

SECTION 4:

Hazard Risk Assessment

4.1 Introduction

Pike County is vulnerable to a range of natural hazards which threaten life and property. Current FEMA regulations and guidance under the Disaster Mitigation Act of 2000 (DMA 2000) require an evaluation of a full range of natural hazards as described in Table 4.1.

Table 4.1: FEMA-approved Multi-hazard Mitigation Planning Requirements

44 CFR Requirement

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.*

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.*

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): *[The risk assessment] must also address National Flood Insurance Program (NFIP) insured structures that have been repetitively damaged floods.*

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 area*

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)(ii)(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)(iii): *For multi-jurisdictional plans, the risk assessment must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.*

During the creation of this 2019 Mitigation Plan, the county identified and analyzed hazards thought to be of potential risk. This was evaluated by reviewing historical data and known vulnerabilities, building upon the *2007 Pike County Mitigation Plan*, and integrating community input. Hazard Profiles were then created based on the probability that an event will occur, potential impact, spatial extent, warning time, and the event duration. Accompanying these hazard profiles, where possible, are an inventory of assets and an estimate of associated losses. Lastly, these profiles are prioritized in a Priority Risk Index (PRI) to guide the Mitigation Strategy in the following section.

4.2 FEMA Declared Disasters

Disaster declarations will help determine the likelihood that certain events will occur and will help provide initial insight into the hazards that may impact Pike County. Since 1968, thirteen presidential disaster declarations have been reported in Pike County. Seven declarations relate to severe storms, four winter storm events, one hurricane, one heavy rain. These carried eight flooding related events and two events which contained mudslides.

Table 4.2: Pike County Presidential Disaster Declarations

Date	Name	Disaster Number
January 1968	Heavy Rains	DR-243
January 1978	Blizzards and Snowstorms	EM-3055
June 1990	Flooding, Severe Storm, Tornado	DR-870
March 1997	Severe Storms/Flooding	DR-1164
March 2000	Severe Storms/Flooding	DR-1321
March 2003	Severe Winter Storm	DR-1453
July 2003	Severe Storms/Flooding	DR-1478
February 2005	Severe Winter Storms, Flooding, and Mudslides	DR-1580
September 2005	Ohio Hurricane Katrina Evacuation	EM-3250
July 2011	Severe Storms/Flooding	DR-4002
June 2012	Severe Storms/Flooding	EM-3346

SOURCE: FEMA DISASTER DECLARATIONS ([HTTPS://WWW.FEMA.GOV/DISASTERS](https://www.fema.gov/disasters))

4.3 Hazard Identifications

As part of the update process, the hazards from the existing plan were reviewed and new hazards were considered. The existing hazards were also cross-checked with hazards in the state plan during the kick off meeting with the planning committee. Table 4.3a includes the hazards from the 2014 state plan that were reviewed by the planning committee during the Mitigation Plan Update meeting on November 16, 2018. Table 4.3a also includes a list of the hazards identified for the 2019 Pike County Hazard Mitigation Plan update. Windstorms were added to the 2019 plan update at the request of the community. Pike County requested hail and invasive species be assessed for potential inclusion into the 2019 plan. There was sufficient historical information on past events to justify including hail into the 2019 plan. There was a lack of available information to justify the addition of invasive species into the plan.

Table 4.3a: State and Pike County Plan Comparison

Hazards	State Plan	Existing 2007 Plan	New 2019 Plan
Coastal Erosion	x		
Dam Failure	x		x
Droughts	x	x	x
Earthquakes	x	x	x
Flood	x	x	x
Seiche/Coastal Flooding	x		
Landslide	x	x	x
Land Subsidence	x	x	x
Invasive Species	x		
Severe Thunderstorms	x	x	x
Windstorms	x		x
Hail Storms	x		x
Winter/Ice Storms	x	x	x
Tornado	x	x	x
Wildfires	x	x	x

4.4 Priority Risk Index

The prioritization and categorization of identified hazards for Pike County is based on the Priority Risk Index (PRI), a tool used to measure the degree of risk for identified hazards in a particular planning area. The methodology is discussed as follows and will be applied to the hazard profiles so a consensus on the highest-threat hazards in Pike County can be determined.

The PRI results allow hazards to be ranked against one another (the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard (probability, impact, spatial extent, warning time and duration). Each degree of risk is assigned a value (1 to 4) and a weighting factor.

To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

$$\text{PRI VALUE} = [(\text{PROBABILITY} \times .30) + (\text{IMPACT} \times .30) + (\text{SPATIAL EXTENT} \times .20) + (\text{WARNING TIME} \times .10) + (\text{DURATION} \times .10)]$$

According to the weighting scheme applied for Pike County, the highest possible PRI value is 4.0.

Table 4.4a shows the weighting factors and criteria for each category. By determining a value for each hazard, they can be relatively compared to other hazards threatening the planning area. Further, hazard impact can be ranked with greater ease. Once PRI calculations are made, the hazard rankings are reviewed by the planning team and adjusted to reflect local knowledge of risks in the planning area. The hazard rank created then guides mitigation strategy efforts and allocation of mitigation resources.

Table 4.4a: Priority Risk Index Criteria

PRI Category	Degree of Risk			Assigned Weighting Factor
	Level	Criteria	Index Value	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	Between 1 and 10% annual probability	2	
	Likely	Between 10 and 90% annual probability	3	
	Highly Likely	90%+ annual probability	4	
Vulnerability	Minor	Only minor property damage and minimal disruption to government functions and services. No shutdown of critical facilities.	1	30%
	Limited	Minor injuries are possible. More than 10% of buildings damaged or destroyed. Temporary shutdown of critical facilities (less than one week).	2	
	Critical	Multiple deaths/injuries possible. More than 25% of buildings damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50% of buildings damaged or destroyed. Complete shutdown of critical facilities for 30 days or more.	4	
Spatial Extent	Negligible	Limited to a specific area.	1	20%
	Small	Small areas affected	2	
	Moderate	Large areas / multiple areas affected	3	
	Large	All areas / all areas affected	4	
Warning Time	More than 24 hours	Self-explanatory	1	10%
	12 to 24 hours	Self-explanatory	2	
	6 to 12 hours	Self-explanatory	3	
	Less than 6 hours	Self-explanatory	4	
Duration	Less than 6 hours	Self-explanatory	1	10%
	Less than 24 hours	Self-explanatory	2	
	Less than one week	Self-explanatory	3	
	More than one week	Self-explanatory	4	

The individual PRI results are calculated by applying the categories explained within each of the hazard profiles. The final PRI results, including the calculated values for each hazard in Pike County, are found at the end of this section in the “Summary of Hazard Risk”.

4.5 Pike County Data & Application

FEMA’s Hazus-MH 4.2 model was used to complete the flood and earthquake vulnerability assessments and estimate the losses from these hazards using the information above. In addition, the digital flood insurance rate map (DFIRM), was obtained from FEMA. A variety of additional local, state and national sources were consulted to complete this update. They are cited throughout the following hazard profiles.

4.6 Hazard Profiles

Hazard profiles are an in depth assessment of both past and potential impact. Hazard profiles have been created for each of the hazards identified for Pike County in Table 4.3a. Each is profiled separately to more easily assign a PRI value and contain the following categories:

DESCRIPTION: A scientific explanation of the hazard, including severity and impacts, and how this is determined

LOCATION: Geographical extent of the hazard (both possible future and past locations);

PREVIOUS OCCURRENCES: The number of previous events and impacts of each hazard

MAGNITUDE (OR EXTENT): The severity of the hazard in the past which is indicative of potential severity in the future. Measures may include wind speed, wave height, or property damage; Subcategories include Speed of Onset, Duration, and Availability of Warning Time

PROBABILITY OF FUTURE EVENTS: The likelihood of future events impacting the county. Given that an exact probability is often difficult to quantify, this characteristic is categorized into the following ranges to be used in hazard profiles (per the PRI criteria):

Unlikely: Less than a 1% annual probability

Possible: Between 1% and 10% annual probability

Likely: Between 10+% and 90% annual probability

Highly Likely: Greater than 90% annual probability

VULNERABILITY ASSESSMENT: The vulnerability assessment will address conditions that may increase or decrease vulnerability such as topography, soil type, land use, and development trends. In addition, estimated potential losses will be calculated using historical data and data provided by Pike County. GIS analysis and hazard modeling will be used to assess this data where available. Information such as the number of structures and critical facilities at risk will be analyzed as well.

PRIORITY RISK INDEX: As discussed in subsection 4.4, the PRI is calculated by applying the above categories for each hazard profile.

4.7 Dam Failure

DESCRIPTION

Dams are classified within four categories (I-IV) based on height, volume and potential impact due to failure.

Table 4.7a: Dam Classes

Class	Height	Volume	Impact
I	> 60 feet	> 5,000 acre-feet	Probable loss of life. Structural damage to high value property anticipated.
II	> 40 feet	> 500 acre-feet	No loss of life anticipated. Damage to homes and businesses is likely.
III	> 25 feet	> 50 acre-feet	Damage restricted to low-value non-residential structures.
IV	< or = 25 feet	< or = 50 acre-feet	Losses restricted mainly to dam.

Source: ODNR Division of Soil and Water Resources Fact Sheet 94-29.

The impact caused by a dam failure would depend on the Class of the dam, its location relative to populations and development, and the dam's type of failure, which include structural, mechanical or hydraulic failures. A dam failure could become a huge disaster

resulting in substantial damage and deaths.

Most dam failures are a combination of structural problems and overloading due to water retention. Spring is the most likely season for dam failure when melting snow and high ground saturation combine with seasonal precipitation. These conditions can cause flash flooding, when sudden amounts of heavy precipitation result in quick rises in water level. Such events can quickly overwhelm a dam and cause it to fail, especially if an underlying condition is present, such as poor maintenance.

There are approximately 80,000 dams in the United States today. Dam owners include state and local authorities, public utilities, private owners and federal agencies. The benefits of dams are numerous: they provide water for drinking, navigation, and agricultural irrigation. Dams also provide hydroelectric power, create lakes for fishing and recreation, and save lives by preventing or reducing floods.

Though dams have many benefits, they also can pose a risk to communities if not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam can cause loss of life and great property damage if development exists downstream. If a levee breaks, scores of properties may become submerged in floodwaters and residents may become trapped by rapidly rising water. The failure of dams and levees has the potential to place large numbers of people and great amounts of property in harm's way.

LOCATION

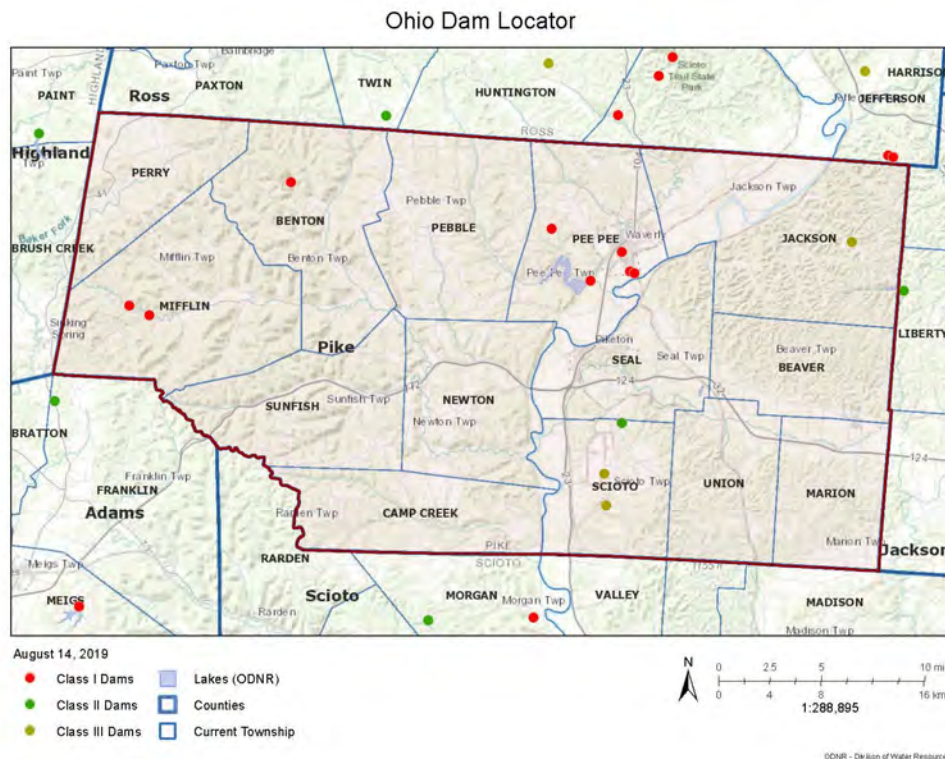
Per the ODNR Dam Locator website, there are 8 Classification I dams in Pike County, 1 in Classification II and 3 in Classification III. The spatial extent would depend on the height of the dam, the volume of the dam, its location within Pike County, and other factors such as precipitation and the extent of failure. The probable spatial extent of any particular dam failure would have to be evaluated on a case by case basis.

The map included below provides the locations of dams in Pike County per the ODNR Dam Locator website.

Table 4.7b: Pike County Dam Class and EAP Status

Dam Name	Class Type	EAP Status As of August 2019
Arnett Lake Dam	I	Not Approved
Cave Lake Dam	I	Approved
Green Acres Levee	I	Approved
Lake White Dam	I	Approved
Long's Retreat Lake Dam	I	Approved
Mills Pride Levee	I	Approved
Pike Lake Dam	I	Approved
Waverly WWTP Levee	I	Approved
Lime Sludge Lagoon Dam (X-611 B)	II	Approved
Big Run Pond Dam (X-230 K)	III	Approved
Hammond Lake Dam	III	Not Approved
Hay Hollow Reservoir Dam	III	Approved

Figure 4.7a: Dams in Pike County



Source: ODNR Dam Locator Map Viewer <https://gis.ohiodnr.gov/MapView/?config=ohiodams>

PREVIOUS OCCURENCES

There are no records of dam failures within Pike County. The Lake White dam outside the Village of Waverly has overtopped three times in the past due to large rainfall events in 1964, 19994 and 2006 but has not failed.

MAGNITUDE

Pike County has eight Class I dams. These are the only dams in the county that would be expected to result in a loss of life due to their failure. All others are only expected to result in property and ecological damage.

SPEED OF ONSET

The speed of onset will vary by the design of each dam and other factors such as precipitation and maintenance. Dam failures are usually not sudden and will most likely be preceded by signs of structural weakening or other problems. But, if these signs go unchecked, the results will appear to have a very sudden onset.

DURATION

The immediate danger posed by a dam failure would likely pass very quickly, but the resulting flooding due to a lack of water control could persist for weeks, months, or even longer. The duration of the actual dam failure could be minutes or days, depending on the extent and speed of the failure.

AVAILABILITY OF WARNING TIME

Dam failures provide a possibility for warning and evacuation, but only if a leak or other structural problem that would lead to failure is detected. If such things go unnoticed, little or no warning will be available.

PROBABILITY OF FUTURE EVENTS

There are no records of dam failures in Pike County. As such, it is difficult to predict an annual chance of dam failure.

VULNERABILITY ASSESSMENT

At this time, no estimation data exists. There is no historical precedent for dam failure in Pike County and the full extent of the areas threatened by the failure of a Class I dam is unknown. This makes loss estimation for this hazard particularly difficult. To assist with assessing vulnerability a mitigation action will be included to obtain Emergency Actions Plans and inundation data for the high hazard dams.

Priority Risk Index

Table 4.7c: PRI Calculation for Dam Failure

PRI Category	Level	Index Value
Probability	Unlikely	1
Vulnerability	Limited	2
Spatial Extent	Moderate	3
Warning Time	More than 24 hours	1
Duration	Less than 24 hours	2

4.8 Drought

Description

The National Drought Mitigation Center (NDMC) defines drought as “...a deficiency in water precipitation over an extended period of time, resulting in water shortages.” Climatic factors such as high temperatures, high wind, and low relative humidity are often associated with drought, however the definition in general is a fluid specification as no single definition of deficiency or time applies to all circumstances. ‘Water shortage’ is the guiding phrase which defines the drought type and category.

Drought types are defined in Table 4.8a as categorized by Wilhite and Glantz. The first three measure the physical phenomenon while the fourth tracks the effects of the water deficit. The fifth category was recently added through research by the Science for Nature and People in an effort to connect “...human and natural systems in order to highlight opportunities to mitigate drought risks” (SNAPP).

Coupled with broad definitions of drought comes a difficulty to predict when and exactly where such disasters will occur. Summer is the season most susceptible to drought impact as it is the warmest and driest part of the year however Pike County typically experiences fall drought. Drought occurs in virtually all-climatic zones, varying significantly from one region to another detailed in Table 4.8a below.

Table 4.8a: Drought Types

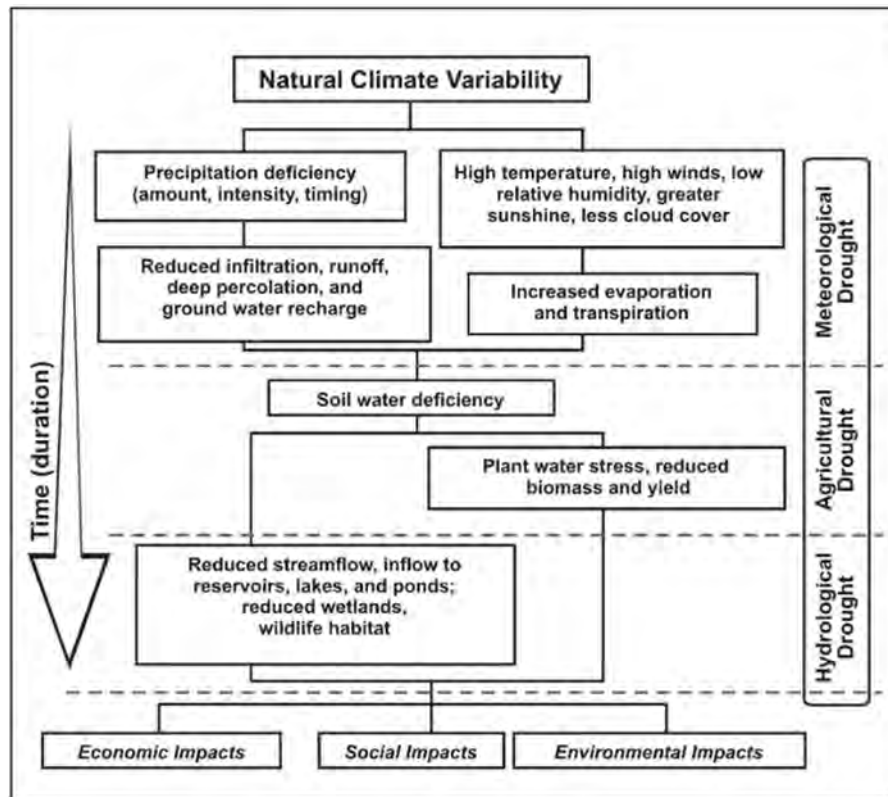
Drought Type	Description
Meteorological Drought ¹	Meteorological drought is usually based on long-term precipitation departures from normal, but there is no consensus regarding the threshold of the deficit or the minimum duration of the lack of precipitation that makes a dry spell an official drought.
Hydrological Drought ¹	Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, and as lake, reservoir, and ground water levels.
Agricultural Drought ¹	Agricultural drought occurs when there is insufficient soil moisture to meet the needs of a specific crop at a particular time. A deficit of rainfall over cropped areas during critical periods of the growth cycle can result in destroyed or underdeveloped crops with greatly depleted yields. Agricultural drought is typically evident after meteorological drought but before a hydrological drought.
Socioeconomic Drought ¹	Socioeconomic drought is a period when water shortages begin to affect people when there is not enough water to meet human and environmental needs.
Ecological Drought ²	A prolonged and widespread deficit in naturally available water supplies – including changes in natural and managed hydrology – that create multiple stresses across ecosystems.

Source 1: Wilhite, D.A.; and M.H. Glantz. 1985. Understanding the Drought Phenomenon: The Role of Definitions. *Water International* 10(3):111–120. NDMC. <https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx>

Source 2: SNAPP. <https://snapppartnership.net/teams/ecological-drought/>

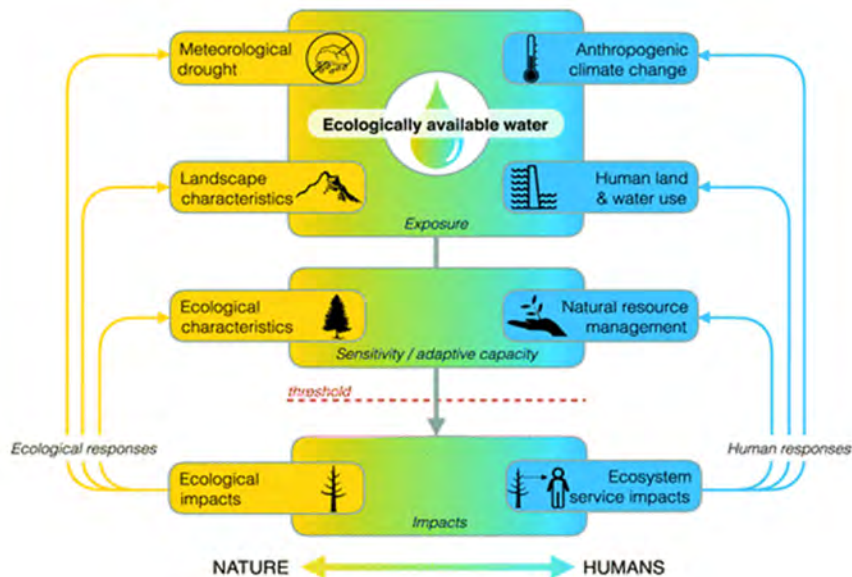
Figures 4.8a and figure 4.8b describe the sequence of the commonly accepted drought types described in Table 4.8a.

Figure 4.8a: NDMC Drought Progression



Source: NDMC. <https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx>

Figure 4.8b: Ecological Drought Progression



Source: SNAPP. <https://snapppartnership.net/teams/ecological-drought/>

The US Drought Monitor records drought severity in five categories as listed in Table 4.8b below.

Table 4.8b: Drought Categories

Category	Name	Description
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

The impacts of droughts can be far-reaching. Droughts vary in geographical area from a region of the United States to one or more areas of several square miles within a state or county. Drought conditions impact both rural and urban areas resulting in significant economic and social consequences. An increased population demand upon water supplies, both individual and municipal, demands from agriculture crops, needs of livestock and human consumption, and industrial and leisure demands all affect drought conditions.

The more common summer droughts, usually accompanied by extremely hot weather, can also lead to outages of electric power. Reduced electric transmission efficiency and significantly increased demand due to increased use of air conditioning cause these outages. These can also be a delayed impact upon agricultural product costs in ensuing months.

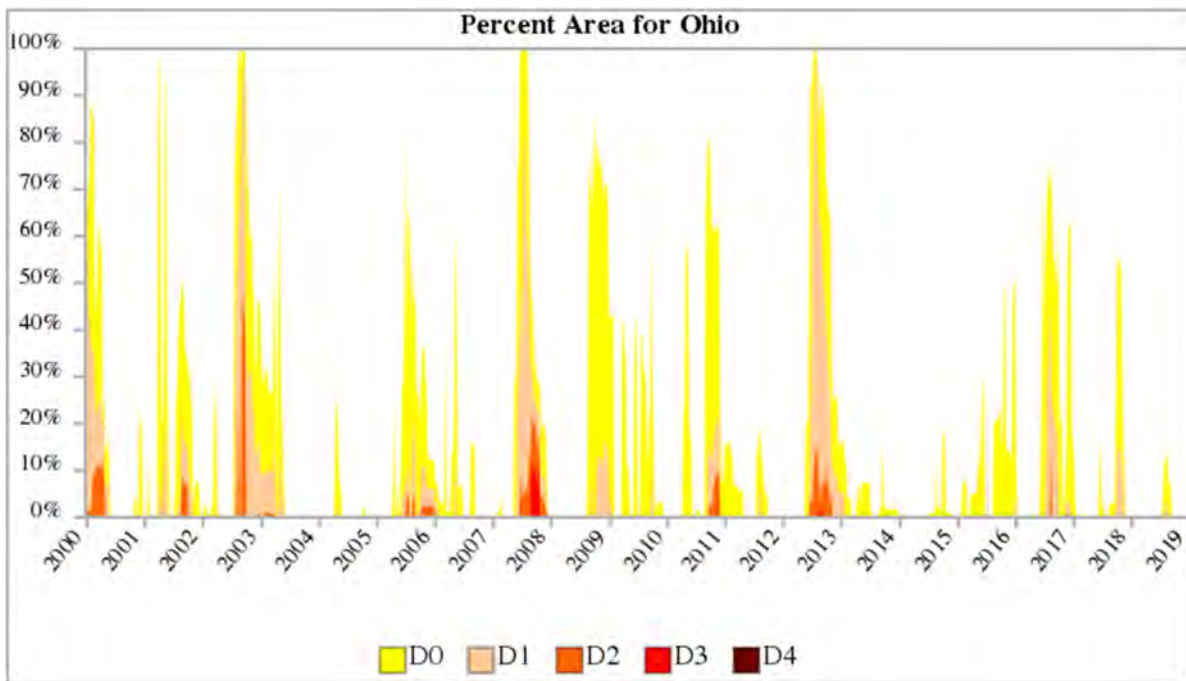
LOCATION

A future drought could affect all or part of Pike County as past events have.

PREVIOUS OCCURRENCES

Figure 4.8c below, illustrates the percent area of Ohio affected by each drought category over the past 20 years. The longest drought in Ohio lasted 44 weeks beginning on July 23, 2002 and ending May 20, 2003. The most intense period of drought occurred in September 2007 where D3 affected 11.45% of Ohio land.

Figure 4.8c: Drought Category vs. Percent Area for Ohio (2000-2018)



Source: <https://www.drought.gov/drought/states/ohio>

Data collected from the U.S. Drought Monitor was compiled for Pike County. Table 4.8c reports the percent of each of the past ten years spent in various categories of drought. The average time spent in drought over the past 10 years paints a relative probability of experiencing that drought category in any given year.

It should be reported that data collected does not represent total area impact for Pike County. Exact locations and effects have not been reported however soybean and cattle would see the largest impact as they are the main crop and livestock respectively.

Table 4.8c: Percent Year in Drought (2008-2018)

	Drought Categories				
Year	Do-D4	D1-D4	D2-D4	D3-D4	D4
2008	8	10	0	0	0
2009	14	0	0	0	0
2010	6	11	0	0	0
2011	0	0	0	0	0
2012	3	19	6	0	0
2013	1	0	0	0	0
2014	3	0	0	0	0
2015	12	0	0	0	0
2016	9	4	0	0	0
2017	1	0	0	0	0
2018	0	0	0	0	0

Data Source: <https://droughtmonitor.unl.edu/Maps/MapArchive.aspx>

According to the *2007 Pike County Mitigation Plan*, Pike County had been affected by droughts at least two times between 1993 and 2003. Both of these occurrences lasted a month or longer.

MAGNITUDE

Even during extended periods of drought, such events rarely result in direct property damage. Most damages associated with drought occur in the agricultural sector as the result of crop and livestock losses. As indicated in the Drought Monitor data, there were 28 straight weeks of drought reported for 2012. According to the 2012 Census of Agriculture, an extreme drought incurring agricultural losses of 50% or more would cost Pike County farmers over \$13,439,500. As indicated in the Drought Monitor data, there were 6 weeks of Severe Drought reported for Pike County in 2012. However, longer periods of drought may be possible.

SPEED OF ONSET

Droughts are difficult to predict and are usually determined based on an identified threshold of historical precipitation. Information such as temperature, precipitation, and rate of soil moisture deletion should be taken into account. It is not the speed of onset, but the length of a drought that does the damage, so it is possible to take measures to prepare for drought like conditions.

DURATION

For a drought to cause severe damage, it must last long enough to show an abnormal shift from previous precipitation patterns. The length of a drought will depend upon the length of time that there is moisture deficiency in the area.

AVAILABILITY OF WARNING TIME

Scientists do not know how to predict drought a month or more in advance for most locations. Because drought depends on temperature and precipitation and climate are inherently variable, drought advisories are based more on monitoring thresholds to averages. Meteorologists working in conjunction with local officials can notify the public of the potential for a drought however this is likely to occur as or after a drought has begun. This information will also allow officials to make informed decisions about the issuance of water conservation warnings and other water preservation measures.

PROBABILITY OF FUTURE EVENTS

The county will continue to face drought challenges. According to the trend over the past 10 years, each year there is a 10% chance of it being abnormally dry, a 7% chance of a moderate drought, and a 1% chance of a severe drought. The county is in agreement that drought is not a commonly experienced hazard and should reflect an “unlikely” probability.

VULNERABILITY ASSESSMENT

Because of the nature and variability of drought, it is difficult to predict what losses would be incurred by its onset. It does help to understand the extent of what could be affected, though. Approximately 25% of the acreage in Pike County is used as crop land and pasture per the Ohio Department of Development Pike County Profile (2017). According to the USDA’s 2012 Census of Agriculture, the total market value of the agricultural products produced and sold by said farmland equaled \$26,879,000 in just one year alone. The loss of even a fraction of that revenue due to drought would be damaging to the County’s economy and potentially devastating to individual farmers.

Priority Risk Index

Table 4.8d: PRI Calculation for Drought

PRI Category	Level	Index Value
Probability	Unlikely	1
Vulnerability	Limited	2
Spatial Extent	Moderate	3
Warning Time	More than 24 hours	1
Duration	More than one week	4

4.9 Earthquake

Description

The earth is divided into layers, the outmost of which is called the crust. The crust is rigid and brittle and is comprised of many individual pieces called plates. Plates meet at “fault lines” where they rub together, rise over, or sink under each other. It is along these fault lines where earthquakes are typically experienced. An earthquake is the resulting ground shaking and radiated seismic energy caused by sudden stress changes in the earth. Fault lines do run through Ohio as shown in figure 4.9a, however the intensity is less substantial because majority are buried and very few are visible at the surface.

Figure 4.9a: Map of Deep Structures

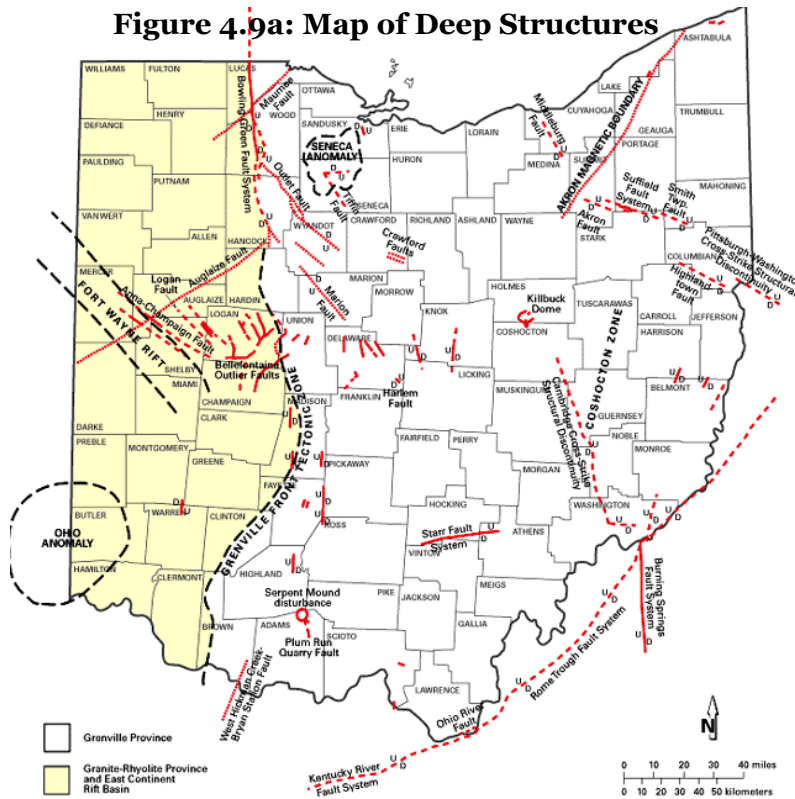
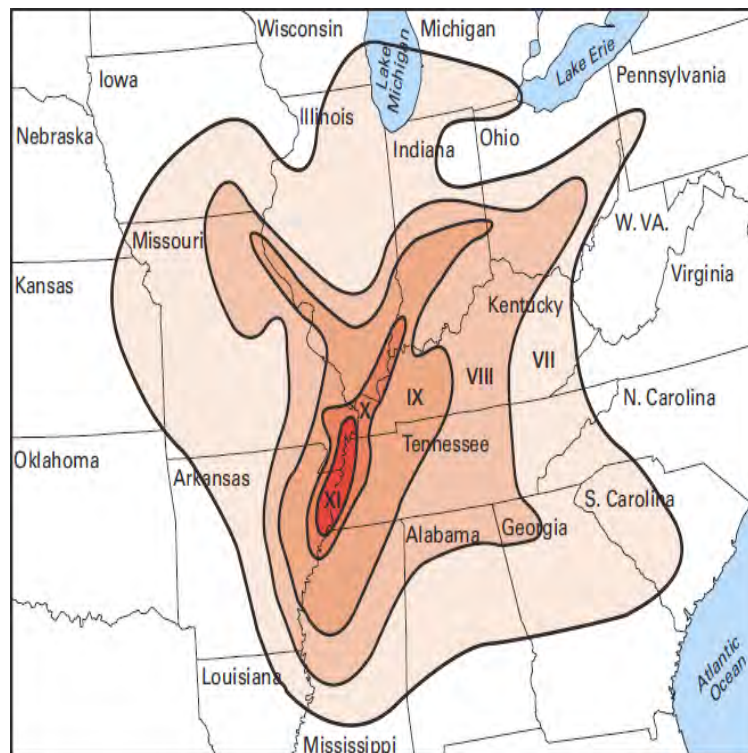


Figure 4.9b: New Madrid Seismic Zone In Ohio



Source <http://geosurvey.ohiodnr.gov/earthquakes-ohioseis/seismic-risk-in-ohio>

Figure 4.9c: Scale Comparison

Modified Mercalli Scale		Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibrations like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some awaken; dishes, windows, doors disturbed; standing autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	4.5
VIII	Panel walls thrown out of frames; walls, monuments, chimneys fall; sand and mud ejected; drivers of autos disturbed	5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	5.5
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	6.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up into air	7

The New Madrid Seismic Zone was the site of the largest earthquake sequence in the continental United States. Shown in Figure 4.9b, Ohio resides on the periphery of an 8.0 magnitude earthquake emanating from the New Madrid Faultline. According to Ohio Department of Natural Resources (ODNR) Geological Survey website, events in 1811 and 1812 were “..sufficient enough to topple chimneys in Cincinnati.” The New Madrid Seismic Zone does stretch across Pike County.

There are several ways to measure the force and power of an earthquake. Two of the most common are the Modified Mercalli Scale and the Magnitude Scale. The Magnitude Scale, also known as the Richter Scale, is a logarithmic (base 10) scale used to measure the magnitude of the largest seismic wave of an earthquake. The Modified Mercalli Scale, on the other hand, is used to evaluate the physical effects of an earthquake on an area. The Magnitude Scale is an objective measurement of an earthquake’s overall power, whereas the Modified Mercalli Scale provides a subjective analysis of the damage it causes. The chart shown at right shown on the following page compares the two scales.

By the New Madrid prediction map in figure 4.9b, Pike County would likely experience no more than a Modified Mercalli intensity of VIII. However, this has a high probability of causing structural damage.

While a Magnitude 8.0 earthquake is a very rare occurrence, it is not impossible. According to the Central United States Earthquake Consortium (CUSEC), the New Madrid fault line has a 25%-40% chance of generating a 6.0 or higher magnitude earthquake within the next 50 years.

LOCATION

The spatial extent of an earthquake depends upon its intensity and the location of its epicenter; the greater the intensity of an earthquake, the larger the area that will feel its effects. The area that feels said effects is determined by the placement of the epicenter.

Seismic activity is concentrated in, but not confined to, three areas of the state, none of which include Pike County. Two earthquakes have been reported in Pike County. In

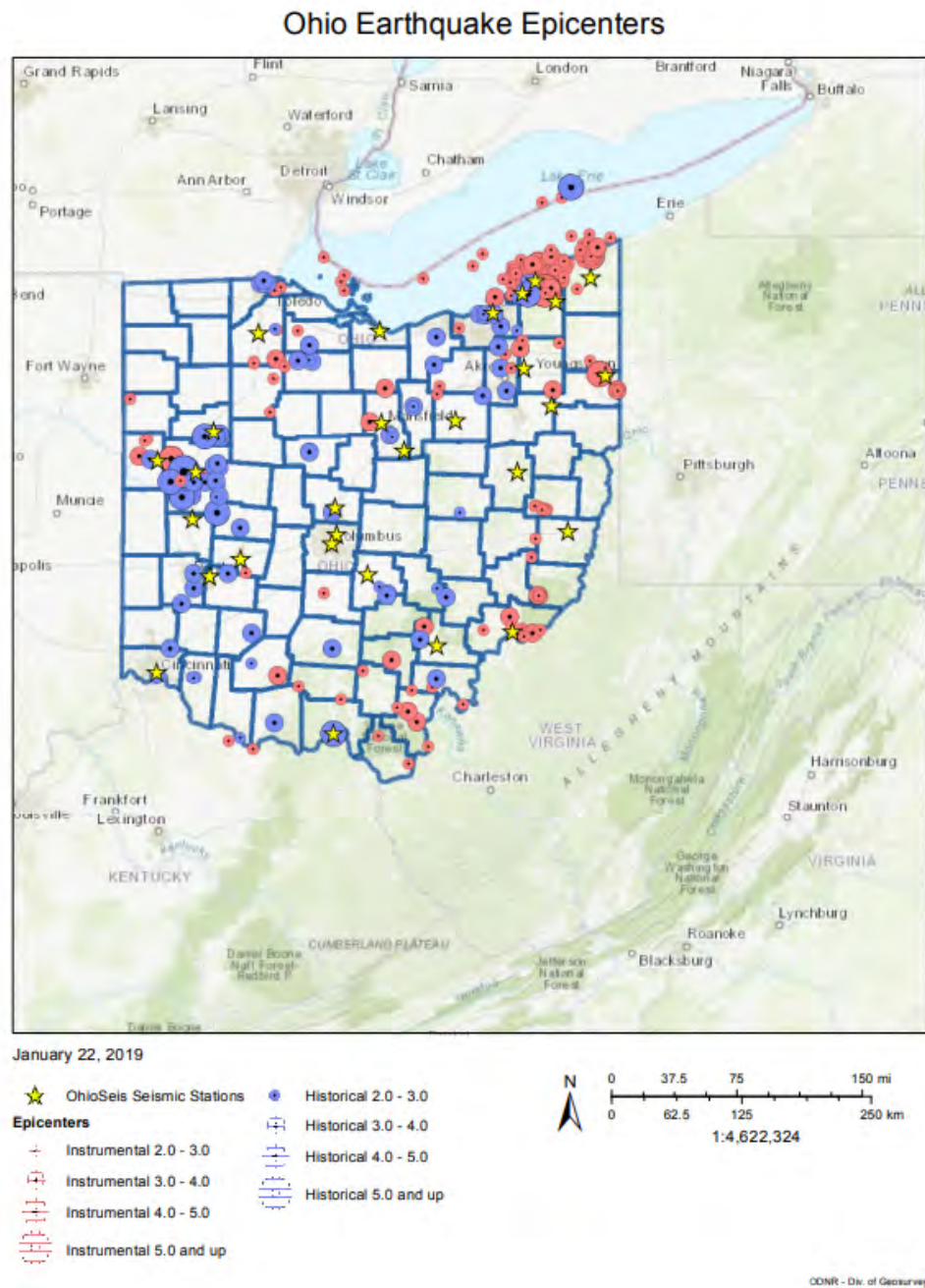
1994 a 2.5 magnitude earthquake was reported in western Sunfish Township. In 2014, a 2.0 magnitude earthquake was reported in southern Union Township.

While the source location of an earthquake could come from almost any geographical location, the most probable source for a damaging earthquake would be the New Madrid Fault, which runs through the Missouri, Arkansas, Mississippi, Kentucky, Tennessee, and Illinois border regions. Ultimately, an earthquake has the potential to affect all of Pike County. It may also be noted that three 4.0 or greater magnitude earthquakes have occurred in adjacent counties

PREVIOUS OCCURRENCES

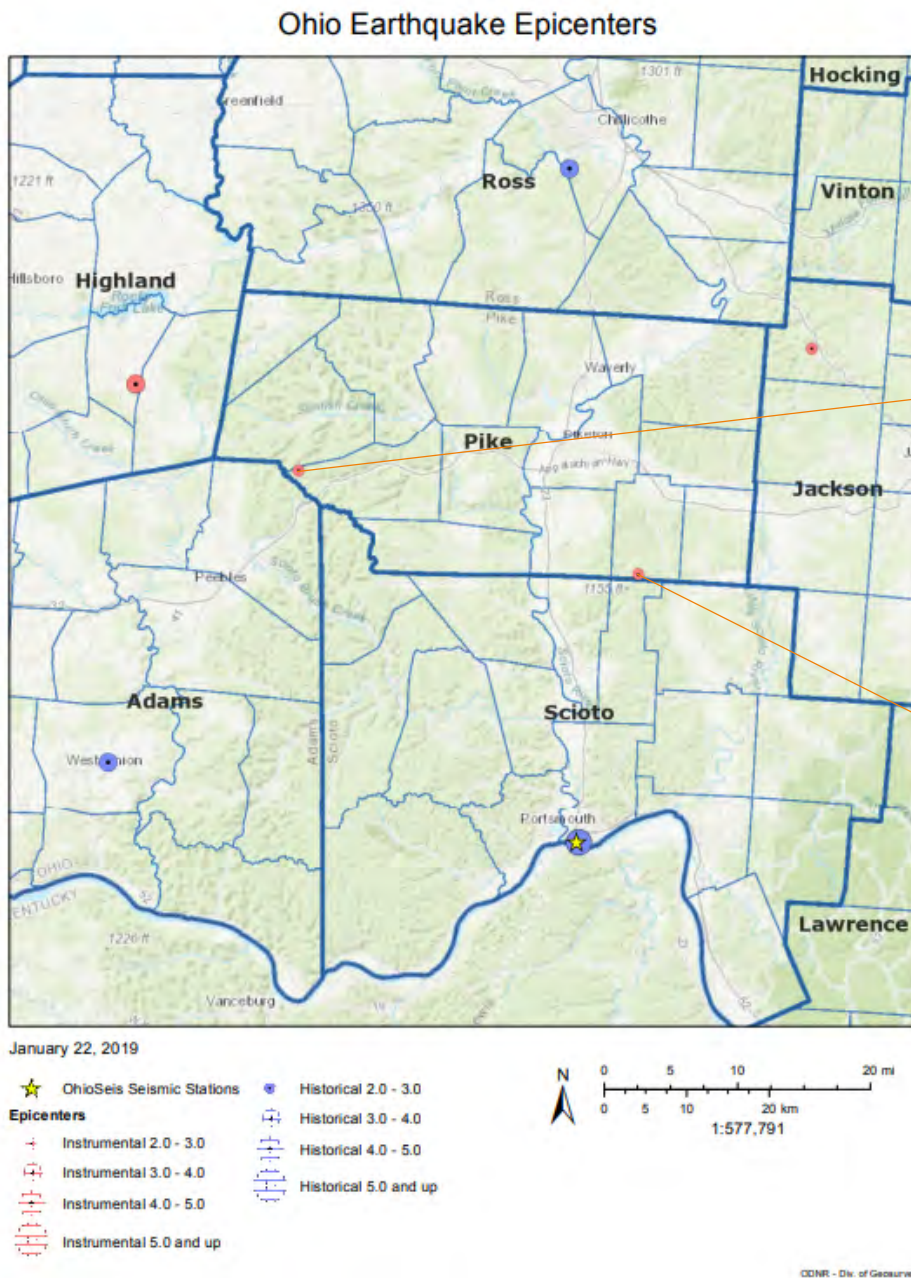
At least 200 earthquakes with epicenters in Ohio have been felt since 1776 and 15 of these events have caused minor to moderate damage. There have been no deaths, only minor injuries in Ohio. Pike County had a 2.0-2.9 magnitude earthquake in 1994 and 2014. Additionally, other instances of seismic activity have been felt but no instance of damage nor injury was reported. Figures 4.9d and 4.9e depict Ohio's epicenter history and Pike County's epicenter history. Figures 4.9f and 4.9g detail the epicenters in Pike County for Sunfish Township and Union Township respectively.

Figure 4.9d: Ohio Epicenters (1776 – 2018)



Source: ODNR Earthquake Epicenter Map Viewer.
<https://gis.ohiodnr.gov/MapView/?config=earthquakes>

Figure 4.9e: Pike County Earthquake Epicenters



Pike County Earthquake History

- Sunfish Township (see Figure 4.8f) experienced one earthquake in 1994. It had a magnitude of 2.5 which correlates to III on the Mercalli Scale.
- Union Township (see Figure 4.8g) experienced one earthquake in 2014, with a magnitude of 2. The Mercalli Scale reading was II.

Source: ODNR Earthquake Epicenter Map Viewer
<https://gis.ohiodnr.gov/MapView/?config=earthquakes>

Figure 4.9f: Sunfish Township Figure 4.9g: Union Township

Earthquake Epicenter

Earthquake Epicenters
Magnitude: 2.5
County: PIKE
Year: 1994
Month: Jul
Day: 9
Hour: 22
Minute: 13
Second: 40.6
Source: UK
Latitude: 39.045
longitude: -83.294
Calculated Depth: 0
Magnitude Type: 1

Earthquake Epicenter

Earthquake Epicenters
Magnitude: 2
County: PIKE
Year: 2014
Month: Dec
Day: 21
Hour: 5
Minute: 52
Second: 58.3018
Source: OSN
Latitude: 38.958
longitude: -82.9257
Calculated Depth: 5
Magnitude Type: 1

Source: ODNR Earthquake Epicenter Map Viewer <https://gis.ohiodnr.gov/MapView/?config=earthquakes>

MAGNITUDE

Collateral damage from earthquakes could be extensive and might include floods, hazardous material spills, landslides, subsidence, dam failures, fire, groundwater contamination, pipeline breaks, infrastructure disruptions, epidemics, and looting. Historically, earthquakes in Pike County were of magnitude 2.0 (Mercalli Scale of II) and 2.5 (Mercalli Scale of III). These earthquakes were very light vibrations that caused no damages nor injury.

DURATION

The initial effects of an earthquake would be over quickly, but aftershocks could be felt up to hours or days afterward. Additionally, if a particular earthquake were powerful enough, the resulting damage to infrastructure could require significant clean up efforts.

SPEED OF ONSET

Earthquakes occur as pressure is released in the earth's crust. This causes earthquakes to appear as though they occur instantaneously, with little to no prior buildup of activity.

AVAILABILITY OF WARNING TIME

Although research is being done on how to best predict earthquakes, accurate prediction of any one single earthquake is almost impossible. Because earthquakes happen very quickly and with very few pre-event effects, the available warning for an earthquake is almost nonexistent.

PROBABILITY OF FUTURE EVENTS

Probability of future earthquake events impacting Pike County is determined by using historical occurrence information. There was one event reported in 1994 and one in 2014. Therefore, the probability of a future earthquake can be defined as "unlikely" (less than 1% annual probability).

VULNERABILITY ASSESSMENT

For the earthquake hazard vulnerability assessment, a probabilistic scenario was created using Hazus 4.2 to estimate the annualized loss for the county. The probabilistic analysis does not require a magnitude or epicenter for the annualized loss estimate. The results are provided for the expected average annual losses in the county. Since there have been two reported earthquake events with a low magnitude, the probabilistic analysis was selected for the earthquake vulnerability analysis to show the expected losses in the county in any year. The losses reported in the table include building damage, inventory loss and business interruption. The historic events reported in the figures above show there were few losses reported from the earthquake hazard in Pike County and the Hazus results reflect this since the results per year are low as well.

Table 4.9a: Hazus-MH Annualized Loss results by Jurisdiction

Location	Annualized Loss
Village of Beaver	\$0
Village of Piketon	\$0
Pike County	\$48,000
Village of Waverly	\$2,000
TOTAL	\$50,000

**Losses of less than \$500 were rounded to \$0 in the table.*

Priority Risk Index

Table 4.9b: PRI Calculation for Earthquake

PRI Category	Level	Index Value
Probability	Unlikely	1
Vulnerability	Minor	1
Spatial Extent	Small	2
Warning Time	Less than 6 hours	4
Duration	Less than 6 hours	1

4.10 Flood

Description

Floods are natural and beneficial functions of soil deposition and water infiltration of overflowing streams and rivers into floodplains. However, where this floodplain intersects with homes, businesses, and other building structures, loss of life and property can result. Floods can occur for a variety of reasons including heavy rain, snow melt, soil saturation, vegetation removal, ground freeze, severe winds, and an overabundance of impervious surfaces such as roads and parking lots. Floods are the most frequently occurring natural disaster in Ohio and cause damage to private and public property every year.

Several types of flooding events are described below:

- **Flash Flooding:**
 - Flash floods occur within a few minutes or hours of heavy rainfall and are capable of destroying buildings, uprooting trees, and scouring new drainage channels. Heavy rains that produce flash floods can also trigger mudslides and landslides. Most flash flooding is caused by slow-moving thunderstorms, repeated thunderstorms in a local area, or by heavy rains from hurricanes and tropical storms. Although flash flooding often occurs in mountainous areas, it is also common in urban centers where much of the ground is covered by impervious surfaces, channels are straighter allowing for higher water velocity, and water is directed through sewer drains straight to the river or stream channel.
- **Sheet Flooding:**
 - Sheet flooding is a uniform layer of water runoff flowing overland as a sheet rather than in a defined channel. This type of flooding more commonly occurs in flat areas such as farmland and is most noted for eroding particles, such as topsoil, from an entire surface area.
- **Urban Flooding:**

- Urban flooding is usually caused by heavy rain over a developed area lacking necessary drainage. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb water. Since sidewalks and roads are impervious, water flows down the surface of the streets, and is then dumped directly into storm drains. Fixed drainage channels in urban areas may be unable to contain the runoff that is generated by relatively small but intense rainfall events. Urbanization increases runoff two to six times over what would occur on natural terrain. As a consequence, high volumes of water can turn parking lots into lakes, flood basements and businesses, and cause ponding in the middle of roads and intersections. Urbanization intensifies the magnitude and frequency of floods by increasing impermeable surfaces, amplifying the speed of drainage collection, reducing the carrying capacity of the land, and occasionally, overwhelming sewer systems.
- **Riverine Flooding:**
 - Riverine flooding is a function of precipitation levels and water runoff volumes within the watershed of a stream or river. It is a natural rising of the water levels culminating in flooding but typically allowing for more warning time.

Floodplains are designated by the frequency of the flood that is large enough to cover them. For example, the 10-year floodplain will be covered by the 10-year flood and the 100-year floodplain by the 100-year flood. Flood frequencies, such as the 100-year flood, are determined by plotting a graph of the size of all known floods for an area and determining how often floods of a particular size occur. A better way to characterize the naming convention is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1-percent chance of occurring in any given year and the 500-year flood has a 0.2-percent chance of occurring in any given year. This can also be referred to as a recurrence interval, defined as the average time interval measured in years, expected to take place between the occurrence of a flood of a particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval.

Most dams, levees, and other flood-related structures have been designed to meet 100-year flood conditions. FEMA develops digital Flood Insurance Rate Maps (DFIRMs) to indicate areas in the U.S. where mandatory flood insurance requirements apply (the 100-year flood). They are also used for planning purposes to identify hazard areas. In 2010, updated DFIRMs were published by FEMA for Pike County in support of the National Flood Insurance Program (NFIP) designating areas according to potential risk and impact due to flooding.

LOCATION

Flooding in Pike County has most often occurred in April and May but can occur at any time. The areas most likely to experience flooding are the communities located within a floodplain. These areas include the Village of Piketon, the Village of Waverly, and Pike County. Areas within Village of Beaver has had floods and flash floods but no damages nor injuries were reported. Still other areas may experience flooding as well but are not at as high of a risk. Maps showing community flood hazard are in Appendix D.

PREVIOUS OCCURRENCES

Since 1968 eight Presidential declarations have been issued for Pike County involving flooding, two of which were in 2012 and the latest of which was in April of 2018. Significant events from the National Center for the Environmental Information (NCEI) since 1997 are included in Table 4.9a. The most notable events are:

- The 1997 countywide flood which claimed 1 life and \$1.5million in damages.
- The July 2003 flood costing \$700,000 in damages
- The October 2006 flood costing \$100,000 in damages

Table 4.10a: NCEI Flood and Flash Flood Data

Date	Location	Death/Injuries	Damage (\$)
3/2/1997	Pike County	1/0	\$1,500,000
6/2/1997	Pike County	0/0	\$5,000
1/7/1998	Village of Waverly	0/0	\$5,000
2/18/2000	Pike County	0/0	\$10,000
4/3/2000	Pike County	0/0	\$3,000
12/16/2000	Pike County	0/0	\$5,000
5/18/2001	Pike County	0/0	\$5,000
5/21/2001	Village of Waverly	0/0	\$3,000
6/6/2001	Village of Waverly	0/0	\$3,000
7/10/2003	Village of Piketon	0/0	\$700,000
8/22/2003	Pike County	0/0	\$10,000
10/4/2006	Village of Waverly	0/0	\$100,000

Date	Location	Death/Injuries	Damage (\$)
3/4/2008	Pike County	0/0	\$2,000
5/2/2010	Village of Waverly	0/0	\$2,000
5/2/2010	Pike County	0/0	\$1,000
4/12/2011	Village of Waverly	0/0	\$1,000
5/22/2011	Village of Waverly	0/0	\$20,000
5/22/2011	Pike County	0/0	\$3,000
4/4/2014	Pike County	0/0	\$10,000
7/29/2016	Pike County	0/0	\$5,000

MAGNITUDE

Extent can be measured in several ways including flow or discharge rate (cubic feet per second), height of flood waters and damages. The USGS drainage areas, discharge rates, and available flood stage for Pike County are included in Table 4.10b below. Maximum discharge and maximum gage height are an indicator for the flood hazard extent.

Table 4.10b: Summary of Discharge Rates in Pike County

Water Feature	Gage Location	Median Discharge (ft ³ /s)	Max Discharge (ft ³ /s - yr)	Drainage Area (sq miles)	Max Gage Height (ft - yr)
Scioto River	Village of Piketon	4200	78700 - 2005	5836	28.52 - 2005

Source: USGS water watch - <https://waterwatch.usgs.gov>

The magnitude and intensity of a flood is determined by a variety of factors. The NFIP standard for floodplain management is based on what is called the 100-Year Flood, which is the flood elevation that has a 1 percent chance of being equaled or exceeded each year.

DURATION

The duration of a flood is dependent on many different factors, such as rainfall, soil conditions, and ground saturation levels. Depending on the conditions, flood waters could recede rapidly, or they could remain for days or more.

SPEED OF ONSET

The speed at which a flood occurs depends on the conditions at the time. They can happen very quickly, as in a flash flood, or they can happen gradually over time, such as

a swelling river. All of this is determined by factors such as soil conditions and precipitation.

AVAILABILITY OF WARNING TIME

Modern meteorology can predict when conditions conducive to flooding will occur and the National Weather Service routinely provides warnings when there is a potential for flood. These warnings are issued via weather radio, television broadcast, and other electronic media. While the NWS does provide warning for flood, not all floods can be predicted. Because of this, not all floods can be warned against, such as some cases of flash flooding.

PROBABILITY OF FUTURE EVENTS

The NCEI data lists 20 events (flood and flash flood) with property losses reported from 1997 to 2016. This results in a 100% annual probability. Therefore, flood was assigned a probability of “highly likely”. It can be expected that flooding will impact the county on an annual basis. However, there are certain areas that are more susceptible to flooding as indicated on the maps with the FEMA DFIRM data included in Appendix D.

VULNERABILITY ASSESSMENT

Losses will most likely occur to properties located within floodplains. However, all current and future buildings and populations should be considered at risk to flooding. The impacts of flooding can be severe. Impacts of flood can include business disruption, mold issues, and damaged contents and equipment. Just a few inches of water in a building could cause thousands of dollars in damage to the flooring and foundation of the structure. In cases where water rises above a few inches, electrical systems and appliances may need to be replaced. Additionally, the County generally tries to acquire those properties that are routinely subjected to flood damages, which further reduces flood loss.

Hazus-MH 4.2 was used to estimate potential riverine flood losses in Pike County. A Digital Elevation model (DEM) was obtained from the USGS for the study area. Hazus-MH was used to estimate floodplain boundaries, potential exposure for each event frequency based on probabilistic scenarios for the 10-, 25-, 50-, 100- and 500-year flood events using a level 1 analysis. A drainage area of 10 square miles was used to generate the stream network. Of note, this boundary is not equivalent to the regulatory flood insurance rate map or FEMA data. However, it does provide comparable flood hazard boundaries that are useful for estimating flood losses. Table 4.10c lists the total building exposure in the county (total replacement value of buildings in the Hazus-MH inventory). Total losses are presented due to flood in Table 4.10d. Total loss includes building loss, content loss, inventory loss, relocation costs, income loss, rental income loss and wage loss. Tables 4.10e and 4.10f include total loss for residential and non residential buildings.

Table 4.10c: Total Building Exposure by Building Type in Pike County based on Hazus-MH Default Inventory

Location	Residential	Commercial	Other	Total Building
Village of Beaver	\$31,000,000	\$5,000,000	\$5,000,000	\$41,000,000
Village of Piketon	\$174,000,000	\$46,000,000	\$16,000,000	\$236,000,000
Pike County	\$1,335,000,000	\$331,000,000	\$150,000,000	\$1,816,000,000
Village of Waverly	\$385,000,000	\$136,000,000	\$92,000,000	\$613,000,000
TOTAL	\$1,925,000,000	\$518,000,000	\$263,000,000	\$2,706,000,000

Table 4.10d: Potential Total Losses from Flood by Return Period

Location	10-year	25-year	50-year	100-year	500-year
Village of Beaver	\$0	\$0	\$0	\$0	\$0
Village of Piketon	\$1,552,000	\$1,698,000	\$1,781,000	\$1,892,000	\$2,061,000
Pike County	\$26,220,000	\$31,407,000	\$35,046,000	\$38,648,000	\$46,858,000
Village of Waverly	\$11,661,000	\$13,785,000	\$15,239,000	\$16,152,000	\$18,589,000
TOTAL	\$39,433,000	\$46,890,000	\$52,066,000	\$56,692,000	\$67,508,000

Table 4.10f: Potential Total Non-Residential Losses from Flood by Return Period

Location	10-year	25-year	50-year	100-year	500-year
Village of Beaver	\$1,000	\$1,000	\$1,000	\$1,000	\$1,000
Village of Piketon	\$748,000	\$786,000	\$803,000	\$820,000	\$853,000
Pike County	\$46,051,000	\$50,741,000	\$53,902,000	\$56,510,000	\$64,047,000
Village of Waverly	\$75,190,000	\$83,933,000	\$91,768,000	\$96,391,000	\$109,623,000
TOTAL	\$121,990,000	\$135,461,000	\$146,474,000	\$153,722,000	\$174,524,000

USER DEFINED FACILITY ANALYSIS

As part of the Pike County Hazard Mitigation plan update, structure data was analyzed for part of the Village of Waverly and Pike County. Data was provided by the Pike County Auditor office. Depth grids were created for all return periods. The structure specific data and depth grids were imported into the Hazus program to determine losses (total dollar loss and building damage percentage). Maps showing the structures included in the Hazus analysis for the 1 percent annual chance event are provided below. Maps for the other return periods are included in Appendix F.

Figure 4.10a: Facility Loss Value Map

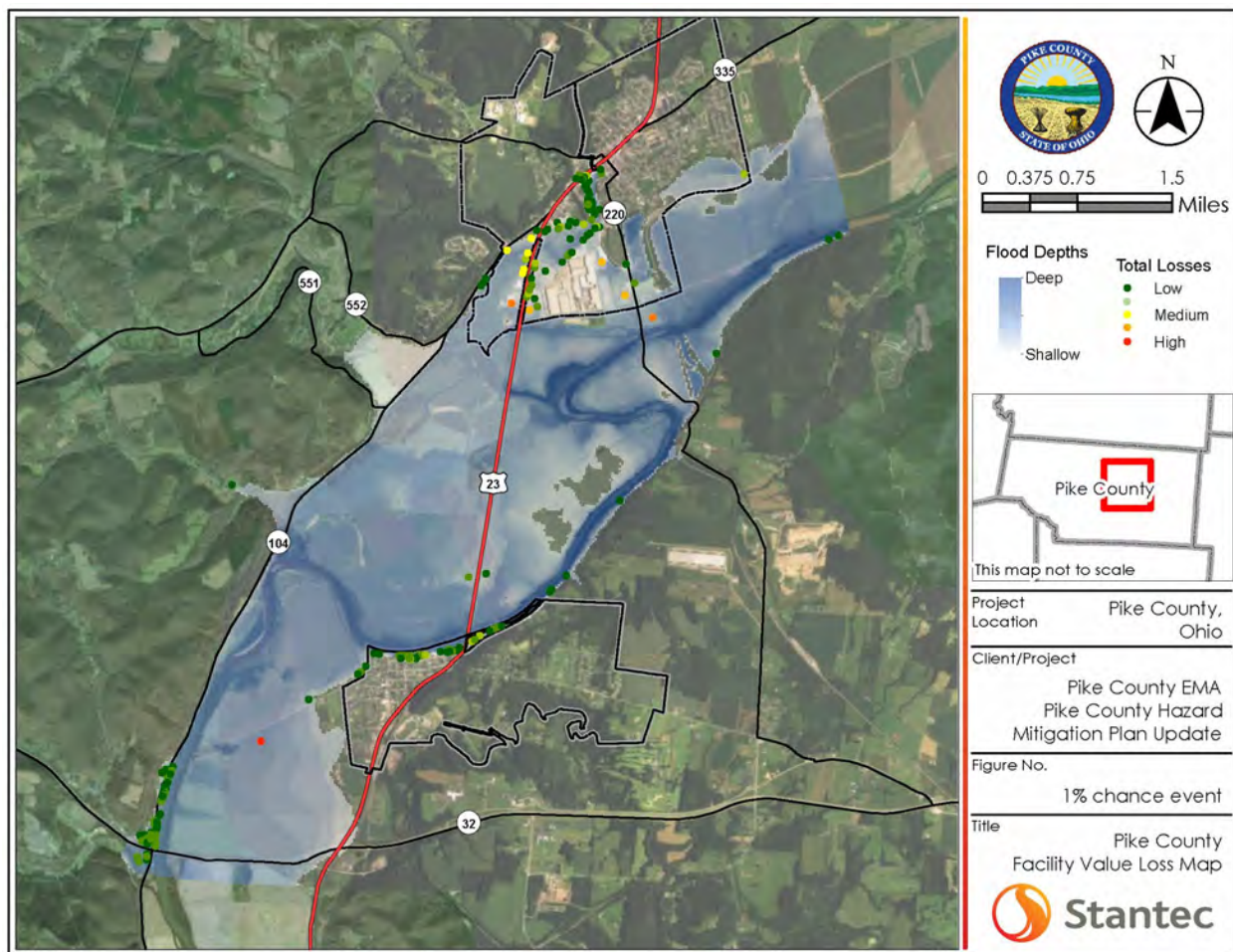
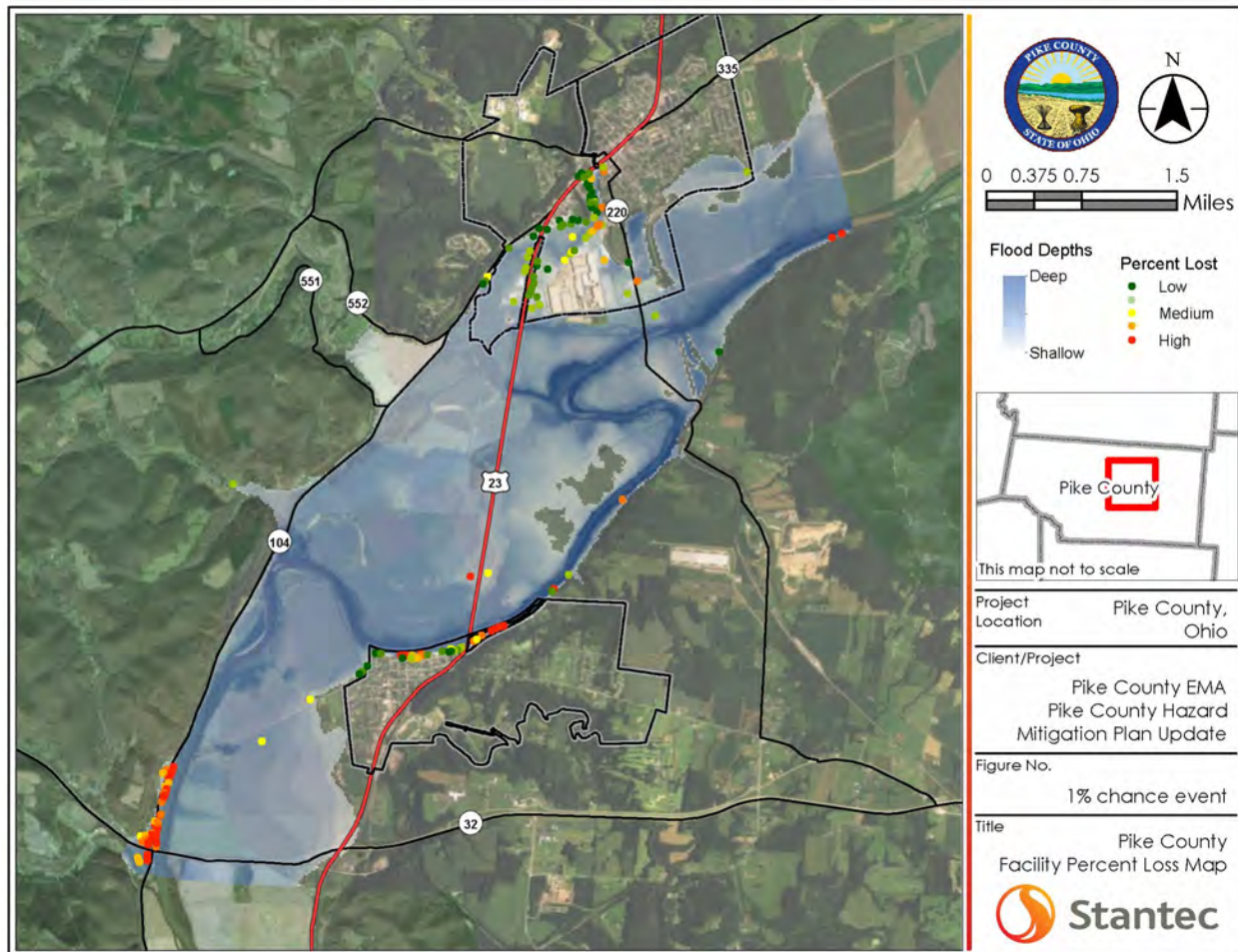


Figure 4.10b: Facility Percent Loss Map



A table with the data export from Hazus with the results for the total loss and building damage percentage is provided in Appendix F. As indicated in the data and the maps, there are some structures which have a low dollar value of loss but higher percentage of damage, whereas other structures may have a higher dollar loss value and a low damage percentage. The maps show areas that might be considered for mitigation action such as culvert replacement, floodproofing, etc. A table with the total losses by return period for the structures included in the Hazus analysis are provided below.

Table 4.10g: Total losses by return period for structures in Hazus analysis

10 percent annual chance event (10-year)	4 percent annual chance event (25-year)	2 percent annual chance event (50-year)	1 percent annual chance event (100-year)	0.2 percent annual chance event (500-year)
\$5,443,480	\$10,121,350	\$14,144,220	\$27,676,480	\$44,633,260

REPETITIVE LOSS PROPERTIES

FEMA defines a repetitive loss property as any insurable building for which two or more claims of more than \$1,000 were paid by the NFIP within any rolling 10-year period since 1978. A repetitive loss property may or may not be currently insured by the NFIP. Currently, there are over 140,000 repetitive loss properties nationwide.

As of March 2019, there are 13 non-mitigated repetitive loss properties located in Pike County, which account for 28 losses and over \$891,000 in claims payments under the NFIP. The average claim amount for these properties is \$31,821. Seven of the thirteen repetitive loss properties are single family residential buildings, there is 1 multi-family building, and 5 other non-residential building. It is expected that without mitigation that these structures will likely continue to experience flood losses. Table 4.10h below presents detailed information on the repetitive loss properties and NFIP claims for Pike County. There are no severe repetitive loss properties in Pike County.

Table 4.10h: Summary of Repetitive Loss Properties

Location	Number of Properties	Types of Properties	Number of Losses	Building Payments	Content Payments	Total Payments	Average Payment
Village of Piketon	5	4 single family, 1 other non-residential	12	\$167,797	\$22,222	\$190,741	\$78,724
Village of Waverly	6	3 single family, 1 multi-family, 2 other non-residential	12	\$480,349	\$92,530	\$572,879	\$286,440
Pike County	2	2 non-residential	4	\$105,322	\$22,943	\$127,544	\$63,772

Priority Risk Index

Table 4.10i: PRI Calculation for Flood

PRI Category	Level	Index Value
Probability	Highly Likely	4
Vulnerability	Limited	2
Spatial Extent	Moderate	3
Warning Time	6 to 12 hours	3
Duration	Less than 24 hours	2

4.11 Hail Storms

Description

Hail is precipitation in the form of irregular pellets of ice large enough that they could cause damage to things on the ground. Most often, hail storm events are associated with high winds and thunderstorm conditions. The majority of damage caused by hail storms is incurred by automobiles and structure roofs, but such storms can potentially deal significant damage to crops as well. Hailstorms are a potentially damaging outgrowth of severe thunderstorms.

Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until they develop to a sufficient weight and fall as precipitation.

Hail typically takes the form of spheres or irregularly-shaped masses greater than 0.75 inches in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size. The most likely time to experience hail is during the summer thunderstorm season.

Hailstone size can range a great deal in size from 5 millimeters (mm) – approximately pea-sized – to greater than 100 mm – approximately melon-sized. Hailstones are categorized using the TORRO Hailstorm Intensity Scale (Table 4.11a). Hailstone size descriptions are in Table 4.11b.

Table 4.11a: TORRO Hailstorm Intensity Scale (in millimeters)

	Intensity Category	Typical Hail Diameter	Probable Kinetic Energy, J-M ²	Typical Damage Impacts	Size Code
H0	Hard Hail	5	0-20	No damage	1
H1	Potentially Damaging	5-15	>20	Slight general damage to plants, crops	1-3
H2	Significant	10-20	>100	Significant damage to fruit, crops, vegetation	1-4
H3	Severe	20-30	>300	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored	2-5
H4	Severe	25-40	>500	Widespread glass damage, vehicle bodywork damage	3-6
H5	Destructive	30-50	>800	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries	4-7
H6	Destructive	40-60		Bodywork of grounded aircraft dented, brick walls pitted	5-8
H7	Destructive	50-75		Severe roof damage, risk of serious injuries	6-9
H8	Destructive	60-90		Severe damage to multiple roof types (including sheet and metal); damage aircraft bodywork	7-10
H9	Super Hailstorms	75-100		Extensive structural damage (including concrete and wooden walls). Risk of severe or even fatal injuries to persons caught in the open	8-10
H10	Super Hailstorms	>100		Extensive structural damage (including destruction of wooden houses and damage to brick-built homes). Risk of severe or even fatal injuries to persons caught in the open	9-10

Table 4.11b: TORRO Hailstorm Size Code Descriptions

Size Codes	Diameter	Relational Size
0	5-9	Pea
1	9-15	Mothball
2	16-20	Marble, grape
3	21-30	Walnut
4	31-40	Pigeon's egg > squash ball
5	41-50	Golf ball > Pullet's egg
6	51-60	Hen's egg
7	61-75	Tennis ball > cricket ball
8	76-90	Large orange > Soft ball
9	91-100	Grapefruit
10	>100	Melon

LOCATION

All locations within Pike County are equally susceptible to hail storms. The spatial extent of a hailstorm is very limited. The average size of a hailstorm is 100 feet to 2 miles wide and 2-5 miles long. Rarely do they affect more than one populated area within the County at a time.

PREVIOUS OCCURRENCES

According to the NCEI, a total of 34 hail events were reported in Pike County between 1980 and 2018. A total of \$15,000 in damages was reported, most of which occurred in Village of Waverly and other areas of unincorporated Pike County. Countywide reported hail events ranged in magnitude from 0.75 inches to 2.75 inches. Table 4.11c below reports the 5 events which caused reported damage. Pike County claimed the largest magnitude hail event in 2014 although there were no reported damages.

Table 4.11c: NCEI Hail Damages in Pike County

Date	Location	Magnitude	Death/Injuries	Damage (\$)
11/10/2002	Village of Piketon	1 in.	0/0	\$5,000
4/11/2007	Village of Waverly	0.75 in.	0/0	\$2,000
7/15/2007	Village of Waverly	1 in.	0/0	\$4,000
6/23/2008	Pike County	0.88 in.	0/0	\$3,000
5/30/2009	Pike County	0.75 in.	0/0	\$1,000

MAGNITUDE

The size of hail and its location will determine the damage caused by a particular hail storm. Of the thirty-four hail events recorded in Pike County since 1980, only five of them have ever caused damage. None have resulted in deaths or injuries. The effects of hail storms are generally limited to property damage, most of which is insured, making the impact of a hail event rather low.

DURATION

Hailstorms generally occur as short episodes rather than steady streams of precipitation.

SPEED OF ONSET

Hail often appears suddenly and passes just as quickly. Whether or not hail occurs is dictated by the conditions within a particular storm.

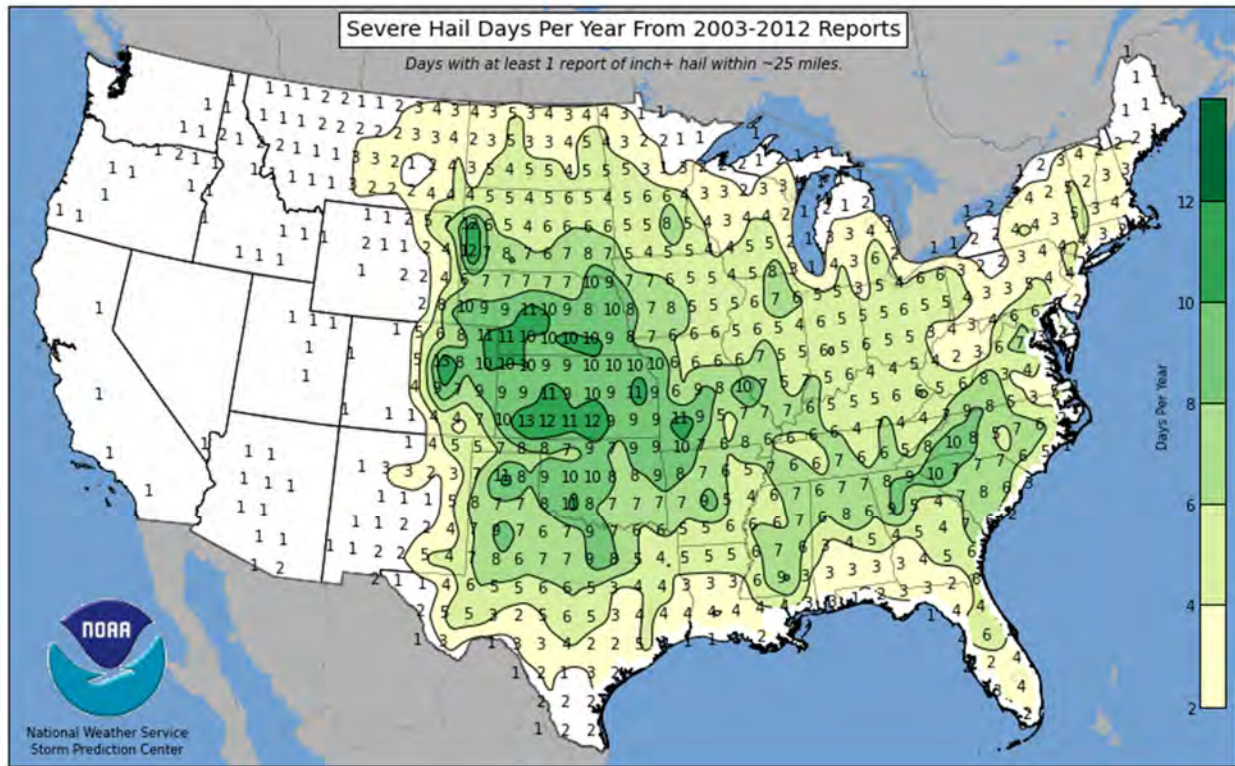
AVAILABILITY OF WARNING TIME

Meteorologists are able to predict if a particular storm system would or would not be capable of producing hail. This makes the issuance of limited warnings possible, but where and when hail will occur is still difficult to predict. As such, the only real warning for hail that may be available is the sound it makes as it strikes the ground.

PROBABILITY OF FUTURE EVENTS

A total of 22 hail events was reported from 1980 to 2018. This results in an approximate annual probability of 58% but only a 13% probability of causing damages. Future hail events can be expected along with future damage to property and vehicles in Pike County. Hail events are most common in the last spring to early fall. Per the National Weather Service, Pike County is located in an area of the United States that receives an average of five days per year with hail events.

Figure 4.11a: United States Average Number of Days per year with Severe Hail Events



Source: NOAA

VULNERABILITY ASSESSMENT

The average loss from a hailstorm is minimal. However, under the right conditions, such as striking a heavily populated area, the losses could be significant. Fortunately, most losses due to hailstorms are insured, which significantly lessens the impact on the people and the community. In addition, although hail storms are a fairly common, they rarely impact more than one localized area at a time. This causes the affected population to be much smaller than what most other hazards would generate.

Priority Risk Index

Table 4.11d: PRI Calculation for Hail

PRI Category	Level	Index Value
Probability	Likely	3
Vulnerability	Minor	1
Spatial Extent	Small	2
Warning Time	Less than 6 hours	4
Duration	Less than 6 hours	1

4.12 Landslides

Description

A landslide is the downward and outward movement of earth, rock, and debris. Both natural and human-induced changes in the environment can trigger landslides. Heavy rains, steep slopes, vertically jointed rocks, and fine grained or shale slopes can serve as an alert to potential landslides problems in Ohio.

There are several types of landslides:

- **Rockfalls:**
 - Are rapid movements of bedrock, which result in bouncing or rolling.
- **Topple:**
 - A section or block of rock that rotates or tilts before falling to the slope below.
- **Slides:**
 - Are movements of soil or rock along a distinct surface of rupture, which separates the slide material from the more stable underlying material.
- **Mudflows:**
 - Sometimes referred to as mudslides, mudflows, lahars, or debris avalanches, are fast-moving rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as heavy rainfall or rapid snowmelt, changing the soil into a flowing river of mud or “slurry.”
- **Slurry:**
 - Can flow rapidly down slopes or through channels and can strike with little or no warning at avalanche speeds. Slurry can travel several miles from its source, growing larger as it picks up trees, cars, and other materials along the way. As the flows reach flatter ground, the mudflow spreads over a broad area where it can accumulate in thick deposits.

Landslides are typically associated with periods of heavy rainfall or rapid snow melt and tend to worsen the effects of flooding that often accompany these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides. Ohio landslides are commonly triggered by vibrations, over steepened slopes, increased weight on slopes, and removal of vegetation. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.

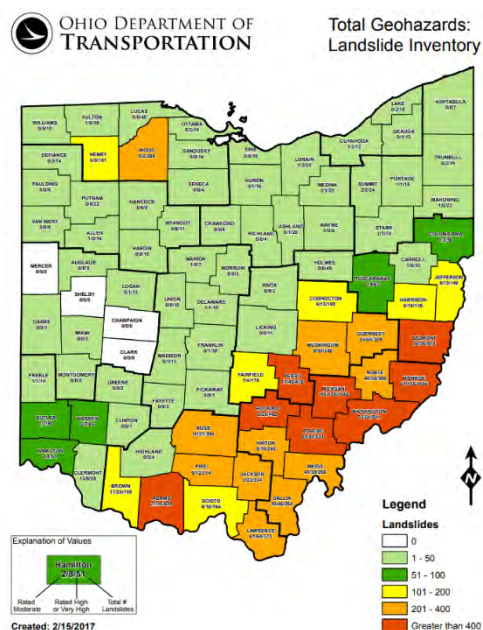
LOCATION

Landslides can occur in any location in the county and range in size. The county expressed that these occur across the county and should reflect a spatial extent of “Moderate”.

PREVIOUS OCCURRENCES

The Ohio Department of Transportation has identified 214 landslides and 64 rockfalls as potential geohazards in Pike County as shown in Figures 4.12a-d. Twelve landslides and fourteen rockfalls are expected to have a high or very high impact on the roadway. The number under the county name indicates sites of moderate, high or very high, and total number of instances respectively.

Figure 4.12a: ODOT Landslide Inventory **Figure 4.12b: ODOT Landslide**



Inventory for Pike County

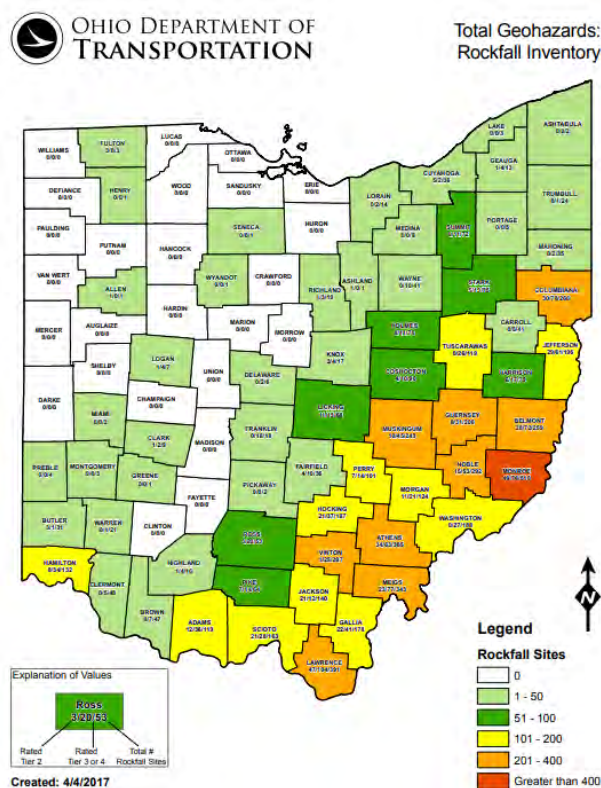


Source: Office of Geotechnical Engineering

<http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/GeoHazards.aspx>

Figure 4.12c: ODOT Rockfall Inventory **Figure 4.12d: ODOT Rockfall**

Inventory for Pike County



Source: Office of Geotechnical Engineering

http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Geotechnical_Documents/Inventory_Rockfall_2017-04-04.pdf

The landslide data above indicates landslides that have occurred whereas the rockfall inventory identifies areas where there is a potential for a rockfall to occur as well as places where they have already occurred. Due to this difference, only landslide data will be used to assess future probability and vulnerability. Of the 214 landslide events that have occurred in Pike County over a thirteen year period, 9 were found to be of moderate concern for impact and 12 we found to be of high or very high concern for impact. This assessment is based on the impact to roadways, structures, and adjacent property verses the probability of additional movement.

MAGNITUDE

The extent of the damage is dependent on structures and infrastructure around or involved in the event. It is also a factor of time, inclement weather, vegetation, and steepness of slope.

DURATION

The duration of a landslide can vary from a rapid change over a few moments to a gradual progression over many years. The County tends to have longer lasting or continuous damage associated with landslides and agrees that duration is “more than 1 week”.

SPEED OF ONSET

The rapid landslide onset is unpredictable and only the potential for the hazard occurring can sometimes be predicted. The very gradual landslides can be extrapolated to predict eventual impact and extensive damage can typically be anticipated and prevented.

AVAILABILITY OF WARNING TIME

Unless it is a gradual landslide there is no availability of warning time. The only ability is to warn of the potential so proper precautions can be taken while in the vicinity.

PROBABILITY OF FUTURE EVENTS

There have been 14 landslides identified by ODOT as high or very high impact over a 13 year period. This suggests that landslides with associated damage are estimated to occur annually recurrences are “highly likely”.

VULNERABILITY ASSESSMENT

Losses attributed to this type of hazard would depend on the size of the collapse and the specific location it affects. A reliable dollar loss damage estimate is difficult to determine due to limited data and information. Annualized losses are assumed to be minor.

Priority Risk Index

Table 4.12: PRI Calculation for Landslides

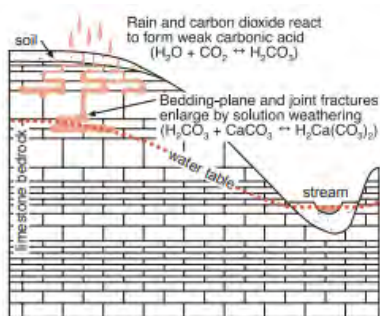
PRI Category	Level	Index Value
Probability	Highly Likely	4
Vulnerability	Minor	1
Spatial Extent	Moderate	3
Warning Time	Less than 6 hours	4
Duration	More than 1 week	4

4.13 Land Subsidence

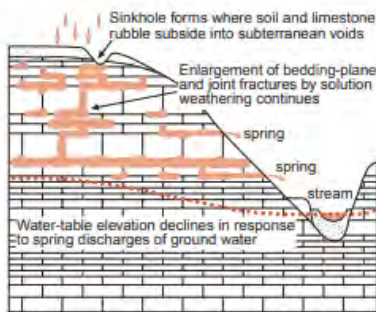
Description

Subsidence, more commonly referred to as sinkholes, is defined as a drop in the earth's surface due to a collapse in bedrock and other underlying material (sand, gravel, limestone) into underground mines or caves. Caves are created naturally by eroding or dissolving rock. Karst is the term used for landforms and landscapes formed by dissolving rock. Karst develops in water soluble rock such as limestone, dolomite, and gypsum and is a significant indicator of sinkholes, caves, and underground drainage. This process is illustrated in Figure 4.13a. As mapped in Figure 4.13b, karst locations in Ohio have been identified to help determine the potential for subsidence.

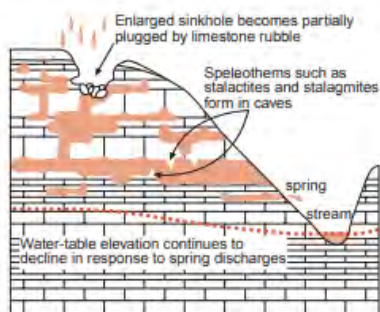
Figure 4.13a: How Sinkholes Form



Rainwater falling through the air reacts with atmospheric carbon dioxide to form carbonic acid ($\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3$). Upon entering the soil, rainwater reacts with carbon dioxide released from decaying vegetation to form additional carbonic acid. As part of the ground-water environment, carbonic-acid-charged water continues to move downward under the force of gravity into underlying limestone bedrock. The water moves laterally along horizontal fractures (bedding planes) and downward along vertical fractures (joints) until it reaches a depth where all fractures and pore spaces within the rock are filled with water (the water table). As the water moves along fractures, both above and below the water table, small amounts of limestone are dissolved by the carbonic acid ($\text{H}_2\text{CO}_3 + \text{CaCO}_3 \rightarrow \text{H}_2\text{Ca}(\text{CO}_3)_2$). Additional limestone is mechanically abraded and removed by the movement of the water.



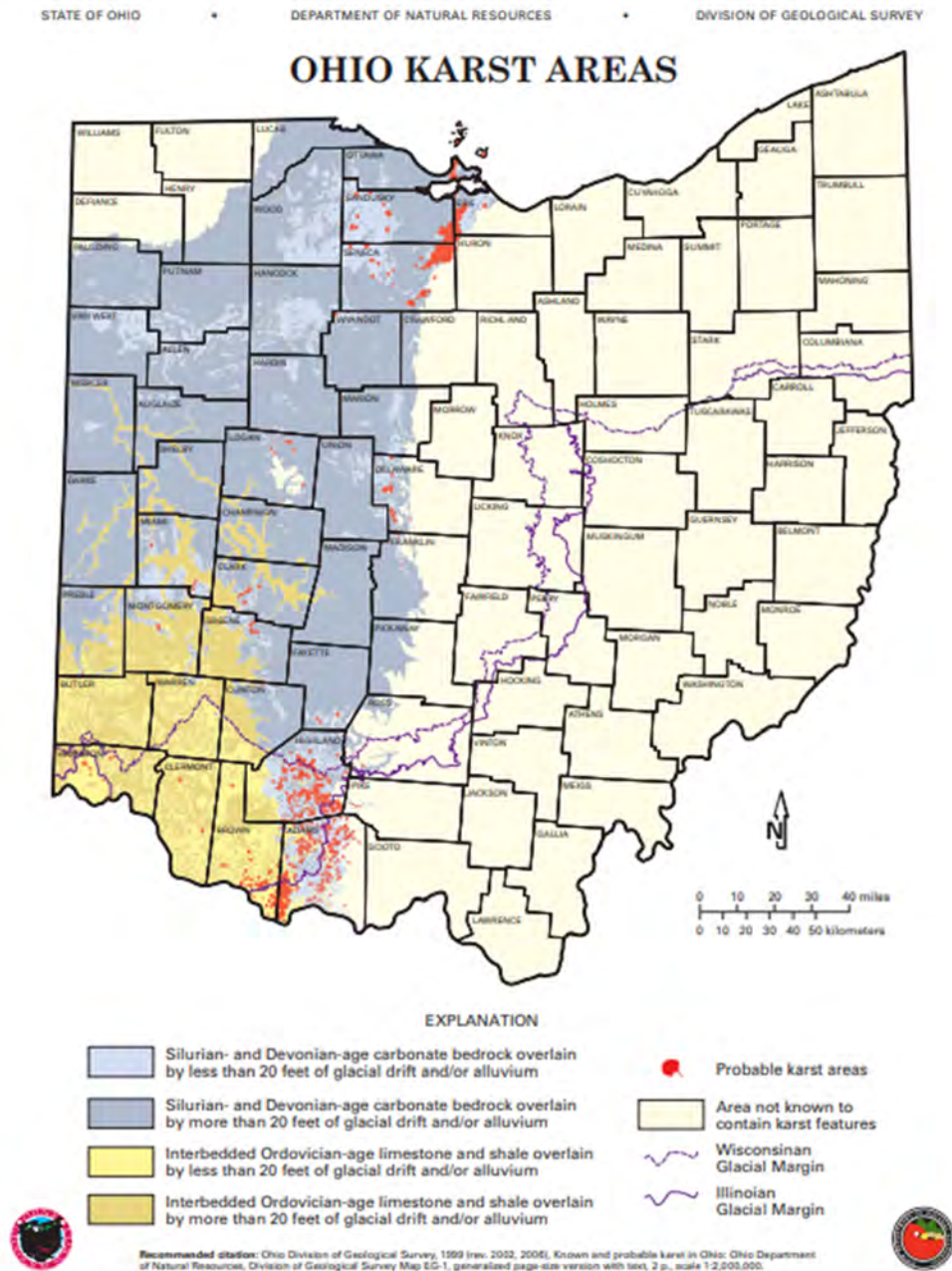
With the passing of time, bedrock fractures become greatly enlarged by the dissolution and abrasion process. Sinkholes (dolines) begin to form on the surface where enlarged vertical fractures allow soil and rock debris to collapse into the earth. Surface drainage is diverted directly into the ground-water environment where sinkholes intersect drainageways, thereby accelerating the rate of fracture enlargement through mechanical abrasion. The water table is lowered as ground water escapes to the surface through springs. The terrain created by the presence of numerous sinkholes and other solution features is called karst.



Over the course of many centuries, sinkholes continue to enlarge and coalesce with other sinkholes as underground voids collapse and ongoing abrasion and/or dissolution continue to remove bedrock. Horizontal and vertical fractures become enlarged to the extent that they can be classified as a cave (an underground passage large enough for a person to enter). The water table continues to drop in elevation as internal drainage networks within the cave system become more integrated and efficient in collecting and discharging ground water. Ground water saturated with calcium carbonate (calcite) and dripping from cave ceilings and walls or flowing along the cave floor evaporates, causing calcite to be deposited as cave formations (speleothems) such as stalactites, stalagmites, flowstone, and travertine.

Source: Ohio Geology. Mapping Ohio's Karst Terrain. 1999. ODNR website

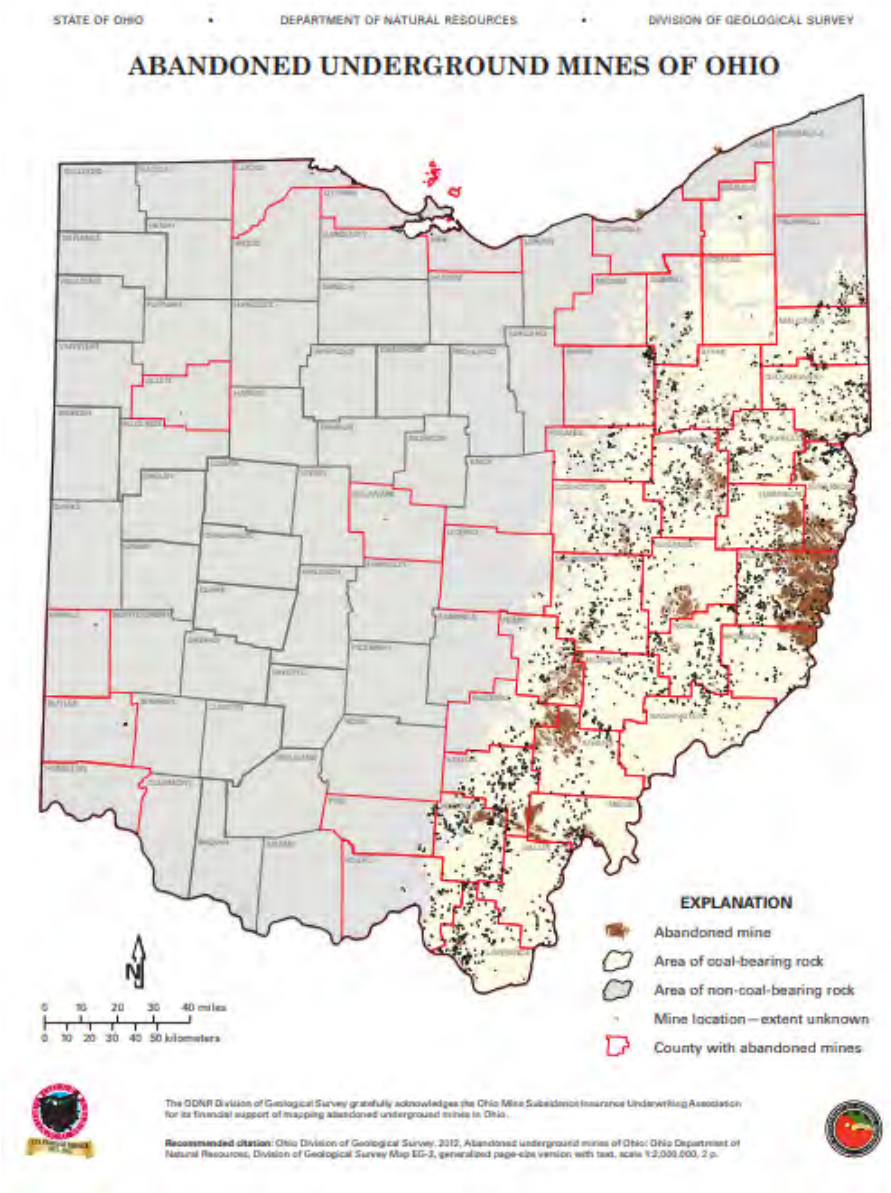
Figure 4.13b: Identified Karst Locations in Ohio



Source: Ohio Karst Areas. Ohio Department of Natural Resources.
<http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/Karst/karstmap.pdf>

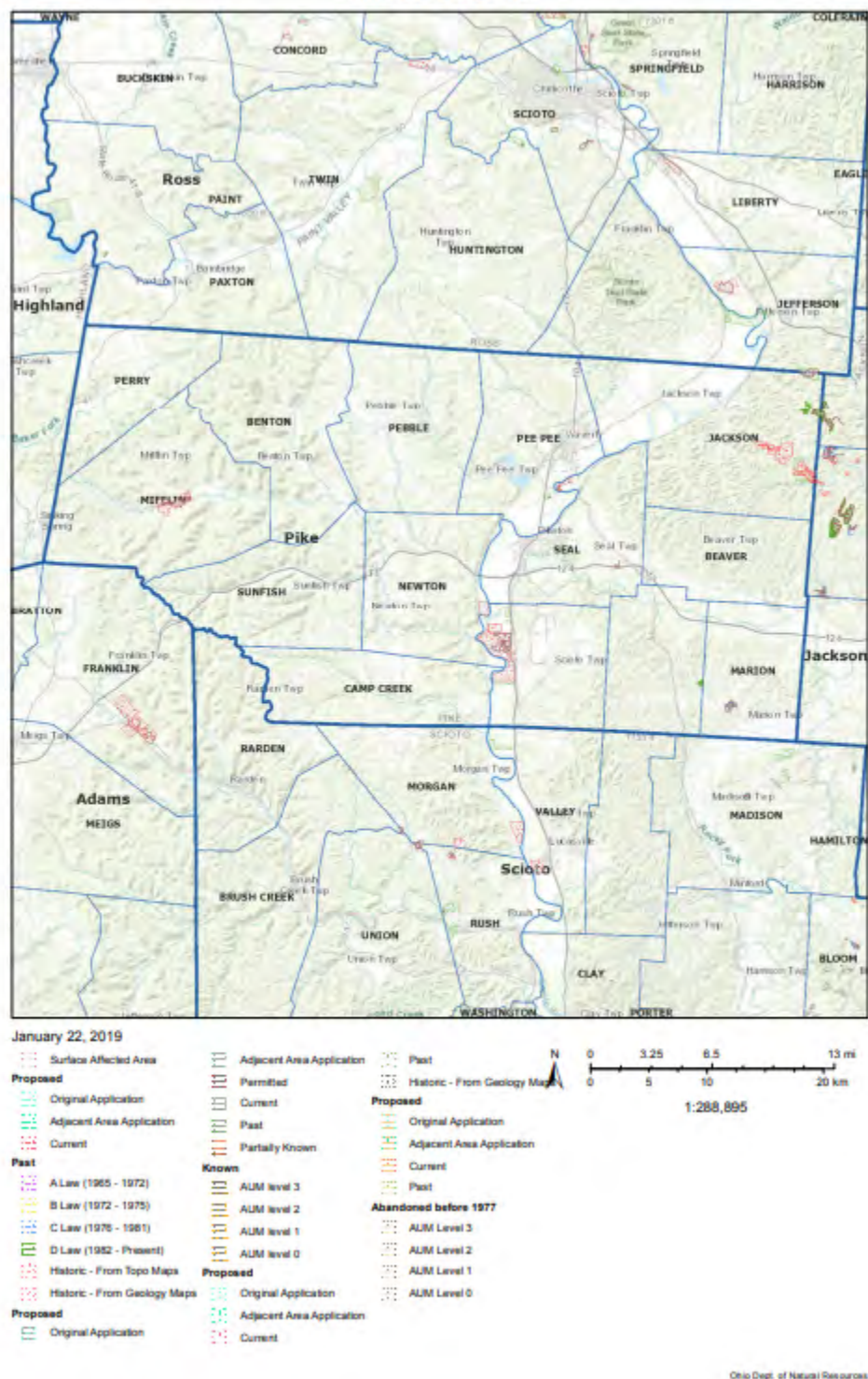
Underground mines can also be a source of sinkholes. Coal mines, most often associated with Appalachian Ohio, vary in depth from less than 100 feet below the surface to 1,000 feet or more. Oftentimes, as miners withdrew, they removed the pillars which supported the mine roof. This is where the mine depth is important. As the amount of solid rock between the mine roof and the surface increases, the more sturdy and less likely subsidence will occur. Figure 4.13c, maps the abandoned the ODNR has identified in Ohio. Pike County is identified as containing abandoned mines which are located predominantly along the eastern edge of the county as shown in Figure 4.13d.

Figure 4.13c: Abandoned Underground Mines in Ohio



Source: ODNR Division of Geological Survey http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/AUM/AUM-map_page-size.pdf

Figure 4.13d: Abandoned Underground Mines in Pike County
Mines of Ohio



Source: ODNR Mines of Ohio Map Viewer. <https://gis.ohiodnr.gov/MapView/?config=OhioMines>

LOCATION

Subsidence is most likely to occur due to karst deposits along the western edge of the county while the eastern side of the county is most likely to see subsidence due to abandoned mines.

PREVIOUS OCCURRENCES

The Village of Waverly indicated that land subsidence has occurred within the City from underground shafts associated with cisterns or old coal shafts from the Erie Canal.

MAGNITUDE

Could vary greatly depending on the size of the mine or karst formation.

DURATION

The duration of a subsidence event could be a gradual sinking but the most often occurrences associated with hazards are rapid and occur within seconds or minutes

SPEED OF ONSET

The rapid subsidence onset is unpredictable and only the potential for the hazard occurring can sometimes be predicted.

AVAILABILITY OF WARNING TIME

Unless it is a gradual subsidence there is no availability of warning time. This makes early detection that much more important so precautionary stabilization efforts can be implemented.

PROBABILITY OF FUTURE EVENTS

While the potential for land subsidence exists, it is not a major threat. There have not been any reported subsidence events in Pike County. Therefore, the probability is categorized as “unlikely”.

VULNERABILITY ASSESSMENT

Losses attributed to this type of hazard would depend on the size of the collapse and the particular location it affects. A reliable dollar loss damage estimate is difficult to determine due to limited data and information. Annualized losses are assumed to be negligible.

Priority Risk Index

Table 4.13: PRI Calculation for Land Subsidence

PRI Category	Level	Index Value
Probability	Unlikely	1
Vulnerability	Limited	2
Spatial Extent	Negligible	1
Warning Time	Less than 6 hours	4
Duration	Less than 6 hours	1

4.14 Severe Thunderstorms / Windstorms

Description

According to the National Weather Service, severe thunderstorms are defined as storms that produce hail that is one inch or larger or produce wind gusts over 58 mph. Both hazard potentials can cause substantial damage to property and resources and pose threat for personal injury as well. Thunderstorms are typically connected with other hazards such as tornadoes, windstorms, or winter storms and are sometimes associated with flooding.

Three conditions must occur for a thunderstorm to form. First, it needs moisture to form clouds and rain. Second, it needs unstable air, such as warm air that can rise rapidly (this often referred to as the “engine” of the storm). Third, thunderstorms need lift, which comes in the form of cold or warm fronts, sea breezes, mountains, or the sun’s heat. When these conditions occur simultaneously, air masses of varying temperatures meet, and a thunderstorm is formed. These storm events can occur singularly, in lines, or in clusters. Furthermore, they can move through an area very quickly or linger for several hours.

Downbursts are also possible with thunderstorm events. Such events are an excessive burst of wind more than 125 miles per hour. They are often confused with tornadoes. Downbursts are caused by down-drafts from the base of a convective thunderstorm cloud. It occurs when rain-cooled air within the cloud becomes heavier than its surroundings. Thus, air rushes towards the ground in a destructive yet isolated manner. There are two types of downbursts. Downbursts less than 2.5 miles wide, duration less than 5 minutes, and winds up to 168 miles per hour are called “microbursts.” Larger events greater than 2.5 miles at the surface and longer than 5 minutes with winds up to 130 miles per hour are referred to as “macrobursts.”

LOCATION

Severe thunderstorms can occur anywhere within Pike County. Particularly vulnerable locations would include floodplain areas as these storms are typically accompanied by heavy rain. Additionally, the flatter and less forested an area is, the more impact potential to structures from heavy winds. Every citizen in the county is potentially at risk during a severe storm, due to the possibility that the storm may produce lightning, flooding, or possibly tornadoes.

PREVIOUS OCCURRENCES

Significant events from the National Center for the Environmental Information (NCEI) since 1995 are included in Table 4.14a, but there have been 210 heavy rain, thunderstorm wind, and high wind events over this time period in Pike County. The most notable events are:

- Severe Thunderstorm winds in 2009 causing \$100,000 in damages
- Severe Thunderstorm winds in 2016 causing \$75,000 in damages
- Severe Thunderstorm winds in 2017 causing \$50,000 in damages
- Countywide high wind damage of \$3.3million in 2008

Only events with damages equal to or greater than \$10,000 are reported in the below Table 4.14a as there are an average of 4.7 thunderstorm wind damages reported each year since 1995.

Table 4.14a: NCEI Thunderstorm Wind and High Wind Damage (1995-2018)

Date	Location	Death/Injuries	Damage (\$)
7/2/1997	Pike County	0/0	\$15,000
7/19/1998	Pike County	0/0	\$10,000
9/20/2000	Pike County	0/0	\$10,000
11/9/2000	Pike County	0/0	\$10,000
3/9/2002	Pike County	0/0	\$12,000
7/22/2008	Village of Waverly	0/0	\$15,000
9/14/2008	Pike County	0/0	\$3,300,000
7/11/2009	Pike County	0/0	\$100,000
3/23/2011	Village of Piketon	0/0	\$10,000
4/20/2011	Village of Waverly	0/0	\$10,000
4/20/2011	Village of Piketon	0/0	\$10,000
5/22/2011	Village of Beaver	0/0	\$20,000
6/29/2012	Pike County	0/0	\$10,000
12/22/2013	Pike County	0/0	\$10,000
5/14/2014	Pike County	0/0	\$20,000
6/23/2016	Pike County	0/0	\$75,000
3/1/2017	Pike County	0/0	\$50,000
4/29/2017	Pike County	0/0	\$15,000

The damages to Pike County from thunderstorm and high winds since 1995 have a total cost of \$3,933,500 with a yearly average of \$171,000. The 2008 countywide high wind event significantly enhances this number from a more modest expectation of \$633,500 total and \$27,000 annual damage costs.

MAGNITUDE

Storm magnitude is measured in terms of wind speed or in terms of associated damage and varies significantly based on the individual storm and the area of impact.

One common way of measuring wind speed is with the Beaufort Wind Force Scale (See Table 4.14b). Originally developed to describe wind conditions on the open ocean, the Beaufort Scale has been modified over time to describe land based conditions as well, as is shown below. One should note that most Severe Thunderstorm and High Wind conditions would rank on the scale as at least a Force 10 wind.

Table 4.14b: Beaufort Wind Force Scale

Force	Wind (MPH)	WMO Classification	Appearance of Wind Effects
			On Land
0	Less than 1	Calm	Calm, smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	13-17	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	18-24	Fresh Breeze	Small trees in leaf begin to sway
6	25-30	Strong Breeze	Larger tree branches moving, whistling in wires
7	31-38	Near Gale	Whole trees moving, resistance felt walking against wind
8	39-46	Gale	Whole trees in motion, resistance felt walking against wind
9	47-54	Strong Gale	Slight structural damage occurs, slate blows off roofs
10	55-63	Storm	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"

Force	Wind (MPH)	WMO Classification	Appearance of Wind Effects
			On Land
11	64-72	Violent Storm	
12	73+	Hurricane	

DURATION

Weather events that produce dangerous wind conditions could last minutes, hours, or more. This factor will depend on the size and strength of each individual storm event.

SPEED OF ONSET

The evolution of storms conducive to the generation of high winds can be monitored with weather radar and other observation. This can allow for the provision of as much warning time as possible. The speed with which a storm arises is entirely dependent on environmental factors, so the speed of onset and warning time will vary event to event.

AVAILABILITY OF WARNING TIME

MODERN METEOROLOGY CAN PREDICT when conditions conducive to severe thunderstorms will occur and the National Weather Service routinely provides warnings when there is a potential for dangerous winds. These warnings are issued via weather radio, television broadcast, and other electronic media. Additionally, the majority of warnings are issued at least a few hours in advance of a given storm.

PROBABILITY OF FUTURE EVENTS

The NCEI data reported a total of 210 thunderstorm and high wind events in the reporting period from 1959 to 2018 (59 years). This results in an approximate annual probability well over 100 percent. Additionally, it is probable that some thunderstorm hazard events were not reported. The thunderstorm hazard event was assigned a probability of highly likely (greater than 90-percent annual chance). It should be noted that not all events included in the percentage calculation include losses.

VULNERABILITY ASSESSMENT

Damage estimates of \$3,933,500 have been reported for this hazard. Annualizing these losses over the data period results in an annual damage estimate of approximately \$171,000 for the County. Future losses can be expected and a single event is capable of causing substantial damage, particularly trees and roofs.

Priority Risk Index

Table 4.14b: PRI Calculation for Thunderstorms

PRI Category	Level	Index Value
Probability	Highly Likely	4
Vulnerability	Limited	2
Spatial Extent	Large	4
Warning Time	More than 24 hours	1
Duration	Less than 24 hours	2

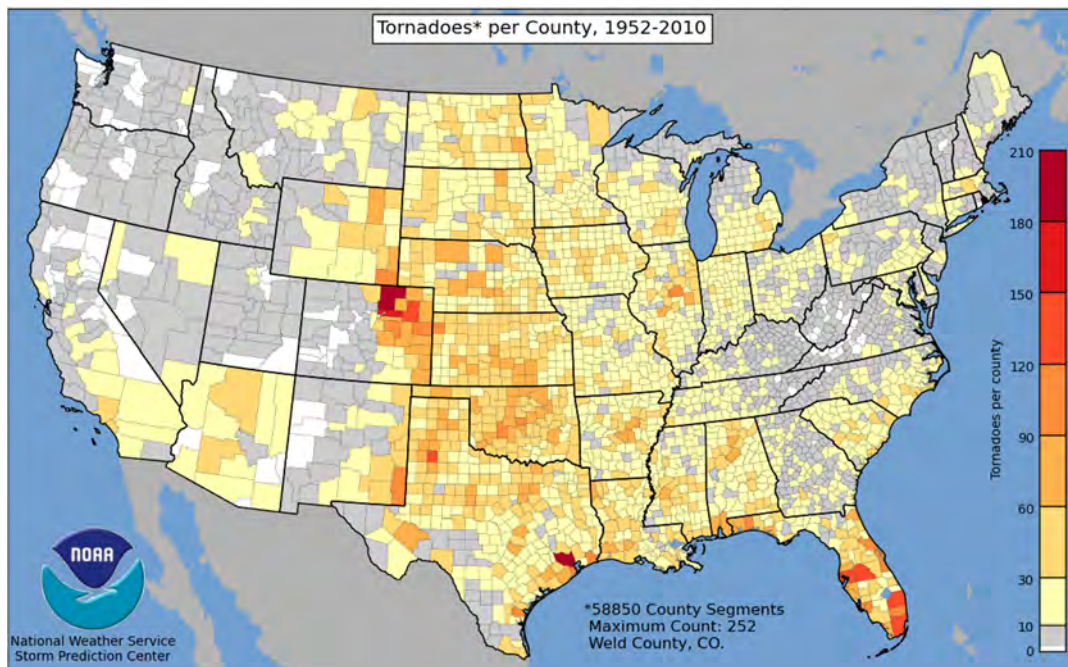
4.15 Tornadoes

Description

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. The National Weather Service states tornado wind speeds normally range from 40 miles per hour to more than 300 miles per hour. The most violent tornadoes have rotating winds of 250 miles per hour or more and can cause extreme destruction and turning normally harmless objects into deadly missiles.

Each year, an average of over 800 tornadoes are reported nationwide, resulting in an average of 80 deaths and 1,500 injuries. Figure 4.15a shows tornado activity per county in the United States based on the number of recorded tornadoes between 1952 and 2010.

Figure 4.15a: Tornado Activity per County in the United States



Tornadoes are more likely to occur during the months of March through May and are most likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touch down briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, including residential dwellings (particularly mobile homes). Tornadic magnitude is reported according to the Fujita and Enhanced Fujita Scales. Tornado magnitudes prior to 2005 were determined using the traditional version of the Fujita Scale (Table 4.15a). Tornado magnitudes that were assessed in 2005 and later were determined using the Enhanced Fujita Scale (Table 4.15b).

Table 4.15a: The Fujita Scale (Effective Prior to 2005)

F-Scale Number	Intensity	Wind Speed	Type Of Damage Done
F₀	GALE TORNADO	40–72 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
F₁	MODERATE TORNADO	73–112 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F₂	SIGNIFICANT TORNADO	113–157 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F₃	SEVERE TORNADO	158–206 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F₄	DEVASTATING TORNADO	207–260 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F₅	INCREDIBLE TORNADO	261–318 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.

F-Scale Number	Intensity	Wind Speed	Type Of Damage Done
F6	INCONCEIVABLE TORNADO	319–379 MPH	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

Source: NOAA Storm Prediction Center

Table 4.15b: The Enhanced Fujita Scale (Effective 2005 and Later)

Ef-Scale Number	Intensity Phrase	3 Second Gust	Type Of Damage Done
EF0	GALE	65–85 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
EF1	MODERATE	86–110 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	SIGNIFICANT	111–135 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	SEVERE	136–165 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
EF4	DEVASTATING	166–200 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.

Ef-Scale Number	Intensity Phrase	3 Second Gust	Type Of Damage Done
EF5	INCREDIBLE	Over 200 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.

Source: NOAA Storm Prediction Center

LOCATION

Tornadoes occur throughout the state of Ohio, and thus Pike County. Tornadoes typically impact a relatively small area, but damage may be extensive. Event locations are completely random and it is not possible to predict areas that are more susceptible to tornado strikes over time. The greatest magnitude tornadoes have affected Pike County unincorporated and Village of Waverly however due to the random strike nature, it is assumed that Pike County is uniformly exposed to this hazard.

PREVIOUS OCCURRENCES

Significant events from the National Center for the Environmental Information (NCEI) since 1993 are included in Table 4.15c. Other significant tornadoes occurring in Pike County include one in 1965 which injured at least 9 people and caused \$250,000 in damages and one in 1978 which injured 2 more people and caused \$25,000 in reported damages.

Table 4.15c: NCEI Tornado Damages

Date	Location	F - Scale	Death/Injuries	Damage
3/7/1956	Pike County	F2	0/0	\$25,000
4/8/1965	Pike County	F2	0/9	\$250,000
9/14/1978	Pike County	F1	0/2	\$25,000
11/17/1993	Route 776 1 W	F0	0/0	\$50,000
4/26/2007	Pike County	EF0	0/0	\$25,000
7/11/2009	Pike County	EF1	0/0	\$5,000
4/20/2011	Village of Piketon	EF0	0/0	\$10,000
4/20/2011	Pike County	EF0	0/0	\$70,000

Date	Location	F - Scale	Death/Injuries	Damage
6/27/2011	Pike County	EF0	0/0	\$3,000
3/2/2012	Pike County	EF0	0/0	\$25,000
3/2/2012	Pike County	EF0	0/0	\$25,000
3/1/2017	Village of Waverly	EF1	0/0	\$30,000

Since 1956, 12 tornadoes have occurred in Pike County.

MAGNITUDE

Tornado extent can be determined by tornado magnitude according to the Fujita and Enhanced Fujita Scale. Pike County has experienced gale, moderate, and significant tornadoes historically. Events of greater magnitudes are possible.

The extent of the tornadoes may also be measured in terms of property damage and human impact (including loss of life and injuries). The greatest amount of damage reported from a single tornado event was \$250,000 in 1965. However, much costlier events are possible. Further, injuries have occurred with this hazard and are possible in the future.

DURATION

The duration of a tornado varies from a brief touch down to carving a path miles in length.

SPEED OF ONSET

Formation of tornadoes can be predicted and monitored, tornadoes often occur suddenly and with very little warning.

AVAILABILITY OF WARNING TIME

The National Weather Service averages about 10-15 minutes of lead time for a tornado. Larger tornadoes that appear on radar provide more warning, but smaller tornadoes not seen on radar could provide less than 10 minutes warning. Whenever the NWS detects a tornado, or foresees the potential for one to occur, an announcement is made over the NOAA Weather Radio system.

Although the NOAA Weather Radios provide a valuable service, the primary means of tornado warning are the weather sirens installed throughout the County. These sirens are maintained and operated by individual communities and are readily accessible for tornado warning.

PROBABILITY OF FUTURE EVENTS

Tornadoes are considered “likely” as there is a 19% annual probability of one occurring each year. In Pike County, they are most likely to occur in early spring as 8 of the 12 events have occurred in March and April.

VULNERABILITY ASSESSMENT

Total damages as reported in the NCEI data for tornado events is approximately a half million dollars. The greatest reported tornado losses on a given day was \$250,000 in 1965 which is equivalent to 2 million dollars in losses in 2017. Annualizing the estimated losses results in an approximate annual loss potential of \$8,758 due to tornadoes.

Priority Risk Index

Table 4.15d: PRI Calculation for Tornadoes

PRI Category	Level	Index Value
Probability	Possible	2
Vulnerability	Critical	3
Spatial Extent	Small	2
Warning Time	More than 24 hours	1
Duration	Less than 6 hours	1

4.16 Wildfires

Description

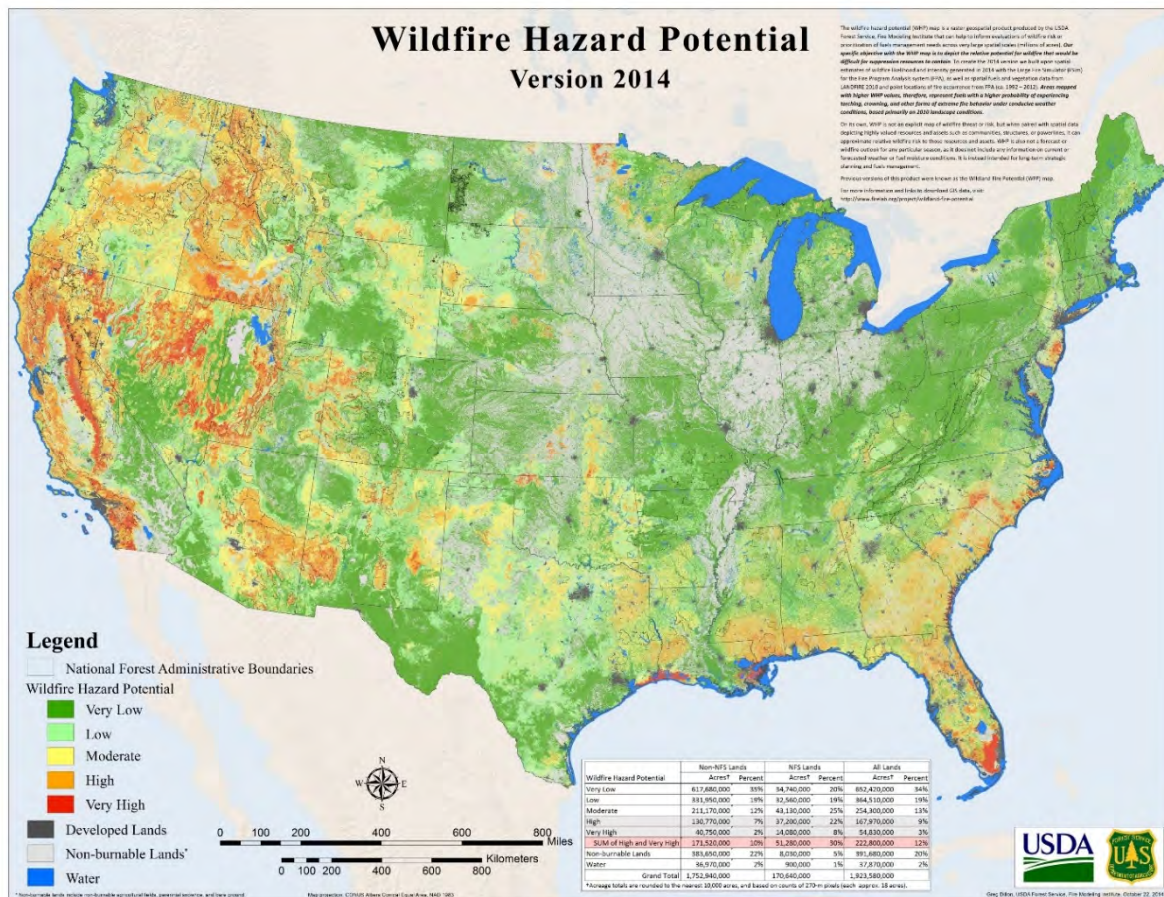
The Ohio Department of Natural Resources Division of Forestry reports that each year 1,000 wildfires burn up to 6,000 acres of Ohio’s protected forest and grassland. Ohio’s wildfire season is typically in fall after leaves drop and early spring before leaves sprout again. Majority of these damaging fires result from careless burning of debris including campfires. In Ohio, fires are prohibited outside municipal limits from 6am to 6pm during the months of March, April, May, October, and November.

LOCATION

According to Ohio State Extension Line, roughly 60% of the county is covered in forest. By technical definition, the majority of vegetated land in Pike County not used for urban

purposes is potentially susceptible to wildfires. The probable extent of any wildfires in Pike County should be very small, limited to small groupings of trees or, at most, several acres of field. The biggest concern wildfires pose to the County is their potential to impact the built environment and initiate structure fires. Per the US Department of Agriculture Forest Service, Fire Modeling Institute, the map below indicates that the wildfire hazard potential for Pike County is in the Low or Very Low category.

Figure 4.16: Wildfire Hazard Potential



Source: US Department of Agriculture Forest Service, Fire Modeling Institute

<https://www.firelab.org/project/wildfire-hazard-potential>

PREVIOUS OCCURRENCES

The 2011 Revised Ohio State Hazard Identification Plan estimates wildfires for Pike County as high-very high hazard level. It reports 427 wildfire occurrences between 1997 and 2007 damaging roughly 2,300 acres and causing about \$90,000 in damage. The State plan reports that “these statistics were taken from wildfire reports filed by local and volunteer fire departments...” (Section 2: HIRA, pg 183).

MAGNITUDE

Past events have been small but the potential for a larger event is high. According to Ohio State Extension Line, roughly 60% of the county is covered in forest. Providing the right conditions, the potential exists for substantial losses, particularly near wildland-urban interface areas

DURATION

The duration of a wildfire will depend entirely on things such as weather conditions, ignition sources, available fuel, location, and fire crew response time and could vary from a few minutes to days. Containment of a wildfire could prove to be more important than the duration it burns, as a wildfire has the potential to start structure fires and damage actual property. However, in Pike County they typically last less than 6 hours.

SPEED OF ONSET

Onset is dependent many variables including the season, temperature and windspeeds, and dryness. It also depends on the fuel that starts the fire, and keeps it going, and the area available for it to spread.

AVAILABILITY OF WARNING TIME

The actual start of a wildfire is likely to occur without any warning, but it is possible to warn citizens when environmental conditions, such as extreme drought, are conducive to producing wildfires. If necessary, the National Weather Service can issue what is known as a “Red Flag Warning”. This warning indicates that weather conditions are ideal for the generation and propagation of wildfires. Should a large wildfire occur in Pike County, it could also be possible to warn those individuals who are down wind (i.e. in the path) of the fire, providing them with time to evacuate.

PROBABILITY OF FUTURE EVENTS

There have been multiple events reported in Pike County according to the Ohio State Hazard Identification Plan. Due to the substantial amount of forest cover in Pike County, it is likely that the probability of future occurrences will be likely. However, the county explained these occur 2-3 times weekly and a probability of “highly likely” will be assessed.

VULNERABILITY ASSESSMENT

Loss estimation for a wildfire event would need to be done on a case-by-case basis. The County expressed that although these occur frequently, they have caused minor damages.

Priority Risk Index

Table 4.16: PRI Calculation for Wildfires

PRI Category	Level	Index Value
Probability	Highly Likely	4
Vulnerability	Minor	1
Spatial Extent	Negligible	1
Warning Time	Less than 6 hours	4
Duration	Less than 6 hours	1

4.17 Winter Storms

Description

Severe winter weather refers to blizzards, ice storms, heavy snow falls, and any other harsh cold weather event. Severe winter storms are a yearly occurrence within Pike County, and all of Southern Ohio. Severe winter weather can often impact the local economy by shutting down a community, causing business closures, and creating hazardous travel conditions. There is no way to eliminate winter storms. But weather prediction technology, like Doppler radar, and informed weather preparedness allows the community to brace itself before these harsh winter events occur.

A winter storm is an event in which varieties of precipitation are formed that only occur at low temperatures such as snow, sleet, freezing rain, or ice. Snow storms generally occur with the clash of different types of air masses with differences in temperature, moisture and pressure; specifically, when warm moist air interacts with cold dry air. Snow storms that produce a lot of snow require an outside source of moisture, such as the Gulf of Mexico or the Atlantic Ocean in the United States.

- **Heavy Snow:**
 - A heavy snow storm is any winter storm that produces six inches or more of snow within a 48-hour period or less.
- **Blizzard:**
 - A blizzard is a severe snow storm with winds more than 35 mph and visibility of less than a 1/4 mile for more than 3 hours.
- **Ice Storm:**
 - An ice storm is defined as a storm with significant amounts of freezing rain and is a result of warm air in between two layers of cold air. With warmer air above, falling precipitation in the form of snow melts, then becomes either super-cooled (liquid below the melting point of water) or re-freezes.
- **Harsh Cold Event:**

- These are miscellaneous other events caused by severe cold including Extreme Cold/Wind Chill and Frost Freeze Event

A winter storm can range from a moderate snow over a period of a few hours to blizzard conditions with blinding wind-driven snow that lasts for several days. Events may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Some winter storms might be large enough to affect several states, while others might affect only localized areas. Occasionally, heavy snow might also cause significant property damages, such as roof collapses on older buildings.

All of the winter storm elements – snow, low temperatures, sleet, ice, etc. – have the potential to cause significant hazard to a community. Even small accumulations can down power lines and trees limbs and create hazardous driving conditions. Furthermore, communication and power may be disrupted for days.

LOCATION

Every location within the County is susceptible to severe winter weather. These events often affect entire regions of the state and are not confined to political boundaries. The spatial extent of a severe winter weather event depends on the characteristics of each individual event. Because of their nature, it is more than likely that most of these events will cover all of Pike County and the surrounding region.

PREVIOUS OCCURRENCES

Significant events from the National Center for the Environmental Information (NCEI) since 1996 indicate three events resulting in over a million dollars in combined associated damage. The following event information was reported for Pike County:

- There have been 11 heavy storms reported from 1997-2018. None of these have caused reported damages, deaths, nor injuries
- There have been 26 winter storms reported from 1996-2018. A winter storm in 1996 resulted in \$500,000 in damage. No injuries or deaths have been reported.
- There have been 3 ice storms reported from 1997-2018. None of these have caused reported damages, deaths, nor injuries
- There was 1 Severe Cold/ Wind Chill event reported in 1996 to have caused \$20,000 in damages. Additionally, a Frost Freeze event cause \$540,000 in crop damage in 2007. None of these have caused deaths or injuries

MAGNITUDE

The severity of the winter storm hazard event can be measured in terms of snow or ice accumulation, probable injuries or by economic costs associated with property damage. Pike County typically receives several inches of snow during winter storm events. In addition, the County has experienced winter weather events that have resulted in injuries, due to car accidents and falls on the ice. Further, two Events have resulted in

combined losses of over a million dollars. “Severe winter weather” is somewhat of a catchall term that encompasses extreme low temperatures, snow fall, ice storms, and high winds. Because of this, not every severe winter weather event will be the same and the magnitude and intensity of any storm would have to be evaluated on a case by case basis.

DURATION

A given severe winter weather event could last for only a few hours or for many days, depending on the prevailing weather conditions. Also, it is entirely possible that several different events could happen one after another, in quick succession.

SPEED OF ONSET

Modern weather forecasting can predict severe weather events well enough to allow at least some preparation before the events strike. Still, the speed of onset of an event will vary due to meteorological conditions.

AVAILABILITY OF WARNING TIME

The National Weather Service can usually provide warning of an impending severe weather event twelve to twenty-four hours before it actually arrives. These warnings are disseminated via NOAA Weather Radio, cable and broadcast television, and other media channels.

PROBABILITY OF FUTURE EVENTS

From looking at historical events, there is greater than a 100% chance of annual occurrence. There is less than a 1% annual probability of severe damage resulting.

VULNERABILITY ASSESSMENT

The losses incurred by this type of hazard will vary each time. This makes it difficult to predict future losses. NCEI data provides a general understanding of what to expect from a severe weather event. Examples of types of damages to expect from a severe winter storm event include frostbite, driving hazards and property damage including roof collapse.

Previous reported losses totaled approximately \$1 million for heavy snow, ice storm, winter storm, freeze events, and episodes of severe cold per the NCEI data. Annualized, this amounts to about \$25,000 for the county. Future losses should be expected due to snow and could be significant.

Priority Risk Index

Table 4.17: PRI Calculation for Winter Storms

PRI Category	Level	Index Value
Probability	Highly Likely	4
Vulnerability	Limited	2
Spatial Extent	Large	4
Warning Time	More than 24 hours	1
Duration	Less than 6 hours	2

4.18 PRI Results

The PRI results are presented in the following Summary of Hazard Risk table:

Table 4.18: Summary of PRI Results for Pike County

Hazard	Category/Degree of Risk					PRI Score
	Probability	Vulnerability	Spatial Extent	Warning Time	Duration	
Dam Failure	Unlikely	Limited	Moderate	More than 24 hours	Less than 24 hours	1.8
Drought	Unlikely	Limited	Moderate	More than 24 hours	More than 1 week	2
Earthquake	Unlikely	Minor	Small	Less than 6 hours	Less than 6 hours	1.5
Flood	Highly Likely	Limited	Moderate	6 to 12 hours	Less than 24 hours	2.9
Hail Storm	Likely	Minor	Small	Less than 6 hours	Less than 6 hours	2.1
Landslide	Highly Likely	Minor	Moderate	Less than 6 hours	More than 1 week	2.9
Land Subsidence	Unlikely	Limited	Negligible	Less than 6 hours	Less than 6 hours	1.6
Severe Thunderstorm /Windstorm	Highly Likely	Limited	Large	More than 24 hours	Less than 24 hours	2.9
Tornado	Possible	Critical	Small	More than 24 hours	Less than 6 hours	2.1
Wildfire	Highly Likely	Minor	Negligible	Less than 6 hours	Less than 6 hours	2.2
Winter Storms	Highly Likely	Limited	Large	More than 24 hours	Less than 24 hours	2.9

Hazard Ranking

The hazards were ranked based on PRI results and divided into high, moderate and low.

Ranking	Hazard
High	Flood Severe Thunderstorm / Windstorm Winter Storm Landslides
Moderate	Wildfire Tornado Hail Storm Drought
Low	Dam Failure Land Subsidence Earthquake

Conclusions on Hazard Risk

The hazards that pose the greatest threat to Pike County include Flood, Severe Thunderstorm / High Wind, Winter Weather and Landslides. However, the other natural hazards listed in the table above also pose a risk to the population and property in the county. Pike County has experienced a population growth of approximately 1000 people from 2000 to 2010 and the population is expected to remain close to the current population level into 2030. A rising population does put more people at risk for nearly all future hazard events.

Pike County has experienced severe hazard events over the past few years including several disaster declarations for severe storms and multiple flooding events. This could be a trend for future more severe and more frequent hazard events in the county. The county is prepared to address these hazards and continues to take steps to reduce their vulnerability. Specific mitigation measures completed, developed and ongoing are defined in Section 5.