STATEMENT OF
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Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to testify at this hearing on the impacts that a major earthquake in the New Madrid seismic zone would have on the Nation and what can be done to prepare for and mitigate those impacts. My testimony will focus on the role of the USGS and our coordination with other Federal agencies, particularly FEMA; will address differences between the New Madrid seismic zone and other active faults around the country; and will provide an overview of USGS work in monitoring and notification of seismic activity.

From today's perspective, the three large earthquakes that struck the lower Mississippi Valley in the winter of 1811 and 1812 seem quite distant in time – but infrequent events nevertheless represent very real risks. If the New Madrid earthquakes of 1811-1812 were to recur today, significant damage to buildings, transportation, and critical infrastructure would occur in at least eight states, resulting in loss of life and economic disruption. While earthquakes are inevitable, their consequences on our built environment are not, and there is much that we can do as a Nation to improve our resilience to these and other natural hazards.

At the U.S. Geological Survey (USGS), we strive to deliver the information and tools that emergency managers, public officials and citizens need to prevent natural hazards from becoming disasters. The USGS has the lead Federal responsibility under the Stafford Act (P.L. 93-288) to provide notification – including forecasts and warnings where possible – for earthquakes, volcanoes and landslides. The USGS is a partner in the congressionally established National Earthquake Hazards Reduction Program (NEHRP) along with the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (the lead agency), and the National Science Foundation (NSF). In collaboration with these Federal partners plus state and local governments and universities, USGS reports on earthquake size, location, and shaking intensity; develops regional and national hazard assessment maps and related products; supports targeted research to improve these products; and builds public awareness of earthquake hazards. Along with our NEHRP partners, USGS is committed to translating research results into actions that can reduce earthquake losses.

Why Are There Earthquakes in the Central United States?

Most earthquakes occur where the brittle plates that form the Earth's crust and uppermost mantle interact, either pressing together, pulling apart, or sliding by one another. Such is the case with California's San Andreas Fault, where the plate that underlies the Pacific Ocean is sliding past the North American plate, and with the subduction zones off the Pacific Northwest and Alaska, where plate collision is forcing oceanic crust to slide beneath North America, generating giant earthquakes and active volcanic chains.

But earthquakes also occur far from present-day tectonic plate boundaries as the stresses from those plate interactions are translated into the more stable interiors. Such intraplate earthquakes in the central and eastern United States are less frequent than earthquakes in California or Alaska, but the hazard they pose is by some measures equally significant. The older, colder crust in the central and eastern United States allows earthquake waves to travel much farther and thereby affect much larger areas than earthquakes of comparable size in the west. That is the case with the New Madrid seismic zone, which stretches from just west of Memphis, Tennessee, up into southern Illinois. Another geologic factor increasing the hazard from New Madrid earthquakes is that earthquake waves tend to be amplified by the soft soils of the Mississippi Valley, adding to the intensity of shaking experienced by communities there.

All these factors came into play during a two-month period in 1811 and 1812 when three earthquakes with moment magnitudes estimated at between 7.5 and 8.0 had a profound effect on the region and were felt as far away as the eastern seaboard. Thousands of aftershocks followed and continued for decades. Although few people lived in the region at the time, the effects on the landscape remain clear nearly two centuries later. These effects include sand blows, formed when strong shaking from a large earthquake caused wet, loose sand deposits to lose cohesion and – acting like a liquid – erupt onto the ground surface through overlying silt and clay layers. Studies of such sand blows show that similar sequences of major earthquakes have happened at least twice before, in about 1450 A.D. and 900 A.D.

Based on geologic research on the paleoseismic record of past earthquakes, the USGS estimates that there is a 7 to 10 percent chance of a New Madrid earthquake the size of those in 1811-12 occurring in the next 50 years. However, the occurrence of even a moderate-sized earthquake located in close proximity to urban centers such as Memphis or St. Louis could be locally devastating. The last magnitude-6 earthquake struck near Charleston, Missouri, in 1895. The chance of such an earthquake occurring in the New Madrid region in the next 50 years is 25 to 40 percent.

These probabilities are derived from the USGS National Seismic Hazard Maps, which are developed from geologic information about faults, evidence of prehistoric earthquakes, instrumental and historical earthquake catalogs generated by seismic monitoring, and ground deformation measurements. The National Seismic Hazard Maps are used to estimate probabilities of large earthquakes and the ground shaking to be expected if those earthquakes occur.

An important facet of the NEHRP partnership is the cooperation between the USGS and FEMA to incorporate these seismic hazard maps into model building codes. These USGS maps are the basis for seismic design maps in the International Building Code and the International

Residential Code, which have been adopted in almost all states. The newest version of these maps has recently been delivered to the Building Seismic Safety Council for incorporation into the next generation of model building codes. Seismic hazard maps are also used in the design of bridges, dams, and other critical facilities; for loss estimation studies; and to set premiums for earthquake insurance.

The USGS has recently begun developing higher-resolution maps and other products that focus on the most vulnerable urban areas. In the central and eastern United States, these include Memphis, St. Louis, and Evansville, Indiana, which is in the Wabash Valley seismic zone along the southern border of Illinois and Indiana. Such maps require detailed mapping of surficial geology and knowledge of sub-surface geology in order to incorporate the local effects into estimates of shaking. They are useful for prioritizing retrofitting of unreinforced masonry buildings, initial seismic design of structures, and urban planning. Urban hazard mapping in the central United States involves a number of state and university partners including St. Louis University, the Illinois State Geological Survey, the Missouri Department of Natural Resources, the Kentucky Geological Survey, the University of Missouri at Rolla, the University of Memphis, and the Indiana Geological Survey.

Delivering Rapid Information for Emergency Response

Just as knowing where earthquakes occur can lead to building codes that save lives through a more resilient built environment, knowing where shaking is most intense immediately after an earthquake also can save lives by providing emergency responders with the situational awareness they need to concentrate their efforts where they matter most.

For that reason, the USGS and our partners have been building the Advanced National Seismic System (ANSS) to modernize the Nation's seismic monitoring infrastructure and provide, within minutes, information about strong shaking and probable damage. The ANSS consists of a national backbone network, regional networks, a 24/7-staffed National Earthquake Information Center, and ground- and structure-based instruments concentrated in high-hazard urban areas. Currently about 15 percent deployed, the ANSS has already greatly improved information available for emergency responders, engineering performance studies, and long-term earthquake hazard assessments.

The USGS provides rapid reports of potentially damaging earthquakes to the National Command Center; the White House; the Departments of Defense, Homeland Security (including FEMA), Transportation, Energy, and the Interior; State and local emergency managers; numerous public and private infrastructure management centers (for example railroads and pipelines); the news media, and the public. These earthquake notifications are delivered as e-mails and text messages to over 100,000 users. A suite of information products are available through the USGS Earthquake Hazards Program website, which receives an average of two million hits per day. For undersea earthquakes, USGS also provides near-real-time seismic data to the National Oceanic and Atmospheric Administration tsunami warning centers, supporting their monitoring and notification mission.

In the central United States, earthquake monitoring is accomplished cooperatively by the USGS, the Center for Earthquake Research and Information at the University of Memphis, St. Louis University, and the University of Kentucky. The ANSS Mid-America Region includes the New Madrid and Wabash Valley seismic zones, as well as ANSS urban strong-motion monitoring targets of Memphis, St. Louis, and Evansville. There currently are 200 real-time seismic stations in the central United States., only 70 of which meet modern standards. Over 500 seismic stations are planned for the central United States. These regional networks process approximately 200 earthquakes for the New Madrid seismic zone annually. The ANSS Mid-America Region also encompasses the East Tennessee and South Carolina seismic zones that pose a threat to Alabama, Georgia, South Carolina, North Carolina, Virginia, West Virginia, Kentucky, and Tennessee. In these areas, roughly 40 stations are processed in real-time to provide information on about 70 earthquakes annually.

Within five minutes after a potentially damaging earthquake in the central United States, notifications are sent to local, state, and Federal emergency management officials and others with the epicenter and preliminary magnitude of the earthquake. Within 20 minutes, an initial ShakeMap is released showing areas of expected higher ground shaking for use in emergency response, utilities, business recovery, and public awareness. Within 60 minutes after the earthquake, seismograms have been analyzed to determine the geometry of the fault, and an improved ShakeMap is released. With ANSS only partially deployed, these ShakeMaps are primarily model-based rather than data-based, due to the sparse and heterogeneous station coverage in the region. As additional sensors are installed, these maps will improve in resolution and accuracy.

Three months ago, the USGS began delivering a new product, known as Prompt Assessment of Global Earthquakes for Response (PAGER), which provides rapid estimates of population exposure to shaking in the same timeframe as ShakeMap. The PAGER system overlays the estimated shaking intensity with a global population database to estimate population impact. This gives emergency responders and aid agencies a rapid estimate of the extent of the likely response required. Such information is particularly valuable in cases where communications may be down. Domestically, PAGER complements the rapid loss estimates that are generated using FEMA’s HAZUS software in conjunction with USGS ShakeMaps.

Using Scenarios to Better Understand What is at Risk

The actions we as a society take before hazardous events strike are even more important than how we respond in the aftermath of a natural disaster. In addition to the geologic factors that raise the hazard from intraplate earthquakes, an important reason why central U.S. earthquakes can be particularly devastating is that the impacted communities are less prepared than their west coast counterparts. Most of the buildings and infrastructure were built without consideration of seismic shaking, in large part because it has been so long since the last damaging earthquakes in the region. In the New Madrid seismic zone, the challenge to strengthen or replace the many vulnerable structures is compounded by the large numbers of jurisdictions that would be affected by a large earthquake.

Scenarios are a tool that can help make such hazards more real by detailing the likely consequences of a repeat New Madrid earthquake sequence on today's society, where the hundreds of settlers in 1811-12 have been replaced by millions of residents in cities, towns, and farms across the region as well as a complicated, interconnected infrastructure that serves not only the local population but the Nation as a whole. The information in a scenario can be used to reduce the vulnerability of lifelines, retrofit critical structures, improve monitoring systems, plan emergency response, and educate our citizens.

Scenarios are being used by FEMA and others to carry out more realistic preparedness exercises. This year's Spills of National Significance (SONS) exercise, which used a New Madrid earthquake scenario developed by the USGS and partners as its trigger for testing spill response, and FEMA's upcoming catastrophic planning exercise based on a New Madrid earthquake, should improve preparedness in the region.

The impacts of an earthquake of magnitude of 7.5 or greater in the New Madrid seismic zone are daunting, starting with significant structural damage to buildings in Arkansas, Mississippi, Alabama, Tennessee, Kentucky, Indiana, Illinois, and Missouri. Lifelines crossing the region, including highways, bridges, and oil and gas pipelines leading to the northeastern United States., would be severely damaged, particularly in the Mississippi Valley. If the earthquakes were to occur when the Ohio and Mississippi Rivers were high, loss of levees would be likely, along with flooding of low-lying communities. The City of Memphis, with over one million people in its metropolitan area, would be the most affected urban center. Memphis has an aging infrastructure, and many of its large buildings, including unreinforced schools and fire and police stations, are particularly fragile when subjected to severe ground shaking. Very few buildings were built using modern building codes that have some provision for seismic-resistant design.

Earthquake hazards involve more than just seismic shaking. The 1811 and 1812 earthquakes caused landslides along the bluffs from Mississippi to Kentucky. Today a repeat event could be expected to produce similar effects in downtown Memphis. At least one highway and one railroad bridge crossing the Mississippi River are unlikely to survive a major New Madrid earthquake, and many old overpasses would likely collapse. A significant hazard in the New Madrid region is a type of ground failure called liquefaction, which in 1811 and 1812 affected a region from south of Memphis to St. Louis. Liquefaction causes soil to flow and form deep cracks that may make roadways in the Mississippi Valley of Arkansas and Missouri (such as I-55) impassible. Liquefaction can cause flooding of fields and roads with water, sand, and mud, disrupting agriculture for an extended period of time. Liquefaction and failure of levees and riverbanks could make the Mississippi River unnavigable for many weeks. Although Memphis is likely to be the focus of major damage in the region, St. Louis, Little Rock and many small and medium-sized cities would also sustain damage.

One characteristic of New Madrid earthquakes is particularly noteworthy. Geologic evidence suggests that the sequence of three large earthquakes in a two-month period in 1811 and 1812 is characteristic of the region. This means that during recovery efforts, subsequent earthquakes as strong as the first shock, rather than just weaker aftershocks, must be considered when deciding where to feed and shelter people and when to start rebuilding.

Much more detailed scenarios are being developed for the forthcoming catastrophic planning exercise being undertaken by FEMA in conjunction with the Mid-America Earthquake Center headquartered at the University of Illinois at Urbana-Champaign as well as by the Earthquake Engineering Research Institute (EERI). This scenario will be similar to the one that EERI produced for a major earthquake striking Seattle.

Building Public Awareness

The citizens of this region will bear the brunt of a future New Madrid earthquake. They need to be educated on the likely consequences of earthquakes, how to recognize a safe building, the importance of retrofitting and how to respond safely. In particular, there is a need to educate people on how to better secure the contents of their homes and workplaces. Damage to contents caused $12 billion of the $40 billion in losses in the 1994 Northridge earthquake that struck southern California.

Through the Central U.S. Earthquake Consortium, the USGS and FEMA are working with state emergency management agencies, departments of transportation, and geological surveys to provide information that they can use in their planning and public education efforts. Activities include developing shaking scenarios for state and local exercises, sponsoring field trips for state and local officials and the business community, and holding local earthquake town hall meetings and other public forums throughout the region. Additional efforts include participating in earthquake awareness week activities, maintaining a Public Earthquake Resource Center at the USGS office at the University of Memphis Center for Earthquake Research and Information, and preparing and distributing educational and informational materials.

Scientific Questions Remain

An integrated picture of what will happen in a future New Madrid seismic zone earthquake -- from rupture on the fault to shaking and damage of buildings and infrastructure -- requires research on all aspects of the earthquake process. Such research may include: mapping the near-surface geology in the urban region; determining the location and geometry of all hazardous faults; measuring the seismic wave speed across the range of near-surface materials; and deploying ANSS sensors in the ground to quantify the way earthquake waves travel in the region and in key engineered structures to better predict how they will respond to severe shaking. These results would provide a more complete picture of where mitigation would do the most good and would better support emergency response. Scientific analysis reduces uncertainty, and further engineering evaluation will help reveal the actual level of vulnerability in our built environment and help prioritize retrofitting. A few of the research questions that the USGS and its NEHRP partners are pursuing include:

- What is the full extent of the New Madrid seismic zone? We are searching for additional geologic evidence, using seismic and geophysical exploration methods to identify active fault systems.
- Are there other areas in mid-America besides the New Madrid zone that can produce large earthquakes? How often do they occur? We know that the Wabash Valley seismic zone has magnitude 6.5 or greater earthquakes with about a 4,000-year recurrence. The

search continues for geological and geophysical evidence that can reduce uncertainty with regard to the timing of prehistoric earthquakes and active fault systems.
- Can we identify areas of high hazard using GPS measurements of ground deformation? In contrast to plate boundaries like California's San Andreas fault, where the rate of major earthquakes is predictable based on measured deformation, large earthquakes in the New Madrid region seem to happen much more frequently than predicted from GPS measurements of ground deformation. The USGS and NSF are supporting research and monitoring activities to better constrain these ground-deformation rates and better understand the process that leads to earthquake rupture in this intraplate setting.
- What level of ground shaking can we expect from future large earthquakes? Data from an expanded ANSS will improve ShakeMap and urban hazard maps. Additional work is needed to measure and map the properties of soils that amplify ground shaking.
- What information is most needed by local officials to promote and prioritize mitigation actions, and by emergency managers to best respond when an earthquake strikes?

Conclusion

While there is still much that we do not know about the earthquake hazard in the heartland, we could significantly improve the resilience of our society and economy through greater preparedness and targeted mitigation. In the future, earthquake monitoring and long-term data and information collection activities will continue to be crucial for decisionmakers seeking to ensure public safety.

Mr. Chairman, this concludes my remarks. I will be pleased to answer any questions you may have.