4.4 Earthquakes

Description

Earthquakes are sudden and rapid movements of the Earth's crust and are caused by the abrupt shifting of rocks deep underneath the earth's surface. These movements vary in length and may last from a few seconds to several minutes.

The seismicity, or seismic activity, of an area refers to the frequency, type, and size of earthquakes experienced over time. Earthquakes are measured using observations from seismometers. The Moment Magnitude Scale (MMS), which was developed in the 1970's, is the most common scale on which earthquakes larger than approximately 5.0 in magnitude are reported for the entire world. Earthquakes smaller than magnitude 5.0, which are more numerous, are reported by national seismological observatories and measured most on the local magnitude scale – also referred to as the Richter Scale. These two scales are numerically similar in their range of validity. Earthquakes of magnitude 3.0 or lower are often almost imperceptible or weak, while earthquakes of magnitude 7.0 or greater can potentially cause serious damage over larger areas.

Damage from an earthquake also depends on the earthquake's depth in the Earth's crust. The shallower an earthquake's epicenter, the more damage to structures it will cause. Alternatively, an earthquake can also be measured by its intensity. The Modified Mercalli Intensity Scale (MMI) ranges in value I to XII, in roman numerals (**Table 4.4.1**).

Earthquakes can happen anywhere without warning; they are low-probability, high-consequence events. Most major earthquakes in the U.S. have occurred in California as well as in Alaska, Hawaii, Oregon, Puerto Rico, Washington, and the entire Mississippi River Valley. There have been recorded earthquakes throughout the U.S., and the Ohio River Valley has experienced earthquakes exceeding the 3.0 magnitude within the last 25 years.

Location

Earthquakes are countywide hazards and can affect all areas and jurisdictions within Clinton County. According to the Ohio Department of Natural Resources (ODNR), Ohio is located on the periphery of the New Madrid Seismic Zone, an area in and around Missouri that was the site of the largest earthquake sequence to occur in the country in the 1800's. Additionally, seismic activity is concentrated in the western Ohio region known as the *western Ohio seismic zone* (also referred to as the *Fort Wayne (Anna) seismogenic zone*), where more than 40 earthquakes have been felt since 1875.

The Grenville Front Tectonic Zone in the Granite-Rhyolite Rift Province and East Continent Rift Basin travels through the middle of Clinton County (**Figure 4.4.2**).

Extent

Earthquakes pose a risk to life and property depending on severity. To monitor earthquakes, the State of Ohio and the ODNR Division of Geological Survey coordinates a 29-station network (**Figure 4.4.3**) of seismograph stations throughout the state to continuously record earthquake activity. The Ohio Seismic Network (OhioSeis) stations are distributed across the state but are concentrated in the most seismically active areas or in areas that provide optimal conditions for detecting earthquakes. While the seismic network cannot predict earthquakes or provide an alert prior to an event, it can provide insight into earthquake risks in the state so that intelligent decisions about building and facility design and construction, insurance coverage, and other planning decisions can be made by individuals, business and industry, and governmental agencies.

According to the ODNR, there are two Ohio Seismic Network monitoring stations in neighboring Greene and Clermont Counties.

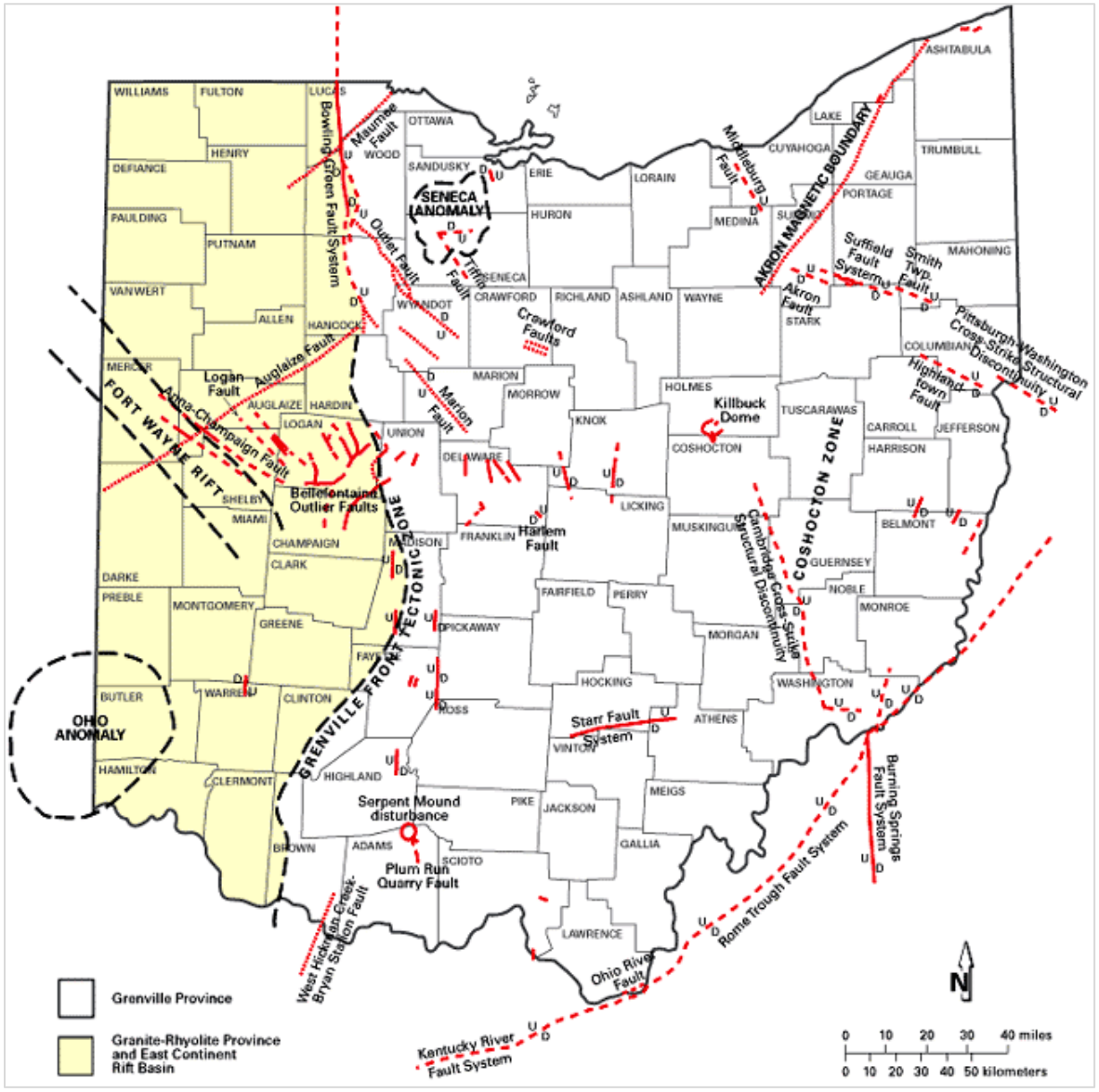
Earthquakes can yield a variety of different outcomes. With the ground shaking associated with earthquake events, buildings have a high potential to be impacted. If soil liquefaction, or the mixing of fine sediment and soil with groundwater occurs, buildings can sink into the ground. Earthquakes also have the potential to rupture dams or levees along a river, resulting in flooding and even tsunamis (see Dam Failure section). Earthquakes can cause landslides or avalanches in high-risk areas and can cause mines to subside. Furthermore, earthquakes that break gas and power lines can result in fires.

Table 4.4.1: Modified Mercalli Intensity Scale

Modified Mercalli Intensity Scale		Magnitude
I	Detected only by sensitive instruments.	1.5
II	Felt by few people 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	Total damage; waves seen on ground surface, lines of sight and level distorted, objects thrown up into air.	7 7.5 8

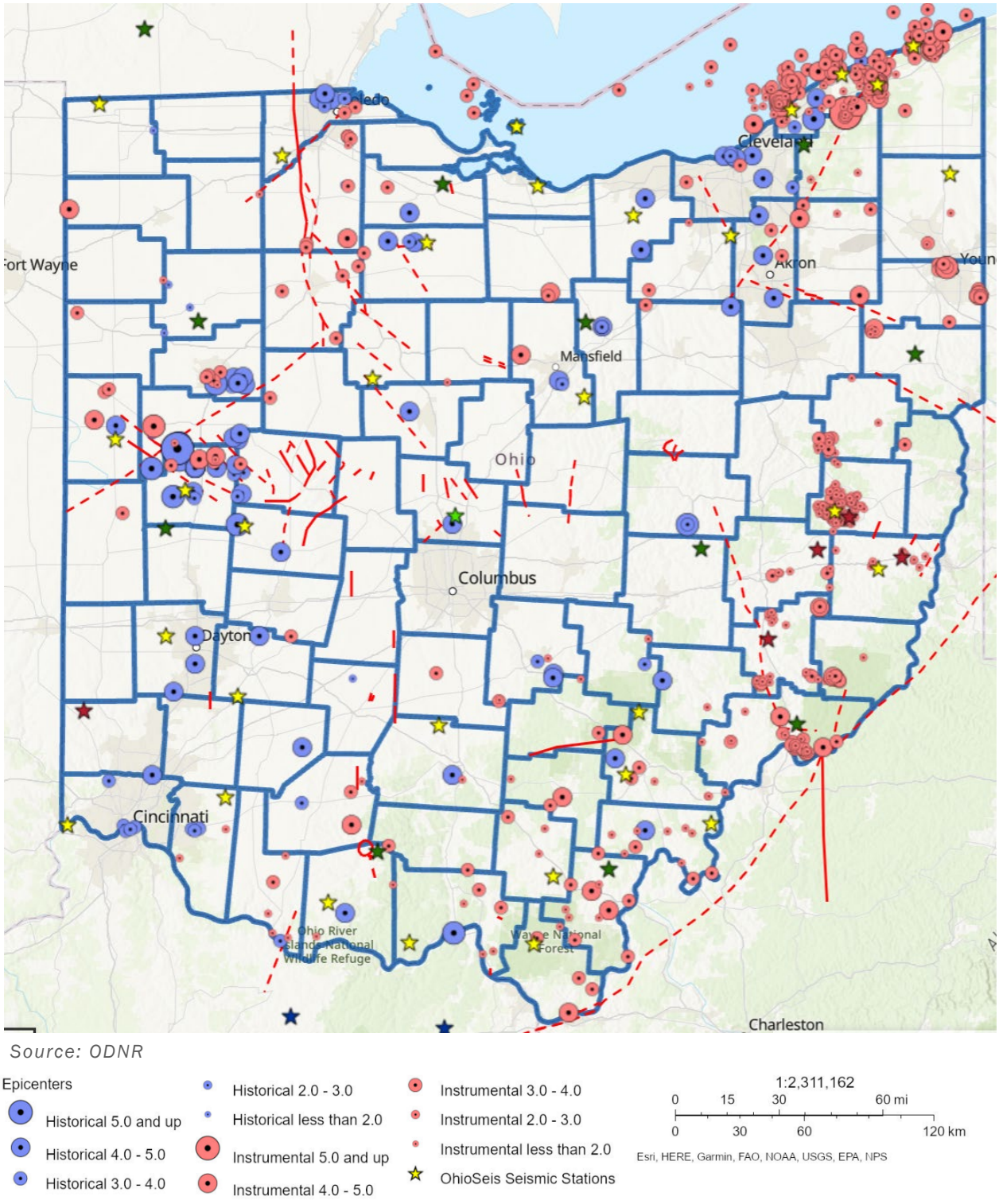
Source: ODNR

Figure 4.4.2: Ohio Faults and Seismic Zones



Source: ODNR

Figure 4.4.3: Earthquake Epicenters and Seismic Monitoring Stations in Ohio



Source: ODNR

History

More than 400 earthquakes of 2.0 magnitude or greater with epicenters in Ohio have occurred since 1776. Most of these events have been small, in the 2.0 to 3.0 magnitude range, while 18 earthquakes have had a magnitude of 4.0 or higher. No deaths are recorded in Ohio from earthquakes. According

to ODNR, Clinton County has had one recorded earthquake between 1854 and 2024, with a magnitude of 3.5. The earthquake occurred in the 1854 in southeast Clinton County. There is limited data available on any property damage.

Figure 4.4.4, below, displays epicenters of all historical earthquakes with a magnitude greater than 1.0. Locations and magnitudes of non-instrumental earthquakes correspond to felt area or maximum epicentral Modified Mercalli Intensities and may be in error by a considerable distance.

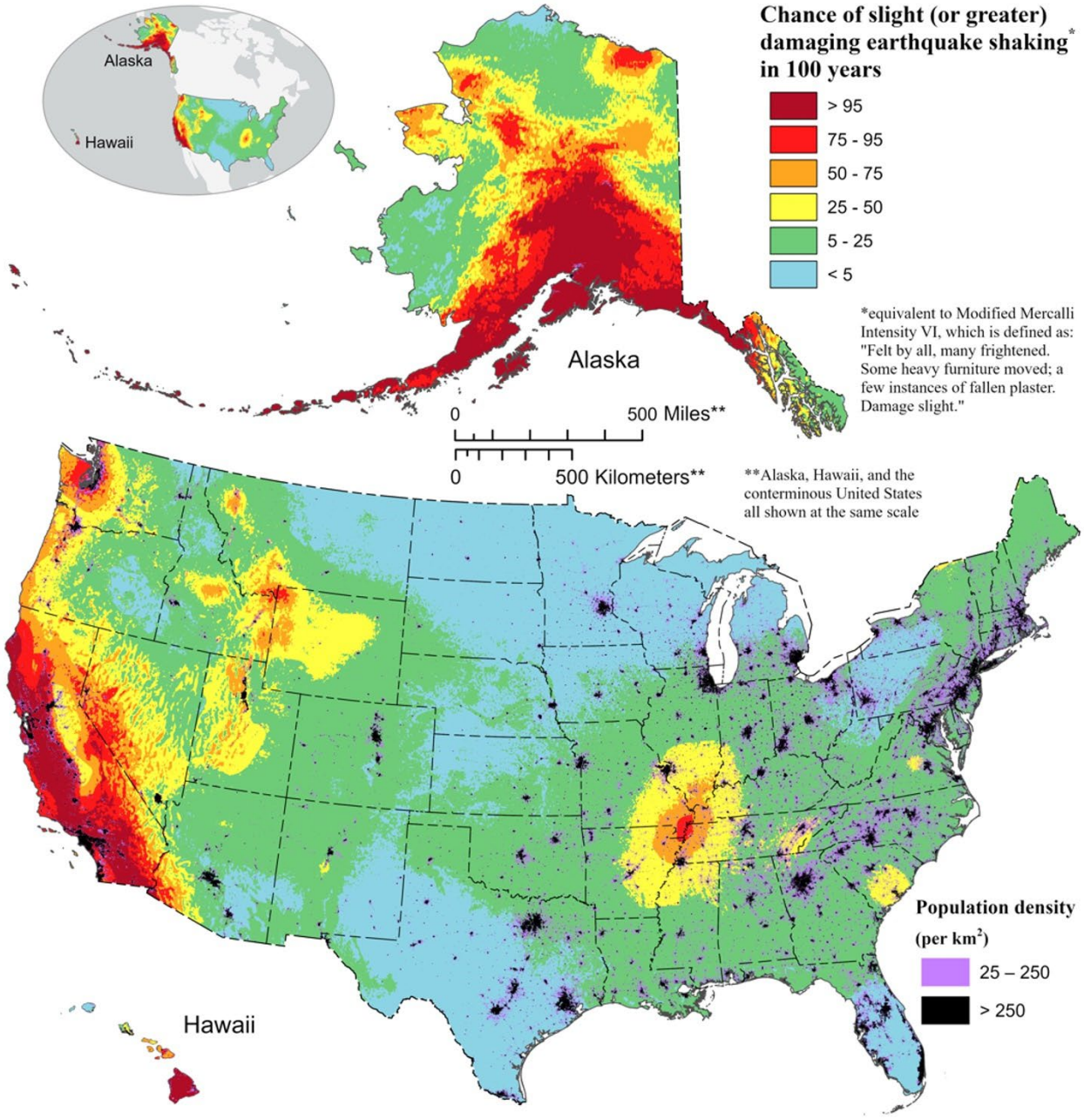
Probability

The USGS has both long-term and short-term probabilistic seismic hazard forecasts. In the 2024 one-hundred-year probabilistic seismic hazard forecast, the United States Geological Survey estimated that there is a 5 to 25 percent chance of potentially minor-damage ground shaking for Clinton County (**Figure 4.4.4**).

The USGS also prepared national seismic hazard maps (NSHMP) for the United States. These time-independent maps are shown for two percent and ten percent probability of earthquake ground-shaking exceedance levels at specified probabilities over a 50-year period at several hundred thousand sites across the United States. The map (**Figure 4.4.5)** identifies that Clinton County has an eight to ten percent peak ground acceleration for two percent probability of exceedance in 50 years.

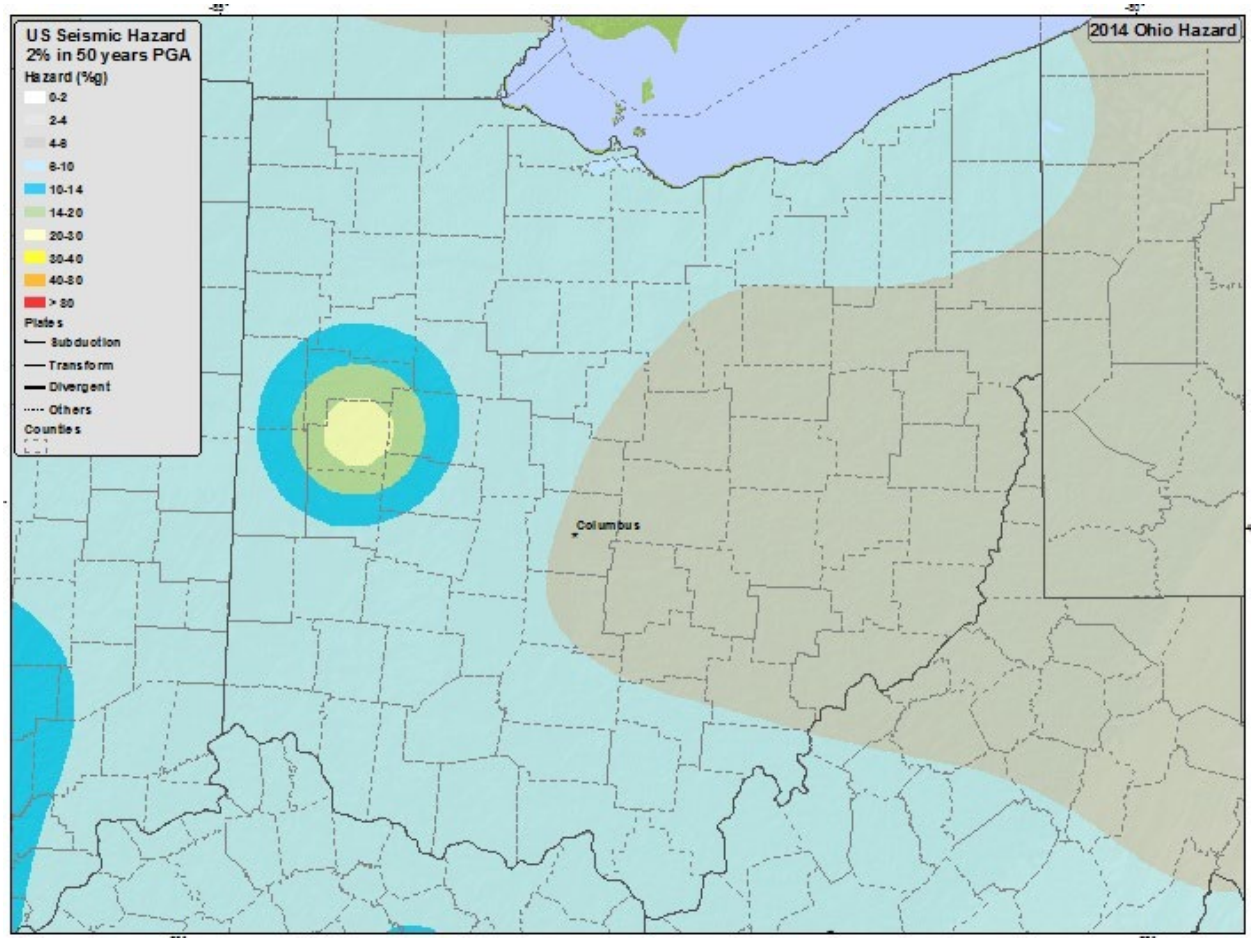
Furthermore, the ODNR indicates that the brief historic record of Ohio earthquakes suggests a risk of moderately damaging earthquakes in the western, northeastern, and southeastern parts of the State.

Figure 4.4.4: Earthquake Shaking and Seismic Design Categories



Source: USGS

Figure 4.4.5: 2014 Seismic Hazard Map of the State of Ohio



Source: USGS

Vulnerability Assessment

Infrastructure Impact

There has been one earthquake in Clinton County since 1854, with a magnitude of 3.5. There is no information on whether the earthquake caused any property damage. Magnitudes under three are not generally noticed by people and cause little, if any, damage. Buildings, roadways, gas and power lines have the potential to be affected. Since the probability of an earthquake occurring in Clinton County is less than one percent, there is a low risk of impact to infrastructure as a result.

Population Impact

There is a relatively low risk of earthquakes occurring in Clinton County. Accordingly, there is a low risk of impact to the population. If an earthquake occurs within the County, the population could be impacted by loss of homes, loss of utilities, and a potential reduction in quality of life.

According to the National Risk Index calculated by FEMA, Clinton County's risk was scored at 73.7 ("relatively low") to earthquakes, as compared to all other U.S. counties, due to its very low expected annual loss, relatively moderate social vulnerability, and relatively moderate community resilience scores. Earthquakes are unlikely to occur in Clinton County; therefore, the population is unlikely to be affected by earthquakes. Socially vulnerable populations may be more affected by earthquakes if they live in older housing units or apartment complexes that do not have adequate earthquake-resilient

infrastructure. The index indicates an expected annual loss of $565,000 due to earthquakes with a less than 0.055 percent chance of an event occurring per year.

Property Damage

With any earthquake event, there is potential for property damage to occur, as ground shaking can lead to damaged buildings. Due to the non-site-specific nature of this hazard, **Table 4.4.6** lists the census tracts in Clinton County, ranked with the highest vulnerability to the lowest vulnerability in terms of total expected annual loss.

Loss of Life

Clinton County has no recorded earthquake events that have resulted in loss of life; however, if an earthquake occurs, there is potential for loss of life. If there are more people and structures in an earthquake prone location, there is likely to be more of an impact. Loss of life can be mitigated by educating the public on proper protection in the event of an earthquake. For example, the USGS resources on preparing for an Earthquake hazard (USGS Resources for Earthquake Preparedness) as well as the Ready Campaign (Ready.gov) are national public service campaigns designed to educate and empower the American people to prepare for, respond to, and mitigate disasters.

Economic Losses

Earthquakes have the potential to damage infrastructure, resulting in the economic burden of clean up and repairs. Potential economic losses and damage associated with Clinton County for earthquakes according to FEMA's National Risk Index are recorded in **Table 4.4.6** below. The table shows Clinton County's census tracts ranked in order from highest to lowest total EAL and broken down by expected losses for buildings, population ($11.6 million for each fatality or 10 injuries), and agriculture per census tract for earthquakes. EAL rates, calculated by FEMA, identify the total value of loss expected each year for a particular community, in this case the census tracts for Clinton County.

Table 4.4.6: Structure and Population Vulnerability from Earthquakes

Census Tract	Expected Annual Loss (Building)	Expected Annual Loss (Population Equivalence)	Expected Annual Loss (Agriculture)	Expected Annual Loss (Total)
39027964400	$70,019	$23,402	$0	$93,421
39027964700	$76,133	$14,694	$0	$90,827
39027965000	$40,591	$34,238	$0	$74,829
39027965100	$47,172	$20,822	$0	$67,994
39027964900	$42,224	$14,085	$0	$56,309
39027964800	$35,380	$15,122	$0	$50,502
39027964502	$30,018	$7,768	$0	$37,786
39027964300	$28,948	$8,452	$0	$37,400
39027964600	$24,893	$6,722	$0	$31,615
39027964501	$16,815	$7,115	$0	$23,930
Total	**$424,193**	**$152,420**	**$0**	**$564,613**

Source: FEMA National Risk Index

Future Trends

Land Use and Development Trends

Because the incidence and likelihood of earthquakes is low in Clinton County, all communities have a low risk. By planning for and managing land use to accomplish social, ecological, and economic sustainability, communities can reduce the negative impacts caused by earthquakes. This can be accomplished through comprehensive land-use plans and supportive federal and state policies. As such, enforcement of stricter building codes that ensure that all new developments are built up to code can reduce risk. Infrastructure (constructed facilities and lifelines) should be designed and constructed to resist earthquake shaking following the current state-of-the-art engineering and technology practices.

In 2023, Clinton County authorized 101 new residential units at a total value of $25,454,000. Though there are more buildings slated for construction, Clinton County's population has decreased 80 individuals from 2020 to 2023. The decline is set to continue such that by 2030 the population will lose an additional 1,343 people (3.2 percent). More buildings but less people may potentially mean more property loss but less population vulnerability. However, with state-of-the-art engineering there is very little potential damage. Given these estimates, there are no known changes in risks associated with earthquakes in Clinton County.

Shifting Weather Patterns and Environmental Trends

Weather patterns have no known effect on the probability or extent of earthquakes.