3 RISK ASSESSMENT

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 severity/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.

The primary phase in the development of a hazard mitigation plan is to identify specific hazards which may impact the planning area. To initiate this process, the Hazard Mitigation Planning Committee (HMPC) reviewed a list of natural hazards provided by the Federal Emergency Management Agency (FEMA). From that list, the HMPC selected pertinent natural hazards of concern that have the potential to impact Maries County. These selected natural hazards are further profiled and analyzed in this plan.

3.1.1 Review of Existing Mitigation Plans

Within the State of Missouri, local hazard mitigation plans customarily include only natural hazards, as only natural hazards are required by federal regulations. Nevertheless, there is an opportunity to include man made or technical hazards within the plan. However, it was decided that only natural hazards were appropriate for the purpose of this plan. Based on past history and future probability, the Hazard Mitigation Planning Committee (HMPC) determined that the following potential hazards would be included in the Maries County Hazard Mitigation Plan:

- Dam Failure
- Drought
- Earthquake
- Extreme Temperatures
- Flooding (Riverine and Flash)
- Land Subsidence/Sinkholes
- Severe Thunderstorms Including High Winds, Hail, and Lightning
- Tornado
- Severe Winter Weather
- Wildfires

Hazards not occurring in the planning area or considered insignificant were eliminated from this plan. **Table 3.1** outlines the hazards eliminated from the plan and the reasons for doing so. Additionally, some hazards were combined in the Maries County Plan to match the hazards listed in the Missouri State Hazard Mitigation Plan.

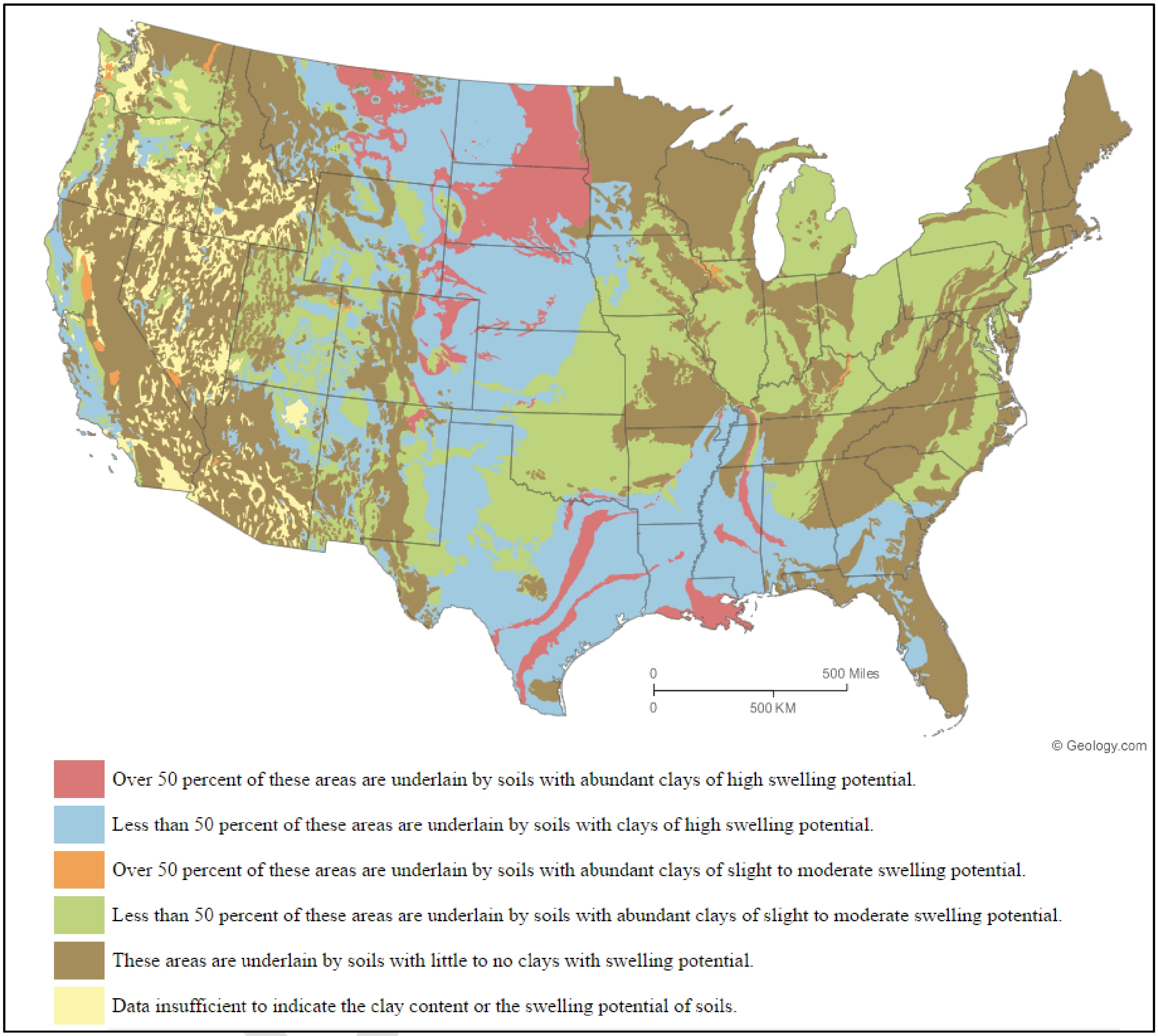
Table 3.1. Table 3.1 Hazards Not Profiled in the Plan

Hazard	Reason for Omission
Avalanche	No mountains in the planning area.
Coastal Erosion	Planning area is located in the Midwest, not on any coast.
Coastal Storm	Planning area is located in the Midwest, not on any coast.
Debris Flow	There are no mountainous areas in the planning area where this type of event occurs.

Hazard	Reason for Omission
Expansive Soils	No expansive soils exist within the planning area. According to the USGS National Geologic Map Database[1], the planning area is underlain by soils with little to no clays with swelling potential (**Figure 3.1**).
Hurricane	Planning area is located in the Midwest, not on any coast.
Levee Failure	According to the US Army Corps of Engineers' National Levee Database [2], and local officials, there are no levees located in the planning area. However, low-head agricultural levees could be present. Unfortunately, no data could be found indicating damages in the event of failure.
Volcano	There are no volcanic areas in the county.

[1] http://ngmdb.usgs.gov/Prodesc/proddesc_10014.htm
[2] http://nld.usace.army.mil/egis/f?p=471:1:0::NO

Figure 3.1. **Swelling clays map of the conterminous United States**



Source: http://ngmdb.usgs.gov/Prodesc/proddesc_10014.htm

3.1.2 Review Disaster Declaration History

In order to assess risk, it was logical to review the disaster declaration history for the State of Missouri and specifically for Maries County. Federal and State disaster declarations are granted when the severity and magnitude of a hazard event surpasses the ability of 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 damages and institutions or industrial sectors affected.

There are three agencies through which a federal disaster declaration can be issued – FEMA, the U.S. Department of Agriculture (USDA) and/or the Small Business Administration. A federally declared disaster generally includes long-term federal recovery programs. The type of declaration is determined by the type of damage sustained during a disaster and what types of institutions or industries are affected.

A declaration issued by USDA indicates that the affected area has suffered at least a 30 percent loss in one or more crops or livestock industries. This type of declaration provides those farmers affected with access to low-interest loans and other programs to assist with disaster recovery and mitigation.

Missouri has been especially hard hit by natural disasters in the recent past. The state has had 77 federally declared disasters since 1953. Of those,43 have occurred since 2003. Most of these disasters have been weather related – severe wind and rainstorms, tornadoes, flooding, hail, ice storms and winter storms. Table 3.2 lists the federal disaster declarations for Maries County from 2003 through 2022.

Table 3.2. FEMA Disaster Declarations that included Maries County, Missouri, 2003-2022

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-1463	Severe Storms, Tornadoes, Flooding	Declaration Date: May 06, 2003 Incident Period: May 04, 2003 to May 30, 2003	PA
EM-3232	Hurricane Katrina Evacuation	Declaration Date: September 10, 2005 Incident Period: August 29, 2005 to October 01, 2005	PA
DR-1676	Severe Winter Storms, Flooding	Declaration Date: January 15, 2007 Incident Period: January 12, 2007 to January 22, 2007	PA

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
EM-3281	Severe Winter Storms	Declaration Date: December 12, 2007 Incident Period: December 08, 2007 to December 15, 2007	PA
DR-1742	Severe Storms, Tornadoes, and Flooding	Declaration Date: February 5, 2008 Incident Period: January 7, 2008 – January 10, 2008	PA
DR-1749	Severe Storms, Flooding	Declaration Date: March 19, 2008 Incident Period: March 17, 2008 to May 09, 2008	IA, PA
DR- 1809	Severe Storms, Flooding, and a Tornado	Declaration Date: November 13, 2008 Incident Period: September 11, 2008 – September 24, 2008	PA
EM-3303	Severe Winter Storm	Declaration Date: January 30, 2009 Incident Period: January 26, 2009 to January 28, 2009	PA
DR-1847	Severe Storms, Tornadoes, Flooding	Declaration Date: June 19, 2009 Incident Period: May 08, 2009 to May 16, 2009	PA
EM-3317	Severe Winter Storm	Declaration Date: February 03, 2011 Incident Period: January 31, 2011 to February 05, 2011	PA
DR-1961	Severe Winter Storm and Snowstorm	Declaration Date: March 23, 2011 Incident Period: January 31, 2011 – February 5, 2011	PA
DR-4130	Severe Storms, Straight-line Winds, Tornadoes, and Flooding	Declaration Date: July 18, 2013 Incident Period: May 29, 2013 to June 10, 2013	PA
DR-4144	Severe Storms, Straight-line Winds, Flooding	Declaration Date: September 6, 2013 Incident Period: August 2, 2013 to August 14, 2013	PA
DR-4238	Severe Storms, Tornadoes, Straight-line Winds, Flooding	Declaration Date: August 7, 2015 Incident Period: May 15, 2015-July 27, 2015	PA
EM-3374	Severe Storms, Tornadoes, Straight-line Winds, Flooding	Declaration Date: January 2, 2016 Incident Period: December 22, 2015-January 9, 2016	PA

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-4250	Severe Storms, Tornadoes, Straight-line Winds, Flooding	Declaration Date: January 21, 2016 Incident Period: December 23, 2015 – January 9, 2016	IA
DR-4317	Severe Storms, Tornadoes, Straight-line Winds, Flooding	Declaration Date: June 2, 2017 Incident Date: April 28, 2017, - May 11, 2017	IA, PA
DR-4451	Severe Storms, Tornadoes, and Flooding	Declaration Date: July 9, 2019 Incident Period: April 29, 2019 – July 6, 2019	PA
EM-3482	Missouri Covid-19	Declaration Date: March 13, 2020 Incident Period: January 20, 2020 and continuing	PA
DR-4490	COVID-19 Pandemic	Declaration Date: March 26, 2020 Incident Period: January 20, 2020 and continuing	IA, PA

Source: Federal Emergency Management Agency: http://www.fema.gov/disasters

3.1.3 Research Additional Sources

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

- Missouri Hazard Mitigation Plans (2013, 2018, 2023)
- Previously approved Maries County Hazard Mitigation Plan (2019)
- Federal Emergency Management Agency (FEMA)
- Missouri Department of Natural Resources (MDNR)
- 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);
- Pipeline and Hazardous Materials Safety Administration
- 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 are cited in the body of the Plan)

Remarkably, 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 January 2023, 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.

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

Table 3.3 lists the hazards that significantly impact each jurisdiction within the planning area and were chosen for further analysis in alphabetical order. "X" indicates the jurisdiction is impacted by the hazard, and a "-" indicates the hazard is not applicable to that jurisdiction. As Maries County is predominately rural, limited variations occur across the county. However, jurisdictions with a high percentage of housing comprised of mobile homes, for example, could be more at risk of damage from a tornado.

Table 3.3. Hazards Identified for Each Jurisdiction

Jurisdiction	Dam Failure	Drought	Earthquake	Extreme Temperature	Flooding (River and Flash)	Land Subsidence/Sinkholes	Severe Winter Weather	Thunderstorms/High Winds/ Lightning/Hail	Tornado	Wildfire
Maries County	x	x	x	x	x	x	x	x	x	x
Belle	x	x	x	x	x	x	x	x	x	x
Vienna	x	x	x	x	x	x	x	x	x	x
School Districts										
Maries County R-I	x	x	x	x	-	x	x	x	x	x
Maries County R-II	x	x	x	x	-	x	x	x	x	x

3.1.5 Multi-Jurisdictional Risk Assessment

For this multi-jurisdictional hazard mitigation plan, each hazard is profiled in which the risks are assessed on a planning area wide basis. Some hazards, such as dam failure, vary in risk across the county. If variations exist within the planning area, discussion is included in each profile. Maries County is uniform across the county in terms of climate, topography, and building construction characteristics. Weather-related hazards will impact the entire county in much the same fashion, as do topographical/geological related hazards such as earthquake. Sinkholes appear throughout the county and are localized in their effects. The areas of urbanization include the cities of Belle and Vienna. Urbanized areas have more assets at a greater density, and therefore have greater vulnerability to weather-related hazards. Rural areas include agricultural assets (livestock/crops) that are also vulnerable to damage. Differences among jurisdictions for each hazard will be discussed in greater detail in the vulnerability section of each hazard.

3.2 Assets at Risk

This section assesses the planning area's population, structures, critical facilities, infrastructure, and other important assets that may be at risk to hazards.

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 values are based on parcel data developed by the State of Missouri Geographic Information Systems (GIS) database. 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 3.4**. 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). 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. Public school district assets and special districts assets are included in the total exposure tables assets by community and county.

Table 3.4 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 3.5** 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 3.4. Maximum Population and Building Exposure by Jurisdiction

Jurisdiction	2020 Population	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Unincorporated Maries County	6,470	8,732	$478,321	$261,237	$739,558
Belle	1,381	639	$84,110	$45,985	$130,095
Vienna	581	334	$46,237	$24,760	$70,998
Total	8,432	9,714	$609,357	$332,321	$941,678

Sources: U.S. Census Bureau Decennial Redistricting Data; 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 the purposes of these calculations, government, school, and utility were calculated at the commercial contents rate.

Table 3.5. Building Value/Exposure by Usage Type

Jurisdiction	Agriculture	Commercial	Education	Government	Industrial	Residential	Total
Maries County	$13,909	$12,956	$0	$517	$22,294	$428,646	$478,321
Belle	$23	$10,576	$3,986	$1,294	$0	$68,231	$84,110
Vienna	$34	$7,227	$5,980	$2,070	$0	$30,928	$46,237
Total	**$13,976**	**$30,759**	**$9,966**	**$3,881**	**$22,294**	**$528,482**	**$609,357**

Source: Missouri GIS Database, SEMA Mitigation Management Section

Table 3.6. Building Counts by Usage Type

Jurisdiction	Residential Counts	Commercial Counts	Industrial Counts	Agricultural Counts	Other (Gov't/Edu)	Total
Maries County	8,732	147	45	5,378	2	8,732
Belle	503	120	0	9	7	639
Vienna	228	82	0	13	11	334
Total	9,714	349	45	5,404	67	9,714

Source: Missouri GIS Database, SEMA Mitigation Management Section

Even though school districts' total assets are included in the tables above, the data in **Table 3.7** below provides additional information based on the data that is available from the districts' completion of the Data Collection Questionnaire and from the Missouri Department of Elementary and Secondary Education (DESE). The 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 3.7. Population and Building Exposure by Jurisdiction-Public School Districts

Public School District	Enrollment	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Maries Country R-I	491	3	$14,281,127	$9,416,944	$23,698,071
Maries Country R-II	730	3	$14,582,374	$4,000,000	$18,582,374

Source: https://apps.dese.mo.gov/MCDS/Reports/SSRS_Print.aspx?ReportId=152b1d45-e617-4184-acf3-82b9287ae2b4 ; 2023 Data Collection Questionnaire

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.

The table below (**Table 3.8**) provides information for critical and essential facilities and infrastructure in the planning area. The list was compiled from the Data Collection Questionnaire as well as

- the 2018 Missouri State Hazard Mitigation Plan and Hazard Mitigation Viewer;
- the Missouri Department of Elementary and Secondary Education (DESE);
- the Missouri Department of Health and Senior Services (DHSS), and;
- information provided by the Meramec Local Emergency Planning District.

Table 3.8. Maries County Critical Facilities by Type and Jurisdiction

HazusID	Jurisdiction	Building Name	Address	City	State	Zip
Emergency Facilities						
	Maries Co.	Dixon Ambulance District	305 S. Ellen Street	Dixon	MO	65456
	Maries Co.	Maries Osage Ambulance District	164 Ballpark Road	Vienna	MO	65582
	Maries Co.	Osage Ambulance District	119 S. Highway 89	Linn	MO	65051
	Maries Co.	St. James Ambulance District	103 N. Louise Avenue	St. James	MO	65559
Fire Department Facilities						
	Maries Co.	Belle Vol. Fire Dept.	PO Box 933, 98 Hwy 28 E.	Belle	MO	65013
	Maries Co.	Vichy Vol. Fire Prot. Assoc.	PO Box 486, 14812 Hwy 63	Vichy	MO	65580
	Maries Co.	Vienna Fire Prot. Dist.	PO Box 386, 308 N Mill St.	Vienna	MO	65582
Law Enforcement Facilities						
	Maries Co.	Maries County Sheriff's Office	211 4th St., PO Box 23	Vienna	MO	65582
	Belle	Belle Police Department	106 East 3rd St., PO Box 813	Belle	MO	65013
	Vienna	Vienna Police Department	PO Box 196, 424 8th St.	Vienna	MO	65582
Medical Facilities						
	Maries Co.	Phelps Health Medical Group Vienna	606 S. Highway 63	Vienna	Mo	65582
	Maries Co.	SSM Health Group – Family Medicine	100 Highway 28	Belle	Mo	65013
School Facilities						
	Maries County R-I	Maries County R-I School District	300 Fourth Street	Vienna	MO	65582
	Maries County R-II	Maries County R-II School District	503 W. Third Street	Belle	MO	65013
	Visitation Inter-Parish	Visitation Inter-Parish Private School	105 N. Coffey Street	Vienna	MO	65582
Childcare Facilities						
	Maries Co.	MOCA Headstart	408 Oak St	Belle	MO	65013
	Maries Co.	Reeves, Rata Lynn	11361 Highway 63 S.	Vienna	MO	65582
	Maries Co.	Smith, Beth Ann	11309 Highway 63 S.	Vienna	MO	65582
	Maries Co.	Kiddie T Junction, LLC	30391 Highway T	Vienna	MO	65582
Long Term Care Facilities						
	Vienna	Maries Manor	174 Ballpark Road	Vienna	MO	65582
	Vienna	Victorian Place of Vienna	112 Parkway Drive	Vienna	MO	65582

Source: 2023 Data Collection Questionnaires, Meramec Local Emergency Planning District, Missouri DHSS https://healthapps.dhss.mo.gov/childcaresearch/, https://healthapps.dhss.mo.gov/showmeltc/default.aspx

Table 3.9 includes a summary of the inventory of critical and essential facilities and infrastructure in the planning area. The list was compiled from the 2023 Data Collection Questionnaire, the Meramec Regional Hazardous Materials Emergency Response Plan and the National Bridge Inventory.

Table 3.9. Inventory of Critical/Essential Facilities and Infrastructure by Jurisdiction

	Airport Facility	Bus Facility	Childcare Facility	Communications Tower	Electric Power Facility	Emergency Operations	Fire Service	Government	Housing	Shelters	Highway Bridges	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
Unincorporated Maries County	1	0	3	0	0	1	1	5	0	0	70	0	0	0	0	1	0	0	0	0	0	1	0	83
City of Belle	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	1	0	8	1	16
City of Vienna	0	0	0	0	0	0	1	3	2	0	0	1	0	0	2	2	2	0	3	2	0	6	1	25
Totals	1	0	4	0	0	1	3	9	2	0	70	1	0	0	2	4	3	0	4	3	0	15	2	124

Source: 2023 Data Collection Questionnaires, National Bridge Inventory, 2022 MLEPD Hazardous Materials Emergency Response Plan

According to the National Bridge Inventory there are a total of 70 bridges in Maries County[1]. **Figure 3.2** shows the locations of State regulated bridges and non-State bridges in the planning area. Scour critical bridges were also examined. 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. There is one scour critical bridge within Maries County. The highway 63 bridge spanning the Gasconade River has a scour index of 3.[2]

[1] http://www.fhwa.dot.gov/bridge/nbi/no10/county.cfm
[2] https://infobridge.fhwa.dot.gov/Data/SelectedBridges#!#OverviewTab

Figure 3.2. Maries County Bridges

Source: MSDIS, MoDOT, MRPC

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 damages 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 3.10** depicts Federally Threatened, Endangered, Proposed and Candidate Species in the county.

Table 3.10. Threatened and Endangered Species in Maries County

Common Name	Scientific Name	Status
Amphibians		
Eastern Hellbender	*Cryptobranchus alleganiensis*	Endangered (F)
Ozark Hellbender	*Cryptobraqnchus alleganiensis bishopi*	Endangered (F)
Fishes		
Niangua Darter	*Etheostoma ninaguae*	Threatened (F) Endangered (S)
Topeka Shiner	*Notropis topeka*	Endangered (S)
Birds		
Bachman's Sparrow	*Peucaea aestivalis*	Endangered (S)
Piping Plover	*Charadrius melodus*	Endangered (F)
Clams		
Ebonyshell	*Fusconaia ebena*	Endangered (S)
Elephantear	*Elliptio crassidens*	Endangered (S)
Pink Mucket	*Lampsilis abrupta*	Endangered (F)
Scaleshell Mussel	*Leptodea Leptodon*	Endangered (F) (S)
Snuffbox Mussel	*Epioblasma triquetra*	Endangered (F)
Spectaclecase (Mussel)	*Cumberlandia monodonta*	Endangered (F)
Flowering Plants		
Eastern Prairie Fringed Orchid	*Platanthera leucophaea*	Threatened (F)
Running Buffalo Clover	*Trifolium stoloniferum*	Endangered (S)
Western Prairie Fringed Orchid	*Plantanthera praeclara*	Endangered (S)
Mammal		
Gray bat	*Myotis grisescens*	Endangered (F) (S)
Indiana bat	*Myotis sodalis*	Endangered (F)
Northern long-eared bat	*Myotis septentrionalis*	Threatened (F)
Eastern spotted skunk	*Spilogale putorius*	Endangered (S)

Note: S = State, F = Federal
Source: U.S. Fish and Wildlife Service, https://ecos.fws.gov/ecp/;
MDC, https://nature.mdc.mo.gov/status/endangered

Natural Resources: The Missouri Department of Conservation (MDC) provides a database of lands owned, leased, or managed for public use. **Table 3.11** provides the names and locations of parks and conservation areas in Maries County.

Table 3.11. Conservation Areas in Maries County

Area Name	Address	Activities Offered
Bell Chute Access	From Vienna, take Highway 63 south 2.50 miles, then Highway 28 2 miles, then Route Y east 6 miles (the last 2 miles are on County Road 513)	Camping, Fishing
Clifty Creek Conservation Area	From Dixon, take Highway 28 northeast, then Route W east until the pavement ends and gravel leads to the area.	Hiking, Bird Watching, Camping, Hunting, Trapping, Archery and Firearms
Clifty Creek Natural Area	From Dixon, take Highway 28 northeast, then Route W east until the pavement ends and gravel leads to the area.	Hiking, Bird Watching, Camping, Hunting, Trapping, Archery and Firearms
Freeburg Towersite	From Vienna, take Highway 63 north 6 miles, then west 0.25 mile on County Road 209	
Paydown Access	From Vienna, take Highway 63 north 5.50 miles, then County Road 201 east (right) 8 miles to the access.	Camping, Fishing
Rinquelin Trail Lake Conservation Area	From Vienna, take Highway 42 west, then Highway 133 south to Route DD, then west to County Road 631, then south to County Road 630, then east to area entrance.	Bird Watching, Camping, Fishing, Hunting, Trapping, Archery and Firearms
Spring Creek Gap Conservation Area	From Vienna, take Highway 63 south approximately 10 miles, or north of Rolla on Highway 63 approximately 14 miles, take Old 63 north about 0.25 mile to the area.	Bird Watching, Camping, Hunting, Trapping, Archery and Firearms

Source: https://mdc.mo.gov/discover-nature/places

Table 3.12 provides information pertaining to community owned/operated parks within Maries County.

Table 3.12. Community Owned Parks in Maries County

Park Name	Address	City
Belle City Park	1507 Parkview Drive	Belle

Maries County Fairgrounds	242 Ballpark Road	Vienna
Vienna Park	132 Ballpark Road	Vienna
Vichy Community Park	US-63	Vichy

Source: Google Search

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 3.13** provides information in regard to properties on the National Register of Historic Places in Maries County.

Table 3.13. Maries County Properties on the National Register of Historic Places

Property	Address	City	Date Listed
Maries County Jail and Sheriff's Residence	Fifth and Mill Street	Vienna	03/01/2002

Source: Missouri Department of Natural Resources – Missouri National Register Listings by County https://mostateparks.com/page/84436/missouri-national-register-listings

Economic Resources: **Table 3.14** provides major non-government employers in the planning area. There are approximately 123 employer establishments within the county, employing on average about 8 individuals each[1].

Table 3.14. Major Non-Government Employers in Maries County

Employer Name	Product or Service	Employees
Kingsford Manufacturing	Charcoal (whls)	100-249
Hippos	Farming	11-50
Maries County Bank	Commercial Banking	5-9
South Central Regional Sale Barn	Livestock Dealers	20-49
Maries Manor	Rehabilitation Services	50-99

Source: https://meric.mo.gov/industry/business-locator, 2023 Data Collection Questionnaires

Agriculture plays an important role in Maries County. The Agribusiness Employment Location Quotient for the Central Missouri non-metropolitan area is 6.33; meaning that there is a much higher share of agribusiness employment compared to its share of total national employment[2]. In addition, there were 929 individuals working in the agriculture industry, comprising 23.8% of the total workforce in 2022[3]. Furthermore, the market value of products sold in 2017 was $32,416,000 million; 85% from livestock sales and 15% from crop sales.[4]

[1] https://www.census.gov/quickfacts/fact/table/mariescountymissouri/HSG650221

[2] https://meric.mo.gov/data/industry/quarterly-census-employment-wages-qcew-in

[3] https://www.bls.gov/oes/current/area_lq_chart/area_lq_chart.htm

[4] https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/2/table/1/state/MO/county/065/year/2017

Table 3.15. Agriculture Related Jobs in Maries County

Agribusiness Location Quotient (central region)	Agriculture Employment	Share of Workforce
6.33	929	23.8%

Source: Missouri Economic Research and Information Center

3.3 Land Use and Development

3.3.1 Development Since Previous Plan Update

Jurisdictions reported on completed developments since the previous plan update in 2019. Maries county has replaced insufficient metal culverts/slabs with upgraded concrete box culverts at low water crossings on Maries Road 219 and Maries Road 621. The city of Belle had a new ambulance base constructed as well as two new restaurants. The city of Vienna reported the construction of a new commercial meat market as well as a new cultivation facility which was listed as a notable employer with 11-50 employees. The Maries County R-I school district has made several facility updates in the last five years and plans several more in the next five-year period. Recently they have added a new concession stand, all new exterior doors, new windows in the elementary and middle school sections of the building and added man traps at the main entrances to the building. Additionally, they paved the parking lots, added external lighting, and new cameras to improve security. **Table 3.16** provides population growth statistics for Maries County.

Table 3.16. Maries County Population Growth, 2010-2020

Jurisdiction	2010 Population	2020 Population	2010-2020 # Change	2010-2020 % Change
Unincorporated Maries County	7,021	6,470	-551	-7.85%
Belle	1,545	1,381	-164	-10.61
Vienna	610	581	-29	-4.75%

Source: U.S. Bureau of the Census 2020 Decennial Redistricting Data, Census 2010 Summary File 1

Typically, population growth or decline is generally accompanied by an increase or decrease in the number of housing units. **Table 3.17** provides the change in numbers of housing units in the planning area from 2010-2020.

Table 3.17. Change in Housing Units, 2010-2020

Jurisdiction	Housing Units 2010	Housing Units 2020	2010-2020 # Change	2010-2020 % Change
Unincorporated Maries County	3,536	3,251	-285	-8.06%
Belle	734	719	-15	-2.04%
Vienna	341	293	-48	-14.08%

Source: U.S. Census Bureau 2020 Decennial Redistricting Data, U.S. Bureau of the Census, Census 2010 Summary File 1

3.3.2 Future Land Use and Development

Jurisdictions reported anticipated future developments within the next five years (2023-2028). A new water tower serving the city of Belle is planned for construction. Additionally, a collaborative effort between two solar energy providers are planning the development of two solar energy farms within the county. The prospective sites are located in unincorporated areas of Maries county, one near Vichy and the other near Dixon.

Unincorporated Maries County is planning to replace multiple low water crossings on county roads throughout the jurisdiction. Additionally, the roads department has a standing policy of increasing the size of any culverts that are replaced throughout the county to manage stormwater and mitigate the risk of flooding.

The city of Vienna is planning a couple of upgrades to the public infrastructure within the next five years. They are hoping to complete some operational upgrades to the city's wastewater treatment facility. That facility is located within a special flood hazard area and the city would like to explore ways to help mitigate the facilities vulnerability to flooding. The city is also planning a renovation of the city hall facility.

The city of Belle did not report any anticipated future development within the next five years.

School Districts' Future Development

The Maries County R-I school district plans to complete a remodel project on the elementary restrooms and an update project on the electrical system in the elementary as well. The Maries County R-II school district reported plans to replace the HVAC system that serves the elementary building.

New developments can impact a jurisdiction's vulnerability to natural hazards. As the number of buildings, critical facilities, and assets increase, vulnerability increases as well. For example, real estate development can increase storm water runoff, which often increases localized flooding. However, some developments such as infrastructure improvements can help reduce vulnerability risks. Unfortunately, quantitative data is not available to further examine each jurisdiction's new development and its correlation to natural hazard vulnerabilities.

3.4 Hazard Profiles, Vulnerability, and Problem Statements

Each hazard that has been determined to be a potential risk to Maries County is profiled individually in this section of the plan document. The profile will consist of a general hazard description, location, severity/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.

Each hazard Identified in Section **3.1.4** will be profiled individually in this section in alphabetical order.

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 location of the hazard in the planning area that are affected by the hazard. Where available, maps are used 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.

Severity/Magnitude/Extent: This includes information about the severity, 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. Severity, magnitude, and extent can also include the speed of onset and the duration of hazard events. Describing the severity/magnitude/extent of a hazard is not the same as describing its potential impacts on a community. Severity/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 was determined by dividing the number of recorded events by the number of years 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 will be reported 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: This section will consider the effects of long-term changes in weather patterns and climate on the identified hazard.

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 will be based on the best available county-level data, which is in the Missouri Hazard Mitigation Plan (2023). With the 2018 Hazard Mitigation Plan Update, SEMA was pleased to provide online access to the risk assessment data and associated mapping for the 114 counties in the State. Through the web-based Missouri hazard Mitigation Viewer, local planners or other interested parties can obtain all State Plan datasets. The Plan Viewer was updated for the 2023 State Hazard Mitigation Plan update. 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 can be found at this link: http://bit.ly/MoHazardMitigationPlanViewer2023

The county-level assessments in the State Plan were also based on the following additional sources:

- Statewide GIS data sets compiled by state and federal agencies; and
- FEMA's HAZUS-MH loss estimation software.

The vulnerability assessments in the Maries 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.

Within the Vulnerability Assessment, the following sub-headings will be addressed:

Vulnerability Overview: This section will provide an overall summary of each jurisdiction's vulnerability to the identified hazards. The summary identifies structures, systems, populations, or other community assets as defined by the community that are susceptible to damage and loss for hazard events.

Potential Losses to Existing Development: This section will describe the potential impacts of each hazard – the consequences of the effect of the hazard on the jurisdiction and its assets (including types and numbers, of buildings, critical facilities, etc.).

Previous and Future Development: This section will include information on how changes in development have impacted the community's vulnerability to this hazard. It will also describe any anticipated future development in the county, and how that would impact hazard risk in the planning area.

Hazard Summary by Jurisdiction: This section will provide an overview of any variation in hazard risk that vary by jurisdiction and provide a factual basis for that variation.

Problem Statements

Each hazard analysis will conclude with a brief summary of the problems created by the hazard in the planning area, and possible ways to resolve those problems.

3.4.1 Dam Failure

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.3, Page 3.148 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- 2023 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.3
- Missouri Department of Natural Resources, Dam and Reservoir Safety, https://dnr.mo.gov/land-geology/dam-reservoir-safety
- Stanford University's National Performance of Dams Program; http://npdp.stanford.edu/
- National Inventory of Dams, https://nid.sec.usace.army.mil/#/
- National Resources Conservation Service http://www.nrcs.usda.gov
- DamSafetyAction.org, https://damsafety.org/missouri
- Missouri Spatial Data Information Service Structure Inventory and All Hazard Risk Dataset https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Total number of Missouri NID dams by County
  - Total number of High, Significant, and Low Hazard dams by County
  - Total number of State Regulated dams by County
  - Total number of Class 1, Class 2, and Class 3 dams by County
  - Total number of structures impacted by USACE dams by County
  - Total number of structures impacted by State dams by County
  - Total value of structures impacted by USACE dams by County
  - Total value of structures impacted by State dams by County
  - Total population impacted by USACE dams by County
  - Total population impacted by State dams by County

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.

Information regarding dam classification systems under both the Missouri Department of Natural Resources (MDNR) and the National Inventory of Dams (NID), which differ, are provided in **Table 3.18** and **Table 3.19**, respectively.

Table 3.18. MDNR 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, Missouri Geological Survey Rolla Office

Table 3.19. 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 Location

<u>Dams in Planning Area</u>

According to the National Inventory of Dams there are 32 recorded dams in Maries County; including five high hazard dams; four significant hazard dams; and 23 low hazard dams. The Missouri Department of Natural Resources also tracks dams in the state and has Identified no Class 1 dams, six Class 2 dams, and 27 Class 3 dams. **Table 3.20** provides the name of the dam, DNR hazard class and NID hazard class for each of the Identified dams in Maries County. There are four state-regulated dams in Maries County. None of the dams are owned or operated by the United States Army Corps of Engineers (USACE). County dams are privately or commercially owned. **Table 3.21** provides the names, locations, and other pertinent information for all NID High Hazard Dams in the planning area.

Table 3.20. Maries County Dams Hazard Risk

Name of Dam	DNR Hazard Class	NID Hazard Class
Apex Lake Dame	3	Low
Blake Lake Dam	3	Low
Bowman Lake Dam	2	High
Cowan Lake Dam	3	Low
Danube Corporation Lower Dam	2	High
Danube Corporation Upper Dam	2	High
Dillon Lake Dam	3	Low
Dudenhoeffer Dam	2	High
Hayes Lake Dam	3	Significant
Hidden Lake Dam	3	Low
Hoban Lake Dame	3	Significant
Holmes Family Lake Dam	3	Significant
Kleffner Lake Dam	3	Low
Koch Lake Dam	3	Low
Kuhrts Lake Dam	3	Low
Lake Maxwell Dam	2	High
Larry Hendrix Dam	3	Low
Miller Lake Dam	3	Low
Murphy Lake Dam	2	High
Nepomuceno Lake Dam	3	Low
Norbert Sandbothe Pond	3	Low
Rinquelin Trail Dam	3	Significant
Share Lake Dam	3	Low
Sherrell Lake Dam	3	Low
Slinkman Lake Dam	3	Low
Swarthout Lake Dam	3	Low
Veasmann Lake Dam	3	Low
Vogt Dam	3	Low
Wensler Lake Dam	3	Low
Whippoorwill Lake Dam	3	Low
Wilson Lake Dam	3	Low
Wilson Lake Dam	3	Low

Source: Missouri Department of Natural Resources, Dam and Reservoir Safety Program; National Inventory of Dams

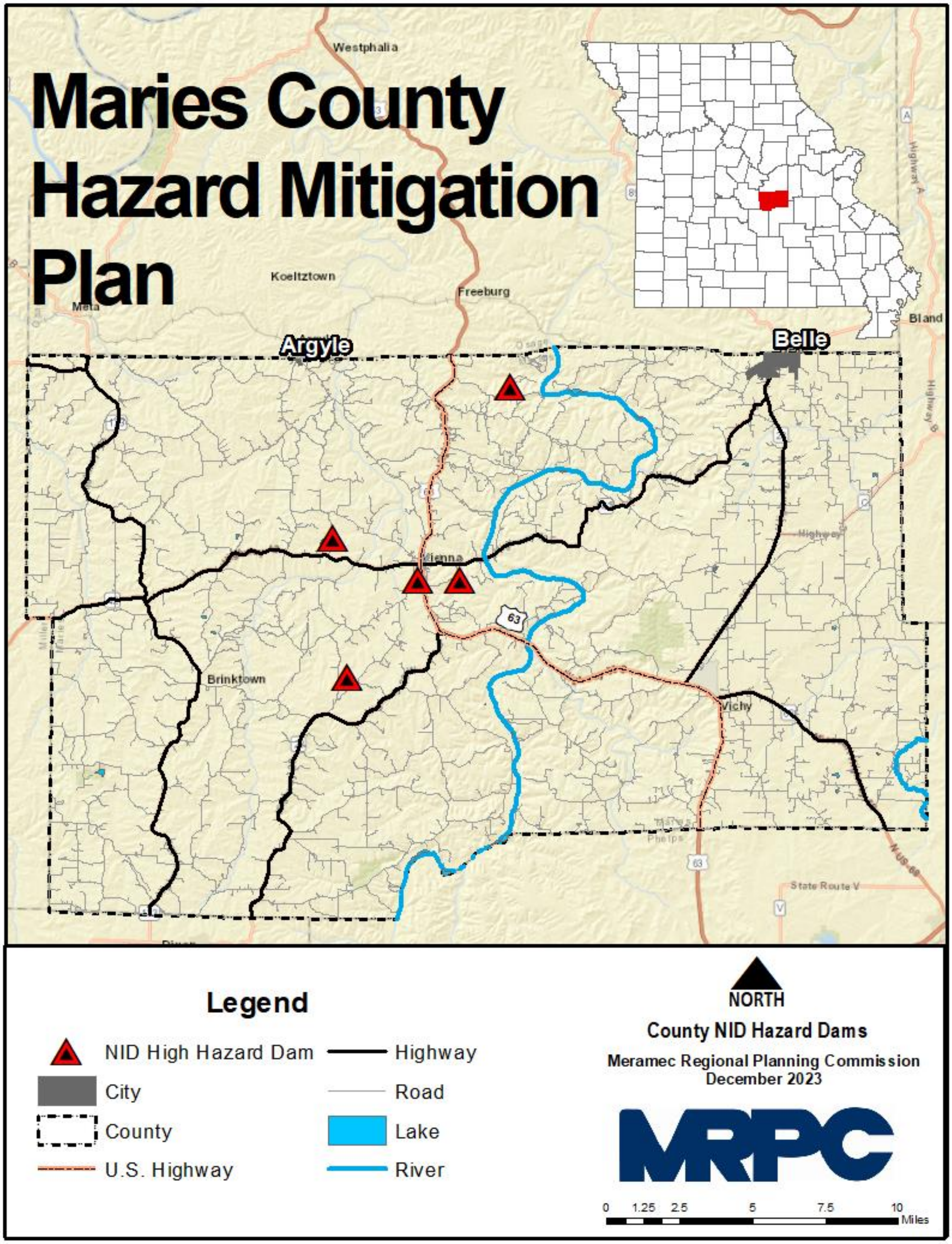
Table 3.21. NID High Hazard Class Dams in the Maries County Planning Area

Dam Name	NID ID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
Bowman Lake Dam	MO30180	High	23	111	TR to Fly Creek	Vienna	--
Danube Corporation Lower Dam	MO30061	High	32	633	Keiser Branch	Westphalia	28
Dudenhoeffer Dam	MO32065	High	55	853	--	Freeburg	--
Lake Maxwell Dam	MO32039	High	80	3,343	Indian Creek	Vienna	1
Murphey Lake Dam	MO30173	High	27	144	Little Fly Creek	Vienna	4

Sources: National Inventory of Dams, http://nid.usace.army.mil/cm_apex/f?p=838:12. ; Missouri Department of Natural Resources, Dam and Reservoir Safety Program

Figure 3.4 depicts locations of NID high hazard dams located in the planning area. If a dam failure were to occur in Maries County, depending upon dam and location, the severity would range between negligible to life threatening. Road infrastructure, residential structures, commercial buildings, and public buildings are all vulnerable to losses. There are no commercial or industrial properties in dam inundation zones within the county. Two dam inundation maps were available from the Missouri Department of Natural Resources. These State regulated dams include Lake Maxwell Dam and Dudenhoeffer Dam (**Figure 3.4** and **Figure 3.6**). No other dam inundation maps were available for the remaining NID High Hazard Dams in the county. The Belle City Park Dam is not listed on MDNR or the National Inventory of Dams. The dam is located between the city park and the abandoned railroad. If the dam failed impact would be minimal as it would flow away from the park and follow the railroad into timber with no structures in the path.

Figure 3.3. NID High Hazard Dam Locations in Maries County



Source: MSDIS, MRPC

Figure 3.4. Lake Maxwell Dam Inundation Zone

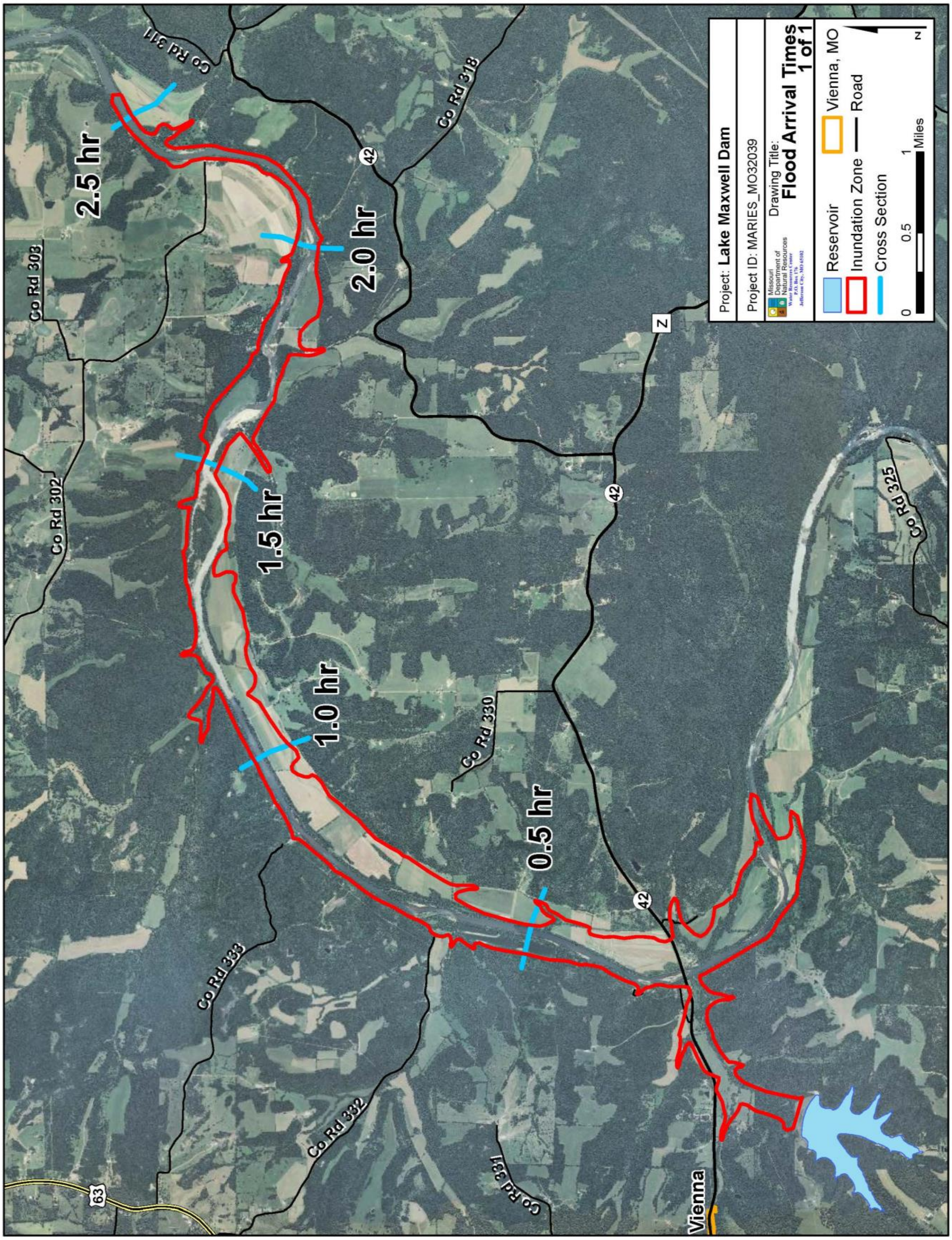
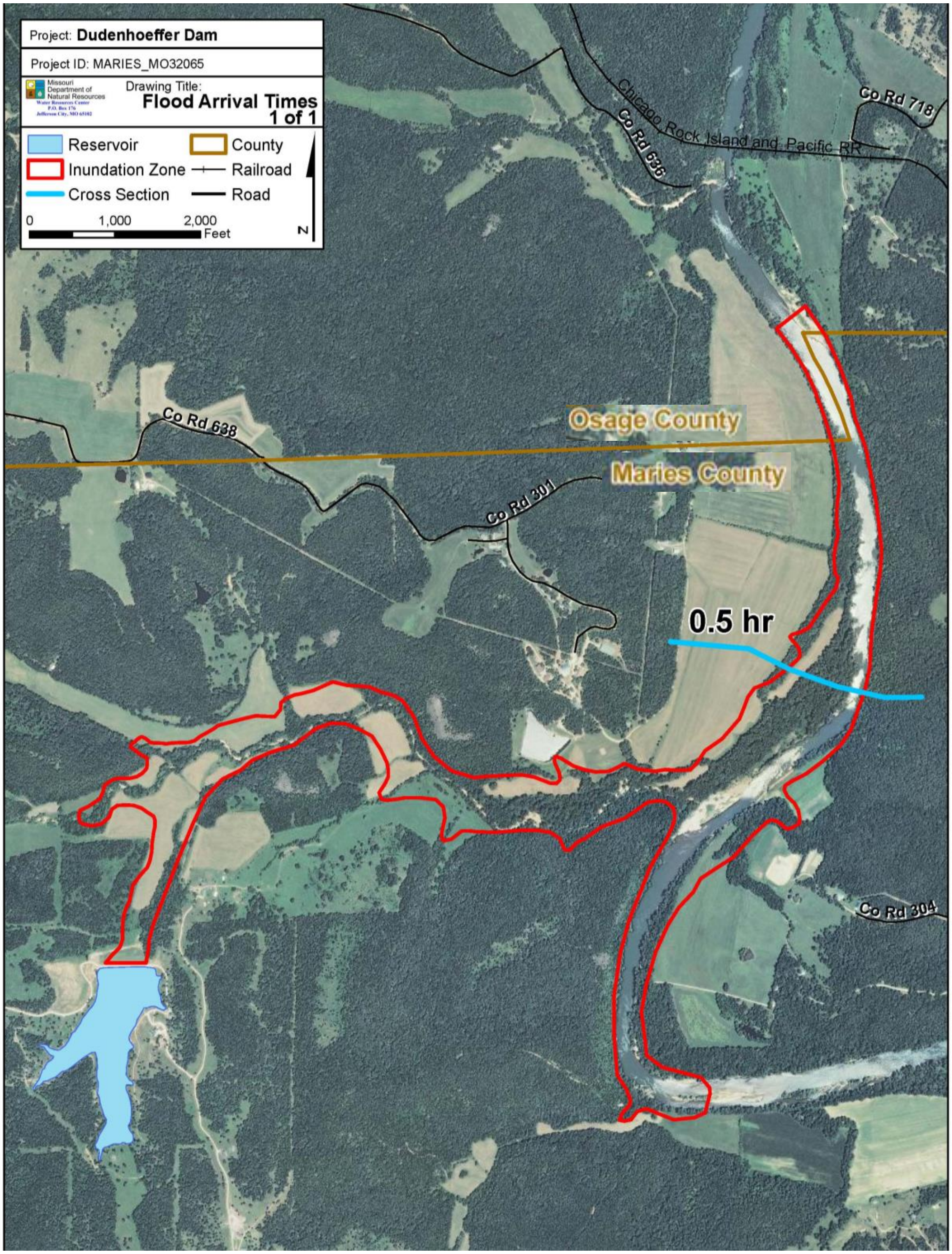


Figure 3.5. Dudenhoeffer Dam Inundation Zone

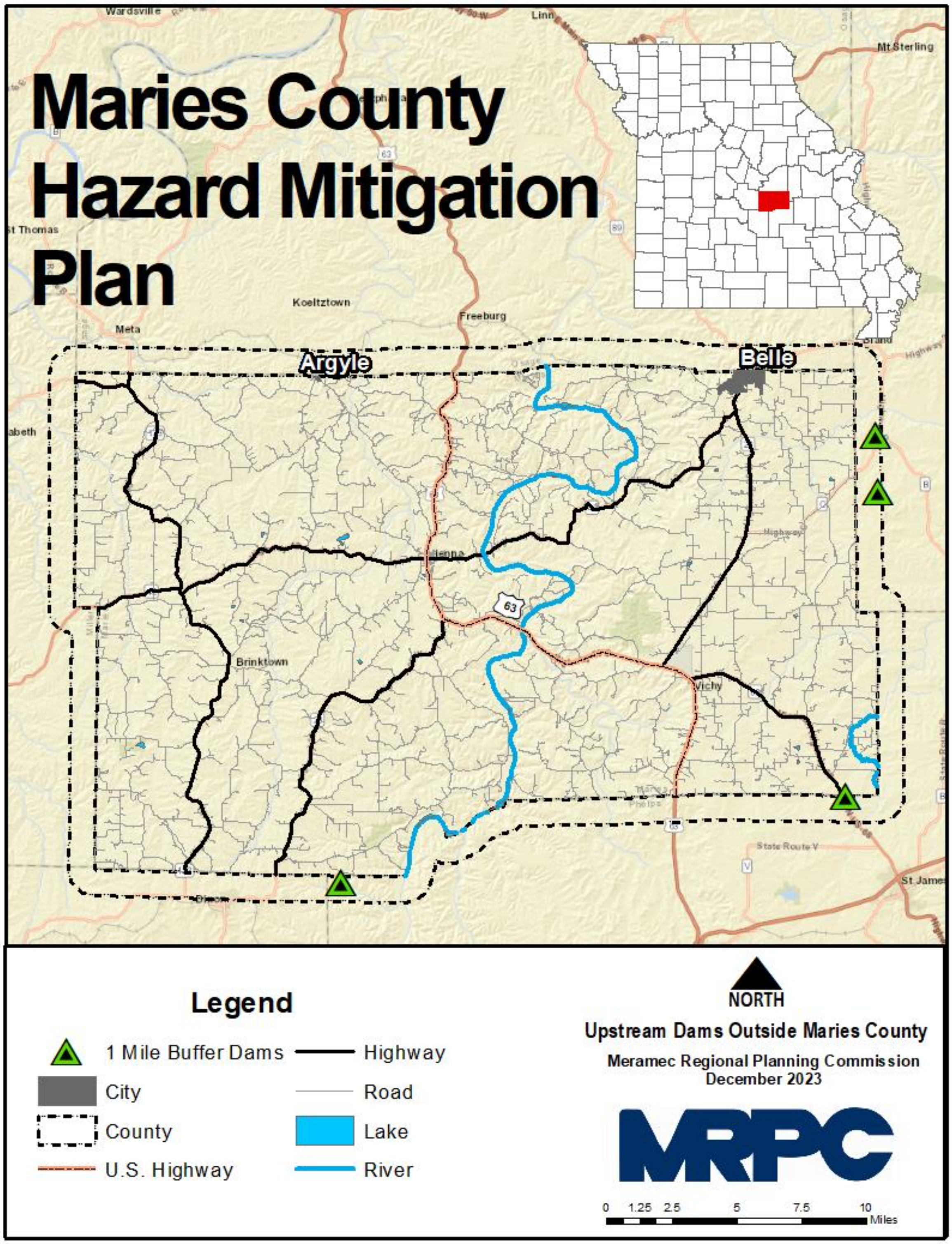


<u>Upstream Dams Outside the Planning Area</u>

Figure 3.6 depicts dams outside of Maries County that could impact the planning area in the event of failure. One unregulated High Hazard dam and three Low Hazard dams (1 regulated) are located within

a 1 mile buffer of the county. According to the Missouri Department of Natural Resources, Missouri Geological Survey, Water Resources Center, there are no high hazard dams that would flow into Maries County from surrounding counties during a failure event.

Figure 3.6. Upstream Dams Outside Maries County



Source: MSDIS, MRPC

Severity/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). The severity/magnitude/extent of dam failure is related to the volume of water behind the dam as well as the potential speed of onset, depth, and velocity. For this reason, dam failures could flood areas outside of mapped flood hazards.

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. All four of the state regulated dams in Maries county were last inspected in 2017 and each received a satisfactory rating on its overall condition. A worst-case scenario in the planning area would be a failure of the Lake Maxwell dam located 1 mile southeast of the city of Vienna. This lake holds 3,343 acre-feet of water. An acre-foot is a unit of volume equal to the amount of water required to cover one acre of land to depth of one foot.

Previous Occurrences

According to Stanford University's National Performance of Dams Program, there were 92 recorded dam Incidents in Missouri between 1917 and 2005. The Association of State Dam Safety Officials reports an additional 20 dam incidents from 2008 to 2017. The problem of unsafe dams in Missouri was underscored by dam failures at Lawrenceton in 1968, Washington County in 1975, Fredricktown in 1977, and a near failure in Franklin County in 1979. A severe rainstorm and flash flooding in October 1998 compromised about a dozen small, unregulated dams in the Kansas City area. But perhaps the most spectacular and widely publicized dam failure in recent years was the failure of the Taum Sauk Hydroelectric Power Plant Reservoir atop Profitt Mountain in Reynolds County, MO.

In the early morning hours of December 14, 2005, a combination of human and mechanical error in the pump station resulted in the reservoir being overfilled. The manmade dam around the reservoir failed and dumped over a billion gallons of water down the side of Profitt Mountain, into and through Johnson's Shut-Ins State Park and into the East Fork of the Black River. The massive wall of water scoured a channel down the side of the mountain that was over 6000 feet wide and 7,000 feet long that carried a mix of trees, rebar, concrete, boulders and sand downhill and into the park[1]. The deluge destroyed Johnson's Shut-Ins State Park facilities, including the campground, and deposited sediment, boulders and debris into the park. The flood of debris diverted the East Fork of the Black River into an older channel and turned the river chocolate brown. Fortunately, the breach occurred in mid-winter. Five people were injured when the park superintendent's home was swept away by the flood, but all were rescued and eventually recovered. Had it been summer, and the campground filled with park visitors, the death toll could have been very high[2]. This catastrophe has focused the public's attention on the dangers of dam failures and the need to adequately monitor dams to protect the vulnerable.

Despite the significance of the immediate damage done by the Taum Sauk Reservoir dam failure, the incident also highlights the long-term environmental and economic impacts of an event of this magnitude. Four years later, the toll of the flooding and sediment on aquatic life in the park and Black River was still being investigated. Even after the removal of thousands of dump truck loads of debris and mud, the river is still being affected by several feet of sediment left in the park. The local economy, heavily reliant upon the tourism from the park and Black River, has also been hit hard.

[1] United States Geological Survey. Damage Evaluation of the Taum Sauk Reservoir Failure using LiDAR. https://www.researchgate.net/publication/268325451_Damage_Evaluation_of_the_Taum_Sauk_Reservoir_Failure_using_LiDAR

[2] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.

Event Description

According to Stanford University's National Performance of Dams Program, only one dam incident has been recorded for Maries County. It occurred on July 16, 1993 at the Hidden Lake Dam located about 3 miles northeast of the unincorporated community of Vichy. The non-regulated dam experienced a failure of the spillway that resulted in a loss of most of the spillway and a part of the dam. No consequential losses were documented with this incident.[1]

Probability of Future Occurrence

As man-made structures, the probability of structural failure increase with age, however actions such as preventative maintenance can offset the degradation. It should also be noted that failures and incidents for regulated dams that have a higher inspection should be less probable. There has been 1 recorded dam incident in Maries County in 100 years resulting in a 1% yearly probability. Due to the number of confounding variables, this calculation is not robust.

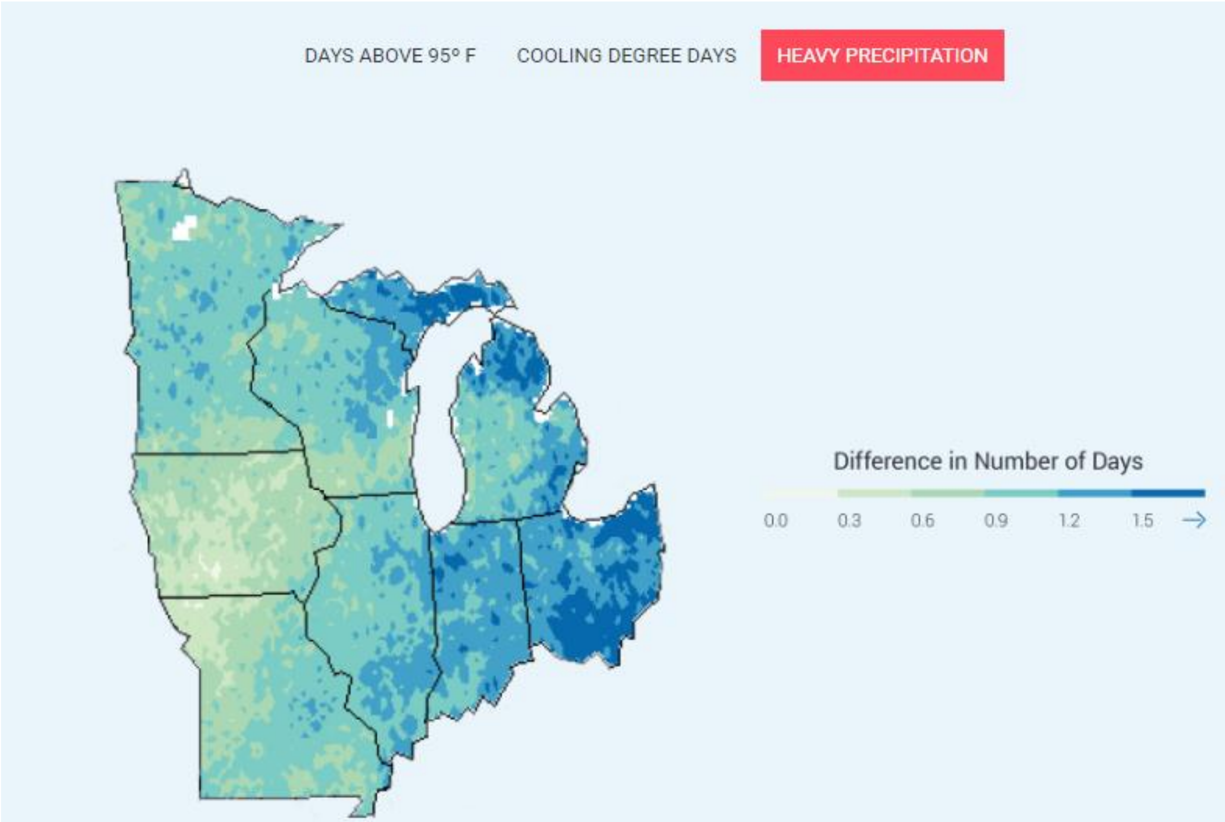
Changing Future Conditions Considerations

Dam failure is 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. The planning area is already feeling the impacts of increased precipitation having witnessed four 100-year floods in the last ten years. **Figure 3.7** below from The National Climate Assessment[2] illustrate the projected increase in the number of days with very heavy precipitation in the Midwest region.

[1] http://npdp.stanford.edu/dam_incidents

[2] https://nca2014.globalchange.gov/highlights/regions/midwest

Figure 3.7. Increase in Frequency of Days with Very Heavy Precipitation



Source: https://nca2014.globalchange.gov/highlights/regions/midwest

Vulnerability

Vulnerability Overview

Data was obtained from the 2023 Missouri State Hazard Mitigation Plan for the vulnerability analysis of dam failure for Maries County. There are however, data limitations regarding dams unregulated by the State of Missouri due to height requirements. These limitations hinder vulnerability analysis; nonetheless, failure potential still exists. **Table 3.22** provides vulnerability analysis data for the failure of State-regulated dams in Missouri.

Table 3.22. Vulnerability Analysis for Failure of State-regulated Dams in Missouri

County	Class 1	Class 2	Class 3	Total	Estimated # of Structures Vulnerable	Average Exposure Value per Structure ($)	Estimated Total Potential Building Exposure ($)	Estimated Total Population Exposure	Estimated Potential Losses ($)
Maries	0	2	2	4	18	$302,429	$5,443,719	32	$1,088,744

Source: 2023 Missouri State Hazard Mitigation Plan

For the vulnerability analysis of State regulated dams, the State developed the following assumptions for overview.

- Class 1 dams: the number of structures in the inundation area was estimated to be 10 or more permanent dwellings or any public building. Inspection of these dams must occur every two years.
- Class 2 dams: the area downstream from the dam that would be affected by inundation contains one to nine permanent dwellings, or one or more campgrounds with permanent water, sewer and electrical services or one or more industrial buildings. Inspection of these dams must occur once every three years.
- Class 3 dams: the area downstream from the dam that would be affected by inundation does not contain any of the structures Identified for Class 1 or Class 2 dams. Inspection of these dams must occur once every five years.

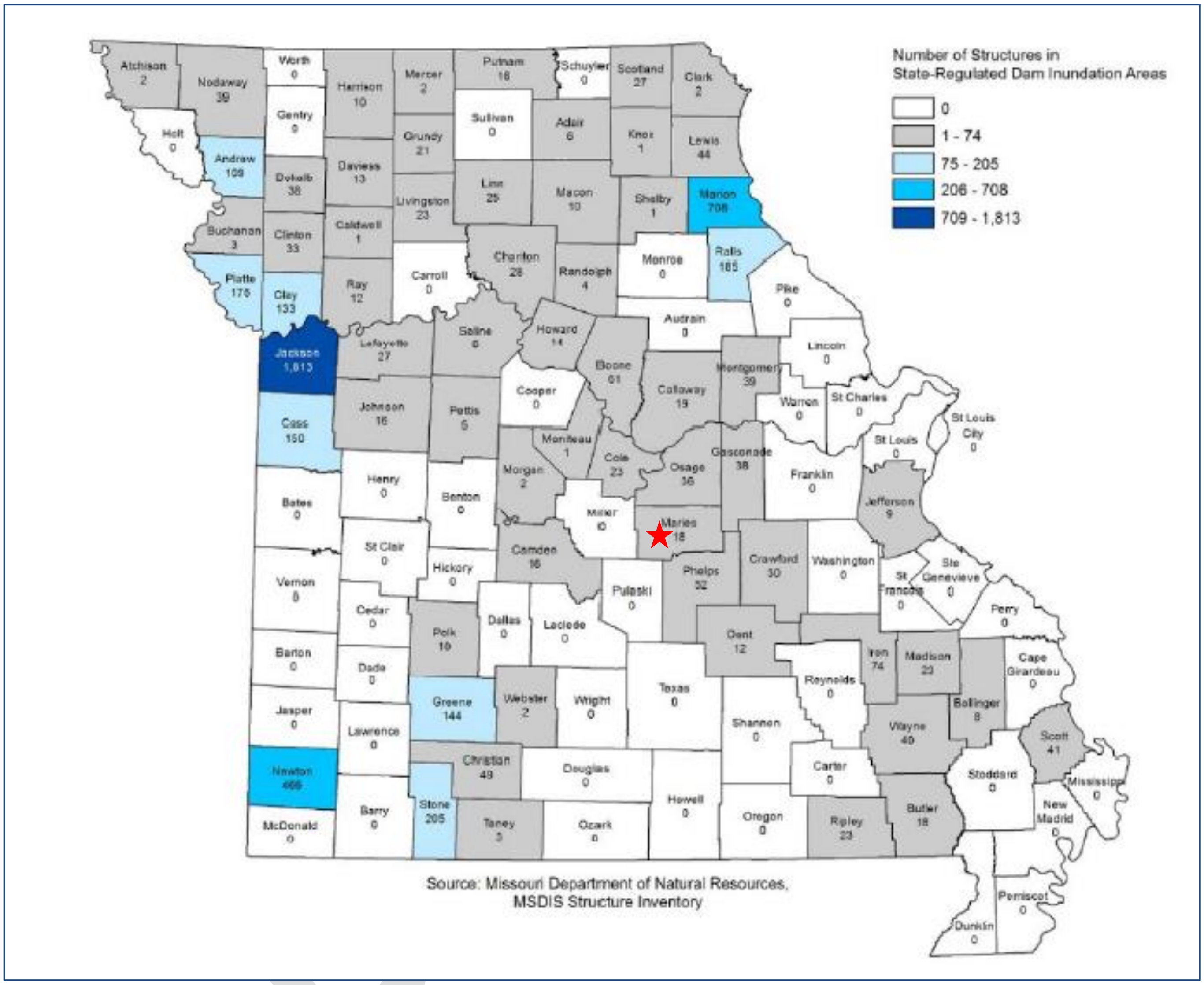
According to the 2023 Missouri State Hazard Mitigation Plan, there is an estimated 18 buildings vulnerable to failure of State-regulated dams (**Figure 3.8**) in Maries County. Furthermore, the state quantified potential loss estimates in terms of property damages. To execute the analysis, the following assumptions were utilized.

- For State-regulated Class 1 and Class 2 dams that have available inundation maps as well as USACE dams for which inundation maps were made available, GIS comparative analysis was accomplished against the building exposure data to determine the types, numbers and estimated values of buildings at risk to dam failure.
- The building exposure data was based on the structure inventory data layer available from the Missouri Spatial Data Inventory Service (MSDIS). The available dam inundation areas were compared against the structure inventory to determine the numbers and types of structures at risk to dam failure.
- To calculate estimated values of buildings at risk, buildings values available in the HAZUS census block data were used to determine an average value for each property type. This average value per property type was then applied to the number of structures in dam inundation areas by type to calculate an overall estimated value of buildings at risk by type.[1]

[1] 2023 Missouri State Hazard Mitigation Plan

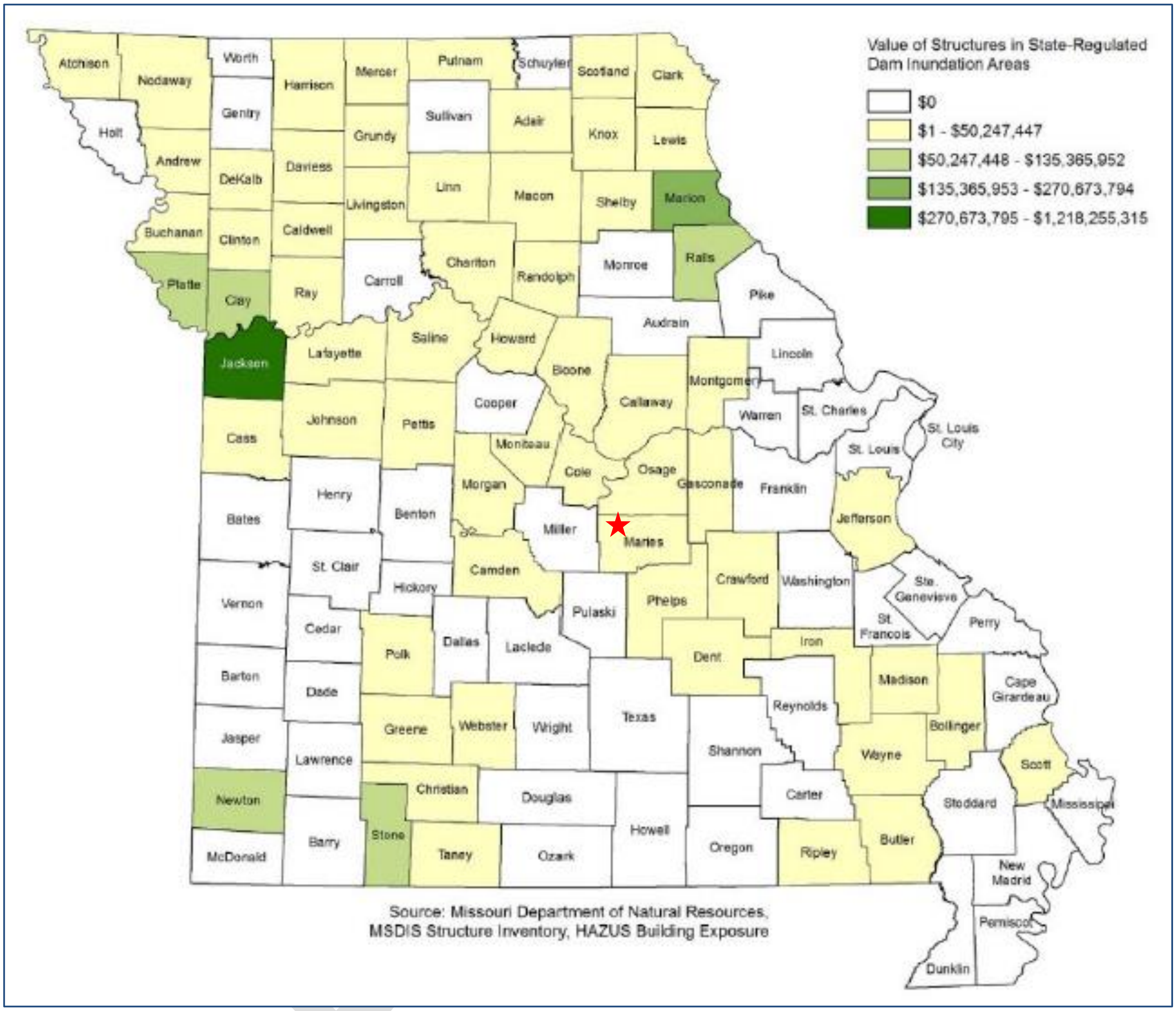
Figure 3.9 and **Figure 3.10** depict the total estimated potential building exposure and population exposure by county, respectively. The estimated building losses from failure of State-regulated dams is $5,443,719 The estimated population exposure to failure of State-regulated dams is 32.

Figure 3.8. Estimated Number of Buildings Vulnerable to Failure of State-regulated Dams



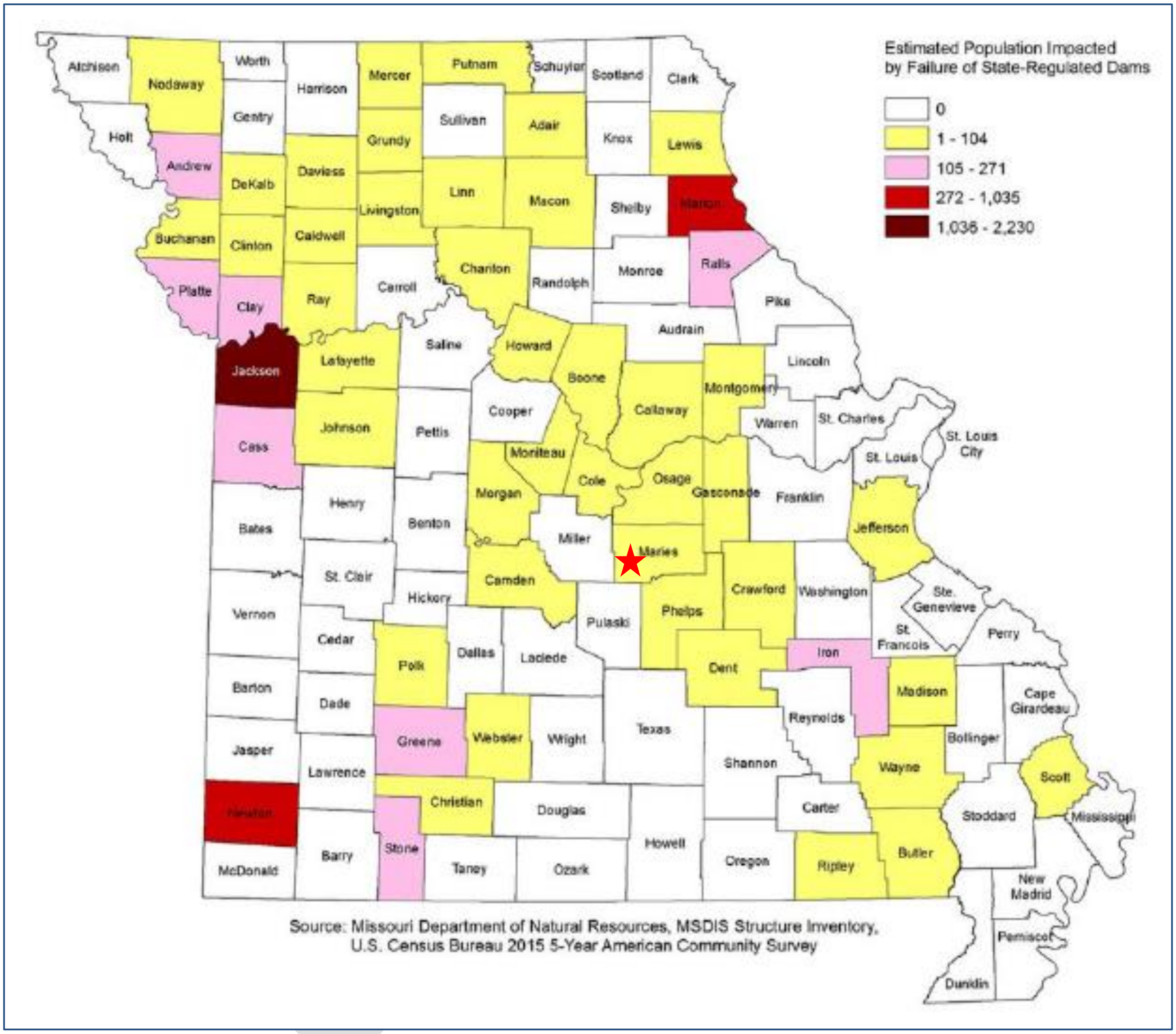
Source: 2023 Missouri State Hazard Mitigation Plan
*Red star indicates Maries County

Figure 3.9. Estimated Value of Structures in State-Regulated Dam Inundation Areas



Source: 2023 Missouri State Hazard Mitigation Plan
*Red star indicates Maries County

Figure 3.10. Estimated Population Exposure to Failure of State-regulated Dams



Source: 2023 Missouri State Hazard Mitigation Plan
*Red star indicates Maries County

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

The majority of dams in Maries County are rural in nature and would have limited impacts upon failure. Of the four high hazard dams in the planning area, only two have inundation zone data available: Lake Maxwell dam and Dudenhoeffer dam. The downstream road crossings and assets affected for those dams are listed below:

Lake Maxwell Dam

- Highway 42
- Maries County Rd 336
- 6 residential properties

Dudenhoeffer Dam

- 1 residential property

Impact of Future Development

Future development within the County that has potential to be influenced by dam failure includes any areas downstream of a dam inside documented inundation zones or within the 100 Year Floodplain. The county is an NFIP member and requires a floodplain permit for any development in the floodplain. No development is planned in any floodplain or areas downstream of dams in the county or cities.

Hazard Summary by Jurisdiction

Variations in vulnerability across the planning area depend mostly on geographic proximity to a dam. Of the five high hazard dams in the county only one is not state regulated, Bowmen Lake Dam, which is located less than a quarter mile from the city limits of Vienna. It is also constructed in 1954 making it one of the oldest dams in the county. According to the National Inventory of Dams it was last inspected in 1981 and its condition is not rated. The remaining dams are located in the unincorporated areas of the county with less likelihood of damages. There are no DNR class 1 dams and only six class 2 dams in the county. Maries County school districts and special districts do not have assets located in known dam breach inundation areas.

Problem Statement

In summary, the hazard risk for dam failure in Maries County ranges between high and low, depending upon the dam. If a dam does fail, the expected impacts could vary from negligible to critical, and could potentially affect road/utility infrastructure, residential structures, commercial buildings, public structures, and human life. It is recommended to encourage land use management practices to decrease the potential for damage from a dam collapse, including the discouragement of development in areas with the potential for sustaining damage from a dam failure. Installation of education programs to inform the public of dam safety measures and preparedness activities would be beneficial. In addition, the availability of training programs to encourage landowners to properly inspect their dams and develop emergency action plans would be advantageous.

3.4.2 Drought

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.6, Page 3.235
- 2023 Missouri State Hazard Mitigation Plan, Chapter 3. Section 3.3.6
- Maps of effects of drought, National Drought Mitigation Center (NDMC) located at the University of Nebraska in Lincoln; http://www.drought.unl.edu/.
- Historical drought impacts, National Drought Mitigation Center (NDMC) located at the University of Nebraska in Lincoln; at http://droughtreporter.unl.edu/ .
- Recorded low precipitation, NOAA Regional Climate Center, (http://www.hprcc.unl.edu).
- Water shortages, Missouri's Drought Response Plan, Missouri Department of Natural Resources, https://dnr.mo.gov/water/hows-water/state-water/drought
- Populations served by groundwater by county, USGS-NWIS, http://maps.waterdata.usgs.gov/mapper/index.html
- Census of Agriculture, https://agcensus.library.cornell.edu/census_parts/2012-missouri/
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/en/Information-Tools/Summary-of-Business/Cause-of-Loss
- Natural Resources Defense Council, http://www.nrdc.org/globalWarming/watersustainability/
- Missouri Department of natural Resources (MDNR), Drought News, Conditions and Resources https://dnr.mo.gov/drought.htm
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
    - Vulnerability to drought by County
    - Crop insurance claims due to drought by County

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 2018 Missouri State Hazard Mitigation Plan, which are as follows.

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

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

- Agricultural drought focus is on soil moisture deficiencies, differences between actual and potential evaporation, reduced ground water or reservoir levels, etc. Plant demand for water depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.
- Socioeconomic drought refers to when physical water shortage begins to affect people[1] - which impacts supply and demand of some economic commodity.

Geographic Location

All areas and jurisdictions in Maries County are susceptible to drought, but particularly cities where thousands of residents are served by the same source of water. These cities use deep hard rock wells that are 1,100 to 1,800 feet deep and can experience drought when recharge of these wells is low. The majority of individuals living in Maries County rely on groundwater resources for drinking water. Approximately 74% of the land in the county is utilized for agricultural purposes. Furthermore, livestock sales comprise 85% of the market of agricultural products sold in Maries County. A drought would directly impact livestock production and the agricultural economy in Maries County[2].

Data was collected from the Missouri Department of Natural Resources (2021 Census of Missouri Public Water Systems) to determine water source by jurisdiction. Maries County and the cities of Belle and Vienna utilize well water as their sole source of water (**Table 3.23**). Communities that exclusively depend upon ground water could experience hardship in the event of a long-term drought.

Table 3.23. 2020 Water Source by Jurisdiction

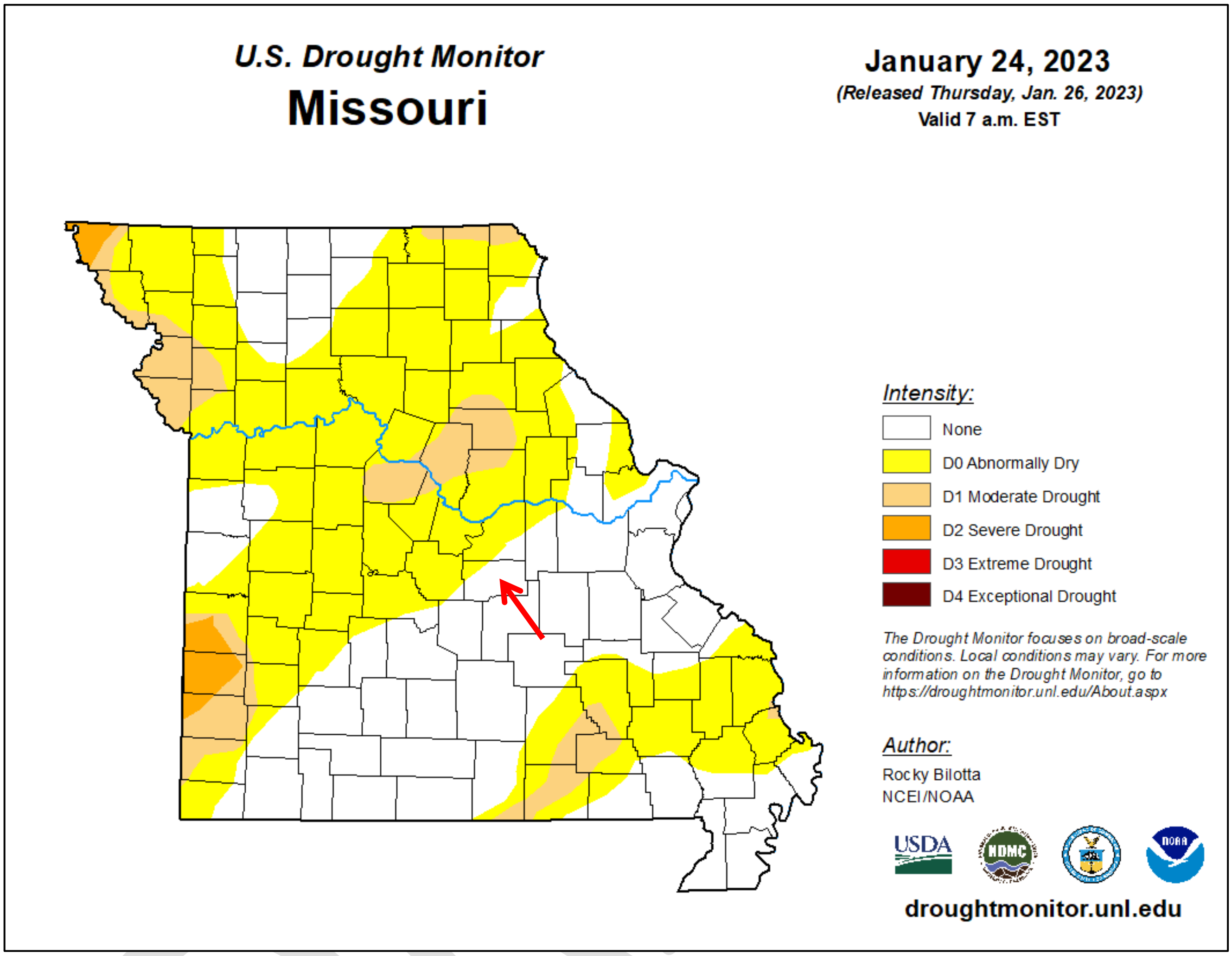
Jurisdiction	% of source that is groundwater
Maries County	100
Belle	100
Vienna	100

Source: Missouri Dept. of Natural Resources, 2020 Census of Missouri Public Water Systems

Figure 3.11 depicts a U.S. Drought Monitor map of Missouri on January 24, 2023. This map illustrates the planning area, which could be in drought at any given moment in time. A red arrow indicates the location of the planning area (Maries County).

[1] http://www.drought.unl.edu/ http://droughtreporter.unl.edu/
[2] https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Missouri/cp29125.pdf

Figure 3.11. U.S. Drought Monitor Map of Missouri on January 24, 2023



Source: U.S. Drought Monitor, http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?MO

Severity/Magnitude/Extent

The National Drought Monitor Center at the University of Nebraska at Lincoln summarized the potential severity 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[1].

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

[1] Ibid

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.

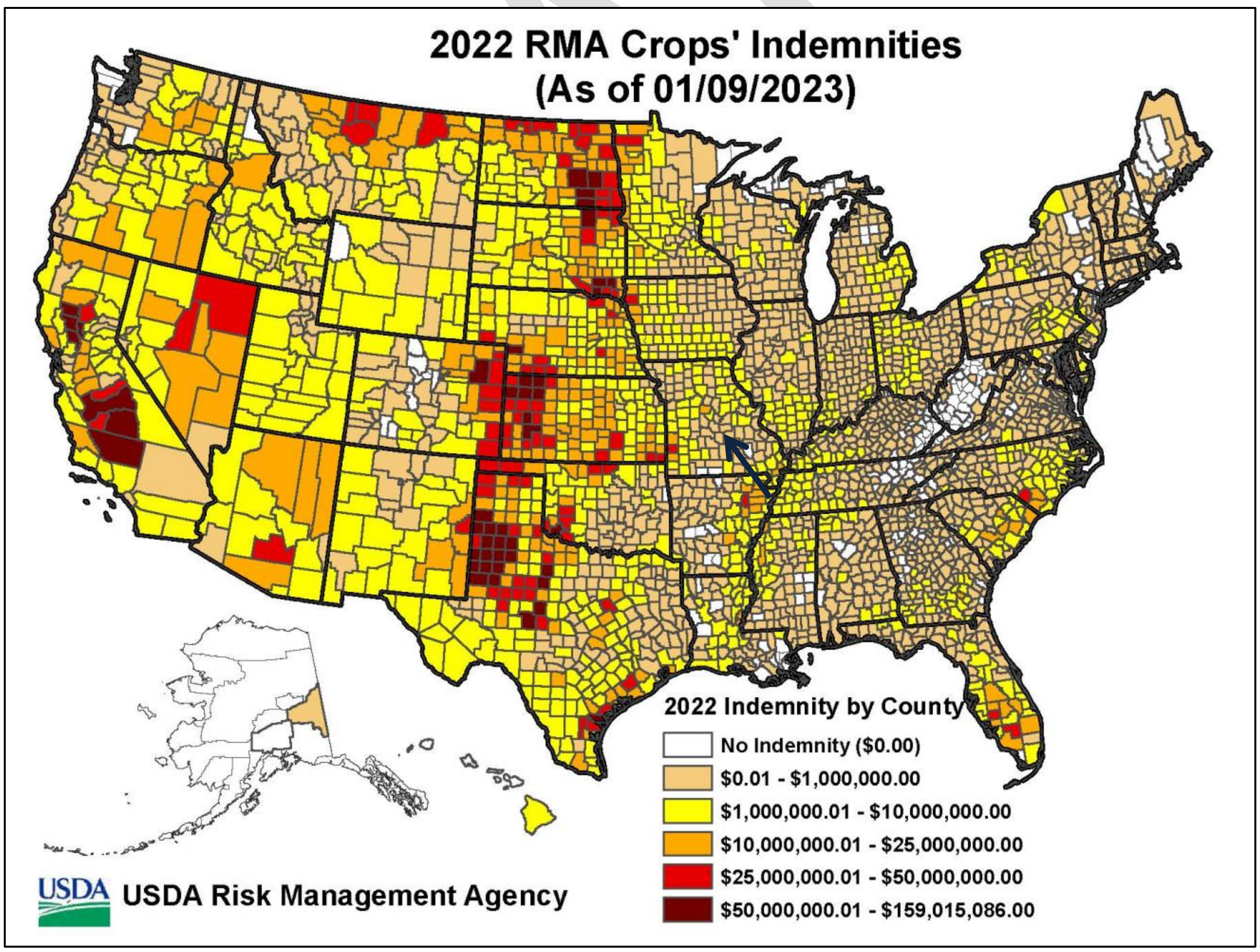
The Palmer Index has proven most effective in identifying long-term drought of more than several months. However, the Palmer Index has been less effective in determining conditions over a matter of weeks. It uses a "0" as normal, and drought is shown in terms of negative numbers; for example, negative 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

Figure 3.12 illustrates RMA crop indemnities for 2022 across the United States. Maries County fell in the $0.01 to $1,000,000 category for crop indemnities.

Figure 3.12. 2021 RMA Crop Indemnities for the United States



Source:https://www.rma.usda.gov/-/media/RMA/Maps/Total-Crop-Indemnity-Maps/Crop-Year-2022/010923map.ashx?la=en *Black arrow indicates Maries County

According to the USDA's Risk Management Agency, there have been 75 crop insurance payments due to drought in Maries County since 2003, totaling $840,454.49. **Table 3.24** illustrates the year, number of payments, and total amount of crop insurance payments.

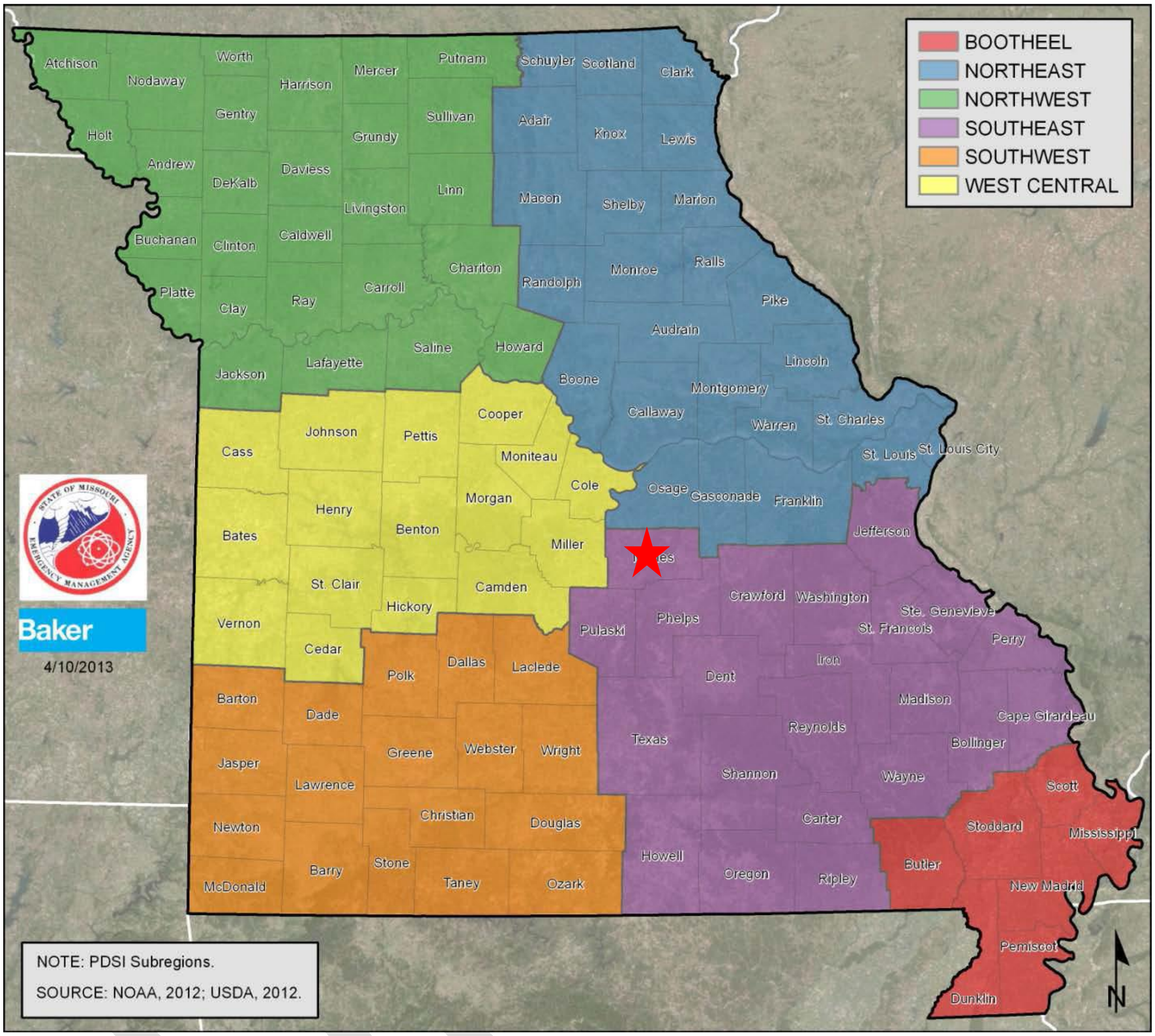
Table 3.24. Maries County Crop Indemnity Payments (2003-2022)

Year	Number of Payments	Total
2003	4	$2,641.00
2004	0	0
2005	3	$3,818.00
2006	7	$7,203.00
2007	1	$4,762.00
2008	0	0
2009	0	0
2010	0	0
2011	7	$41,286.00
2012	19	$427,833.99
2013	3	$5,471.00
2014	2	$3,825.00
2015	0	0
2016	0	0
2017	5	$11,187.20
2018	15	$162,593.90
2019	0	0
2020	1	$6,687.10
2021	1	$639.20
2022	7	$162,507.10
TOTAL	**75**	**$840,454.49**

Source: https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss

Figure 3.13 illustrates the Palmer Drought Severity Index sub-regions of Missouri. Maries County is categorized under the Southeast sub-region.

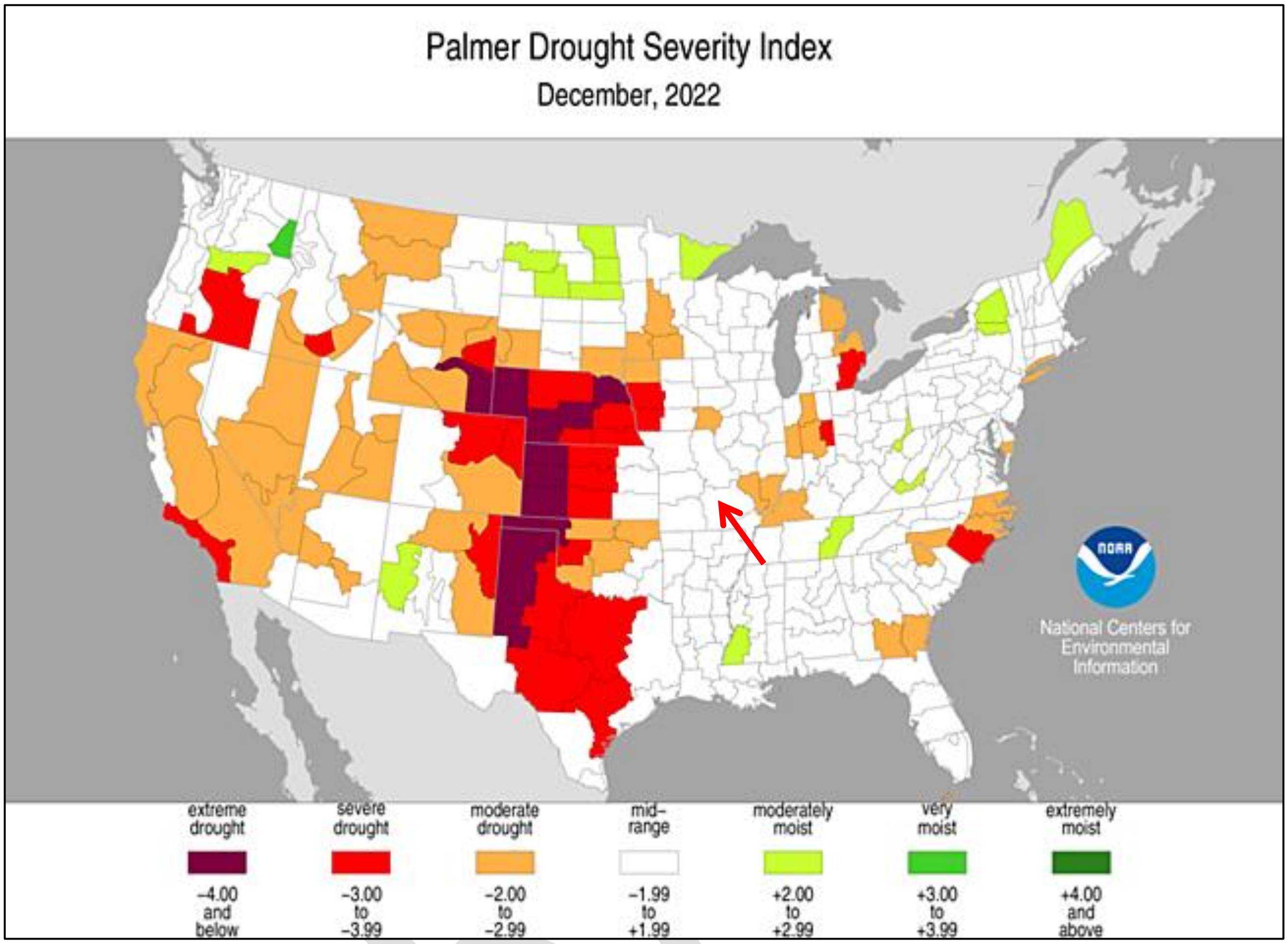
Figure 3.13. Palmer Drought Severity Index: Missouri Sub-regions



Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County

Figure 3.14 is an example of the Palmer Modified Drought Index for the United States for December, 2022.

Figure 3.14. Palmer Modified Drought Index National Map December, 2022



*Source: [http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/;](http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/) *Red arrow indicates Maries County*

Table 3.25 offers Palmer Drought Severity Index data for Maries County between 2013 and 2022. This information exemplifies drought conditions on a monthly basis for Missouri's Southeast sub-region within the United States.

Table 3.25. Palmer Drought Severity Index for Maries County, MO (2013 – 2022)

	Year									
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2019**	**2022**
Jan.	Mid-range	Moderately moist	Mid-range	Very moist	Mid-range	Severe drought	Moderately Moist	Extremely moist	Very Moist	Mid-range
Feb.	Mid-range	Mid-range	Mid-range	Very moist	Mid-range	Mid-range	Moderately Moist	Extremely moist	Moderately moist	Mid-range
March	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Mid-range	Moderately Moist	Extremely moist	Moderately moist	Mid-range
April	Mid-range	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Moderately Moist	Extremely moist	Moderately moist	Mid-range

May	Mid-range	Mid-range	Mid-range	Moderately moist	Very moist	Mid-range	Very moist	Extremely moist	Moderately moist	Mid-range
June	Mid-range	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Very moist	Very moist	Mid-range	Mid-range
July	Mid-range	Mid-range	Moderately moist	Moderate moist	Moderately moist	Mid-range	Very moist	Very moist	Moderately moist	Mid-range
Aug.	Moderately moist	Mid-range	Very moist	Very moist	Moderately moist	Mid-range	Extremely moist	Very moist	Mid-range	Mid-range
Sept.	Moderately moist	Mid-range	Moderately moist	Very moist	Mid-range	Mid-range	Very moist	Very moist	Mid-range	Mid-range
Oct.	Moderately moist	Mid-range	Mid-range	Very moist	Mid-range	Mid-range	Very moist	Very moist	Mid-range	Mid-range
Nov.	Moderately moist	Mid-range	Very moist	Very moist	Moderate drought	Mid-range	Extremely moist	Very moist	Mid-range	Mid-range
Dec.	Moderately moist	Mid-range	Extremely moist	Moderately moist	Severe Drought	Mid-range	Very moist	Moderately moist	Mid-range	Mid-range

Source: https://www.ncei.noaa.gov/access/monitoring/historical-palmers/maps/psi/201101-202012

Probability of Future Occurrence

To calculate the probability of future occurrence of drought in Maries County, historical climate data was analyzed. There were 14 months of recorded drought (**Table 3.26**) over a 20-year span (January, 2003 to December, 2022). The number of months in drought (14) was divided by the total number of months (240) and multiplied by 100 for the annual average percentage probability of drought (**Table 3.27**). Although drought is not predictable, long-range outlooks and predicted impacts of climate change could indicate an increase change of drought.

Table 3.26. Palmer Drought Severity Index for Maries County, MO (2003 – 2022)

	Year											
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
2003												
2004												
2005						X						
2006												
2007										X	X	
2008												
2009												
2010												
2011												
2012					X	X	X	X	X	X	X	X
2013												
2014												
2015												
2016												
2017											X	X
2018	X											
2019												
2020												
2021												
2022												

Source: https://www.ncei.noaa.gov/access/monitoring/historical-palmers/maps/psi/200101-202012
*x indicates drought

Table 3.27. Annual Average Percentage Probability of Drought in Maries County, MO

Location	Annual Avg. % P of Drought
Maries County	5.83%

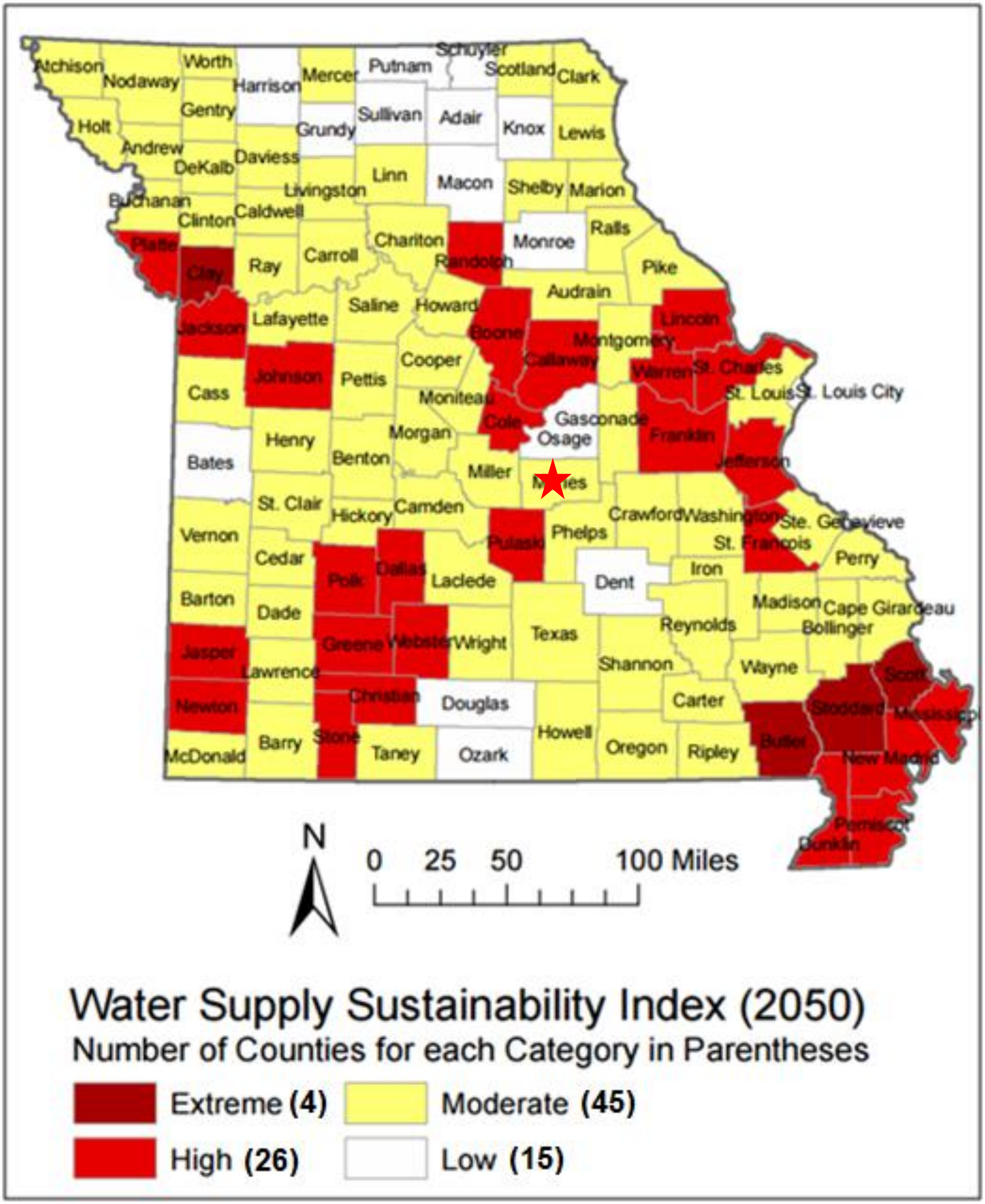
Source: NOAA National Centers for Environmental Information, Historical Palmer Drought Indices
*P = probability; see page 3.44 for definition.

Changing Future Conditions Considerations

It is thought that human activity has not been a major component in historical droughts, although it is uncertain how droughts will behave in the future. Future projections predict that increases in spring precipitation will transition to insufficient levels in the summer[1]. Future increases in evaporation rates due to higher temperatures may increase the intensity of naturally occurring droughts[2]. Increases in drought frequency or severity could affect crop yields. Maries County is an agriculture-dependent county and decreases in yields would likely cause significant economic stress on the people of the planning area. 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. Maries County is predicted to experience moderate water shortages as a result of global warming (**Figure 3.1**) by the year 2050.

[1] https://nca2018.globalchange.gov/chapter/21/
[2] 2023 Missouri State Hazard Mitigation Plan

Figure 3.1. Water Supply Sustainability Index (2050) with Climate Change Impacts



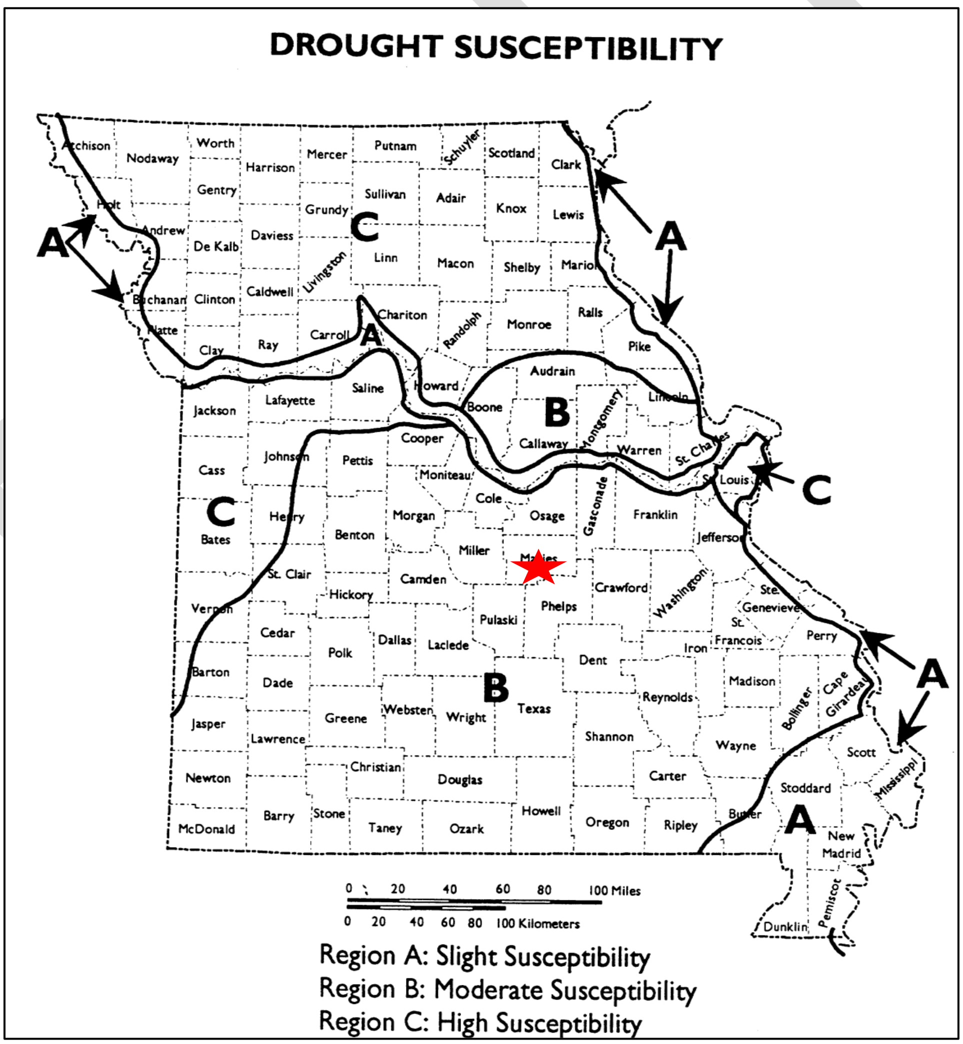
Source: Natural Resources Defense Council (NRDC), Climate Change, Water, and Risk
*Red star indicates Maries County

Vulnerability

Vulnerability Overview

Data was obtained from the 2023 Missouri State Hazard Mitigation Plan for the drought vulnerability analysis. **Table 3.27** depicts the ranges for drought vulnerability factor ratings created by SEMA. The array ranges between 1 (low) and 5 (high). The factors considered include social vulnerability, crop exposure ratio, annualized crop claims paid and likelihood of occurrence. Once the ranges were determined and applied to all factors considered in the analysis, the ratings were combined to determine an overall vulnerability rating for drought. Maries County is determined as having a low vulnerability to crop loss (**Table 3.28**) as a result of a drought. Additionally, SEMA has divided the State into 3 regions in regards to drought susceptibility (**Figure 3.2**). Maries County is included in Region B (Moderate Susceptibility). Region B is described as having groundwater sources that are suitable in meeting domestic and municipal water needs, but due to required well depths, irrigation wells are very expensive. Also, the topography is commonly unsuitable for row-crop irrigation[1].

Figure 3.2. Drought Susceptibility in Missouri



Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County

[1] 2023 Missouri State Hazard Mitigation Plan

Table 3.28. Ranges for Drought Vulnerability Factor Ratings

Factors Considered	Low (1)	Medium-low (2)	Medium (3)	Medium-high (4)	High (5)
Social Vulnerability Index	1	2	3	4	5
Crop Exposure Ratio Rating	$379,000 - $22,460,000	$23,369,000 - $51,704,000	$53,142,000 - $84,855,000	$84,855,000 - $159,192,000	$181,201,000 - $239,334,000
Annualized USDA Crop Claims Paid	$0	$1 - $2,170,363	$2,170,364 - $3,625,266	$3,625,267 - $6,069,160	$6,096,161 - $11,136,989
Likelihood of Occurrence of Severe or Extreme Drought	0.15 – 0.35	0.38 – 0.50	0.54 – 0.69	0.73 – 1.00	1.23 – 1.31
Total Drought Vulnerability Rating	4-7	8-10	11-13	14-16	17-20

Source: 2023 Missouri State Hazard Mitigation Plan

Table 3.29. Vulnerability of Maries County to Drought

SOVI index rating	USDA RMA Total Drought Crop Claims	Avg Annualized Crop Claims	USDA Claims Rating	2012 Crop Exposure	Crop Exposure Rating	Likelihood of severe drought %	Drought occurrence rating	Total Rating	Total rating (text) drought
3	$1,669,551	$166,955	1	$4,731,000	1	0.31	1	6	Low

Source: 2023 Missouri State Hazard Mitigation Plan

Potential Losses to Existing Development

Drought is not limited to a hazard that affects just agriculture, but can extend to encompass the nation's whole economy. Its impact can adversely affect a small town's water supply, the corner grocery store, commodity markets, or tourism. Additionally, extreme droughts have the ability to damage roads, water mains, and building foundations. On average, drought costs the U.S. economy about $7 billion to $9 billion a year, according to the National Drought Mitigation Center. Moreover, drought prone regions are also prone to increased fire hazards[1].

Impact of Previous and Future Development

Impacts of drought on future development within Maries County would be negligible. Population projections as provided by the Missouri Office of Administration suggest that Maries County will increase by approximately 2000 individuals by 2030[2]. Moreover, with an increasing population, water use and demand would be expected to increase as well; potentially straining the water supply systems. Long term drought could expose vulnerabilities during construction/upgrades of water distribution and sewer infrastructures. Furthermore, any agriculture related development in terms of crop or livestock production would also be at risk.

[1] https://drought.unl.edu/
[2] Missouri Office of Administration https://mcdc.missouri.edu/applications/MO-county-factsheets/?c=29065

Hazard Summary by Jurisdiction

The variations between jurisdictions are non-existent to minimal. All communities in Maries County utilize ground/well water as their water source. In all cities, drought conditions would be the same as those experienced in rural areas, but the magnitude would be different with only lawns and local gardens impacted. Long term drought, spanning months at a time, could negatively impact the amount of potable drinking water available.

Problem Statement

In summary, drought within Maries County is considered a moderate risk. Maries County has a significant agricultural economy. Drought would impact commodities, specifically livestock and crops. Potential impacts to local economies and infrastructures are foreseeable in the event of a long-term drought.

The county and city should develop water monitoring plans as an early warning system. Each sector should inventory and review their groundwater operation plans. A water conservation awareness program should be presented to the public either through pamphlets, workshops or a drought information center. Voluntary water conservation should be encouraged to the public. The county and both cities should continually look for and fund water system improvements, new systems, and new wells.

3.4.3 Earthquakes

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.4, Page 3.192
- 2023 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.4
- U.S. Seismic Hazard Map, United States Geological Survey, https://www.usgs.gov/programs/earthquake-hazards/maps;
- Impact of Earthquakes on the Central USA http://www.cusec.org/documents/aar/NMSZ_CAT_PLANNING_SCENARIO.pdf
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Total population impacted by earthquakes by County
  - Total number of structures impacted by earthquakes by County
  - Total value of structures impacted by earthquakes by County
  - Property loss ratio to earthquakes by County
- 6.5 Richter Magnitude Earthquake Scenario, New Madrid Fault Zone map, https://iowageologicalsurvey.org/;
- Facts about the New Madrid Seismic Zone, https://dnr.mo.gov/land-geology/hazards/earthquakes/science/facts-new-madrid-seismic-zone
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM

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. Stresses can build along these faults and tears in the crust, until one side of the fault slips, generating compressive and shear energy that produces 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.

The closest fault to Maries County is the New Madrid Seismic Zone (NMSZ). The NMSZ extends 120 miles south from Charleston, Missouri, following Interstate 55 to near Marked Tree, Arkansas. These faults cross five state lines, the Mississippi River in three places, and the Ohio River in two places. It is the most active seismic area in the United States east of the Rocky Mountains and averages about 200 measured events per year. Tremors large enough to be felt occur annually. On average every 18 months, the fault releases a shock of magnitude 4.0 or greater, which is capable of localized damage. A magnitude 5.0 or greater occurs about once per decade, can cause significant damage, and be felt in several states. Unfortunately, the faults in the NMSZ are difficult to study due to concealment by alluvium soil deposits. However, improved monitoring techniques in recent years have led to great strides in understanding of this complex area[1].

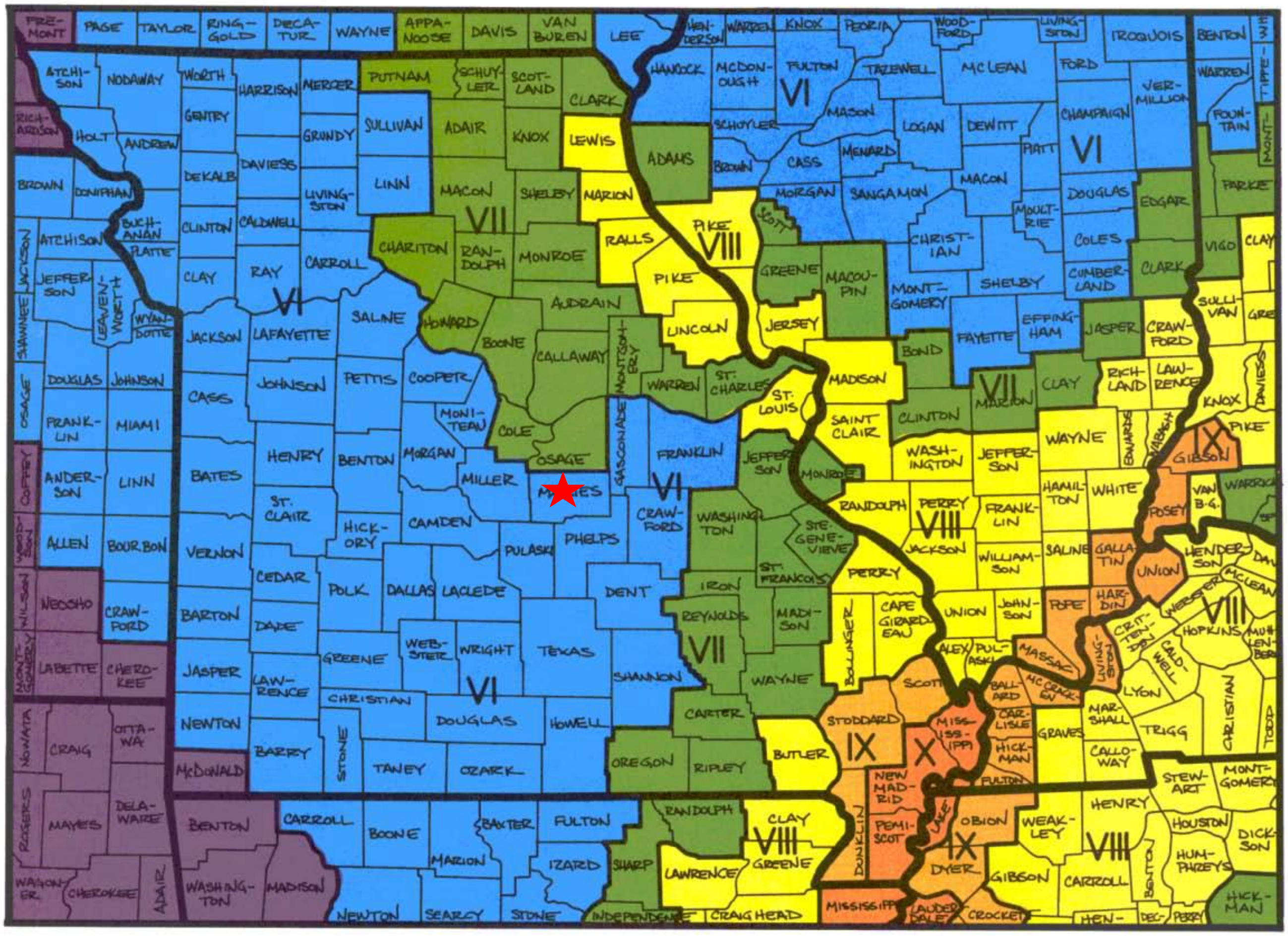
[1] Missouri State Emergency Management Agency, Missouri Department of Natural Resources, About the New Madrid Seismic Zone

Geographic Location

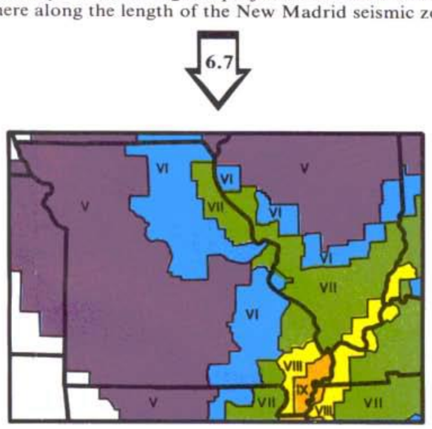
There are eight earthquake source zones in the Central United States, one of which is located within the state of Missouri—the New Madrid Seismic Zone. Other seismic zones, because of their close proximity, also affect Missourians. These are the Wabash Valley Fault, Illinois Basin, and the Nemaha Uplift. The most active zone is the New Madrid Fault, which runs from Northern Arkansas through Southeast Missouri and Western Tennessee and Kentucky to the Illinois side of the Ohio River Valley.

Figure 3.3 depicts impact zones for a magnitude 7.6 earthquake along the New Madrid Fault along with associated Modified Mercalli Intensities. Maries County is indicated by a red star. Furthermore, the Modified Mercalli Intensities for potential 6.7 and 8.6 magnitude earthquakes are illustrated. In the event of a 6.7 magnitude earthquake, Maries County would experience a Modified Mercalli Intensity of V (**Figure 3.4**). This intensity is categorized as being almost felt by everyone. 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. Additionally, in the occurrence of 7.6 and 8.6 magnitude earthquakes; the county would experience Modified Mercalli Intensities of VI and VII respectively. There will 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.

Figure 3.3. Impact Zones for Earthquake Along the New Madrid Fault

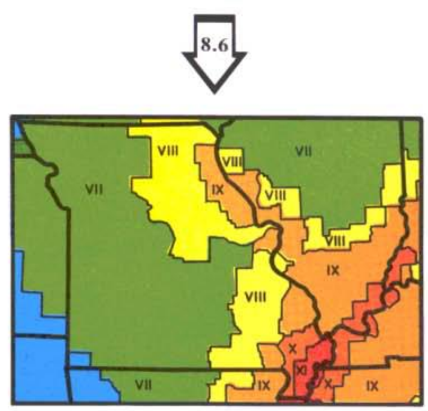


This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.



7.6

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: sema.dps.mo.gov; *Red star indicates Maries County

Figure 3.4. Projected Earthquake Intensities

MODIFIED MERCALLI INTENSITY SCALE

I People do not feel any Earth movement.

II A few people might notice movement.

III Many people indoors feel movement. Hanging objects swing.

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

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

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

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

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

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

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

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

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

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

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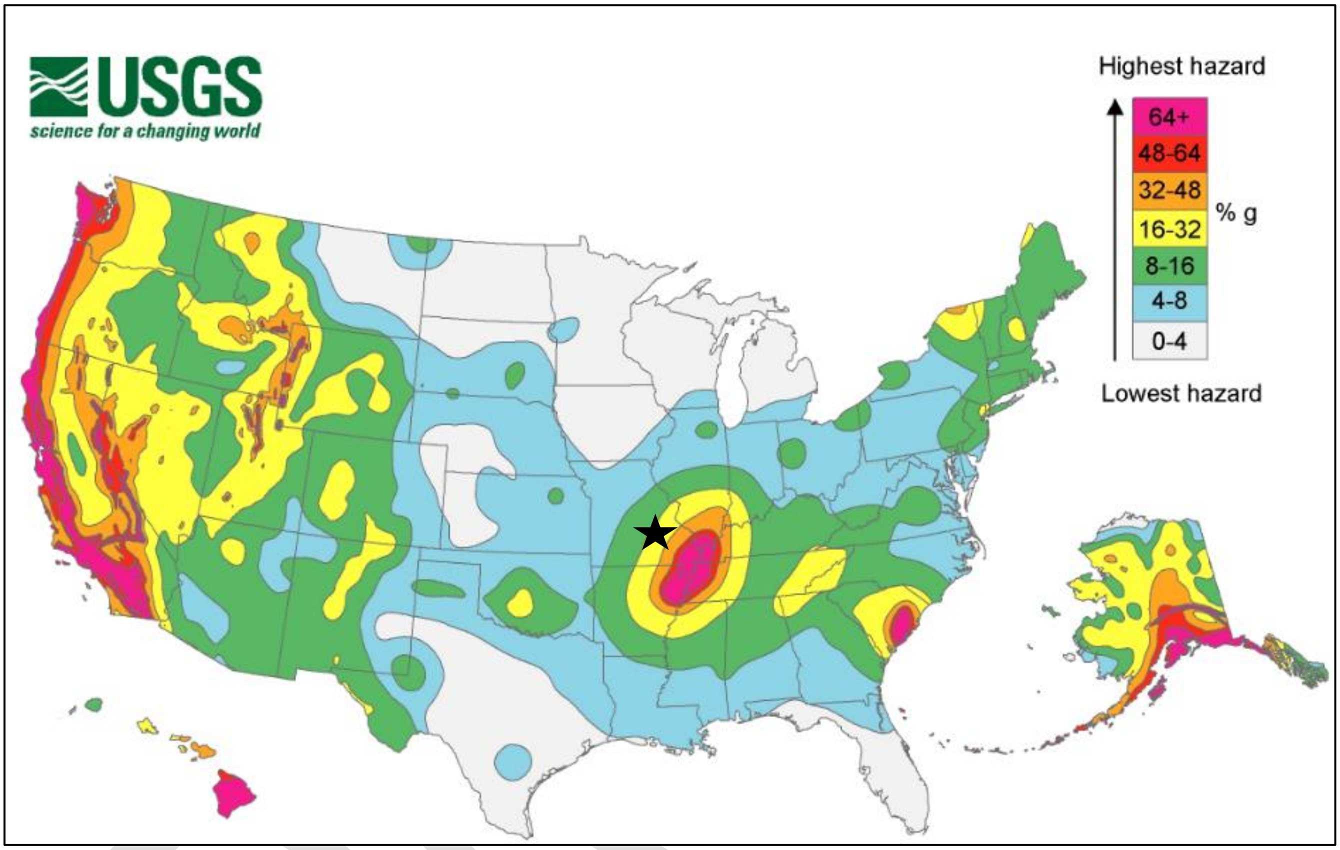
Source: sema.dps.mo.gov

Figure 3.5 illustrates the seismicity in the United States. A black star indicates the location of Maries County. The seismic hazard map displays earthquake peak ground acceleration (PGA) that has a 2% chance of being exceeded in 50 years; which has a value between 16-32% g.

Figure 3.5. United States Seismic Hazard Map



Source: USGS, http://earthquake.usgs.gov; *Black star indicates Maries County

Severity/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. Each whole number increase in magnitude represents a tenfold increase in measured amplitude; an estimate of energy. For example, comparing a 5.3 and a 6.3 earthquake shows that a 6.3 earthquake is ten times bigger than a magnitude 5.3 earthquake on a seismogram, but is 31.622 times stronger (energy release)[1]. **Table 3.30** further define Richter Scale intensities.

[1] Measuring the Size of an Earthquake, http://earthquake.usgs.gov/learn/topics/measure.php

Table 3.30. Richter Scale of Earthquake Magnitude

Magnitude Level	Category	Effects	Earthquake per Year
Less than 1.0 to 2.9	Micro	Generally not felt by people, though recorded on local instruments	More than 100,000
3.0-3.9	Minor	Felt by many people; no damage	12,000-100,000
4.0-4.9	Light	Felt by all; minor breakage of objects	2,000-12,000
5.0-5.9	Moderate	Some damage to weak structures	200-2,000
6.0-6.9	Strong	Moderate damage in populated areas	20-200
7.0-7.9	Major	Serious damage over large areas; loss of life	3-20
8.0 and higher	Great	Severe destruction and loss of life over large areas	Fewer than 3

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

There have been no earthquakes documented in Maries County since 1931.

Most of Missouri's earthquake activity has been concentrated in the southeast corner of the state, which lies within the New Madrid seismic zone. The written record of earthquakes in Missouri prior to the nineteenth century is virtually nonexistent; however, there is geologic evidence that the New Madrid seismic zone has had a long history of activity. The first written account of an earthquake in the region was by a French missionary on a voyage down the Mississippi River. He reported feeling a distinct tremor on Christmas Day 1699 while camped in the area of what is now Memphis, TN. Whatever the seismic history of the region may have been before the first Europeans arrived, after Dec. 16, 1811, there could be no doubt about the area's potential to generate severe earthquakes. On that date, shortly after 2 a.m., the first tremor of the most violent series of earthquakes in the United States history struck southeast Missouri. In the small town of New Madrid, about 290 kilometers south of St. Louis, residents were aroused from their sleep by the rocking of their cabins, the cracking of timbers, the clatter of breaking dishes and tumbling furniture, the rattling of falling chimneys, and the crashing of falling trees. A terrifying roaring noise was created as the earthquake waves swept across the ground. Large fissures suddenly opened and swallowed large quantities of river and marsh water. As the fissures closed again, great volumes of mud and sand were ejected along with the water.

The earthquake generated great waves on the Mississippi River that overwhelmed many boats and washed others high upon the shore. The waves broke off thousands of trees and carried them into the river. High river banks caved in, sand bars gave way, and entire islands disappeared. The violence of the earthquake was manifested by great topographic changes that affected an area of 78,000 to 130,000 square kilometers.

On Jan. 23, 1812, a second major shock, seemingly more violent than the first, occurred. A third great earthquake, perhaps the most severe of the series, struck on Feb. 7, 1812.
The three main shocks probably reached intensity XII, the maximum on the Modified Mercalli scale, although it is difficult to assign intensities, due to the scarcity of settlements at the time. Aftershocks continued to be felt for several years after the initial tremor. Later evidence indicates that the epicenter of the first earthquake (Dec. 16, 1811) was probably in northeast Arkansas. Based on historical accounts, the epicenter of the Feb. 7, 1812, shocks was probably close to the town of New Madrid.

Although the death toll from the 1811-12 series of earthquakes has never been tabulated, the loss of life was very slight. It is likely that at the time of the earthquakes if the New Madrid area had been as heavily populated as at present, thousands of persons would have perished. The main shocks were felt over an area covering at least 5,180,000 square kilometers. Chimneys were knocked down in Cincinnati, Ohio, and bricks were reported to have fallen from chimneys in Georgia and South Carolina. The first shock was felt distinctly in Maries, D.C., 700 miles away, and people there were frightened badly. Other points that reported feeling this earthquake included New Orleans, 804 kilometers away; Detroit, 965 kilometers away; and Boston, 1,769 kilometers away.
The New Madrid seismic zone has experienced numerous earthquakes since the 1811-12 series, and at least 35 shocks of intensity V or greater have been recorded in Missouri since 1811.

Small earthquakes continue to occur frequently in Missouri. An average of 200 earthquakes are detected every year in the New Madrid Seismic Zone alone. Most are detectable only with sensitive instruments, but on an average of every 18 months, southeast Missouri experiences an earthquake strong enough to crack plaster in buildings[1].

Probability of Future Occurrence

No earthquakes have been reported in Maries County since 1931. Additionally, the USGS database shows that there is a 0.44% chance of a major earthquake within 50 km of the county within the next 50 years.[2] The county, located in south central Missouri, is a good distance from the southeast corner of the state where the New Madrid Fault resides. Should a significant earthquake occur, it would have the potential to cause only limited damage within the county.

The 2018 Missouri Hazard Mitigation Plan states that there have been 31 recorded earthquake events greater than or equal to M 4.0 in the 43-year period from 1973 to 2018. According to this data, annual probability calculates to 72 percent. Additionally, the USGS estimated in 2006 that the probability of a repeat of the 1811-1812 earthquakes (magnitude 7.5 – 8.0) was seven to ten percent in a 50-year time period (Source: http://pubs.usgs.gov/fs/2006/3125). Given the historical frequency of earthquake events, this hazard is determined to have a high probability of occurrence within the State.

[1] Missouri State Hazard Mitigation Plan 2018
[2] https://www.usgs.gov/programs/earthquake-hazards/science/national-seismic-hazard-model#overview

Changing Future Conditions Considerations

Scientists are beginning to believe that there may be a correlation 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 that are caused by changing future conditions.[1]

Vulnerability

Vulnerability Overview

As stated in the 2023 Missouri Hazard Mitigation Plan, the impacts and severity of earthquakes on Missouri can be significant. The New Madrid earthquakes of 1811-1812 are among the largest that have happened on the North American continent. Losses at the time were limited due to low population and little development. However, a similar quake at this time would result in devastating damage.

The most important direct earthquake hazard is ground shaking, which affects structures close to the earthquake epicenter. However, ground shaking can also affect structures located great distances from epicenters, particularly where thick clay-rich soils can amplify ground motions. Certain types of buildings are more vulnerable to ground shaking than others. Unreinforced masonry structures, tall structures without adequate lateral resistance and poorly maintained structures are specifically susceptible to large earthquakes.

According to MDNR's Missouri Geological Survey, damage from earthquakes in the New Madrid Seismic Zone will vary depending on the earthquake magnitude, the character of the land and the degree of urbanization. Maries County is rural with few clusters of population. Infrastructure in the region such as highways, bridges, pipelines, communication lines and railroads might suffer damage, which would adversely affect Maries County, even if the county itself did not suffer heavy damage. Infrastructure could take a significant time to repair.

An important tool for homeowners to address the risk of earthquake damage to property is the purchase of earthquake insurance coverage. The Missouri Department of Insurance, Financial Institutions and Professional Registration (DIFP) prepared a report in 2022 on the state of earthquake insurance coverage in Missouri. The report notes that earthquake coverage has become less available and less affordable. The cost of earthquake coverage has increased significantly, particularly in the high-risk New Madrid area. Insurers have increasingly pulled out of high-risk areas of the state or have subjected such areas to stricter underwriting standards. Policyholders are required to self-insure to a significant extent through higher deductibles and the application of separate deductibles to structure and contents. Some insurers will only sell policies with a deductible equal to 20 or 25% of policy limits. In 91 of Missouri's 115 counties, fewer than 20 percent of residences have earthquake coverage. Only in St. Charles County are at least half of residences insured from damage caused by earthquakes. In 2021 the percentage of residential policies with earthquake coverage in Maries County was 16.7 percent with the average cost of coverage at $50 per year.[2]

[1] Missouri State Hazard Mitigation Plan 2023

[2] The State of Earthquake Coverage Report https://insurance.mo.gov/earthquake/

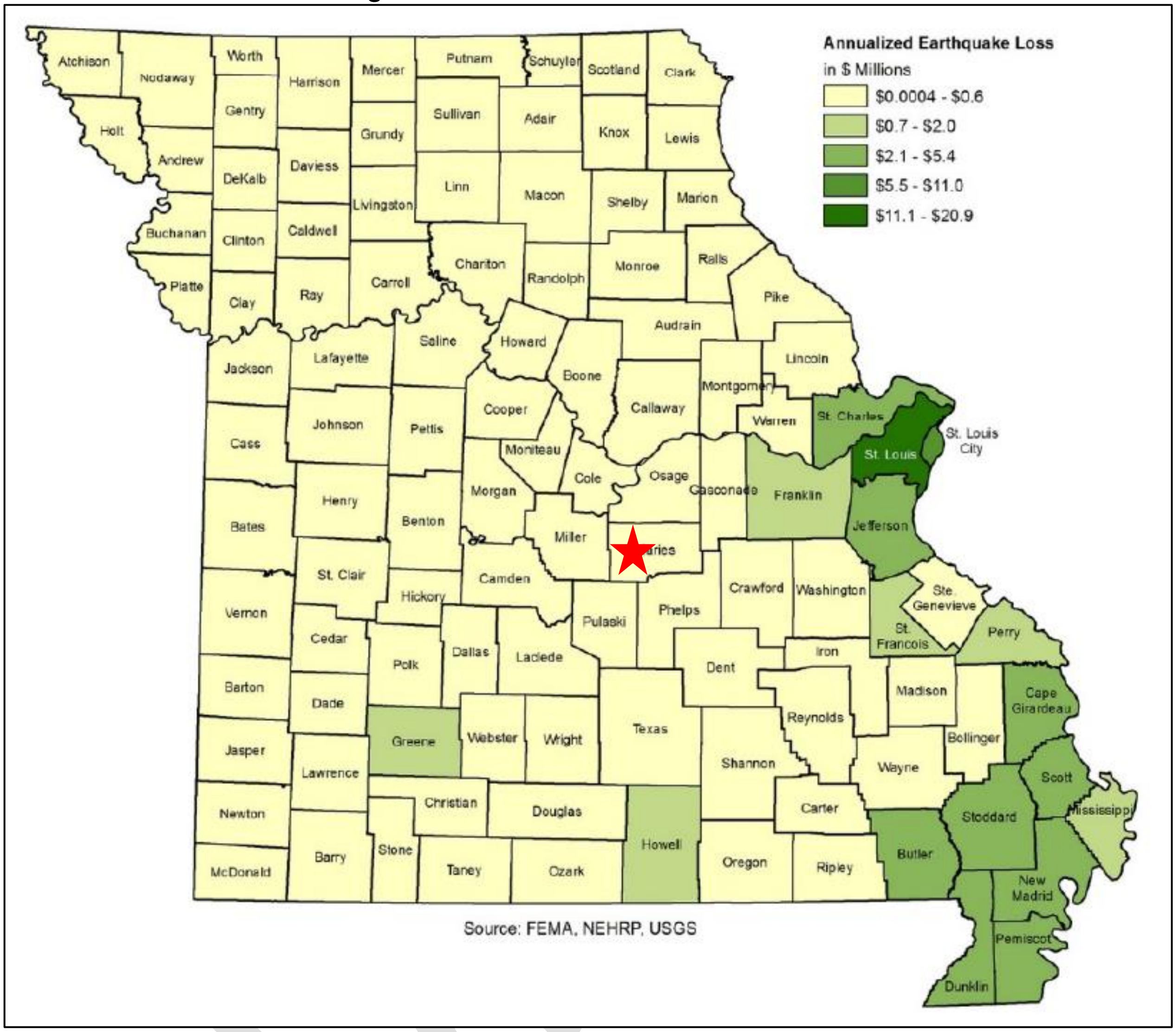
Potential Losses to Existing Development

SEMA utilized Hazus V 3.2 to analyze vulnerability and estimate losses to earthquakes. Hazus is a program developed by FEMA which is a nationally applicable standardized methodology that encompasses models for assessing potential losses from earthquakes, floods, and hurricanes. All Hazus analyses were run using Level 1 building inventory database comprised of updated demographic and aggregated data based on the 2010 census. An annualized loss scenario that enabled an "apples to apples" comparison of earthquake risk for each county was synthesized from a FEMA nationwide annualized loss study (FEMA 366 Hazus Estimated Annualized Earthquake Losses for the United States, April 2017). A second scenario, based on an event with a two percent probability of exceedance in 50 years, was done to model a worst case earthquake using a level of ground shaking recognized in earthquake-resistant design.

Annualized loss is the maximum potential annual dollar loss resulting from eight return periods (100, 200, 500, 750, 1,000, 1,500, 2,000, and 2,500 years) averaged on a 'per year' basis[1]. This is the scenario that FEMA uses to compare relative risk from earthquakes and other hazards at the county level nationwide. The Hazus earthquake loss estimation is depicted in **Figure 3.6** which shows annualized loss scenario direct economic losses to buildings. In this scenario, the annualized earthquake loss for buildings in Maries County in any one year is estimated to be $400 to $600,000. **Table 3.31** provides information on total estimated losses, estimated losses per capita and loss ratio. This results in the county being ranked 67th in the state for expected loss with low vulnerability for this hazard. This loss ratio indicates impacts on local economies in the event of an earthquake, and the difficulty for jurisdictions to recover from said event.[2]

[1] 2023 Missouri State Hazard Mitigation Plan
[2] Ibid

Figure 3.6. HAZUS-MH Earthquake Loss Estimation: Annualized Loss Scenario –Direct Economic Losses to Buildings.



*Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County*

Table 3.31. HAZUS-MH Earthquake Loss Estimation-Maries County: Annualized Loss Scenario

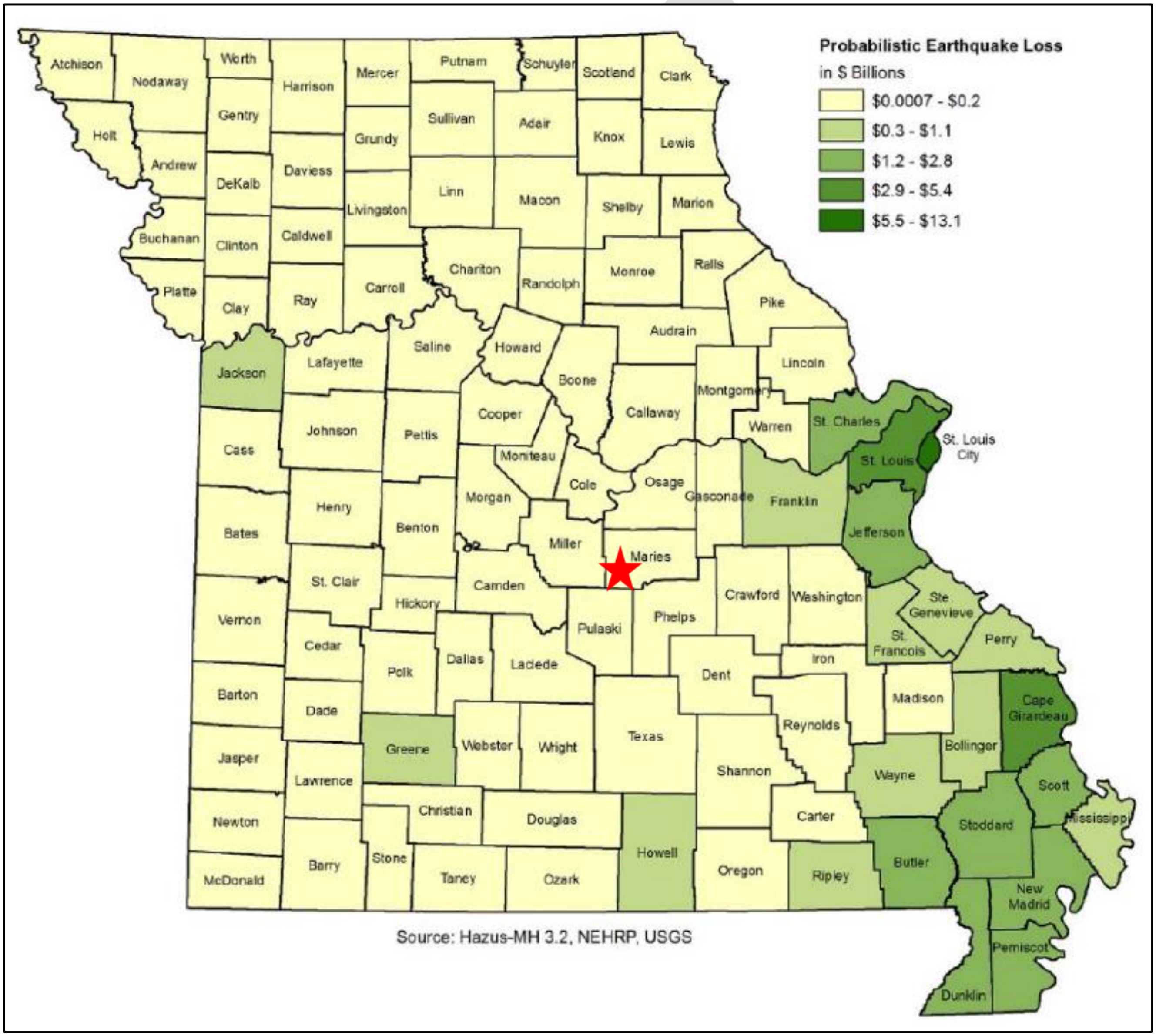
Total Losses in $ Thousands	Loss Per Capita, In $ Thousands	Loss Ratio in $ Per Million	Statewide Ranking for Expected Losses
$48	$0.0053	$51	67th

Source: Hazus 2.1
**Loss ratio is the sum of structural and nonstructural damage divided by the entire building inventory value within a county*

Likewise, SEMA developed a second scenario which incorporated a 2% probability of exceedance in 50 years. This model was to demonstrate a worst case scenario. This scenario is equivalent to the 2,500 year earthquake scenario in HAZUS-MH. The methodology is based on probabilistic seismic hazard shaking grids developed by the U.S. Geological Survey (USGS) for the National Seismic

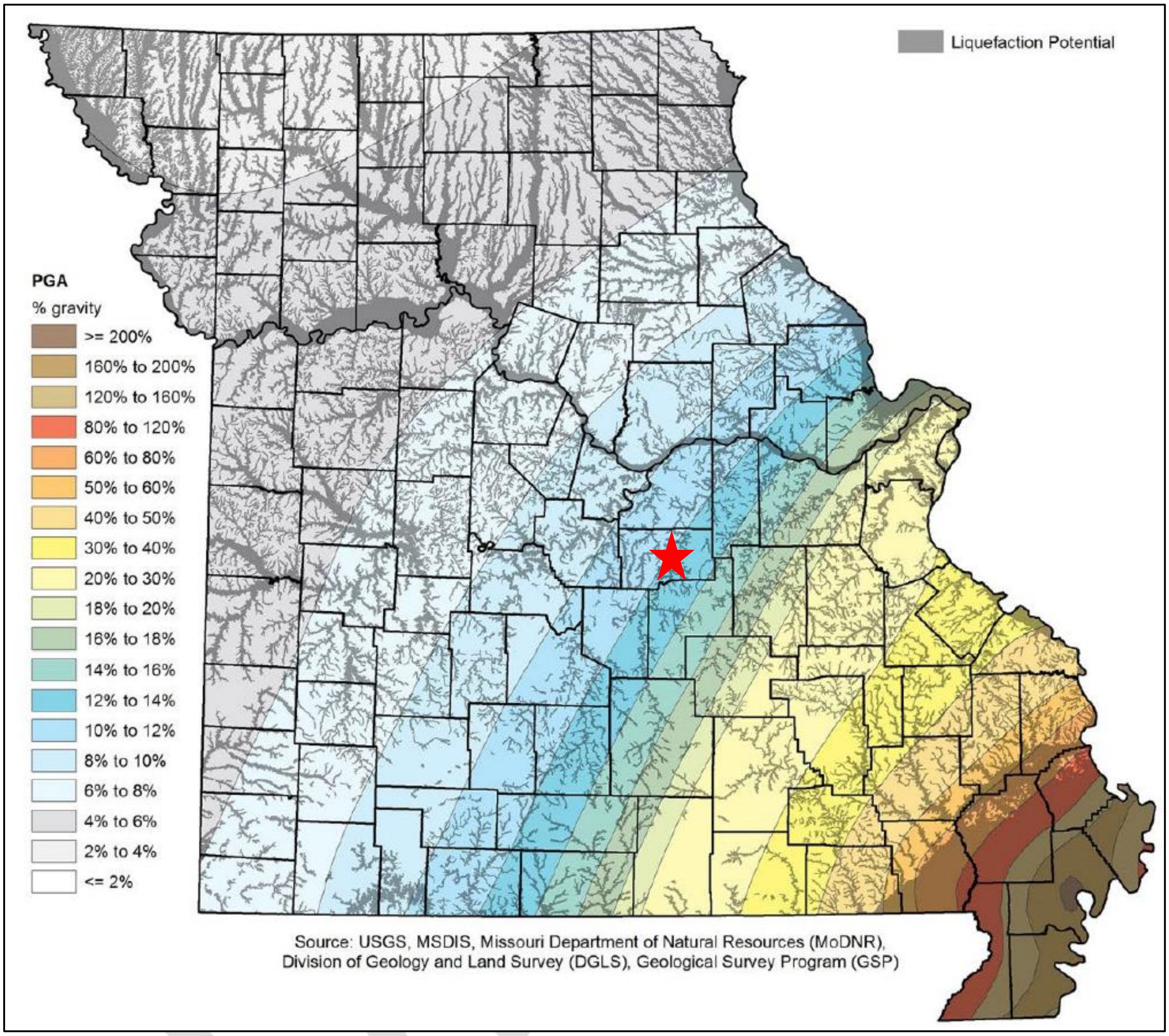
Hazard Maps that are included with HAZUS-MH. The USGS updated this mapping in 2014. **Figure 3.7** illustrates direct economic loss to buildings. Maries County is anticipated to lose between $700,000 and $200,000,000 in a 50 year scenario. **Figure 3.8** provides estimates of peak ground acceleration and spectral acceleration (ground shaking potential) at intervals of 0.3 and 1.0 seconds, respectively. These acceleration events have a 2% probability of exceedance in the next 50 years. A 7.7 magnitude earthquake was utilized in this scenario, which is typically utilized for New Madrid fault planning scenarios in Missouri. Furthermore, this pattern of shaking can be seen in with corresponding potential for damage and areas with soils potentially susceptible to liquefaction. Maries County is estimated to have peak ground acceleration between 10 percent and 16 percent.

Figure 3.7. HAZUS-MH Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Total Building Loss



*Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County*

Figure 3.8. Hazus Earthquake 2% Probability of Exceedance in 50 Years – Ground Shaking and Liquefaction Potential



*Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County*

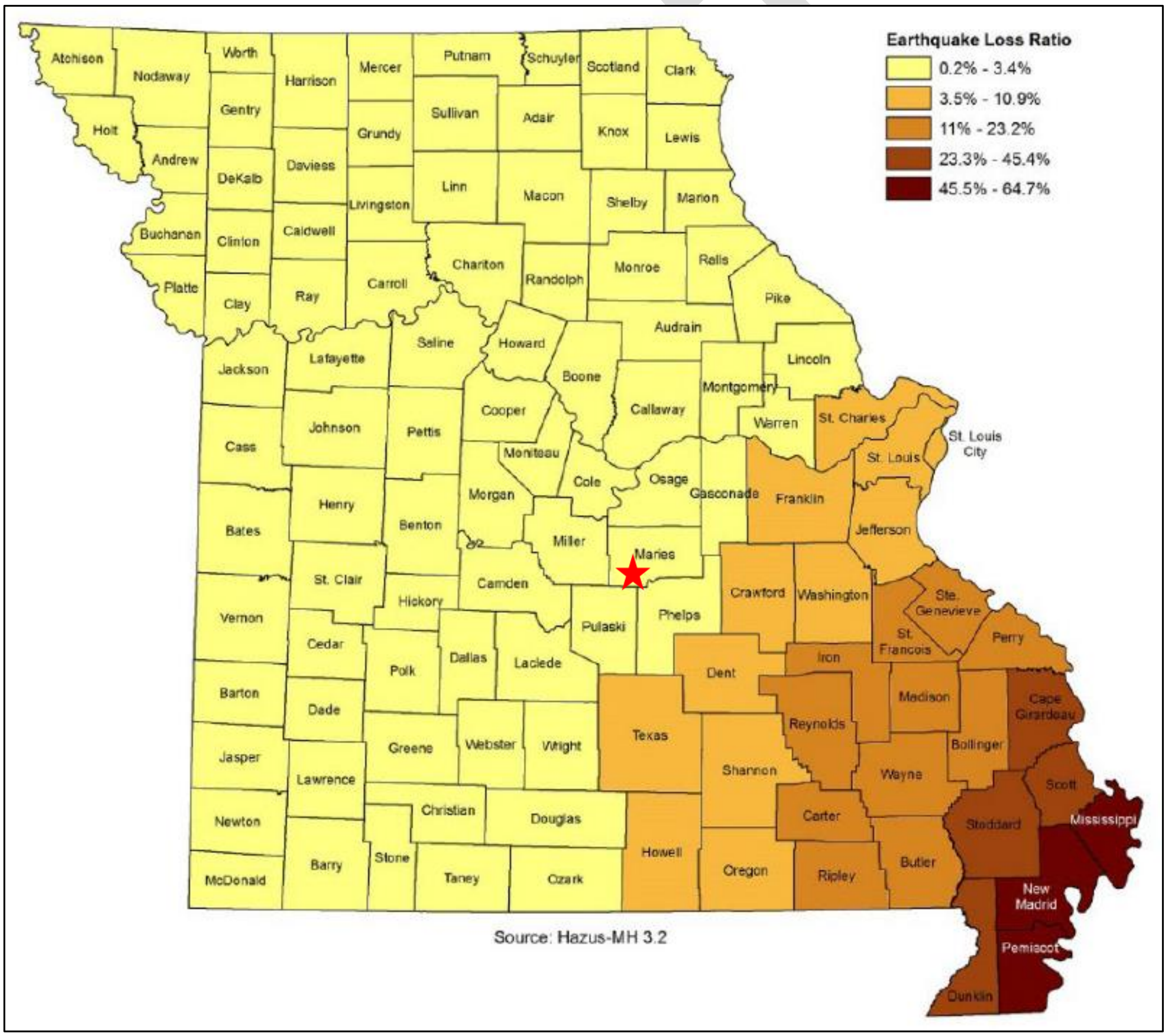
Table 3.32 provides information on estimated direct economic losses for Maries County, including structural, nonstructural, inventory, contents, relocation costs, capital related loss, wages and rental income loss. According to the 2023 Missouri Hazard Mitigation Plan, Maries County's loss ratio is 2.15 percent. Maries County ranks 68^{st} in the state for direct economic losses in this scenario. **Figure 3.9** depicts loss ratio by county, which is the ratio of the building structure and nonstructural damage to the value of the entire building inventory. The loss ratio is a measure of the disaster impact to community sustainability, which is generally considered at risk when losses exceed 10 percent of the built environment (FEMA).

Table 3.32. HAZUS-MH Earthquake Loss Estimation 2% Probability of Exceedance in 50 Years Scenario Direct Economic Losses Results Summary for Maries County*

Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
$5,576	$14,984	$5,419	$178	2.15	$3,465	$561	$790	$1,077	$32,050

Source: 2023 Missouri Hazard Mitigation Plan
**All values in thousands*

Figure 3.9. Hazus Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Loss Ratio



*Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County*

Impact of Previous and Future Development

Future development is not expected to increase the risk other than contributing to the overall exposure of what could be damaged as a result of an earthquake. Since the last update, there has been limited development in the City of Vienna to include development of 2 commercial properties and one new 4-plex residential rental property. The city of Belle reported the construction of a new ambulance facility. As new development arises, minimum standards of building codes should be established in all jurisdictions to decrease the potential damage/loss should an earthquake occur.

The Revised Statutes of MO, Section 160.451 require that: The governing body of each school district which can be expected to experience an intensity of ground shaking equivalent to a Modified Mercalli Intensity of VII or above from an earthquake occurring along the New Madrid Fault with a potential magnitude of 7.6 on the Richter Scale shall establish an earthquake emergency procedure system in every school building under its jurisdiction[1].

Hazard Summary by Jurisdiction

There will be a range in intensities within any small areas such as a town or county, with the highest intensity generally occurring at only a few sites. Maries County is not near the New Madrid Seismic Zone, but it will most likely endure mild secondary effects from the earthquake, such as fire, structure damage, utility disruption, environmental impacts, and economic disruptions/losses. However, damages could differ if there are structural variations in the planning area's built environment. For example, if one community has a higher percentage of residences built prior to 1939 than the other participants, that community is likely to experience higher damages. **Table 3.33** depicts the percent of residences built prior to 1939 in Maries County. In addition, if school districts have buildings built prior to 1939, those facilities may be at higher risk of damage should an earthquake occur. If a major earthquake should occur, Maries County would likely be impacted by the number of refugees traveling through the area seeking safety and assistance.

Table 3.33. Maries County Residences Built Prior to 1939

Jurisdiction	Number of Residences Built Prior to 1939	% of Residences Built Prior to 1939
Unincorporated Maries County	441	13.7%
Belle	72	10.5%
Vienna	28	7.0%

Source: US Census Bureau 2017-2021 ACS Data

[1] https://revisor.mo.gov/main/OneSection.aspx?section=160.451

Problem Statement

In a worst-case scenario, the county is expected to encounter $32,050,000 in total economic losses to buildings. The unincorporated areas of the county have a higher risk of damage to buildings due to having a higher percentage of the homes having been built prior to 1939.

Jurisdictions should encourage the purchase of earthquake hazard insurance. As well as establishing structurally sound emergency shelters in several parts of the county. In addition, stringent minimum standards of building codes should be established. Lastly, outreach and education should be utilized more frequently to prepare citizens for the next occurrence.

3.4.4 Extreme Temperatures

Hazard Profile

Some specific sources for this hazard are:

- 2018 Missouri State hazard Mitigation Plan, Chapter 3, Section 3.3.7, Page 3.253 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- 2023 Missouri State hazard Mitigation Plan, Chapter 3, Section 3.3.7
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- Heat Index Chart & typical health impacts from heat, National Weather Service; National Weather Service Heat Index Program, https://www.weather.gov/safety/heat-index;
- Wind Chill chart, National Weather Service, http://www.nws.noaa.gov/om/cold/wind_chill.shtml ;
- Daily temperatures averages and extremes, High Plains Regional Climate Summary, https://hprcc.unl.edu/climate_extremes.php, http://climod.unl.edu/;
- Hyperthermia mortality, Missouri; Missouri Department of Health and Senior Service, http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper1.pdf;
- Hyperthermia mortality by Geographic area, Missouri Department of Health and Senior Services,
- http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper2.pdf;
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide

    - Average annual occurrence for extreme heat by County
    - Vulnerability to extreme heat by County
    - Average annual occurrence for extreme cold by County
    - Vulnerability to extreme cold by County

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 days. 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 3.10** uses both of these factors to produce a guide for the apparent temperature or relative intensity of heat conditions. Other factors that should be taken into account include duration of exposure to high temperatures, wind and activity.

The NWS has increased its efforts to more effectively alert the general public and local authorities on the hazards of heat waves. The Heat Index (HI) is an effective tool in helping people understand the dangers of high temperatures and how temperature and relative humidity together provide a more accurate gauge of heat intensity. The HI, provided in degrees Fahrenheit, is an accurate measure of how hot it actually feels when the relative humidity is added to the air temperature. Because HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15 degrees Fahrenheit. Also, strong winds, particularly with very hot, dry air, can be extremely dangerous.

High humidity, a common factor in Missouri, can magnify the effects of extreme heat. While heat-related illness and death can occur from exposure to intense heat in just one afternoon, heat stress on the body has a cumulative effect. The persistence of a heat wave increases the threat to public health.

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 and furnaces. Cold temperatures can also overpower a building's heating system and cause water and sewer lines to freeze and rupture. Extreme cold also increases the likelihood for ice jams on flat rivers and 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 those who are isolated being most at risk. About 10 percent of people over the age of 65 have some kind of bodily temperature-regulating defect, and three to four 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.

The NWS Wind Chill Temperature (WCT) index, shown in **Figure 3.11**, 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 Wind Chill Temperature index chart 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 3.10. Heat Index (HI) Chart

NWS Heat Index — Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

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

Figure 3.11. Wind Chill Chart

Wind Chill Chart — Temperature (°F)

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

Frostbite Times: 30 minutes | 10 minutes | 5 minutes

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

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

Effective 11/01/01

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

Geographic Location

Extreme temperature is considered to be an area-wide hazard event. In such a case, the chance of variation in temperatures across Maries County is minimal to nonexistent.

Strength/Magnitude/Extent

The National Weather Service (NWS) has an alert system in place (advisories, watches, 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.

The NWS also has an alert system in place (advisories, watches, or warnings) when a deadly combination of wind and cold air threatens. People in an area with a wind chill alert should avoid going outside during the coldest parts of the day. If going outside is unavoidable, it is important to dress in layers and cover exposed skin to protect against frostbite and hypothermia.

Previous Occurrences

Table 3.34 provides data in relation to record extreme temperature events between 2003 and 2022 in Maries County. Maximum heat index/wind chill values and temperatures are shown for each extreme temperature event. Fortunately, there were zero recorded injuries and fatalities during this time.

Table 3.34. Maries County Recorded Extreme Temperature Events 2003 – 2022

Month, Year	# of Event Days	Fatalities	Injuries	Temperature (F°)	Heat Index Values / Wind Chill (F°)
6/01/2012	30	0	0	>100	>100
7/01/2012	31	0	0	>100	>104
8/01/2012	31	0	0	103	106
2/14/2021	3	0	0	-6	-23
Total	**95**	**0**	**0**	**-**	**-**

Source: http://www.ncdc.noaa.gov/stormevents/

Extreme temperature can cause stress to crops and animals. According to the NOAA Storm Events Data Base, there were no reported agricultural losses due to heat for Maries County from 2003 - 2022. However, USDA Risk management reports 21 crop indemnity payments for a total of

$137,536.91 during the same period. **Table 3.33** below lists all USDA crop indemnity payments due to heat per year from 2013 to 2022. 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.

Table 3.35. Crop Indemnity due to extreme temperature 2013 - 2022

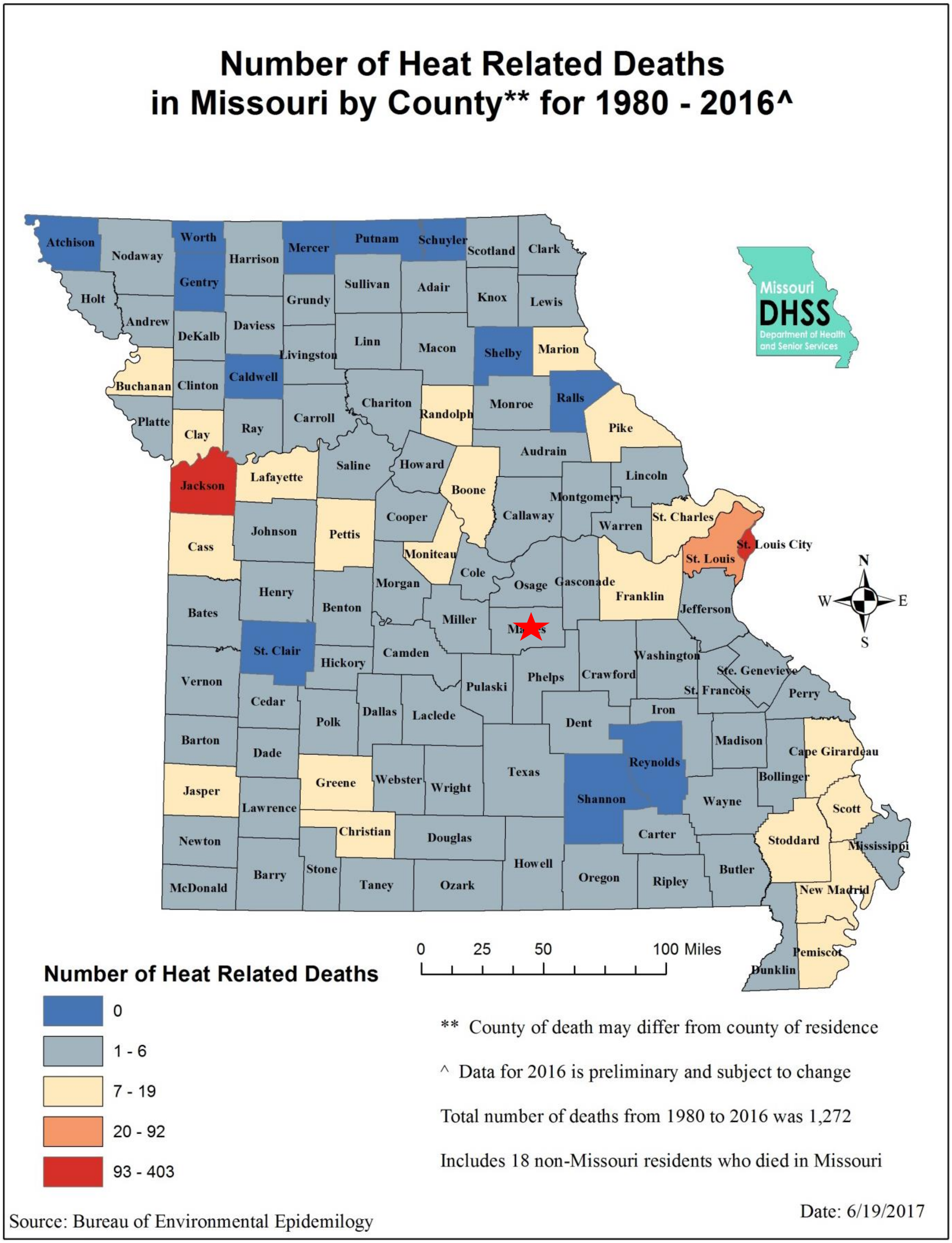
Year	Number of Payments	Total
2003	0	0
2004	0	0
2005	0	0
2006	1	$1,448.00
2007	1	$339.00
2008	0	0
2009	0	0
2010	0	0
2011	4	$13,910.00
2012	10	$56,997.01
2013	1	$813.00
2014	1	$834.00
2015	0	0
2016	0	0
2017	0	0
2018	0	0
2019	1	$28,394.00
2020	0	0
2021	0	0
2022	2	$34,801.90
TOTAL	**21**	**$137,539.91**

From 2004 through 2018, there were 10,527 fatalities in the U.S. attributed to summer heat[1]. This translates to an annual average of 702 deaths. During the same time period, zero deaths were recorded in Maries County, according to NOAA Storm Events Data Base. **Figure 3.12** illustrates heat related deaths by county in Missouri between 1980 and 2016. The national Weather Service stated that among natural hazards, no other natural disaster – not lightning, hurricanes, tornadoes, floods or earthquakes – causes more deaths than excessive heat.

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.

[1] MMWR Morb Mortal Wkly Rep, http://dx.doi.org/10.15585/mmwr.mm6924a1

Figure 3.12. Heat Related Deaths in Missouri 1980 - 2016

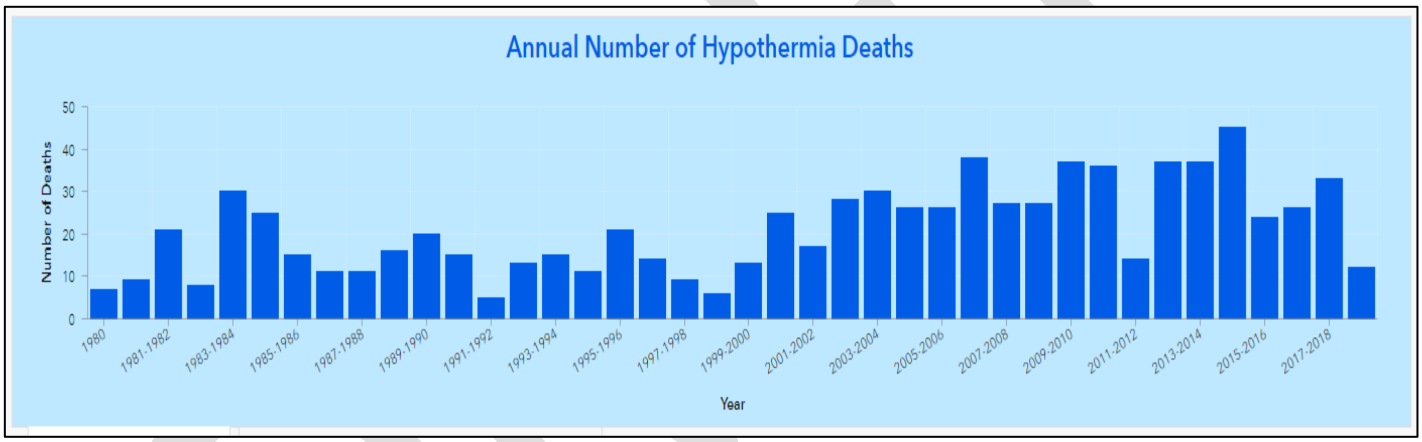


Source: https://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/stat-report.pdf
*Red star indicates Maries County

According to the Missouri Department of Health and Senior Services, 840 people died in Missouri due to extreme cold conditions between 1980 and 2018, see **Figure 3.13**. As with extreme heat, the elderly are more vulnerable to cold-related deaths. Elderly or disabled individuals fall outside their homes and are not able to call for help or reach the safety of shelter during periods of extreme cold. According to the 2018 Missouri State Hazard Mitigation plan, during the winters of 1989-2012, a total of 414 hypothermia deaths occurred, with 186 (44.9%) being 65 years of age or older. As with extreme heat, substance abuse can be a contributing factor for hypothermia related fatalities for people between the ages of 25 and 64. Between 1989 and 2012, substance abuse factored into the hypothermia deaths of 107 of the 208 (51.4%) deaths in this age group. Fortunately, hypothermia deaths in people under the age of 25 are rare in Missouri, accounting for only 19 (4.6%) of the total extreme cold related deaths during this timeframe. There were two (0.5%) deaths of children under the age of five. Over 72 percent of hypothermia deaths are among males – 299 of the total 414. The remaining 115 (27.8%) were female.

In regards urban versus rural, hypothermia deaths tend to be higher in rural areas than in urban communities. There were 183 (44.2%) cold related deaths in the Kansas City and St. Louis metropolitan areas, while 231 (55.8%) occurred in other parts of the state.

Figure 3.13. Hypothermia Deaths, Missouri: Winter Seasons 1980-2018

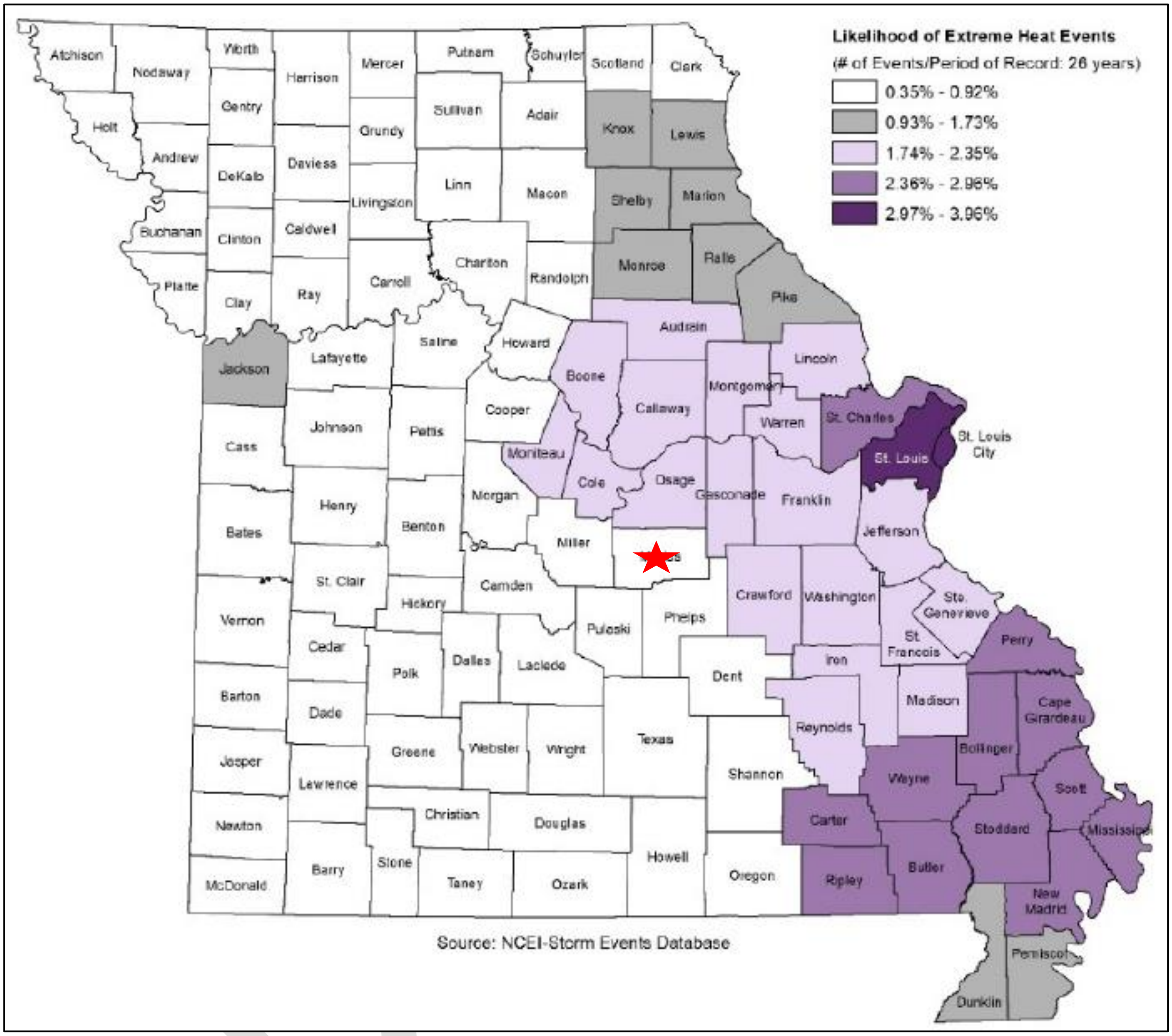


Source: Missouri DHSS, http://health.mo.gov/living/healthcondiseases/hypothermia/pdf/hypo1.pdf

Probability of Future Occurrence

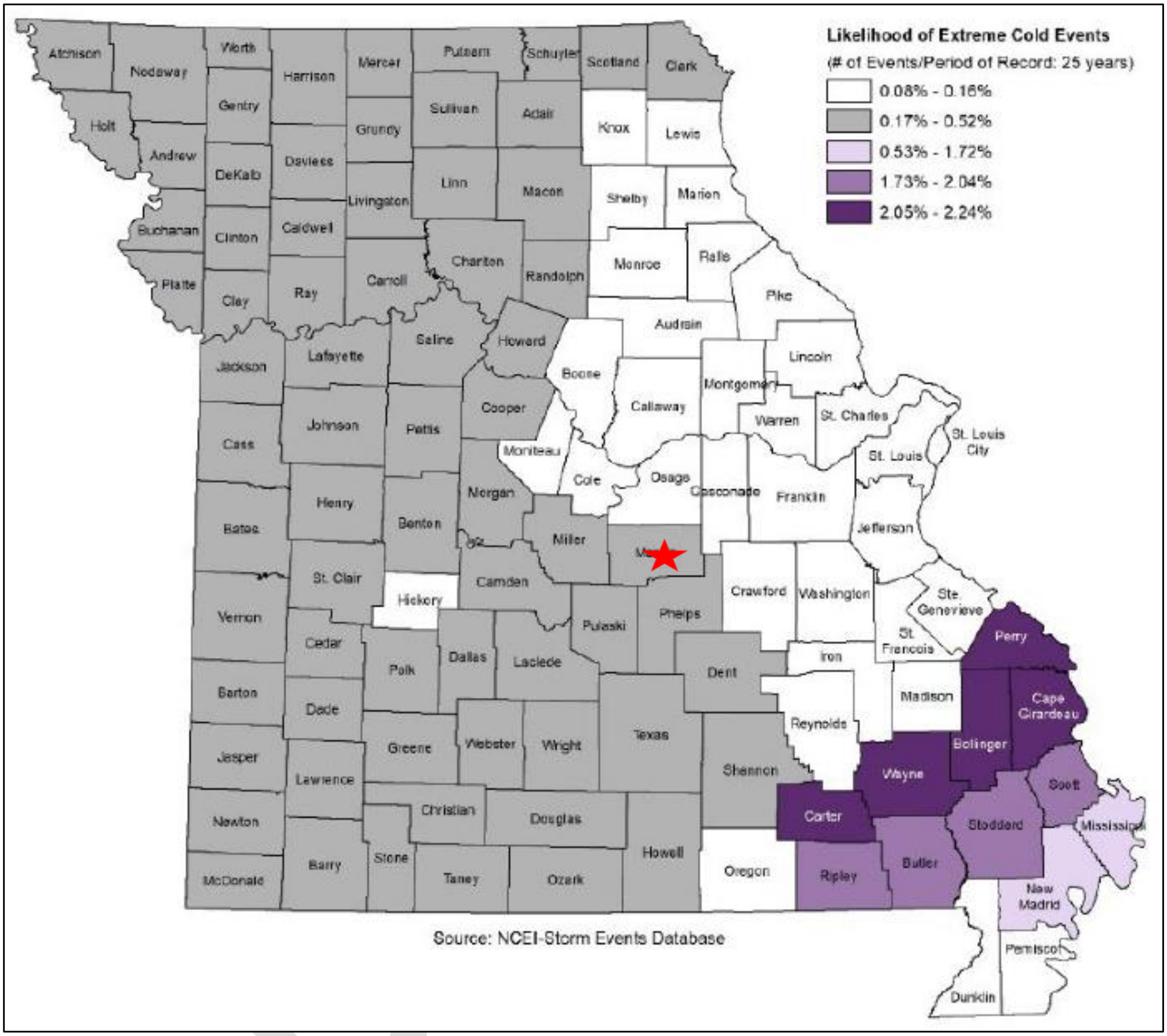
Figure 3.14 illustrates the average annual occurrence for extreme heat statewide. Based on information provided in the 2023 Missouri State Hazard Mitigation Plan, Maries County has an average of .35 to .92 events per year based on data from 26 years. **Figure 3.15** illustrates the average annual occurrence for extreme cold statewide. Maries County has an average of 0.17 to 0.52 events per year based on data from 25 years. It should be noted that there are data limitations due to underreporting of extreme heat and cold events.

Figure 3.14. Average Annual Occurrence for Extreme Heat



*Source: 2023 Missouri State Hazard Mitigation Plan; *Red star indicates Maries County*

Figure 3.15. Average Annual Occurrence for Extreme Cold



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Changing Future Conditions Considerations

According to the 2023 Missouri Hazard Mitigation Plan, under a higher emissions pathway, historically unprecedented warming is projected by the end of the century. Even under a pathway of lower greenhouse gas emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. For example, in southern Missouri, the annual maximum number of consecutive days with temperatures exceeding 95 degrees F is projected to increase by up to 20 days. Temperature increases will cause future heat waves to be more intense, a concern for this region which already experiences hot and humid conditions. If the warming trend continues, future heat waves are likely to be more intense and cold spells are projected to decrease.

Furthermore, higher temperatures are experienced more acutely by vulnerable populations such as the elderly, the very young, the homeless, the ill and disabled, and those living in poverty. Higher demands and costs for electricity to run air conditioners can stress power systems. Higher temperatures can also cause harmful algal blooms in warmer water – resulting in poor water quality.

Mitigation against the impacts of future temperature increases may include increasing education on heat stress prevention, organizing cooling centers, allocating additional funding to repair and maintain roads damaged by buckling and potholes and reducing nutrient runoff that contributes to algal blooms. Local governments should also prepare for increased demand on utility systems. Improving energy efficiency in public buildings will also present an increasingly valuable savings potential.

Vulnerability

Vulnerability Overview

Maries County, along with the rest of the state of Missouri is vulnerable to extreme heat and cold events. **Table 3.36** shows the typical health impacts of extreme temperature. Jurisdictions with higher percentages of individuals below the age of 5, and above the age of 65 tend to be more at risk for extreme temperature (**Table 3.39**). People who are overweight, ill or on certain medication can also be more vulnerable. However, even those without underlying risk factors are susceptible if they participate in outdoor activities during extreme temperatures. The exposure to extreme temperatures of farm workers and livestock is also a major concern.

Table 3.36. Typical Health Impacts of Extreme Temperatures

Heat Index (HI) or Wind Chill (WC)	Disorder
< -51°	Frostbite possible within 5 minutes
-32° - -50°	Frostbite possible within 10 minutes
-18° - -31°	Frostbite possible within 30 minutes
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, https://www.weather.gov/safety/heat-index, https://www.weather.gov/bou/windchill

The method used by state planners to determine vulnerability to extreme temperatures across Missouri was statistical analysis of data from several sources: National Centers for Environmental Information (NCEI) storm events data (1996- December 31, 2021), percentage of population over 65 data from the U.S. Census (2019) and the calculated Social Vulnerability Index for Missouri counties from the hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina. Four factors were considered in determining overall vulnerability to extreme temperatures – total population, percentage of population over 65, likelihood of occurrence and social vulnerability. Based on natural breaks in the data, a rating value of one through five was assigned with one being low, two being low-medium, three being medium, four being medium-high and five being high.

Table 3.37 shows the population, percent of population over 65 and social vulnerability index data for Maries County overall.

Table 3.37. Population, Percent of Population Over 65 and SOVI Data for Maries County

County	Total Population Rating	Percentage of Population Over 65	Percent of Population Over 65 Rating	SOVI Ranking	SOVI Rating
Maries	1	27.3	4	Medium	3

Source: 2023 Missouri Hazard Mitigation Plan

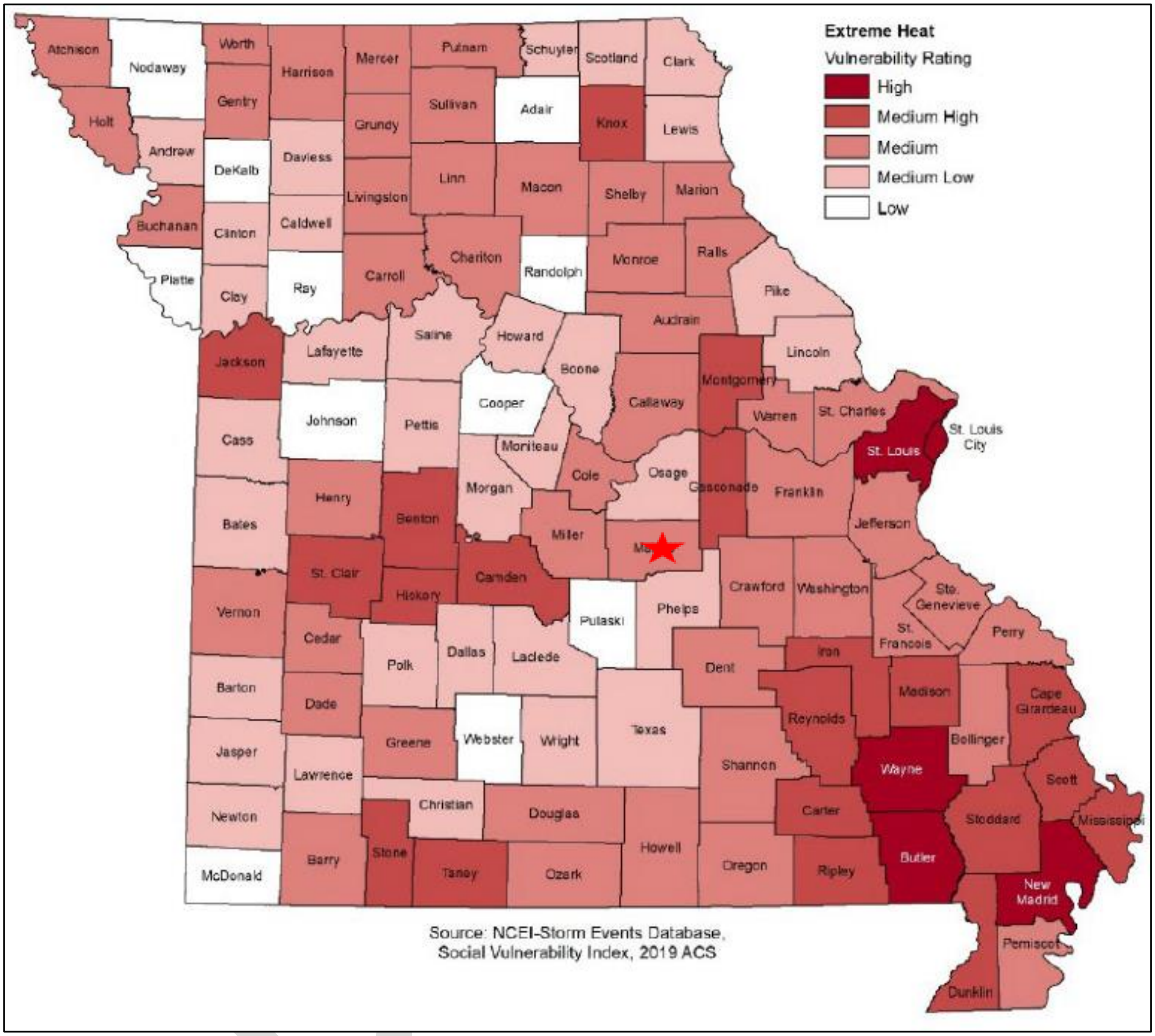
Table 3.38 illustrates the likelihood of occurrence and overall vulnerability rating for extreme temperatures for Maries County. Figure 3.16 and Figure 3.17 provide a vulnerability summary for extreme heat and extreme cold, respectively. Maries County has medium vulnerability for extreme heat and medium high vulnerability for extreme cold.

Table 3.38. Maries County Likelihood of Occurrence and Overall Vulnerability Rating for Extreme Temperatures

Heat					Cold				
Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description	Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description
11	0.42	1	9	Medium	5	0.2	2	10	Medium High

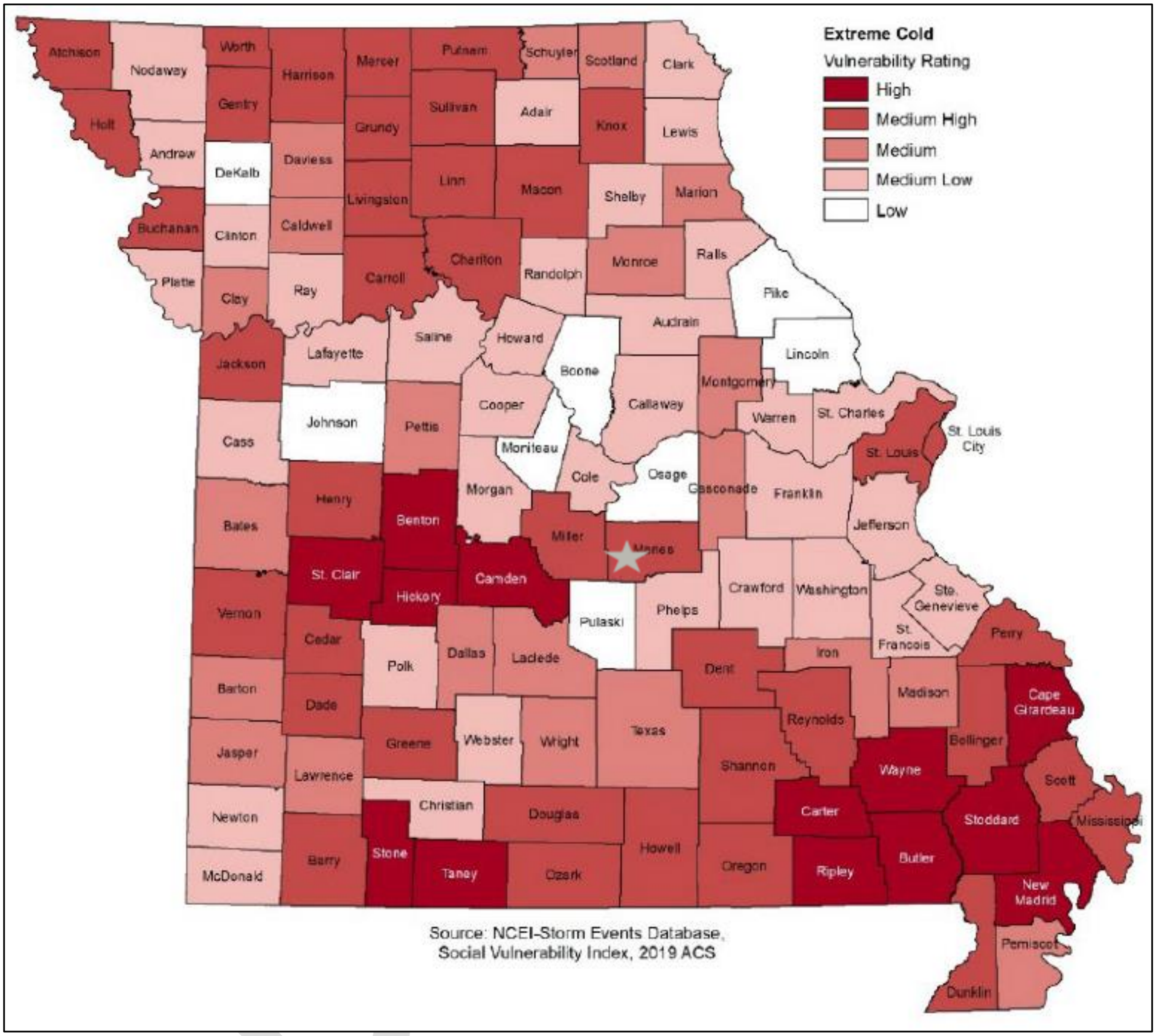
Source: 2023 Missouri Hazard Mitigation Plan

Figure 3.16. Vulnerability Summary for Extreme Heat



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.17. Vulnerability Summary for Extreme Cold



*Source: 2023 Missouri Hazard Mitigation Plan, *Gray star indicates Maries County*

Potential Losses to Existing Development

Extreme Heat/Heat Wave

Of greatest concern during extreme heat events are hyperthermia injuries and deaths. The 2023 Missouri Hazard Mitigation plan states that there were 1,272 heat-related deaths reported in Missouri from 1980 through 2016. Of those, 826 (64.9%) deaths occurred in the metropolitan areas of Kansas City and St. Louis while 428 (33.6%) deaths occurred in rural parts of the state. Over half of the deaths (62.3%) occurred in those age 65 or older. People in this demographic group are more vulnerable to this hazard for a number of reasons. Many live alone and have medical conditions that put them at higher risk. The lack of air conditioning or the refusal to use it for fear of higher utility bills further increases their risk. Deaths among children under the age of five are often linked to being left in vehicles during hot weather. Between 1980 and 2016 there were 29 (2.3%) heat-related deaths of children less than five years old. In the age group between 5 years and 65 years deaths are generally due to over exertion at work or in sports activities, complicating medical conditions or substance abuse.

During extreme heat events structural, road, and electrical infrastructure are vulnerable to damage. Depending upon temperatures and duration of extreme heat, losses will vary.

Extreme Cold

Of greatest concern during extreme cold events are hypothermia injuries and deaths. The 2023 Hazard Mitigation Plan states that a total of 840 hypothermia deaths have occurred between 1980 and 2018. Approximately half of those deaths were of people aged 65 years and older. Substance abuse is often a contributing cause of cold-related deaths in those aged 20 to 64 and was a factor in 48% of hypothermia related deaths in those of that age group. Fortunately, hypothermia related deaths in children are very rare with on 5 documented deaths in the reporting period. Hypothermia related deaths are more common in rural areas with only 39.9% occurring in metropolitan areas while 60% occurred in other areas of the state.

Extreme cold events can also put energy supplies at increased risk, damage water and wastewater systems, and cause natural gas pipelines to fracture and leak. Losses will vary based upon severity and duration of extreme cold temperature events.

Impact of Previous and Future Development

Population trends from 2010 to 2020 for Maries County indicate that the population in unincorporated areas has fallen by an estimated 7.85 percent. The city of Belle's population has decreased by 10.6 percent, while the city of Vienna's population fell by 4.75 percent. Overall, the county's population has shrunk by 7.9 percent. Population change can result in increased age groups that are more susceptible to extreme heat and cold. Additionally, population change can increase the strain on each jurisdiction's electricity and road infrastructure through increased use or decrease in maintenance revenue. Local government and local emergency management should take extreme temperature into consideration when upgrades occur to the local power grid.

Hazard Summary by Jurisdiction

Those at greatest risk for temperature-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 or have medical conditions that make them more vulnerable. To determine jurisdictions within the planning area with populations more vulnerable to extreme temperature, demographic data was obtained from the 2017-2021 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 temperature or with medical conditions that made them more vulnerable. **Table 3.39** 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 3.39. County Population Under Age 5 and Over Age 65 (2016-2020)

Jurisdiction	Population Under 5 Years	Population 65 Years and over
Unincorporated Maries County	3.3%	16.6%
Belle	8.0%	16.4%
Vienna	7.6%	27.1%

Source: U.S. Census Bureau, 2017-2021 American Community Survey 5-Year Estimates

Due to lack of data, buildings that lack air-conditioning could not be analyzed for this report. Additionally, school policy data in regard to extreme heat or cold were not available.

In summary, the risks of extreme heat or cold can impact the health/lives of citizens within the county, specifically the young and elderly. The city of Vienna has the highest percentage of individuals 65 and over, with 27.1 percent and the second highest percentage of children under 5 years by only four tenths of a precent at 7.6 percent.

Problem Statement

In summary, the risks of extreme heat and cold can impact the health/lives of citizens within the county, specifically the young and elderly. Based on the vulnerability analysis, the city of Vienna has the highest risk because it has a large populations of people aged 65 and over and a large population of children under the age of 5.(**Table 3.39**).

Many people do not realize how deadly a heat wave can be. Extreme heat is a natural disaster that is not as dramatic as floods or tornadoes. Working with the Phelps-Maries County Health Department and EMD, local governments should encourage residents to:

- Stay indoors as much as possible and limit exposure to the sun;
- Stay on the lowest floor out of the sunshine if air conditioning is not available;
- Consider spending the warmest part of the day in public buildings such as libraries or other public or community buildings. Circulating air can cool the body by increasing the evaporation rate of perspiration;
- Eat light, well-balanced meals at regular intervals and avoid using salt tablets unless directed by a physician;
- Hydrate by drinking plenty of water. Individuals with epilepsy or heart, kidney or liver disease who are on fluid restricted diets or have problems with fluid retention should consult their physicians on liquid intake;
- Limit consumption of alcoholic beverages;
- Dress in loose-fitting, lightweight and light-colored clothes that cover as much skin as possible;
- Protect your face and head by wearing a wide-brimmed hat. Wear sunscreen;
- Check on family, friends and neighbors who do not have air conditioning and are generally alone;
- Never leave children or pets in closed vehicles;
- Avoid strenuous work during the warmest part of the day and use the buddy system when working in extreme heat and take frequent breaks.

People who work outdoors should be educated about the dangers and warning signs of heat disorders. Buildings, ranging from homes (particularly those of the elderly) to factories, should be equipped with properly installed, working air conditioning units, or have fans that can be used to generate adequate ventilation. However, although fans are less expensive to operate than air conditioning, they may not be effective, and may even be harmful when temperatures are very high. As the air temperature rises, air flow is increasingly ineffective in cooling the body. At temperatures above 100° F, the fan may be delivering overheated air to the skin at a rate that exceeds the capacity of the body to get rid of this heat – even with perspiring – and the net effect is to add heat rather than to cool the body. An air conditioner is a much better option. Charitable organizations and the health department should work together to provide fans, when appropriate, to at-risk residents during times of critical heat. When temperatures are too high, however, these groups should work to get at-risk populations into cooling shelters.

Extreme cold can also be life-threatening, and the following precautions should be taken when someone is suffering from hypothermia:

- Call 9-1-1 for immediate medical assistance;
- Move the victim to a warm place;
- Monitor the victim's blood pressure and breathing;
- If necessary, provide rescue breathing and CPR;
- Remove wet clothing;
- Dry off the victim;
- Take the victim's temperature;
- Warm the body core first, NOT the extremities. Warming the extremities first can cause the victim to go into shock and can also drive cold blood toward the heart and lead to heart failure;
- Do not warm the victim too fast – rapid warming may cause heart arrhythmias

All jurisdictions should make sure they have plans in place to provide both cooling and warming shelters during times of extreme temperatures. School districts should have policies in place to minimize strenuous exercise outdoors during heat waves and to consider policies for delaying or cancelling school during times of extreme cold to reduce risk to students waiting for buses.

3.4.5 Flooding (Riverine and Flash)

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.1, Page 3.80 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Watershed map, Environmental Protection Agency, http://cfpub.epa.gov/surf/county.cfm?fips_code=19169
- 2023 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.1,
- FEMA Map Service Center, Digital Flood Insurance Rate Maps (DFIRM) for all jurisdictions, if available, https://msc.fema.gov/portal/home
- NFIP Community Status Book, http://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-community-status-book
- NFIP claims status, BureauNet, http://bsa.nfipstat.fema.gov/reports/reports.html
- Flood Insurance Administration—Repetitive Loss List (this must be requested from the State Floodplain Management agency or FEMA)
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/en/Information-Tools/Summary-of-Business/Cause-of-Loss
- FEMA Data Visualization Tool, https://www.fema.gov/data-visualization-floods-data-visualization
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Risk MAP, DFIRM, and Hazus based depth grids used in Hazus Analysis
  - Flood losses by County 1978-2018
  - Number of flood insurance claims by County
  - Total building exposure to flooding (1% annual chance) by County
  - Buildings impacted by flooding (1% annual chance) by County
  - Flood insurance coverage by County
  - Number of flood insurance policies by County
  - NFIP participation status by County
  - Number of state facilities impacted by flooding (1% annual chance) by County
  - Critical facilities impacted by flooding (1% annual chance) by County

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 failure is discussed in **Section 3.4.1.** 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 (SFHA). Digital flood insurance risk maps are not yet available for Maries County. Risk mapping, assessment, and planning (RiskMap) is a FEMA program which provides communities with flood information and tools to enhance their mitigation plan and take action to better protect their citizens. The project kick-off meeting for RiskMAP in Maries County was held in December 2018 and a flood study review meetings were held in November 2019, January 2020, and March 2022. The maps below were generated using data gathered during the RiskMAP project and are currently the best source of data available. **Figure 3.31** is a map of Maries County showing the floodplain boundaries. Following the county-wide map is a city of Vienna map. Finally, **Figure 3.36** shows a map of the school districts in Maries County with an overlay of the SFHA. No school districts within the county have properties located in the floodplain. **Table 3.39** shows Maries County NCEI flood events by location between 2003 and 2022.

Figure 3.18. Map of Maries County with Special Flood Hazard Areas.

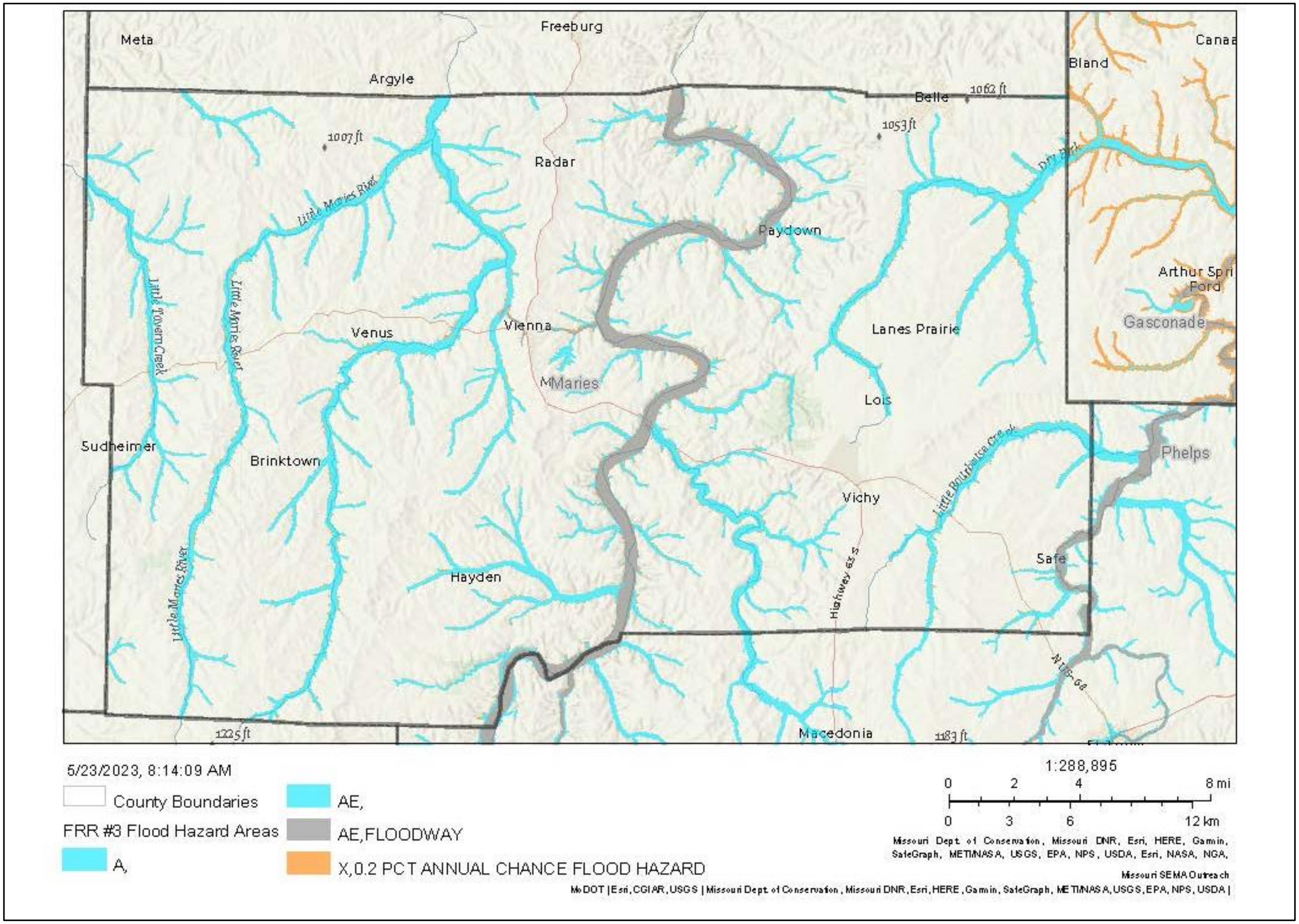


Figure 3.19. Vienna, Missouri Special Flood Hazard Areas (SFHAs)

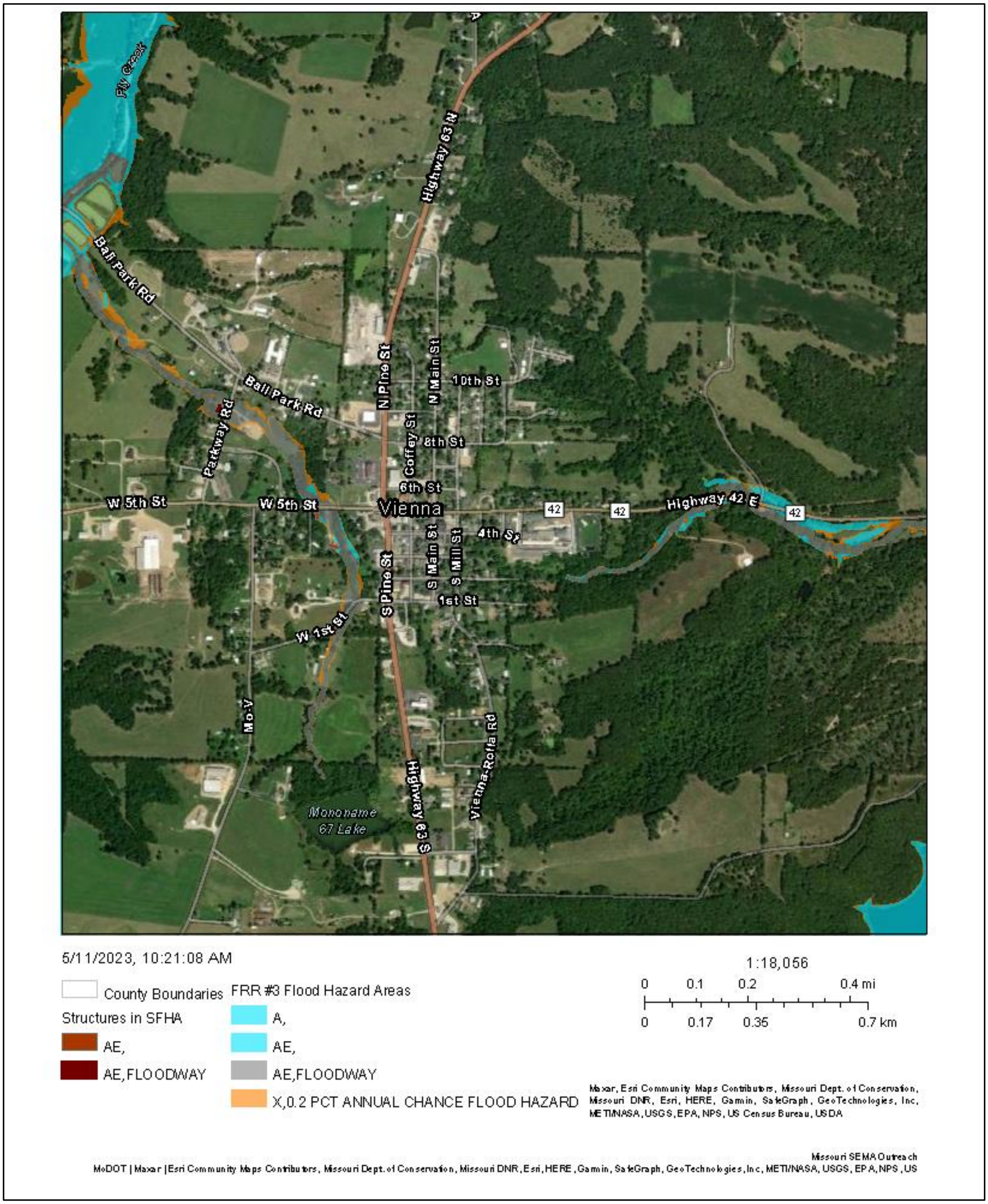


Figure 3.20. Maries County School Districts and Special Flood Hazard Areas (SFHAs)

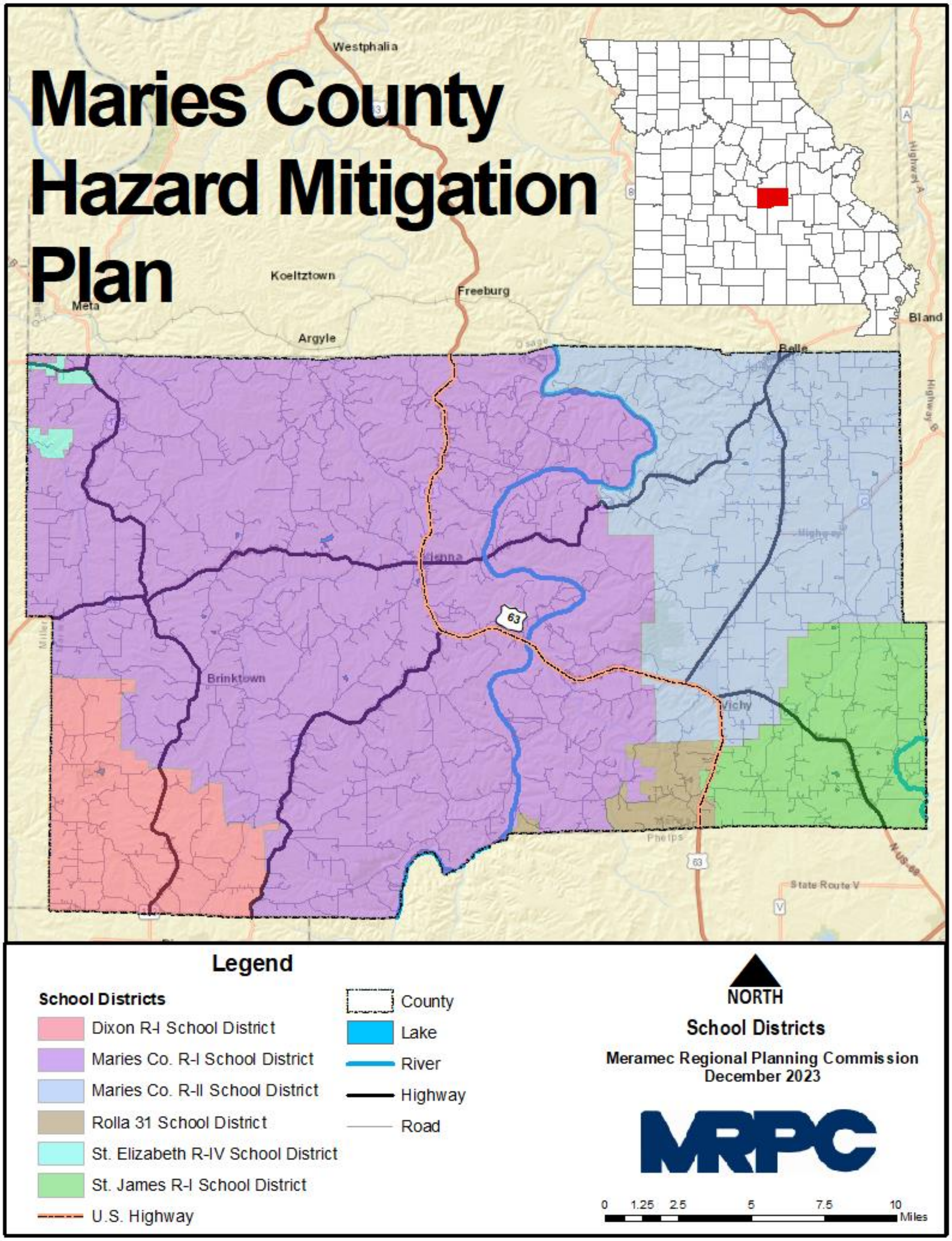


Table 3.40. Summary of Maries County NCEI Flood Events by Location, 2003-2022

Location	# of Events
Maries County	1
Belle	2
Hayden	1
Shantytown	3
Veto	3
Vienna	4
(VIH) Rolla/Vichy Arp	1

Source: National Centers for Environmental Information Storm Events Database

Flash flooding occurs in SFHAs and 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. After review of NCEI data, Vienna is the community most prone to flash flooding events. Brinktown and Shantytown, unincorporated areas of the county, also have a high rate of flash flood events. **Table 3.41** provides information in regard to flash flood events between 2003 and 2022.

Table 3.41. Maries County NCEI Flash Flood Events by Location, 2003-2022

Location	# of Events
Maries County	1
Belle	5
Brinktown	6
High Gate	1
Safe	1
Shantytown	7
Summerfield	2
Van Cleve	3
Vichy	2
Vienna	9
(VIH) Rolla/Vichy Arp	3
Yarna	2

Source: National Centers for Environmental Information

Severity/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.

Flooding presents a danger to life and property, often resulting in injuries, and in some cases, fatalities. Floodwaters can interact with hazardous materials. Hazardous materials stored in large containers, like bulk propane tanks, could break loose or puncture as a result of flood activity. When this happens, evacuation of citizens could be 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 sewer back-up occurs, this can result in costly clean-up for home and business owners as well as present a health hazard.

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. Further information regarding scour critical bridges can be found in **Section 3.2.2**.

National Flood Insurance Program (NFIP) Participation

Table 3.42 depicts jurisdictions within the planning area that participate in NFIP. In addition, **Table 3.43** provides the number of policies in force, amount of insurance in force, number of closed losses, and total payments for Maries County.

Table 3.42. NFIP Participation in Maries County

Community ID #	Community Name	NFIP Participant (Y/N)	Current Effective Map Date	Regular-Emergency Program Entry Date
-	Belle, City of	N	-	-
290816	Maries County	Y	07/01/1987 (L)	07/01/1987
290647	Vienna, City of	Y	-	11/01/1979

Source: NFIP Community Status Book,, https://www.fema.gov/flood-insurance/work-with-nfip/community-status-book

Table 3.43. NFIP Policy and Claim Statistics as of 07/30/2023

Community Name	Policies in Force	Insurance in Force	Closed Losses	Total Payments
Maries County	12	$2,602,000	111	$3,781,983.14
City of Vienna	0	0	2	3,310.16

Source: NFIP Community Status Book, [08/08/2023]; SEMA
**Closed Losses are those flood insurance claims that resulted in payment.*

Of all the participating jurisdictions, Maries County has the most insurance payments totaling $3,781,983.14.

Repetitive Loss/Severe Repetitive Loss Properties

Repetitive Loss Properties (RL) are those properties with at least two flood insurance payments of $1,000 or more in a 10-year period. According to SEMA, there are 9 repetitive loss properties in Maries County that have had 26 losses with total payments of $505,282.49. No repetitive loss properties have been mitigated with the planning area.

Table 3.44. Repetitive Loss Properties in Maries County

Jurisdiction	# of Properties	# Mitigated	Building Payments	Content Payments	Total Payments	# of Losses
Maries County	9	0	$450,828.93	$54,453.56	$505,282.49	26

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.

According to SEMA, there are 5 severe repetitive loss properties in Maries County that have had 19 losses with total payments equaling $715,511.86. No severe repetitive loss properties have been mitigated in the planning area.

Table 3.45. Severe Repetitive Loss Properties in Maries County

Jurisdiction	# of Properties	# Mitigated	Building Payments	Content Payments	Total Payments	# of Losses
Maries County	5	0	$652,709.79	$62,802.07	$715,511.86	19

Previous Occurrences

Between 2003 and 2022, there were 31 recorded flood-related crop insurance claims with total losses of $391,311.90 due to flooding within Maries County[1]. **Table 3.43**Error! Reference source not found. shows crop losses for the period 2003 through 2022.

Table 3.46. Recorded USDA Crop Insurance Losses (Flood) for Maries County 2003 - 2022

Year	Number of Payments	Total
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0
2008	2	$46,418.00
2009	5	$40,658.00
2010	0	0
2011	0	0
2012	0	0
2013	15	$179,638.50

[1] http://www.rma.usda.gov/data/cause.html

Year	Number of Payments	Total
2014	0	0
2015	4	$90,752.40
2016	1	$13,963.00
2017	4	$19,882.00
2018	0	0
2019	0	0
2020	0	0
2021	0	0
2022	0	0
TOTAL	**31**	**$391,311.90**

Table 3.47 provides information regarding Presidential Flooding Disaster Declarations between 2003 and 2022 for Maries County.

Table 3.47. Maries County Presidential Flooding Disaster Declarations 2001 to 2020

Declaration No.	Date	State	Incident Description
DR-1463	05/06/2003	Missouri	Severe Storms, Tornadoes, Flooding
DR-1676	01/12/2007	Missouri	Severe Winter Storms and Flooding
DR-1742	01/07/2008	Missouri	Severe Storms, Tornadoes and Flooding
DR-1749	03/17/2008	Missouri	Severe Storms and Flooding
DR-1809	09/11/2008	Missouri	Severe Storms, Flooding, and a Tornado
DR-1847	05/08/2009	Missouri	Severe Storms, Tornadoes, and Flooding
DR-4130	09/06/2013	Missouri	Severe Storms, Straight-line Winds, Tornadoes, and Flooding
DR-4144	10/08/2013	Missouri	Severe Storms, Straight-line Winds, and Flooding
DR-4238	08/31/2015	Missouri	Severe Storms, Straight-line Winds, and Flooding
EM-3374	12/22/2015	Missouri	Severe Storms, Tornadoes, Straight-Line Winds, and Flooding
DR-4250	01/21/2016	Missouri	Heavy Rains, Widespread Flash Flooding, and Flooding
DR-4317	06/02/2017	Missouri	Severe Storms, Tornadoes, Straight-line Winds and Flooding
DR-4451	07/09/2019	Missouri	Severe Storms, Tornadoes, and Flooding

Source: FEMA, Disaster Declarations for Missouri, Flooding

Data was obtained from the NCEI regarding flash and river flooding over the last 20 years. **Table 3.48** and **3.49** provide this information. Additionally, narratives available for each event are included.

Table 3.48. NCEI Maries County Riverine Flood Events Summary, 2003 to 2022

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2005	1	0	0	0	0
2008	2	0	0	0	0
2009	1	0	0	0	0
2010	2	0	0	15.00K	0
2011	3	0	0	200.00K	0
2013	1	0	0	0	0
2016	1	0	0	0	0
2017	1	1	0	500.00K	0
2018	2	0	0	0	0
2021	1	0	0	0	0
Total	**15**	**0**	**0**	**715.00K**	**0**

Source: NCEI, data accessed [2/3/23]

Narratives on flood events:

1. **01/05/2005:** Several periods of heavy rain in conjunction with little vegetation over the winter months set the stage for widespread flooding across much of extreme southeast Kansas and southern and central Missouri. In Maries County, numerous roads and low lying areas were inundated and impassable by motorists countywide.

2. **03/19/2008:** Excessive rainfall developed over southern Missouri during the evening of 17 March. A line of training convection assumed a position roughly along a line from Anderson to Ozark to Licking. This convection expanded with time, eventually covering nearly all of extreme southeast Kansas and the Missouri Ozarks. Moderate to heavy rain continued into the overnight period and did not stop until the morning of 19 March.

3. **09/03/2009:** Following the landfall of Hurricane Gustav along the Louisiana coast, Gustav's extra-tropical circulation tracked directly into southern Missouri. The remnant moisture from Gustav created widespread rainfall amounts ranging from two to six inches across the region. Pre-existing dry soil conditions and thick summertime vegetation limited flooding from becoming widespread and significant. However, some localized flooding was observed.

   Three to six inches of rain fell over maries County. Numerous low water crossings across the county flooded. A section of County Road 511 at its intersection with Clifty Creek had three feet of fast moving water over the road.

4. **10/29/2009:** Showers and thunderstorms produced flooding across Southwest Missouri wth isolated wind damage in Neosho. Several low water crossings were reported flooded across Maries County.

5. **01/24/2010:** A slow moving storm system brought an extended period of heavy rainfall which produced flooding across portions of the Missouri Ozarks. Numerous road closures were reported as streams and creeks swelled and low water crossings and roads became impassable. A low water crossing, on County Road 406 along a branch of the Dry Fork River was flooded and impassable.

6. **05/20/2010:** A slow moving upper level storm system, moved across the region, acting to transport significant amounts of moisture up and over a stalled frontal boundary laid out across

the Ozarks. Isolated embedded thunderstorms produced small hail and locally heavy rainfall. Wide spread flooding and flash flooding occurred as a result of the duration of heavy rainfall in conjunction with isolated heavy rainfall from thunderstorms. A water rescue was performed along County Road 624. Excessive rainfall caused the Maries River to flood over a low water crossing which a motorist attempted to drive across.

7. **03/14/2011:** A vigorous shortwave moving across the Ozarks produced thunderstorms with heavy rain which caused several reports of flooding. Emergency manager reported numerous low water crossings were flooded across Maries County.

8. **04/25/2011:** Multiple rounds of thunderstorms produced very heavy rainfall across the Ozarks over the course of a week. A persistent trough over the central plains brought multiple upper level storm systems over the region which produced intense thunderstorms with very heavy rainfall. Some areas saw storm total rainfall amounts up to a foot or more. A housing area off State Highway E near the Gasconade River was cut off due to flooding of County Road 540. Several low water crossings and rural roads were flooded and impassable. The total cost estimate for flooding damages for Maries County for this entire episode has been included. This includes roads, bridges, and structures which were affected.

9. **06/01/2013:** Heavy rainfall led to flooding across the Missouri Ozarks. Numerous low water crossings in Maries County were flooded.

10. **07/02/2016:** Several rounds of thunderstorms over the holiday weekend produced severe weather across the Missouri Ozarks. There were reports of wind damage and large hail. Heavy rainfall led to flash flooding as well. Water flooded over County Road 624 at the low water crossing along the Maries River.

11. **04/30/2017:** Multiple rounds of severe thunderstorms and extremely heavy rainfall over several days led to historic and devastating flash floods, record breaking river levels, large hail, wind damage, and at least one tornado across the Missouri Ozarks region. Most counties across the Missouri Ozarks region were declared a federal disaster from the President and FEMA. Several homes and roads sustained flood damage across the county with damages to infrastructure, businesses and homes in Maries County estimated at $500,000.

12. **03/29/2018:** Several rounds of thunderstorms caused heavy rainfall and minor flooding. Route E was closed due to flooding.

13. **03/12/2021:** Heavy rainfall affected the region from the late morning of the 12th to the evening of the 14th as a cold front stalled over northern Arkansas, moved back to the north as a warm front, and then moved east of the region again as a cold front during the 3 day period. Multiple rounds of heavy rainfall produced widespread rainfall amounts between two and three inches with some local areas receiving in excess of 8 inches during the three-day period. A water rescue was performed successfully at a low water crossing on County Road 527 at the Spring Creek. No injuries occurred.

Table 3.49. NCEI Maries County Flash Flood Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2003	1	0	0	0	0
2004	1			0	0
2005	3	0	0	0	0
2006	1	0	0	0	0
2007	2			0	0
2008	7	0	0	1.00K	0
2009	3	0	0	25.00K	0
2011	3	0	0	0	0
2012	3			5.00K	0
2013	6	0	0	500.00K	0
2015	3	0	0	250.00K	0
2016	6	0	0	0	0
2018	2	0	0	0	0
2020	1	0	0	0	0
Total	**42**	**0**	**0**	**781.00K**	**0**

Source: NCEI, data accessed [2/3/23]

Narratives on flash flood events:

1. **07/18/2003**: Brief flooding was also observed on Highway Z east of Vienna.

2. **07/30/2004:** Flash flooding washed out a section of Highway 42 near the community of Belle.

3. **01/05/2005:** Several periods of heavy rain in conjunction with little vegetation over the winter months set the stage for widespread flooding across much of extreme southeast Kansas and southern and central Missouri. In Maries County, numerous roads and low lying areas were inundated and impassable by motorists countywide.

4. **04/20/2005:** Several low water crossings in far southwest Maries County became impassable after heavy thunderstorms affected the area. A section of County Road 628 near Highway BB had several inches of water flowing over the roadway.

5. **06/10/2005**: Thunderstorms caused flash flooding in a couple of areas across Maries County. Sections of County Roads 623 and 621 were inundated.

6. **08/27/2006:** A section of Highway AA near the Little Maries Creek became impassable to motorists from flash flooding.

7. **05/10/2007**: Heavy thunderstorms caused flash flooding in several areas. A few marginally severe hail was also observed. Numerous low water crossings along the Big Maries Creek became impassable to motorists due to flash flooding.

8. **09/25/2007:** A few thunderstorms developed over southwest and central Missouri. These storms produced minor flooding and marginally severe wind gusts. The Little Maries River flooded over a section of a county road in northwest Maries County.

9. **01/07/2008:** An unusual mid-winter tornado outbreak occurred over southwest and central Missouri. 31 tornadoes struck the region within a 15 hour timeframe on 7 January into early

morning 8 January. Two tornadoes intensified to EF-3 status while five tornadoes caused EF-2 damage. All other tornadoes during this outbreak were surveyed and give EF-0 and EF-1 status. Multiple training supercells spawned most of these tornadoes that occurred along the Interstate 44 corridor. Toward the end of this episode, a broken squall line spawned numerous EF-) and EF-1 tornadoes across the southern Missouri Ozarks.

Excessive rainfall caused flash flooding in several areas of Maries County. A couple of specific locations along Highway FF that were impacted include low water crossings at Spring Creek and Mill Creek.

10. **02/17/2008**: Widespread excessive rainfall impacted almost all of extreme southeast Kansas and the Missouri Ozarks during the overnight period of 16 February into 17 February. Widespread rainfall amounts of one to three and a half inches fell. The heaviest amounts fell over the upper White River basin as three and a half inches were observed near Table Rock Lake. Meanwhile areas of the Osage Plains from southeast Kansas into west central Missouri measured around an inch. A section of County Road 827 five miles north of Dixon experienced flash flooding and was impassable to motorists.

11. **03/18/2008:** Excessive rainfall developed over southern Missouri during the evening of 17 March. A line of training convection assumed a position roughly along a line from Anderson to Ozark to Licking. This convection expanded with time, eventually covering nearly all of extreme southeast Kansas and the Missouri Ozarks. Moderate to heavy rain continued into the overnight period and did not stop until the morning of 19 March. Four to five inches of rain fell over Maries County. Major damage to county roads occurred, while all locations that typically experience flooding during periods of heavy rain were flooded. A few sections of Highway 63 became impassable to motorists.

12. **04/03/2008:** Marginally severe thunderstorms produced hail and flash flooding over several counties in southwest and central Missouri. Wet soil conditions from record breaking rainfall caused enhanced runoff leading to an unusual onset of flash flooding. One half of an inch to three quarters of an inch of rain fell over Maries County. Numerous roads and low water crossings within the county experienced flash flooding.

13. **04/10/2008:** Repeated development of storms along and north of an advancing warm front led to a large swath of greater than three inches of rain south of a line from Stockton to West Plains. This excessive rain occurred on wet soil conditions from record rainfall in February and March. One to two inches of rain fell over Maries County. All low areas that typically flood during periods of excessive rainfall were flooded. The Emergency Management Director stated that widespread flash flooding began after approximately one half of an inch of rain occurred.

14. **08/05/2008:** A cluster of severe thunderstorms developed along a west to east oriented cold front during the evening of 5 August. Several observations of large hail and damaging winds occurred from these storms. Nearly five inches of rain fell over a rural area along the Phelps and Maries county line. This excessive rain caused significant flash flooding in this area. Radar estimated rainfall exceeding five inches fell within this area of flash flooding. The Maries County Emergency Management Director surveyed the flooding and described it as major flash flooding. Sections of county roads 444, 442, 440, 521, 523, 527 and 450 were all impassable to motorists.

15. **09/14/2008:** Storm total rainfall amounts ranged from one to six inches during the evening and overnight hours of 13 September into the morning of 14 September. Widespread flooding of small streams, creeks and main stem rivers resulted. Three to five inches of rain fell over Maries

County resulting in widespread flooding of small creeks and streams. Numerous county roads were flooded and all low water crossings were impassable to motorists.

16. **05/08/2009:** An intense squall line impacted extreme southeast Kansas and the Missouri Ozarks with mainly damaging winds. However, 19 tornadoes along with large hail was also observed. Due to the straight line nature of the winds, damage was widespread and intense. Two to four inches of rain fell over Maries County that resulted in widespread flooding of county roads. Several roads, low water crossings and culverts were washed out.

17. **05/27/2009:** A marginally severe thunderstorm impacted Phelps County and Maries County with large hail and damaging winds. Flash flooding also resulted from two to five inches of rain. A small tributary of the Bourbeuse River flooded a section of Highway P just east of its intersection with Highway 63.

18. **06/10/2009:** Widespread strong to severe thunderstorms impacted portions of southeast and central Missouri. The primary hazards with these storms were severe wind gusts that caused damage to trees, power poles and a few structures. Two weak tornadoes also occurred. Excessive rainfall caused flooding over a section of Highway 42, one half of a mile southwest of its intersection with Highway 28. This stream that flooded is a tributary of the Dry Fork Creek.

19. **05/12/2011:** An upper level low over western Kansas combined with a cold front moved into the region and produced severe thunderstorms. Numerous severe storms and a few supercells produced very large hail and high wind gusts as the front moved through the region. Two to two and a half feet of water was flowing over County Road 624 in the vicinity of Maries Creek. Flooding was reported of low water crossings.

20. **07/12/2011:** An upper level disturbance moving across the Ozarks and a stationary front positioned across the Ozarks caused a cluster of strong to severe storms to develop which caused wind damage and localized flash flooding. Excessive rainfall caused flooding to occur along the Little Maries River at the intersection with County Road 634. This low water crossing was impassable to motorists with two feet of swift water flowing over the bridge.

21. **03/15/2012:** A stationary closed off low pressure system over the southern Plains developed several rounds of severe storms which produced large hail and heavy rainfall. A section of Highway 42 was impassable due to flash flooding.

22. **03/17/2012:** The same weather system that began on 3/15/2012 caused a low water crossing to be washed out on County Road 454 making the road impassable. Several other low water crossings were reported to be flooded across Maries County.

23. **04/14/2012:** A stalled out front combined with several upper level disturbances moving across the Ozarks produced several rounds of thunderstorms which produced heavy rainfall and caused flooding. Three feet of water was reported over Farm Road 624 along the Maries River.

24. **05/31/2013:** A slow moving trough across the central portions of the country helped develop several rounds of severe thunderstorms and flash flooding across the Missouri Ozarks. Highway 42 was flooded one half mile west of Highway 28.

25. **06/16/2013:** A weak frontal boundary along with several upper level impulses that moved over the Missouri Ozarks resulted in isolated severe thunderstorms that produced large hail, wind damage and flash flooding. Highway 68 near Highway H was flooded.

26. **08/02/2013:** Multiple boundaries across the Ozarks region, combined with a very moist and unstable air mass, and an upper level shortwave produced significant rainfall across portions of the area. While some wind damage was reported, the primary impact from the storms was areas of significant flooding. Most locations received between one and three inches of rain. However, scattered reports in excess of six inches occurred over several days. The Maries River was reported out of its banks and flowing three to five feet deep over the low water crossing on County Roads 623 and 642.

27. **08/07/2013:** A stalled frontal boundary led to multiple rounds of thunderstorms which rained over the same areas and produced intense rainfall rates and rainfall totals. Most areas received between one and five inches of rainfall with some localized areas receiving up to 20 inches of rainfall in several days. This caused devastating floods and flash floods with some rivers reaching all-time record levels. Joint agencies from the federal, state and local assessed over 18 million dollars in damages to property and infrastructure region-wide. Over 380 homes and over 130 businesses were damaged due to the floods. In Maries County, Highway 42 was impassable near the intersection of Highway T due to flood waters. Highway N was closed due to flooding. Numerous roads were under water and impassable throughout the county. One resident was evacuated from their home on County Road 213 on the northwest side of Vienna. Several high water rescues were performed. Several homes were flooded and low water crossings were damaged.

28. **07/01/2015:** A slow moving front caused multiple rounds of thunderstorms which led to severe weather and flash flooding across the Missouri Ozarks. Numerous roads were closed including Highway 133, Highway DD, Highway BB, and Highway T due to flooding.

29. **12/28/2015:** A slow moving and strong weather system caused several rounds of very heavy and record breaking rainfall to occur across the Missouri Ozarks which led to historic flooding. Numerous low water crossings were flooded. Several county roads and homes sustained flood damage.

30. **08/03/2016:** Several rounds of severe thunderstorms affected the Missouri Ozarks. Heavey rainfall produced flash flooding. The low water crossing Highway 42 was flooded and impassable.

31. **08/05/2016:** Several rounds of severe thunderstorms affected the Missouri Ozarks. Heavy rainfall produced flash flooding. Several inches of water was estimated flowing over Highway 63 north of Vichy and several other areas of Highway 63 between Vichy and Vienna had water over the roadway. Water over the roadway was also reported on Highway 42 west of Vienna. There were multiple county roads across the county that were flooded and impassable.

32. **08/12/2016:** Several rounds of strong to severe thunderstorms caused minor flooding and wind damage reports. Flood water was over Highway 63 and Highway 42.

33. **09/07/2018:** The remnants of Tropical Storm Gordon tracked from the Mississippi Coast into southwest Missouri. Widespread rainfall occurred over the Ozarks Region, with pockets of excessive rainfall leading to flash flooding. The Maries River rose out of its banks and flooded over the roadway at County Road 624, north of Dixon, closing the road.

34. **06/04/2020** A complex of strong to severe thunderstorms that developed over the Central Plains during the evening of the 3rd tracked southeastward into the Missouri Ozarks and southeast Kansas during the early and mid-morning hours of the 4th. The storms produced wind gusts over 60 mph and caused widespread damage to roofs, trees and power lines. County Road 624

was flooded and impassable due to flooding along the Maries River.

Probability of Future Occurrence

From the data obtained from the NCEI[1], there were 15 riverine flood events (**Table 3.48)** over a period of 20 years. This information was utilized to determine the annual average percent probability of riverine flooding (**Table 3.50**). The probability of riverine flooding in Maries County per year is 75 percent (15 events/20 years x 100). Furthermore, data was obtained for flash flooding within the county. Maries County endured 42 flash flooding events (**0**) over a 20 year period. The probability of flash flooding in Maries County per year is 100% (42 events/20 years x 100) with an average of 2.1 events per year (**Table 3.51**).

Table 3.50. Annual Average % Probability of Riverine Flooding in Maries County

Location	Annual Avg. % P	Avg. Number of Events
Maries County	75%	.75

*P = probability; see page 3.24 for definition.

Table 3.51. Annual Average % Probability of Flash Flooding in Maries County

Location	Annual Avg. % P	Avg. Number of Events
Maries County	100%	2.1

*P = probability; see page 3.24 for definition.

Changing Future Conditions Considerations

Generally, annual precipitation increased in the Midwest during the past century (by up to 20% in some locations), with much of the increase driven by intensification of the heaviest rainfalls. This tendency towards more intense precipitation events is projected to continue into the future[2]. As the number of heavy rain events increases, more flooding and pooling water can be expected. The expected increases in rainfall frequency and intensity are likely to put additional stress on natural hydrological systems and community stormwater systems[3].

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 can break loose or sustain a puncture as a result of flooding. 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.

[1] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI
[2] https://nca2014.globalchange.gov/downloads/low/NCA3_Full_Report_18_Midwest_LowRes.pdf
[3] 2018 MO State Hazard Mitigation Plan

Community sanitation to evaluate flood-affected flood 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. Additional information on scour bridges can be found on page 3.16. Floodwaters can also cause erosion undermining roadbeds. In some instances, steep slopes that are saturated with water may cause mud or rockslides onto roadways. These damages 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 a well as present a health hazard.

For the vulnerability analysis of flooding for Maries County, data was obtained from the 2018 Missouri State Hazard Mitigation Plan. The 2018 Plan used the most recent release of Hazus, version 6.0, to model flood vulnerability and estimate flood losses due to the depth of flooding. Additional hazard data inputs were utilized, as available, to perform Hazus Level 2 analyses. This included the extensive use of the FEMA special flood hazard area data and RiskMAP flood risk datasets.

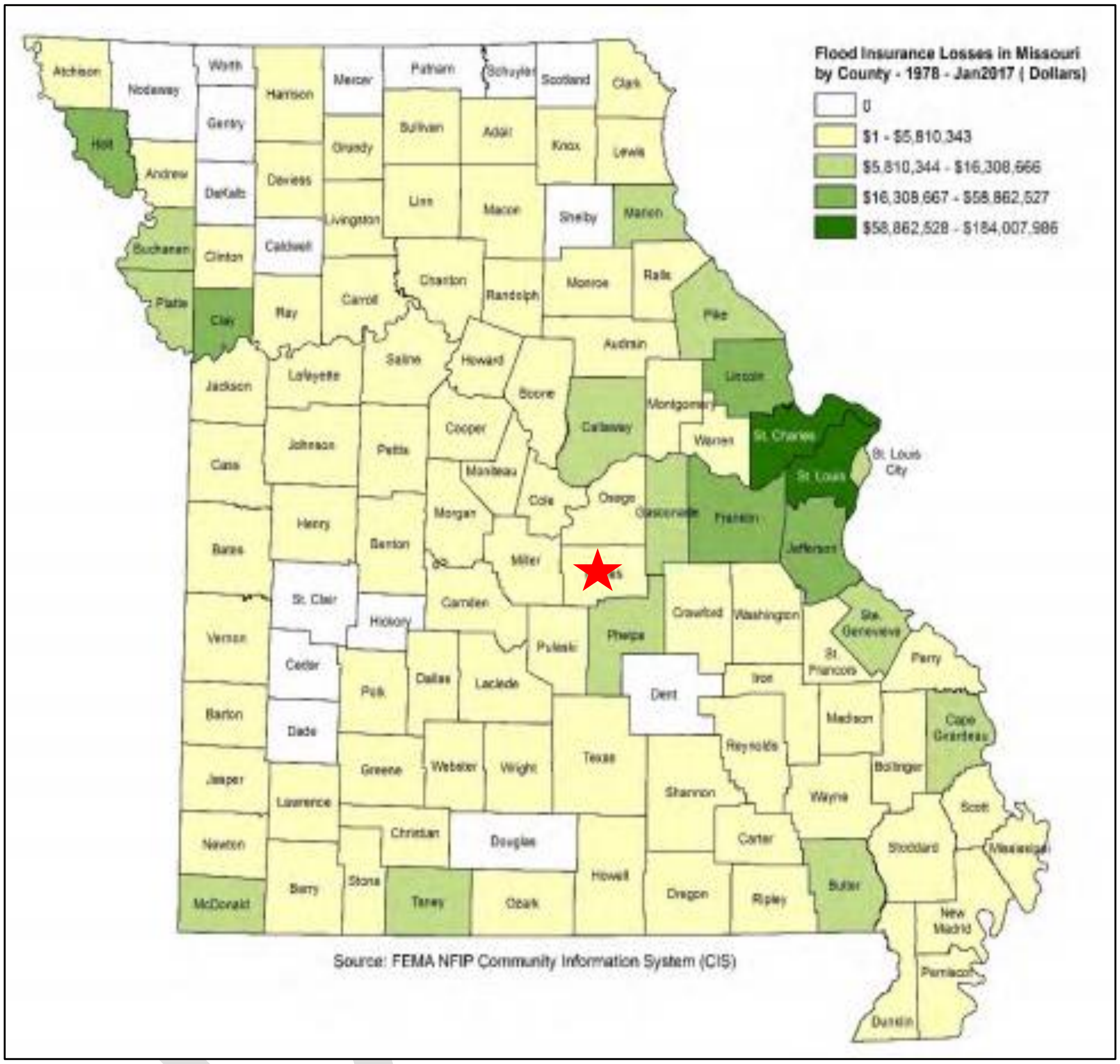
For the Hazus analysis, the flood hazard area and depth of flooding was determined for each county using one of three methods – depending on the data available for that county. Maries County does not have digital FIRMS, but does have RiskMAP flood datasets available. The regulatory special flood hazard area was utilized along with the 1-percent annual chance flood depth grid, a non-regulatory product. Flood depth grids are rasters where depth is calculated as the difference in feet between the water surface elevation and the ground surface elevation.

In addition to the RiskMap flood dataset, SEMA analyzed National Flood Insurance Program (NFIP) flood-loss data to determine areas of Missouri with the greatest flood risk. Missouri flood-loss information was obtained from PIVOT which FEMA's Federal Insurance and Mitigation Administration's new web-based processing system. With this flood-loss data there are limitations noted, including:

- Only losses to participating NFIP communities are represented
- Communities joined the NFIP at various times since 1978
- The number of flood insurance policies in effect may not include all structures at risk to flooding
- Some of the historic loss areas have been mitigated with property buyouts

Figure 3.37 depicts the amount of flood insurance losses in Missouri by county for the period 1978-January 2017. Maries County falls in the $1 - $5,810,343 range of payments.

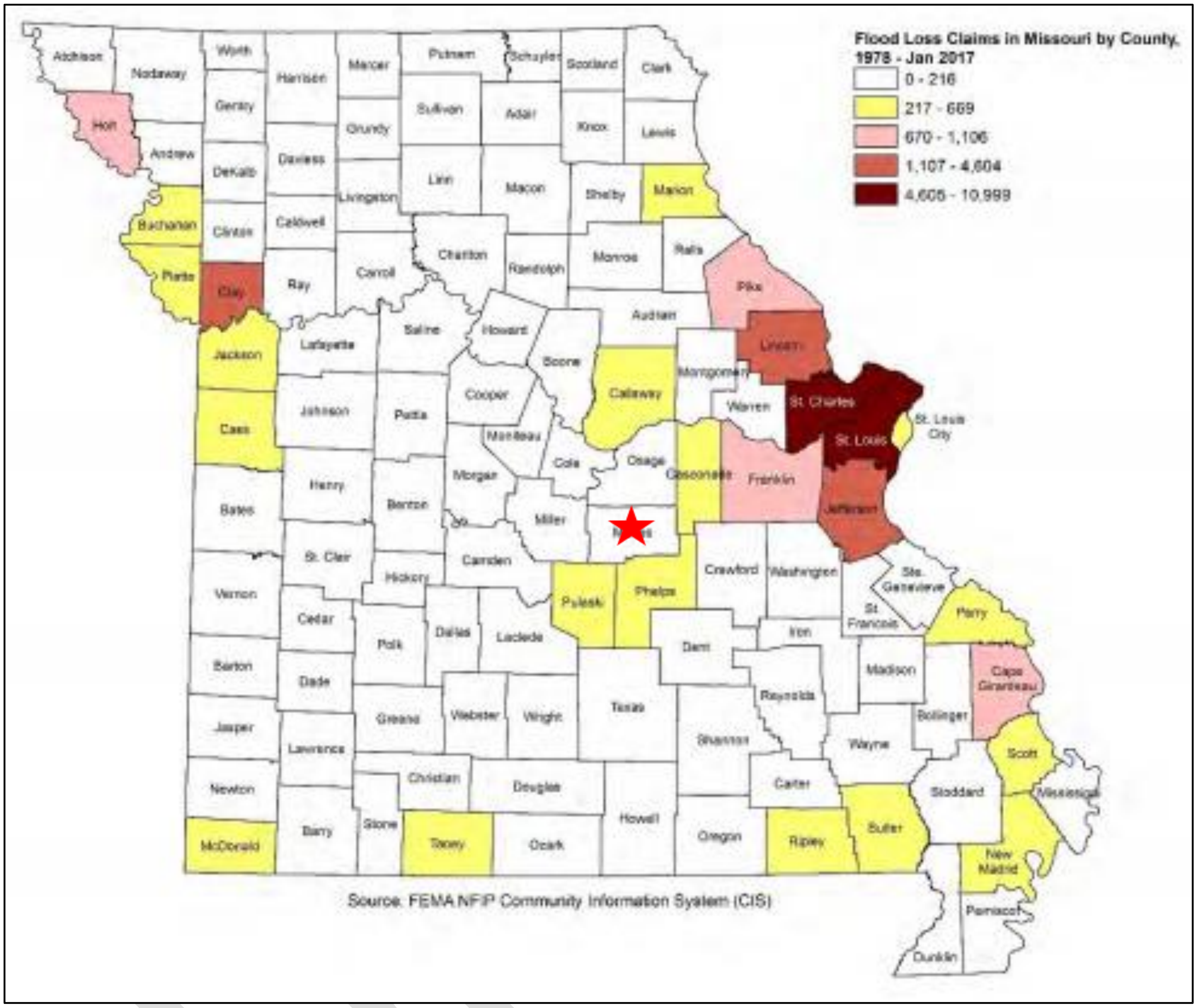
Figure 3.21. Map of Funds Paid Historically for Flood Insurance Losses in Missouri by County 1978 - January 2017



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.38 illustrates the number of flood loss claims made in Missouri during the same time period. Maries County had 0 - 216 claims during that timeframe.

Figure 3.22. Flood Loss Claims in Missouri by County, 1978 – January 2017



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Furthermore, the state analyzed potential loss estimates to flooding. The purpose of the analysis is to determine where flood losses can occur and the degree of severity using consistent methodology. These results were generated from DFIRM data coupled with LiDAR derived building footprints. Additionally, a Hazus analysis provided the number of buildings impacted, estimates of the building repair costs, and the associated loss of building contents and business inventory. **Table 3.52** provides information regarding total direct building loss and income loss to Maries County. **Table 3.53** provides information on exposure of buildings. According to the Missouri Spatial Data Information Service (MSDIS) there are 141 Residential structures at risk of flood. Hazus shows the number of building exposed to flood damage at 180, with 112 potentially substantially damaged in a one percent annual chance of a flood.

Table 3.52. Total Direct Building Loss and Income Loss to Maries County

County-wide Building Loss	Structural Damage	Contents Loss	Inventory Loss	Total Direct Loss	Total Income Loss	Total Direct and Income Loss	Calc. Loss Ratio
$980,656,500	$13,085,600	$7,409,300	$130,000	$20,624,900	$12,415,100	$33,040,000	1.33%

Source: 2023 Missouri State Hazard Mitigation Plan

Table 3.53. Maries County Structures Exposure

# MSDIS Residential Structures Exposed	# Hazus Buildings Exposed	# Substantially Damaged
141	180	112

Source: 2023 Missouri State Hazard Mitigation Plan

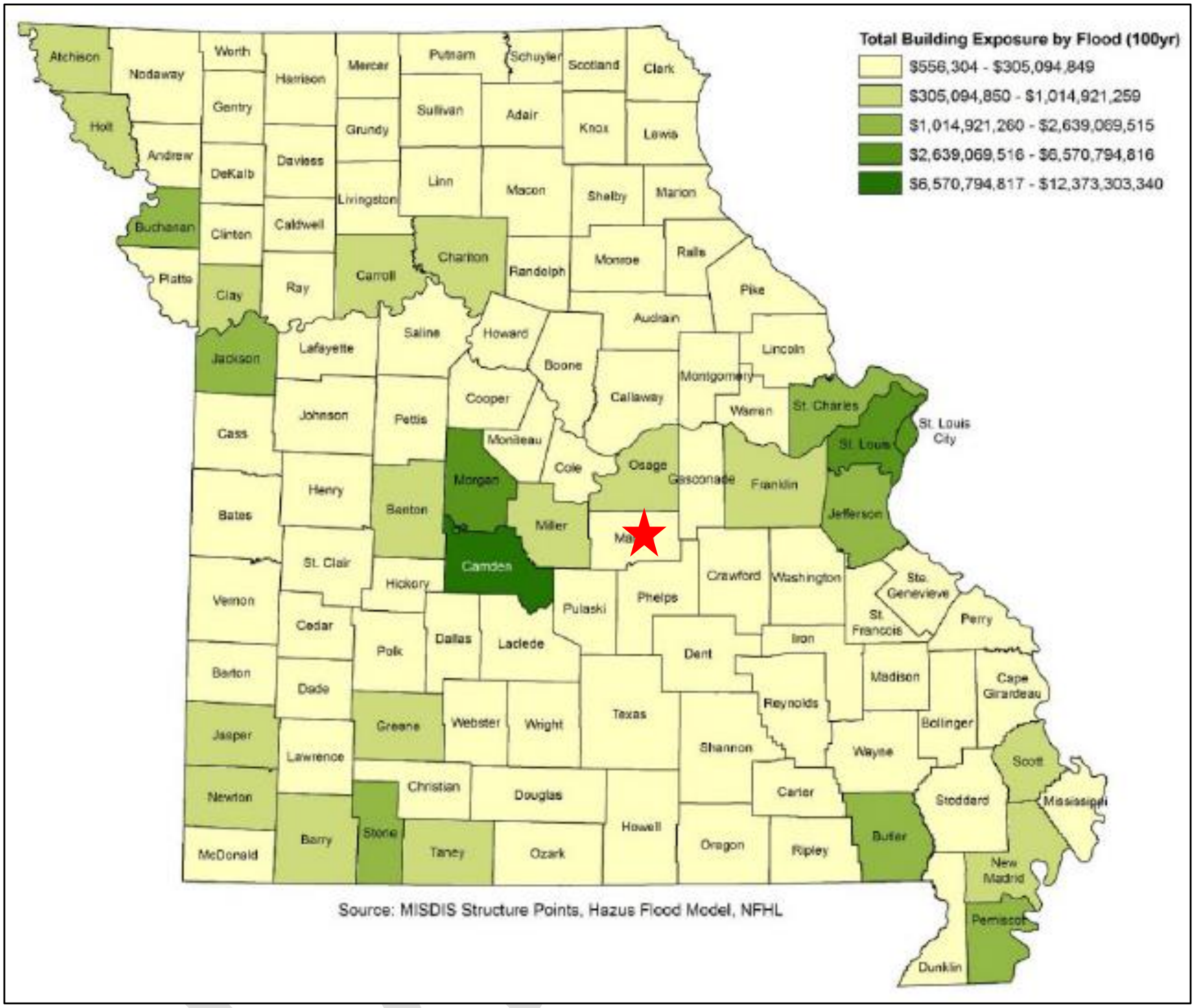
Table 3.54 presents the results of the primary indicators for Maries County – Residential, agricultural, commercial, education, government and industrial. This table illustrates the number of affected structures and estimated losses. **Figure 3.23** shows the building exposure for the Hazus Base-Flood Scenario. **Figure 3.40** illustrates the building impacted ratio for a 100-year flood.

Table 3.54. Maries County Total Building Loss and Income Loss

# Residential Structures	Total $$ of Loss	# Agriculture Structures	Total $$ of Loss	# Commercial Structures	Total $$ of Loss	# of Education Structures	Total $$ of Loss	# of Government Structures	Total $$ of Loss	# of Industrial Structures	Total $$ of Loss	Total # Population Affected	Total Loss – Hazus Layer
141	$22,837,804	32	$657,636	7	$3,059460	0	$0	0	$0	0	$0	524	$26,554,900

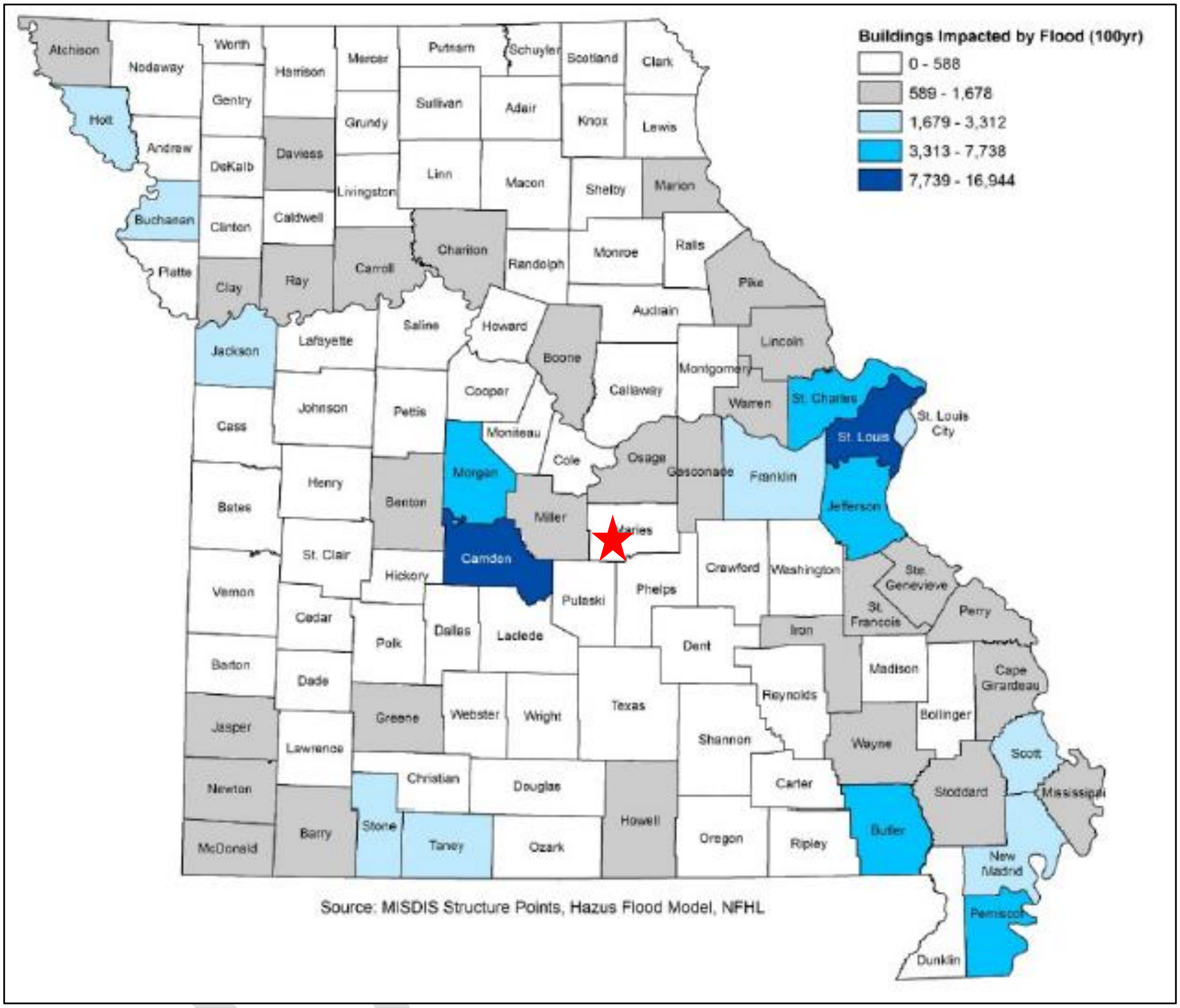
Source: 2023 Missouri State Hazard Mitigation Plan

Figure 3.23. Hazus Countywide Base-Flood Scenarios: Building Exposure



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.24. Hazus Countywide Base-Flood Scenarios: Building Impacted Ratio



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

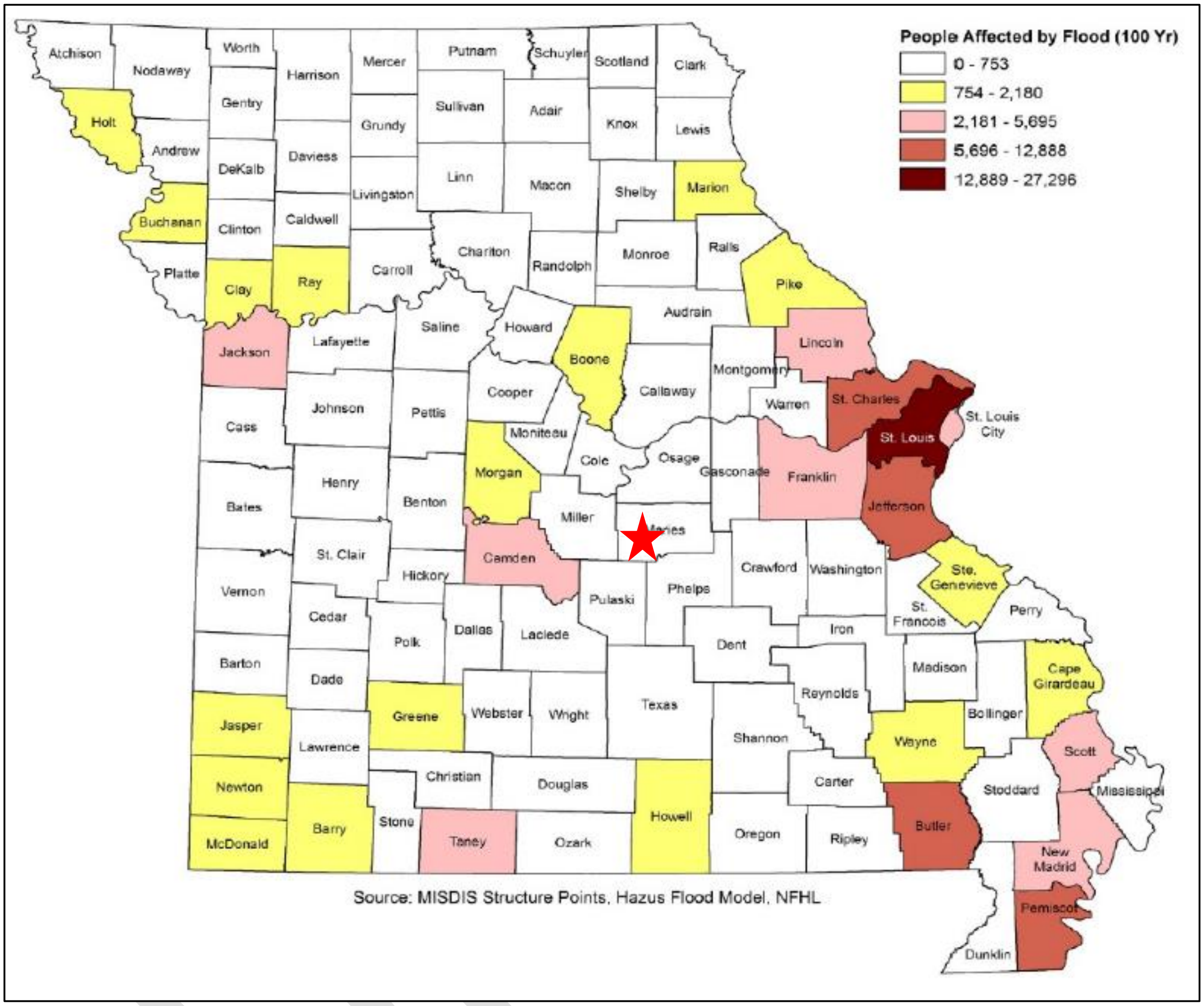
Lastly, the State determined the estimated number of displaced households and need for shelters within Maries County in the event of a 100 year flood. **Table 3.55** and **Figure 3.25** illustrate this information.

Table 3.55. Estimated Displaced People and Shelter Needs for Maries County

County	Displaced People	Displaced Population Requiring Shelter
Maries	524	111

Source: 2023 Missouri State Hazard Mitigation Plan

Figure 3.25. Hazus Countywide Base-Flood Scenarios: Displaced People



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Potential Losses to Existing Development

According to the HAZUS model, Maries County has a building loss ratio of 1.33 percent for countywide base-flood scenarios. However, the unprecedented flooding in 2013 suggests that future flood events could cause significant disruption in the county. With the annual average probability for flooding and for flash floods at 100 percent, Maries County's existing development is vulnerable to flood. Developments located in low-lying areas, near rivers or streams, or where drainage systems are not adequate are prone to flooding.

Impact of Previous and Future Development

Impact of future development is correlated to floodplain management and regulations set forth by the county and jurisdictions. Future development within low-lying areas near rivers and streams, or where interior drainage systems are not adequate to provide drainage during heavy rainfall events should be avoided. Additionally, future development would also increase impervious surface causing additional water run-off and drainage problems during heavy rainfall events.

Hazard Summary by Jurisdiction

Vulnerability to flooding varies slightly across the planning area. The jurisdictions most vulnerable to flooding include the city of Vienna and the unincorporated community of Shantytown. Since 2003 there have been 57 Incidents of flooding or flash flooding in Maries County; 13 incidents in Vienna; and 10 incidents in and around Shantytown (**Table 3.48**). There have been no injuries or deaths associated with floods during this time period. The county has 16 repetitive loss and seven severe repetitive loss properties.

Those areas at greatest risk to riverine flooding are those populated areas along the Gasconade and Maries rivers and their tributaries. The Nagogami Resort development on the border with Phelps County is one area where there is a concentration of homes located in the floodplain and this area frequently floods. Although landowners are encouraged to elevate their homes, the area is not eligible for a floodplain buyout because the land is leased. A similar situation exists at the Moreland Resort that is located between Vichy and Vienna on the Gasconade River.

Due to the rural nature of Maries County and topography that includes a large number of rivers and tributaries, the county has a significant number of low water crossings and gravel roads that are vulnerable to flooding and flood damage. In regards to county infrastructure, there are a number of county roads and low water crossings that regularly flood – MR(Maries Road) 210, MR219, MR501, MR508, MR510, MR513, MR601, MR 614, MR625, MR628, MR634, MR636, and MR639 . In addition, there are a number of state highways in the county that are vulnerable to flooding and closure – highways 133, DD, BB, T, Z, N, AA, FF and P. Larger highways like 63, 68 and 42 also have areas that are vulnerable to flooding and damage from water running over the roadway.

A very small portion of the City of Vienna resides in a SFHA. The preliminary data developed by the RiskMAP project shows 5 structures within the city of Vienna located within a SFHA. Additionally, according to the jurisdictional questionnaires, school districts do not have assets located within an identified Special Flood Hazard Area.

The city of Belle is not a member of the NFIP and does not have any identified special flood hazard areas within the city boundaries. But the community is still vulnerable to flash floods and affected by closures to roads around the city.

Problem Statement

Maries County and the city of Vienna has adopted a Floodplain Management Ordinance that regulates construction in the floodplain. Local governments should make a strong effort to further improve emergency warning systems to ensure that future deaths and injuries do not occur. Local governments should consider making improvements to roads and low water crossings that consistently flood by placing them on a hazard mitigation projects list, and actively seek funding to successfully complete the projects.

3.4.6 Land Subsidence/Sinkholes

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.5, Page 3.218
  https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- http://www.dnr.mo.gov/geology/geosrv/envgeo/sinkholes.htm
- http://www.businessinsider.com/where-youll-be-swallowed-by-a-sinkhole-2013-3
- http://water.usgs.gov/edu/sinkholes.html
- http://pubs.usgs.gov/fs/2007/3060/
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  http://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9NOu-oPFWi9hkst/view - User Guide
    - Total number of sinkholes by County
    - Vulnerability to sinkholes by County
    - Total number of mines by County
    - Vulnerability to mines by County
    - Total value of structures impacted by sinkholes by County
    - Total population impacted by sinkholes by County

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 collapse. 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.

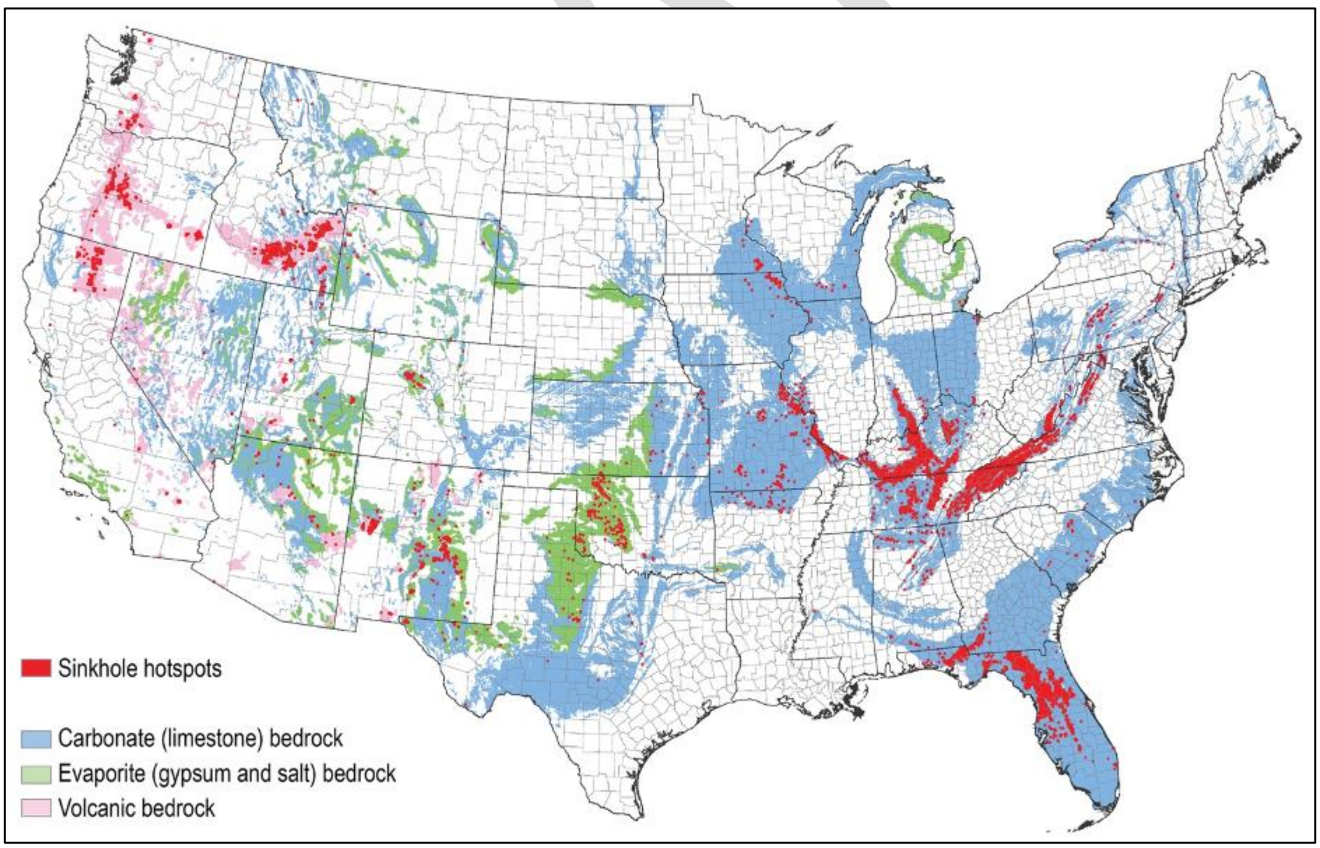
According to the U.S. Geological Survey (USGS), the most damage from sinkholes tends to occur in

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 other have vertical walls. Some hold water and form natural ponds.

Geographic Location

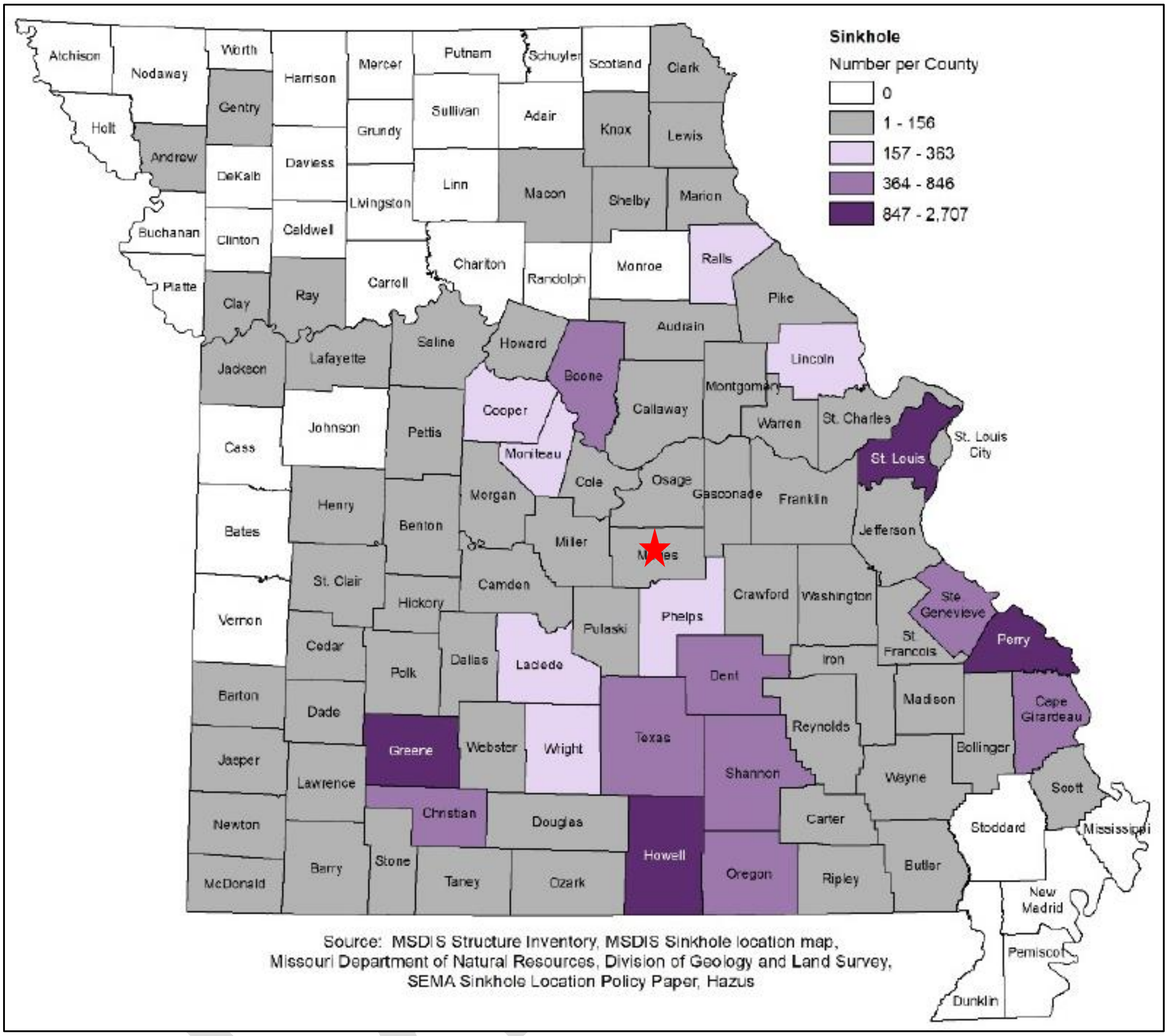
Error! Reference source not found. depicts karst topography across the United States. Missouri's k arst topography is comprised of carbonate rocks such as limestone, dolomite, and marble. Variability in areas prone to sinkholes does not differ greatly across the county. According to the 2023 Missouri State Hazard Mitigation Plan there are 16 sinkholes that have been recorded within Maries County (**Figure 3.27**). In addition, the Plan states that there are 286 mines in Maries County - as shown in **Figure 3.28**. According to the Missouri Department of Natural Resources, Maries County primarily produces refractory clay but has deposits of barite with lead, sedimentary limonite and hematite. Activities such as mining or drilling are known to be responsible for the formation of sinkholes.

Figure 3.26. Karst Map of the Conterminous United States - 2020



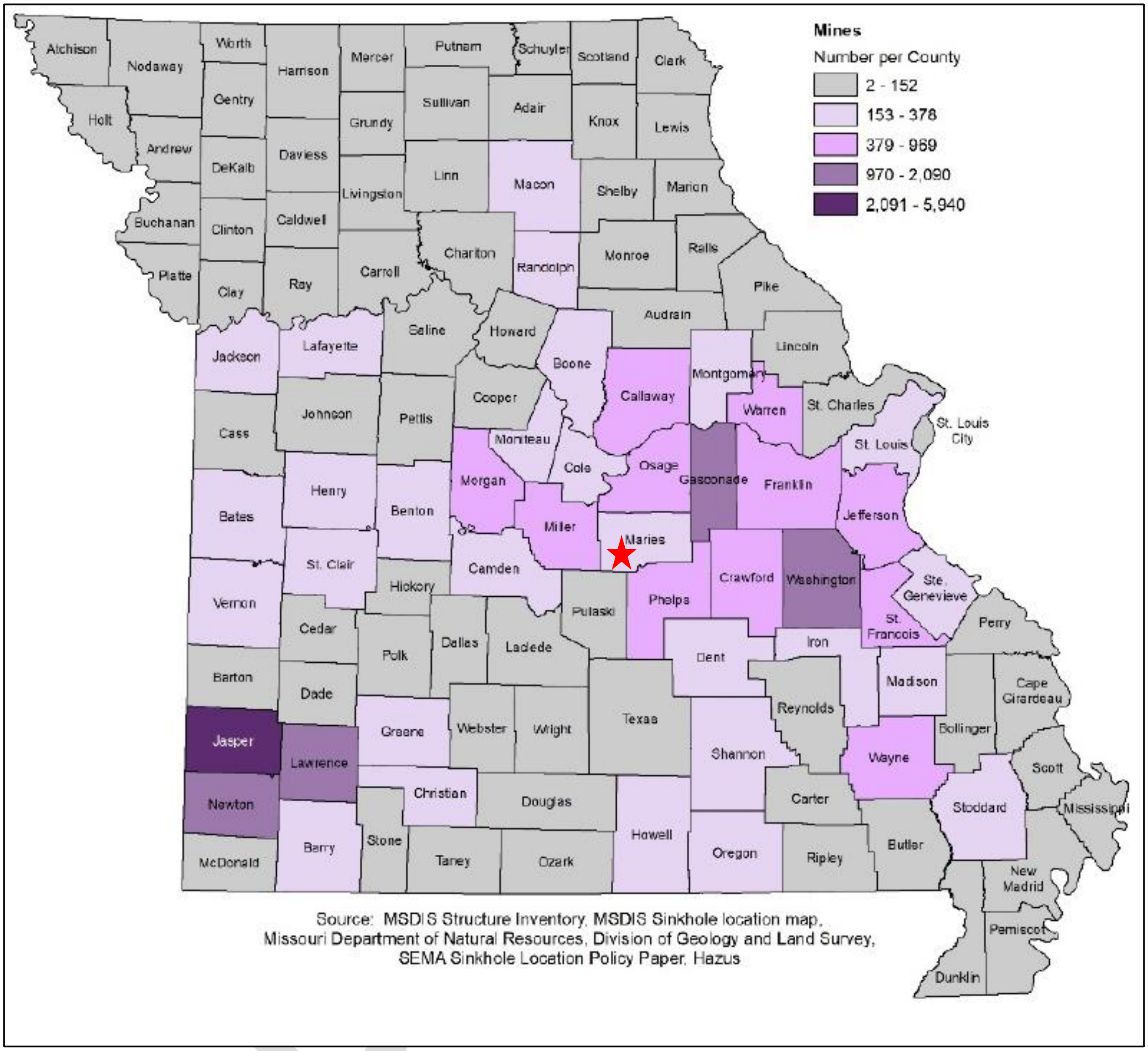
Source: https://www.usgs.gov/media/images/karst-map-conterminous-united-states-2020

Figure 3.27. Sinkholes Counts per County



*Source: 2023 Missouri Hazard Mitigation Plan; *Red star indicates Maries County*

Figure 3.28. Mines Counts Per County



*Source: 2023 Missouri Hazard Mitigation Plan; *Red star indicates Maries County*

Severity/Magnitude/Extent

Unlike earthquakes or other geologic hazards, there currently is no scale for measuring or determining the severity of sinkholes. However, geological and mining parameters can affect the magnitude and extent of sinkhole subsidence. As previously noted, natural sinkholes develop in areas where the rock below the surface is limestone, carbonate rock, salt beds or any type of rock that can naturally be dissolved by groundwater circulating through it. Artificial sinkholes form due to groundwater pumping, water main and sewer collapses and mine collapses.[1]

[1] 2018 Missouri Hazard Mitigation Plan

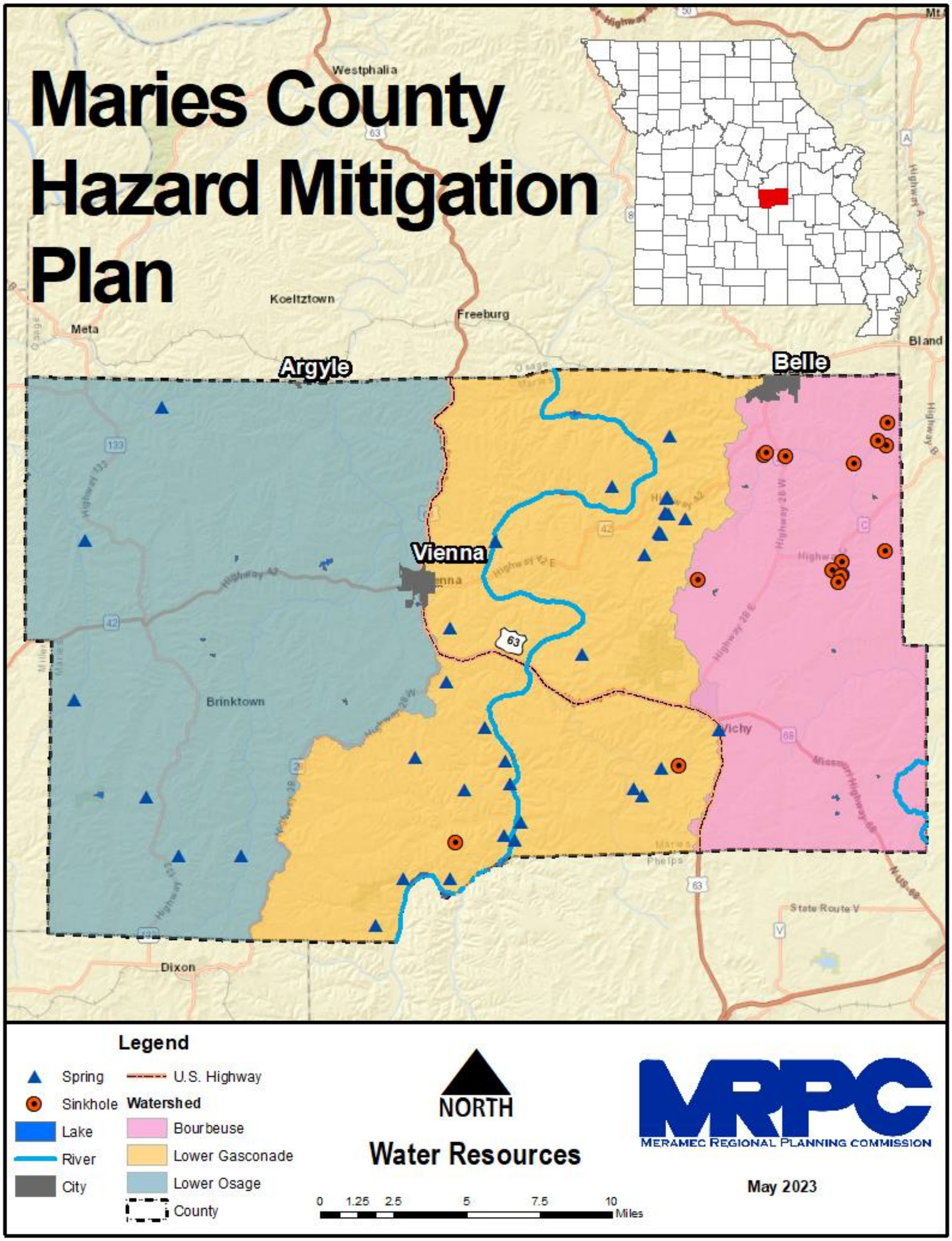
Sinkholes vary in size and location, and these variances will determine the impact of the hazard. A sinkhole could result in the loss of a personal vehicle, a building collapse, or damage to infrastructure such as roads, water, or sewer lines. Groundwater contamination is also possible from a sinkhole.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

The 2023 State Plan mentions 15 documented sinkhole “notable events” that have occurred since 2004. The plan stated that sinkholes are common to Missouri and the probability is high that they will occur in the future. To date, Missouri sinkholes have rarely had major impacts on development, nor have they caused serious damage.

Previous Occurrences

Sinkhole formation is a regular occurrence in Missouri, but rarely are events of any significance. However, they have been occasional damages related to sinkholes. There are sinkholes and sinkhole areas in Maries County however, there have been no recorded incidents of death or damage. There are no recorded sinkholes in either the city of Vienna or the city of Belle. The majority of recorded sinkholes are located in rural, unincorporated areas in the northeast part of the county.

Figure 3.29. Maries County Watershed/Water Resources



Probability of Future Occurrence

Due to the lack of data for previous sinkhole events in Maries County, the probability of future occurrence could not be calculated.

Changing Future Conditions Considerations

Climate models predict both an increase in the length of dry periods as well as an increase in the severity of the heaviest rainfall events. This leads to the prime conditions for sinkhole formation: low levels of groundwater due to extended drought combined with a heavy influx of rainfall.

Vulnerability

Vulnerability Overview

Unfortunately, no statistics are available for the number of subsurface locations that may potentially collapse in the future, forming a sinkhole. Sinkholes vary in size and location. These factors will determine the impact of the hazard, which could manifest as the loss of a personal vehicle, a building collapse or damage to infrastructure such as roads, water or sewer lines. Groundwater contamination is also a possible impact of a sinkhole. Because of the relationship of sinkholes to groundwater, pollutants captured in sinkholes (or dumped) can affect a community's groundwater system.

A statewide sinkhole inventory has been created by MoDNR's Missouri Geological Survey that will be used in addition to new data being developed for some newly mapped floodplain areas. The new data is being developed using the methods outlined in the Missouri Sinkhole Analysis Policy paper "Analysis and Communication of Flood Risk for Sinkholes in Missouri" funded in 2016 by SEMA. These inventories are polygon features which will be used for count analysis within ArcGIS.

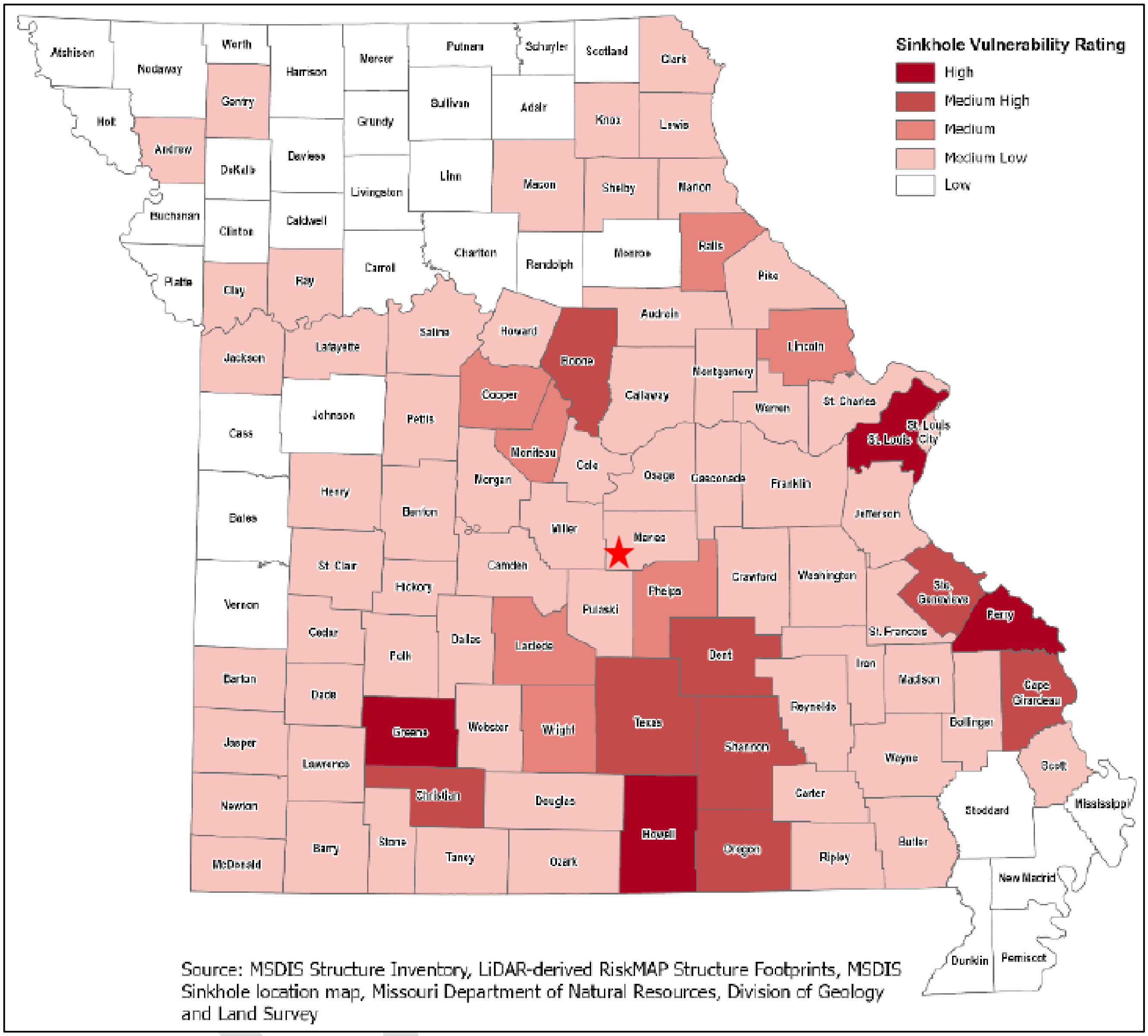
The sinkhole hazard layer was used in conjunction with the MSDIS structure file and LiDAR-derived RiskMAP structure footprints to determine structures that fall within sinkhole areas as well as structures that are within a buffered distance of 50 feet of sinkholes. Based on natural breaks in the data, a rating value of 5 categories from low to high was assigned. According to the state plan, if a county has 1-156 sinkholes, the risk is considered 2 – medium-low. See **Table 3.56**. and **Figure 3.30** further illustrate the sinkhole values.

Table 3.56. Sinkhole/Mine Rating Values for Maries County

Factor	1 (Low)	2 (Medium-low)	3(Medium)	4 (Medium-high)	5 (High)
Sinkholes per county	0	1-156	157-363	364-846	847-2707

Source: 2023 Missouri Hazard Mitigation Plan

Figure 3.30. Sinkhole Rating Value by County



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

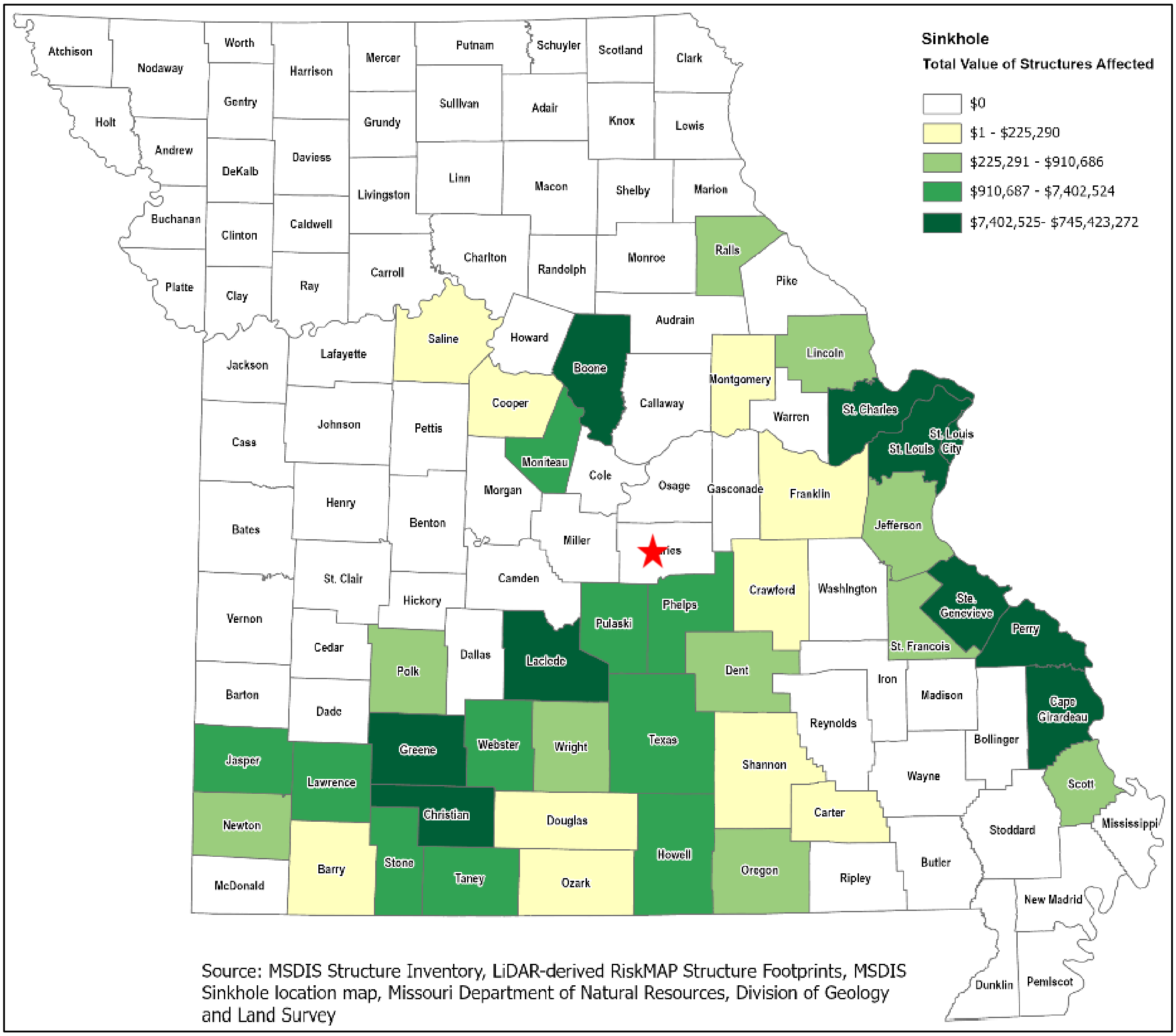
Potential Losses to Existing Development

The most likely type of damage to occur in conjunction with a sinkhole collapse is property damage related to foundation disturbance. Signs include cracks in interior and exterior walls; doors and windows that no longer sit square or open and close properly; depressions forming in the yard; cracks in the street, sidewalk, foundation or driveway; and turbidity in local well water. All of these can be early indicators that a sinkhole is forming in the vicinity[1]. In the event of a sudden collapse, an open sinkhole can form in a matter of minutes and swallow lawns, automobiles, and homes. This has occurred in some parts of Missouri, particularly in the southwest part of the state, but there have been no dramatic Incidents like this in Maries County.

[1] http://sinkhole.org/commonsigns.php

The 2023 Missouri Hazard Mitigation Plan devised a method of estimating potential losses using GIS data. **Figure 3.31** shows the ranking of structures that could potentially be impacted by sinkholes by county. This map shows that Maries County has $0 value of structures affected.

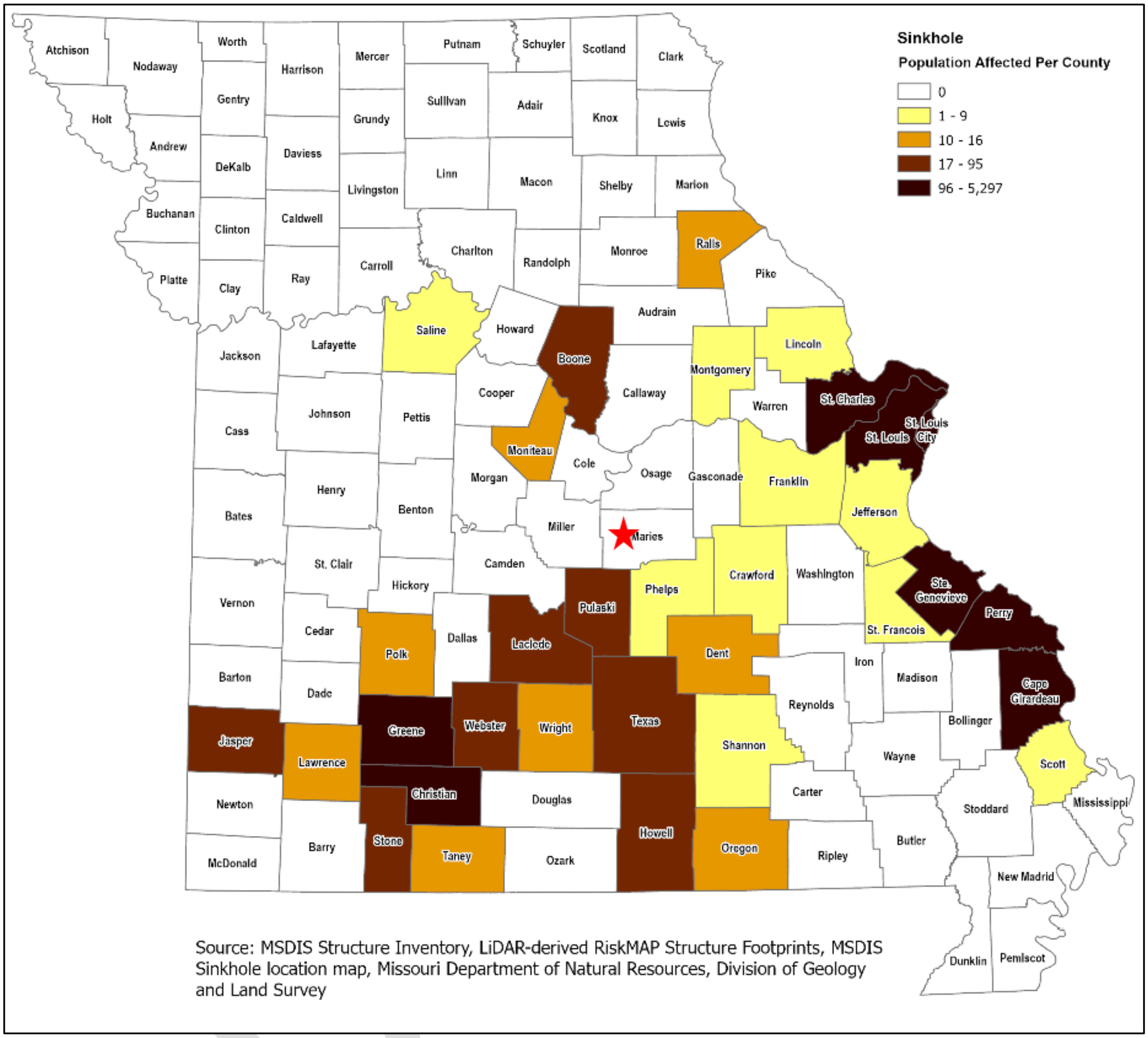
Figure 3.31. Ranking of Structures Potentially Impacted by Sinkholes by County



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.32 shows the population potentially impacted by sinkholes and again, Maries County shows that one to 0 people are expected to be affected by sinkholes.

Figure 3.32. Ranking of Population Potentially Impacted by Sinkholes by County



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Impact of Previous and Future Development

Future development over or near abandoned mines and in locations at risk of sinkhole formation will increase the hazard vulnerability. Information regarding regulations limiting construction near sinkholes is very limited. According to the state plan, Maries County's risk in regards to these hazards is low.

Hazard Summary by Jurisdiction

According to the state plan, Maries County's sinkhole rating is medium low. Based on the location of known sinkholes, the communities and school districts have less vulnerability than the unincorporated areas of the county. As there are no documented sinkholes within the two communities, the jurisdiction most likely to be impacted by sinkholes is unincorporated Maries County. All school district facilities are located within the two communities and so are also at lower risk than some areas of the county. Information provided by the Missouri Department of Natural Resources indicates that most documented sinkholes are located in rural areas in the northeast quarter of the county.

Problem Statement

Sinkholes and sinkhole/mining areas are well documented by both the US Geological Survey and the Missouri Department of Natural Resources Geologic Resources Section. The risk of sinkhole collapse can be lessened by avoiding the construction of structures in these areas and avoiding those activities that significantly alter the local hydrology, such as drilling and mining. In addition, communities should avoid leaking water and sewer lines through appropriate maintenance and monitoring. Local residents should be educated on the risks associated with sinkholes and mines and advised to avoid placing themselves and their property in danger by building in sinkhole/mining areas. Communities with building codes should include prohibitions on building in known sinkhole/mining areas.

3.4.7 Severe Thunderstorms Including High Winds, Hail, and Lightning

Some Specific Sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.8, Page 3.280 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- FEMA 320, Taking Shelter from the Storm, 3rd edition, http://www.weather.gov/media/bis/FEMA_SafeRoom.pdf
- Lightning Map, National Weather Service, https://www.vaisala.com/sites/default/files/documents/WEA-MET-Annual-Lightning-Report-2020-B212260EN-A.pdf
- Death and injury statistics from lightning strikes, National Weather Service.
- Wind Zones in the U.S. map, FEMA, https://www.fema.gov/pdf/library/ism2_s1.pdf;
- Annual Windstorm Probability (65+knots) map U.S. 1980-1994, NSSL, http://www.nssl.noaa.gov/users/brooks/public_html/bigwind.gif
- Hailstorm intensity scale, The Tornado and Storm Research Organization (TORRO), https://www.torro.org.uk/research/hail/hscale;
- NCEI data;
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss;
- National Severe Storms Laboratory – hail map, http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif
- MSDIS Structure Inventory and All Hazard Risk Dataset (available in both GIS and Excel format) https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  http://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Average annual high wind events by County
  - Average annual hail events by County
  - Average annual lightning events by County
  - Vulnerability to severe thunderstorm event by County
  - Annualized property loss for high wind events by County
  - Annualized property loss for lightning events by County
  - Annualized property loss ratio for high wind events by County
  - Annualized property loss ratio for hail events by County
  - Annualized property loss ratio for lightning events by County

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 (**Section 3.4.5**) and tornadoes (**Section 3.4.9**)

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 has been known to fall more than 10 miles away from the rainfall area. Thunder is simply the sound that lightning makes. Lightning is a huge discharge of electricity that shoots through the air causing vibrations and creating the sound of thunder.

Hail

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

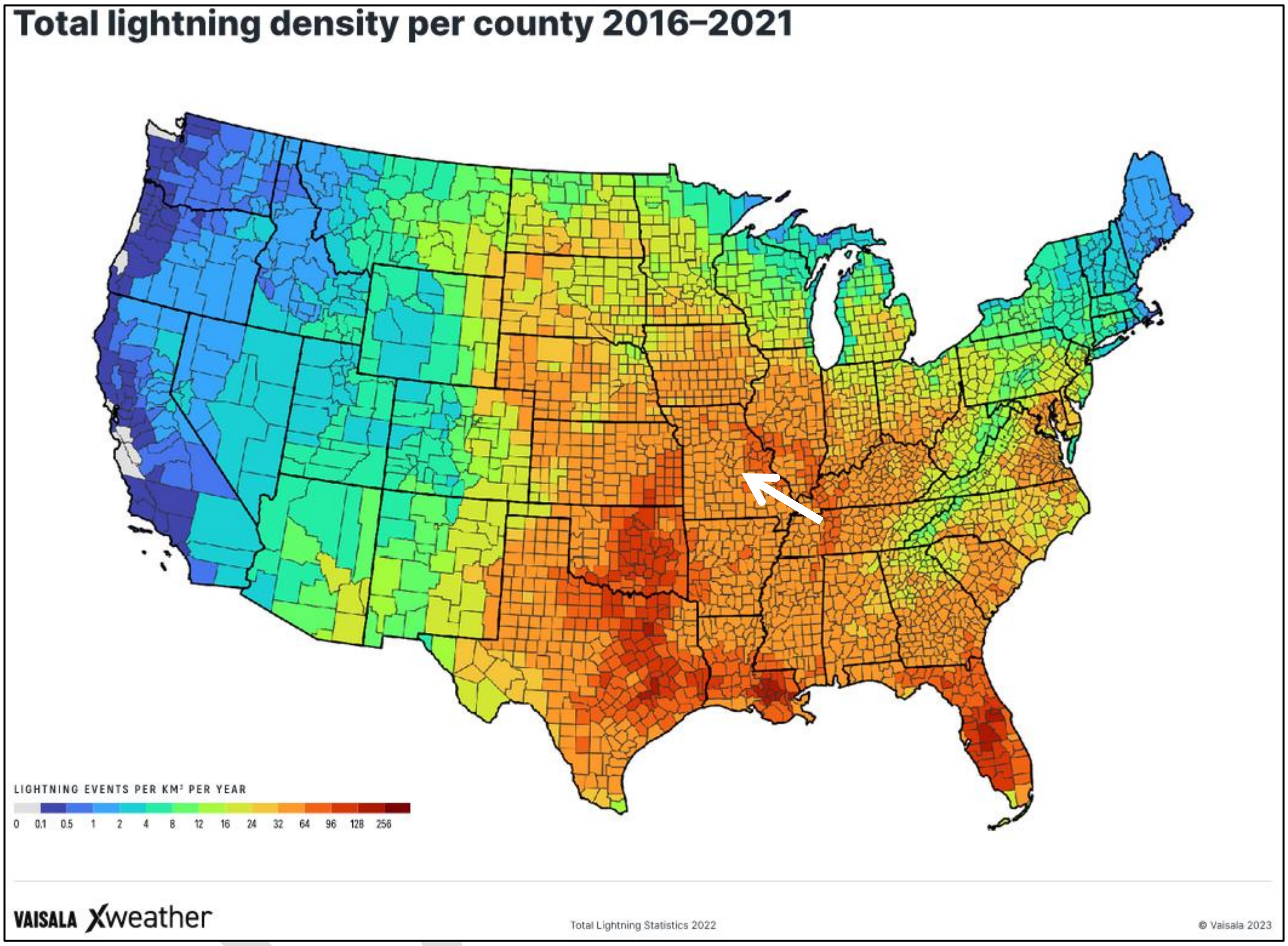
At the time when the updraft can no longer support the hailstone, it will fall down to the earth. For example, a ¼" diameter or pea sized hail requires updrafts of 24 miles per hour, while a 2 ¾" diameter or baseball sized hail requires an updraft of 81 miles per hour. According to the NOAA, the largest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

Geographic Location

Thunderstorms, high winds, hail, and lightning events are an area-wide hazard that can take place anywhere across the county. Furthermore, while these events do not vary greatly across the planning area; they are more frequently reported in urbanized areas. Additionally, densely developed urban areas are more likely to experience damaging events.

Figure 3.33 depicts the location and frequency of lightning in Missouri. Additionally, the map indicates that the flash density of Maries County ranges between 32 and 64 flashes per square kilometer per year.

Figure 3.33. Location and Frequency of Lightning in Missouri



Source: National Weather Service, https://indd.adobe.com/view/d0591066-471e-41b9-83e1-4dc937aaeb96 * Maries County is indicated by a white arrow.

There are four wind zones that are characterized across the United States. These zones range from Zone I to Zone IV. All of Missouri as well as most of the Midwest fall within Zone IV. Within Zone IV, winds can reach up to 250 mph (**Figure 3.34**).

Figure 3.34. Wind Zones in the United States

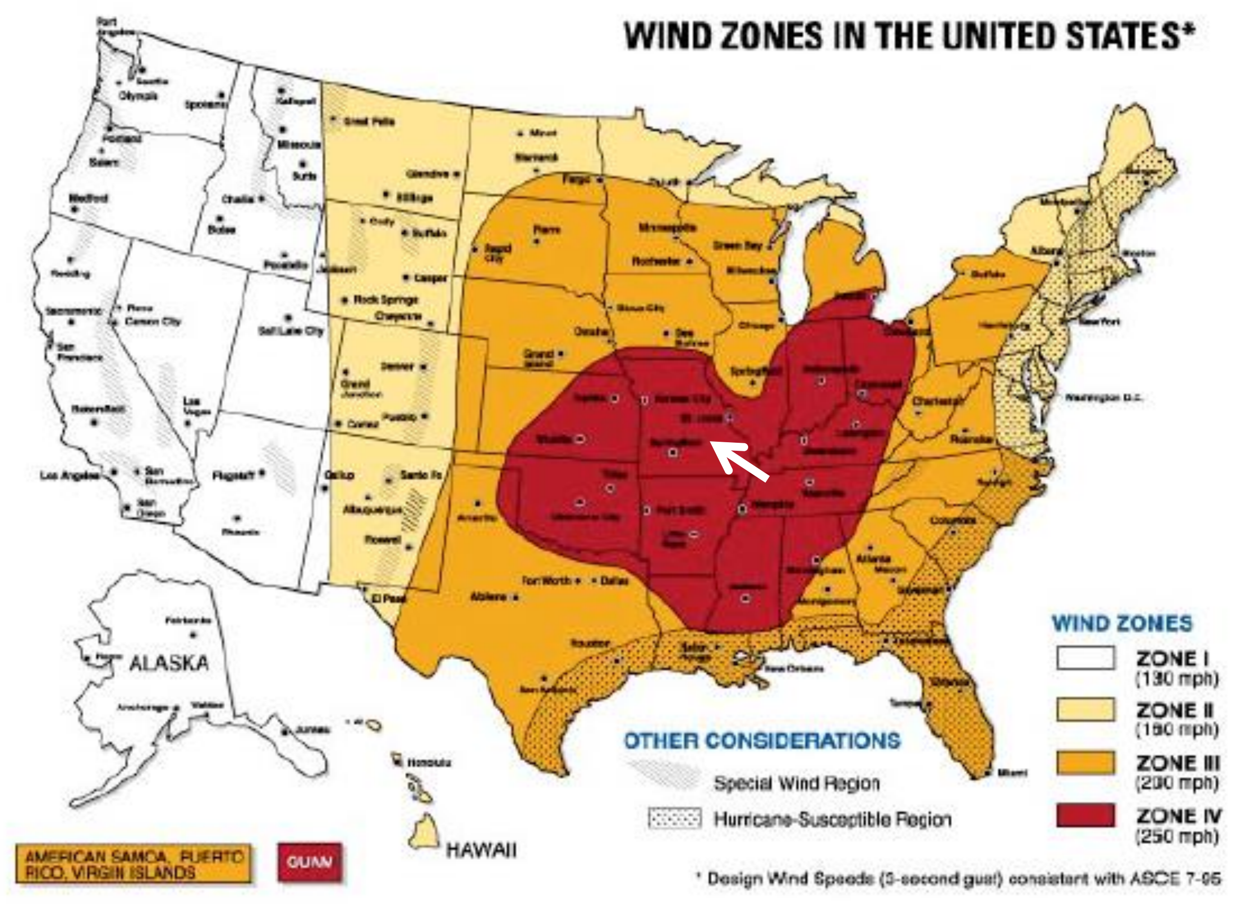


Figure I.2 Wind zones in the United States

Source: FEMA 320, Taking Shelter from the Storm, 3rd edition, https://www.fema.gov/pdf/library/ism2_s1.pdf
**Maries County is indicated by a white arrow.*

Severity/Magnitude/Extent

Based on information provided by the Tornado and Storm Research Organization (TORRO), **Table 3.57** below describes typical damage impacts of the various sizes of hail.

Table 3.57. Tornado and Storm Research Organization Hailstorm Intensity Scale

Intensity Category	Diameter (mm)	DiameterSize (inches) Description		Typical Damage Impacts
Hard Hail	5	0.2	Pea	No damage
Potentially Damaging	5 - 15	0.2 - 0.6	Mothball	Slight general damage to plants, crops
Significant	10 - 20	0.4 - 0.8	Marble, grape	Significant damage to fruit, crops, vegetation
Severe	20 - 30	0.8 - 1.2	Walnut	Severe damage to fruit and crops, damage to glass, plastic structures, paint and wood scored

Severe	25 - 40	1.0 – 1.6	Pigeon's egg > squash ball	Widespread glass damage, vehicle bodywork damage
Destructive	30 – 50	1.2 – 2.0	Golf ball > pullet's egg	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
Destructive	40 - 60	1.6 - 2.4	Hen's egg	Bodywork of grounded aircraft dented, brick walls pitted
Destructive	50 – 75	2.0 – 3.0	Tennis ball > cricket ball	Severe roof damage, risk of serious injuries
Destructive	60 – 90	2.4 – 3.5	Large orange > soft ball	Severe damage to aircraft bodywork
Super Hailstorms	75 – 100	3.0 – 3.9	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.
Super Hailstorms	>100	3.9+	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. https://www.torro.org.uk/research/hail/hscale

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

Due to the lack of available parameters, heavy rain is utilized in the place of thunderstorms in **0**. Moreover, thunderstorm wind and strong wind was included with high winds. NCEI data was obtained for lightning, and hail events between 2003 and 2022 as well (**Table 3.59**, **Table 3.60,** and **Table 3.59).** However, 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.

Table 3.58. NCEI Maries County Heavy Rain Events Summary, 2003 to 2022

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Rainfall (Inch)
2018	2	0	0	0	4.28
2019	2	0	0	0	5.33
Total	**4**	**0**	**0**	**0**	**-**

Source: NCEI, data accessed [2/7/2023]

Table 3.59. NCEI Maries County High Wind Events Summary, 2003 to 2022 (Thunderstorm)

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Estimated Gust (kts.)
2003	5	0	0	0	65
2004	2	0	0	0	55
2005	5	0	0	2K	60
2006	1	0	0	0	50
2007	2	0	0	20K	54
2008	3	0	0	4K	55
2009	2	0	0	12K	50
2010	2	0	0	35K	61
2011	4	0	0	3K	52
2012	2	0	0	0	52
2013	2	0	0	0	52
2014	2	0	0	0	52
2015	4	0	0	10K	52
2016	2	0	0	0	53
2017	3	0	0	5K	52
2019	2	0	0	0	52
2020	1	0	0	50K	52
2021	5	0	0	0	57
2022	1	0	0	10K	52
Total	**55**	**0**	**0**	**151K**	**-**

Source: NCEI, data accessed [2/7/2023]

Table 3.60. NCEI Maries County Lightning Events Summary, 2003 to 2022

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damage
-	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**

Source: NCEI, data accessed [2/7/2023

Table 3.61. NCEI Maries County Hail Events Summary, 2003 to 2022

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Hail Size (inch)
2003	6	0	0	0	1.00
2004	7	0	0	0	4.50
2005	5	0	0	0	1.25
2006	6	0	0	0	1.00
2007	1	0	0	0	0.75
2008	5	0	0	0	1.75
2011	5	0	0	0	1.25
2012	8	0	0	0	1.75
2013	4	0	0	0	1.75
2016	3	0	0	0	1.50
2017	1	0	0	0	1.00
2019	1	0	0	0	1.00
2020	1	0	0	0	0.88
2022	1	0	0	0	0.88
Total	54	**0**	**0**	**0**	**-**

Source: NCEI, data accessed [2/7/2023]

Agriculture is an important piece of the economy for Maries County. The table below (**0**) summarize past crop damages as indicated by crop insurance claims. The table illustrates the magnitude of the impact on the planning area's agricultural economy. It should be noted that the USDA Risk Management Agency data does not align directly with the breakdown of hazards listed here. The claims database only listed "Hail", "Excessive Moisture/Precipitation/ Rain", and "Wind/Excessive Wind" as causes of loss categories that align with this hazard. Between 2003 and 2022 a total of 94 insurance claims were paid out for damages due to excessive moisture, precipitation. The total claims paid for this cause were $643,518.20.

For the time period 20*0*3-202*2*, there was one crop insurance claim made for wind and excessive wind damage for $4,678.00.

Table 3.62. Crop Insurance Claims Paid In Maries County from Severe Thunderstorms 2003-2022

Crop Year	Number of Claims	Cause of Loss Description	Insurance Paid
2004	1	Excessive Moisture/Precipitation/Rain	$3,643.00
2008	1	Excessive Moisture/Precipitation/Rain	$1,668.00
2009	3	Excessive Moisture/Precipitation/Rain	$3,120.00
2010	4	Excessive Moisture/Precipitation/Rain	$1,487.00
2011	1	Excessive Moisture/Precipitation/Rain	$1,181.00
2012	1	Excessive Moisture/Precipitation/Rain	$645.00
2013	16	Excessive Moisture/Precipitation/Rain	$101,868.50
2014	2	Excessive Moisture/Precipitation/Rain	$3,614.00
2015	25	Excessive Moisture/Precipitation/Rain	$272,552.60
2016	2	Excessive Moisture/Precipitation/Rain	$40,170.00
2017	9	Excessive Moisture/Precipitation/Rain	$24,800.00
2018	3	Excessive Moisture/Precipitation/Rain	$14,723.00
2019	10	Excessive Moisture/Precipitation/Rain	$30,341.80
	1	Wind/Excess Wind	$4,678.00
2020	4	Excessive Moisture/Precipitation/Rain	$9,266.90
2021	8	Excessive Moisture/Precipitation/Rain	$85,477.40
2022	4	Excessive Moisture/Precipitation/Rain	$48,960.00
Total	**95**	**-**	**$648,196.20**

Source: USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss

Probability of Future Occurrence

From the data obtained from the NCEI[1], annual average percent probabilities were calculated for heavy rainfall, high winds, lightning, and hail. Heavy rainfall has a 20 percent annual average percent probability of occurrence (4 events/20 years x 100) (**Table 3.63**). Heavy rainfall events can be found in **0**.

The annual average percent probability for high winds within the county is 100 percent (55 event/20 years * 100) with an average 2.75 events per year (**Table 3.64).** High wind events can be found in **Table 3.59.**

Lightning events have a 0 percent annual average percent probability of occurrence (0 events/20

[1] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

years x 100) (**Table 3.61**) Lightning events can be found in **Table 3.60**.

Lastly, the annual average percent probability of hail occurrence is 100 percent (54 events/20 years x 100) with an average of 2.70 events per year (**Table 3.66**). Hail events can be found in **0**.

Table 3.63. Annual Average % Probability of Heavy Rain in Maries County

Location	Annual Avg. % P
Maries County	20%

*P = probability; see page 3.24 for definition.

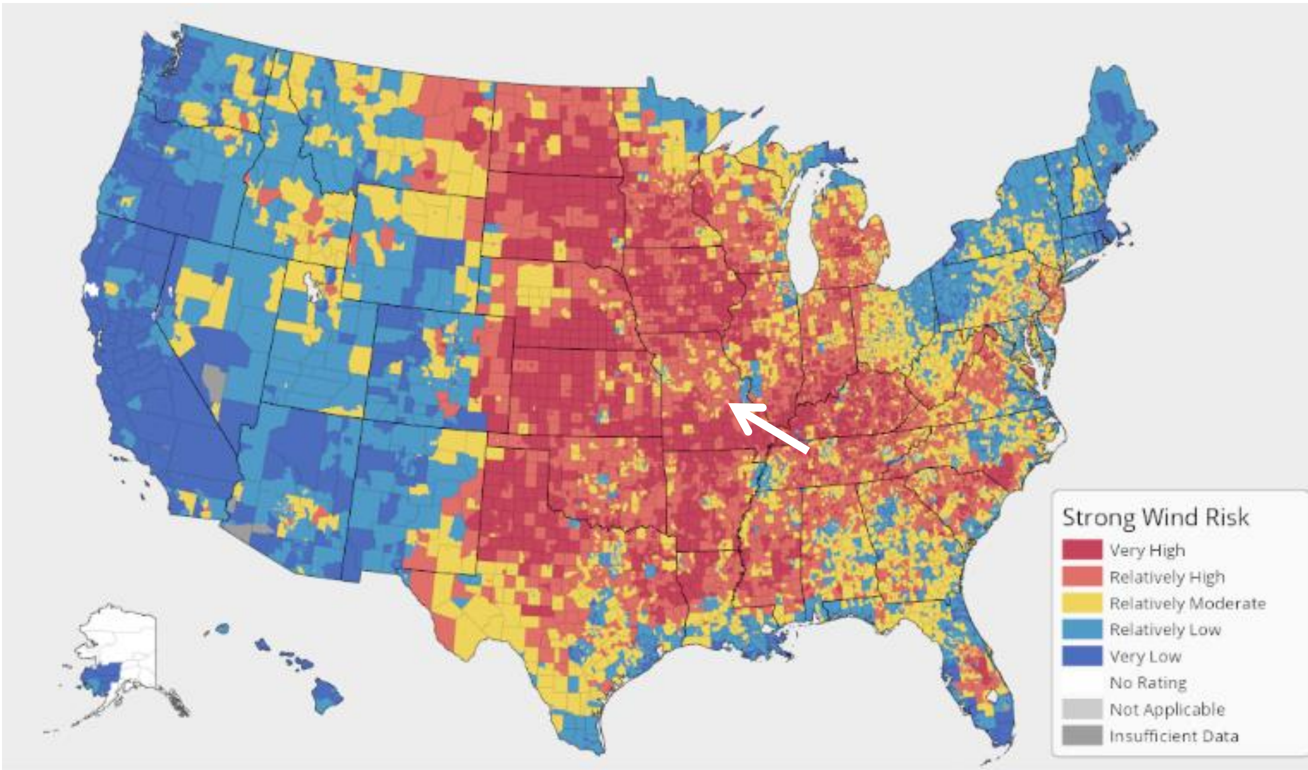
Table 3.64. Annual Average % Probability of High Winds in Maries County

Location	Annual Avg. % P	Avg. # of Events
Maries County	100%	2.75

*P = probability; see page 3.24 for definition.

0 depicts a map illustrating the risk of losses due to high wind events. In the National Risk Index, a Strong Wind Risk Index score and rating represent a community's relative risk for Strong Wind when compared to the rest of the United States. A Strong Wind Expected Annual Loss score and rating represent a community's relative level of expected building, population, and agriculture loss each year due to Strong Wind when compared to the rest of the United States.

Figure 3.35. National Risk Index for High Winds Events



Source: FEMA, https://hazards.fema.gov/nri/strong-wind, White arrow points to Maries County

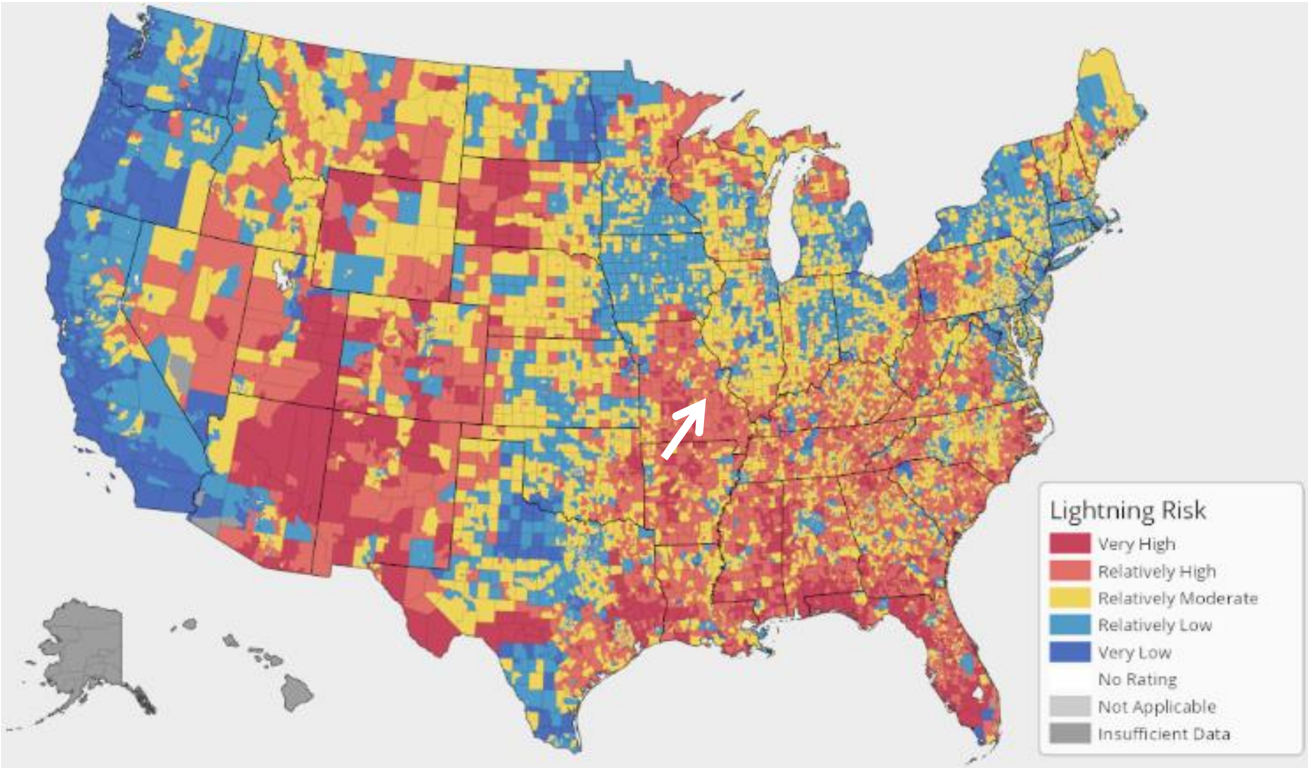
Table 3.65. Annual Average % Probability of Lightning in Maries County

Location	Annual Avg. % P
Maries County	0%

*P = probability; see page 3.24 for definition.

Figure 3.36 depicts a map illustrating the risk of losses due to lightning events in the United States. In the National Risk Index, a Lightning Risk Index score and rating represent a community's relative risk for Lightning when compared to the rest of the United States. A Lightning Expected Annual Loss score and rating represent a community's relative level of expected building and population loss each year due to Lightning when compared to the rest of the United States.

Figure 3.36. National Risk Index for Lightning Events



Source: FEMA, https://hazards.fema.gov/nri/lightning, White arrow points to Maries County

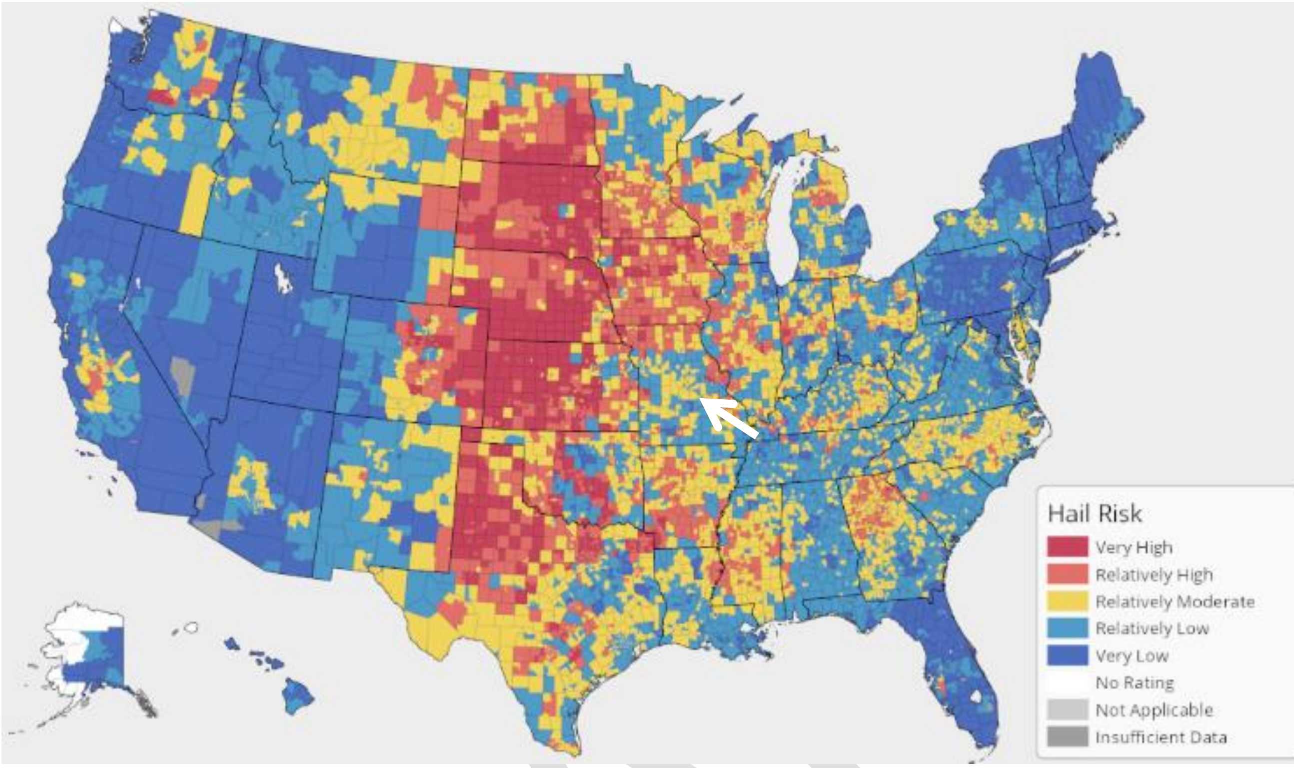
Table 3.66. Annual Average % Probability of Hail in Maries County

Location	Annual Avg. % P	Avg. # of Events
Maries County	100%	2.70

*P = probability; see page 3.24 for definition.

Figure 3.37 depicts a map illustrating the risk of losses due to hail events. In the National Risk Index, a Hail Risk Index score and rating represent a community's relative risk for Hail when compared to the rest of the United States. A Hail Expected Annual Loss score and rating represent a community's relative level of expected building, population, and agriculture loss each year due to Hail when compared to the rest of the United States.

Figure 3.37. National Risk Index for Hail Events



Source: FEMA, https://hazards.fema.gov/nri/hail, White arrow points to Maries County

Changing Future Conditions Considerations

Extreme events such as tornadoes and severe thunderstorms occur in shorter time periods and smaller areas than other extreme phenomena. This makes it difficult to detect trends and develop future projections. Compared to damages from other types of extreme weather, those occurring due to thunderstorm-related weather hazards have increased the most since 1980. There is some indication that in a warmer world an increase in the number of days with conditions conducive to severe thunderstorms is possible[1].

Vulnerability

Vulnerability Overview

Severe thunderstorm losses are usually attributed to the associated hazards of hail, downburst winds, lightning, and heavy rains. Losses due to hail and high wind are typically insured losses that are localized and do not result in Presidential disaster declarations. However, in some cases, impacts are severe and widespread and assistance outside state capabilities is necessary. Hail and wind also can have devastating impacts on crops. Severe thunderstorms/heavy rains that lead to flooding are discussed in the flooding hazard profile.

Hailstorms cause damage to property, crops, and the environment, and can injure and even kill livestock. In the United States, hail causes more than $1 billion in damage to property and crops each year. Even relatively small hail can shred plants to ribbons in a matter of minutes. Vehicles, roofs of buildings and homes, and landscaping are also commonly damaged by hail. Hail has been known to

[1] https://nca2018.globalchange.gov/chapter/2/

cause injury to humans, occasionally fatal injury.

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

Most lightning damages occur to electronic equipment located inside buildings. But structural damage can also occur when a lightning strike causes a building fire. In addition, lightning strikes can cause damages to crops, if fields or forested lands are set on fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. [1]

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for vulnerability overview and analysis. Since severe thunderstorms occur frequently throughout Missouri, the method used to determine vulnerability to severe thunderstorms was statistical analysis of data from several sources including: National Centers for Environmental Information (NCEI) storm events data (1996 to December 31, 2016 – which will differ slightly from data collected for the Maries County plan which is 1999-2019), HAZUS Building Exposure Value data, housing density and mobile home data from the U.S. Census (2015 ACS), and the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina.[2]

From the data collected, six factors were considered in determining vulnerability to lightning as follows: housing density, building exposure, percentage of mobile homes, social vulnerability, likelihood of occurrence, and average annual property loss. A rating value of one through five was assigned to each factor. Rating values are as follows:

1) Low
2) Low-medium
3) Medium
4) Medium-high
5) High

Table 3.67 illustrates the factors considered and ranges for the rating values assigned.

Once the ranges were determined and applied to all factors considered in the analysis for wind, hail and lightning, they were rated individually and factored together to determine an overall vulnerability rating for thunderstorms. **Table 3.68** provides the calculated ranges applied to determine overall vulnerability of Missouri counties to severe thunderstorms.

[1] http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx

[2] 2018 Missouri Hazard Mitigation Plan

Table 3.67. Ranges for Severe Thunderstorm Vulnerability Factor Ratings

Factors Considered	Low (1)	Medium Low (2)	Medium (3)	Medium High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4-46	47-140	141-283	284-871	872-2,865
Building Exposure ($1,000)	$286,351-$3,053,773	$3,381,480-$9,044,465	$11,043,270-$24,814,360	$30,225,497-$50,440,776	$96,532,305-$153,542,314
Percent Mobile Homes	0.23-4.38	4.39-8.24	8.25-13	13.01-23.77	23.78-34.58
Social Vulnerability	1	2	3	4	5
Wind					
Likelihood of Occurrence (# of events/ yrs. of data)	0.88-3.27	3.28-5.31	5.32-8.77	8.78-15.23	15.24-23.5
Average Annual Property Loss (annual property loss/ yrs of data)	$0	$1-$144,538	$144,539-$315,712	$315,713-$724,312	$724,313-$2,006,385
Hail					
Likelihood of Occurrence (# of events/ yrs. of data)	1.12-3.12	3.13-4.92	4.93-7.23	7.24-11.42	11.43-17.23
Average Annual Property Loss (annual property loss/ yrs. of data)	$0	$1-$138,907	$139,908-$377,884	$377,885-$7,846,346	$7,846,347-$32,787,692
Lightning					
Likelihood of Occurrence (# of events/ yrs. of data)	0	0.01-0.12	0.13-0.23	0.24-0.35	0.36-0.65
Average Annual Property Loss (annual property loss/ yrs. Of data)	$0	$1-$6,038	$6,039-$15,192	$15,193-$30,846	$30,847-$48,000

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.68. Ranges for Severe Thunderstorm Combined Vulnerability Rating

	Low (1)	Medium Low (2)	Medium (3)	Medium High (4)	High (5)
Severe Thunderstorm Combined Vulnerability	11-16	17-19	20-23	24-29	30-36

Source: 2023 Missouri Hazard Mitigation Plan

According to the Hazus data included in the 2023 state plan, Maries County has total building exposure to severe thunderstorms of $995,884,000. **Table 3.69** shows housing density, building exposure, SOVI and mobile home data for Maries County. The county's building exposure and housing density rating is low, while the SOVI ranking and the percent of mobile homes in the county, at 20.1 percent of the housing stock, are both rated as medium. **Table 3.70**, also pulled from the state plan, provides data on the number of events and likelihood of occurrence and occurrence rating for high wind, hail and lightning.

Table 3.69. Maries County Housing Density, Building Exposure, SOVI and Mobile Home Data

Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Ranking Rating	Percent Mobile Homes	Percent Mobile Homes Rating
$995,884,000	1	8.75	1	Medium	3	9.7	3

Source: 2023 Missouri Hazard Mitigation Plan

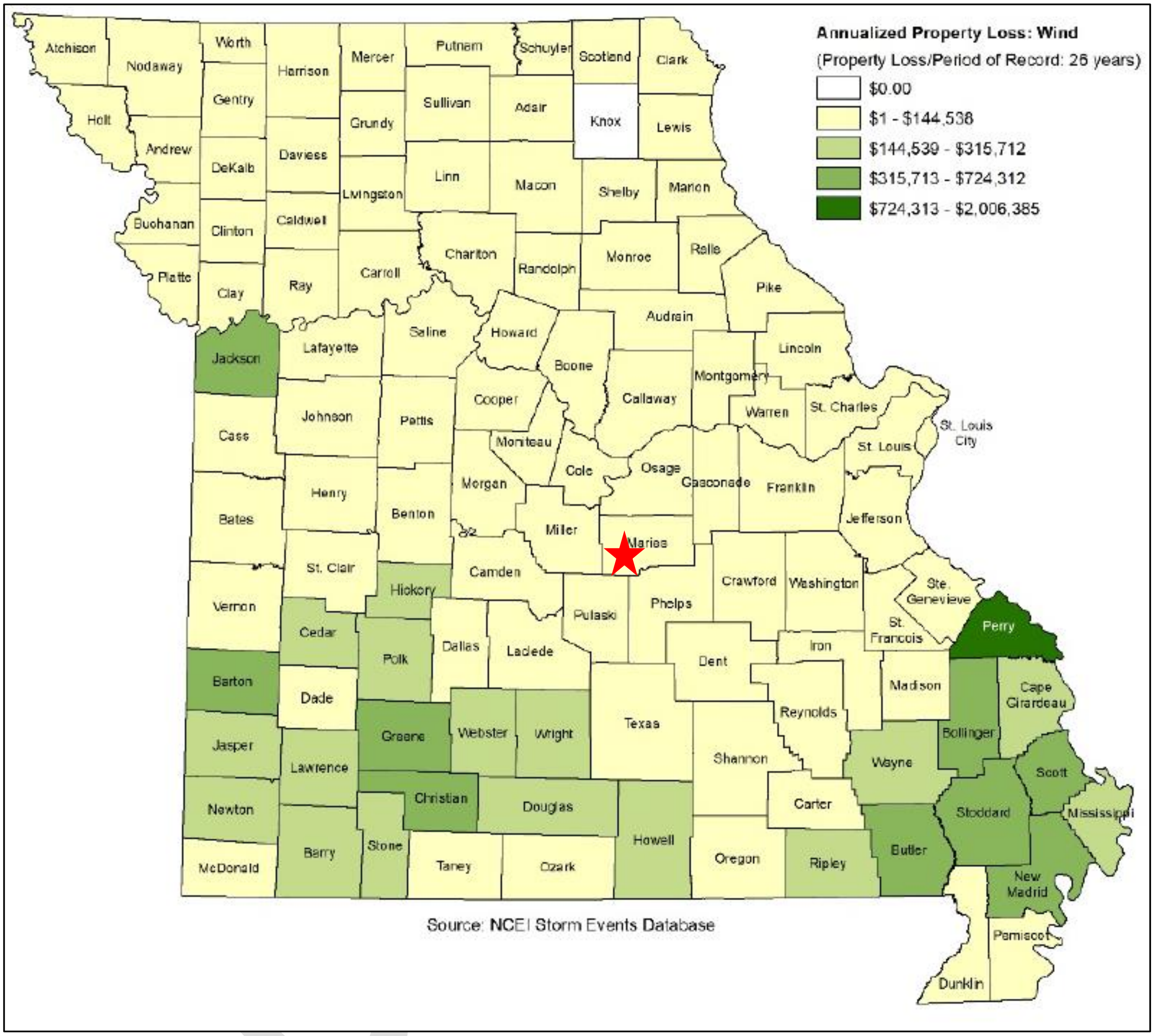
Table 3.70. Number of High Wind, Hail and Lightning Events, Likelihood of Occurrence and Associated Ratings for Maries County

High Wind			Hail			Lightning		
Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating
62	2.38	1	69	2.65	1	0	0.000	1

Source: 2023 Missouri Hazard Mitigation Plan

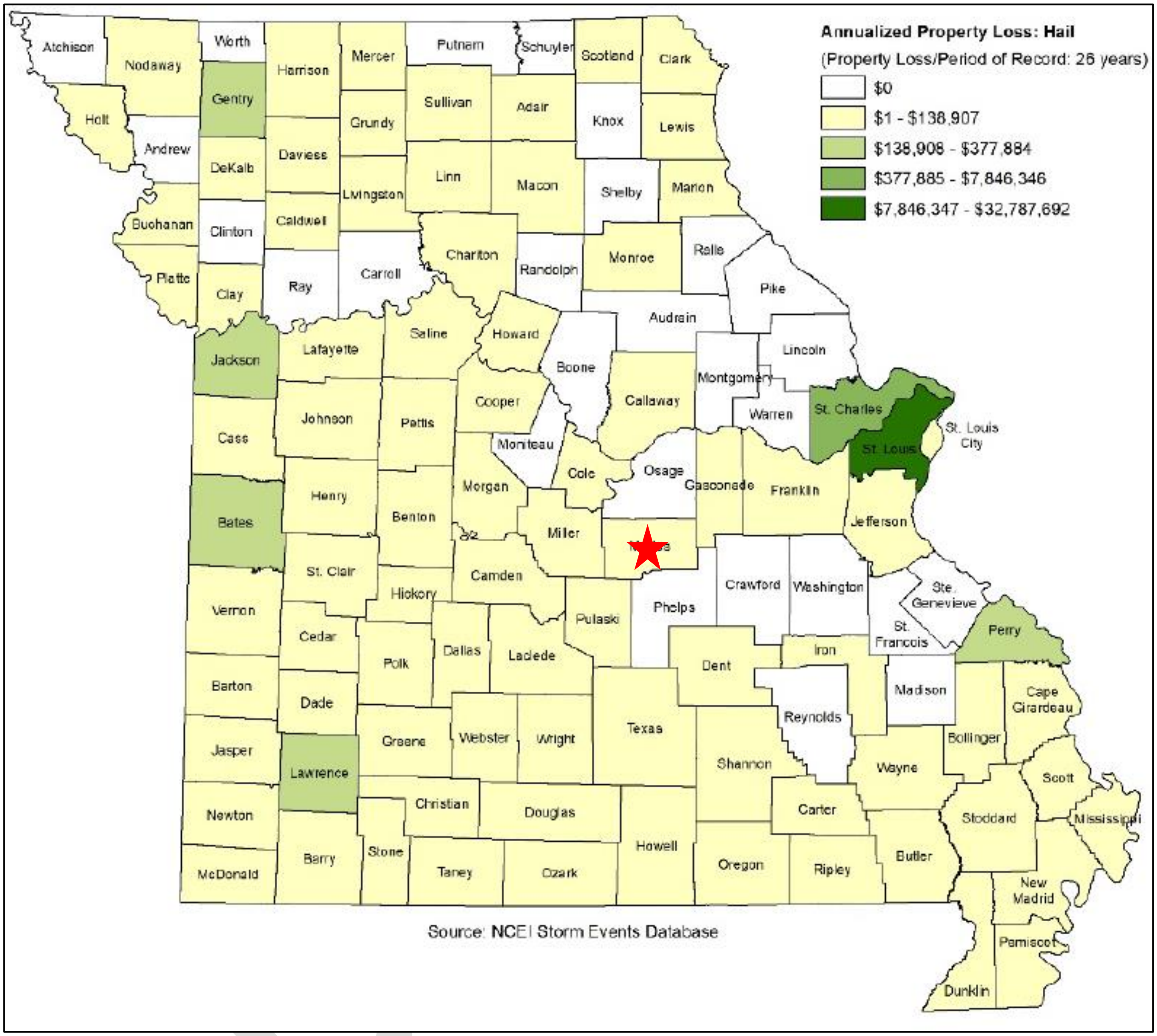
Figure 3.38 through **Figure 3.40** have been pulled from the 2023 Missouri Hazard Mitigation Plan and further depict the annualized damages caused by high winds, hail, and lightning events in Missouri.

Figure 3.38. Annualized High Wind Damages (40 MPH and Higher)



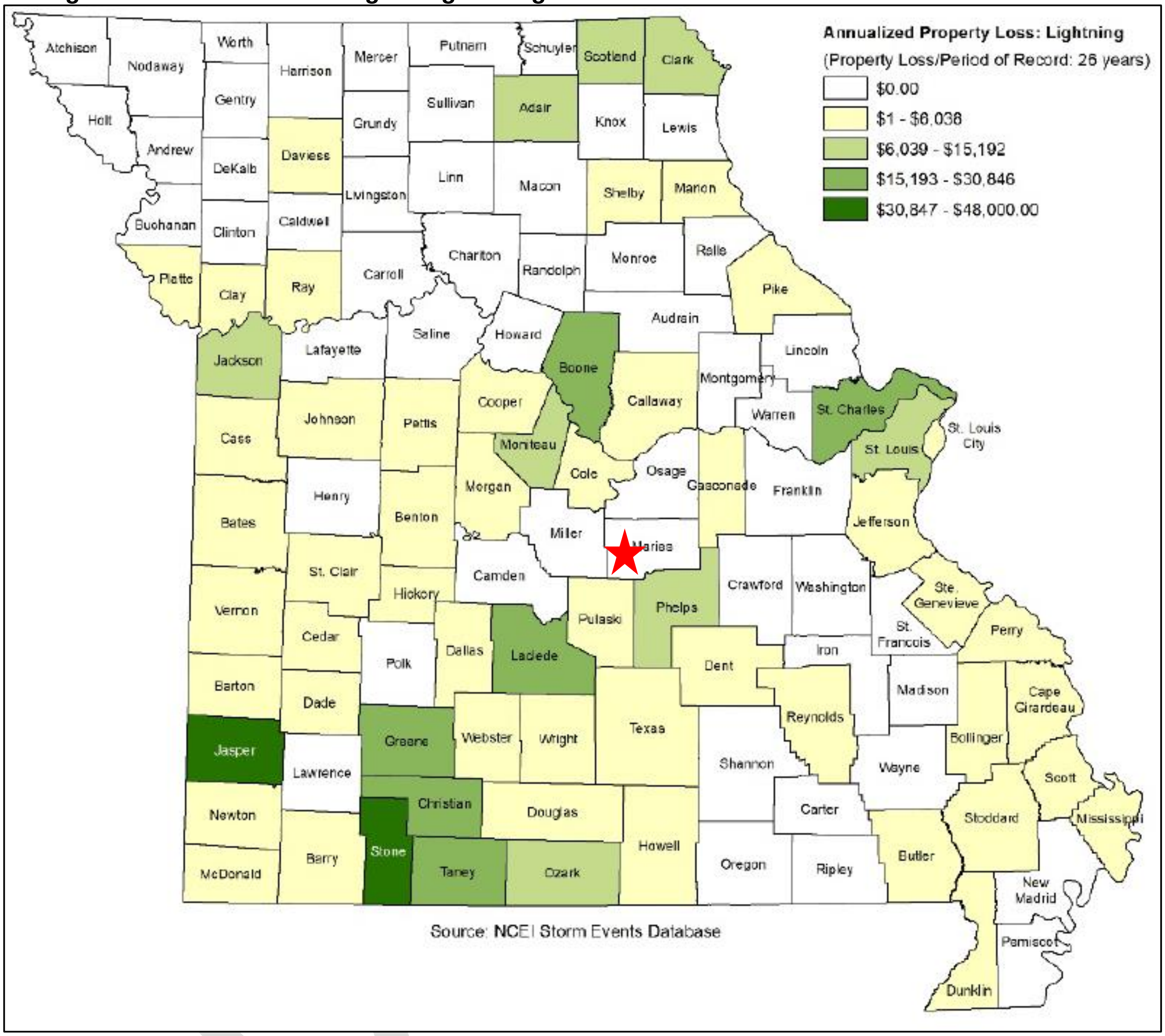
*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.39. Annualized Hail Damages



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.40. Annualized Lightning Damages



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Table 3.67 provides additional data obtained from the National Centers for Environmental Information for property loss to complete the overall vulnerability analysis.

Table 3.71. Annualized Property Loss and Associated Ratings for Maries County

High Wind		Hail		Lightning	
Total Annualized Property Loss	Total Annualized Property Loss Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating
$11,038	1	$192	1	$0	1

Source: 2023 Missouri State Hazard Mitigation Plan

After ranges were applied to all factors in the analysis for wind, hail, and lightning, they were weighted equally and factored together to determine an overall vulnerability rating. Following, a combined vulnerability rating was calculated. The calculated ranges applied to determine overall vulnerability of Missouri counties to severe thunderstorms can be found in **Table 3.68**. **Table 3.72** provides the calculated vulnerability rating for the severe thunderstorm hazard. **Figure 3.41** that follows provides the mapped results of this analysis by county[1].

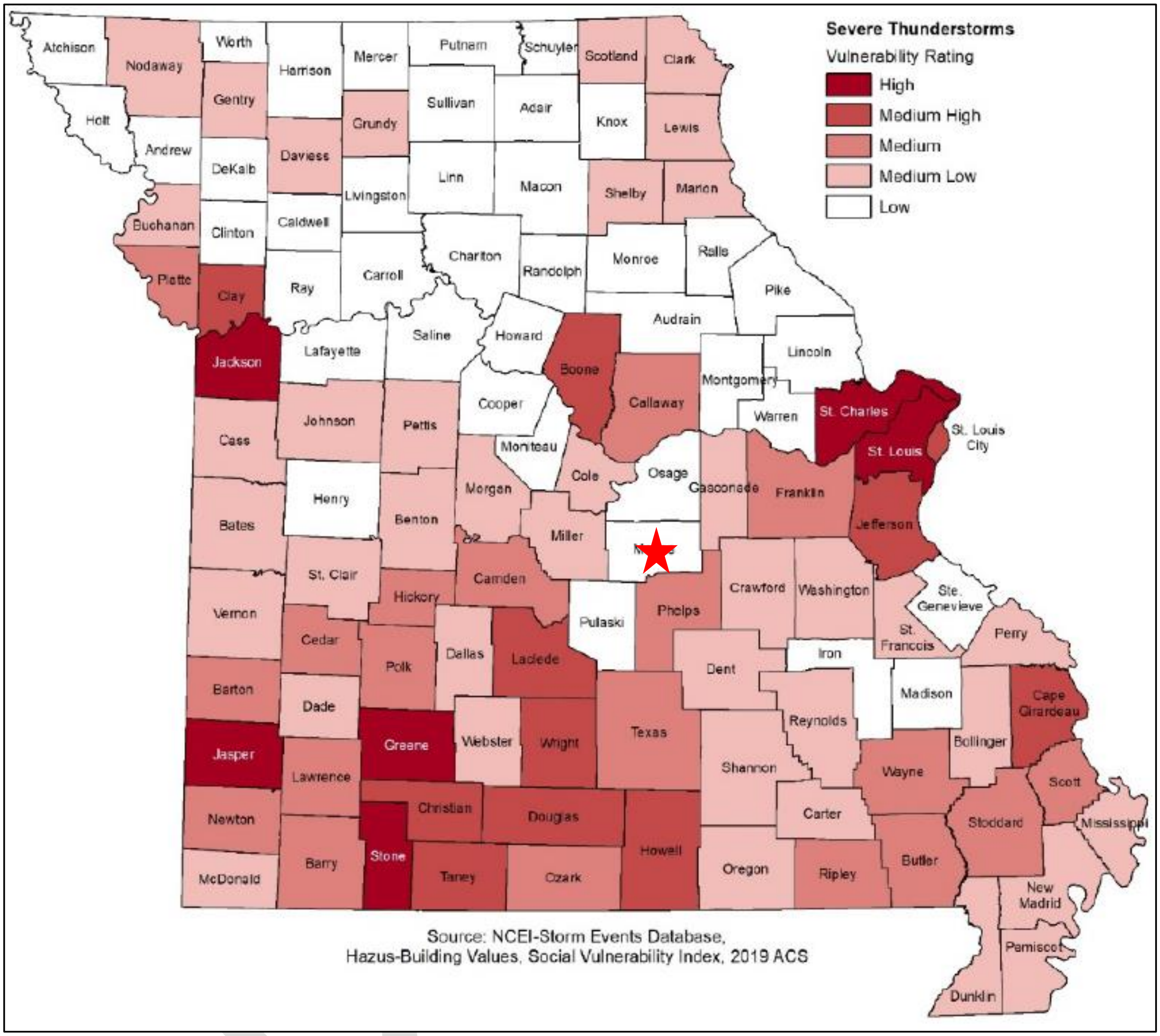
Table 3.72. Severe Thunderstorm Vulnerability Rating for Maries County

Total Sum of All Factor Ratings	Overall Vulnerability Rating for Thunderstorms	Overall Vulnerability Rating for Thunderstorms Description
15	1	Low

Source: 2023 Missouri State Hazard Mitigation Plan

[1] 2018 Missouri State Hazard Mitigation Plan

Figure 3.41. Vulnerability Summary for Severe Thunderstorms



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Potential Losses to Existing Development

According to the NCEI Maries County experienced approximately $151,000 in property damages from severe thunderstorms between 2003 and 2022. The USDA reports a total of $648,196.20 in crop insurance payouts in the same time period. This is a combined average of $39,959.81 in losses due to this hazard per year. Most of the property damage caused by storms is covered by private insurance and data is not available. In addition, most damage from severe thunderstorms occurs to vehicles, roofs, siding, and windows. However, there is a variety of impacts from severe thunderstorms. Moreover, secondary effects from hazards, falling trees and debris, can cause destruction within the planning area.

Impact of Previous and Future Development

Population trends from 2010 to 2020 for Maries County indicate that the population in unincorporated areas has fallen by an estimated 7.85 percent. The city of Belle's population has decreased by 10.6 percent. The city of Vienna's population has decreased by 4.75 percent. Overall, the county has decreased its population by 8.11 percent. It is difficult to determine future impacts. However, anticipated development in each jurisdiction will result in increased exposure. Likewise, increased development of residential structures will increase jurisdiction's vulnerability to damages from severe thunderstorms/ high winds/lightning/hail.

Hazard Summary by Jurisdiction

Although thunderstorms/high winds/lightning/hail events are area-wide, there are demographics indicating higher losses in one jurisdiction as compared to another. Jurisdictions with high percentages of housing built before 1939 are more prone to damage from severe thunderstorms. Unincorporated Maries County has both a higher percentage of housing built before 1939 at 13.7 percent and a higher percentage of mobile homes at 19.4 percent, which are also more prone to damage.

Problem Statement

The NCEI Storm Events Database notes over 113 thunderstorm and wind events in Maries County from 2003 - 2022, with about $151,000.00 in property and crop damages reported. Early warnings are possibly the best hope for residents when severe weather strikes. Cities that do not already possess warning systems – whether that is storm sirens or automated email/text/phone call systems - should plan to invest in such a system. Additional public awareness also includes coverage by local media sources. Storm shelters are another important means of mitigating the effects of severe thunderstorms. A community-wide shelter program should be adopted for residents who may not have adequate shelter in their homes. Residents should also be encouraged to build their own storm shelters to prepare for emergencies. Local governments should encourage residents to purchase weather radios to ensure that everyone has sufficient access to information in times of severe weather.

3.4.8 Severe Winter Weather

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.9, Page 3.321 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Average Number of House per year with Freezing Rain, American Meteorological Society. "Freezing Rain Events in the United States." http://ams.confex.com/ams/pdfpapers/71872.pdf;
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss;
- Any local Road Department data on the cost of winter storm response efforts.
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  o Average annual severe winter weather events by County
  o Vulnerability to severe winter weather events by County
  o Annualized property loss for severe winter weather events by County
  o Annualized property loss for severe winter weather events by County

Hazard Profile

Hazard Description

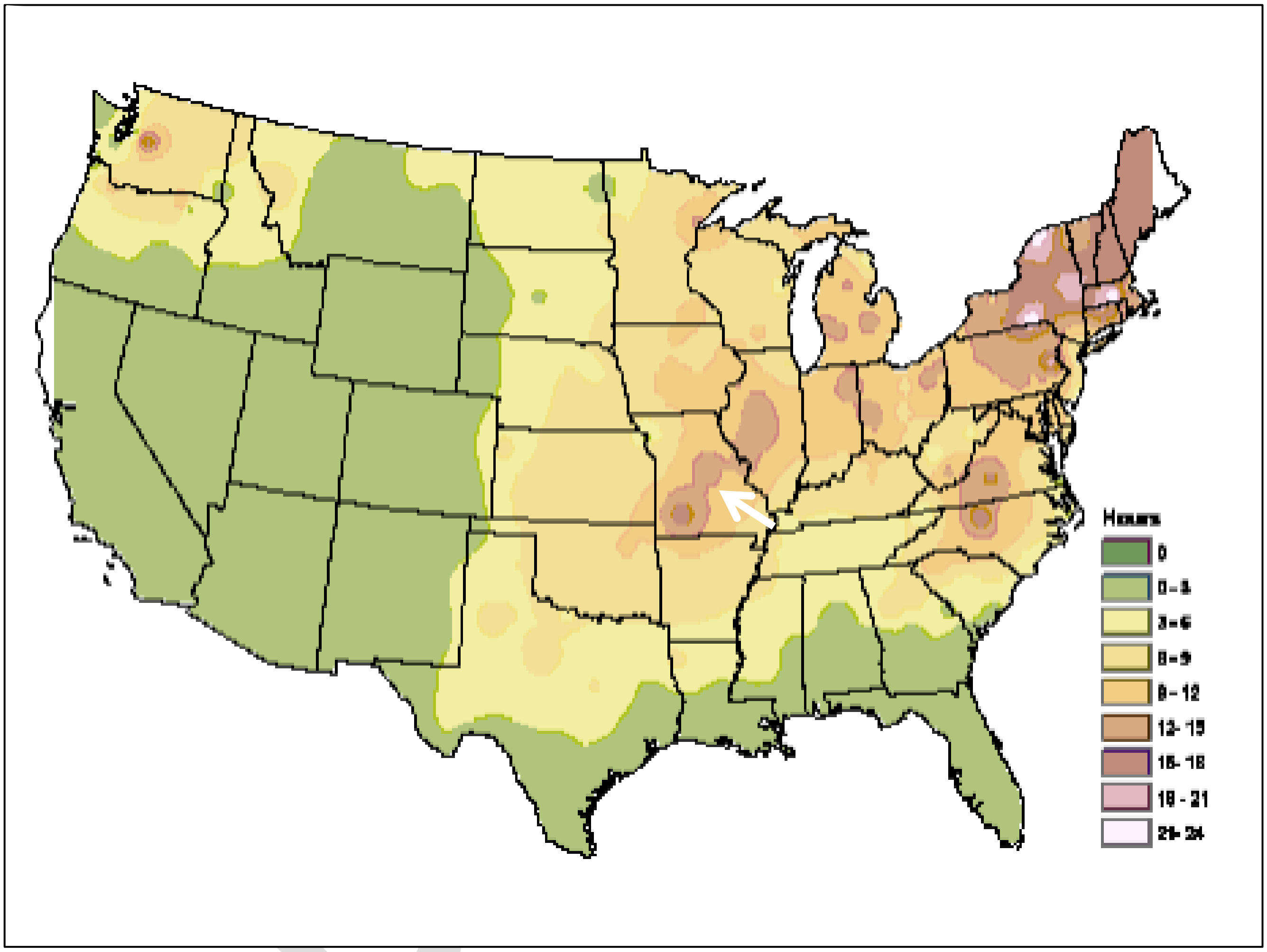
A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. The National Weather Service describes different types of winter storm events as follows.

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

Geographic Location

Severe winter weather typically strikes Missouri more than once every year. Maries County receives winter weather events from heavy snow to freezing rain annually. Major snowstorms typically occur once each year, causing multiple school closings, as well as suspending business and government activity. All of Maries County is vulnerable to heavy snow, ice, and freezing rain. **Figure 3.42** illustrates statewide average number of hours per year with freezing rain. Maries County receives approximately 9 to 12 hours.

Figure 3.42. 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.

Previous Occurrences

Data was obtained from the NCEI for winter weather reported events and damages between 2003 and 2022 **(Table 3.73**). This data includes variables such as blizzard, freezing fog, frost/freeze, heavy snow, ice storm, sleet, winter storm, and winter weather. Additionally, narratives for specific events are listed below.

Table 3.73. NCEI County A Winter Weather Events Summary, 2003 - 2022

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Winter Storm	02/23/2003	0	0	0
Winter Storm	03/05/2003	0	0	0
Ice Storm	01/25/2004	0	0	0
Winter Storm	11/30/2006	0	500.00K	0
Ice Storm	01/12/2007	0	3.300M	0
Winter Storm	01/20/2007	0	0	0
Frost/Freeze	04/07/2007	0	0	4.860M
Ice Storm	12/09/2007	0	50.00K	0
Ice Storm	02/11/2008	0	0	0
Ice Storm	02/21/2008	0	0	0
Winter Storm	01/26/2009	0	0	0
Winter Storm	02/28/2009	0	0	0
Blizzard	02/01/2011	0	0	0
Winter Storm	02/21/2013	0	0	0
Winter Storm	01/05/2014	0	0	0
Winter Storm	03/02/2014	0	0	0
Ice Storm	01/13/2017	0	0	0
Winter Storm	01/11/2019	0	0	0
Winter Weather	02/15/2019	0	0	0
Winter Weather	01/17/2020	0	0	0
Winter Weather	02/05/2020	0	0	0

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Winter Weather	12/31/2020	0	0	0
Winter Storm	01/01/2021	0	25.00K	0
Winter Weather	01/27/2021	0	0	0
Winter Weather	02/08/2021	0	0	0
Winter Weather	02/10/2021	0	0	0
Winter Weather	02/14/2021	0	0	0
Winter Weather	02/17/2021	0	0	0
Frost/Freeze	04/20/2021	0	0	0
Winter Storm	02/02/2022	0	0	0
Winter Weather	02/17/2022	0	0	0
Winter Weather	02/23/2022	0	0	0
Winter Weather	03/11/2022	0	0	0
Total	**33**	**0**	**3.875M**	**4.860M**

Source: NCEI, data accessed [2/10/2023]

Notable Winter Narratives:

1. **11/30/2006:** A major winter storm caused a combination of freezing rain, sleet, and heavy snow to fall over sections of southwest and central Missouri. The frozen precipitation began on the 30th, the precipitation type was freezing rain and sleet, with ice accumulations up to four inches in some areas. The second wave of precipitation occurred overnight causing large amount of snow to accumulate over the ice. Storm total accumulations ranging from 13 to 17 inches occurred from the Lake of the Ozarks Region, over to Vernon and Cedar counties. The combination of the ice and snow weighted down all exposed objects. As a matter of fact, some areas experienced disaster as many roofs on businesses, barns, outbuildings, and schools collapsed due to the weight of the accumulated precipitation.

2. **01/12/2007 – 01/14/2007:** One of the greatest disasters to ever impact southwest Missouri, including the Springfield metro area, occurred in the form of an ice storm. Several counties, mainly along and north of the interstate 44 corridor, experienced ice accumulations up to two and a half inches. Power outages and catastrophic tree damage were the main impacts resulting from this historic event. Power outages occurred for over three weeks in many areas. Several indirect fatalities due to the extreme elements were documented. In Maries County there was significant damage to trees and power lines due to one and one-half inches of ice over the entire county.

3. **04/07/2007 – 04/09/2007:** Unusually warm conditions during the month of March caused early season growth in vegetation across the Missouri Ozarks. Hay along with the wheat crop had begun to mature. During the nights of April 7th through the 9th, temperatures dropped into the upper teens to mid-20s, causing a hard freeze on matured vegetation. The wheat crop suffered approximately 90% damage. Hay crops along with fescue seed also sustained major damage. Total crop losses for 34 counties across the southwestern quadrant of Missouri were estimated at $147,905,541.

4. **12/09/2007:** A major ice storm impacted southwest Missouri and the Ozarks. Areas

experienced accumulation ranging from one quarter of an inch to one and one quarter inches of ice. Intermittent periods of light freezing rain occurred through the morning of 10 December. Maries County had ice accumulations ranging from one quarter of an inch to three quarters of an inch. Power outages were common as several trees and power lines were damaged.

5. **01/01/2021:** A storm system lifted northward through Arkansas and into Missouri from New Year's Eve into New Year's Day. Freezing rain spread into southeast Kansas and southern and central Missouri during the evening hours of Thursday, December 31. The freezing rain continued into January 1, 2021, before transitioning over to minor accumulations of snow. Ice accumulations overnight and into January 1, 2021, resulted in tree damage and scattered power outages. Once the freezing rain changes to snow with a dusting to 1.5 inches of accumulation was reported**.**The ASOS unit 1 mile north northwest of Vichy Missouri reported a flat ice accumulation of 0.68 inches.

Maries County has been included in five federal disaster declarations for winter weather since 2003.[1]

Winter storms, cold, frost, and freeze all can influence or negatively impact crop production. However, data obtained from the USDA's Risk Management Agency for insured crop losses indicates that there were 3 claims paid in Maries County between 2003 and 2022 for severe winter weather with a total payout of $29,546.00.

Table 3.74. Crop Insurance Claims Paid in Maries County from Winter Weather 2003-2022

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2007	All Other Crops	Cold wet weather	$339.00
2013	Soybeans	Cold wet weather	$813.00
2019	Wheat	Cold wet weather	$28,394.00
Total	**3**	**-**	**$29,546.00**

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

Probability of Future Occurrence

From the data obtained from the NCEI[2], annual average percent probabilities were calculated for winter weather within Maries County (**Table 3.73)**. There were 33 recorded events (**Table 3.73**) over a 20-year period. There is 100 percent annual average probability of winter weather occurrence (33 events/20 years)**,** with an average of 1.65 events per year.

Table 3.75. Annual Average % Probability of Winter Weather in Maries County

Location	Annual Avg. % P	Avg. # of Events
Maries County	100%	1.65

*P = probability; see page 3.24 for definition.

[1] https://www.fema.gov/data-visualization-summary-disaster-declarations-and-grants
[2] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

Changing Future Conditions Considerations

Increasing temperatures could lead to an overall shorter winter season with fewer days of extreme cold. While this could reduce the number of severe winter storms, it could also lead to an increase in the frequency of severe thunderstorms, flooding, and drought. Snowmelt results in less surface runoff than rainfall events. This allows water to infiltrate to replenish groundwater supplies. Additionally, we could be trading snow for ice, which would result in increased traffic complications and damage to utility infrastructure.

Vulnerability

Vulnerability Overview

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

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

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

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

Data was obtained from the 2023 Missouri State Hazard Mitigation Plan for vulnerability information regarding Maries County. Various data sources were utilized for statistical analysis including the following:

- National Centers for Environmental Information (NCEI) storm event data (1996 to December 31, 2021)
- HAZUS Building Exposure Value data
- Housing density data from the U.S. Census 2019
- Calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina

From the statistical data collected, five factors were considered in determining overall vulnerability to severe winter weather as follows: housing density, building exposure, social vulnerability, likelihood of occurrence and average annual property loss. A rating value of one through five was assigned to each factor:

1) Low
2) Low-medium
3) Medium
4) Medium-high
5) High

Table 3.76 provides the factors considered and the ranges for the rating values assigned. After the individual ratings were determined for the common factors, a combined vulnerability rating was computed for severe winter weather. Those can be seen in **Table 3.77**. The housing density, building exposure and SOVI data for Maries County can be found in **Table 3.78**.

Table 3.76. Ranges for Severe Winter Weather Vulnerability Factor Ratings

Factors Considered	Low (1)	Medium-Low (2)	Medium (3)	Medium-High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4-46	47-140	141-283	284-871	872-2,865
Building Exposure ($1,000)	$286,351-$3,053,773	$3,381,480-$9,044,465	$11,043,270-$24,814,360	$30,225,497-$50,440,776	$96,532,305-$153,542,314
Social Vulnerability	1	2	3	4	5
Likelihood of Occurrence (# of events/ yrs. of data)	1-1.5	1.6-1.8	1.9-2.2	2.3-2.7	2.8-4
Average Annual Property Loss (annual property loss/ yrs. of data)	0	$1-$329,423	$329,424-$961,962	$961,963-$2,572,692	$2,572,693-$4,738,269

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.77. Ranges for Severe Winter Weather Combined Vulnerability Rating

	Low (1)	Medium-Low (2)	Medium (3)	Medium-High (4)	High (5)
Severe Winter Weather Combined Vulnerability	6-8	9-10	11-12	13-15	16-21

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.78. Housing Density, Building Exposure and SOVI Data for Maries County

Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Rating
$995,884,000	1	8.75	1	Medium	3

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.79 provides the last piece of the data gathered from NCEI to complete the overall vulnerability analysis and the total overall vulnerability rating for severe winter weather. The total number of winter weather events includes blizzard, heavy snow, ice storm winter storm and winter weather events. The likelihood of occurrence is 1.38 or 100 percent per year. The total annualized property loss is $151,154, which provides a total annualized property loss rating of two and an overall vulnerability rating of eight – which translates to an overall Low vulnerability rating for the county for severe winter weather.

Table 3.79. Additional Statistical Data Compiled for Vulnerability Analysis for Maries County

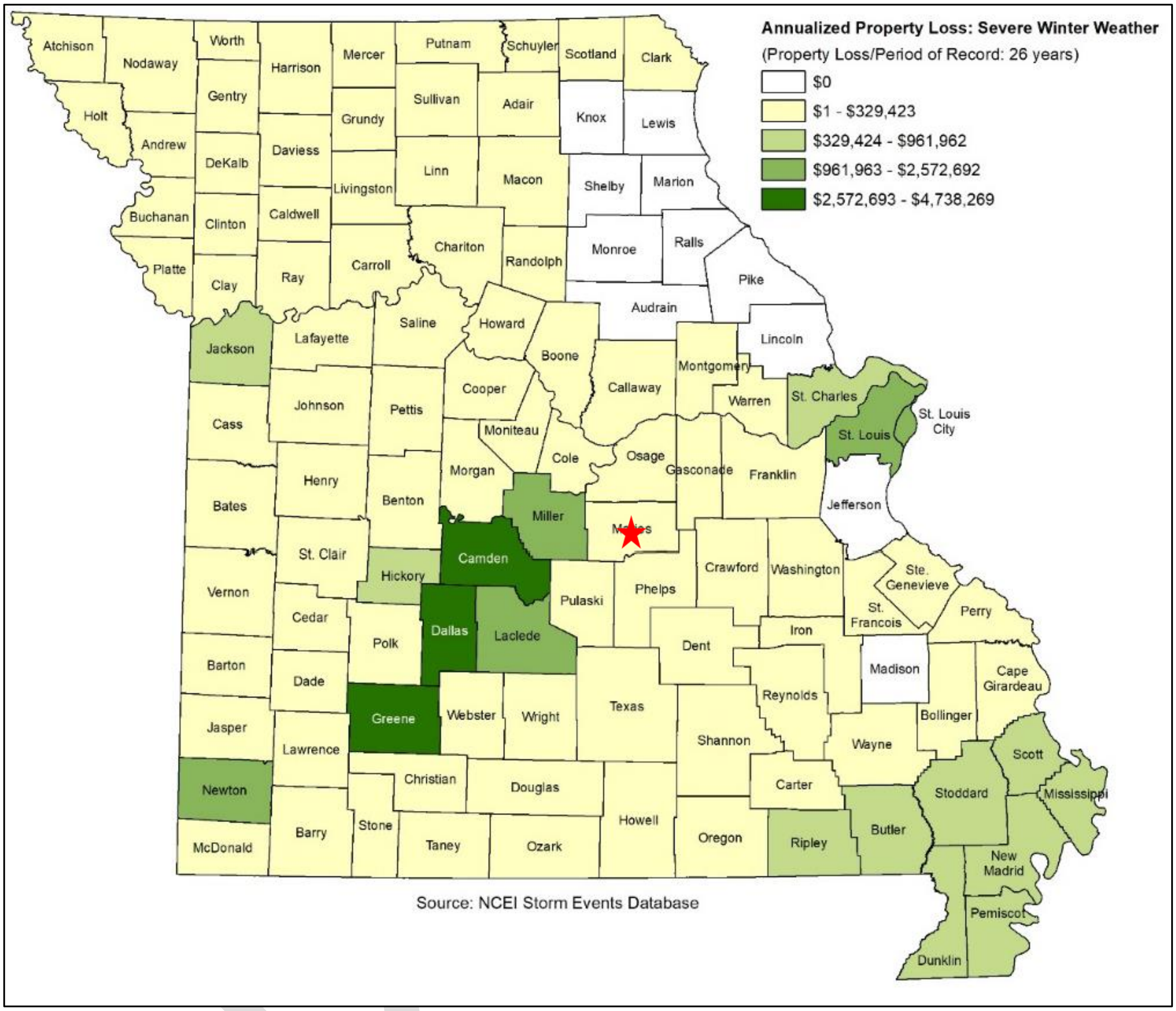
Total number of Winter Weather Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
38	1.38	1	$151,154	2	8	Low

Source: 2023 Missouri Hazard Mitigation Plan

Error! Reference source not found. illustrates the annualized winter weather damages. Maries County f alls into the $1 - $329,423 category.

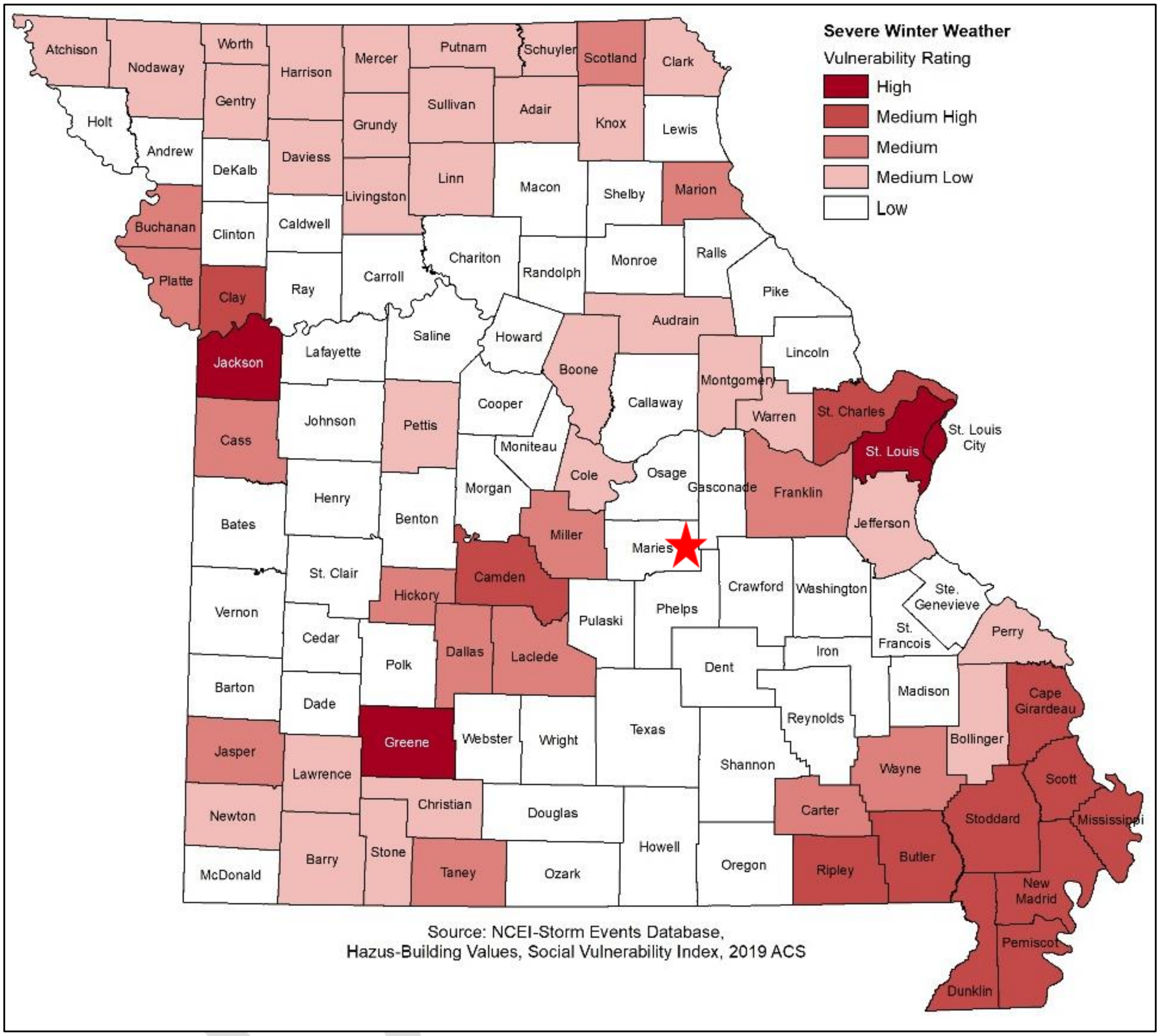
Figure 3.44 provides an illustration of the vulnerability summary of all Missouri counties for severe winter weather. Again, Maries County falls into the Low rating for overall vulnerability.

Figure 3.43. Annualized Winter Weather Damages



*Source: 2023 Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.44. Vulnerability Summary for Severe Winter Weather



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Potential Losses to Existing Development

Severe winter storms can often close schools and businesses for multiple days and make roadways hazardous for travel. Heavy ice accumulation may damage electrical infrastructures, causing prolonged power outages for large portions of the region. In addition, freezing temperatures make water lines vulnerable to freeze/thaw. Fallen tree limbs also pose a threat to various structures/infrastructures across the county. According to the 2018 state plan, Maries County can expect annual property losses of $7,381 due to severe winter storms.

Impact of Previous and Future Development

Data for future development for the planning area is sparse. However, winter weather will affect the county as a whole. Any future development is at risk to damages and increased exposure. In addition, the county's population within the cities is anticipated to increase, which would increase the number of individuals at risk during a winter weather event.

Hazard Summary by Jurisdiction

Variations in impacts are not anticipated for severe winter weather across the planning area. Yet, areas with a higher number of mobile homes and higher number of homes built before 1939 tend to experience increased damage. Unincorporated Maries County has both the highest abundance of mobile homes at 19.4% of residences, and the highest percentage of homes built before 1939 at 13.7% making the unincorporated area more prone to increased exposure to damage that the incorporated cities. In addition, rural areas of the county may be more susceptible to power outages due to more power infrastructure being exposed to the risk of damage from winter storms.

Problem Statement

In summary, Maries County is expected to experience at least one severe winter weather event annually; however, the county has a low vulnerability rating. Jurisdictions should enhance their weather monitoring to be better prepared for severe weather hazards. If jurisdictions monitor winter weather, they can dispatch road crews to prepare for the hazard. County and city crews can also trim trees along power lines to minimize the potential for outages due to snow and ice. Citizens should also be educated about the benefits of being proactive to alleviate property damage as well as preparing for power outages.

3.4.9 Tornado

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.10, Page 3.355 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- NWS Enhanced F Scale for Tornado Damage including damage indicators and degrees of damage www.spc.noaa.gov/faq/tornado/ef-scale.html;
- Tornado Activity in the U.S. map (1950-2006), FEMA 320, Taking Shelter from the Storm, 3rd edition;
- Tornado Alley in the U.S. map, http://tornadochaser.com/education/tornado-alley/
- National Centers for Environmental Information, https://www.ncdc.noaa.gov/stormevents/;
- Midwest Regional Climate Center, https://mrcc.purdue.edu/gismaps/cntytorn.htm;
- MSDIS Structure Inventory and All Hazard Risk Dataset
  (available in both GIS and Excel format)
  https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
    - Number of Tornadoes by County
    - Percentage of Mobile Homes in 2015 by County
    - Average annual tornado events by County
    - Vulnerability to tornado events by County
    - Annualized property loss for tornado events by County
    - Annualized property loss for tornado events by County

Hazard Profile

Hazard Description

The NWS defines a tornado as "a violently rotating column of air extending from a thunderstorm to the ground." It is usually spawned by a thunderstorm and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly. Often, vortices remain suspended in the atmosphere as funnel clouds. When the lower tip of a vortex touches the ground, it becomes a tornado.

High winds not associated with tornadoes are profiled separately in this document in **Section 3.4.7,** Severe Thunderstorms Including High Winds, Hail, and Lightning.

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 due to its unique geography and presence of the jet stream. The jet stream is a high-velocity stream of air that separates the cold air of the north from the warm air of the south. During the winter, the jet stream flows west to east from Texas to the Carolina coast. As the sun moves north, so does the jet stream, which at summer solstice flows from Canada across Lake Superior to Maine. During its move northward in the spring and its recession south during the fall, the jet stream crosses

Missouri, causing the large thunderstorms that breed tornadoes.

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

A typical tornado can be described as a funnel-shaped cloud in contact with the Earth's surface that is "anchored" to a cloud, usually a cumulonimbus. 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

In Missouri, tornadoes occur most frequently between April and June, with April and May usually producing the most tornadoes. However, tornadoes can arise at any time of the year. While tornadoes can happen at any time of the day or night, they are most likely to occur between 3 p.m. and 9 p.m. Furthermore, tornadoes can and do occur anywhere across the state of Missouri, including Maries County.

Severity/Magnitude/Extent

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

Tornado magnitude is classified according to the EF- Scale (or the Enhanced Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renowned severe storm researcher). The EF- Scale (**0**) 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 3.80. Enhanced F Scale for Tornado Damage

Fujita Scale			Derived EF Scale		Operational EF Scale	
F #	Fastest 1/4 - Mile (mph)	3 Second Gust (mph)	EF #	3 Second Gust (mph)	EF #	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 3.81.** 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.

Table 3.81. Enhanced Fujita Scale with Potential Damage

Enhanced Fujita Scale			
Scale	Wind Speed (mph)	Relative Frequency	Potential Damage
EF0	**65-85**	**53.5%**	Light. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e. those that remain in open fields) are always rated EF0).
EF1	**86-110**	**31.6%**	Moderate. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	**111-135**	**10.7%**	Considerable. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes complete destroyed; large trees snapped or uprooted; light object missiles generated; cars lifted off ground.
EF3	**136-165**	**3.4%**	Severe. Entire stores of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.
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%	<u>Explosive.</u> Strong frame houses levelled off foundations and swept away; automobile-sized missiles fly through the air in excess of 300 ft.; steel reinforced concrete structure badly damaged; high rise buildings have significant structural deformation; incredible phenomena will occur.

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

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

Previous Occurrences

Table 3.82 illustrates NCEI data reported for tornado events and damages from 2003 to 2022 in the planning area.

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.

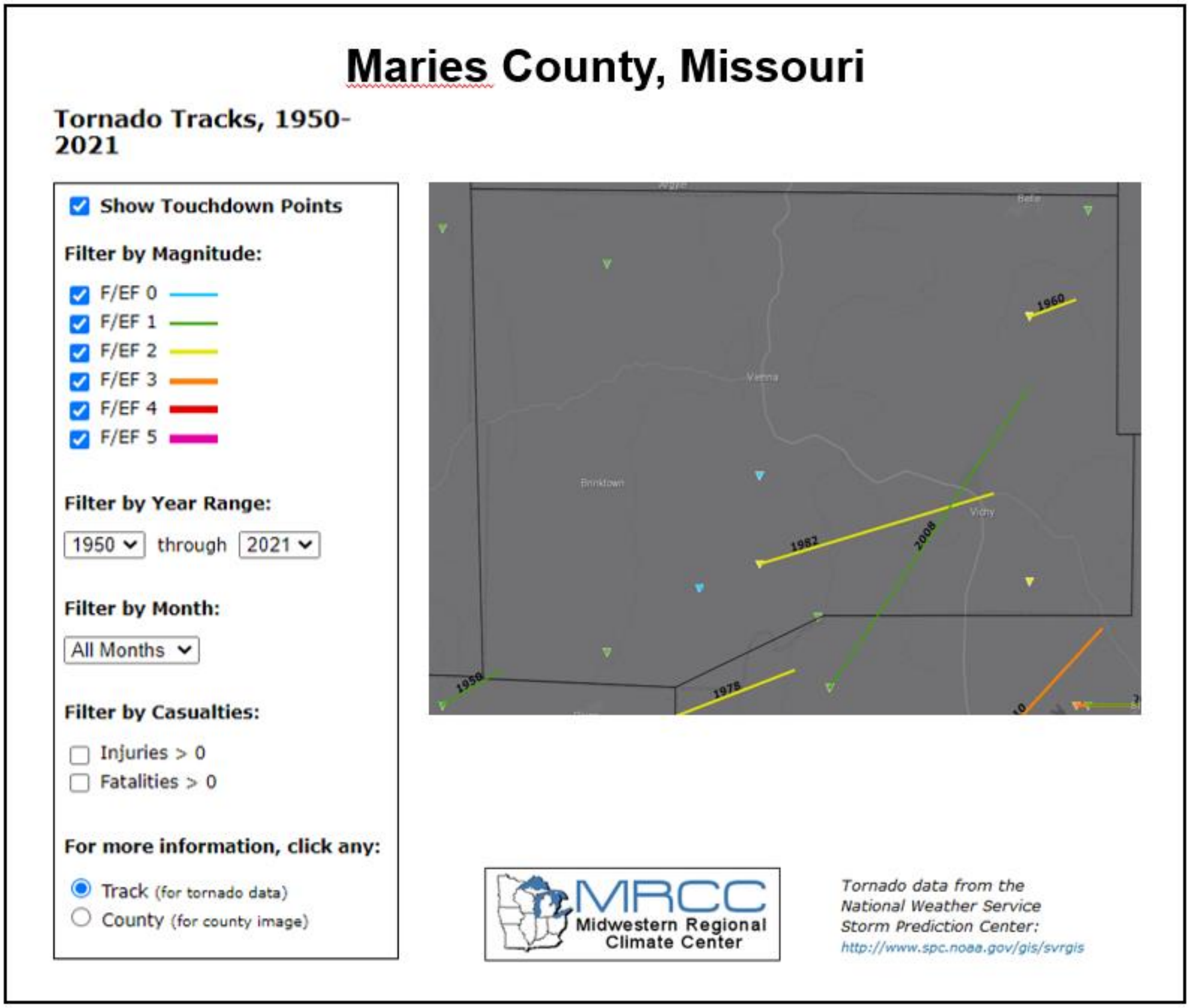
Table 3.82. Recorded Tornadoes in Maries County, 2003 – 2022

Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	F/EF Rating	Death	Injury	Property Damage	Crop Damages
5/4/2003	4S Vienna	4S Vienna	0.2	20	F0	0	0	0	0
1/7/2008	2SSW Veto	0ESE Lanes Prairie	11.29	100	EF0	0	1	5.00M	0
7/1/2015	2WSW Hayden	2WSW Hayden	.2	50	EF0	0	0	0	0
Total	**-**	**-**	**11.69**	**170**	**-**	**0**	**1**	**$5.00M**	**0**

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

Figure 3.45 depicts historic tornado paths across Maries County.

Figure 3.45. Maries County Map of Historic Tornado Paths (1950 – 2021)



Source: https://mrcc.purdue.edu/gismaps/cntytorn.htm

According to the USDA Risk Management Agency's record, there were no insurance payments in Maries County for crop damages as a result of tornadoes between 2003 and 2022.

Probability of Future Occurrence

From the data obtained from the NCEI[1], an annual average percent probability was calculated for tornadoes within Maries County (**Table 3.79**). There is a 15.0 percent annual average probability of a tornado occurrence (3 events/20 years x 100). Tornado events can be found in **Table 3.82**. In addition, **Figure 3.46,** obtained from the National Oceanic and Atmospheric Administration, illustrates the number of recorded tornados per county across the United States and shows the total number of documented tornados in Maries County as 1 – 20 in 72 years resulting in an annual average probability of 1.4% - 27.8%

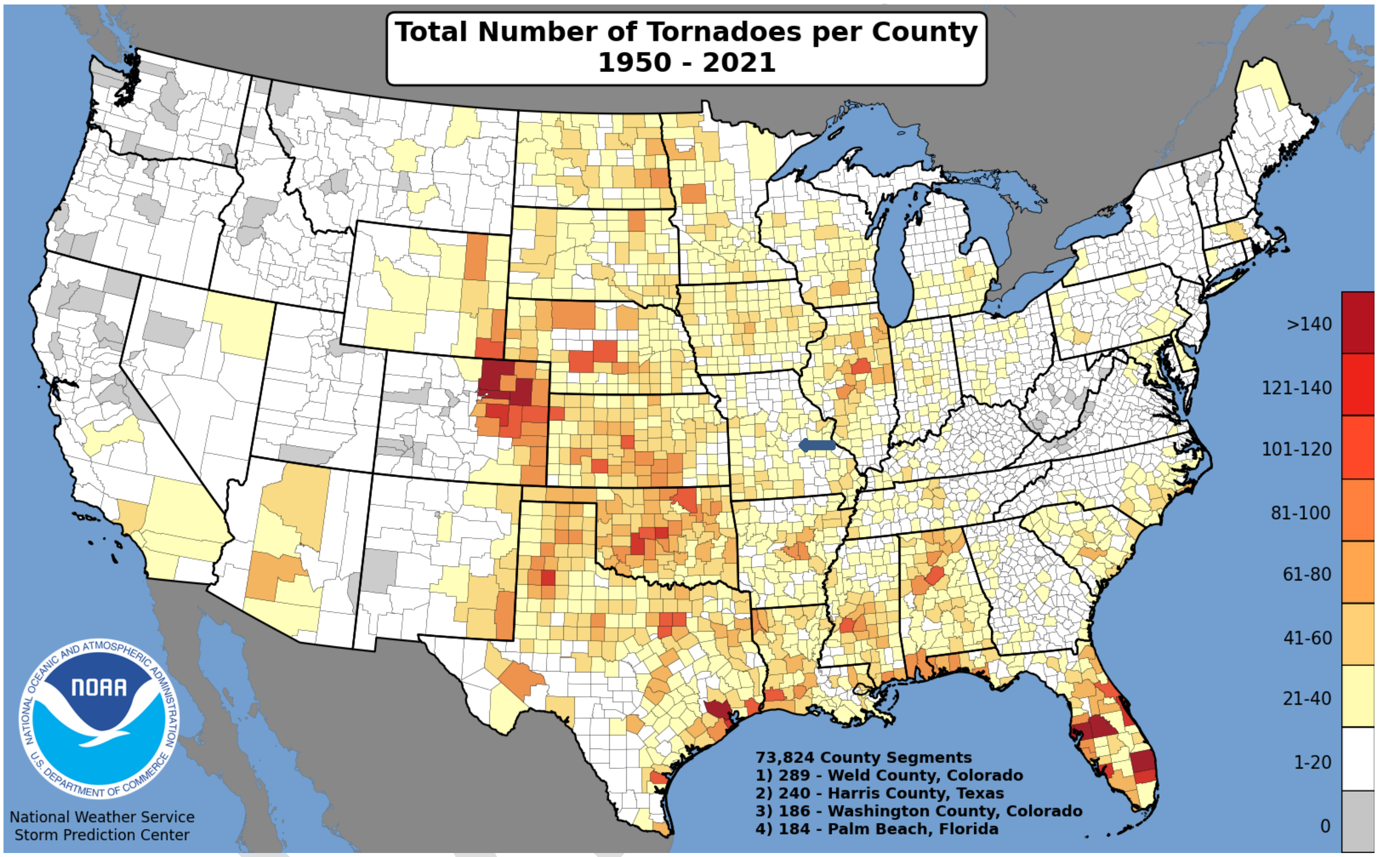
[1] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

Table 3.83. Annual Average % Probability of Tornadoes in Maries County

Location	Annual Avg. % P
Maries County	15.0%

*P = probability; see page 3.24 for definition.

Figure 3.46. Tornado Activity in the United States



*Source: https://www.spc.noaa.gov/wcm/ustormaps/tornadoes-by-county.png *Blue arrow indicates Maries County*

Changing Future Conditions Considerations

While the growing intensity and frequency of severe weather events can be directly attributed to climate change, a link between tornadoes and changing climate conditions is not well understood. Studies have shown that over the last 20 years the number of days with tornadoes has fallen although other trends such as the number of outbreaks with 30+ tornadoes, the density of tornado clusters, and the strength of tornados are increasing. The distribution of tornadoes has also shifted slightly eastward. At this time the cause of these trends remains unclear[1].

[1] https://www.c2es.org/content/tornadoes-and-climate-change/

Vulnerability

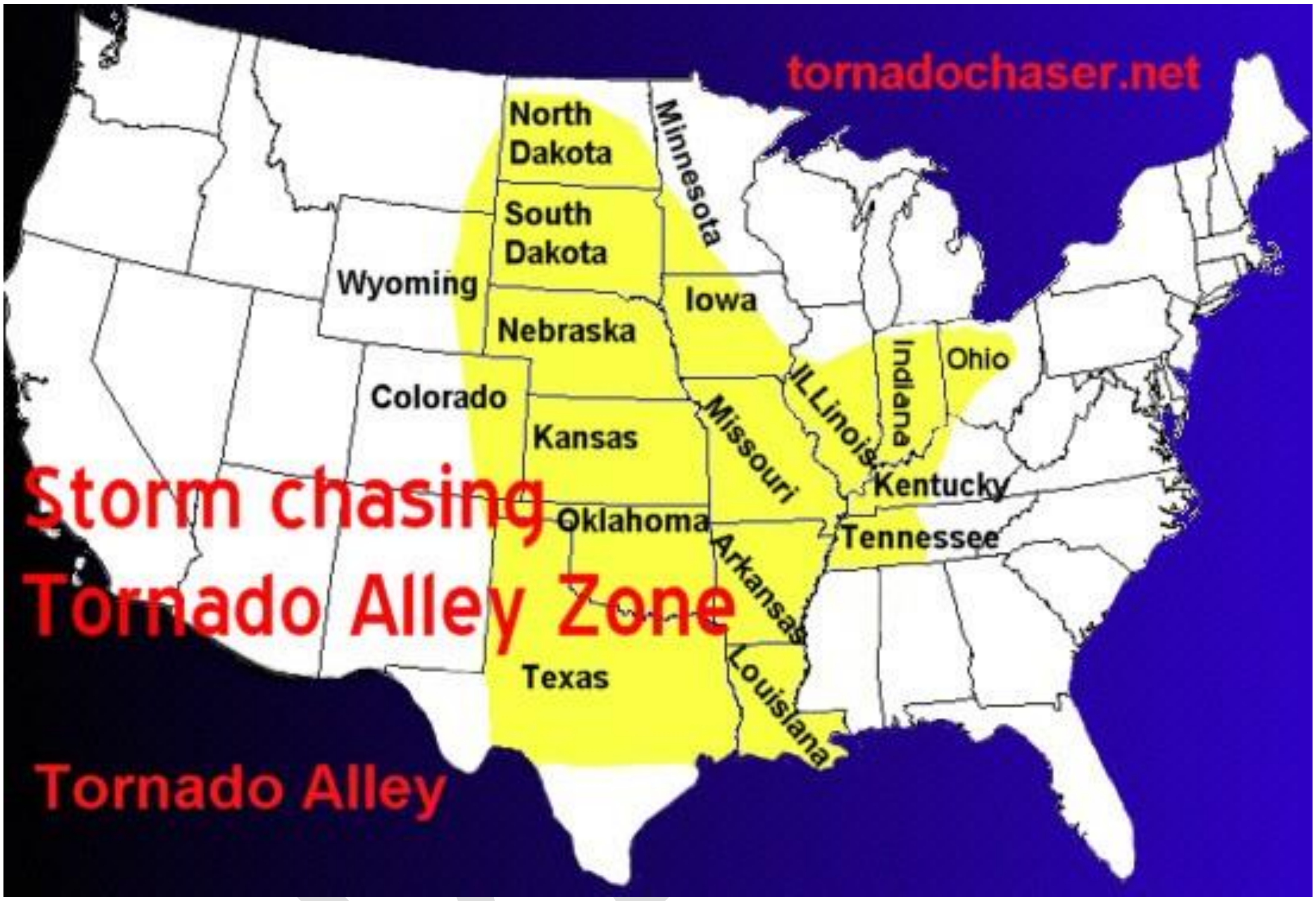
Vulnerability Overview

Many tornadoes are capable of great destruction and every tornado is a potential killer. Tornadoes can topple buildings, destroy mobile homes, uproot trees, hurl people and animals through the air for hundreds of yards and fill the air with lethal, windblown debris. Sticks, glass, roofing material and lawn furniture all become deadly missiles when driven by tornado winds.[1] Maries County resides in a region of the United States that has a high frequency of dangerous and destructive tornadoes. This region seen in **Figure 3.47** is referred to as "Tornado Alley".

The 2023 Missouri Hazard Mitigation Plan used statistical analysis of data from several sources to determine vulnerability to tornadoes across the state. HAZUS building exposure value data, population density and mobile home data from the U.S. Census 2019 the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina, and storm events data (1950 to December 31, 2021) from the National Centers for Environmental Information (NCEI). One limitation to the NCEI data is that many tornadoes that may have occurred in uninhabited areas and some in inhabited areas, may not have been reported. In addition, NOAA data cannot show a realistic frequency distribution of different Fujita scale tornado events, except for recent years. For these reasons a parametric model based on a combination of many physical aspects of the tornado to predict future expected losses was not used. The statistical model used for this analysis was probabilistic based purely on tornado frequency and historic losses.

[1] 2018 Missouri Hazard Mitigation Plan

Figure 3.47. Tornado Alley in the U.S.



Source: http://tornadochaser.net/

Six factors were considered in determining overall vulnerability to tornadoes as follows: building exposure, population density, social vulnerability, percentage of mobile homes, likelihood of occurrence and annual property loss. Based on natural breaks in the statistical data, a rating value of one through five was assigned to each factor. These rating values correspond to the following descriptive terms:

1) Low
2) Low-medium
3) Medium
4) Medium-high
5) High

0 provides the factors used and ranges for the rating values assigned. Once the ranges were established and applied to all factors, the ratings were combined to determine overall vulnerability. **Table 3.85** illustrates the ranges for tornado combined vulnerability rating.

Table 3.84. Ranges for Tornado Vulnerability Factor Ratings

Factors Considered	Low (1)	Medium-Low (2)	Medium (3)	Medium-High (4)	High (5)
Common Factors					
Building Exposure ($1,000)	$286,351-$3,053,773	$3,381,480-$9,044,465	$11,043,270-$24,814,360	$30,225,497-$50,440,776	$96,532,305-$153,542,314
Population Density (#per sq. mile)	8-113	114-434	435-1,163	1,164-1,958	1,959-4,855
Social Vulnerability	1	2	3	4	5
Percent Mobile Homes	0.23-4.38	4.39-8.24	8.25-13	13.01-23.77	23.78-34.58
Likelihood of Occurrence (# of events/ yrs. of data)	0-19	20-29	30-40	41-53	54-74
Total Annualized Property Loss ($ / yrs. of data)	$906-$268,132	$268,133-$1,010,663	$1,010,664-$2,400,000	$2,400,001-$4,499,038	$4,499,039-$39,592,934

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.85. Ranges for Tornado Combined vulnerability Rating

	Low (1)	Medium-Low (2)	Medium (3)	Medium-High (4)	High (5)
Tornado Combined Vulnerability	7-10	11-12	13-14	15-16	17-21

Source: 2023 Missouri Hazard Mitigation Plan

Table 3.86 provides data on building exposure, population density, SOVI and mobile home data for Maries County that is used to determine overall vulnerability.

Table 3.86. Building Exposure, Population Density, SOVI and Mobile Home Data for Maries County

Total Building Exposure (Hazus)	Exposure Rating	Population Density	Population Rating	SOVI Ranking	SOVI Rating	Percent Mobile Homes	Mobile Home Rating
$995,884,000	1	16.50	1	Medium	3	9.7	3

Source: 2023 Missouri Hazard Mitigation Plan

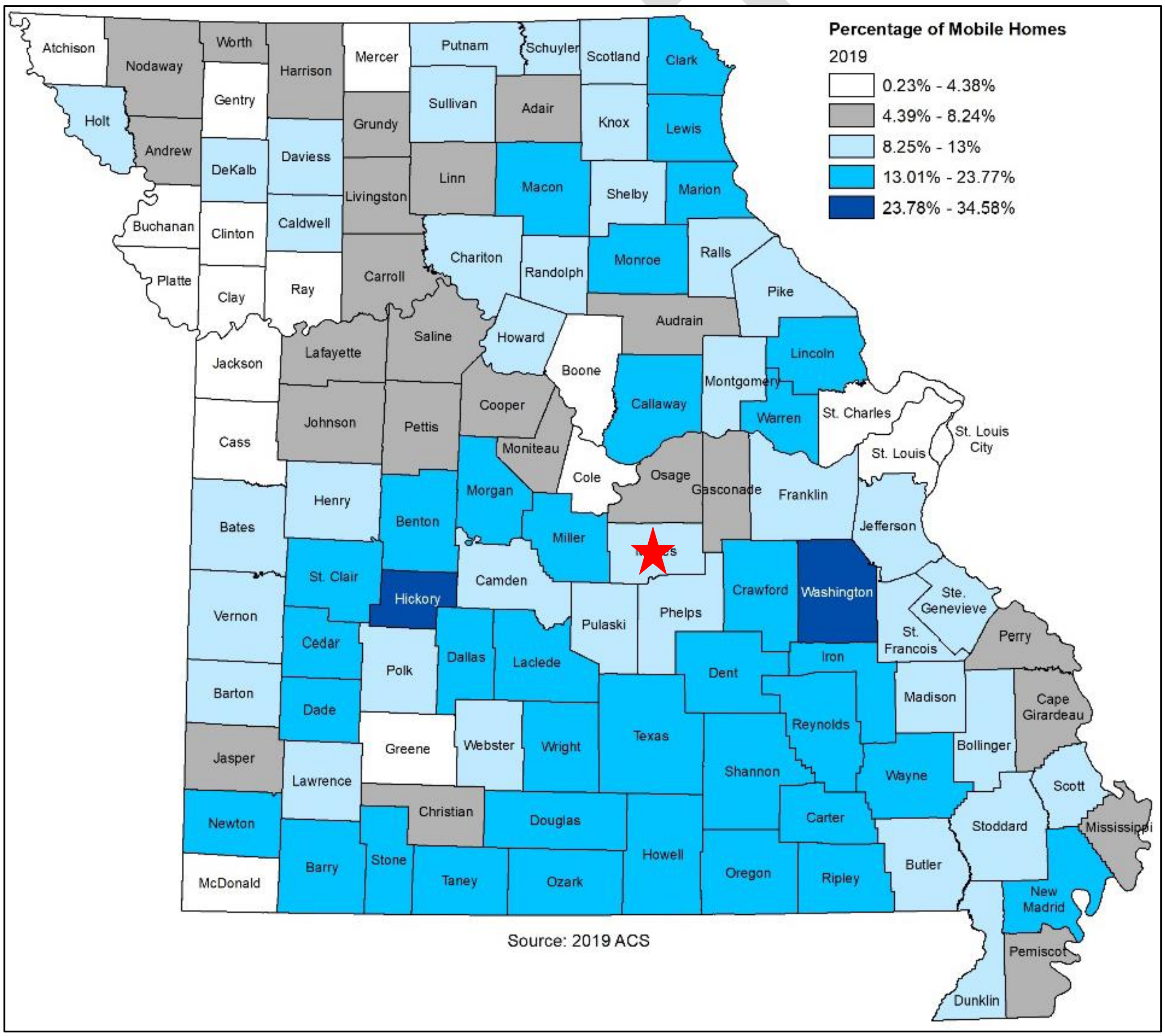
0 provides additional data, obtained from the National Centers for Environmental Information to complete the overall vulnerability analysis and the total overall vulnerability rating for tornadoes. **Figure 3.48** shows the percent of mobile homes per county throughout the state with Maries County determined to have medium mobile home density at 8.25 percent to 13 percent. Error! Reference s ource not found. provides the annualized property loss for tornadoes in Missouri and illustrates that Maries County falls into the lowest category at $906 - $268,132. Finally, **Figure 3.50** shows the county's overall vulnerability to tornadoes – Medium Low.

Table 3.87. Likelihood of Occurrence, Annual Property Loss and Overall Vulnerability Rating for Tornadoes for Maries County

Total Number of Tornadoes	Likelihood of Occurrence	Likelihood of occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
8	0.111	1	$74,656	1	10	Medium Low

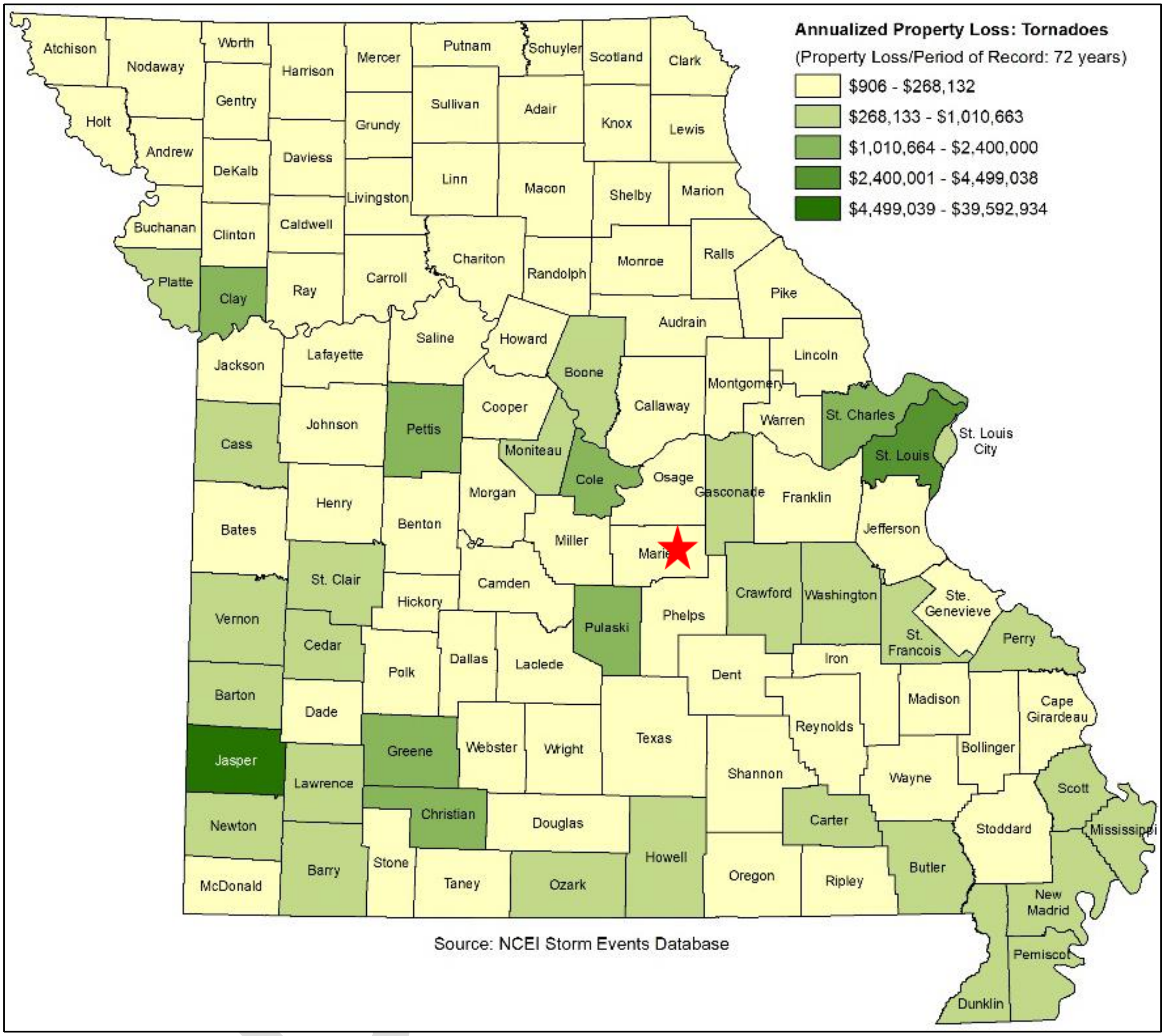
Source: 2023 Missouri Hazard Mitigation Plan

Figure 3.48. Missouri – Percent of Mobile Homes Per County



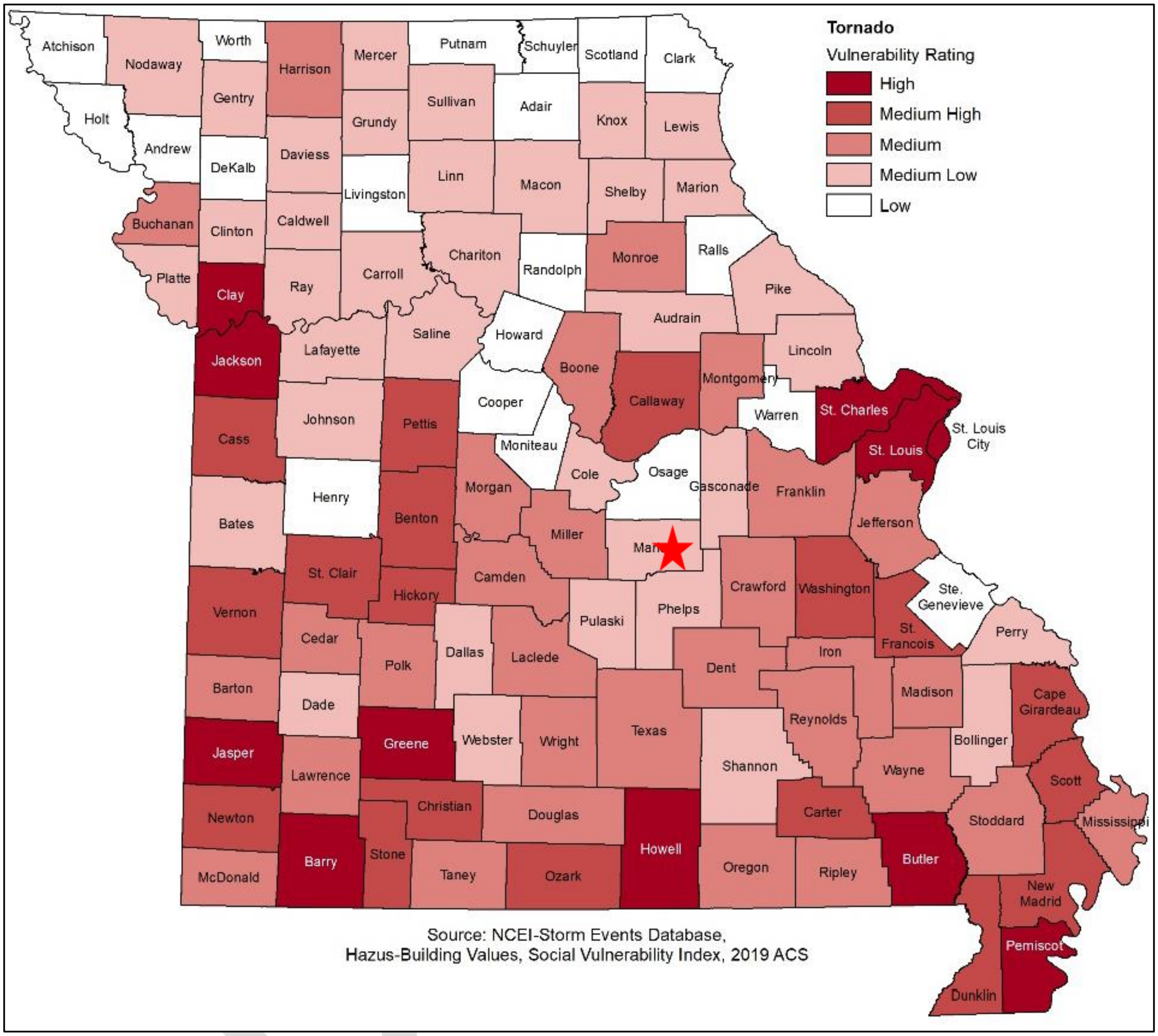
*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.49. Annualized Property Loss for Tornadoes



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.50. Overall Vulnerability to Tornadoes



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Potential Losses to Existing Development

There has been a total of $5,000,000 in property damage and 1 injury within Maries County due to tornadoes between 2003 and 2022. With this information we can estimate that each year there will be approximately $250,000 in loss to existing development. Additionally, the largest recorded tornado in the planning area was an F2 tornado occurring on April 16, 1982. Utilizing this information, we can infer that there is potential for another tornado of equivalence.

Impact of Previous and Future Development

As populations and development increases across the county, the vulnerability will increase as well. In order to protect jurisdictions from increased tornado vulnerabilities future analysis, training, and implementation should be considered at the planning, engineering, and architectural design stages.

Hazard Summary by Jurisdiction

As previously stated, a tornado event could occur anywhere in the planning area. However, some jurisdictions would suffer heavier damages because of the age of housing or high concentration of mobile homes. See **Table 3.33** for jurisdictions most vulnerable to damage due to the age of the structure. Based on structure age, the unincorporated Maries County would have higher vulnerability due to 13.7 percent of its housing stock being built prior to 1939. Furthermore, data was obtained from the U.S. Census Bureau for the number of mobile homes in Maries County and its jurisdictions. From the information provided in **Table 3.88,** unincorporated Maries County, with 623 mobile homes – 19.4 percent of housing, is most vulnerable to losses due to the number of mobile homes located within the jurisdiction.

Table 3.88. Percentage of Mobile Homes in Maries County, 2017-2021

Jurisdiction	Number of Mobile Homes	Percentage of Mobile Homes*
Unincorporated Maries County	623	19.4%
Belle	50	7.3%
Vienna	30	7.5%

Source: U.S. Census Bureau, 2016-2020 5-Year American Community Survey
**Number of mobile homes per jurisdiction/total occupied housing units per jurisdiction*
***Total housing units for all jurisdictions = 4,294*

Problem Statement

Early warnings are possibly the best hope for residents when severe weather strikes. While more than two hours warning is not possible for tornadoes, citizens must immediately be aware when a city will be facing a severe weather incident. Jurisdictions that do not already possess warning systems should plan to purchase a system. Storm shelters are another important means of mitigating the effects of tornadoes. Additional public awareness also includes coverage by local media sources. A community-wide shelter program should be adopted for residents who may not have adequate shelter in their homes. Residents should also be encouraged to develop home emergency action plans and build their own storm shelters to prepare for emergencies.

3.4.10 Wildfires

The specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.11, Page 3.390 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard _Mitigation_Plan2018.pdf
- Missouri Department of Conservation Wildfire Data Search at http://mdc4.mdc.mo.gov/applications/FireReporting/Report.aspx
- Statistics, Missouri Division of Fire Safety at https://dfs.dps.mo.gov/;
- National Statistics, US Fire Administration at https://www.usfa.fema.gov/statistics/;
- Fire/Rescue Mutual Aid Regions in Missouri at https://dfs.dps.mo.gov/programs/resources/mutual-aid.php;
- Forestry Division of the Missouri Dept. of Conservation at https://mdc.mo.gov/your-property/fire-management;
- National Fire Incident Reporting System (NFIRS), http://www.dfs.dps.mo.gov/programs/resources/fire-Incident-reporting-system.php
- Firewise, www.firewise.org
- University of Wisconsin Slivis Lab, http://silvis.forest.wisc.edu/maps/wui_main
- MSDIS Structure Inventory and All Hazard Risk Dataset (available in both GIS and Excel format) https://drive.google.com/drive/folders/0Bzg99s866kWocFB5Y3hCRlRuWWM
- Missouri Hazard Mitigation Viewer http://bit.ly/MoHazardMitigationPlanViewer2018 - Website https://drive.google.com/file/d/1bPkcojgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Likelihood of Occurrence of wildfire by County
  - Average annual land burned (acres) by County
  - Number of structures within the WUI Interface/Intermix Area
  - Potential loss, average annual land burned by County

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 Missouri Division of Fire Safety (MDFS) indicates that approximately 80 percent of the fire departments in Missouri are staffed with volunteers. Whether paid or volunteer, these departments are often limited by lack of resources and financial assistance.

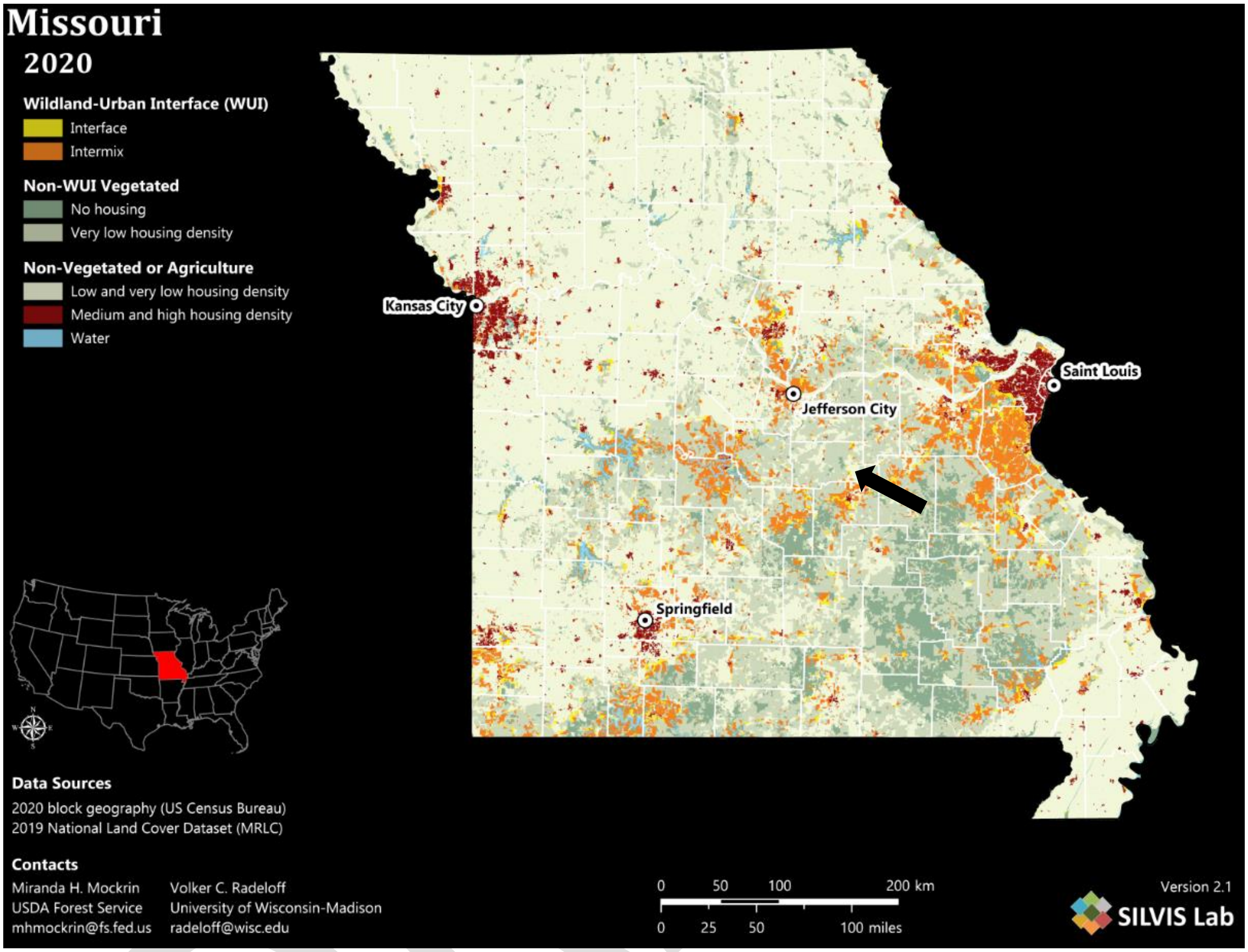
The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from wildfires. To accomplish this task, eight forestry regions have been established in Missouri for fire suppression. The Forestry Division works closely with volunteer fire departments and federal partners to assist with fire suppression activities. Currently, approximately 900 rural fire departments in Missouri have mutual aid agreements with the Forestry Division to obtain assistance in wildfire protection if needed. Over 300 have mutual aid agreements with the State to obtain assistance in wildfire protection if needed. A cooperative agreement with the Mark Twain National Forest is renewed annually.

Most Missouri fires occur during the spring season between February and May. The length and severity of both structural and wildland fires depend largely on weather conditions. Each year, an average of about 3,200 wildfires burn more than 52,000 acres of forest and grassland in Missouri. Spring in Missouri is usually characterized by low humidity and high winds. These conditions result in higher fire danger. 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

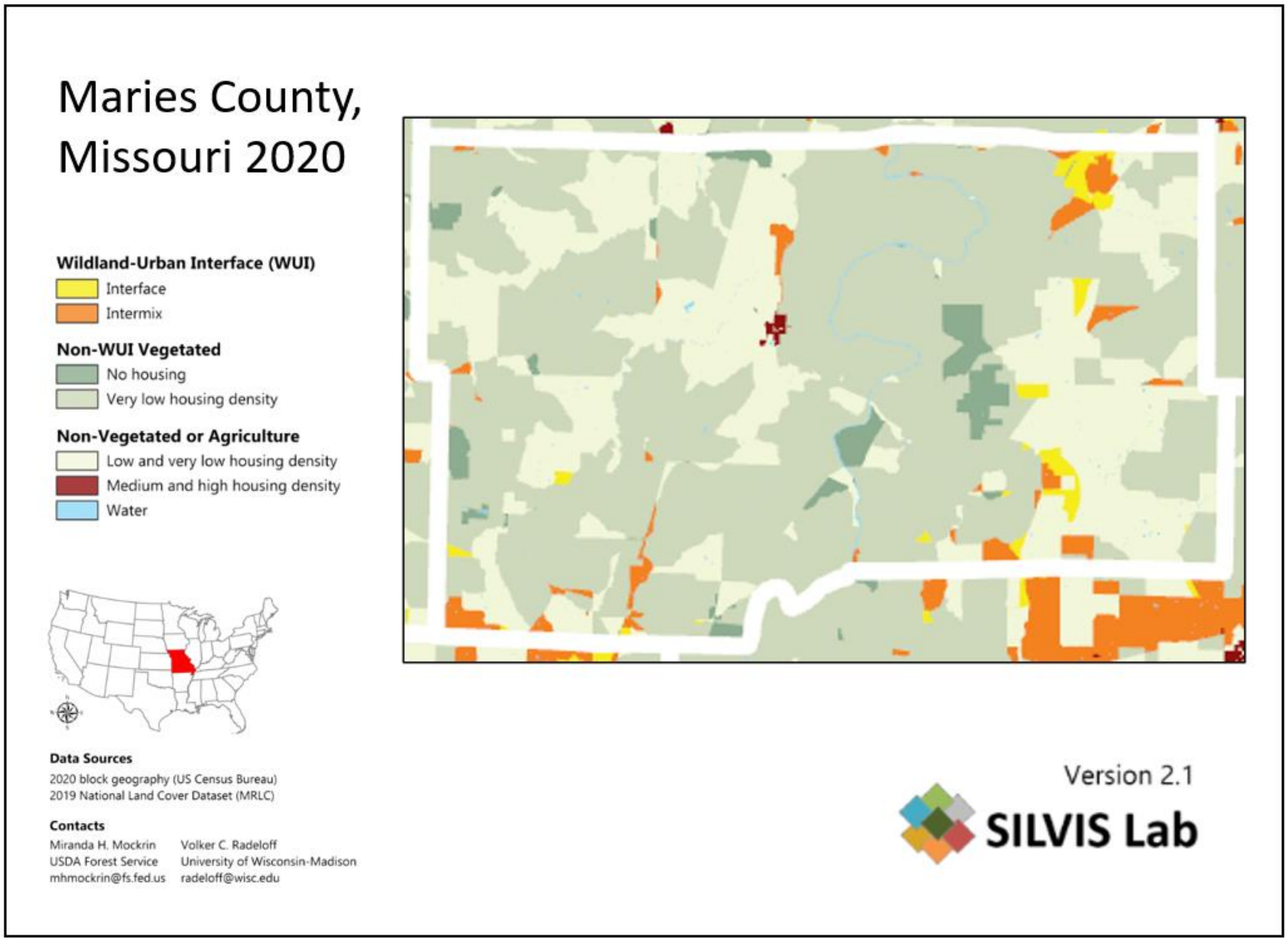
The risk of wildfire does not vary widely across the planning area. However, damages due to wildfires are expected to be higher in communities with more wildland–urban interface (WUI) areas. WUI refers to the zone of transition between unoccupied land and human development. Within the WUI, there are 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 (**Figure 3.51**). To determine specific WUI areas and variations, data was obtained from ArcGIS, Streets and SILVIS (**Figure 3.52**). According to the WUI area map of Maries County many unincorporated communities across the county and the City of Belle partially reside in a WUI area.

Figure 3.51. 2020 Missouri Wildland Urban Interface (WUI)



Source: http://silvis.forest.wisc.edu/maps/wui; black arrow points to Maries County

Figure 3.52. Maries County Wildlife Urban Interface



Source: https://geoserver.silvis.forest.wisc.edu/geodata/wui_change_2020/maps/gifs/white/MO_WUI_v21_white_2020.gif

Strength/Magnitude/Extent

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

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

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

The severity of wildfires in Missouri is considered low to moderate, and wildfires in Missouri often 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. Large fires have the potential to kill people, livestock, fish and wildlife as well as destroy crops and pastures. Wildfires can destroy not only natural areas, but homes, businesses and other facilities. Loss of life due to wildfires is not common in Missouri, but injuries to residents and firefighters can include falls, sprains, abrasions or heat-related injuries such as dehydration.

Previous Occurrences

Between 2003 and 2022 there were 303 wildfires reported in Maries County, according to wildfire reporting to the Missouri Department of Conservation[1]. This is an average of 15.15 wildfires per year. The size of the fires varied from as small as .01 acre to as large as 500 acres. **Table 3.89** shows the cause of wildfires, number of wildfires and acres burned for the period 2003-2022. Debris fires account for both the largest number of fires and the greatest number of acres burned.

Table 3.89. 2003-2022 Maries County Wildfires by Cause

Cause	Number	Acres	% Number	% Acres
Arson	4	7	1.32%	0.15%
Debris	129	2,327	42.57%	48.89%
Equipment	18	65	5.94%	1.37%
Miscellaneous	103	1,912.82	33.99%	40.19%
Not Reported	3	231	0.99%	4.85%
Unknown	46	216.59	15.18%	4.55%
Totals	**303**	**4759.41**	100.00%	100.00%

Probability of Future Occurrence

From the data obtained from the Missouri Department of Conservation[2] (Appendix: F), 303 wildfire events occurred in Maries County between 2003 and 2022. This information was utilized to determine the annual average percent probabilities of wildfires. Since multiple occurrences are anticipated per year (303 events/20 years), the probability of wildfires per year is 100% with an average of 15.15 events per year Table 3.91.

Table 3.90. Annual Average Percentage Probability of Wildfires in Maries County

Location	Annual Avg. % P	Avg. Number of Events
Maries County	100%	15.15

*P = probability; see page 3.24 for definition.

[1] http://mdc7.mdc.mo.gov/applications/FireReporting/Report.aspx
[2] http://mdc7.mdc.mo.gov/applications/FireReporting/Report.aspx

Changing Future Conditions Considerations

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Missouri, although the composition of trees in the forests may change. More droughts would reduce forest productivity and changing future conditions are also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could 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 are likely to increase, while the population of hickory trees is likely to decrease.[1]

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.[2]

Vulnerability

Vulnerability Overview

According to the 2023 Missouri State Hazard Mitigation Plan, the Department of Conservation historical wildfire data was the best resource for data on wildfires. The Missouri State Hazard Mitigation Plan used data from 2004-2016 and determined that Maries County should expect to have 15.2 wildfires per year, impacting 251.3 acres **(Table 3.91**).

The state plan also indicates that Maries County is at a higher possible likelihood for building damage from wildfires due to 2,040 buildings valued at $248,747,397 and 3,366 individuals vulnerable. **Figure 3.53** illustrates the likelihood of wildfire events based on data from 2004-2016. **Figure 3.53** provides a map that illustrates the average annual acreage burned.

Table 3.91. Statistical Data for Wildfire Vulnerability in Maries County

Number of Wildfires 2004-2016	Likelihood of Occurrence (#/year)	Total Acres Burned	Average Annual Acreage Burned
273	15.2	4,522.85	251.3

Source: 2023 Missouri State Hazard Mitigation Plan

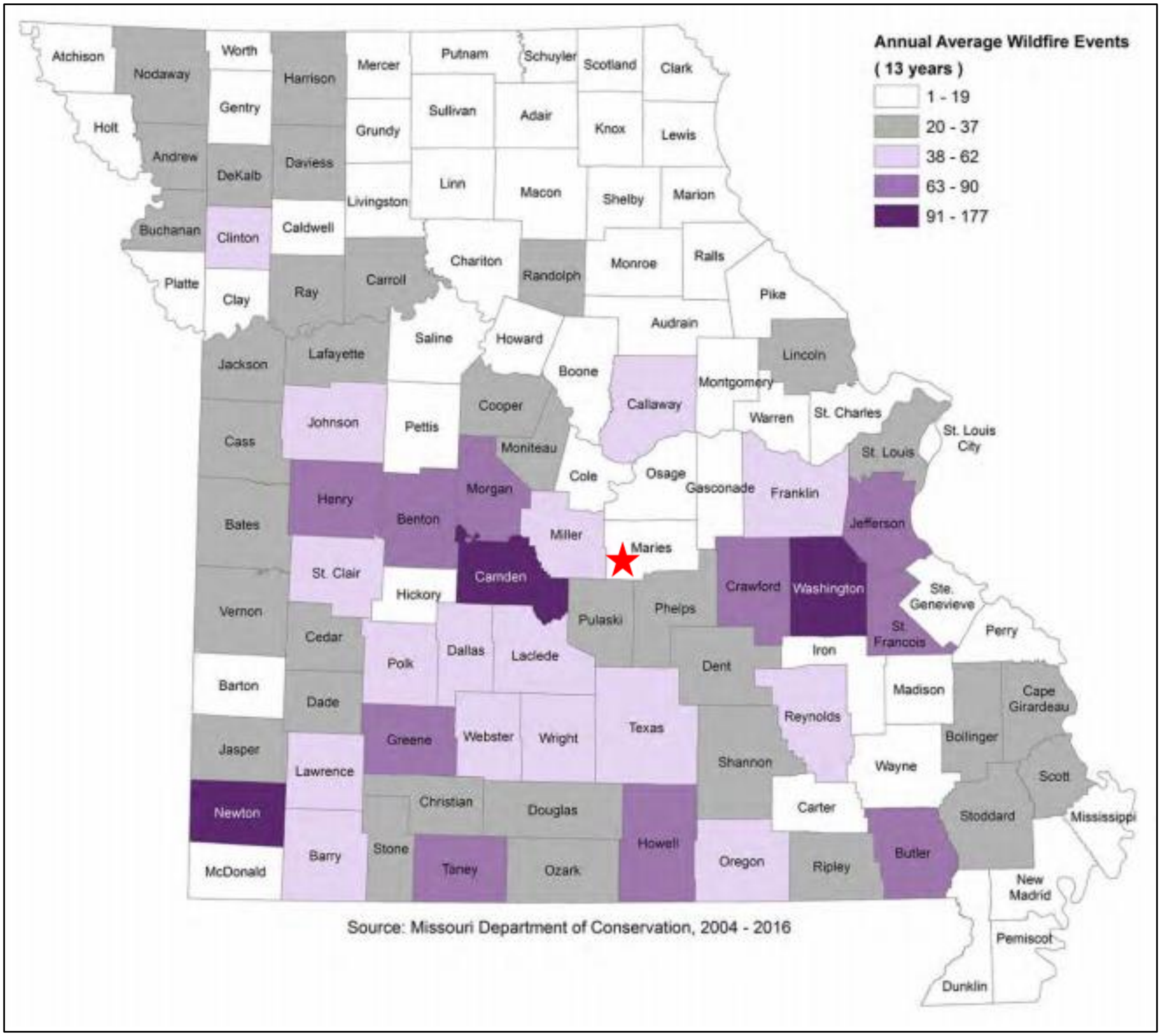
The method used to determine vulnerability to wildfires in the 2018 Missouri Hazard Mitigation plan was a GIS comparative analysis of wildland urban interface and intermix (WUI) areas against building exposure data to determine the types, numbers and estimated values of buildings at risk to wildfire.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

The results of that analysis, including estimated number of structures, value of structures and

[1] 2018 Missouri Hazard Mitigation Plan
[2] Ibid

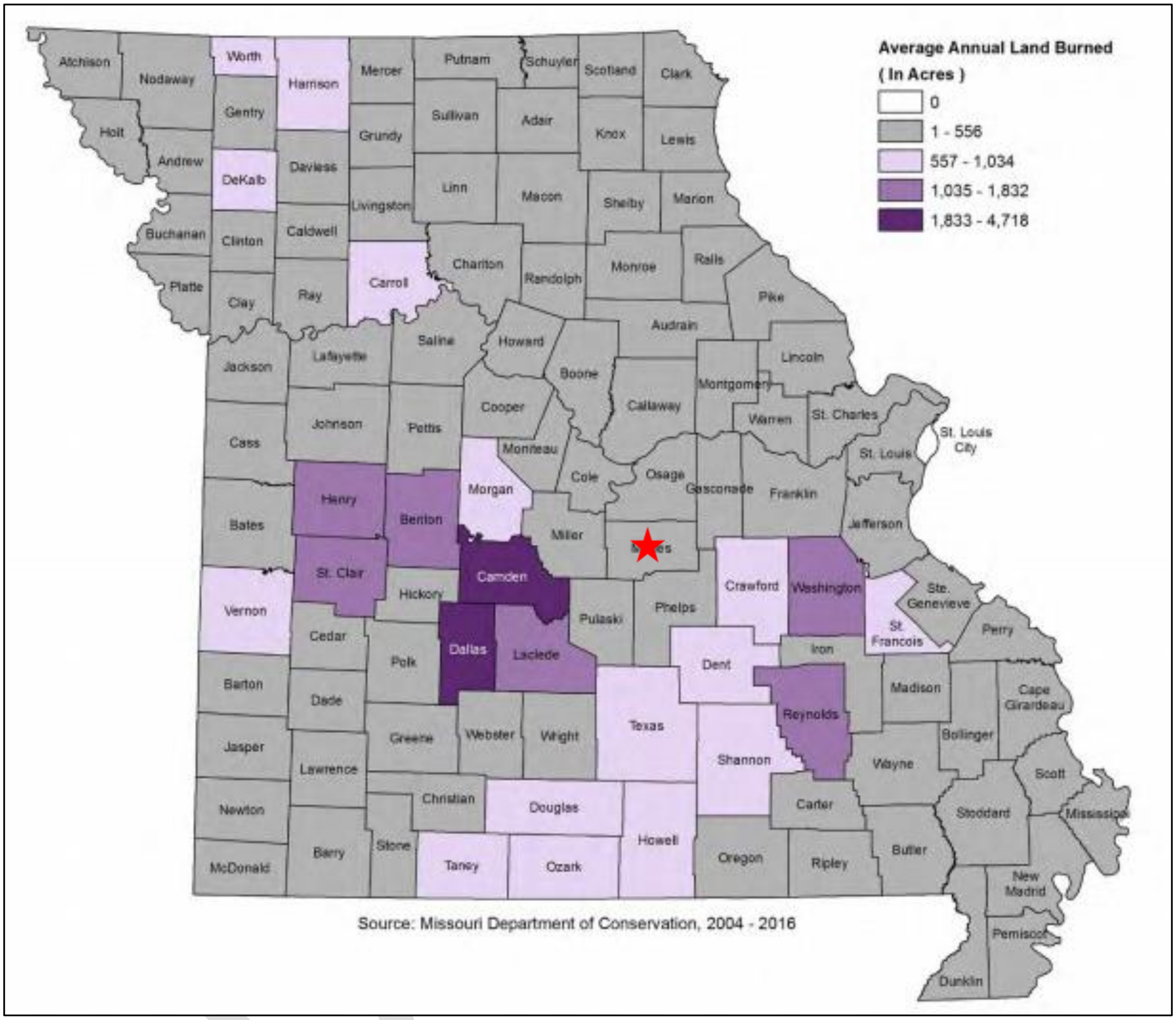
population are illustrated in **Table 3.92.** The total estimated number of structures vulnerable to wildfires is 2,040. The overall value of structures vulnerable to wildfire in Maries County is estimated at $248,747,397. To further illustrate vulnerability in Maries County, maps from the 2023 Missouri Hazard Mitigation plan illustrating these numbers and comparing them statewide are included. The number of structures in the WUI interface and intermix areas statewide are shown in **Figure 3.55**. **Figure 3.56** shows the estimated value of structures in the WUI interface and intermix areas. **Figure 3.57** illustrates the number of people at risk to wildfire in the WUI interface and intermix areas.

Figure 3.53. Likelihood of Wildfire Events, 2004-2016



*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.54. Average Annual Acreage Burned



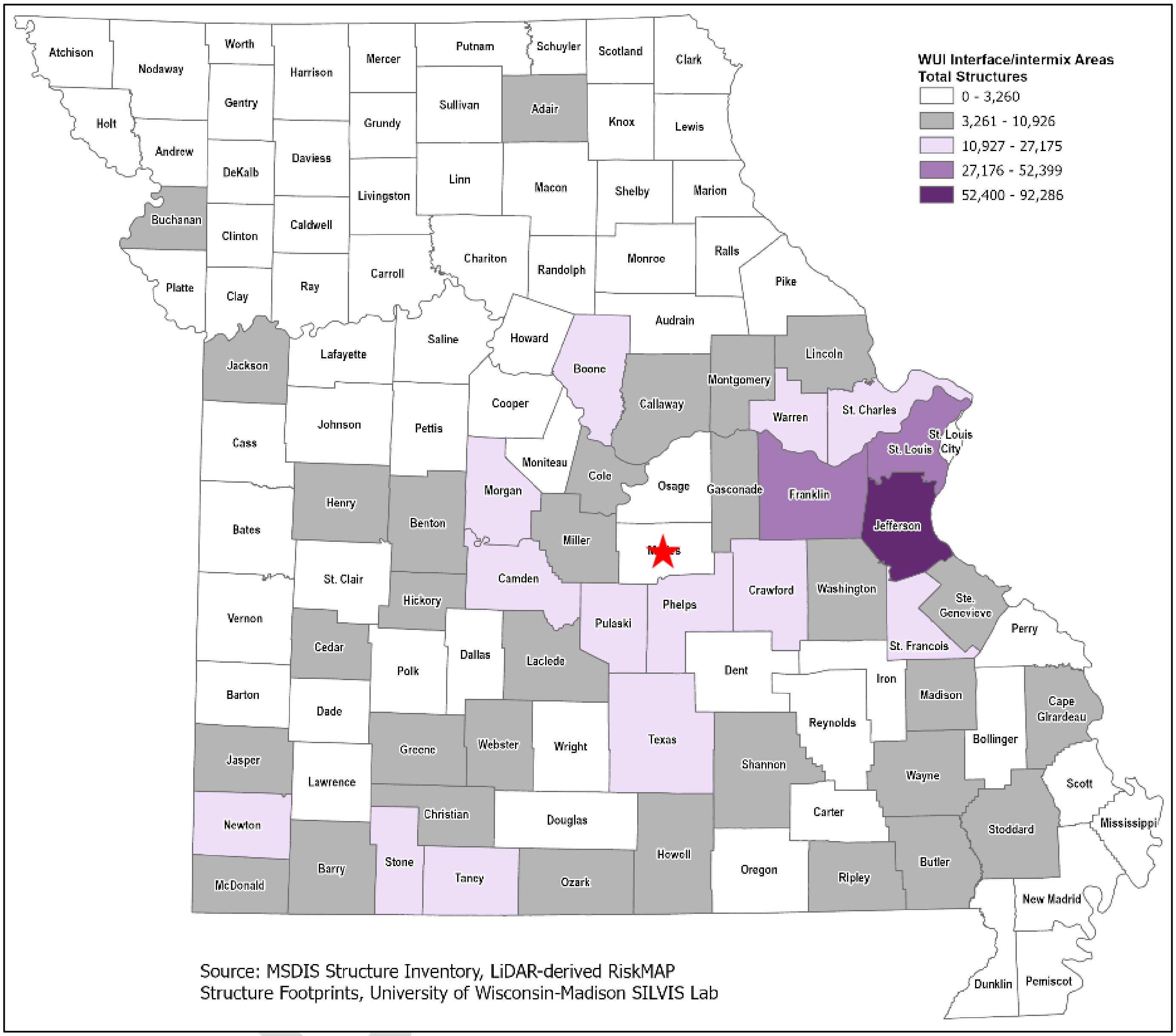
*Source: 2023 Missouri State Hazard Mitigation Plan, *Red star indicates Maries County*

Table 3.92. Estimated Numbers and Values of Structures and Population Vulnerable to Wildfire in Maries County

Maries County	Number of Structures	Value of Structures	Population
Agriculture	435	$1,281,656	
Commercial	141	$26,085,404	
Education	2	$4,670,800	
Government	3	$1,707,600	
Industrial	2	$2,316,933	
Residential	1457	$212,685,003	
Totals	**2040**	**$248,747,397**	**3366**

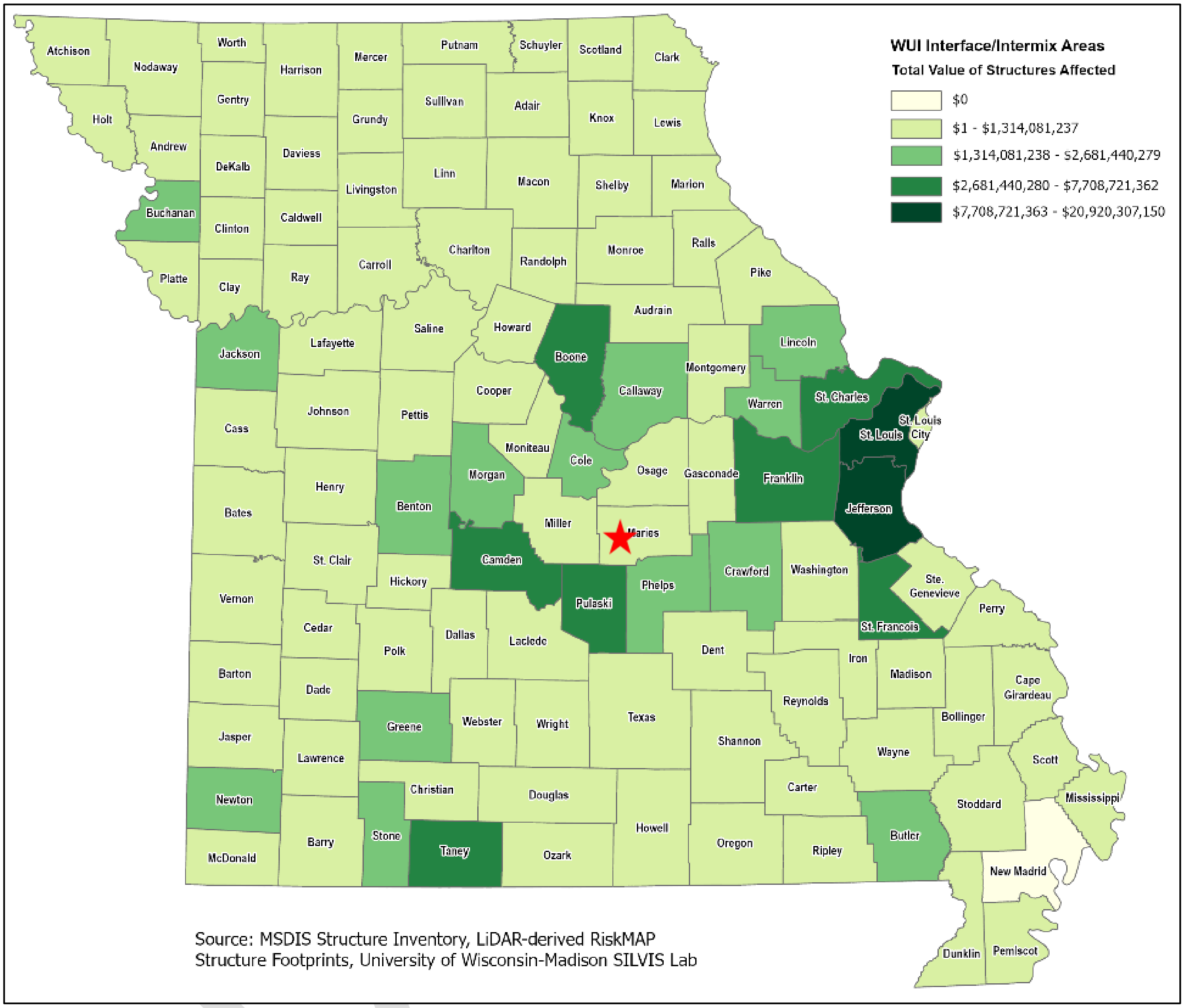
Source: 2023 Missouri State Hazard Mitigation Plan

Figure 3.55. Number of Structures in WUI Interface and Intermix Areas



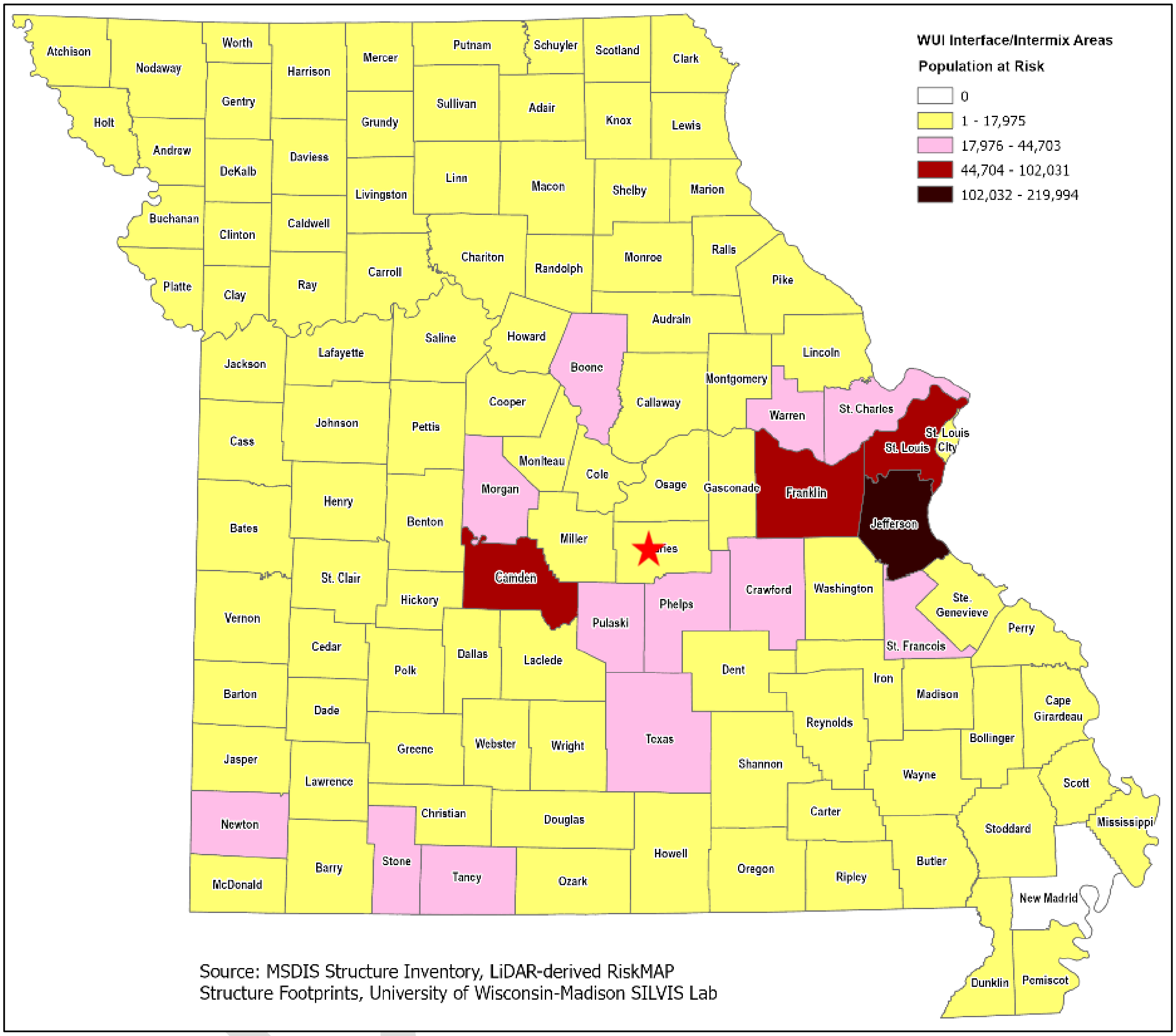
*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.56. Value of Structures in the WUI Interface and Intermix Areas



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Figure 3.57. Population at Risk to Wildfire in WUI Interface and Intermix Areas



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Potential Losses to Existing Development

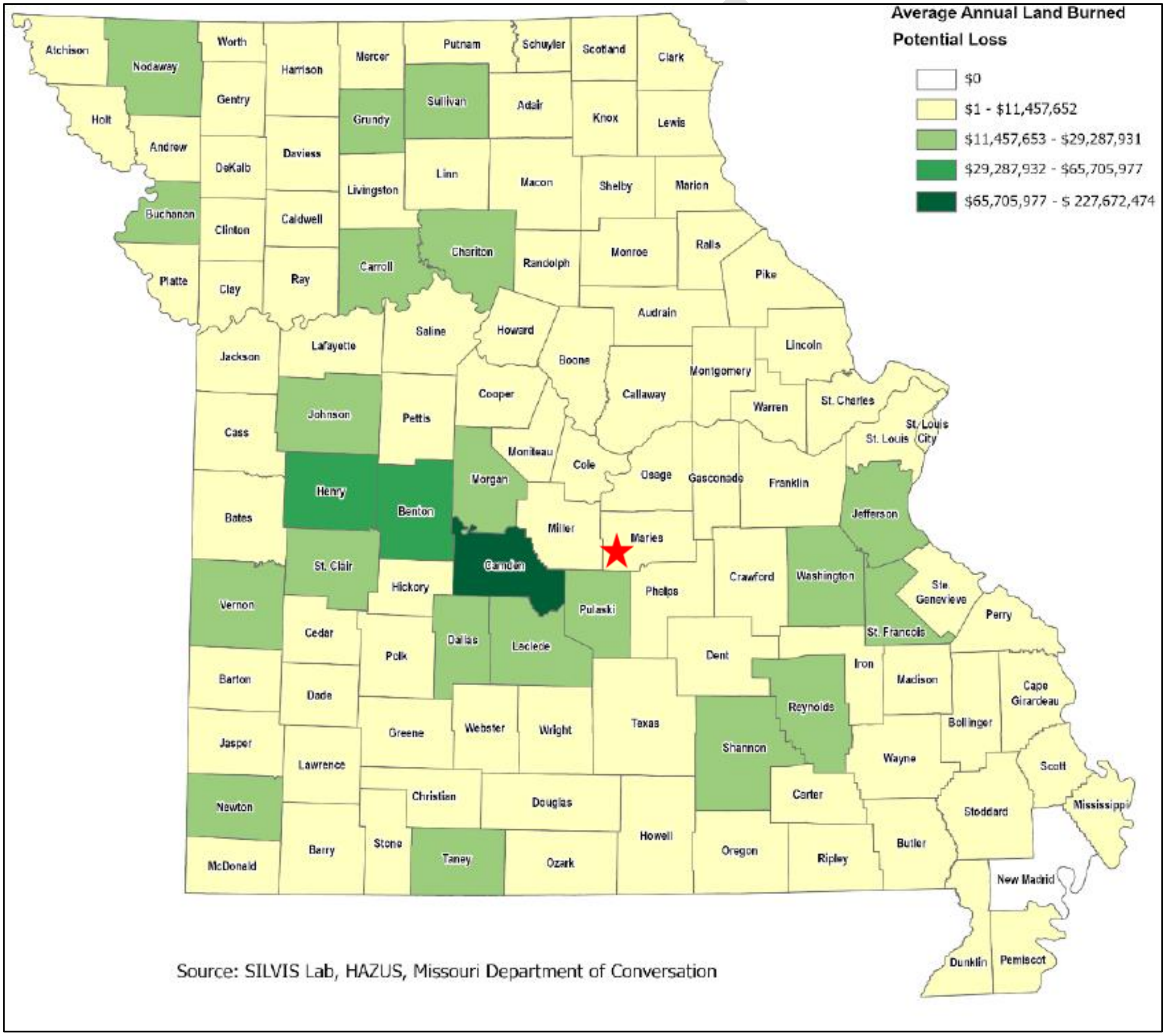
As there was no data available on Maries County specific losses, data was used from the 2023 Missouri State Hazard Mitigation Plan. The factors considered for estimating potential losses due to wildfires were average acreage burned each year per county and the average value of structures per acre in the WU-Interface/Intermix areas. **Table 3.93** and **Figure 3.58** that follows provide the potential loss figures for Maries County based on this methodology.

Table 3.93. Wildfire Potential Loss Estimates for Maries County

Total WUI Acreage	Total Structure Value Within WUI	Average Value/Acre within WUI	Average Annual Acreage Burned	Potential Loss
18,145.40	$248,747,397	$13,709	251.27	$3,444,544

Source: 2023 Missouri Hazard Mitigation Plan

Figure 3.58. Annualized Wildfire Damages



*Source: 2023 Missouri Hazard Mitigation Plan, *Red star indicates Maries County*

Impact of Previous and Future Development

Few future developments are anticipated in WUI areas, however due to lack of data, it is difficult to enumerate. Additionally, as previously mentioned, many unincorporated communities within the county and the city of Belle reside in a WUI area. This increases the risk of fire hazards for future development.

Hazard Summary by Jurisdiction

As long as drought conditions are not severe, future wildfires in Maries County should have a low-medium adverse impact on the community, depending on the proximity to population centers. Nonetheless, homes, businesses, and schools located in unincorporated areas are at higher risk from wildfires due to proximity to woodland and more importantly, distance from fire services. All cities and school districts are in WUI areas but are closer to fire services.

Problem Statement

An estimated 2,040 structures and 3,366 people are vulnerable to wildfires in Maries County. Wildfires are expected to occur on an annual basis. To mitigate adverse impacts a comprehensive community awareness and educational campaign on wildfire danger should be designed and implemented. This campaign should include the development of capabilities, systems, and procedures for pre-deploying fire-fighting resources during times of high wildfire hazards; training of local fire departments for wildfire scenarios; encouraging the development and dissemination of maps relating to the fire hazards (WUI areas) to help educate and assist builders and homeowners in being engaged in wildfire mitigation activities; and guidance of emergency services during response. Residents should be educated on the dangers of wildfires and what steps they can take to mitigate their vulnerability. This could include landscaping and water supply.