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 Future Land Use and Development** discusses areas of planned future development
- **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 Pulaski 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 Pulaski County Hazard Mitigation Plan:

- Dam Failure
- Drought
- Earthquake
- Extreme Temperatures
- Fires (Urban/Structural and Wild)
- Flooding
- Land Subsidence/Sinkholes
- Thunderstorm/High Winds/Lightning/Hail
- Tornado
- Severe Winter Weather

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 Pulaski County Plan to match the hazards listed in the Missouri State Hazard Mitigation Plan.

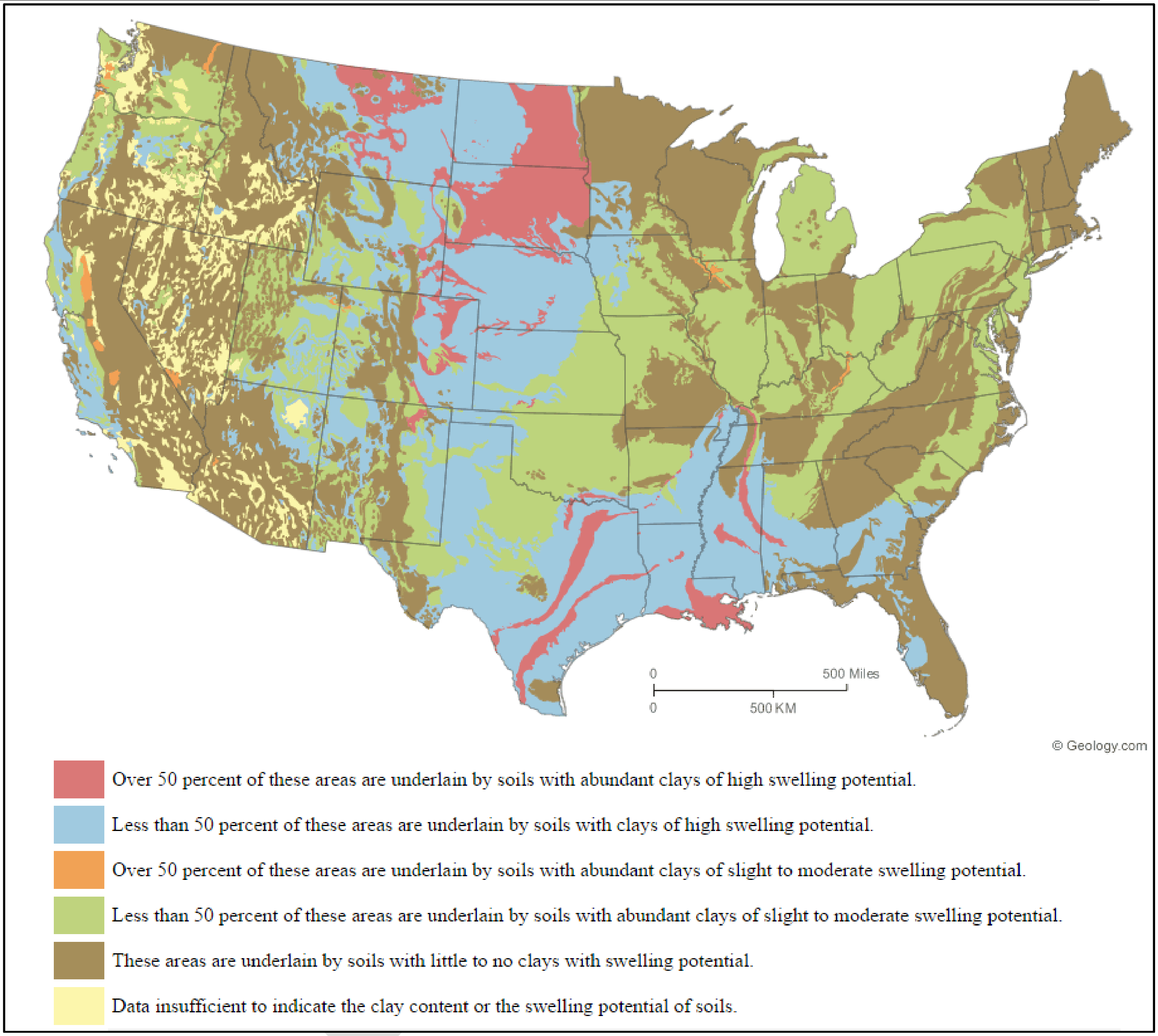
Table 3.1. Table 3.1 Hazards Not Profiled in the Plan

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.

Hazard	Reason for Omission
Debris Flow	There are no mountainous areas in the planning area where this type of event occurs.
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] https://levees.sec.usace.army.mil/#/

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 Pulaski 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 73 federally declared disasters since 1953. Of those, 45 have occurred between 2000 and 2019. All but two of these disasters have been weather related – severe wind and rain storms, tornadoes, flooding, hail, ice storms and winter storms. **Table 3.2** lists the federal disaster declarations for Pulaski County from 1990 through 2019.

Table 3.2. FEMA Disaster Declarations that included Pulaski County, Missouri, 1990-2019

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-995	Flooding, Severe Storm	Declaration Date: July 9, 1993 Incident Period: June 10, 1993 to October 25, 1993	IA, PA
DR-1006	Flooding, Severe Storm, Tornadoes	Declaration Date: December 1, 1993 Incident Period: November 13, 1993 to November 19, 1993	IA
DR-1023	Severe Storm, Flooding, Tornadoes	Declaration Date: April 21, 1994 Incident Period: April 9, 1994 to May 5, 1994	IA

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-1412	Severe Storms, Tornadoes	Declaration Date: May 6, 2002 Incident Period: April 24, 2002 to June 10, 2002	PA
DR-1463	Severe Storms, Tornadoes, Flooding	Declaration Date: May 6, 2003 Incident Period: May 4, 2003 to May 30, 2003	IA, PA
EM-3232	Hurricane Katrina Evacuation	Declaration Date: September 10, 2005 Incident Period: August 29, 2005 to October 1, 2005	PA
DR-1676	Severe Winter Storms, Flooding	Declaration Date: January 15, 2007 Incident Period: January 12, 2007 to January 22, 2007	PA
EM-3281	Severe Winter Storms	Declaration Date: December 15, 2007 Incident Period: December 8, 2007 to December 15, 2007	PA
DR-1749	Severe Storms, Flooding	Declaration Date: March 19, 2008 Incident Period: March 17, 2008 to May 9, 2008	IA, 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 8, 2009 to May 16, 2009	PA
EM-3317	Severe Winter Storm	Declaration Date: February 3, 2011 Incident Period: January 31, 2011 to February 5, 2011	PA
DR-1961	Severe Winter Storm, Snowstorm	Declaration Date: March 23, 2011 Incident Period: January 31, 2011 to February 5, 2011	PA
DR-1980	Severe Storms, Tornadoes, Flooding	Declaration Date: May 9, 2011 Incident Period: April 19, 2011 to June 6, 2011	IA

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (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-4317	Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Declaration Date:June 2, 2017 Incident Period: April 28, 2017 to May 11, 2017	IA, PA
DR-4451	Severe Storms, Tornadoes, And Flooding	Declaration Date: July 9, 2019 Incident Date: April 29, 2019 to July 5, 2019	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)
- 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 March 2014, as entered by the NWS. Due to changes in the data collection and processing procedures over time, there are unique periods of record available depending on the event type. The following timelines show the different time spans for each period of unique data collection and processing procedures.

1. Tornado: From 1950 through 1954, only tornado events were recorded.
2. Tornado, Thunderstorm Wind and Hail: From 1955 through 1992, only tornado, thunderstorm wind and hail events were keyed from the paper publications into digital data. From 1993 to 1995, only tornado, thunderstorm wind and hail events have been extracted from the Unformatted Text Files.
3. All Event Types (48 from Directive 10-1605): From 1996 to present, 48 event types are recorded as defined in NWS Directive 10-1605.

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. However, not all hazards impact every jurisdiction such as dam failure. “X” indicates the jurisdiction is impacted by the hazard, and a "-" indicates the hazard is not applicable to that jurisdiction. As Pulaski 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 to damages from a tornado.

Table 3.3. Hazards Identified for Each Jurisdiction

Jurisdiction	Dam Failure	Drought	Earthquake	Extreme Temperatures	Wildfires	Flooding (River and Flash)	Land Subsidence/Sinkholes	Thunderstorms/High Winds/ Lightning/Hail	Tornado	Severe Winter Weather
Pulaski County	-	x	x	x	x	x	x	x	x	x
City of Crocker	-	x	x	x	x	x	x	x	x	x
City of Dixon	-	x	x	x	x	x	x	x	x	x
City of Richland	-	x	x	x	x	x	x	x	x	x
City of St. Robert	-	x	x	x	x	x	x	x	x	x
City of Waynesville	-	x	x	x	x	x	x	x	x	x
School Districts										
Dixon. R-I	-	x	x	x	x	x	x	x	x	x
Crocker Co. R-II	-	x	x	x	x	x	x	x	x	x
Swedeborg R-III	-	x	x	x	x	x	x	x	x	x
Richland R-IV	-	x	x	x	x	x	x	x	x	x
Laquey R-V	-	x	x	x	x	x	x	x	x	x
Waynesville R-VI	-	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. Pulaski 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 are widespread in the county, but more localized in their effects. Areas of urbanization include Crocker, Dixon, Richland, St. Robert, and Waynesville. These 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 damages. 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 2019 Census Bureau data. Building counts values are based on parcel data provided by the 2018 Missouri State Hazard Mitigation Plan, which can be found at the following website,
https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf .

Table 3.4. Maximum Population and Building Exposure by Jurisdiction

Jurisdiction	2018 Population	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Unincorporated Pulaski County	36,733	-	-	-	-
Crocker	1,027	-	-	-	-
Dixon	1,436	-	-	-	-
Richland	1,770	-	-	-	-
St. Robert	5,822	-	-	-	-
Waynesville	5,226	-	-	-	-
Total	52,014	19,605	$5,334,660,000	-	$5,334,660,000

Sources: U.S. Census Bureau, 2014-2018 5-Year American Community Survey; 2018 Missouri State Hazard Mitigation Plan

Table 3.5. Building Counts by Usage Type

Jurisdiction	Residential Counts	Commercial Counts	Industrial Counts	Agricultural Counts	Other (Govt./ Education)	Total
Pulaski County	11,913	538	36	2,017	5,101	19,605

Source: 2018 MO State Hazard Mitigation Plan

Table 3.6 below, provides additional information for school districts, including the number of buildings, building values (building exposure) and contents value (contents exposure). These numbers will represent the total enrollment and building count for the public school districts regardless of the county in which they are located.

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

Public School District	Enrollment	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Dixon R-I	950	3	$20,564,080	-	$20,564,080
Crocker R-II	588	6	Not Provided	Not Provided	Not Provided
Swedeborg R-III	50	1	$2,949,530	-	$2,949,530
Richland R-IV	553	11	$15,220,044	$3,274,763	$18,494,807
Laquey R-V	659	4	$20,106,565	$5,019,280	$25,125,845
Waynesville R-VI	6,685	22	$214,273,370	$32,431,741	$246,705,111

Source: https://ogi.oa.mo.gov/DESE/schoolSearch/index.html; 2018 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.

Table 3.7 includes a summary of the inventory of critical and essential facilities and infrastructure in the planning area. The list was compiled from the 2020 Data Collection Questionnaire, the Missouri Department of Health and Senior Services, and the National Bridge Inventory.

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

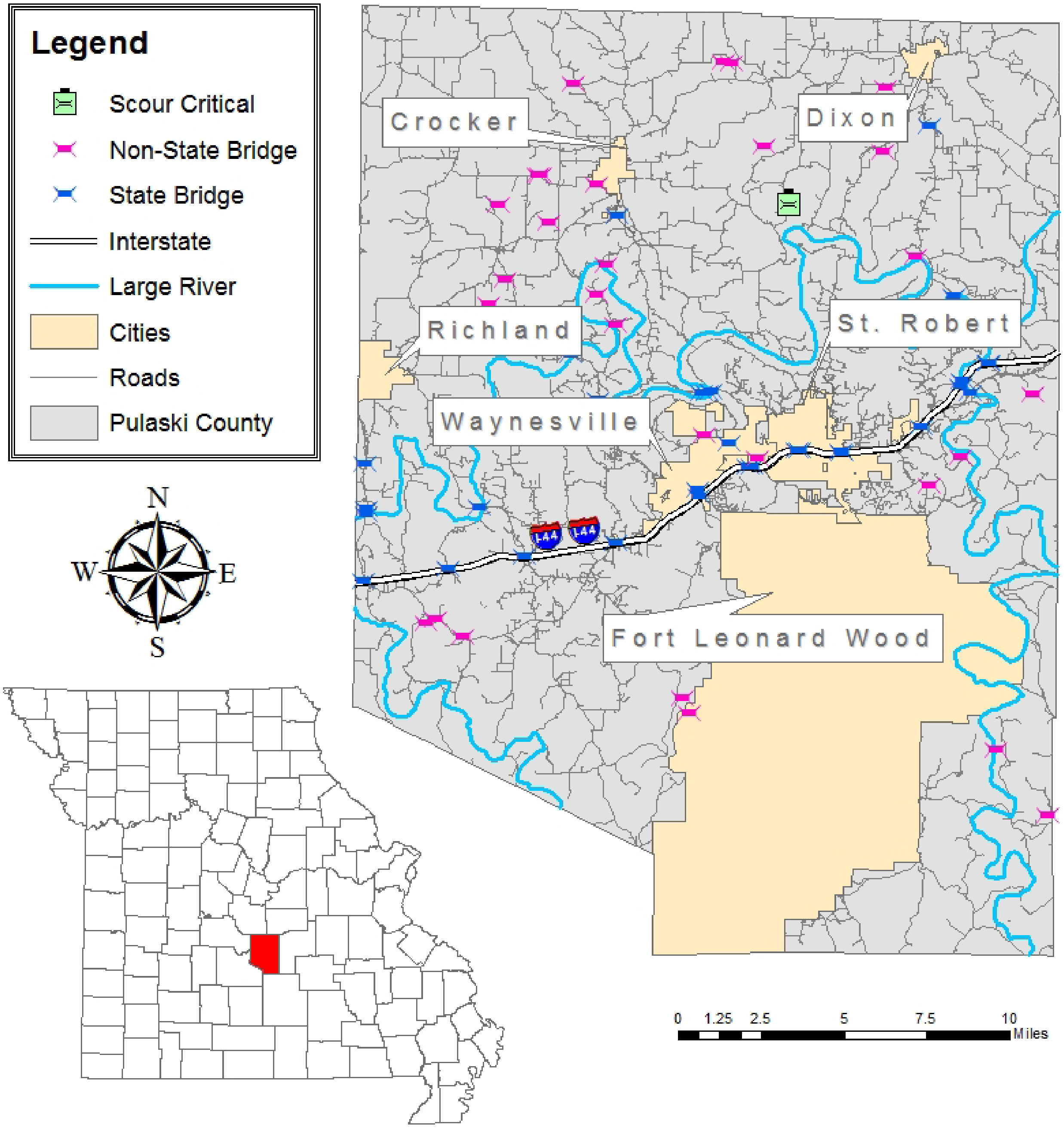
	Airport Facility	Bus Facility	Childcare Facility	Communications Tower	Electric Power Facility	Emergency Operations	Fire Service	Government	Housing	Shelters	State & Non-State Structures (Bridge)	Hospital/Health Care	Military	Natural Gas Facility	Pipeline/Pump Station	Nursing Homes	Police Station	Potable Water Facility	Rail	Sanitary Pump Stations	School Facilities	Stormwater Pump Stations	Tier II Chemical Facility	Wastewater Facility	Total
Unincorporated Pulaski County	3*	-	-	1	-	1	2	3	10,301	-	39	-	1		-	-	1	3	2	-	4	-	9	5	10,375
City of Crocker	-	-	2	3	-	1	1	1	586	1	1	-	-	-	-	-	1	1	1	7	2	-	6	1	615
City of Dixon	-	-	1	-	-	-	1	2	995	3	-	2	-		-	1	1	2	1	-	3	-	10	1	1,023
City of Richland	2	-	1	1	-	1	1	3	834	5	-	2	-		-	2	1	3	-	-	3		3	1	863
City of St. Robert	-	1	3	2	-	1	1	3	1,468	3	2	1	-		-	-	1	5	-	27	-	-	14	3	1,535
City of Waynesville	1	-	9	2	-	4	1	1	1,661	1	4	1	-	1	-	2	1	7	-	7	5	1	9	1	1,719
Totals	6	1	16	9	-	8	7	13	15,845	13	46	6	1	1	-	5	6	21	4	41	17	1	51	12	16,130

Source: 2020 Data Collection Questionnaires, National Bridge Inventory, Missouri Department of Health and Senior Services, Meramec Regional Emergency Response Commission, 2010 US Census (Housing units) * Airports are located on Fort Leonard Wood.

According to the National Bridge Inventory there are a total of 106 bridges in Pulaski County[3]. **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 Pulaski County. The Bunker Road bridge spanning the Middle Creek has a scour index of 3. The most recent housing data available was from the 2010 census. However, the Missouri Hazard Mitigation plan estimates that housing units have increased between 2010 and 2015 in Pulaski County by .04 to .1 percent.

[3] http://www.fhwa.dot.gov/bridge/nbi/no10/county.cfm

Figure 3.2. Pulaski County Bridges



Pulaski County Hazard Mitigation Plan	**County Bridges**	Meramec Regional Planning Commission
MRPC 4 Industrial Drive St. James, MO 65559	This map was created by the Meramec Regional Planning Commission's Environmental Department. To the best of the author's knowledge, the data presented here is true and correct. However, no responsiblity is assumed by the author or MRPC for the accuracy of the information displayed on this map. October 2015	

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

Table 3.8. Threatened and Endangered Species in Pulaski County

Common Name	Scientific Name	Status
Amphibians		
Eastern Hellbender	*Cryptobranchus alleganiensis alleganiensis*	Endangered (S)
Clams		
Pink Mucket	*Lampsilis abrupta*	Endangered (F) (S)
Scaleshell Mussel	*Leptodea leptodon*	Endangered (F) (S)
Snuffbox Mussel	*Epioblasma triquetra*	Endangered (S)
Spectaclecase	*Cumberlandia monodonta*	Endangered (F) (S)
Elephantear	*Elliptio crassidens*	Endangered (S)
Ebonyshell	*Reginaia ebenus*	Endangered (S)
Sheepnose (Bullhead)	*Plethobasus cyphyus*	Endangered (S)
Fishes		
Niangua Darter	*Etheostoma nianguae*	Threatened (F) Endangered (S)
Topeka Shiner	*Notropis topeka*	Endangered (S)
Birds		
Northern Harrier	*Circus cyaneus*	Endangered (S)
Peregrine Falcon	*Falco peregrinus*	Endangered (S)
Flowering Plants		
Western Prairie Fringed Orchid	*Platanthera praeclara*	Endangered (S)
Mammal		
Gray bat	*Myotis grisescens*	Endangered (F) (S)
Indiana bat	*Myotis sodalis*	Endangered (F) (S)
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, http://www.fws.gov/midwest/Endangered/lists/missouri-cty.html; MDC Endangered Field Guide, 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 3.9** provides the names and locations of parks and conservation areas in Pulaski County.

Table 3.9. Conservation Areas in Pulaski County

Area Name	Address	City
Dixon Townsite	From Dixon, take Hwy 133 W. 3 miles	Near Dixon
Fort Leonard Wood (Bloodland Lake)	From St. Robert, take I-44 E. 1 mile. Exit 161.	Fort Leonard Wood
Fort Leonard Wood Towersite	From St. Robert, take the S. outer road of I-44 E. 1 mile.	Fort Leonard Wood
Gasconade Hills CA	From Dixon, take Hwy 28 S. 10 miles, then Co. rd. 28-462 W.	Near Dixon
Mitschele Access	From Richland, take Hwy 7 S. about 5 miles	Near Richland
Riddle Bridge Access	From St. Robert, take Route Y N. 6 miles	Near St. Robert
Ross Access	From Duke, take Route K W. to Western Rd. then Windsor Lane N. 0.5 miles	Near Duke
Roubidoux Creek CA	From Waynesville, take Hwy 17 N. 1 mile	Near Waynesville
Ryden Cave CA	From Duke, take Route K W. 1.5 miles	Near Duke
Schlicht Springs Access	From Crocker, take Hwy 133 S.W. for 5 miles, then Resort Road S. (left) 1.35 miles, then Riverside Road E. (left) 1 mile to access	Near Crocker
Waynesville (Laughlin/Roubidoux Parks)	The park is downstream from the Roubidoux Spring near the Hwy 17 bridge over Roubidoux Creek	Waynesville

Source: https://nature.mdc.mo.gov/discover-nature/find/places?area_name=&counties=5743&location%5Bdistance%5D=50&location%5Borigin%5D=

00 provides information pertaining to community owned/operated parks within Pulaski County.

Table 3.10. Community Owned Parks in Pulaski County

Park Name	Address	City
Dixon City Park	Hwy 133	Dixon
Crocker Community Park	Off Hwy 17	Crocker
Shady Dell Park	Myers Drive	Richland
George M Reed Roadside Park	Old Route 66	St. Robert
St. Robert City Park	Williamson Drive	St. Robert
Roy Laughlin Park	Spring Road	Waynesville
Trail of Tears Memorial Park	Laughlin Park	Waynesville
Waynesville City Park	North Street	Waynesville

Source: http://visitpulaskicounty.org

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 3.11** provides information in regards to properties on the National Register of Historic Places in Pulaski County.

Table 3.11. Pulaski County Properties on the National Register of Historic Places

Property	Address	City	Date Listed
Decker Cave Archeological Site	Restricted	Buckhorn	2/12/1971
Devil's Elbow Historic District	Timber and Teardrop roads	Devil's Elbow	4/17/2017
Calloway Manes Homestead	NW of Richland	Richland	6/6/1980
Old Stagecoach Stop	Linn St., Courthouse Sq.	Waynesville	11/24/1980
Onyx Cave	14705 Private Drive 541	Newburg	5/21/1999
Piney Beach	Hooker vicinity	Hooker	4/17/2017
Pulaski County Courthouse	Pulaski County Courthouse	Waynesville	7/17/1979

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

Economic Resources: **Table 3.12** provides major non-government employers in the planning area. There are approximately 698 employer establishments within the county, employing on average 12 individuals each[4].

[4] https://www.census.gov/quickfacts/fact/table/pulaskicountymissouri,US/PST045219

Table 3.12. Major Non-Government Employers in Pulaski County

Employer Name	Product or Service	Employees
Army Air Force Exchange Svc	Department Stores	100-249
Battelle Science Technology	Research Service	100-249
Candlewood Suites Ihg Army	Hotels & Motels	100-249
Cracker Barrel Old Country Store	Full-Service Restaurant	100-249
Lowe’s Home Improvement	Home Center	100-249
Piney Ridge Center	Mental Health Services	100-249
Tiger Typhoon Center	Water Park	100-249
Walmart Supercenter	Department Store	250-499
EDP Enterprises Inc	Food Service	500-999

Source: https://meric.mo.gov/industry/business-locator, 2020 Data Collection Questionnaires

Agriculture plays an important role in Pulaski County. However, the Agribusiness Employment Location Quotient for the county is 0.04; meaning that there is a relatively low share of agribusiness employment to its share of total national employment[5]. In addition, there were 78 individuals working in the agriculture industry, comprising 0.88% of the total workforce in 2018[6]. Furthermore, the market value of products sold in 2017 was $12.2 million; 95% from livestock sales and 5% from crop sales.

3.3 Future Land Use and Development

Table 3.13 provides population growth statistics for Pulaski County.

Table 3.13. Pulaski County Population Growth, 2010-2018

Jurisdiction	2010 Population	2018 Population	2010-2018 # Change	2010-2018 % Change
Unincorporated Pulaski County	38,586	37,259	-1,327	-3.44
Crocker	1,110	1,152	42	3.78
Dixon	1,549	1,256	-293	-18.92
Richland	1,863	1,895	32	1.72
St. Robert	4,340	5,767	1,427	32.8
Waynesville	4,826	5,262	436	9.03

Source: U.S. Bureau of the Census, 2014-2018 5 Year American Community Survey; Census 2010 Summary File 1

Typically population growth or decline is generally accompanied by an increase or decrease in the

[5] https://meric.mo.gov/media/pdf/rural-missouri-asset-mapping

[6] https://data.census.gov/cedsci/table?q=United%20States&tid=ACSST5Y2018.S2401&g=0400000US29_0500000US29169,29161&t=Occupation&vintage=2018
https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/2/table/1/state/MO/county/169/year/2017

number of housing units. **Table 3.14** provides the change in numbers of housing units in the planning area from 2010-2018.

Table 3.14. Change in Housing Units, 2010-2018

Jurisdiction	Housing Units 2010	Housing Units 2018	2010-2018 # Change	2010-2018 % change
Unincorporated Pulaski County	11,461	11,256	-205	-1.79
Crocker	604	494	-110	-18.21
Dixon	783	593	-190	-24.27
Richland	996	903	-93	-9.34
St. Robert	1,707	3,313	1,606	94.08
Waynesville	1,981	2,499	518	26.15

Source: U.S. Census Bureau, 2014-2018 5 Year American Community Survey; U.S. Bureau of the Census, Census 2010 Summary File 1

Jurisdictions reported anticipated future developments within the next five years (2020-2025). Pulaski County and most of the cities did not anticipate any major future developments within the next five years. The city of St. Robert is in the process of moving its wastewater treatment facility out of the floodplain.

Crocker R-II indicated that they would be building a new bus barn in the next five years. All other school districts indicated that they did not have any major development or construction planned for the next five years.

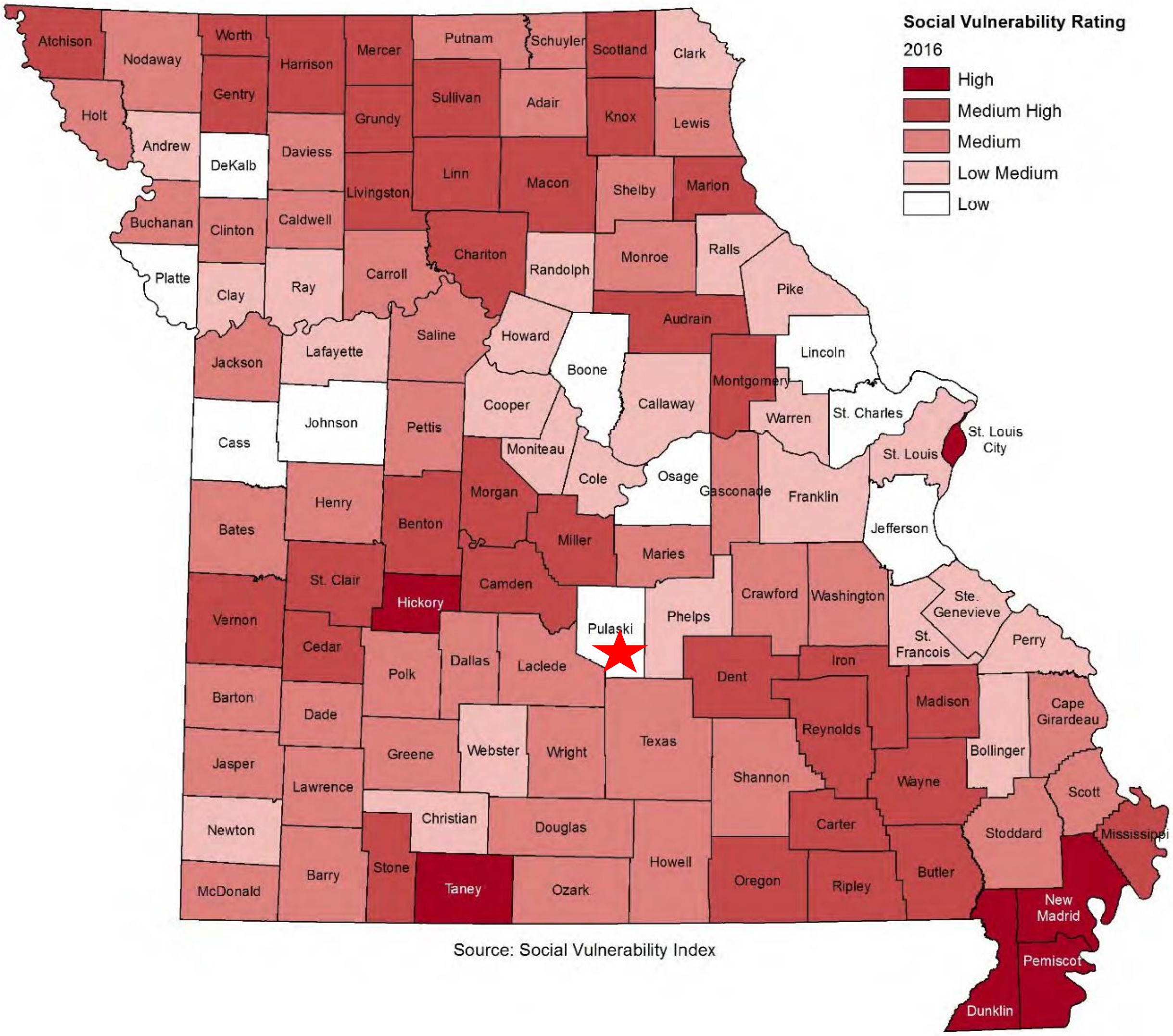
New development can impact a jurisdiction's vulnerability to natural hazards. As the number of buildings, critical facilities, and assets increase, vulnerability increases as well. For example, real estate development can increase storm water runoff, which often increases localized flooding. However,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

Socioeconomic Profile

The Missouri State Hazard Mitigation Plan provides ratings for social vulnerability for each of the counties in the state based on 42 socioeconomic and built environment variables that research suggests contribute to a community's ability to prepare for, respond to and recover from hazards. Based on that data, Pulaski County has a "low" social vulnerability rating (Figure 3.3). Furthermore, business incentives are available in the County including Missouri Works, a program for qualified job creators which enables the retention of withholding tax or tax credits that can be transferrable, refundable and/or saleable; BUILD, a financial incentive for the location or expansion of large business projects; sales tax exemptions exist for qualified manufacturers; and industrial infrastructure grants are available up to $2 million or $20,000 per job created[7].

[7] https://ded.mo.gov/programs/business/missouri-works

Figure 3.3. Social Vulnerability Rating for Pulaski County



Source: Social Vulnerability Index

3.4 Hazard Profiles, Vulnerability, and Problem Statements

Each hazard that has been determined to be a potential risk to Pulaski 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. Where available, use maps to indicate the specific locations of the planning area that are vulnerable to the subject hazard. For some hazards, the entire planning area is at risk.

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.

The discussion on the probability of future occurrence should also consider changing future conditions, including the effects of long-term changes in weather patterns and climate on the identified hazards. NOAA has a new tool that can provide useful information for this purpose.

- NOAA Climate Explorer, https://crt-climate-explorer.nemac.org/

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 to damages from natural hazards. The vulnerability assessments will be based on the best available county-level data, which is in the Missouri Hazard Mitigation Plan (2018). With the 2018 Hazard Mitigation Plan Update, SEMA is pleased to provide online access to the risk assessment data and associated mapping for the 114 counties in the State. Through the web-based Missouri hazard Mitigation Viewer, local planners or other interested parties can obtain all State Plan datasets. This effort removes from local mitigation planners a barrier to performing all the needed local risk assessments by providing the data developed during the 2018 State Plan Update. The Missouri Hazard Mitigation viewer can be found at this link: http://bit.ly/MoHazardMitigationPlanViewer2018.

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 Pulaski 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 include a brief review of the vulnerability of each hazard.

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

Future Development: This section will include information on anticipated future development in the county, and how that would impact hazard risk in the planning area.

Previous and Future Development: This section will include information on how changes in development have impacted the community's vulnerability to this hazard. Describe how any changes in development that occurred in known hazard prone areas since the previous plan have increased or decreased the community's vulnerability. Describe any anticipated future development in the county, and how that would impact hazard risk in the planning area.

Problem Statements

Each hazard analysis must conclude with a brief summary of the problems created by the hazard in the planning area, and possible ways to resolve those problems. Additionally, variations in risk between geographic areas will be included.

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
- Missouri Department of Natural Resources, Dam and Reservoir Safety, http://dnr.mo.gov/env/wrc/dam-safety/statemap.htm
- Stanford University's National Performance of Dams Program; http://npdp.stanford.edu/index.html
- National Inventory of Dams, http://geo.usace.army.mil/
- MO DNR Dam & Reservoir Safety Program;
- National Resources Conservation Service http://www.nrcs.usda.gov
- Missouri Spatial Data Information Service, http://msdis.missouri.edu
- 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 3.15** and **Table 3.16**, respectively.

Table 3.15. 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, http://dnr.mo.gov/env/wrc/docs/rules_reg_94.pdf

Table 3.16. 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 and Stanford National Performance of Dams Program, there are 13 recorded dams in Pulaski County; Each dam within the County is considered as a low hazard dam. **Table 3.17** provides the name of the dam, DNR hazard class and NID hazard class for each of the identified dams in Pulaski County. There are no state-regulated dams in Pulaski 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 3.17. Pulaski County Dams Hazard Risk

Name of Dam	DNR Hazard Class*	NID Hazard Class
Alexander Farms Dam		Low
Armistead Dam		Low
Big Basin		Low
Bloodland Lake		Low
Bloodland Quad No.3 Dam		Low
Cardin Lake Dam		Low
Engineer Lake		Low
Molar Pond Dam		Low
Penn's Pond (Federal)		Low
Red Lake (Federal)		Low
Robert's Dam		Low
Schultz Lake Dam		Low
Woolridge Lake Dam		Low

Source: National Performance of Dams Program (NPDP) was used since it is the most up to date information.
* There are no state regulated dams in Pulaski County, so there are no Hazard Class Ratings.

If a dam failure were to occur in Pulaski County, the severity would likely be limited since very few, if any people or critical facilities would be affected by the failure of one of the county's dams. None of the dams are located within an incorporated area and no critical facilities are located in the path of a possible dam failure.

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

From the data available there are no upstream dams outside of the planning area that would impact Pulaski County in the event of failure.

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). Based on the hazard class definitions, failure of any of the High Hazard/Class I dams could result in a serious threat of loss of human life, serious damage to residential, industrial or commercial areas, public utilities, public buildings, or major transportation facilities. Catastrophic failure of any high hazard dams has the potential to result in greater destruction due to the potential speed of onset and greater depth, extent, and velocity of flooding. For this reason, dam failures could flood areas outside of mapped flood hazards. However, review of the flow of water, should a breach occur, indicated that damage would be limited mainly to the dam owner's properties. Based on the locations, and probable flow of water should a breach occur, dams located in Pulaski County pose little or no risk to all jurisdictions.

Previous Occurrences

According to Stanford University's National Performance of Dams Program and the Missouri State Emergency Management Agency, there were 86 recorded dam incidents in Missouri between 1917 and 2008. For the 42-year period from 1975 to 2016 for which dam failure statistics are available, 19 dam failures and 68 incidents are recorded. Fortunately, only one drowning has been associated with a dam failure in the state. 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[8]. 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[9]. 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 is 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[10].

Event Description

According to Stanford University's National Performance of Dams Program, no dam incidents have been recorded for Pulaski County[11].

Probability of Future Occurrence

Since it is unknown which dams, if any might fail at any given time, determining the probability of future occurrence is not possible[12]. Dam failure within the county has not occurred according to available data. In addition, Pulaski County there are no state or USACE regulated dams which means that the dams are all uninspected which further complicates determining the probability of future occurrences.

[8] United States Geological Survey. Damage Evaluation of the Taum Sauk Reservoir Failure using LiDAR. http://mcgsc.usgs.gov/publications/t_sauk_failure.pdf
[9] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.
[10] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.
[11] http://npdp.stanford.edu/dam_incidents
[12] 2018 Missouri State Hazard Mitigation Plan

Vulnerability

Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for the vulnerability analysis of dam failure for Pulaski 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.

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.

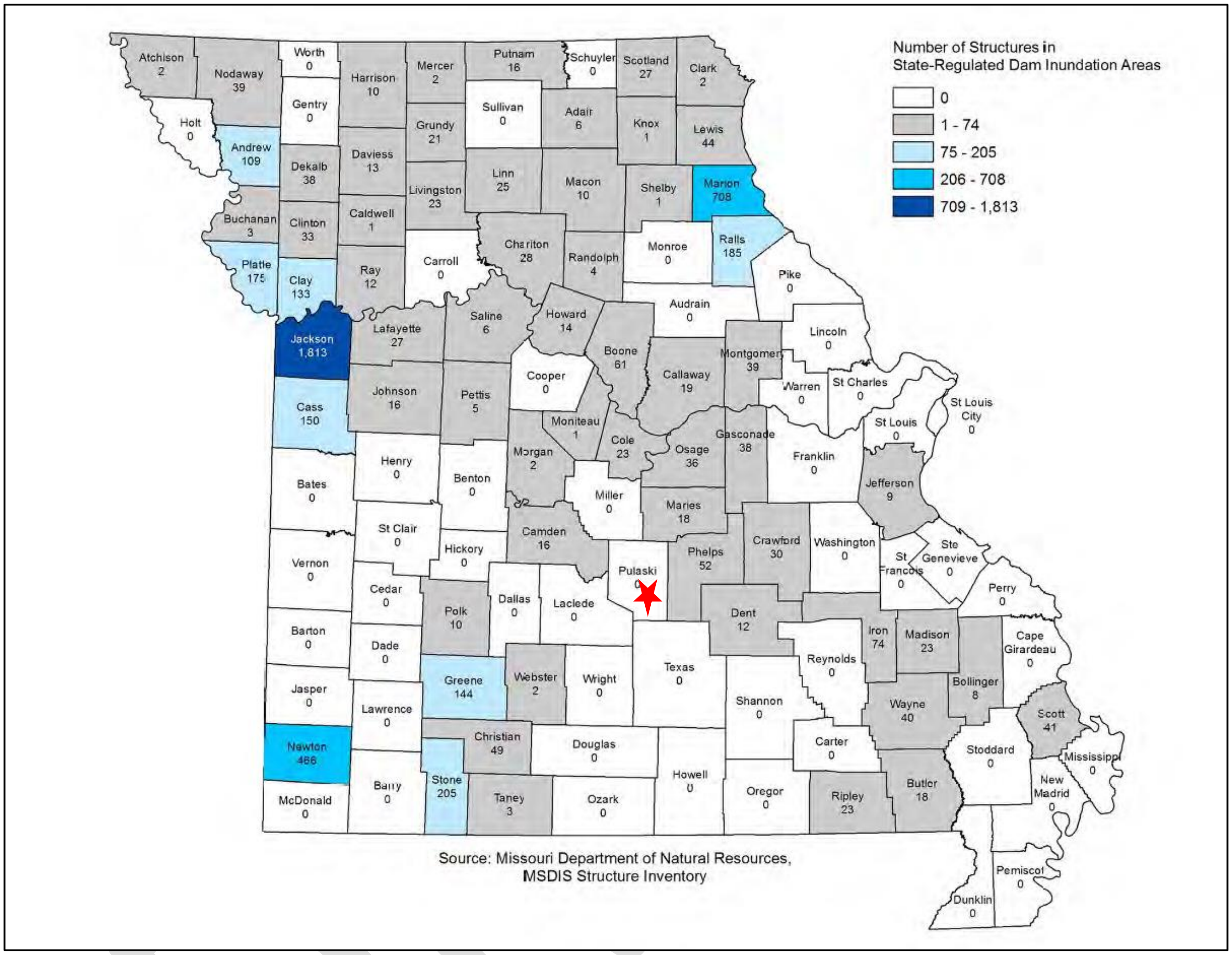
According to the 2018 Missouri State Hazard Mitigation Plan, there are no buildings vulnerable to failure of State-regulated dams (**Figure 3.4**) in Pulaski County. Furthermore, the state quantified potential loss estimates in terms of property damages. To execute the analysis, the following assumptions 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 athe 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.[13]

04 and **05** depict the total estimated building losses and population exposure by county, respectively. The estimated building losses from failure of State-regulated dams are $1 – $2 million. The estimated population exposure to failure of State-regulated dams ranges between 1 and 130.

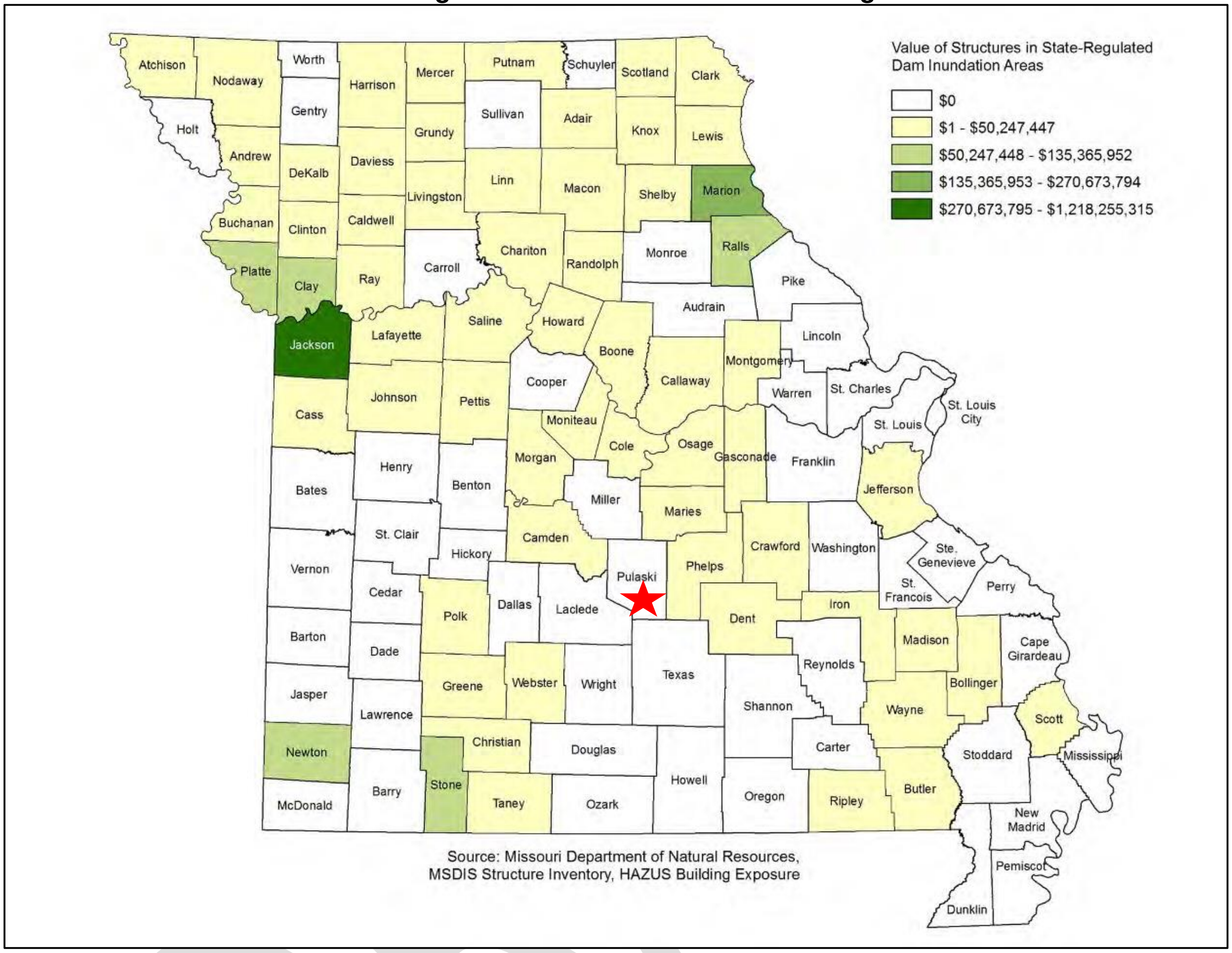
[13] 2018 Missouri State Hazard Mitigation Plan

Figure 3.4. Estimated Number of Buildings Vulnerable to Failure of State-regulated Dams



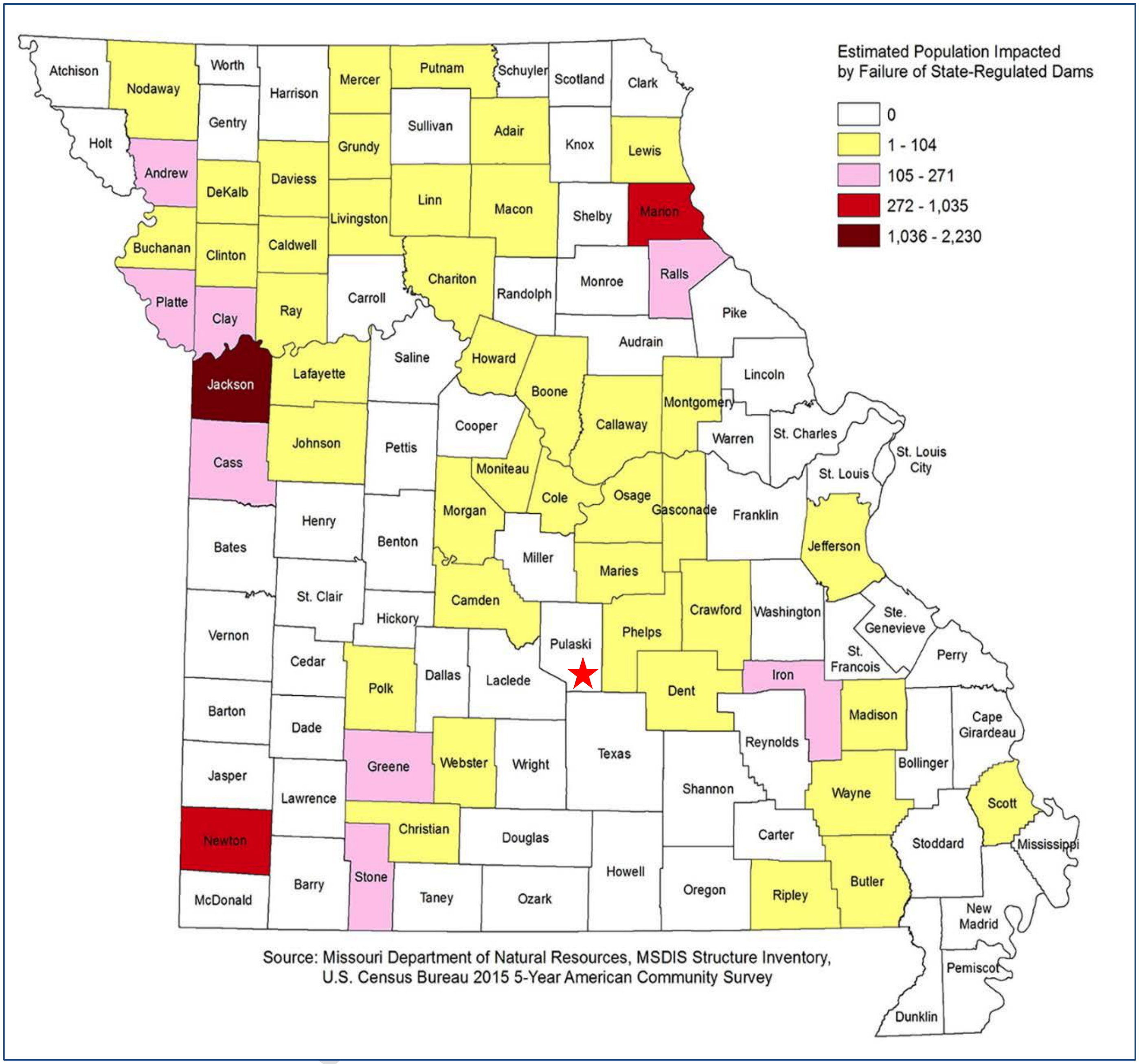
Source: 2018 Missouri State Hazard Mitigation Plan
*Red star indicates Pulaski County

Figure 3.5. Estimated Building Losses from Failure of State-regulated Dams



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

Figure 3.6. Estimated Population Exposure to Failure of State-regulated Dams



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

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

Due to the locations of dams in Pulaski County, a dam failure would have little to no impact on the existing development of the County. Families living near the dam may experience washed out roadways, or property damage. There are no dams in Pulaski County that are economically significant enough to have an adverse economic impact on jurisdictions.

Impact of Future Development

Anticipated future development in the County is not foreseeable to impact the amount of damages caused by a dam failure. Since the planning area is rural in nature, and most dams are privately owned, little to no development is expected.

Hazard Summary by Jurisdiction

There are no variations in vulnerability across the planning area.

Problem Statement

In summary, the hazard risk for dam failure in Pulaski County is very low. If a dam does fail, the expected impacts are miniscule, and would be restricted to properties of private land owners. 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. Install public education programs to inform the public of dam safety measures and preparedness activities. Offer training programs for dam owners to encourage them to inspect their dams and so that they may learn how to develop and exercise emergency action plans.

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
- 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, http://dnr.mo.gov/pubs/WR69.pdf
- Populations served by groundwater by county, USGS-NWIS, http://maps.waterdata.usgs.gov/mapper/index.html
- Census of Agriculture, http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Missouri/and http://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Missouri/
- USDA Risk Management Agency, Insurance Claims, http://www.rma.usda.gov/data/cause.htm
- Natural Resources Defense Council, http://www.nrdc.org/globalWarming/watersustainability/
- Missouri Department of natural Resources (MDNR), Drought News, Conditions and Resources
- 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[14] - which impacts supply and demand of some economic commodity.

Geographic Location

All areas and jurisdictions in Pulaski 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 Pulaski County rely on groundwater resources for drinking water. Approximately 31.9% of the land in the county is utilized for agricultural purposes. Furthermore, livestock sales comprise 84% of the market of agricultural products sold in Pulaski County. A drought would directly impact livestock production and the agriculture economy in Pulaski County[15].

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[16].

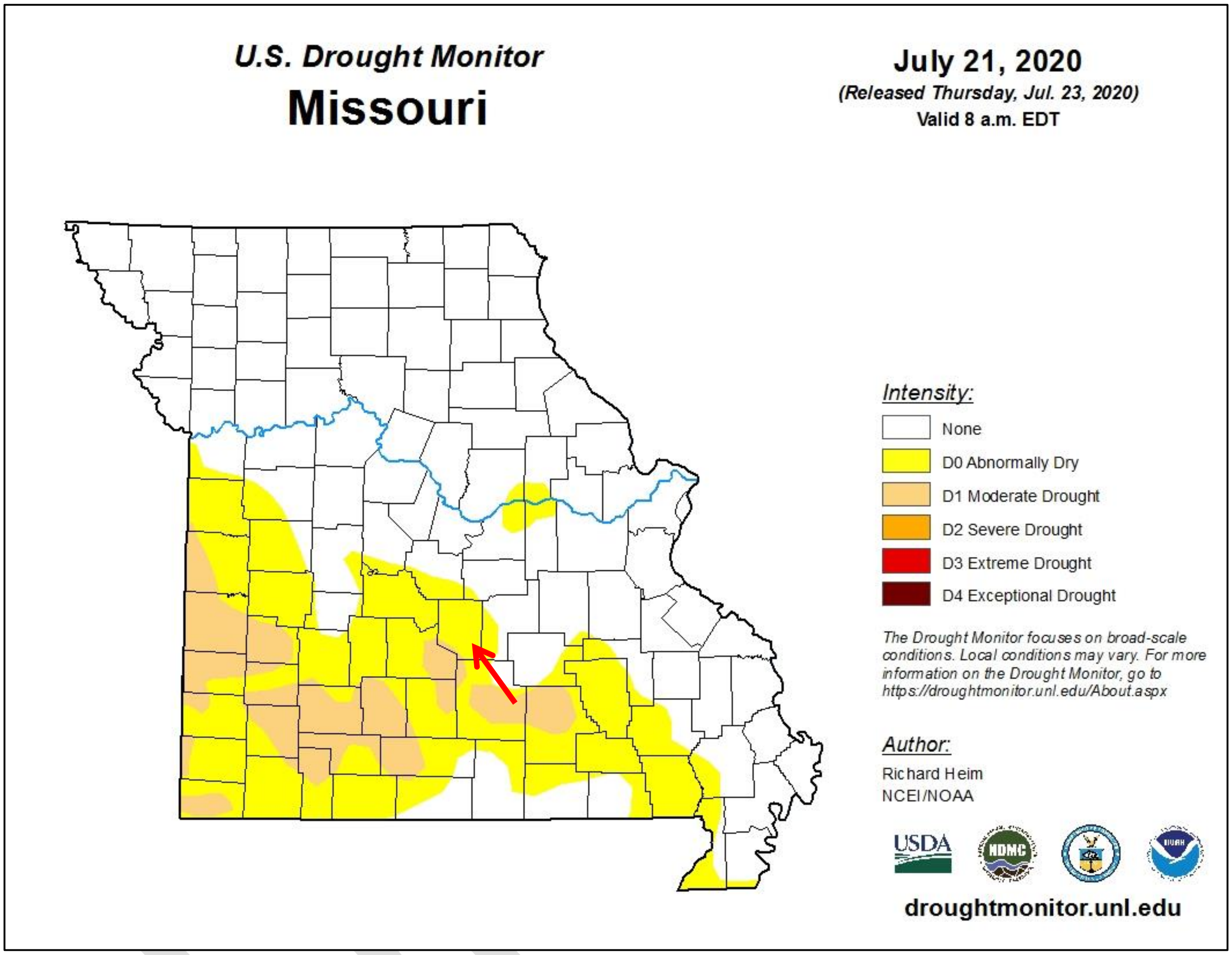
Figure 3.7 depicts a U.S. Drought Monitor map of Missouri on July 21, 2020. This map illustrates the planning area, which could be in drought at any given moment in time. A red arrow indicates the location of the planning area (Pulaski County).

[14] http://www.drought.unl.edu/ http://droughtreporter.unl.edu/

[15] http://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Missouri/cp29161.pdf

[16] Ibid

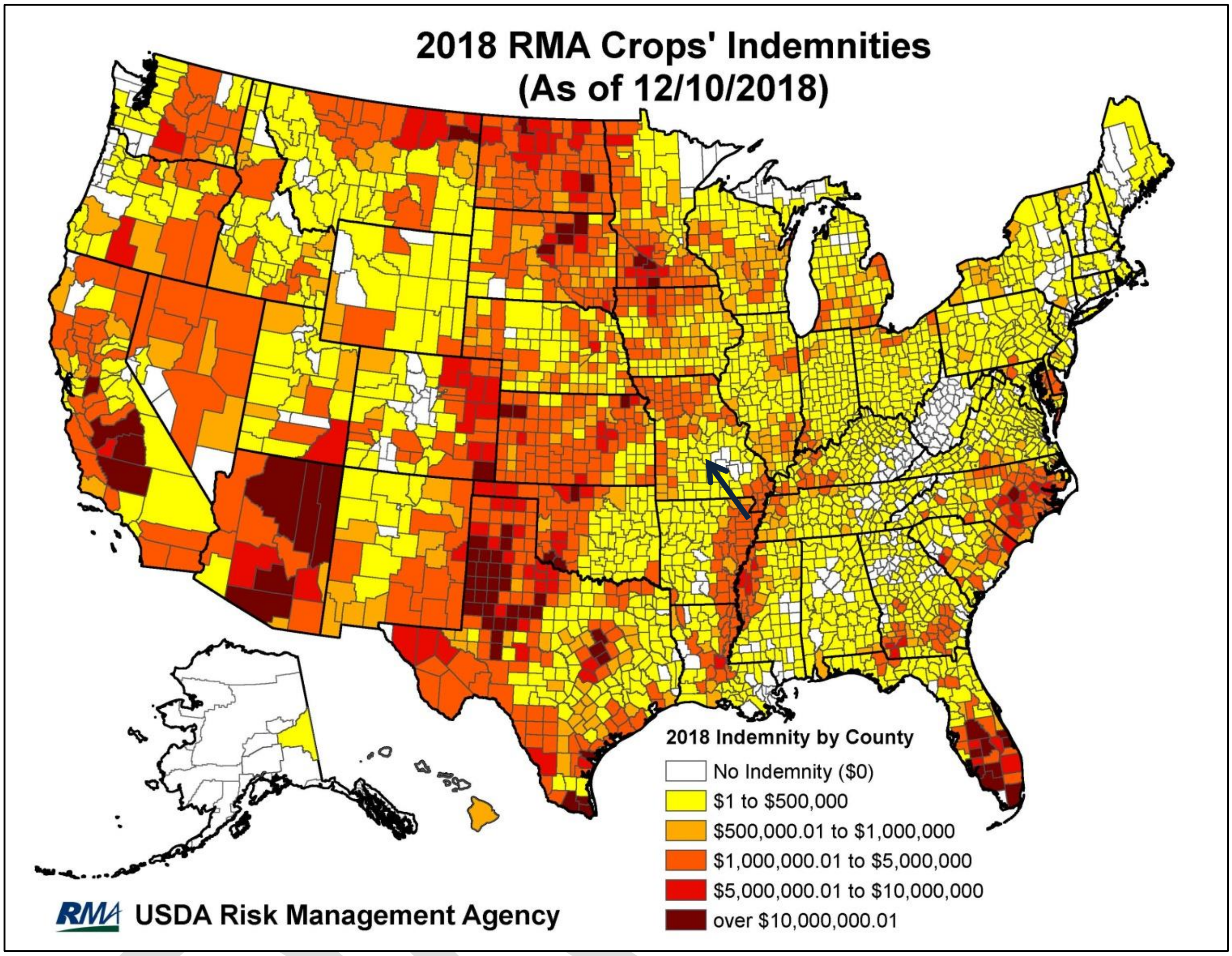
Figure 3.7. U.S. Drought Monitor Map of Missouri on July 21, 2020



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

Figure 3.8 illustrates RMA crop indemnities for 2018 across the United States. Pulaski County fell in the range of $1 to $500,000 for crop indemnities.

Figure 3.8. 2018 RMA Crop Indemnities for the United States



Source: http://www.rma.usda.gov/data/indemnity/ *Black arrow indicates Pulaski County

According to the USDA's Risk Management Agency, there have been 13 crop insurance payments due to drought in Pulaski County since 1999, totaling $163,949.98. **Table 3.18** illustrates the year, number of payments, and total amount of crop insurance payments.

Table 3.18. Pulaski County Crop Indemnity Payments (1999-2019)

Year	Number of Payments	Total
1999	4	$24,451.00
2000	N/A	N/A
2001	N/A	N/A
2002	0	0
2003	0	0
2004	0	0
2005	0	0

Year	Number of Payments	Total
2006	0	0
2007	1	$2107.00
2008	0	0
2009	0	0
2010	0	0
2011	0	0
2012	4	$98,471.90
2013	0	0
2014	0	0
2015	0	0
2016	0	0
2017	1	$9521.00
2018	3	$29,399.08
2019	0	0
TOTAL	**13**	**$163,949.98**

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

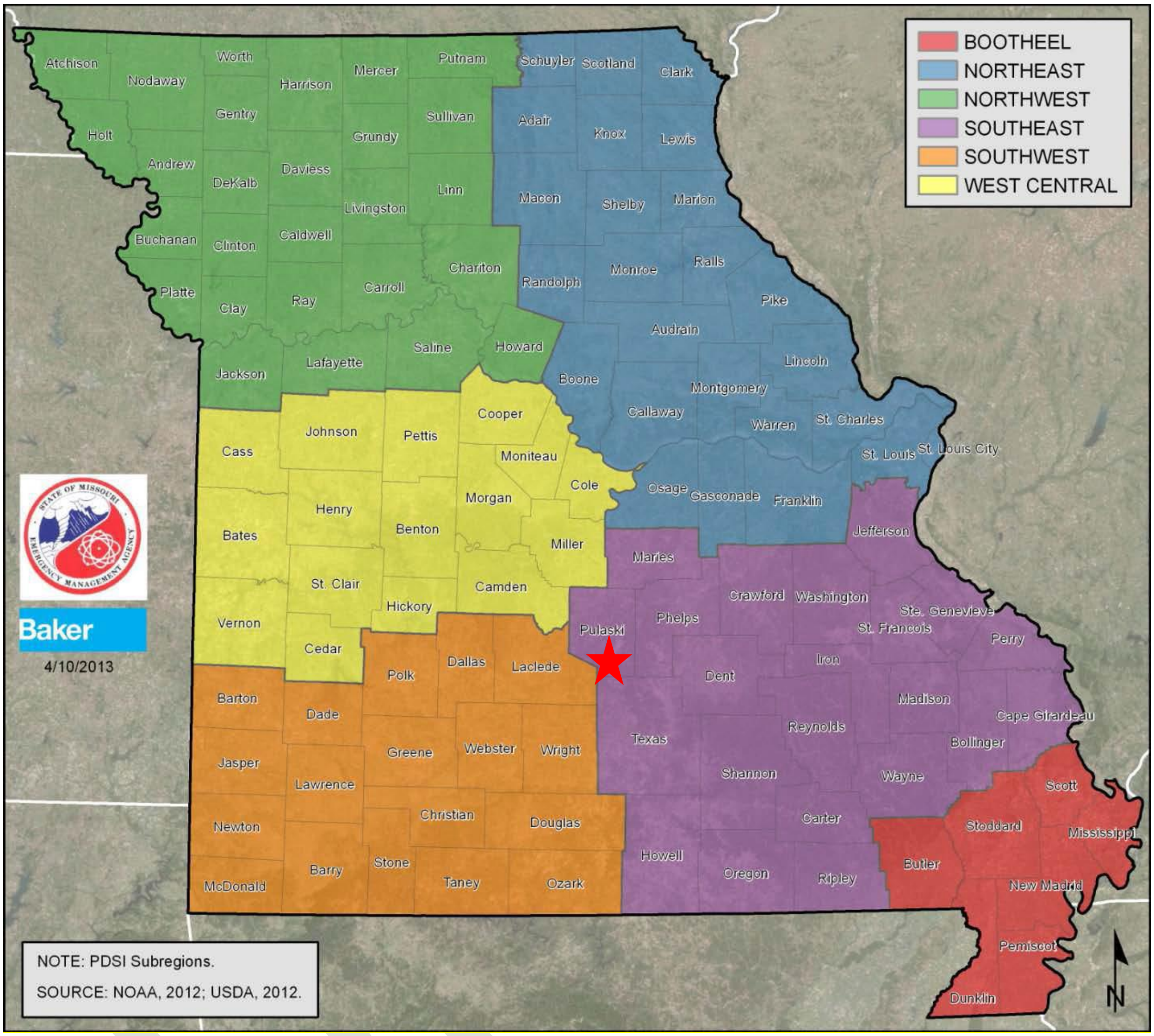
The Palmer Drought Indices measure dryness based on recent precipitation and temperature. The indices are based on a "supply-and-demand model" of soil moisture. Calculation of supply is relatively straightforward, using temperature and the amount of moisture in the soil. However demand is more complicated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

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

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

Figure 3.9 illustrates the Palmer Drought Severity Index sub-regions of Missouri. Pulaski County is categorized under the Southeast sub-region.

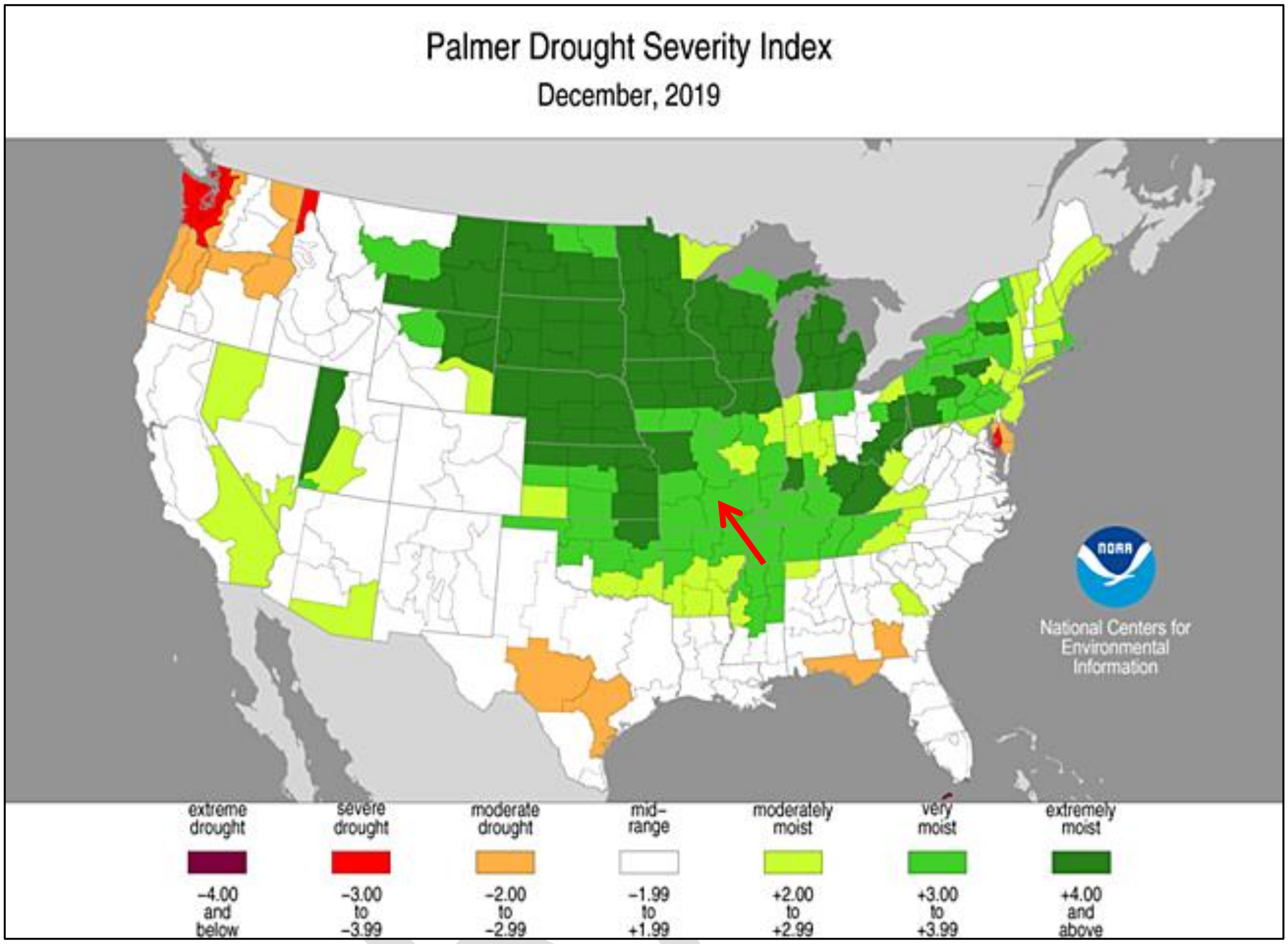
Figure 3.9. Palmer Drought Severity Index: Missouri Sub-regions



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

Figure 3.10 is an example of the Palmer Modified Drought Index for the United States on December, 2019.

Figure 3.10. Palmer Modified Drought Index National Map December, 2019



*Source: http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/; *Red arrow indicates Pulaski County*

Data was collected from the Missouri Department of Natural Resources (2018 Census of Missouri Public Water Systems) to determine water source by jurisdiction. Each of the participating communities within Pulaski County utilizes well water as the primary source of water. These communities could experience hardship in the event of a long-term drought. **Table 3.19** provides information in regard to the percent of source that is groundwater for each jurisdiction in the county.

Table 3.19. 2018 Water Source by Jurisdiction

Jurisdiction	% of source that is groundwater
Crocker	100
Dixon	100
Richland	100
St. Robert	100
Waynesville	100

Source: Missouri Dept. of Natural Resources, 2017 Census of Missouri Public Water Systems

Previous Occurrences

Table 3.20 offers Palmer Drought Severity Index data for Pulaski County between 2010 and 2018. This information exemplifies drought conditions on a monthly basis for Missouri's Southeast sub-region within the United States.

Table 3.20. Palmer Drought Severity Index for Pulaski County, MO (2010 – 2019)

	Year									
Month	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Jan.	Extremely moist	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Very moist	Mid-range	Severe drought	Moderately moist
Feb.	Mid-range	Mid-range	Mid-range	Mid-range	Mid-range	Mid-range	Very moist	Mid-range	Mid-range	Moderately moist
March	Mid-range	Mid-range	Mid-range	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Mid-range	Moderately moist
April	Mid-range	Very moist	Mid-range	Mid-range	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Moderately moist
May	Mid-range	Very moist	Moderate drought	Mid-range	Mid-range	Mid-range	Moderately moist	Very moist	Mid-range	Very moist
June	Mid-range	Mid-range	Moderate drought	Mid-range	Mid-range	Mid-range	Mid-range	Moderately moist	Mid-range	Very moist
July	Mid-range	Mid-range	Severe drought	Mid-range	Mid-range	Moderately moist	Moderately moist	Moderately moist	Mid-range	Very moist
Aug.	Mid-range	Mid-range	Severe drought	Moderately moist	Mid-range	Very moist	Very moist	Moderately moist	Mid-range	Extremely moist
Sept.	Mid-range	Mid-range	Severe drought	Moderately moist	Mid-range	Moderately moist	Very moist	Mid-range	Mid-range	Very moist
Oct.	Mid-range	Mid-range	Moderate drought	Moderately moist	Mid-range	Mid-range	Very moist	Mid-range	Mid-range	Very moist
Nov.	Mid-range	Mid-range	Severe drought	Moderately moist	Mid-range	Very moist	Very moist	Moderate drought	Mid-range	Extremely moist
Dec.	Mid-range	Mid-range	Severe drought	Moderately moist	Mid-range	Extremely moist	Moderately moist	Severe drought	Mid-range	Very moist

Source: http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/psi/

Probability of Future Occurrence

To calculate the probability of future occurrence of drought in Pulaski County, historical climate data was analyzed. There were 34 months of recorded drought (**Table 3.21**) over a 21 year span (January, 1999 to December, 2019). The number of months in drought (53) was divided by the total number of months (252) and multiplied by 100 for the annual average percentage probability of drought (**Table 3.22**). Although drought is not predictable, long-range outlooks and predicted impacts of climate change could indicate an increase change of drought.

Table 3.21. Palmer Drought Severity Index for Pulaski County, MO (1999 – 2019)

	Year											
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
1999							x		x	x	x	
2000			x	x	x						x	
2001			x	x								
2002											x	
2003	x		x									
2004		x							x			
2005			x		x	x				x		x
2006		x				x						
2007			x					x			x	
2008												
2009												
2010				x		x		x		x		x
2011	x						x			x		
2012			x	x	x	x	x	x			x	x
2013												
2014		x	x									
2015										x		
2016	x					x						
2017		x							x	x	x	x
2018	x											
2019									x			

Source: https://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/zin/199901-201912
*x indicates drought

Table 3.22. Annual Average Percentage Probability of Drought in Pulaski County, MO

Location	Annual Avg. % P of Drought
Pulaski County	21.03%

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

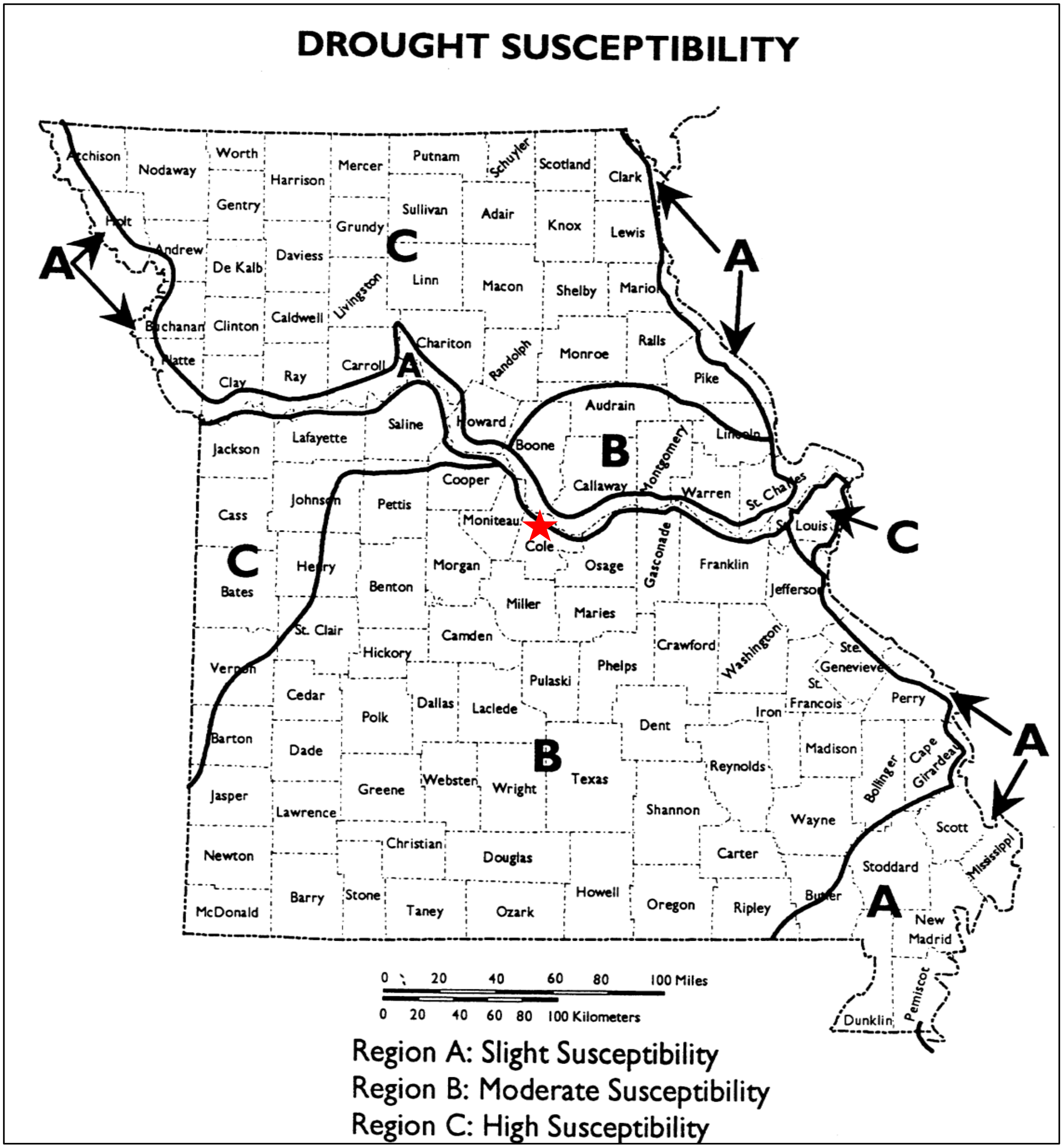
Vulnerability

Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for the drought vulnerability analysis. **Table 3.23** 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. **Table 3.23** provides the factors considered and the ranges for the rating values assigned. 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. Pulaski County is determined as having low to medium vulnerability to crop loss (**Table 3.24**) as a result of a drought. Additionally, SEMA has divided the State into 3 regions in regards to drought susceptibility (**Figure 3.11**). Pulaski 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[17].

[17] 2018 Missouri State Hazard Mitigation Plan

Figure 3.11. Drought Susceptibility in Missouri



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

Table 3.23. 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	$866,000 - $10,669,000	$10,669,001 - $33,252,000	$33,252,001 - $73,277,000	$73,277.001 - $155,369,000	$155,369,001 - $256,080,000
Annualized USDA Crop Claims Paid	<$340,000	$340,000 - $669,999	$670,000 – $999,999	$1M - $1,299,999	>$1,300,000
Likelihood of Occurrence of Severe or Extreme Drought	1-1.9%	2-3.9%	4-5.9%	6-8.9%	9-10.72%
Total Drought Vulnerability Rating	7-8	9-10	11-12	13-14	15-17

Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.24. Vulnerability of Pulaski 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
4	$100,579	$11,175	1	$2,008,000	1	6.42	4	10	Low-medium

Source: 2018 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[18].

Impact of Future Development

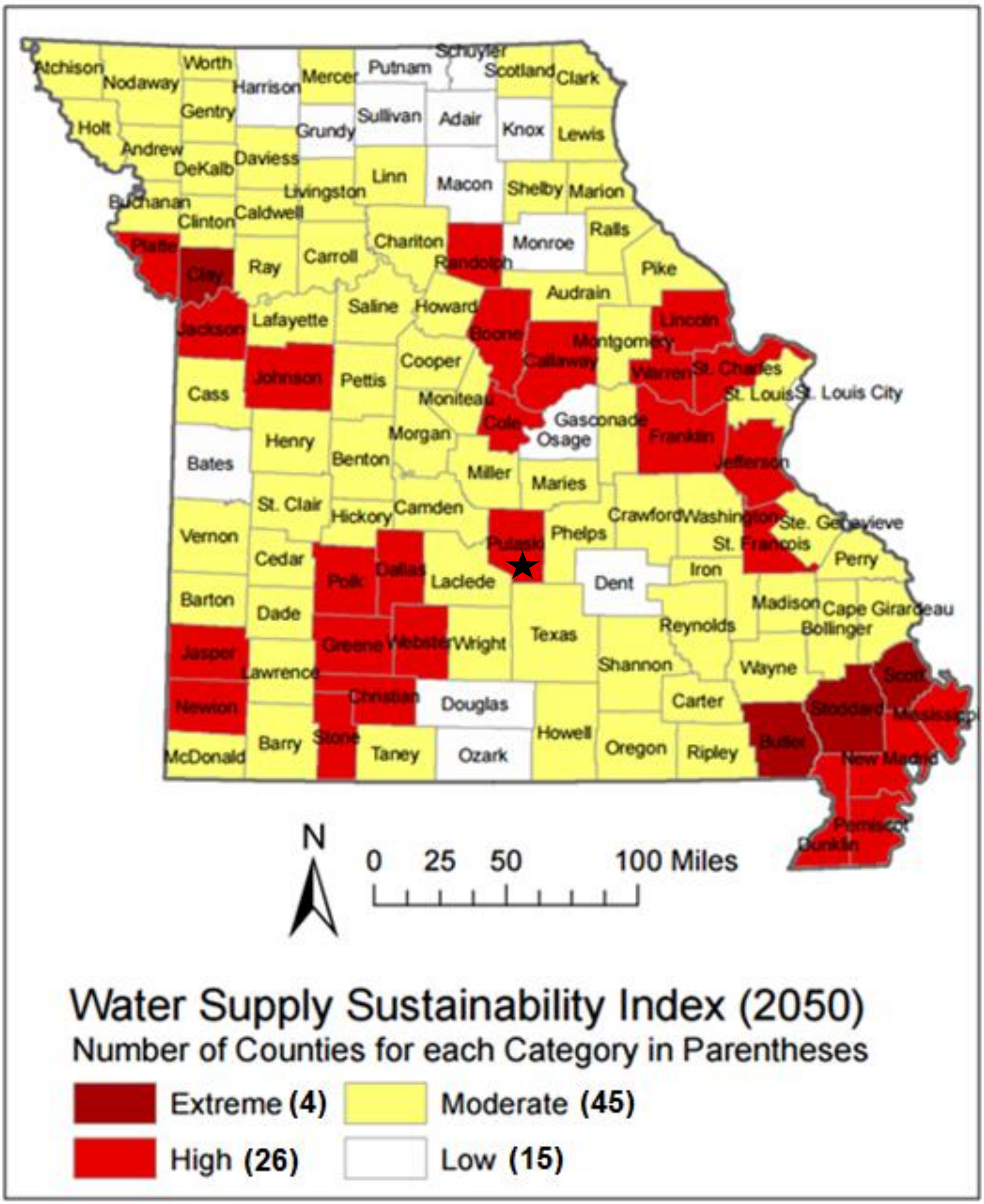
Impacts of drought on future development within Pulaski County would be negligible. Population projections as provided by the Missouri Office of Administration suggest that Pulaski County will increase by approximately 1,000 individuals within the next 10 years[19]. Moreover, with an increasing population, 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.

[18] 2015 Boone County Hazard Mitigation Plan
[19] Missouri Office of Administration http://oa.mo.gov/budget-planning/demographic-information/population-projections/2000-2030-projections

Impact of Climate Change

A new analysis, performed for the Natural Resources Defense Council, examined the effects of climate change on water supply and demand in the contiguous United States. The study found that more than 1,100 counties will face higher risks of water shortages by mid-century as a result of climate change. Two of the principal reasons for the projected water constraints are shifts in precipitation and potential evapotranspiration (PET). Climate models project decreases in precipitation in many regions of the U.S., including areas that may currently be described as experiencing water shortages of some degree. Pulaski County is predicted to experience high water shortages as a result of global warming (**Figure 3.12**) by the year 2050.

Figure 3.12. Water Supply Sustainability Index (2050) with Climate Change Impacts



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

Hazard Summary by Jurisdiction

The variations between jurisdictions are non-existent to minimal. Pulaski County and the communities of Crocker, Dixon, Richland, St. Robert, and Waynesville 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 Pulaski County is considered low-moderate risk. Climate change predictions also suggest low-moderate risks by the year 2050. Pulaski County has a strong 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 all cities 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
- U.S. Seismic Hazard Map, United States Geological Survey, http://earthquake.usgs.gov/hazards/products/conterminous/2014/HazardMap2014_lg.jpg;
- 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, http://www.igsb.uiowa.edu/Browse/quakes/quakes.htm;
- Probability of magnitude 5.0 or greater within 100 Years, United States Geological Survey, https://geohazards.usgs.gov/eqprob/2009/index.php

Hazard Profile

Hazard Description

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

The closest fault to Pulaski County is the New Madrid Seismic Zone (NMSZ). The NMSZ is the most active seismic area in the United States east of the Rocky Mountains. Unfortunately, the faults in the NMSZ are poorly understood due to concealment by alluvium deposits. Moreover, the NMSZ is estimated to be 30 years overdue for a 6.3 magnitude earthquake[20].

Geographic Location

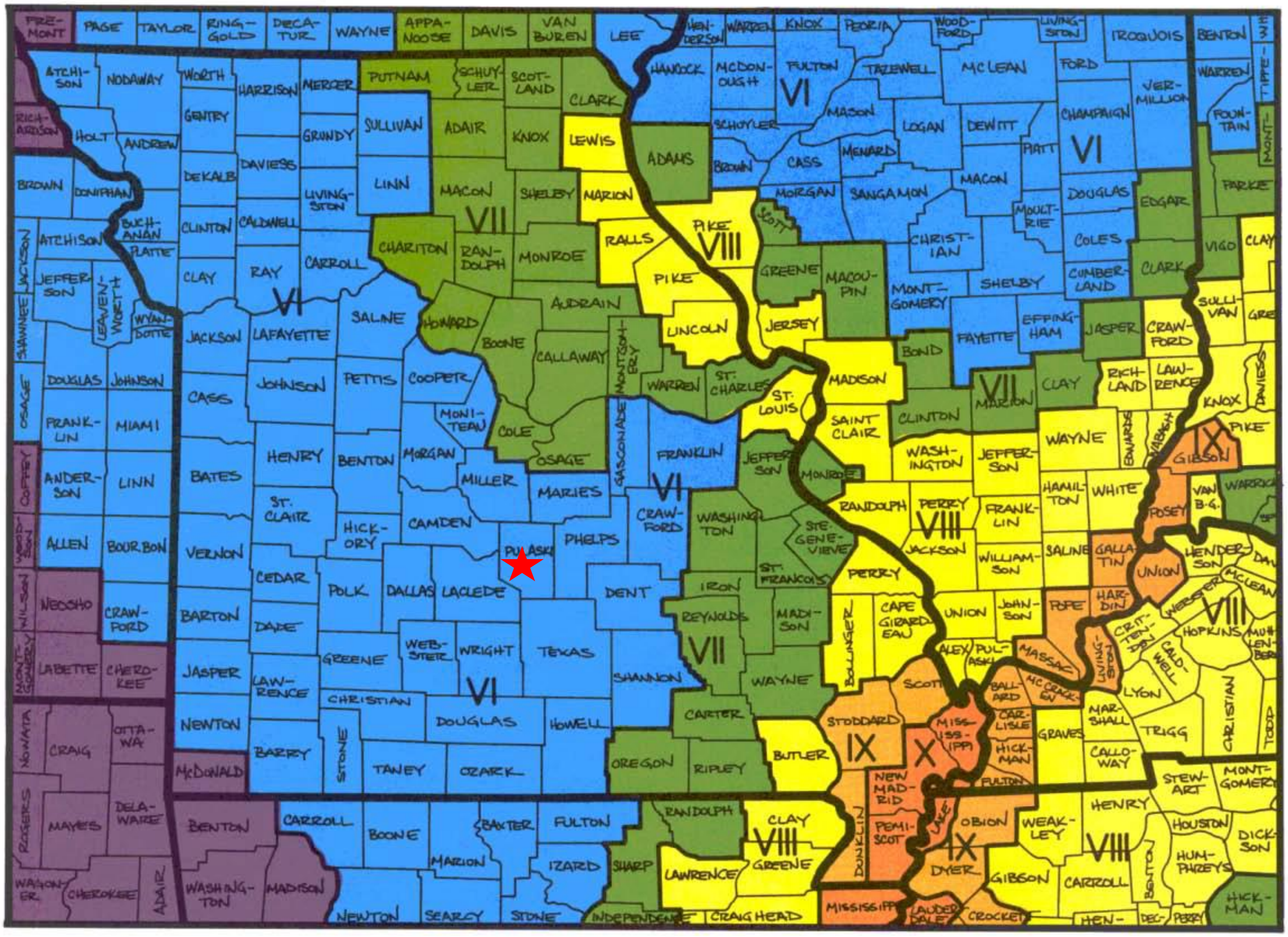
There are eight earthquake source zones in the Central United States, one of which is located within the state of Missouri—the New Madrid Fault. Other seismic zones, because of their close proximity, also affect Missourians. These are the Wabash Valley Fault, Illinois Basin, and the Nemaha Uplift. The 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 3.13 depicts impact zones for a magnitude 7.6 earthquake along the New Madrid Fault along with associated Modified Mercalli Intensities. Pulaski County is indicated by a red star. Furthermore,

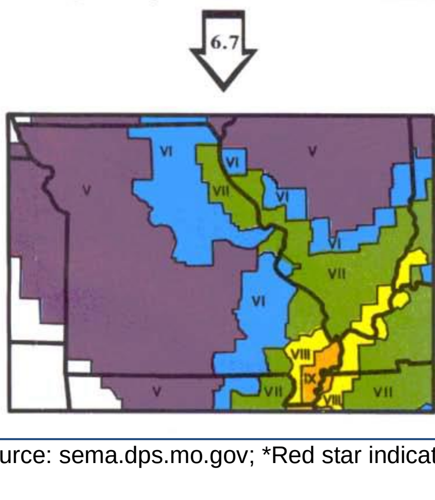
[20] Missouri Department of Natural Resources, Facts about the New Madrid Seismic Zone

the Modified Mercalli Intensities for potential 6.7 and 8.6 magnitude earthquakes are illustrated. In the event of a 6.7 magnitude earthquake, Pulaski County would experience a Modified Mercalli Intensity of V (**Figure 3.14**). 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. Earthquake intensities will not vary across the planning area, which is the case for most Missouri counties**. Figure 3.14** and **Table 3.25** further define Richter Scale intensities.

Figure 3.13. Impact Zones for Earthquake Along the New Madrid Fault

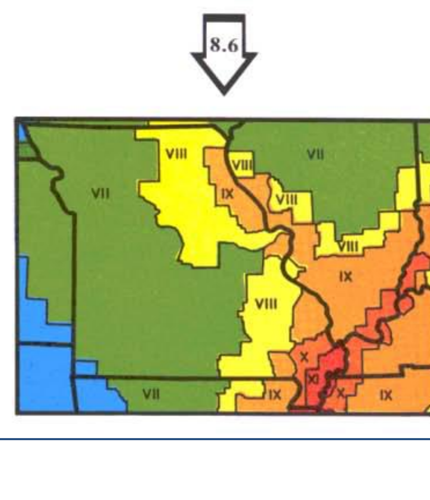


This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.



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

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



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

Figure 3.14. 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.

Prepared and distributed by
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JEFFERSON CITY, MO 65102
Telephone: 573-526-9100

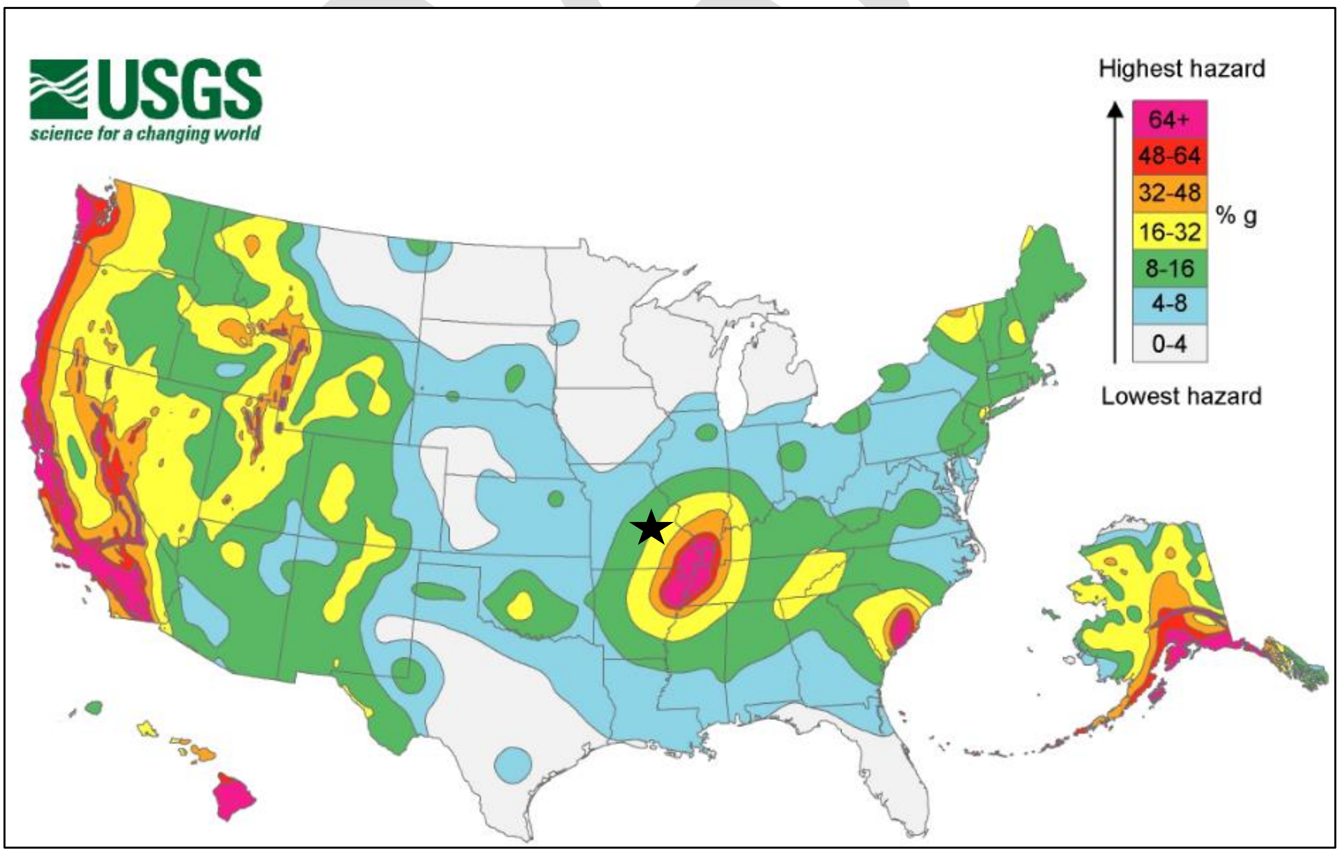
Source: sema.dps.mo.gov

Table 3.25. 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

Figure 3.15 illustrates the seismicity in the United States. A black star indicates the location of Pulaski 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 3.15. United States Seismic Hazard Map



Source: USGS, http://earthquake.usgs.gov; *Black star indicates Pulaski 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 a 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)[21].

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

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

[21] Measuring the Size of an Earthquake, https://www.usgs.gov/faqs/how-are-earthquakes-recorded-how-are-earthquakes-measured-how-magnitude-earthquake-determined?qt-news_science_products=0#qt-news_science_products

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 if at the time of the earthquakes 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 Washington, 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. Numerous earthquakes originating outside of the state's boundaries have also affected Missouri. Five of the strongest earthquakes that have affected Missouri since the 1811-12 series are described below.

On Jan. 4, 1843, a severe earthquake in the New Madrid area cracked chimneys and walls at Memphis, Tennessee. One building reportedly collapsed. The earth sank at some places near New Madrid; there was an unverified report that two hunters were drowned during the formation of a lake. The total felt area included at least 1,036,000 square kilometers.

The Oct. 31, 1895, earthquake near Charleston, MO probably ranks second in intensity to the 1811-12 series. Every building in the commercial area of Charleston was damaged. Cairo, Illinois, and Memphis, Tennessee, also suffered significant damage. Four acres of ground sank near Charleston and a lake was formed. The shock was felt over all or portions of 23 states and at some places in Canada.

A moderate earthquake on April 9, 1917, in the Ste. Genevieve/St. Mary's area was reportedly felt over a 518,000 square kilometer area from Kansas to Ohio and Wisconsin to Mississippi. In the epicentral area people ran into the street, windows were broken, and plaster cracked. A second shock of lesser intensity was felt in the southern part of the area.

The small railroad town of Rodney, MO experienced a strong earthquake on Aug. 19, 1934. At nearby Charleston, windows were broken, chimneys were overthrown or damaged, and articles were knocked from shelves. Similar effects were observed at Cairo Mounds and Mound City, IL, and at Wickliff, KY. The area of destructive intensity included more than 596 square kilometers.

The Nov. 9, 1968, earthquake centered in southern Illinois was the strongest in the central United States since 1895. The magnitude 5.5 shock caused moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. The felt areas include all or portions of 23 states[i].

Several area residents observed a small seismic occurrence during the early morning hours of July 8, 2003 in Crawford County. According to information from the USGS, a micro-earthquake happened about 20 miles northeast of Rolla and measured 2.9 on the Richter scale. The earthquake originated at a depth of about 3.1 miles beneath the earth's surface. In southern parts of Missouri, earthquakes of this magnitude happen frequently, but are an unusual event in Dent County.

Small earthquakes continue to occur frequently in Missouri. Averages 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[22].

Vulnerability

Vulnerability Overview

As stated in the 2018 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 it 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. Infrastructure in the region such as highways, bridges, pipelines, communication lines and railroads might suffer damage, which would adversely affect Pulaski 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 earthquake insurance coverage. The Missouri Department of Insurance, Financial Institutions and Professional Registration (DIFP) prepared a report in 2017 on the state of earthquake insurance coverage in Missouri. The report notes that earthquake coverage has become less available and less affordable over the last 15 years. The cost of earthquake insurance has increased from an average of $50 per year to $149 per year. In high risk counties the increases have been more substantial – from $57 per year in 2000 to $405 per year in 2017. The number of residences covered by earthquake insurance has dropped over the last 15 years – likely due to the increased cost of premiums. In 2018 the percentage of residential policies with earthquake coverage in Pulaski

[22] Missouri State Hazard Mitigation Plan 2018

County was less than 12.4 percent with the average cost of coverage at $96 per year.[23]

Probability of Future Occurrence

No earthquakes have been reported in Pulaski County since 1998. 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 moderate damage within the county.

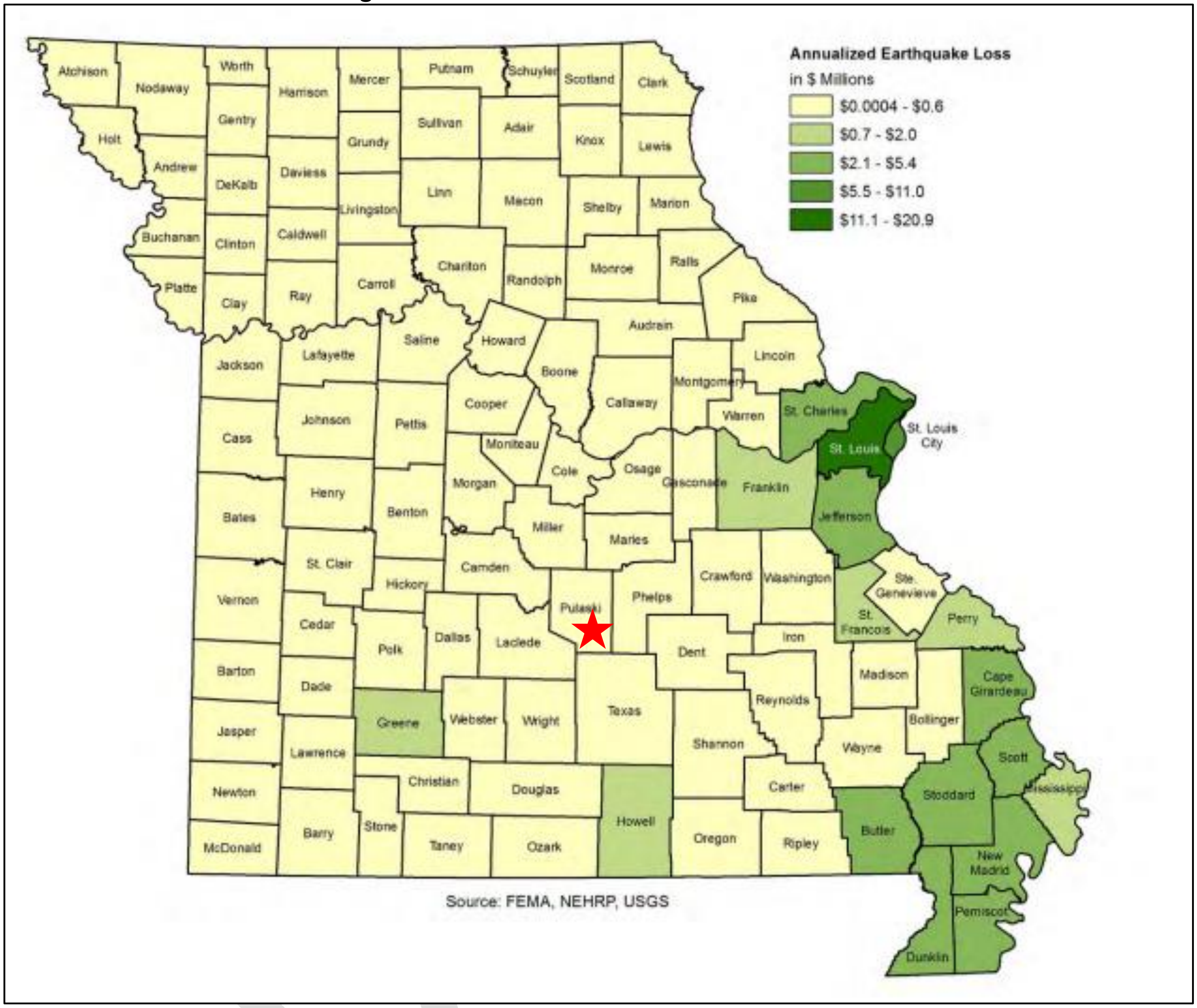
The 2018 Missouri Hazard Mitigation Plan states that there have been 31 recorded earthquake events greater than or equal to M 4.0 in the 43-year period from 1973 to 2018. According to this data, annual probability calculates to 72 percent. Additionally, the USGS estimated in 2006 that the probability 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.

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[24]. 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 3.16** which shows annualized loss scenario direct economic losses to buildings. In this scenario, the annualized earthquake loss for buildings in Pulaski County in any one year is estimated to be $4,000 to $600,000. **Table 3.26** provides information on total estimated losses, estimated losses per capita and loss ratio. This results in the county being ranked 24th 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.[25]

[23] The State of Earthquake Coverage Report https://insurance.mo.gov/earthquake/
[24] 2018 Missouri State Hazard Mitigation Plan
[25] Ibid

Figure 3.16. HAZUS-MH Earthquake Loss Estimation: Annualized Loss Scenario –Direct Economic Losses to Buildings.



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

Table 3.26. HAZUS-MH Earthquake Loss Estimation-Pulaski County: Annualized Loss Scenario

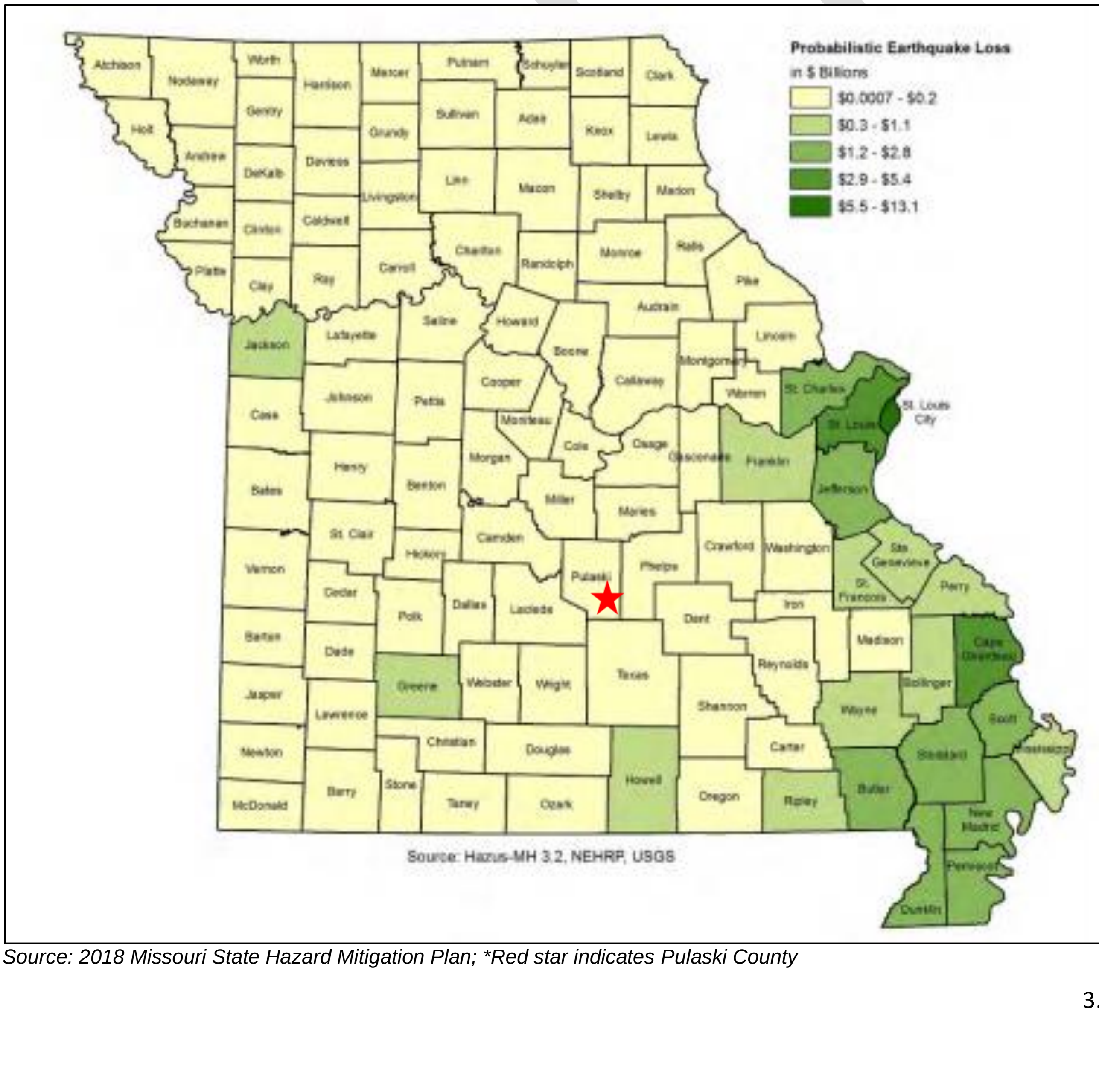
Total Losses in $ Thousands	Loss Per Capita, In $ Thousands	Loss Ratio in $ Per Million	Statewide Ranking for Expected Losses
$342	$0.0065	$64	24th

Source: Hazus 2.1
**All $values are in thousands*
***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

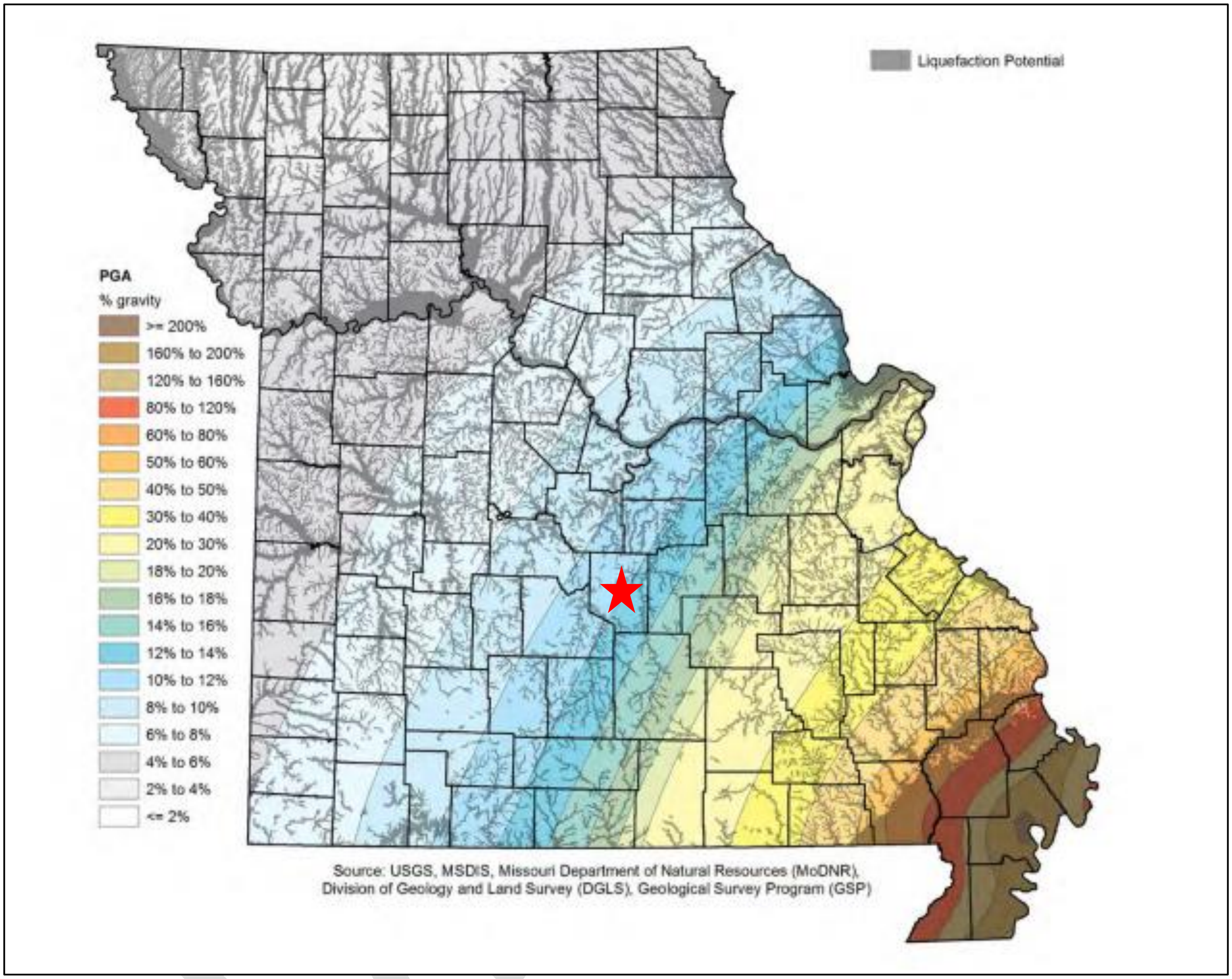
2,500 year earthquake scenario in HAZUS-MH. The methodology is based on probabilistic seismic hazard shaking grids developed by the U.S. Geological Survey (USGS) for the National Seismic Hazard Maps that are included with HAZUS-MH. The USGS updated this mapping in 2014. **Figure 3.17** illustrates direct economic loss to buildings. Pulaski County is anticipated to lose between $700,000 and $200,000,000 in a 50 year scenario. Moreover, in the same event the county is estimated to experience between 3.1 percent and 7 percent loss (damage) of the tota**l.** Error! Reference source not found. further exemplifies the county's loss ratio. **Figure 3.18** provides estimates of peak ground acceleration and spectral acceleration (ground shaking potential) at intervals of 0.3 and 1.0 seconds, respectively which have a two percent probability of exceedance in the next 50 years. 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. Pulaski County is estimated to have peak ground acceleration between 10 percent and 14 percent.

Figure 3.17. HAZUS-MH Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Total Building Loss



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

Figure 3.18. Hazus Earthquake 2% Probability of Exceedance in 50 Years – Ground Shaking and Liquefaction Potential



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

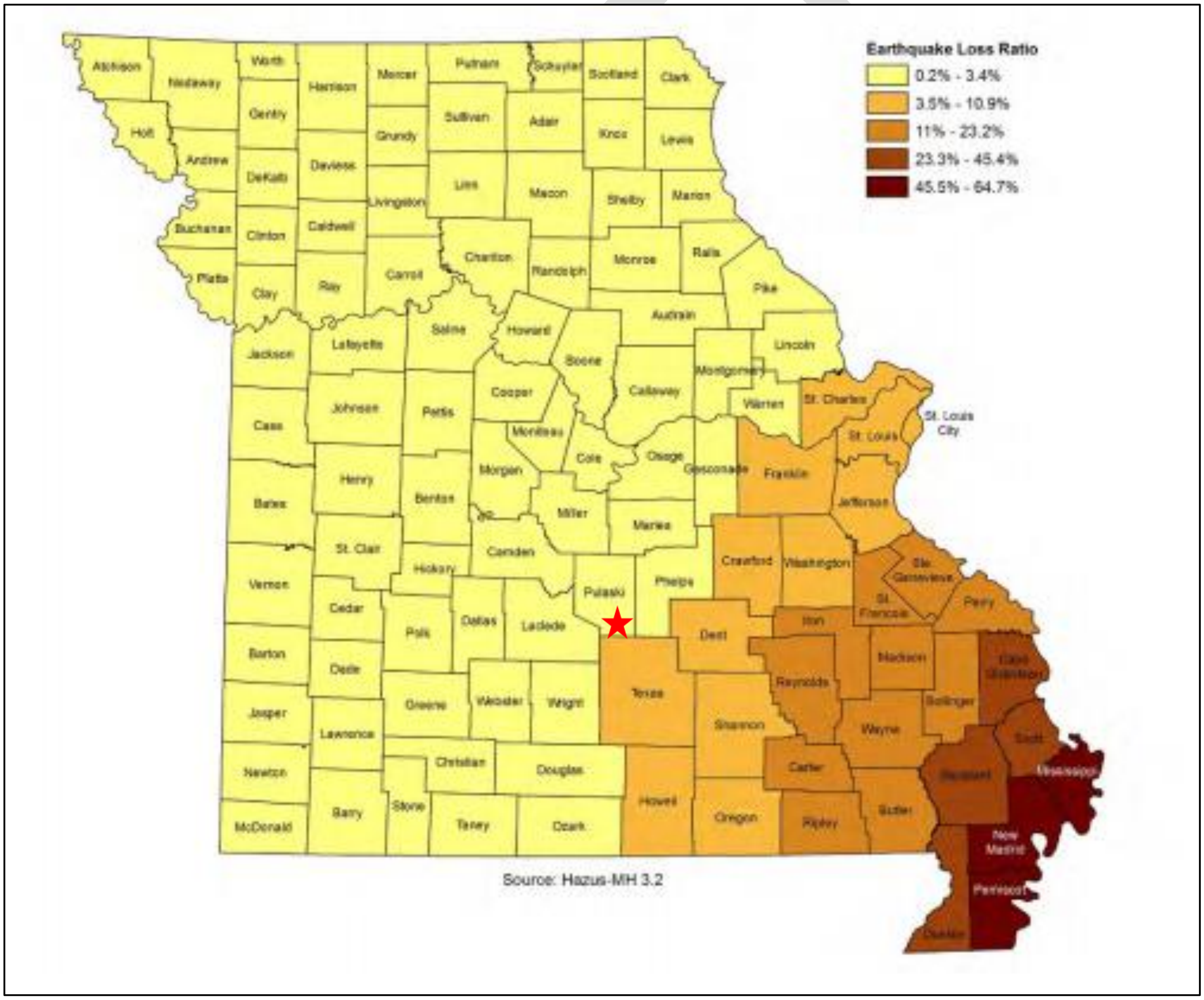
Figure 3.19 depicts a map of the modeled earthquake impacts by county based on building losses, including structural and nonstructural damage, content and inventory loss, and wage and income loss. Pulaski County shows a loss ratio of 0.2 percent to 3.4 percent. **Figure 3.19** depicts loss ratio by county, 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 3.27** provides information on estimated direct economic losses for Pulaski County, including structural, nonstructural, inventory, contents, relocation costs, capital related loss, wages and rental income loss. According to the 2018 Missouri Hazard Mitigation Plan, Pulaski County's loss ratio is 2.15 percent. Pulaski County ranks 88th in the state for direct economic losses in this scenario.

Table 3.27. HAZUS-MH Earthquake Loss Estimation 2% Probability of Exceedance in 50 Years Scenario Direct Economic Losses Results Summary for Pulaski 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
$37,007	$98,954	$30,192	$359	2.55	$16,823	$4,313	$5,918	$11,663	$205,229

Source: 2018 Missouri Hazard Mitigation Plan
**All values in thousands*

Figure 3.19. Hazus Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Loss Ratio



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

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.[26]

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. There has not been any significant development since the last update in any of the cities or county since the last update. 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[27].

Hazard Summary by Jurisdiction

Since earthquake intensity is not likely to vary greatly throughout the planning area, the risk will be the same throughout. Pulaski County is not near the New Madrid Shock 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 3.28** depicts the percent of residences built prior to 1939 in Pulaski 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. However, all school districts indicated that school facilities in the county were built later than 1939. If a major earthquake should occur, Pulaski County would likely be impacted by the number of refugees traveling through the area seeking safety and assistance.

Table 3.28. Percent of Pulaski County Residences Built Prior to 1939

Jurisdiction	Number of Residences Built Prior to 1939	% of Residences Built Prior to 1939
Unincorporated Pulaski County	419	3.7%
Crocker	44	8.9%
Dixon	88	14.8%
Richland	63	7.0%

[26] Missouri State Hazard Mitigation Plan 2018
[27] 2015 Boone County Hazard Mitigation Plan

Jurisdiction	Number of Residences Built Prior to 1939	% of Residences Built Prior to 1939
St. Robert	74	2.2%
Waynesville	62	2.5%

Source:https://data.census.gov/cedsci/table?q=United%20States%20Housing&g=0100000US&tid=ACSDP1Y2018.DP04&t=Housing

Problem Statement

In a worst case scenario, the county is expected to encounter $205,229,000 in total economic losses to buildings. Dixon has a higher risk of damage to buildings due to over 14 percent of the homes having been built prior to 1939.

Jurisdictions should encourage 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
- 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, www.weather.gov/os/heat/index.shtml ;
- 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, http://www.hprcc.unl.edu/data/historical/index.php?state=ia&action=select_state&submit=Select+State, 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;
- 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 3.20** 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. For example – using the Heat Index Chart in Figure 3.23 - if the air temperature is 96 degrees Fahrenheit, (found in the top of the table), and the relative humidity is 55 percent (found on the left of the table), the Heat

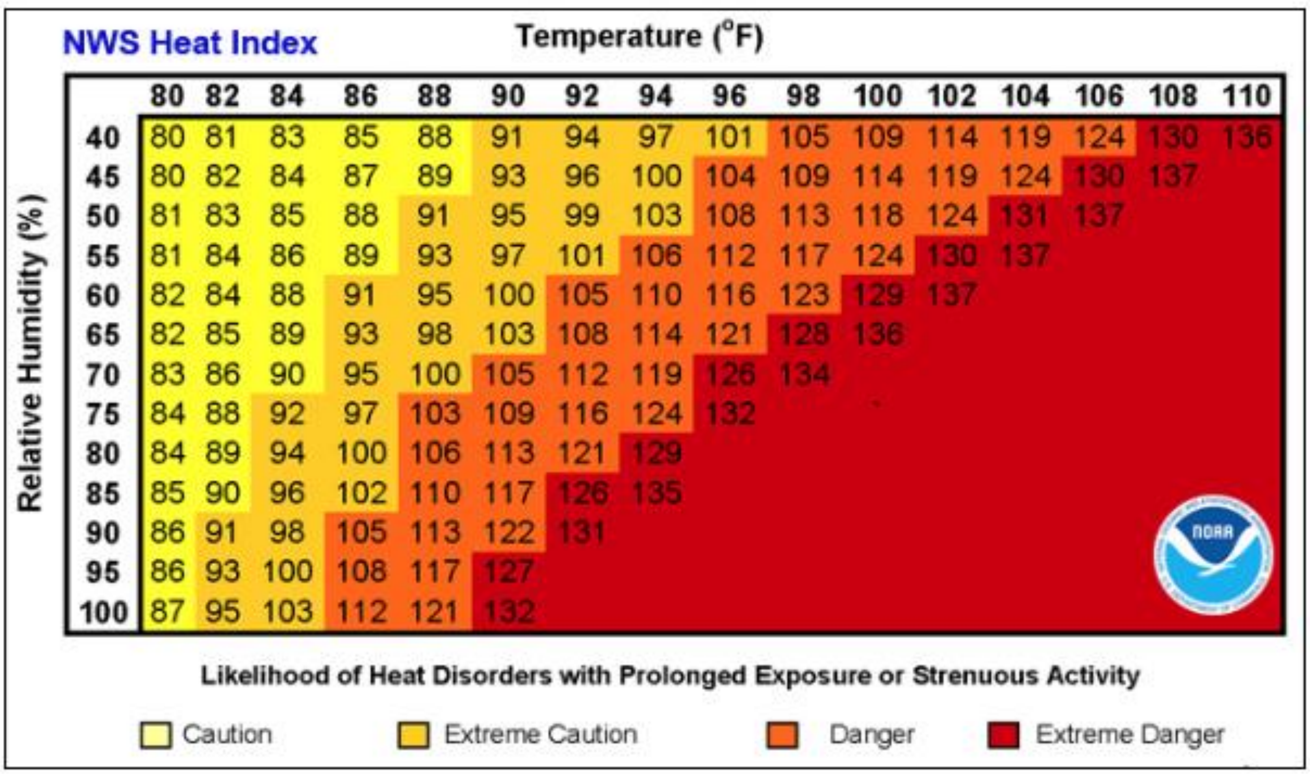
Index is 112 degrees Fahrenheit (the intersection of the 96 degree row and the 55 percent column). Because HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15 degrees Fahrenheit. Also, strong winds, particularly with very hot, dry air, 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.

Figure 3.20. 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.

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 fire, which can be caused by fireplaces and emergency heaters; and frozen/burst pipes.

The NWS Wind Chill Temperature (WCT) index, shown in **Figure 3.21,** uses advances in science, technology and computer modeling to provide an accurate understandable and useful formula for calculating the dangers from winter winds and freezing temperatures. The figure below presents wind chill temperatures which are based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature.

Figure 3.21. Wind Chill Chart

Wind Chill Chart

Wind (mph)	Temperature (°F)																	
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 Pulaski County is minimal to nonexistent.

Strength/Magnitude/Extent

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

The NWS Wind Chill Temperature (WCT) index uses advances in science, technology, and computer modeling to provide an accurate, understandable, and useful formula for calculating the dangers from winter winds and freezing temperatures. **Figure 3.21** 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.

Extreme heat can cause stress to crops and animals. However, according to the NOAA Storm Events Data Base, there were no reported agricultural losses for Pulaski County during that 20 year time period. Data specifically on agricultural losses due to extreme heat was not available on the USDA Risk Management website. Extreme heat can also strain electricity delivery infrastructure overloaded during peak use of air conditioning during extreme heat events. Another type of infrastructure damage from extreme heat is road damage. When asphalt is exposed to prolonged extreme heat, it can cause buckling of asphalt-paved roads, driveways, and parking lots.

From 1988 through 2011, there were 3,496 fatalities in the U.S. attributed to summer heat. This translates to an annual average of 146 deaths. During the same time period, zero deaths were recorded in Pulaski County, according to NOAA Storm Events Data Base. The national Weather Service stated that among natural hazards, no other natural disaster – not lightning, hurricanes, tornadoes, floods or earthquakes – causes more deaths.

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

Table 3.29 lists typical symptoms and health impacts due to exposure to extreme heat.

Table 3.29. Typical Health Impacts of Extreme Heat

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

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

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

Previous Occurrences

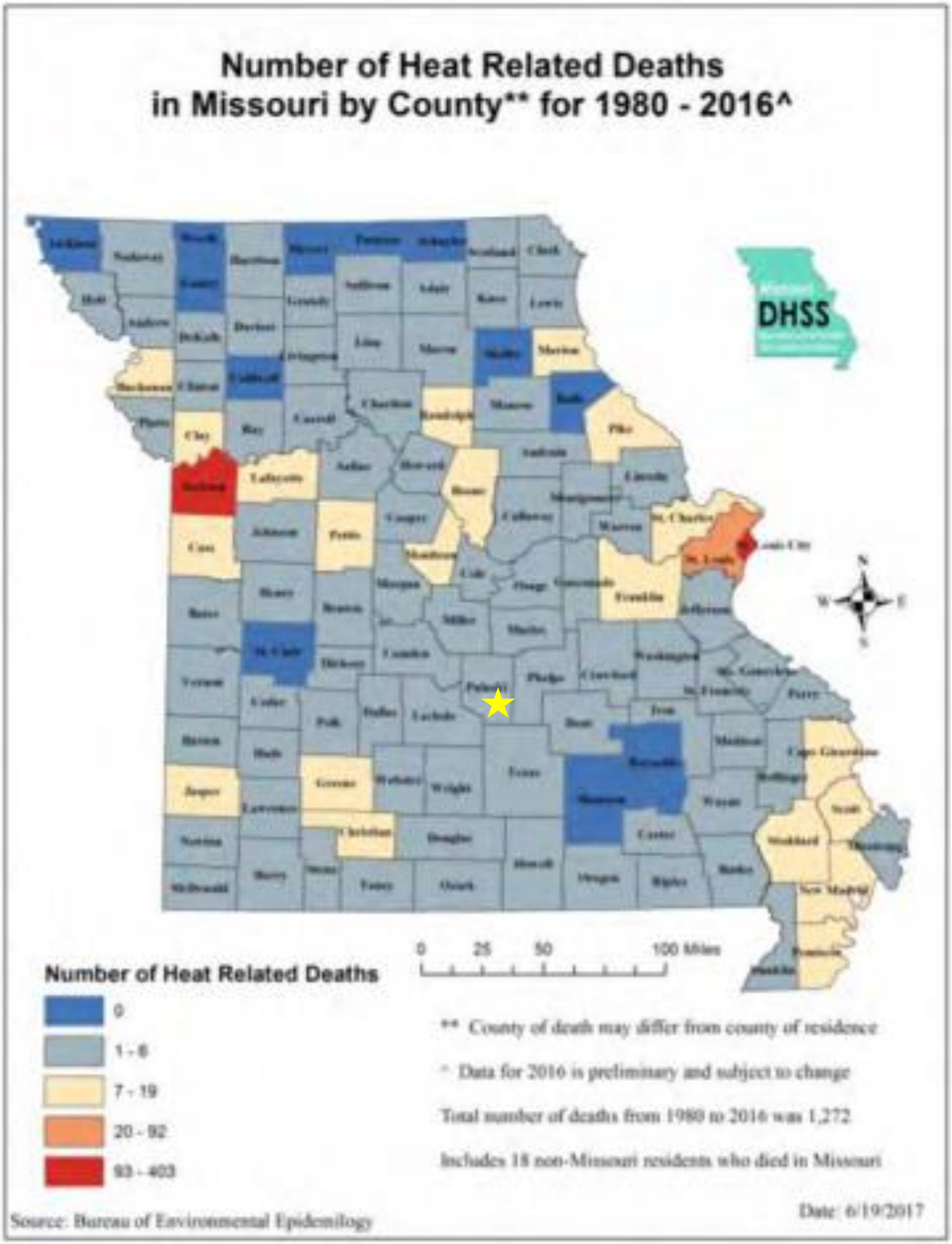
Table 3.30 provides data in relation to record heat events between 1999 and 2019 in Pulaski County. Maximum heat index values and temperatures are shown for each extreme temperature event. Fortunately, there were zero recorded injuries and fatalities during this time. In addition, **Figure 3.22** illustrates heat related deaths by county in Missouri between 1980 and 2016.

Table 3.30. Pulaski County Recorded Heat Events 1999 – 2019

Month, Year	# of Event Days	Fatalities	Injuries	Temperature (F°)	Heat Index Values (F°)
7/23/1999	9	0	0	95+	105-115
8/01/1999	18	0	0	95+	100+
8/27/2000	5	0	0	100+	100-110
9/01/2000	4	0	0	100	100+
7/17/2001	15	0	0	90-100	100-110
8/01/2001	9	0	0	-	100-110
6/01/2012	30	0	0	90+	100+
7/01/2012	31	0	0	100	104+
8/01/2012	31	0	0	90+	106
Total	**152**	**0**	**0**	**-**	**-**

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

Figure 3.22. Heat Related Deaths in Missouri 2000 - 2016

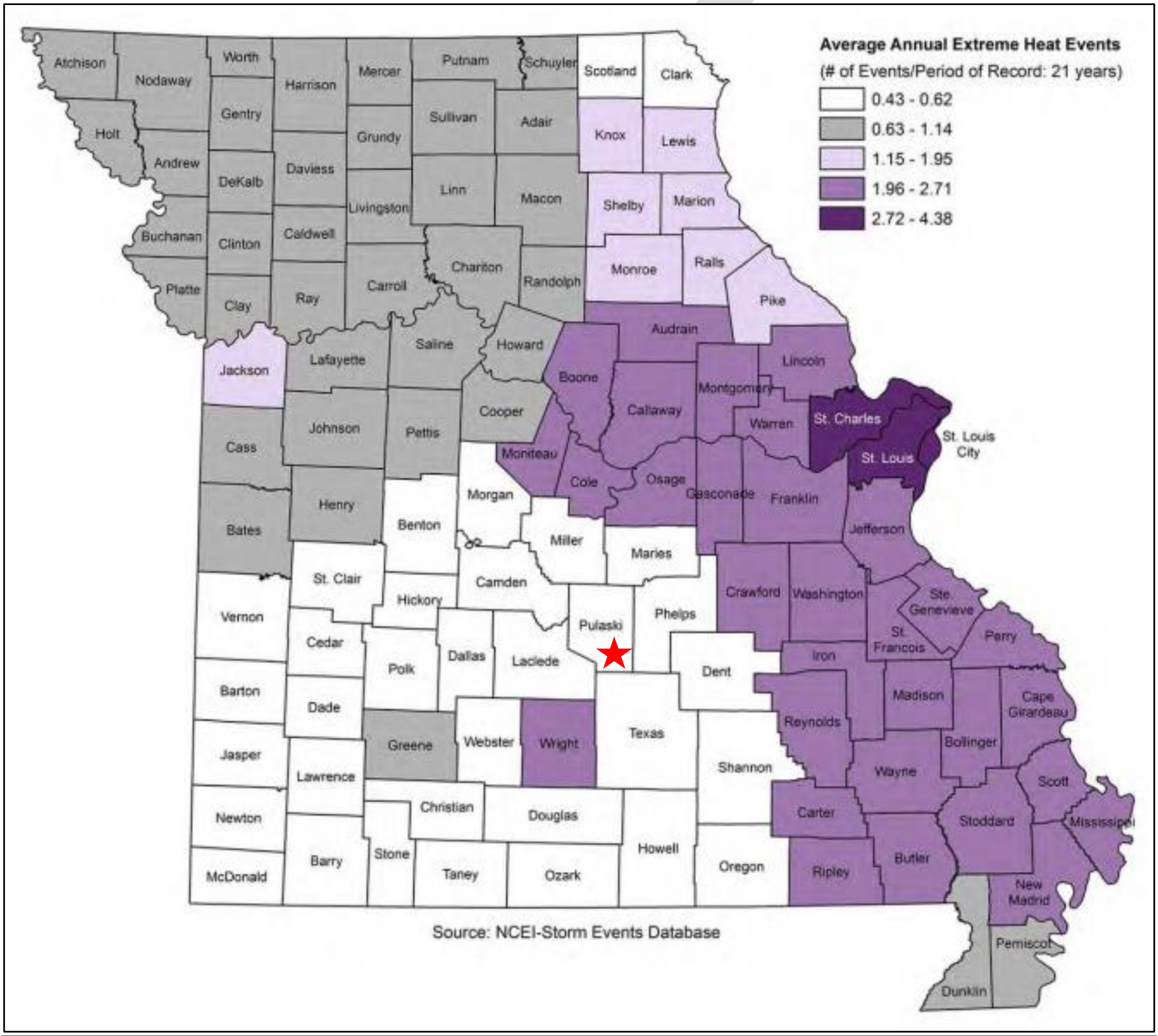


Source: https://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/stat-report.pdf
*Yellow star indicates Pulaski County

Probability of Future Occurrence

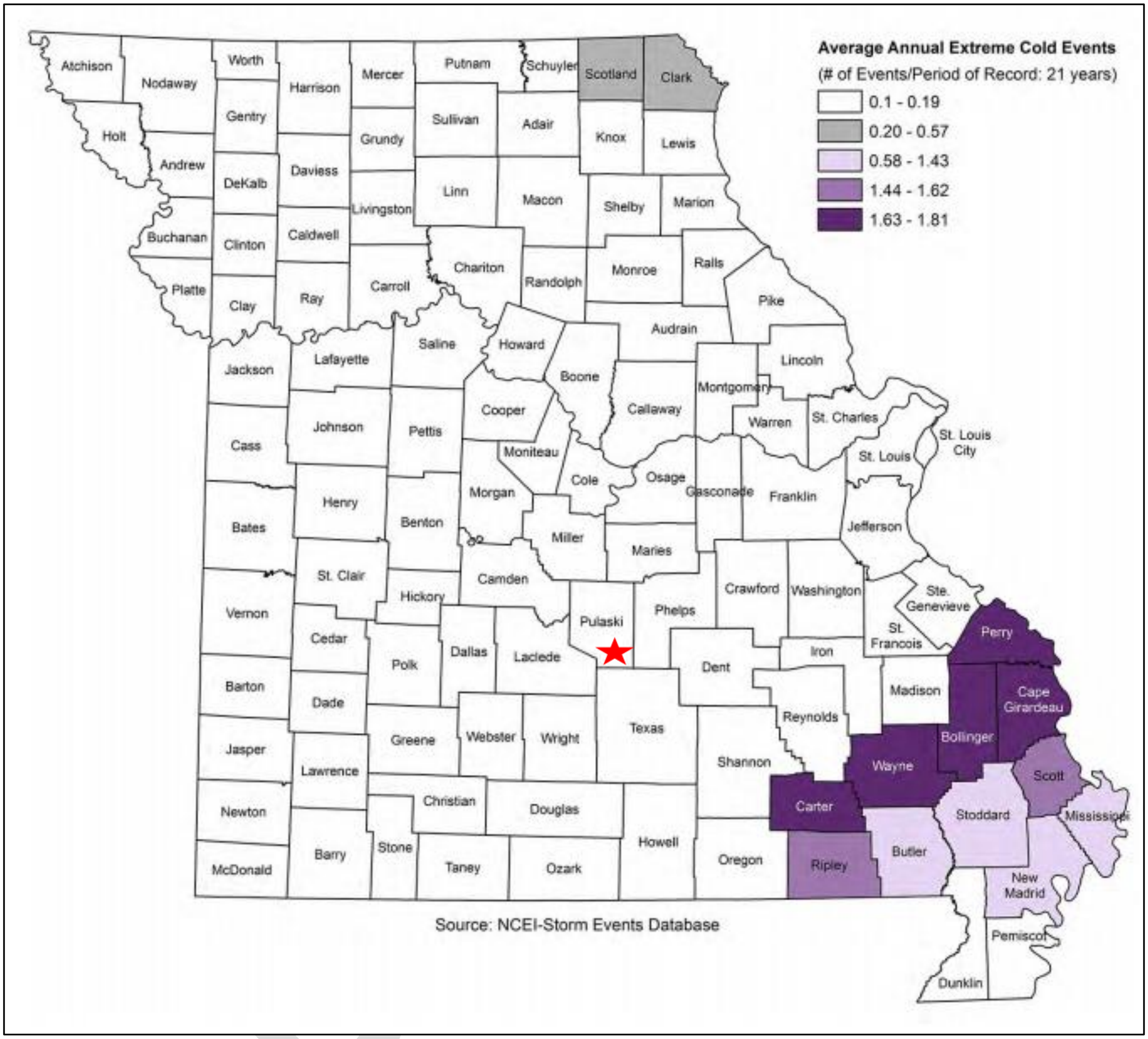
Figure 3.23 illustrates the average annual occurrence for extreme heat statewide. Based on information provided in the 2018 Missouri State Hazard Mitigation Plan, Pulaski County has an average of .43 to .62 events per year based on data from 21 years. **Figure 3.24** illustrates the average annual occurrence for extreme cold statewide. Pulaski County has an average of 0.1 to 0.19 events per year based on data from 21 years. It should be noted that there are data limitations due to underreporting of extreme heat and cold events.

Figure 3.23. Average Annual Occurrence for Extreme Heat



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

Figure 3.24. Average Annual Occurrence for Extreme Cold



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Changing Future Conditions Considerations

According to the 2018 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

Pulaski County, along with the rest of the state of Missouri is vulnerable to extreme heat and cold events. **Table 3.31** shows the typical health impacts of extreme heat. 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 heat (**Table 3.34**). People who are overweight, ill or on certain medication can also be more vulnerable to high temperatures. Unincorporated Pulaski County has an estimated 6.7 percent of individuals are 65 or older. The city of St. Robert had the lowest number of older residents with 8.0 percent aged 65 and over. Crocker had the highest rate overall with 19.9 percent of residents falling into the 65 and older category and Dixon was also high at 19.8 percent. However, even young and healthy individuals are susceptible if they participate in strenuous physical activities during hot weather. The exposure to extreme temperatures of farm workers and livestock is also a major concern.

Table 3.31. Typical Health Impacts of Extreme Heat

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

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

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, 2016), total population and percentage of population over 65 data from the U.S. Census (2015 ACS) and the calculated Social Vulnerability Index for Missouri counties from the hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina. 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 3.32 shows the population, percent of population over 65 and social vulnerability index data for Pulaski County overall.

Table 3.32. Population, Percent of Population Over 65 and SOVI Data for Pulaski County

County	Total Population (2015 ACS)	Total Population Rating	Percentage of Population Over 65	Percent of Population Over 65 Rating	SOVI Ranking	SOVI Rating
Pulaski	3,920	1	7.2	1	Medium High	4

Source: 2018 Missouri Hazard Mitigation Plan

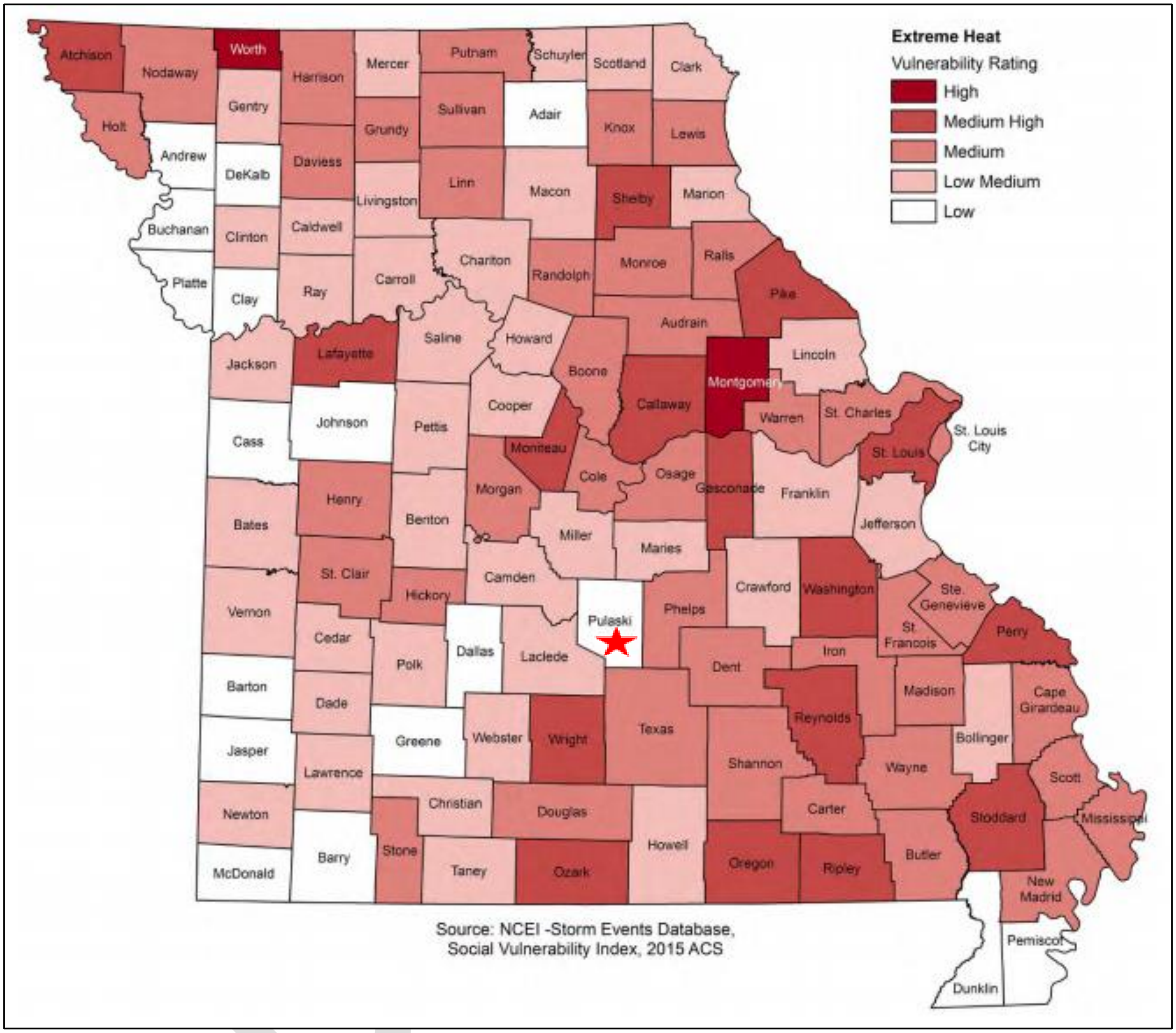
Table 3.33 illustrates the likelihood of occurrence and overall vulnerability rating for extreme temperatures for Pulaski County. **Figure 3.25** and **Figure 3.26** provide a vulnerability summary for extreme heat and extreme cold, respectively. Pulaski County has Low-medium vulnerability for extreme heat and Medium vulnerability for extreme cold.

Table 3.33. Pulaski 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	0.52	1	7	Low	3	0.14	1	7	Low Medium

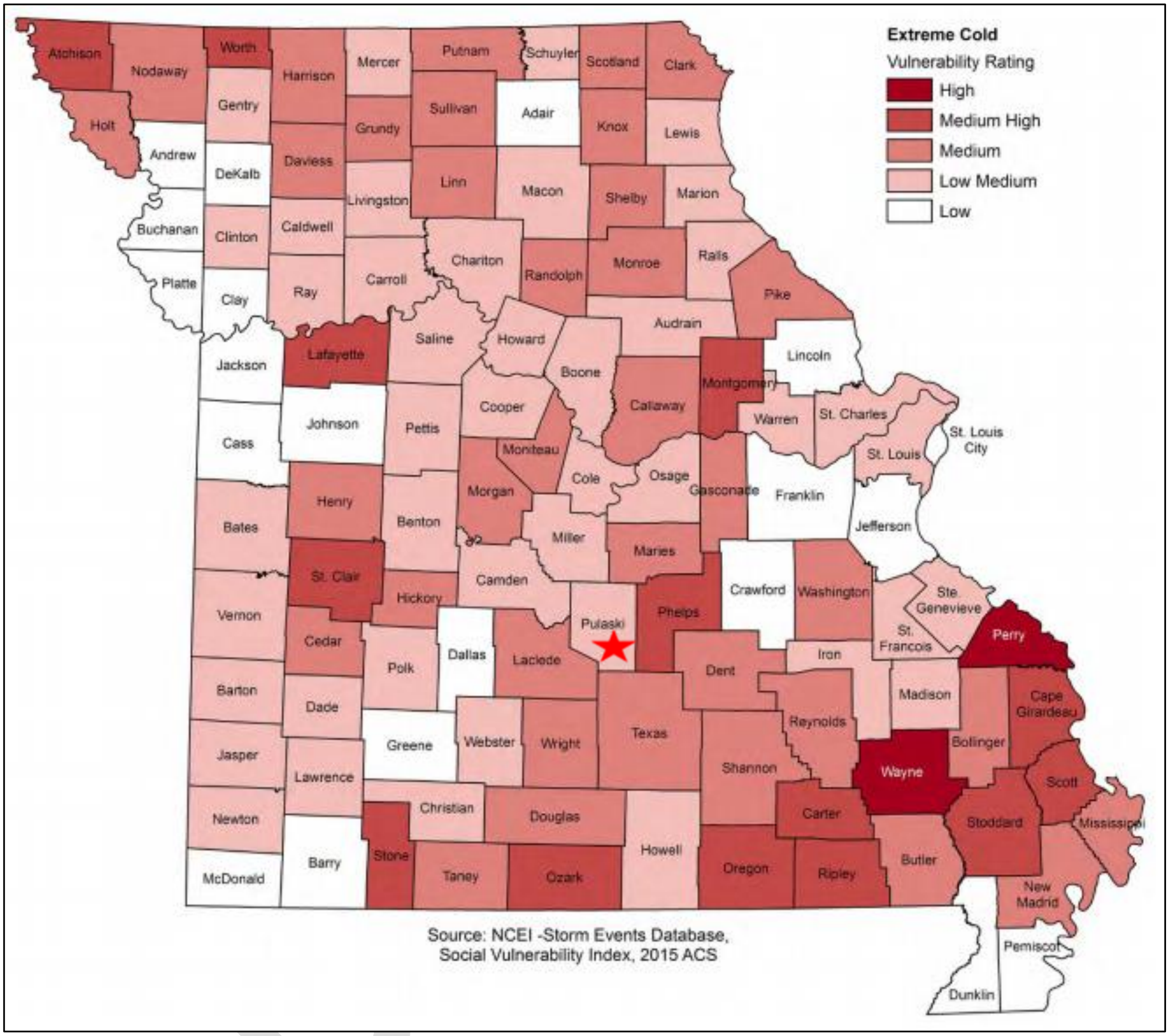
Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.25. Vulnerability Summary for Extreme Heat



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.26. Vulnerability Summary for Extreme Cold



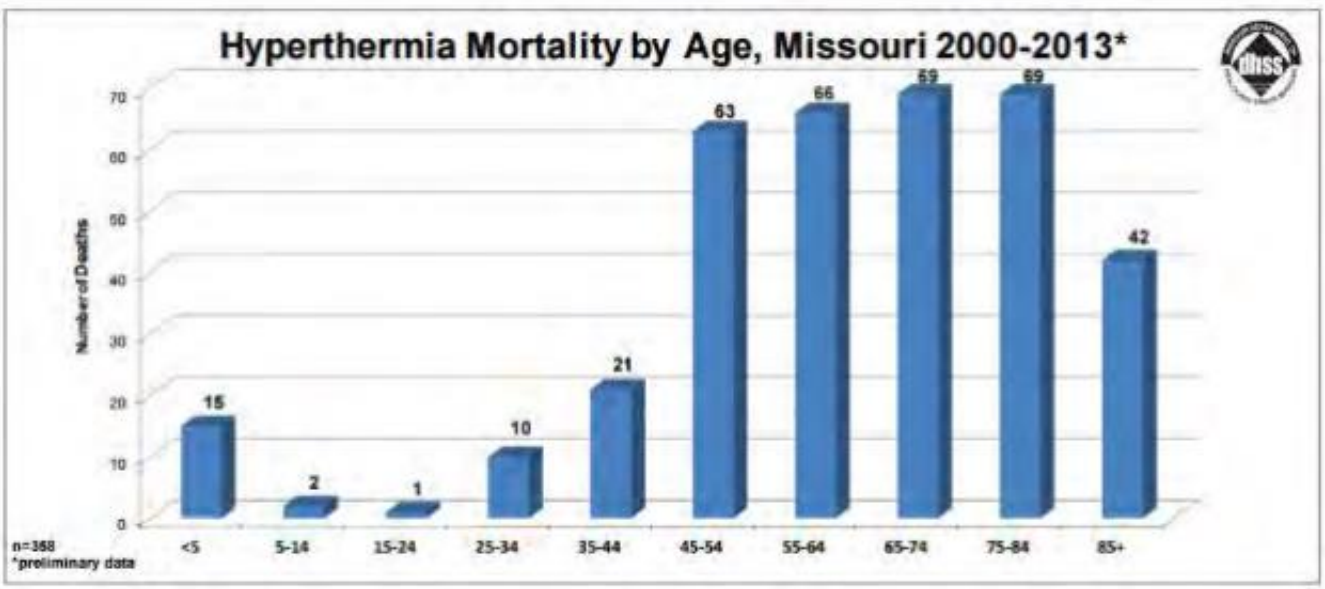
*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

Extreme Heat/Heat Wave

Of greatest concern during extreme heat events are hyperthermia injuries and deaths. The 2018 Missouri Hazard Mitigation plan states that there were 358 heat-related deaths reported in Missouri from 2000 through 2013. There were 217 (61%) deaths in the metropolitan areas of Kansas City and St. Louis and 141 (39%) deaths in rural parts of the state. Half of the deaths were 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 2000 and 2013 there were 15 (4%) 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. **Figure 3.27** shows the hyperthermia mortality rate by age for the 2000-2013 timeframe.

Figure 3.27. Hyperthermia Mortality of Age, Missouri 2000-2013



Source: Missouri DHSS, http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper4.pdf

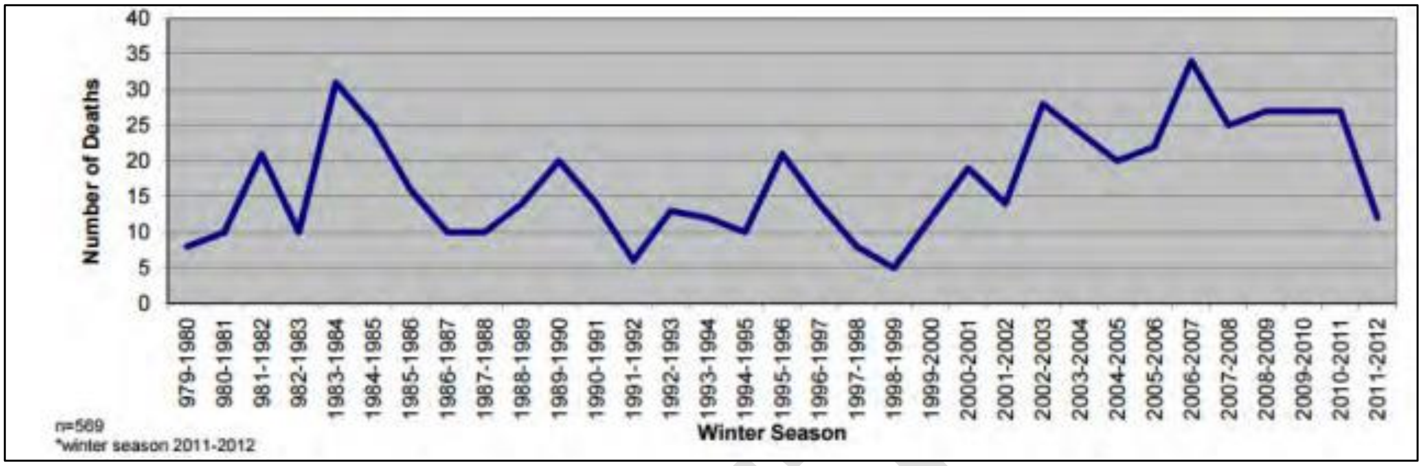
During extreme heat events structural, road, and electrical infrastructure are vulnerable to damages. Depending upon temperatures and duration of extreme heat, losses will vary.

Extreme Cold

According to the Missouri Department of Health and Senior Services, 569 people died in Missouri due to extreme cold conditions between 1979 and 2012, see **Figure 3.28**. 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 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%) of the 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 3.28. Hypothermia Deaths, Missouri: Winter Seasons 1979-2012



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

Impact of Future Development

Population trends from 2000 to 2018 for Pulaski County and the city of Dixon indicate that the population in unincorporated areas has fallen by an estimated 3.44 percent. The city of Dixon's population has decreased by a significant 18.92 percent. The city of Crocker's population has grown by an estimated 3.78 percent. The city of Richland's population has increased by 1.72 percent and the city of St. Robert has grown by a significant 32.8 percent. The city of Waynesville's population has increased by an estimated 9.03 percent. Population growth can result in increased age groups that are more susceptible to extreme heat and cold. Additionally, as populations increase, so does the strain on each jurisdiction's electricity and road infrastructure. Local government and local emergency management should take extreme heat and cold in consideration when upgrades occur to the local power grid.

Hazard Summary by Jurisdiction

Those at greatest risk for heat-related illness and deaths include children up to five years of age, people 65 years of age and older, people who are overweight, and people who are ill or on certain medications or have medical conditions that make them more vulnerable. To determine jurisdictions within the planning area with populations more vulnerable to extreme heat, demographic data was obtained from the 2014-2018 census on population percentages in each jurisdiction comprised of those under age 5 and over age 65. Data was not available for overweight individuals and those on medications vulnerable to extreme heat or with medical conditions that made them more vulnerable. **Table 3.34** 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 3.34. County Population Under Age 5 and Over Age 65 (2014-2018)

Jurisdiction	Population Under 5 Years	Population 65 Years and over
Incorporated Pulaski County	%	%
Crocker	9.0%	19.9%
Dixon	5.0%	19.8%

Jurisdiction	Population Under 5 Years	Population 65 Years and over
Richland	3.3%	17.3%
St. Robert	4.1%	8.0%
Waynesville	8.5%	11.4%

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates

Due to lack of data, strategic 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 cities of Crocker and Dixon have a high percentage of individuals 65 and over, 19.9 percent and 19.8 percent respectively.

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 Pulaski 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 loos-fitting, lightweight and light colored clothes that dover 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

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

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 cities of Crocker and Dixon have the highest risk because both have large populations of people aged 65 and over (**Table 3.34**).

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 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 https://mdc12.mdc.mo.gov/Applications/MDCFireReporting/Home/FireReportSearch
- Statistics, Missouri Division of Fire Safety;
- National Statistics, US Fire Administration;
- Fire/Rescue Mutual Aid Regions in Missouri;
- Forestry Division of the Missouri Dept. of Conservation;
- National Fire Incident Reporting System (NFIRS), http://www.dfs.dps.mo.gov/programs/resources/fire-incident-reporting-system.php
- University of Wisconsin Slivis Lab, http://silvis.forest.wisc.edu/data/wui-change/
- 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.

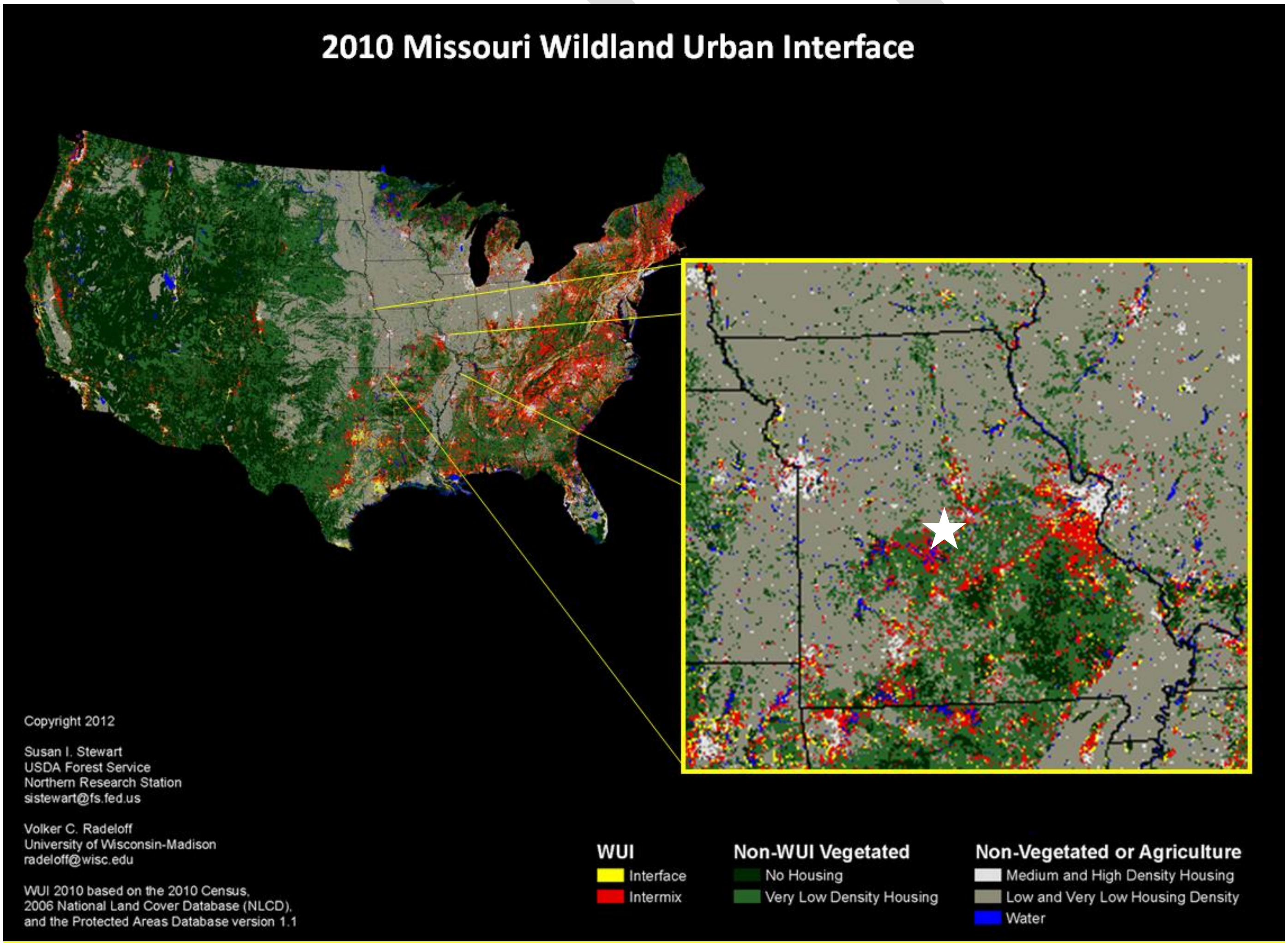
The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from wildfires. To accomplish this task, eight forestry regions have been established in Missouri for fire suppression. The Forestry Division works closely with volunteer fire departments and federal partners to assist with fire suppression activities. Currently, approximately 700 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 of 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 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

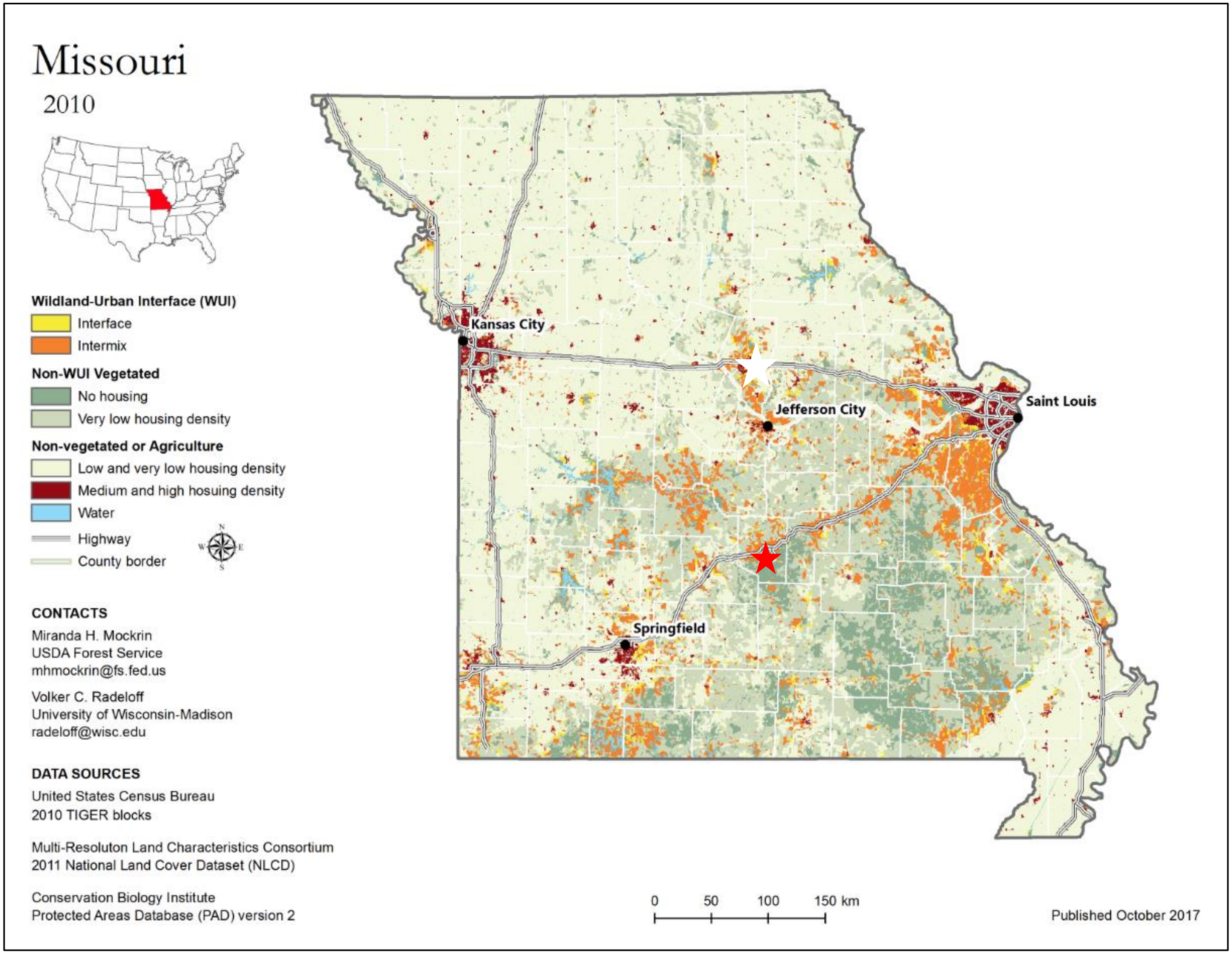
The risk of wildfire does not vary widely across the planning area. However, damages due to wildfires are expected to be higher in communities with more wildland–urban interface (WUI) areas. WUI refers to the zone of transition between unoccupied land and human development and needs to be defined in the plan. Within the WUI, there are two specific areas identified: 1) Interface and 2) Intermix. The interface areas are those areas that abut wildland vegetation and the Intermix areas are those areas that intermingle with wildland areas (**Figure 3.29**). To determine specific WUI areas and variations, data was obtain from ArcGIS, Streets and SILVIS (**Figure 3.30**). According to the WUI area map of Pulaski County, all cities partially reside in a WUI area.

Figure 3.29. 2010 Missouri Wildland Urban Interface (WUI)



Source: http://silvis.forest.wisc.edu/maps/wui; White star roughly estimates Pulaski County's location

Figure 3.30. Pulaski County Wildlife Urban Interface



*Source: http://silvis.forest.wisc.edu/GeoData/WUI_cp12/maps/gifs/white/Missouri_WUI_cp12_white_2010.gif; *Red star indicates Pulaski County*

Strength/Magnitude/Extent

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

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

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

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 2000 and 2019 there were 571 wildfires reported in Pulaski County, according to wildfire reporting to the Missouri Department of Conservation[28]. This is an average of 28.5 wildfires per year. The size of the fires varied from as small as .1 acre to as large as 300 acres. **Table 3.35** shows the cause of wildfires, number of wildfires and acres burned for the period 2000-2019. Debris fires account for the largest number of fires and the greatest number of acres burned.

Table 3.35. 2000-2019 Pulaski County Wildfires by Cause

Cause	Number	Acres	% Number	% Acres
Equipment	29	164.8	5%	3%
Debris	252	2,346.72	44%	42%
Arson	32	213.24	6%	4%
Lightning	1	.5	<1%	<1%
Unknown	170	2,373.93	30%	42%
Unreported	16	104.5	3%	2%
Railroad	2	2.5	<1%	<1%
Smoking	4	9.35	<1%	<1%
Miscellaneous	58	416.65	10%	7%
Totals	**571**	**5,632.19**	**100%**	**100%**

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

Records for school and special districts are not available at this time.

Probability of Future Occurrence

From the data obtained from the Missouri Department of Conservation[29] (Appendix: F), 571 wildfire events occurred in Pulaski County between 2000 and 2019. This information was utilized to determine the annual average percent probabilities of wildfires. Since multiple occurrences are anticipated per year (571 events/20 years), the probability of wildfires per year is 100% with an average of 28.55 events per year **Table 3.37**.

Table 3.36. Annual Average Percentage Probability of Wildfires in Pulaski County

Location	Annual Avg. % P	Avg. Number of Events
Pulaski County	100%	28.55

*P = probability; see page 3.24 for definition.

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.[30]

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.[31]

Vulnerability

Vulnerability Overview

According to the 2018 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 Pulaski County should expect to have 35.62 wildfires per year, impacting 270 acres (**Table 3.37**).

[29] http://mdc7.mdc.mo.gov/applications/FireReporting/Report.aspx
[30] 2018 Missouri Hazard Mitigation Plan
[31] Ibid

The state plan also indicates that Pulaski County is at the low-medium possible likelihood for building damage from wildfires – likely from the low population numbers in the county. **Figure 3.31** illustrates the likelihood of wildfire events based on data from 2004-2016. **Figure 3.31** provides a map that illustrates the average annual acreage burned.

Table 3.37. Statistical Data for Wildfire Vulnerability in Pulaski County

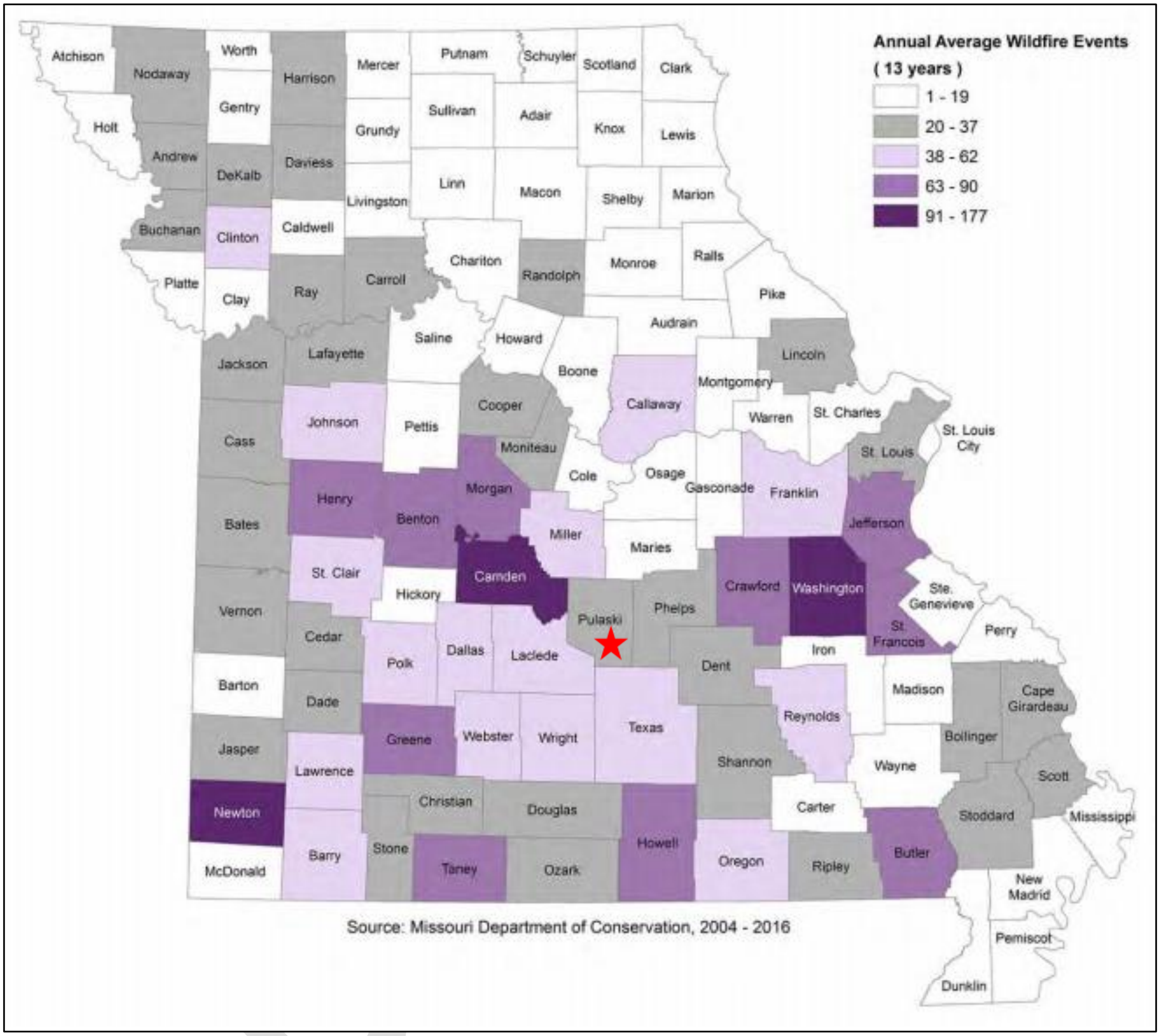
Number of Wildfires 2004-2016	Likelihood of Occurrence (#/year)	Total Acres Burned	Average Annual Acreage Burned
463	35.62	3513.45	270

Source: 2018 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), HAZUS building exposure value data and wildland urban interface and intermix area data from the University of Wisconsin-Madison SILVIS Lab.

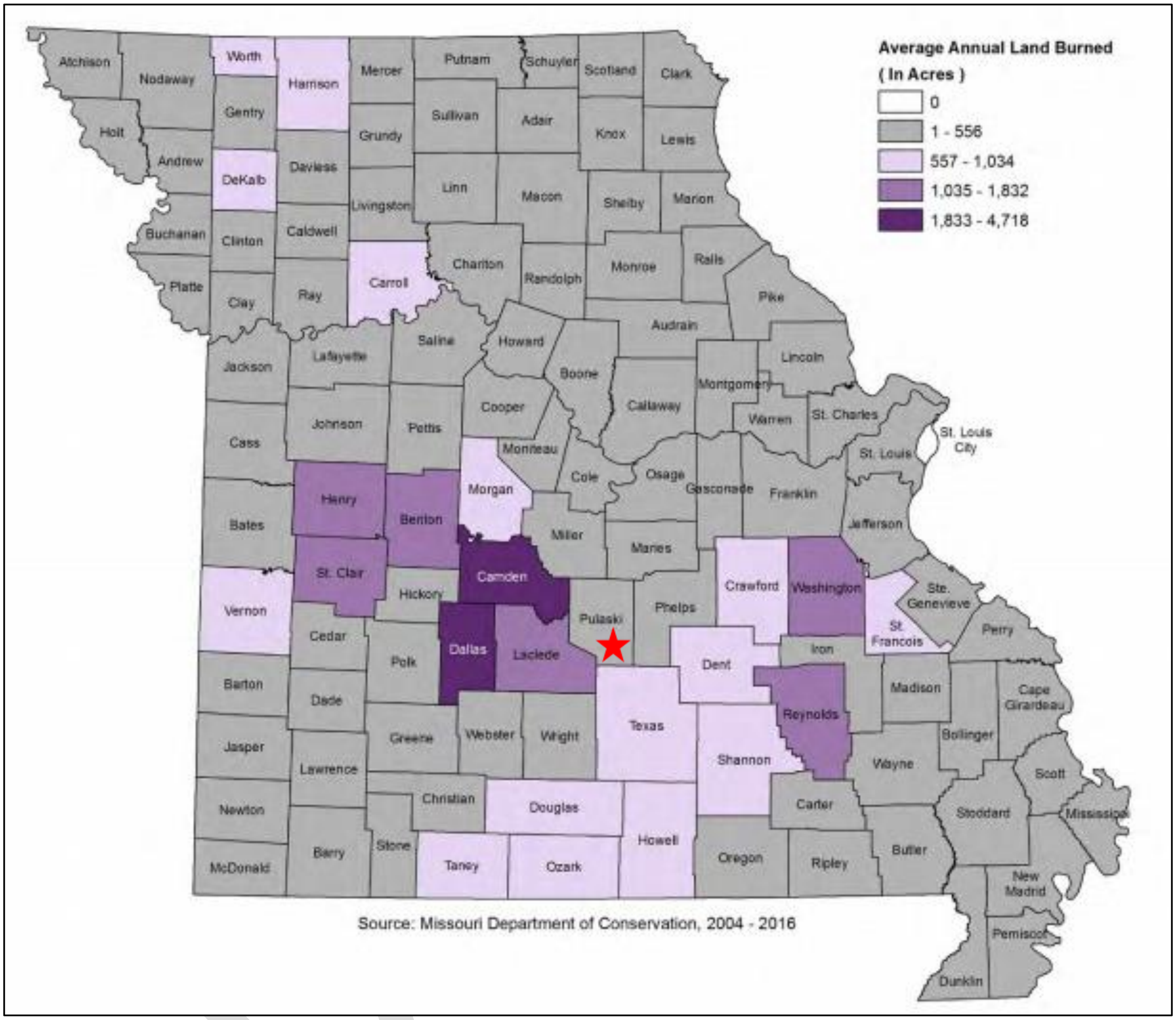
The results of that analysis, including estimated number of structures, value of structures and population are illustrated in **Table 3.38.** The total estimated number of structures vulnerable to wildfires is 13,588. The overall value of structures vulnerable to wildfire in Pulaski County is estimated at $5,360,526,096. To further illustrate vulnerability in Pulaski County, maps from the 2018 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 3.33** . Pulaski County shows that it has between 3,218 and 9,827 structures within these areas. **Figure 3.34** shows the estimated value of structures in the WUI interface and intermix areas. **Figure 3.35** illustrates the number of people at risk to wildfire in the WUI interface and intermix areas.

Figure 3.31. Likelihood of Wildfire Events, 2004-2016



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.32. Average Annual Acreage Burned



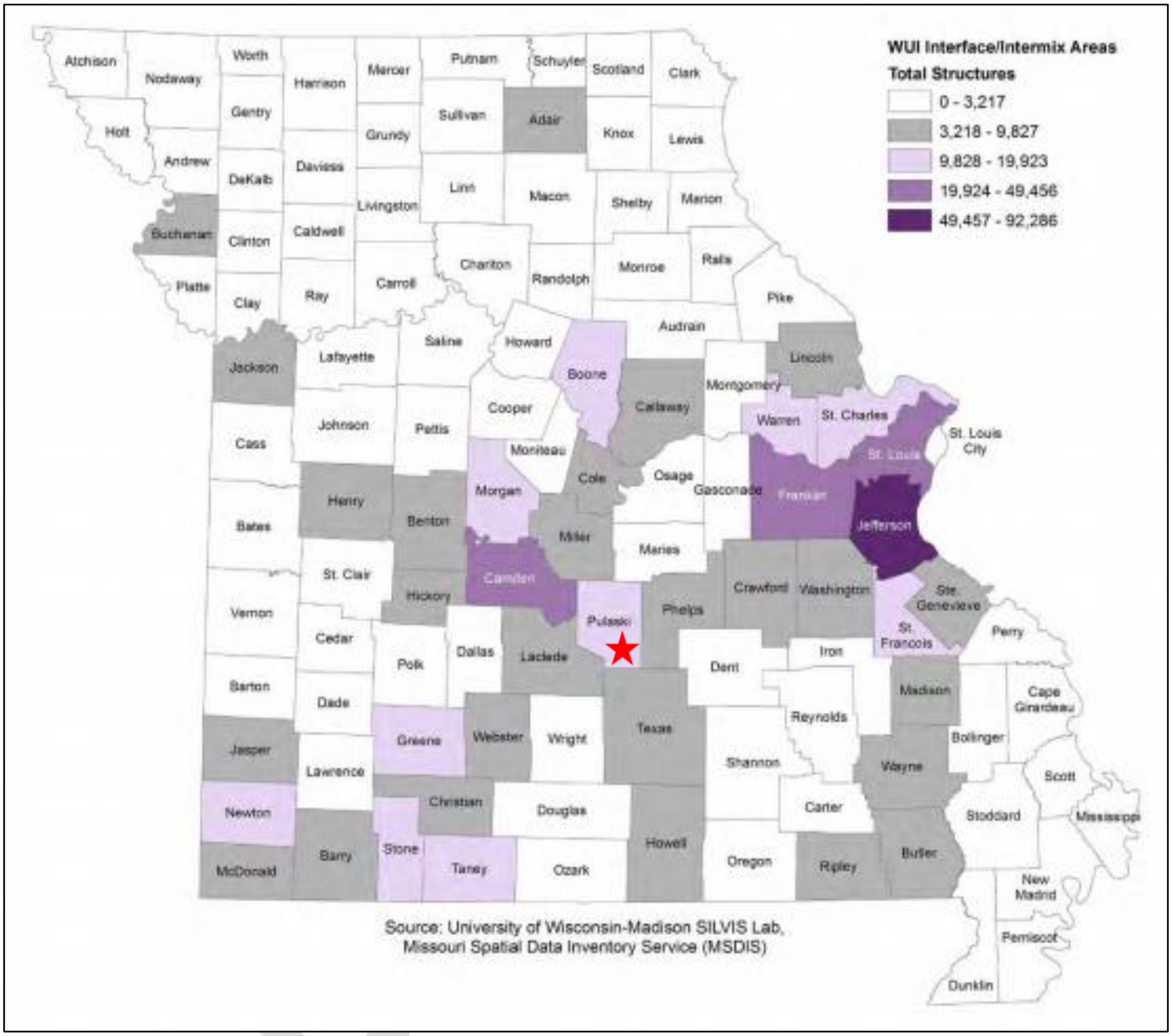
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County,*

Table 3.38. Estimated Numbers and Values of Structures and Population Vulnerable to Wildfire in Pulaski County

Pulaski County	Number of Structures	Value of Structures	Population
Agriculture	666	$133,293,474	
Commercial	357	$228,206,195	
Education	25	$29,989,773	
Government	2,065	$1,945,023,500	
Industrial	32	$16,595,380	
Residential	10,443	$3,007,417,775	
Totals	**13,588**	**$5,360,526,096**	**28,614**

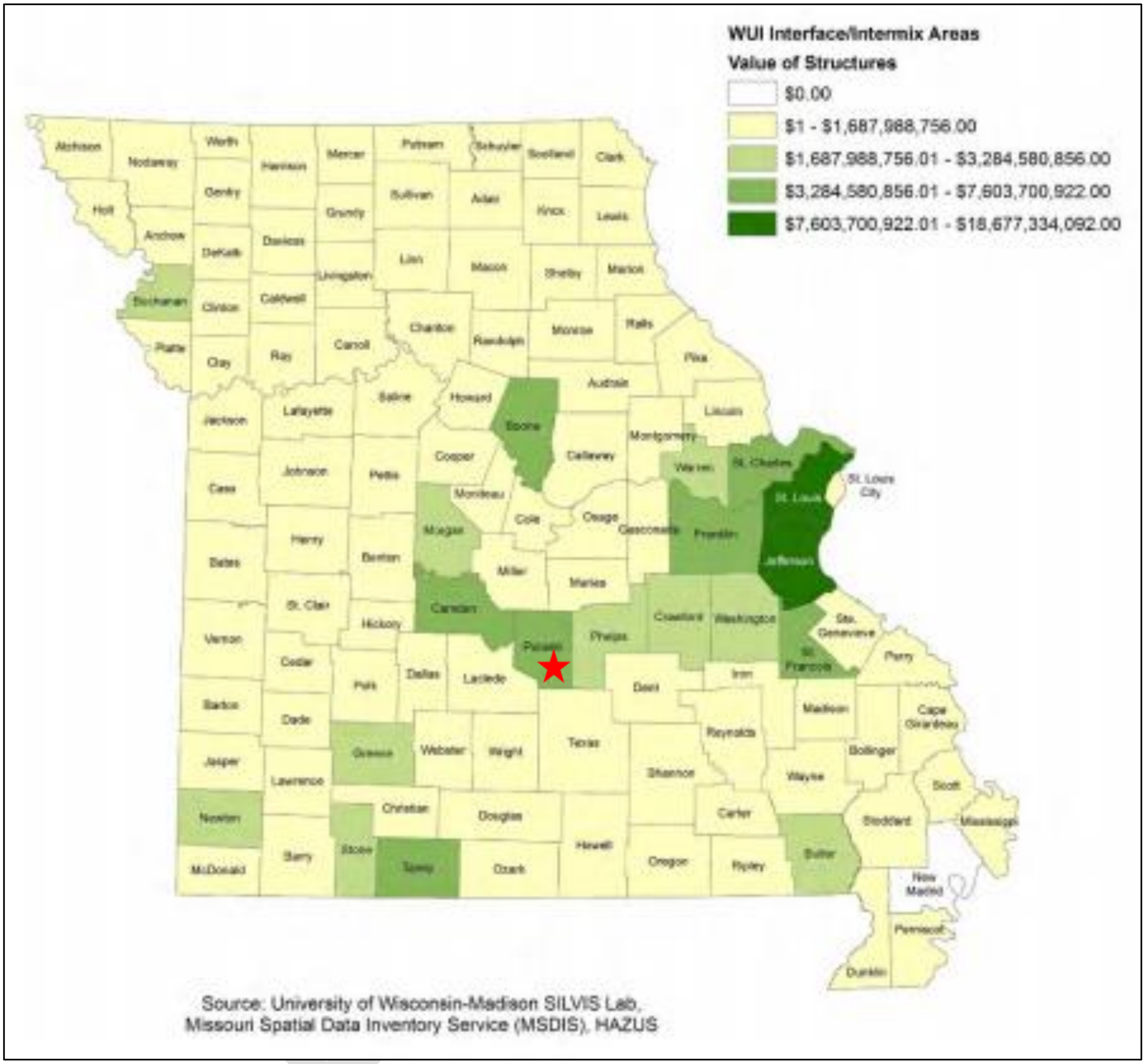
Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.33. Number of Structures in WUI Interface and Intermix Areas



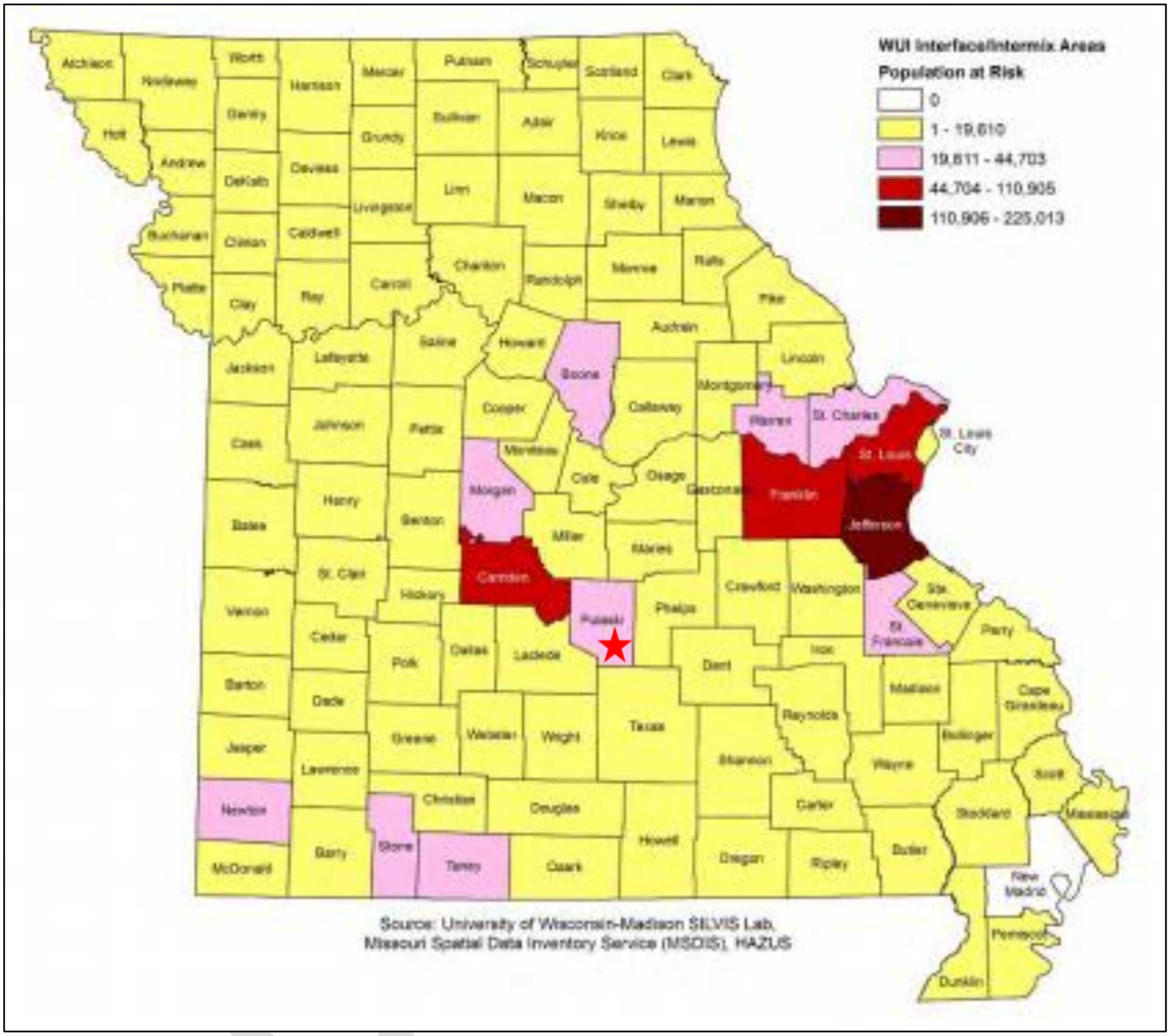
*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County,*

Figure 3.34. Value of Structures in the WUI Interface and Intermix Areas



Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County

Figure 3.35. Population at Risk to Wildfire in WUI Interface and Intermix Areas



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

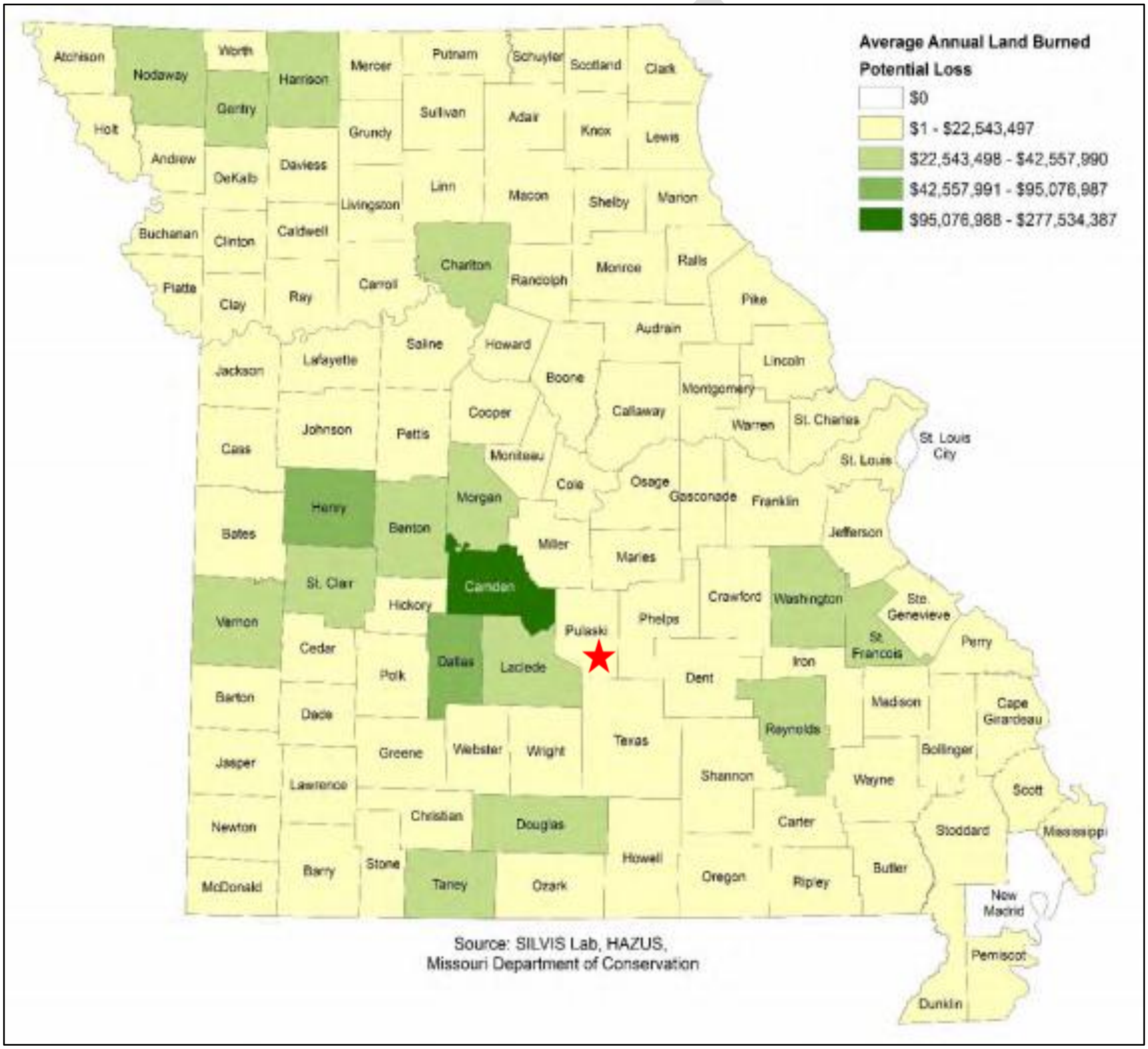
As there was not data available on Pulaski County specific losses, data was used from the 2018 Missouri State Hazard Mitigation Plan. The factors considered for estimating potential losses due to wildfires were average acreage burned each year per county and the average value of structures per acre in the WU-Interface/Intermix areas. **Table 3.39** and **Figure 3.36** that follows provide the potential loss figures for Pulaski County based on this methodology.

Table 3.39. Wildfire Potential Loss Estimates for Pulaski County

Total WUI Acreage	Total Structure Value Within WUI	Average Value/Acre within WUI	Average Annual Acreage Burned	Potential Loss
92,929.66	$5,360,526,096	$57,684	270	$15,574,598

Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.36. Annualized Wildfire Damages



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Impact of 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, each jurisdiction within the county resides 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 Pulaski County should have a negligible adverse impact on the community, as it would affect a small percentage of the population. 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. Both cities and school districts are in WUI areas, but are closer to fire services.

Problem Statement

An estimated 13,588 structures and 28,614 people are vulnerable to wildfires in Pulaski 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.

3.4.6 Flooding (Flash and River)

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, https://mywaterway.epa.gov/
- FEMA Map Service Center, Digital Flood Insurance Rate Maps (DFIRM) for all jurisdictions, if available, msc.fema.gov/portal
- 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, http://www.rma.usda.gov/data/cause.htm
- FEMA Data Visualization Tool, https://www.fema.gov/data-visualization-floods-data-visualization
- 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). Below are FIRMs for the cities of Crocker, Dixon, Richland, St. Robert and Waynesville (**Figure 3.37 through** Error! Reference source not found.**1**). **Table 3.40** shows Pulaski County NCEI flood events by location between 1999 and 2019.

Figure 3.37. City of Crocker, Missouri Special Flood Hazard Areas (SFHAs)

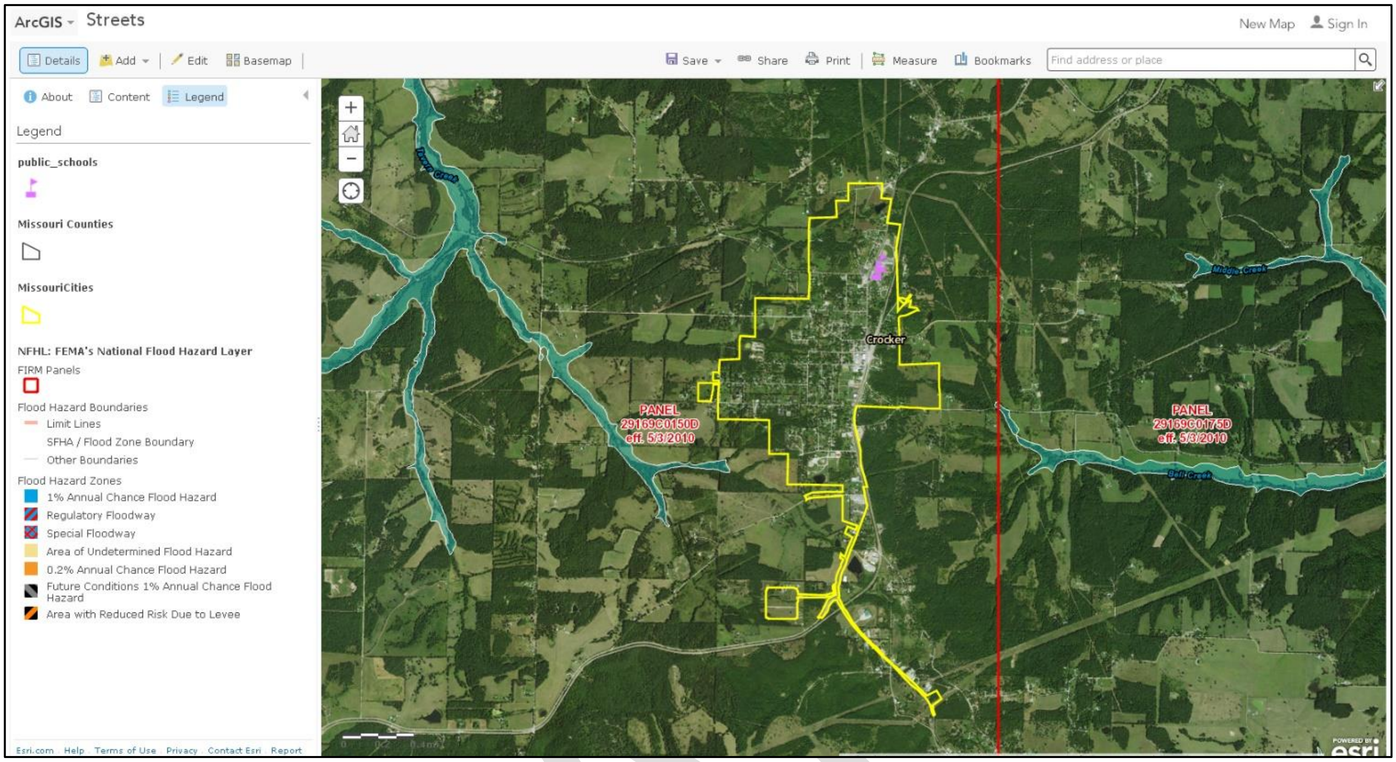


Figure 3.38. City of Dixon, Missouri Special Flood Hazard Areas (SFHAs)

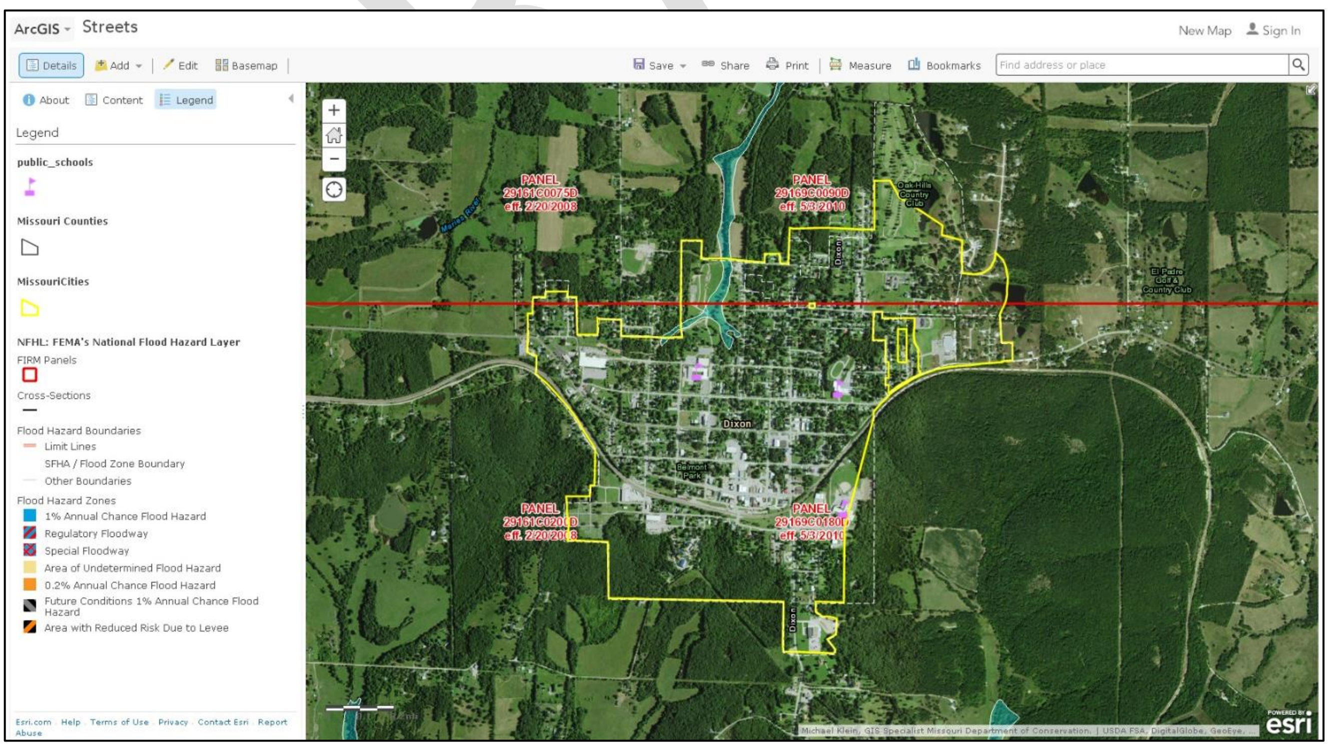


Figure 3.39. City of Richland, Missouri Special Flood Hazard Areas (SFHAs)

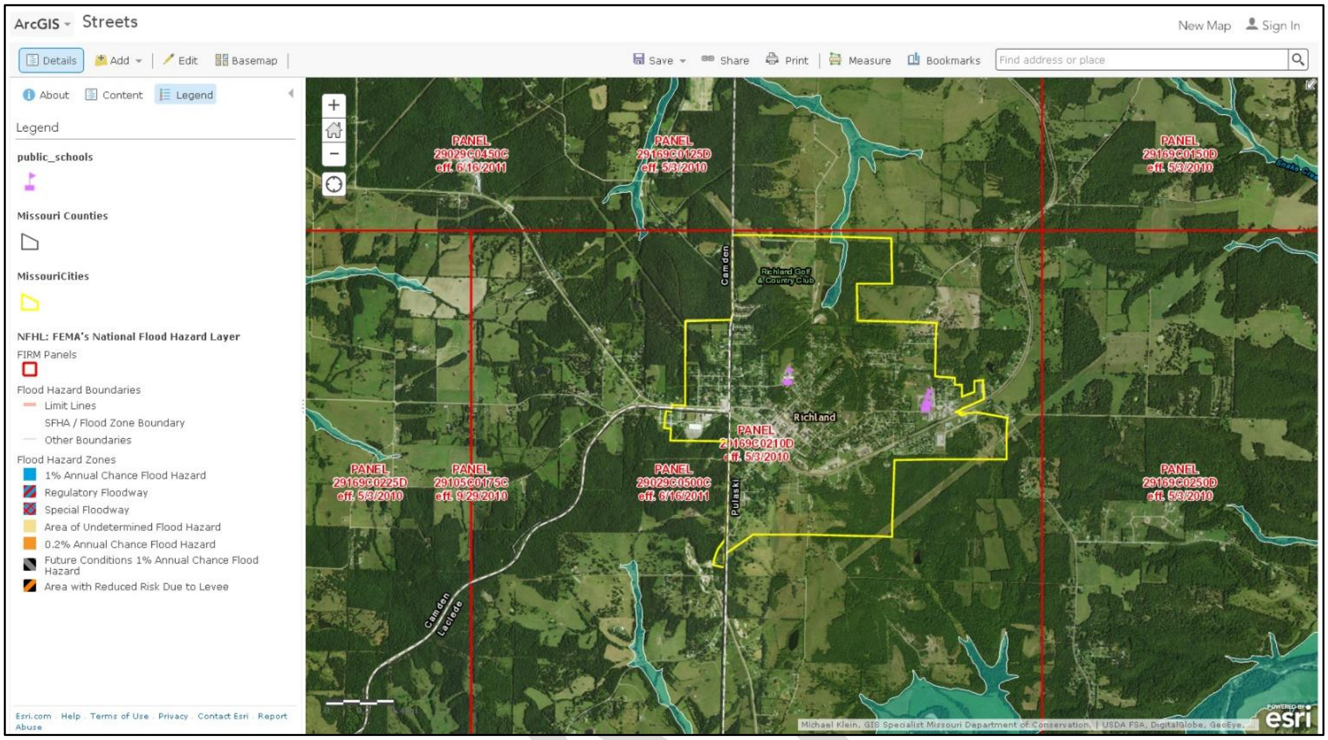


Figure 3.40. City of St. Robert, Missouri Special Flood Hazard Areas (SFHAs)

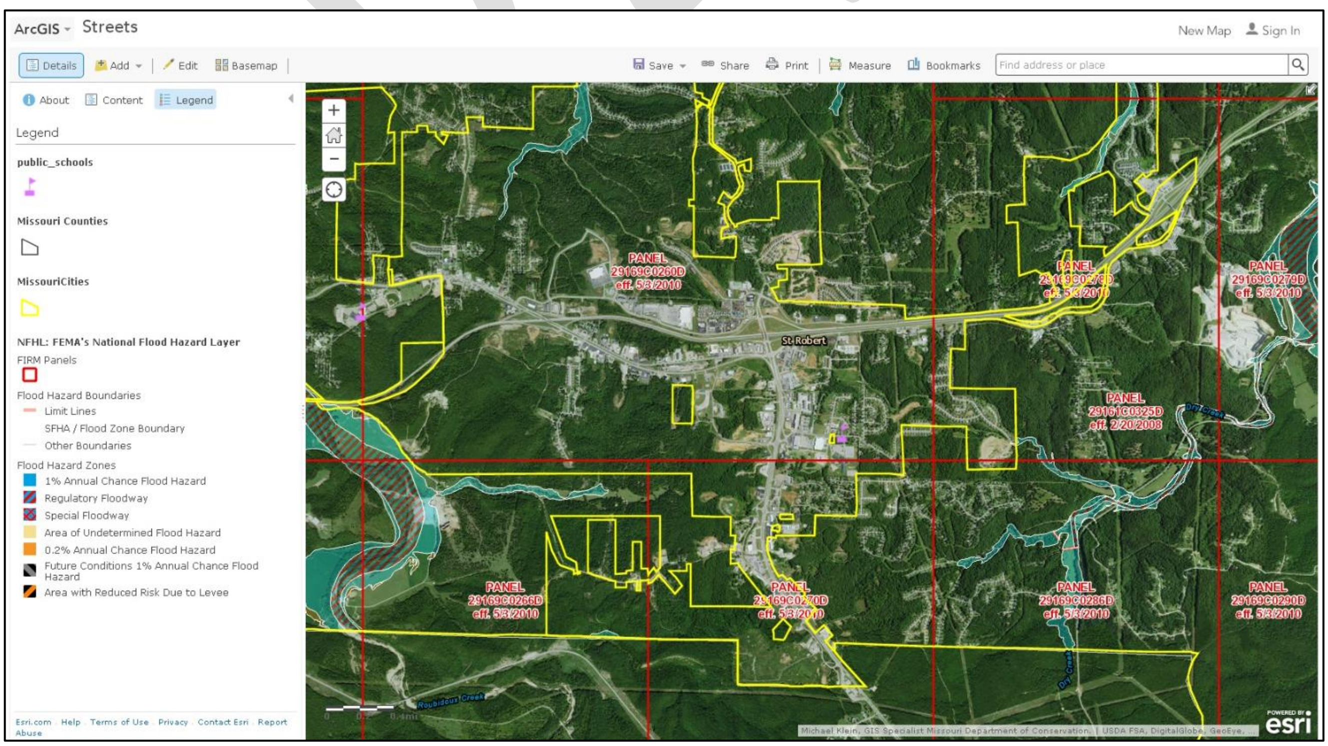


Figure 3.41. City of Waynesville, Missouri Special Flood Hazard Areas (SFHAs)

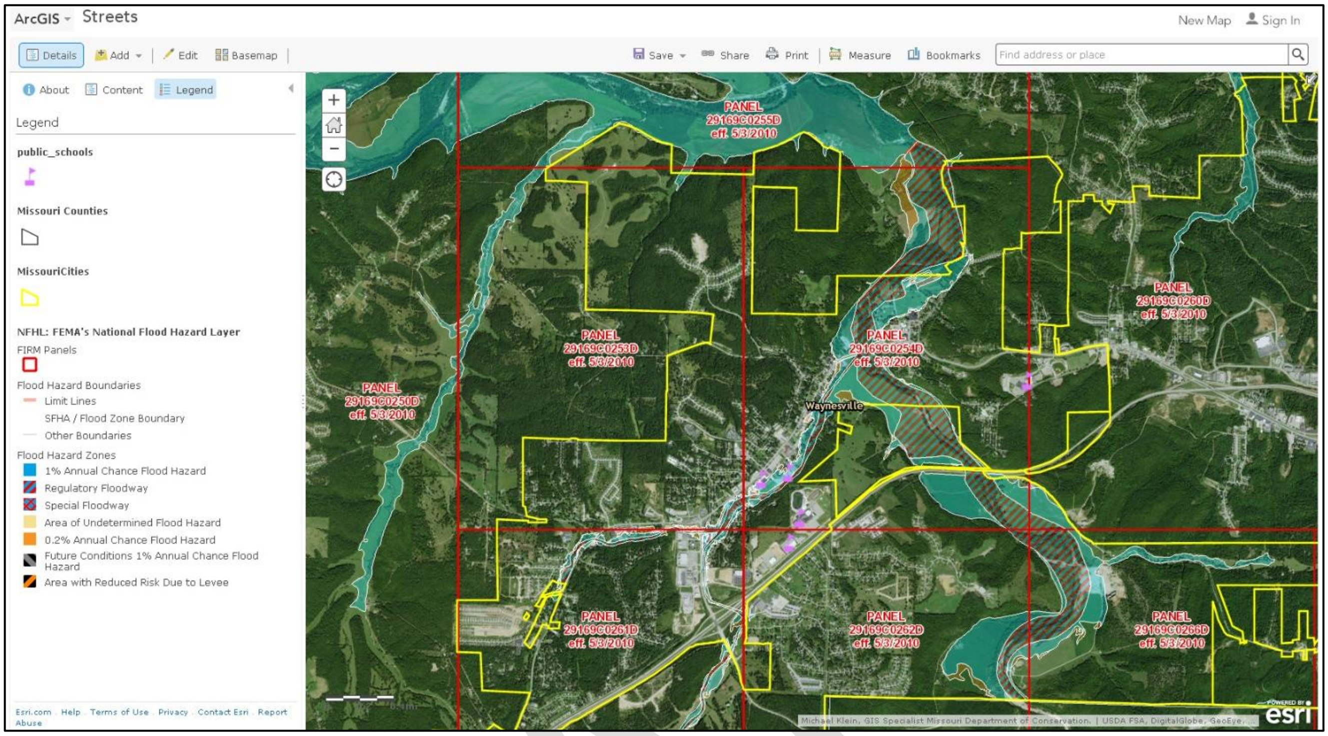


Table 3.40. Summary of Pulaski County NCEI Flood Events by Location, 1999-2019

Location	# of Events
Pulaski County	8
Crocker	2
Gospel Ridge	2
Helm	6
Waynesville	3

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, Crocker and Dixon are the communities most prone to flash flooding events. Helm is an unincorporated area of the county, but this community also has a high rate of flash flood events. **Table 3.41** provides information in regards to flash flood events between 1999 and 2019.

Table 3.41. Pulaski County NCEI Flash Flood Events by Location, 1999-2019

Location	# of Events
Pulaski County - Countywide	1
Big Piney	1
Bloodland	1
Buckhorn	1
Crocker	9
Devils Elbow	1
Dixon	9

Location	# of Events
Fort Leonard Wood	1
Franks	2
Hancock	1
Hanna	1
Hawkeye	2
Helm	5
Laquey	1
Richland	2
St. Robert	3
Swedeborg	1
Turkey Ridge	3

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 2018 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.

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

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

When roads and bridges are inundated by water, damage can occur as the water scours materials around bridge abutments and gravel roads. Floodwaters can also cause erosion undermining road beds. In some instances, steep slopes that are saturated with water may cause mud or rock slides 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 as well as present a health hazard. Further information regarding scour critical bridges can be found in **Section 3.2.2**.

Between 1999 and 2019, there were 8 recorded flood-related crop insurance claims with total losses of $482,033 due to flooding within Pulaski County[32]. **Table 3.42** shows crop losses for the period 1999 through 2019 (years with no losses are not shown).

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

Table 3.42. Recorded USDA Crop Insurance Losses (Flood) for Pulaski County 1998 – 2018

2007	2008	2009	2013	2015
$8,089	$13,876	$3,456	$292,580	$16,032

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

National Flood Insurance Program (NFIP) Participation

Table 3.43 depicts jurisdictions within the planning area that participate in NFIP. In addition, **Table 3.44** provides the number of policies in force, amount of insurance in force, number of closed losses, and total payments for Pulaski County and cities.

Table 3.43. NFIP Participation in Pulaski County

Community ID #	Community Name	NFIP Participant (Y/N)	Current Effective Map Date	Regular-Emergency Program Entry Date
290826	Pulaski County		05/03/2010	04/17/1985
290656	Richland		-	09/10/1984
290662	St. Robert		05/03/2010(M)	11/30/2004
290300	Waynesville		05/03/2010	10/06/1976

Source: NFIP Community Status Book, 5/18/18; BureauNet, http://www.fema.gov/national-flood-insurance-program/national- flood-insurance-program-community-status-book; M= No elevation determined – all Zone A, C, and X: NSFHA = No Special Flood Hazard Area; E=Emergency Program;

Table 3.44. NFIP Policy and Claim Statistics as of 08/12/2020

Community Name	Policies in Force	Insurance in Force	Closed Losses	Total Payments
Pulaski County	51	NA	NA	$4,687,290
Richland	1	$280,000	-	-
St. Robert	13	$2,887,900	-	-
Waynesville	45	$8,066,300	117	$1,605,577.69

Source: NFIP Community Status Book, [09/02/2020]; SEMA
**Closed Losses are those flood insurance claims that resulted in payment.*

Pulaski County has the highest number of policies, losses and total payments with $4,687,290.00 compared to Waynesville's $1,605,577.69.

RiskMAP

Risk mapping, assessment, and planning 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 Discovery meeting for RiskMAP in Pulaski County was held in February 2020. Project Initiation is anticipated to be conducted in the fall of 2020 with hydrologic and hydraulic modeling to begin in the winter. Draft models are anticipated to be available in the summer of 2021.

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.

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, as of 08/12/2020, there are 31 repetitive loss properties unincorporated Pulaski County. There have been 82 losses to those properties with total payments of $3,510.984. The city of Waynesville has ten repetitive loss properties which have had 25 losses with total payments of $609.99. **Due to Federal restrictions on data sharing, the state was unable to provide full Repetitive Loss data or current Severe Repetitive Loss data. The Property Type was not available for Repetitive Loss properties and the Severe Repetitive Loss data, which was obtained from the 2018 MO State Hazard Mitigation Plan, does not specify if the properties are mitigated or non-mitigated.*

Table 3.45. Severe Repetitive Loss Data for Pulaski County

Number of SRL Properties	Number of Paid NFIP Claims	Total Paid Losses	Average Payment
3	12	$430,859.20	$35,904.93

Previous Occurrences

Table 3.46 provides information regarding Presidential Flooding Disaster Declarations between 1998 and 2019 for Pulaski County.

Table 3.46. Pulaski County Presidential Flooding Disaster Declarations 1998 to 2019

Declaration No.	Date	State	Incident Description
DR-995	07/09/1993	Missouri	Missouri Flooding, Severe Storm
DR-1006	12/01/1993	Missouri	Missouri Flooding, Severe Storms, Tornadoes
DR-1023	04/21/1994	Missouri	Missouri Severe Storms, Tornadoes, Flooding
DR-1463	05/06/2003	Missouri	Missouri Severe Storms, Tornadoes, Flooding
DR-1676	01/12/2007	Missouri	Missouri Severe Winter Storms and Flooding

DR-1749	03/17/2008	Missouri	Missouri Severe Storms and Flooding
DR-1847	05/08/2009	Missouri	Missouri Severe Storms, Tornadoes, and Flooding
DR-1980	05/09/2011	Missouri	Missouri Severe Storms, Tornadoes, and Flooding
DR-4144	10/08/2013	Missouri	Missouri Severe Storms, Straight-line Winds, and Flooding
EM-3374	01/02/2016	Missouri	Missouri Severe Storms, Tornadoes, Straight-Line Winds, and Flooding
DR-4250	01/21/2016	Missouri	Heavy Rains, Widespread Flash Flooding, and Flooding
DR-4317	06/02/17	Missouri	Missouri Severe Storms, Tornadoes, Straight-line Winds, 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 3.47** and **Table 3.48** provide this information. Additionally, narratives available for each event are included.

Table 3.47. NCEI Pulaski County Riverine Flood Events Summary, 1999 to 2019

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2002	6	0	0	200.00K	0
2005	2	0	0	0	0
2008	2	0	0	0	0
2010	2	0	0	0	0
2011	2	0	0	500.00K	0
2015	1	0	0	200.00K	0
2017	1	0	0	0	0
2018	3	0	0	0	0
2019	2	0	0	0	0
Total	**21**	**0**	**0**	**900.00K**	**0**

Source: NCEI, data accessed [8/12/2020]

Narratives on flood events:

1. **1/31/2002:** Hardest hit areas were in Pulaski and Shannon Counties where Cave, Spring, and Creek roadways along the Big Piney River, and Highway H between 16 and 106, were closed for nearly 24 hours.

2. **05/08/2002:** After several inches of rain, residents of Waynesville along the Roubidoux River were evacuated because of high water. The high water also covered Spring Street and the RV Park which caused campers to evacuate to higher ground.

3. **01/05/2005:** Numerous roads and low lying areas were inundated and impassable by motorists countywide. Some locations that were affected by flooding include, Highway O near Dixon, areas near Jones Creek, a section of Texas Road, and a section of Cave Road near St. Robert.

4. **1/13/2005:** The primary areas that flooded were low water crossings and low lying areas.

5. **03/19/2008:** This flooding is a continuation of the flash flooding. Poor drainage areas continued to flood roadways and lowlands near rivers and creeks.

6. **09/03/2008:** A few locations within Pulaski County flooded from rainfall amounts that ranged from four to six inches. These locations included a section of Highway O at its intersection with Jones Creek, a section of Canyon Road at its intersection with Mill Creek, and a section of Highway O southwest of Dixon.
7. **04/02/2010:** A portion of State Route H was closed due to high water.

8. **05/15/2010:** Multiple low water crossings were closed due to flooding across the county.

9. **04/25/2011:** Numerous low water crossings and rural roads were flooded in the county. The most intense flooding was in the southern portion of the County. The total cost estimate for flooding damages for Pulaski County for this entire episode has been included. This includes roads, bridges, and structures which were affected.

10. **05/19/2011:** Route O was closed due to flooding.

11. **07/07/2015:** Superior Road was closed due to flooding. Numerous roads, bridges, and low water crossings were heavily damaged.

12. **05/03/2017:** State Highway O was closed due to flooding.

13. **02/20/2018:** State Highway DD in Pulaski County had some water over it.

14. **02/24/2018:** State Highway O was closed due to flooding.

15. **12/31/2018:** The low water crossing at State Highway O had nearly a foot of running water over the roadway and was impassable.

16. **03/09/2019:** The low-water crossing at Highway O where it crosses Jones Creek was flooded and impassable for several hours.

17. **05/21/2019:** Superior Road in the river side park along the Gasconade River was closed due to flooding. This also closed the RV Park.

Table 3.48. NCEI Pulaski County Flash Flood Events Summary, 1999 to 2019

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2002	3	0	0	500.00K	0
2005	7	0	0	25.00K	0
2006	1	0	0	0	0
2007	4	0	0	2.00K	0
2008	7	0	0	1,000.00K	0
2009	5	0	0	20.00K	0
2010	1	0	0	0	0
2012	3	0	0	0	0
2013	14	0	0	5,100.00K	0
2014	1	0	0	0	0
2015	7	7	0	$20.00K	0

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2016	1	0	0	0	0
2017	2	1	0	$5,410.00K	0
2018	1	0	0	0	0
2019	1	0	0	0	0
Total	**58**	**1**	**0**	**$7,208.00K**	**0**

Source: NCEI, data accessed [8/10/2020]

Narratives on flash flood events:

1. **04/20/2005:** Numerous roads and low lying areas were inundated with flash flooding. Several areas were impassable to motorists.

2. **06/09/2005:** Heavy thunderstorms caused flash flooding in the community of Richland. Several homes and businesses were flooded.

3. **06/10/2005:** Heavy thunderstorms cause flash flooding in a few buildings in downtown Dixon.

4. **08/22/2005:** Thunderstorms with heavy rain cause flash flooding to occur over several sections of Missouri Avenue on the south side of St. Robert.

5. **05/29/2006:** Excessive rainfall caused flash flooding on several streets in the city of Waynesville.

6. **03/30/2007:** Heavy thunderstorms produce flooding rains in the Laquey area. A low water crossing on Red Oak Road was flooding and impassable. County road crews were called out to repair several roads that were washed out as a result of the heavy rainfall and flooding across the county.

7. **05/10/2007:** Excessive rainfall created flooding in areas of Pulaski County. Jones Creek was flooding over Highway O causing impassable conditions to motorists.

8. **08/20/2007:** The Gasconade River rapidly flooded areas near the Gasconade Hills Resort from excessive rainfall associated with Tropical Storm Erin. A section of Route H two miles south of Interstate 44 was affected.

9. **09/07/2007:** Thunderstorms with excessive rainfall caused creeks and streams near Dixon to experience minor flooding.

10. **01/07/2008:** Excessive rainfall caused Jones Creek to flood areas near the intersection of Highway O and Creek Road.

11. **03/18/2008:** Rainfall amounts ranged from five to nine inches over Pulaski County. Southern sections of the county experienced the greatest rainfall, though all areas that typically experiences flooding during periods of excessive rain were affected. Damage was reported on county roads and bridges.

12. **03/31/2008:** Saturated antecedent conditions existed prior to this period of excessive rainfall. Some regional locations experienced record rainfall totals from February and March. One to three inches of rain fell across the county causing widespread flash flooding of low water crossings, county roads, and low lying areas near creeks and rivers. Ultimately, all locations

that typically flood during periods of excessive rainfall were flooded.

13. **04/10/2008:** One to two inches of rain fell over Pulaski County. All low areas that typically flood during periods of excessive rainfall were flooded. One specific location that flooded included a section of Highway O approximately one and a half miles west of Highway 28.

14. **05/07/2008:** A few roads across the county were flooded. The area that appeared to be impacted the greatest was near Fort Leonard Wood.

15. **05/25/2008:** The Roubidoux River flooded a section of Dyer Street.

16. **09/14/2008:** Three to five inches of rain fell over Pulaski County resulting in flooding of small streams, creeks, and two rivers. The Gasconade and Big Piney rivers appeared to be impacted the greatest as they flooded numerous roads and low lying areas. Low water crossings countywide were impassable to motorists. Also, a section of Highway 133 at Fox Crossing was closed due to flooding, while numerous city streets in Dixon were flooded. A section of Highway O at its intersection with Jones Creek was flooded.

17. **05/08/2009:** Two to four inches of rain caused flash flooding over sections of Fort Leonard Wood.

18. **06/10/2009:** Excessive rain caused flooding along a section of Smokey Road just south of its intersection with Highway AB. This stream that flooded was a tributary of the Gasconade River.

19. **06/15/2009:** Two to five inches of rain fell over central and northern Pulaski County. Flash flooding resulted over several locations including a section of Texas Road, a section of Highway O, and a section of Highway U. The section of Texas Road that flooded was completely washed out.

20. **06/16/2009:** Excessive rain caused Tavern Creek to flood a section of Highway U west of Crocker.

21. **10/29/2009:** Route O near Jones Creek was closed due to flooding.

22. **07/08/2010:** State Highway Y, near the intersection of Lydia Lane was water covered.

23. **03/15/2012:** A portion of Highway 28 south of Dixon was flooded.

24. **04/14/2012:** A foot of water was reported flowing over Highway O along Jones Creek.

25. **05/29/2012:** Two feet of water was reported over the road near the intersection of Highway O and Creek Road.

26. **08/06/2013:** Mitchell Creek flooded residential and business areas of Waynesville.
    a. Several roadways at Fort Leonard Wood were under water and impassable due to flash flooding.
    b. There were reports from social media of severe flooding near downtown Waynesville and water entering numerous homes.
    c. This storm report will be a summary of the total damage for the Waynesville area and Pulaski County for this flooding event. Approximately 90 percent of the roads in the county were damaged with 65 percent of the roads had major damage. There were 25

low water crossings that were totally washed out and numerous more needed repairs. There were up to 100 homes and businesses that were inundated by flood waters. Numerous cars were flooded or washed away. Most of the homes flooded were along Mitchell Creek and Roubidoux River near downtown Waynesville. Over 100 people were rescued from swift and high water. There were two flash flood fatalities which occurred near downtown Waynesville.

d. A rescue boat with several personnel capsized in high water and was later rescued.
e. Interstate 44 was closed due to high water.
f. Highway 7 just north of Interstate 44 was closed due to high water.
g. Route N near Springfield Road was closed due to high water.
h. Route N near Stockton Road was closed due to high water.
i. Two sheriff deputies were stranded near Highway 7 and the Gasconade River by high water.
j. Route U near Tavern Creek was closed due to flooding.
k. Pulaski County Sheriff reported at least 100 hundred homes and businesses were flooded.

27. **08/07/2013:** Widespread flooding was reported around the Dixon area from the Maries River. Several homes had water in them and numerous streets were impassable.
    a. Numerous roads were closed due to flood waters. Several water rescues were performed across the county. No injuries were reported from the water rescues. The Emergency Operations Center reported around three inches of rain during the overnight hours.

28. **04/03/2014:** Mitchel Creek overflowed with 2 feet of water over Dyer Road.

29. **07/07/2015:** Walnut Road near the Big Piney River was flooded and impassable.

30. **12/26/2015:** There were five international soldiers stationed at Fort Leonard Wood in a car which was swept off of Highway U at Tavern Creek because of flash flooding. All five victims from the car drowned. Several vehicles were washed off of roadways in two separate incidents around Crocker. One occurred along the headwaters of Tavern Creek. The other incident was near the Gasconade River. Two people drowned when their car was swept off of Highway O near Dixon. Route DD was closed due to flooding. Route HH was closed due to flooding at Bell Creek. Nearly all low water crossings across the county were flooded. There were several rural and county roads that sustained damage from flooding. There were a few homes and businesses that had flood damage as well. Route U was closed due to flooding. Water was over the road at Tavern Creek. Route O was closed due to flooding near the intersection of Highway 28.

31. **09/16/2016:** Highway O at Jones Creek was flooded and impassable.

32. **04/30/2017:** An 18 year old male drowned after his vehicle entered a flooded area on Buffalo Road west of Crocker. Several homes and businesses sustained flood damage across the county. Numerous roads and bridges were severely damaged or washed away across the county. There was some infrastructure damage to Fort Leonard Wood base, including damage to Water Pump Station, roads, bridge, golf course, and the East Gate Access Control Point.

33. **09/07/2018:** High water flooded over two low water crossings on Highway U along Tavern Creek.

34. **06/04/2019:** Nearly a foot of water was reported over several roads in Dixon.

Probability of Future Occurrence

From the data obtained from the NCEI [33], there were 21 riverine flood events (**Table 3.47)** over a period of 21 years. This information was utilized to determine the annual average percent probability of riverine flooding (**Table 3.49**). The probability of riverine flooding in Pulaski County per year is 100 percent (21 events/21 years x 100) with an average of 1 events per year. Furthermore, data was obtained for flash flooding within the county. Pulaski County endured 58 flash flooding events (**Table 3.48**) over a 21 year period. The probability of flash flooding in Pulaski County per year is 100% (58 events/21 years x 100) with an average of 2.8 events per year (**Table 3.50**).

Table 3.49. Annual Average % Probability of Riverine Flooding in Pulaski County

Location	Annual Avg. % P	Avg. Number of Events
Pulaski County	100%	1

*P = probability; see page 3.24 for definition.

Table 3.50. Annual Average % Probability of Flash Flooding in Pulaski County

Location	Annual Avg. % P	Avg. Number of Events
Pulaski County	100%	2.8

*P = probability; see page 3.24 for definition.

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. 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 road beds. In some instances, steep slopes that are saturated with water may cause mud or rock slides onto roadways. These damages

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

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 Pulaski County, data was obtained from the 2018 Missouri State Hazard Mitigation Plan. The 2018 Plan used the most recent release of Hazus, version 4.0, 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. Pulaski County does have digital FIRMS, the regulatory special flood hazard area was utilized. Next, depth grids were generated using cross sections from the FIRM database and/or hydraulic models in combination with the terrain elevation data from which the DFIRM was derived.

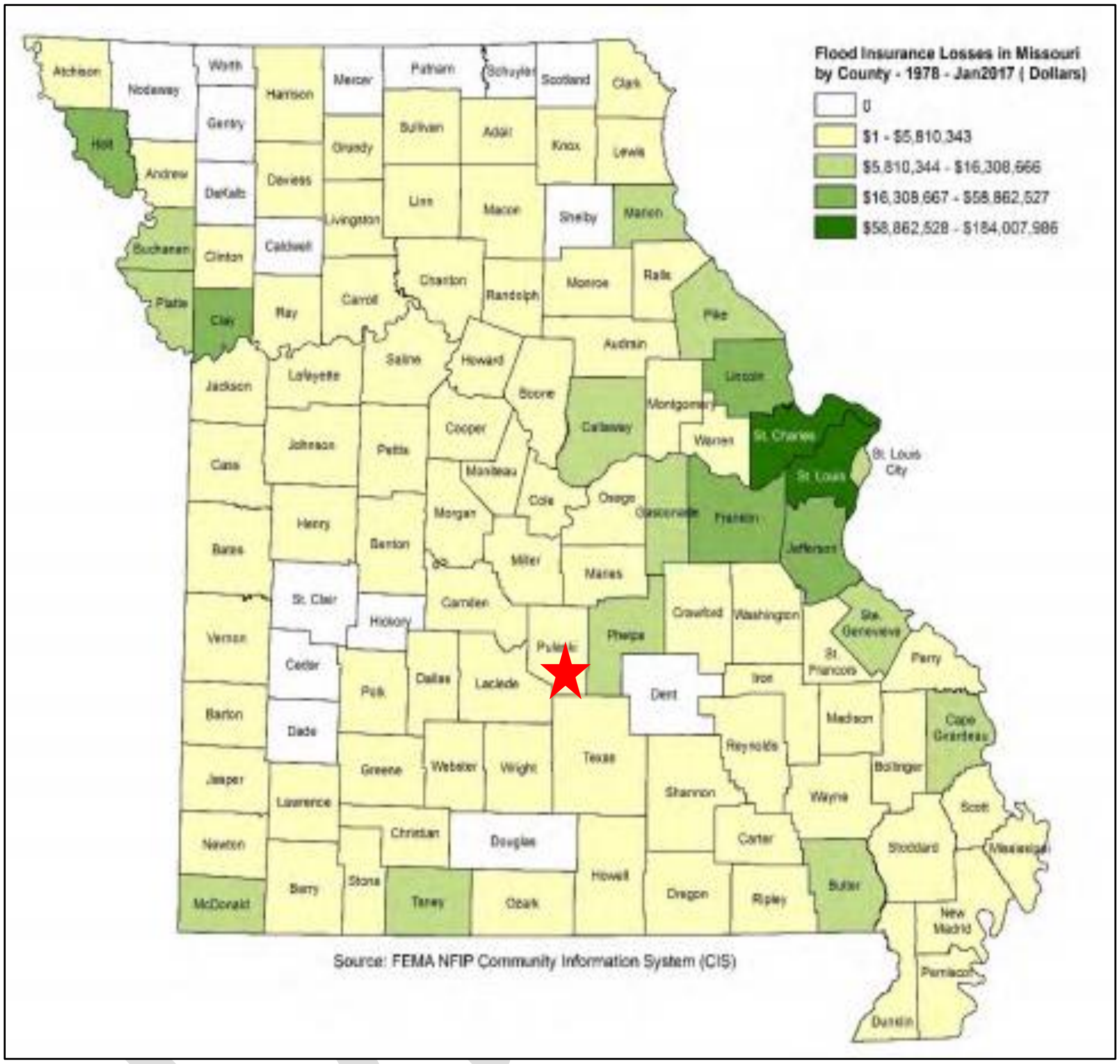
This method was preferred of the three methods, along with RiskMAP flood risk datasets.

In addition to the DFIRM, 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 BureauNet which documents losses from 1978 to the present (November 30, 2017 for the State Plan). 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. Two buyouts of repetitive loss properties has occurred in the city of Waynesville and one in unincorporated Pulaski County.

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

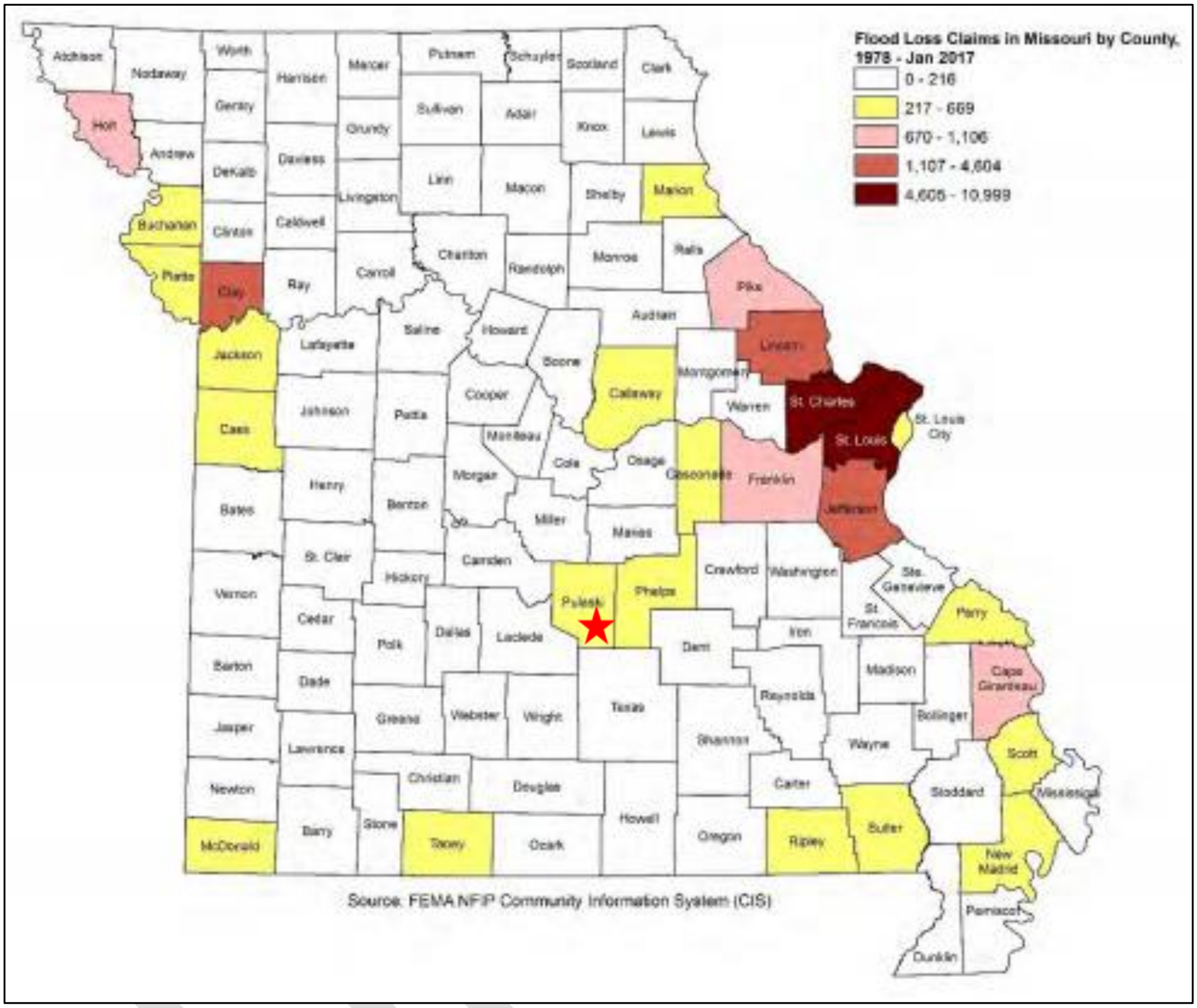
Figure 3.42. Map of Funds Paid Historically for Flood Insurance Losses in Missouri by County 1978 - January 2017



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

03 illustrates the number of flood loss claims made in Missouri during the same time period. Pulaski County had 0 – 216 claims during that timeframe.

Figure 3.43. Flood Loss Claims in Missouri by County, 1978 – January 2017



Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski 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 and Hazus floodplain data. **Table 3.51** provides information regarding total direct building loss and income loss to Pulaski County. **Table 3.52** provides information on exposure of buildings. According to the Missouri Spacial Data Information Service (MSDIS) there are 202 residential structures at risk of flood. Hazus shows the number of building exposed to flood damage at 260, with 137 potentially substantially damaged in a one percent annual chance of a flood.

Table 3.51. Total Direct Building Loss and Income Loss to Pulaski 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
$5,334,660,000	$79,599,000	$48,555,000	$545,000	$128,699,000	$187,000	$128,886,000	1.49

Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.52. Pulaski County Structures Exposure

# MSDIS Residential Structures Exposed	# Hazus Buildings Exposed	# Substantially Damaged
202	260	137

Source: 2018 Missouri State Hazard Mitigation Plan

This same analysis indicates that 2,051 people would be displaced in Pulaski County and 1,314 would need to be sheltered in the event of a major flood.

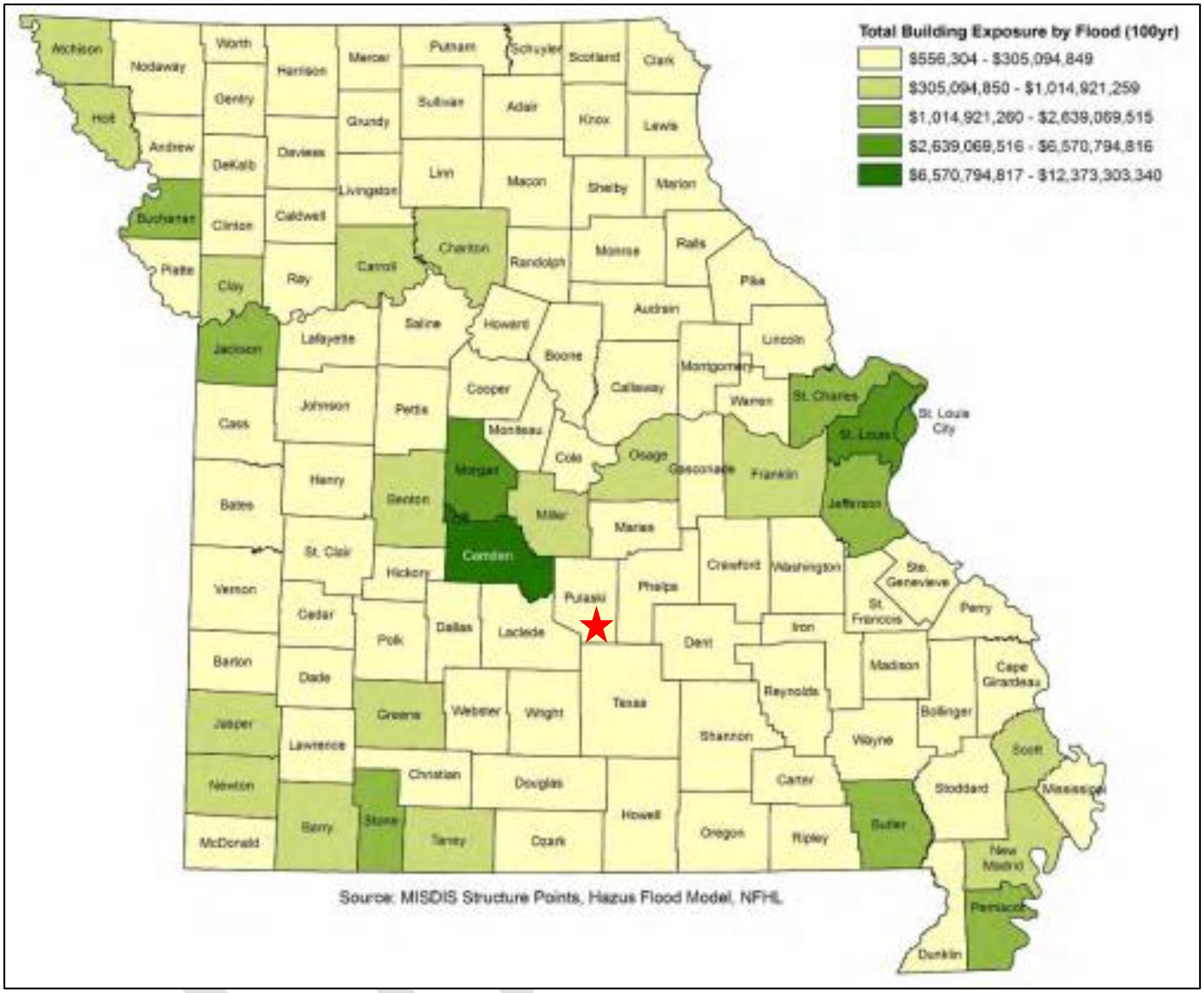
Table 3.53 presents the results of the primary indicators for Pulaski County – residential, agricultural, commercial, education, government and industrial. This table illustrates the number of affected structures and estimated losses. **Figure 3.44** shows the building exposure for the Hazus Base-Flood Scenario. Figure 3.50 illustrates the building impacted ratio for a 100-year flood.

Table 3.53. Pulaski 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
202	$287,984	132	$200,140	13	$639,233	4	$1,199,591	0	$0	2	$51,606	574	$2,845,554

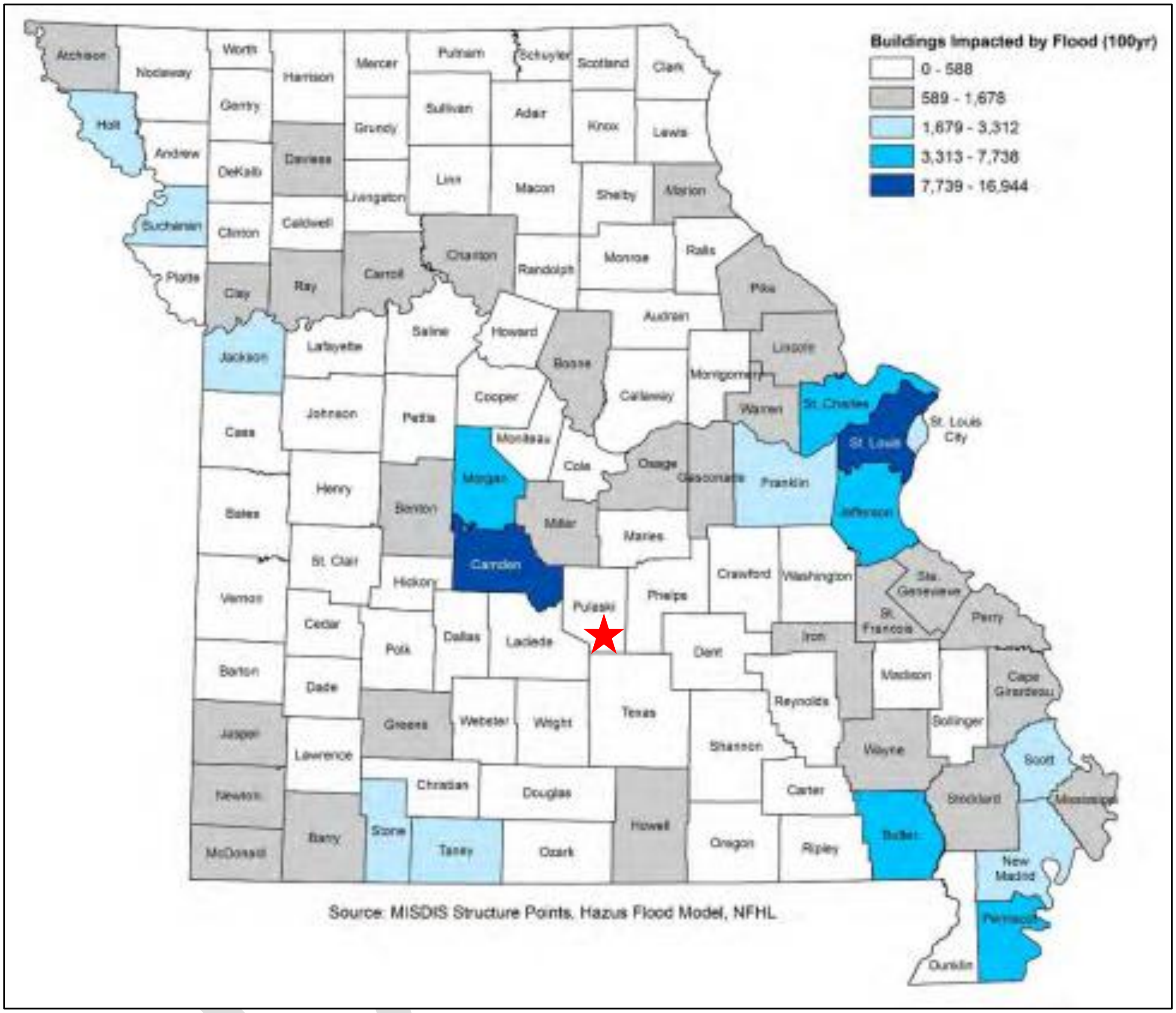
Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.44. Hazus Countywide Base-Flood Scenarios: Building Exposure



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.45. Hazus Countywide Base-Flood Scenarios: Building Impacted Ratio



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

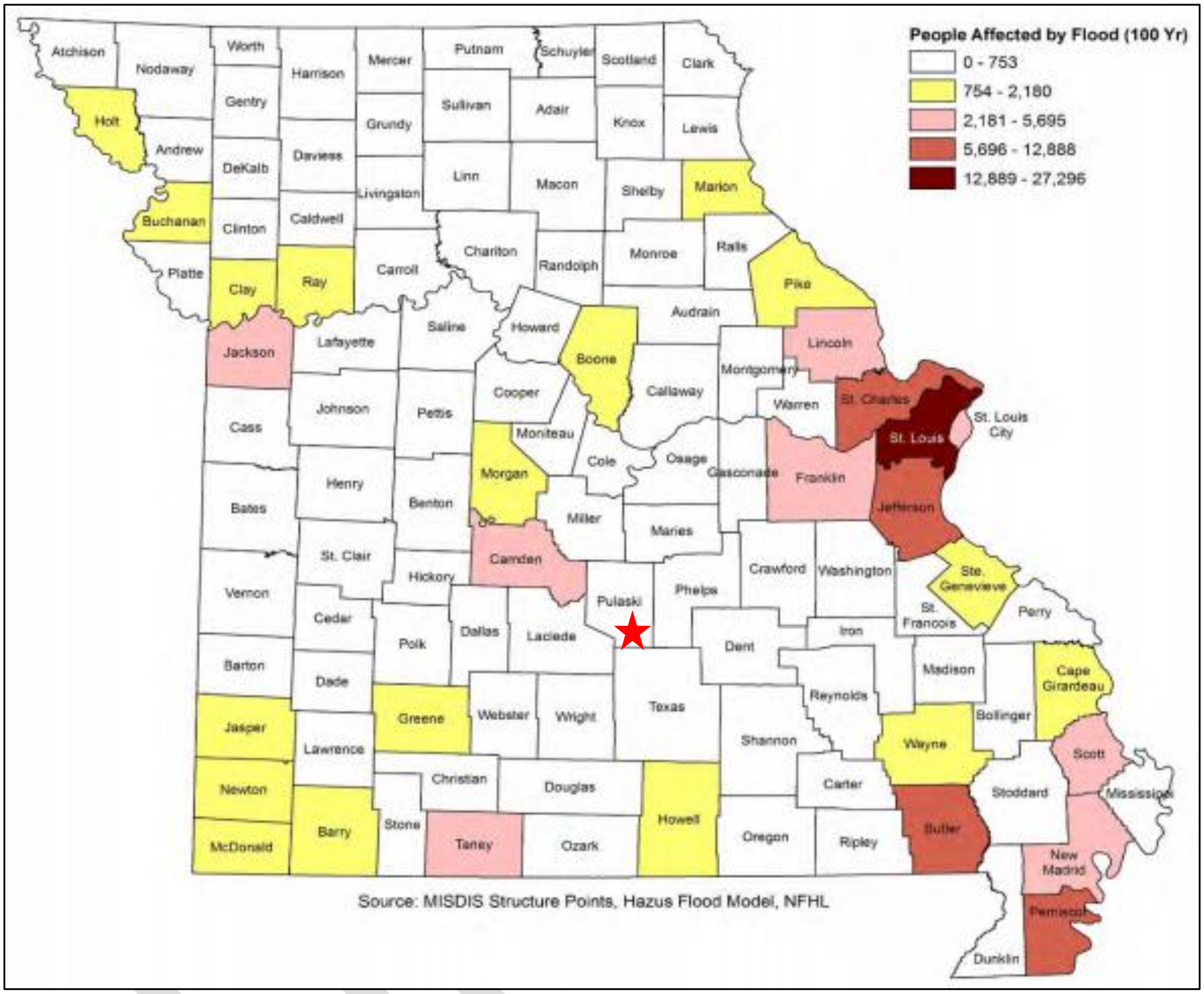
Lastly, the State determined the estimated number of displaced households and need for shelters within Pulaski County in the event of a 100 year flood. **Table 3.54** and **Figure 3.46** illustrate this information.

Table 3.54. Estimated Displaced People and Shelter Needs for Pulaski County

County	Displaced People	Displaced Population Requiring Shelter
Pulaski	2,051	1,314

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.46. Hazus Countywide Base-Flood Scenarios: Displaced People



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

Although the Hazus model indicates that the next flash flood in Pulaski County will likely have minimal impact on the day-to-day activities of the county overall, the unprecedented flooding in 2015 suggests that future flood events could cause significant disruption in the county. The December 2015 flash flood caused significant damage to Waynesville and Pulaski County and resulted in seven deaths. The following roads and low water crossings will be threatened in future floods and include Highway O, Highway U, Route DD, Route HH, Highway 133, Cave Road, Texas Road, Creek Road, Canyon Road, Smokey Road, Tavern Creek, and Dyer Street in Waynesville. Sections of Waynesville lie on and near the Roubidoux River which increases the vulnerability to flooding. In addition, according to the Data Questionnaire, the Waynesville R-VI School District has two district facilities within the floodplain; 6th GC and the Middle School. Furthermore, Richland R-IV has district facilities in the floodplain, but was not specified. So although these two school districts may be affected during flooding, overall, few buildings lie in the floodplain.

Impact of Future Development

Impact of future development is correlated to floodplain management and regulations set forth by the county and jurisdictions[34]. 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 Unincorporated Pulaski County, Richland, and Waynesville. The City of Crocker and area of Helm have the most recorded NCEI flood events. Since 1999 there have been 79 incidents of flooding or flash flooding in Pulaski County; 11 incidents in Crocker and Helm (**Table 3.47**, **Table 3.47**). The city of Waynesville has 10 repetitive loss properties, whereas the county has 31 repetitive loss properties.

Those areas at greatest risk to riverine flooding are those populated areas along the Roubidoux Creek and Gasconade River and their tributaries.

A small portion of the cities of Dixon, Richland, St. Robert, and significant portions of Waynesville reside in a SFHA.

The city of Crocker is not a member of the NFIP and does not have any identified floodplain 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

The county has already adopted a Floodplain Management Ordinance concerning construction in the floodplain. The county should consider buyouts of properties that are flood prone and have had repetitive losses to mitigate future disasters. Local governments should make a strong effort to further improve warning systems to insure 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 successful complete the projects.

[34] 2015 Boone County Hazard Mitigation Plan

3.4.7 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://strangesounds.org/2013/07/us-sinkhole-map-these-maps-show-that-around-40-of-the-u-s-lies-in-areas-prone-to-sinkholes.html
- 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/
- 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.

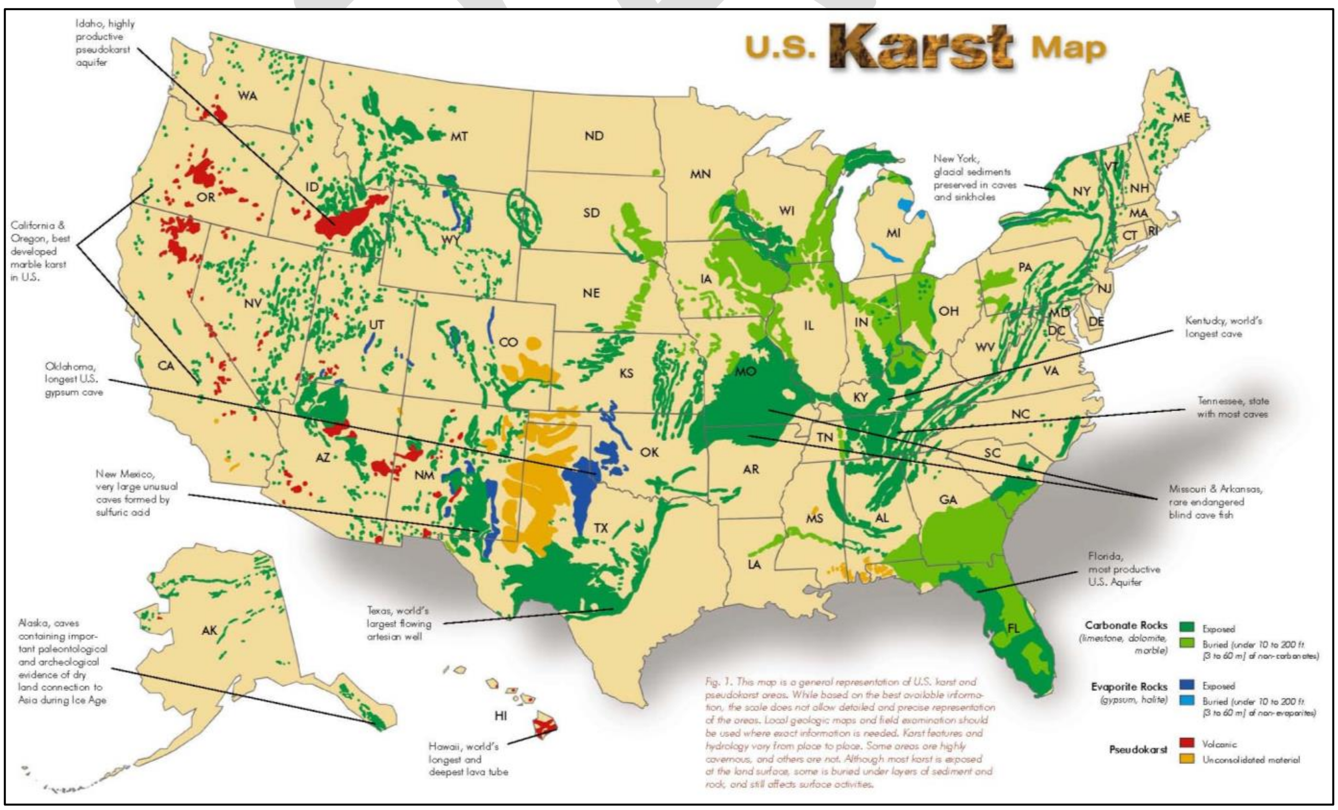
According to the U.S. Geological Survey (USGS), the most damage from sinkholes tends to occur in Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. Fifty-nine percent of Missouri is underlain by thick, carbonate rock that makes Missouri vulnerable to sinkholes. Sinkholes occur 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.

According to SEMA, there were approximately 82 mining activities in Pulaski County. The only detailed information available in regards to current mining in Pulaski County emanates from the Missouri Department of Natural Resources. There is only one mine on recorded for Pulaski County; which produces iron. Error! Reference source not found. depicts mines in Missouri by County.

Geographic Location

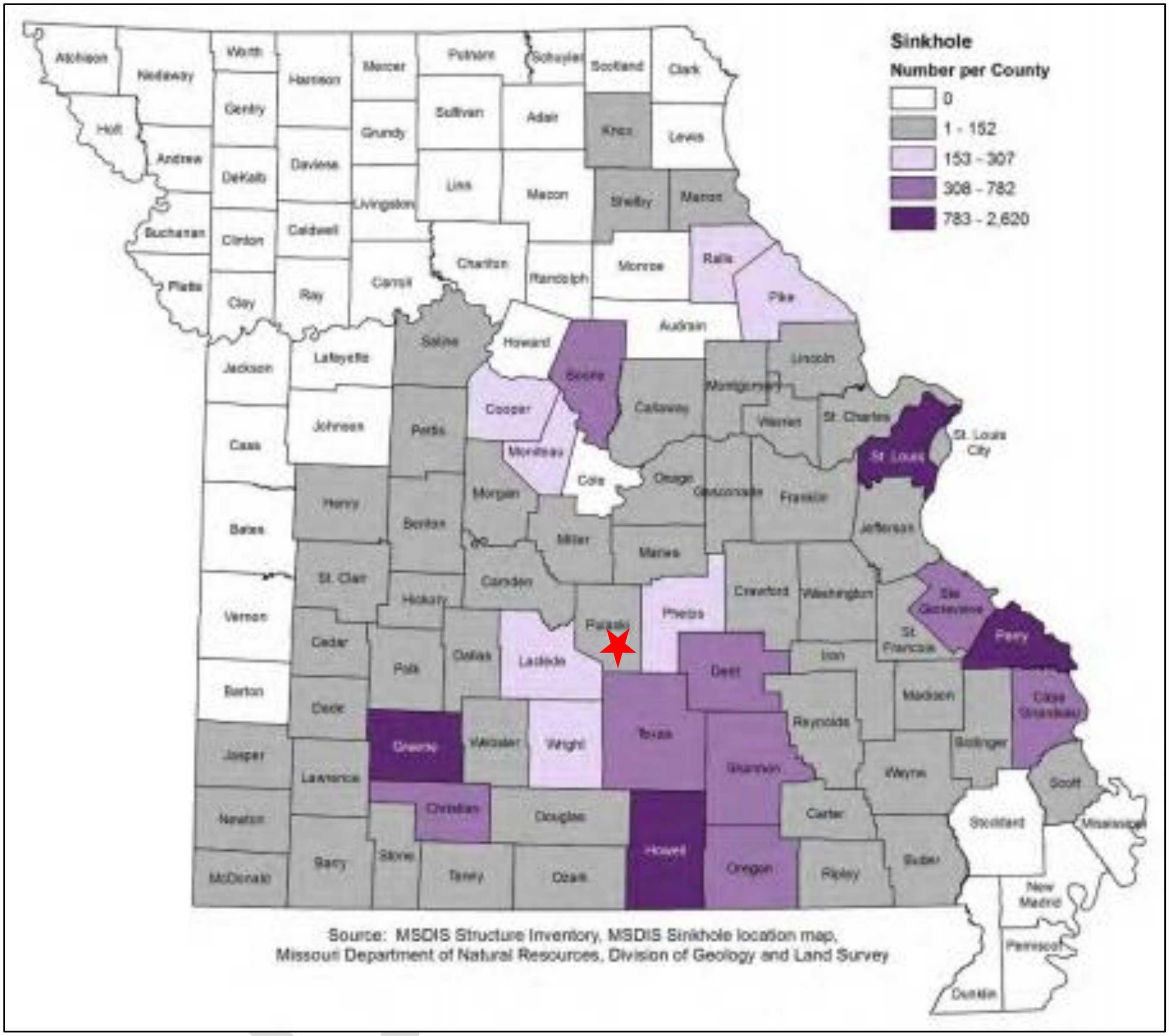
Figure 3.47 depicts karst topography across the United States. Missouri's kart topography is comprised of carbonate rocks such as limestone, dolomite, and marble. Variability in areas prone to sinkholes does not differ greatly across the county. According to the 2018 Missouri State Hazard Mitigation Plan there are nine sinkholes that have been recorded within Pulaski County (**Figure 3.48**). In addition, the Plan states that there are 243 mines in Pulaski County - as shown in **Figure 3.49**. According to the Missouri Department of Natural Resources, Pulaski 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 3.47. U.S. Karst Map



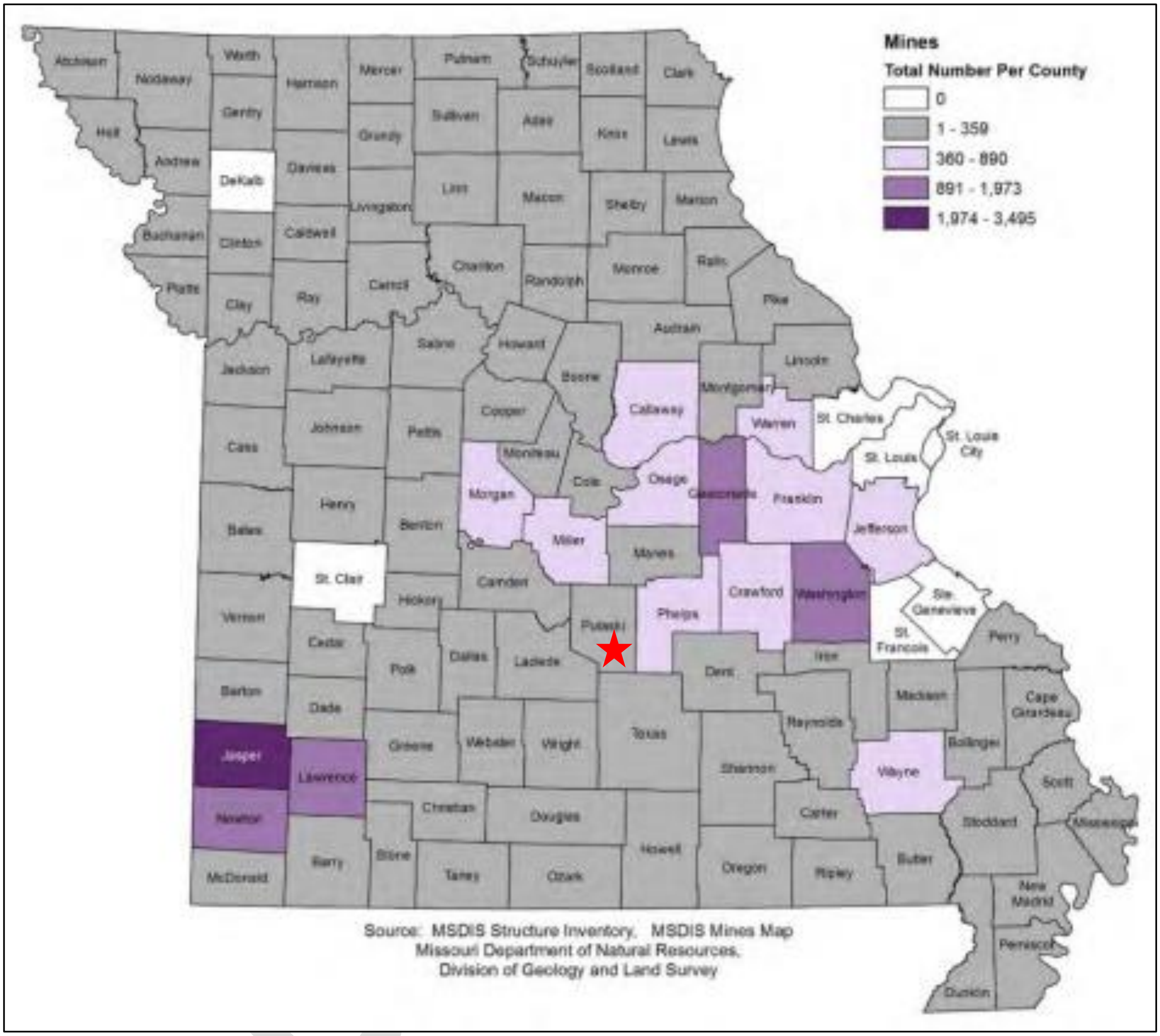
Source: http://www.northeastern.edu/protect/wp-content/uploads/US_KarstMap.jpg

Figure 3.48. Sinkholes Counts per County



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

Figure 3.49. Mines Counts Per County



*Source: 2018 Missouri Hazard Mitigation Plan; *Red star indicates Pulaski 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.[35]

[35] 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 2018 State Plan mentions 18 documented sinkhole "notable events". 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

Although there are numerous sinkholes and sinkhole areas in Pulaski County, and incidents have occurred in other counties in southern Missouri, there has been one recorded incident of death due to sinkholes in the County. On Monday, September 16, 2013, while returning home from deer hunting, a 31-year old male fell into a 70-foot deep sinkhole and died. Based on the map of sinkholes in Pulaski County, some of the communities may be more vulnerable to this hazard than the unincorporated parts of the county due to population density and the likelihood of future development. St. Robert has sinkholes within its boundaries and there are several known sinkholes near, but not within the borders of Waynesville. Crocker, Dixon and Richland appear to lie further outside the zone of sinkhole occurrences.

Probability of Future Occurrence

Due to the lack of data for previous sinkhole events in Pulaski County, a probability could not be calculated.

Vulnerability

Vulnerability Overview

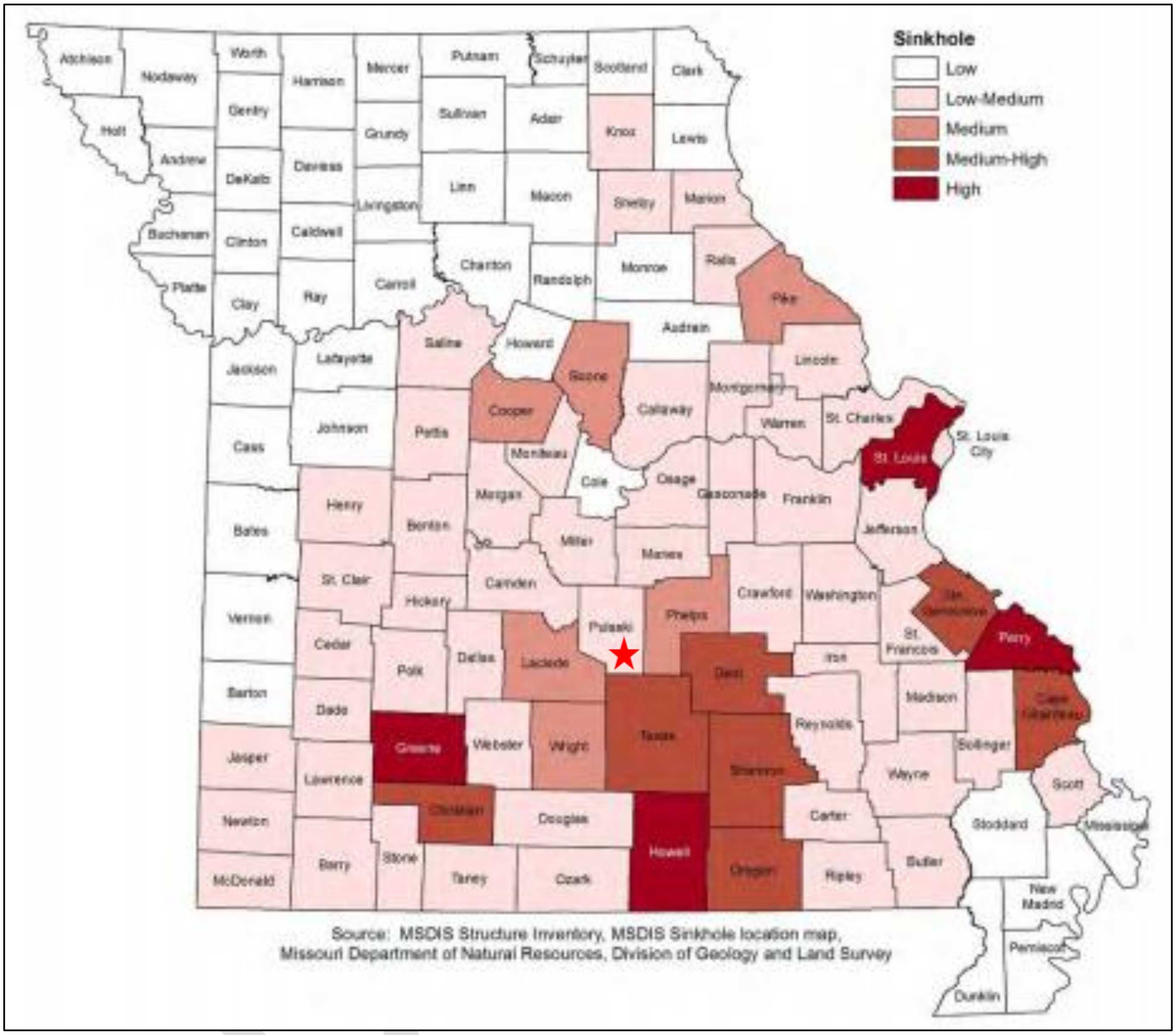
Unfortunately, no statistics are available for the number of subsurface locations that may potentially collapse in the future, forming a sinkhole. According to the state plan, if a county has fewer than 200 sinkholes, the risk is considered 2 - low-medium. For mines, the state plan calculates that Pulaski County's risk is also rated as 1 – low. See **Table 3.55**. **Figure 3.50** and **Figure 3.51** further illustrate the sinkhole and mining rating values respectively.

Table 3.55. Sinkhole/Mine Rating Values for Pulaski County

Factor	1 (Low)	2 (Low-medium)	3(Medium)	4 (Medium-high)	5 (High)
Sinkholes per county	0	1-200	201-400	401-800	801+
Mines per county	0-100	101-250	251-500	501-750	751+

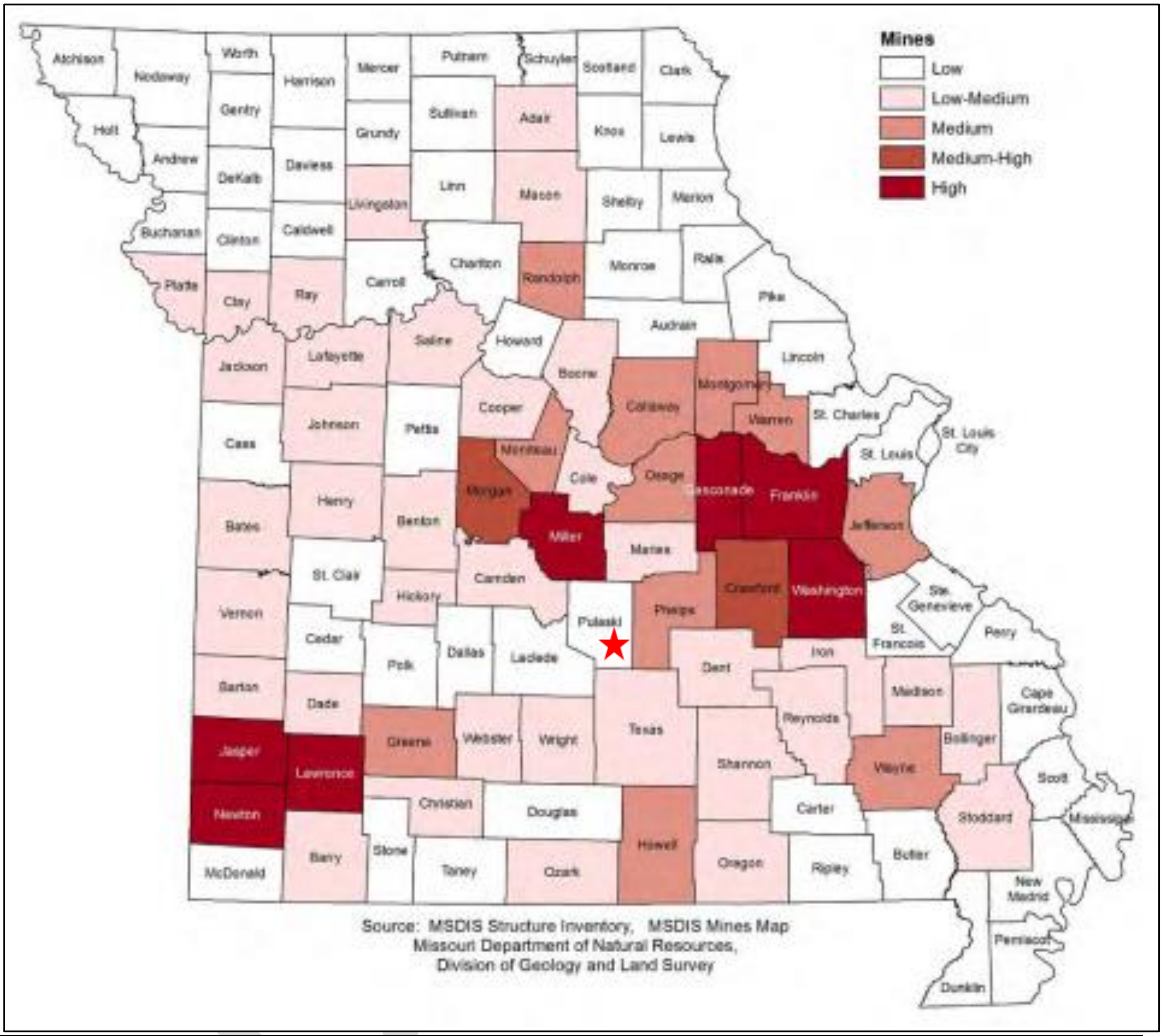
Source: 2018 Missouri Hazard Mitigation Plan, Yellow highlight shows values for Pulaski County

Figure 3.50. Sinkhole Rating Value by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.51. Mine Rating Value By County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

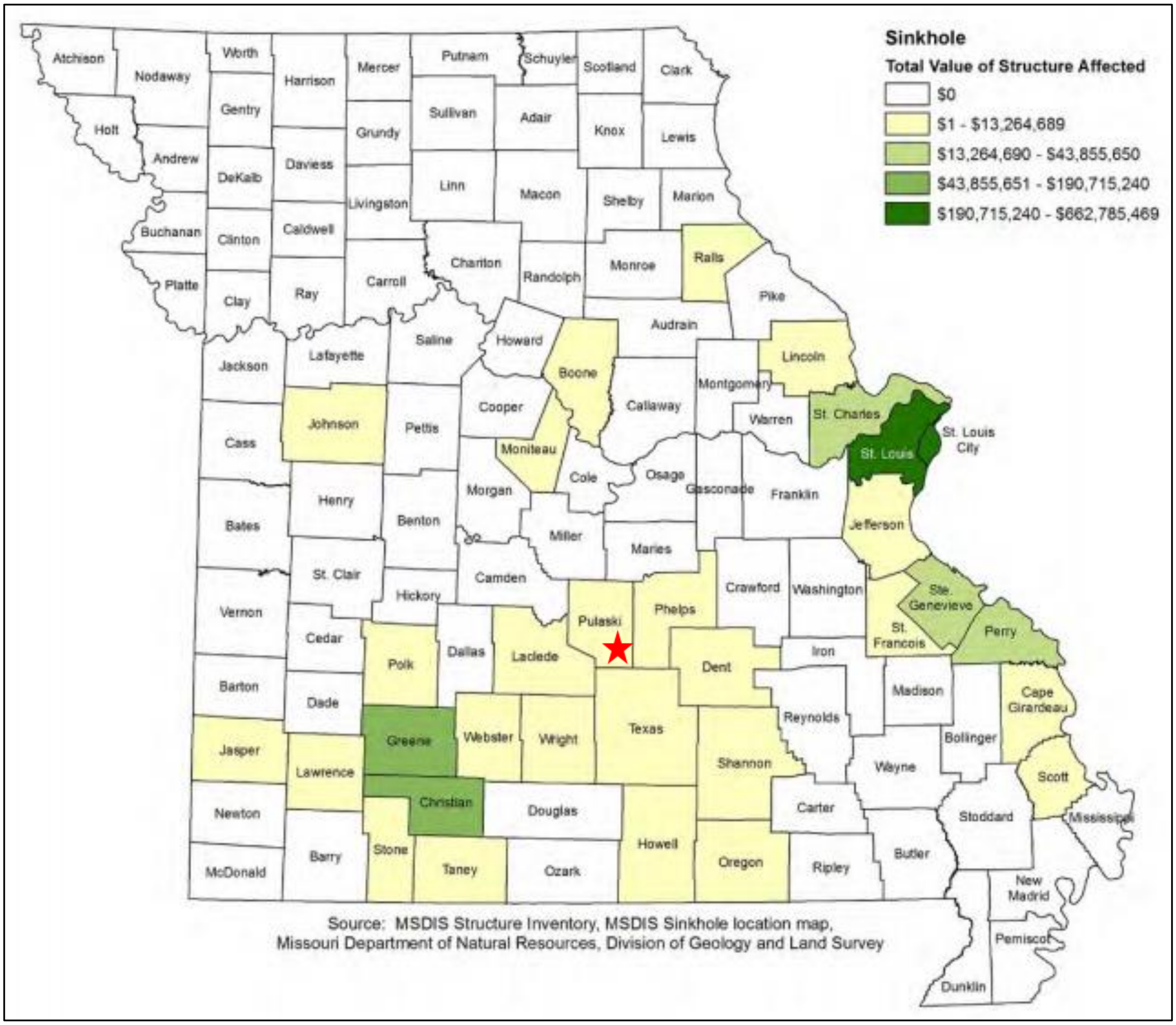
Potential Losses to Existing Development

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[36]. 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 Pulaski County.

[36] https://ufonline.ufl.edu/infographics/how-to-spot-a-sinkhole/

The 2018 Missouri Hazard Mitigation Plan devised a method of estimating potential losses using GIS data. **Figure 3.52** shows the ranking of structures that could potentially be impacted by sinkholes by county. This map shows that Pulaski County has $1-$13,264,689 total value of structures affected.

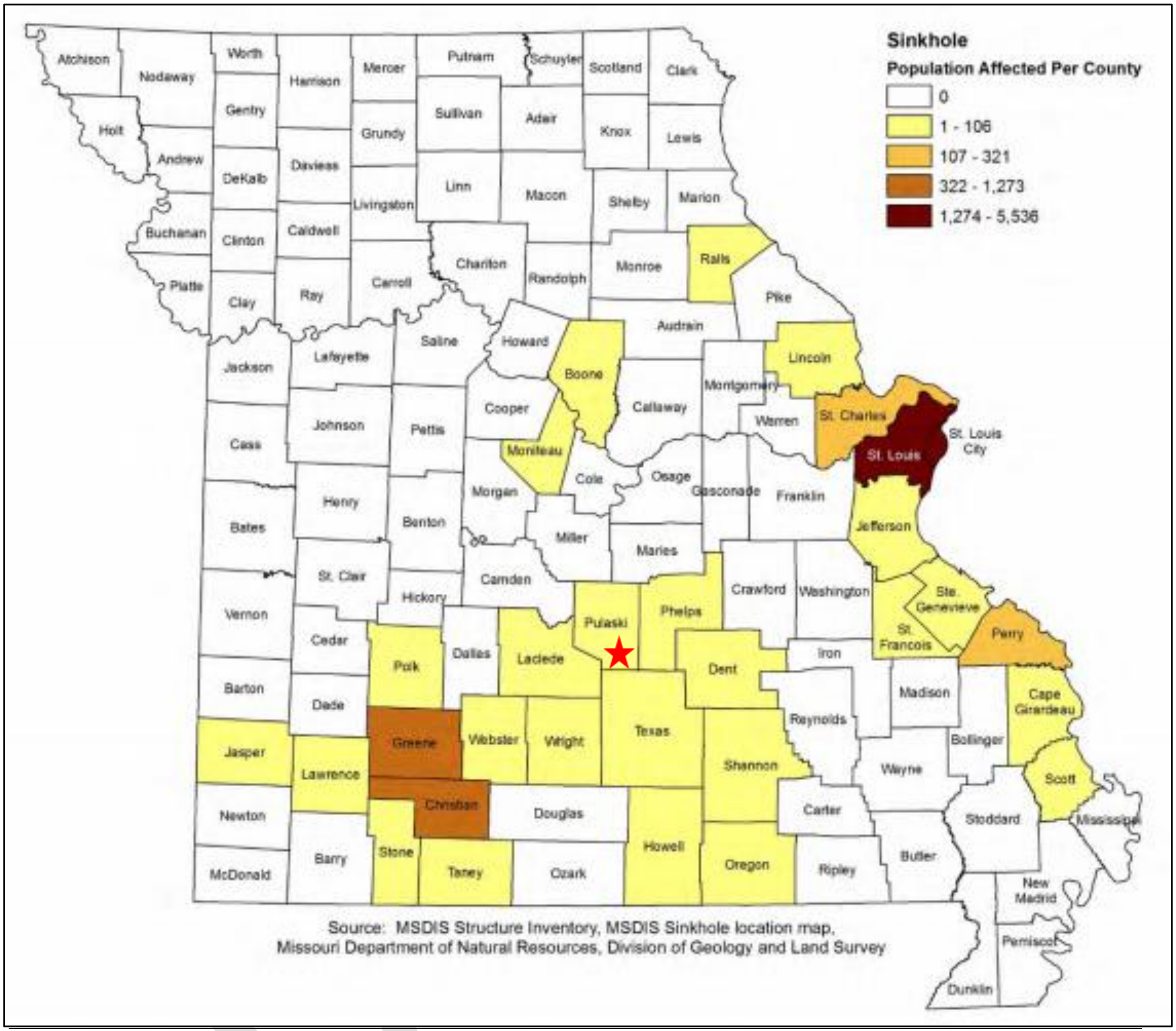
Figure 3.52. Ranking of Structures Potentially Impacted by Sinkholes by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.53 shows the population potentially impacted by sinkholes; Pulaski County shows that 1 - 106 of the county population could be affected by sinkholes.

Figure 3.53. Ranking of Population Potentially Impacted by Sinkholes by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Impact of 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, Pulaski County's risk in regards to these hazards is moderately low.

Hazard Summary by Jurisdiction

According to the state plan, Pulaski County's risk is low to moderate. Based on the location of known sinkholes, the jurisdictions most likely to be impacted by sinkholes are St. Robert and Waynesville and the Waynesville R-VI School District. As evidenced by the map of sinkholes in Pulaski County, there is at least one known sinkhole in the city limits of St. Robert and several in close proximity to the city of Waynesville. There are also a number of sinkholes in the northern portion of Fort Leonard Wood where the housing areas and elementary schools are located. The other jurisdictions, both cities and school districts, are located in areas of the county where the concentration of sinkholes is much lower.

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.

3.4.8 Thunderstorm/High Winds/Lightning/Hail

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, http://www.lightningsafety.noaa.gov/stats/08_Vaisala_NLDN_Poster.pdf
- Death and injury statistics from lightning strikes, National Weather Service.
- Wind Zones in the U.S. map, FEMA, http://www.fema.gov/plan/prevent/saferoom/tsfs02_wind_zones.shtm;
- 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), http://www.torro.org.uk/site/hscale.php;
- NCEI data;
- USDA Risk Management Agency, Insurance Claims, http://www.rma.usda.gov/data/cause.htm
- National Severe Storms Laboratory – hail map, http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif
- 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 0**) 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.

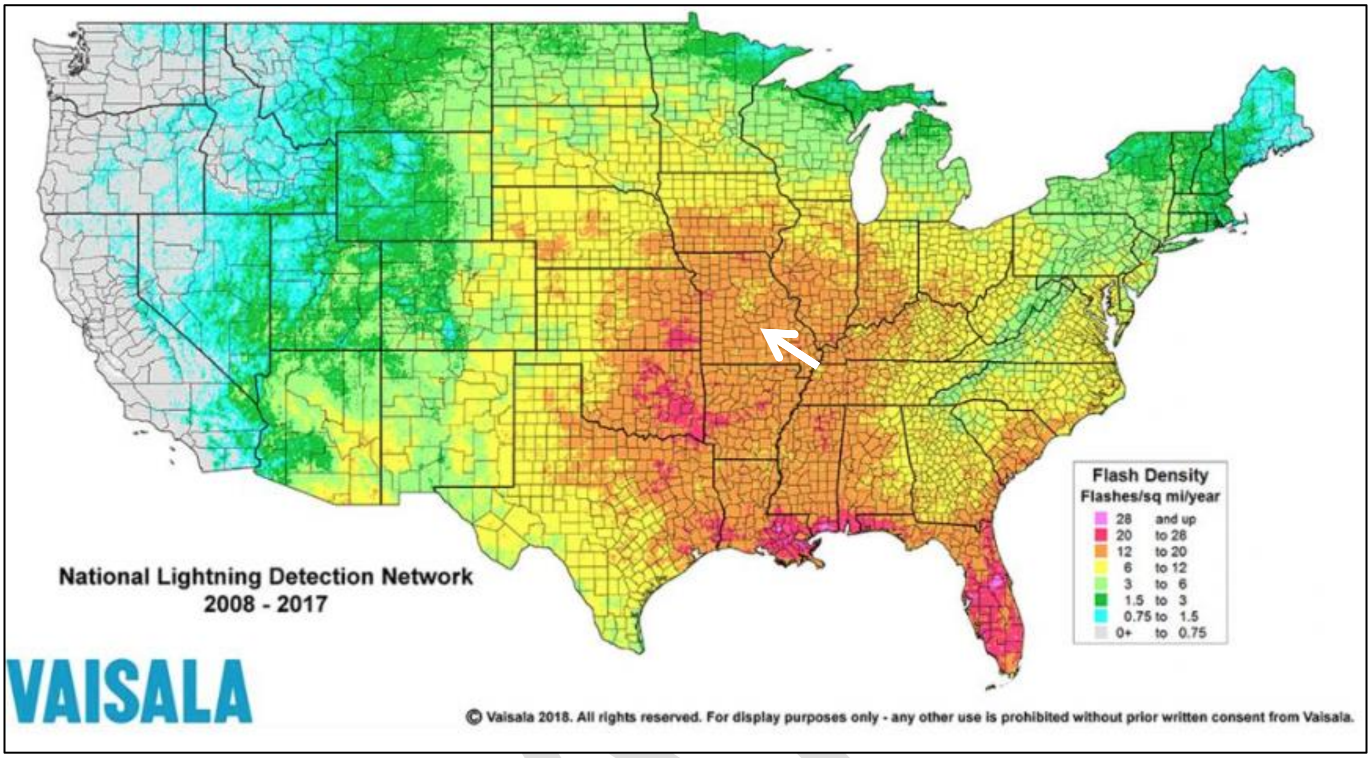
At the time when the updraft can no longer support the hailstone, it will fall down to the earth. For example, a ¼" diameter or pea sized hail requires updrafts of 24 miles per hour, while a 2 ¾" diameter or baseball sized hail requires an updraft of 81 miles per hour. According to the NOAA, the largest 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 United States. Furthermore, 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 3.54 depicts the location and frequency of lightning in Missouri. Additionally, the map indicates that the flash density of Pulaski County ranges between 12 and 20 flashes per square kilometer per year.

Figure 3.54. Location and Frequency of Lightning in Missouri



Source: National Weather Service,
http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN .aspx
** Pulaski 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 3.55**).

Figure 3.55. 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
**Pulaski County is indicated by a white arrow.*

Severity/Magnitude/Extent

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

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

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

Based on information provided by the Tornado and Storm Research Organization (TORRO), **Table 3.56** below describes typical damage impacts of the various sizes of hail.

Table 3.56. Tornado and Storm Research Organization Hailstorm Intensity Scale

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

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

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

Between 1999 and 2019, there was 1 recorded crop insurance claim for Thunderstorms, lightning, high wind, and hail in Pulaski County.

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.

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Previous Occurrences

Due to the lack of available parameters, heavy rain is utilized in the place of thunderstorms in **Table 3.57** for events between 2009 and 2019. Moreover, thunderstorm wind and strong wind was included with high winds. NCEI data was obtained for lightning, and hail events between 1999 and 2019 as well (**Table 3.58** 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 3.57. NCEI Pulaski County Heavy Rain Events Summary, 2009 to 2019

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Rainfall (Inch)
2009	1	0	0	0	3.15
2011	1	0	0	0	2.74
2012	2	0	0	0	3.59
2013	3	0	0	0	6.00
2015	3	0	0	0	10.28
2016	1	0	0	0	4.01
2017	2	0	0	0	6.37
2018	8	0	0	0	4.44
2019	3	0	0	0	2.95
TOTAL	**24**	**0**	**0**	**0**	**-**

Source: NCEI, data accessed [7/23/2020]

Table 3.58. NCEI Pulaski County High Wind Events Summary, 1999 to 2019 (Thunderstorm)

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Estimated Gust (kts.)
1999	1	0	0	0	62 kts.
2000	6	0	0	$57K	68 kts.
2001	2	0	0	0	57 kts.
2002	2	0	0	$10K	62 kts.
2003	6	0	0	0	70 kts.
2004	4	0	0	$100K	70 kts.
2005	8	0	0	0	55 kts.
2006	2	0	0	0	55 kts.
2007	1	0	0	0	50 kts.
2008	10	0	0	$15K	61 kts.
2009	5	0	0	$20.5K	70 kts.
2010	10	0	0	$14K	56 kts.
2011	3	0	0	$6K	52 kts.
2012	8	0	0	$11K	52 kts.
2013	6	0	0	$20K	61 kts.
2014	4	0	0	$5K	52 kts.
2015	3	0	0	0	52 kts.
2016	4	0	0	$5K	55 kts.
2017	10	0	0	$41K	67 kts.
2018	5	0	0	$5K	60 kts.
2019	11	0	0	$142K	55 kts.
TOTAL	**109**	**0**	**0**	**$4,515K**	**-**

Source: NCEI, data accessed [7/23/2020]

Table 3.59. NCEI Pulaski County Lightning Events Summary, 1999 to 2019

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damage
2011	1	1	0	0	0
2016	1	0	0	$25K	0
Total	**2**	**1**	**0**	**$25K**	**0**

Source: NCEI, data accessed [7/23/2020]

Table 3.60. NCEI Pulaski County Hail Events Summary, 1999 to 2019

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Hail Size (inch)
1999	1	0	0	0	1.75
2000	2	0	0	0	1.5
2001	8	0	0	$20K	1
2002	6	0	0	0	1.75
2003	20	0	0	0	2.75
2004	3	0	0	0	0.88
2005	11	0	0	0	0.88
2006	5	0	0	0	1.75
2007	7	0	0	0	1.5
2008	15	0	0	0	1.75
2009	2	0	0	0	1.25
2010	6	0	0	0	0.88
2011	8	0	0	0	1.75
2012	11	0	0	0	1.50
2013	2	0	0	0	1.75
2014	3	0	0	0	1.0
2015	2	0	0	0	1.0
2016	7	0	0	0	1.5
2017	7	0	0	0	1.5
2018	2	0	0	0	1
2019	2	0	0	$2K	1.25
Total	**93**	**0**	**0**	**$22K**	**-**

Source: NCEI, data accessed [7/23/2020]

Agriculture is an important piece of the economy for Pulaski County. The table below (**Table 3.61**) summarize past crop damages as indicated by crop insurance claims. The tables illustrate the magnitude of the impact on the planning area's agricultural economy. 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 "Excessive Moisture/Precipitation/ Rain" and "Wind/Excessive Wind" as two causes of loss categories that align with this hazard. Between 1998 and 2018 a total of 65 insurance claims were paid out for damages due to excessive moisture, precipitation. The total claims paid for this cause were $463,824.50.

For the time period 1999-2019, there were no crop insurance claim made for wind and excessive wind damage.

Table 3.61. Crop Insurance Claims Paid In Pulaski County from Excessive Moisture/ Precipitation/Rain 1999-2019

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2002	All Other Crops	Excessive Moisture/Precipitation/Rain	$1,811.00
2003	All Other Crops	Excessive Moisture/Precipitation/Rain	$252.00
2008	All Other Crops	Excessive Moisture/Precipitation/Rain	$35,999.00
2010	All Other Crops	Excessive Moisture/Precipitation/Rain	$3,563.00
2013	All Other Crops	Excessive Moisture/Precipitation/Rain	$6,406.00
2014	All Other Crops	Excessive Moisture/Precipitation/Rain	$1,367.00
2015	Wheat All Other Crops	Excessive Moisture/Precipitation/Rain	$15,174.00 $28,477.00
2017	All Other Crops	Excessive Moisture/Precipitation/Rain	$3,659.00
2019	All Other Crops	Excessive Moisture/Precipitation/Rain	$11,928
Total	**-**	Excessive Moisture/Precipitation/Rain	**$**

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 [37], annual average percent probabilities were calculated for heavy rainfall, high winds, lightning, and hail. Heavy rainfall has a 100 percent annual average percent probability of occurrence (24 events/11 years x 100) (**Table 3.62**). Heavy rainfall events can be found in **Table 3.57**. The annual average percent probability for high winds within the county is 100 percent (109 events/21 years x 100) (**Table 3.63).** High wind events can be found in **Table 3.58.**

Lightning events has a 9.5 percent annual average percent probability (2 events/21 years x 100). Lightning events can be found in **Table 3.59.**

Lastly, the annual average percent probability of hail occurrence is 100% (93 events/21 years) with an average of 4.4 events per year (**Table 3.65**). Hail events can be found in **Table 3.60**.

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

Table 3.62. Annual Average % Probability of Heavy Rain in Pulaski County

Location	Annual Avg. % P
Pulaski County	100%

*P = probability; see page 3.24 for definition.

Table 3.63. Annual Average % Probability of High Winds in Pulaski County

Location	Annual Avg. % P	Avg. # of Events
Pulaski County	100%	5.19

*P = probability; see page 3.24 for definition.

Table 3.64. Annual Average % Probability of Lightning in Pulaski County

Location	Annual Avg. % P
Pulaski County	9.5%

*P = probability; see page 3.24 for definition.

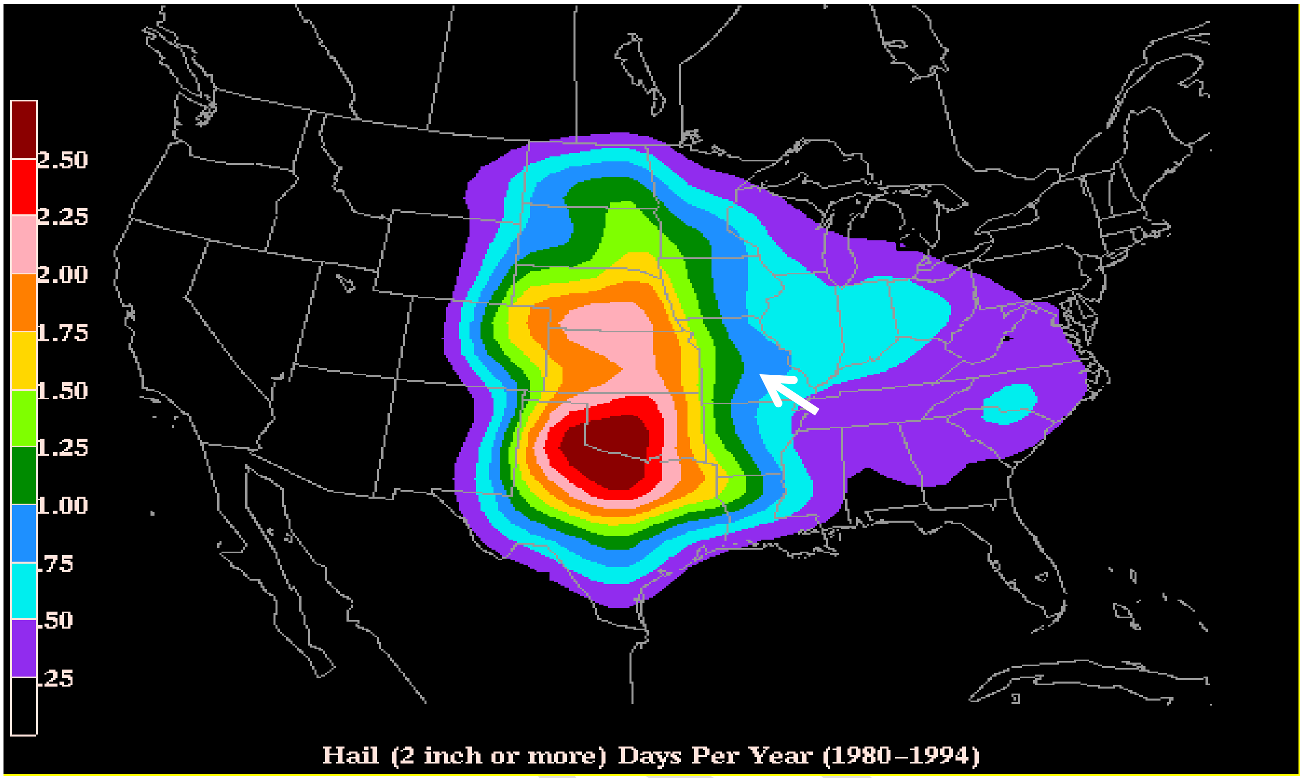
Table 3.65. Annual Average % Probability of Hail in Pulaski County

Location	Annual Avg. % P	Avg. # of Events
Pulaski County	100%	4.4

*P = probability; see page 3.24 for definition.

Figure 3.56 depicts a map based on hailstorm data from 1980-1994. It shows the probability of hailstorm occurrence (2" diameter or larger) based on number of days per year. The location of Pulaski County is identified with a white arrow.

Figure 3.56. Annual Hailstorm Probability (2″ diameter or larger), 1980 - 1994



Source: NSSL,http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif
** White arrow indicates Pulaski County*

Vulnerability

Vulnerability Overview

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

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

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

Most lightning damages occur to electronic equipment located inside buildings. But structural damage can also occur when a lightning strike causes a building fire. In addition, lightning strikes can cause damages to crops, if fields or forested lands are set on fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. [38]

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, HAZUS Building Exposure Value data, housing density and mobile home data from the U.S. Census (2018 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.[39]

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 3.66 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 3.67** provides the calculated ranges applied to determine overall vulnerability of Missouri counties to severe thunderstorms.

[38] http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx and http://www.lightningsafety.noaa.gov/ Potential Losses to Existing Development
[39] 2018 Missouri Hazard Mitigation Plan

Table 3.66. Ranges for Severe Thunderstorm Vulnerability Factor Ratings

Factors Considered	Low (1)	Low Medium (2)	Medium (3)	Medium High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2836.23
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Percent Mobile Homes	0.2-4.5%	4.6-8.8%	8.9-14%	14.1-21.2%	21.3-33.2%
Social Vulnerability	1	2	3	4	5
					Wind
Likelihood of Occurrence (# of events/ yrs. of data)	0.90 - 2.90	2.91 - 4.57	4.58 - 7.00	7.01 - 12.05	12.06 - 20.86
Average Annual Property Loss (annual property loss/ yrs of data)	$0.00 – $81,047.62	$81,047.63 – $200,428.57	$200,428.58 – $363,500.00	$363,500.01 – $837,242.86	$837,242.87 – $2,481,809.52
					Hail
Likelihood of Occurrence (# of events/ yrs. of data)	1.19 - 2.76	2.77 - 4.86	4.87 - 7.81	7.82 - 12.38	12.39 - 18.10
Average Annual Property Loss (annual property loss/ yrs. of data)	$0.00 - $41,547.62	$41,547.63 – $171,980.95	$171,980.96 – $467,857.14	$467,857.15 – $9,714,523.81	$9,714,523.82 – $40,594,285.71
					Lightning
Likelihood of Occurrence (# of events/ yrs. of data)	0-.05	.06-0.14	0.15-0.29	0.30-0.43	0.44-0.67
Average Annual Property Loss (annual property loss/ yrs. Of data)	$0-$476.19	$476.20-$1,904.76	$1,904.77-$7,476.19	$7,476.20-$13,142.86	$13,142.87-$57,000

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.67. Ranges for Severe Thunderstorm Combined Vulnerability Rating

	Low (1)	Low Medium (2)	Medium (3)	Medium High(4)	High (5)
Severe Thunderstorm Combined Vulnerability	12-16	17-19	20-23	24-29	30-36

Source: 2018 Missouri Hazard Mitigation Plan

According to the Hazus data included in the 2018 state plan, Pulaski County has total building exposure to severe thunderstorms of $5,334,660,000. **Table 3.68** shows housing density, building exposure, SOVI and mobile home data for Pulaski County. The county's building exposure and housing density rating is low, while the percent of mobile homes in the county is rated as low at 9.7 percent of the housing stock. **Table 3.69**, 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 3.68. Pulaski 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
$5,334,660,000	2	33.60	1	Low	1	9.7	3

Source: 2018 Missouri Hazard Mitigation Plan

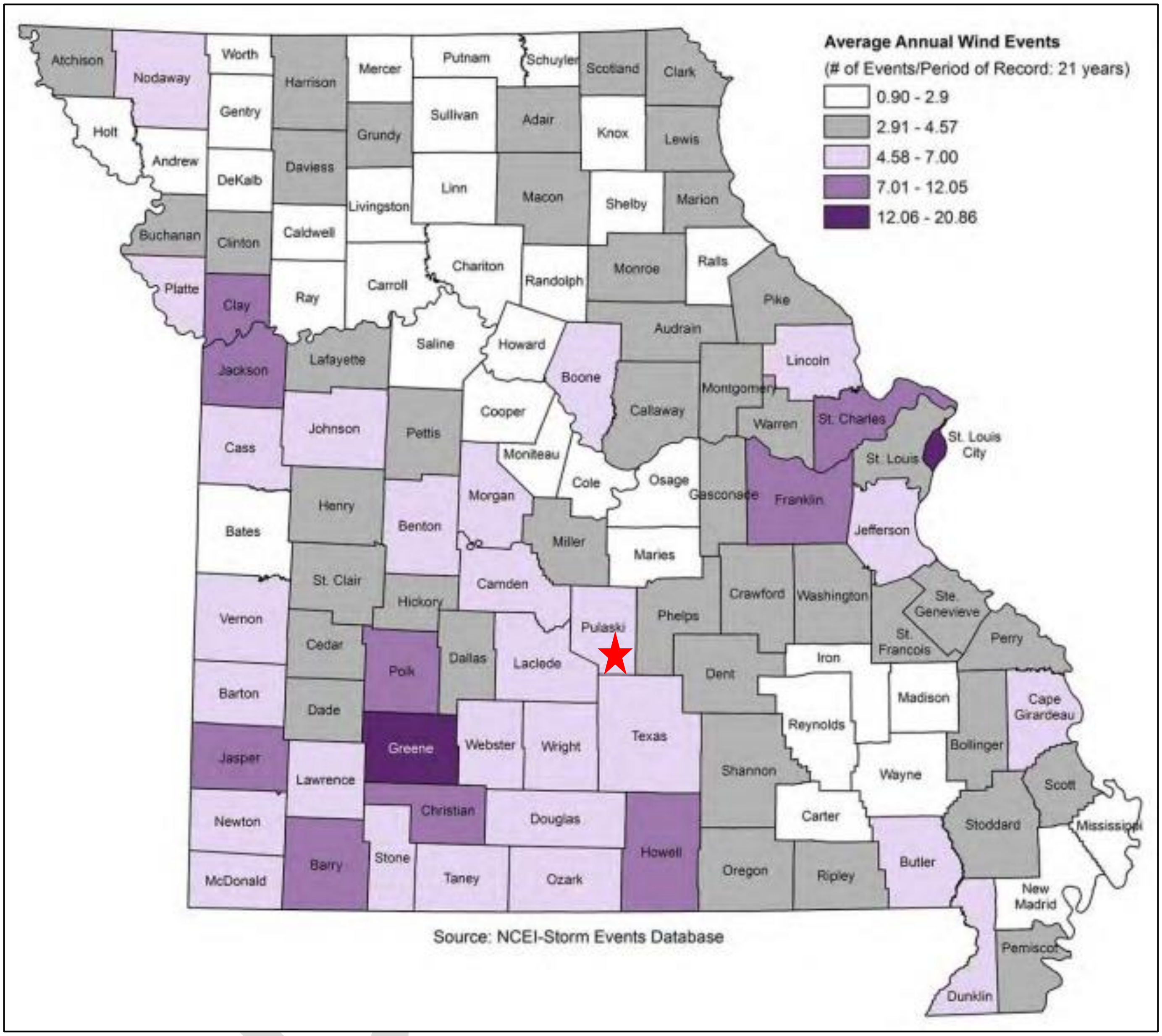
Table 3.69. Number of High Wind, Hail and Lightning Events, Likelihood of Occurrence and Associated Ratings for Pulaski County

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
101	4.810	3	140	6.667	3	2	0.095	2

Source: 2018 Missouri Hazard Mitigation Plan

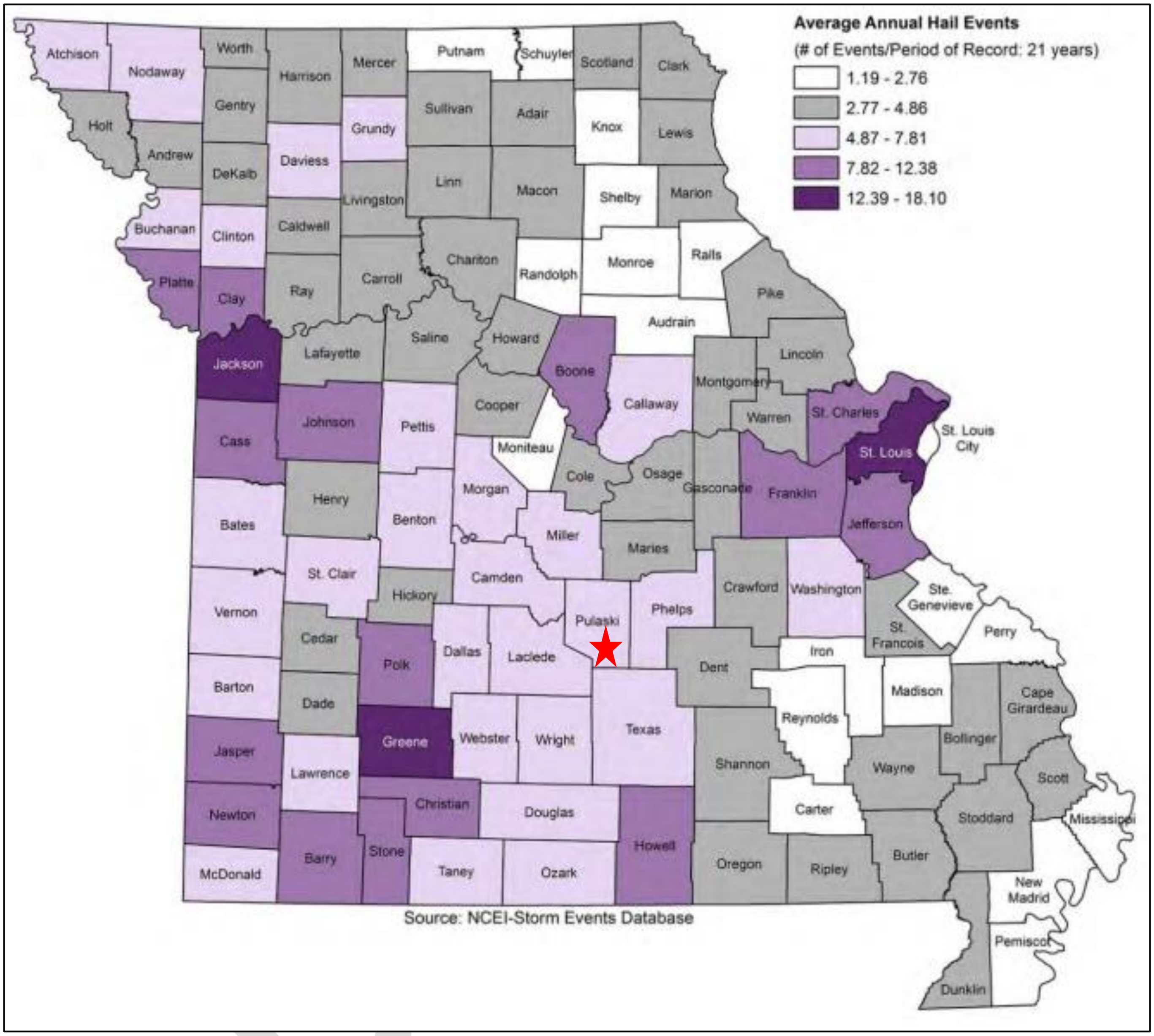
Figure 3.57 through **Figure 3.59** have been pulled from the 2018 Missouri Hazard Mitigation Plan and further depict the average annual likelihood of occurrence of high winds, hail, and lightning events in Missouri.

Figure 3.57. Average Annual High Wind Events (40 MPH and Higher)



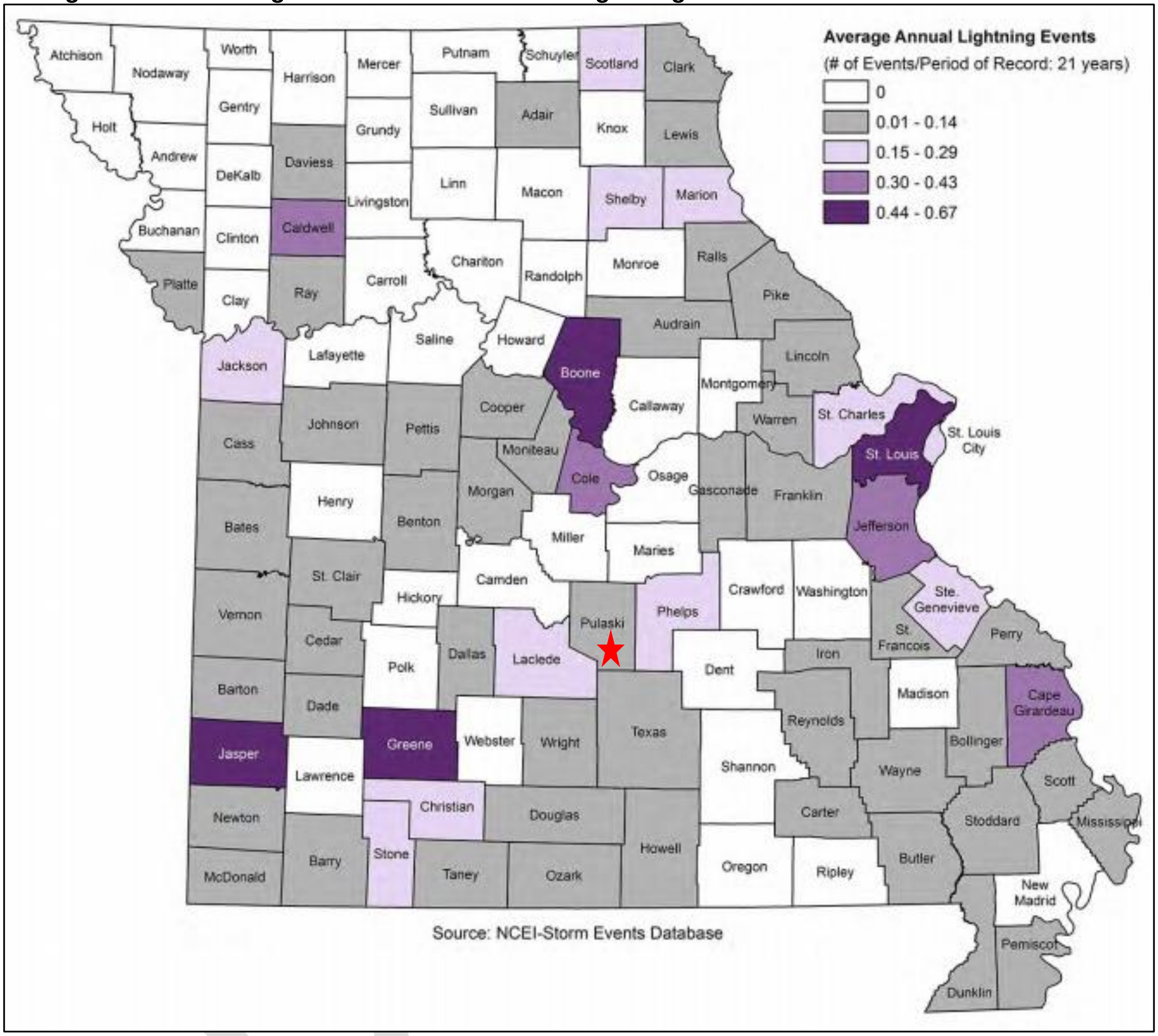
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.58. Average Annual Occurrence of Damaging Hail Events



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.59. Average Annual Occurrence of Lightning Events



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Table 3.70 provides additional data obtained from the National Centers for Environmental Information for property loss to complete the overall vulnerability analysis.

Table 3.70. Annualized Property Loss and Associated Ratings for Pulaski 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
$22,786	1	$1,429	1	$1,190	2

Source: 2018 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 3.67**. **Table 3.71** provides the calculated vulnerability rating for the severe thunderstorm hazard. **Figure 3.60** that follows provides the mapped results of this analysis by county[40].

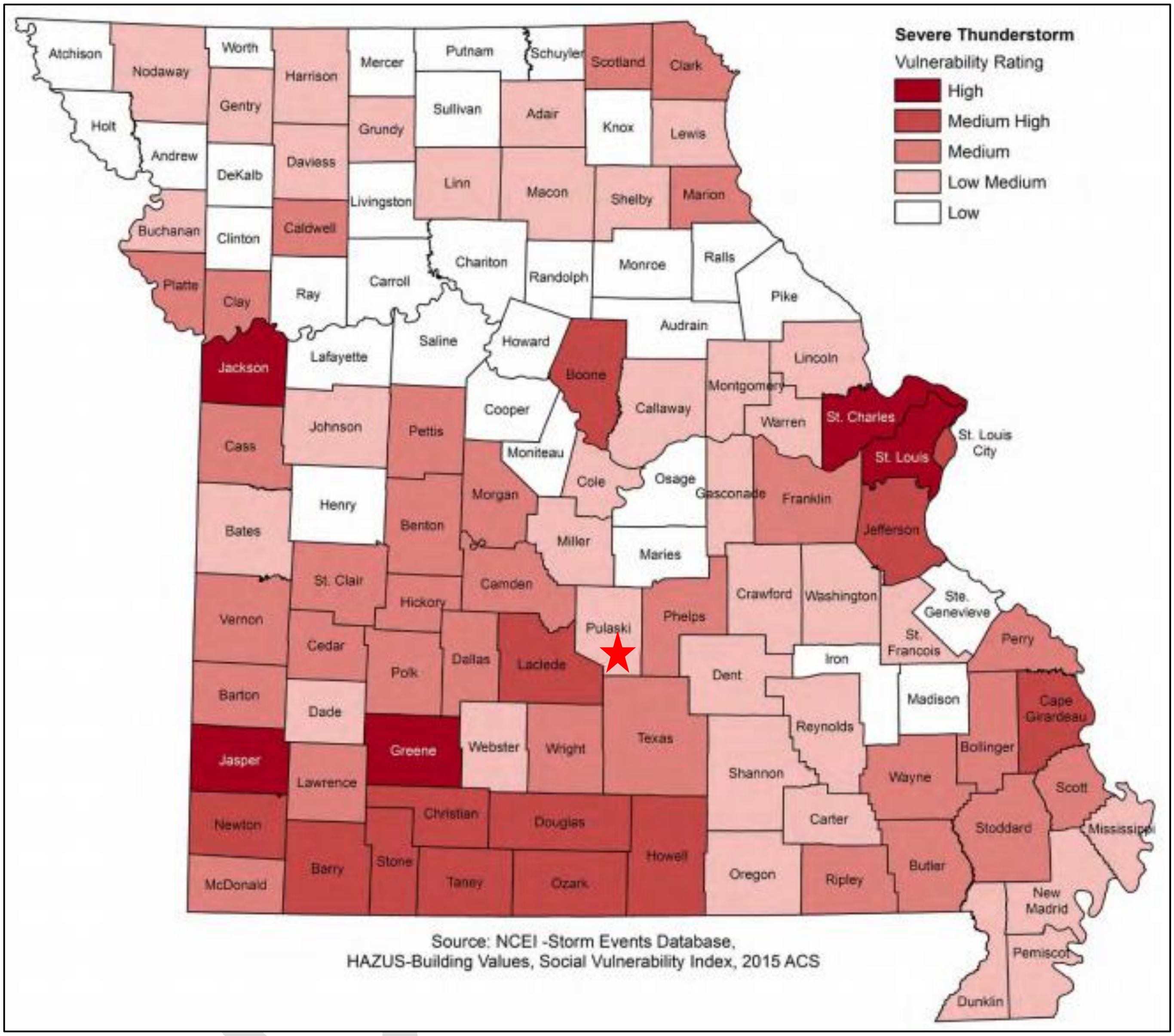
Table 3.71. Severe Thunderstorm Vulnerability Rating for Pulaski County

Total Sum of All Factor Ratings	Overall Vulnerability Rating for Thunderstorms	Overall Vulnerability Rating for Thunderstorms Description
19	2	Low Medium

Source: 2018 Missouri State Hazard Mitigation Plan

[40] 2018 Missouri State Hazard Mitigation Plan

Figure 3.60. Vulnerability Summary for Severe Thunderstorms



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

According to the NCEI Pulaski County experienced approximately $4,562,000 in property damages from severe thunderstorms between 1999 and 2019. This is an average of $217,238.10 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[41].

[41] 2015 Boone County Hazard Mitigation Plan

Previous and Future Development

Population trends from 2010 to 2018 for Pulaski County indicate that the population in unincorporated areas has fallen by an estimated 3.44 percent. The city of St. Robert's population has increased by a significant 32.8 percent. The city of Dixon, however, has fallen by 18.92 percent. Most communities had modest increases. So it is reasonable to assume that similar growth in the communities will continue and the population in unincorporated areas may fall slightly. 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 damages from severe thunderstorms. The jurisdiction with the highest percent of houses build before 1939 is the City of Dixon with 14.8 percent. Additionally, the city of Richland has a higher percentage of mobile homes and unsecured buildings, which are more prone to damages.

Problem Statement

The NCEI Storm Events Database notes over 228 thunderstorm and wind events in Pulaski County since 1999, with over $4,562,000.00 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.

3.4.9 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; https://www.fema.gov/fema-p-320-taking-shelter-storm-building-safe-room-yourhome-or-small-business
- Tornado Alley in the U.S. map, http://tornadochaser.com/education/tornado-alley/
- National Centers for Environmental Information, http://www.NCEI.noaa.gov/stormevents/
- Tornado History Project, map of tornado events, http://www.tornadohistoryproject.com/tornado/Missouri
- 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 3.4.8,** Thunderstorm/High Wind/Hail/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.

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 occur anywhere across the state of Missouri, including Pulaski 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 Enhance Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renowned severe storm researcher). The EF- Scale (**Table 3.72**) 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 3.72. Enhanced F Scale for Tornado Damage

Fujita Scale			Derived EF Scale		Operational 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 3.73.** 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 3.73. 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%**	Explosive. Strong frame houses levelled off foundations and swept away; automobile-sized missiles fly through the air in excess of 300 ft.; steel reinforced concrete structure badly damaged; high rise buildings have significant structural deformation; incredible phenomena will occur.

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

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

Previous Occurrences

Table 3.74 illustrates NCEI data reported for tornado events and damages from 1993 to 2019 in the planning area. Prior to 1993, only highly destructive tornadoes were recorded.

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.

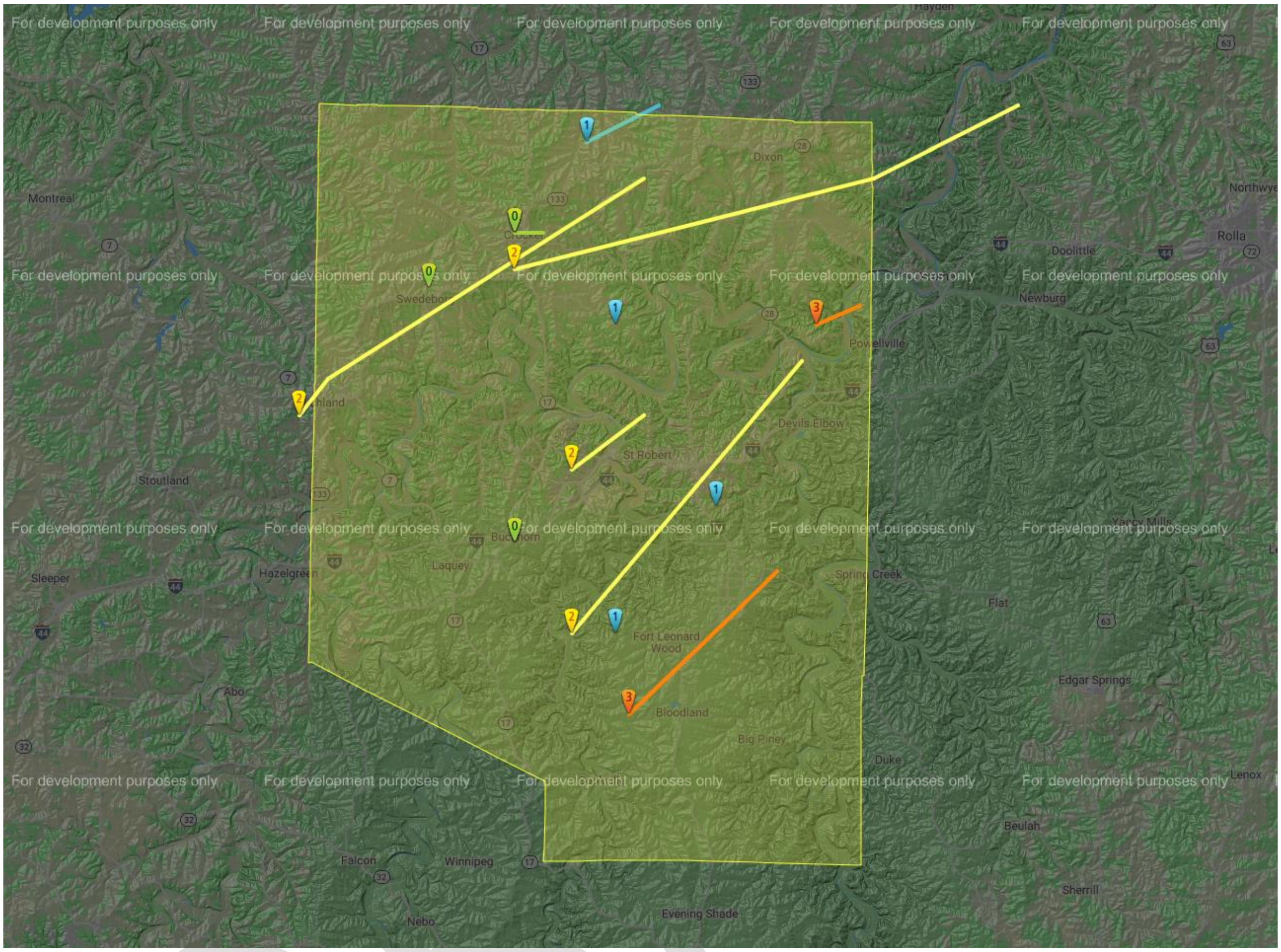
Table 3.74. Recorded Tornadoes in Pulaski County, 1999 – 2019

Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	F/EF Rating	Death	Injury	Property Damage	Crop Damages
10/23/2001	-	Crocker	.5	75	F0	0	0	0	0
05/04/2003	-	Swedeborg	.2	20	F0	0	0	0	0
05/06/2003	5N Waynesville	5N Waynesville	1	100	F1	0	0	$500,000	0
01/07/2008	2NNW Hooker	3SSE Franks	1.77	400	EF3	0	3	$1,000,000	0
12/31/2010	2W Bloodland	3ENE (TBN) Ft. Leonard Wood	7.5	500	EF3	0	4	$90,000,000	0
05/23/2019	Laquey	Hanna	9.79	440	EF1	0	0	$155,000	
Total	**-**	**-**	**-**	**-**	**-**	**0**	**9**	**$91,735,000**	**0**

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

Figure 3.61 depicts historic tornado paths across Pulaski County.

Figure 3.61. Pulaski County Map of Historic Tornado Paths (1974 – 2015)



Source: http://www.tornadohistoryproject.com/tornado/Missouri

According to the USDA Risk Management Agency's record, there were no insurance payments in Pulaski County for crop damages as a result of tornadoes between 1999 and 2019.

Probability of Future Occurrence

From the data obtained from the NCEI[42], an annual average percent probability was calculated for tornadoes within Pulaski County (**Table 3.75).** There is a 28 percent annual average probability of a tornado occurrence (6 events/21 years x 100). Tornado events can be found in **Table 3.74**. In addition, Figure 3.62**,** obtained from the 2018 Missouri State Hazard Mitigation Plan, also illustrates tornado probabilities across the United States and further shows Pulaski County's average probability of 30 percent.

Table 3.75. Annual Average % Probability of Tornadoes in Pulaski County

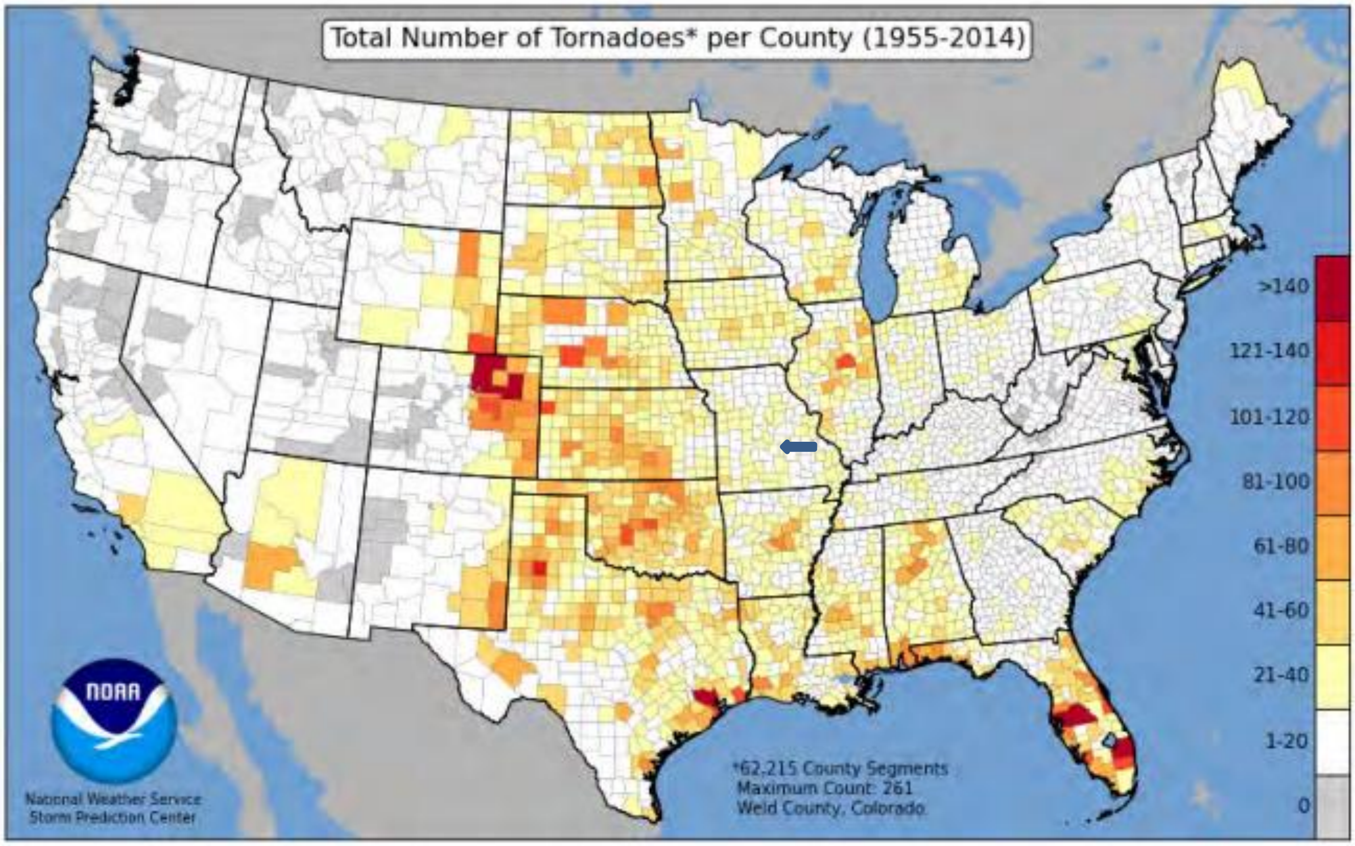
Location	Annual Avg. % P

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

Pulaski County	30%

*P = probability; see page 3.24 for definition.

Figure 3.62. Tornado Activity in the United States



*Source: 2018 Missouri State Hazard Mitigation Plan, *Blue arrow indicates Pulaski County*

Vulnerability

Vulnerability Overview

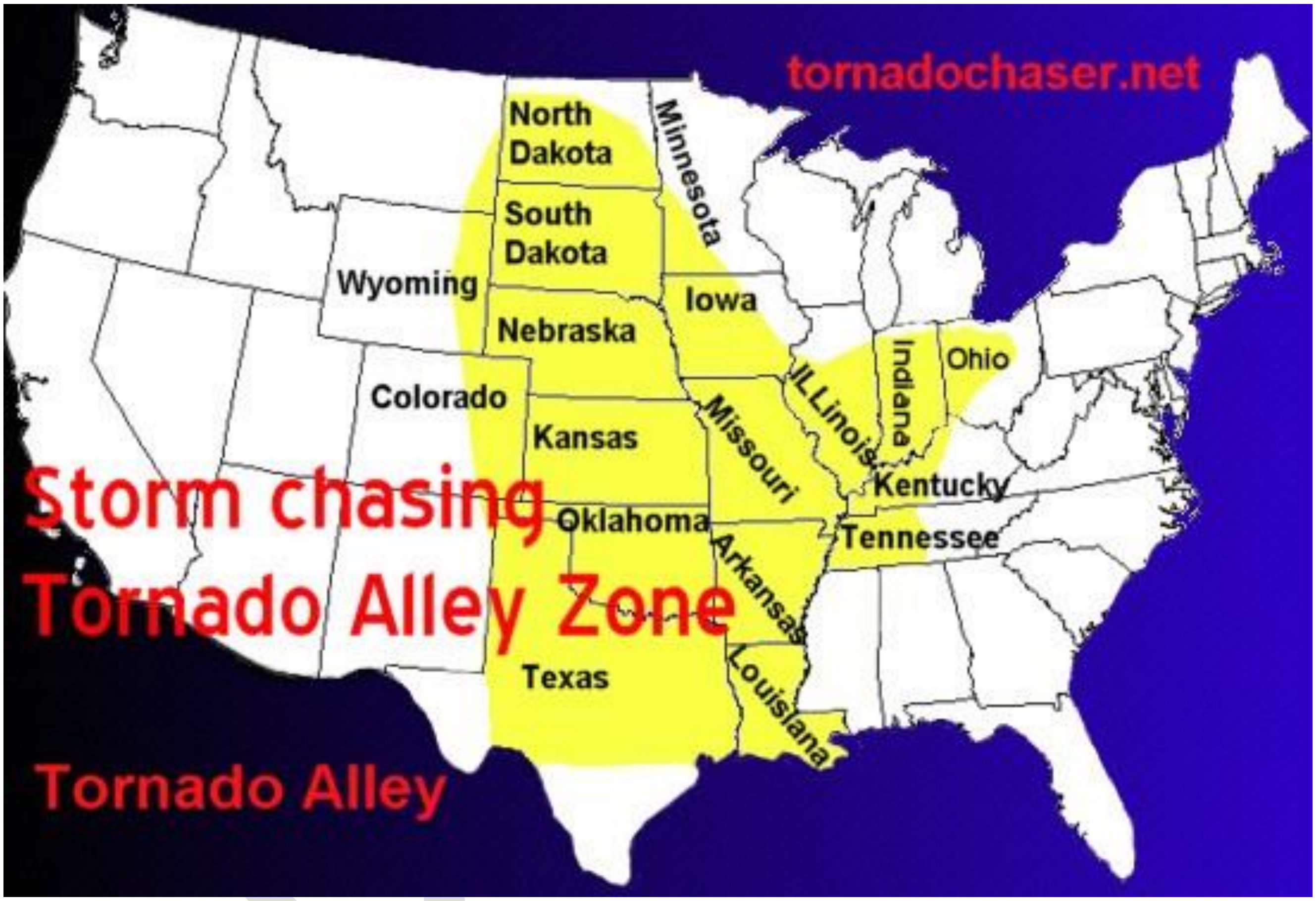
Many tornadoes are capable of great destruction and every tornado is a potential killer. Tornadoes can topple buildings, destroy mobile homes, uproot trees, hurl people and animals through the air for hundreds of yards and fill the air with lethal, windblown debris. Sticks, glass, roofing material and lawn furniture all become deadly missiles when driven by tornado winds.[43] Pulaski County resides in a region of the United States that has a high frequency of dangerous and destructive tornadoes. This region seen in **Figure 3.63** is referred to as "Tornado Alley".

The 2018 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 (2015 ACS), the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina, and storm events data (1950 to

[43] 2018 Missouri Hazard Mitigation Plan

December 31, 2016) 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.

Figure 3.63. Tornado Alley in the U.S.



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

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

Table 3.76 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 3.77** illustrates the ranges for tornado combined vulnerability rating.

Table 3.76. Ranges for Tornado Vulnerability Factor Ratings

Factors Considered	Low (1)	Low-medium (2)	Medium (3)	Medium-High (4)	High (5)
Common Factors					
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Population Density (#per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2,836.23
Social Vulnerability	1	2	3	4	5
Percent Mobile Homes	0.2-4.5%	4.51-8.8%	8.81-14%	14.01-21.2%	21.21-33.2%
Likelihood of Occurrence (# of events/ yrs. of data)	0.119 - 0.208	0.209 - 0.313	0.314 - 0.417	0.418 - 0.552	0.553 - 0.791
Total Annualized Property Loss ($ / yrs. of data)	$974 - $281,874	$281,875 - $991,825	$991,826 - $2,099,000	$2,099,001 - $5,047,474	$5,047,475 - $42,467,109

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.77. Ranges for Tornado Combined vulnerability Rating

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

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.78 provides data on building exposure, population density, SOVI and mobile home data for Pulaski County that is used to determine overall vulnerability.

Table 3.78. Building Exposure, Population Density, SOVI and Mobile Home Data for Pulaski County

Total Building Exposure (Hazus)	Exposure Rating	Population Density	Population Rating	SOVI Ranking	SOVI Rating	Percent Mobile Homes	Mobile Home Rating
$5,334,660,000	2	97.28	1	Low	1	9.7	3

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.79 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 3.64** shows the percent of mobile homes per county throughout the state with Pulaski County determined to have medium high mobile home density at 8.9 percent to 14 percent. **Figure 3.65** provides the average annual occurrence of tornadoes in Missouri and illustrates that

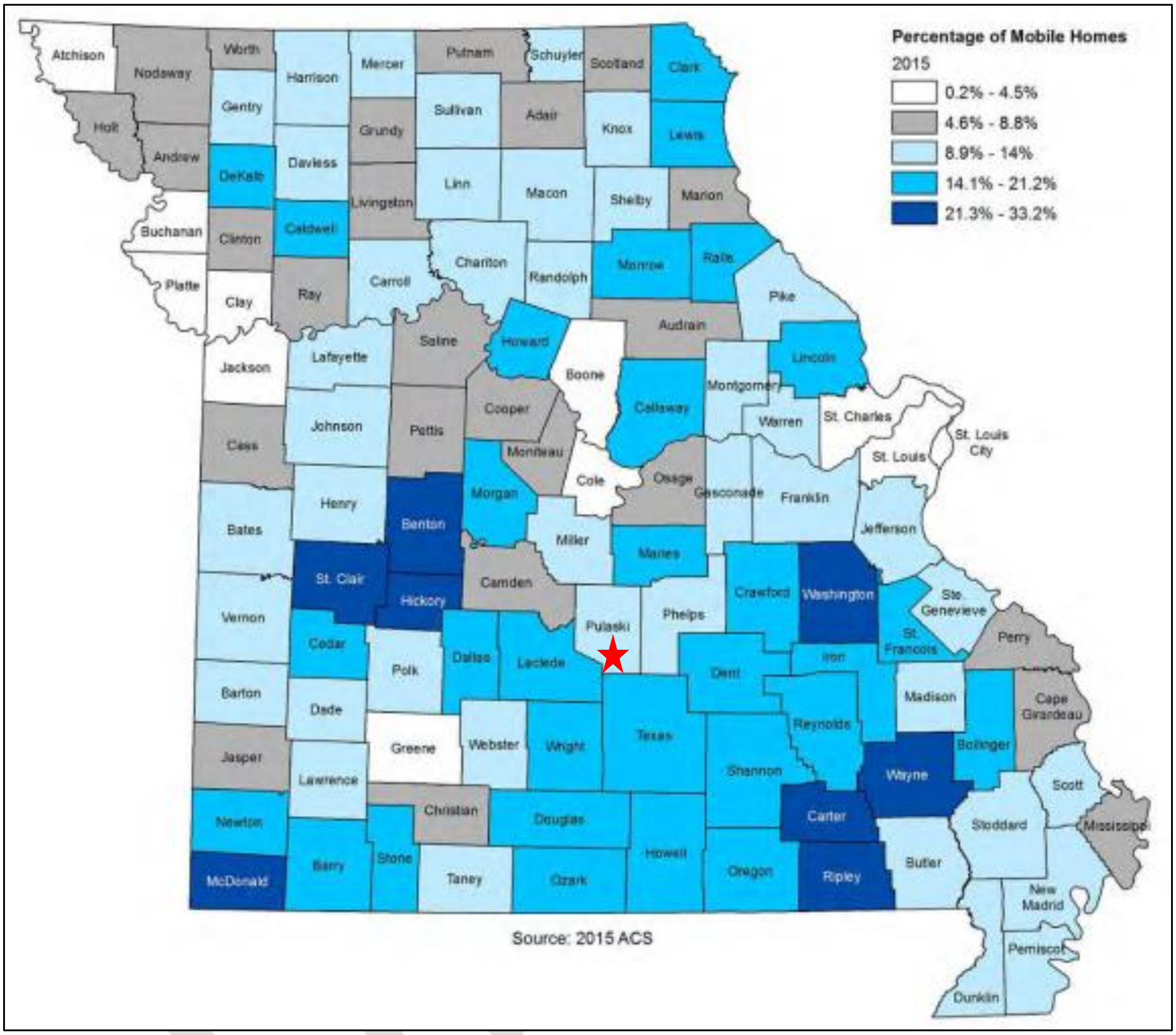
Pulaski County falls into the low medium quadrant for historical events – 20 to 30 percentile. Finally, **Figure 3.66** shows the county's overall vulnerability to tornadoes – Low – Medium.

Table 3.79. Likelihood of Occurrence, Annual Property Loss and Overall Vulnerability Rating for Tornadoes for Pulaski 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
16	0.239	2	$1,520,299	3	12	Low-Medium

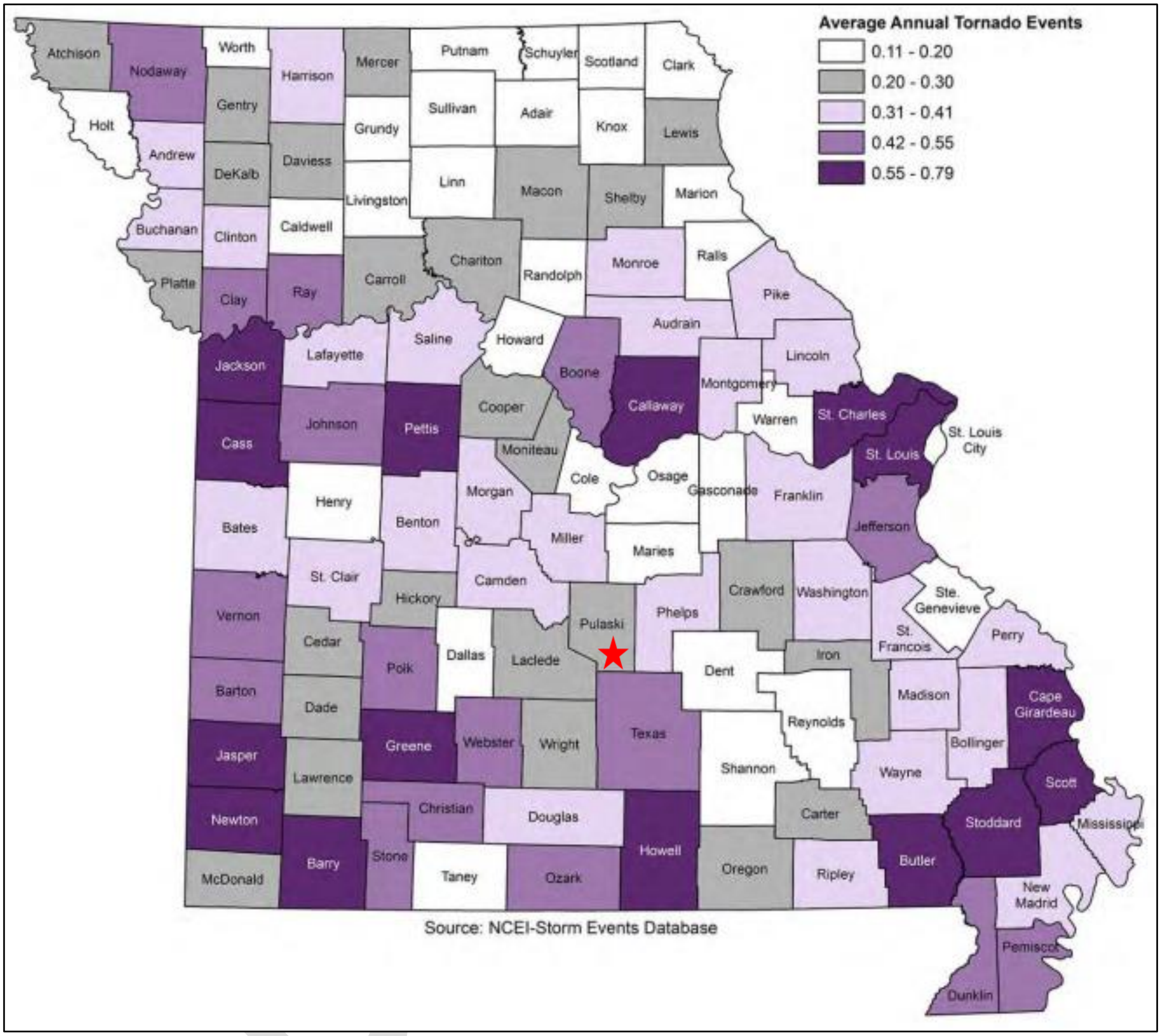
Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.64. Missouri – Percent of Mobile Homes Per County



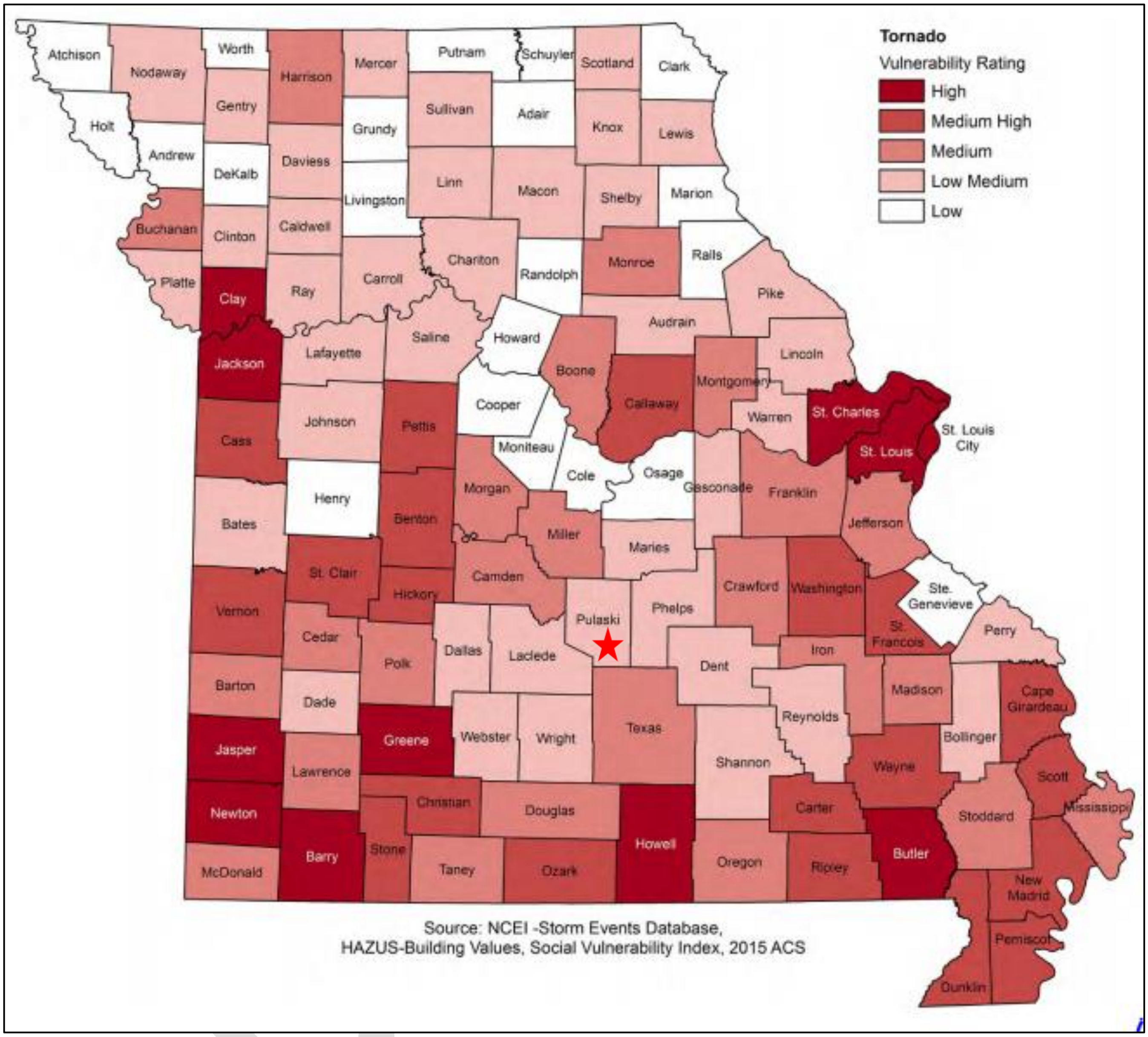
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.65. Average Annual Occurrence for Tornadoes



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.66. Overall Vulnerability to Tornadoes



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

There has been a total of $91,655,000 in damage due to tornadoes within Pulaski County in the previous 20 years. With this information we can estimate that each year there will be approximately $4,582,750 in loss to existing development. Additionally, the largest recorded tornado in the planning area has been an F-1. Utilizing this information we can infer that there is potential for another tornado of equivalence.

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 3.28** for jurisdictions most vulnerable to damage due to the age of the structure. Based on structure age, the city of Dixon would have higher vulnerability due to 14.8 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 Pulaski County and its jurisdictions. From the information provided in **Table 3.80,** the city of Richland, with 126 mobile homes – 14.0 percent of housing in the count, is most vulnerable to losses due to the number of mobile homes residing within the jurisdiction. Unincorporated Pulaski County has 1,241 or 11.0 percent of the occupied housing stock as mobile homes. The city of Crocker has 53 or 10.7 percent.

Table 3.80. Percentage of Mobile Homes in Pulaski County, 2018

Jurisdiction	Number of Mobile Homes	Percentage of Mobile Homes*
Unincorporated Pulaski County	1,241	11.0%
Crocker	53	10.7%
Dixon	56	9.4%
Richland	126	14.0%
St. Robert	325	9.8%
Waynesville	12	0.5%

Source: U.S. Census Bureau, 2014-2018 5-Year American Community Survey
**Number of mobile homes per jurisdiction/total occupied housing units per jurisdiction*
***Total housing units for all jurisdictions = 19,058*

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 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.

3.4.10 Winter Weather/Snow/Ice/Severe Cold

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
- Wind chill chart, National Weather Service, http://www.nws.noaa.gov/om/winter/windchill.shtml;
- 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, http://www.rma.usda.gov/data/cause.htm
- 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/
- 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

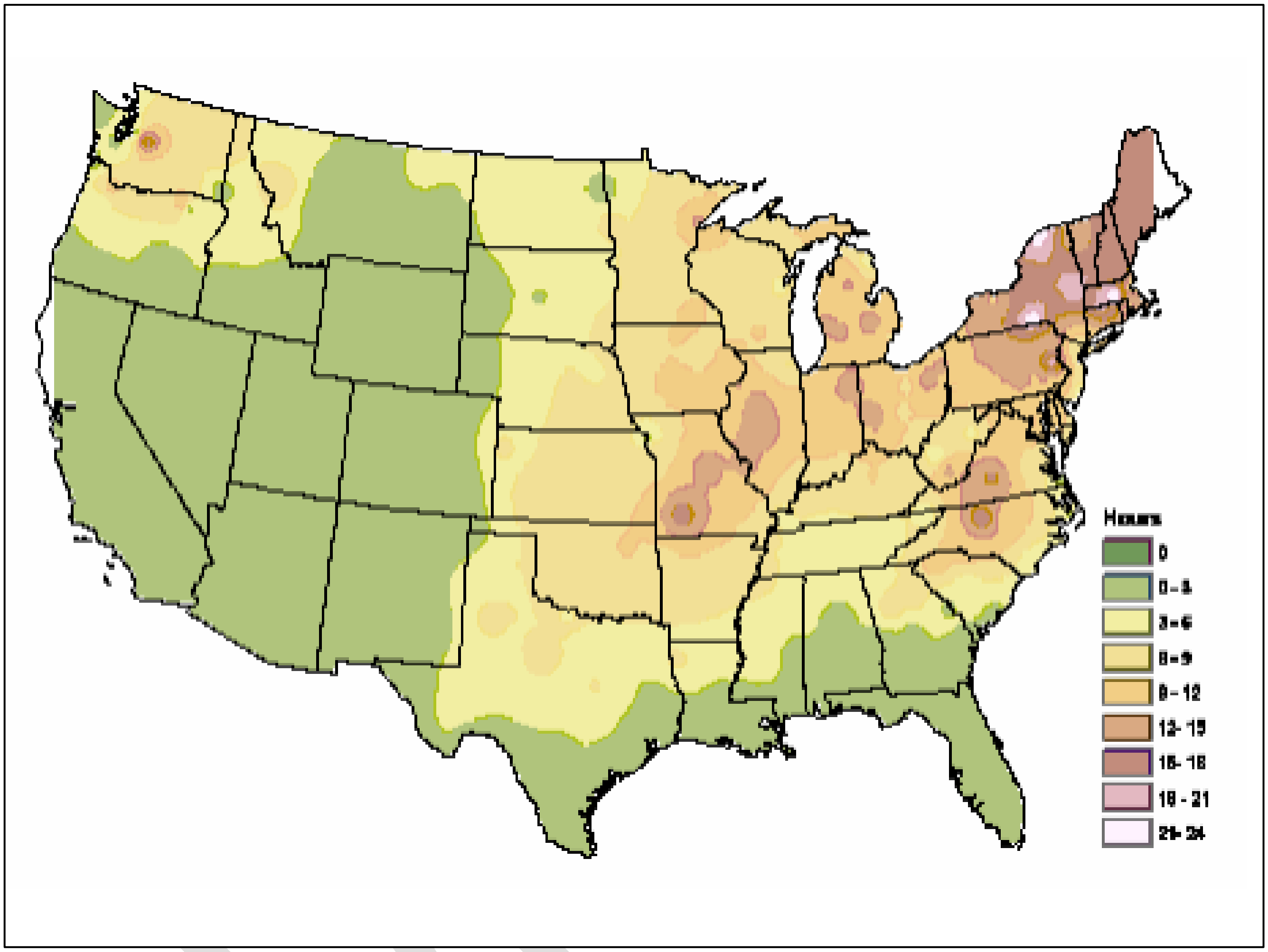
A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. The National Weather Service describes different types of winter storm events as follows.

- **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. Pulaski County receives winter weather events from heavy snows to freezing rain annually. Major snowstorms typically occur once each year, causing multiple school closings, as well as suspending business and government activity. Pulaski County is vulnerable to heavy snow, ice, extreme cold temperatures and freezing rain. **Figure 3.67** illustrates statewide average number of hours per year with freezing rain. Pulaski County receives approximately 9 to 12 hours.

Figure 3.67. 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 extreme cold, heavy snowfall, ice, and strong winds which can push the wind chill well below zero degrees in the planning area. 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.

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

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

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

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.

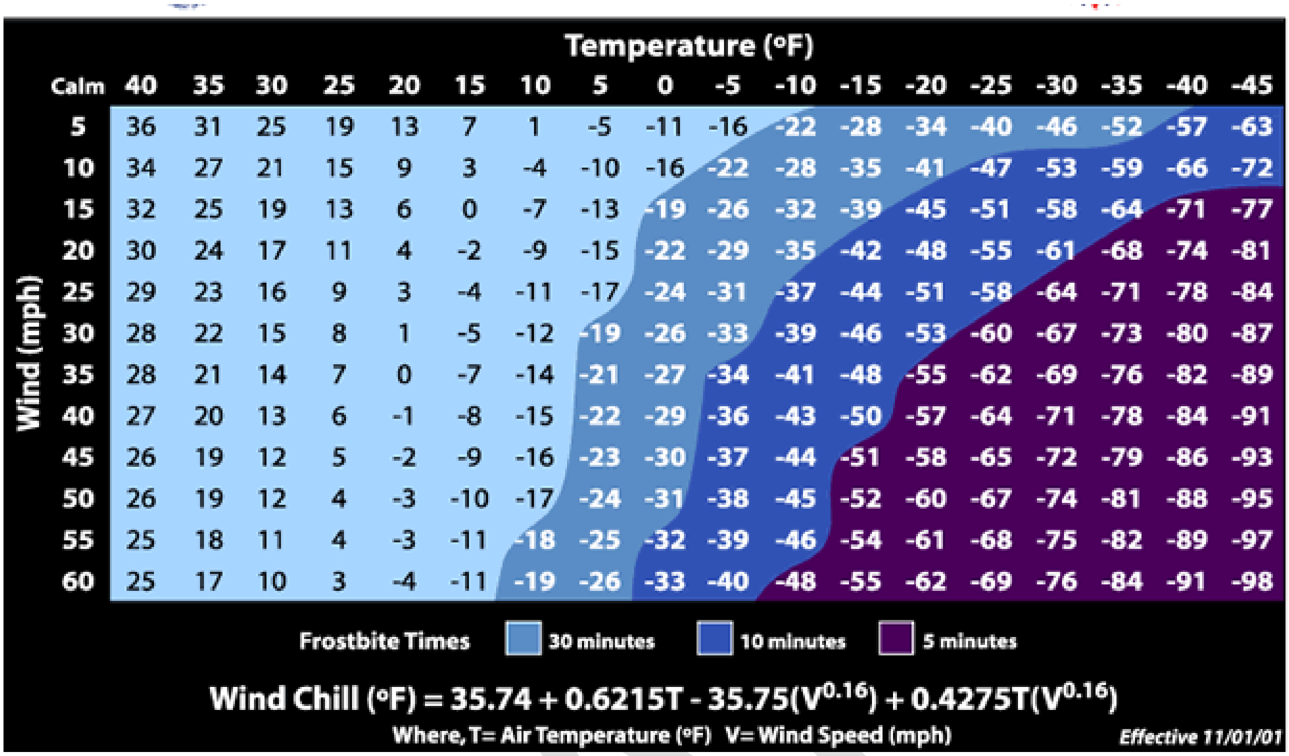
Overhead power lines and infrastructure are also vulnerable to damages from winter storms. In particular, ice accumulation during winter storms can damage power lines and equipment. Damages also occur to lines and equipment from falling trees and tree limbs weighted down by ice. Potential losses could 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.

Wind can greatly amplify the impact of cold ambient air temperatures. Provided by the National Weather Service, **Figure 3.68** below shows the relationship of wind speed to apparent temperature and typical time periods for the onset of frostbite.

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 no claims paid in Pulaski County between 1999 and 2019 for severe winter weather.

Figure 3.68. Wind Chill Chart



Wind (mph) / Temperature (°F): 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: National Weather Service, http://www.nws.noaa.gov/om/winter/windchill.shtml

Previous Occurrences

Data was obtained from the NCEI for winter weather reported events and damages between 1999 and 2019 **(Table 3.81**). This data includes variables such as blizzard, cold/wind chill, extreme cold/wind chill, heavy snow, ice storm, sleet, winter storm, and winter weather. Additionally, narratives for specific events are listed below.

Table 3.81. NCEI County A Winter Weather Events Summary, 1999 - 2019

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Winter Storm	01/01/1999	0	50,000	0
Extreme Cold/Wind Chill	12/12/2000	0	0	0
Heavy Snow	12/12/2000	0	0	0
Ice Storm	12/15/2000	0	0	0
Extreme Cold/Wind Chill	01/01/2001	0	0	0
Ice Storm	12/21/2001	0	0	0
Winter Storm	03/02/2002	0	0	0
Winter Storm	12/04/2002	0	0	0
Winter Storm	12/24/2002	0	0	0

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Winter Storm	02/23/2003	0	0	0
Winter Storm	11/30/2006	0	50,000	0
Winter Storm	01/20/2007	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
Winter Storm	02/20/2015	0	0	0
Winter Storm	02/28/2015	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	12/16/2019	0	0	0
Total	**23**	**0**	**100K**	**0**

Source: NCEI, data accessed [7/27/2020]

Notable Winter Narratives:

1. **01/01/1999:** A band of snow and sleet (in addition to the ice) fell from southwest to central Missouri. Three to six inch amounts occurred in southwest Missouri in the Springfield, Galena, Ozark, and Buffalo areas. Heavier amounts of 5 to 10 inches occurred in central Missouri near the Lake of the Ozarks. The heaviest 8 to 10 inches of snow occurred in Morgan and northern Miller Counties.

2. **12/12/2000 – 12/31/2000:** A major winter storm dropped as much as 14 inches of snow across the Missouri Ozarks on 12/12/2000. Due to the weight of the snowfall, some roofs and carports were damaged along with some minor power outages. The heavy snow was followed by abnormally cold air moving into the Ozarks in the middle of December and this pattern continued through the early part of January. On 12/15/2000 an ice storm added to the accumulation of ice and snow. The combination of deep snow cover and an abnormally strong arctic air mass kept temperatures 10 to 20 degrees below normal.

3. **01/12/2007 – 01/14/2007:** Considered one of the greatest disasters to impact southwest Missouri. Several counties, mainly along and north of I-44 corridor, experienced ice accumulations up to two and a half inches. In Pulaski County there was significant damage to trees and power lines due to one and one half inches of ice over the entire county.

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. Pulaski 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. **01/26/2009 – 01/28/2009:** A significant winter storm brought a combination of freezing

drizzle, freezing rain, sleet and snow to the Missouri Ozarks. A significant accumulation of wintry mix of freezing rain, sleet and snow resulted in treacherous travel conditions. Ice accretion of near one quarter inch or less was followed by one to three inches of sleet and snow.

6. **02/28/2009:** A winter storm brought heavy snowfall to portions of central and south central Missouri. A relatively narrow band of four to eight inch accumulations set up northwest to southeast from the Truman Lake area to the eastern Ozarks. Heavy snow with accumulations of four to seven inches.

7. **02/01/2011:** A major winter storm brought heavy wintry precipitation to the Missouri Ozarks and southeast Kansas on February 1, 2011. Snowfall amounts ranged from around 20 to 24 inches in parts of west central into central Missouri to trace amounts over south central Missouri. In addition to the heavy snowfall, winds of 15 to 30 mph with some gusts near 40 mph occurred during the day and nighttime hours of February 1st creating significant blowing and drifting of snow along with bitterly cold wind chills. This created blizzard conditions with near zero visibility at times and snow drifts up to several feet. Travel was extremely treacherous with some roads impassable.

8. **02/21/2013:** A winter storm brought a mix of snow and sleet accompanied by thunder. Sleet accumulations ranged from one to two inches with snow accumulations ranging from one to two inches.

9. **01/05/2014:** A winter storm brought heavy snow to much of the Missouri Ozarks with accumulations of six to 12 inches generally along and north of I-44. Northwest winds of 20 to 35 mph resulted in significant blowing and drifting snow along with bitterly cold wind chills. Pulaski County had snow accumulations of six to 10 inches.

10. **03/02/2014:** A winter storm impacted the Missouri Ozarks. Precipitation began as a mixture of freezing rain and sleet across much of the region, with rain changing to freezing rain and sleet across far southern Missouri as the storm progressed. Many locations across southern Missouri also saw thunderstorms with reports of thunder sleet. Precipitation changed to snow during the day and as Arctic air mass overspread the area. In Pulaski County sleet accumulations of around ½ inch with snow accumulations of one to two inches.

11. **02/20/2015:** Winter storm brought significant amounts of freezing rain to portions of southeast Missouri with ice accretion up to around one quarter of an inch.

12. **02/28/2015:** Winter storm brough significant snowfall with total snow accumulation of 4 to 6 inches.

13. **01/13/2017:** Up to three quarters of an inch of ice accumulated on elevated objects and tree limbs across the county during the ice storm. There were scattered power outages reported.

14. **01/11/2019:** Rain became mixed with sleet, freezing rain, and snow before changing over to all snow. Main roads became snow covered with several accidents being reported. Total snowfall ranged from 4 to 6 inches across the far northern areas of the county, to 2 inches reported by the COOP observer at Fort Leonard Wood.

15. **02/15/2019:** Widespread 3 to 5 inches of snow fell across the county, with a measured 3.3 inches reported in Dixon and 4.5 inches 2 miles west southwest.

16. **12/16/2019:** Cooperative observer 4 miles north of Fort Leonard Wood reported a storm total of 2.0 inches of snow.

Pulaski County has been included in three federal disaster declarations for ice storms since 2007.[44] Data obtained from the USDA's Risk Management Agency for insured crop losses indicates that there were no claims paid in Pulaski County between 1999 and 2019 for severe winter weather.

Probability of Future Occurrence

From the data obtained from the NCEI [45], annual average percent probabilities were calculated for winter weather within Pulaski County (**Table 3.81)**. There were 23 recorded events (**Table 3.81**) over a 21 year period. There is 100 percent annual average probability of winter weather occurrence (23 events/21 years)**,** with an average of 1.09 events per year.

Table 3.82. Annual Average % Probability of Winter Weather in Pulaski County

Location	Annual Avg. % P	Avg. # of Events
Pulaski County	100%	1.09

*P = probability; see page 3.24 for definition.

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.

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

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 2018 Missouri State Hazard Mitigation Plan for vulnerability information regarding Pulaski 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, 2016)
- HAZUS Building Exposure Value data
- Housing density data from the U.S. Census (2015 ACS)
- 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 3.83 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 ratings was computed for severe winter weather. Those can be seen in **Table 3.84**. The housing density, building exposure and SOVI data for Pulaski County can be found in **Table 3.85**.

Table 3.83. Ranges for Severe Winter Weather Vulnerability Factor Ratings

Factors Considered	Low (1)	Low Medium (2)	Medium (3)	Medium High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2836.23
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Social Vulnerability	1	2	3	4	5
Likelihood of Occurrence (# of events/ yrs. of data)	1.05-1.43	1.44-1.76	1.77-2.10	2.11-2.67	2.68-4.57
Average Annual Property Loss (annual property loss/ yrs. Of data)	$0-$143,095.24	$143,095.25-$406,666.67	$406,666.68-$1,191,000.95	$1,191,000.96-$3,184,761.90	$3,184,761.91-$5,861,666.67

Source: 2018 Missouri Hazard Mitigation Pl

Table 3.84. Ranges for Severe Winter Weather Combined Vulnerability Rating

	Low (1)	Low-medium (2)	Medium (3)	Medium-high-4	High (5)
Severe Winter Weather Combined Vulnerability	7-8	8-10	10-12	12-15	15-22

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.85. Housing Density, Building Exposure and SOVI Data for Pulaski County

Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Rating
$5,344,660,000	2	33.60	1	Low	1

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.86 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 1.29 or 100 percent per year. The total annualized property loss is $406,667, which provides a total annualized property loss rating of two and an overall vulnerability rating of seven – which translates to an overall Low vulnerability rating for the county for severe winter weather.

Table 3.86. Additional Statistical Data Compiled for Vulnerability Analysis for Pulaski County

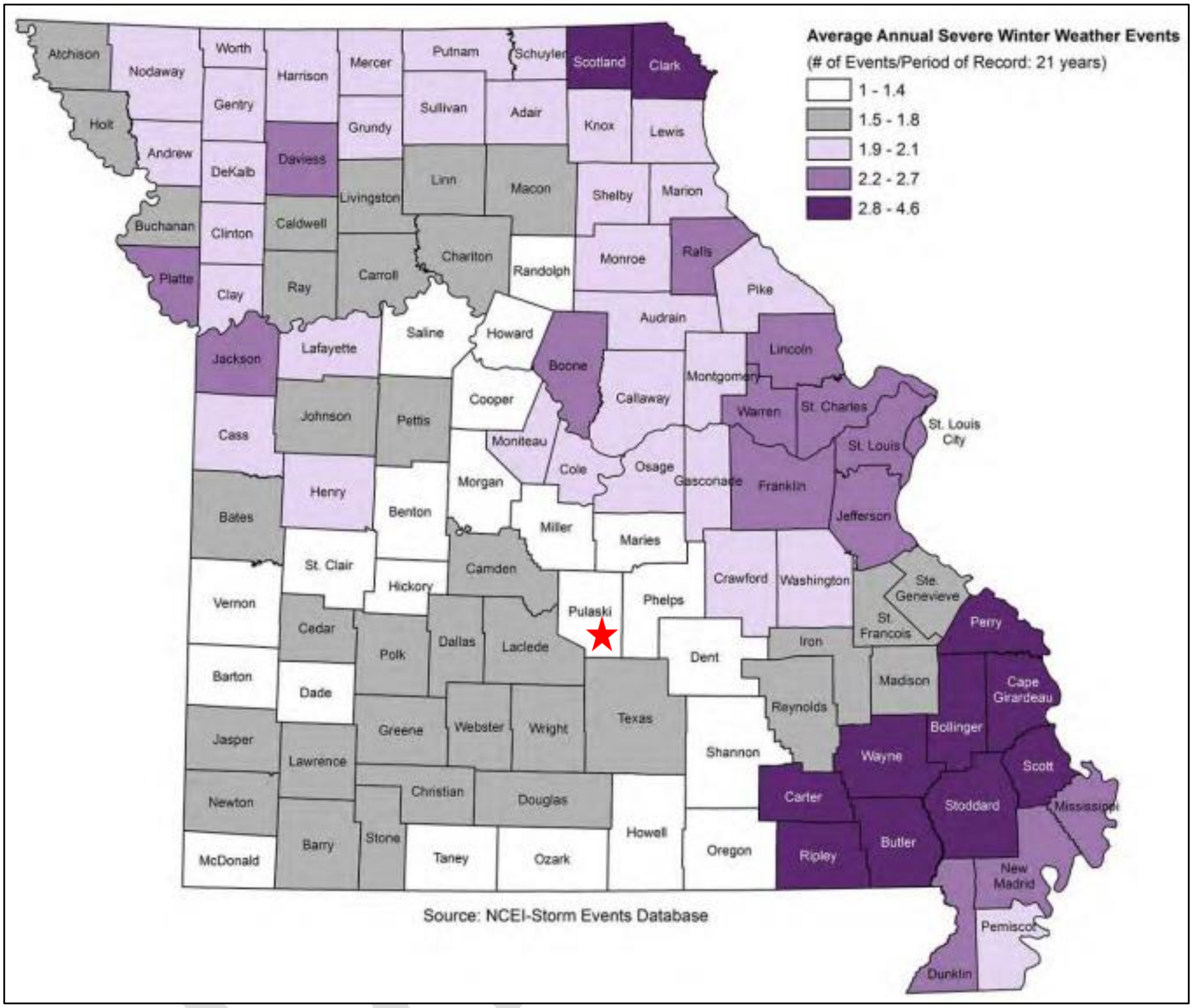
Total number of Winter Weather Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
27	1.2857	1	$406,667	2	7	Low

Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.69 illustrates the average annual occurrence of severe winter weather statewide. Pulaski County falls into the Low category of 1 to 1.4 events per year.

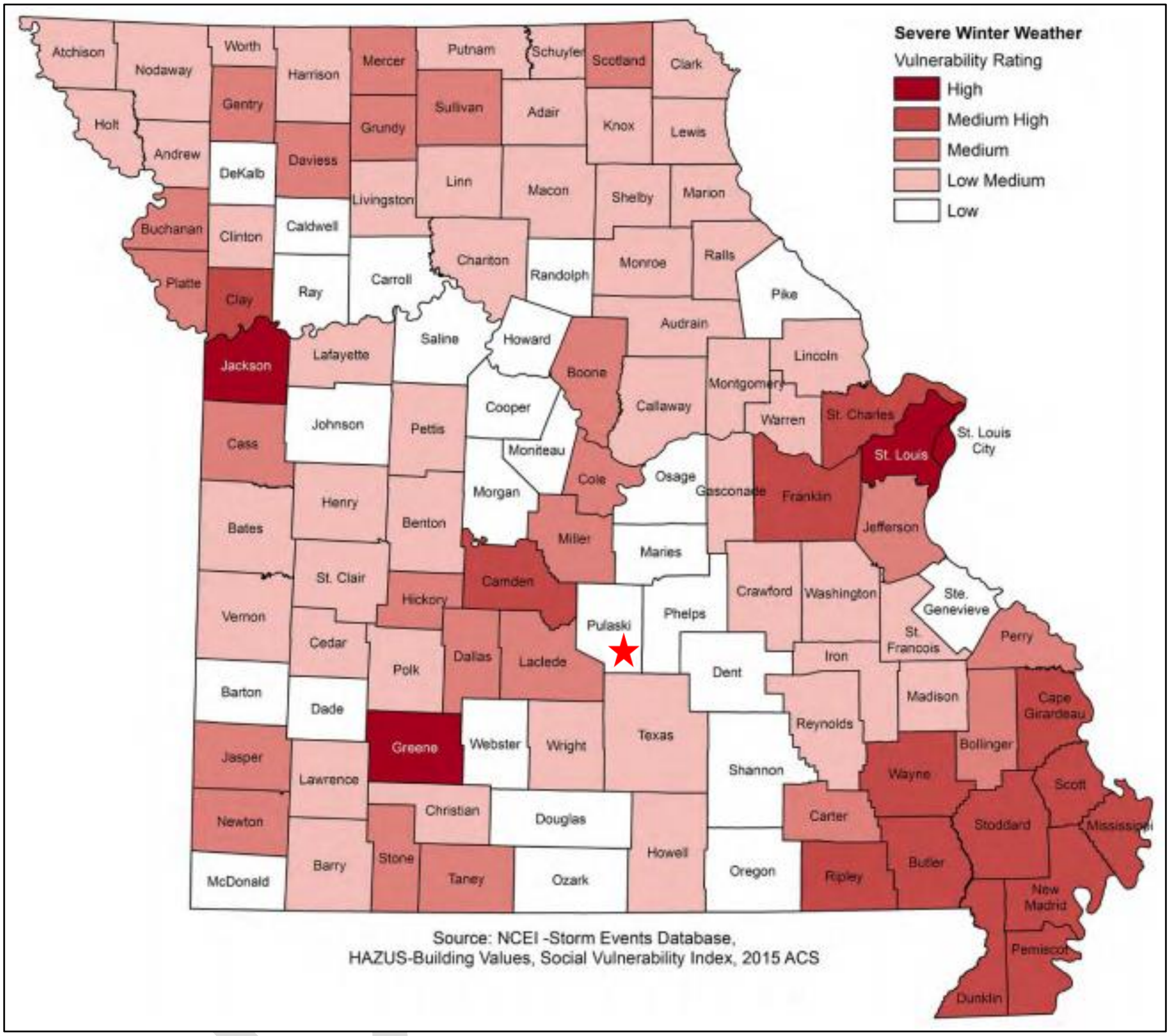
Figure 3.70 provides an illustration of the vulnerability summary of all Missouri counties for severe winter weather. Again, Pulaski County falls into the Low rating for overall vulnerability.

Figure 3.69. Average Annual Occurrence of Severe Winter Weather Events



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Figure 3.70. Vulnerability Summary for Severe Winter Weather



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Pulaski County*

Potential Losses to Existing Development

The next severe winter storm will most likely 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, Pulaski County can expect annual property losses of $406,667 due to severe winter storms.

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 high number of mobile homes tend to experience increased damages. The city of Richland has the highest abundance of mobile homes, making the area more prone to increase exposure to damage. 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, Pulaski 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 preparing for power outages.