

3 RISK ASSESSMENT

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44 CFR Requirement §201.6(c)(2): [The plan shall include] A risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.

The goal of the risk assessment is to estimate the potential loss in the planning area, including loss of life, personal injury, property damage, and economic loss, from a hazard event. The risk assessment process allows communities and school/special districts in the planning area to better understand their potential risk to the identified hazards. It will provide a framework for developing and prioritizing mitigation actions to reduce risk from future hazard events.

This chapter is divided into four main parts:

- **Section 3.1 Hazard Identification** identifies the hazards that threaten the planning area and provides a factual basis for elimination of hazards from further consideration;
- **Section 3.2 Assets at Risk** provides the planning area's total exposure to natural hazards, considering critical facilities and other community assets at risk;
- **Section 3.3 Land Use and Development** discusses development that has occurred since the last plan update and any increased or decreased risk that resulted. This section also discusses areas of planned future development and any implications on risk/vulnerability;
- **Section 3.4 Hazard Profiles and Vulnerability Analysis** provides more detailed information about the hazards impacting the planning area. For each hazard, there are three sections: 1) Hazard Profile provides a general description and discusses the threat to the planning area, the geographic location at risk, potential Strength/Magnitude/Extent, previous occurrences of hazard events, probability of future occurrence, risk summary by jurisdiction, impact of future development on the risk; 2) Vulnerability Assessment further defines and quantifies populations, buildings, critical facilities, and other community/school or special district assets at risk to natural hazards; and 3) Problem Statement briefly summarizes the problem and develops possible solutions.

3.1 HAZARD IDENTIFICATION

Requirement §201.6(c)(2)(i): [The risk assessment shall include a] description of the type...of all natural hazards that can affect the jurisdiction.

Natural hazards can be complex, occurring with a wide range of intensities. Some events are instantaneous and offer no window of warning, such as earthquakes. Some offer a short warning in which to alert the public to take actions, such as tornadoes or severe thunderstorms. Others occur less frequently and are typically more expensive, with some warning time to allow the public time to prepare, such as flooding.

Each year there are increases in human-caused incidents, which can be just as devastating as natural disasters. For the purpose of this plan “human-caused hazards” are technological hazards and terrorism. These are distinct from natural hazards primarily in that they originate from human activity. In contrast, while the risks presented by natural hazards may be increased or decreased as a result of human activity, they are not inherently human-induced. The term “technological hazards” refers to the origins of incidents that can arise from human activities such as the manufacture, transportation, storage, and use of hazardous materials. For the sake of simplicity, this guide assumes that technological emergencies are accidental and that their consequences are unintended.

3.1.1 Review of Existing Mitigation Plans

The MPC previously developed a multi-jurisdiction Hazard Mitigation Plan dated 2019 and Monroe County, Monroe City, Paris, Madison, Paris R-II School District, Holliday C-2 School District, Madison C-3 School District, Monroe City R-I School District, and Holy Rosary School participated in the multi-jurisdictional county-wide plan. The 2019 Hazard Mitigation Plan was consulted in development of the risk assessment and information included and updated where appropriate.

The MPC decided to include natural hazards and public health risks. The human-caused and technological hazards were eliminated from further analysis due to these hazards are not necessary for plans to meet the requirements of the Disaster Mitigation Act of 2000.

3.1.2 Review Disaster Declaration History

Declarations may be granted when the severity and magnitude of an event surpasses the ability of the local government to respond and recover. Disaster assistance is supplemental and sequential. When the local government’s capacity has been surpassed, a state disaster declaration may be issued, allowing for the provision of state assistance. If the disaster is so severe that both the local and state governments’ capacities are exceeded; a federal emergency or disaster declaration may be issued allowing for the provision of federal assistance.

FEMA also issues emergency declarations, which are more limited in scope and do not include the long-term federal recovery programs of major disaster declarations. Determinations for declaration type are based on scale and type of damage and institutions or industrial sectors affected.

Table 3.1 provides the federal FEMA disaster declarations that included Monroe County from 1965 to present.

Table 3.1. FEMA Disaster Declarations that included Monroe County, Missouri, 1965-Present

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
372	Severe Storm	4/19/1973	-
3017	Drought	9/24/1976	-
995	Flood	7/9/1993	-
1403	Severe Ice Storm	2/6/2002	PA
1463	Severe Storm	5/6/2003	IA, PA
1524	Severe Storm	6/11/2004	IA
3232	Hurricane	9/10/2005	PA
1631	Severe Storm	3/16/2006	IA, PA
3281	Severe Storm	12/12/2007	PA
1773	Severe Storm	6/25/2008	IA, PA
3303	Severe Ice Storm	1/30/2009	-
1934	Severe Storm	8/17/2010	PA
3317	Severe Storm	2/3/2011	PA
1961	Severe Storm	2/23/2011	PA
4238	Severe Storm	8/7/2015	PA
4451	Severe Storm	7/9/2019	PA
3482	Biological	3/13/2020	PA
4490	Biological	3/26/2020	PA

Source: Federal Emergency Management Agency,
<https://www.fema.gov/data-visualization-summary-disaster-declarations-and-grants>

3.1.3 Research Additional Sources

The additional sources of data on locations and past impacts of hazards in the planning area:

- Missouri Hazard Mitigation Plans (2010, 2013, 2018, and 2023)
- Previously approved planning area Hazard Mitigation Plan (2019)
- Federal Emergency Management Agency (FEMA)
- Missouri Department of Natural Resources
- National Drought Mitigation Center Drought Reporter
- US Department of Agriculture's (USDA) Risk Management Agency Crop Insurance Statistics
- National Agricultural Statistics Service (Agriculture production/losses)

- Data Collection Questionnaires completed by each jurisdiction
- State of Missouri GIS data
- Environmental Protection Agency
- Flood Insurance Administration
- Hazards US (Hazus)
- Missouri Department of Transportation
- Missouri Division of Fire Marshal Safety
- Missouri Public Service Commission
- National Fire Incident Reporting System (NFIRS)
- National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI)
- County and local Comprehensive Plans to the extent available
- County Emergency Management
- County Flood Insurance Rate Map, FEMA
- Flood Insurance Study, FEMA
- SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin
- U.S. Army Corps of Engineers
- U.S. Department of Transportation
- United States Geological Survey (USGS)
- Various articles and publications available on the internet (sources within the body of the plan)

Note that the only centralized source of data for many of the weather-related hazards is the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI). Although it is usually the best and most current source, there are limitations to the data which should be noted. The NCEI documents the occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. In addition, it is a partial record of other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occurs in connection with another event. Some information appearing in the NCEI may be provided by or gathered from sources outside the National Weather Service (NWS), such as the media, law enforcement and/or other government agencies, private companies, individuals, etc. An effort is made to use the best available information but because of time and resource constraints, information from these sources may be unverified by the NWS. Those using information from NCEI should be cautious as the NWS does not guarantee the accuracy or validity of the information.

The NCEI damage amounts are estimates received from a variety of sources, including those listed above in the Data Sources section. For damage amounts, the NWS makes a best guess using all available data at the time of the publication. Property and crop damage figures should be considered as a broad estimate. Damages reported are in dollar values as they existed at the time of the storm event. They do not represent current dollar values.

The database currently contains data from January 1950 to March 2014, as entered by the NWS. Due to changes in the data collection and processing procedures over time, there are unique periods of record available depending on the event type. The following timelines show the different time spans for each period of unique data collection and processing procedures.

1. Tornado: From 1950 through 1954, only tornado events were recorded.
2. Tornado, Thunderstorm, Wind, and Hail: From 1955 through 1992, only tornado, thunderstorm wind and hail events were keyed from the paper publications into digital data. From 1993 to

1995, only tornado, thunderstorm, wind, and hail events have been extracted from the Unformatted Text Files.

3. All Event Types (48 from Directive 10-1605): From 1996 to present, 48 event types are recorded as defined in NWS Directive 10-1605.

Note that injuries and deaths caused by a storm event are reported on an area-wide basis. When reviewing a table resulting from an NCEI search by county, the death or injury listed in connection with that county search did not necessarily occur in that county.

3.1.4 Hazards Identified

The jurisdictions in Monroe County differ in their susceptibilities to certain hazards. The hazards identified were based on the input from the planning team members, available historical data and the hazard modeling results described with the hazard mitigation plans. The jurisdictions and hazards chosen that significantly impact the planning area are listed in alphabetical order in Table 3.2. The chart includes an “x” to indicate the jurisdiction is impacted by the hazard and a “-” indicates the hazard is not applicable to that jurisdiction.

Table 3.2. Hazards Identified for Each Jurisdiction

Jurisdiction	Dam Failure	Drought	Earthquake	Extreme Temperatures	Flooding (River and Flash)	Land Subsidence/Sinkholes	Levee Failure	Severe Winter Weather	Thunderstorm/Lightning/Hail/High Wind	Tornado	Wildfire	Pandemic
County	x	x	x	x	x	x	x	x	x	x	x	X
Village of Holliday	X	x	x	x	x	x	-	x	x	x	x	X
City of Madison	x	x	x	x	x	x	-	x	X	x	x	X
City of Monroe City	x	x	x	x	x	x	-	x	x	x	x	X
City of Paris	X	X	X	X	X	X	-	X	X	X	X	X
Village of Stoutsville	X	X	X	X	X	X	-	X	X	X	X	x
Schools and Special Districts												
Monroe City R-1 School District	-	-	-	X	-	-	-	-	X	x	-	X
Holliday C-2 School District	-	-	-	X	-	-	-	-	X	X	-	X
Madison C-3 School District	-	-	-	X	-	-	-	-	X	X	-	X
Middle Grove C-1 School District	-	-	-	X	-	-	-	-	X	X	-	X
Paris R-2 School District	-	-	-	X	-	-	-	-	X	X	-	X
Holy Rosary School	-	-	-	x	-	-	-	-	x	x	-	X
PWSD #2 of Monroe	-	X	X	X	X	X	-	X	-	-	-	-
Paris Rural Fire Protection District	X	X	X	X	X	X	X	X	X	X	X	X

3.1.5 Multi-Jurisdictional Risk Assessment

For this multi-jurisdictional plan, the risks are assessed for each jurisdiction where they deviate from the risks facing the entire planning area. The planning area is fairly uniform in terms of climate and topography as well as building construction characteristics. Accordingly, the geographic areas of occurrence for weather-related hazards do not vary greatly across the planning area for most hazards. Paris and Monroe City are slightly more urbanized within the planning area and have more assets that are vulnerable to weather-related hazards and varied development trends impact the future vulnerability. Similarly, more rural areas have more assets (crops/livestock) that are vulnerable to animal/plant/crop disease. These differences are discussed in greater detail in the vulnerability sections of each hazard.

The hazards that vary across the planning area in terms of risk include dam failure, flash flood, grass or wildland fire, levee failure, and sinkholes/land subsidence. The difference in hazards is explained in each hazard profile under a separate heading.

3.2 ASSETS AT RISK

This section assesses the population, structures, critical facilities and infrastructure, and other important assets in the planning area that may be at risk of natural hazards. Table 3.3 shows the total population, building count, estimated value of buildings, estimated value of contents and estimated total exposure to parcels by jurisdiction.

3.2.1 Total Exposure of Population and Structures

Unincorporated County and Incorporated Cities

In the following three tables, population data is based on 2020 Census Bureau data. Building counts and building exposure values are based on parcel data developed by the State of Missouri Geographic Information Systems (GIS) database. This data, organized by County, is available on Google Drive through the link provided on the previous page. Contents exposure values were calculated by factoring a multiplier to the building exposure values based on usage type. The multipliers were derived from the Hazus and are defined below in **Table 3.3**. Land values have been purposely excluded from consideration because land remains following disasters, and subsequent market devaluations are frequently short term and difficult to quantify. Another reason for excluding land values is that state and federal disaster assistance programs generally do not address loss of land (other than crop insurance). It should be noted that the total valuation of buildings is based on county assessors' data which may not be current. In addition, government-owned properties are usually taxed differently or not at all, and so may not be an accurate representation of true value. Note that public school district assets and special districts assets are included in the total exposure tables assets by community and county.

Table 3.3 shows the total population, building count, estimated value of buildings, estimated value of contents and estimated total exposure to parcels for the unincorporated county and each incorporated city. For multi-county communities, the population and building data may include data on assets located outside the planning area. **Table 3.4** that follows provides the building value exposures for the county and each city in the planning area broken down by usage type. Finally, **Table 3.5** provides the building count total for the county and each city in the planning area broken out by building usage types (residential, commercial, industrial, and agricultural).

Table 3.3. Maximum Population and Building Exposure by Jurisdiction

Jurisdiction	2020 Annual Population	Building Count	Building Exposure (\$)	Contents Exposure (\$)	Total Exposure (\$)
Monroe City	2,661	992	\$119,815	\$67,795	\$187,610
Paris	1,161	719	\$81,426	\$47,576	\$129,002
Madison	515	311	\$33,186	\$18,003	\$51,189
Holliday	114	85	\$9,643	\$4,535	\$14,178
Stoutsville	37	48	\$2,818	\$1,437	\$4,255
Uninc. Monroe County	4,215	10,328	\$369,243	\$194,285	\$563,528
Totals	8,703	12,483	\$616,131	\$333,631	\$949,762

Source: U.S. Bureau of the Census; Building Count and Building Exposure, Missouri GIS Database from SEMA Mitigation Management; Contents Exposure derived by applying multiplier to Building Exposure based on Hazus MH 2.1 standard contents multipliers per usage type as follows: Residential (50%), Commercial (100%), Industrial (150%), Agricultural (100%). For purposes of these calculations, government, school, and utility were calculated at the commercial contents rate.

Table 3.4. Building Values/Exposure by Usage Type

Jurisdiction	Residential	Commercial	Industrial	Agricultural	Total
Monroe City	\$86,796	\$12,327	\$7,077	\$69	\$106,269
Paris	\$22,654	\$12,327	\$2,654	\$41	\$37,676
Madison	\$27,903	\$3,688	\$0	\$23	\$31,614
Holliday	\$7,774	\$527	\$0	\$11	\$8,312
Stoutsville	\$2,662	\$105	\$0	\$50	\$2,817
Uninc. Monroe County	\$319,815	\$19,175	\$9,731	\$16,288	\$365,009
Totals	\$467,604	\$48,149	\$19,462	\$16,432	\$551,697

Source: Missouri GIS Database, SEMA Mitigation Management Section

Table 3.5. Building Counts by Usage Type

Jurisdiction	Residential Counts	Commercial Counts	Industrial Counts	Agricultural Counts	Total
Monroe City	815	117	8	30	970
Paris	569	117	3	18	707
Madison	262	36	0	10	308
Holliday	73	5	0	5	83
Stoutsville	25	1	0	22	48
Uninc. Monroe County	3,003	182	11	7,124	10,320
Totals	4,747	458	22	7,209	12,388

Source: Missouri GIS Database, SEMA Mitigation Management Section; Public School Districts and Special Districts

The number of enrolled students at the participating public-school districts is provided in **Table 3.6** below. Additional information includes the number of buildings, building values (building exposure) and contents value (contents exposure). These numbers will represent the total enrollment and building count for the public-school districts regardless of the county in which they are located.

Table 3.6. Population and Building Exposure by Jurisdiction-Public School Districts

Public School District	Enrolment	Building Count	Building Exposure (\$)	Contents Exposure (\$)	Total Exposure (\$)
Holliday C-2 School District	50	3	\$2,660,000	\$1,000,000	\$3,660,000
Madison C-3 School District	188	6	\$10,091,257	\$1,900,217	\$11,991,474
Middle Grove C-1 School District	32	-	-	-	-
Monroe City R-1 School District	764	3	\$46,820,000	\$6,040,000	\$52,860,000
Paris R-2 School District	462	4	\$22,293,206	\$5,788,125	\$28,081,331
Holy Rosary School	185	1	\$5,100,000	\$1,300,000	\$6,400,000

Source: <http://mcids.dese.mo.gov/quickfacts/Pages/District-and-School-Information.aspx>. The Building Exposure, Contents Exposure, and Total Exposure amounts come from the completed Data Collection Questionnaires from Public School Districts. In general, the school districts obtain this information from their insurance coverage amounts.

3.2.2 Critical and Essential Facilities and Infrastructure

This section will include information from the Data Collection Questionnaire and other sources concerning the vulnerability of participating jurisdictions’ critical, essential, high potential loss, and transportation/lifeline facilities to identified hazards. Definitions of each of these types of facilities are provided below.

- Critical Facility: Those facilities essential in providing utility or direction either during the response to an emergency or during the recovery operation.
- Essential Facility: Those facilities that if damaged, would have devastating impacts on disaster response and/or recovery.
- High Potential Loss Facilities: Those facilities that would have a high loss or impact on the community.
- Transportation and lifeline facilities: Those facilities and infrastructure critical to transportation, communications, and necessary utilities.

Table 3.7 includes a summary of the inventory of critical and essential facilities and infrastructure in the planning area. The list was compiled from the Data Collection Questionnaire as well as the following sources:

- Mark Twain Regional Council of Governments list of critical facility inventory

Table 3.7. Inventory of Critical/Essential Facilities and Infrastructure by Jurisdiction

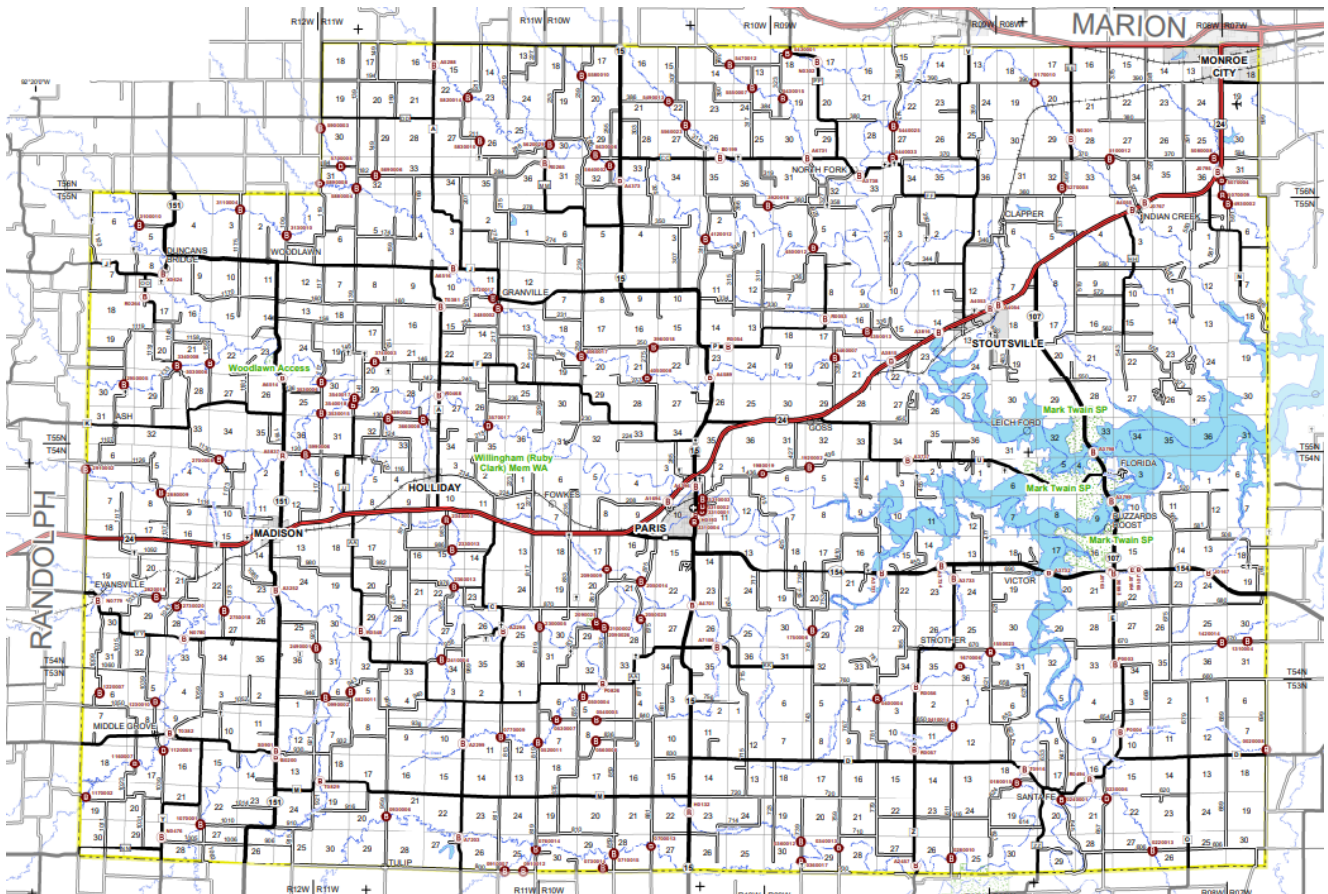
Jurisdiction	Airport Facility	Bus Facility	Childcare Facility	Communications Tower	Electric Power Facility	Emergency Operations	Fire Service	Government	Housing	Shelters	Highway Bridge	Hospital/Health Care	Military	Natural Gas Facility	Nursing Homes	Police Station	Potable Water Facility	Rail	Sanitary Pump Stations	School Facilities	Stormwater Pump Stations	Tier II Chemical Facility	Wastewater Facility	TOTAL
City of Madison				x		X		X	X	X										X			X	7
City of Monroe City	X		X	X	X	X	X	X	X	X	X	X			X	X		X		X			X	16
City of Paris			X	X	X	X	X	X	X			X			X					X			X	11
Village of Holliday							X			X									X	X			X	5
Monroe County				X	X	X		X		X	X							X		X			X	9
Totals	1		2	4	3	4	3	4	3	4	2	2	0	0	2	1	0	2	1	5	0	0	5	48

Source: Missouri 2023 State Hazard Mitigation Plan and Hazard Mitigation Viewer; Data Collection Questionnaires; Hazus, etc.

Bridges: The term “scour critical” refers to one of the database elements in the National Bridge Inventory. This element is quantified using a “scour index”, which is a number indicating the vulnerability of a bridge to scour during a flood. Bridges with a scour index between 1 and 3 are considered “scour critical”, or a bridge with a foundation determined to be unstable for the observed or evaluated scour condition.

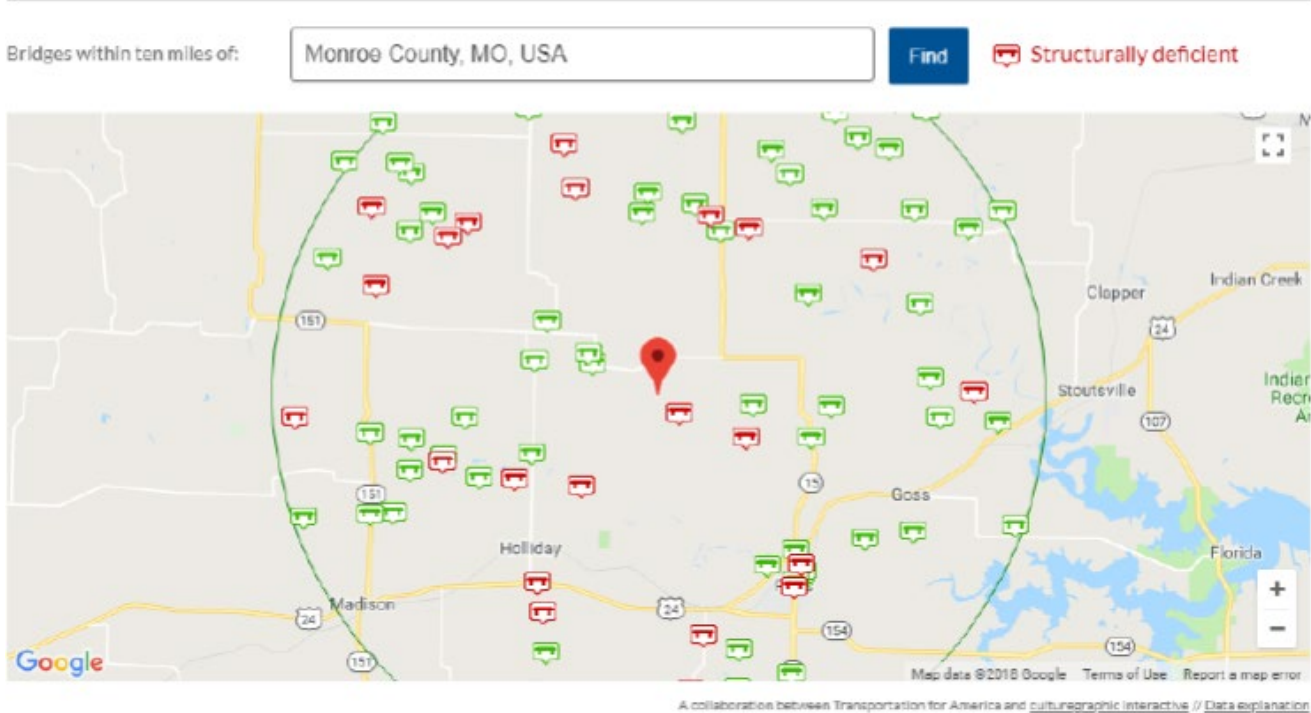
Figure 3.1 is a map depicting Monroe County Bridges. Bridges are denoted by a red or white “B” symbol.

Figure 3.1. Monroe County Bridges



Source: <https://www.modot.org/sites/default/files/documents/MonroeCo2021.pdf>

Figure 3.2. Monroe County Structurally Deficient Bridges



Source: <https://t4america.org/maps-tools/bridges/>

3.2.3 Other Assets

Assessing the vulnerability of the planning area to disaster also requires data on the natural, historic, cultural, and economic assets of the area. This information is important for many reasons.

- These types of resources warrant a greater degree of protection due to their unique and irreplaceable nature and contribution to the overall economy.
- Knowing about these resources in advance allows for consideration immediately following a hazard event, which is when the potential for damage is higher.
- The rules for reconstruction, restoration, rehabilitation, and/or replacement are often different for these types of designated resources.
- The presence of natural resources can reduce the impacts of future natural hazards, such as wetlands and riparian habitats which help absorb floodwaters.
- Losses to economic assets like these (e.g., major employers or primary economic sectors) could have severe impacts on a community and its ability to recover from disaster.

Threatened and Endangered Species: **Table 3.8** shows Federally Threatened, Endangered, Proposed and Candidate Species in the county.

Table 3.8. Threatened and Endangered Species in Monroe County

Common Name	Scientific Name	Status
Indiana Bat	Myotis Sodalis	Endangered
Gray Bat	Myotis Griseus	Endangered
Northern Long-Eared Bat	Myotis Septentrionalis	Threatened

Source: U.S. Fish and Wildlife Service, <http://www.fws.gov/midwest/Endangered/lists/missouri-cty.html>; see also <https://ecos.fws.gov/ipac/>

Natural Resources: Monroe County has seven conservation and Recreation areas as well as parks. The Missouri Department of Conservation (MDC) provides a database of lands the MDC owns, leases or manages for public use. **Table 3.9** provides the names and locations of parks and conservation areas in Monroe County.

Table 3.9. Parks in Monroe County

Park / Conservation Area	Address	City
Cedar Bluff Access	From Paris, take Highway 24 west 1 mile, then County Road 857 south 2.5 miles	Paris
Paris Access	On highway 15 and Business Highway 24 near the north edge of Paris	Paris
Santa Fe Access	From Santa Fe, take Route D east 0.70 miles	Santa Fe
White (Robert M II) CA	From Mexico, take Highway 15 north 8 miles, then Route Z east 2 miles, and Route Z7 east 2 miles	
Willingham (Ruby Clark) Mem WA	From Holliday, take Highway 24 east 1.5 miles, then County Road 217 north 0.50 miles, then County Road 214 east 0.50 miles, and County Road 223 north	Holliday
Woodlawn Access	From Madison, take Highway 151 north about 5 miles	Madison
Mark Twain State Park	37352 Shrine	Florida
North Park	Bounded by North Locust Street, North Chestnut Street, Court Street and Charles Street	Monroe City
South Park	Bounded by Park Street, East Cleveland Street, South Davis Street and South Washington Street	Monroe City
Gordon Hill Park	Northwest corner of Lawn Street and County Line Road	Monroe City
Kendrick Park	In Kendrick Trailer Court east of the intersection of Easy Street and Widow Lane	Monroe City
Dalpa Thompson Park	Wedge area bounded by East Dover Street, East Cleveland Street and South Oak Street	Monroe City
St. Jude's Square	301 North Main Street	Monroe City
Winter Street Park	West of the intersection of Winter Street and Cemetery Road	Monroe City
Oelschalger Park	Bounded by Park Place, North Chestnut Street, Catherine Street and Court Street	Monroe City
Founder's Park	Bounded by Catherine Street, Charles Street, North Locust and paved alley west of Methodist Church	Monroe City
Capelle Street	Northwest corner of South Capelle Street and East Summer Street	Monroe City
Talitha's Point	Wedge are on Highway 24 & 36 East between North Washington Street and Prairie Street	Monroe City
Industrial Park	2 Brasch Road	Paris

Source: <http://mdc7.mdc.mo.gov/applications/moatlas/AreaList.aspx?txtUserID=guest&txtAreaNm=s> and community websites.

Historic Resources: The National Register of Historic Places is the official list of registered cultural resources worthy of preservation. It was authorized under the National Historic Preservation Act of 1966 as part of a national program. The purpose of the program is to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archeological resources. The National Register is administered by the National Park Service under the Secretary of the Interior. Properties listed in the National Register include districts, sites, buildings, structures and objects that are significant in American history, architecture, archeology, engineering, and culture.

Table 3.10 provides the properties in Monroe County on the National Register of Historic Places.

Table 3.10. Monroe County Properties on the National Register of Historic Places

Property	Address	City	Date Listed
Farmers and Merchants Bank Building	201-207 S. Main Street	Monroe City	1/12/122
Mark Twain Birthplace State Historic	2.5 mile S of Florida	Florida	5/21/69
Mark Twain State Park Picnic Shelter	19199 Buzzards Roost Road	Florida	3/4/85
Paris Male Academy	411 E Monroe Street	Paris	7/19/90
St. Jude Episcopal Church	301 North Main Street	Monroe City	11/22/00
Union Covered Bridge	S27, T54N, R11W	Paris	6/15/70
Violette, Merritt, House	Off MO 107	Florida	9/8/83
Washington School	529 S Locust Street	Monroe City	12/29/94

Source: Missouri Department of Natural Resources – Missouri National Register Listings by County
<http://dnr.mo.gov/shpo/mnrlist.htm>

Economic Resources: **Table 3.11** provides major non-government employers in the planning area.

Table 3.11. Major Non-Government Employers in Monroe County

Employer Name	Main Locations	Product or Service	Employees
Cedar Crest Baptist Camp		Religious	100-249
Learning Opportunities	Monroe City	Learning/Employment Center	50-99
Aspeg	Monroe City	Manufacturing	100
JC Shoemyer	Monroe City	Vehicles	80
Sheltered Workshop	Monroe City	Learning/Employment Center	50
C & R Supermarket	Monroe City	Grocery Store	45
Farmer's Elevator	Monroe City	Agriculture	40
Monroe City R-1 School	Monroe City	Education	100
Monroe City Manor	Monroe City	Nursing Home	65
Paris R-2 School	Paris	Education	50
Holy Rosary School	Monroe City	Education	25
Holliday C-2 School	Holliday	Education	25
Madison C-3 School	Madison	Education	45
Monroe Manor	Paris	Nursing Home	30
Lakeside Casting	Monroe City	Zinc Die Casting	85

Source: Data Collection Questionnaires; local Economic Development Commissions

Agriculture: Agriculture plays a very important role in Monroe County's economy. **Table 3.12** provides a summary of the agriculture-related jobs in Monroe County.

Table 3.12. Agriculture-Related Jobs in Monroe County

Item	Monroe
Hired farm labor	
farms	173
workers	359
\$1,000 payroll	3,605
Farms with-	
1 worker	78
workers	78
2 workers	55
workers	110
3 or 4 workers	29
workers	90
5 to 9 workers	10
workers	(D)
10 workers or more	1
farms	(D)
workers	(D)
Workers by days worked:	
150 days or more	67
farms	127
workers	
Farms with-	
1 worker	34
farms	34
workers	
2 workers	22
farms	44
workers	
3 or 4 workers	7
farms	23
workers	
5 to 9 workers	3
farms	(D)
workers	
10 workers or more	1
farms	(D)
workers	(D)
Less than 150 days	123
farms	232
workers	
Farms with-	
1 worker	62
farms	62
workers	
2 workers	32
farms	64
workers	
3 or 4 workers	22
farms	67
workers	
5 to 9 workers	7
farms	39
workers	
10 workers or more	-
farms	-
workers	-
Reported only workers working	
150 days or more	50
farms	81
workers	
\$1,000 payroll	1,542
Reported only workers working	
less than 150 days	106
farms	198
workers	
\$1,000 payroll	755
Reported both - workers working	
150 days or more and workers	
working less than 150 days	17
farms	46
150 days or more, workers	
less than 150 days, workers	34
\$1,000 payroll	1,308
Total migrant workers	
farms	-
workers	-
Migrant farm labor on farms with hired labor	
farms	-
workers	-
Migrant farm labor on farms reporting only	
contract labor	-
farms	-
workers	-
Unpaid workers	
farms	394
workers	933

Source: https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Missouri/st29_2_0007_007.pdf

3.3 LAND USE AND DEVELOPMENT

3.3.1 Development Since Previous Plan Update

Population data can sometimes be used to determine the potential for future development. An increase in population will spur a need for additional housing and attract commercial development. As indicated by the information in **Table 3.13**, Monroe County has experienced a decrease in population. However, no development changes have affected any of the below jurisdictions' overall vulnerability since the previous plan update.

Table 3.13. County Population Growth, 2010-2020

Jurisdiction	Total Population 2010	Total Population 2020	2010-2020 # Change	2000-2020 % Change
Monroe County	8,840	8,666	-174	-2%
Monroe City	2,531	2,661	130	4.9%
Paris	1,220	1,161	-59	-5.1%
Madison	554	515	-39	-7.6%
Holliday	137	114	-23	-22.8%
Stoutsville	36	37	1	2.8%

Source: U.S. Bureau of the Census, Decennial Census, Annual Population Estimates, American Community Survey 5-year Estimates; Population Statistics are for entire incorporated areas as reported by the Census bureau

Along with the overall population decrease, there has been a decline in the number of housing units. **Table 3.14** provides the change in number of housing units in the planning area from 2010-2020.

Table 3.14. Change in Housing Units, 2010-2020

Jurisdiction	Housing Units 2010	Housing Units 2020	2010-2020 # Change	2000-2020 % Change
Monroe County	4,798	4,514	-284	-5.9%
Monroe City	1,267	1,404	-137	-10.8%
Paris	643	637	-6	-0.9%
Madison	292	247	-45	-15.4%
Holliday	80	83	3	3.75%
Soutsville	34	30	-4	-13.3%

Source: U.S. Bureau of the Census, Decennial Census, American Community Survey 5-year Estimates; Population Statistics are for entire incorporated areas as reported by the U.S. Census Bureau

Population growth or decline is generally accompanied by an increase or decrease in the number of housing units. With the trend of population decline for the entire county there is little reason to expect increased development.

3.3.2 Future Land Use and Development

School District's Future Development

Monroe City R-I School has submitted a Notice of Interest to SEMA for a safe room. The NOI is set to expire in August 2024. The Action Worksheet (Monroe City R-I 2024.01) is included in Chapter 4 on page 4.36.

Special District's Future Development

There were no special districts indicating future development.

3.4 HAZARD PROFILES, VULNERABILITY, AND PROBLEM STATEMENTS

Each hazard will be analyzed individually in a hazard profile. The profile will consist of a general hazard description, location, strength/magnitude/extent, previous events, future probability, a discussion of risk variations between jurisdictions, and how anticipated development could impact risk. At the end of each hazard profile will be a vulnerability assessment, followed by a summary problem statement.

Hazard Profiles

Requirement §201.6(c)(2)(i): [The risk assessment shall include a] description of the...location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

The level of information presented in the profiles will vary by hazard based on the information available. With each update of this plan, new information will be incorporated to provide better evaluation and prioritization of the hazards that affect the planning area. Detailed profiles for each of the identified hazards include information categorized as follows:

- **Hazard Description:** This section consists of a general description of the hazard and the types of impacts it may have on a community or school/special district.
- **Geographic Location:** This section describes the geographic areas in the planning area that are affected by the hazard. Where available, use maps to indicate the specific locations of the planning area that are vulnerable to the subject hazard. For some hazards, the entire planning area is at risk.
- **Strength/Magnitude/Extent:** This includes information about the strength, magnitude, and extent of a hazard. For some hazards, this is accomplished with description of a value on an established scientific scale or measurement system, such as an EF2 tornado on the Enhanced Fujita Scale. This section should also include information on the typical or expected strength/magnitude/extent of the hazard in the planning area. Strength, magnitude, and extent can also include the speed of onset and the duration of hazard events. Describing the strength/magnitude/extent of a hazard is not the same as describing its potential impacts on a community. Strength/magnitude/extent defines the characteristics of the hazard regardless of the people and property it affects.
- **Previous Occurrences:** This section includes available information on historic incidents and their impacts. Historic event records form a solid basis for probability calculations.
- **Probability of Future Occurrence:** The frequency of recorded past events is used to estimate the likelihood of future occurrences. Probability can be determined by dividing the number of recorded events by the number of years of available data and multiplying by 100. This gives the percent chance of the event happening in any given year. For events occurring more than once annually, the probability should be reported as 100% in any given year, with a statement of the average number of events annually. For hazards such as drought that may have gradual onset and extended duration, probability can be based on the number of months in drought in a given time-period and expressed as the probability for any given month to be in drought.

- **Changing Future Conditions Considerations:**

In addition to the probability of future occurrences, changing future conditions should also be considered, including the effects of long-term changes in weather patterns and climate on the identified hazards.

Vulnerability Assessments

Requirement §201.6(c)(2)(ii) :[The risk assessment shall include a] description of the jurisdiction’s vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.

Requirement §201.6(c)(2)(ii)(A) :The plan should describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas.

Requirement §201.6(c)(2)(ii)(B) :[The plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) of this section and a description of the methodology used to prepare the estimate.

Requirement §201.6(c)(2)(ii)(C): [The plan should describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.

Requirement §201.6(c)(2)(ii): (As of October 1, 2008) [The risk assessment] must also address National Flood Insurance Program (NFIP) insured structures that have been repetitively damaged in floods.

Following the hazard profile for each hazard will be the vulnerability assessment. The vulnerability assessment further defines and quantifies populations, buildings, critical facilities, and other community assets at risk of damage from natural hazards. The vulnerability assessments should be based on the best available data. The vulnerability assessments can also be based on data that was collected for the 2023 State Hazard Mitigation Plan Update. With the 2023 Hazard Mitigation Plan Update, SEMA is pleased to provide online access to the risk assessment data and associated mapping for the 114 counties in the State, including the independent City of St. Louis. Through the web-based Missouri Hazard Mitigation Viewer, local planners or other interested parties can obtain all State Plan datasets. This effort removes from local mitigation planners a barrier to performing all the needed local risk assessments by providing the data developed during the 2023 State Plan Update.

The Missouri Hazard Mitigation Viewer includes a Map Viewer with a legend of clearly labeled features, a north arrow, a base map that is either aerial imagery or a street map, risk assessment data symbolized the same as in the 2023 State Plan for easy reference, search and query capabilities, ability to zoom to county level data and capability to download PDF format maps. The Missouri Hazard Mitigation Viewer can be found at this link: <http://bit.ly/MoHazardMitigationPlanViewer2018>.

The vulnerability assessments in the Monroe County Plan will also be based on:

- Written descriptions of assets and risks provided by participating jurisdictions;
- Existing plans and reports;
- Personal interviews with planning committee members and other stakeholders; and
- Other sources as cited.

- **Vulnerability Overview:**
This section consists of a general overview narrative of the planning area’s vulnerability to the hazard. Within this section, the magnitude/severity of the hazard is discussed. The magnitude of the impact of a hazard event (past and perceived) is related directly to the vulnerability of the people, property, and the environment it affects. This is a function of when the event occurs, the location affected by the resilience of the community, and the effectiveness of the emergency response and disaster recovery efforts.
- **Potential Losses to Existing Development:**
This section provides the potential losses existing to development.
- **Previous and Future Development:**
This section will include information on how changes in development have impacted the community’s vulnerability to this hazard.
- **Hazard Summary by Jurisdiction:**
For hazard risks that vary by jurisdiction, this section will provide an overview of the variation and the factual basis for that variation.

Problem Statements

Each hazard analysis concludes with a brief summary of the problems created by the hazard in the planning area, and possible ways to resolve those problems. Jurisdiction-specific information in those cases where the risk varies across the planning area is included.

3.4.1 Flooding (Riverine and Flash)

Hazard Profile

Hazard Description

A flood is partial or complete inundation of normally dry land areas. Riverine flooding is defined as the overflow of rivers, streams, drains, and lakes due to excessive rainfall, rapid snowmelt, or ice. There are several types of riverine floods, including headwater, backwater, interior drainage, and flash flooding. Riverine flooding is defined as the overflow of rivers, streams, drains, and lakes due to excessive rainfall, rapid snowmelt or ice melt. The areas adjacent to rivers and stream banks that carry excess floodwater during rapid runoff are called floodplains. A floodplain is defined as the lowland and relatively flat area adjoining a river or stream. The terms “base flood” and “100- year flood” refer to the area in the floodplain that is subject to a one percent or greater chance of flooding in any given year. Floodplains are part of a larger entity called a basin, which is defined as all the land drained by a river and its branches.

Flooding caused by dam and levee failure is discussed in Section 3.4.3 and Section 3.4.2 respectively. It will not be addressed in this section.

A flash flood occurs when water levels rise at an extremely fast rate as a result of intense rainfall over a brief period, sometimes combined with rapid snowmelt, ice jam release, frozen ground, saturated soil, or impermeable surfaces. Flash flooding can happen in Special Flood Hazard Areas (SFHAs) as delineated by the National Flood Insurance Program (NFIP) and can also happen in areas not associated with floodplains.

Ice jam flooding is a form of flash flooding that occurs when ice breaks up in moving waterways, and then stacks on itself where channels narrow. This creates a natural dam, often causing flooding within

minutes of the dam formation.

In some cases, flooding may not be directly attributable to a river, stream, or lake overflowing its banks. Rather, it may simply be the combination of excessive rainfall or snowmelt, saturated ground, and inadequate drainage. With no place to go, the water will find the lowest elevations – areas that are often not in a floodplain. This type of flooding, often referred to as sheet flooding, is becoming increasingly prevalent as development outstrips the ability of the drainage infrastructure to properly carry and disburse the water flow.

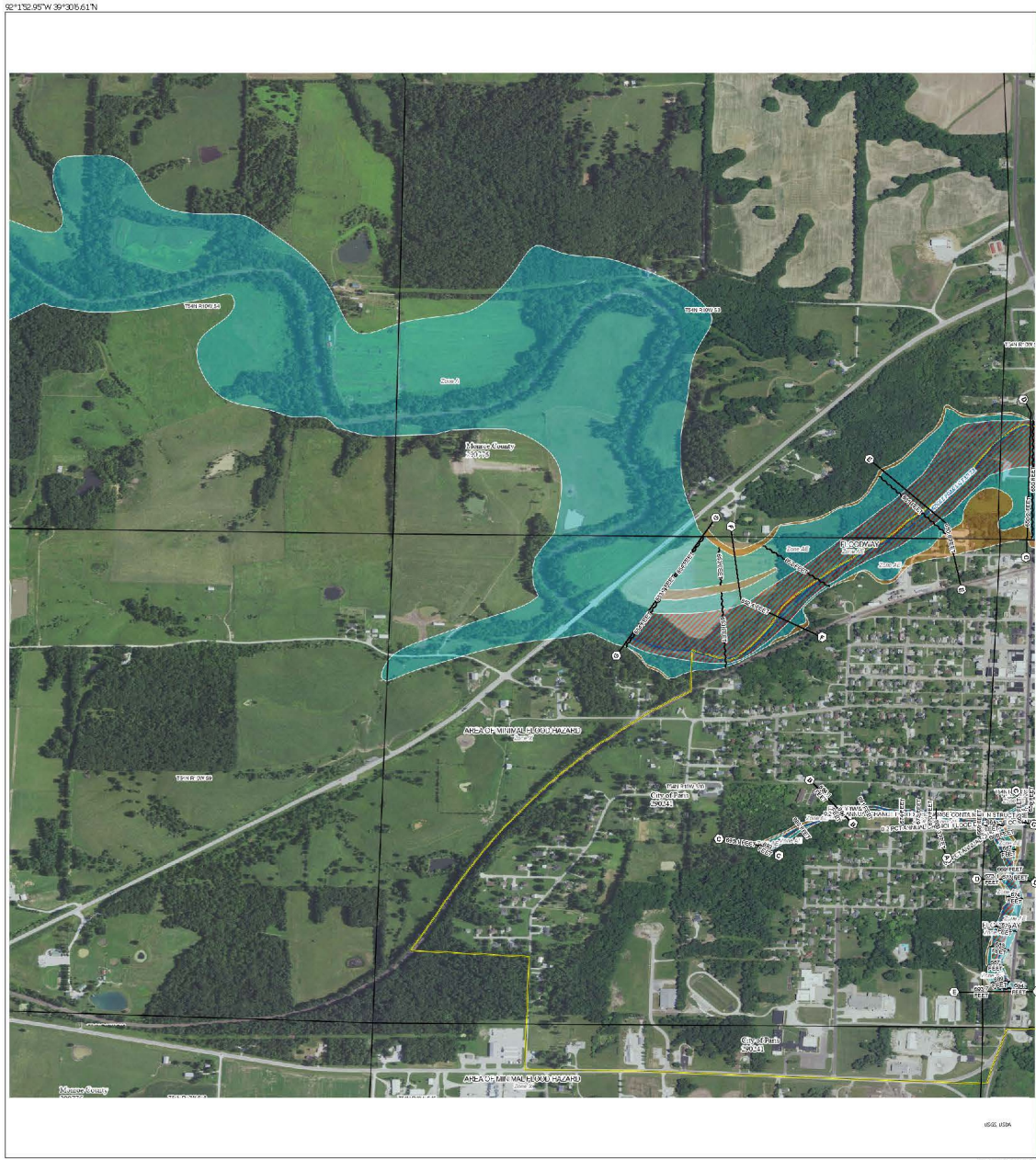
Most flash flooding is caused by slow-moving thunderstorms or thunderstorms repeatedly moving over the same area. Flash flooding is a dangerous form of flooding which can reach full peak in only a few minutes. Rapid onset allows little or no time for protective measures. Flash flood waters move at very fast speeds and can move boulders, tear out trees, scour channels, destroy buildings, and obliterate bridges. Flash flooding can result in higher loss of life, both human and animal, than slower developing river and stream flooding.

In certain areas, aging storm sewer systems are not designed to carry the capacity currently needed to handle the increased storm runoff. Typically, the result is water backing into basements, which damages mechanical systems and can create serious public health and safety concerns. This combined with rainfall trends and rainfall extremes all demonstrate the high probability, yet generally unpredictable nature of flash flooding in the planning area.

Although flash floods are somewhat unpredictable, there are factors that can point to the likelihood of flash floods occurring. Weather surveillance radar is being used to improve monitoring capabilities of intense rainfall. This, along with knowledge of the watershed characteristics, modeling techniques, monitoring, and advanced warning systems has increased the warning time for flash floods.

Geographic Location

Riverine flooding is most likely to occur in (Special Flood Hazard Areas) SFHAs. Below is a FIRM for Monroe County.



FLOOD HAZARD INFORMATION

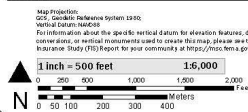
SEE THIS REPORT FOR A DETAILED LEGEND AND INDEX MAP FOR EACH FIRM PANEL LAYOUT

	Without Base Flood Elevation (BFE)
	0.2% Annual Chance Flood Hazard, Areas with BFE or Depth
	Area with Flood Risk due to Levee
	Area of Minimal Flood Hazard
	Channel, Culvert, or Storm Sewer
	Levee, Dike, or Floodwall
	Levee Section with 1% Annual Chance
	Water Surface Elevation
	Channel Bankline
	Channel Bankline
	Profile Baseline
	Right-of-Way Feature
	Base Flood Elevation Line (BFE)
	Levee or Dike
	Jurisdiction Boundary

NOTES TO USERS

For information and details about the Flood Hazard Rate Map, please refer to the accompanying Flood Hazard Rate Map Report, which is available on the FEMA website at www.fema.gov. This report provides information about the map's purpose, the data used to create the map, and the map's limitations. It also provides information about the map's use and the map's accuracy. The map is intended for informational purposes only and should not be used for any other purpose. The map is not a guarantee of accuracy and should not be used for any other purpose. The map is not a guarantee of accuracy and should not be used for any other purpose. The map is not a guarantee of accuracy and should not be used for any other purpose.

SCALE



NATIONAL FLOOD INSURANCE PROGRAM FLOOD INSURANCE RATE MAP

PANEL 392 of 555

COMMUNITY CITY OF PAOLI MONROE COUNTY

NUMBER 29044 290776

MAP NUMBER 2913700332B EFFECTIVE DATE October 17, 2006

Flash flooding occurs in SFHAs and those locations in the planning area that are low-lying. They also occur in areas without adequate drainage to carry away the amount of water that falls during intense rainfall events. NCDC database was used to determine which jurisdictions are most prone to flash flooding during a 20-year time period.

Table 3.15 shows the number of flash flood events by location recorded in NCDC for the 20-year period.

Table 3.15. Monroe County NCEI Flood Events by Location, 2003-2023

Location	# of Events
Unincorporated County	1

Source: National Centers for Environmental Information, 8/8/2023

Flash flooding occurs in SFHAs and those locations in the planning area that are low-lying. They also occur in areas without adequate drainage to carry away the amount of water that falls during intense rainfall events. NCEI data was used to determine which jurisdictions are most prone to flash flooding during the 20-year time period. **Table 3.16** shows the number of flash flood events by location recorded in NCEI for the 20-year period.

Table 3.16. Monroe County NCEI Flash Flood Events by Location, 2003-2023

Location	# of Events
Unincorporated County	11
-Unincorporated County (unspecified)- 3 flood events	
-Unincorporated County (Woodlawn)- 3 flood events	
-Unincorporated County (Tulip)- 1 flood events	
-Unincorporated County (Victor)- 1 flood events	
-Unincorporated County (Santa Fe)- 1 flood events	
-Unincorporated County (Duncan's Bridge)- 1 flood events	
-Unincorporated County (Middle Grove)- 1 flood events	
Holliday	2
-Holliday (unspecified)- 2 flood events	
Paris	1
-Paris (unspecified)- 1 flood events	
Monroe City	4
-Monroe City (unspecified)- 4 flood events	

Source: National Centers for Environmental Information, 8/8/2023

Strength/Magnitude/Extent

Missouri has a long and active history of flooding over the past century, according to the 2023 State Hazard Mitigation Plan. Flooding along Missouri's major rivers generally results in slow-moving disasters. River crest levels are forecast several days in advance, allowing communities downstream sufficient time to take protective measures, such as sandbagging and evacuations. Nevertheless, floods exact a heavy toll in terms of human suffering and losses to public and private property. By contrast, flash flood events in recent years have caused a higher number of deaths and major property damage in many areas of Missouri.

According to the U.S. Geological Survey, two critical factors affect flooding due to rainfall: rainfall duration and rainfall intensity – the rate at which it rains. These factors contribute to a flood's height, water velocity and other properties that reveal its magnitude.

National Flood Insurance Program (NFIP) Participation

Table 3.17 provides details on NFIP participation for the communities in the planning area. **Table 3.18** provides details on the number of policies in force, amount of insurance in force, number of closed losses, and total payments for each jurisdiction, where applicable.

Table 3.17. NFIP Participation in Monroe County

Community ID #	Community Name	NFIP Participant (Y/N/Sanctioned)	Current Effective Map Date	Regular-Emergency Program Entry Date
290776	Monroe County	No	10/17/06	10/17/07
290688	Monroe City	Yes	10/17/06	9/4/86
290684	Madison	Yes	NSFHA	9/10/84
290241	Paris	Yes	10/17/06	3/5/76
290476	Holliday	No	10/17/06	5/5/05

Source: NFIP Community Status Book, 8/8/2023; PIVOT (information from STATE) [Community Status Book | FEMA.gov](#); M= No elevation determined – all Zone A, C, and X: NSFHA = No Special Flood Hazard Area; E=Emergency Program

City of Monroe City

- Adoption of minimum NFIP floodplain management criteria* by local regulation – September 4, 1986
- Adoption of latest FIRM – October 17, 2006
- Designee to implement and enforce local floodplain management regulations – Brian Miller
- Designee to implement NFIP commitments/requirements – Brian Miller
- Substantial improvement/substantial damage provisions implemented after an event are in development. Tamitha Ague, City Administrator, or Brian Miller, Building Inspector & Building Commissioner are the contacts.
City Admin: tague@monroecity.org
Building Inspector/Commissioner: (573) 721-0741

City of Madison

- Adoption of minimum NFIP floodplain management criteria* by local regulation – September 10, 1984
- Adoption of latest FIRM – October 17, 2006
- Designee to implement and enforce local floodplain management regulations – Melissa O'Bannon
- Designee to implement NFIP commitments/requirements – Melissa O'Bannon
- Substantial improvement/substantial damage provisions implemented after an event are in development. Melissa O'Bannon, City Clerk, is the contact person at cityofmadisonmo@gmail.com or (660) 291-5235.

City of Paris

- Adoption of minimum NFIP floodplain management criteria* by local regulation – March 5, 1976
- Adoption of latest FIRM – October 17, 2006
- Designee to implement and enforce local floodplain management regulations – Barb McCall
- Designee to implement NFIP commitments/requirements – Barb McCall
- Substantial improvement/substantial damage provisions implemented after an event are in development. Barb McCall, City Superintendent, is the contact person at <mailto:superintendent@parismo.net> or (660) 327-4630.

Monroe County – County reports they do not participate in the NFIP due to not enough flood activity in the planning area to warrant the expense of NFIP participation.

Village of Holliday – Does not participate in the NFIP due to not having a flood plain administrator.

Table 3.18. NFIP Policy and Claim Statistics as of Date

Community Name	Policies in Force	Insurance in Force	Closed Losses	Total Payments
Monroe County	0	0	9	\$152,580.39

Source: NFIP Community Status Book, [8/8/2023]; PIVOT (information from STATE), [Community Status Book |](#)

[FEMA.gov](#) *Closed Losses are those flood insurance claims that resulted in payment.

No information could be found on the community with the most insurance payments and how much those payments were.

Repetitive Loss/Severe Repetitive Loss Properties

Repetitive Loss Properties are those properties with at least two flood insurance payments of \$1,000 or more in a 10-year period. According to the Flood Insurance Administration, jurisdictions included in the planning area have a combined total of one repetitive loss property. As of August 8, 2023, the one property has been mitigated, leaving zero un-mitigated repetitive loss properties.

Table 3.19. Monroe County Repetitive Loss Properties

Jurisdiction	# of Properties	Type of Property	# Mitigated	Building Payments	Content Payments	Total Payments	Average Payment	# of Losses
City of Paris	1	Unknown	1	Unknown	Unknown	\$11,680	\$3,893	3

Source: Flood Insurance Administration as of August 9, 2023

Severe Repetitive Loss (SRL): A SRL property is defined it as a single family property (consisting of one-to-four residences) that is covered under flood insurance by the NFIP; and has (1) incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage with the amount of each claim payment exceeding \$5,000 and with cumulative amounts of such claims payments exceeding \$20,000; or (2) for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property.

Monroe County does not currently have any Severe Repetitive Loss (SRL) properties.

Due to Federal restrictions on data sharing, the state was unable to provide full Repetitive Loss data or current Severe Repetitive Loss data. The Property Type was not available for Repetitive Loss properties and the Severe Repetitive Loss data, which was obtained from the 2023 MO State Hazard Mitigation Plan, does not specify if the properties are mitigated or non-mitigated.

Previous Occurrences

06/25/2008 - Severe Storms and Flooding- During June through Aug. 2008, Missouri experienced a slow-moving storm system that generated high winds, hail, tornadoes, record rainfall, flooding and flash flooding across the entire state. On June 1, Gov. Matt Blunt directed activation of the State Emergency Operations Plan and declared a state of emergency for the entire state.

Gov. Blunt ordered 165 members of the Missouri National Guard to assist with local security missions, levee monitoring, sandbagging, and liaison operations with land officials. The Missouri Department of Transportation also assisted with sandbagging operations after the Corps of Engineers and State Emergency Management Agency (SEMA) coordinated the delivery of more than 1.2 million sandbags. On June 15, Gov. Blunt requested that a major disaster declaration be approved for Missouri by President George Bush, requesting that Missouri receive both Public and Individual Assistance.

On June 25, President Bush approved the request for Public and Individual Assistance for the affected counties. The President also granted Small Business Administration disaster loans for qualifying businesses and homeowners.

Jurisdictions included in that declaration were Adair, Andrew, Atchison, Audrain, Bates, Buchanan, Callaway, Cape Girardeau, Carroll, Cass, Chariton, Christian, Clark, Daviess, Gentry, Greene, Grundy, Harrison, Holt, Howard, Jefferson, Johnson, Knox, Lewis, Lincoln, Linn, Livingston, Macon, Marion, Mercer, Miller, Mississippi, **Monroe**, Morgan, New Madrid, Nodaway, Pemiscot, Perry, Pettis, Pike, Platte, Polk, Putnam, Ralls, Randolph, Ray, Saline, Schuyler, Scotland, Scott, Shelby, St. Charles, St. Louis, the independent City of St. Louis, Ste Genevieve, Stone, Sullivan, Taney, Vernon, Webster, and Worth Counties.

Table 3.20 and Table 3.21 share Flash Flood and Riverine Flood events over the past 20 years.

Table 3.20. NCEI Monroe County Flash Flood Events Summary, 2003-2023

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
2003	1	0	0	0	0
2004	2	0	0	0	0
2007	2	0	0	0	0
2008	3	0	0	\$1,000	0
2009	4	0	0	0	0
2010	1	0	0	0	0
2011	1	0	0	0	0
2014	1	0	0	0	0
2016	1	0	0	0	0
2017	1	0	0	0	0
2018	1	0	0	0	0
2020	1	0	0	0	0

Source: NCEI, data accessed [8/14/2023]

Table 3.21. NCEI Monroe County Riverine Flood Events Summary, 2003 to 2023

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
2008	1	0	0	0	0

Source: NCEI, [8/14/2023]

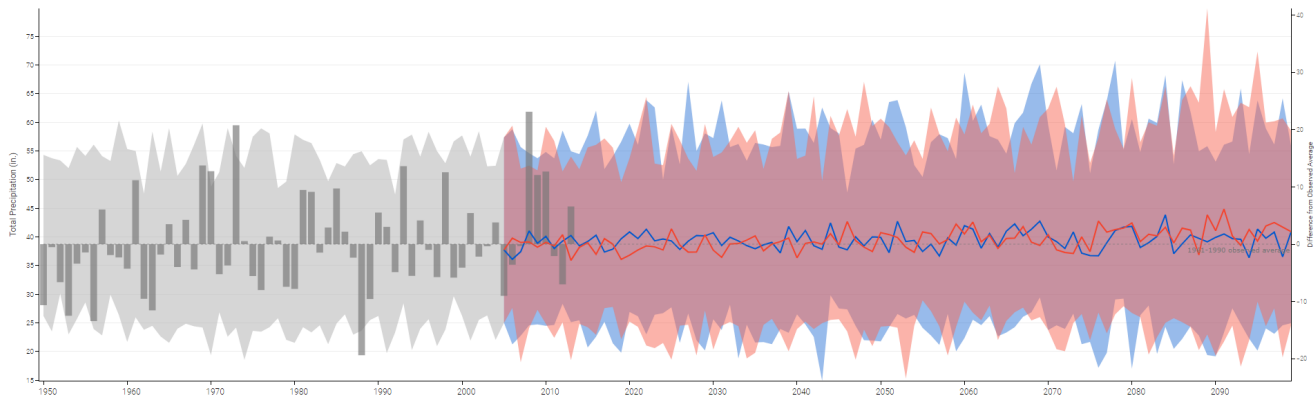
09/13/2008 - A cold front moved through the region and interacted with the remnants of Hurricane Ike. Widespread heavy rain was reported across Missouri and Illinois causing major flooding across the region. Many small creeks in the St. Louis Metropolitan area that had not flooded for years became raging rivers flooding roads, homes and businesses. Also, winds from the remnants of Hurricane Ike caused tree, power line, and building damage in some locations.

Probability of Future Occurrence

With the history of flooding in the planning area, it is likely that flooding of various levels will occur. The probability of a flash flood event occurring in the planning area in any given year is 60%. Although Flood events occur in the planning area there is only a 10% probability of occurring in any given year.

Changing Future Conditions Considerations

According to the National Climate Assessment, extreme rainfall events and flooding have increased during the last century, and these trends are expected to continue.



Vulnerability

Vulnerability Overview

Flooding presents a danger to life and property, often resulting in injuries, and in some cases, fatalities. Floodwaters themselves can interact with hazardous materials. Hazardous materials stored in large containers could break loose or puncture as a result of flood activity. Examples are bulk propane tanks. When this happens, evacuation of citizens is necessary.

Public health concerns may result from flooding, requiring disease and injury surveillance. Community sanitation to evaluate flood-affected food supplies may also be necessary. Private water and sewage sanitation could be impacted, and vector control (for mosquitoes and other entomology concerns) may be necessary.

When roads and bridges are inundated by water, damage can occur as the water scours materials around bridge abutments and gravel roads. Floodwaters can also cause erosion undermining roadbeds. In some instances, steep slopes that are saturated with water may cause mud or rockslides onto roadways. This damage can cause costly repairs for state, county, and city road and bridge

maintenance departments. When sewer back-up occurs, this can result in costly clean-up for home and business owners as well as present a health hazard.

Potential Losses to Existing Development

The existing development is at risk of very minimal damage as the majority of flood and flash flood events occur in the rural areas.

Impact of Previous and Future Development

Any future development in floodplains would increase risk in those areas. For the three communities participating in the National Flood Insurance Program, enforcement of the floodplain management regulations will ensure mitigation of future construction in those areas. However, even if structures are mitigated, evacuation may still be necessary due to rising waters. In addition, floods that exceed mitigated levels may still cause damages.

EMAP Consequence Analysis

Table 3.22. EMAP Impact Analysis: Flooding

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the flood areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the flood or HazMat spills.
Economic Condition of Jurisdiction	Local economy and finances adversely affected, possibly for an extended period of time.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

Vulnerability to flooding varies by jurisdiction as each community has a different layout, however, no critical facilities are in flood prone areas. Each jurisdiction's vulnerability to flooding can be found on the FIRM map and listed within this section. There are a total of 29 low water crossings in Monroe County.

Problem Statement

Flooding or flash flooding affects the rural areas of Monroe County. Possible solutions are to increase the education to residents, promote the use of social media or texting, utilize radio broadcasting, and work with officials to identify flood prone areas.

3.4.2 Levee Failure

Hazard Profile

Hazard Description

Levees are earth embankments constructed along rivers and coastlines to protect adjacent lands from flooding. Floodwalls are concrete structures, often components of levee systems, designed for urban areas where there is insufficient room for earthen levees. When levees and floodwalls and their appurtenant structures are stressed beyond their capabilities to withstand floods, levee failure can result in injuries and loss of life, as well as damage to property, the environment, and the economy.

Levees can be small agricultural levees that protect farmland from high-frequency flooding. Levees can also be larger, designed to protect people and property in larger urban areas from less frequent flooding events such as the 100-year and 500-year flood levels. For purposes of this discussion, levee failure will refer to both overtopping and breach as defined in FEMA's Publication "So You Live Behind a Levee" (<http://mrcc.isws.illinois.edu/1913Flood/awareness/materials/SoYouLiveBehindLevee.pdf>).

Following are the FEMA publication descriptions of different kinds of levee failure.

Overtopping: When a Flood Is Too Big

Overtopping occurs when floodwaters exceed the height of a levee and flow over its crown. As the water passes over the top, it may erode the levee, worsening the flooding and potentially causing an opening, or breach, in the levee.

Breaching: When a Levee Gives Way

A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters may pass. A breach may occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. The resulting torrent can quickly swamp a large area behind the failed levee with little or no warning.

Earthen levees can be damaged in several ways. For instance, strong river currents and waves can erode the surface. Debris and ice carried by floodwaters—and even large objects such as boats or barges—can collide with and gouge the levee. Trees growing on a levee can blow over, leaving a hole where the root wad and soil used to be. Burrowing animals can create holes that enable water to pass through a levee. If severe enough, any of these situations can lead to a zone of weakness that could cause a levee breach. In seismically active areas, earthquakes and ground shaking can cause a loss of soil strength, weakening a levee and possibly resulting in failure. Seismic activity can also cause levees to slide or slump, both of which can lead to failure.

Geographic Location

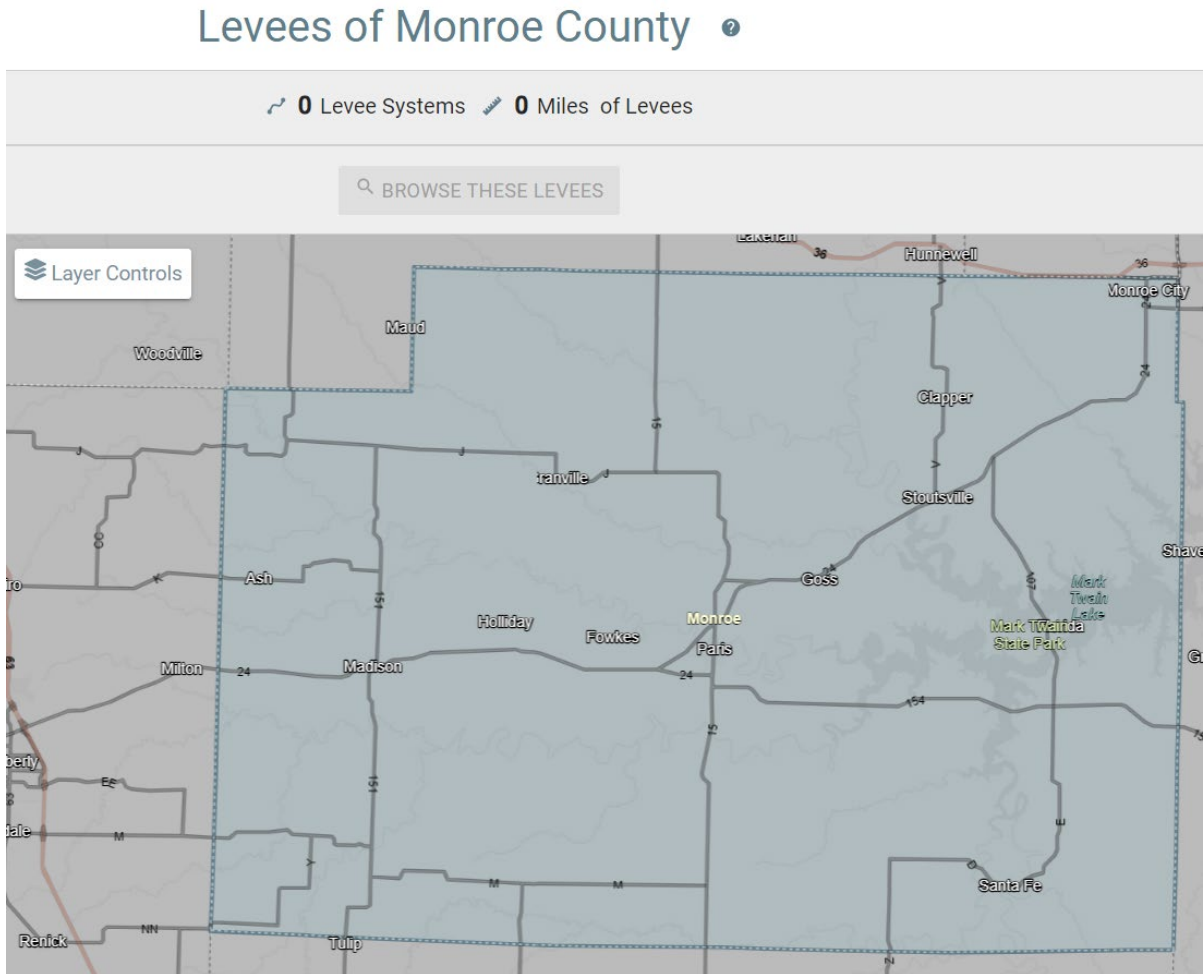
Missouri is a state with many levees. Currently, there is no single comprehensive inventory of levee systems in the state. Levees have been constructed across the state by public entities and private entities with varying levels of protection, inspection oversight, and maintenance. The lack of a comprehensive levee inventory is not unique to Missouri.

There are two concurrent nation-wide levee inventory development efforts, one led by the United State Army Corps of Engineers (USACE), and one led by Federal Emergency Management Agency (FEMA). The National Levee Database (NLD), developed by USACE, captures all USACE related levee projects, regardless of design levels of protection. The Midterm Levee Inventory (MLI), developed by FEMA, captures all levee data (USACE and non-USACE) but primarily focuses on levees that provide 1% annual-chance flood protection on FEMA Flood Insurance Rate Maps (FIRMs).

It is likely that agricultural levees and other non-regulated levees within the planning area exist that are not inventoried or inspected. These levees that are not designed to provide protection from the 1-

percent annual chance flood would overtop or fail in the 1-percent annual chance flood scenario. Therefore, any associated losses would be taken into account in the loss estimates provided in the Flood Hazard Section.

Figure 3.3. County Levees Shown on DFIRM as Providing Protection from the 1-Percent Annual Chance Flood



Source: FEMA Flood Insurance Rate Map, 8/9/2023

Strength/Magnitude/Extent

Levee failure is typically an additional or secondary impact of another disaster such as flooding or earthquake. The main difference between levee failure and losses associated with riverine flooding is magnitude. Levee failure often occurs during a flood event, causing destruction in addition to what would have been caused by flooding alone. In addition, there would be an increased potential for loss of life due to the speed of onset and greater depth, extent, and velocity of flooding due to levee breach.

As previously mentioned, agricultural levees and levees that are not designed to provide flood protection from at least the 1-percent annual chance flood likely do exist in the planning area. However, none of these levees are shown on the Preliminary DFIRM, nor are they enrolled in the USACE Levee Safety Program. As a result, an inventory of these types of levees is not available for analysis. Additionally, since these types of levees do not provide protection from the 1-percent annual chance flood, losses associated with overtopping or failure are captured in the Flood Section of this plan.

Previous Occurrences

The only levees in the planning area are low-head agricultural levees that are not tracked for breaches or incidents. A breach or incident would not cause widespread damage.

Probability of Future Occurrence

Due to the lack of information on low-head agricultural levees, the probability of future occurrence of levee failure cannot be calculated.

Changing Future Conditions Considerations

As stated in the 2023 Missouri State Hazard Mitigation Plan, the impact of changing future conditions on levee failure will most likely be related to changes in precipitation and flood likelihood. Climate change projections suggest that precipitation may increase and occur in more extreme events, which may increase the risk of flooding, putting stress on levees and increasing likelihood of levee failure. Furthermore, aging levee infrastructure and a lack of regular maintenance (including checking for seepage and removing trees, roots and other vegetation that can weaken a levee) coupled with more extreme weather events may increase risk of future levee failure.

Vulnerability

Vulnerability Overview

The USACE regularly inspects levees within its Levee Safety Program to monitor their overall condition, identify deficiencies, verify that maintenance is taking place, determine eligibility for federal rehabilitation assistance (in accordance with P.L. 84-99), and provide information about the levees on which the public relies. Inspection information also contributes to effective risk assessments and supports levee accreditation decisions for the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA).

The USACE now conducts two types of levee inspections. Routine Inspection is a visual inspection to verify and rate levee system operation and maintenance. It is typically conducted each year for all levees in the USACE Levee Safety Program. Periodic Inspection is a comprehensive inspection led by a professional engineer and conducted by a USACE multidisciplinary team that includes the levee sponsor. The USACE typically conducts this inspection every five years on the federally authorized levees in the USACE Levee Safety Program.

Both Routine and Periodic Inspections result in a rating for operation and maintenance. Each levee segment receives an overall segment inspection rating of Acceptable, Minimally Acceptable, or Unacceptable. **Figure 3.4** below defines the three ratings.

Figure 3.4. Definitions of the Three Levee System Ratings

Levee System Inspection Ratings	
Acceptable	All inspection items are rated as Acceptable.
Minimally Acceptable	One or more levee segment inspection items are rated as Minimally Acceptable or one or more items are rated as Unacceptable and an engineering determination concludes that the Unacceptable inspection items would not prevent the segment/system from performing as intended during the next flood event.
Unacceptable	One or more levee segment inspection items are rated as Unacceptable and would prevent the segment/system from performing as intended, or a serious

deficiency noted in past inspections (previous Unacceptable items in a Minimally Acceptable overall rating) has not been corrected within the established timeframe, not to exceed two years.

There is no specific information on levees that exist within the Monroe County planning area.

Potential Losses to Existing Development

Levees have been constructed across the planning area by public entities and private entities with varying levels of protection, inspection oversight and maintenance. Due to only having low-head agricultural levees in the planning area damage is very minimal.

Impact of Previous and Future Development

Impact on future development in the planning area is directly related to the floodplain management and regulations set forth by Monroe County and individuals through levee management and regulations which are not clearly defined. It is difficult to predict the impact on future development due to most private levees not being regulated or inspected by one agency or on a regular basis. Any new construction that falls in the floodplain will have to adhere to Monroe County's construction and zoning regulations.

Hazard Summary by Jurisdiction

Currently no jurisdictions or areas in the planning area are protected by a levee.

Problem Statement

Low-head agricultural levees are not regulated or inspected on a regular basis. Residents need to be informed on how to perform inspections on low-head agricultural levees.

3.4.3 Dam Failure

Hazard Profile

Hazard Description

A dam is defined as a barrier constructed across a watercourse for the purpose of storage, control, or diversion of water. Dams are typically constructed of earth, rock, concrete, or mine tailings. Dam failure is the uncontrolled release of impounded water resulting in downstream flooding, affecting both life and property. Dam failure can be caused by any of the following:

1. Overtopping: Inadequate spillway design, debris blockage of spillways or settlement of the dam crest.
2. Piping: Internal erosion caused by embankment leakage, foundation leakage, and deterioration of pertinent structures appended to the dam.
3. Erosion: Inadequate spillway capacity causing overtopping of the dam, flow erosion, and inadequate slope protection.
4. Structural Failure: Caused by an earthquake, slope instability, or faulty construction.

Data of dams in Monroe County has been collected from two sources: a listing by the Missouri Department of Natural Resources (MoDNR) and the National Inventory of Dams (NID). Each has its own system of classifying dams. For the purpose of planning, the NID information was used. Neither the MoDNR nor the NID hazard potential classification references the condition of the dam.

Table 3.23. MoDNR Dam Hazard Classification Definitions

Hazard Class	Definition
Class I	Contains 10 or more permanent dwellings or any public building
Class II	Contains 1 to 9 permanent dwellings or 1 or more campgrounds with permanent water, sewer, and electrical services or 1 or more industrial buildings
Class III	Everything else

Source: Missouri Department of Natural Resources, http://dnr.mo.gov/env/wrc/docs/rules_reg_94.pdf

Table 3.24. NID Dam Hazard Classification Definitions

Hazard Class	Definition
Low Hazard	A dam located in an area where failure could damage only farm or other uninhabited buildings, agricultural or undeveloped land including hiking trails, or traffic on low volume roads that meet the requirements for low hazard dams.
Significant Hazard	A dam located in an area where failure could endanger a few lives, damage an isolated home, damage traffic on moderate volume roads that meet certain requirements, damage low-volume railroad tracks, interrupt the use or service of a utility serving a small number of customers, or inundate recreation facilities, including campground areas intermittently used for sleeping and serving a relatively small number of persons.
High Hazard	A dam located in an area where failure could result in any of the following: extensive loss of life damage to more than one home, damage to industrial or commercial facilities, interruption of a public utility serving a large number of customers, damage to traffic on high-volume roads that meet the requirements for hazard class C dams or a high-volume railroad line, inundation of a frequently used recreation facility serving a relatively large number of persons, or two or more individual hazards described for significant hazard dams.

Source: National Inventory of Dams

Geographic LocationDams Located Within the Planning Area**Table 3.25. High Hazard Dams in the Monroe County Planning Area**

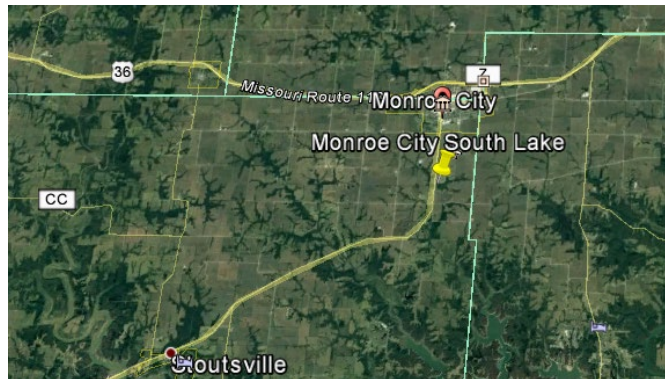
Dam Name	Emergency Action Plan (EAP/AP)	Dam Height (Ft)	Normal Storage (Acre-Ft)	Last Inspection Date	River	Nearest Downstream City	Distance To Nearest City (Miles)	Dam Owner
Jack Simpson		20	54	-	Middle Fork	Florida	0	Unknown
Lake Tom Saywer Dam		25	67	-	Salt River	Florida	0	Mark Twain State Park
Herbangie Lake Dam		43	377	12/6/2006	Middle For Salt River	Victor	1	State
Kendrick, Evert Dam		25	174	-	Long Branch	Santa Fe	6	Evert Kendrick
Dodge Lake Dam-Sect 5		25	107	-	Brush Creek	Stoutsville	6	Hazel Dodge
Dodge Lake Dam-Sect 32		25	107	-	Brush Creek	Stoutsville	7	Hazel Dodge
Clapper Lake Dam		20	214	-	Indian Creek	Indian Creek	4	Anna Belle Morkin
Monroe City South Lake Dam		31	829	6/13/1979	Little Indian Creek	Stoutsville	6	Local Government
City of Monroe Dam A		26	278	-	Sharpsburg Branch	Monroe City	1	Local Government
Dye Lake Dam		25	334	-	Cooked Creek	Stoutsville	0	Roy Dye
Central Stone Co Lake Dam		25	107	-	Elk Fork Salt River	Victor	11	Central Stone Co
Qualles Lake Dam		39	128	-	Flat Creek	Paris	0	Charles Unterbrink
Millard Lake Dam		15	152	-	Elm Branch	Clapper	6	WH Millard
Wilkerson Dam		26	38	-	Middle For Salt River	Duncans Bridge	-	Joe Wilkerson
Brown Lake Dam		25	40	-	Milligan Creek	Middle Grove	0	Clifford Brown
McCowan Dam		25	80	-	Hardin Creek	Middle Grove	1	Robert D. McCowan
Burbridge Coal Dam		25	54	-	Burbridge Creek	Perry	3	-
Bergthold Dam		20	257	-	Bear Bridge	Victor	11	John Bergthold
Wood Acres Dam		28	240	-	Pigeon Roost Creek	Santa Fe	10	Wood Acres
Fischer Lake Dam No 1		33	84	-	Indian Creek	Louisiana	-	DR. T.J. Fischer
Fred Mayes Lake Dam		32	122	-	Middle Fork Salt River	Duncan's Bridge	-	Fred Mayes
David Charlick IRR Res		29	181	-	Otter Creek	Louisiana	-	Billy & Dallas Mitchell
Bill Dawson IRR Res		21	325	6/13/1979	Long Branch	Louisiana	-	Ronnie Deal
Roger O'Bannon IRR Res		23	202	-	Reese Fork Branch	Louisiana	-	Rodger O'Bannon

Bright Dam		28	53	-	Elk Fork	Paris	-	George Bright Jr.
Fisher Dam		24	81	-	Crooked Creek	Maud	-	Billy Fisher
Olson Dam		25	64	-	Pooles Branch	Paris	-	Glorida English Olson
Riley Dam		20	164	-	Pooles Branch	Paris	-	Bob Riley
Geisler Dam		26.8	38	-	Middle Fork Salt River	Paris	-	James Geisler
Wilma Walkup Dam		31	41	-	Buck Creek	Stoutsville	-	Wilma Walkup
Lillie Farrell Dam		31	56	11/1/2000	Horseshoe Branch	North Fork	-	Lillie Farrell
Vandewert Dam		29	71	-	Flat Branch	Paris	22	Wayne Vandewert
Timber Ridge, LLC		29	44.97	-	Flat Creek	Madison	3	Daryl Nicks
Thomas Dam		29	31.29	-	Baker Branch	Paris	22	Doug Thomas
Donnie Poore Dam		32	60.04	-	Crooked Creek	Shelbina	5.2	Donnie Poore

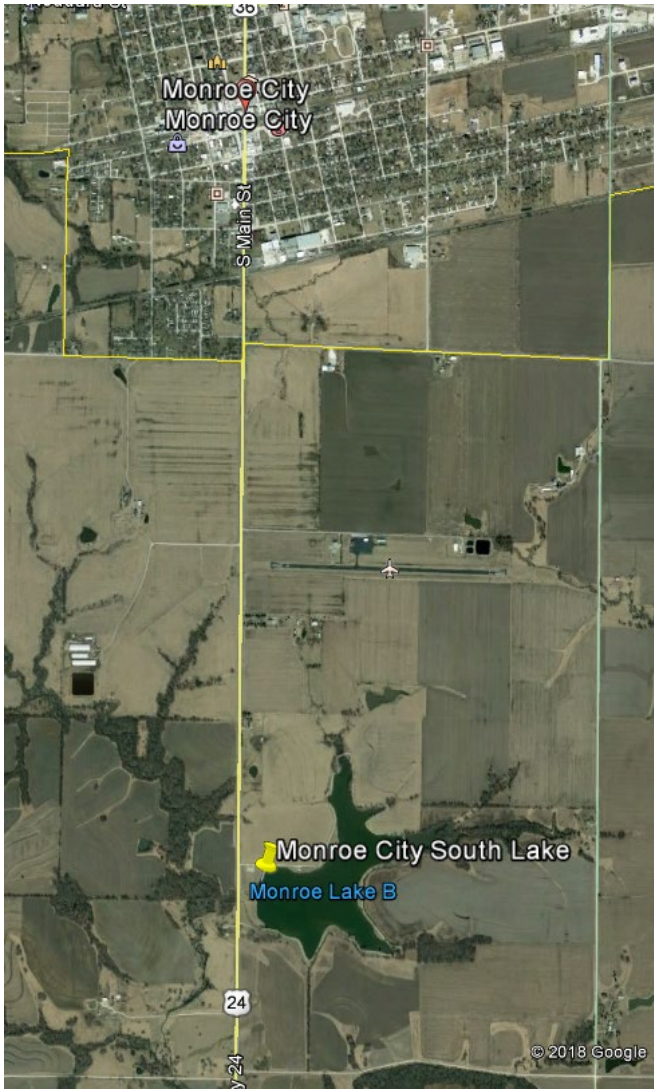
Sources: Missouri Department of Natural Resources, <https://dnr.mo.gov/geology/wrc/dam-safety/damsinmissouri.htm> and National Inventory of Dams, http://nid.usace.army.mil/cm_apex/f?p=838:12.

Highlighted Dams indicate State regulated dams. In order to be State regulated, the dam height requirement is 35 ft.

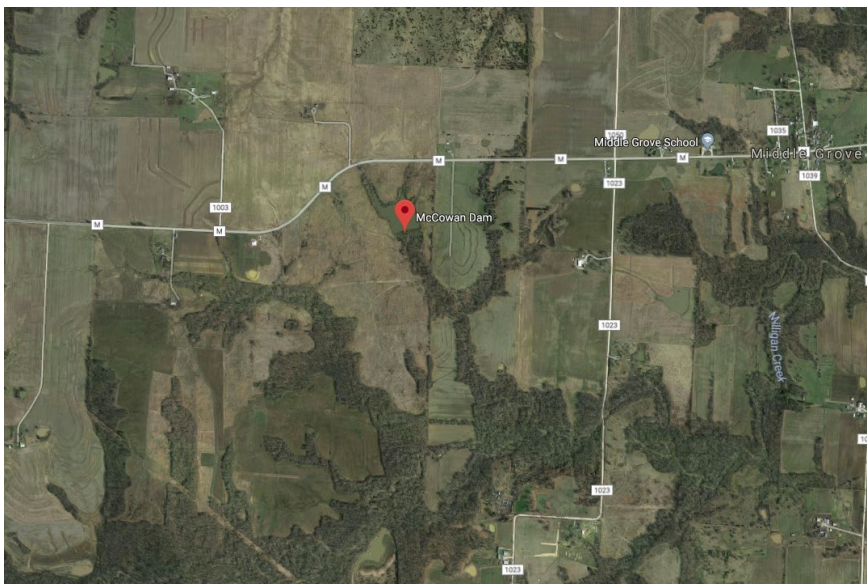
Figure 3.5. High Hazard Dam Locations in Monroe County



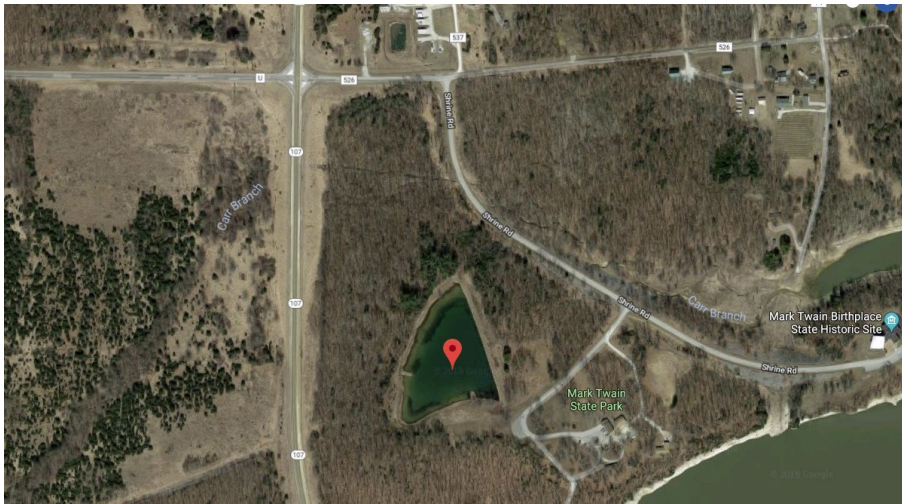
Source: U.S. Army Corps of Engineers, Missouri Department of Natural Resources



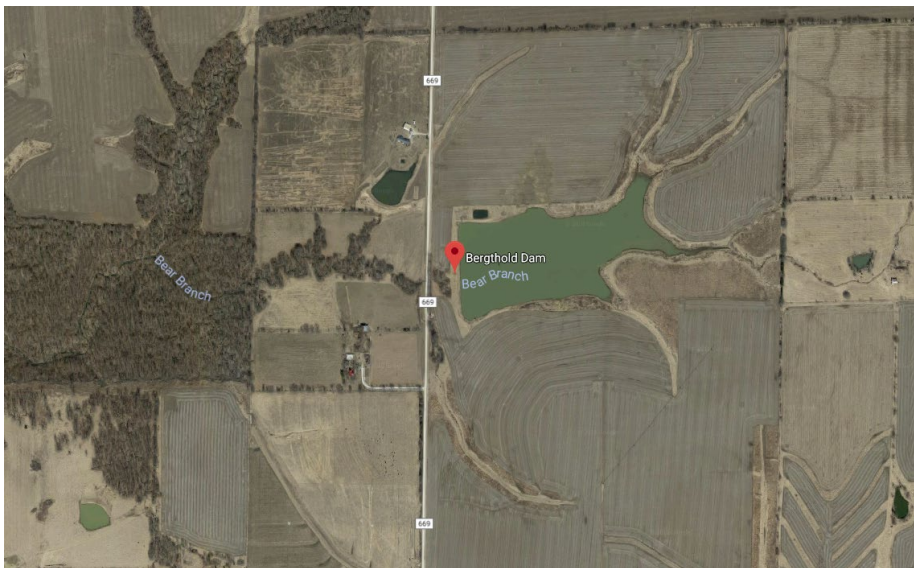
Source: Google Maps- (1) South Lake Dam



Source: Google Maps- (2) McCowan Dam



Source: Google Maps- (3) Lake Tom Sawyer Dam



Source: Google Maps- (4) Bergthold Dam

Upstream Dams Outside the Planning Area

The Missouri Department of Natural Resources was consulted to see if dams located outside of the county would impact it in the event of failure. It was determined that there are no upstream dams that would place Monroe County in any danger.

Strength/Magnitude/Extent

The severity/magnitude of dam failure would be similar in some cases to the impacts associated with flood events (see the flood hazard vulnerability analysis and discussion). Based on the hazard class definitions, failure of any of the High Hazard/Class I dams could result in a serious threat of loss of human life, serious damage to residential, industrial or commercial areas, public utilities, public buildings, or major transportation facilities. Catastrophic failure of any high hazard dams has the potential to result in greater destruction due to the potential speed of onset and greater depth, extent, and velocity of flooding. Note that for this reason, dam failures could flood areas outside of mapped flood hazards. Dam classifications are based on the downstream impacts, not the condition of the dam.

Previous Occurrences

To determine previous occurrences of dam failure within Monroe County, the Monroe County Missouri Natural Hazard Mitigation Plan was referenced, as well as the 2023 Missouri State Hazard Mitigation Plan and the Stanford University's National Performance of Dams Program (<http://npdp.stanford.edu/> <http://npdp.stanford.edu/>). No record of dam failure within Monroe County boundaries was found.

Probability of Future Occurrence

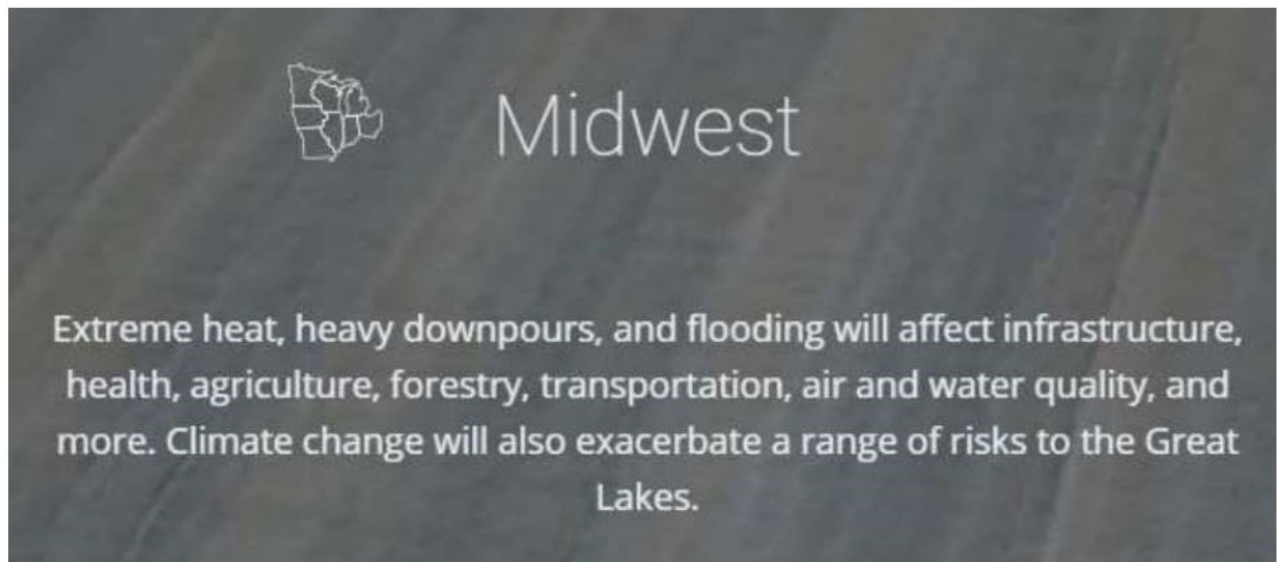
Based on the number of high hazard dams in the planning area and no record of previous occurrences, the probability of future occurrences cannot be determined.

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, studies have been conducted to investigate the impact of climate change scenarios on dam safety. Dam failure is already tied to flooding and the increased pressure flooding places on dams. The impacts of changing future conditions on dam failure will most likely be those related to changes in precipitation and flood likelihood. Changing future conditions projections suggest that precipitation may increase and occur in more extreme events, which may increase risk of flooding, putting stress on dams and increasing likelihood of dam failure.

The safety of dams for the future climate can be based on an evaluation of changes in design floods and the freeboard available to accommodate an increase in flood levels. The results from the studies indicate that the design floods with the corresponding outflow floods and flood water levels will increase in the future, and this increase will affect the safety of the dams in the future. Studies concluded that the total hydrological failure probability of a dam will increase in the future climate and that the extent and depth of flood waters will increase by the future dam break scenario.

According to the National Climate Assessment, extreme rainfall events and flooding have increased during the last century, and these trends are expected to continue and are expected to affect levees.



Source: National Climate Assessment; <https://nca2014.globalchange.gov/>

Vulnerability

Vulnerability Overview

Vulnerability to dam failure is a factor due to multiple dams in the planning area, including several High Hazard Dams, indicating that loss of life is possible in the event of failure. Neighboring communities are also at risk if they are downstream from a dam. Should Monroe City South Lake Dam be compromised, the Village of Stoutsville is the closest downstream community and would be impacted. The planning committee chose only to address the high hazard dams within the planning area due to the pre-determined risk associated by these dams.

Potential Losses to Existing Development: (including types and numbers, of buildings, critical facilities, etc.)

The Department of Natural Resources Water Resource Center was consulted, and it was confirmed that while Monroe City South Lake Dam is classified as Class I, an inundation map is not available for this level of dam as it is unregulated. In order to be considered a regulated dam, the dam must be 35 ft tall, and Monroe City South Lake Dam measures 31 ft tall.

Impact of Previous and Future Development

Future development in the inundation area of the Monroe City South Lake Dam could impact the number of damages caused by a failure of the high hazard dam in Monroe County. The Monroe City South Lake Dam is located within a mile of residents in Monroe County. There is no significant future development anticipated within the county, but with increased development there is risk for higher impact in the event of a dam failure.

EMAP Consequence Analysis

Table 3.26. EMAP Impact Analysis: Dam Failure

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for inundation area and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the inundation area at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads and/or utilities may postpone delivery of some services. Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may reduce deliveries.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the inundation area of the incident. Some severe damage possible.
Environment	Localized impact expected to be severe for inundation area and moderate to light for other adversely affected areas.
Economic Condition of Jurisdiction	Local economy and finances adversely affected, possibly for an extended period of time, depending on damage and length

	of investigation.
Public Confidence in the Jurisdiction's Governance	Localized impact expected to primarily adversely affect dam owner and local entities.

Hazard Summary by Jurisdiction

Of the 35 dams in Monroe County, all but two (Herbangie Dam, 43 ft high; and Qualles Lake Dam, 39 ft. high) are less than 35 feet in height and thus are the responsibility of the individual landowners to inspect and maintain. Two dams are rated hazard 1 the Bill Dawson Irrigation dam and the Monroe City South Dam. All the dams are small in terms of dam height and storage area and are not a threat to significant population areas or critical facilities. Stoutsville is at risk if Monroe City South Lake Dam fails as the closest downstream jurisdiction. Monroe County, Monroe City, and Paris are all at risk of dam failure, however with proper inspection the risk is low, as only two of the dams are rated hazard 1. Schools in the planning area are unlikely to be affected by a compromised dam due to the low water capacity of the dams. No further analysis of the hazard dam failure will be conducted for the hazard mitigation plan.

Problem Statement

Jurisdictions within Monroe County that have control of dams do not properly inspect the dam to ensure the safety of the dam from failing. Jurisdictions and residents need to be informed of the proper way to inspect a dam and look for initial problems.

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. The 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 energy to buildings and other structures on the earth's surface.

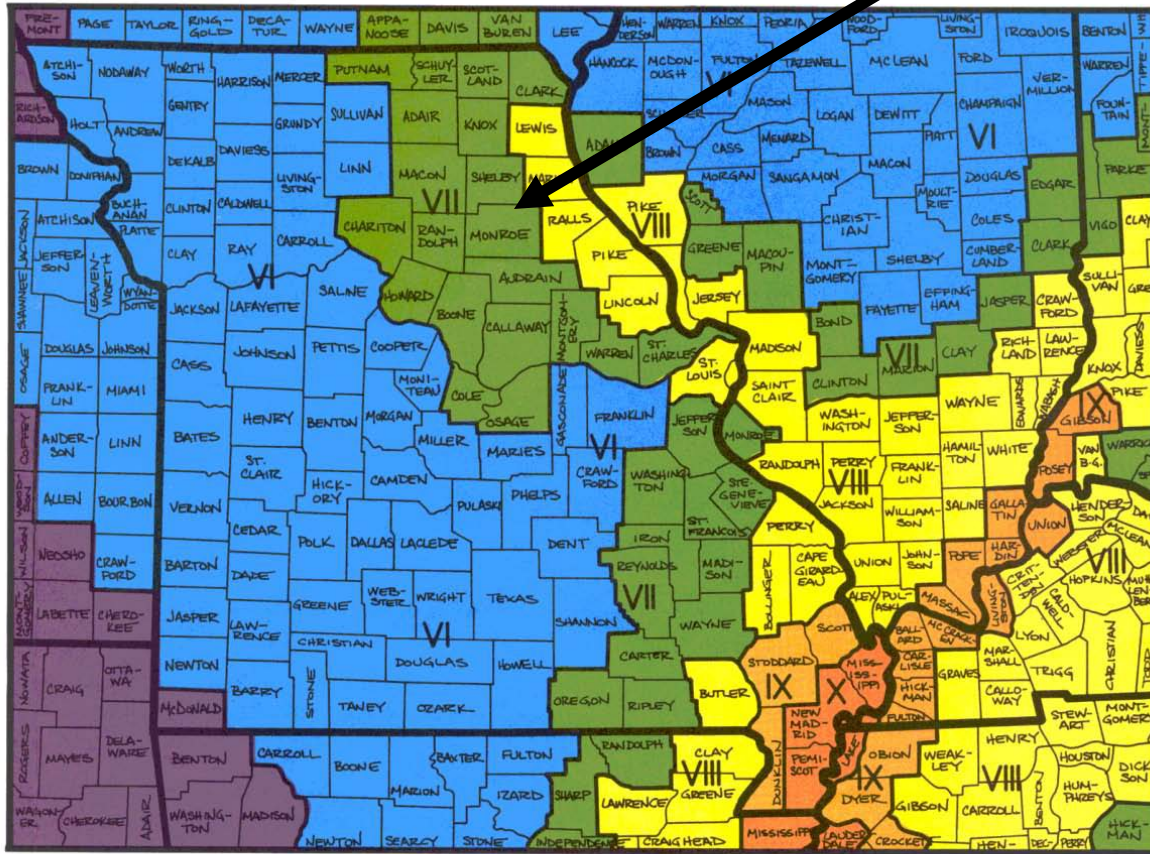
Some earthquakes occur in the middle of plates, as is the case for seismic zones in the Midwestern United States. The most seismically active area in the Midwest is the New Madrid Seismic Zone. The possibility of the occurrence of a catastrophic earthquake in the central and Eastern United States is real as evidenced by history. The impacts of significant earthquakes affect large areas, terminating public services and systems needed to aid the suffering and displaced. As with hurricanes, mass relocation may be necessary, but the residents who are suffering from the earthquake can neither leave the heavily impacted areas nor receive aid or even communication in the aftermath of a significant event.

Geographic Location

Seismic activity in the New Madrid Seismic Zone of Southeastern Missouri is very significant both historically and at present. On December 16, 1811, and January 23 and February 7 of 1812, three earthquakes struck the central U.S. with magnitudes estimated to be 7.5-8.0. These earthquakes caused violent ground cracking and volcano-like eruptions of sediment (sand blows) over an area of >10,500 km², and uplift of a 50 km by 23 km zone (the Lake County uplift). The shaking was felt over a total area of over 10 million km² (the largest felt area of any historical earthquake). Of all the historical earthquakes that have the U.S., an 1811-style event would do the most damage if it recurred today. If an 1811 earthquake occurred in Monroe County the earthquake intensity would not vary within the county. Damage would be to buildings of good design and construction, slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures and some chimneys broken.

The following SEMA map (**Figure 3.7**) 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. The below figure indicates Monroe County and the affects that could be felt from the earthquake.

Figure 3.6. Impact Zones for Earthquake Along the New Madrid Fault

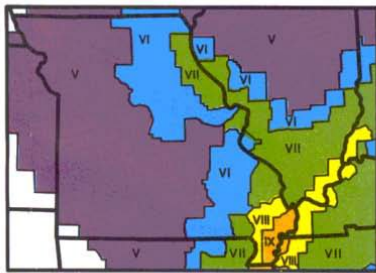


This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude - 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

6.7

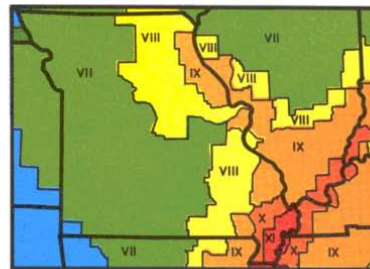
7.6

8.6



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 *Planning area indicated by arrow

Figure 3.7. Projected Earthquake Intensities

MODIFIED MERCALLI INTENSITY SCALE

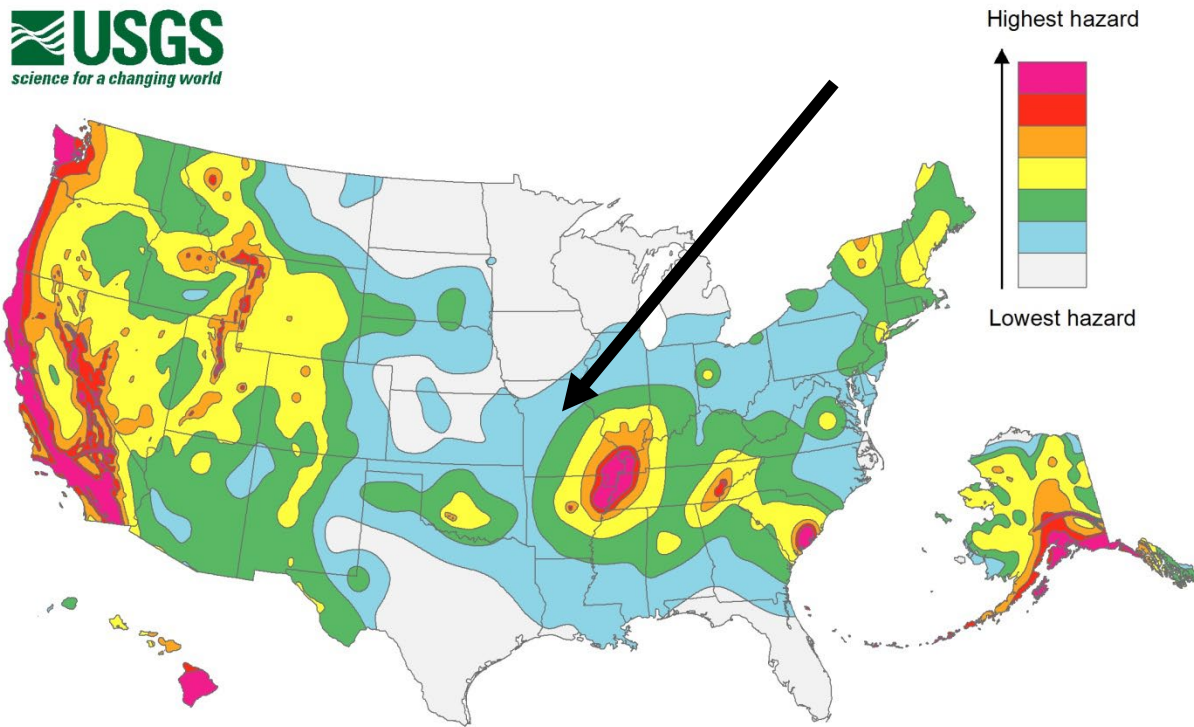
<p>I People do not feel any Earth movement.</p> <p>II A few people might notice movement.</p> <p>III Many people indoors feel movement. Hanging objects swing.</p> <p>IV Most people indoors feel movement. Dishes, windows, and doors rattle. Walls and frames of structures creak. Liquids in open vessels are slightly disturbed. Parked cars rock.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>
--	--

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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 JEFFERSON CITY, MO 65102
 Telephone: 573-526-9100

Monroe County is located in the second to lowest hazard rating indicated in the map illustrating seismicity shown in Figure 3.9 below.

Figure 3.8. United States Seismic Hazard Map



Source: United States Geological Survey at https://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg
 *Planning area indicated by arrow

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

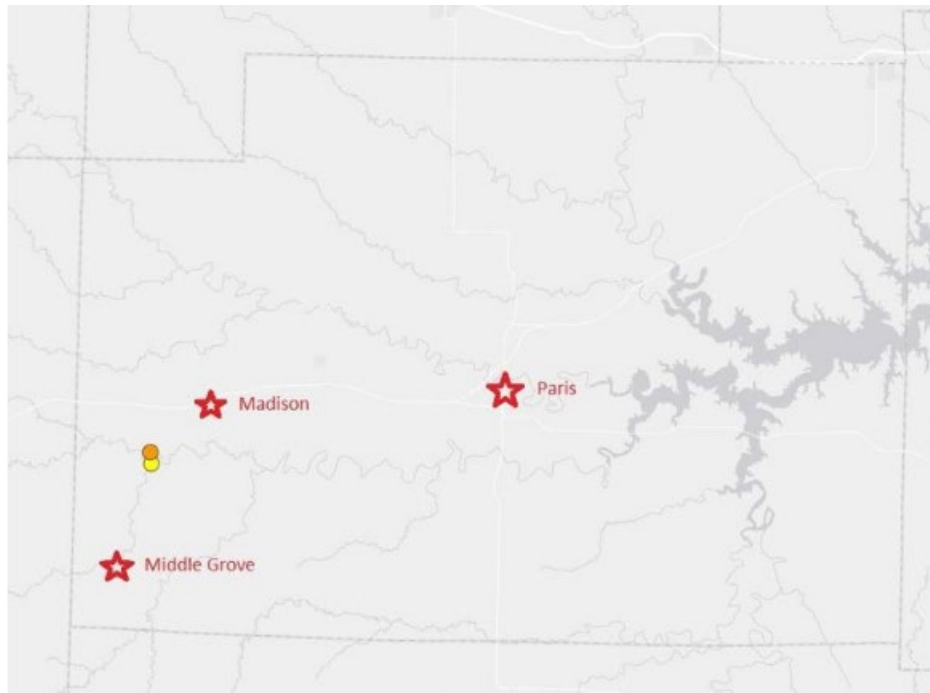
intensity scale is based on the responses to the quake, such as people awakening, movement of furniture, damage to chimneys, etc. The intensity scale currently used in the United States is the Modified Mercalli (MM) Intensity Scale. It was developed in 1931 and is composed of 12 increasing levels of 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

In December 2022, two minor earthquakes were reported in rural Monroe County. According to the U.S. Geological Survey (USGS), a magnitude 2.4 earthquake was reported on December 3, 2022, around 2:19 a.m., 3 miles southwest of Madison. It had a depth of 656 feet.

A magnitude 2.6 earthquake was reported Monday around 5:10 p.m., about 2.5 miles southwest of Madison. Its depth was about 4,593 feet.

Source: KOMU News



The yellow dot shows the location of the 12/3/2023 earthquake and the orange dot shows the location of the 12/5/2023 earthquake.

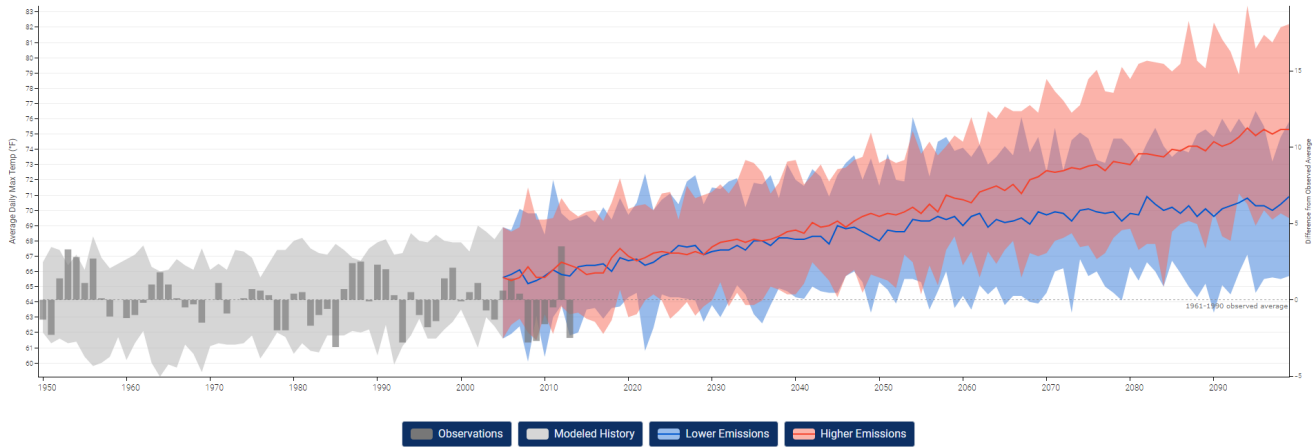
Probability of Future Occurrence

Although there have been reported earthquakes in recent years, the events were minor and isolated. HomeFacts Earthquake information was not available at the time of this plan update, so while the probability of a future occurrence in Monroe County is assumed to be very low, the probability cannot be given at this time.

Changing Future Conditions Considerations

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, currently no studies quantify the relationship to a high level of detail, so recent earthquakes should not be linked with climate change. While not conclusive, early research suggests that more intense earthquakes and tsunamis may eventually be added to the adverse consequences which are caused by changing future conditions.

According to the National Climate Assessment, earthquakes have increased during the last century, and these trends are expected to continue, as depicted below.



Vulnerability

Vulnerability Overview

According to the data obtained from the 2023 State Plan, Monroe County was listed as Moderate for Hazard Ranking.

The State of Earthquake Coverage Report states that the average premium for earthquake coverage in Monroe County in 2022 was \$40.

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. Data included below for the planning area from State Plan Table A.10.

County	Total Losses (in \$ Thousands)	Loss Per Capita (in \$ Thousands)	Annualized Loss Ratio (in \$ per Million)
Monroe	\$19	\$0.0022	\$20

Impact of Previous and Future Development

Since the earthquake intensity is not likely to vary greatly throughout Monroe County, the risk will be the same throughout. However, damages could differ if there are structural variations in the planning area built environment. For example, older structures in the downtown Paris and Monroe City districts and those structures which are not in prime condition are likely to experience higher damage.

EMAP Consequence Analysis

Table 3.27. EMAP Impact Analysis: Earthquakes

Subject	Detrimental Impacts
Public	Adverse impact expected to be severe for unprotected personnel and moderate to light for protected personnel.
Responders	Adverse impact expected to be severe for unprotected personnel and moderate to light for protected personnel.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require relocation of operations and lines of succession execution. Disruption of lines of communication and destruction of facilities may extensively postpone delivery of services.
Property, Facilities, and Infrastructure	Damage to facilities and infrastructure in the area of the incident may be extensive for facilities, people, infrastructure, and HazMat.
Environment	May cause extensive damage, creating denial or delays in the use of some areas. Remediation needed.
Economic Condition of Jurisdiction	Local economy and finances adversely affected, possibly for an extended period of time.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

The earthquake intensity is not likely to vary greatly throughout the planning area and all jurisdictions within the planning area will be the same throughout. However, Holliday could see a greater amount of structural damage due to having a higher percentage (42%) of residences built prior to 1939 than other jurisdictions in the planning area. In Paris 27.8% of the residences were built prior to 1939 and could see higher damage than the City of Madison that only has 7.8% of the residences built prior to 1939 and puts them at a lower risk.

Problem Statement

Although Monroe County is not located in an area that will likely see catastrophic damage from an earthquake, the County will be impacted by the loss of communications, transportation, the disruption of roads, rail and pipelines, water transportation, and the area will see a significant amount of refugees fleeing from Southern Missouri if a quake hits that area. Education is minimal for earthquakes due to the low likelihood of impact. Monroe City and Paris consist of a few older tall buildings that are not able to withstand an earthquake event. There is one Emergency Management Director for the County that knows where all the generators and emergency buildings are. Not all citizens utilize social media and texting.

3.4.5 Land Subsidence/Sinkholes

Hazard Profile

Hazard Description

Sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that naturally can be dissolved by ground water circulating through them. As the rock dissolves, spaces and caverns develop underground. The sudden collapse of the land surface above them can be dramatic and range in size from broad, regional lowering of the land surface to localized collapse. However, the primary causes of most subsidence are human activities: underground mining of coal, groundwater or petroleum withdrawal, and drainage of organic soils. In addition, sinkholes can develop as a result of subsurface void spaces created over time due to the erosion of subsurface limestone (karst).

Land subsidence occurs slowly and continuously over time, as a general rule. On occasion, it can occur abruptly, as in the sudden formation of sinkholes. Sinkhole formation can be aggravated by flooding.

In the case of sinkholes, the rock below the surface is rock that has been dissolving by circulating groundwater. As the rock dissolves, spaces and caverns form, and ultimately the land above the spaces collapses. In Missouri, sinkhole problems are usually a result of surface materials above openings into bedrock caves eroding and collapsing into the cave opening. These collapses are called “cover collapses” and geologic information can be applied to predict the general regions where collapse will occur. Sinkholes range in size from several square yards to hundreds of acres and may be quite shallow or hundreds of feet deep.

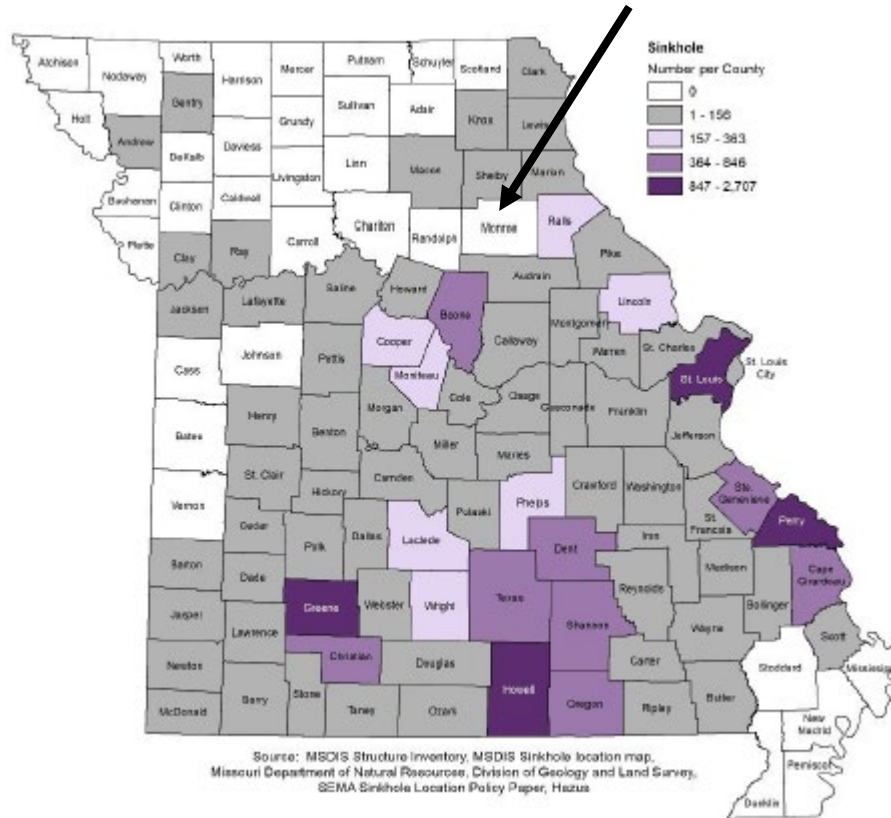
According to the U.S. Geological Survey (USGS), the most damage from sinkholes tends to occur in Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. Fifty-nine percent of Missouri is underlain by thick, carbonate rock that makes Missouri vulnerable to sinkholes. Sinkholes occur in Missouri on a fairly frequent basis. Most of Missouri’s sinkholes occur naturally in the State’s karst regions (areas with soluble bedrock). They are a common geologic hazard in southern Missouri, but also occur in the central and northeastern parts of the State. Missouri sinkholes have varied from a few feet to hundreds of acres and from less than one to more than 100 feet deep. The largest known sinkhole in Missouri encompasses about 700 acres in western Boone County southeast of where Interstate 70 crosses the Missouri River. Sinkholes can also vary in shape like shallow bowls or saucers whereas others have vertical walls. Some hold water and form natural ponds.

According to the 2023 Missouri State Hazard Mitigation Plan, there are zero sink holes and two mineral mines in the planning area.

Geographic Location

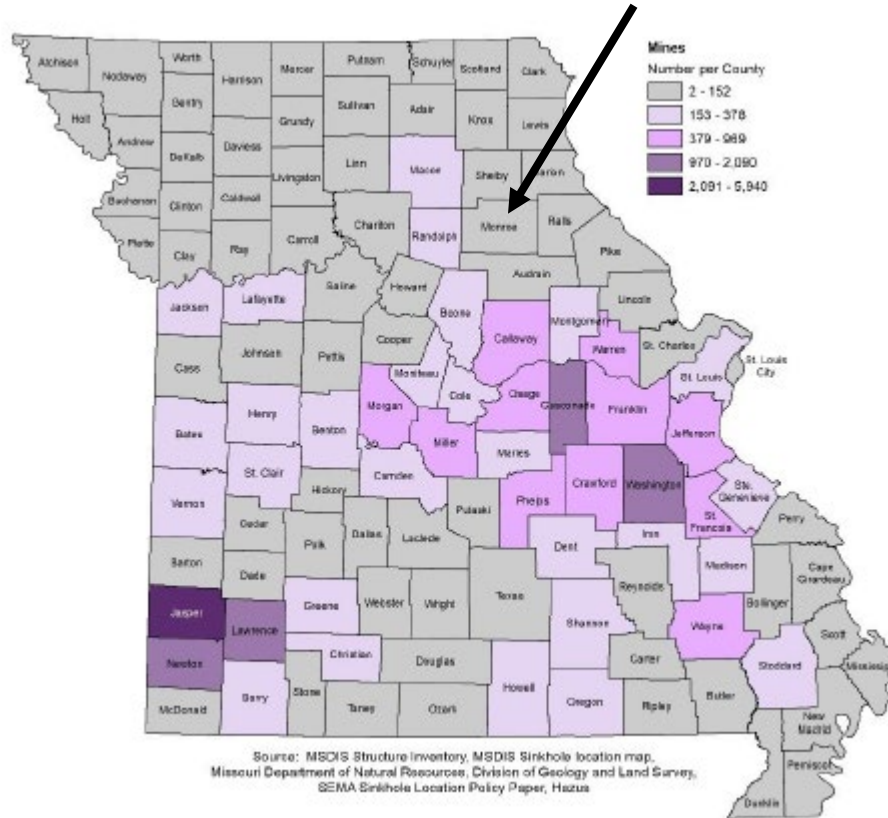
The Missouri Department of Natural Resources GIS application shows zero documented sinkholes in the planning area, which aligns with the information listed in the 2023 Missouri State Hazard Mitigation Plan.

Figure 3.9. Sinkhole Counts per County



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

Figure 3.10. Mine Counts per County



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

Strength/Magnitude/Extent

Sinkholes vary in size and location, and these variances will determine the impact of the hazard. A sinkhole could result in the loss of a personal vehicle, a building collapse, or damage to infrastructure such as roads, water, or sewer lines. Groundwater contamination is also possible from a sinkhole. Because of the relationship of sinkholes to groundwater, pollutants captured or dumped in sinkholes could affect a community’s groundwater system. A sinkhole collapse could be triggered by large earthquakes. Sinkholes located in floodplains can absorb floodwaters but make detailed flood hazard studies difficult to model.

Previous Occurrences

As noted in the 2023 State Plan, sinkholes are a regular occurrence in Missouri, but rarely are events of any significance. However, it is possible the damage can be substantial. The Missouri State Hazard Mitigation Plan lists 15 notable sinkhole events with none of them occurring in the planning area.

Monroe County has no sinkholes, and the likeliness of a future occurrence would be considered negligible. However, the potential for this type of hazard to occur in Monroe County is almost nonexistent.

Probability of Future Occurrence

The likelihood of a sinkhole occurring of any significance is low based on the past history of the sinkholes recorded. Due to data limitations precluding probability calculation, such as the lack of a centralized

database for sinkhole occurrences in the state.

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, direct effects from changing climate conditions such as an increase in droughts could contribute to an increase in sinkholes. These changes raise the likelihood of extreme weather, meaning the torrential rain and flooding conditions which often lead to the exposure of sinkholes are likely to become increasingly common. Certain events such as heavy precipitation following a period of drought can trigger a sinkhole due to low levels of groundwater combined with a heavy influx of rain.

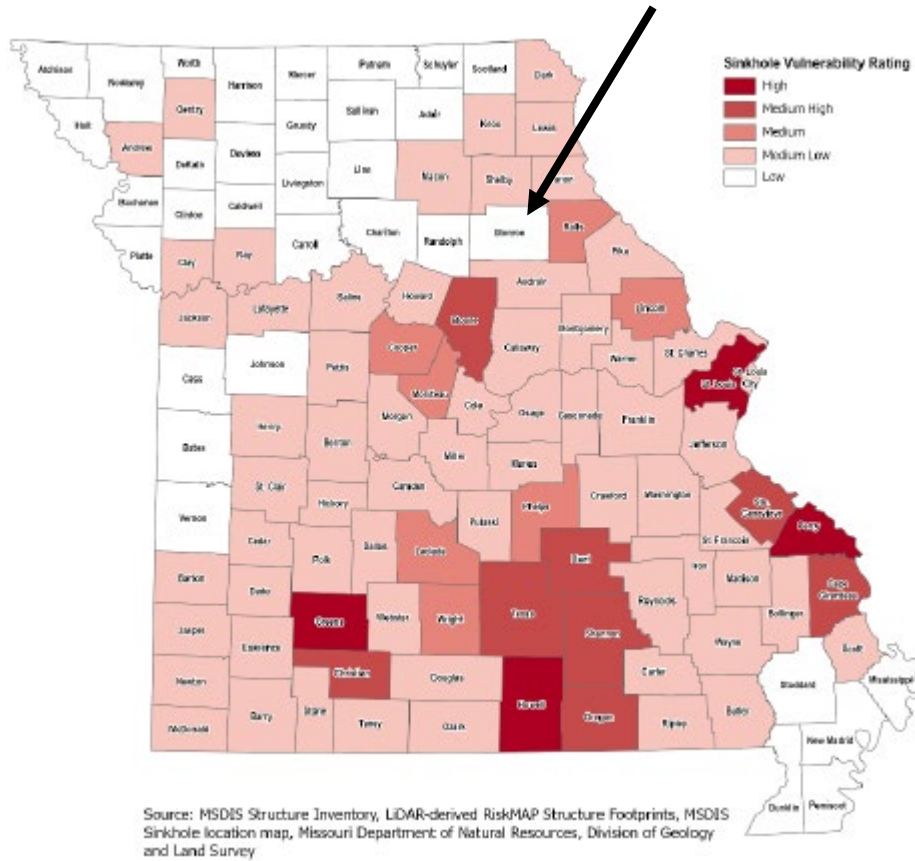
Vulnerability

Vulnerability Overview

Sinkholes in the planning area are not common occurrence due to composition of the land. While some sinkholes may be considered a slow changing nuisance; other more sudden, catastrophic collapses can destroy property, delay construction projects, and contaminate groundwater resources.

The Missouri Department of Natural Resources shows the location of no sinkholes for the planning area. Nonetheless, sinkholes can vary from a few feet to hundreds of acres and from less than one foot to more than 100 feet deep. They can also vary in shape like shallow bowls or saucers whereas others have vertical walls, some hold water and form natural ponds. There are no statistics on the number of voids present in the subsurface that will collapse in the future to form new surface sinkholes; however, areas have been identified that have the greatest potential for future sinkholes and land subsidence.

Figure 3.11. Sinkhole Rating Value by County



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

Potential Losses to Existing Development

The potential impact of sinkholes on existing structures is difficult to determine due to the lack of data on historic damages caused by sinkholes and the mapping of potential sinkholes is difficult if not impossible to predict where a sinkhole will collapse and how significant the collapse will be.

Because sinkhole collapses are not predictable and previous events have not occurred in the rural area, there is not significant data to estimate the future losses due to a sinkhole.

Impact of Previous and Future Development

As more development occurs on unmapped rural areas, the vulnerability to the hazard will increase; however, sinkholes are unpredictable and the development in rural areas is difficult to limit due to the lack of occurrence.

There are currently no sinkholes in the planning area. Monroe County participating jurisdictions have no plans to limit construction due to sinkholes.

EMAP Consequence Analysis**Table 3.28. EMAP Impact Analysis: Land Subsidence/Sinkholes**

Subject	Detrimental Impacts
Public	Localized impact expected to be moderate to light for incident areas and light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Environment	Localized impact expected to be moderate to light for incident areas and moderate to light for other areas affected by the sinkhole.
Economic Condition of Jurisdiction	Local economy and finances adversely affected, possibly for an extended period of time.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response and recovery not timely and effective.

Hazard Summary by Jurisdiction

The risk for the development is uniform throughout the planning area and has not affected one jurisdiction specifically.

Problem Statement

Sinkholes can occur at any time and without warning and vary by size. There can be a disruption of transportation services and residents in the dangerous areas are not educated on what to do if a sinkhole occurs.

Education needs to occur on the danger areas of a sinkhole occurring and what to do if a sinkhole does occur.

3.4.6 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.

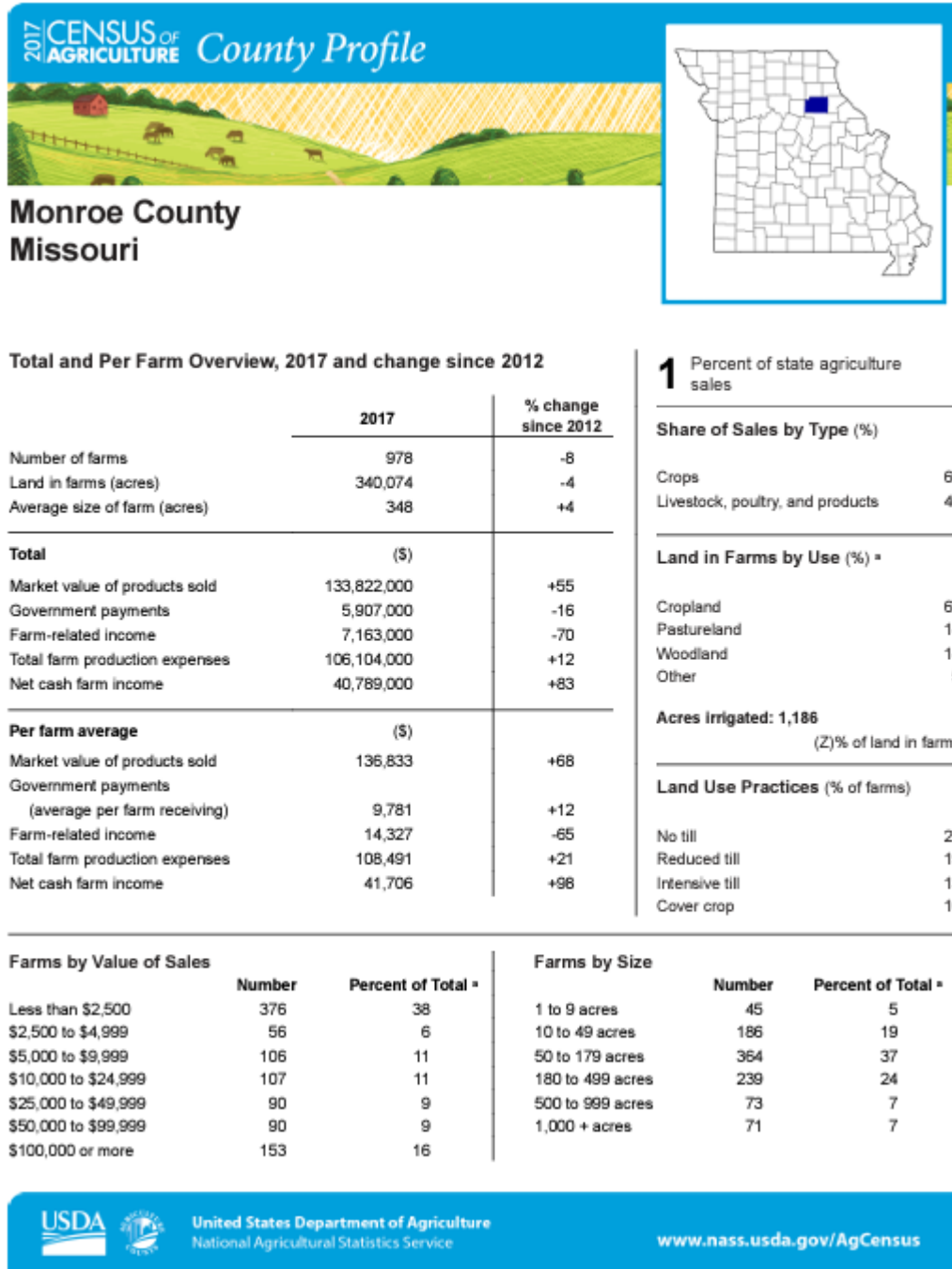
- Meteorological drought is defined in terms of the basis of the degree of dryness (in comparison to some “normal” or average amount) and the duration of the dry period. A meteorological drought must be considered region-specific since the atmospheric conditions that result in deficiencies of precipitation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

Droughts are regional in nature. All areas of the United States are vulnerable to the risk of drought and extreme heat. Droughts can be widespread or localized events. The extent of the droughts varies both in terms of the extent of the heat and range of precipitation. The severity of a drought depends on locations, duration, and geographical extent. Additionally, drought severity depends on the water supply, usage demands made by human activities, vegetation, and agricultural operations. Drought brings several different problems that must be addressed. The quality and quantity of crops, livestock and other agricultural assets will be affected during a drought. Drought can adversely impact forested areas leading to an increased potential for extremely destructive forest and woodland fires that could threaten residential, commercial, and recreational structures.

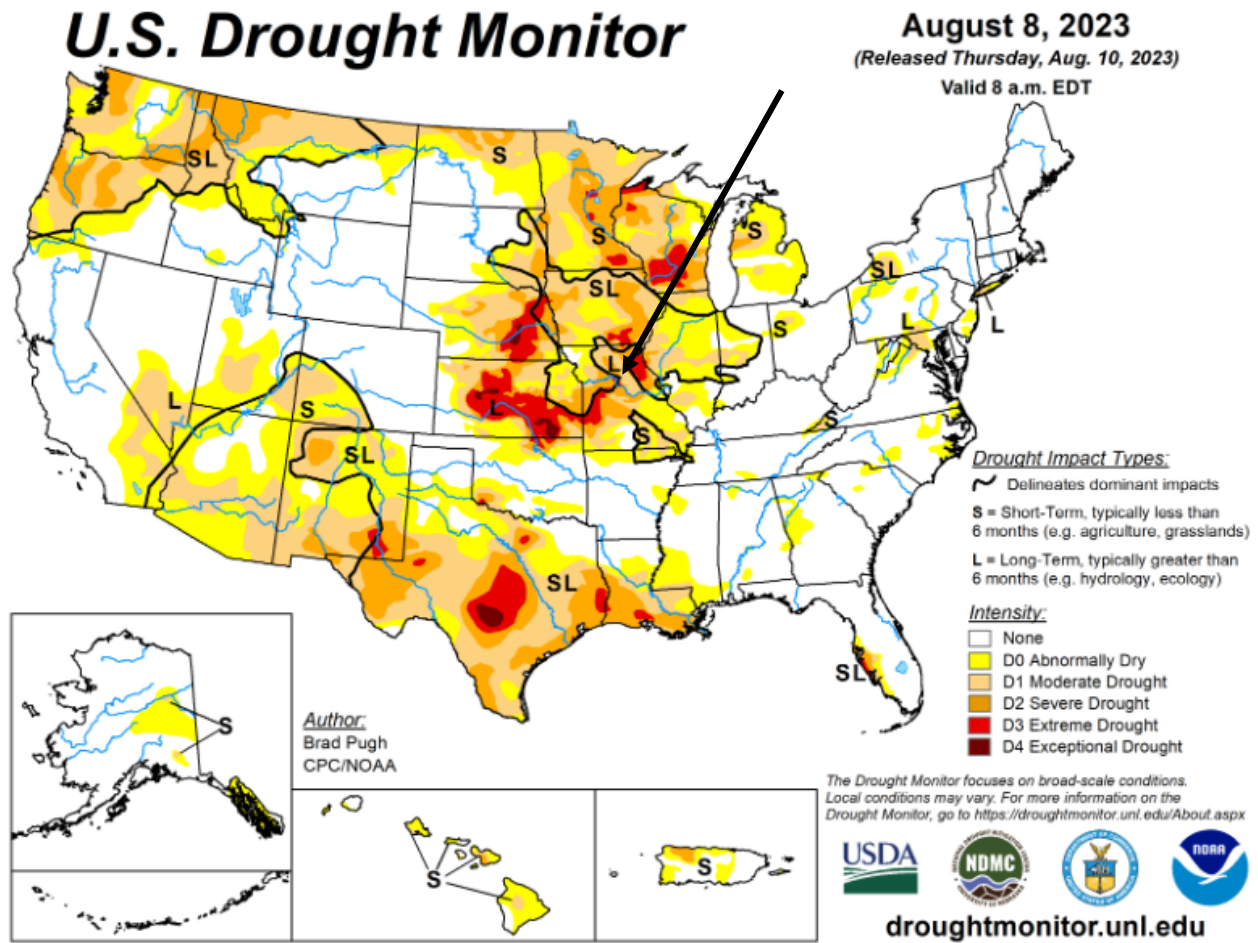
According to the 2017 Census of Agriculture, Monroe County consists of 340,074 acres of farmland. Crop and livestock sales in Monroe County generate 60% and 40%, respectively, of state agriculture sales. A drought would directly impact crop and livestock production, and the agriculture economy in Monroe County and state.

Figure 3.12. Census of Agriculture, Monroe County



Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Missouri/cp29137.pdf

Figure 3.13. U.S. Drought Monitor Map of Missouri on Date



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

Drought occurs periodically in Missouri with the most severe and costly in historical times occurring in 2012. Other major droughts, usually characterized by deficient rainfall combined with unusually high summer temperatures were in 2018 and 2013. Although droughts are not the spectacular weather events that floods, blizzards, or tornadoes can be, historically they produce more economic damage to the State than all other weather events combined.

Table 3.29. Insured Crop Loss Payments in Monroe County as a Result of Drought

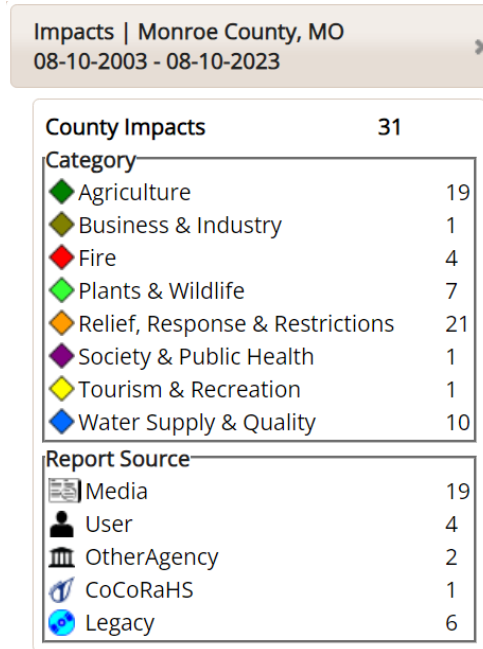
Year	Total Payments
2023 (as of 8/2023)	\$144,873
2022	\$616,209
2021	\$459,041
2020	\$299,223
2019	\$2,135
2018	\$1,400,325
2017	\$30,471
2016	\$9,887
2015	\$100,904
2014	\$28,887
2013	\$2,705,609
2012	\$37,715,956

Source: USDA's Risk Management Agency

According to the National Center for Environmental Information, during the 20-year period from 2003 to 2023 (so far), Monroe County had 31 reported drought impacts. The following are the categories:

- Agriculture
- Business & Industry
- Fire
- Plants & Wildlife
- Relief, Response, & Restrictions
- Society & Public Health
- Tourism & Recreation
- Water Supply & Quality

Figure 3.14. NCEI Drought Impacts



Source: <https://droughtreporter.unl.edu/map/>

Probability of Future Occurrence

According to the 2023 State Plan, Monroe County has a medium total rating for droughts and is very likely to experience droughts in the future, with a 22.30% chance likelihood of a severe drought.

Changing Future Conditions Considerations

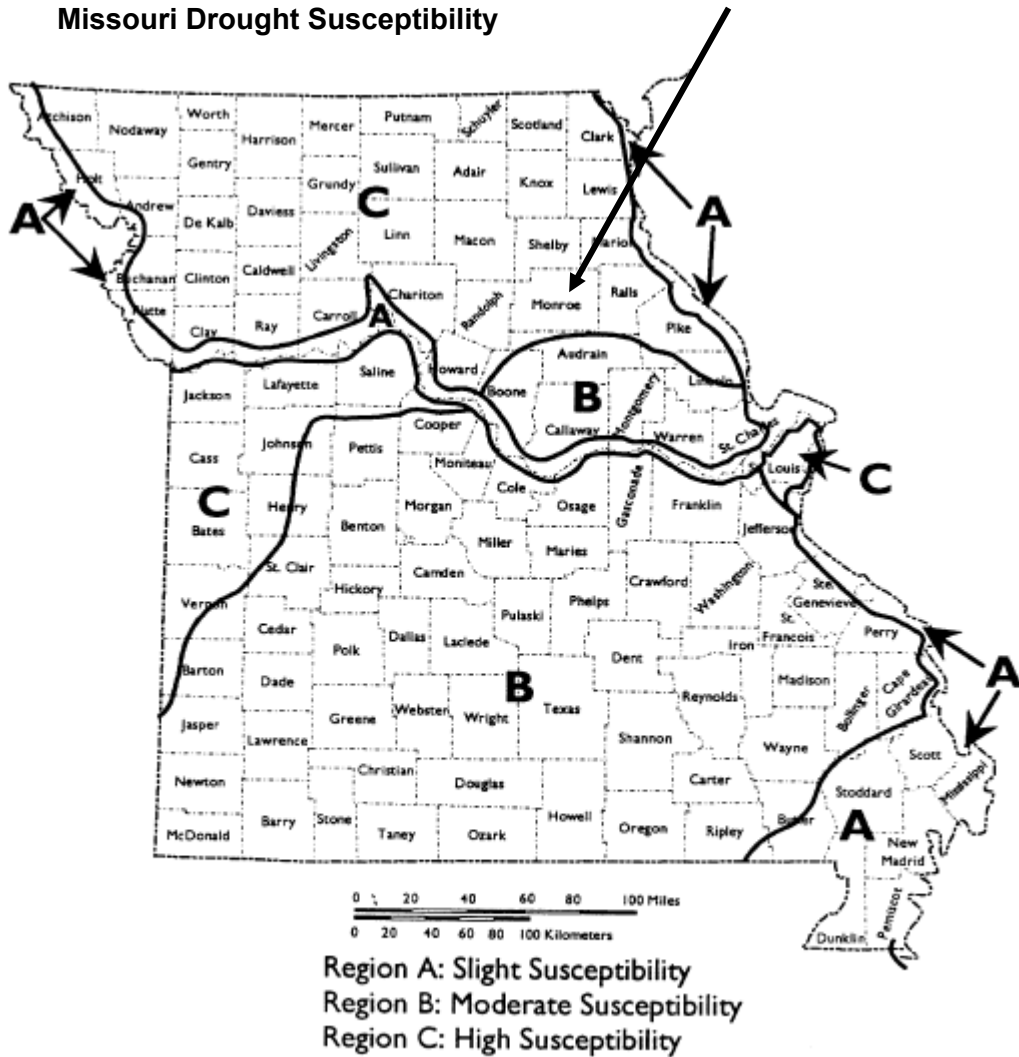
The 2023 Missouri State Hazard Mitigation Plan states that severe drought, a natural part of Missouri’s climate, is a risk to this agriculture dependent state. Future increases in evaporation rates due to higher temperatures may increase the intensity of naturally occurring droughts. The number of heavy rainfall events is predicted to increase, yet researchers currently expect little change in total rainfall amounts, indicating the periods between heavy rainfalls will be marked by an increasing number of dry days. Higher temperatures and increased evapotranspiration increase the likelihood of a drought. This could lead to agricultural drought and suppressed crop yields.

Vulnerability

Vulnerability Overview

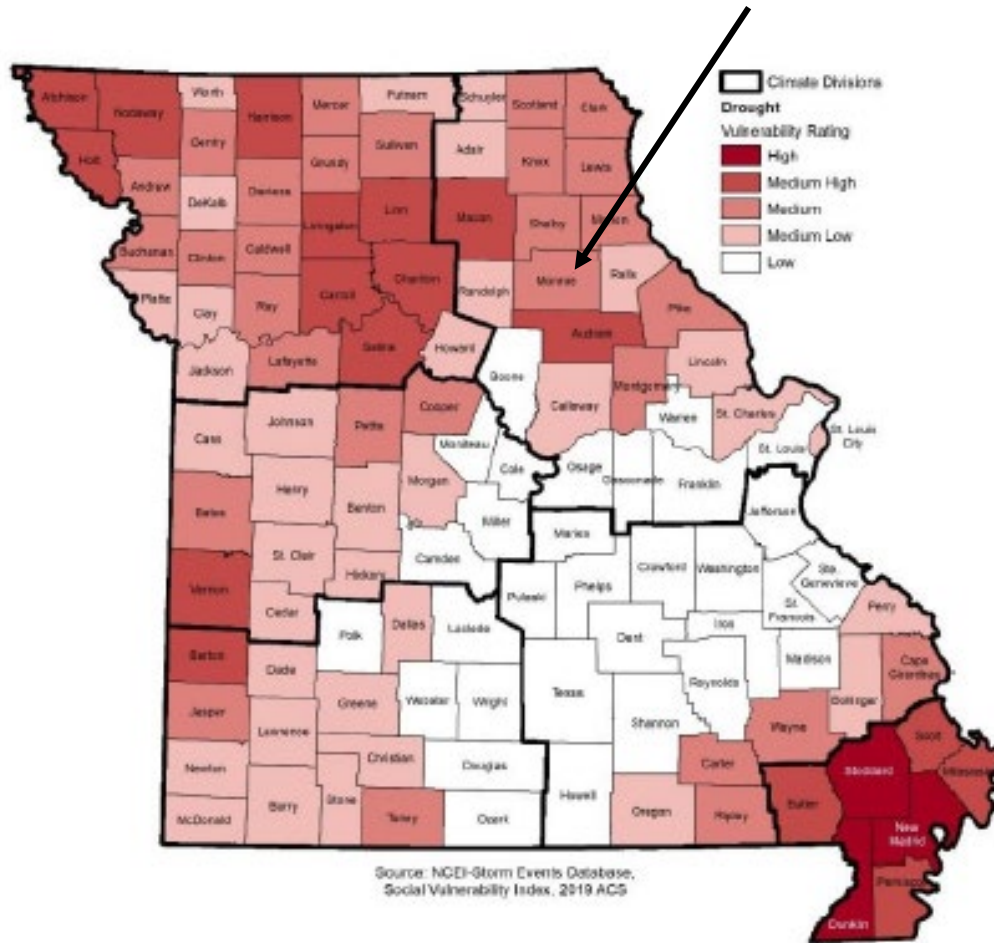
According to the analysis from the 2023 State Plan, Monroe County is located in Region C with a High Susceptibility for droughts (Figure 3.16), and a medium vulnerability for droughts (Figure 3.17).

Figure 3.15. Missouri Drought Susceptibility



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

Figure 3.16. Missouri Drought Vulnerability by County



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

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.

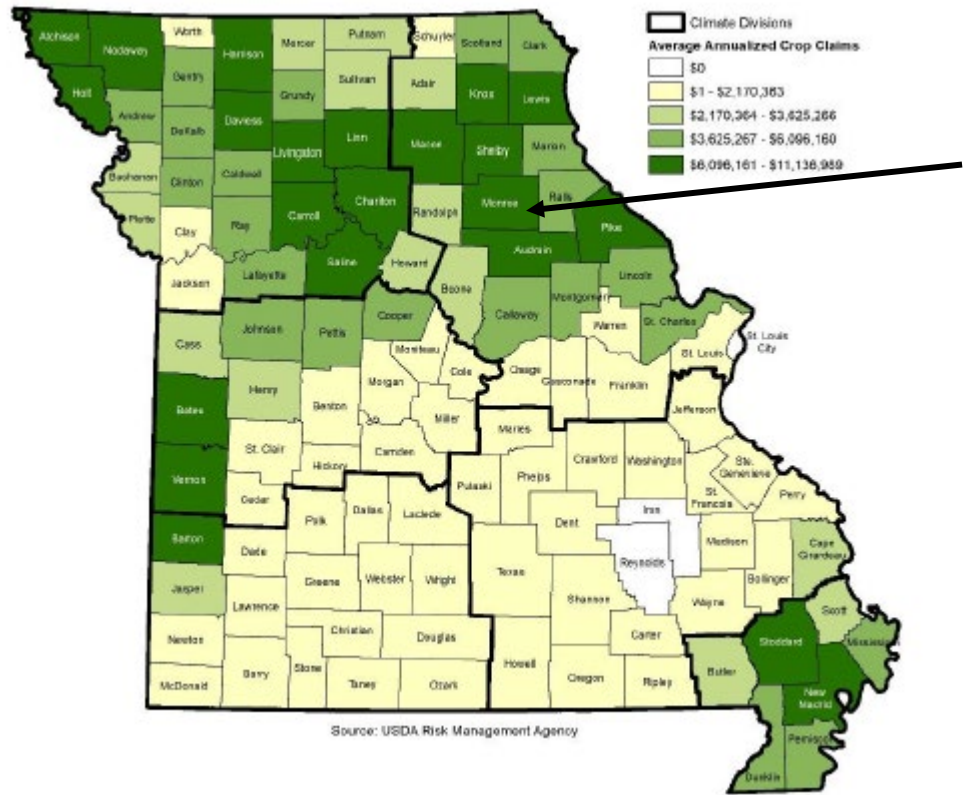
To determine the anticipated potential losses the historical losses were annualized to determine potential future losses for Monroe County to be \$3,626,127 in any given year.

Impact of Previous and Future Development

Future development will remain vulnerable to drought. Typically, some urban and rural areas are more susceptible than others. For example, urban areas are subject to water shortages during periods of drought. Excessive demands of the populated area place a limit on water resources. In rural areas,

crops and livestock may suffer from extended periods of heat and drought. As the size of farms increases, more crops will be exposed to drought-related agricultural losses. Dry conditions can lead to the ignition of wildfires that could threaten residential, commercial, and recreational areas.

Figure 3.17. Annualized Drought Crop Insurance Claims Paid from 2012-2021



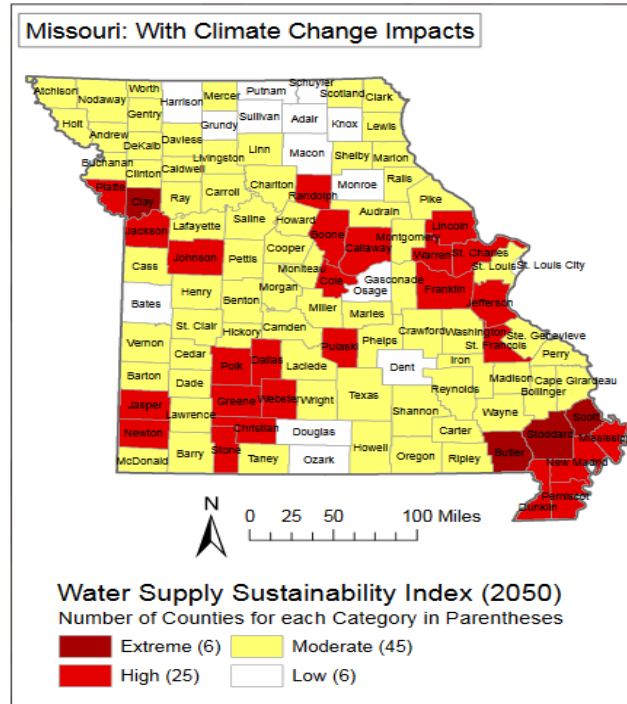
Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

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.

Figure 3.19 below shows Monroe County ranked as Low on the Water Supply Sustainability Index.

Figure 3.18. Climate Change Impacts on Water Supply in Missouri



EMAP Consequence Analysis

Table 3.30. EMAP Impact Analysis: Drought

Subject	Detrimental Impacts
Public	Most damage expected to be agricultural in nature. However, water supply disruptions may adversely affect people.
Responders	Nature of hazard expected to minimize any serious damage to properly equipped and trained personnel.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan. Nature of hazard expected to minimize serious damage to services, except for moderate impact on water utilities.
Property, Facilities, and Infrastructure	Nature of hazard expected to minimize any serious damage to facilities.
Environment	May cause disruptions in wildlife habitat, increasing interface with people, and reducing numbers of animals.
Economic Condition of Jurisdiction	Local economy and finances dependent on abundant water supply adversely affected for duration of drought.
Public Confidence in the Jurisdiction’s Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

The entire planning area will be affected by drought of some degree. The unincorporated agricultural

areas of Monroe County are the most vulnerable to drought while the drought condition will also affect the cities except the magnitude would be different with only lawns and local gardens being impacted. In addition, damage to crops, produce, livestock, soils, and building foundations could be weakened due to shrinking and expanding soil.

Problem Statement

Monroe County residents are not informed on water conservation, not all citizens comply with water usage warnings when issued, water use is greatly affected, businesses and residents have continual problems with water shortages.

Water conservation needs to occur to ensure all citizens comply with water shortage warnings and plans need to be established for businesses and residents on how to survive a drought.

3.4.7 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 in **Figure 3.11** 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 in 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 of 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.

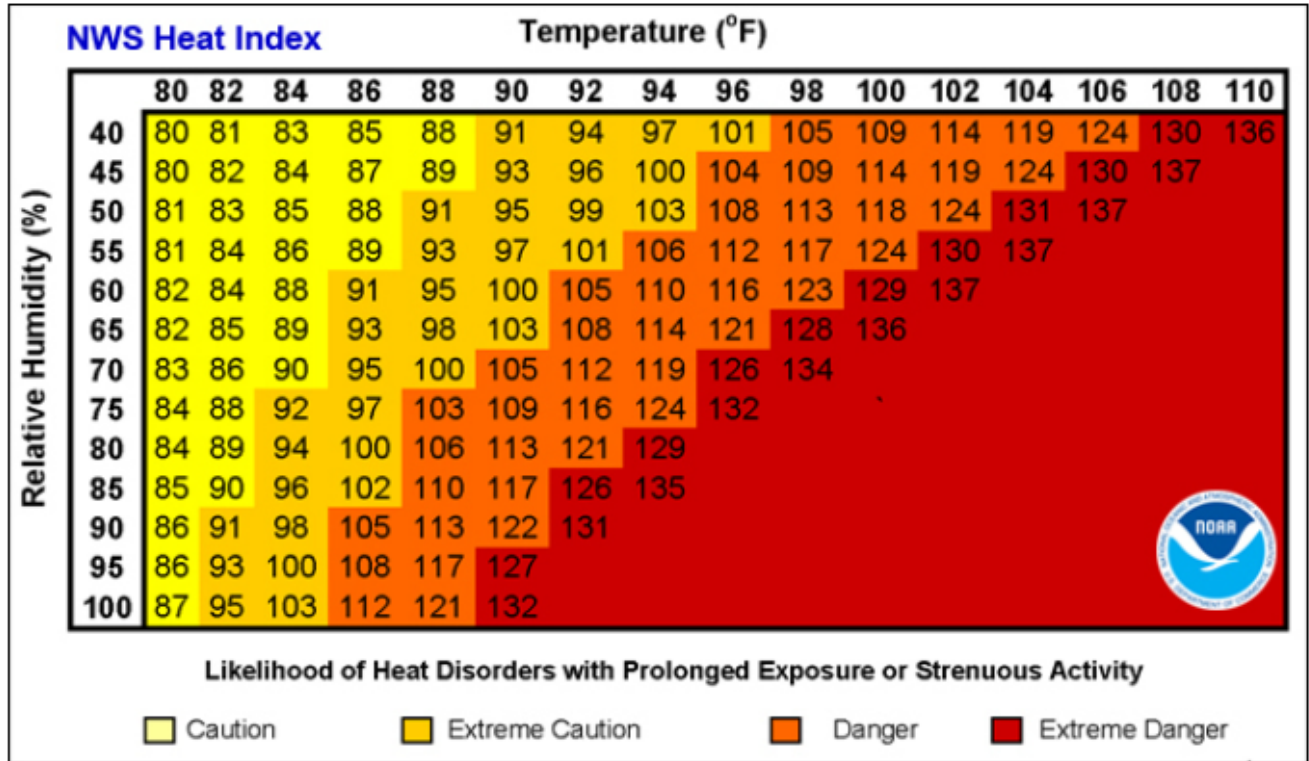
Geographic Location

The entire planning area is subject to extreme heat, and there is no variation amongst the participating jurisdictions.

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 nighttime 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 3.19. Heat Index (HI) Chart

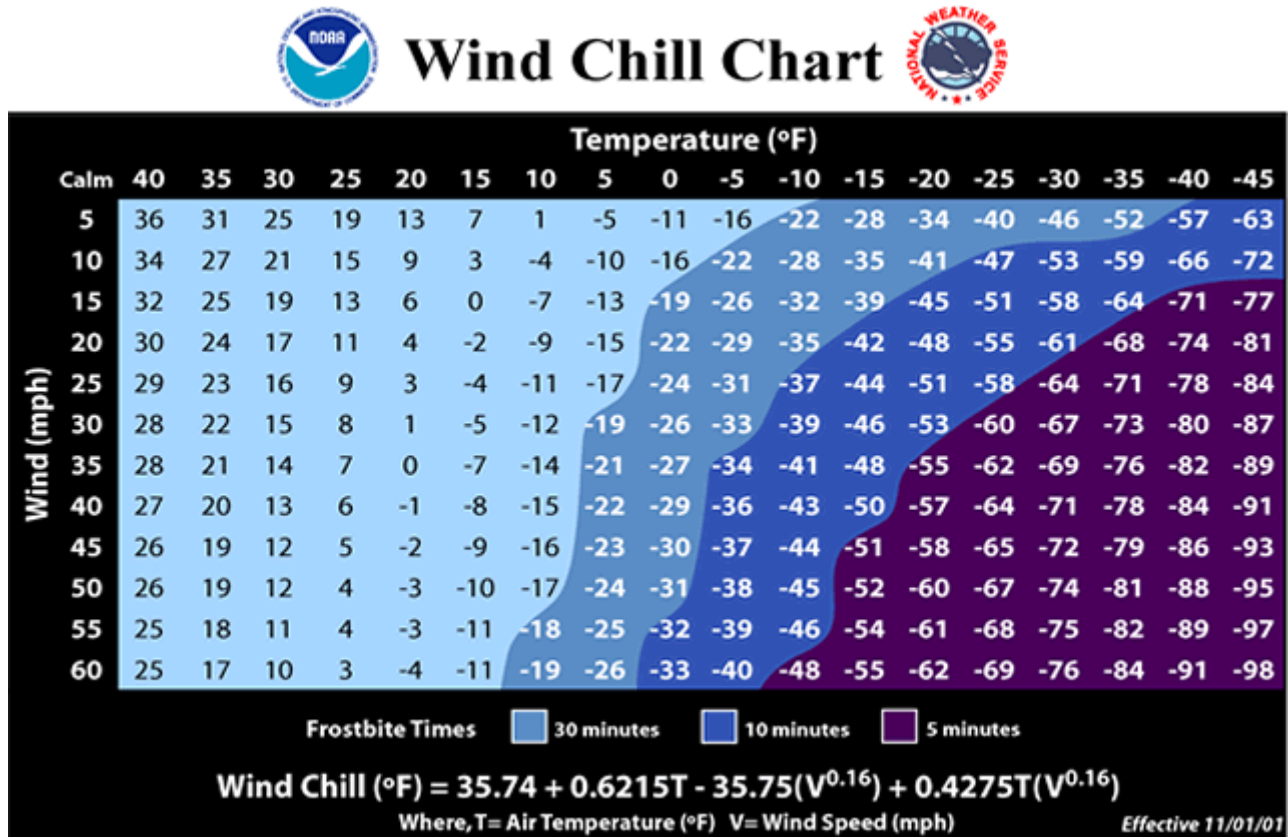


Source: National Weather Service (NWS); <https://www.weather.gov/safety/heat-index>

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 3.20. Wind Chill Chart

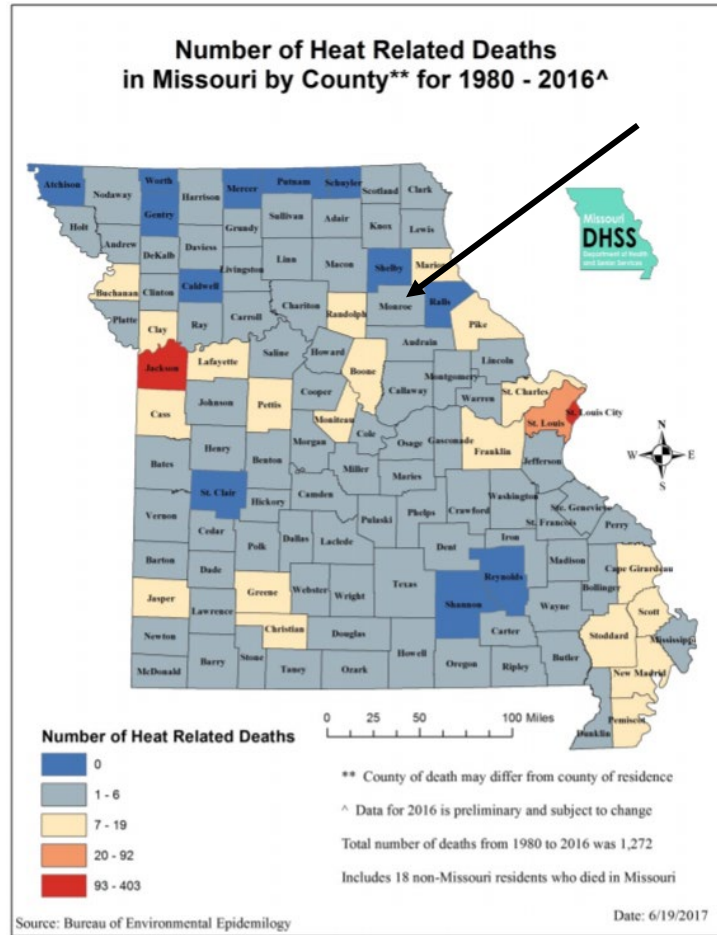


Source: <https://www.weather.gov/safety/cold-wind-chill-chart>

Previous Occurrences

The recorded events in the National Centers for Environmental Information (NCEI) database state there have been 21 recorded events of excessive heat in the 20-year period of 2003 to 2023. There were 0 deaths or injuries associated with these events. The NCEI database shows 0 recorded events of extreme cold/wind chill. There were 0 deaths or injuries associated with these events. **Figure 3.22** illustrates 1-6 heat related deaths in Monroe County between the time of 1980 to 2016, however, no supporting documentation could be found to include in this plan.

Figure 3.21. 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 10-year time period from 2013 to 2022 were \$5,384,710. 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 to 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, 0 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, or earthquakes—causes more deaths.

Probability of Future Occurrence

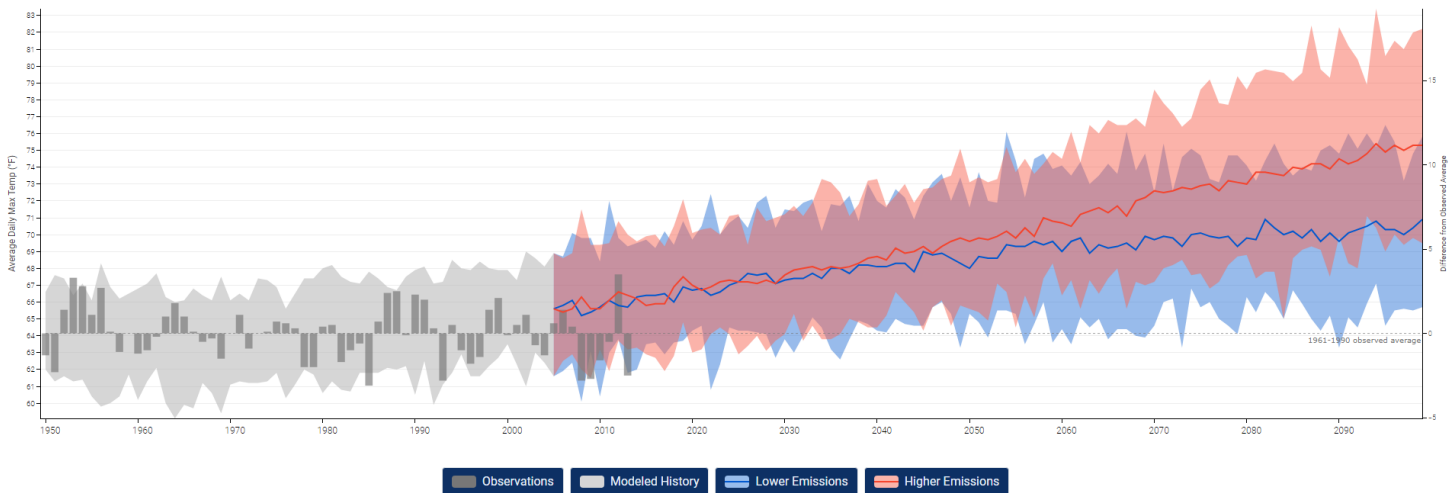
NOAA information dating back to 2003 indicates 9 years with extreme heat events (2007, 2009, 2010, 2011, 2012, 2014, 2015, 2016, 2017). Based on this historical data, the calculated probability of an extreme heat event in any given year is 45%.

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. The impacts of extreme heat events are experienced most acutely by the elderly and other vulnerable populations. High temperatures are exacerbated in urban environments, a phenomenon known as the urban heat island effect, which in turn tends to have higher concentrations of vulnerable populations. Higher demand for electricity as people try to keep cool amplifies stress on power systems and may lead to an increase in the number of power outages. Atmospheric concentrations of ozone occur at higher air temperatures, resulting in poorer air quality, while harmful algal blooms flourish in warmer water temperatures, resulting in poorer water quality.

According to the National Climate Assessment, extreme temperature events in the Midwest have increased during the last century, and these trends are expected to continue, as depicted below.

Figure 3.22. Extreme Temperatures and Emissions in the Midwest, 21st Century



Source: <https://nca2014.globalchange.gov/report/regions/midwest>

Vulnerability

Vulnerability Overview

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 3.31 lists typical symptoms and health impacts due to exposure to extreme heat.

Table 3.31. 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

During the 10-year time period from 2013 to 2022, there were \$5,384,710 in crop insurance claims paid as a result of losses to extreme temperatures. Monroe County is one of the highest counties in insurance payments for extreme heat. The anticipated loss in any given year can be expected to be the annual average of \$538,471. Illness and loss of life are the highest concerns with extreme heat, however, there have been 0 related to extreme heat reported in the above-mentioned period reviewed.

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.

EMAP Consequence Analysis

Table 3.32. EMAP Impact Analysis: Extreme Temperatures

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan. Extent of agricultural damage depends on duration. Water supplies and electricity may be disrupted.
Property, Facilities, and Infrastructure	Nature of hazard expected to minimize any serious damage to facilities. Asphalt parking lots and roads are routinely damaged during periods of extreme heat as the hot asphalt becomes less rigid and can be displaced by heavy equipment or automobiles.
Environment	Potential for crop damage; May cause disruptions in wildlife habitat, increase interface with people, and reduce numbers of animals.
Economic Condition of Jurisdiction	Local economy and finances dependent on stable electricity and water supply adversely affected for duration of heat wave.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

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 2020 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. **Table 3.33** 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.

Table 3.33. Monroe County Population Under Age 5 and Over Age 65, 2020 Census Data

Jurisdiction	Population Under 5 yrs	Population 65 yrs and over
*Monroe County	481	2,036
Village of Holliday	0	37
City of Madison	19	80
City of Monroe City	214	508
City of Paris	83	312
Village of Stoutsville	5	4

Source: U.S. Census Bureau, (*) includes entire population of each city or county

All schools in Monroe County have air conditioning which does not put school age children at risk during extreme temperatures. Due to this, the schools do not have a policy in effect to close if there are extreme temperatures.

Problem Statement

Not everyone in Monroe County utilizes social media and texting; elderly and young children are most vulnerable to a heat wave. Cooling locations in the county need to be identified and open to everyone for extended hours. Utilization of social media and texting needs to be promoted. Monroe County has a growing population of residents over 65 years, who are at a greater risk for extreme-temperature related illnesses, injuries, and death. Possible solutions include organizing outreach to the vulnerable elderly populations, including establishing and promoting accessible heating or cooling centers in the community and creating a database in coordination with the Health Department to track those individuals at high risk.

3.4.8 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 (discussed separately in **Section 3.4.1**) and tornadoes (discussed separately in **Section 3.4.10**).

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 it 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.

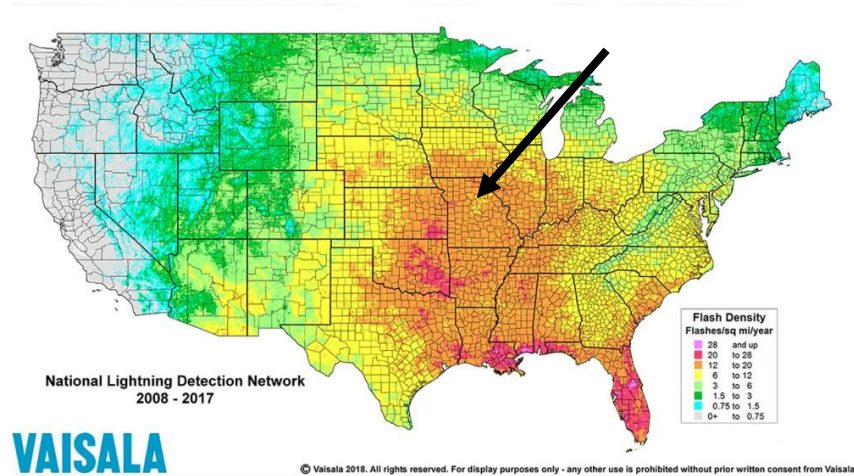
At the time when the updraft can no longer support the hailstone, it will fall down to the earth. For example, a ¼" diameter or pea sized hail requires updrafts of 24 miles per hour, while a 2 ¾" diameter or baseball sized hail requires an updraft of 81 miles per hour. According to the NOAA, the largest 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

All of Monroe County is susceptible to thunderstorms/high winds/hail and lighting events. Although these events occur similarly throughout the planning area, they are more frequently reported in more urbanized areas. In addition, damage is more likely to occur in more densely developed urban areas.

Figure 3.24 shows the lightning density in the nation, with the planning area indicated by an arrow.

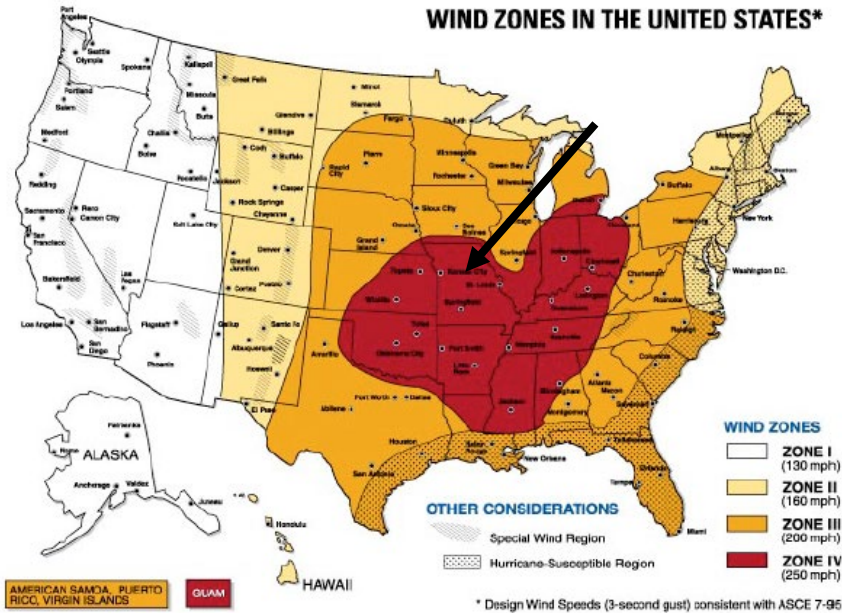
Figure 3.23. Location and Frequency of Lightning in Missouri



Source: National Weather Service, <http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx>.

Figure 3.25 shows wind zones in the United States, with the planning area indicated by an arrow.

Figure 3.24. 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), **Table 3.34** below describes typical damage impacts of the various sizes of hail.

Table 3.34. 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/hyscale.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

Source for Tables 3.35 through 3.38: NOAA

Table 3.35. Reported Events/Damages in Monroe County from Thunderstorms 2013-2023

Wind Magnitude	Number of Events	Property Damages	Crop Damages
52 kts	2	0	0
56 kts	6	0	0
60 kts	1	0	0
61 kts	5	0	0
64 kts	1	0	0
65 kts	3	0	0
65 kts	1	0	0
78 kts	1	0	0

April 2017 (78 kts)- Just south of Monroe City, along U.S. Highway 24, several power poles were snapped, and tree damage was observed. Cedar and oak trees were damaged. On the far southwest portions of Monroe City, nine homes sustained roof damage where shingles were removed. Also, several large tree limbs, between three and nine inches in diameter were blown down. One large tree was blown down, crushing a medium sized storage shed. In town, the roof of a retail store was removed and displaced approximately 80 yards to the east northeast. Another nearby business sustained minor roof damage. Also, 3 large storage sheds sustained minor roof damage. Additional tree damage was observed on the east side of Monroe City in a residential area.

Table 3.36. Reported Events/Damages in Monroe County from High Winds 2013-2023

No data available.

Table 3.37. Reported Events/Damages in Monroe County from Hail 2013-2023

Hail Size (Inches)	Number of Events	Property Damages	Crop Damages
.75	2	0	0
.88	1	0	0
1.00	13	0	0
1.25	1	0	0
1.75	2	10K	0

March 2023 (1.75")- Ahead of a strong cold front, discrete supercells developed and rapidly moved northeast across the region during the early afternoon. Then as the front moved through the activity became more linear before moving out by late evening. There were numerous reports of large hail, damaging winds and two tornadoes. The golf ball sized hail resulted in several broken windows on a house in Stoutsville.

May 2019 (1.75")- Storms developed along an old outflow boundary. Several of the storms produced severe weather including large hail and flash flooding in Monroe City.

Table 3.38. Reported Events/Damages in Monroe County from Lightning 2013-2023

No data available.

Limitations to the use of NCEI reported lightning events include the fact that only lightning events that result in fatality, injury, and/or property and crop damage are in the NCEI.

The tables below (**Table 3.39 through Table 3.42**) summarize past crop damages as indicated by crop insurance claims. The tables illustrate the magnitude of the impact on the planning area's agricultural economy. The information obtained from the Risk Management Agency website did not indicate crop payments for thunderstorms.

Table 3.39. Crop Insurance Claims Paid in Monroe County from High Winds, 2013-2023

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2022	Corn	Wind/Excess Wind	\$7,061
2021	Corn, Soybeans	Wind/Excess Wind	\$17,495
2013	Corn	Wind/Excess Wind	\$57,791
Total			\$82,347

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

Table 3.40. Crop Insurance Claims Paid in Monroe County from Lightning, 2013-2023

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2015	Corn	Other (Lightning)	\$42,953
2013	Wheat, Soybeans	Other (Lightning)	\$88,816
Total			\$131,769

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

Table 3.41. Crop Insurance Claims Paid in Monroe County from Hail, 2013-2023

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2021	Corn	Hail	\$3,798
2018	Soybeans	Hail	\$3,173
2017	Soybeans	Hail	\$3,363
2014	Wheat	Hail	\$5,415
Total			\$15,749

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

Probability of Future Occurrence

Thunderstorms

Thunderstorm wind events 52 knots and greater have a probability of occurring 2 times per year in the planning area in any given year. These rates are expected to continue in the future.

High Winds

High wind events with 52 knots or greater are expected to occur infrequently over a 10-year period.

Lightning

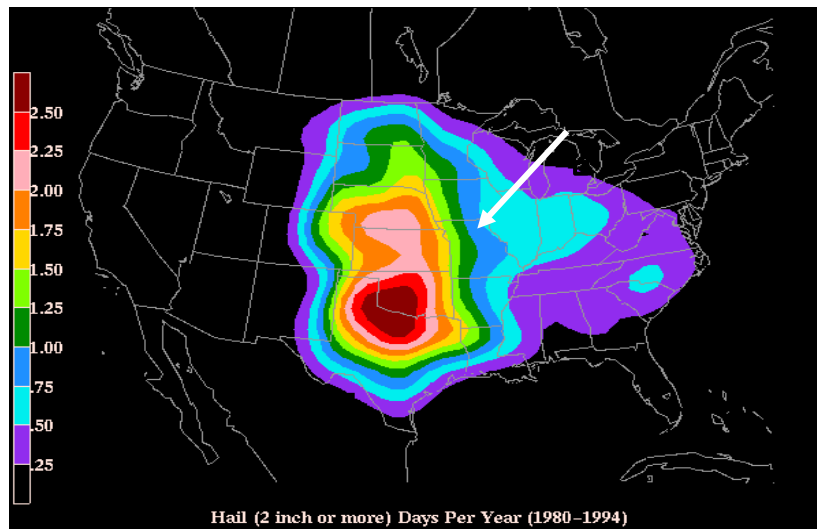
Lightning events are expected to occur infrequently over a 10-year period.

Hail

Based on this data, there have been 19 events in a 10-year period, producing an average of 1.9 hail events each year in Monroe County. Based on history, the probability of a hail event in any given year is 100 percent. Thus, making the probability as likely in any given year.

Figure 3.26 based on hailstorm data from 1980-1994. It shows the probability of hailstorm occurrence (2" diameter or larger) based on number of days per year. Monroe County is located in the region to receive between .75 and 1 hailstorm annually.

Figure 3.25. Annual Hailstorm Probability (2" diameter or larger), 1980-1994



Source: NSSL, http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif

*Planning area indicated by arrow

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, 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 damage. 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.

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 is 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 damage occurs 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 damage 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/>

Potential Losses to Existing Development

Thunderstorms and Lightning

Most damage occurs to electronic equipment located inside buildings, but structural damage can also occur when a lightning strike causes a building fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. There have not been any fatalities or injuries due to lightning in Monroe County during the 10-year period reviewed. No property or crop damage was reported in relation to the specified major weather events during the 10-year reporting period.

Hail

There were 4 reported crop insurance claims for a 10-year period. The USDA RMA data does not depict each individual claim, but rather summarizes the total for each crop type/cause of loss. This amount does not take into account that most buildings and structures are privately insured thus insurance would help the building owner recover from hail damage.

High Winds

There were 7 reported crop insurance claims for a 10-year period. The USDA RMA data does not depict each individual claim, but rather summarizes the total for each crop type/cause of loss. This amount does not take into account that most buildings and structures are privately insured thus insurance would help the building owner recover from high wind damage.

Previous and Future Development

Monroe County's trends in increased development will likely increase vulnerability to thunderstorms, high winds, hail, and lightning. With more development of housing neighborhoods and businesses, the increased population will be vulnerable to all the hazards.

EMAP Consequence Analysis

Table 3.42. EMAP Impact Analysis: Severe Thunderstorms

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the storm or HazMat spills.
Economic Condition of Jurisdiction	Losses to private structures covered, for the most part, by private insurance.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

Thunderstorms/high winds/lightning/hail events are area wide. NCEI data did not seem to indicate that any particular community had higher losses as compared to another.

Problem Statement

Thunderstorms can damage power lines with the high winds or fallen debris such as tree limbs. Not everyone in the county utilizes social media, texting or has access to a weather radio; smaller communities do not have warning sirens, and rural areas do not have warning sirens.

Possible solutions could be the installation of warning sirens in smaller communities or campgrounds, rural citizens are educated on how to utilize social media and texting, and weather radios are accessed by residents more than what is currently being used.

3.4.9 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.

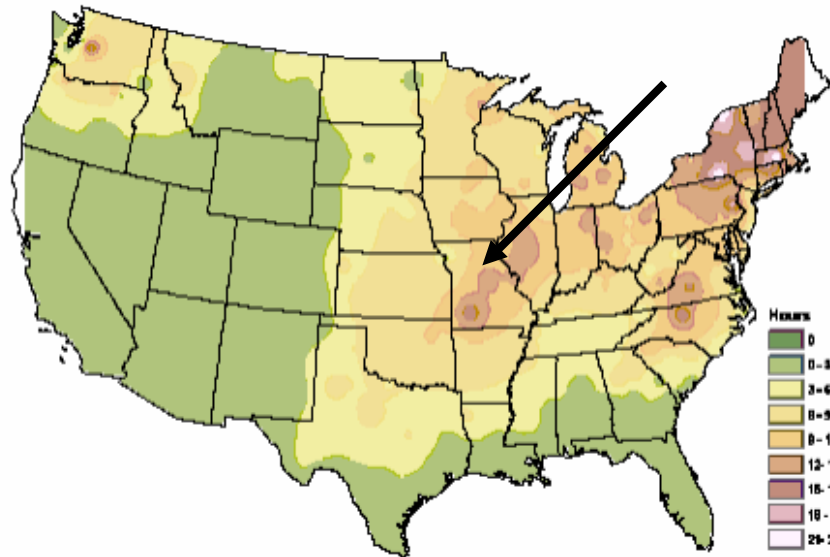
- **Blizzard**—Winds of 35 miles per hour or more with snow and blowing snow reducing visibility to less than $\frac{1}{4}$ mile for at least three hours.
- **Blowing Snow**—Wind-driven snow that reduces visibility. Blowing snow may be falling snow and/or snow on the ground picked up by the wind.
- **Snow 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 Monroe County is vulnerable to heavy snow, extreme temperatures and freezing rain. The snow season normally extends from late November through mid-March, but significant amounts of snow have fallen as early as November 24 to as late as April 10.

Figure 3.27 shows the average number of hours per year with freezing rain. Monroe County received approximately 9-12 hours of freezing rain each year.

Figure 3.26. 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

Table 3.43 includes NCEI reported events and damages for the past 10 years.

Table 3.43. NCEI Monroe County Winter Weather Events Summary, 2013-2023

Type of Event	Inclusive Dates	Magnitude	# of Injuries	Property Damages	Crop Damages
Winter Storm	12/21/2023	N/A	0	0	0
Winter Storm	02/04/2014	N/A	0	0	0
Blizzard	11/25/2018	N/A	0	0	0
Heavy Snow	01/11/2019	N/A	0	0	0
Winter Storm	01/01/2021	N/A	0	0	0
Heavy Snow	01/14/2022	N/A	0	0	0
Heavy Snow	02/01/2022	N/A	0	0	0
Heavy Snow	02/17/2022	N/A	0	0	0
Winter Storm	12/22/2022	N/A	0	0	0

Source: NCEI, data accessed August 10, 2023

November 25, 2018- A strong area of low pressure tracked east across Kansas, Missouri, and central Illinois on November 25th, bringing heavy snowfall and gusty winds to the region. This caused blizzard conditions across portions of central and northeast Missouri, as well as west central Illinois, with less than a quarter of a mile visibility at times during the afternoon and evening. Strong northwest winds between 25 and 35 mph with gusts near 50 mph at times were reported during the storm. The heaviest snowfall reports were over portions of northeast Missouri and west central Illinois. Before the precipitation changed over to snow, there were a few strong to severe storms, but no reports of severe weather were received. Between 3 and 4 inches of snow fell across Monroe County with winds gusting up to 40 mph at times. This caused reduced visibilities of less than a quarter of a mile at times and hazardous driving conditions.

February 1, 2022- A cold front, that was draped northeast-southwest across western Iowa and eastern Nebraska/Kansas, moved south and entered the county warning area during the morning of February 1st. Broad moist isentropic ascent and overrunning precipitation developed across the entire county warning area gradually through the late morning into the afternoon of February 1st, with the baroclinic zone initially serving as the focus for rain. This first round of precipitation stayed nearly all rain, but snow did begin to mix with rain in northern Missouri and west-central Illinois during the afternoon hours of February 1st as colder air advanced south behind the front. The cold air became more established in the northwest half of the CWA with wet snow and a snowfall rate approaching 1/hr across parts of northeast Missouri and west central Illinois north of the I-70 corridor during the early morning hours of February 2nd. The first round brought a wide swath of at least 6-10 inches of snow (with some sleet mixed in) across central/east-central Missouri and west-central Illinois. A second round of heavy snow fell along and south of the I-70 corridor with snowfall rates in excess of 0.5 per hour and occasionally brief periods of 1.5 per hour on Thursday, February 3rd. An additional 6-8 of snow fell in this area during the morning/afternoon hours of February 3rd with lighter snowfall over northeast Missouri and west central Illinois. Eight to twelve inches of snow fell across Monroe County.

February 17, 2022- A strong storm system developed with a cold front moving slowly south across the region. A round of sleet and freezing rain developed north of the boundary across portions of central/northeast Missouri and west central Illinois. Then the mixed precipitation changed over to all snow before coming to an end. Some locations reported between half an inch and 1.5 inches of sleet, as well as up to 11 inches of snow.

Table 3.44 shows the USDA's Risk Management Agency payments for insured crop losses in the planning area as a result of cold conditions and snow for the past 10 years.

Table 3.44. Crop Insurance Claims Paid in Monroe County as a Result of Cold Conditions and Snow, 2013-2023

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid (\$)
2023	Wheat	Cold Wet Weather	\$40,145
2022	Soybeans	Cold Wet Weather, Frost	\$2,225
2021	Wheat, Corn, Soybeans	Cold Winter, Cold Wet Weather	\$489,872
2020	Wheat, Corn, Soybeans	Cold Winter, Cold Wet Weather, Frost	\$10,267
2019	Wheat, Corn	Cold Winter, Cold Wet Weather	\$149,495
2018	Wheat, Corn, Soybeans	Cold Wet Weather, Freeze	\$100,226
2017	Wheat, Corn, Soybeans	Cold Wet Weather	\$11,934
2016	Wheat, Soybeans	Cold Winter, Cold Wet Weather	\$112,025
2015	Wheat, Corn, Soybeans	Cold Winter, Cold Wet Weather	\$120,968
2014	Wheat, Corn, Soybeans	Cold Winter, Cold Wet Weather, Freeze	\$315,329
2013	Wheat, Corn, Soybeans	Cold Winter, Cold Wet Weather, Freeze	\$104,945
Total			\$1,513,482

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

Probability of Future Occurrence

According to NCDC, during the 10-year period from 2013 to 2023, the planning area experienced four winter storm events, one blizzard event, and four heavy snow events. This translates to an annual probability of approximately 0.9 per year a winter weather event will occur.

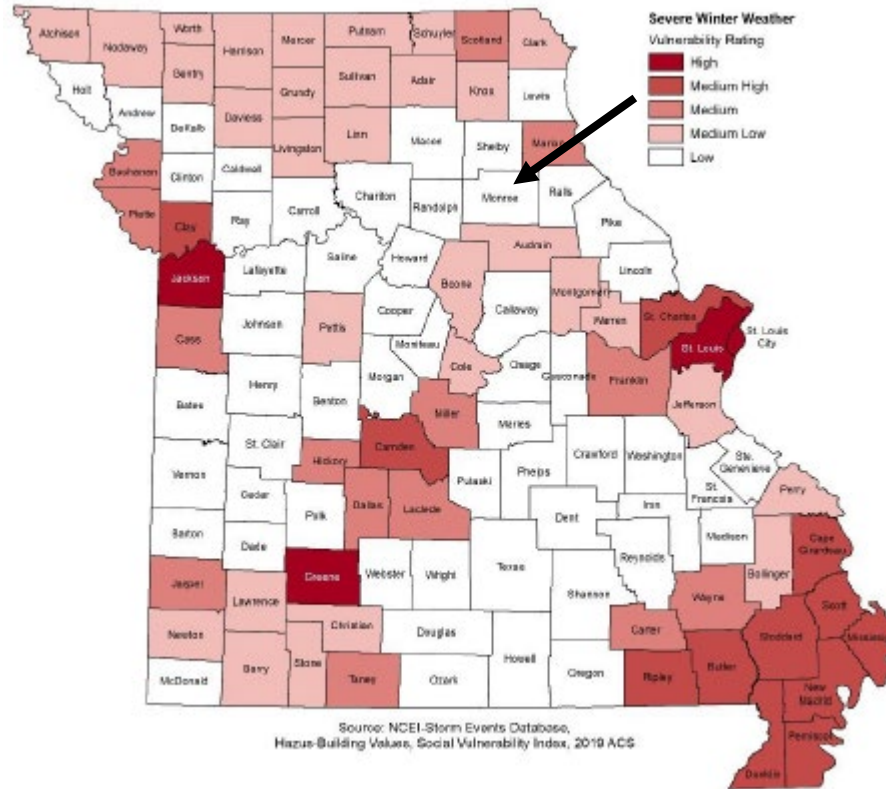
Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation 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, plants, 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

Figure 3.27. Severe Winter Weather Vulnerability by County



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

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 damage 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. Damage also occurs to lines and equipment from falling trees and tree limbs weighted down by ice. Potential losses could include the 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 the 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.

Potential Losses to Existing Development

Monroe County including the jurisdictions of Paris, Monroe City, and Madison have very old downtown districts that are comprised of buildings that suffer from harsh winter weather. The loss of income is experienced by existing businesses due to power outages. In general, heavy winter storms increase wear and tear on roadways through the cost of such damages is difficult to determine.

Previous and Future Development

Future development could potentially increase vulnerability to this hazard by increasing demand on the utilities and increasing the exposure of infrastructure networks.

EMAP Consequence Analysis

Table 3.45. EMAP Impact Analysis: Severe Winter Weather

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for affected areas and moderate to light for other less affected areas.
Responders	Adverse impact expected to be severe for unprotected personnel and moderate to light for trained, equipped, and protected personnel.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan. Localized disruption of roads and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the areas of the incident. Power lines and roads most adversely affected.
Environment	Environmental damage to trees, bushes, etc.
Economic Condition of Jurisdiction	Local economy and finances may be adversely affected, depending on damage.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

Although crop loss as a result of severe winter storms occurs more in the unincorporated portions of the planning area, the density of vulnerable populations is higher in the urban areas of the planning areas. So, it is considered that the magnitude of this hazard is relatively equal. The factors of probability, warning time, and duration is also equal across the planning area. Therefore, the conclusion is the hazard does not substantially vary by jurisdiction.

Problem Statement

Monroe County does not have adequate shelters for residents in the event of a winter storm that are easily accessible with roads that can become hazardous for motorists and emergency responders, power lines can break from ice accumulation and not everyone utilizes social media or texting.

Education needs to occur to ensure all residents are aware of the shelters in the county. Residents should be educated on emergency supplies to have, and the utilization of social media, texting, and radio broadcasting should increase for notification purposes.

3.4.10 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 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 in the entire planning area and no area is immune from tornado damage.

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 damaged 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 with 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 (see **Table 3.46**) attempts to rank 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 3.46. 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 Number	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 **Table 3.47**. 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 of damage is located online at www.spc.noaa.gov/efscale/ef-scale.html.

Table 3.47. Enhanced Fujita Scale with Potential Damage

Enhanced Fujita Scale			
Scale	Wind Speed (mph)	Relative Frequency	Potential Damage
EF0	65-85	53.5%	Light. Peel 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.
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. The 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

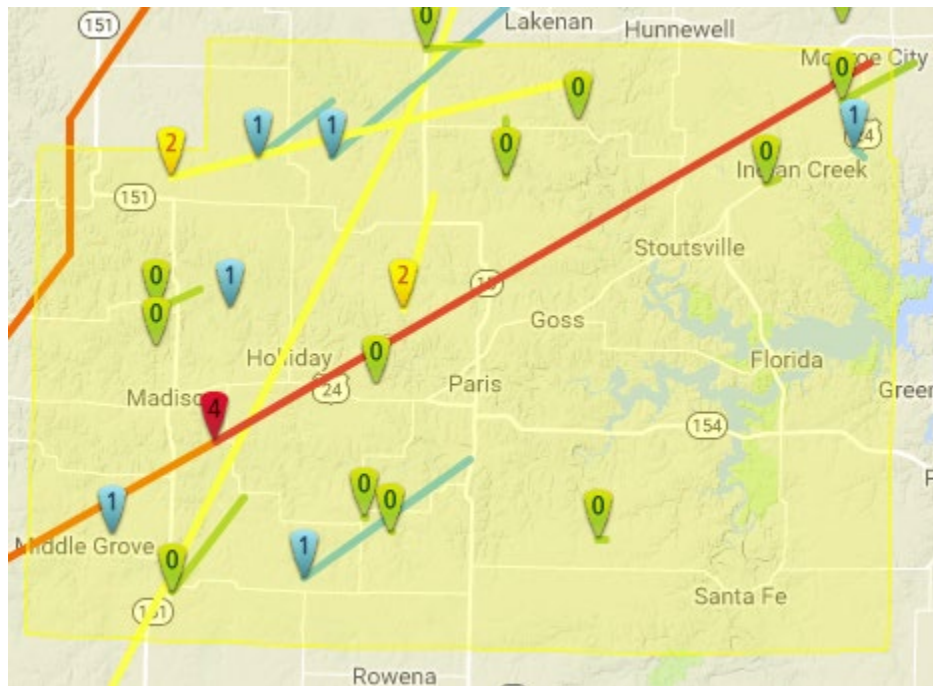
There are limitations to the use of NCEI tornado data that must be noted. For example, one tornado may contain multiple segments as it moves geographically. A tornado that crosses a county line or state line is considered a separate segment for the purposes of reporting to the NCEI. Also, a tornado that 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 3.48. Recorded Tornadoes in Monroe County, 1993 – Present

Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	F/EF Rating	Death	Injury	Property Damage	Crop Damages
05/10/2003	39.62/-91.93	North Fork	.2	40	0	0	0	0	0
05/10/2003	1SW Monroe City	2ENEMonroe City	1.5	50	0	0	0	0	0
03/12/2006	2N Madison	2N Madison	.1	50	0	0	0	0	0
03/12/2006	3SW Middle	2SE Madison	9	300	2	0	0	0	0
03/12/2006	2SE Madison	Monroe City	29	500	4	0	0	0	0
03/01/2007	4N Madison	4S SE Woodlawn	2.07	50	0	0	0	0	0
03/01/2017	4ENE Woodlawn	4N Granville	3.36	60	1	0	0	0	0
03/01/2017	2N Granville	5NW North Fork	6.49	100	1	0	0	0	0
10/02/2017	1NNW Woodlawn	2N North Fork	15.14	100	2	0	1	60.00K	0
10/17/2017	4NW Tulip	5 S SW Holliday	3.97	40	0	0	0	0	0
10/17/2017	4SE Granville	4ENE Granville	4.07	90	2	2	0	50.00K	0
10/17/2017	3WSWNorth Fork	3 W North Fork	1.72	50	0	0	0	0	0
05/15/2009	6S SE Holliday	6S SE Holliday	.11	30	0	0	0	0	0
05/15/2009	5WNW Santa Fe	2S SW Strother	.26	40	0	0	0	0	0
02/27/2011	6WNW NorthFork	5WNW NorthFork	1.27	20	0	0	0	0	0
06/27/2011	2S SW Monroe	2S Monroe City	.43	40	1	0	0	0	0
04/17/2013	2NE Tulip	3S Paris	7.45	70	1	0	0	0	0
04/17/2013	6 S SW Paris	6S SW Paris	0.07	40	0	0	0	0	0
04/17/2013	1SWIndian Creek	1SWIndian Creek	.45	60	0	0	0	0	0
07/04/1995	2SWDuncans	0to3W Shelbyville	160	24	1	0	0	4.50K	2.50K
	Total					2	1	114.50K	2.50K

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

Figure 3.28. Monroe County Map of Historic Tornado Events



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

The USDA Risk Management Agency reported in 2007 there were insurance payments in the amount of \$1,778.00 for Monroe County as a result of a tornado.

Probability of Future Occurrence

The National Centers for Environmental Information reported 24 tornadoes in Monroe County in a 73-year time period, which calculates to a 32.9 percent chance of a tornado in any given year. Therefore, it is a low probability that some portion of Monroe County will experience tornado activity in any given year.

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, 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 has 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 38.5 tornadoes a year, such research is closely followed by meteorologists in the state.

Vulnerability

Vulnerability Overview

Monroe County is located in a region of the U.S. with high frequency of dangerous and destructive

tornadoes referred to as “Tornado Alley”. The high frequency has been determined by looking at the total number of tornadoes in the 17 states included in tornado alley. **Figure 3.30** is based on areas where dangerous tornadoes are more likely to occur. Monroe County remains to have a moderate risk of tornadoes.

Figure 3.29. Tornado Alley in the U.S.



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

Potential Losses to Existing Development

In Monroe County, the NCEI estimate for crop damages from 1950 to 2023 is \$250,000 and the annualized property damage is \$142,280 over the 73 years.

To estimate vulnerability to tornadoes, the impacts of an F0 tornado are reviewed due to this being the most common in the period with wind speed of approximately 100 mph and a length of 1.07 miles and width of 42.7 yards in Monroe County.

Previous and Future Development

Due to the decrease in population in Monroe County, vulnerability to tornadoes is anticipated to remain the same. Future development for public buildings such as schools, government offices, as well as buildings with high occupancy and campgrounds should consider including a tornado saferoom to protect occupants in the event of a tornado.

EMAP Consequence Analysis**Table 3.49. EMAP Impact Analysis: Tornadoes**

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the storm or HazMat spills.
Economic Condition of Jurisdiction	Local economy and finances adversely affected, possibly for an extended period of time.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

Tornadoes can occur in the entire planning area however all unincorporated area could suffer damages.

Problem Statement

Monroe County has inadequate tornado shelters throughout the county, not everyone utilizes social media and/or texting, the rural areas do not have warning sirens, smaller communities do not have warning sirens, lack of awareness for available shelters, and more education needs to occur.

Possible solutions could be awareness made of existing tornado shelters, education on what to do in the event of a tornado, and smaller communities could install warning sirens. A strong emphasis could be made for everyone in the county to own a weather radio.

3.4.11 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.

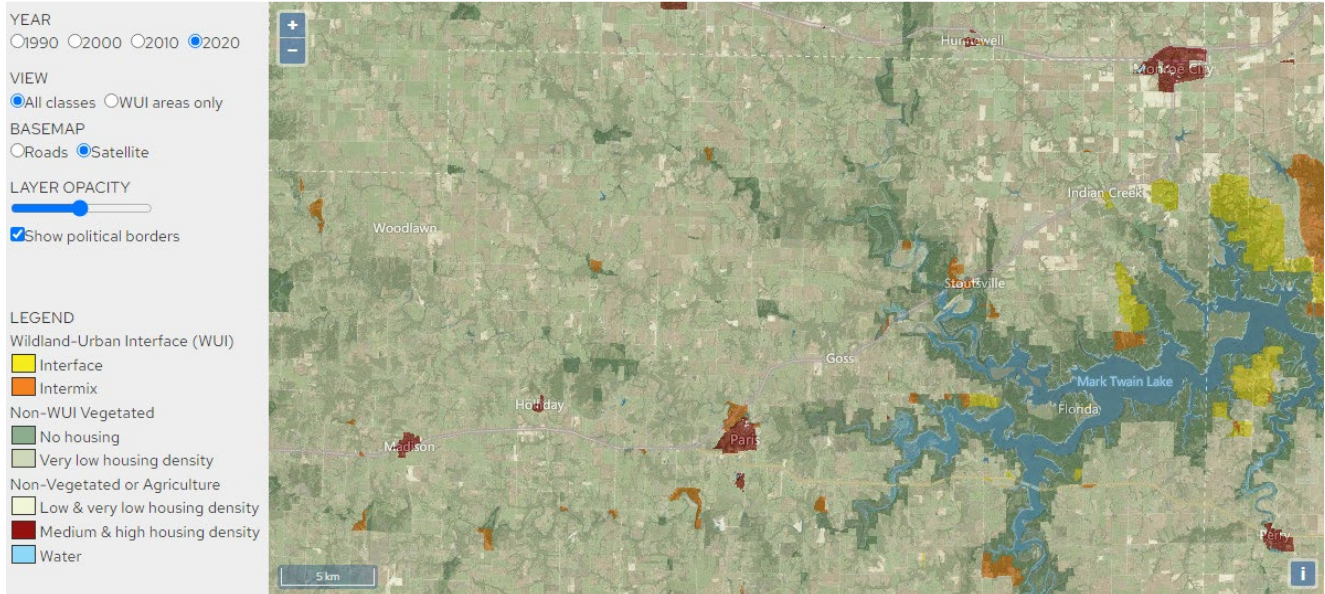
The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from wildfires. To accomplish this task, eight forestry regions have been established in Missouri for fire suppression. The Forestry Division works 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 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 to 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

Wildland-urban interface (WUI) 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.

At this time, Wildland-Urban Interface area does not have information specifically identified for Monroe County. If this information becomes available prior to the next update of this plan, it will be incorporated.

Figure 3.30. Wildfire Vulnerability Based on Housing Density**Wildland-Urban Interface (WUI) Change 1990-2020**

Source: <https://silvis.forest.wisc.edu/data/wui-change/>

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 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 to 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.

At this time, no information is available on the severity of damage from the notable planning area on wildland fires.

Previous Occurrences

According to information obtained from the Missouri Division of Fire Safety (MDFS) website, as well as the Missouri Department of Conservation Wildfire Data Search, there were 209 reported wildland or grass fires in Monroe County from 2013 to 2023. In total, these 209 fires burned 2,561 acres and no injuries were reported. 57 of the fires had an unknown or an unspecified “miscellaneous” cause for

starting, resulting in 867 acres burned, 23 were started by equipment (powerline and railroad were listed) resulting in 184 acres burned, and 129 were started by debris, smoking, lightning, or campfire resulting in 1,510 acres burned. <https://mdc12.mdc.mo.gov/Applications/MDCFireReporting/>

At this time, no information is available from school districts and special districts about previous fire events and the damage resulting from them.

Probability of Future Occurrence

When analyzing the wildland fires, there has been an average of 20.9 fires burning 256.1 acres per year. However, it was reported these fires did not result in major damage. It is highly likely that a wildfire could occur in the planning in any given year.

Changing Future Conditions Considerations

According to the 2023 Missouri State Hazard Mitigation Plan, 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.

Additionally, stated in the 2023 State Plan, 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.

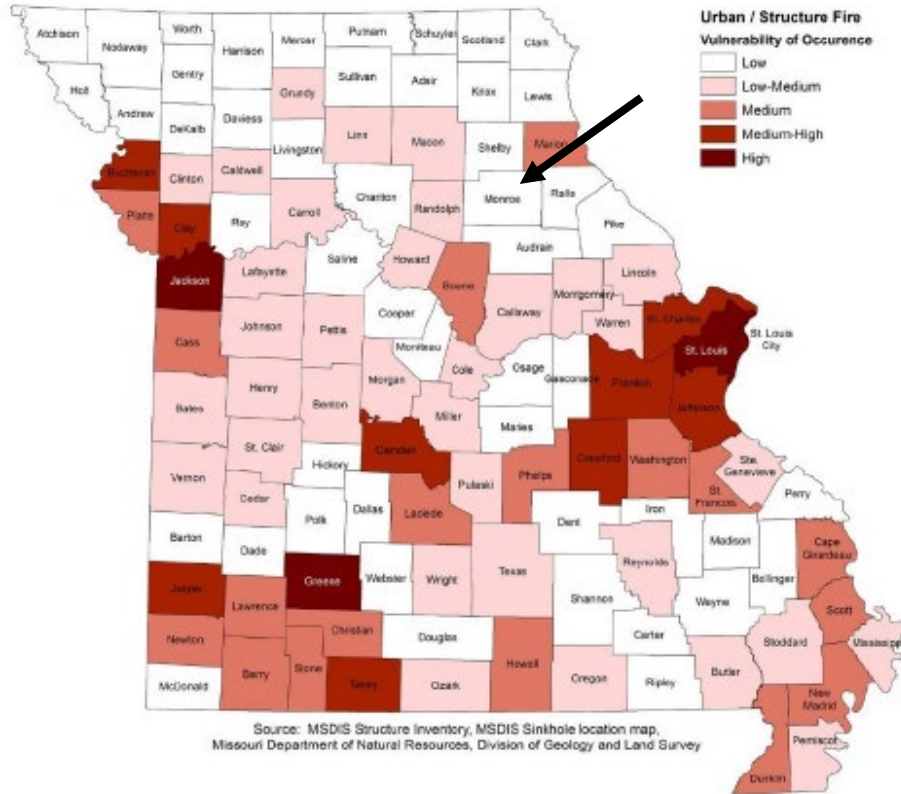
Vulnerability

Vulnerability Overview

Wildfires in the planning area are most likely to occur every year with very little resulting damage. The wildfires occur in the unincorporated areas and are limited to undeveloped land. The jurisdictions and school districts are largely surrounded by developed land. In years of significant drought or excessive heat, the potential for a wildfire in planning area increases.

As outlined in the 2023 Missouri State Hazard Mitigation Plan, Monroe County was given a low vulnerability rating being based on housing density, building exposure, social vulnerability, likelihood of occurrence, annual property loss, and number of deaths/injuries. The data for wildfires are insufficient due to only 60% of fire departments in Missouri reporting to the National Fire Incident Reporting System. The majority of the fire departments in the planning area are comprised of volunteers and are limited in the time spent to report information.

Figure 3.31. Vulnerability to Structural and Urban Fire



Source: 2023 Missouri State Hazard Mitigation Plan *Planning area indicated by arrow

Potential Losses to Existing Development

The potential loss to existing development due to wildfire is difficult to determine due to lack of sufficient historical data. An average number of fires per year has been determined; however, there are no losses reported associated with the data. Information on historical losses was sought after through various sources including the Missouri Division of Fire Safety and The Missouri Department of Conservation.

Impact of Previous and Future Development

Future and previous development in the wildland-urban interface would increase vulnerability to the hazard.

EMAP Consequence Analysis**Table 3.50. EMAP Impact Analysis: Wildfire**

Subject	Detrimental Impacts
Public	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Responders	Localized impact expected to limit damage to personnel in the incident areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations. Localized disruption of roads and/or utilities caused by incident may postpone delivery of some services.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by smoke or HazMat remediation.
Economic Condition of Jurisdiction	Local economy and finances may be adversely affected, depending on damage and length of investigations.
Public Confidence in the Jurisdiction's Governance	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Hazard Summary by Jurisdiction

The rural jurisdictions in the planning area are all surrounded by undeveloped agricultural land and face the possibility of wildfire. The 5 participating school districts are located in a rural area and do not face danger of wildfire due to natural barriers in place around the school.

As long as drought conditions are not seriously inflamed, future wildfires in Monroe County should have a negligible adverse impact on the community, as it would affect a small percentage of the population. Nonetheless, homes and businesses located in unincorporated areas are at higher risk from wildfires due to proximity to wood and distance from fire services. Variations in both structural/urban and wildfires are not able to be determined at this time due to lack of data. However, both fire types are expected to occur on an annual basis across the county.

Problem Statement

Residents do not comply with burn bans, education is not available for the levels of burn bans, many residents lack education in fire safety and not all residents utilize social media and texting. Education needs to occur on the dangers associated with not complying with the burn bans, more education for fire safety, and encourage utilization of social media, texting, and radio broadcasting.

3.4.12 Pandemic

Hazard Profile

Hazard Description

According to the Center for Disease Control, a pandemic is a global outbreak of disease. Pandemics happen when a new virus emerges to infect people and can spread between people sustainably. Because there is little to no pre-existing immunity against the new virus, it spreads worldwide.

Geographic Location

All of Monroe County is susceptible to a pandemic outbreak due to its main characteristic of being on a global level.

Strength/Magnitude/Extent

Risk depends on characteristics of the virus, including how well it spreads between people; the severity of resulting illness; and the medical or other measures available to control the impact of the virus (for example, vaccines or medications that can treat the illness) and the relative success of these. In the absence of vaccine or treatment medications, nonpharmaceutical interventions become the most important response strategy. These are community interventions that can reduce the impact of disease.

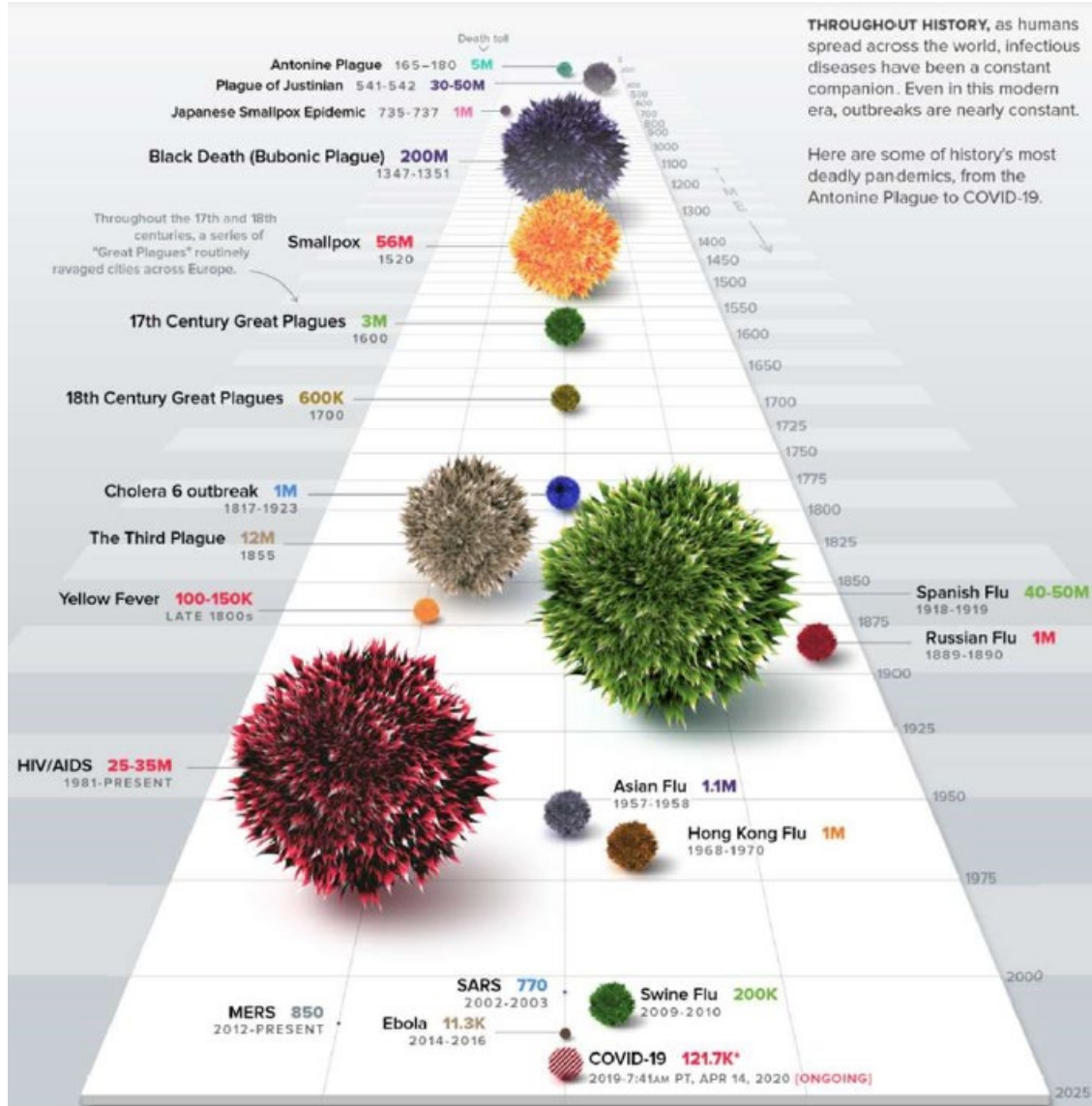
Previous Occurrences

The planning area, in addition to others across the globe, is currently in the midst of a pandemic. The virus that causes COVID-19 is infecting people and spreading easily from person-to-person. On March 11, 2020, the COVID-19 outbreak was characterized as a pandemic by the World Health Organization. According to the Center for Disease Control, this is the first pandemic known to be caused by a new coronavirus. In the past century, there have been four pandemics caused by the emergence of new influenza viruses. As a result, most research and guidance around pandemics is specific to influenza, but the same premises can be applied to the current COVID-19 pandemic.

Pandemics of respiratory disease follow a certain progression outlined in a “Pandemic Intervals Framework.” Pandemics begin with an investigation phase, followed by recognition, initiation, and acceleration phases. The peak of illnesses occurs at the end of the acceleration phase, which is followed by a deceleration phase, during which there is a decrease in illnesses. Different countries can be in different phases of the pandemic at any point in time and different parts of the same country can also be in different phases of a pandemic.

As humans have spread across the world, so have infectious diseases. Even in this modern era, outbreaks are nearly constant, though not every outbreak reaches pandemic level. Figure 3.43 below outlines the history of pandemics dating back to 165.

Figure 3.43. History of Pandemics



Source: <https://www.visualcapitalist.com/history-of-pandemics-deadliest/>

Probability of Future Occurrence

The threat of pandemics in the planning area, and across the globe, remains a concern.

Changing Future Conditions Considerations

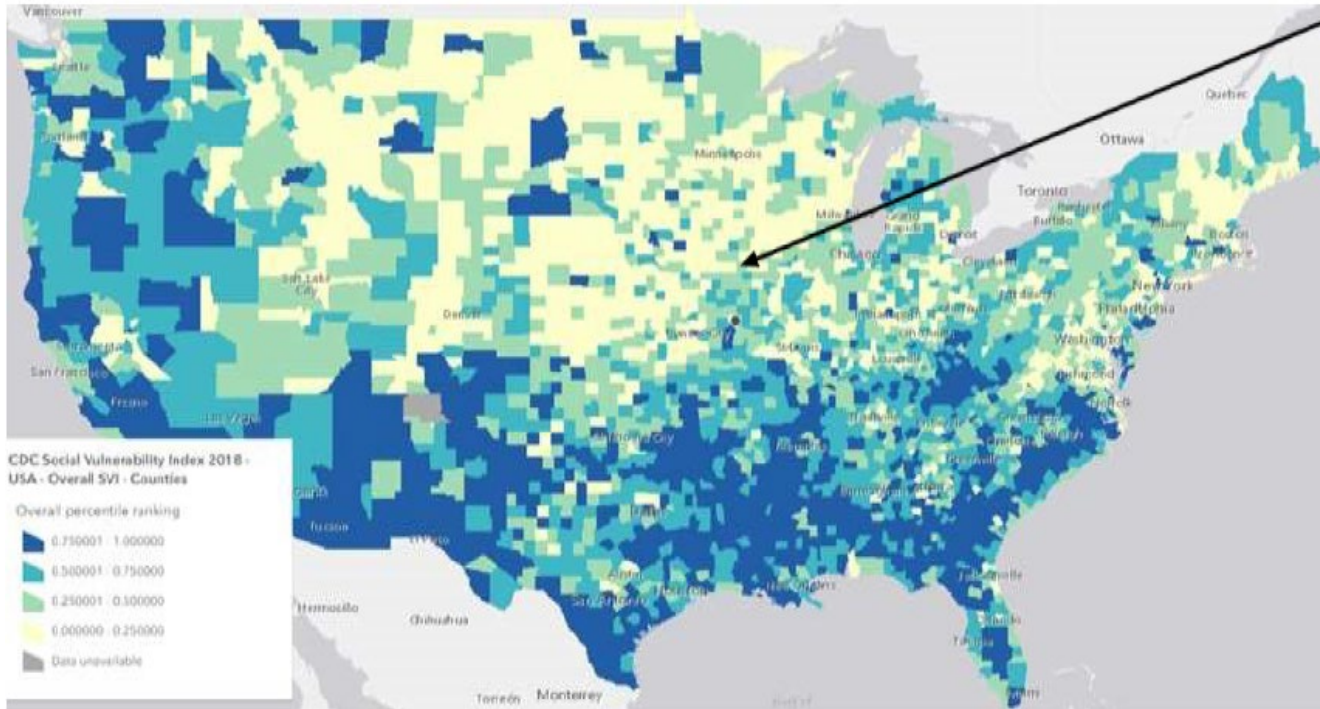
Climate change and weather patterns are widely thought to have direct impacts on the probability and severity of future pandemic outbreaks. Habitat loss due to climate is bringing animals that can transmit disease in contact with humans more often. Floods can enhance the spread of infectious agents like insects, bacteria, and viruses. Increasing temperatures and humidity affect the development, survival and spread of not only pathogens, but also their hosts (often animals).

Vulnerability

Vulnerability Overview

Each jurisdiction and its population, businesses, and school districts are vulnerable to a pandemic outbreak. Due to an increasing elderly population throughout the planning area, an outbreak of an infectious or viral disease could have major impacts on the communities and the assets each possess.

Figure 3.44. Social Vulnerability Rating in the United States



Source: <https://livingatlas.arcgis.com/policy/browse/?loc=-94.542,39.439,5&col=88f17b4580e846609f92c9f75a9d9eee,2c8fdc6267e4439e968837020e7618f3,48638a1be455429287d6756985013910,02a82293e2dd475391cb3699b5e82d61,d89c527f2e6b4d658db0948ea9d49cd9,48a70b524601428ba297e3106b751401,be559110b5c34591b1a767fbb807bcbf,e0427fbc472f4a45b7d94d182a5e9591,142e65436bed4063973380feae6ed248&viz=2c8fdc6267e4439e968837020e7618f3&hs=1>

*Arrow indicates Shelby County

Potential Losses to Existing Development

During a pandemic, COVID-19 for example, people have been ordered to stay home, schools adjourned the remainder of the year, restaurants and bars are forced to close their doors. It is very likely the livelihood of the population and some of the planning area's most beloved assets and businesses will not be able to recover from the pandemic due to extreme economic loss and health threats.

Impact of Previous and Future Development

Pandemics create unprecedented disruption for global health and the development of communities. Urbanization in the developing world is bringing more and more rural residents into denser neighborhoods, while population increases are putting greater pressure on the environment. In conjunction, air traffic has nearly doubled in the past decade. These macro trends are having major impacts on the spread of infectious disease.

Hazard Summary by Jurisdiction

The planning area is largely rural, and many have a sense of "safeness" when it comes to an infectious or viral pandemic, in the sense that most of the population can securely distance themselves from one

another, whereas larger cities do not have that luxury. Unfortunately, pandemics happen on a global level and no community is immune.

Problem Statement

In order to keep transmission rates low during a pandemic outbreak, residents need to safely distance themselves as best as possible and follow the numerous Center for Disease Control guidelines. Due to the lack of accessibility to ongoing public health information and broadband connectivity, it is especially challenging to inform residents about current and upcoming pandemic updates. It is an issue in rural America to convey the severity of pandemic outbreaks and provide preparedness instruction because social media, website posts, podcasts, etc. are not an option for every resident in the planning area.