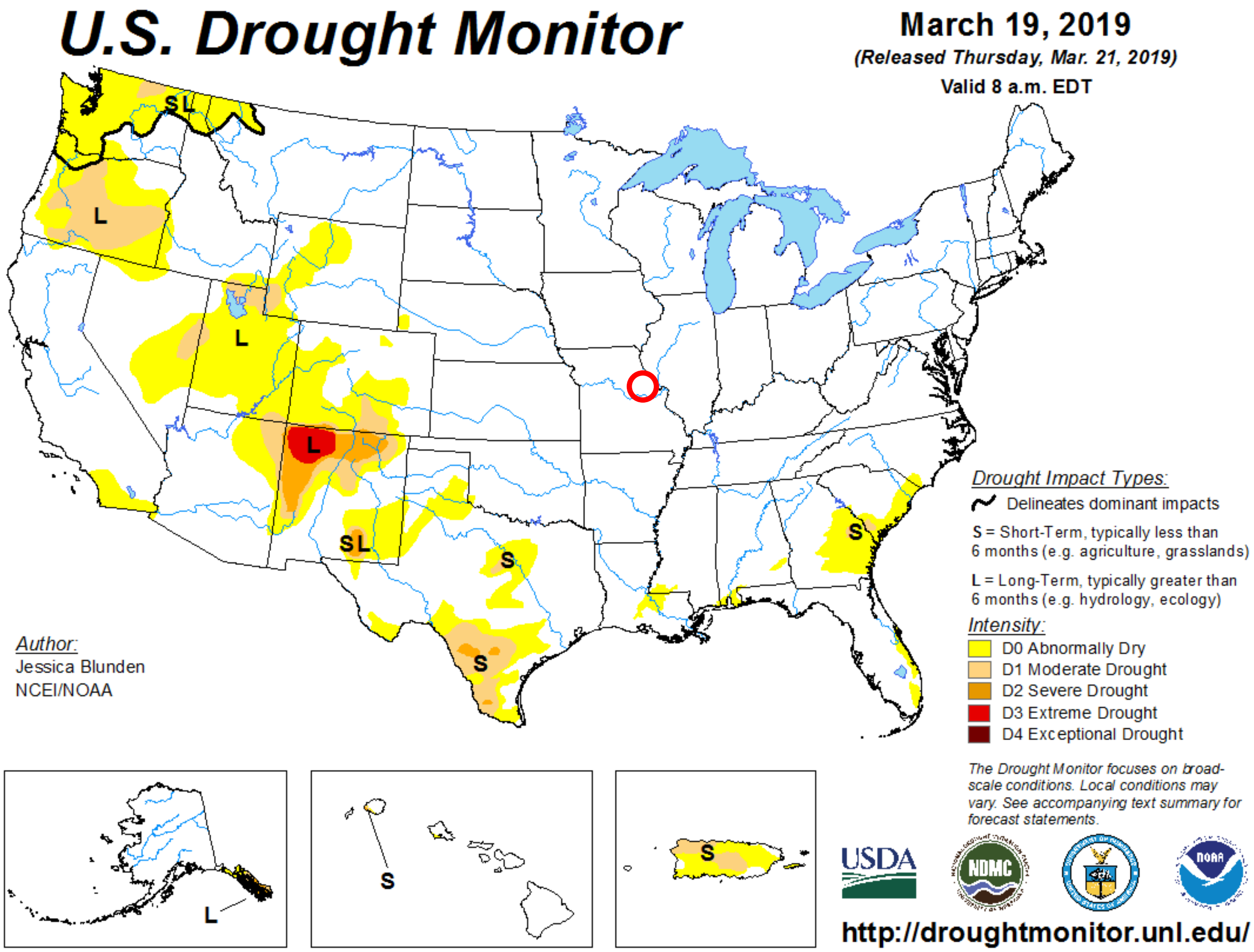
- Socioeconomic drought refers to when physical water shortage begins to affect people.

Geographic Location

The entire planning area is at risk to drought. Drought most directly impacts the agricultural sector which spreads evenly across the county, comprising 80% of surface land. There is no likelihood of this farmland being significantly reduced in the near term.

A recent map from the U.S. Drought Monitor shows a snapshot of the drought forecast for the planning area on March 21, 2019. Remember that it is only a snapshot of conditions at a given moment in time. A red circle shows the approximate location of the planning area.

Figure 3.12. U.S. Drought Monitor Map of Missouri on March 21, 2019



Source: U.S. Drought Monitor, https://droughtmonitor.unl.edu/Maps/MapArchive.aspx

Strength/Magnitude/Extent

The Palmer Drought Indices measure dryness based on recent precipitation and temperature. The indices are based on a “supply-and-demand model” of soil moisture. Calculation of supply is relatively straightforward, using temperature and the amount of moisture in the soil. However, demand is more complicated as it depends on a variety of factors, such as evapotranspiration and recharge rates. These rates are harder to calculate. Palmer tried to overcome these difficulties by developing an algorithm that approximated these rates and based the algorithm on the most readily available data — precipitation and temperature.

The Palmer Index has proven most effective in identifying long-term drought of more than several months. However, the Palmer Index has been less effective in determining conditions over a matter of weeks. It uses a “0” as normal, and drought is shown in terms of negative numbers; for example, negative 2 is moderate drought, negative 3 is severe drought, and negative 4 is extreme drought. Palmer's algorithm also is used to describe wet spells, using corresponding positive numbers.

Palmer also developed a formula for standardizing drought calculations for each individual location based on the variability of precipitation and temperature at that location. The Palmer index can therefore be applied to any site for which sufficient precipitation and temperature data is available.

Previous Occurrences

The table below shows crop losses attributable to drought from year 2000 to 2020. For the nearly 20-year period, crop losses due to drought totaled $8.29M.

Table 3.25 Drought Losses 2000 – 2020

Year	Acres	Dollars
2000	847.73	1,788.00
2001	856.96	31,089.00
2002	8,596.29	460,696.20
2003	2,867.60	156,194.40
2004	0.00	0.00
2005	5,928.15	307,623.20
2006	2,482.71	83,227.00
2007	6,675.58	361,704.34
2008	0.00	0.00
2009	0.00	0.00
2010	0.00	0.00
2011	9,029.07	646,578.21
2012	21,974.04	5,655,328.61
2013	4,734.20	353,614.00
2014	0.00	0.00
2015	86.61	8,842.80
2016	33.81	8,111.04
2017	511.82	36,351.10
2018	2,872.85	177,735.32
2019	0.00	0.00
2020	38.07	2,608.00
TOTAL	67,535.47	8,291,491.22

Source: USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/data/cause

The NOAA Storm Events database lists two long-term drought events between January 2000 and December 31, 2020. According to SEMA's Declared Disasters in Missouri website, there were no drought disasters declared between 1957 and 2017.

Probability of Future Occurrence

There is not enough consistent data to accurately calculate probability of occurrence. However, if we use the twenty one-year data from USDA in the chart above, we then have a range of 252 months of data. There are 15 years during which crop losses were reported. Assuming one month of drought for each of the 15 years, we then have 15 months. Hence, 15 months of 252 months were in drought, from which we can conclude an 5.95% change of drought in any given month. The 2018 State Plan forecasts Warren County to be in a severe drought or greater 9% -10.7% of the year.

Changing Future Conditions Considerations

Severe drought, a natural part of Missouri's climate, is a risk to the agriculture-dependent state. Although some predict climate change to increase precipitation, they also believe temperatures to rise thereby causing evaporation rates to burn off moisture thus increasing the potential for drought.

Vulnerability

Vulnerability Overview

The 2018 Missouri State Plan shows Warren County in Region B. Region B has moderate drought susceptibility. Groundwater resources are adequate to meet domestic and municipal needs, but crop irrigation well depths are prohibitively expensive. The State Plan ranks Warren County Drought Vulnerability as High.

Potential Losses to Existing Development

The National Drought Monitor Center at the University of Nebraska at Lincoln summarized the potential impacts of drought as follows: Drought can create economic impacts on agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to losses in yields in crop and livestock production, drought is associated with increases in insect infestations, plant disease, and wind erosion. Droughts also bring increased problems with insects and disease to forests and reduce growth. The incidence of forest and range fires increases substantially during extended droughts, which in turn place both human and wildlife populations at higher levels of risk. Income loss is another indicator used in assessing the impacts of drought because so many sectors are affected. Finally, while drought is rarely a direct cause of death, the associated heat, dust and stress can all contribute to increased mortality. The 2018 State Plan annualizes crop losses to Warren County at $1M to $1.27M per year.

Impact of Previous and Future Development

Warren County continues to experience a reduction in agricultural acreage with the land use shifting toward residential and recreational areas as well as some light industrial facilities. This will mitigate crop and livestock impacts but may increase impacts to people and industries. As of this date, this are no known large-scale development plans that could impact the water supply.

Changing Future Conditions Considerations

A new analysis, performed for the Natural Resources Defense Council, examined the effects of climate change on water supply and demand in the contiguous United States. The study found that more than 1,100 counties will face higher risks of water shortages by mid-century as a result of climate change. Two of the principal reasons for the projected water constraints are shifts in precipitation and potential evapotranspiration (PET). Climate models project decreases in precipitation in many regions of the U.S., including areas that may currently be described as experiencing water shortages of some degree.

Warren County continues to experience a reduction in agricultural acreage with the land use shifting toward residential and recreational areas as well as some light industrial facilities. This will mitigate crop and livestock impacts but may increase impacts to people and industries. As of this date, this are no known large-scale development plans that could impact the water supply.

Hazard Summary by Jurisdiction

No area of Warren County is at more risk than others, although, agriculture will face the most financial risk.

Problem Statement

Agriculture-related businesses in Warren County will continue to face the risk of drought due to the county's geographic location. It will be helpful for communities to promote about water conservation measures and notify the residents when drought conditions might occur.

3.4.6 Extreme Temperatures

Hazard Profile

Hazard Description

Extreme temperature events, both hot and cold, can impact human health and mortality, natural ecosystems, agriculture and other economic sectors. According to information provided by FEMA, extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. Ambient air temperature is one component of heat conditions, with relative humidity being the other. The relationship of these factors creates what is known as the apparent temperature. The Heat Index chart shown below uses both of these factors to produce a guide for the apparent temperature or relative intensity of heat conditions.

Extreme cold often accompanies severe winter storms and can lead to hypothermia and frostbite for people without adequate clothing protection. Cold can cause fuel to congeal in storage tanks and supply lines, stopping electric generators. Cold temperatures can also overpower a building's heating system and cause water and sewer pipes to freeze and rupture. Extreme cold also increases the likelihood for ice jams on flat rivers or streams. When combined with high winds from winter storms, extreme cold becomes extreme wind chill, which is hazardous to health and safety.

The National Institute on Aging estimates that more than 2.5 million Americans are elderly and especially vulnerable to hypothermia, with the isolated elders being most at risk. About 10 percent of people over the age of 65 have some kind of bodily temperature-regulating defect, and 3-4 percent of all hospital patients over 65 are hypothermic.

Also at risk, are those without shelter, those who are stranded, or who live in a home that is poorly insulated or without heat. Other impacts of extreme cold include asphyxiation (unconsciousness or death from a lack of oxygen) from toxic fumes from emergency heaters; household fires, which can be caused by fireplaces and emergency heaters; and frozen/burst pipes.

Geographic Location

Extreme heat and extreme cold are area-wide hazard events, and the risk of extreme heat and extreme cold does not vary across the planning area.

Strength/Magnitude/Extent

The National Weather Service (NWS) has an alert system in place (advisories or warnings) when the Heat Index is expected to have a significant impact on public safety. The expected severity of the heat determines whether advisories or warnings are issued. A common guideline for issuing excessive heat alerts is when for two or more consecutive days: (1) when the maximum daytime Heat Index is expected to equal or exceed 105 degrees Fahrenheit (°F); and the night time minimum Heat Index is 80°F or above. A heat advisory is issued when temperatures reach 105 degrees and a warning is issued at 115 degrees.

Figure 3.13. Heat Index (HI) Chart

NWS 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

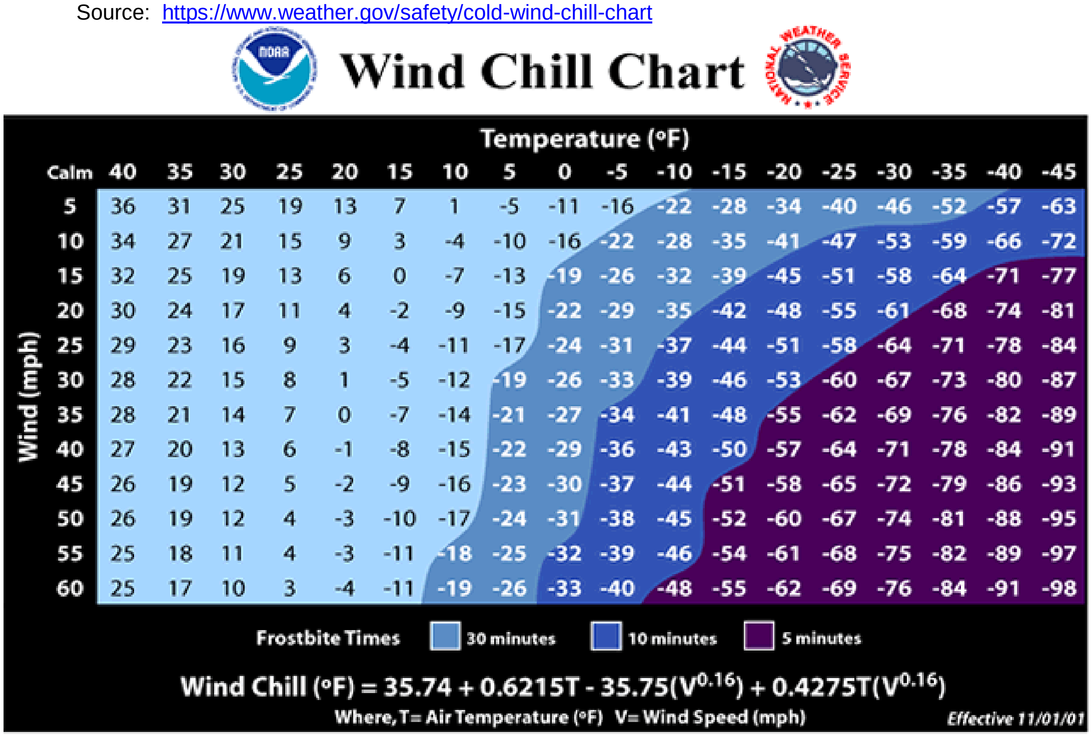
Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service (NWS); https://www.weather.gov/safety/heat-index
Note: Exposure to direct sun can increase Heat Index values by as much as 15°F. The shaded zone above 105°F corresponds to a HI that may cause increasingly severe heat disorders with continued exposure and/or physical activity.

The NWS Wind Chill Temperature (WCT) index uses advances in science, technology, and computer modeling to provide an accurate, understandable, and useful formula for calculating the dangers from winter winds and freezing temperatures. The figure below presents wind chill temperatures which are based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature.

Figure 3.14. Wind Chill Chart

Source: https://www.weather.gov/safety/cold-wind-chill-chart



Wind Chill Chart

Wind (mph) \ Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

Wind Chill (°F) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Previous Occurrences

The NOAA Storm Events database records one Extreme Cold/Wind Chill event and two Cold/Wind Chill events for the years 2000 through 2020. No deaths or injuries were recorded.

December 16, 2000 – Extreme Cold and Wind Chill was reported for Warren and surrounding counties.

January, 2010 – The first twelve days of January 2010 was one of the coldest outbreaks in many years. For some locations throughout the state, it was the first time the temperature dropped below zero in about 10 years.

January 6, 2014 - The winter storm that brought heavy snow to much of the area followed that up with the coldest temperatures in 20 years. Some of the temperatures include Warrenton at -12 degrees. Wind Chill values the morning of the 6th ranged from -25 to -33.

The same database reports 51 Heat/Excessive Heat events during the same period. These are summarized in the table that follows. Deaths and Injuries referenced "outside county" were reported from nearby jurisdictions. Deaths and Injuries reported as "inside county" denotes issues that occurred within the planning area.

Table 3.26 Heat Events in Warren County, 2000-2020

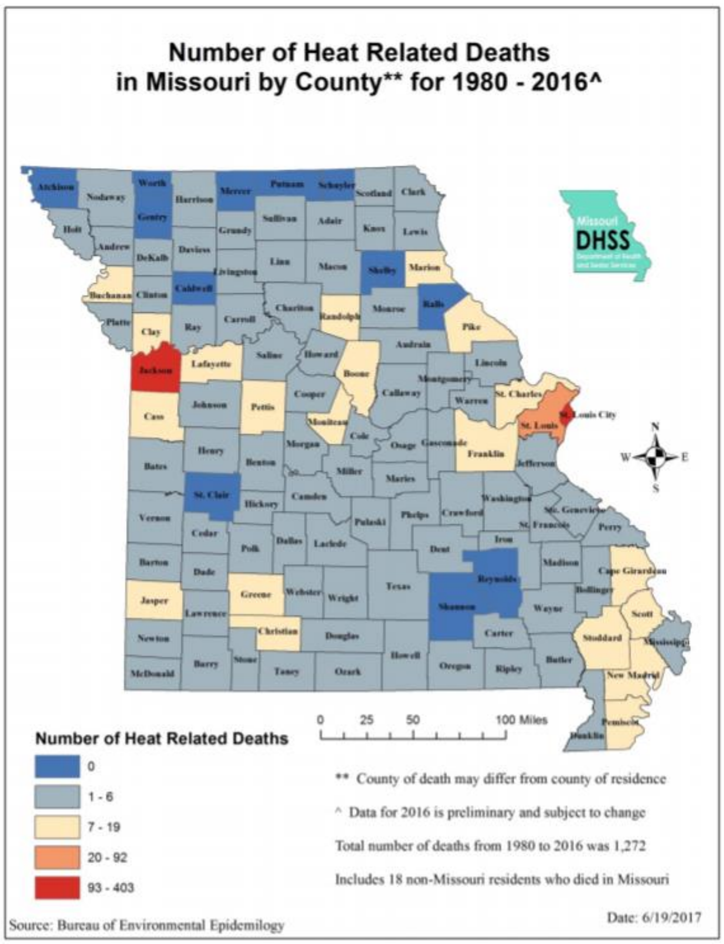
Date	Event	Deaths	Injuries	Property Damage	Crop Damage	Summary
7/7/2001	H	0	0	0	0	Heat Index 105-110.
7/17/2001	H	0	0	0	0	Heat Index ranging from 110 to 115
7/21/2001	H	0	0	0	0	3 deaths in region
7/29/2001	H	0	0	0	0	Heat Index 105-110

Date	Event	Deaths	Injuries	Property Damage	Crop Damage	Summary
8/1/2001	H	0	0	0	0	Heat Index 105
8/7/2001	H	0	0	0	0	Heat Index 102-110, 1 death outside county
8/21/2001	H	0	0	0	0	Heat Index 105-110
7/8/2002	H	0	0	0	0	Heat Index 105-110, 1 death outside county
7/20/2002	H	0	0	0	0	Heat Index 105-110
7/26/2002	H	0	1	0	0	Heat Index 105-115, 1 injury in county
8/1/2002	H	0	0	0	0	1 death outside county
8/15/2003	H	0	1	0	0	5 straight days of 100 or higher., 1 injury in county, 2 deaths outside county
8/24/2003	H	0	0	0	0	Heat Index 105-110
7/20/2004	H	0	0	0	0	Heat Index 105-110
7/20/2005	H	0	0	0	0	6 straight days of Heat Index 105-120
7/17/2006	H	0	0	0	0	Heat Index 105-110
7/29/2006	H	0	0	0	0	Heat Index 105-110
8/1/2006	H	0	0	0	0	
8/5/2007	EH	0	0	0	0	3rd warmest August on record, 1300 injuries state-wide
6/21/2009	EH	0	0	0	0	Heat Index 100-107
6/18/2010	EH	0	0	0	0	Heat Index 105-110
7/14/2010	EH	0	0	0	0	Heat Index 105, 34 injuries outside county
7/17/2010	EH	0	0	0	0	Heat Index 105, 13 injuries outside county
7/22/2010	EH	0	0	0	0	Heat Index 105-110, 23 injuries outside county
8/2/2010	EH	0	0	0	0	Heat Index 110, 1 death, 13 injuries outside county
8/8/2010	EH	0	0	0	0	High moisture levels pushed Heat Index to 110-115, 1 death, 85 injuries outside county
7/1/2011	H	0	0	0	0	Heat Index 105, 6 related injuries outside county
7/10/2011	H	0	0	0	0	Temperature 100, 1 death outside county
7/17/2011	EH	0	0	0	0	100 degree highs for 6 days, 8 deaths outside county
8/1/2011	EH	0	0	0	0	Heat Index 105-110
8/6/2011	H	0	0	0	0	Heat Index 105-110
8/31/2011	H	0	0	0	0	Heat Index 105-110, 2 deaths outside county
9/1/2011	H	0	0	0	0	Heat Index 105, 2 deaths outside county
6/27/2012	EH	0	0	0	0	107 degrees in Columbia, 1 death, 20 injuries outside county
7/1/2012	EH	0	0	0	0	Temperature hit 105, 17 deaths, 54 heat related injuries outside county
7/16/2012	EH	0	0	0	0	Heat Index 105-106, 19 related illnesses outside county
7/22/2012	EH	0	0	0	0	Temperature at 108, 67 people treated outside county
7/31/2012	EH	0	0	0	0	6 people treated outside county
8/1/2012	EH	0	0	0	0	6 people treated outside county
8/31/2013	H	0	0	0	0	Heat Index 105-110
9/1/2013	H	0	0	0	0	Heat Index 105-110, 56 injuries outside county

Date	Event	Deaths	Injuries	Property Damage	Crop Damage	Summary
7/26/2014	EH	0	0	0	0	Heat Index 105-110
8/20/2014	EH	0	0	0	0	Heat Index 105-110
7/12/2015	EH	0	0	0	0	Heat Index 110
7/17/2015	EH	0	0	0	0	Heat Index 105-110
7/25/2015	EH	0	0	0	0	Heat Index 105
6/15/2016	H	0	0	0	0	Heat Index 105
6/22/2016	H	0	0	0	0	Heat Index 105, 51 injuries outside county
7/18/2016	EH	0	0	0	0	Heat Index up to 110, 1 death, 70 injuries outside county
7/18/2017	EH	0	0	0	0	Heat Index 105-110, 51 heat related illnesses outside county

Source: NOAA Storm Events Database

Figure 3.15. Heat Related Deaths in Missouri 2000 - 2016



Source: https://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/stat-report.pdf

Extreme heat can cause stress to crops and animals. According to USDA Risk Management Agency, losses to insurable crops during the 20-year time period from year 2000 to 2020 were $2,697,094.70. Extreme heat can also strain electricity delivery infrastructure overloaded during peak use of air conditioning during extreme heat events. Another type of infrastructure damage from extreme heat is road damage. When asphalt is exposed to prolonged extreme heat, it can cause buckling of asphalt-paved roads, driveways, and parking lots.

From 1988-2011, there were 3,496 fatalities in the U.S. attributed to summer heat. This translates to an annual national average of 146 deaths. During the same period, no deaths were recorded in the planning area, according to NCEI data. The National Weather Service stated that among natural hazards, no other natural disaster—not lightning, hurricanes, tornadoes, floods, n o r earthquakes—causes more deaths. Warren County is a mix of urban rural area where heat islands are largely non-existent and people are able to open windows to catch a breeze; both these factors contribute to much fewer deaths in rural areas.

Probability of Future Occurrence

Fifty-one heat events were recorded for the 21-year period between 2000 and 2020. This equates to 23.80% chance of a heat related event in any given year. There are no recorded deaths attributable to extreme cold.

Changing Future Conditions Considerations

According to the 2018 State Plan, average daily temperatures in Missouri are expected to increase significantly between now and the end of this century which is happening as we speak. This will cause future heat waves to be more intense, affecting the elderly and infirm to a higher degree than young, able-bodied individuals. This will likely result in higher summertime electricity consumption & possible power outages, and shortages of heating oil and fuel. Winter temperatures are expected to moderate.

Vulnerability

Vulnerability Overview

Extreme heat and extreme cold events are common occurrences in Missouri. The method used to determine vulnerability to extreme temperatures across Missouri was statistical analysis of data from several sources; National Centers for Environmental Information (NCEI) storm events data (1996 to December 31, 2016), total population and percentage of population over 65 data from the U.S. Census (2015 ACS), and the calculated Social Vulnerability Index for Missouri counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina.

From the statistical data collected, four factors were considered in determining overall vulnerability to extreme temperatures as follows: total population, percentage of population over 65, likelihood of occurrence, and social vulnerability. Based on natural breaks in the statistical data, a rating value of 1 through 5 was assigned to each factor. These rating values correspond to the following descriptive terms:
1) Low
2) Low-medium
3) Medium
4) Medium-high
5) High

Table 3.27 Likelihood of Occurrence/Overall Vulnerability Rating for Extreme Temperature

HEAT					COLD				
Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description	Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description
51	2.43	4	11	Medium	2	0.1	1	8	Low Medium

Source: 2018 State Plan

Those at greatest risk for heat-related illness include infants and children up to five years of age, people 65 years of age and older, people who are overweight, and people who are ill or on certain medications. However, even young and healthy individuals are susceptible if they participate in strenuous physical activities during hot weather. In agricultural areas, the exposure of farm workers, as well as livestock, to extreme temperatures is a major concern.

Table 3.27 Typical Health Impacts of Extreme Heat

Heat Index (HI)	Disorder
80-90° F (HI)	Fatigue possible with prolonged exposure and/or physical activity
90-105° F (HI)	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity
105-130° F (HI)	Heatstroke/sunstroke highly likely with continued exposure

Source: National Weather Service Heat Index Program, www.weather.gov/os/heat/index.shtml

Potential Losses to Existing Development

Historical data show zero death and zero heat-related illness for the last 21 years in Warren County. We can conclude a similar trend to continue. For agricultural losses, the historical USDA Crop Insurance payments can be estimated and annualized to determine average annual loss. Data shows 19,080 acres impacted by heat incidents for the 21 years between 2000 and 2020 at a loss of $2,697,094.70.

The NOAA Storm Events database records one Extreme Cold/Wind Chill event and two Cold/Wind Chill events for the years 2000 through 2020. No deaths or injuries were recorded. The risk of extreme cold does not vary across the planning area.

Impact of Previous and Future Development

Population growth can result in increases in the age-groups that are most vulnerable to extreme heat. Population growth also increases the strain on electricity infrastructure, as more electricity is needed to accommodate the growing population. There are no jurisdictions expected to experience significant growth in the next five years.

Hazard Summary by Jurisdiction

Those at greatest risk for heat-related illness and deaths include children up to five years of age, people 65 years of age and older, people who are overweight, and people who are ill or on certain medications. To determine jurisdictions within the planning area with populations more vulnerable to extreme heat, demographic data was obtained from the 2010 census on population percentages in each jurisdiction comprised of those under age 5 and over age 65. Data was not available for overweight individuals and those on medications vulnerable to extreme heat.

The NOAA Storm Events database records one Extreme Cold/Wind Chill event and two Cold/Wind Chill events for the years 2000 through 2020. No deaths or injuries were recorded.

The table below summarizes vulnerable populations in the participating jurisdictions. Note that school and special districts are not included in the table because students and those working for the special districts are not customarily in these age groups. For both extreme heat and extreme cold, the vulnerable populations are at higher risk. The risk of extreme heat and extreme cold does not vary across the planning area.

Table 3.28 Warren County Population Under Age 5 and Over Age 65, 2020 estimated Data

Jurisdiction	Population Under 5 Years	Population 65 Years and over
Warren County*	2,348	6,471
Innsbrook	31	196
Marthasville	98	134
Pendleton	0	8
Truesdale	98	123
Warrenton	643	1,387
Wright City	260	436

Source: ESRI Business Analyst (*) includes entire population of each city or county

All public schools serving Warren County have air-conditioned classrooms although not all have air conditioning throughout. Each school has a process for early dismissal due to extreme heat. All nursing homes are air conditioned.

Problem Statement

Aging residents and those who are extremely young are vulnerable to prolonged periods of extreme heat and cold. It will be helpful for communities to have generators in case of power outages during extreme weather events and to update the list of special needs vulnerable populations.

3.4.7 Severe Thunderstorms Including High Winds, Hail, and Lightning

Hazard Profile

Hazard Description

Thunderstorms

A thunderstorm is defined as a storm that contains lightning and thunder which is caused by unstable atmospheric conditions. When cold upper air sinks and warm moist air rises, storm clouds or ‘thunderheads’ develop resulting in thunderstorms. This can occur singularly, as well as in clusters or lines. The National Weather Service defines a thunderstorm as “severe” if it includes hail that is one inch or more, or wind gusts that are at 58 miles per hour or higher. At any given moment across the world, there are about 1,800 thunderstorms occurring. Severe thunderstorms most often occur in Missouri in the spring and summer, during the afternoon and evenings, but can occur at any time. Other hazards associated with thunderstorms are heavy rains resulting in flooding and tornadoes, each discussed separately in this section.

High Winds

A severe thunderstorm can produce winds causing as much damage as a weak tornado. The damaging winds of thunderstorms include downbursts, microbursts, and straight-line winds. Downbursts are localized currents of air blasting down from a thunderstorm, which induce an outward burst of damaging wind on or near the ground. Microbursts are minimized downbursts covering an area of less than 2.5 miles across. They include a strong wind shear (a rapid change in the direction of wind over a short distance) near the surface. Microbursts may or may not include precipitation and can produce winds at speeds of more than 150 miles per hour. Damaging straight-line winds are high winds across a wide area that can reach speeds of 140 miles per hour.

Lightning

All thunderstorms produce lightning which can strike outside of the area where it is raining and is has been known to fall more than 10 miles away from the rainfall area. Thunder is simply the sound that lightning makes. Lightning is a huge discharge of electricity that shoots through the air causing vibrations and creating the sound of thunder.

Hail

According to the National Oceanic and Atmospheric Administration (NOAA), hail is precipitation that is formed when thunderstorm updrafts carry raindrops upward into extremely cold atmosphere causing them to freeze. The raindrops form into small frozen droplets. They continue to grow as they come into contact with super-cooled water which will freeze on contact with the frozen rain droplet. This frozen droplet can continue to grow and form hail. As long as the updraft forces can support or suspend the weight of the hailstone, hail can continue to grow before it hits the earth.

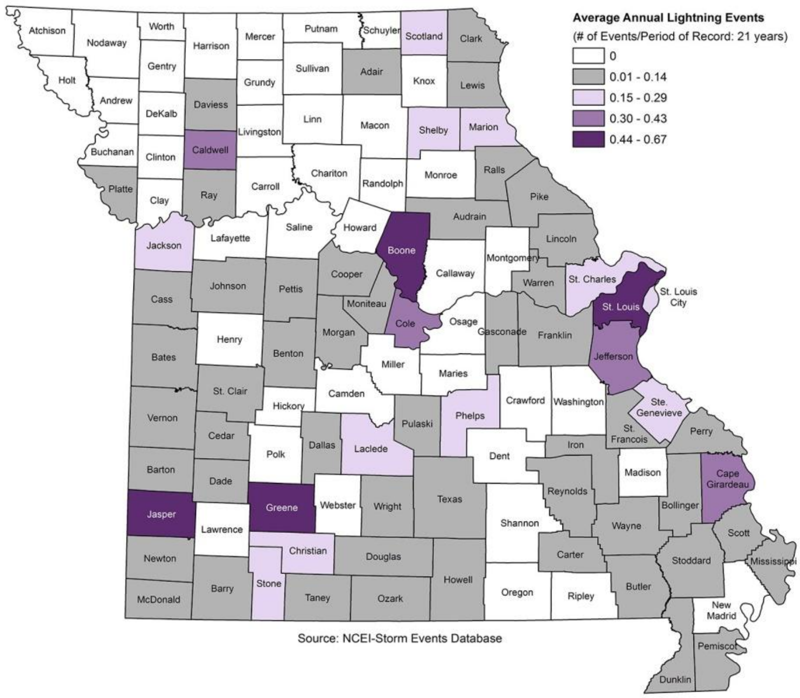
At the time when the updraft can no longer support the hailstone, it will fall down to the earth. For example, a ¼” diameter or pea sized hail requires updrafts of 24 miles per hour, while a 2 ¾” diameter or baseball sized hail requires an updraft of 81 miles per hour. According to the NOAA, the largest hailstone in diameter recorded in the United States was found in Vivian, South Dakota on July 23, 2010. It was eight inches in diameter, almost the size of a soccer ball. Soccer-ball-sized hail is the exception, but even small pea-sized hail can do damage.

Geographic Location

Thunderstorms/high winds/hail/lightning events are an area-wide hazard that can happen anywhere in Warren County. Although these events occur similarly throughout the planning area, they are more frequently reported in more urbanized areas. In addition, damages are more likely to occur in more densely developed urban areas.

The figure below, taken from the 2018 Missouri State Plan, shows zero reported incidents of lightning in the planning area. That is not to say that lightning does not strike in Warren County, 0.01-0.14 events are reported.

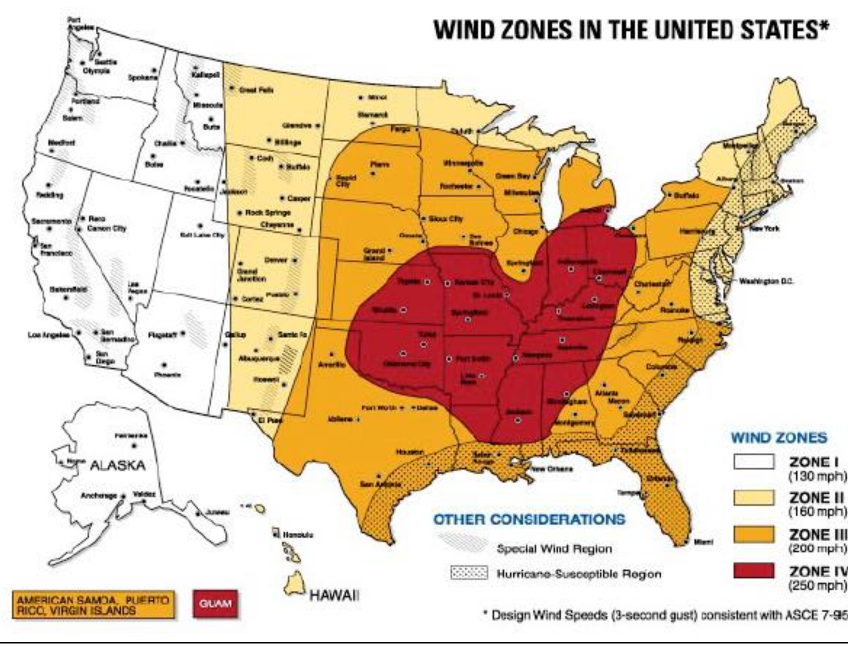
Figure 3.16. Location and Frequency of Lightning in Missouri



Source: NCEI-Storms Database, 2018 Missouri State Plan

The figure below shows wind zones in the United States. The purple zone, Zone IV, covers the entire State of Missouri which includes the planning area.

Figure 3.17. Wind Zones in the United States



Source: FEMA 320, Taking Shelter from the Storm, 3rd edition, https://www.fema.gov/pdf/library/ism2_s1.pdf

Strength/Magnitude/Extent

Based on information provided by the Tornado and Storm Research Organization (TORRO), the table below describes typical damage impacts of the various sizes of hail.

Table 3.29 Tornado and Storm Research Organization Hailstorm Intensity Scale

Intensity Category	Diameter (mm)	Diameter (inches)	Size Description	Typical Damage Impacts
Hard Hail	5-9	0.2-0.4	Pea	No damage
Potentially Damaging	10-15	0.4-0.6	Mothball	Slight general damage to plants, crops
Significant	16-20	0.6-0.8	Marble, grape	Significant damage to fruit, crops, vegetation
Severe	21-30	0.8-1.2	Walnut	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
Severe	31-40	1.2-1.6	Pigeon's egg > squash ball	Widespread glass damage, vehicle bodywork damage
Destructive	41-50	1.6-2.0	Golf ball > Pullet's egg	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
Destructive	51-60	2.0-2.4	Hen's egg	Bodywork of grounded aircraft dented, brick walls pitted
Destructive	61-75	2.4-3.0	Tennis ball > cricket ball	Severe roof damage, risk of serious injuries
Destructive	76-90	3.0-3.5	Large orange > Soft ball	Severe damage to aircraft bodywork
Super Hailstorms	91-100	3.6-3.9	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
Super Hailstorms	>100	4.0+	Melon	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open

Source: Tornado and Storm Research Organization (TORRO), Department of Geography, Oxford Brookes University
Notes: In addition to hail diameter, factors including number and density of hailstones, hail fall speed and surface wind speeds affect severity. http://www.torro.org.uk/site/hscale.php

Straight-line winds are defined as any thunderstorm wind that is not associated with rotation (i.e., is not a tornado). It is these winds, which can exceed 100 miles per hour, which represent the most common type of severe weather. They are responsible for most wind damage related to thunderstorms. Since thunderstorms do not have narrow tracks like tornadoes, the associated wind damage can be extensive and affect entire (and multiple) counties. Objects like trees, barns, outbuildings, high-profile vehicles, and power lines/poles can be toppled or destroyed, and roofs, windows, and homes can be damaged as wind speeds increase.

The onset of thunderstorms with lightning, high wind, and hail is generally rapid. Duration is less than six hours and warning time is generally six to twelve hours. Nationwide, lightning kills 75 to 100 people each year. Lightning strikes can also start structural and wildland fires, as well as damage electrical systems and equipment.

Previous Occurrences

Thunderstorms, high winds, lightning, and hail are common throughout the planning area. The NOAA National Centers for Environmental Information reports 59 Thunderstorm Wind Events over the 20-year period between 2000 and 2020, with no injury and damage. The USDA Risk Management Agency reports no Thunderstorm damage during the same period.

Table 3.30 Thunderstorm Wind Events, 2000 – 2020

Year	No. Events	Deaths	Injuries	Damage
2000	7	0	0	$ -
2001	5	0	0	$ -
2003	4	0	0	$ -
2004	2	0	0	$ -
2005	5	0	0	$ -
2006	5	0	0	$ -
2007	3	0	0	$ -
2009	1	0	0	$ -
2010	3	0	0	$ -
2011	7	0	0	$ -
2012	2	0	0	$ -
2013	2	0	0	$ -
2014	4	0	0	$ -
2015	1	0	0	$ -
2016	5	0	0	$ -
2017	2	0	0	$ -
2020	1	0	0	$ -
TOTAL	**59**	**0**	**0**	**$ -**

Source: NOAA National Centers for Environmental Information

Subsequently, a search of the NOAA National Centers for Environmental Information and insurance claims from the USDA Risk Management Agency produced no record of damaging lightning for the past 20 years. This does not mean there was no lightning damage, just that damage was not sufficiently significant to attract enough attention to be reported.

Both the NOAA National Centers for Environmental Information and USDA Risk Management Agency insurance claims from 1999 through 2018 report Hail Events. The NOAA National Centers for Environmental Information lists 80 incidents of hail greater than ½” in diameter, some reaching nearly three inches. No injuries or damage were recorded.

Table 3.31 Hail Events, 2000 – 2020

Year	No. Events	Hail Size Range(Inches)
2000	2	1-3/4
2001	1	1-3/4
2003	4	3/4 - 1
2004	2	1
2005	6	1 - 1-3/4
2006	5	3/4 - 1
2007	0	0
2008	6	1 - 1-3/4
2009	0	0
2010	0	0

Year	No. Events	Hail Size Range(Inches)
2011	18	1-41/2
2012	11	3/4 – 21/2
2013	0	0
2014	3	3/4 – 1 1/2
2015	4	1 - 2
2016	1	1
2017	1	1
2018	2	1-11/2
2019	1	1-3/4
2020	2	1 – 2 3/4
TOTAL	69	

Source: NOAA National Centers for Environmental Information

USDA Risk Management Agency insurance claims for the corresponding period shows $389,000 of crop damage.

Table 3.32 Crop Insurance Claims Paid in Warren County from Hail, 2000-2020

Crop Year	Acres	Dollars
2000	0.00	0.00
2001	0.00	0.00
2002	0.00	0.00
2003	0.00	0.00
2004	71.00	1,412.00
2005	0.00	0.00
2006	0.00	0.00
2007	0.00	0.00
2008	0.00	0.00
2009	0.00	0.00
2010	0.00	0.00
2011	1200.29	393,376.15
2012	0.00	0.00
2013	0.00	0.00
2014	74.95	2,554.00
2015	39.1	115,518.00
2016	0.00	0.00
2017	0.00	0.00
2018	0.00	0.00
2019	0.00	0.00
2020	0.00	0.00
Total	1,385.34	512,860.15

USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/data/cause

The NOAA National Centers for Environmental Information reports just three High Wind events, two during 2001 and one in 2019. The winds ranged in speeds of 40-53 knots. There were no injuries or damages included in the report. However, USDA Risk Management Agency insurance claims for the corresponding period show nearly $136,123 in crop damage claims.

Table 3.33 Crop Insurance Claims Paid in Warren County from High Winds, 2000-2020

Crop Year	Acres	Dollars
2000	1.80	14.60
2001	0.00	0.00
2002	0.00	0.00
2003	26.00	413.00
2004	0.00	0.00
2005	0.00	0.00
2006	0.00	0.00
2007	0.00	0.00
2008	0.00	0.00
2009	0.00	0.00
2010	0.00	0.00
2011	850.78	124,559.80
2012	0.00	0.00
2013	102.80	11,151.00
2014	0.00	0.00
2015	0.00	0.00
2016	0.00	0.00
2017	0.00	0.00
2018	0.00	0.00
2019	0.00	0.00
2020	34.00	3,479.00
Total	979.58	136,123.80

Probability of Future Occurrence

The annual probability of future occurrence for Thunderstorm Wind is 285% in any given year, considering 60 events occurred during a 21-year period. The annual probability of occurrence for Hail events is even higher at 380%, given 80 events over a 21-year period. High Wind events are less likely with a probability of 328% during any given year. Lightning is more difficult to judge with no reports of incidents or damages during the past 21 years. However, we know it happens in Warren County hundreds, perhaps thousands of times per year; and occasionally, deaths, injuries, and property damage will be the result.

Changing Future Conditions Considerations

NASA's Earth Observatory provides an analysis on how climate change could, theoretically, increase potential storm energy by warming the surface and putting more moisture in the air through evaporation. The presence of warm, moist air near the surface is a key ingredient for summer storms that meteorologists have termed "convective available potential energy," or CAPE. With an increase in CAPE, there is greater potential for cumulus clouds to form. The study also counters this with the theory that warming in the Arctic could lead to less wind shear in the mid-latitude areas prone to summer storms, making the storms less likely.

Predicted increases in temperature could help create atmospheric conditions that are fertile breeding grounds for severe thunderstorms and tornadoes in Missouri. Possible impacts include an increased risk to life and property in both the public and private sectors. Public utilities and manufactured housing developments will be especially prone to damages. Jurisdictions already affected should be prepared for more of these events, and should thus prioritize mitigation actions such as construction of safe rooms for vulnerable populations, retrofitting and/or hardening existing structures, improving warning systems and public education, and reinforcing utilities and additional critical infrastructure.