Vulnerability

Vulnerability Overview

Severe thunderstorm losses are usually attributed to the associated hazards of hail, downburst winds, lightning and heavy rains. Losses due to hail and high wind are typically insured losses that are localized and do not result in presidential disaster declarations. However, in some cases, impacts are severe and widespread and assistance outside state capabilities is necessary. Hail and wind also can have devastating impacts on crops. Severe thunderstorms/heavy rains that lead to flooding are discussed in the flooding hazard profile. Hailstorms cause damage to property, crops, and the environment, and can injure and even kill livestock. In the United States, hail causes more than $1 billion in damage to property and crops each year. Even relatively small hail can shred plants to ribbons in a matter of minutes. Vehicles, roofs of buildings and homes, and landscaping are also commonly damaged by hail. Hail has been known to cause injury to humans, occasionally fatal injury.

In general, assets in the County vulnerable to thunderstorms with lightning, high winds, and hail include people, crops, vehicles, and built structures. Although this hazard results in high annual losses, private property insurance and crop insurance usually cover the majority of losses. Considering insurance coverage as a recovery capability, the overall impact on jurisdictions is reduced.

Most lightning damages occur to electronic equipment located inside buildings. But structural damage can also occur when a lightning strike causes a building fire. In addition, lightning strikes can cause damages to crops, if fields or forested lands are set on fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx and http://www.lightningsafety.noaa.gov/

The 2018 State Plan lists Severe Thunderstorm Building Exposure for Warren County at $3.48B.

Potential Losses to Existing Development

Based on past loss trends and growth trends in Warren County, we anticipate losses to remain about where they are currently; totaling to average just under $90K per year in property and crop losses due to high wind, thunderstorms, hail, and lightning.

Previous and Future Development

Development trends are not anticipated to have an impact on potential losses.

Hazard Summary by Jurisdiction

Although this hazard poses the same risk across the county, the special needs, vulnerable populations are at more risk. As per American Factfinder, there are 913 housing units in the county that were built in 1939 or earlier that might be vulnerable with the impact of high winds and hail damage. Although the school districts are considered as vulnerable population, they do have an emergency plan and emergency alert system in case of any thunderstorm events.

Problem Statement

Severe thunderstorms, high wind, hail, and lightning will continue to strike Warren County. The 2018 State Plan forecasts the county to be exposed to up to $3.48B in losses. Possible solutions include

review of local ordinance and building codes to address high winds and/or construction techniques to include structural bracing, straps and clips, or anchor bolts.

3.4.8 Severe Winter Weather

Hazard Profile

Hazard Description

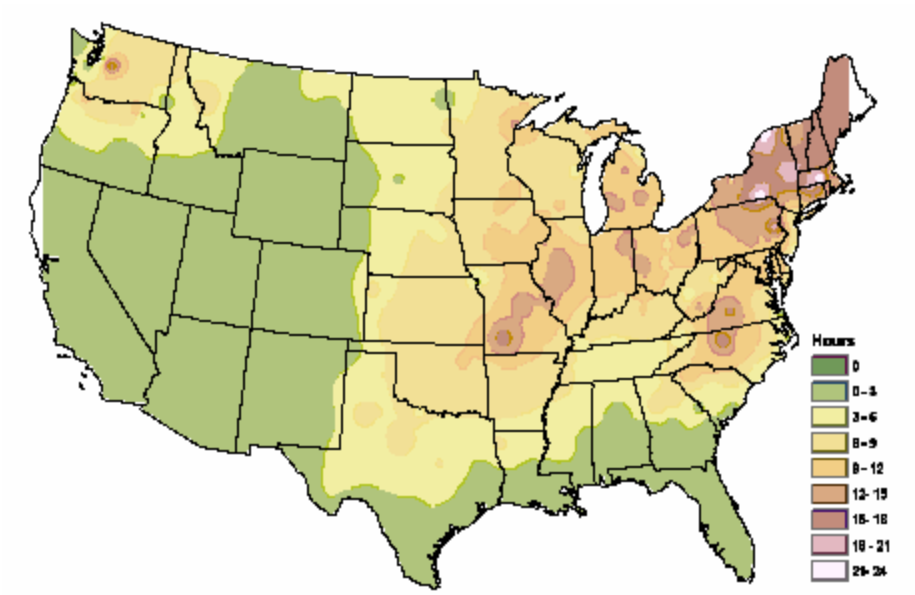
A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. The National Weather Service describes different types of winter storm events as follows.

- **Blizzard**—Winds of 35 miles per hour or more with snow and blowing snow reducing visibility to less than ¼ mile for at least three hours.
- **Blowing Snow**—Wind-driven snow that reduces visibility. Blowing snow may be falling snow and/or snow on the ground picked up by the wind.
- **Snow Squalls**—Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant.
- **Snow Showers**—Snow falling at varying intensities for brief periods of time. Some accumulation is possible.
- **Freezing Rain**—Measurable rain that falls onto a surface with a temperature below freezing. This causes it to freeze to surfaces, such as trees, cars, and roads, forming a coating or glaze of ice. Most freezing-rain events are short lived and occur near sunrise between the months of December and March.
- **Sleet**—Rain drops that freeze into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects.

Geographic Location

The entire Warren County planning area is vulnerable to heavy snow, ice, extreme cold temperatures and freezing rain. The figure below shows the county within the area of a circle that receives 12-18 hours of freezing rain per year.

Figure 3.18. NWS Statewide Average Number of Hours per Year with Freezing Rain



Source: American Meteorological Society. "Freezing Rain Events in the United States." http://ams.confex.com/ams/pdfpapers/71872.pdf

Strength/Magnitude/Extent

Severe winter storms include heavy snowfall, ice, and strong winds which can push the wind chill well below zero degrees in the planning area. For severe weather conditions, the National Weather Service issues some or all of the following products as conditions warrant across the State of Missouri. NWS local offices in Missouri may collaborate with local partners to determine when an alert should be issued for a local area.

Winter Weather Advisory — Winter weather conditions are expected to cause significant inconveniences and may be hazardous. If caution is exercised, these situations should not become life threatening. Often the greatest hazard is to motorists.

Winter Storm Watch — Severe winter conditions, such as heavy snow and/or ice are possible within the next day or two.

Winter Storm Warning — Severe winter conditions have begun or are about to begin.

Blizzard Warning — Snow and strong winds will combine to produce a blinding snow (near zero visibility), deep drifts, and life-threatening wind chill.

Ice Storm Warning -- Dangerous accumulations of ice are expected with generally over one quarter inch of ice on exposed surfaces. Travel is impacted, and widespread downed trees and power lines often result.

Wind Chill Advisory -- Combination of low temperatures and strong winds will result in wind chill readings of -20 degrees F or lower.

Wind Chill Warning -- Wind chill temperatures of -35 degrees F or lower are expected. This is a life-threatening situation.

Previous Occurrences

The table shows NCEI reported events and damages in Warren County for the past 20 years.

Table 3.34 NCEI Warren County Winter Weather Events Summary, 2000 - 2020

Type of Event	Inclusive Dates	Magnitude	# of Injuries	Property Damages	Crop Damages
Winter Storm	1/27/2000 - 1/29/2000	NA	0	$ 0	$ 0
Winter Storm	3/11/2000	NA	0	$ 0	$ 0
Heavy Snow	12/13/2000 - 12/13/2000	NA	0	$ 0	$ 0
Winter Storm	1/26/2001	NA	0	$ 0	$ 0
Winter Storm	2/25/2002 - 2/26/2002	NA	0	$ 0	$ 0
Winter Storm	3/2/2002 - 3/2/2002	NA	0	$ 0	$ 0
Winter Storm	3/25/2002 - 3/26/2002	NA	0	$ 0	$ 0
Winter Storm	12/24/2002 - 12/24/2002	NA	0	$ 0	$ 0
Winter Storm	1/1/2003 - 1/2/2003	NA	0	$ 0	$ 0
Winter Storm	2/23/2003 - 2/24/2003	NA	0	$ 0	$ 0
Winter Storm	12/9/2003 - 12/10/2003	NA	0	$ 0	$ 0
Winter Storm	12/13/2003 - 12/13/2003	NA	0	$ 0	$ 0
Winter Storm	1/25/2004 - 1/25/2004	NA	0	$ 0	$ 0
Winter Storm	11/24/2004 - 12/24/2004	NA	0	$ 0	$ 0
Winter Storm	12/8/2005 - 12/8/2005	NA	0	$ 0	$ 0
Winter Storm	11/29/2006 - 11/30/2006	NA	0	$ 0	$ 0
Winter Storm	12/1/2006 - 12/1/2006	NA	0	$ 0	$ 0
Ice Storm	1/12/2007 - 1/12/2006	NA	0	$ 0	$ 0
Winter Weather	12/15/2007	NA	0	$ 0	$ 0
Cold/wind Chill	1/1/2010 - 1/12/2010	NA	0	$ 0	$ 0
Heavy Snow	1/19/2011 - 1/20/2011	NA	0	$ 0	$ 0
Winter Storm	1/31/2011 - 1/31/2011	NA	0	$ 0	$ 0
Winter Storm	2/1/2011 - 2/1/2011	NA	0	$ 0	$ 0
Blizzard	2/1/2011 - 2/2/2011	NA	0	$ 0	$ 0
Heavy Snow	2/21/2013 - 2/21/2013	NA	0	$ 0	$ 0
Heavy Snow	3/24/2013 - 3/24/2013	NA	0	$ 0	$ 0
Winter Storm	12/21/2013 - 12/22/2013	NA	0	$ 0	$ 0
Winter Storm	1/5/2014 - 1/5/2014	NA	0	$ 0	$ 0
Cold/wind Chill	1/6/2014 - 1/7/2014	NA	0	$ 0	$ 0
Winter Storm	2/4/2014 - 2/5/2014	NA	0	$ 0	$ 0
Heavy Snow	11/15/2018 - 11/15/2018	NA	0	$ 0	$ 0
Heavy snow	1/11/2019 – 1/13/2019	NA	0	$ 0	$ 0
TOTAL	30 events		0	$ 0	$ 0

Source: NCEI, data accessed [12/17/2020]

Table 3.35 Presidential Declarations, Warren County Severe Winter Storms, 2000 - 2020

The table below lists Presidential Declared Severe Winter Storms that included the planning area. Note that the declaration dates will not coincide with the dates of the disasters.

Declaration Date	Description	Declaration Type	Disaster No.
January 14, 2007	Severe Winter Storm	Presidential	1676-DR
December 12, 2007	Severe Winter Storm	Presidential	3281-DR
December 27, 2007	Severe Winter Storm	Presidential	1736-DR
January 30, 2009	Severe Winter Storm	Presidential	3303-DR

Source: FEMA Declared Disasters

Winter weather, in the form of ice, sleet, freezing rain, and freezing temperatures can extract a toll on crop production in the planning area. The table below shows the USDA's Risk Management Agency payments for insured crop losses in the planning area as a result of freezing temperatures and cold winter conditions for the past 20 years. No losses due to ice, sleet, freezing rain, or snow were reported.

Table 3.36 Crop Insurance Claims Paid in Warren County as a Result of Cold Conditions, 2000 – 2020

Crop Year	Acres	Dollars
2000	0.00	0.00
2001	0.00	0.00
2002	336.68	22,436.00
2003	0.00	0.00
2004	0.00	0.00
2005	190.19	3,493.00
2006	0.00	0.00
2007	330.13	16,301.00
2008	26.90	2,820.00
2009	248.72	4,242.00
2010	43.22	8,084.00
2011	344.15	142,160.55
2012	88.6	40,959.00
2013	0.00	0.00
2014	138.38	13,495.00
2015	305.10	51,328.00
2016	0.00	0.00
2017	0.00	0.00
2018	0.00	0.00
2019	54.25	12,713.05
2020	38.07	2,608.00
TOTAL	2,144.39	320,639.60

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

Probability of Future Occurrence

Warren County experienced harsh winter weather that resulted in crop losses during 12 of the past 20 years. From this data, we can calculate the annual probability of winter weather crop losses as 57%, or an average of .58 events per year.

Changing Future Conditions Considerations

According to the 2018 State Plan, a shorter overall winter season and fewer days of extreme cold may have both positive and negative indirect impacts. Warmer winter temperatures may result in changing distributions of native plant and animal species and/or an increase in pests and non-native species. Warmer winter temperatures will result in a reduction of lake ice cover. Reduced lake ice cover impacts aquatic ecosystems by raising water temperatures. Water temperature is linked to dissolved oxygen levels and many other environmental parameters that affect fish, plant, and other animal populations. A lack of ice cover also leaves lakes exposed to wind and evaporation during a time of year when they are normally protected. As both temperature and precipitation increase during the winter months, freezing rain will be more likely. Additional wintertime precipitation in any form will contribute to saturation and increase the risk and/or severity of spring flooding. A greater proportion of wintertime precipitation may fall as rain rather than snow.

Vulnerability

Vulnerability Overview

Heavy snow can bring a community to a standstill by inhibiting transportation (in whiteout conditions), weighing down utility lines, and by causing structural collapse in buildings not designed to withstand the weight of the snow. Repair and snow removal costs can be significant. Ice buildup can collapse utility lines and communication towers, as well as make transportation difficult and hazardous. Ice can also become a problem on roadways if the air temperature is high enough that precipitation falls as freezing rain rather than snow.

Buildings with overhanging tree limbs are more vulnerable to damage during winter storms when limbs fall. Businesses experience loss of income as a result of closure during power outages. In general heavy winter storms increase wear and tear on roadways though the cost of such damages is difficult to determine. Businesses can experience loss of income as a result of closure during winter storms.

Overhead power lines and infrastructure are also vulnerable to damages from winter storms. In particular ice accumulation during winter storm events damage to power lines due to the ice weight on the lines and equipment. Damages also occur to lines and equipment from falling trees and tree limbs weighted down by ice. Potential losses could include cost of repair or replacement of damaged facilities, and lost economic opportunities for businesses.

Secondary effects from loss of power could include burst water pipes in homes without electricity during winter storms. Public safety hazards include risk of electrocution from downed power lines. Specific amounts of estimated losses are not available due to the complexity and multiple variables associated with this hazard. Standard values for loss of service for utilities reported in FEMA's 2009 BCA Reference Guide, the economic impact as a result of loss of power is $126 per person per day of lost service.

The method the state used to determine vulnerability to severe winter weather across Missouri was statistical analysis of data from several sources: National Centers for Environmental Information (NCEI) storm events data (1996 to December 31, 2016), HAZUS Building Exposure Value data, housing density 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, five factors were considered in determining overall vulnerability to severe winter weather as follows: housing density, building exposure, social vulnerability, likelihood of occurrence, and average annual property loss. 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

To determine potential financial loss estimates to severe winter weather in Missouri, the available historical property loss data was annualized. In the case of frequently occurring weather-related hazards such as severe winter weather, annualized historical loss data is considered to be the best resource for determining future potential losses. As discussed above in the vulnerability overview for this hazard, the planning team obtained historical loss data from the NCEI Storm Event Database for Blizzard, Heavy Storm Ice Storm, Winter Storm and Winter Weather for the period from 1996 to December 2016. The 2018 State Plan gives Warren County an Overall Vulnerability Rating of "Low Medium" and estimates the annualized property loss to be $286.

Table 3.37 Annualized Winter Weather Property Loss for Warren County

Annualized Blizzard Property Loss ($)	Annualized Heavy Snow Property Loss ($)	Annualized Ice Storm Property Loss ($)	Annualized Winter Storm Property Loss ($)	Annualized Winter Weather Property Loss ($)	Total Annualized Winter Weather Property Loss ($)
$0	$0	$4,571	$0	$0	$4,571

Source: 2018 Missouri State Hazard Mitigation Plan

Potential Losses to Existing Development

Annual crop losses due to winter weather have averaged $16,031.95 per year for the past 20 years and Missouri estimates annualized property losses due to ice to be $4,571. There is no reason to doubt an average annual winter weather loss to Warren County of around $20,000.

Previous and Future Development

The not so fast pace development forecast for Warren County will not impact future losses.

Hazard Summary by Jurisdiction

All areas of the planning area are at equal risk. All public schools serving Warren County have temperature controlled classrooms. Each school has a process for early dismissal due to severe winter weather. All nursing homes are temperature controlled.

Problem Statement

Severe winter weather is a risk for Warren County. However, historical trends do not indicate a significant risk to life or property. Exercise of good judgement will yield the best results at the lowest

costs. It will be helpful for communities to have generators in case of power outages during severe winter weather events and to update the list of special needs vulnerable populations.

3.4.9 Tornado

Hazard Profile

Hazard Description

Essentially, tornadoes are a vortex storm with two components of winds. The first is the rotational winds that can measure up to 500 miles per hour, and the second is an uplifting current of great strength. The dynamic strength of both these currents can cause vacuums that can overpressure structures from the inside.

Although tornadoes have been documented in all 50 states, most of them occur in the central United States. The unique geography of the central United States allows for the development of thunderstorms that spawn tornadoes. The jet stream, which is a high-velocity stream of air, determines which area of the central United States will be prone to tornado development. The jet stream normally separates the cold air of the north from the warm air of the south. During the winter, the jet stream flows west to east from Texas to the Carolina coast. As the sun “moves” north, so does the jet stream, which at summer solstice flows from Canada across Lake Superior to Maine. During its move northward in the spring and its recession south during the fall, the jet stream crosses Missouri, causing the large thunderstorms that breed tornadoes.

Tornadoes spawn from the largest thunderstorms. The associated cumulonimbus clouds can reach heights of up to 55,000 feet above ground level and are commonly formed when Gulf air is warmed by solar heating. The moist, warm air is overridden by the dry cool air provided by the jet stream. This cold air presses down on the warm air, preventing it from rising, but only temporarily. Soon, the warm air forces its way through the cool air and the cool air moves downward past the rising warm air. This air movement, along with the deflection of the earth’s surface, can cause the air masses to start rotating. This rotational movement around the location of the breakthrough forms a vortex, or funnel. If the newly created funnel stays in the sky, it is referred to as a funnel cloud. However, if it touches the ground, the funnel officially becomes a tornado.

A typical tornado can be described as a funnel-shaped cloud that is “anchored” to a cloud, usually a cumulonimbus that is also in contact with the earth’s surface. This contact on average lasts 30 minutes and covers an average distance of 15 miles. The width of the tornado (and its path of destruction) is usually about 300 yards. However, tornadoes can stay on the ground for upward of 300 miles and can be up to a mile wide. The National Weather Service, in reviewing tornadoes occurring in Missouri between 1950 and 1996, calculated the mean path length at 2.27 miles and the mean path area at 0.14 square mile.

The average forward speed of a tornado is 30 miles per hour but may vary from nearly stationary to 70 miles per hour. The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. Tornadoes are most likely to occur in the afternoon and evening, but have been known to occur at all hours of the day and night.

Geographic Location

Tornadoes can occur anywhere in the planning area.

Strength/Magnitude/Extent

Tornadoes are the most violent of all atmospheric storms and are capable of tremendous destruction. Wind speeds can exceed 250 miles per hour and damage paths can be more than one mile wide and 50 miles long. Tornadoes have been known to lift and move objects weighing more than 300 tons a distance of 30 feet, toss homes more than 300 feet from their foundations, and siphon millions of tons of water from water bodies. Tornadoes also can generate a tremendous amount of flying debris or "missiles," which often become airborne shrapnel that causes additional damage. If wind speeds are high enough, missiles can be thrown at a building with enough force to penetrate windows, roofs, and walls. However, the less spectacular damage is much more common.

Tornado magnitude is classified according to the EF- Scale (or the Enhance Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renowned severe storm researcher). The EF- Scale, below, ranks tornadoes according to wind speed based on the damage caused. This update to the original F Scale was implemented in the U.S. on February 1, 2007.

Table 3.38 Enhanced F Scale for Tornado Damage

FUJITA SCALE			DERIVED EF SCALE		OPERATIONAL EF SCALE	
F Number	Fastest ¼-mile (mph)	3 Second Gust (mph)	EF Nu	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over 200

Source: The National Weather Service, www.spc.noaa.gov/faq/tornado/ef-scale.html

The wind speeds for the EF scale and damage descriptions are based on information on the NOAA Storm Prediction Center as listed in the table below. The damage descriptions are summaries. For the actual EF scale it is necessary to look up the damage indicator (type of structure damaged) and refer to the degrees of damage associated with that indicator. Information on the Enhanced Fujita Scale's damage indicators and degrees or damage is located online at www.spc.noaa.gov/efscale/ef-scale.html.

Table 3.39 Enhanced Fujita Scale with Potential Damage

Enhanced Fujita Scale			
Scale	Wind Speed (mph)	Relative Frequency	Potential Damage
EF0	65-85	53.5%	Light. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e. those that remain in open fields) are always rated EF0).
EF1	86-110	31.6%	Moderate. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	111-135	10.7%	Considerable. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes complete destroyed; large trees snapped or uprooted; light object missiles generated; cars lifted off ground.
EF3	136-165	3.4%	Severe. Entire stores of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some
EF4	166-200	0.7%	Devastating. Well-constructed houses and whole frame houses completely levelled; cars thrown and small missiles generated.

Enhanced Fujita Scale			
Scale	Wind Speed (mph)	Relative Frequency	Potential Damage
EF5	>200	<0.1%	Explosive. Strong frame houses levelled off foundations and swept away; automobile-sized missiles fly through the air in excess of 300 ft.; steel reinforced concrete structure badly damaged; high rise buildings have significant structural deformation; incredible phenomena will occur.

Source: NOAA Storm Prediction Center, http://www.spc.noaa.gov/efscale/ef-scale.html

Enhanced weather forecasting has provided the ability to predict severe weather likely to produce tornadoes days in advance. Tornado watches can be delivered to those in the path of these storms several hours in advance. Lead time for actual tornado warnings is about 30 minutes. Tornadoes have been known to change paths very rapidly, thus limiting the time in which to take shelter. Tornadoes may not be visible on the ground if they occur after sundown or due to blowing dust or driving rain and hail.

Previous Occurrences

The table below shows tornadoes recorded in the NCEI database for Warren County since 2000. Combined, these tornadoes accounted for $20,000 in losses for the planning area. The map, also below, shows recorded paths for Warren County tornadoes from 2000 to 2020.

There are limitations to the use of NCEI tornado data that must be noted. For example, one tornado may contain multiple segments as it moves geographically. A tornado that crosses a county line or state line is considered a separate segment for the purposes of reporting to the NCEI. Also, a tornado that lifts off the ground for less than 5 minutes or 2.5 miles is considered a separate segment. If the tornado lifts off the ground for greater than 5 minutes or 2.5 miles, it is considered a separate tornado. Tornadoes reported in Storm Data and the Storm Events Database are in segments.

Table 3.40 Recorded Tornadoes in Warren County, 2000 – 2020

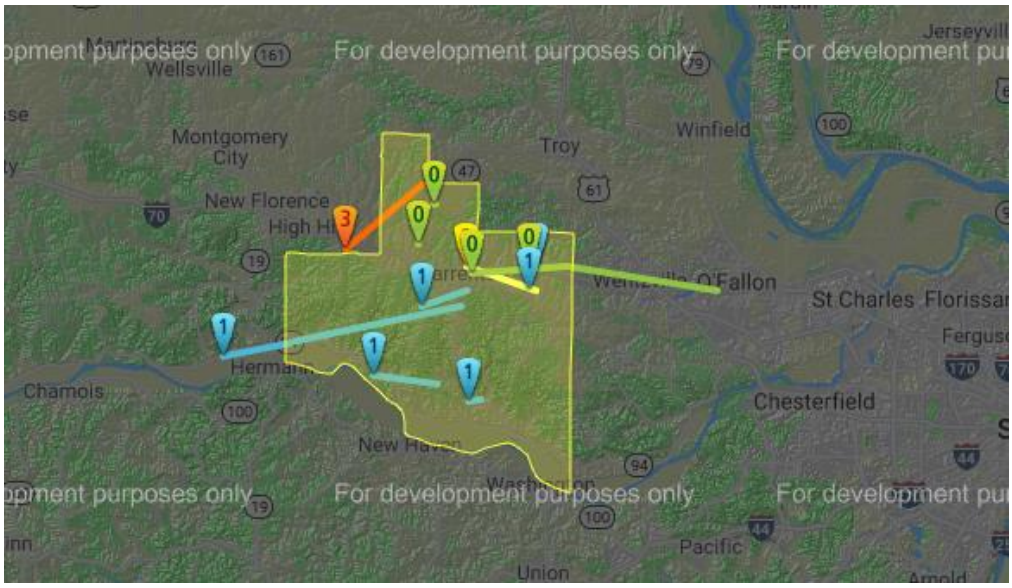
Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	EF Rating	Death	Injury	Property Damage ($)	Crop Damages
4/10/2001	1W Wright City	1W Wright City	0.1	50	F0	0	0	20,000	0
3/13/2006	10 NW Warrenton	9NNW Warrenton	2	50	F0	0	0	0	0
4/23/2010	3NNE Pendleton	3NNE Pendleton	0.1	10	EF0	0	0	0	0
4/23/2010	6S SE New Truxton	6S SE New Truxton	0.12	10	EF0	0	0	0	0
1/29/2013	1N Concord Hill	2NE Concord Hill	1.17	40	EF1	0	0	0	0
4/26/2016	2NW Bernheimer	2N Holstein	5.46	100	EF1	0	0	0	0
3/6/2017	3W Case	2SSW Truesdale	15.46	150	EF1	0	0	0	0
TOTAL	7 events					0	0	20,000	0

Source: National Centers for Environmental Information, http://www.NCEI.noaa.gov/stormevents/

The NCEI data above lists no crop damages associated with the recorded tornadoes since 2000.

The map below shows tornado paths since 2000.

Figure 3.19. Warren County Map of Historic Tornado Events



Source: Missouri Tornado History Project, http://www.tornadohistoryproject.com/tornado/Missouri

Probability of Future Occurrence

There were 7 tornado events during the past 21 years. That makes the probability for a tornado in any one year 33%.

Changing Future Conditions Considerations

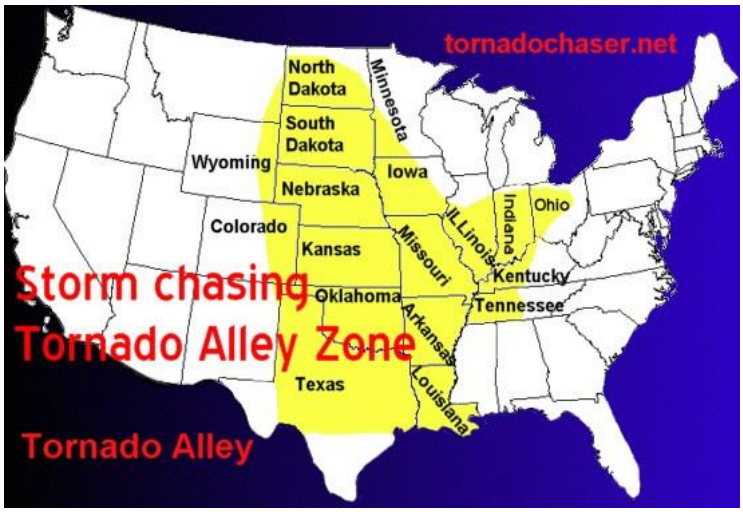
Scientists do not know how the frequency and severity of tornadoes will change. Research published in 2015 suggests that changes in heat and moisture content in the atmosphere, brought on by a warming world, could be playing a role in making tornado outbreaks more common and severe in the U.S. The research concluded that the number of days with large outbreaks have been increasing since the 1950s and that densely concentrated tornado outbreaks are on the rise. It is notable that the research shows that the area of tornado activity is not expanding, but rather the areas already subject to tornado activity are seeing the more densely packed tornadoes. Because Missouri experiences on average around 39.6 tornadoes a year, such research is closely followed by meteorologists in the state.

Vulnerability

Vulnerability Overview

Missouri's location in the central U.S. puts it squarely in the center of "Tornado Alley", an area of the country with high frequency of dangerous and destructive tornadoes.

Figure 3.20. Tornado Alley in the U.S.



Source: http://www.tornadochaser.net/tornalley.html

The method used to determine vulnerability to tornadoes across Missouri was statistical analysis of data from several sources: HAZUS building exposure value data, population density and mobile home data from the U.S. Census (2015 ACS), 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, and storm events data (1950 to December 31, 2016) from the National Centers for Environmental Information (NCEI). It is important to realize that one limitation to the NCEI data is that many tornadoes that might have occurred in uninhabited areas, as well as some in inhabited areas, may not have been reported. The incompleteness of the data suggests that it is not appropriate for use in parametric modeling. In addition, NOAA data cannot show a realistic frequency distribution of different Fujita scale tornado events, except for recent years. Thus, a parametric model based on a combination of many physical aspects of the tornado to predict future expected losses was not used. The statistical model used for this analysis was probabilistic based purely on tornado frequency and historic losses. It is based on past experience and forecasts the expected results for the immediate or extended future.

From the statistical data collected, six factors were considered in determining overall vulnerability to tornadoes as follows: building exposure, population density, social vulnerability, percentage of mobile homes, likelihood of occurrence, and annual property loss. 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:

Low
Low-medium
Medium
Medium-high
High

Table 3.41 Annualized Vulnerability for Tornadoes in Warren County

No. Tornadoes	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
Warren	14	0.209	$49,187	1	11	Low Medium

Source: 2018 Missouri State Hazard Mitigation Plan

Previous and Future Development

No significant increase in risk to the county from tornadoes is anticipated for Warren County due to its limited development opportunities.

Hazard Summary by Jurisdiction

Tornado events are likely to occur countywide; although statistics show that Pendleton, Warrenton and Wright City have been most affected by tornadoes in the past. No parts of the county are exempt from this hazard.

Problem Statement

Tornados occur in Warren County and they are completely random, striking at will wherever they please. The risk of a tornado is the same in any part of the county but the likelihood of death, injury, and damage is most likely in more developed parts of the county. Many residences within the county are without basements or safe rooms and few community safe rooms are available. Residents of the county could mitigate risk from tornadoes by installing sirens or other means of advanced warning and by providing personal and community safe rooms.

3.4.10 Wildfire

Hazard Profile

Hazard Description

The fire incident types for wildfires include: 1) natural vegetation fire, 2) outside rubbish fire, 3) special outside fire, and 4) cultivated vegetation, crop fire.

The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from wildfires. To accomplish this task, eight forestry regions have been established in Missouri for fire suppression. The Forestry Division works closely with volunteer fire departments and federal partners to assist with fire suppression activities. Currently, more than 900 rural fire departments in Missouri have mutual aid agreements with the Forestry Division to obtain assistance in wildfire protection if needed.

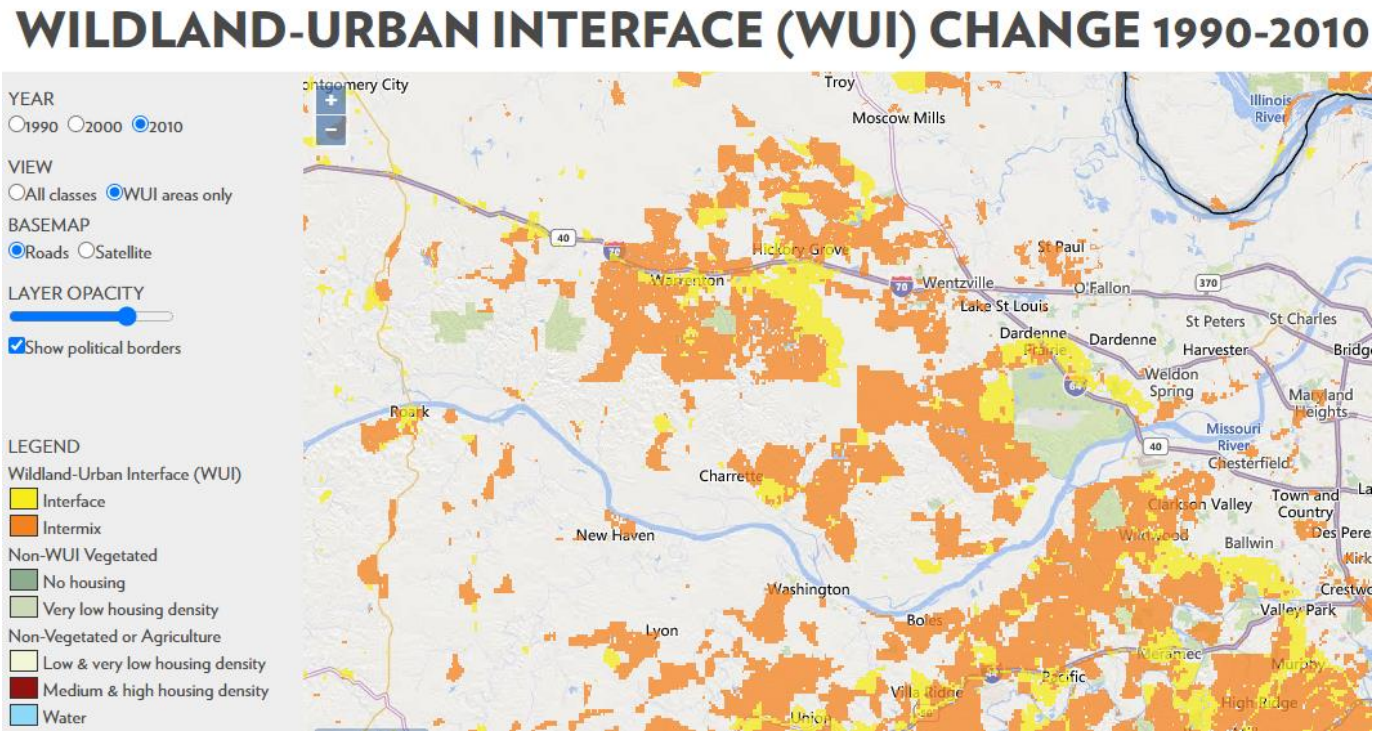
Most of Missouri fires occur during the spring season between February and May. The length and severity of wildland fires depend largely on weather conditions. Spring in Missouri is usually characterized by low humidity and high winds. These conditions result in higher fire danger. In addition, due to the recent lack of moisture throughout many areas of the state, conditions are likely to increase the risk of wildfires. Drought conditions can also hamper firefighting efforts, as decreasing water supplies may not prove adequate for firefighting. It is common for rural residents burn their garden spots, brush piles, and other areas in the spring. Some landowners also believe it

is necessary to burn their forests in the spring to promote grass growth, kill ticks, and reduce brush. Therefore, spring months are the most dangerous for wildfires. The second most critical period of the year is fall. Depending on the weather conditions, a sizeable number of fires may occur between mid-October and late November.

Geographic Location

Damages due to wildfires would be higher in communities with more wildland–urban interface (WUI) areas. The term refers to the zone of transition between unoccupied land and human development and needs to be defined in the plan. Within the WUI, there are two specific areas identified: 1) Interface and 2) Intermix. The interface areas are those areas that abut wildland vegetation and the Intermix areas are those areas that intermingle with wildland areas. No community is more at risk than another.

Figure 3.21. Warren County Wildland / Urban Interface



Source: University of Wisconsin-Madison (SILVIS LAB)

Strength/Magnitude/Extent

Wildfires damage the environment, killing some plants and occasionally animals. Firefighters have been injured or killed, and structures can be damaged or destroyed. The loss of plants can heighten the risk of soil erosion and landslides. Although Missouri wildfires are not the size and intensity of those in the Western United States, they could impact recreation and tourism in and near the fires.

Wildland fires in Missouri have been mostly a result of human activity rather than lightning or some other natural event. Wildfires in Missouri are usually surface fires, burning the dead leaves on the ground or dried grasses. They do sometimes “torch” or “crown” out in certain dense evergreen stands like eastern red cedar and shortleaf pine. However, Missouri does not have the extensive stands of evergreens found in the western US that fuel the large fire storms seen on television news stories.

While very unusual, crown fires can and do occur in Missouri native hardwood forests during prolonged periods of drought combined with extreme heat, low relative humidity, and high wind. Tornadoes, high winds, wet snow and ice storms in recent years have placed a large amount of woody material on the forest floor that causes wildfires to burn hotter and longer. These conditions also make it more difficult for fire fighters suppress fires safely.

Often wildfires in Missouri go unnoticed by the general public because the sensational fire behavior that captures the attention of television viewers is rare in the state. Yet, from the standpoint of destroying homes and other property, Missouri wildfires can be quite destructive.

No information is available for the planning area that connects damages from wildfires to associated structural fires.

Previous Occurrences

The following table captures wildfires reported to the Missouri Department of Natural Resources for Warren County inclusive of January 2002 through December 2018. Data was not available prior to 2002.

Table 3.42 Warren County Wildfires, 2002 - 2018

Cause	Number of Incidents	Acres Burned
Arson	3	3.1
Campfire	2	5.13
Children	1	0.1
Debris	103	220
Equipment	12	15
Fireworks	0	0
Lightning	4	2
Miscellaneous	23	108
Not Reported	0	0
Railroad	0	0
Powerline	2	0.02
Smoking	11	6.75
Unknown	66	1161
TOTAL	**227**	**1,521**

Source: Missouri Department of Natural Resources, Fire Reporting, December 2020

No wildfire events were reported by school districts.

Probability of Future Occurrence

There were 227 wildfire events reported over a 17-year period for an average of 13 fire events per year. However, during the same reporting period, no damage to structures occurred, leading us to conclude that damage to structures from wildfires, while possible, is unlikely.

Changing Future Conditions Considerations

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Missouri, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and changing future conditions are also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. Forests cover about one-third of the state, dominated by oak and hickory trees. As the climate changes, the abundance of pines in Missouri's forests is likely to increase, while the population of hickory trees is likely to decrease 0.
Higher temperatures will also reduce the number of days prescribed burning can be performed. Reduction of prescribed burning will allow for growth of understory vegetation – providing fuel for destructive wildfires. Drought is also anticipated to increase in frequency and intensity during summer months under projected future scenarios. Drought can lead to dead or dying vegetation and landscaping material close to structures which creates fodder for wildfires within both the urban and rural settings.

Vulnerability

Vulnerability Overview

With over 14 million acres, Missouri ranks seventh in the northeast region of the U.S. in forest land area. Although the National Fire Incident Reporting System does capture data on wildfires, it was determined that the Department of Conservation historical wildfire data was the best resource. The Department of Conservation data has more individual events recorded per county. Therefore, this data appeared to be more comprehensive. Some fire departments report to both data sets. So, adding the two sets of data together would have double-counted fires. From the Department of Conservation wildfire data from 1993 to 2016, it was determined that the average annual number of wildfires in Missouri was 3,209 burning an average annual 52,099 acres.

The table below was taken from the 2018 State Plan. The method used to determine vulnerability to wildfires fires across Missouri was a GIS comparative analysis of wildland urban interface and intermix (WUI) areas against building exposure data to determine the types, numbers, and estimated values of buildings at risk to wildfire. This GIS-based analysis utilized data from several sources: the Missouri Spatial Data Inventory Service (MSDIS), HAZUS building exposure value data, and wildland urban interface and intermix area data from the University of Wisconsin-Madison SILVIS Lab.

To calculate estimated values of buildings at risk, buildings values available in the HAZUS census block data were used to determine an average value for each property type. This average value per property type was then applied to the number of structures in the WUI areas, by type, to calculate an overall estimated value of buildings at risk by type. In addition to counts and values of structures at risk, an estimated population impacted for each county was calculated based on the number of residential properties in the WUI areas multiplied by the average household size.

Table 3.43 Wildfire Vulnerability of Warren County, 2018 State Plan

County	Number of Structures	Value of Structures	Population
Warren	**12,829**	**$2,753,420,083**	**26,132**
Agriculture	2,477	$500,505,037	
Commercial	128	$67,144,917	
Education	14	$22,689,333	
Government	22	$14,264,105	
Industrial	20	$17,896,080	
Residential	10,168	$2,130,920,610	

Source: 2018 Missouri State Plan

Impact of Previous and Future Development

There is significant growth in unincorporated areas of the county, City of Warrenton, Innsbrook, Marthasville and Wright City increasing the exposure to wild fire damage. However, as stated earlier, the risk is low now and does not promise to increase significantly in the near term.

Hazard Summary by Jurisdiction

There is significant growth in unincorporated areas of the county, City of Warrenton, Innsbrook, Marthasville and Wright City increasing the exposure to wild fire damage. The new building permit data is provided under future land use & development section on page 3.18.

Problem Statement

Wildfires in Warren County are frequent and numerous; however, damage is slight and limited to crop land and pastures. Jurisdictions concerned about wildfires spreading into their built environment should review their land use code and/or local ordinances to address density and quantity of development within the WUI area, as well as, emergency access, landscaping and water supply.

3.4.11 Hazardous Materials Release (Fixed Facility and Transportation Accidents)

Hazard Profile

Hazard Description

A hazardous material is any substance or material in a quantity or form that may pose a reasonable risk to health, the environment, or property. The category of hazardous materials release includes incidents involving substances such as toxic chemicals, fuels, nuclear wastes and/or products, and other radiological and biological or chemical agents. For the purposes of this analysis, only accidental or incidental releases of hazardous materials from two different kinds of incidents are addressed: fixed facility and transportation- related accidents. In consideration of recent worldwide and national events, incidents involving terrorism or national attacks, which involve hazardous materials of any type, are addressed in Section 2.1 CBRNE Attack, Section 3.5.2 Terrorism, and

Section 2.8 Special Events.

Hazardous Materials Fixed-Facility Accident
Generally, with a fixed facility, the hazards are pre-identified. The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 requires industries to report on the storage, use and releases of hazardous substances to federal, state, and local governments. Facilities in Missouri must submit an emergency and hazardous chemical inventory form to the Missouri Emergency Response Commission, their Local Emergency Planning Committee (LEPC), and local fire departments annually. The inventory forms require basic facility identification information, employee contact information for both emergencies and non- emergencies, and information about chemicals stored or used at the facility.

Warren County houses 53 Tier II facilities including 20 Tier II facilities with extremely hazardous substances (EHS).

Hazardous Materials Transportation Accidents
Transportation accidents address the transport of hazardous materials by rail, road, water, pipeline, and air. In these events, the exact location of a hazardous materials accident is not possible to predict. The close proximity of railroads, highways, waterways, pipelines, airports, and industrial facilities to populated areas, schools, and businesses could put a large number of individuals in danger at any time. In addition, essential service facilities, such as police and fire stations, hospitals, nursing homes, and schools near major transportation routes in the State are also at risk from potential hazardous materials transportation incidents.

Pipelines
Pipelines in Missouri include both large-diameter lines carrying energy products to population centers, as well as small-diameter lines delivering natural gas to local businesses and residences. For the purposes of hazardous materials incidents, pipeline transport focuses on hazardous liquids, including crude oil, petroleum products, anhydrous ammonia and carbon dioxide. Within Missouri, there are approximately 1,847 miles of pipeline carrying crude oil, 1,372 miles of pipeline carrying highly volatile liquids, flammables, and toxic liquids; and 1,913 miles of pipeline carrying refined petroleum products.

Geographic Location

Hazardous materials releases can occur anywhere in Warren County. However, the highest probability will be near major highways, railroads, pipelines, and fixed Tier II facilities. The first map below identifies the major transportation routes in the planning area, the second map shows major pipelines, and the following table identities Tier II facilities.

Figure 3.22. Major Transportation Routes in Warren County

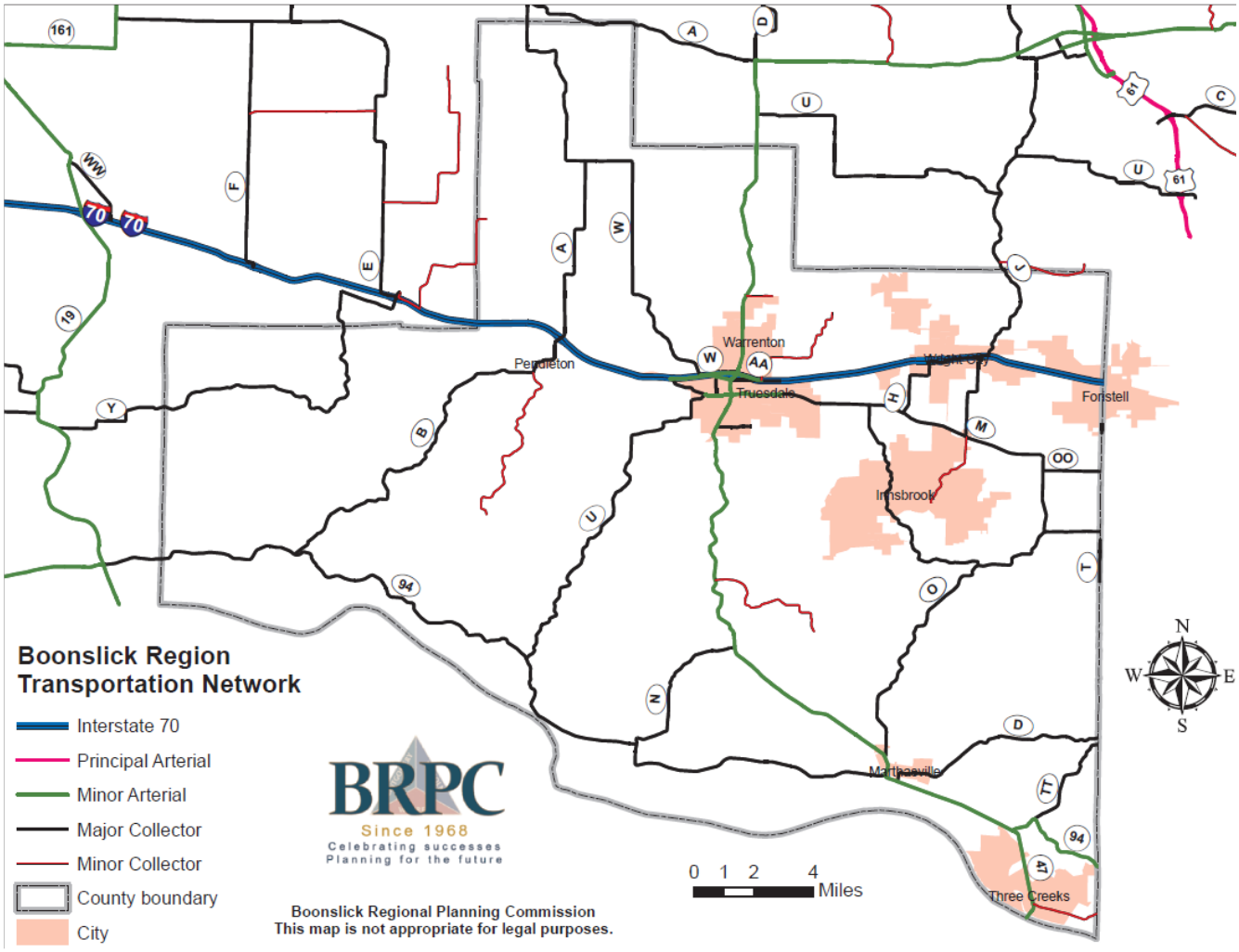
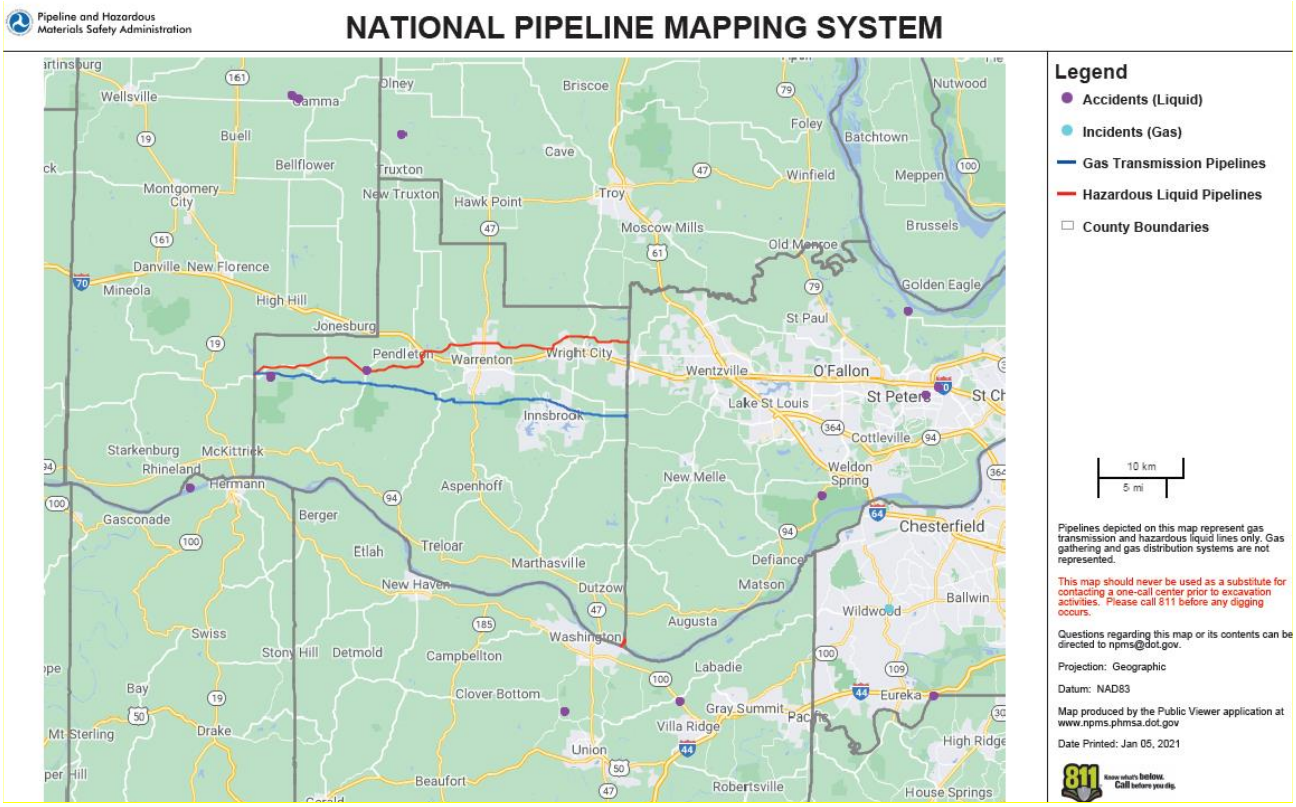


Figure 3.23. Major Pipelines in Warren County



Extent

The entire State of Missouri is susceptible to this type of hazard. However, the magnitude of a hazardous materials release incident will vary in every case depending on the amount spilled or released, type of chemical, method of release, location of release, time of day, and weather conditions. Close coordination between the Missouri Department of Natural Resources, the U.S. Environmental Protection Agency (EPA), the local jurisdiction, and the spiller (responsible party) will be required to minimize the potential impacts to public health and the environment.

Hazardous Materials Fixed-Facility Accident

The severity of consequences is rated as moderate but may be either low or high depending on the type and amount of chemical released. This means the chemical is expected to move into the surrounding environment at a concentration sufficient to cause serious injuries and/or death, unless prompt and effective corrective actions are taken. Injuries and/or death would be expected only for personnel exposed over an extended period or when individual personal health conditions create complications.

Hazardous Materials Transportation Accident

The severity of the consequences is rated as moderate, but may be either low or high depending on the location of the accident and the time of day. This rating means injuries and/or death are expected only for exposed personnel over extended periods of time or when individual personal health conditions create complications.

Previous Occurrences

As per the national pipeline mapping system, there were 3 incidents with liquid spillover in Warren County. Two incidents took place in 2007 in unincorporated Warren County with no major damage and the other one took place in 2006 close to Village of Pendleton with no major damage.

The 2018 Missouri State Hazard Mitigation Plan is the sources for the below information. The environmental emergency response (EER) and Missouri environmental emergency response tracking system (MEERTS) database provides specific details on all reported releases of hazardous substances such as date, county, material released, property use, incident cause, clean-up method and more. Specific information from this database was used to prepare inforamtion comparing fixed facility (bulk chemical plant, bulk petroleum plant, and manufacturing facilities); aircraft/airport; pipeline/pump station; railroad/railyard; road/highway/right-of-way; and water/waterway/marina incidents reported between 1/1/2007 and 12/31/2011 and those incidents reported between 1/1/2012 and 12/31/2016. The decrease in reported incidents is noted as red text. Please check the website at http://dnr.mo.gov/env/esp/meerts.htm for further information.

Table 3.44 Warren County Fixed Facility / Transportation Hazmat Releases, 2007 - 2016

Fixed Facility			Railroad/Railyard			Road/Highway/ ROW			Water/Waterway/ Marina			Pipeline/ Pump Station			Total Incidents		
2007-2011	2012-2016	Δ	2007 - 2011	2012-2016	Δ	2007-2011	2012-2016	Δ	2007-2011	2012-2016	Δ	2007-2011	2012-2016	Δ	2007-2011	2012-2016	Δ
3	1	2	0	1	1	67	48	19	3	3	0	1	0	1	74	53	**21**

Source: 2018 Missouri Hazard Mitigation Plan

Probability of Future Occurrence

According to the 2018 State Plan, as shown in the table above, Warren County experienced a total of 127 fixed facility and transportation-related hazardous materials releases within a ten-year period between 2007 and 2016. That's over 12 events per year for a probability of 100%. Hence, there is no doubt that Warren County will continue to be at risk for hazardous materials release.

Changing Future Conditions Considerations

Accidental or incidental releases of hazardous materials are non-natural incidents and therefore, there are no implications for impacts from climate change.

Vulnerability

Vulnerability Overview

The entire state of Missouri is susceptible to this type of hazard, depending on a number of factors such as the type of chemical, amount released or spilled, the method of release, location of release, time of day, and weather conditions.

The impact of this type of disaster will likely be localized to the immediate area surrounding the incident. The initial concern will be for people, then the environment. If contamination occurs, the spiller is responsible for the cleanup actions and will work closely with the Missouri Department of Natural Resources, EPA, and the local jurisdiction to ensure that cleanup is done safely and in accordance with federal and state laws.

As mentioned, it is difficult to determine the potential losses to existing development because of the variable nature of a hazardous materials spill. For example, a spill of a toxic airborne chemical in a populated area could have great potential for loss of life and by contrast, the spill of a very small amount of a chemical in a remote agricultural area where remediation of soil would be easier could be less costly. For example, the materials needed for a very small spill of a less hazardous chemical in an easily remediated area are listed below. The cost for the essential personnel and equipment are taken from the current State of Missouri contract for Hazardous Substance Cleanup and Disposal Services (C313018001-C313018003).

Table 3.45 Potential Cost Estimate for HAZ-MAT Spill Remediation

Associated Costs	Cost per hour / unit	Number of Hours / Units	Total Cost
Project Manager	$92.65	8	$741.20
Equipment Operator	$95.76	8	$766.08
Response Vehicle	$30.66	8	$245.28
Track Hoe	$81.75	8	$654.00
Environmental Tech	$76.95	8	$615.60
Duct tape	$7.63	6	$45.78
Sampling Containers	$13.08	20	$261.60
PPE - Level B Protection	$267.05	3 staff @ 1 day	$801.15
Vermiculite (19 lb. bag)	$32.70	4	$130.80
55 Gallon Drum	$87.20	20	$1,744.00
85 Gallon Over-pack Drum	$272.50	20	$5,450.00
Total			**$11,455.49**

Source: The maximum cost for the essential personnel and equipment are taken from the current State of Missouri contracts for Hazardous Substance Cleanup and Disposal Services (C313018001-C313018003).

To estimate a potential cost, the estimated $11,456 cost per incident was then applied to the average annual number of reported incidents of 900 to calculate an average annual minimal cost. The annual cost of remediation of spills is calculated as follows; 900 average annual incidents X $11,456 per incident = $10,309,941. The majority of the cost of chemical clean-ups is borne by the party responsible for the spill, in some instances private, for-profit companies. Because the nature of this hazard is so variable, it is difficult to create a potential dollar loss estimate for each county or for any geographic region. The damage that would be expected would be based on the type of chemical released, weather conditions, location of the spill, size of the spill, etc.

Impact of Previous and Future Development

Losses to existing development are primarily due to the cost of jurisdictions responding to accidents within their boundaries. There is little expected increase due to future development. Because Warren County is bisected by two major highways, accidents will continue to be an issue, one aggravated by highways designed to carry far fewer vehicles.

Hazard Summary by Jurisdiction

Communities located near transportation routes and fixed facilities will be at risk, although, the risk is present throughout the planning area.

Problem Statement

Hazardous materials releases in Warren County will remain a risk and the deterioration of the region's infrastructure will likely contribute to additional incidents. Planners should consider ways to minimize risk by investing in updated transportation systems.

3.4.12 Nuclear Power Plant

Hazard Profile

Hazard Description

There are presently four fixed nuclear facilities or reactors that, under extreme circumstances and conditions, could pose a threat to citizens of Missouri. These four reactors fall into two categories: research reactors and commercial nuclear power reactors. The first category, research reactors, represents a hazard only to personnel or others on-site at the facility. Therefore, these reactors are not included in state radiological plans involving off-site emergency preparedness. For the second category, commercial nuclear power reactors, a worst-case scenario involving a significant release of radioactive material could force the evacuation of the general population within a 10-mile radius of the facility. A release of this magnitude could also contaminate food and water sources within a 50-mile radius.

The magnitude of releases from nuclear plant sites varies depending on the nature of the accident type, reactor design, and meteorological conditions during the release. The Nuclear Regulatory Commission and FEMA have developed regulatory guidance that both the State and utility must meet to protect the health and safety of the general population within the 10-mile emergency planning zone (EPZ). Four classes of emergency action levels are used for early notification of incidents, with clear instructions for emergency organizations within the EPZ. The four emergency classifications listed in progression of severity are notification of unusual event, alert, site area emergency, and general emergency. These levels are discussed below.

- **Notification of Unusual Event**—This classification describes unusual events that are in process or have occurred and indicates a potential degradation of the safety level of the plant. No releases of radioactive material requiring off-site response or monitoring are expected unless safety systems are further degraded.
- **Alert**—This classification describes unusual events that are in process or have occurred and indicate a potential degradation of the level of plant safety. Any releases are expected to be limited to small fractions of the U.S. Environmental Protection Agency (EPA) Protective Action Guideline (PAG) exposure levels.
- **Site Area Emergency**—This classification level describes events in process or having occurred that involve actual or likely major failures of the plant functions needed to protect the public. No releases are expected to exceed EPA PAG exposure levels except near the site boundary.

- **General Emergency**—This classification describes an event in process or having occurred that involves actual or imminent substantial core degradation or melting, with the potential for loss of containment integrity. Releases can reasonably be expected to exceed the EPA PAG exposure levels off-site for more than the immediate site area.

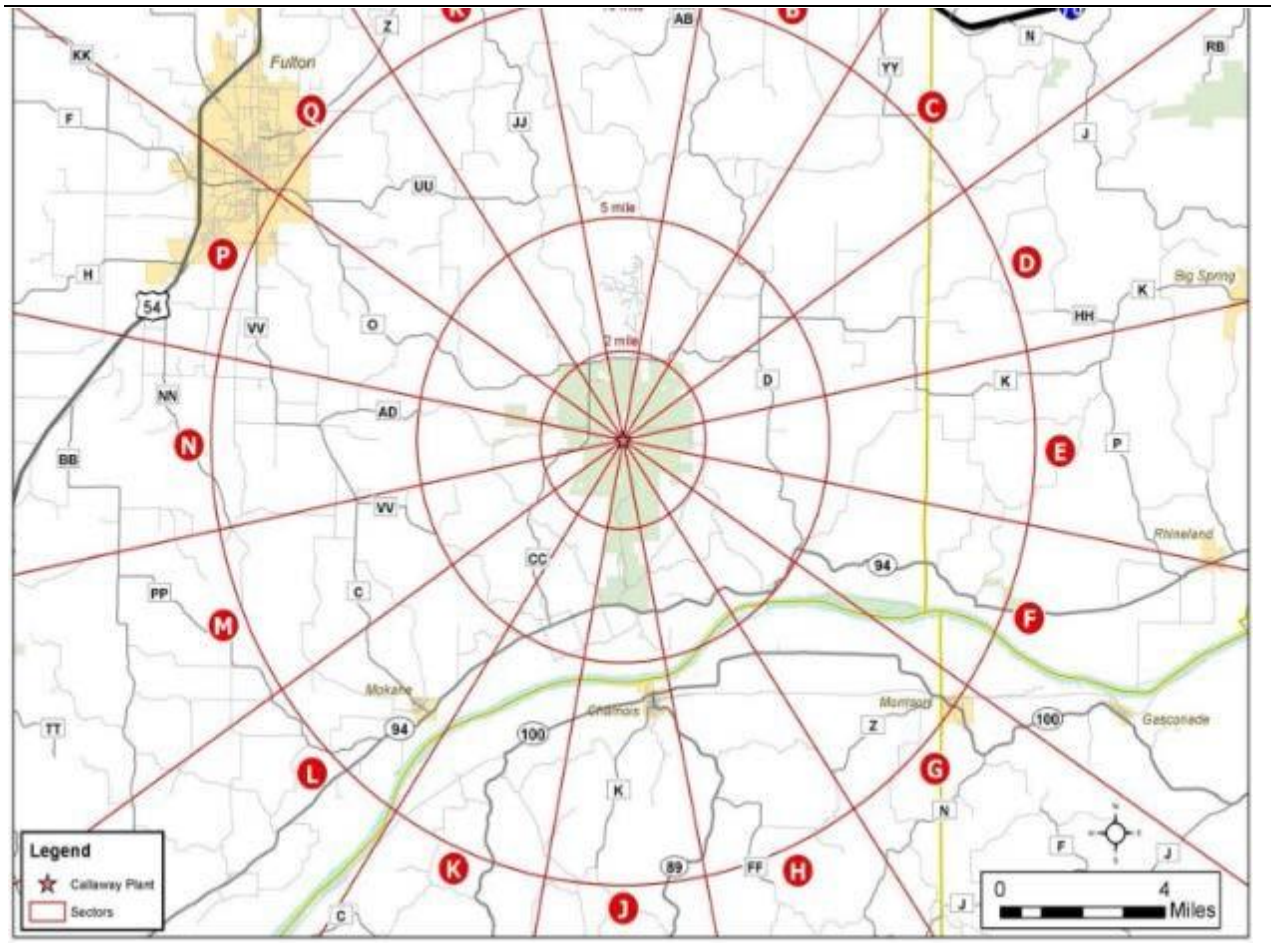
Geographic Location

Two commercial nuclear power reactors could have an impact on the health and safety of Missouri citizens. These reactors are the Callaway Energy Center and the Cooper Nuclear Station, both of which are used for electrical power generation. Both utilities have emergency plans that conform to NUREG-0654, FEMA-REP-1 Rev.1, Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants. The utilities and the State are required to demonstrate annually various elements of preparedness through radiological emergency drills evaluated by inspectors representing FEMA and the NRC.

The **Callaway Energy Center (CEC)** consists of one unit with a pressurized water reactor capable of providing 1360 megawatts of electricity. The physical plant is located in Callaway County, Missouri, and is owned and operated by Ameren Missouri. The 525-acre site is located 10 miles southeast of Fulton, 25 miles northeast of Jefferson City, 5 miles north of the Missouri River, and 80 miles west of St. Louis.

The population within the 2.5 mile radius of the plant is approximately 90 residents. Approximately 8,000 people reside within a 10-mile radius of the plant, according to the 2010 census. The plume exposure pathway has been expanded beyond the 10-mile radius to include the City of Fulton (population 12,112). Thus, the population within the plume exposure pathway is approximately 20,000. Any noticeable fluctuations in the region would be of very short duration and can primarily be attributed to lodging facilities and recreational areas. Land within a five-mile radius of the plant site is mostly rural/undeveloped. The plant began operating in December 1984. The plant's operating license was renewed by the Nuclear Regulatory Commission in 2015, extending its life to the year 2044.

Figure 3.24. Callaway Nuclear Plant Emergency Planning Zones



Strength/Magnitude/Extent

The consequences of a radiological incident originating from one of the commercial nuclear power plants affecting the State can range in severity from a relatively small, insignificant incident, to a high degree of radioactive contamination within the two to 10-mile radius surrounding the facility. The most crucial concerns during a severe incident are safe evacuation and controlled access to the areas affected by a release of radioactive materials. In the aftermath, the main concerns are as follows: the extent of property needing to be decontaminated, contaminated food sources, and the time required to reach acceptable exposure rates and to allow the safe reentry of the public.

Previous Occurrences

There have been no incidents reported during the operational life of the Callaway plant which began in 1984.

Probability of Future Occurrence

Historically, due to their safe operation records, fixed nuclear facilities have not represented a high risk to the State. The Reactor Safety Study conducted by the NRC rated the chances of a major nuclear disaster as very low (a probability of one in one million per plant operating year). The report concluded that the worst accident type that could affect a nuclear power plant would be one resulting in a meltdown, which could be expected to occur once in 20,000 years of reactor operation. The