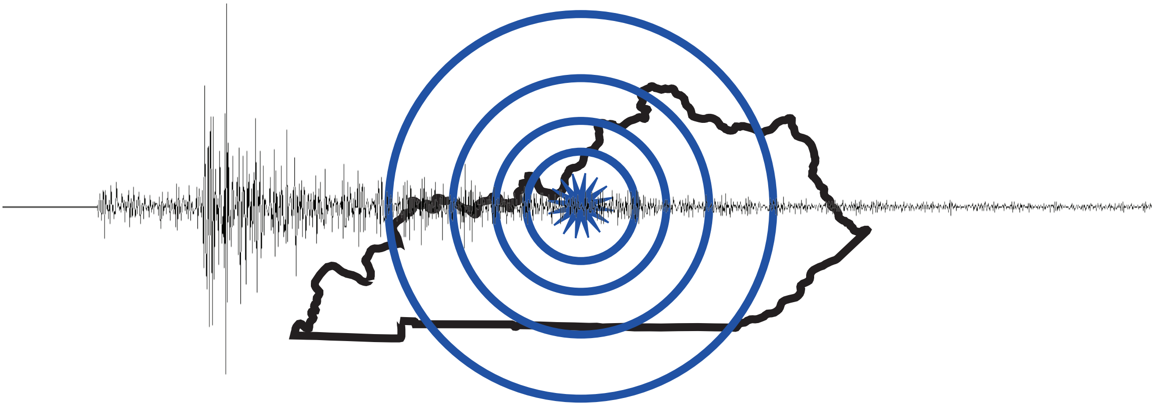
EARTHQUAKES IN KENTUCKY



Hazards, Mitigation, and Emergency Preparedness

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Kentucky Geological Survey
James C. Cobb, State Geologist and Director
University of Kentucky, Lexington

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For further information contact:
Technology Transfer Officer
Kentucky Geological Survey
228 Mining and Mineral Resources Building
University of Kentucky
Lexington, KY 40506-0107

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Earthquakes in Kentucky:
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N. Seth Carpenter
Zhenming Wang
Mike Lynch

Earthquakes are frequently in the news and have long been a topic of concern for citizens of the commonwealth. Although the study of earthquakes in and around Kentucky has been going on for several decades and has advanced greatly, our understanding of earthquakes in this region is still limited and subject to debate and discussion among scientists. The discussion does not focus on if there will be earthquakes in the region, but on where, how big, and how often they will occur. In other words, there will certainly be earthquakes in and around Kentucky in the future, but it is impossible to predict exactly where and when. This makes assessing seismic hazards (i.e., potential earthquake impact) in Kentucky very difficult. Consequently, it is a challenge to formulate policies to mitigate earthquake hazards.

The purpose of this booklet is to provide basic information on earthquakes and potential earthquake hazards in Kentucky. It also provides some measures that can be taken to mitigate these hazards and to increase emergency preparedness in case of an earthquake.

Earthquakes in and Around Kentucky

Earthquakes affecting Kentucky primarily occur in several seismic zones in and around the state (Fig. 1): the New Madrid and Wabash Valley Seismic Zones in the west and Eastern Tennessee Seismic Zone in the east. The largest recorded earthquake inside Kentucky's borders was the Sharpsburg earthquake of July 27, 1980, in Bath County. Its magnitude was 5.2, and it caused an estimated $3 million in damage in Maysville. The 2003 Bardwell earthquake in western Kentucky (magnitude 4.0) caused some minor damage in Carlisle County, and the 2012 Perry County earthquake (magnitude 4.2) caused some minor damage in Letcher and Perry Counties in southeastern Kentucky, including the Letcher County Courthouse. The most

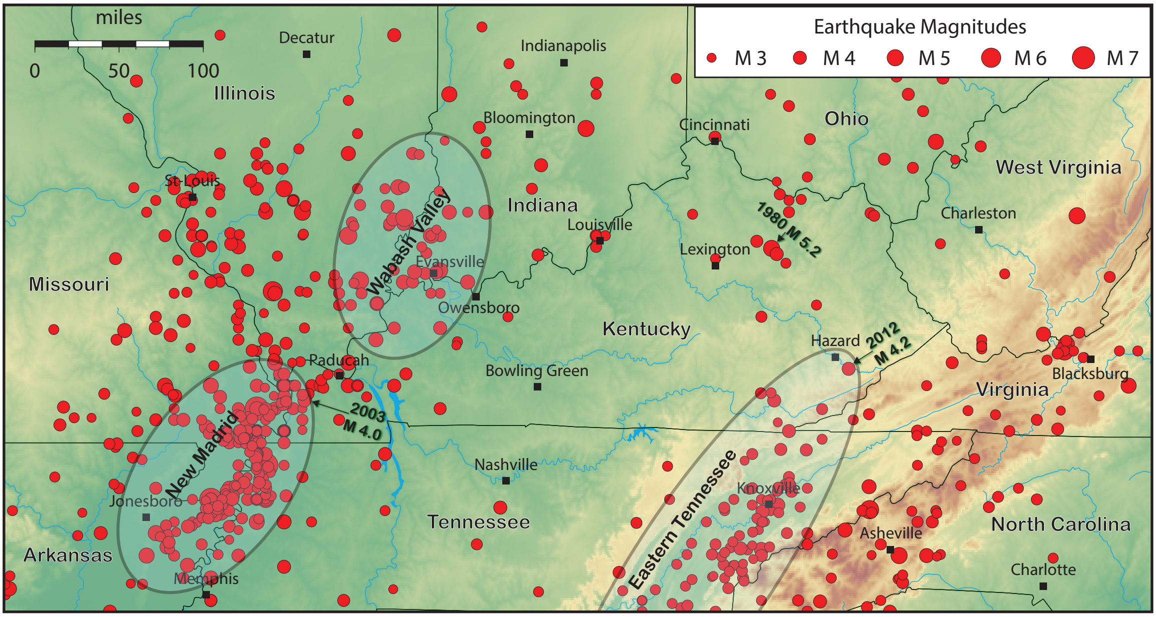


Figure 1. Earthquake epicenters (magnitude 3 or greater, shown by red dots) and seismic zones (lightly shaded ovals) in and around Kentucky.

significant earthquakes affecting Kentucky, as well as the entire central United States, occurred from December 1811 to February 1812 in the New Madrid Seismic Zone. At least three large earthquakes, each estimated to have had magnitude greater than 7.0, occurred during that short timeframe. Although the state was sparsely settled at that time, these earthquakes affected the entire commonwealth of Kentucky. The New Madrid Seismic Zone is the most active zone in the central and eastern United States, as evidenced by ongoing seismicity and the presence of an active fault that changed the course of the Mississippi River and dammed Reelfoot Lake in 1812 (Fig. 2).

Following the damaging Sharpsburg earthquake, a program of earthquake monitoring and research was initiated in the 1980's in a joint effort by the Kentucky Geological Survey and the Department of Geology (now Earth and Environmental Sciences), both at the University of Kentucky. The partnership currently operates a seismic network of 17 seismic stations and 15 strong-motion stations (Fig. 3). The network is capable of monitoring any earthquake occurring in Kentucky with a magnitude greater than 2.0, as well as larger earthquakes in the United States and around the world. The network also records seismic waves generated by mining blasts and seismicity induced by other human activities, including subsurface fluid extraction and injection (e.g., fracking). To view real-time recordings from these seismic stations, visit the KGS website at www.uky.edu/KGS/geologichazards/equake3.htm. Scientists at the University of Kentucky have also conducted research on earthquake hazards in different seismic zones and on building earthquake-resilient communities.

Seismic Hazards

An earthquake occurs when a fault suddenly ruptures and releases elastic energy in the form of seismic waves (Fig. 4). Rupture begins at the hypocenter (shown at the surface as the epicenter), and if it continues to the surface, it creates a *surface rupture hazard,* which can cause damage to any building or structure built on it. Surface

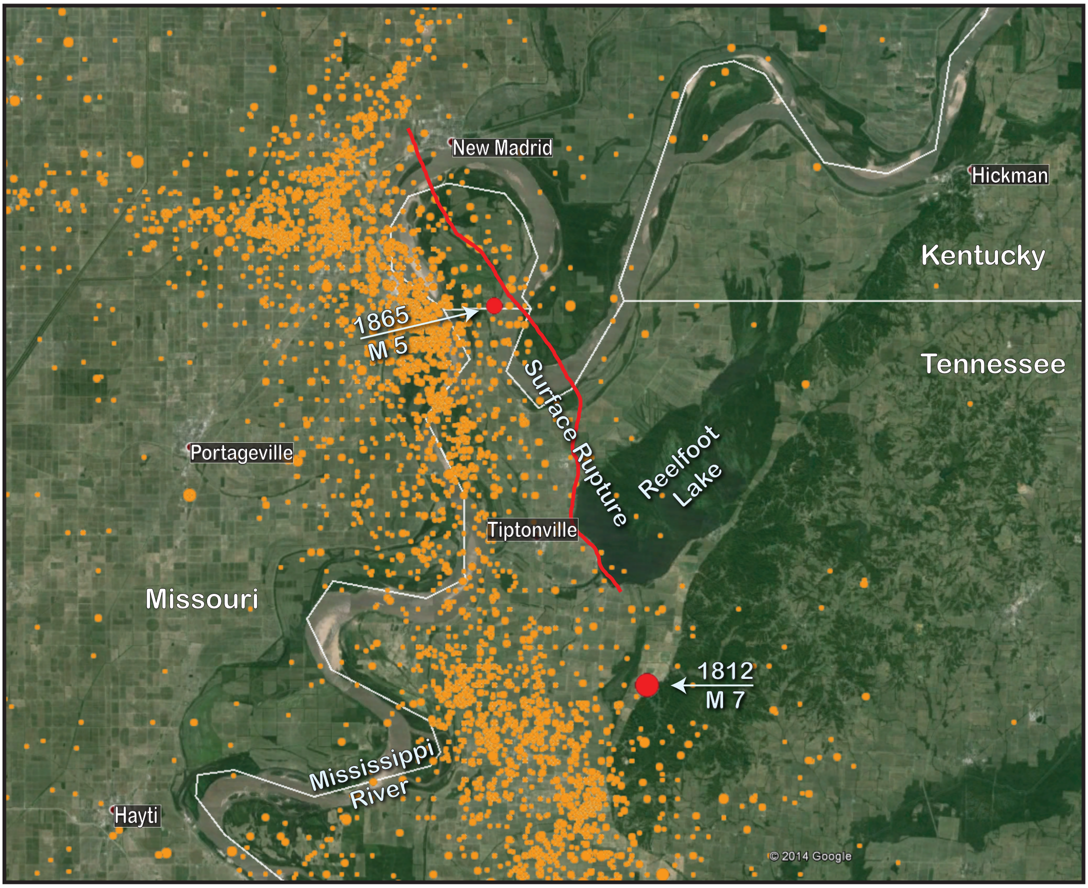


Figure 2. Surface expression of the Reelfoot Fault (red line), significant historical earthquake epicenters (including the 1812 magnitude 7 and 1865 magnitude 5, shown by red dots), and recent seismicity (shown by orange dots). Map made with Google Earth.

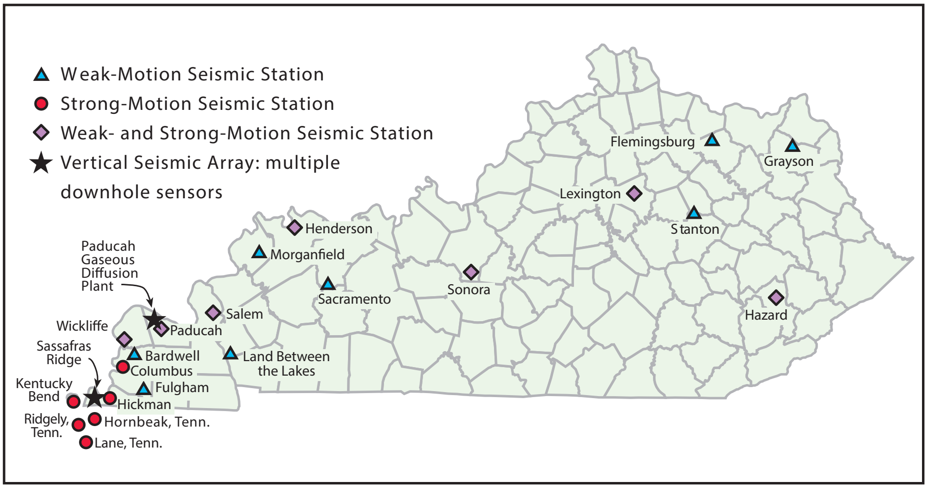


Figure 3. Kentucky Seismic and Strong-Motion Network. Weak-motion stations help monitor small earthquakes, and strong-motion stations record the shaking of large, close-by earthquakes.

rupture can also dam or change a river's course. For example, the surface rupture of the Reelfoot Fault dammed Reelfoot Lake and changed the course of the Mississippi River in 1812 (Fig. 2). Strong seismic waves propagating along the ground surface create a *ground-motion hazard* that can cause damage or even result in collapses of buildings and other structures. Figure 5(a) shows typical damage experienced in Maysville, Ky., from the 1980 Sharpsburg earthquake, and Figure 5(b) shows a building collapse caused by the 2008 Wenchuan, China, earthquake (magnitude 7.9). Surface rupture and ground motion are the primary hazards generated directly by an earthquake. However, not all earthquakes generate surface rupture, particularly

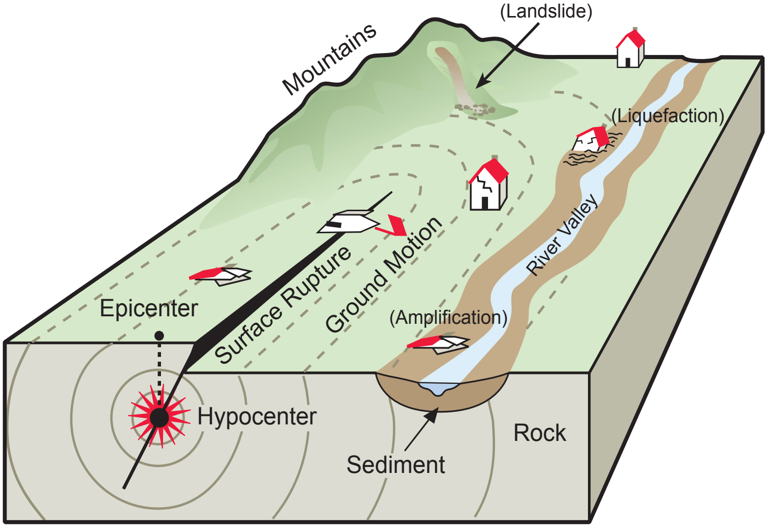


Figure 4. Features and hazards produced from a large, surface-rupturing earthquake. Strong ground shaking occurs throughout the region and amplification, liquefaction, and landslides are induced at certain locations by the shaking.

quakes smaller than magnitude 6. For example, the 2011 Mineral, Va., earthquake (magnitude 5.8) did not generate surface rupture.

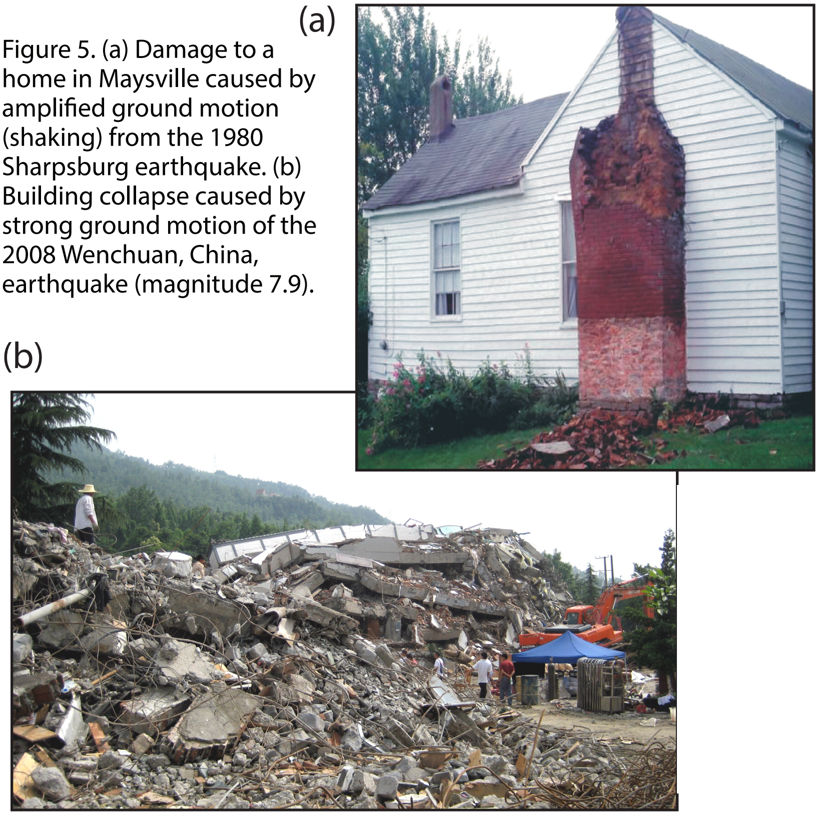
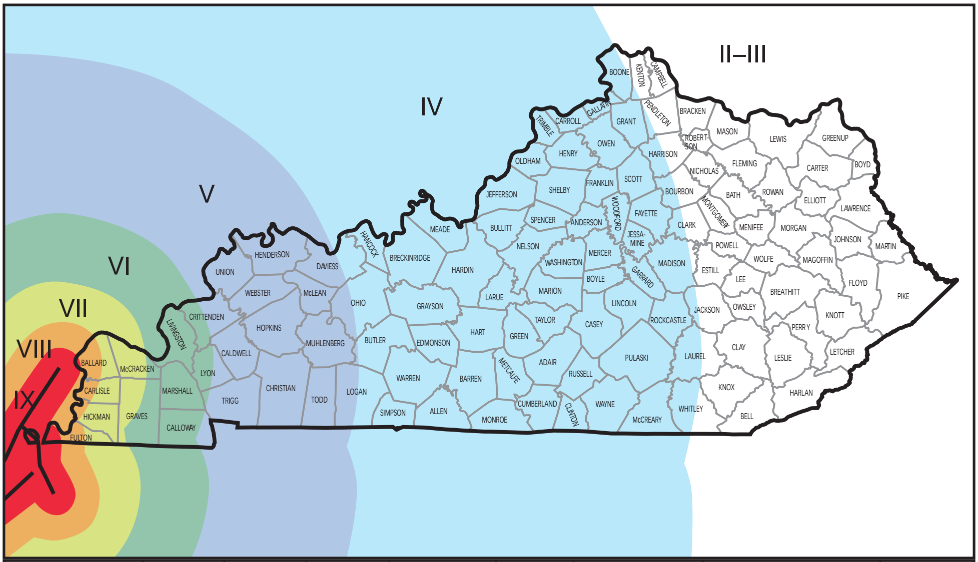


Figure 5. (a) Damage to a home in Maysville caused by amplified ground motion (shaking) from the 1980 Sharpsburg earthquake. (b) Building collapse caused by strong ground motion of the 2008 Wenchuan, China, earthquake (magnitude 7.9).

Ground motion can also result in secondary hazards at sites with certain conditions. Soft sediments overlying hard bedrock along river valleys tend to amplify ground motion, which is known as *amplification hazard*. For example, amplified ground motion caused by loose lake deposits contributed to the heavy damage in Mexico City during the earthquake of September 19, 1985. Studies have also shown that amplified ground motion by Ohio River alluvial deposits contributed to the damage in Maysville during the Sharpsburg earthquake of July 27, 1980 (Fig. 5(a)). Soft and saturated sandy soils can be liquefied by strong ground motion, a process called liquefaction. Liquefaction can cause damage by destabilizing foundations of buildings, bridges, and other facilities. The 1811-12 New Madrid earthquakes caused widespread liquefaction along the Mississippi River. Strong ground motion can also trigger landslides, known as *earthquake-induced landslides,* in areas with steep slopes.

As shown in Figure 4, ground-motion hazards can have an impact on a large area, and they are responsible for the majority of the damage from an earthquake. Thus, ground-motion hazard is of major concern. The level of ground motion at a site primarily depends on its distance from the fault that ruptured and the magnitude of the earthquake. Ground motion can be estimated from scientific information about earthquakes. Figure 6



Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderately Heavy	Heavy
PGA (%g)	< 0.17	0.17–1.4	1.4–3.9	3.9–9.2	9.2–18	18–34	34–65	65–124
Instrumental Intensity	II	III	IV	V	VI	VII	VIII	IX

Figure 6. Predicted peak ground acceleration (PGA), in units of the percentage of the acceleration of gravity, on hard rock from a magnitude-7.5 earthquake in the New Madrid Seismic Zone. Map colored according to instrumental intensities.[1]

shows the peak ground acceleration (acceleration of the ground expressed as a percentage of the acceleration of gravity) that could be expected throughout Kentucky from a magnitude-7.5 earthquake in the New Madrid Seismic Zone. These accelerations are calculated for bedrock sites; some areas could experience higher shaking because of amplification, whereas others might experience reduced shaking because of deamplification.

Mitigation

The purpose of mitigation is to eliminate or reduce the impact of seismic hazards on humans and their built environment.

Ground Motion. Ground-motion hazard can be mitigated by strengthening build-

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[1] Modified from Wald, D.J., Quitoriano, V., Dengler, L.A., and Dewey, J.W., 1999, Utilization of the Internet for rapid community intensity maps: Seismological Research Letters, v. 70, p. 680–697.

ings and infrastructure through better seismic design and construction. Thus, developing and implementing better seismic provisions in modern building codes are the most effective ways to avoid earthquake disasters. Figure 7 shows the peak ground acceleration recommended for mitigation considerations in Kentucky.[2] The ground motions for each county (calculated at the county seat) are those that would result from the largest credible earthquakes in and around the state (Figs. 1–2).

Surface Rupture. Surface rupture cannot be reduced or eliminated. The only way to mitigate the surface rupture hazard is to avoid it (i.e., do not build any house or other facility on or near an active fault). Although many faults have been mapped in Kentucky, most are not active, which means they have not ruptured in the past 11,000 years. The only place where an active fault has been identified in Kentucky is the Reelfoot Fault in westernmost Kentucky (Fig. 2).

Amplification, Liquefaction, and Landslides. These hazards are induced by strong ground motion under certain conditions at specific sites. Predicting which sites will experience one or more of these

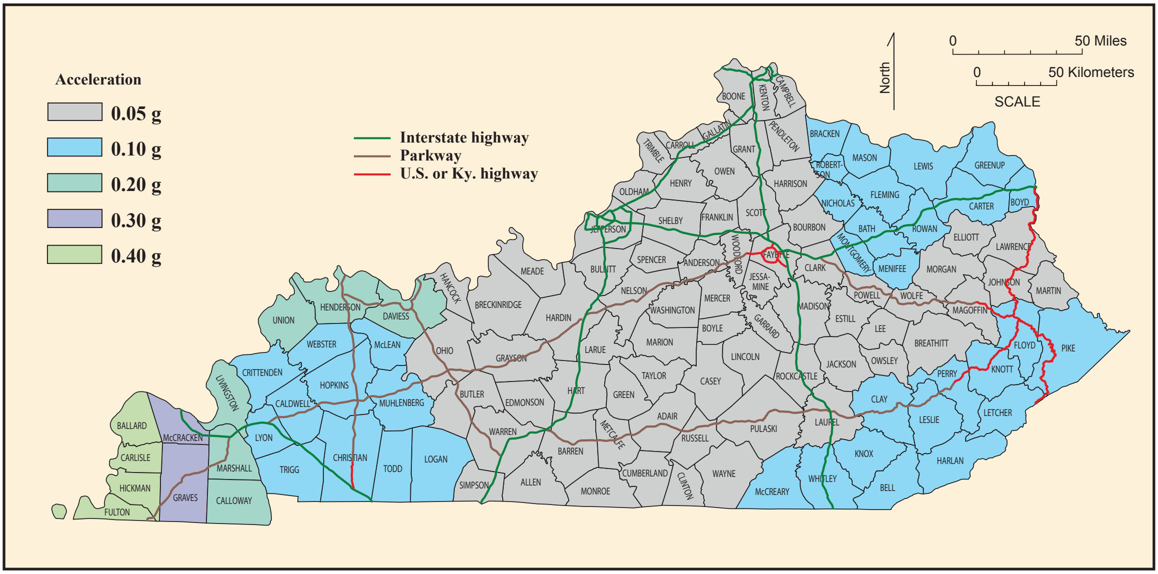

Figure 7. Peak ground acceleration on hard rock, in units of g (acceleration due to gravity), recommended for mitigation considerations in Kentucky.

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[2] Updated from Wang, Z., 2010, Ground motion for the maximum credible earthquake in Kentucky: Kentucky Geological Survey, ser. 12, Report of Investigations 22, 9 p.

hazards during an earthquake is very difficult and requires site investigations, generally conducted by professional geologists or engineers.

Mitigation Measures for Kentucky

Kentucky clearly faces certain seismic hazards, as shown in Figures 6 and 7. The best way to minimize earthquake impacts on communities is to build a seismic-hazard-resistant environment, in particular for buildings and infrastructure. This is the major goal of mitigation.

When developing mitigation measures for Kentucky, it is important to compare the earthquake hazard with other natural hazards that Kentucky faces, particularly weather-related hazards such as tornadoes, floods, and ice storms, for two reasons. First, these other natural hazards occur much more often, as evidenced by several recent disasters. In January 2009, a massive ice storm struck several states in the central United States, causing 36 fatalities and more than $0.5 billion in damage in Kentucky alone. In May 2011, a historic flood inundated many areas in Kentucky, Illinois, and Missouri. The damage that it caused to infrastructure, private property, crops, and commerce from Paducah, Ky., to New Madrid, Mo., exceeded $360 million. In March 2012, tornadoes ripped through several states in the central United States and caused 24 fatalities and more than $150 million in damage in Kentucky. Although smaller earthquakes happen frequently in and around Kentucky (Figs. 1–2), large, damaging earthquakes occur much less frequently. This contrasts with areas that experience greater seismic activity, and therefore have greater seismic hazard, such as California. Comparing seismic activity in California with the activity in and around Kentucky helps to illustrate that Kentucky has lower seismic hazard. Therefore, implementing seismic design requirements for residential and commercial buildings in western Kentucky that are similar to or even higher than those in areas of higher seismic hazard, such as California, is not justified.

Second, in most areas in Kentucky, the forces that structures are expected to experience from earthquakes are less than the forces that they experience from other natural disasters, tornadoes in particular. The Kentucky building and residential codes already require buildings in most areas to be constructed to resist forces from these other natural hazards. Therefore, in Kentucky, it would be more realistic and cost-effective to consider mitigating seismic hazards in conjunction with other more frequently occurring natural hazards, tornadoes in particular. The mitigation measures required for these other natural hazards can also help mitigate seismic hazards.

Emergency Preparedness

Although earthquakes are difficult, even impossible, to predict, certain things such as emergency planning, emergency kits, and drills can be prepared to minimize harm, and steps can be taken to minimize damage. A helpful preparedness checklist is available from FEMA at www.fema.gov/media-library/assets/documents/3234. Some places to start include:

Home/Family

Identify hazards in the home that might pose risks of injury in an earthquake.

- Furniture and appliances, particularly those with water- or gas-supply pipes, that could tip over should be secured to walls.
- Heavy or glass objects on higher shelves should be moved lower.
- Overhead light fixtures that might fall should be braced or reinforced.

Schools

Identify hazards that can result in injuries to students or staff.

- Shelves in libraries, classrooms, etc., should be stiffened or attached to walls.
- A shallow lip on shelves holding books and supplies can prevent items from falling during ground shaking.
- Overhead light fixtures, false ceilings, and overhead ductwork should be braced.
- Any hazardous materials should be stored in a way that prevents spilling.
- Students and staff should be educated on safe reactions to an earthquake, and drills should be conducted.
- A response plan should be drawn up that addresses injuries, communications, damage, evacuation, and other issues related to earthquakes.

Business/Industry

As with homes and schools, hazards at the workplace should be identified and mitigated.

- Plans for dealing with injuries, communications, evacuations, damage, business continuation, and other emergency issues should be drawn up.
- The emergency plan should be made available to all employees.

If the Ground Starts to Shake

If You Are Inside:

Drop to the floor; take cover under a sturdy table or other piece of furniture, holding the legs; or crouch in an inside corner or against a supporting wall, covering your head with your arms (see Figure 8).

Stay in place until the shaking stops.

If You Are Outside:

Do not run indoors; move away from buildings, streetlights, and utility wires.

In a vehicle, stop as quickly as you safely can and stay in the vehicle. Try to avoid stopping close to buildings, trees, overpasses, and utility wires.

Proceed cautiously once the shaking stops. Be alert to damaged roads and bridges.

When the Shaking Stops:

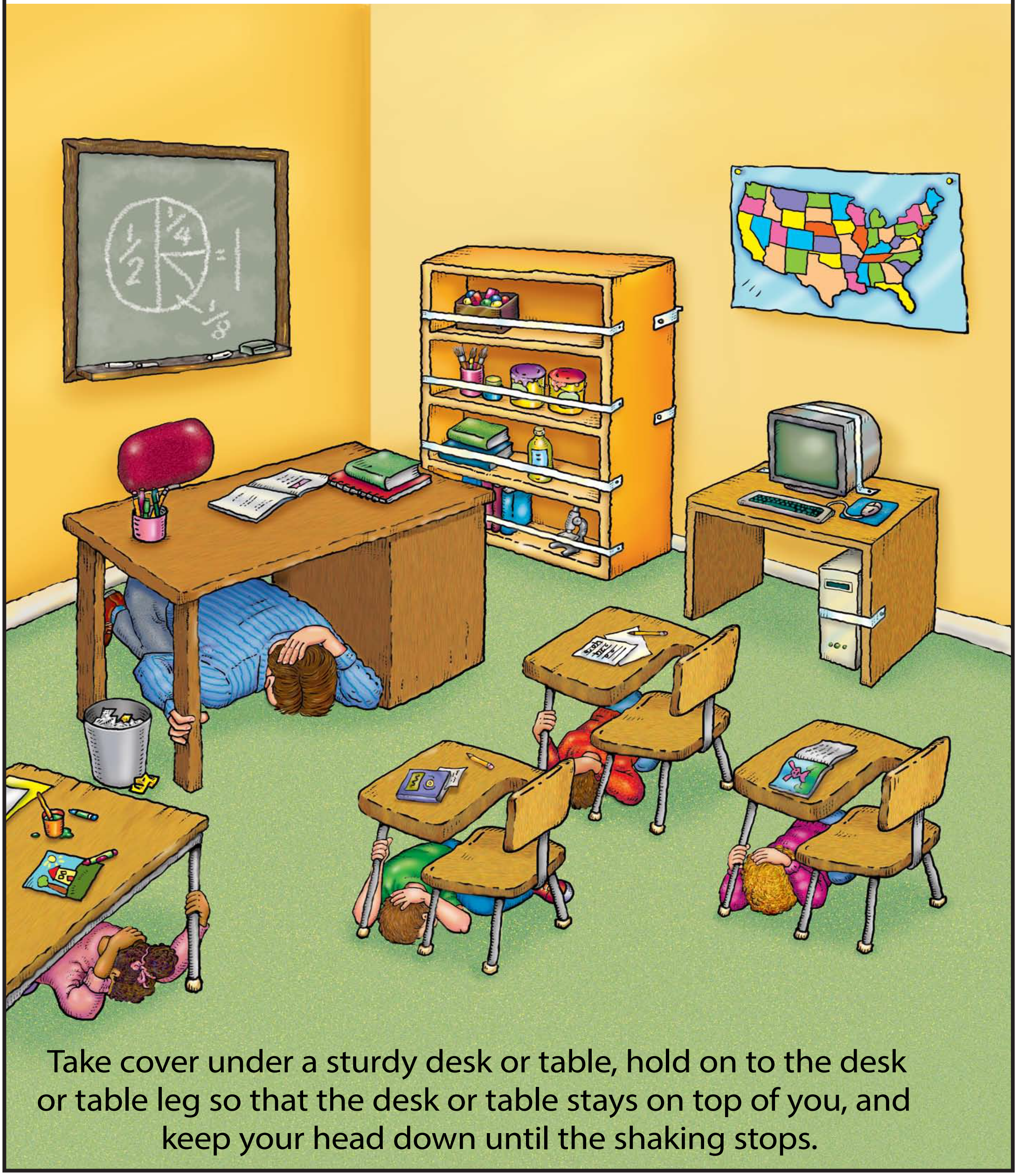
Check for injuries, trapped people, and people with special needs. Carefully leave a damaged building, watching for hazards from loose items overhead, broken glass and other hazards on floors, gas leaks, fires, and electrical or chemical hazards.

Notify authorities as soon as possible of such hazards.

Only when a building is safe should important records be retrieved and damage documented.

When earthquake shaking begins...

Drop, Cover, and Hold



Take cover under a sturdy desk or table, hold on to the desk or table leg so that the desk or table stays on top of you, and keep your head down until the shaking stops.

Figure 8. What to do when an earthquake strikes. Courtesy of FEMA.

This booklet was produced by:

Kentucky Geological Survey
228 Mining and Mineral Resources Building
University of Kentucky
Lexington, KY 40506
859-257-5500
www.uky.edu/KGS

Kentucky Division of Emergency Management
Boone Center National Guard
110 Minuteman Parkway
Frankfort, KY 40601
800-255-2587
kyem.ky.gov