

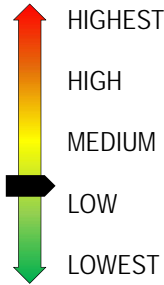


Earthquake

An earthquake is a sudden release of energy that creates a movement in the earth's crust. Most earthquake-related property damage and deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the extent and duration of the shaking. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (in mountain regions and along hillsides), and liquefaction.

2.0 RISK ASSESSMENT

2.2.3 Earthquake

An earthquake is a sudden motion or trembling that is caused by a release of strain accumulated within or along the edge of the Earth's tectonic plates.				
 <p>Vulnerability</p>	Period of Occurrence:	Earthquakes can occur at any time	Hazard Index Ranking:	Low
	Warning Time:	None	State Risk Ranking:	6
	Probability:	Occasional (may or may not occur on annual basis)	Severity:	Minor (localized, less than 10% of land area affected)
	Type of Hazard:	Natural	Disaster Declarations:	None

Hazard Introduction and Overview

Earth consists of four layers: the inner core (innermost layer), outer core, mantle, and crust (outermost layer). Further, the crust consists of many tectonic plates that are slowly moving, sliding past, and bumping into one another. Most earthquakes originate along the edges of these tectonic plates, called fault lines. The rough edges of the tectonic plates become lodged against each other. When a plate moves enough, the edges become dislodged, causing an earthquake. The epicenter of the earthquake is the location directly above the ruptured fault. (USGS, n.d.).

Some earthquakes have foreshocks, which are smaller earthquakes that happen at the same location as the larger earthquake that follows. The largest, main earthquake is called the main shock, which always has aftershock that follow. Current technology doesn't allow scientists to determine that an earthquake is a foreshock until the larger earthquake follows.

Regulators and researchers have documented earthquakes induced by human activity in the United States, Japan, and Canada. The cause of these human-caused earthquakes was the injection of fluids into deep wells for waste disposal and secondary recovery of oil, and filling large reservoirs for water supplies. Deep mining and nuclear testing can also cause small to moderate quakes. A common misconception is that hydraulic fracturing, or "fracking," is causing *all* of the induced earthquakes. In reality, fracking "is directly causing a small percentage of the felt-induced earthquakes observed in the United States. Most induced earthquakes in the United States are a result of the deep disposal of fluids (wastewater) related to oil and gas production" (Rubinstein and Mahani, 2015).



Location and Extent

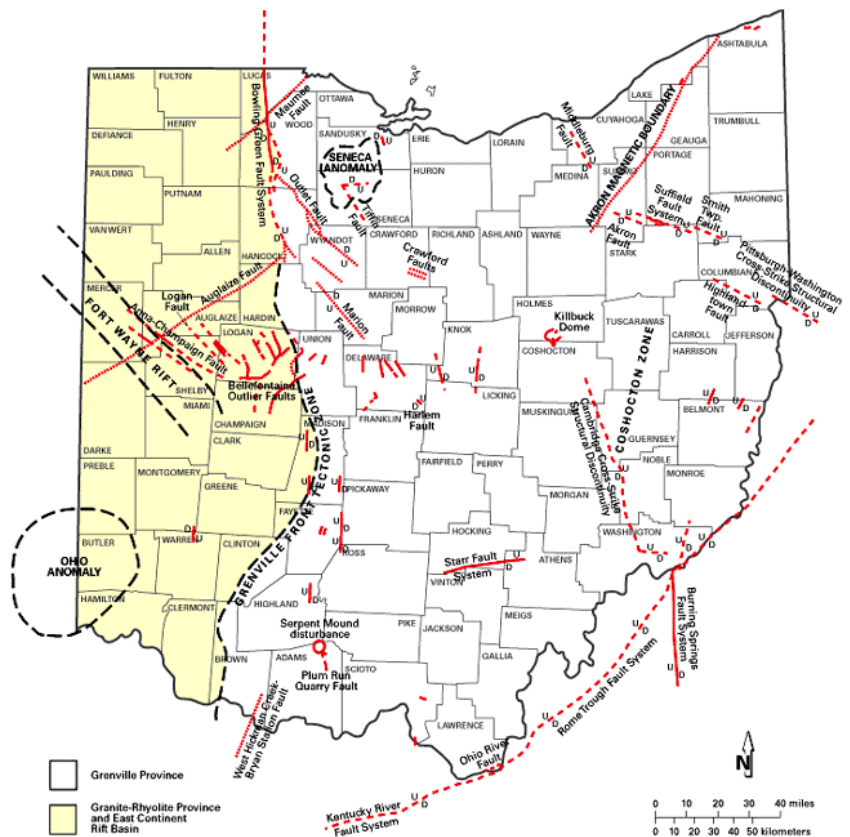
Earthquakes are one of nature’s most damaging hazards, and are more widespread than is often realized. The area of greatest seismic activity in the United States is along the Pacific Coast in the states of California and Alaska; however, as many as 40 states can be characterized as having moderate earthquake risk. Although most people do not think of Ohio as an earthquake-prone state, at least 170 earthquakes with epicenters in Ohio have been felt since 1776.

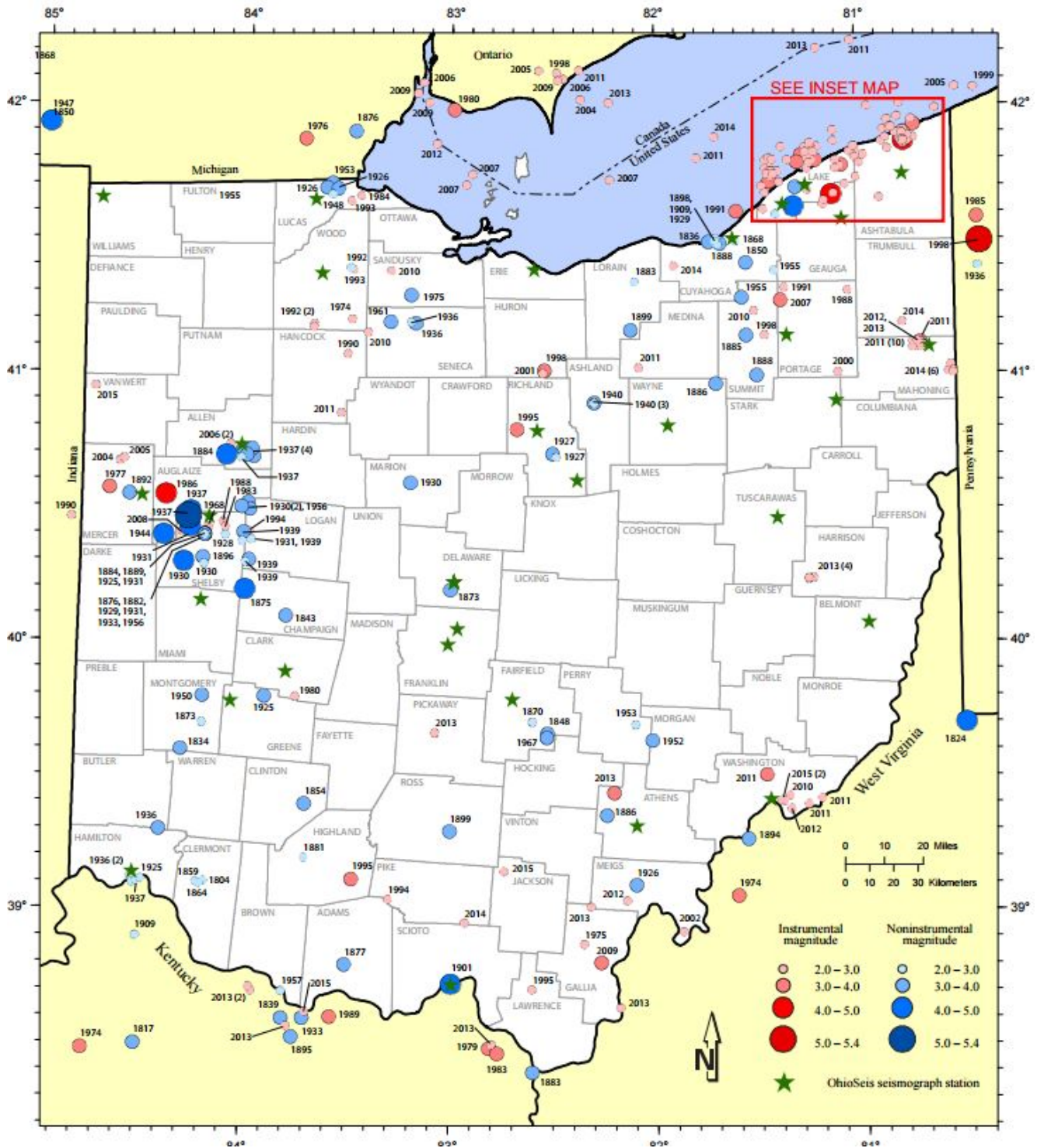
Earthquake epicenters occur on fault lines; however, their effects can be felt miles away. Although Ohio is not considered to be at high risk for an earthquake, there are several fault lines, some well-known and some speculative, traversing the state. Two (2) such fault lines underlie Washington County.

The map at right illustrates fault lines in Ohio and was modified by the USGS from a Division of Geological Survey Map PG-23. This map portrays a number of deep faults and other structures that have been identified by a variety of geologic studies. Very few of the faults are visible at the surface.

As shown, two fault lines underlie Washington County. Running under the Ohio River is the Rome Through Fault System. This system directly intersects the Burning Springs Fault System on the Washington County border. The other system beneath the county is the Cambridge Cross – Strike Structural Discontinuity.

The location of earthquakes that have occurred in Washington County been confined to three of the county’s twenty-two townships, located in the southern area of the county near the City of Marietta. The below image shows the location of epicenters within Ohio. Washington County has experienced seven epicenters since 2010.





Source: Educational Leaflet No. 9 Revised Edition 2015 Division of Geological Survey



Although there are numerous intensity scales to evaluate the effect of earthquakes, the Modified Mercalli Intensity Scale (MMI) is the scale currently used in the U.S. The MMI was developed in 1931 by seismologists Harry Wood and Frank Neumann. The MMI scale assigns value to a site after an earthquake based on observed effects, ranging from acceptable to catastrophic. The MMI scale is shown in the table below.

MODIFIED MERCALLI AND MAGNITUDE SCALE COMPARISON		
	<i>Modified Mercalli Scale</i>	<i>Magnitude Scale</i>
I	Felt by few people under especially favorable conditions.	1.5
II	Felt by few persons at rest, especially on upper floors of buildings.	2.0
III	Felt quite noticeably indoors, especially on upper floors of buildings. Many do not recognize it as an earthquake. Standing vehicles may rock slightly. Vibration feels like passing truck.	2.5
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation of a heavy truck striking building; standing vehicles rock noticeably.	3.0
V	Felt by nearly everyone; many awakened. Some dishes and windows broken. Unstable objects overturned.	3.5
VI	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.	4.0
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by vehicle drivers.	4.5
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse; damage great in poorly built structures; fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Disturbs	5.0
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Underground pipes broken.	5.5
X	Some well-built wooden structures are destroyed; most masonry and frame structures with foundations destroyed; train rails bent.	6.0
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Underground pipelines taken out of service. Train rails bent greatly.	6.5
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level are distorted. Objects thrown into the air.	7.0



Hazard Impacts

The severity of the effects of earthquakes are dependent on the amount of energy released from the fault or epicenter. The effects of an earthquake can be felt far beyond the site of its occurrence. They usually occur without warning and after just a few seconds can cause massive damage and extensive casualties. Common effects of earthquakes are ground motion and shaking, surface ruptures, and ground failure. The most significant human risk during an earthquake is structure movement and collapse. Contents within structures may fall or fail and injure or kill occupants inside of the structures.

Earthquakes can cause a variety of cascading effects, including fires due to broken electrical lines and gas mains, structural damage and utility and communication system outages, and, less commonly, tsunamis. Ground shaking refers to the vibration of the ground during an earthquake. Generally, the severity of ground shaking increases as magnitude increases, and decreases as distance from the causative fault increases.

Historical Occurrences

The Ohio Department of Natural Resources maintains the Ohio Earthquake Database, which lists all earthquakes detected in the Washington County since 2010. According to the database, there have been 23 earthquakes in Washington County since 2010, for an average of 2.3 events per year. The earthquakes, along with their location, magnitude, and year of occurrence are listed in the following table.

OHIO EARTHQUAKE DATABASE - WASHINGTON COUNTY				
<i>Magnitude</i>	<i>Depth (km)</i>	<i>Month</i>	<i>Day</i>	<i>Year</i>
1.5	5	January	6	2019
1.9	5	November	24	2018
2.5	4	March	25	2018
2.6	9	January	26	2018
2.2	1	February	12	2017
2.6	4	December	9	2017
2.1	3.9	December	28	2017
1.2	5	June	3	2016
1.5	5	April	27	2016
2.6	5	May	11	2016
2.1	5	May	18	2016
1.2	5	June	3	2016
1.7	4	December	18	2015
2.1	3	March	3	2015
2.5	3	July	19	2015
1.7	4	December	18	2015
2.1	2	March	28	2013
2.1	2	May	29	2012
2.1	4	September	18	2012



<i>Magnitude</i>	<i>Depth (km)</i>	<i>Month</i>	<i>Day</i>	<i>Year</i>
3	5	August	31	2011
3.1	5	August	31	2011
2.6	5	September	4	2011
2.8	5	October	24	2010

Source: ODNR, Ohio Earthquake Database

Of the earthquakes listed in the above table, most are minor events. The highest magnitude event occurred in 2011, and was a 3.1 magnitude event. This event did not cause damage, but the quake was felt in parts of southern Ohio and West Virginia.

Marietta Earthquake – October, 2010

In the early morning of October 24th, 2010, a 2.8 magnitude event occurred about five miles ENE of Marietta. Residents were awoken by the event and described a loud boom followed by brief shaking that rattled glassware. No damage was reported.

Marietta Earthquake – August, 2011

On August 31st, 2011, two earthquakes struck the Marietta area of Washington County. The first was a 2.8 magnitude event that occurred at 5:35 a.m. and was felt by a number of residents. A stronger aftershock occurred at 1:36 p.m. and was widely felt in Marietta and neighboring communities. No damage was reported for either event, though residents described hearing a loud boom and feeling the ground shaking during the aftershock.

Marietta Earthquake – September, 2011

In the morning of September 4th, 2011, a small 2.6 magnitude earthquake was felt about 13 miles southeast of Marietta. Residents reported feeling the event, but no damage was reported.

Marietta Earthquake – July, 2015

The most recent event in the ODNR database was a 2.2 magnitude earthquake that occurred at 9:34 a.m. on July 19th, 2015. This event was recorded by the monitoring station in Marietta but no reports of feeling the earthquake were received.

All data on historical events are from the ODNR Division of Geological Survey (<http://geosurvey.ohiodnr.gov/earthquakes-ohioseis/quakes-felt-in-ohio/catalog-of-past-ohio-quakes/20-quakes-by-year/2010-to-present>).



Loss and Damages

The effects of a potential earthquake striking Washington County was analyzed using the HAZUS program from the Federal Emergency Management Agency. The output was provided by the Ohio EMA. The scenario depicts a 5.4 magnitude occurring in downtown Marietta, within two blocks of the Marietta College campus. The table below, compiled from the HAZUS output via the loss estimation workbook provided by Ohio EMA, shows the number of structures damaged and the estimated damage cost.

WASHINGTON COUNTY EXPECTED BUILDING DAMAGE BY OCCUPANCY (HAZUS)										
	None		Slight		Moderate		Extensive		Complete	
	Count	%	Count	%	Count	%	Count	%	Count	%
Agriculture	74.06	0.42	20.83	0.39	22.25	0.70	11.57	1.10	3.29	1.15
Commercial	530.80	3.01	215.40	4.06	239.66	7.49	119.52	11.39	37.62	13.19
Education	31.32	0.18	12.72	0.24	14.78	0.46	6.92	0.66	2.26	0.79
Government	27.18	0.15	9.55	0.18	11.00	0.34	4.72	0.45	1.54	0.54
Industrial	109.33	1.08	69.30	1.31	85.14	2.66	48.41	4.61	14.81	5.19
Other Residential	2523.18	14.31	934.92	17.61	895.81	27.98	330.01	31.44	74.09	25.97
Religion	84.81	0.48	31.60	0.60	28.47	0.89	14.49	1.38	4.61	1.62
Single Family	14168.01	80.36	4013.99	75.62	1903.94	59.48	514.03	48.97	147.03	51.54
TOTAL	17,630		5,308		3,201		1,050		285	

Source: FEMA, HAZUS Data

WASHINGTON COUNTY HAZUS BUILDING-RELATED ECONOMIC LOSS ESTIMATES (MILLIONS OF DOLLARS)							
Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses	Wage	0.00	2.03	26.52	1.39	1.93	31.87
	Capital Related	0.00	0.87	20.29	0.98	0.50	22.64
	Rental	5.66	5.79	11.96	0.55	0.96	24.92
	Relocation	19.89	4.67	21.33	2.75	7.78	56.42
	Subtotal	25.55	13.36	80.11	5.67	11.17	135.86
Capital Stock Losses	Structural	30.30	11.81	28.53	9.40	7.67	87.71
	Non-Structural	117.21	53.54	79.62	30.25	22.39	303.01
	Content	47.21	15.70	45.79	21.83	13.46	143.99
	Inventory	0.00	0.00	1.16	3.69	0.15	5.00
	Subtotal	194.72	81.06	155.10	65.17	43.67	539.72

Source: FEMA, HAZUS Data



The Ohio EMA's "loss estimate workbook for HAZUS results" provided the figures included in the table below.

EARTHQUAKE EXPOSURE ESTIMATE – MIP DATA ENTRY		
<i>Structure Type</i>	<i>Number</i>	<i>Loss Estimate</i>
Residential	5,101	\$1,227,121,559.74
Non-Residential	678	\$590,194,007.11
Critical Facilities	203	\$93,142,712.04
TOTALS	5,886	\$1,910,458,278.89

Source: Ohio EMA HAZUS-MH Loss Estimate Workbook Calculation

Vulnerability Assessment

This section summarizes the risk to Washington County from earthquakes. Washington County conducted an online survey for the public to share its thoughts on hazard vulnerabilities. The following table presents the results of that survey regarding earthquakes.

PUBLIC SENTIMENT, EARTHQUAKE – WASHINGTON COUNTY					
<i>Hazard</i>	<i>Level of Concern</i>				<i>Total Responses</i>
	<i>Not at All</i>	<i>Somewhat</i>	<i>Concerned</i>	<i>Very</i>	
Earthquake	20 (55.56%)	16 (44.44%)	1 (2.78%)	0 (0.00%)	36
In the past ten years, do you remember this hazard occurring in your community?				4 (11.11%)	36
Have you noticed an increase in the occurrences or intensity of this hazard?				6 (16.67%)	36
Have you noticed a decrease in the occurrences or intensity of this hazard?				1 (2.78%)	36

Source: Online Public Survey Results

The following table assigns point totals based on the research presented in this profile for each category that appears in Ohio EMA's Mitigation Information Portal (MIP) tool.

EARTHQUAKE VULNERABILITY SUMMARY			
<i>Category</i>	<i>Points</i>	<i>Description</i>	<i>Notes</i>
Frequency	3	Medium	23 incidents since 2010, for an average of 2.3 per year, none of these events have result in damages.
Response	2	One day	Historical data indicate that earthquakes have caused little to no damage in Washington County; thus, the response would be minimal.
Onset	4	Less than 6 hours	Earthquakes occur with little or no warning.
Magnitude	1	Less than 10% of land area affected	The highest magnitude event was a 3.1 magnitude. This event did not cause any damage.
Business	1	Less than 24 hours	No historical earthquakes disrupted the county's economy.
Human	1	Minimum (minor injuries)	Past earthquakes in Washington County have been low magnitude and have not caused any human injuries or deaths.
Property	1	Less than 10% of property affected	Earthquakes in Washington County have been low magnitude and caused little to no damage.
Total	13	Low	

