3 RISK ASSESSMENT

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

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

This chapter is divided into four main parts:

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

3.1 HAZARD IDENTIFICATION

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

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

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

3.1.1 Review of Existing Mitigation Plans

The MPC previously developed a multi-jurisdiction Hazard Mitigation Plan dated 2015 and Audrain County, Mexico, Vandalia, Laddonia, Farber, Martinsburg, Benton City, Mexico 59 School District, Van Far R-I School District and Community R-VI School District participated in the multi-jurisdictional county wide-plan. The 2015 Hazard Mitigation Plan was consulted in development of the risk assessment and information included and updated where appropriate.

The MPC decided to include only natural hazards, as only natural hazards are required by federal regulation to be included. The human-caused and technological hazards were eliminated from further analysis due to these hazards are not necessary for plans to meet the requirements of the Disaster Mitigation Act of 2000.

3.1.2 Review Disaster Declaration History

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

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

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

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
439	Severe Storms & Flooding	6/10/1974	IA, PA
3017	Drought	9/24/1976	PA
995	Severe Storms & Flooding	6/10/1993-10/25/1993	IA, PA
1403	Severe Winter Ice Storm	1/29/2002-2/13/2002	IA, PA
1463	Severe Storms, Tornadoes, and Flooding	5/4/2003-5/30/2003	IA, PA
3232	Hurricane Katrina Evacuation	8/29/2005/-10/1/2005	PA
1736	Severe Winter Storms	12/6/2007-12/15/2007	PA
3281	Severe Winter Storms	12/8/2007-12/15/2007	PA
1749	Severe Storms and Flooding	3/17/2008-5/9/2008	IA, PA
1773	Severe Storms and Flooding	6/1/2008-8/13/2008	IA, PA
1809	Severe Storms, Flooding, and a Tornado	9/11/2008-9/24/2008	PA
3303	Severe Winter Storm	1/26/2009-1/28/2009	PA
3317	Severe Winter Storm	1/31/2011-2/5/2011	PA
1961	Severe Winter Storm and Snowstorm	1/31/2011-2/5/2011	PA
4238	Severe Storms, Tornadoes, Straight-Line Winds, Flooding	5/15/2015-7/27/2015	PA
3374	Severe Storms, Tornadoes, Straight-Line Winds, Flooding	12/22/2015-1/9/2016	PA

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

3.1.3 Research Additional Sources

The list below is additional sources of data utilized for the hazards in the planning area:

- Missouri Hazard Mitigation Plans (2010, 2013, and 2018)
- Previously approved planning area Hazard Mitigation Plan
- Federal Emergency Management Agency (FEMA)
- Missouri Department of Natural Resources
- National Drought Mitigation Center Drought Reporter
- US Department of Agriculture's (USDA) Risk Management Agency Crop Insurance Statistics
- National Agricultural Statistics Service (Agriculture production/losses)
- Data Collection Questionnaires completed by each jurisdiction
- State of Missouri GIS data
- Environmental Protection Agency
- Flood Insurance Administration
- Hazards US (Hazus)
- Missouri Department of Transportation
- Missouri Division of Fire Marshal Safety
- Missouri Public Service Commission
- National Fire Incident Reporting System (NFIRS)
- National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI);
- County and local Comprehensive Plans to the extent available
- County Emergency Management
- County Flood Insurance Rate Map, FEMA
- Flood Insurance Study, FEMA
- SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin
- U.S. Army Corps of Engineers
- U.S. Department of Transportation
- United States Geological Survey (USGS)
- Various articles and publications available on the internet (you should state that you will give citations to the sources in the body of the plan)

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

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

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

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

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

3.1.4 Hazards Identified

Table 3.2. **Hazards Identified for Each Jurisdiction**

Jurisdiction	Dam Failure	Drought	Earthquake	Extreme Temperatures	Flooding (River and Flash)	Land Subsidence/Sinkholes	Severe Winter Weather	Thunderstorm/Lightning/Hail/ High Wind	Tornado	Wildfire
Audrain County	x	x	x	x	x	x	x	x	x	x
Laddonia	x	x	x	x	x	x	x	x	x	x
Mexico	X	X	X	X	X	X	X	X	X	X
Vandalia	X	X	X	X	X	X	X	X	X	X
Community R-VI School District		X	X	X			X	X	X	

3.1.5 Multi-Jurisdictional Risk Assessment

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

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

3.2 ASSETS AT RISK

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

3.2.1 Total Exposure of Population and Structures

Unincorporated County and Incorporated Cities

In the following three tables, population data is based on 2017 American Community Survey. Building counts and building exposure values are based on parcel data provided by the State of Missouri Geographic Information Systems (GIS) database which can be obtained directly from the SEMA Mitigation Management Section. Contents exposure values was not available for the jurisdictions. Land values have been purposely excluded from consideration because land remains following disasters, and subsequent market devaluations are frequently short term and difficult to quantify. Another reason for excluding land values is that state and federal disaster assistance programs generally do not address loss of land (other than crop insurance). It should be noted that the total valuation of buildings is based on county assessors' data which may not be current. In addition, government-owned properties are usually taxed differently or not at all, and so may not be an accurate representation of true value. Note that public school district assets and special districts assets are included in the total exposure tables assets by community and county.

Table 3.3 shows the total population, building count (where available), estimated value of buildings (where available), estimated total exposure to parcels for the unincorporated county and each incorporated city (where available).

Table 3.3. **Maximum Population and Building Exposure by Jurisdiction**

Jurisdiction	2017 Annual Population Estimate	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Laddonia	603	-	Not available	Not available	Not available
Mexico	11,528	-	Not available	Not available	Not available
Vandalia	4,201	-	Not available	Not available	Not available
Audrain County	25,763	25,592	$2,689,090	Not available	$2,689,090
Totals	42,095	-	$2,689,090	-	$2,689,090

Source: U.S. Bureau of the Census, Annual population estimates/ 5-Year American Community Survey 2017; Building Count and Building Exposure, Missouri GIS Database from SEMA Mitigation Management; Contents Exposure was not available for the jurisdictions.

Table 3.4 Population and Building Exposure by Jurisdiction-Public School Districts

Public School District	Enrollment	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Community R-VI School District	315	2	$18,192,630	-	$18,192.630

Source: http://mcds.dese.mo.gov/quickfacts/Pages/District-and-School-Information.aspx.

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

- 2018 Missouri State Hazard Mitigation Plan and Hazard Mitigation Viewer http://bit.ly/MoHazardMitigationPlanViewer2018
- Mark Twain Regional Council of Governments list of critical facility inventory.
- Hazus contains an inventory of critical facilities that can be exported for each jurisdiction.

The “x”s in Table 3.5 indicates the critical/essential facilities and infrastructure is present in the jurisdiction marked with an “x”. For example each jurisdiction has an “x” in Highway Bridge this indicates there is a Highway Bridge in every jurisdictions. The “x” does not represent the number of facilities or infrastructure in the jurisdiction.

Table 3.5 Inventory of Critical/Essential Facilities and Infrastructure by Jurisdiction

Jurisdiction	Airport Facility	Bus Facility	Childcare Facility	Communications Tower	Electric Power Facility	Emergency Operations	Fire Service	Government	Housing	Shelters	Highway Bridge	Hospital/Health Care	Military	Natural Gas Facility	Nursing Homes	Police Station	Potable Water Facility	Rail	Sanitary Pump Stations	School Facilities	Stormwater Pump Stations	Tier II Chemical Facility	Wastewater Facility	TOTAL
Laddonia	-	-	-	-	-	-	X	-	X	-	X	-	-	X	-	-	-	X	-	-	-	-	X	6
Mexico	-	-	X	X	X	X	X	X	X	X	X	X	-	X	X	X	X	X	X	X	-	-	X	18
Vandalia	-		X	X	X	X	X	X	X	X	X	X	-	X	X	X	X	X	X	X	-	-	X	18
Audrain County	X	-	X	X	X	X	X	X	-	X	X	X	-	X	X	-	-	X	-	X	-	-	-	14
Totals	1	-	3	3	3	3	4	3	3	3	4	3	-	4	3	2	2	4	2	3	-	-	3	56

Source: Missouri 2018 State Hazard Mitigation Plan and Hazard Mitigation Viewer; Data Collection Questionnaires; Hazus, etc.

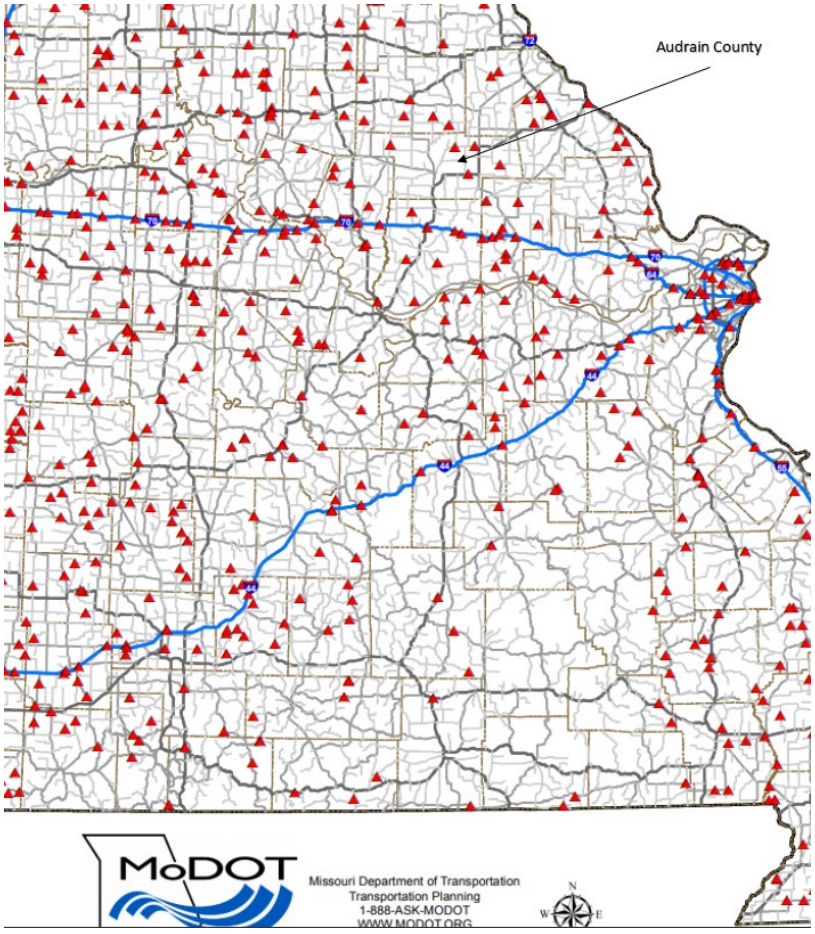
Missouri bridges are rated based on the National Bridge Inspection Standards developed by the Federal Highway Administration. Figure 3.1 indicates there are 308 bridges in Audrain County with 165 in good condition, 131 in fair condition, and 12 in poor condition according to 2017 data obtained. Figure 3.2 indicates the bridges in Audrain County with a poor rating.

Figure 3.1. Audrain County Bridges

County	Bridge Counts					Bridge Area (Square Meters)				
	All	Good	Fair	Poor	SD	All	Good	Fair	Poor	SD
AUDRAIN (007)	308	165	131	12	15	59,952	36,845	20,708	2,399	2,950

Source: http://www.fhwa.dot.gov/bridge/nbi/no10/county.cfm

Figure 3.2. Audrain County Bridges with a Poor Rating



Source: https://www.modot.org/Bridges

3.2.3 Other Assets

Table 3.6 shows the Threatened and Endangered Species in Audrain County.

Table 3.6 Threatened and Endangered Species in Audrain County

Common Name	Scientific Name	Status
Gray Bat	Myotis grisescens	Endangered
Indiana Bat	Myotis sodalist	Endangered
Northern Long-eared Bat	Myotis septentrionalis	Threatened
Running Buffalo Clover	Trifolium stoloniferum	Endangered

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

Natural Resources: Audrain County has eleven conservation and Recreation areas. The Missouri Department of Conservation (MDC) provides a database of lands the MDC owns, leases or manages for public use. **Table 3.7** provides the names and locations of parks and conservation areas in the planning area.

Table 3.7 Parks in Audrain County

Park / Conservation Area	Address	City
Diggs (Marshall I) CA	From Wellsville, take Route ZZ west 3 miles, then Route RA west 0.50 mile.	Martinsburg
Jacks (Maude Shores) CA	From Centralia, take Highway 22 west 7 miles, then Route Y north 4 miles, then County Road 132 west 1 mile to junction with County Road 173.	Audrain County
Lowe (William) CA	From Mexico, take Business Highway 54 south, then Teal Lake Road east 0.50 mile to the area.	Mexico
Mexico (Kiwanis Lake)	From intersection of Highway 54 and I-70, go north on Highway 54 to Mexico. Take the first Mexico exit and go west (left) on 54/Clark. Take Clark to Hendricks Drive, then west (left) on Hendricks about 0.25 mile to Plunkett Park.	Audrain County
Mexico (Lakeview Park Lake)	From the junction of Highway 54 and I-70, take Highway 54 north, take the first Mexico exit and proceed north on 54/Clark about 1 mile to Lakeview Road.	Mexico
Mexico (Northeast Park)	From the junction of Highway 54 and I-70, take Highway 54 north, take the first Mexico exit and turn west (left) on 54/Clark. Take Clark to Grand and Grand north to Anderson.	Mexico
Mexico (Teal Lake)	From Highway 54 at Mexico, exit at Business 54/Clark and go north to Teal Lake Road and head east to the lake.	Mexico

Northcutt (Clarence L) Mem CA	From Mexico, take Highway 22 west 5.50 miles, take Route E north 1.75 miles, then County Road 214 west 0.25 mile.	Mexico
Sears (F O and Leda J) Mem WA	From Rush Hill, take Route B north 3.50 miles.	Rush Hill
Vandalia CL	From Laddonia take Route K east 4 miles and then County Road 524 east 2 miles. From Vandalia take Route W south for 4 miles and County Road 524 west 2 miles.	Vandalia
White (Robert M II) CA	From Mexico, take Highway 15 north 8 miles, then Route Z east 2 miles, and Route ZZ east 2 miles.	Mexico

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

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 3.8 Audrain County Properties on the National Register of Historic Places

Property	Address	City	Date Listed
Audrain County Courthouse	101 N. Jefferson St	Mexico	7/25/2012
Lincoln School	301 Lincoln St	Vandalia	2/16/1998
Ross House	501 S Muldrow St	Mexico	7/26/1978
Simmons, Arthur, Stables Historic District	621 and 701 W. Blvd	Mexico	12/04/2004

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

Economic Resources: **Table 3.9** provides major Non-Government employers in the planning area.

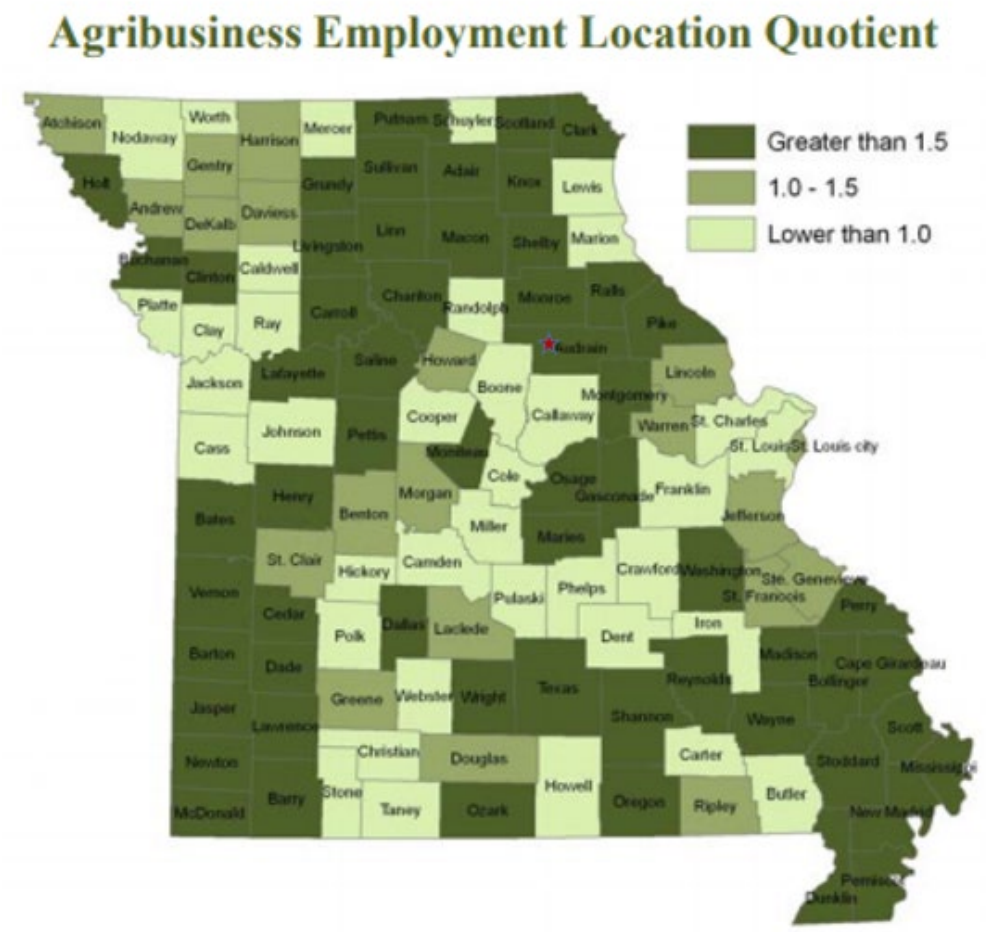
Table 3.9 Major Non-Government Employers in Audrain County

Employer Name	Main Locations	Product or Service	Employees
County Market	U.S. 54, Vandalia	Grocery Store	44
Target Aluminum	800 W. State St, Vandalia		24
Harbison-Walker Refractories	1000 Booker St, Vandalia, MO		200
Tri-County Nursing Home	601 N. Galloway Rd, Vandalia, MO	Nursing Home	127
Eastern Women's Correctional Center	1101 US-54, Vandalia, MO	Correctional Center	375-400

Source: Data Collection Questionnaires; local Economic Development Commissions

Agriculture- Agriculture plays an important role in the Audrain County economy, explain. As described in **Figure 3.3**, Audrain County is greater than 1.5 in Agribusiness Employment.

Figure 3.3. Agribusiness Employment Location Quotient



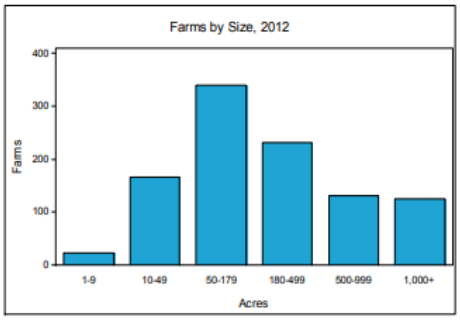
Source: https://www.missourieconomy.org/pdfs/missouri_farms_and_agribusiness.pdf

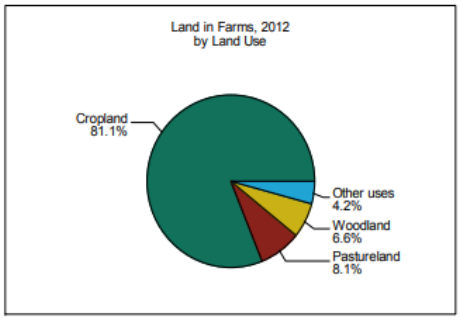
Figure 3.4. 2012 Census of Agriculture

2012 CENSUS OF AGRICULTURE
COUNTY PROFILE

Audrain County
Missouri

	2012	2007	% change
Number of Farms	1,015	1,102	- 8
Land in Farms	436,483 acres	424,880 acres	+ 3
Average Size of Farm	430 acres	386 acres	+ 11
Market Value of Products Sold	$151,194,000	$136,611,000	+ 11
Crop Sales $89,658,000 (59 percent) Livestock Sales $61,536,000 (41 percent)			
Average Per Farm	$148,960	$123,967	+ 20
Government Payments	$5,605,000	$6,482,000	- 14
Average Per Farm Receiving Payments	$8,366	$9,053	- 8





Source: https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/County_Profiles/Missouri/cp29007.pdf

Audrain County – Missouri

Ranked items among the 114 state counties and 3,079 U.S. counties, 2012

Item	Quantity	State Rank	Universe [1]	U.S. Rank	Universe [1]
MARKET VALUE OF AGRICULTURAL PRODUCTS SOLD ($1,000)					
Total value of agricultural products sold	151,194	16	114	781	3,077
Value of crops including nursery and greenhouse	89,658	14	114	722	3,072
Value of livestock, poultry, and their products	61,536	19	114	769	3,076
VALUE OF SALES BY COMMODITY GROUP ($1,000)					
Grains, oilseeds, dry beans, and dry peas	88,259	13	114	542	2,926
Tobacco	-	-	12	-	436
Cotton and cottonseed	-	-	7	-	635
Vegetables, melons, potatoes, and sweet potatoes	222	37	109	1,464	2,802
Fruits, tree nuts, and berries	(D)	38	107	(D)	2,724
Nursery, greenhouse, floriculture, and sod	282	48	107	1,631	2,678
Cut Christmas trees and short rotation woody crops	(D)	39	55	(D)	1,530
Other crops and hay	791	99	113	2,105	3,049
Poultry and eggs	88	48	113	1,440	3,013
Cattle and calves	32,807	9	114	477	3,056
Milk from cows	2,344	28	96	977	2,038
Hogs and pigs	25,773	9	109	222	2,827
Sheep, goats, wool, mohair, and milk	276	16	110	606	2,988
Horses, ponies, mules, burros, and donkeys	224	35	114	1,148	3,011
Aquaculture	(D)	38	46	1,161	1,366
Other animals and other animal products	(D)	(D)	114	(D)	2,924
TOP CROP ITEMS (acres)					
Soybeans for beans	170,815	1	111	37	2,162
Corn for grain	117,379	2	108	221	2,638
Wheat for grain, all	19,857	10	108	465	2,537
Winter wheat for grain	19,857	10	108	372	2,480
Forage-land used for all hay and haylage, grass silage, and greenchop	19,506	77	114	998	3,057
TOP LIVESTOCK INVENTORY ITEMS (number)					
Hogs and pigs	55,182	9	108	270	2,889
Cattle and calves	32,227	50	114	892	3,063
Layers	3,963	27	113	902	3,040
Sheep and lambs	2,219	8	109	414	2,897
Broilers and other meat-type chickens	1,584	25	109	818	2,723

Other County Highlights, 2012

Economic Characteristics	Quantity
Farms by value of sales:	
Less than $1,000	190
$1,000 to $2,499	49
$2,500 to $4,999	54
$5,000 to $9,999	91
$10,000 to $19,999	80
$20,000 to $24,999	35
$25,000 to $39,999	69
$40,000 to $49,999	63
$50,000 to $99,999	116
$100,000 to $249,999	141
$250,000 to $499,999	73
$500,000 or more	54
Total farm production expenses ($1,000)	156,313
Average per farm ($)	154,003
Net cash farm income of operation ($1,000)	37,461
Average per farm ($)	36,907

Operator Characteristics	Quantity
Principal operators by primary occupation:	
Farming	566
Other	449
Principal operators by sex:	
Male	933
Female	82
Average age of principal operator (years)	57.8
All operators by race [2]:	
American Indian or Alaska Native	4
Asian	-
Black or African American	4
Native Hawaiian or Other Pacific Islander	-
White	1,529
More than one race	4
All operators of Spanish, Hispanic, or Latino Origin [2]	2

See "Census of Agriculture, Volume 1, Geographic Area Series" for complete footnotes, explanations, definitions, and methodology.
- Represents zero. (D) Withheld to avoid disclosing data for individual operations.
[1] Universe is number of counties in state or U.S. with item. [2] Data were collected for a maximum of three operators per farm.

Source: https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/County_Profiles/Missouri/cp29007.pdf

3.3 LAND USE AND DEVELOPMENT

3.3.1 Development Since Previous Plan Update

According to the data questionnaire there has been growth throughout the Mexico jurisdiction and minimal growth in the unincorporated area of Audrain County. Growth in an area increases risk for the planning area as there can be more structural damage to the planning area.

The U.S. Census Bureau shows Audrain County is expected to have grown by .92% since the last census was performed. **Table 3.10** provides the population growth statistics for all cities in Audrain County as well as the county as a whole. Population statistics represent the 2010 U.S. Census and American Community Survey 5-year estimates.

Table 3.10 County Population Growth, 2010-2017

Jurisdiction	Total Population 2010	Total Population 2017	2010-2017 # Change	2000-2017 % Change
Audrain County	25,529	25,763	+234	+.92%
Laddonia	513	603	+90	+17.54%
Mexico	11,543	11,528	-15	-.13%
Vandalia	3,899	4,201	-302	-7.75%

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

Population growth or decline is generally accompanied by increases or decreases in the number of housing units. All jurisdictions in Audrain County have shown an increase in housing. Overall there has been a .18% increase in housing in the Audrain County area as reflected in Table 3.11.

Table 3.11 Change in Housing Units, 2010-2017

Jurisdiction	Housing Units 2010	Housing Units 2017	2010-2017 # Change	2000-2017 % Change
Audrain County	10,852	10,872	+20	+0.18%
Laddonia	274	301	+27	+9.85%
Mexico	5,272	5,359	+87	+1.65%
Vandalia	1,295	1,358	+63	+4.86%

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

U.S. Census information is compiled every 10 years, with the last Census completed in 2010 estimates were used for the above data. According to American Fact Finder estimates show that in 2017 number of Housing units are expected to increase in all jurisdictions within Audrain County. Vulnerability to hazards will be affected based on population, and where new housing units have been built. Vulnerability is expected to increase as housing increases in the jurisdictions.

3.3.2 Future Land Use and Development

Participating Jurisdictions and School District's Future Development

According to the Data Collection Questionnaire, Mexico is expected to see future development and the with minimal growth in the unincorporated area of the County. Vandalia and Laddonia is not expecting future development. There is no anticipated future development for schools within the planning area. As development occurs in Mexico the vulnerability for the City will increase.

3.4 HAZARD PROFILES, VULNERABILITY, AND PROBLEM STATEMENTS

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

Hazard Profiles

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

Each hazard identified in Section **3.1.4** will be profiled individually in this section. Levee failure was removed as an identified hazard due to there was not a participating jurisdiction affected by levee failure. The level of information presented in the profiles will vary by hazard based on the information available. With each update of this plan, new information will be incorporated to provide better evaluation and prioritization of the hazards that affect the planning area. Detailed profiles for each of the identified hazards include information categorized as follows:

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

Vulnerability Assessments

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

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

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

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

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

Following the hazard profile for each hazard will be the vulnerability assessment. The vulnerability assessment further defines and quantifies populations, buildings, critical facilities, and other community assets at risk to damages from natural hazards. The vulnerability assessments should be based on the best available data. The vulnerability assessments can also be based on data that was collected for the 2018 State Hazard Mitigation Plan Update. 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, including the independent City of St. Louis. Through the web-based Missouri Hazard Mitigation Viewer, local planners or other interested parties can obtain all State Plan datasets. This effort removes from local mitigation planners a barrier to performing all the needed local risk assessments by providing the data developed during the 2018 State Plan Update.

The Missouri Hazard Mitigation Viewer includes a Map Viewer with a legend of clearly labeled features, a north arrow, a base map that is either aerial imagery or a street map, risk assessment data symbolized the same as in the 2018 State Plan for easy reference, search and query capabilities, ability to zoom to county level data and capability to download PDF format maps. The Missouri Hazard Mitigation Viewer can be found at this link: http://bit.ly/MoHazardMitigationPlanViewer2018.

The vulnerability assessments in the Audrain 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:** An overview summary an overall summary of each jurisdiction's vulnerability to the identified hazards. The overall summary of vulnerability identifies structures, systems, populations or other community assets as defined by the community that are susceptible to damage and loss for hazard events.

- **Potential Losses to Existing Development:** For each participating jurisdiction, the plan will describe the potential impacts of the hazard. Impact refers to the consequences of effect of the hazard on the jurisdiction and its assets. Assets are determined by the community and may include people, structures, facilities, systems, capabilities, and/or activities that have value to the community.

- **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.

- **Hazard Summary by Jurisdiction:** For hazard risks that vary by jurisdiction, this section will provide an overview of the variation and the factual basis for that variation.

Problem Statements

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

3.4.1 Flooding (Riverine and Flash)

Hazard Profiles

Hazard Description

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

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

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

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

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

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

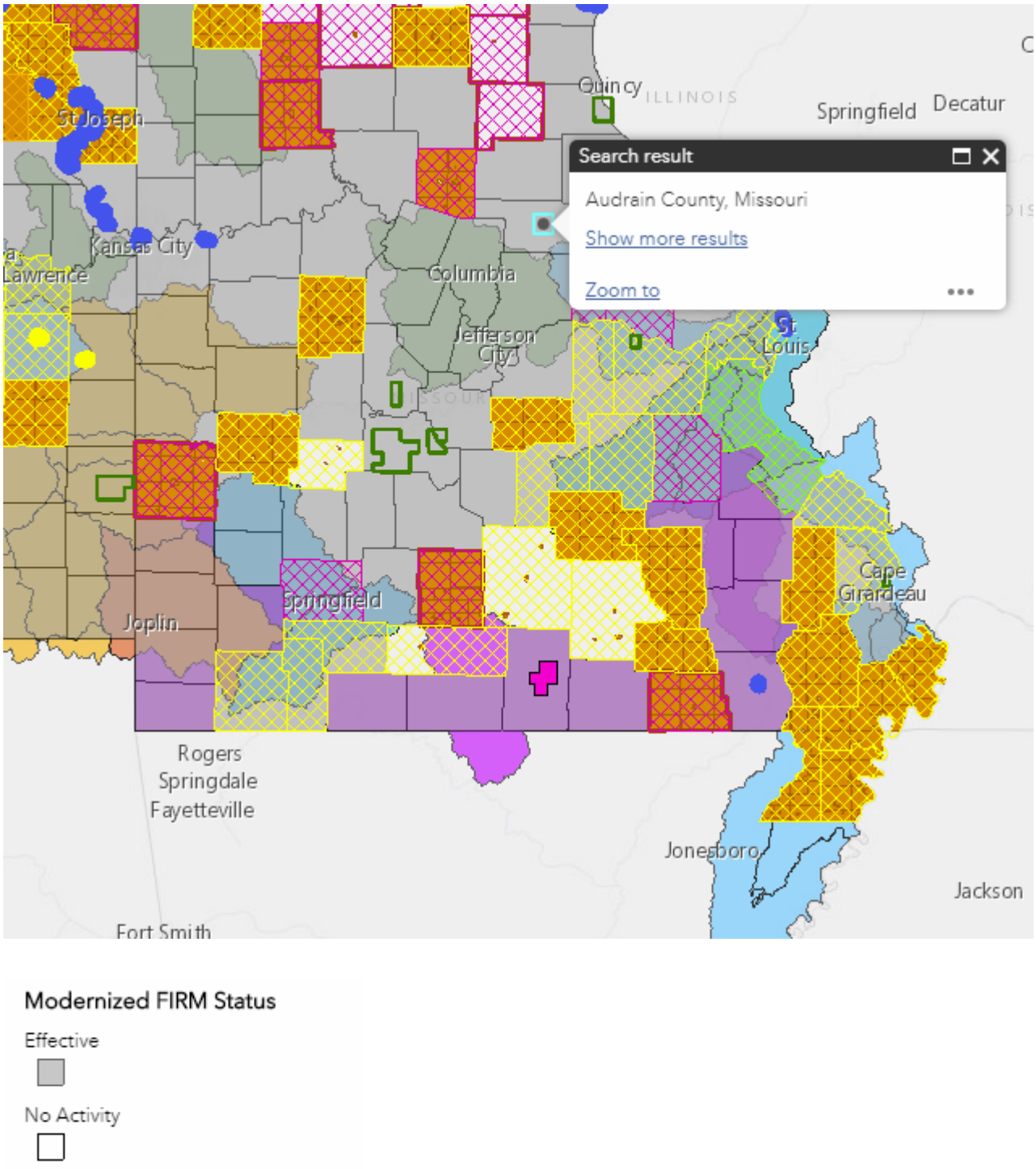
In certain areas, aging storm sewer systems are not designed to carry the capacity currently needed to handle the increased storm runoff. Typically, the result is water backing into basements, which damages mechanical systems and can create serious public health and safety concerns. This combined with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

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

Geographic Location

Riverine flooding is most likely to occur in (Special Flood Hazard Areas) SFHAs. Below is a Risk MAP Study Status Map. There are several areas in the unincorporated county at risk for river flooding.

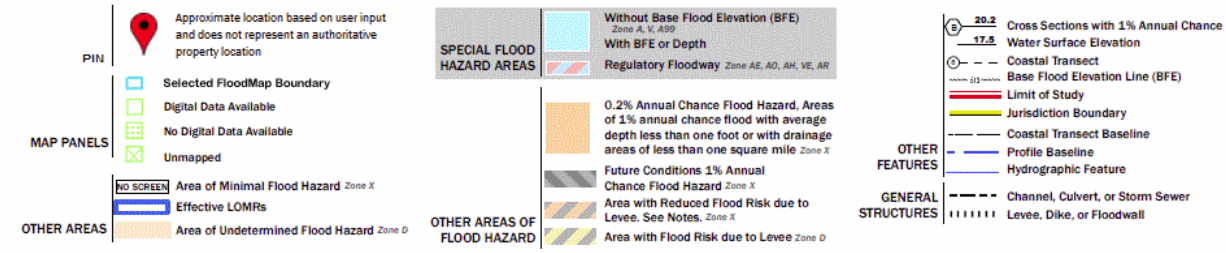
Figure 3.5. Risk MAP Study Status Map



Source: http://fema.maps.arcgis.com/apps/webappviewer/index.html?id=48cfac9a9ffb4003b565aaccf464d0ac

Figure 3.6.

Key:



Source: FEMA Map Service Center; https://msc.fema.gov/portal/home

The following are flood hazard maps for all jurisdictions to fully reflect the flooding hazard for Audrain County.

Figure 3.7. Village of Benton City

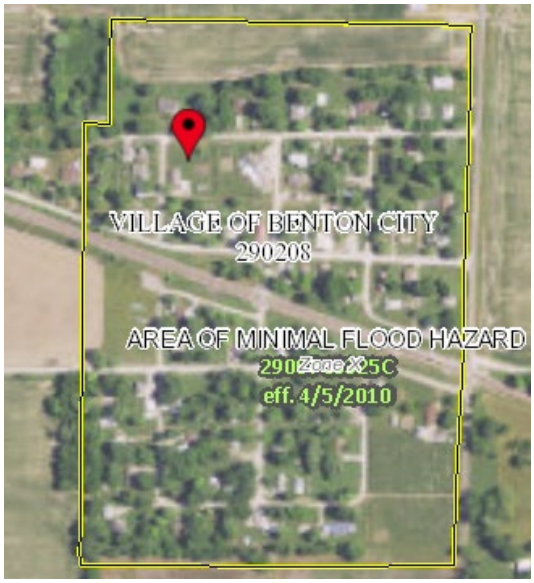


Figure 3.8. City of Farber

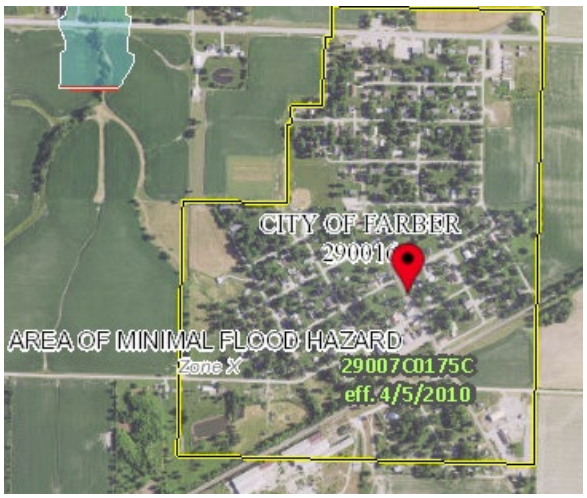


Figure 3.9. City of Laddonia

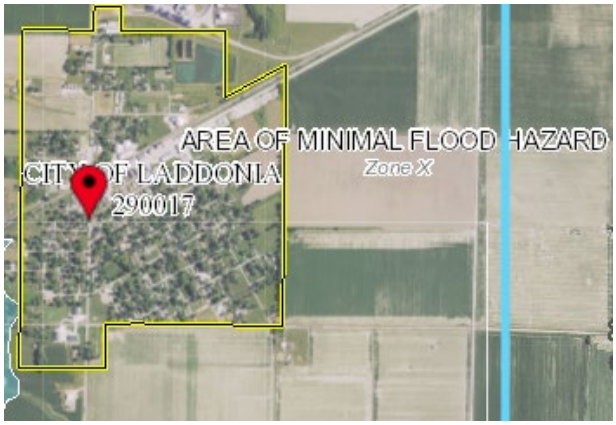


Figure 3.10. Town of Martinsburg

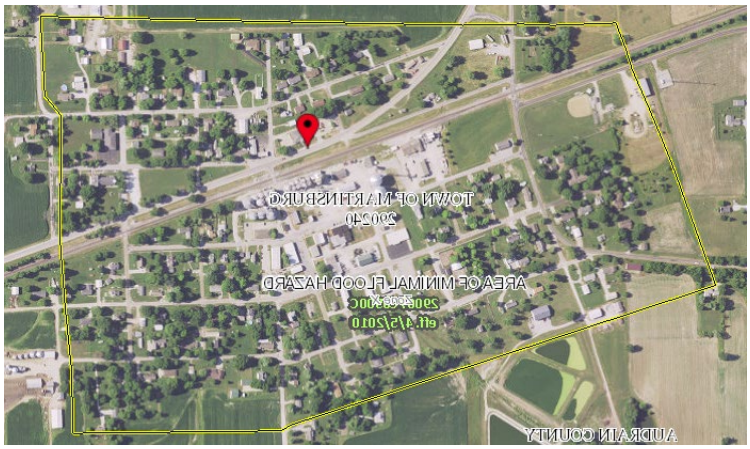


Figure 3.11. City of Mexico

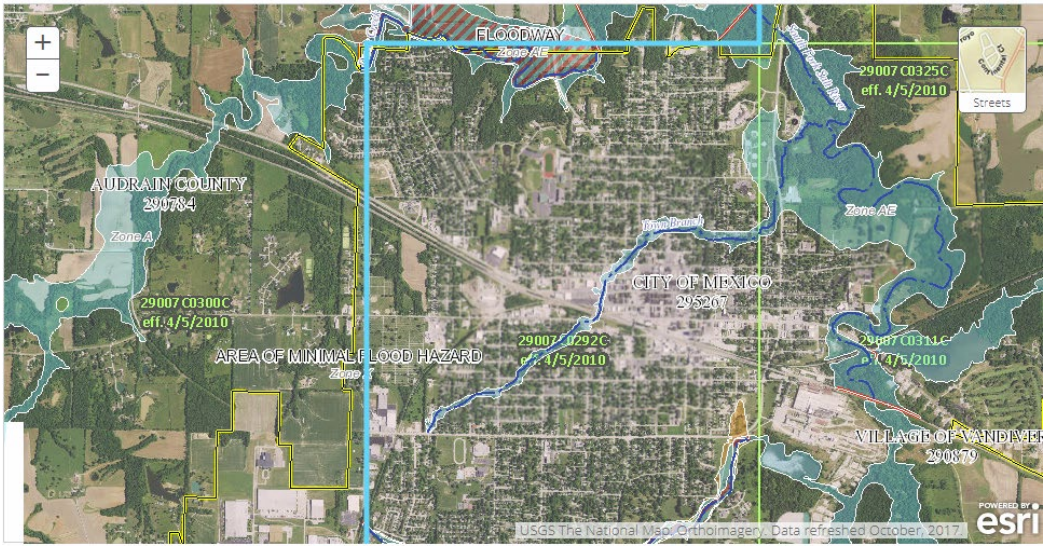


Figure 3.12. City of Vandalia

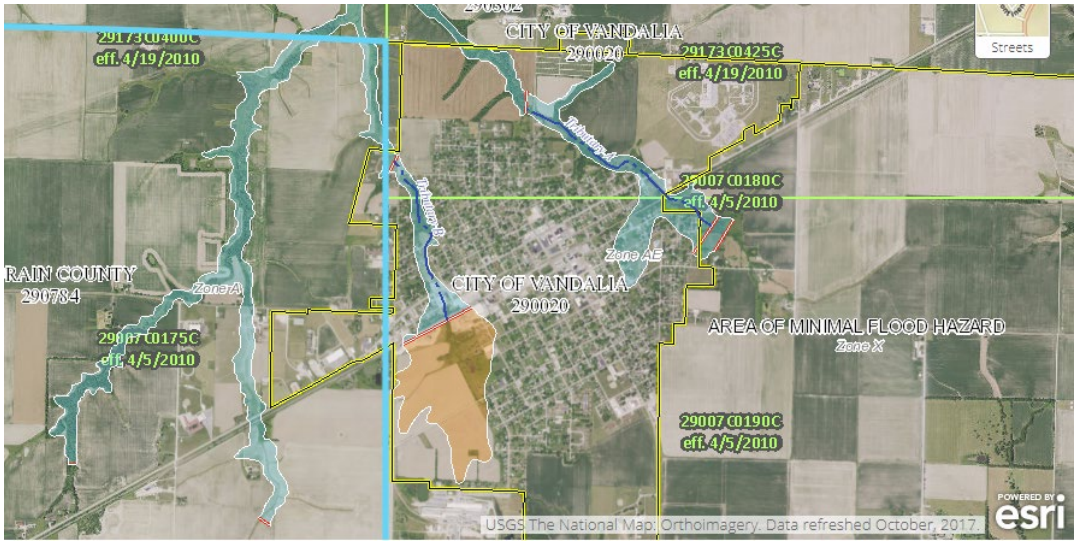


Figure 3.13. Village of Rush Hill

Figure 3.14. Vandiver Village

Figure 3.15. Mexico 59 School District

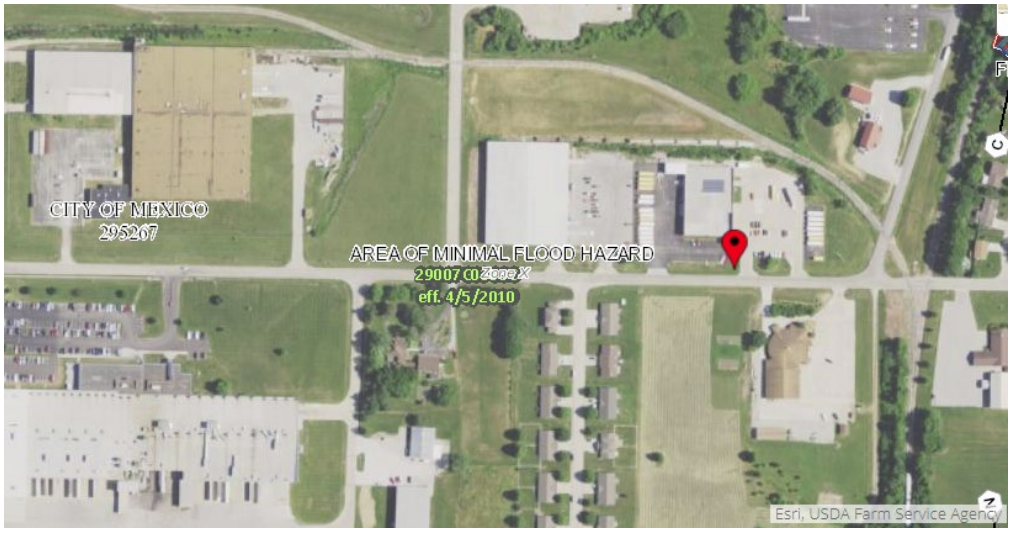


Figure 3.16. Van-Far R-1 School District

Figure 3.17. Community R-VI School District

Source: FEMA Map Service Center; https://msc.fema.gov/portal/home

Table 3.12 Audrain County NCEI Flood Events by Location, 1998-2018

Location	# of Events
Unincorporated Audrain County	5
-Unincorporated Audrain County (unspecified)-3 flood events	
-Unincorporated Audrain County- Bassinger Corner- 1 flood events	
Martinsburg	1

Source: National Centers for Environmental Information, February 14, 2019

Flash flooding occurs in SFHAs and those locations in the planning area that are low-lying. They also occur in areas without adequate drainage to carry away the amount of water that falls during intense rainfall events. NCEI database was used to determine which jurisdictions are most prone to flash flooding during a 20-year time period. **Table 3.12** shows the number of flash flood events by location recorded in NCEI for the 20-year period.

Table 3.13. **Audrain County NCEI Flash Flood Events by Location, 1998-2018**

Location	# of Events
Unincorporated Audrain County	27
-Unincorporated Audrain County (unspecified)- 0 flood events	
-Unincorporated Audrain County- West Portion- 2 flood events	
-Unincorporated Audrain County- Mexico- 2 flood events	
-Unincorporated Audrain County- East Portion- 1 flood events	
-Unincorporated Audrain County- Thompson- 3 flood events	
-Unincorporated Audrain County- Carroll- 1 flood events	
-Unincorporated Audrain County- Skinner- 3 flood events	
-Unincorporated Audrain County- Worchester- 1 flood events	
-Unincorporated Audrain County- Vandalia Airport- 1 flood events	
-Unincorporated Audrain County- Bassinger Corner- 2 flood events	
-Unincorporated Audrain County- Rowena- 2 flood events	
-Unincorporated Audrain County- Littleby- 1 flood events	
Laddonia	1
Vandalia	1

Source: National Centers for Environmental Information, February 14, 2019

Strength/Magnitude/Extent

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

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

National Flood Insurance Program (NFIP) Participation

Table 3.14. **NFIP Participation in Audrain County**

Community ID #	Community Name	NFIP Participant (Y/N/Sanctioned)	Current Effective Map Date	Regular-Emergency Program Entry Date
290017	City of Laddonia	Y	04/05/2010	08/24/1984
295267	City of Mexico	Y	04/05/2010	05/26/1972
290020	City of Vandalia	Y	04/05/2010	02/04/1988
290784	Audrain County	S	04/05/2010	S-04/05/2011

Source: NFIP Community Status Book, February 15, 2019; 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

Audrain County is currently listed as a sanctioned community because the current effective maps were not adopted within 1 year of issuance; however the National Flood Insurance Program requirements are being reviewed by the County and will be taken into consideration over the next 5 years.

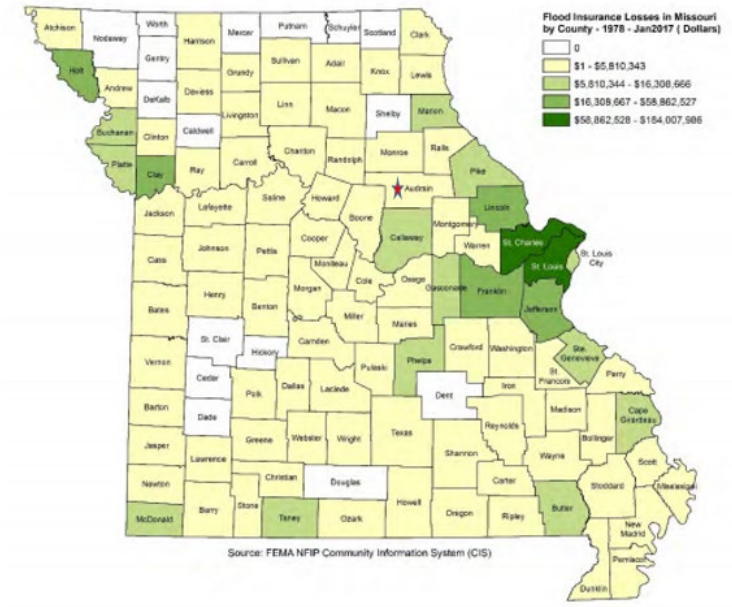
Table 3.15. **NFIP Policy and Claim Statistics as of September 2018**

Community Name	Policies in Force	Insurance in Force	Closed Losses	Total Payments
City of Laddonia	0	0	1	$1,236.90
City of Mexico	4	$924,00	27	$87,925.72
City of Vandalia	6	$548,000	9	$64,532.02

Source: NFIP Community Status Book; BureauNet, https://bsa.nfipstat.fema.gov/reports/1040.htm#29; *Closed Losses are those flood insurance claims that resulted in payment. Loss statistics are for the period as of September 2018.

According to Table 3.15, the City of Mexico has the most insurance payments (27) totaling $87,925.72, followed by the City of Vandalia with (9) insurance payments totaling $64,532.02.

Figure 3.18. Map of Dollars Paid Historically for Flood Insurance Losses in Missouri by County, 1978- January 2017

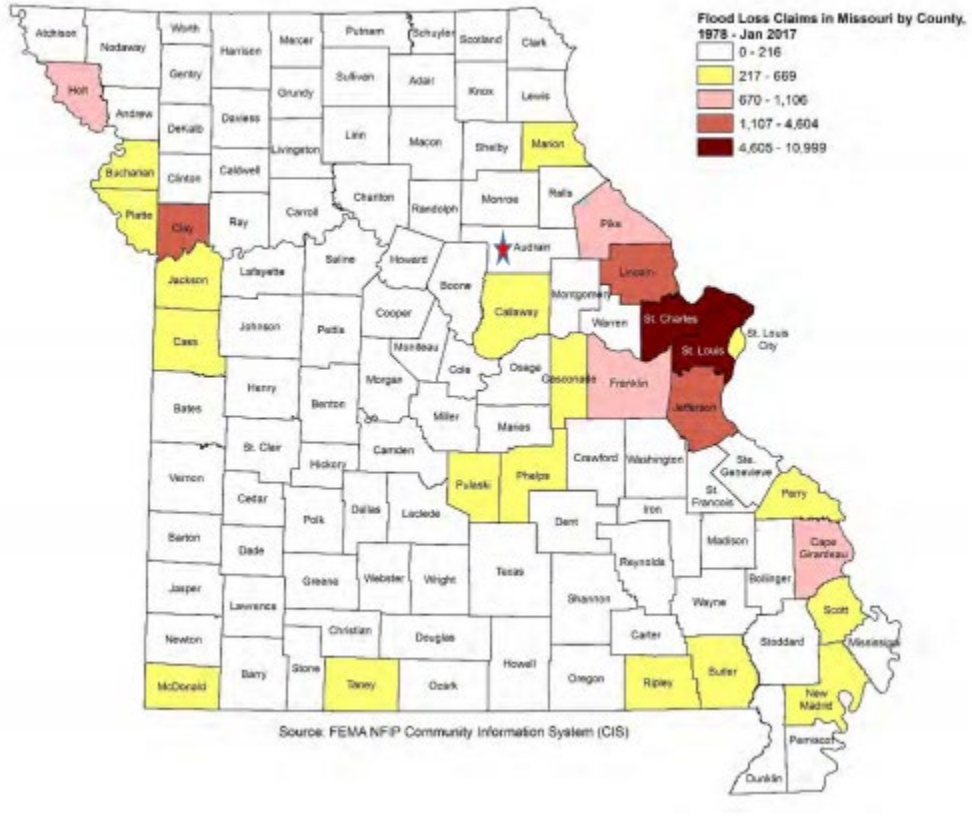


Source: 2018 Missouri State Hazard Mitigation Plan, *Red star shows Audrain County

Figure 3.18 shows that during the period of 1978-January 2017, Audrain County received between

$1 -$5,810,343 in Flood Insurance.

Figure 3.19. Flood Loss Claims in Missouri by County, 1978-January 2017



Source: 2018 Missouri State Hazard Mitigation Plan, *Red star shows Audrain County

Figure 3.19 demonstrates that between the period of 1978 and January 2017, Audrain County had between 0-216 Flood Loss Claims.

Figure 3.20. Recorded USDA Crop Insurance Loses; Top Ten Counties by Total Loss 2012-2016

County	2012	2013	2014	2015	2016	Grand Total
Stoddard	$344,316	$8,782,483	$5,500,784	$6,520,277	$7,664,965	$28,812,826
★ Audrain	$973,580	$1,134,222	$791,187	$21,852,880	$452,196	$25,204,066
New Madrid	$479,458	$7,426,593	$3,987,505	$9,426,484	$3,085,689	$24,405,730
Pike	$120,407	$3,614,292	$1,980,227	$16,635,442	$270,813	$22,621,182
Shelby	$704,864	$2,697,133	$972,552	$16,955,139	$298,701	$21,628,390
Lewis	$408,102	$3,397,578	$1,576,051	$15,306,941	$302,021	$20,990,693
Holt	$1,659,398	$1,971,826	$1,485,805	$13,206,294	$1,635,537	$19,958,861
Barton	$559,147	$10,103,017	$890,560	$7,084,910	$563,852	$19,201,487
Vernon	$320,605	$7,746,873	$988,839	$9,563,041	$513,037	$19,132,396
Chariton	$570,716	$2,396,539	$1,194,688	$12,658,808	$474,623	$17,295,375
Total	$6,140,593	$49,270,556	$19,368,202	$129,210,219	$15,261,438	$219,251,009

Source: 2018 Missouri State Hazard Mitigation Plan, *Red star shows Audrain County

According to the 2018 Missouri State Hazard Mitigation Plan, the above Figure 3.9 demonstrates the actual recorded insurance payments due to flood-related crop losses Statewide from 2012-2016 for the top ten counties by total loss. These losses are caused by excess moisture and flooding.

Repetitive Loss/Severe Repetitive Loss Properties

Repetitive Loss Properties are those for which two or more losses of at least $1,000 each have been paid under the National Flood Insurance Program (NFIP) within any 10-year period since 1978. According to the Flood Insurance Administration, jurisdictions included in the planning area have a combined total of 4 repetitive loss properties. As of December 31, 2018, there were no reports of properties that have been mitigated, leaving 4 un-mitigated repetitive loss properties. The report that was received from Flood Insurance Administration did not identify the type of property.

Table 3.16. **Audrain County Repetitive Loss Properties**

Jurisdiction	# of Properties	Type of Property	# Mitigated	Building Payments	Content Payments	Total Payments	Average Payment	# of Losses
City of Mexico	2	1 Single family 1 Non-residential	-	$10,241.12	$20,920.83	$31,161.98	$4,451.71	7
City of Vandalia	2	1 Single family 1 Non-residential	-	$36,191.35	$27,056.05	$63,247.40	$7,905.93	8

Source: Flood Insurance Administration as of 12/31/2018

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.

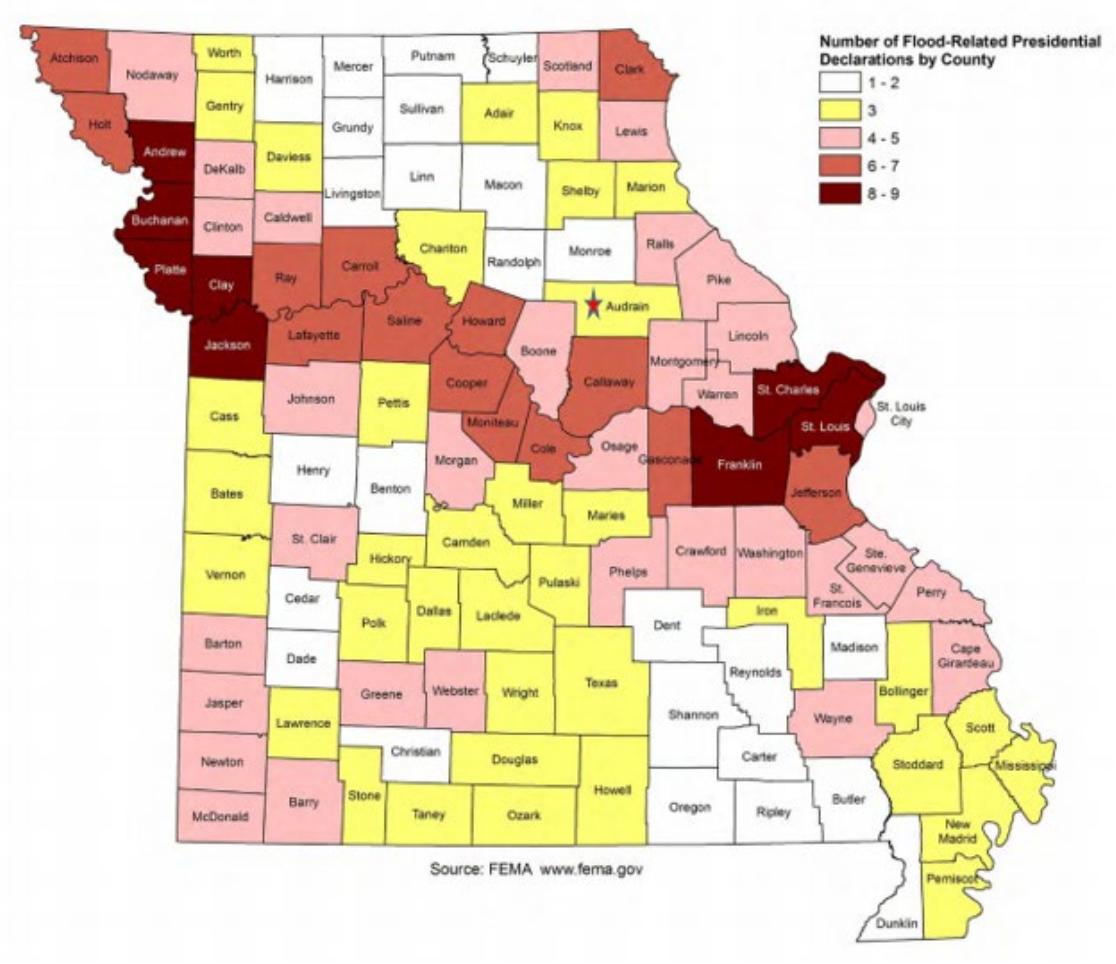
There are 4 validated Severe Repetitive Loss property(ies) in the county, and the community, 2 properties in the City of Mexico, and 2 properties in the City of Vandalia. The report did not specify the structure types (residential, commercial, etc.). There are no records for mitigated properties for Audrain County. The total paid NFIP insurance for the properties in City of Mexico is $31,161.98, with 7 total losses and $63,247.40 for the City of Vandalia with 8 total losses.

Previous Occurrences

Table 3.17. **Presidential Flooding Disaster Declarations**

Declaration Date	Disaster Number	Incident Type	Counties Declared	Type of Assistance
7/9/1993	DR 995	Flooding, Severe Storm	Audrain	IA
3/19/2009	DR-1749	Severe Storms and Flooding	Audrain	PA
11/13/2008	DR-1809	Severe Storms, Flooding and a tornado	Audrain	PA
1/2/2016	DR-3374	Flooding, Severe Storm	Audrain	PA

Figure 3.21. Number of Flood-Related Presidential Declarations by County



Source: 2018 Missouri State Hazard Mitigation Plan, *Red star shows Audrain County

NCEI information for the last 20 years for both flash and river flooding shown in **Table 3.17 and Table 3.18**.

Table 3.18. **NCEI Audrain County Flash Flood Events Summary, 1998 to 2018**

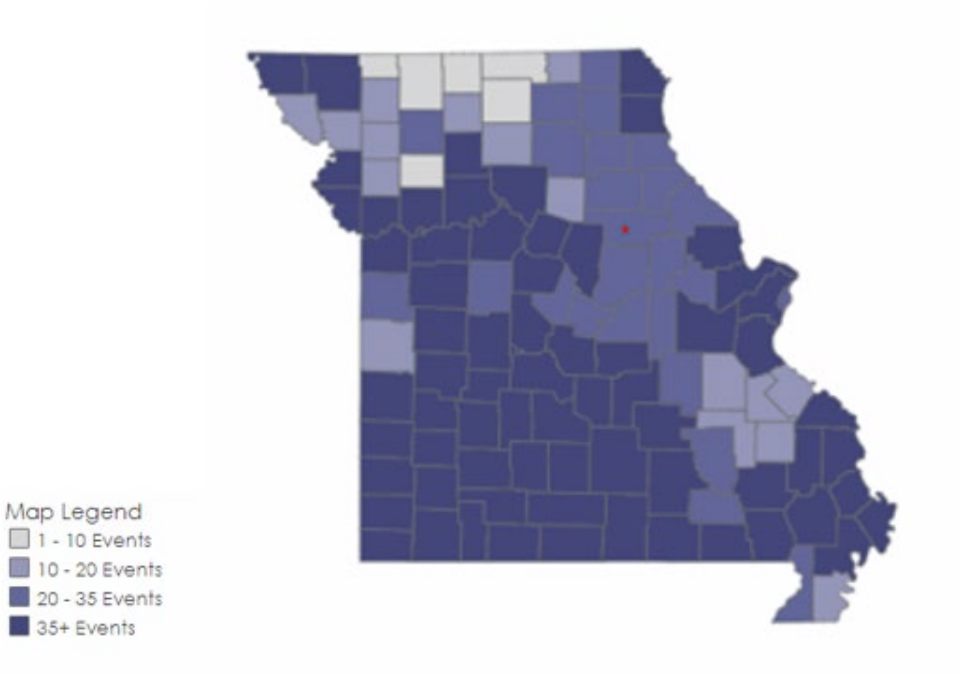
Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
06/29/1998	1	0	0	0	0
09/17/1998	1	0	0	0	0
10/05/1998	1	0	0	0	0
06/12/1999	1	0	0	0	0
05/07/2002	1	0	0	0	0
05/08/2003	1	0	0	0	0
06/25/2003	1	0	0	0	0
08/26/2004	1	0	0	0	0
01/12/2005	1	0	0	0	0
06/11/2006	1	0	0	0	0
06/27/2007	1	0	0	0	0

07/25/2008	1	0	0	0	31.00K
07/27/2008	1	0	0	0	0
07/29/2008	1	0	0	0	0
09/12/2008	1	0	0	0	0
09/13/2008	1	0	0	0	0
04/29/2009	1	0	0	0	0
10/08/2009	1	0	0	0	0
04/24/2010	1	0	0	0	0
07/26/2010	1	0	0	0	0
07/29/2010	1	0	0	0	0
07/30/2010	1	0	0	0	0
06/10/2011	1	0	0	0	0
04/30/2012	1	0	0	0	0
06/07/2015	1	0	0	0	0
06/21/2015	1	0	0	0	0
08/02/2016	1	0	0	0	0
06/24/2017	1	0	0	0	0

Source: NCEI, data accessed February 15, 2019

06/24/2017- A warm front moved northeastward through the area triggered numerous showers and thunderstorms causing widespread flash flooding and a few isolated severe events. Between 4 and 5 inches of rain fell in a short amount of time on already saturated soils causing flash flooding. Numerous roads were flooded including Highway 54 in various places between Vandalia and Mexico.

Figure 3.22. Historical Flood Impact



Source: https://www.fema.gov/data-visualization-floods-data-visualization, *Red star shows Audrain County

The FEMA Data Visualization Tool as shown above in Figure 3.22, Audrain County had between 20-35 events of flood impact.

Table 3.19. **NCEI Audrain County Riverine Flood Events Summary, 1998 to 2018**

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
01/28/2001	1	0	0	0	0
02/24/2001	1	0	1	0	0
04/10/2001	1	0	0	0	0
09/13/2008	1	0	0	0	0
06/01/2013	1	0	0	2.00k	0

Source: NCEI, February 15, 2019

02/24/2001- Audrain County, MO- Rainfall from 2 to 21/2 inches caused localized flooding across Audrain County. A 17 year-old boy suffered minor injuries when the van he was driving was overtaken by floodwater on County Road 820. After driving into the water, he managed to escape the stalled vehicle by crawling out a window. He was swept into the creek channel but managed to swim and walk to higher ground. The van was found a half mile downstream the next day. The road routinely floods during heavy rain.

06/01/2013- Martinsburg, MO- The Meramec River at Arnold started June in flood and rose to major flood levels cresting on the 4th. The river at Arnold is highly affected by backwater from the Mississippi River. The river fell below flood stage on the 23rd. Damage was limited to a few closed roads.

Probability of Future Occurrence

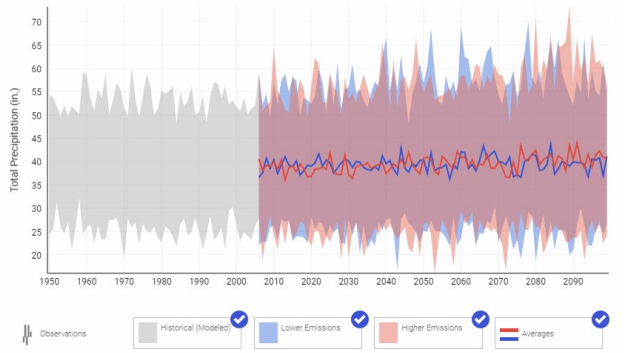
Flash Flooding in the planning area has occurred frequently in the last 20 years with 28 events making flash flooding a 100% with an average of 1.4 flash flood events per year probability flooding will occur in any given year.

Riverine Flooding in the planning area has occurred in the last 20 years with 5 events making riverine flooding a 25% probability flooding will occur in any given year.

Changing Future Conditions Considerations

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

Figure 3.23. U.S. Climate Resilience Toolkit- Annual Total Precipitation for Audrain County

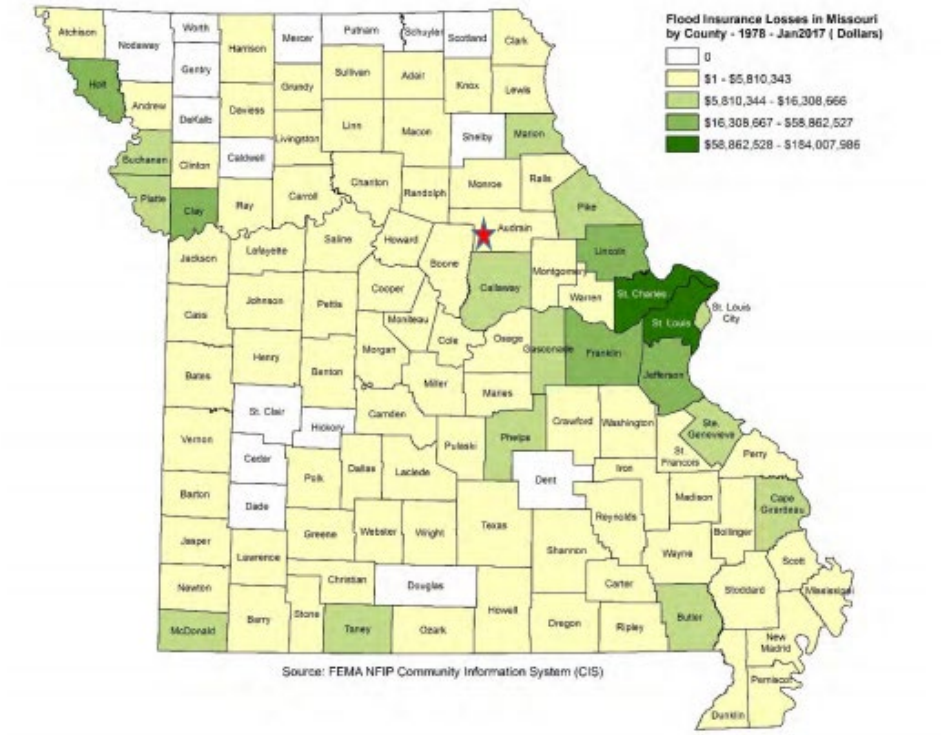


Source: US Climate Resilience Toolkit; https://toolkit.climate.gov/tools/climate-explorer

Vulnerability

Vulnerability Overview

Figure 3.24. Map of Dollars Paid Historically for Flood Insurance Losses in Missouri by County, 1978- January 2017



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

According to the 2018 Missouri State Hazard Mitigation Plan, Audrain ranged at the lower end of Flood Insurance Losses between $1-$5,810,343.

The 2018 Missouri State Hazard Mitigation Plan demonstrates Audrain County's loss ratio at 0.28%. This ratio represents a total direct building loss and income loss.

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.

Potential Losses to Existing Development

Using the data obtained from Flood Insurance Administration the City of Mexico and City of Vandalia have a history of repetitive loss, and are most vulnerable to have another event occur. All other participating jurisdictions were consulted and no flood prone assets were identified.

Impact of Previous and Future Development

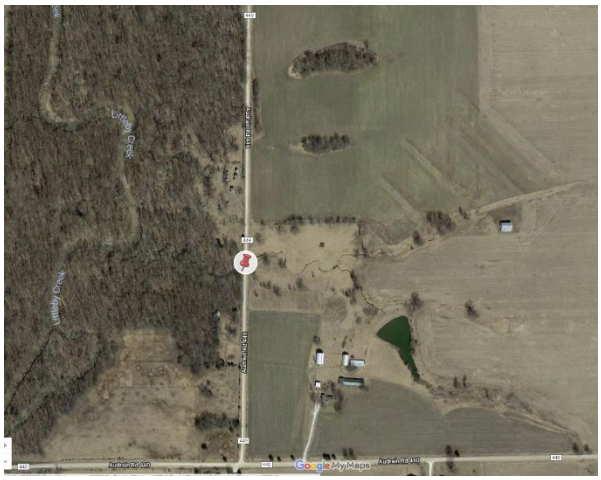
Any future development in floodplains would increase risk in those areas. For the 3 communities participating in the National Flood Insurance Program, enforcement of the floodplain management regulations will ensure mitigation of future construction in those areas. However, even if structures are mitigated, evacuation may be necessary due to rising waters. In addition, floods that exceed mitigated levels may still cause damages.

Hazard Summary by Jurisdiction

Vulnerability to flooding varies by jurisdiction as each community has a different layout, as described above the City of Mexico and City of Vandalia have a history of repetitive loss and would be more vulnerable to another loss in the future. The floodplain maps in the Geographic Location section depict the flood area in each jurisdiction. Table 3.18 reflects the NCEI Flash Flood Events in Unincorporated Audrain County at 27 events, Laddonia at 1 event, and Vandalia at 1 event with a total of 29 events in the planning area. The jurisdictions affected by flooding includes Mexico, Vandalia and Laddonia.

There are a total of four un-mitigated repetitive loss properties in the planning area.
Four properties located within the SFHA and has been damaged by recent flood events. Possible solutions include relocating of the structures and updating the local ordinance to require critical facilities to be located outside the SFHA. No buildings of the Community R-VI School District is within the SFHA.

Figure 3.25. Low Water Crossings in Audrain County



Source:

https://www.google.com/maps/d/viewer?mid=12yvevtWW9gxTGgnnWV4IvDrQ_xY&ll=39.241380190243746%2C-91.75720168579164&z=17

Problem Statement

Local governments should make a strong effort to improve emergency warning systems to insure future deaths and injuries do not occur. Local governments should consider making improvements to roads and low water crossings that consistently flood by placing them on a hazard mitigation projects list, and actively seek funding to successfully complete the projects.

3.4.2 Dam Failure

Hazard Profile

Hazard Description

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

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

Information can be obtained from:

- National Resources Conservation Service: http://www.nrcs.usda.gov
- DamSafetyAction.org: https://damsafety.org/missouri

Table 3.20. **MoDNR Dam Hazard Classification Definitions**

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

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

Table 3.21. **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

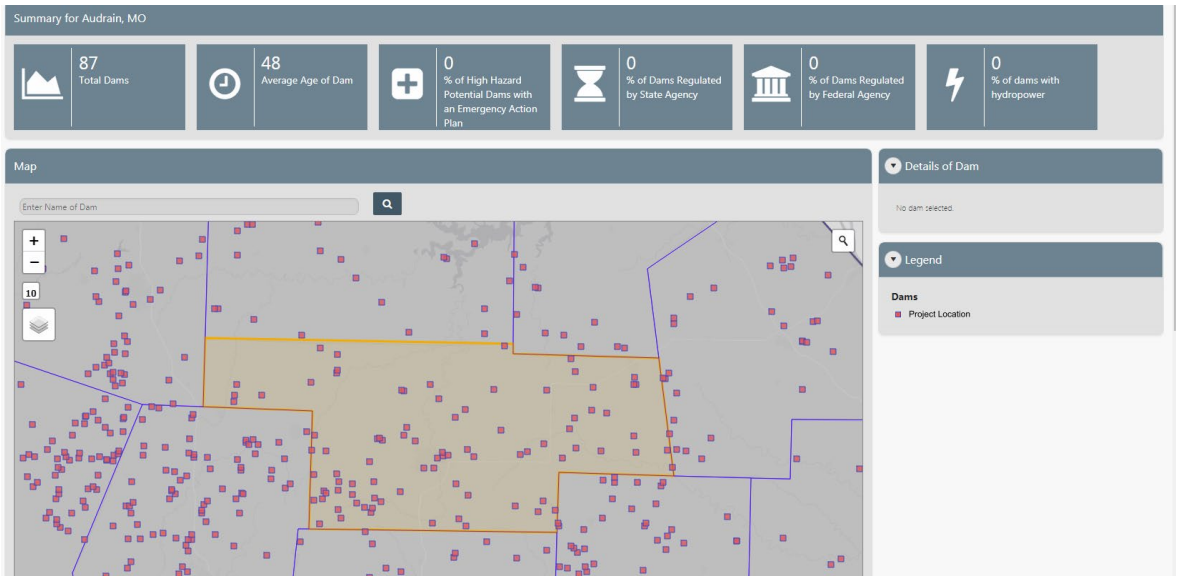
Figure 3.26. Dams in Audrain County- MoDNR Data

COUNTY	LOCATION	ID_NO	NAME	YEAR COMPLETE	LENGTH	DAMHT	RESAREA	DRAINAGE AREA (acres)	STATE REGULATED	HAZARD CLASS
AUDRAIN	S35, T51 N, R09W	MO10065	MISSOURI POWER AND LIGHT DAM	1900	0	26	28	769	N	1
AUDRAIN	S08 , T50 N, R08W	MO10066	OREN MCGEE'S DAM	1964	0	15	5	235	N	3
AUDRAIN	S36, T51 N, R09W	MO10082	TEAL LAKE DAM	1969	0	20	78	3387	N	1
AUDRAIN	S25, T50 N, R10W	MO10048	FEUTZ LAKE DAM EAST UPPER	1962	0	20	8	185	N	3
AUDRAIN	S25, T51 N, R09W	MO10105	C + A LAKE DAM	1919	0	27	39	1869	N	2
AUDRAIN	S13, T51 N, R10W	MO10122	LOCKE LAKE DAM WEST	1953	0	15	15	210	N	3
AUDRAIN	S15, T50 N, R10W	MO10229	BASTIAN LAKE DAM	1969	0	23	19	145	N	3
AUDRAIN	S35, T52 N, R06W	MO10296	VANDALIA COMMUNITY LAKE DAM	1956	0	21	38	503	N	2
AUDRAIN	S18, T50 N, R10W	MO10383	WILLIAMS DAM SOUTH SEC 18	1973	0	25	30	470	N	2
AUDRAIN	S16, T50 N, R09W	MO10440	SYDENSTRICKER DAM	1973	850	20	8	340	N	3
AUDRAIN	S19, T50 N, R09W	MO10441	BASTIAN LAKE DAM	1973	0	18	30	270	N	3
AUDRAIN	S27, T51 N, R08W	MO10442	FAIRCHILD DAM	1972	1533	21	4	128	N	3
AUDRAIN	S13, T50 N, R10W	MO10443	AUGUST H FENCK SR DAM	1969	0	15	20	1140	N	3
AUDRAIN	S30, T51 N, R08W	MO10470	BLACKMORE LAKE DAM	1962	0	32	25	120	N	2
AUDRAIN	S16, T51 N, R09W	MO10471	MONONAME 102	1967	0	19	7	93	N	3
AUDRAIN	S08, T51 N, R06W	MO10521	FOREE LAKE DAM	1970	0	26	15	120	N	2
AUDRAIN	S18, T51 N, R09W	MO10677	LOCKE LAKE DAM EAST	1957	0	15	10	100	N	3
AUDRAIN	S13, T51 N, R10W	MO10678	LOCKE LAKE DAM NORTH	1953	0	25	18	310	N	2
AUDRAIN	S21, T51 N, R08W	MO10679	DIANE LAKE DAM (DRY)	1967	0	20	9	1030	N	3
AUDRAIN	S33, T50 N, R08W	MO10680	ROGERS LAKE DAM	1973	0	15	25	430	N	3
AUDRAIN	S22, T52 N, R06W	MO10734	ALTON LAKE DAM	1964	0	15	21	1020	N	3
AUDRAIN	S30, T51 N, R08W	MO10735	BURLINGTON LAKE DAM	1900	0	28	17	735	N	3
AUDRAIN	S36, T50 N, R09W	MO10858	BUCKNER LAKE DAM	1968	0	24	10	98	N	3
AUDRAIN	S14, T50 N, R07W	MO10859	NORFOLK LAKE DAM/(DRY)	1940	0	15	14	200	N	2
AUDRAIN	S08, T50 N, R10W	MO10860	SHELLABARGER DAM SOUTH	1970	0	20	18	130	N	2
AUDRAIN	S28, T50 N, R10W	MO10866	HOLLANDER DAM	1967	0	15	10	150	N	3
AUDRAIN	S23, T52 N, R09W	MO10871	MONONAME 610	1971	0	15	7	47	N	3
AUDRAIN	S36, T53 N, R11W	MO11154	DONALDSON LAKE DAM	1977	0	15	16	380	N	2
AUDRAIN	S10, T50 N, R10W	MO11158	SHELLABARGER LAKE DAM	1974	0	20	20	135	N	2
AUDRAIN	S24, T50 N, R11W	MO11161	OBERLAG LAKE DAM	1975	1163	19	8	85	N	3
AUDRAIN	S15, T51 N, R09W	MO11163	DEIMEKE LAKE DAM	1976	430	22	5	26	N	3
AUDRAIN	S20, T50 N, R10W	MO11164	BRUNS DAM	0000	0	15	10	230	N	3
AUDRAIN	S31, T50 N, R10W	MO11166	PRATER DAM SOUTH	0000	0	15	11	80	N	3
AUDRAIN	S21, T52 N, R09W	MO11190	BOYES LAKE DAM	1977	0	16	40	350	N	3
AUDRAIN	S20, T52 N, R09W	MO11191	SWEITZER LAKE DAM	1975	0	20	16	165	N	3
AUDRAIN	S09, T51 N, R09W	MO11192	KALLENBACH&BECKER LAKE DAM	1977	0	30	15	190	N	3
AUDRAIN	S17, T52 N, R05W	MO11208	KOHL IRRIGATION LAKE-SOUTH	1975	0	14	18	355	N	1
AUDRAIN	S17, T52 N, R05W	MO11209	TALBERT LAKE DAM	1974	0	15	10	255	N	3
AUDRAIN	S17, T52 N, R05W	MO11210	KOHL IRRIGATION LAKE-NORTH	1976	3299	17	1	602	N	3
AUDRAIN	S19, T51 N, R08W	MO11244	LIERHEIMER LAKE DAM	1978	0	25	27	340	N	2
AUDRAIN	S25, T52 N, R12W	MO11330	SIMS LAKE DAM	1975	1830	17	1	230	N	3
AUDRAIN	S05, T52 N, R06W	MO11356	ROBINSON LAKE DAM	1976	2400	21	5	215	N	3
AUDRAIN	S08, T52 N, R06W	MO11357	CARLSON LAKE DAM	1978	0	16	11	110	N	3
AUDRAIN	S30, T51 N, R06W	MO11360	BECKER LAKE DAM	1976	2227	18	10.3	325	N	3
AUDRAIN	S23, T51 N, R06W	MO11362	BESHEARS LAKE DAM	1976	0	28	11	635	N	3
AUDRAIN	S05, T51 N, R06W	MO11363	ROBERTSON DAM	0000	0	10	26	575	N	3
AUDRAIN	S34, T52 N, R06W	MO11367	HAMMETT LAKE DAM	1978	1747	24	7	236	N	3
AUDRAIN	S17, T52 N, R10W	MO11401	COOK LAKE DAM	1978	0	19	9	65	N	2
AUDRAIN	S23, T52 N, R11W	MO11402	HENRY LAKE DAM	0000	0	20	13	64	N	3
AUDRAIN	S25, T51 N, R11W	MO11403	GALLAWAY LAKE DAM	1976	0	22	10	87	N	3
AUDRAIN	S30, T51 N, R10W	MO11404	SALISBURY LAKE DAM	1974	1675	21	1	589	N	3
AUDRAIN	S01, T50 N, R11W	MO11405	BAY LAKE DAM	1977	0	15	16	60	N	3
AUDRAIN	S05, T50 N, R10W	MO11406	SHELLABARGER DAM NORTH	0000	0	25	5	50	N	3
AUDRAIN	S18, T50 N, R10W	MO11408	PRATER DAM NORTH	0000	0	20	18	130	N	2
AUDRAIN	S18, T50 N, R10W	MO11409	WILLIAMS DAM NORTH SEC 18	0000	0	25	5	17	N	2
AUDRAIN	S36, T51 N, R05W	MO11444	HEIM LAKE DAM	1976	0	31	14	110	N	3
AUDRAIN	S24, T51 N, R05W	MO11446	HEIM LAKE DAM	1976	0	24	7	15	N	3
AUDRAIN	S21, T51 N, R05W	MO11447	BARBER LAKE DAM	0000	0	25	19	120	N	3
AUDRAIN	S17, T51 N, R05W	MO11448	RAY LAKE DAM	0000	0	20	33	240	N	3
AUDRAIN	S17, T50 N, R10W	MO11457	COCHRAN DAM	0000	0	25	6	185	N	2
AUDRAIN	S08, T52 N, R10W	MO11469	SUDBROCK LAKE DAM	1975	0	25	8	162	N	2
AUDRAIN	S28, T50 N, R08W	MO11470	BRAUN LAKE DAM	0000	0	25	8	50	N	3
AUDRAIN	S05, T52 N, R10W	MO11472	SPROCK FARMS INC LAKE DAM	1974	914	13	6	205	N	3
AUDRAIN	S33, T52 N, R08W	MO11476	LEIRHEIMER LAKE DAM	1976	0	12	18	220	N	3
AUDRAIN	S25, T52 N, R09W	MO11483	MAY LAKE DAM	1978	0	24	9	120	N	3
AUDRAIN	S33, T52 N, R12W	MO11571	BORMET LAKE DAM	1977	0	15	19	396	N	3
AUDRAIN	S27, T52 N, R12W	MO11572	HANAK LAKE DAM	0000	0	20	9	370	N	3
AUDRAIN	S24, T52 N, R08W	MO12069	AZDELL LAKE DAM	0000	0	20	22	130	N	2

AUDRAIN	S08, T50 N, R08W	MO12070	MCGEE DAM	0000	0	15	13	540	N	3
AUDRAIN	S24, T50 N, R10W	MO12071	FEUTZ LAKE DAM EAST LOWER	0000	0	25	40	550	N	2
AUDRAIN	S05, T51 N, R08W	MO31281	PEHLE LAKE DAM	1976	0	20	20	250	N	2
AUDRAIN	S24, T50 N, R07W	MO31462	WELSCHMEYER LAKE DAM	1977	540	20	13	94	N	3
AUDRAIN	S23, T50 N, R07W	MO31463	WIEBURG LAKE DAM	0000	0	20	12	150	N	3
AUDRAIN	S20, T50 N, R07W	MO31464	BROWN LAKE DAM	0000	0	32	25	230	N	3
AUDRAIN	S07, T51 N, R07W	MO31469	RIECHERS LAKE DAM	1976	0	20	20	140	N	3
AUDRAIN	S23, T51 N, R07W	MO31470	FREYER LAKE DAM EAST	0000	0	25	14	75	N	3
AUDRAIN	S21, T51 N, R07W	MO31471	FREYER LAKE DAM	0000	0	25	22	130	N	3
AUDRAIN	S28, T51 N, RO7W	MO31472	DEIMEKE LAKE DAM	1976	0	15	20	7700	N	3
AUDRAIN	S23, T52 N, R07W	MO31473	POUND LAKE DAM	1977	3695	20	1	173	N	3
AUDRAIN	S31, T53 N, R07W	MO31474	BLACK LAKE DAM	1977	0	15	12	37	N	3
AUDRAIN	S13, T51 N, R11W	MO31499	SCHNARRE-RIDDER LAKE DAM	1976	963	23	1	51	N	3
AUDRAIN	S35, T51 N, R10W	MO31645	CARTER LAKE DAM	1973	645	22	16	269	N	3
AUDRAIN	S23, T50 N, R10W	MO50007	FEUTZ LAKE DAM	1971	827	21	8	301	N	3
AUDRAIN	S12, T50 N, R10W	MO50005	BROWN	1967	870	15	6.2	269	N	3
AUDRAIN	S22, T52 N, R12W	MO50006	FASHING	1972	725	21	11	448	N	3
AUDRAIN	S20,T51N,R06W	MO50701	BROOKS DAM	1997	700	21.2	3.3	134	N	3
AUDRAIN	S16,T50N,R08W	MO51169	RUFKAHR DAM	2003	450	25	1	154	N	3
AUDRAIN	S22,T50N,R10W	MO51396	FEUTZ DAM	2006	630	14	3	102	N	3

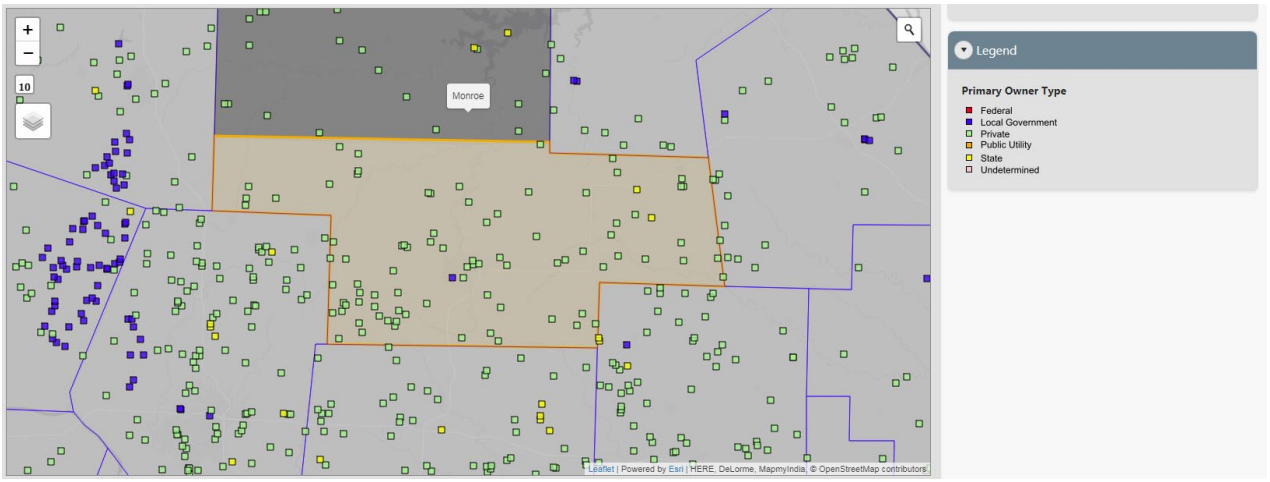
Source: Missouri Department of Natural Resources, Dam and Reservoir Safety https://dnr.mo.gov/geology/wrc/dam-safety/damsinmissouri.htm *Highlighted Dams represent Class 1 Dams

Figure 3.27. Dams located within the Audrain County- NID Data



Source: National Inventory of Dams (NID) http://nid.usace.army.mil/cm_apex/f?p=838:12,

Figure 3.28. Audrain County Dams by Owner Type



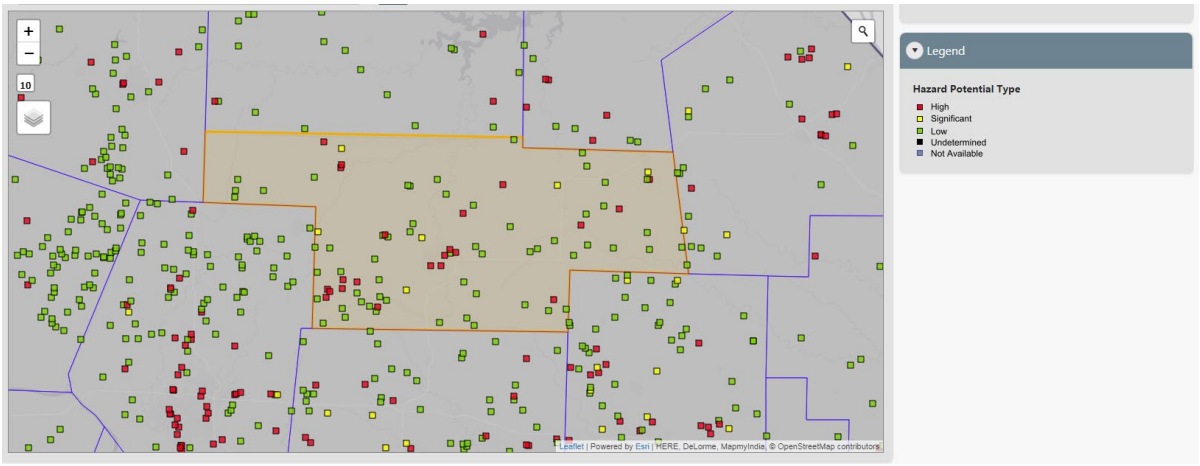
Source: National Inventory of Dams (NID) http://nid.usace.army.mil/cm_apex/f?p=838:12,

Geographic Location

There are 87 dams located inside the county boundaries, and 21 high hazard dams using both the NID and the MoDNR data.

The below table list the names, locations, and other pertinent information for all high hazard dams in the planning area.

Figure 3.29. High Hazard Dams in the Audrain County Planning Area



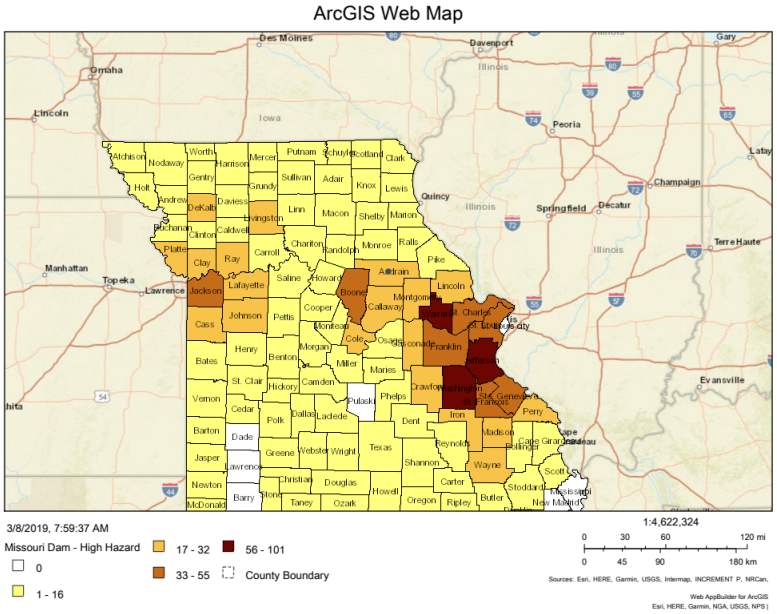
Source: National Inventory of Dams (NID) http://nid.usace.army.mil/cm_apex/f?p=838:12,

Table 3.22. **Dams in Audrain County**

Dam Name	Emergency Action Plan (EAP)AP	Dam Height (Ft)	Normal Storage (Acre-Ft)	Last Inspection Date	River	Nearest Downstream City	Distance To Nearest City (Miles)	Dam Owner
Azdell Lake Dam	Not required	20ft	235	-	TR-Littleby Creek	Rush Hill	7.5	Willa Azdell
Kohl Irrigation Lake	Not required	14ft	135	7/9/1980	TR-Shady Creek	Vandalia	2.4	Fred Kohl
Vandalia Community Lake	Not required	21ft	427	-	TR-Hickory Creek	Farber	5.0	MO Dept of Conservation
Foree Lake Dam	Not required	26ft	209	-	TR-West Fork Cuivre River	Laddonia	3.8	Elmer Foree
Pehle Lake Dam	Not required	20ft	220	-	TR-Bean CR	Mexico	6.4	Howard Pehle
Blackmore Lake Dam	Not required	32ft	428	-	TR-South Fork Salt River	Mexico	3.2	George Blackmore
Lierheimer Lake Dam	Not required	25ft	361	-	TR-South Fork Salt River	Mexico	2	Richard Lerheimer
C+A Lake Dam	Not required	27ft	563	-	TR-South Fork Salt River	Mexico	1.4	ILL Central Gulf RR Co
Teal Lake Dam	Not required	20ft	835	-	TR-South Fork Salt River	Mexico	2.4	City of Mexico
Missouri Power and Light Dam	Not required	26ft	389	-	TR-South Fork Salt River	Mexico	1.5	City of Mexico
Locke Lake Dam North	Not required	25ft	241	-	TR-Skull Lick Creek	Mexico	6.1	Kathryn Locke
Shellabarger Dam South	Not required	20ft	193	-	TR-Davis Creek	Mexico	11.2	Gene Shellabarger
Shellabarger Dam	Not required	20ft	214	-	TR-David Creek	Mexico	10.4	Wayne Shellabarger
Cochran Dam	Not required	25ft	80	-	TR-Davis Creek	Mexico	12.6	Richard Cochran
Williams Dam East	Not required	25ft	67	-	TR-David Creek	Mexico	7.1	Hugh and Jim Williams
Williams Dam South	Not required	25ft	401	-	TR-Davis Creek	Mexico	13.9	Hugh and Jim Williams
Prater Dam North	Not required	20ft	193	-	TR-Davis Creek	Mexico	14.8	Robert Prater
Feutz Lake Dam East Lower	Not required	25ft	535	-	TR-Beaver Dam Creek	Mexico	13.5	Emil/Wallace Fuetz
Donaldson Lake Dam	Not required	15ft	128	-	TR-Scattering BR-Long	Mexico	20.5	WC Donaldson
Sudbrock Lake Dam	Not required	25ft	107	-	Sudbrock Lake Dam	Mexico	16.9	Delbert Sudbrock
Cook Lake Dam	Not required	19ft	91	-	TR-Goodwater Creek	Mexico	16.6	Earl Cook

Sources: Missouri Department of Natural Resources, https://dnr.mo.gov/geology/wrc/dam-safety/damsinmissouri.htm and National Inventory of Dams, http://nid.usace.army.mil/cm_apex/f?p=838:12. Contact the MoDNR Dam and Reservoir Safety Program at 800-361-4827 to request the inundation maps for your county to show geographic locations at risk, extent of failure and to perform GIS analysis of those assets at risk to dam failure.

Figure 3.30. High Hazard Dams in Audrain County and Areas Impacted in the Event of Breach.

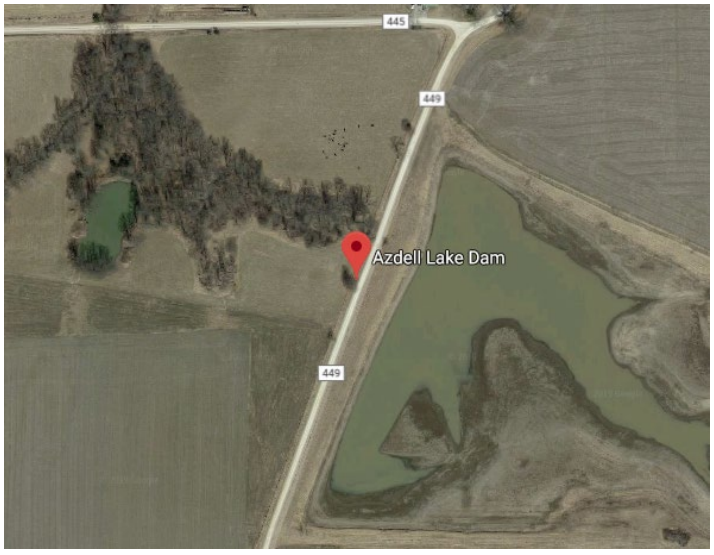


Source: Missouri Hazard Mitigation Viewer; http://bit.ly/MoHazardMitigationPlanViewer2018

Figure 3.31. High Hazard Dams in Audrain County

Source: Google Maps

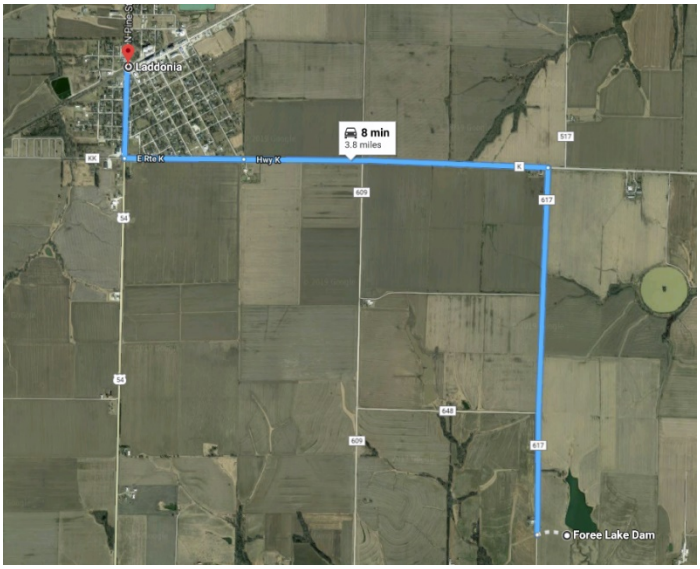
Azdell Lake Dam



Kohl Irrigation Lake Dam

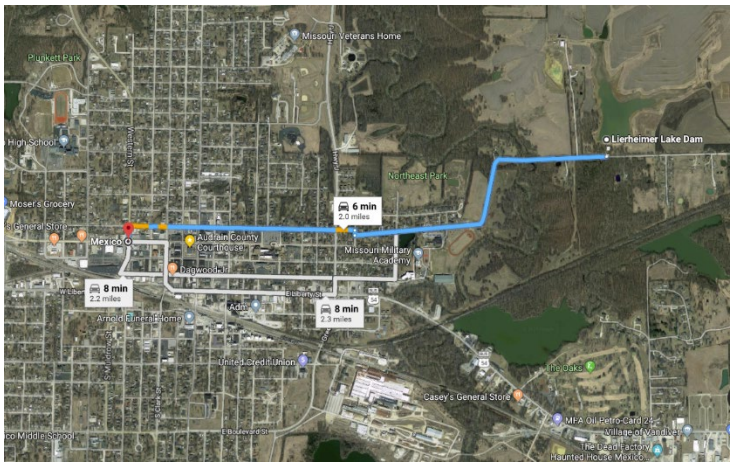
Vandalia Community Lake Dam

Foree Lake Dam

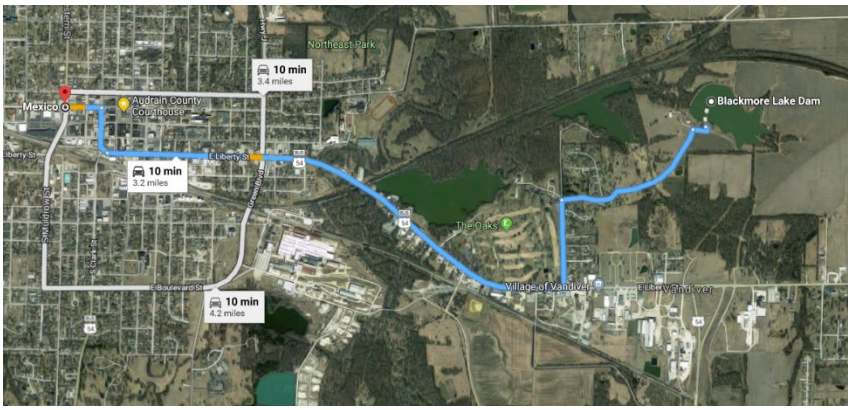


Pehle Lake Dam

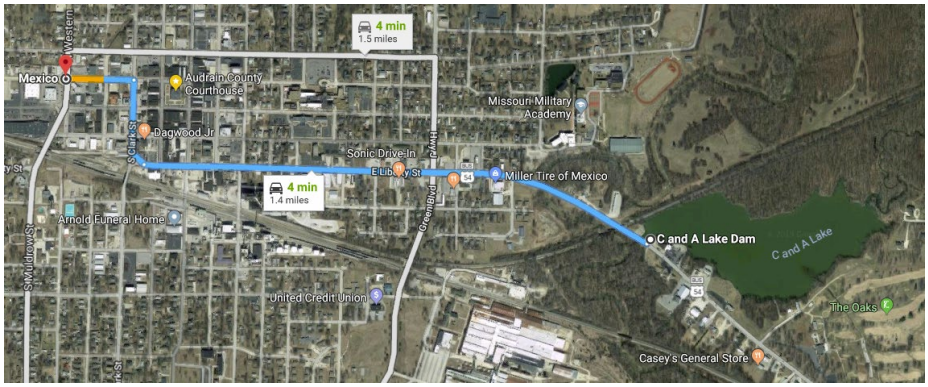
Lierheimer Lake Dam



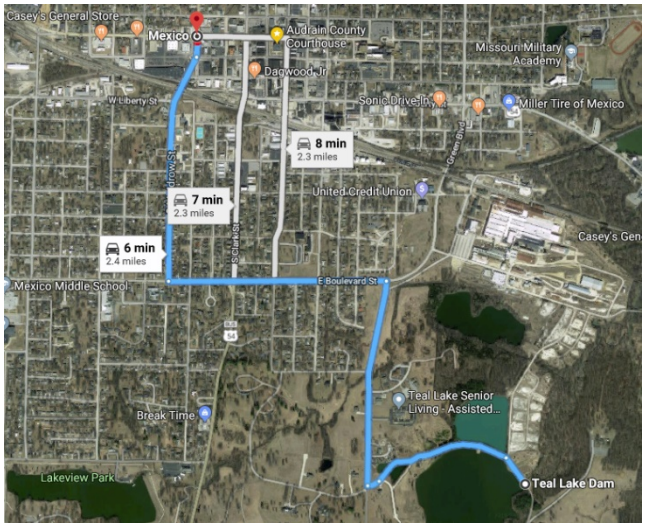
Blackmore Lake Dam



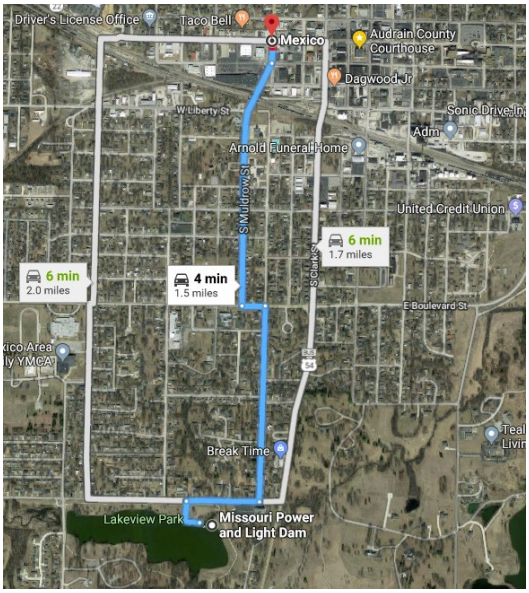
C and A Lake Dam



Teal Lake Dam



Missouri Power and Light Dam

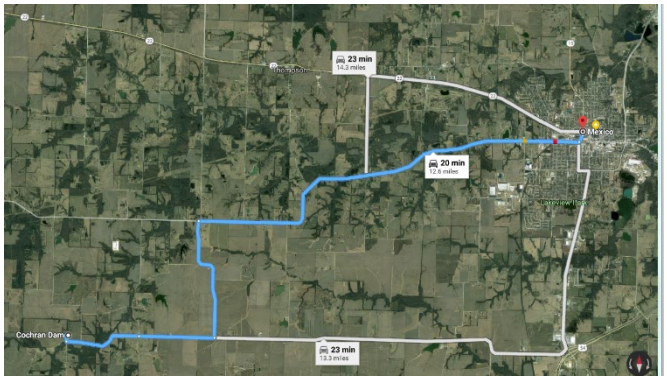


Locke Lake Dam North

Shellabarger Dam-South

Shellabarger Dam- North

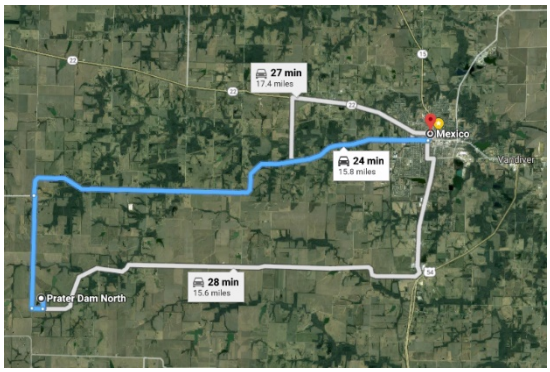
Cochran Dam



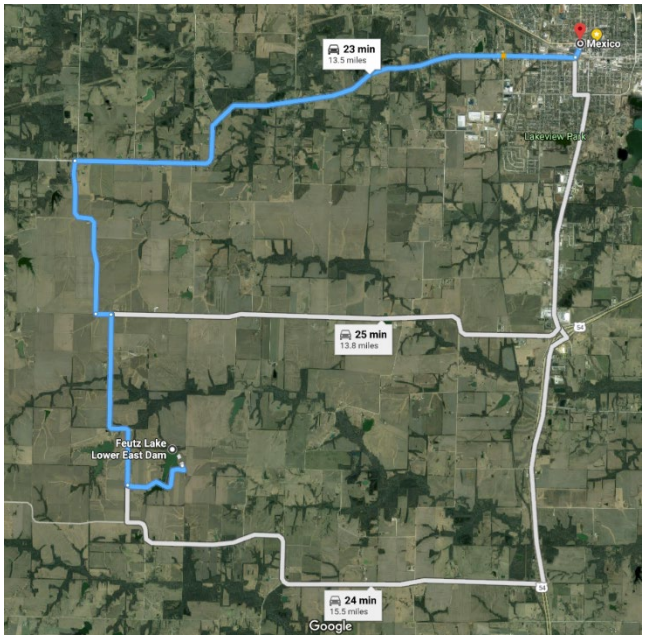
Williams Dam East

Williams Dam South

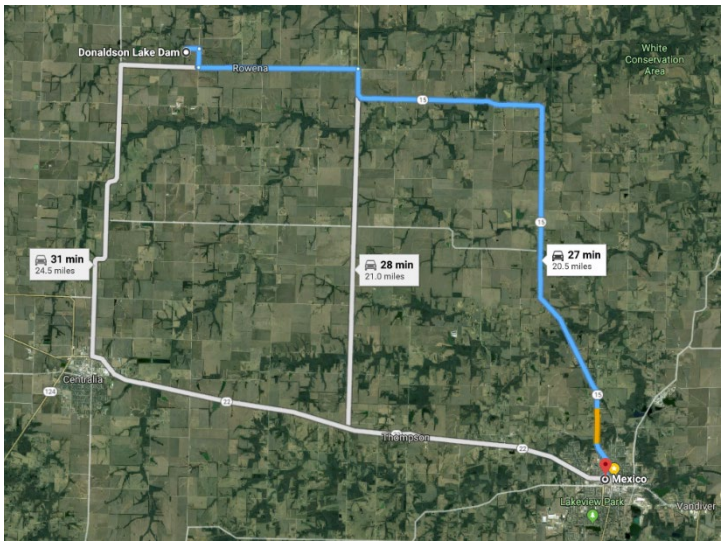
Prater Dam North



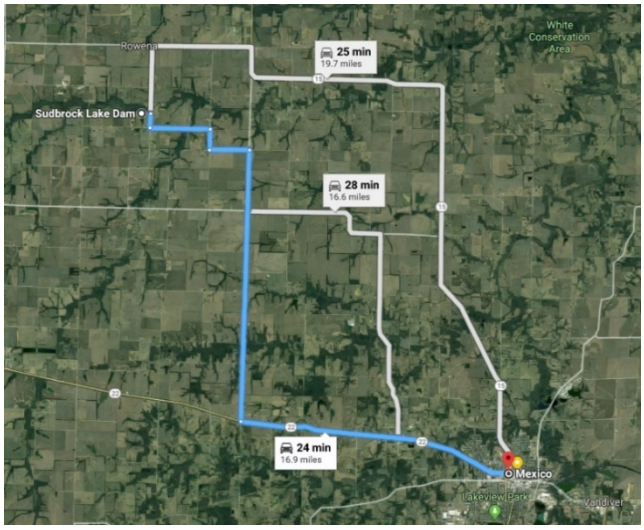
Feutz Lake Dam East Lower



Donaldson Lake Dam



Sudbrock Lake Dam



Cook Lake Dam

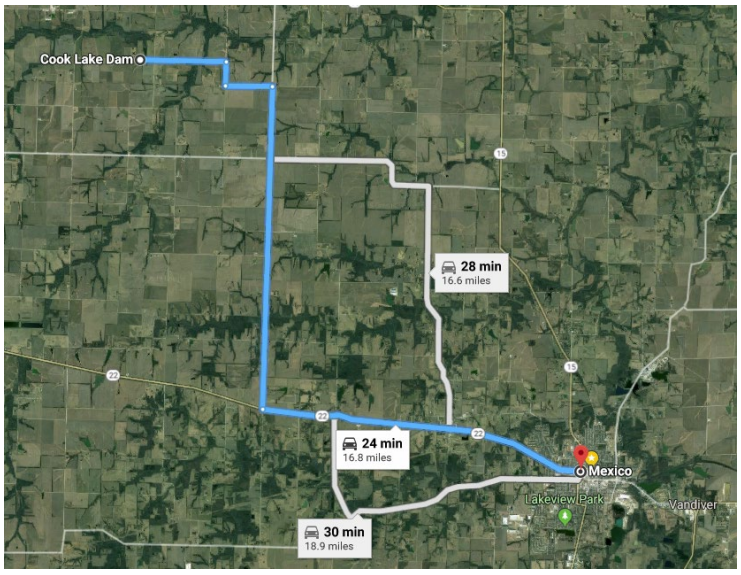
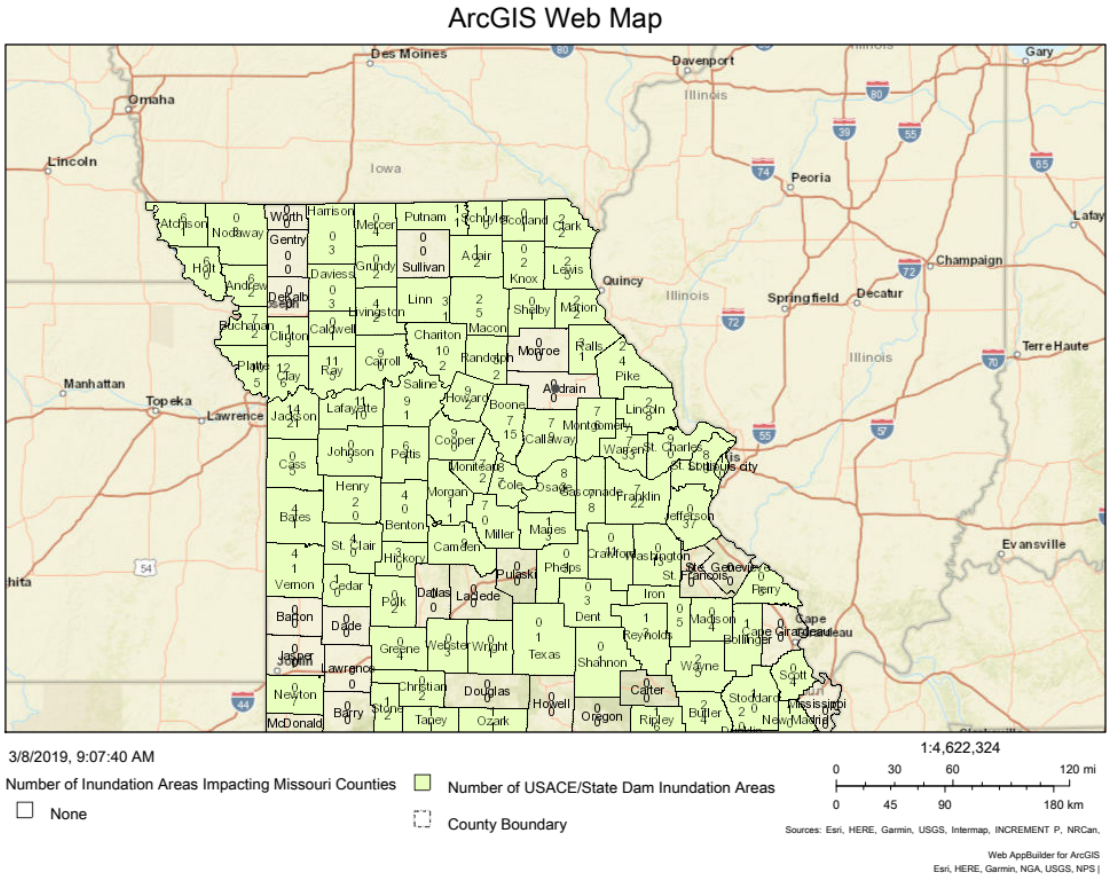


Figure 3.32. Number of Inundated Areas Impacting Audrain County



Source: Missouri Hazard Mitigation Viewer

Upstream Dams Outside the Planning Area

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

Strength/Magnitude/Extent

The strength/magnitude of dam failure would be similar in some cases to flood events (see the flood hazard vulnerability analysis and discussion). The strength/magnitude/extent of dam failure is related to the volume of water behind the dam as well as the potential speed of onset, depth, and velocity. Note that for this reason, dam failures could flood areas outside of mapped flood hazards.

There are no State regulated dams in the planning area. In order to be State regulated the dam must be 35 feet in height. Thus, it is the responsibility of the individual landowners to inspect and maintain. Audrain County consist of 3 Class 1 dams and 21 high hazard dams however they are located in rural areas and are not a threat to significant population areas or critical facilities. No further analysis of hazard dam failure will be conducted for the hazard mitigation plan. Jurisdictions and Schools in the planning area are unlikely to be affected by a compromised dam due to the low water capacity of the dams.

Previous Occurrences

To determine previous occurrences of dam failure within Audrain County, previously approved county hazard mitigation plan, the 2018 Missouri State Hazard Mitigation Plan, and the Stanford University's National Performance of Dams Program (http://npdp.stanford.edu) were consulted. There are no records of dam failure within the county boundaries.

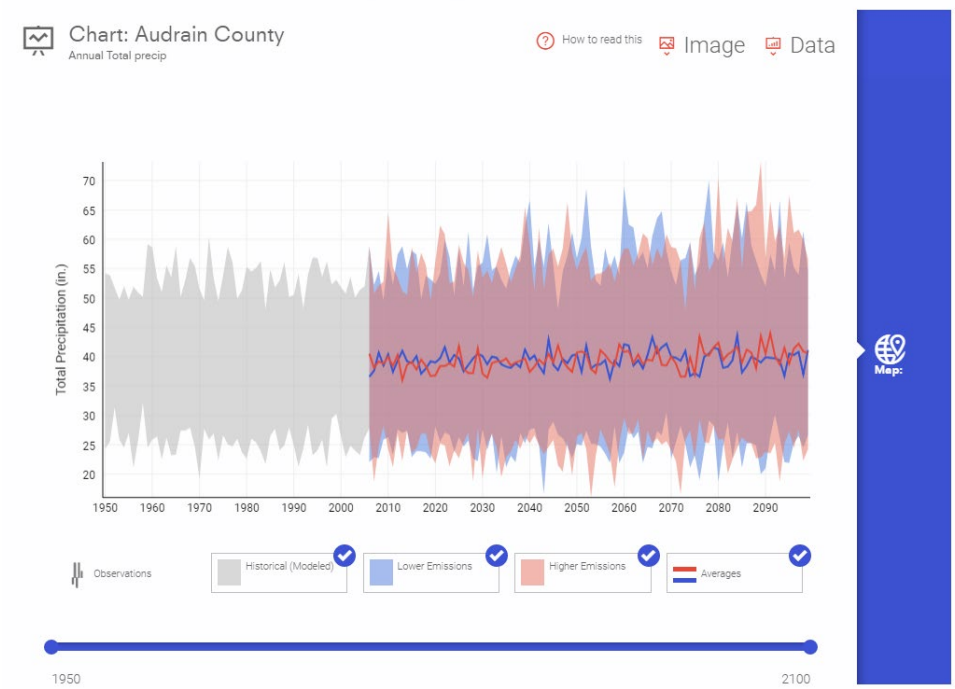
Probability of Future Occurrence

Audrain County consist of 3 Class 1 dams and 21 High Hazard dams in the county which puts areas in the county in danger of being affected by a dam breech. However due to no record of previous occurrences the probability of a future occurrence cannot be calculated.

Changing Future Conditions Considerations

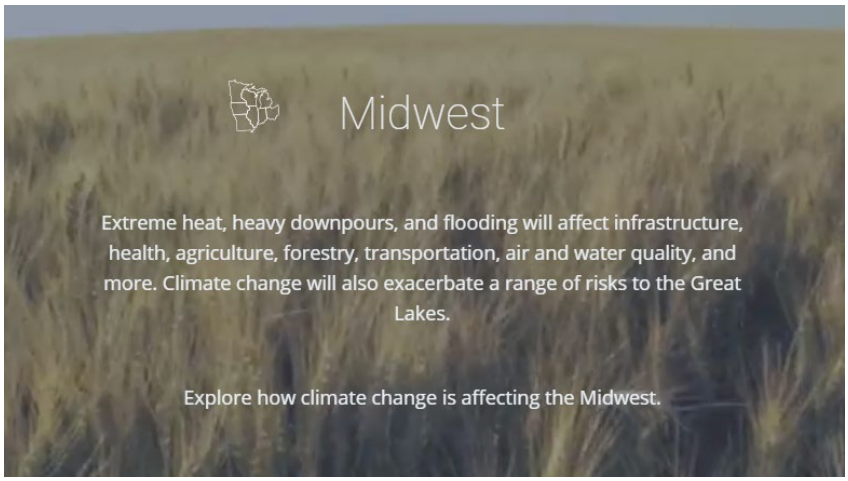
Figure 3.33 shows the projected precipitation for Audrain County and shows there is not a large decrease in the amount of precipitation and indicates the amount water held by dams will remain steady.

Figure 3.33. Projected Precipitation for Audrain County



Source: US Climate Resilience Toolkit; https://toolkit.climate.gov/tools/climate-explorer

Figure 3.34.



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

Landowners should be aware of the changing climate, and regularly inspect private dams to ensure the safety of life and lower the loss of infrastructure damages.

Vulnerability

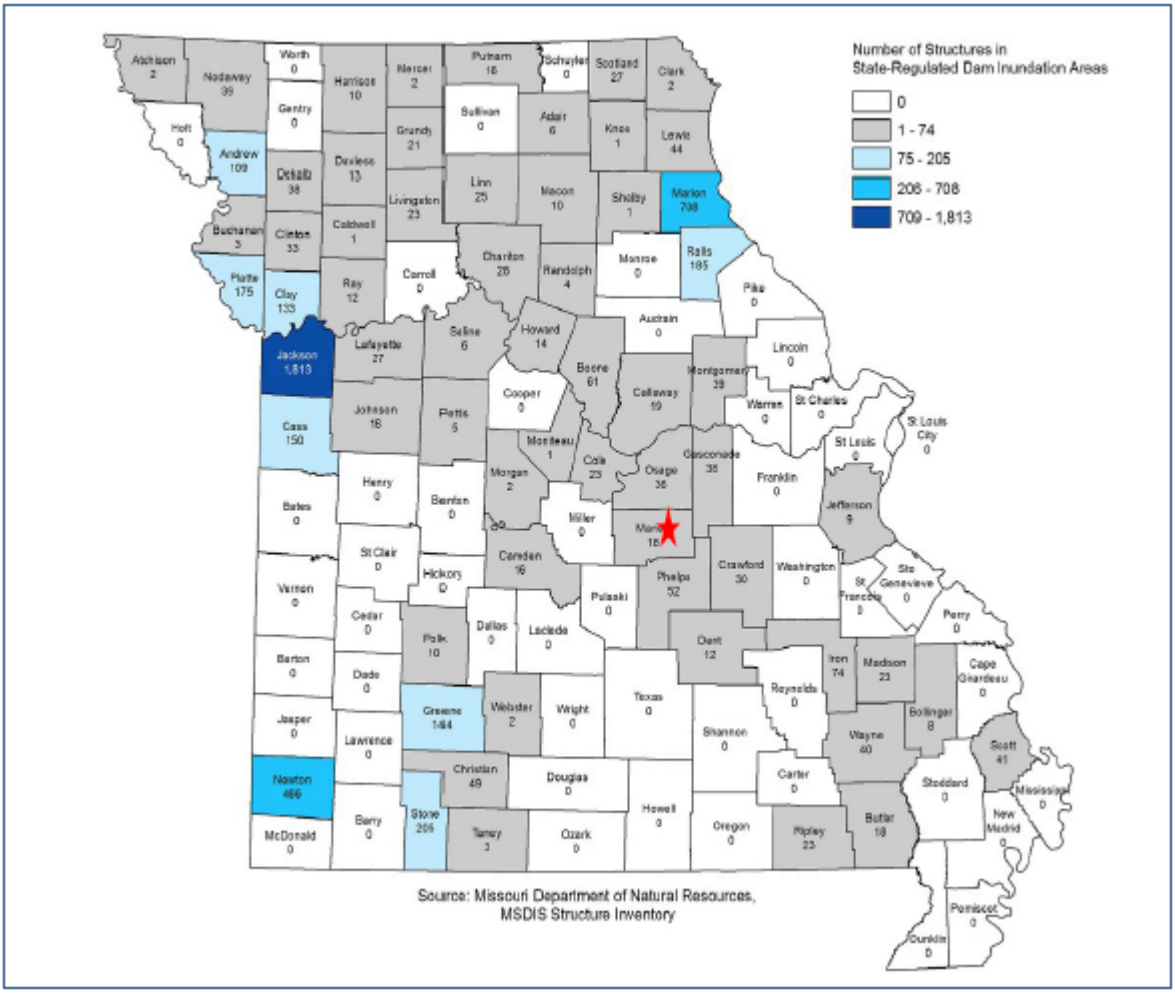
Vulnerability Overview

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

According to the 2018 Missouri State Hazard Mitigation Plan, there is are no buildings vulnerable to failure of State-Regulated dam (Figure 3.38) in Audrain County.

Figure 3.38 depict the estimated number of buildings vulnerable to dam failure of State regulated dams.

Figure 3.35. Estimated Number of Buildings Vulnerable to Dam Failure of State Regulated Dams



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

The dams located within Audrain County are not State regulated dams, therefore there are no inspection reports to consult. State regulated dams must be 35 feet tall, all of the dams within Audrain County are below this height.

There are no inundation areas in Audrain County.

Impact of Previous and Future Development

There are 21 high hazard dams within the planning area, none of which are state regulated. Prior to

future development in those areas, the jurisdiction should be contacted and a review of impact of new development in the event of a breech in dam should be reviewed.

Hazard Summary by Jurisdiction

Of the 87 dams in Audrain County, 21 dams have been classified as high hazard dams. All dams are small in terms of height and storage area and are not a threat to significant population areas or critical facilities. Jurisdictions and Schools in the planning area are unlikely to be affected by a compromised dam due to the low water capacity of the dam.

Problem Statement

A lack of regular inspection/maintenance of un-regulated high hazard dams was noted by the Mitigation Planning Committee. Possible solutions include the training landowners how to properly inspect dams, and encourage dams to be inspected on a regular schedule.

3.4.3 Earthquakes

Hazard Profile

Hazard Description

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

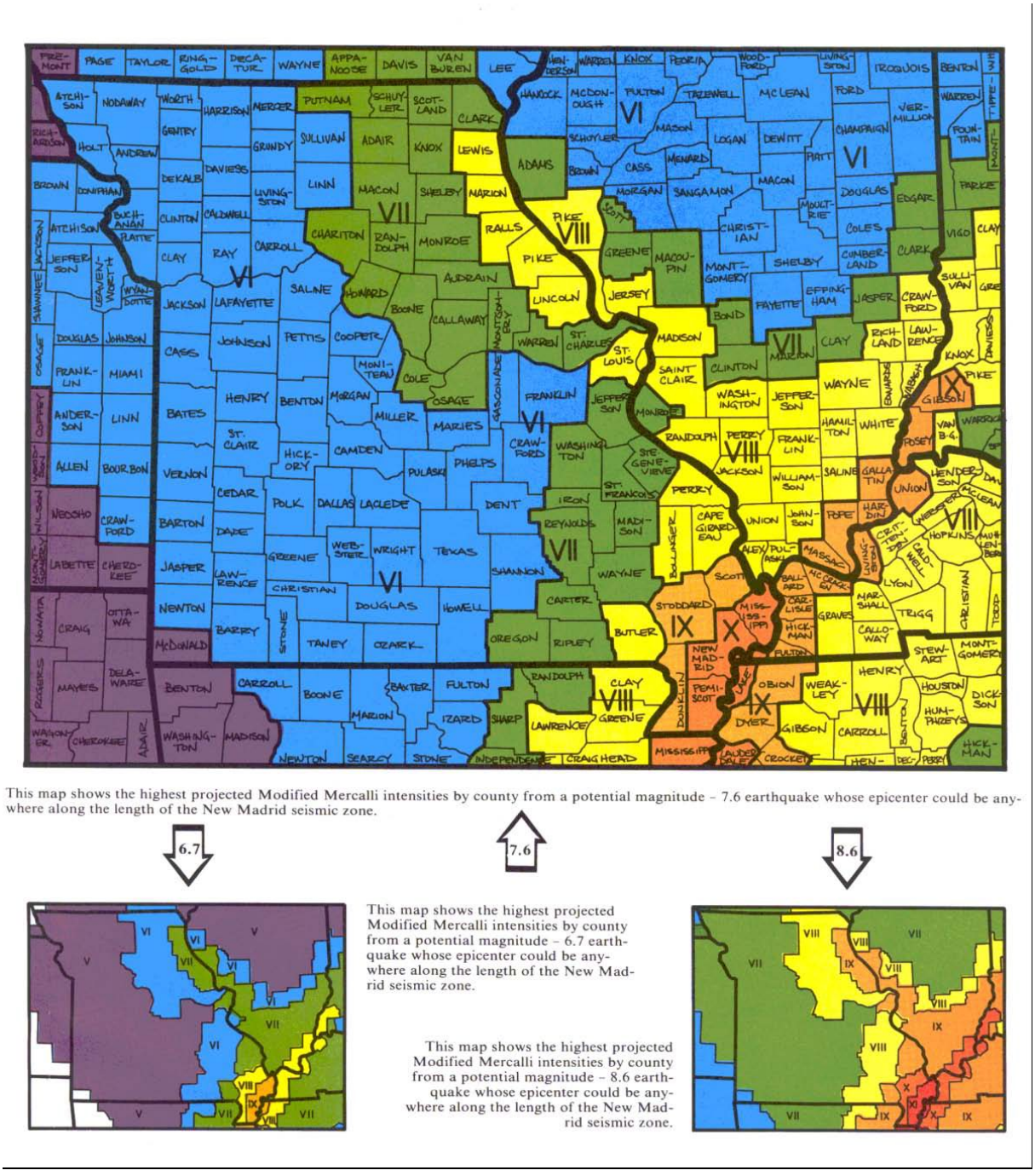
Some earthquakes occur in the middle of plates, as is the case for seismic zones in the Midwestern United States. The most seismically active area in the Midwest is the New Madrid Seismic Zone. The possibility of the occurrence of a catastrophic earthquake in the central and Eastern United States is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

Geographic Location

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

The following SEMA map (Figure 3.27) shows the highest projected Modified Mercalli intensities by county from a potential magnitude 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid Seismic Zone. The below figure indicates Audrain County and the affects that could be felt from the earthquake.

Figure 3.36. Impact Zones for Earthquake Along the New Madrid Fault



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

6.7

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.

7.6

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.

8.6

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

Figure 3.37. Projected Earthquake Intensities

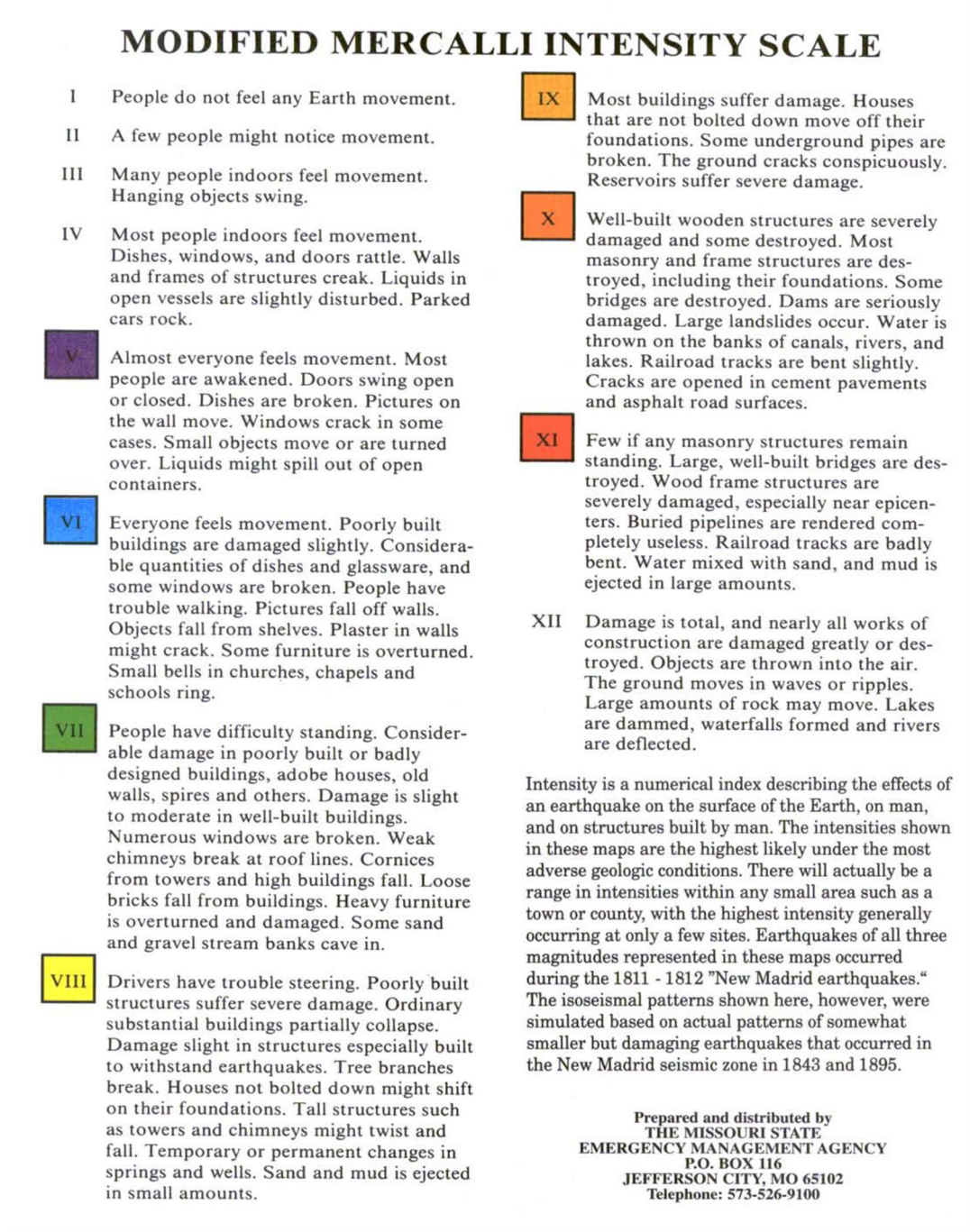
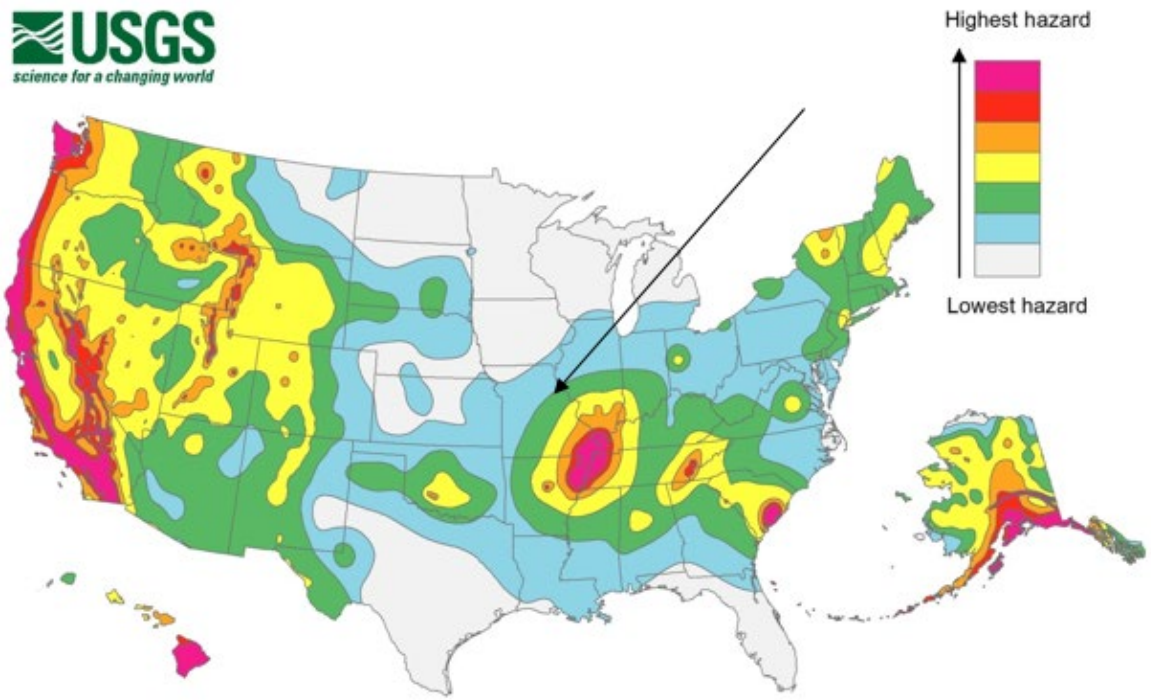


Figure 3.38. United States Seismic Hazard Map



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

Strength/Magnitude/Extent

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

Richter Magnitude Scale

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

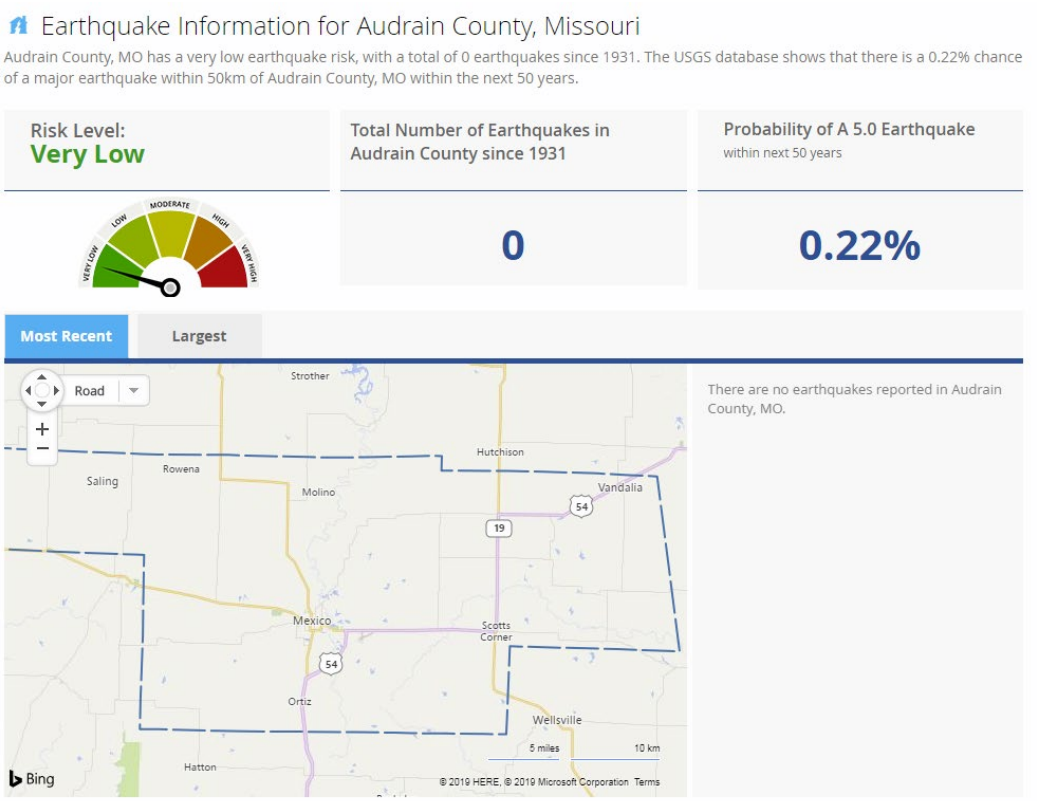
Modified Mercalli Intensity Scale

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

Previous Occurrences

There has been 0 Earthquakes reported in Audrain County since 1931.

Figure 3.39. Probability of Earthquake in Audrain County

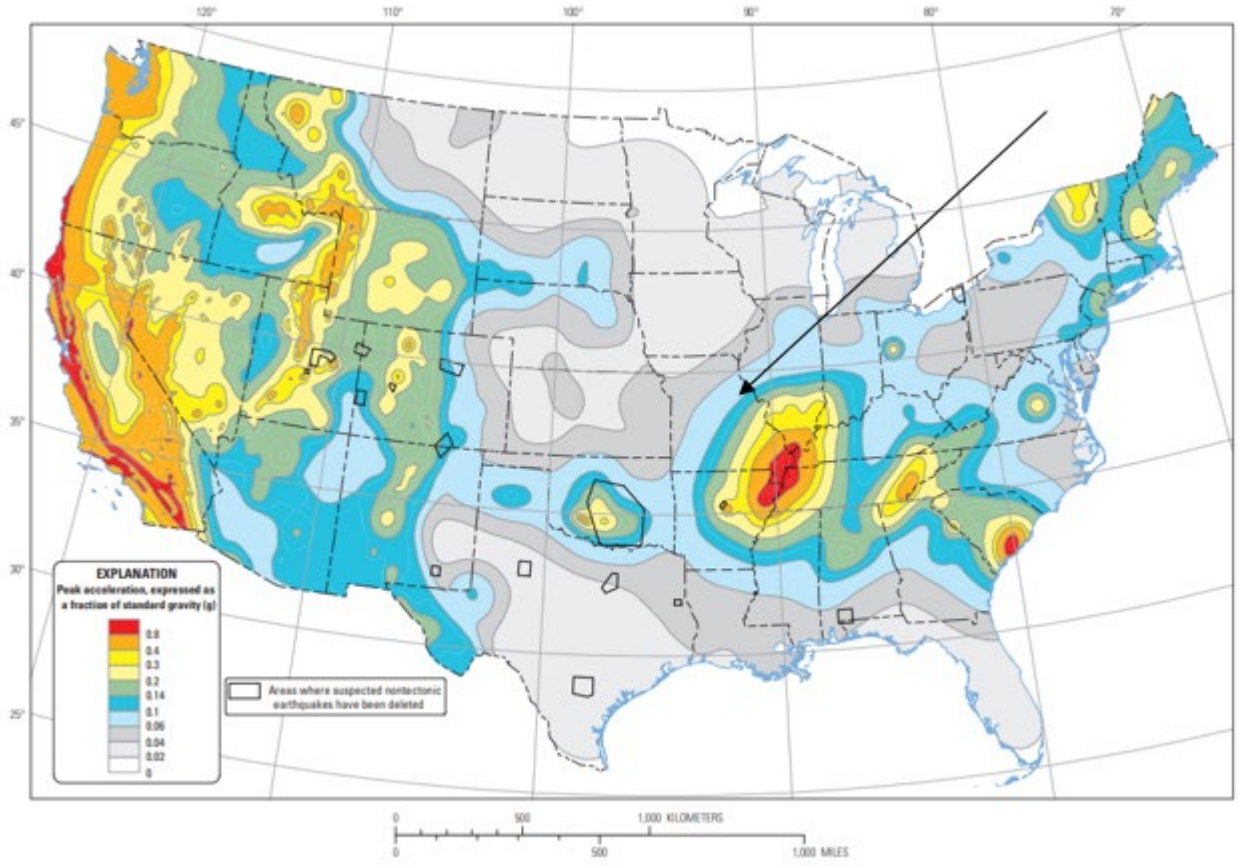


Source: https://www.homefacts.com/earthquakes/Missouri/Audrain-County.html

Probability of Future Occurrence

As described in Figure 3.30 Audrain County, MO has a very low earthquake risk, with a total of 0 earthquakes since 1931. The USGS database shows that there is a 0.22% chance of a major earthquake within 50km of Audrain County, MO in the next 50 years.

Figure 3.40. Two-percent probability of exceedance in 50 years map of peak ground acceleration



Two-percent probability of exceedance in 50 years map of peak ground acceleration

Source: https://earthquake.usgs.gov/hazards/hazmaps/conterminous/index.php#2014

Changing Future Conditions Considerations

Scientists are beginning to believe there may be a connection between changing climate conditions and earthquakes. Changing ice caps and sea-level redistribute weight over fault lines, which could potentially have an influence on earthquake occurrences. However, currently no studies quantify the relationship to a high level of detail, so recent earthquakes should not be linked with climate change. While not conclusive, early research suggests that more intense earthquakes and tsunamis may eventually be added to the adverse consequences that are caused by changing future conditions.

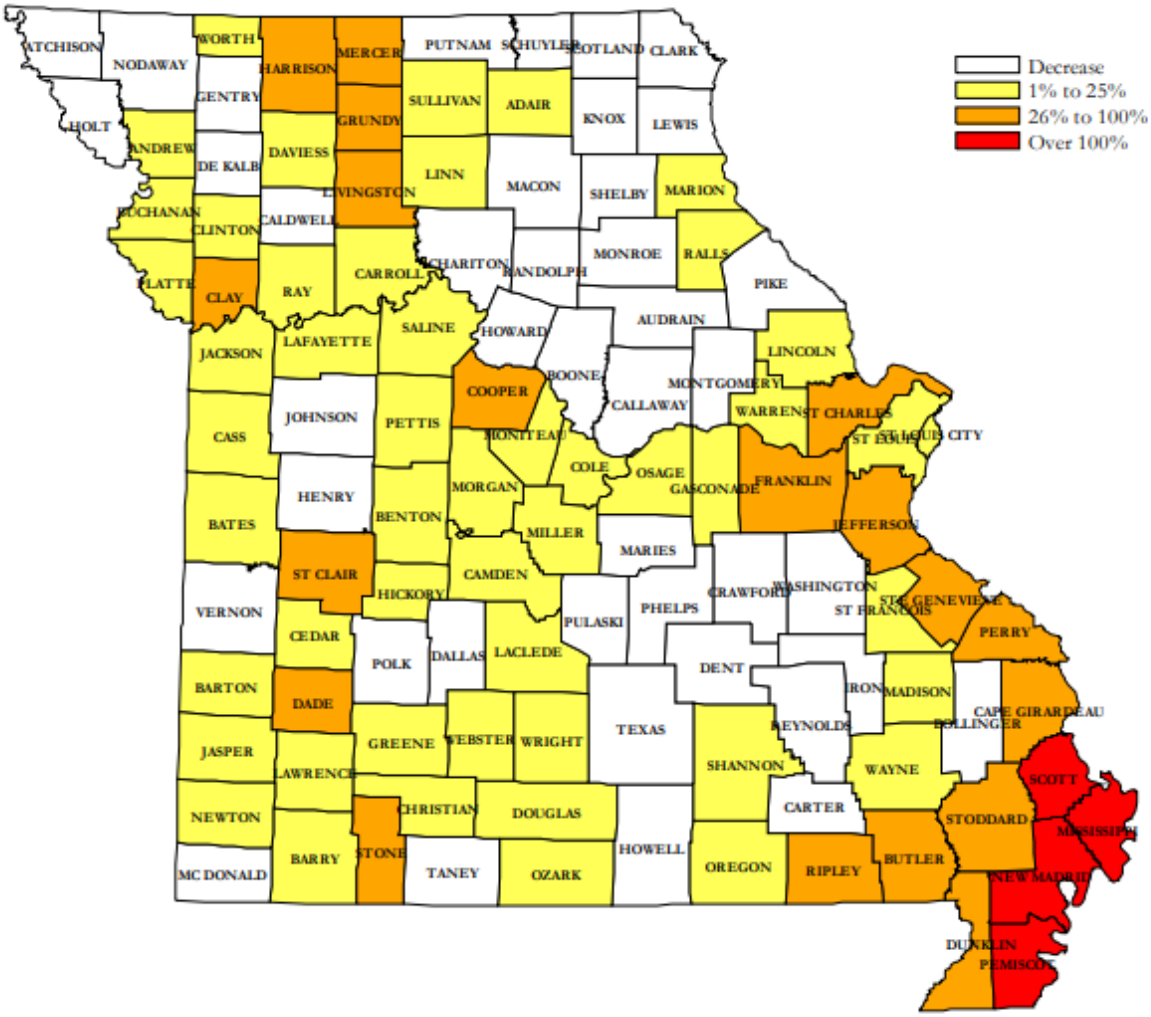
Vulnerability

Vulnerability Overview

According to the HAZUS -MH data obtained from the 2018 State Plan, Audrain County is listed as having a 6 to 10% Probability of Exceedance in 50 years of an earthquake. The total loss is estimated at $44,495.

The State of Earthquake Coverage Report states that the average premium for earthquake coverage in Audrain County during 2017 was $75, with the average premium $110k-$140k coverage at $38.

Figure 3.41. % Change in Cost of Earthquake Coverage between 2009-2017 $110-$140k Coverage Limits



Source: The State of Earthquake Coverage Report;
https://insurance.mo.gov/earthquake/documents/OverviewofResidentialEarthquakeInsurance2017.pdf

Potential Losses to Existing Development

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

Impact of Previous and Future Development

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

Hazard Summary by Jurisdiction

Since earthquake intensity is not likely to vary greatly throughout the planning area, the risk will be the same throughout. Audrain County is not near the New Madrid Shock Zone, but it will likely endure mild effects from the earthquake such as structure damage environmental impacts and economic disruption/losses. However, damages could vary due to structural variations in the planning area's built environment. For example, Laddonia has 31.8% residential structures built prior to 1939 and is likely to experience higher damages than Mexico with 15% or Vandalia with 14.1% of the residential structures built prior than 1939. Mexico has several buildings surrounding the courthouse in the downtown district that could receive structural damage from an earthquake. Audrain County would likely be impacted by the number of refugees traveling through the area seeking safety and assistance.

Problem Statement

Although Audrain County is not located in an area that will likely see catastrophic damage from an earthquake, the County will be impacted by the loss of communications, transportation, the disruption of roads, rail and pipelines, water transportation, and the area will see a significant amount of refugees fleeing from Southern Missouri if a quake hits that area. Education is minimal for earthquakes do to the low likely hood of impact. There is one Emergency Management Director for the County that knows where all the generators and emergency buildings are. Not all citizens utilize social media and texting. An emergency plan for earthquakes needs to be made available to all residents and stated what would happen in the event of an earthquake with details for communications and transportation. Downtown building owners need to know plan in case damage is done to their building. Residents need to be made aware of where the generators and emergency buildings are located. Utilization of social media and texting needs to be encouraged.

3.4.4 Land Subsidence/Sinkholes

Hazard Profile

Hazard Description

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

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

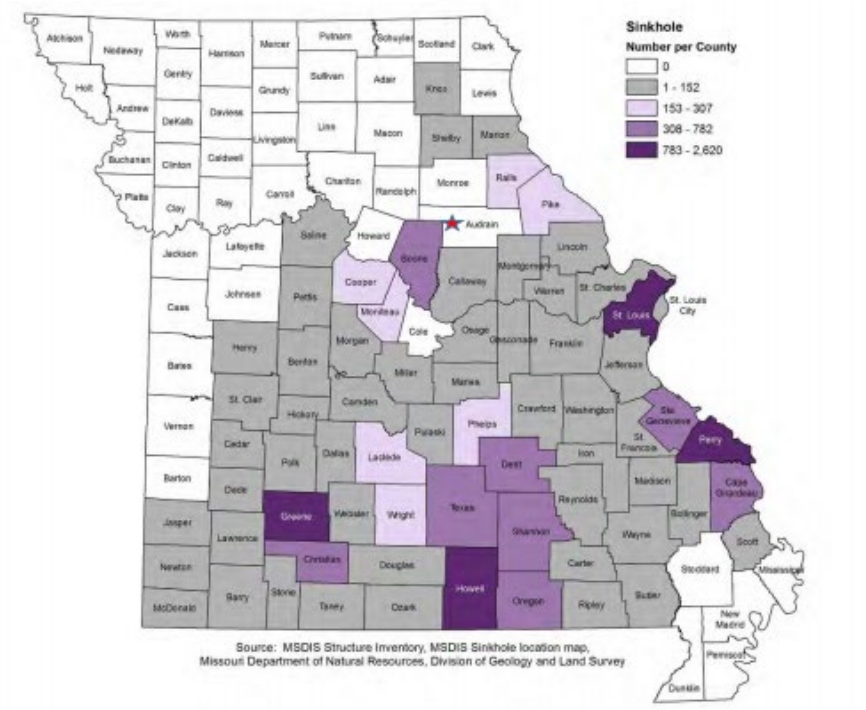
In the case of sinkholes, the rock below the surface is rock that has been dissolving by circulating groundwater. As the rock dissolves, spaces and caverns form, and ultimately the land above the spaces collapse. In Missouri, sinkhole problems are usually a result of surface materials above openings 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 is shape like shallow bowls or saucers whereas other have vertical walls. Some hold water and form natural ponds.

According to the 2018 Missouri State Hazard Mitigation Plan, there are 94 mines in Audrain County and 0 sinkholes.

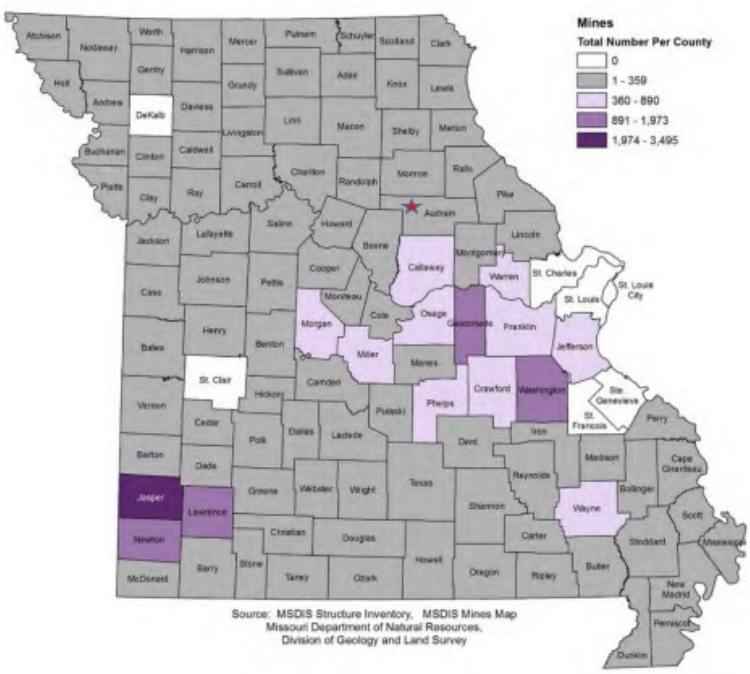
Geographic Location

Figure 3.42. Sinkholes in Audrain County



Source: 2018 Missouri State Hazard Mitigation Plan; *Star shows Audrain County

Figure 3.43. Mine Counts per County



Source: 2018 Missouri State Hazard Mitigation Plan; *Star shows Audrain County

Table 3.23. Audrain County Sinkhole and Mine Counts

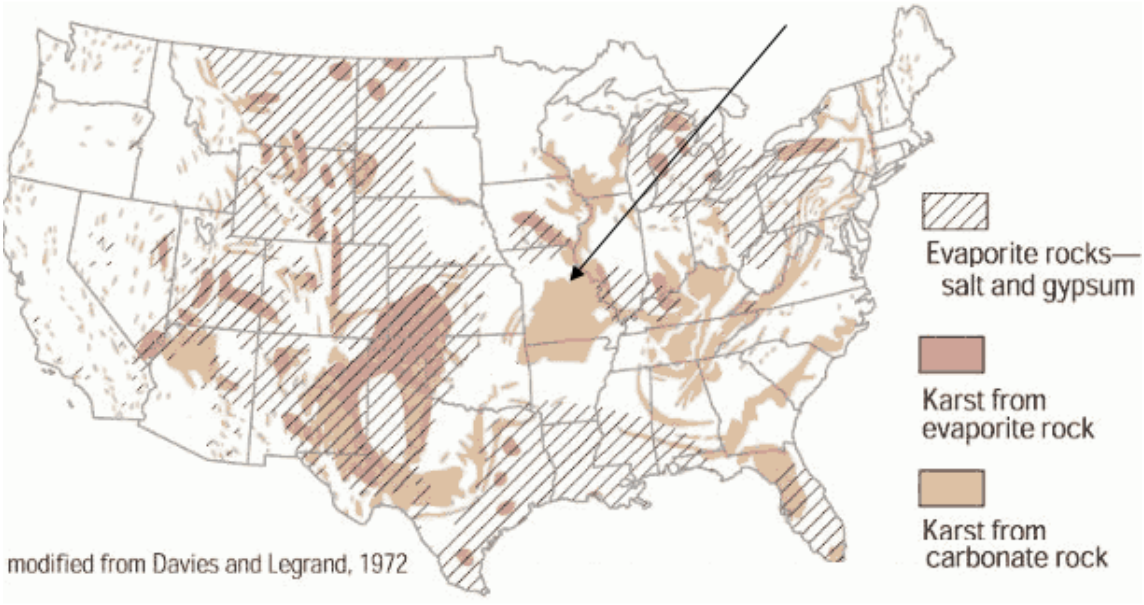
County	Number of Sinkholes Per County	Number of Mines Per County
Audrain	0	94

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.44. Sinkholes in Missouri

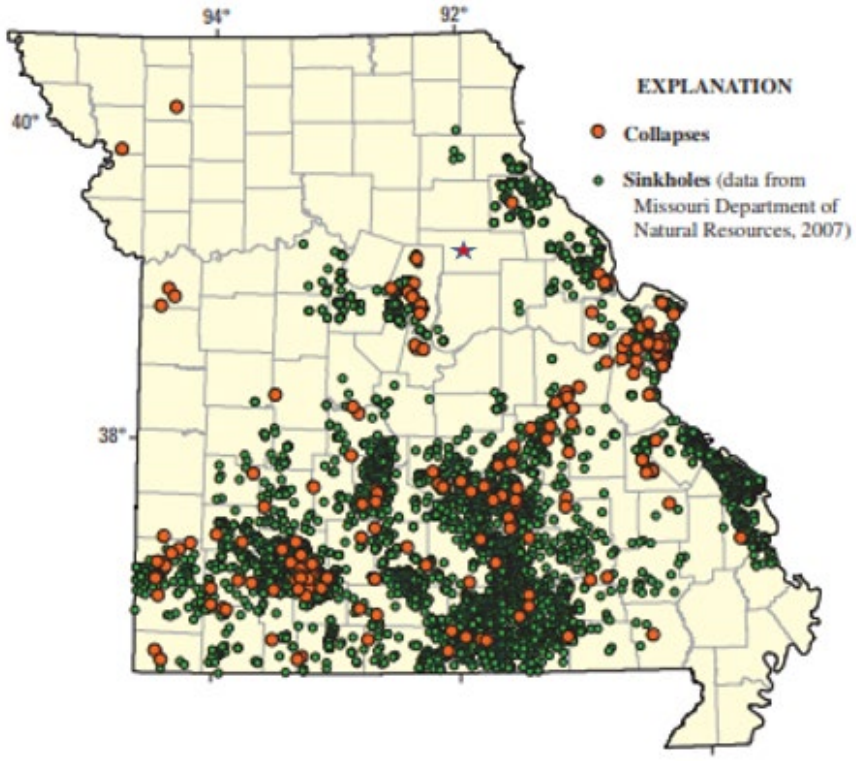
Source: Missouri Department of Natural Resources; http://www.dnr.mo.gov/geology/geosrv/envgeo/sinkholes.htm

Figure 3.45. Karst in Missouri



Source: 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

Figure 3.46. Collapses and Sinkholes in Audrain County



Source: http://www.businessinsider.com/where-youll-be-swallowed-by-a-sinkhole-2013-3

Strength/Magnitude/Extent

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

Previous Occurrences

As noted in the 2018 State Plan, sinkholes are a regular occurrence in Missouri, but rarely are the events of any significance. Notable events are outlined. There is no record of previous occurrences in Audrain County.

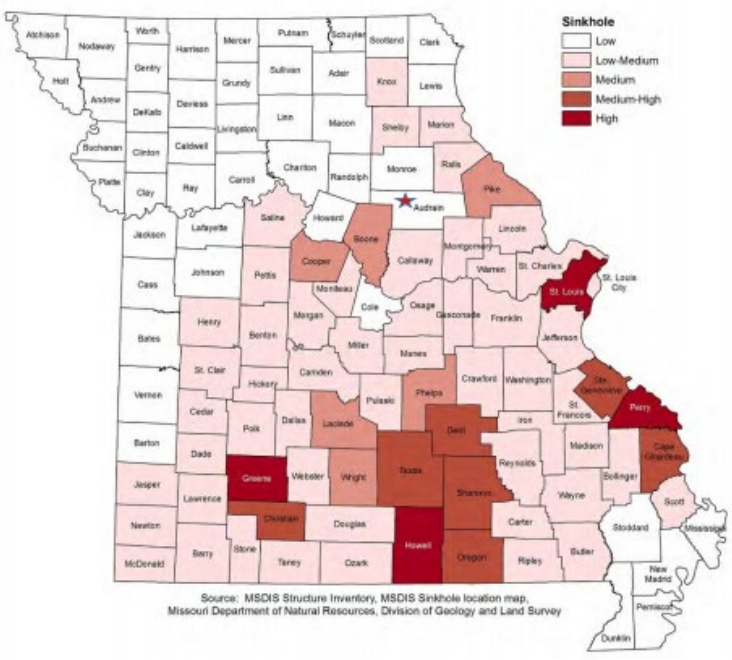
Probability of Future Occurrence

Figure 3.47. Sinkhole Rating Values

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 +

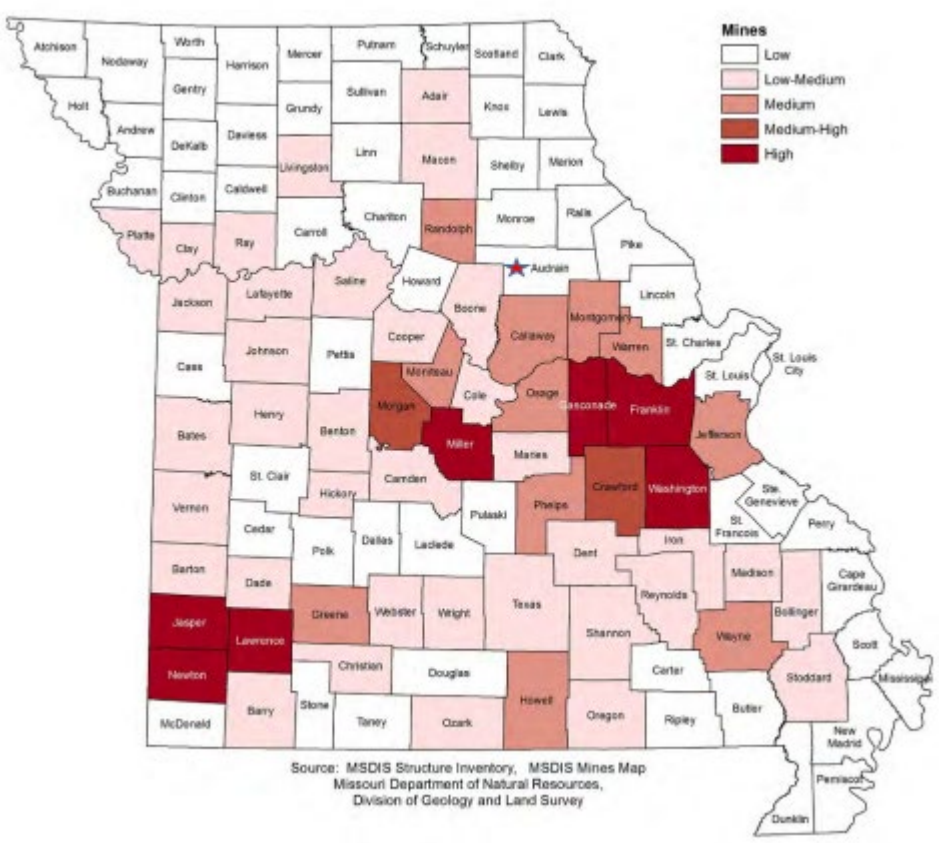
Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.48. Sinkhole Rating by County



Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.49. Mine Rating Value by County



Source: 2018 Missouri State Hazard Mitigation Plan; *Star shows Audrain County

There are no records of previous event dates in the planning area, the probabilities cannot be calculated due to limited information. As represented in the figures above, the sinkholes and mines located in Audrain County have been rated low risk.

Changing Future Conditions Considerations

According to the 2018 Missouri State Hazard Mitigation Plan, direct effects from changing climate conditions such as an increase in droughts and could contribute to an increase in sinkholes. These changes raise the likelihood of extreme weather, meaning the torrential rain and flooding conditions which often lead to the exposure of sinkholes are likely to become increasingly common. Certain events such as a heavy precipitation following a period of drought can trigger a sinkhole due to low levels of groundwater combined with a heavy influx of rain.

Vulnerability

Vulnerability Overview

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

The Missouri Department of Natural Resources shows no sinkholes for the planning area.

Potential Losses to Existing Development

The potential impact of sinkholes on existing structures is difficult to determine due to the lack of data on historic damages caused by sinkholes and the mapping of potential sinkholes is difficult if not impossible to predict where a sinkhole will collapse and how significant the collapse will be. Because sinkhole collapse is not predictable and previous events have occurred in the rural area there is not significant data to estimate the future losses due to a sinkhole.

Impact of Previous and Future Development

As more development occurs on unmapped rural areas the vulnerability to the hazard will increase; however sinkholes are unpredictable and the development in rural areas is difficult to limit due to the lack of occurrence. There are currently no sinkholes in the planning area, and Audrain County participating jurisdictions have no plans to limit construction due to sinkholes.

Hazard Summary by Jurisdiction

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

Problem Statement

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

3.4.5 Drought

Hazard Profile

Hazard Description

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

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

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

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

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

Geographic Location

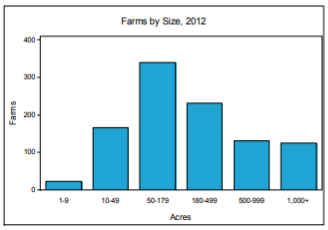
Droughts are regional in nature. All areas of the United States are vulnerable to the risk of drought and extreme heat. Droughts can be widespread or localized events. The extent of the droughts varies both in terms of the extent of the heat and range of precipitation. The severity of a drought depends on locations, duration, and geographical extent. Additionally drought severity depends on the water supply, usage demands made by human activities, vegetation and agricultural operations. Drought brings several different problems that must be addressed. The quality and quantity of crops, livestock and other agricultural assets will be affected during a drought. Drought can adversely impact forested areas leading to an increased potential for extremely destructive forest and woodland fires that could threaten residential, commercial, and recreational structures. According to the 2012 Census of Agriculture, Audrain County consist of 436,483 acres land in farms, crop sales generate $89,658,000 and livestock sales generate $61,536,000. A drought would directly impact livestock production and the agriculture economy in Audrain County.

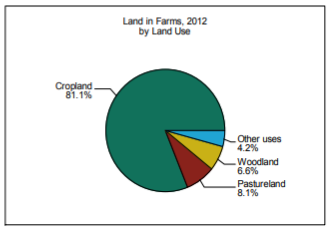
Figure 3.50. Census of Agriculture, Audrain County

2012 CENSUS OF AGRICULTURE
COUNTY PROFILE

Audrain County
Missouri

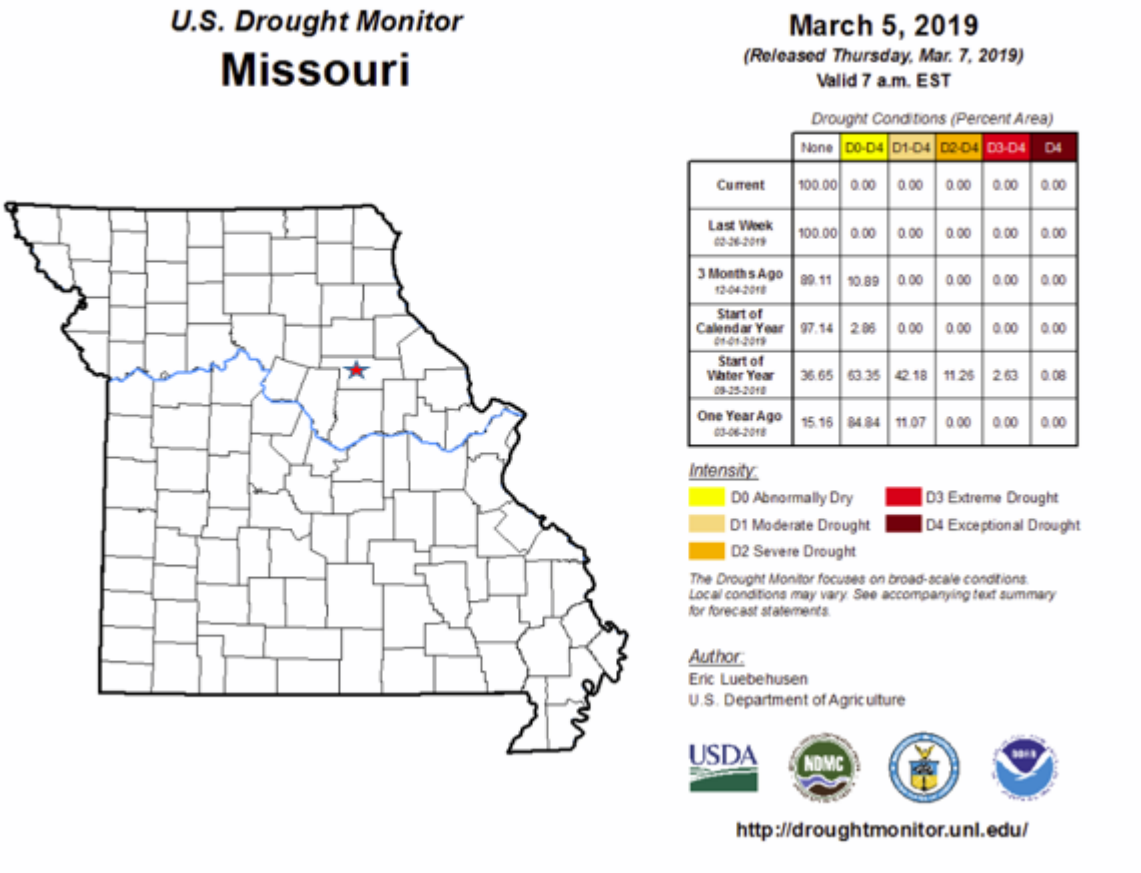
	2012	2007	% change
Number of Farms	1,015	1,102	- 8
Land in Farms	436,483 acres	424,880 acres	+ 3
Average Size of Farm	430 acres	386 acres	+ 11
Market Value of Products Sold	$151,194,000	$136,611,000	+ 11
Crop Sales $89,658,000 (59 percent) Livestock Sales $61,536,000 (41 percent)			
Average Per Farm	$148,960	$123,967	+ 20
Government Payments	$5,605,000	$6,482,000	- 14
Average Per Farm Receiving Payments	$8,366	$9,053	- 8





Source: https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/County_Profiles/Missouri/cp29007.pdf

Figure 3.51. U.S. Drought Monitor Map of Missouri on March 5, 2019



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

Strength/Magnitude/Extent

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

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

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

Previous Occurrences

Drought occurs periodically in Missouri with the most severe and costly times occurring in 2018. Although droughts are not the spectacular weather events that floods, blizzards or tornadoes can be, historically they produce more economic damage to the State than all other weather events combined.

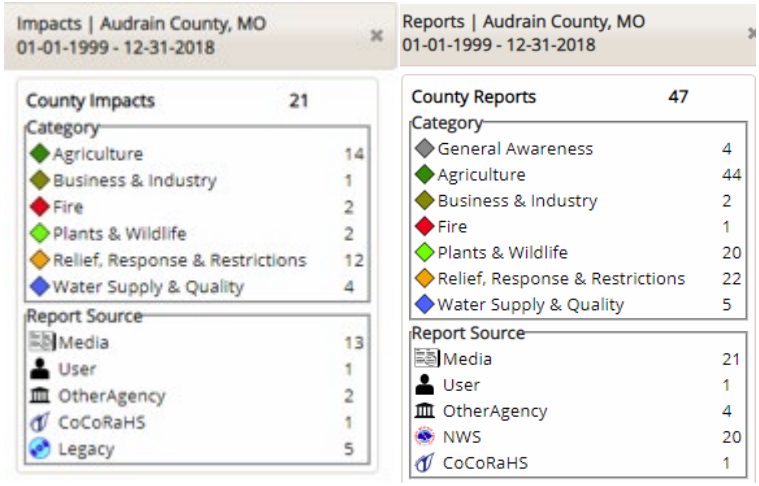
Table 3.24. **Drought Payment in Audrain County**

Drought Year	Insurance Payment
2014	$4,826.80
2015	$401,419.90
2016	$9,058.00
2017	$94,969.00
2018	$2,742,063.22
Total	**$3,252,336.92**

Source: USDA; http://www.rma.usda.gov/data/cause.html

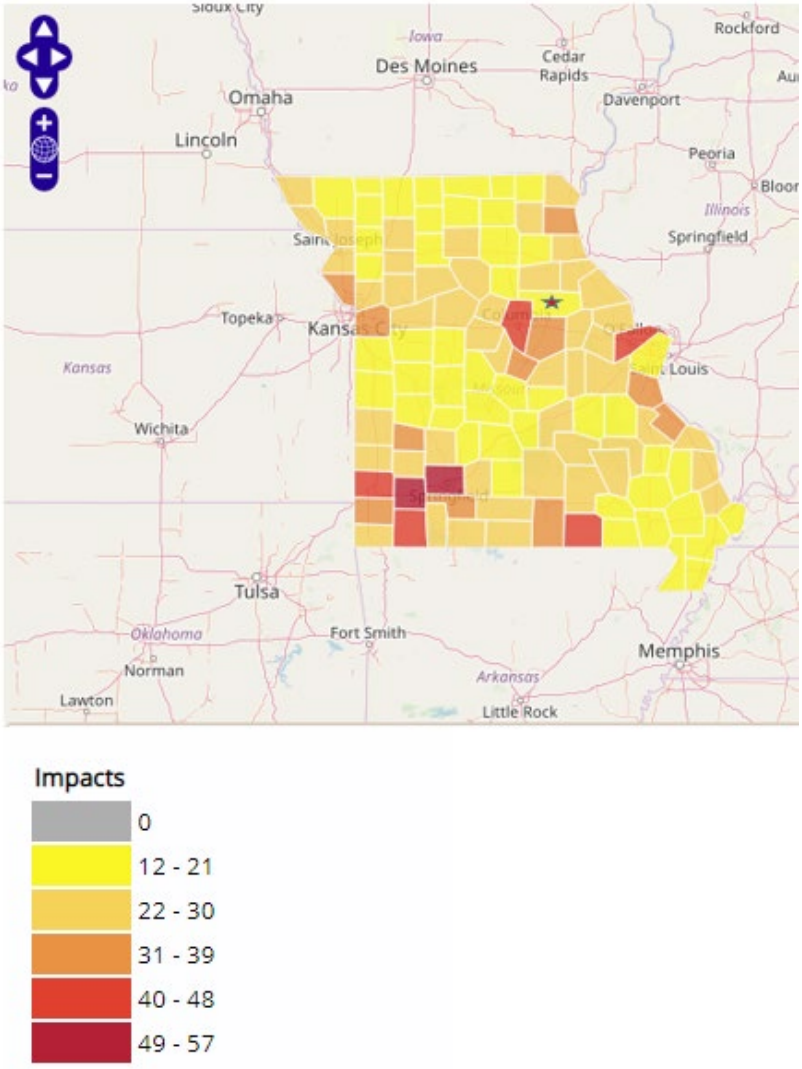
According to the National Drought Mitigation Center's Drought Impact Reporter, during the 20-year period from January 1998 to December 2017, Audrain County had 21 drought impacts and 47 reports.

Figure 3.52. Drought Impacts in Audrain County



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

Figure 3.53. Audrain County Drought Impact (January 1999 -December 2018)



Source: Drought Impact Reporter; http://droughtreporter.unl.edu/ ; *Star show Audrain County

Probability of Future Occurrence

According to the 2018 State Plan Audrain County has a High total rating for droughts. And is very likely to experience droughts in the future, with a 10.72% chance likelihood of a severe drought.

Table 3.25. **Vulnerability of Audrain County to Drought**

County	SOVI Index Rating	USDA RMA Total Drought Crop Claims	Average Annualized Crop Claims	USDA Claims Rating	2012 Crop Exposure	Crop Exposure Rating	Likeli-hood of Severe Drought (%)	Drought Occurrence Rating	Total Rating	Total Rating (Text) Drought
Audrain	1	$65,477,602	$7,275,289	5	$89,658,000	4	10.72	5	15	High

Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.26. **Ranges for Drought Vulnerability Factor Ratings**

Factors Considered	Low (1)	Low-medium (2)	Medium (3)	Medium-high-4	High (5)
Social Vulnerability Index	1	2	3	4	5
Crop Exposure Ratio Rating	$886,000 - $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	$670,000- $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

Although drought is not predictable, long-range outlooks and predicted impacts of climate change could indicate an increased chance of drought.

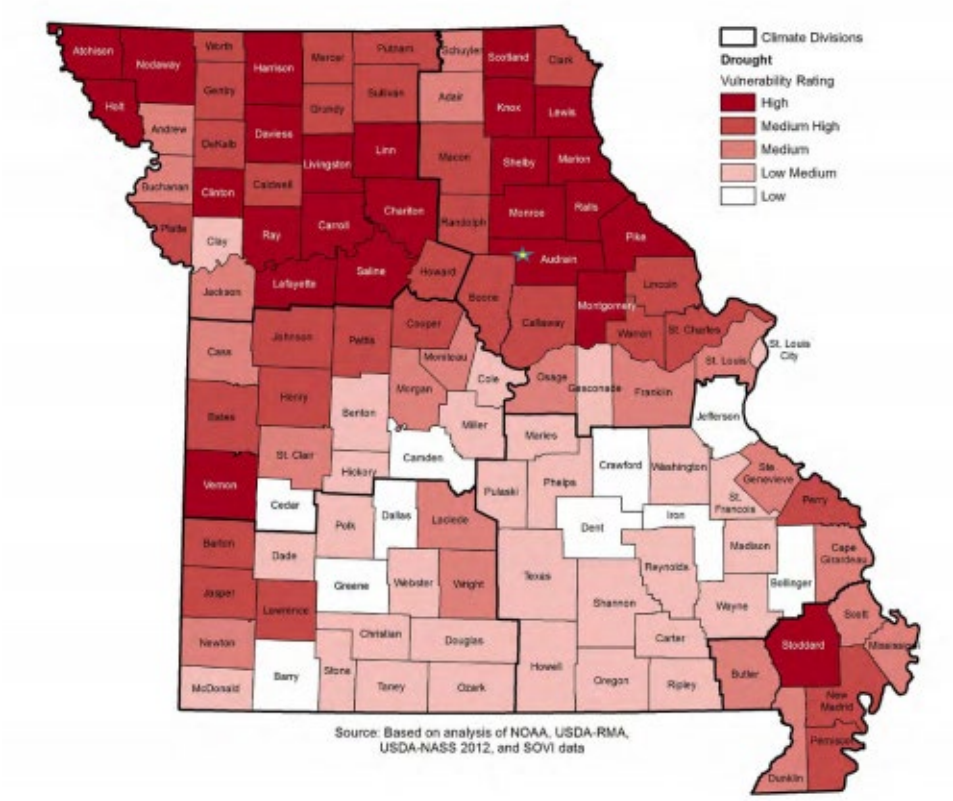
Changing Future Conditions Considerations

In the 2018 Missouri State Plan, Severe drought, a natural part of Missouri's climate, is a risk to this agriculture-dependent state. Future increases in evaporation rates due to higher temperatures may increase the intensity of naturally-occurring droughts. The number of heavy rainfall events is predicted to increase, yet researchers currently expect little change in total rainfall amounts, indicating that the periods between heavy rainfalls will be marked by an increasing number of dry days. Higher temperatures and increased evapotranspiration increase the likelihood of a drought. This could lead to agricultural drought and suppressed crop yields

Vulnerability

Vulnerability Overview

Figure 3.54. Missouri Drought Vulnerability by County



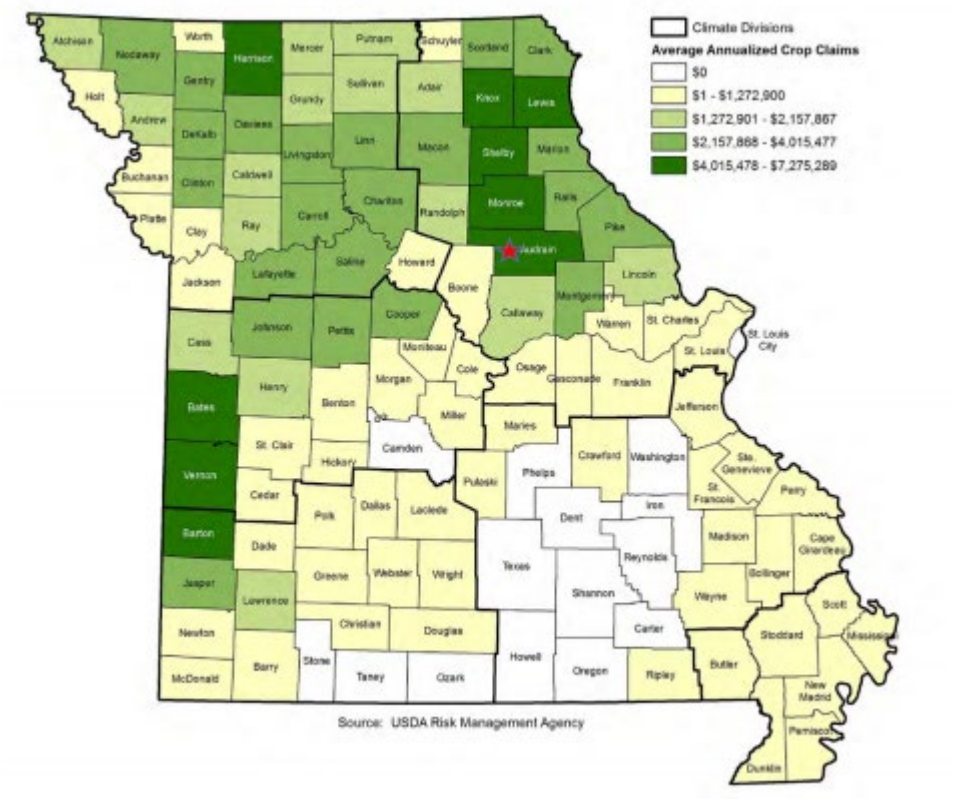
Source: 2018 Missouri State Hazard Mitigation Plan

According to the analysis from the 2018 State Plan, Audrain County is a high vulnerability County for droughts.

Potential Losses to Existing Development

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

Figure 3.55. Annualized Drought Crop Insurance Claims Paid from 2007-2016



Source: 2018 Missouri State Hazard Mitigation Plan

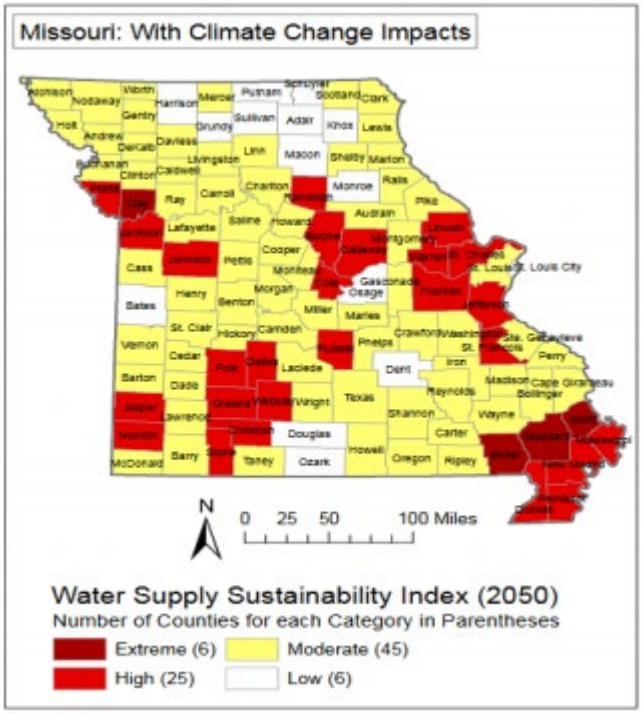
Future development will remain vulnerable to drought. Typically, some urban and rural areas are more susceptible than others. For example, urban area are subject to water shortages during periods of drought. Excessive demands of the populated area place a limit on water resources.

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

Changing Future Conditions Considerations

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

Figure 3.56. Climate Change Impacts



Source: http://www.nrdc.org/globalWarming/watersustainability/

Hazard Summary by Jurisdiction

The entire planning area will be affected by drought of some degree. The unincorporated agricultural areas of Audrain County are the most vulnerable to drought while the drought condition will also affect the cities except the magnitude would be different with only lawns and local gardens will be impacted. In addition damage to crops, produce, livestock, soils and building foundations could be weakened due to shrinking and expanding soil.

Problem Statement

Audrain County is at a high risk for a severe drought which is an extra strain placed on the water supply system. Possible solutions include the development of agreements with neighboring communities for a secondary water source and review of local ordinance/regulation for inclusion of water-use restrictions during periods of drought.

3.4.6 Extreme Temperatures

Hazard Profile

Hazard Description

Extreme temperature events, both hot and cold, can impact human health and mortality, natural ecosystems, agriculture and other economic sectors. According to information provided by FEMA, extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. Ambient air temperature is one component of heat conditions, with relative humidity being the other. The relationship of these factors creates what is known as the apparent temperature. The Heat Index chart shown in **Figure 3.60** uses both of these factors to produce a guide for the apparent temperature or relative intensity of heat conditions.

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

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

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

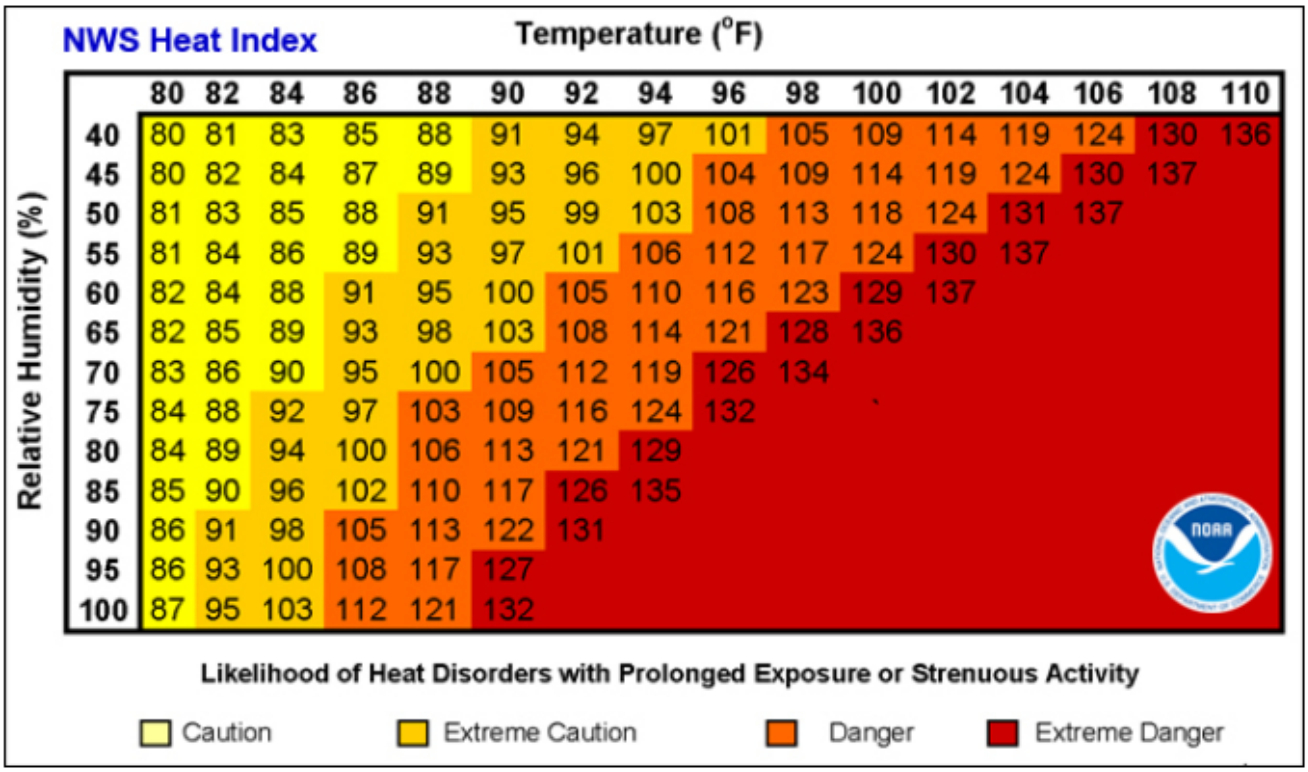
Geographic Location

The entire planning area is subject to extreme heat and all participating jurisdictions are affected.

Strength/Magnitude/Extent

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

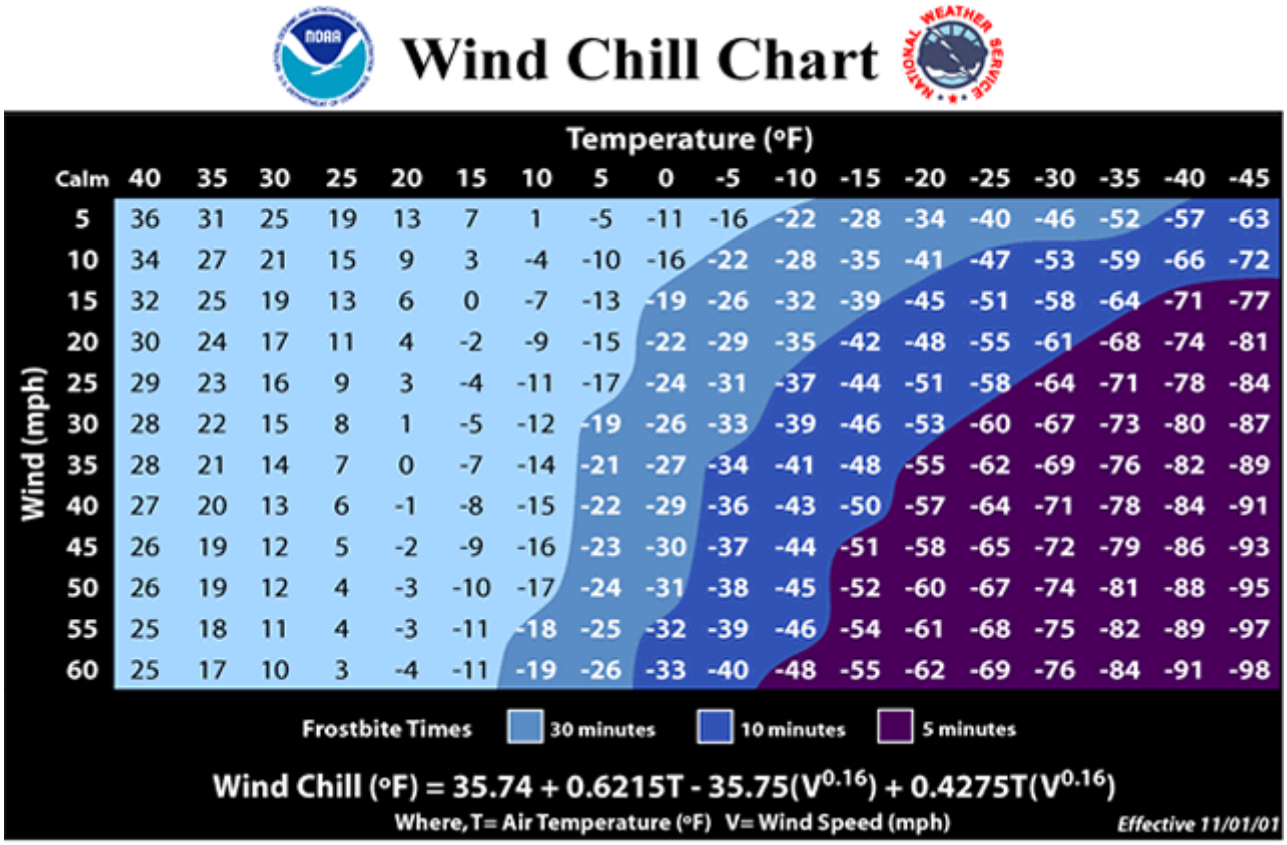
Figure 3.57. Heat Index (HI) Chart



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

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

Figure 3.58. Wind Chill Chart

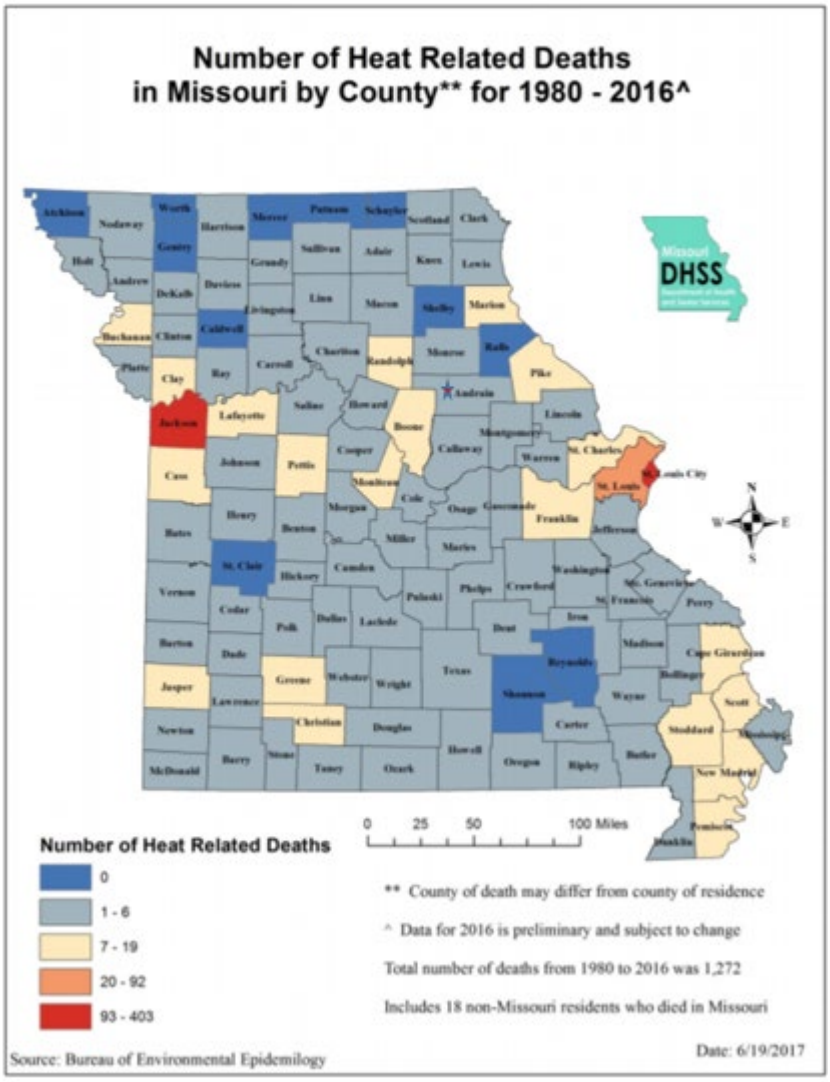


Source: https://www.weather.gov/safety/cold-wind-chill-chart

Previous Occurrences

The recorded events in the National Centers for Environmental Information (NCEI) database and state there have been 20 recorded events of excessive heat in the 20 year period of 1999-2018. There were no deaths or injuries associated with these events. The NCEI database show 1 recorded event of extreme cold/wind chill, with 0 deaths or injuries associated with this event. Figure 3.62 illustrates between 1-6 heat related deaths in Audrain County between the time of 1980-2016, no supporting documentation could be found to include in this plan.

Figure 3.59. Heat Related Deaths in Missouri 2000 - 2016



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

Table 3.27. **Agricultural Insurance Claims Due to Extreme Temperature- Heat**

2008	$ 0
2009	$ -
2010	$ -
2011	$ 2,772,289.90
2012	$ 4,408,668.50
2013	$941,088
2014	$ -
2015	$15,318.17
2016	$5,893.00
2017	$ -
2018	$67,764.60
Total	$ 8,211,022.17

Source: http://www.rma.usda.gov/data/cause.html

Extreme heat can cause stress to crops and animals. According to USDA Risk Management Agency, losses to insurable crops during the 20-year time period from 2008 to 2018 were $8,211,022.17. Extreme heat can also strain electricity delivery infrastructure overloaded during peak use of air conditioning during extreme heat events. Another type of infrastructure damage from extreme heat is road damage. When asphalt is exposed to prolonged extreme heat, it can cause buckling of asphalt-paved roads, driveways, and parking lots.

From 1988-2011, there were 3,496 fatalities in the U.S. attributed to summer heat. This translates to an annual national average of 146 deaths. During the same period, 0 deaths were recorded in the planning area, according to NCEI data. The National Weather Service stated that among natural hazards, no other natural disaster—not lightning, hurricanes, tornadoes, floods, or earthquakes—causes more deaths.

Probability of Future Occurrence

NCEI, dating back to 1998 indicates 3 years without extreme heat events (1998, 2013, 2018). In eight years there were multiple extreme heat events. Based on this historical data, the calculated probability of an extreme heat event in any given year is 86%. The probability was determined by taking the number of years with an extreme heat event (18) divided by the number of years (21) data was obtained for. Based on the historical data, the calculated probability of an extreme cold event in any given year is 4.8%. The probability was determined by taking the number of years with an extreme cold event (1) divided by the number of years (21) data was obtained for.

Changing Future Conditions Considerations

According to the 2018 Missouri State Plan, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. The impacts of extreme heat events are experienced most acutely by the elderly and other vulnerable populations. High temperatures are exacerbated in urban environments, a phenomenon known as the urban heat

island effect, which in turn tend to have higher concentrations of vulnerable populations. Higher demand for electricity as people try to keep cool amplifies stress on power systems and may lead to an increase in the number of power outages. Atmospheric concentrations of ozone occur at higher air temperatures, resulting in poorer air quality, while harmful algal blooms flourish in warmer water temperatures, resulting in poorer water quality.

Vulnerability

Vulnerability Overview

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

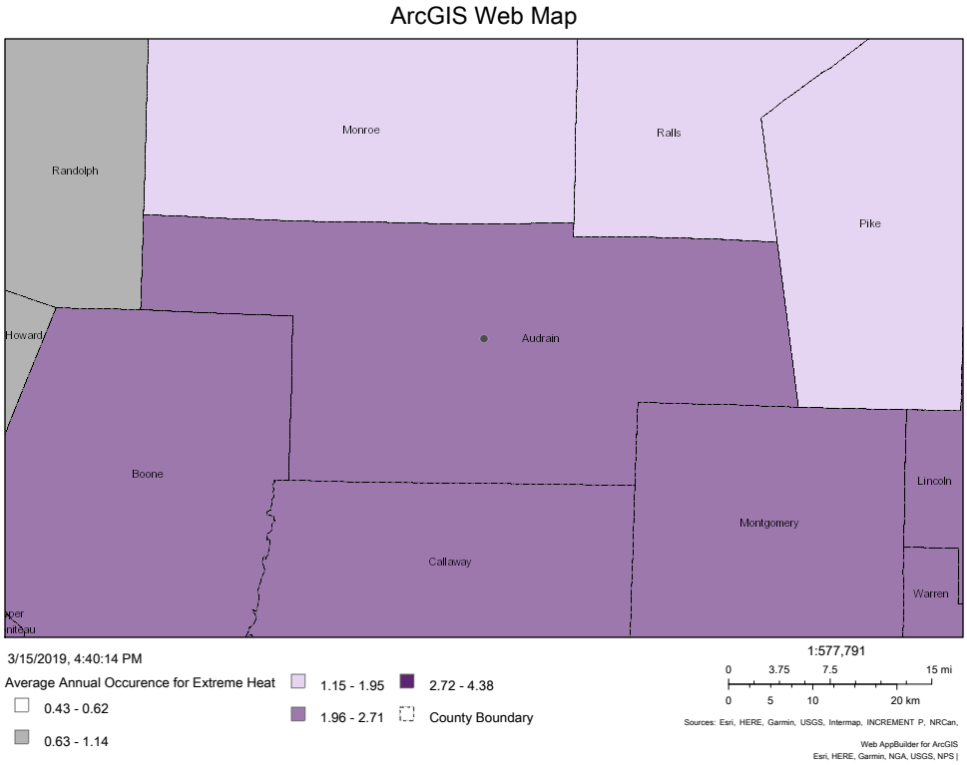
Table 3.28 lists typical symptoms and health impacts due to exposure to extreme heat.

Table 3.28. **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

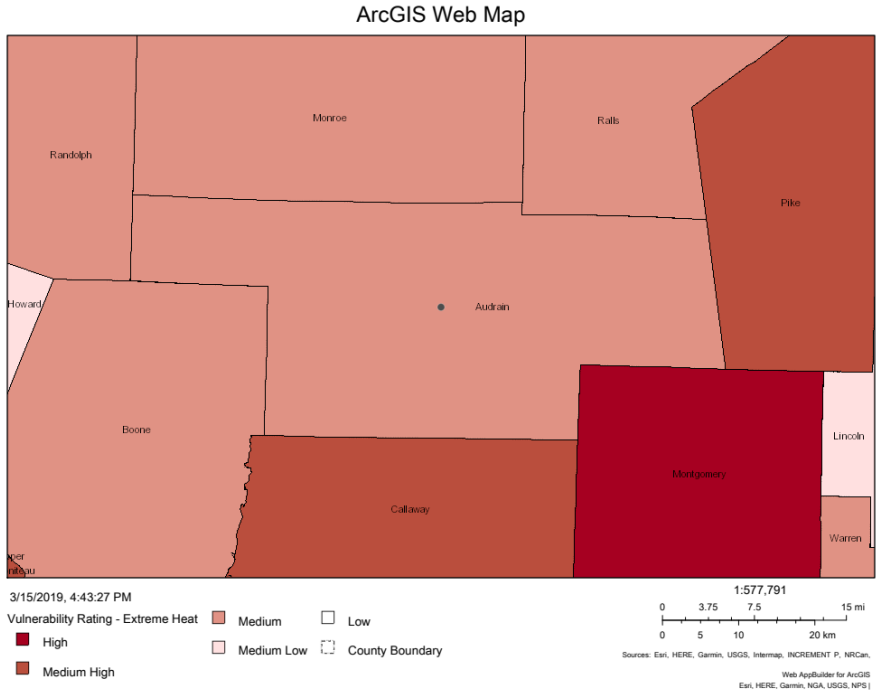
Source: National Weather Service Heat Index Program, www.weather.gov/os/heat/index.shtml

Figure 3.60. Average Annual Occurrence for Extreme Heat



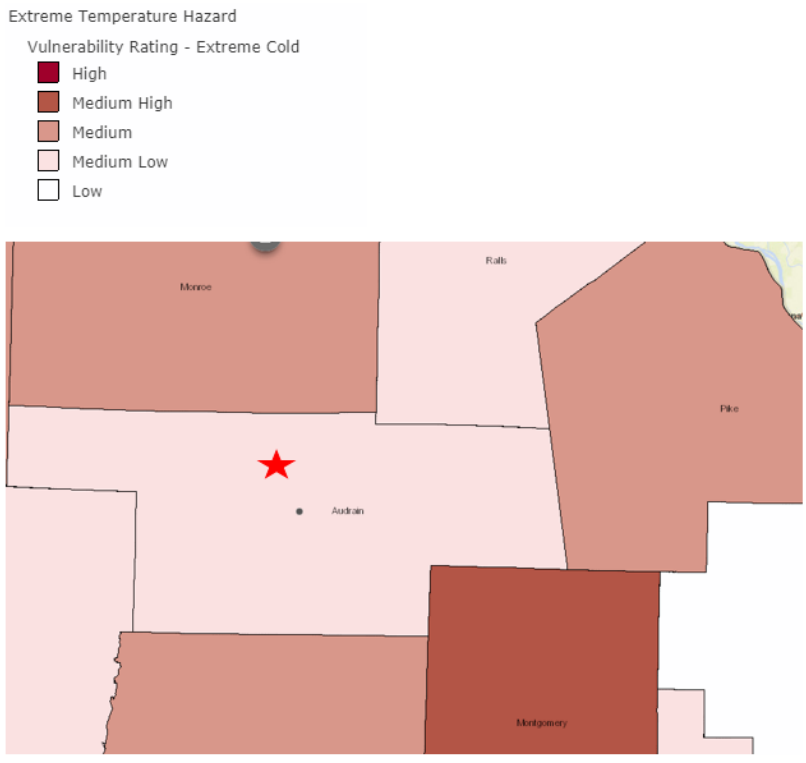
Source: http://bit.ly/MoHazardMitigationPlanViewer2018

Figure 3.61. Vulnerability Rating-Extreme Heat



Source: http://bit.ly/MoHazardMitigationPlanViewer2018

Figure 3.62. Vulnerability Rating-Extreme Cold



Source: http://bit.ly/MoHazardMitigationPlanViewer2018

Potential Losses to Existing Development

During the twenty year period from 1998-2018 there were $8,211,022.17 in crop insurance claims paid as a result of losses to extreme temperatures. The anticipated loss in any given year can be expected to be the annual average of $410,551.11. Illness and loss of life are the most concern with extreme heat.

Impact of Previous and Future Development

Population growth can result in increases in the age-groups that are most vulnerable to extreme heat. Population growth also increases the strain on electricity infrastructure, as more electricity is needed to accommodate the growing population.

According to the 2013-2017 American Community Survey 5-Year estimates, Audrain County, Benton City, Farber, Laddonia, Martinsburg, Mexico, Vandalia, Village of Rush Hill and Vandiver Village will have an increase of population under 5 years, and population of 65 years and over.

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. The population at the greatest risk for cold related illness and deaths include people 65 years of age and older. To determine jurisdictions within the planning area with populations more vulnerable to extreme heat and cold, demographic data was obtained from the 2010 census on population percentages in each jurisdiction comprised of those under age 5 and over age 65. Data was not available for overweight individuals and those on medications vulnerable to extreme heat. **Table 3.28** 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 3.29. **Audrain County Population Under Age 5 and Over Age 65, 2010 Census Data**

Jurisdiction	Population Under 5 yrs	Population 65 yrs and over
Audrain County	1,730	4,084
Laddonia	26	87
Mexico	875	1,960
Vandalia	175	479

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

Problem Statement

Audrain County has a growing population of residents over 65 years, who are at a greater risk for extreme-temperature related illnesses, injuries, and death. Possible solutions include organizing outreach to the vulnerable elderly populations, including establishing and promoting accessible heating or cooling centers in the community and creating a database in coordination with the Health Department to track those individuals at high risk.

3.4.7 Severe Thunderstorms Including High Winds, Hail, and Lightning

Hazard Profile

Hazard Description

Thunderstorms

A thunderstorm is defined as a storm that contains lightning and thunder which is caused by unstable atmospheric conditions. When cold upper air sinks and warm moist air rises, storm clouds or 'thunderheads' develop resulting in thunderstorms. This can occur singularly, as well as in clusters or lines. The National Weather Service defines a thunderstorm as "severe" if it includes hail that is one inch or more, or wind gusts that are at 58 miles per hour or higher. At any given moment across the world, there are about 1,800 thunderstorms occurring. Severe thunderstorms most often occur in Missouri in the spring and summer, during the afternoon and evenings, but can occur at any time. Other hazards associated with thunderstorms are heavy rains resulting in flooding (discussed separately in **Section 3.4.1**) and tornadoes (discussed separately in **Section 3.4.10**).

High Winds

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

Lightning

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

Hail

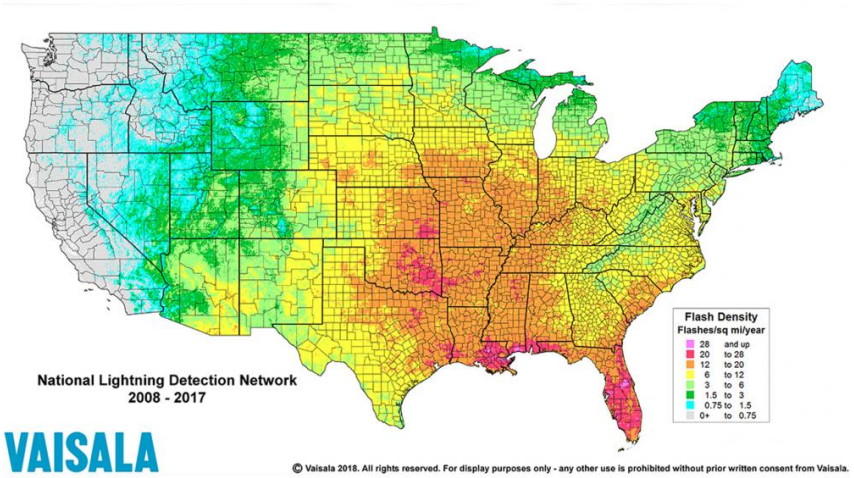
According to the National Oceanic and Atmospheric Administration (NOAA), hail is precipitation that is formed when thunderstorm updrafts carry raindrops upward into extremely cold atmosphere causing them to freeze. The raindrops form into small frozen droplets. They continue to grow as they come into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

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

Geographic Location

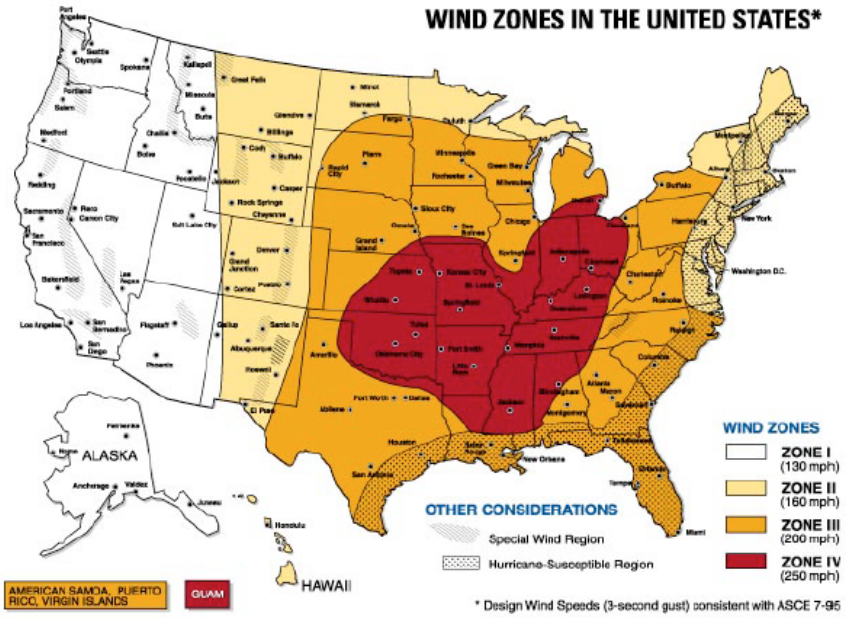
Thunderstorms/high winds/hail/lightning events are an area-wide hazard that can happen anywhere in the county. Although these events occur similarly throughout the planning area, they are more frequently reported in more urbanized areas. In addition, damages are more likely to occur in more densely developed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

Figure 3.63. Location and Frequency of Lightning in Missouri



Source: National Weather Service, http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx . Note: indicate location of planning area with a colored square or arrow.

Figure 3.64. Wind Zones in the United States



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

Strength/Magnitude/Extent

Based on information provided by the Tornado and Storm Research Organization (TORRO), Table 3.30 below describes typical damage impacts of the various sizes of hail.

Table 3.30. **Tornado and Storm Research Organization Hailstorm Intensity Scale**

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

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

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

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

Previous Occurrences

The following four tables include NCEI reported events and damages for at least the past 11 years for all four included hazards when information is available.

Table 3.31. **Reported Events and Damage in Audrain County from Thunderstorms 2008-2018. Events summarized by size.**

Wind Magnitude	Number of Events	Property Damages	Crop Damages
50-55	15	$0.00	$0.00
56-60	12	$0.00	$0.00
61-65	7	$0.00	$0.00
66-70	0	$0.00	$0.00
71-75	1	$0.00	$0.00
76+	0	$0.00	$0.00

Table 3.32. **Reported Events and Damage in Audrain County from High Winds 2008-2018. Events summarized by size.**

Wind Magnitude	Number of Events	Property Damages	Crop Damages
No Reports	0	0	$0.00

Table 3.33. **Reported Events and Damage in Audrain County from Hail 2008-2018. Events summarized by size.**

Hail Size (Inches)	Number of Events	Property Damages	Crop Damages
0.75	2	$0.00	$0.00
0.88	10	$0.00	$0.00
1	11	$0.00	$0.00
1.25	0	$0.00	$0.00
1.75	2	$0.00	$0.00
2.75	1	$0.00	$0.00

Table 3.34. **Reported Events Damages in Audrain County from Lightning 2008-2018. Events summarized by size.**

Reported Lightning	Number of Events	Property Damages	Crop Damages
No Reports	0	$0.00	$0.00

Source: https://www.ncdc.noaa.gov/

The tables below (**Table 3.35 through Table 3.38**) summarize past crop damages as indicated by crop insurance claims. The tables illustrate the magnitude of the impact on the planning area's agricultural economy. The information from the prior table was obtained from National Climatic Data Center and the following information was obtained from USDA which shows there is a discrepancy in the information.

Table 3.35. **Crop Insurance Claims Paid in Audrain County from Thunderstorms, 2008-2018.**

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
-	-	-	$0.00

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

Table 3.36. **Crop Insurance Claims Paid in Audrain County from High Winds, 2008-2018.**

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2011	Corn	Wind/Excess Wind	$15.5
2011	Corn	Wind/Excess Wind	$18,380.50
2011	Soybeans	Hot Wind	$20,272.00
2012	Corn	Wind/Excess Wind	$3,181.00
2012	Soybeans	Wind/Excess Wind	$9,596.00
2012	Corn	Hot Wind	$467,353.00
2013	Corn	Wind/Excess Wind	$208,446.00
2013	Corn	Hot Wind	$19,120.50
2014	Soybeans	Wind/Excess Wind	$34,448.00
2014	Corn	Wind/Excess Wind	$85,519.00
2017	Corn	Hot Wind	$5,545
2018	Corn	Wind/Excess Wind	$225,610.70
2018	Corn	Wind/Excess Wind	$80,476.56
2018	Soybeans	Wind/Excess Wind	$89.75
Total			$1,147,053.51

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

Table 3.37. **Crop Insurance Claims Paid in Audrain County from Lightning, 2008-2018.**

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2011	Soybeans	Other (Snow, Lightning, Etc.	$9,168.00
2012	Soybeans	Other (Snow, Lightning, Etc.	$809.00
2012	Soybeans	Other (Snow, Lightning, Etc.	$9,935.00
2012	Soybeans	Other (Snow, Lightning, Etc.	$21,094.00
2013	Wheat	Other (Snow, Lightning, Etc.	$834.00
2013	Corn	Other (Snow, Lightning, Etc.	$7,652.00
2013	Corn	Other (Snow, Lightning, Etc.	$3,474.00
2014	Wheat	Other (Snow, Lightning, Etc.	$1,037.00
2015	Soybeans	Other (Snow, Lightning, Etc.	$216.00
Total			$54,219.00

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

Table 3.38. **Crop Insurance Claims Paid in Audrain County from Hail, 2008-2018.**

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2008	Corn	Hail	$14,891.00
2009	Corn	Hail	$1,616.00
2011	Wheat	Hail	$1,260.10
2011	Wheat	Hail	$68.00
2011	Corn	Hail	$18,380.50
2011	Corn	Hail	$15.50
2012	Soybeans	Hail	$4,784.00
2014	Soybeans	Hail	$48,444.00
2014	Soybeans	Hail	$4,329.00
2015	Wheat	Hail	$1,520.00
2016	Soybeans	Hail	$1,593.00
2016	Soybeans	Hail	$3,141.00
2018	Wheat	Hail	$2,356.00
2018	Soybeans	Hail	$3,409.00
Total			$105,807.10

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

Probability of Future Occurrence

Thunderstorms

NCEI, dating back to 2008 indicates 4 years with thunderstorms. In all four years there were multiple thunderstorms. Based on this historical data, the calculated probability of a thunderstorm in any given year is 100% with a probability of 3.2 events per year.

High Winds

Based on this data, there have been 14 events in a 11 year period, producing an average of 1.4 high wind events each year in Audrain County. Based on history, the probability of a high wind event in any given year is 100 percent. Thus making the probability as likely in any given year.
88

Lightning

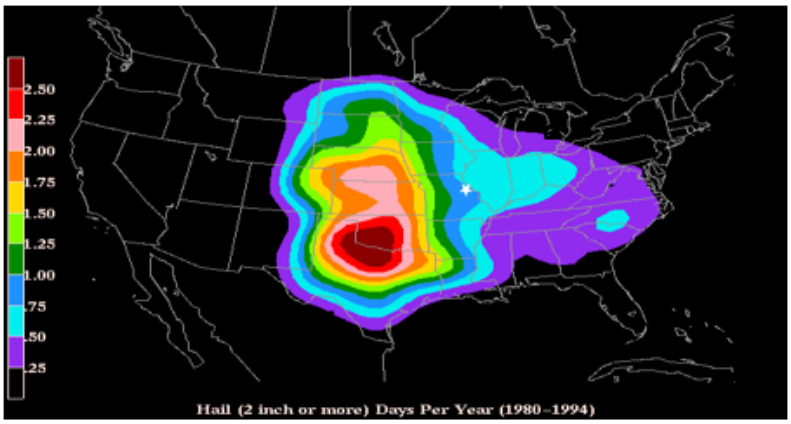
Due to no reports, adequate calculations cannot be configured at this time.

Hail

Based on this data, there have been 26 events in a 11 year period, producing an average of 2.6 hail events each year in Audrain County. Based on history, the probability of a hail event in any given year is 100 percent. Thus making the probability as likely in any given year.

Figure 3.68 is 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. Audrain County is located in the region to receive between .75 and 1 hailstorm annually.

Figure 3.65. Annual Hailstorm Probability (2" diameter or larger), U 1980- 1994



Source: NSSL, http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif Note: *White star indicates approximate location of Audrain County

Changing Future Conditions Considerations

According to the 2018 Missouri State Plan, predicted increases in temperature could help create atmospheric conditions that are fertile breeding grounds for severe thunderstorms and tornadoes in Missouri. Possible impacts include an increased risk to life and property in both the public and private sectors. Public utilities and manufactured housing developments will be especially prone to damages. Jurisdictions already affected should be prepared for more of these events, and should thus prioritize mitigation actions such as construction of safe rooms for vulnerable populations, retrofitting and/or hardening existing structures, improving warning systems and public education, and reinforcing utilities and additional critical infrastructure.

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.

Potential Losses to Existing Development

Most damages occur to electronic equipment located inside buildings, but structural damage can also occur when a lightning strike causes a building fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. There has not been any fatalities or injuries due to lightning in Audrain County during the 11 year period reviewed. When the review period was extended to 20 years there was 0 reported lightning events in which individuals injured. There have been several insurance claims due to wind, lightning and hail due to loss of property.

Hail

There were 14 reported crop insurance claims for a 11 year period resulting in $105,807.10 in insurance payments.

High Winds

There were 14 reported crop insurance claims for a 11 year period resulting in $1,147,053.51 in insurance payments.

Lightning

The total number of Lightning crop insurance claims for a 11 year period could not be determined as claims were listed under “Other (Snow, Lightning, Etc.)”.

Previous and Future Development

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

Hazard Summary by Jurisdiction

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

Problem Statement

Thunderstorms can damage power lines with the high winds or fallen debris such as tree limbs. Not everyone in the county utilizes social media, texting or have access to a weather radio, communities would benefit from updated sirens. Possible solutions include review of local ordinance and building codes to address high winds and/or construction techniques to include structural bracing, straps and clips, or anchor bolts.

3.4.8 Severe Winter Weather

Hazard Profile

Hazard Description

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

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

Geographic Location

The entire Audrain County is vulnerable to heavy snow, ice, extreme cold temperatures and freezing rain. Insert a map (**Figure 3.68**) and either show the county graphically or include narrative indicating the zone in which the county located, and how many hours of freezing rain is indicated annually.

Figure 3.66. NWS Statewide Average Number of Hours per Year with Freezing Rain

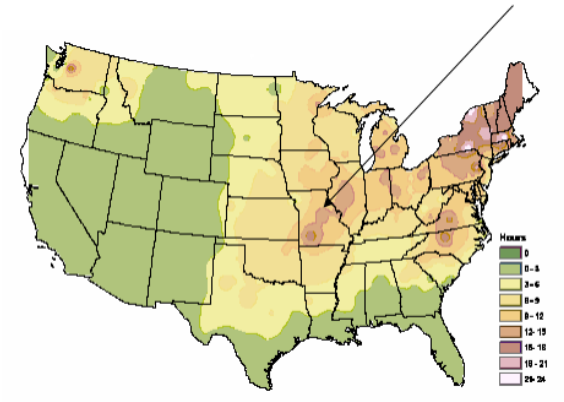


Figure 1. Average number of hours per year with freezing rain in the United States.

Source: American Meteorological Society. "Freezing Rain Events in the United States." http://ams.confex.com/ams/pdfpapers/71872.pdf
*Arrow indicates approximate location of Audrain County

Strength/Magnitude/Extent

Severe winter storms include heavy snowfall, ice, and strong winds which can push the wind chill well below zero degrees in the planning area.

For severe weather conditions, the National Weather Service issues some or all of the following products as conditions warrant across the State of Missouri. NWS local offices in Missouri may collaborate with local partners to determine when an alert should be issued for a local area.

- Winter Weather Advisory — Winter weather conditions are expected to cause significant inconveniences and may be hazardous. If caution is exercised, these situations should not become life threatening. Often the greatest hazard is to motorists.
- Winter Storm Watch — Severe winter conditions, such as heavy snow and/or ice are possible within the next day or two.
- Winter Storm Warning — Severe winter conditions have begun or are about to begin.
- Blizzard Warning — Snow and strong winds will combine to produce a blinding snow (near zero visibility), deep drifts, and life-threatening wind chill.
- Ice Storm Warning -- Dangerous accumulations of ice are expected with generally over one quarter inch of ice on exposed surfaces. Travel is impacted, and widespread downed trees and power lines often result.
- Wind Chill Advisory -- Combination of low temperatures and strong winds will result in wind chill readings of -20 degrees F or lower.
- Wind Chill Warning -- Wind chill temperatures of -35 degrees F or lower are expected. This is a life-threatening situation.

Previous Occurrences

Table 3.38 includes NCEI reported events and damages for at least the past 20 years. Events include blizzard, cold/wind chill, extreme cold/wind chill, heavy snow, ice storm, sleet, winter storm, and winter weather.

Table 3.39. **NCEI Audrain County Winter Weather Events Summary, 2009- 2018**

Type of Event	Inclusive Dates	Magnitude	# of Injuries	Property Damages	Crop Damages
Blizzard	2/1/2011		0	$0.00	$0.00
Cold/Wind Chill	1/1/2010		0	$0.00	$0.00
Cold/Wind Chill	1/6/2014		0	$0.00	$0.00
Extreme Cold	No Reports				
Heavy Snow	1/19/2011		0	$0.00	$0.00
Heavy Snow	2/21/2013		0	$0.00	$0.00
Heavy Snow	2/25/2013		0	$0.00	$0.00
Heavy Snow	3/24/2013		0	$0.00	$0.00
Ice Storm	No Reports				
Sleet	No Reports				
Winter Storm	1/31/2011		0	$0.00	$0.00
Winter Storm	2/1/2011		0	$0.00	$0.00

Winter Storm	12/21/2013		0	$0.00	$0.00
Winter Storm	1/5/2014		0	$0.00	$0.00
Winter Storm	2/4/2014		0	$0.00	$0.00
Winter Weather	1/6/2010		0	$0.00	$0.00

Source: NCEI, data accessed 3/20/19

Table 3.40. **Presidential Disaster Declarations for Winter Storms**

Disaster Number	IH Program Declared	IA Program Declared	PA Program Declared	HM Program Declared	State	Declaration Date	Disaster Type	Incident Type	Title	Incident Begin Date	Incident End Date	Disaster Close Out Date	Place Code	Declared County/Area	Declaration Request Number
1961	No	No	Yes	Yes	MO	3/23/2011	DR	Severe Sto	SEVERE WINTER STORM AND SNOWSTORM	1/31/2011	2/5/2011	12/2/2015	99007	Audrain (County)	11026
3317	No	No	Yes	No	MO	2/3/2011	EM	Severe Sto	SEVERE WINTER STORM	1/31/2011	2/5/2011	1/6/2012	99007	Audrain (County)	11007
3303	No	No	Yes	No	MO	1/30/2009	EM	Severe Ice	SEVERE WINTER STORM	1/26/2009	1/28/2009	11/8/2011	99007	Audrain (County)	9012
1736	No	No	Yes	Yes	MO	12/27/2007	DR	Severe Ice	SEVERE WINTER STORMS	12/6/2007	12/15/2007	8/27/2014	99007	Audrain (County)	7934
3281	No	No	Yes	No	MO	12/12/2007	EM	Severe Ice	SEVERE WINTER STORMS	12/8/2007	12/15/2007	3/15/2011	99007	Audrain (County)	7931
1403	No	Yes	Yes	Yes	MO	2/6/2002	DR	Severe Ice	SEVERE WINTER ICE STORM	1/29/2002	2/13/2002	2/11/2011	99007	Audrain (County)	2015

Source: https://www.fema.gov/data-visualization-summary-disaster-declarations-and-grants

Winter storms, cold, frost and freeze take a toll on crop production in the planning area. **Table 3.40** shows the USDA's Risk Management Agency payments for insured crop losses in the planning area as a result of cold conditions and snow for the past 11 years.

Table 3.41. **Crop Insurance Claims Paid in Audrain County as a Result of Cold Conditions and Snow 2008-2018**

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
2008	Wheat	Frost	$4,538.00
2008	Wheat	Cold Wet Weather	$33,515.00
2008	Wheat	Cold Wet Weather	$14,119.00
2008	Wheat	Cold Wet Weather	$1,364.50
2008	Wheat	Cold Wet Weather	$20,494.00
2008	Corn	Cold Wet Weather	$9,076.00
2009	Wheat	Cold Winter	$8,035.00
2009	Wheat	Cold Wet Weather	$26,104.00
2009	Wheat	Cold Wet Weather	$20,581.00
2009	Wheat	Cold Wet Weather	$42,620.00
2009	Wheat	Cold Wet Weather	$34,975.00
2009	Wheat	Cold Wet Weather	$40,798.00
2009	Corn	Frost	$9,712.00
2009	Corn	Cold Wet Weather	$10,972.00
2009	Corn	Cold Wet Weather	$1,179.50
2009	Grain Sorghum	Freeze	$7,258.00
2009	Soybeans	Frost	$2,684.00
2009	Soybeans	Cold Wet Weather	$1,421.50
2009	Soybeans	Cold Wet Weather	$8,988.00
2009	Soybeans	Cold Wet Weather	$17,789.00
2010	Wheat	Cold Winter	$2,839.00

2010	Wheat	Cold Winter	$6,665.00
2010	Wheat	Cold Winter	$73,863.00
2010	Wheat	Cold Wet Weather	$1,302.00
2010	Wheat	Cold Wet Weather	$22,062.00
2010	Wheat	Cold Wet Weather	$5,315.00
2010	Wheat	Cold Wet Weather	$3,645.00
2010	Wheat	Cold Wet Weather	$115,061.00
2010	Corn	Cold Wet Weather	$2,254.00
2010	Corn	Cold Wet Weather	$311.50
2011	Wheat	Cold Winter	$20,049.00
2011	Wheat	Cold Wet Weather	$7,995.00
2011	Wheat	Cold Wet Weather	$272.00
2011	Wheat	Cold Wet Weather	$6,926.00
2011	Corn	Cold Wet Weather	$17,638.00
2011	Corn	Cold Wet Weather	$16,179.00
2011	Soybeans	Cold Wet Weather	$5,406.20
2012	Wheat	Cold Wet Weather	$3,410.00
2012	Corn	Cold Winter	$1,545.00
2012	Corn	Cold Wet Weather	$117,584.00
2012	Soybeans	Cold Wet Weather	$3,238.00
2013	Wheat	Cold Wet Weather	$10,399.00
2013	Corn	Cold Wet Weather	$14,146.00
2013	Corn	Cold Wet Weather	$1,663.00
2013	Soybeans	Cold Wet Weather	$992.00
2014	Wheat	Freeze	$16,287.00
2014	Wheat	Freeze	$4,036.00
2014	Wheat	Cold Winter	$29,561.50
2014	Wheat	Cold Winter	$46,196.20
2014	Wheat	Cold Wet Weather	$18,322.50
2014	Wheat	Cold Wet Weather	$9,111.50
2014	Oats	Cold Wet Weather	$3,277.00
2014	Corn	Cold Wet Weather	$5,732.00
2014	Soybeans	Cold Wet Weather	$3,344.60
2015	Wheat	Hail	$1,520.00
2015	Wheat	Cold Winter	$4,285.44
2015	Wheat	Cold Winter	$62,300.06
2015	Wheat	Cold Wet Weather	$3,038.00
2015	Wheat	Cold Wet Weather	$27,212.00
2015	Corn	Cold Wet Weather	$43,358.00
2015	Corn	Cold Wet Weather	$365.00
2015	Soybeans	Cold Wet Weather	$6,796.50
2015	Soybeans	Cold Wet Weather	$9,273.33
2017	Corn	Cold Wet Weather	$73,380.00

2017	Soybeans	Cold Wet Weather	$6,046.00
2018	Wheat	Cold Winter	$1,513.00
2018	Wheat	Cold Winter	$5,963.00
2018	Wheat	Cold Wet Weather	$4,785.00
2018	Corn	Cold Wet Weather	$24,034.50
2018	Soybeans	Cold Winter	$8,734.00
2018	Soybeans	Cold Wet Weather	$15,508.55
2018	Soybeans	Cold Wet Weather	$54,962.75

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

Probability of Future Occurrence

The entire planning area is vulnerable to the effects of winter storm/blizzard, ice storms, winter weather, cold/wind chill and heavy snow. All effects of winters tend to make driving more treacherous and can impact the response of emergency vehicles. The probability of utility and infrastructure failure increases during winter weather due to the freezing rain accumulation on utility poles and power lines. Elderly populations are considered particularly vulnerable to the impact of winter weather. NCEI, dating back to 1999 indicates 4 years with severe winter weather. In all four years there were multiple severe winter weather. Based on this historical data, the calculated probability of a severe winter weather in any given year is 20%. The probability was determined by taking the number of years with a severe winter weather event (4) divided by the number of years (20) data was obtained for.

Changing Future Conditions Considerations

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

Vulnerability

Vulnerability OverviewThe method used to determine vulnerability to severe winter weather across Missouri was statistical analysis of data from several sources: National Centers for Environmental Information (NCEI) storm events data (1996 to December 31, 2016), HAZUS Building Exposure Value data, housing density data from the U.S. Census (2015 ACS), and the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina. From the statistical data collected, five factors were considered in determining overall vulnerability to severe winter weather as follows: housing density, building exposure, social vulnerability, likelihood of occurrence, and average annual property loss. Based on natural breaks in the statistical data, a rating value of 1 through 5 was assigned to each factor. These rating values correspond to the following descriptive terms: 1) Low 2) Low-medium 3) Medium 4) Medium-high 5) High

Table 3.42. **Ranges for Severe Winter Weather Vulnerability Factor Rating**

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 State Hazard Mitigation Plan

Table 3.43. **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

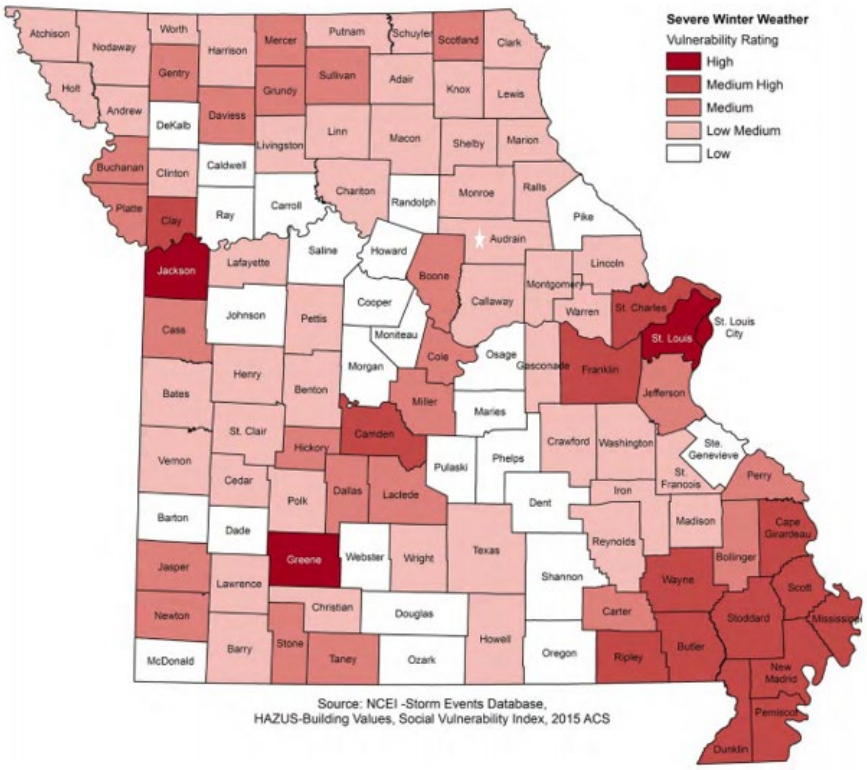
Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.44. **Housing Density, Building Exposure, and SOVI Data by County**

County	Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Rating
Audrain	$2,689,090,000	1	15.62	1	Medium High	4

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.67. Vulnerability Summary for Severe Winter Weather



Source: 2018 Missouri Hazard Mitigation Plan, *Star indicates Audrain County

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

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

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

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

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.

Previous and Future Development

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

Hazard Summary by Jurisdiction

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

Problem Statement

Audrain County is expected to experience at least one severe winter weather events annually; the county has a low-medium vulnerability rating. Jurisdictions should enhance their weather monitoring to be better prepared for sever weather hazards. If jurisdictions monitor winter weather, they can dispatch road crews to prepare for the hazard. County and city crews can also trim trees along power lines to minimize the potential for outages due to snow and ice. Citizens should also be educated about the benefits of being proactive to alleviate property damage as well as preparing for power outages. Education needs to occur to ensure all residents are aware of the shelters in the County, residents are educated on emergency supplies to have and the utilization of social media and texting increases.

3.4.9 Tornado

Hazard Profile

Hazard Description

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

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

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

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

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

Geographic Location

Tornados can occur in the entire planning area and no area is immune from tornado suffering.

Strength/Magnitude/Extent

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

Tornado magnitude is classified according to the EF- Scale (or the Enhance Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renowned severe storm researcher). The EF-Scale (see **Table 3.4444**) 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 3.45. **Enhanced F Scale for Tornado Damage**

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

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

The wind speeds for the EF scale and damage descriptions are based on information on the NOAA Storm Prediction Center as listed in **Table 3.4545**. The damage descriptions are summaries. For the actual EF scale it is necessary to look up the damage indicator (type of structure damaged) and refer to the degrees of damage associated with that indicator. Information on the Enhanced Fujita Scale's damage indicators and degrees or damage is located online at www.spc.noaa.gov/efscale/ef-scale.html.

Table 3.46. **Enhanced Fujita Scale with Potential Damage**

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

EF4	166-200	0.7%	Devastating. Well-constructed houses and whole frame houses completely levelled; cars thrown and small missiles generated.
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

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 3.47. **Recorded Tornadoes in Audrain County, 1993 – Present**

Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	F/EF Rating	Death	Injury	Property Damage	Crop Damages
1/07/2008	3SW Ortiz	3SW Ortiz	.3 miles	40 yards	EF0	0	0	$0.00	$0.00
12/27/2008	2NE Rush Hill	2NE Rush Hill	3.55 miles	30 yards	EF1	0	0	$0.00	$0.00
7/20/2010	2S Mexico MEM ARPT	2S Mexico MEM ARPT	.58 miles	40 yards	EF0	0	0	$0.00	$0.00
4/19/2016	1SW Bassinger Corner	1SW Bassinger Corner	2.01 miles	15 yards	EF0	0	0	$0.00	$0.00
	Total	-	-	-	-	0	0	$0.00	$0.00

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

Figure 3.71 shows historic tornado paths in the planning area.

Figure 3.68. Audrain County Map of Historic Tornado Events

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

Data from the USDA Risk Management Agency showed no insurance payments in the Audrain County for crop damages as a result of tornadoes within period of 2008-2018.

Probability of Future Occurrence

The National Centers for Environmental Information reported 4 tornadoes in Audrain County in a 20 year time period, which calculates to a 20 percent chance of tornado in any given year. Therefore it is a low probability that some portion of Audrain County will experience tornado activity in any given year.

Changing Future Conditions Considerations

According to the 2018 Missouri State Hazard Mitigation Plan, Scientists do not know how the frequency and severity of tornadoes will change. Research published in 2015 suggests that changes in heat and moisture content in the atmosphere, brought on by a warming world, could be playing a role in making tornado outbreaks more common and severe in the U.S. The research concluded that the number of days with large outbreaks have been increasing since the 1950s and that densely concentrated tornado outbreaks are on the rise. It is notable that the research shows that the area of tornado activity is not expanding, but rather the areas already subject to tornado activity are seeing the more densely packed tornadoes. Because Missouri experiences on average around 39.6 tornadoes a year, such research is closely followed by meteorologists in the state.

Vulnerability

Vulnerability Overview

Audrain County is located in a region of the U.S. with high frequency of dangerous and destructive tornadoes referred to as “Tornado Alley”. **Figure 3.73** illustrates areas where dangerous tornadoes historically have occurred.

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

statistical data, a rating value of 1 through 5 was assigned to each factor. These rating values correspond to the following descriptive terms: 1) Low 2) Low-medium 3) Medium 4) Medium-high 5) High

Table 3.48. **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

Table 3.49. **Ranges for Tornado Combined Vulnerability Rating**

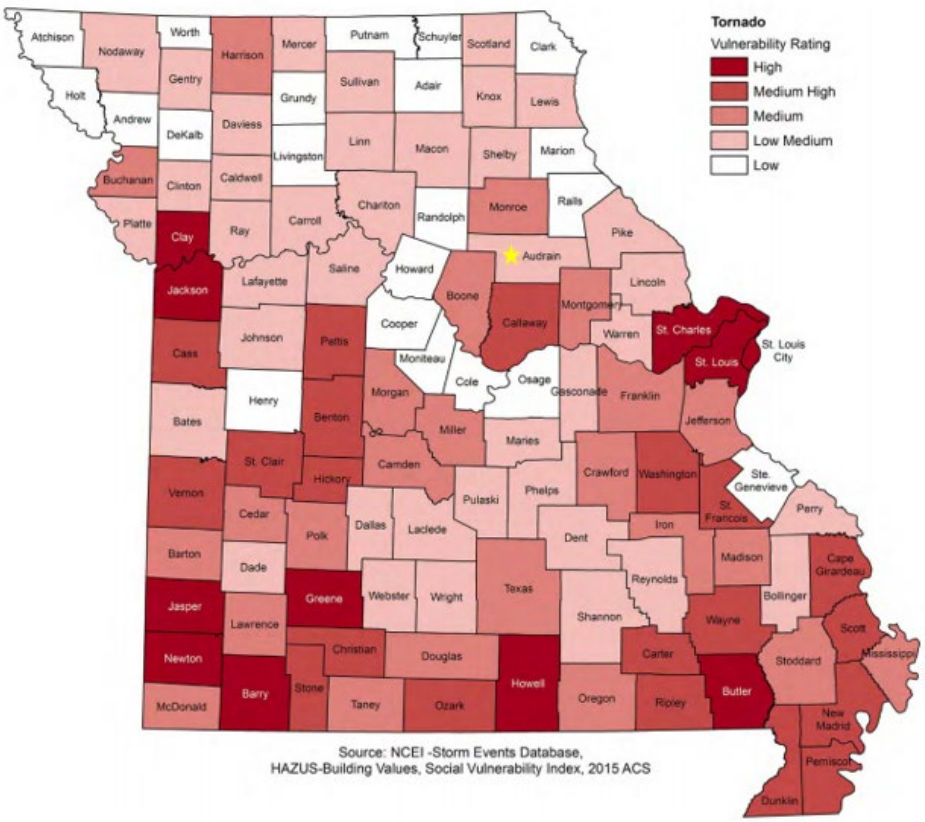
	Low (1)	Low-medium (2)	Medium (3)	Medium-High (4)	High (5)
Tornado Combined Vulnerability	7-10	11-12	13-14	15-16	17-21

Table 3.50. **Building Exposure, Population Density, SOVI, and Mobile Home Data for Audrain County**

County	Total Building Exposure (Hazus)	Exposure Rating	Population Density	Population Rating	SOVI Index Ranking	SOVI Rating	Percent Mobile Homes	Mobile Home Rating
Audrain	$2,689,090,000	1	37.70	1	Medium High	4	7.6	2

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.69. Overall Vulnerability for Tornadoes



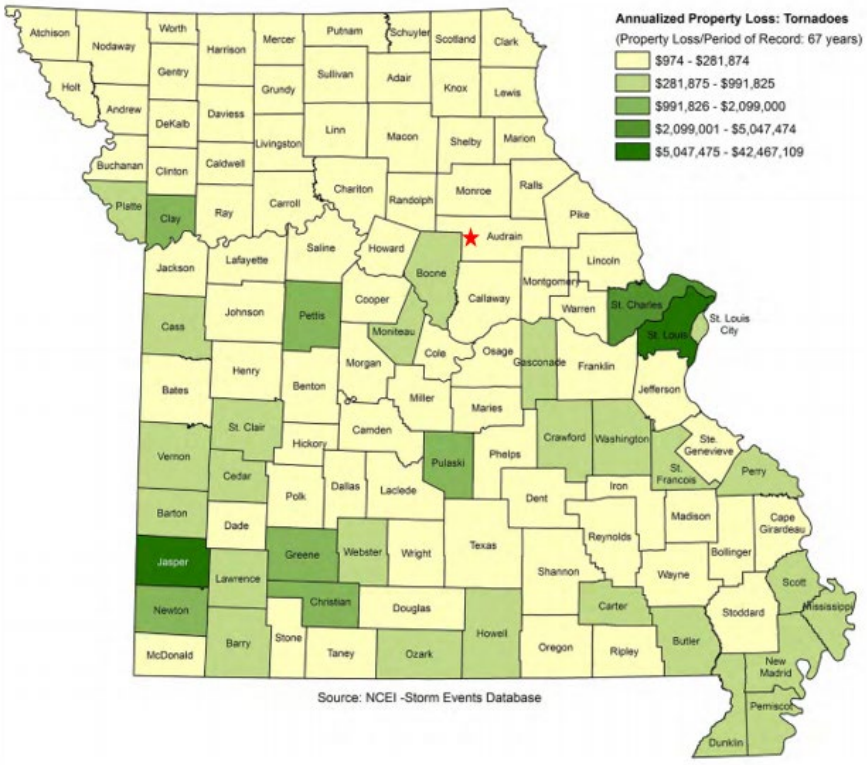
Source: 2018 Missouri State Hazard Mitigation Plan, *Star indicates Audrain County

Figure 3.70. Tornado Alley in the U.S.

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

Potential Losses to Existing Development

Figure 3.71. Annualized Property Loss for Tornadoes



Source: 2018 Missouri State Hazard Mitigation Plan, *Star indicates Audrain County

The above Figure 3.74 shows that in the past 67 years, Audrain has had minimal property ($974-$281,874) loss from Tornadoes.

Previous and Future Development

Vulnerability to tornadoes is anticipated to remain the same. Future development for public buildings such as schools, government offices, as well as buildings with high occupancy and campgrounds should consider including a tornado safe room to protect occupants in the event of a tornado.

Hazard Summary by Jurisdiction

Tornado event could occur anywhere in the planning area, but some jurisdictions would suffer heavier damages because of the age of the housing or the high concentration of mobile homes. Communities that have adopted building codes may also be less vulnerable to damages.

Problem Statement

Audrain County has inadequate tornado shelters throughout the county, not everyone utilizes social media and/or texting, the rural areas do not have warning sirens, lack of awareness for available shelters and more education needs to occur.
Possible solutions include promoting the use of NOAA weather radios and conducting public education and outreach activities to increase awareness of tornado risk.

3.4.10 Wildfire

Hazard Description

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

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

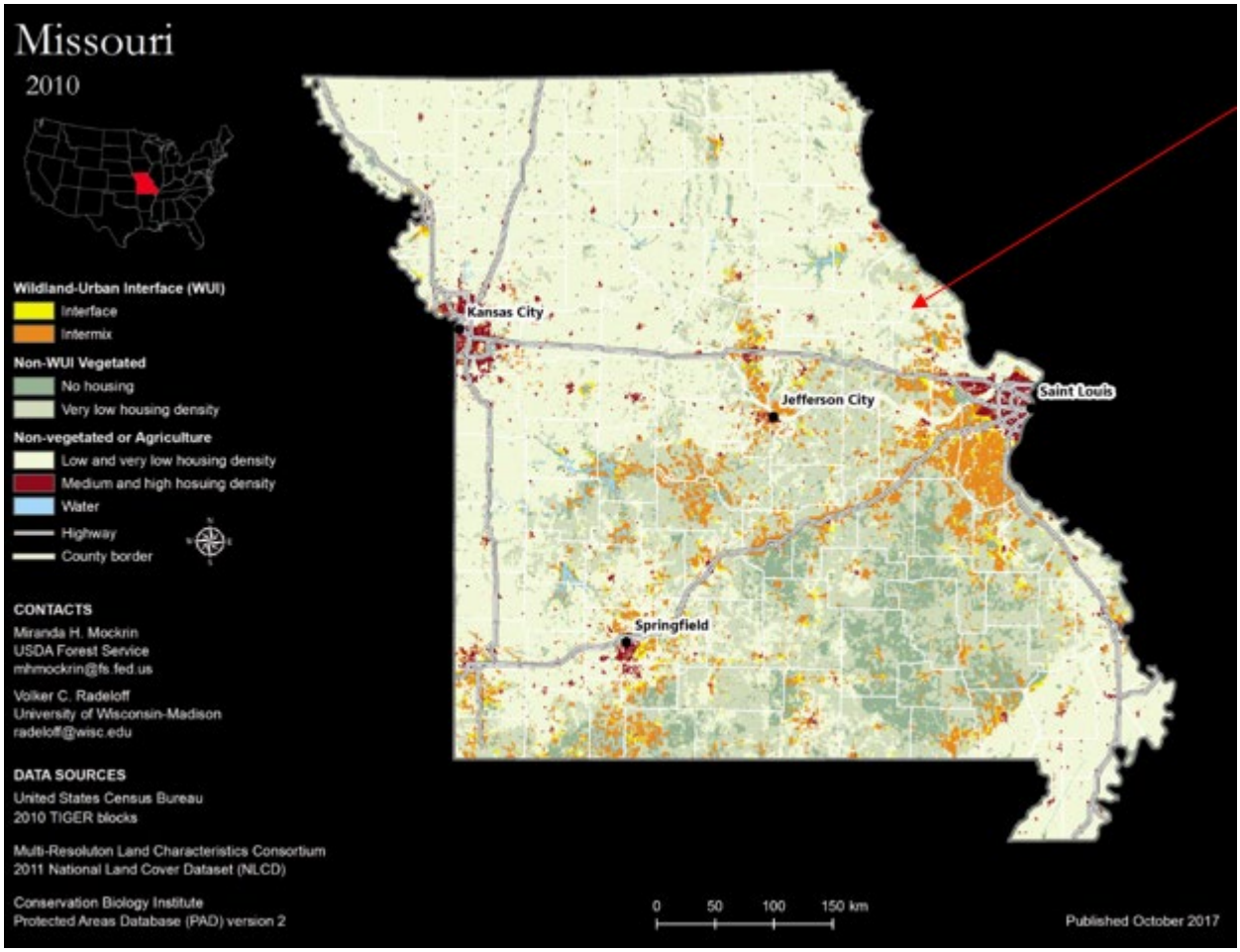
Most of Missouri fires occur during the spring season between February and May. The length and severity of wildland fires depend largely on weather conditions. Spring in Missouri is usually characterized by low humidity and high winds. These conditions result in higher fire danger. In addition, due to the recent lack of moisture throughout many areas of the state, conditions are likely to increase the risk of wildfires. Drought conditions can also hamper firefighting efforts, as decreasing water supplies may not prove adequate for firefighting. It is common for rural residents burn their garden spots, brush piles, and other areas in the spring. Some landowners also believe it is necessary to burn their forests in the spring to promote grass growth, kill ticks, and reduce brush. Therefore, spring months are the most dangerous for wildfires. The second most critical period of the year is fall. Depending on the weather conditions, a sizeable number of fires may occur between mid-October and late November.

Geographic Location

The Wildland-Urban Interface term refers to the zone of transition between unoccupied land and human development and needs to be defined in the plan. Within the WUI, there are two specific areas identified: 1) Interface and 2) Intermix. The interface areas are those areas that abut wildland vegetation and the Intermix areas are those areas that intermingle with wildland areas.

According to the 2018 Missouri State Plan the Wildland-Urban Interface estimated the numbers and values of structures and population vulnerable to wildfire as the following: Total number of structures 266 valued at $66,082,616 and a population of 475. The break down of the structures consist of 56 Agriculture valued at $13,113,032, 14 Commercial valued at $9,098,00, 1 Education valued at $1,447,833, 6 Government valued $3,780,529, 2 Industrial valued at $2,251,329 and 187 Residential valued at $37,391,885.

Figure 3.72. 2010 Missouri Wildland Urban Interface



Source: http://silvis.forest.wisc.edu/data/wui-change/, *Arrow indicates approximate location of Audrain 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.

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

Include information about the severity of damages from notable planning area structural fires and wildland fires. If no information is available, state this in the plan.

Previous Occurrences

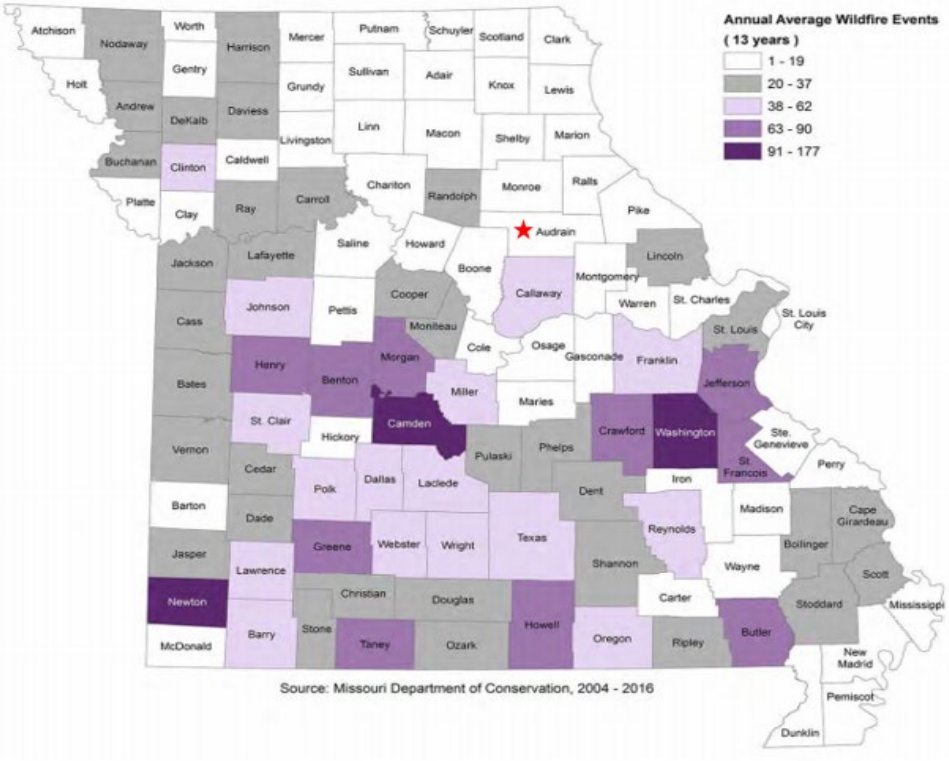
According to the Missouri Division of Fire Safety (MDFS) Website as well as the Missouri Department of Conversation Wildfire Data Search at there were 97 reported wildland or grass fires in Audrain County from 2008-2018. In total, these 97 fires burned 549.83 acres and no injuries were reported. During the ten year reporting period, nineteen of the fires had an unknown cause for starting and burning 269.73 acres, Sixty-four were started by debris and burnt 248.18 acres, six of the fires were started by equipment and burnt 28.76 acres. Three of the fires were started by smoking and burnt 3.26 acres. One of the fires were started by lightning, and burnt 0.1 acres.

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

Probability of Future Occurrence

Wildfires in the planning area are most likely to occur every year with very little resulting damage. The wildfires occur in the unincorporated areas and are limited to undeveloped land. The jurisdictions and school districts are largely surrounded by undeveloped land but have not been affected by wildfires. In years of significant drought or excessive heat the potential for a wildfire in planning area increases.

Figure 3.73. Likelihood of Wildfire Events, 2004-2016



Source: 2018 Missouri State Hazard Mitigation Plan, *Star indicates Audrain County

When analyzing the wildland fires, there has been an average of 8.18 fires burning 5011110 acres per year. However, it was reported these fires did not result in major damages. The probability score to be likely in any given year that a wildfire could occur in the planning area.

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 forest are likely to increase, while the population of hickory trees is likely to decrease.

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.

Vulnerability

Vulnerability Overview

According to the 2018 Missouri State Hazard Mitigation Plan, Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Missouri, although the composition of trees in the forests may change. More droughts would reduce forest productivity, and changing future conditions are also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could more than offset the losses from those factors. Forests cover about one-third of the state, dominated by oak and hickory trees. As the climate changes, the abundance of pines in Missouri's forests is likely to increase, while the population of hickory trees is likely to decrease 0. Higher temperatures will also reduce the number of days prescribed burning can be performed. Reduction of prescribed burning will allow for growth of understory vegetation – providing fuel for destructive wildfires. Drought is also anticipated to increase in frequency and intensity during summer months under projected future scenarios. Drought can lead to dead or dying vegetation and landscaping material close to structures which creates fodder for wildfires within both the urban and rural settings.

Potential Losses to Existing Development

Figure 3.74. Estimated Numbers and Values of Structures and Population Vulnerable to Wildfire in Audrain County

County	Number of Structures	Value of Structures	Population
Audrain	**266**	**$66,082,616**	**475**
Agriculture	56	$13,113,032	
Commercial	14	$9,098,007	
Education	1	$1,447,833	
Government	6	$3,780,529	
Industrial	2	$2,251,329	
Residential	187	$36,391,885	

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.75. Wildfire Potential Loss Estimates

County	Total WUI Acreage	Total Structure Value Within WUI	Average Value/Acre within WUI	Average Annual Acreage Burned	Potential Loss
Audrain	2,157.85	$66,082,616	$30,624	40	$1,224,970

Source: 2018 Missouri State Hazard Mitigation Plan

According to the 2018 Missouri State Hazard Mitigation Plan, Audrain County is estimated to have on average 40 acres burned with a potential loss of $1,224,970.00.

Impact of Previous and Future Development

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

Hazard Summary by Jurisdiction

The rural jurisdictions in the planning area are all surrounded by undeveloped agricultural land and face the possibility of a wildfire. The school districts are located in a rural area and do not face danger of wildfire due to barriers in place around the school. As long as drought conditions are not seriously inflamed, future wildfires in Audrain County should have a negligible adverse impact on the community, as it would affect a small percentage of the population. Nonetheless, homes and businesses located in unincorporated areas are at higher risk from wildfires due to proximity to wood and distance from fire services. Variations in both structural/urban and wildfires are not able to be determined at this time due to lack of data. However, both fire types are expected to occur on an annual basis across the county.

Problem Statement

Residents do not comply with burn bans, education is not available for the levels of burn bans, many residents lack education in fire safety and not all residents utilize social media and texting. Education needs to occur on the dangers associated with not complying with the burn bans, more education for fire safety and encourage utilization of social media and texting. Do to Audrain County's high drought rating, they may be more susceptible to fires.