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Understanding Earthquake Hazards in Urban Areas

Evansville Area Earthquake Hazards Mapping Project

The region surrounding Evansville, Indiana, has experienced minor damage from earthquakes several times in the past 200 years (yr). Because of this history and the proximity of Evansville to the Wabash Valley and New Madrid seismic zones, there is concern among nearby communities about hazards from earthquakes. Earthquakes currently cannot be predicted, but scientists can estimate how strongly the ground is likely to shake as a result of an earthquake and are able to design structures to withstand this estimated ground shaking. Earthquake-hazard maps provide one way of conveying such information and can help the region of Evansville prepare for future earthquakes and reduce earthquake-caused loss of life and financial and structural loss.

The Evansville Area Earthquake Hazards Mapping Project (EAEHMP) has produced three types of hazard maps for the Evansville area: (1) probabilistic seismic-hazard maps show the ground motion that is expected to be exceeded with a given probability within a given period of time; (2) scenario ground-shaking maps show the expected shaking from two specific scenario earthquakes; (3) liquefaction-potential maps show how likely the strong ground shaking from the scenario earthquakes is to produce liquefaction. These maps complement the U.S. Geological Survey's National Seismic Hazard Maps (see *http://pubs.usgs.gov/fs/2008/3017/*) but are more detailed regionally and take into account surficial geology, soil thickness, and soil stiffness; these elements greatly affect ground shaking.

Probabilistic Seismic Hazard Maps

The probabilistic seismic-hazard maps produced by the EAEHMP account for all known earthquakes source regions that can affect the Evansville region. They incorporate information about seismic activity and the locations of active faults, as well as estimates of the time interval between earthquakes. These maps consider a time period of 50 yr, which is the typical lifetime of a building. The maps also depict a range of ground-vibration frequencies, because structures behave differently in response to different types of earthquake waves (for example, long wavelength rumbles or shorter wavelength shaking). For each point on the map and for some specific level of probability, the maps address the question: "what level of shaking is likely to be exceeded?" For example, the maps of the Evansville region show the ground motions that have both a 2 percent (fig. 1) and a 10 percent chance of being exceeded within the next 50 yr; the predicted motions are larger for the 2-percent map because they allow for the more infrequent, large earthquakes.

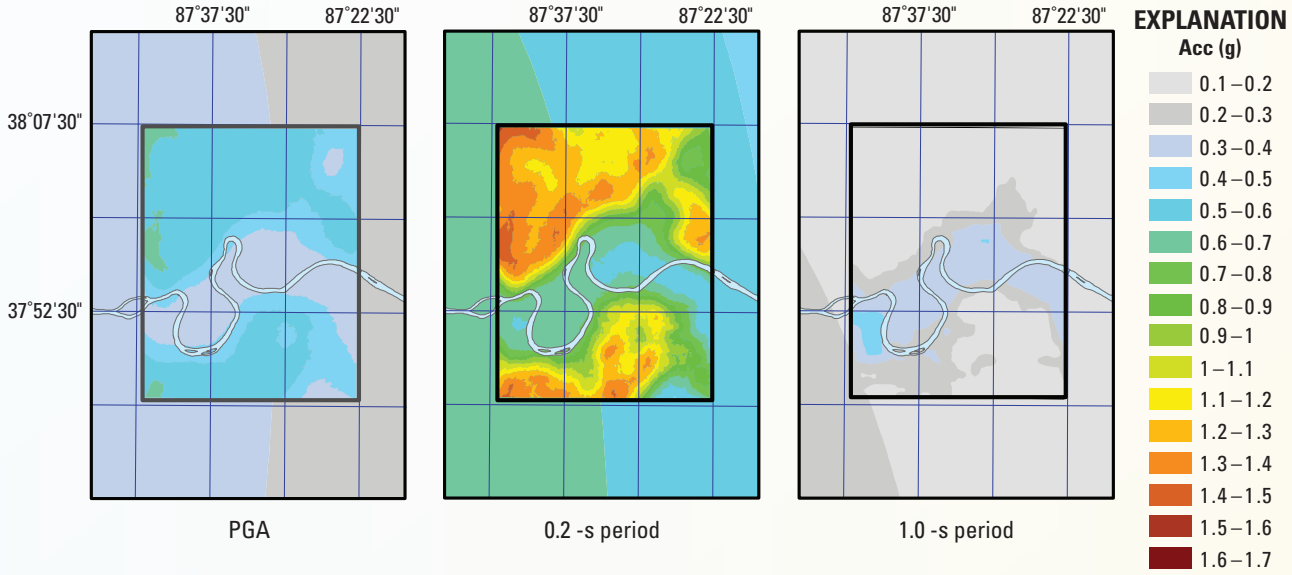

Figure 1. Probabilistic seismic-hazard maps. These maps show the ground motions that have a 2-percent probability of being exceeded in 50 years. The new maps developed for the Evansville area, which incorporate local geology, are shown on top of the 2008 USGS national maps assuming a firm rock site condition. Three different maps are shown for Peak Ground Acceleration (PGA), high frequencies (0.2-second (s) period) and low frequencies (1.0-second period). Warmer colors show higher hazard. (Acc, acceleration; g, acceleration of gravity)

The probabilistic maps for Evansville show strong local variations of ground motions. The ground motions are clearly correlated with variations in the thickness of soft soils above bedrock. Locations along the Ohio River, where soft soils are relatively thick, experience greater ground motions at longer wavelengths, which is a problem for larger structures like high-rise buildings and bridges. In contrast, regions away from the river, where soils are thinner, experience greater ground motions at shorter wavelengths, which is a problem for smaller structures like homes.

These probabilistic seismic-hazard maps can be useful to zoning and planning officials in deciding about new development and can be useful to the financial and insurance industries in their assessment of seismic risk to a portfolio of structures.

Scenario-Based Ground Motion Maps

The second product produced by the EAEHMP is a set of scenario ground-motion maps. Figure 2 shows these maps for a period of vibration of 0.2 seconds. These maps differ from probabilistic seismic-hazard maps in that they consider a single earthquake source. As a result, the maps show the expected ground motions from a particular earthquake. The scenario maps may be particularly useful to emergency responders in anticipating and preparing for the potential effects of earthquakes.

The two greatest concerns for the Evansville region are earthquakes from New Madrid and the Wabash Valley. The New Madrid earthquakes of 1811–1812, although over 100 miles (mi) away, produced the strongest ground shaking (Mercalli intensity VII) historically recorded near Evansville, and earthquakes from the New Madrid seismic zone are considered a viable threat to the region. The Wabash Valley, although less active in historic times, also poses a significant earthquake threat, particularly given its proximity to the region. Scenarios were thus developed for each of these seismic zones, using maximum credible (that is, worst case) earthquake magnitudes. For the New Madrid, a magnitude 7.7 earthquake was modeled from the northern section of the seismic zone, and for the Wabash Valley, a magnitude 6.8 was modeled approximately 25 mi from the Evansville region.

The resulting scenario ground-motion models predict strong local variations across the Evansville area, with similar patterns for both the New Madrid and the Wabash valley scenarios. Ground motions along the Ohio River tend to be high at long periods (a problem for large structures), whereas ground motions away from the river tend to be high at short periods (a problem for small structures). In general, ground motions tend to increase towards the earthquake source, which is to the northwest for the earthquake in the Wabash Valley seismic zone and to the southwest for the earthquake in the New Madrid seismic zone.

If either of these scenario earthquakes were to occur today, significant damage would be expected. The Wabash Valley earthquake scenario is expected to produce a modified Mercalli intensity between VIII and IX along the Ohio River. This intensity would result in considerable damage to masonry structures. Wood-frame structures could be thrown off of their foundations. Intensities closer to VII would be experienced in much of the remaining area. At this level of ground shaking, chimneys would be damaged and masonry walls cracked. For the New Madrid scenario, intensities along the Ohio River are expected to be between VII and VIII and near VI elsewhere in the Evansville area.

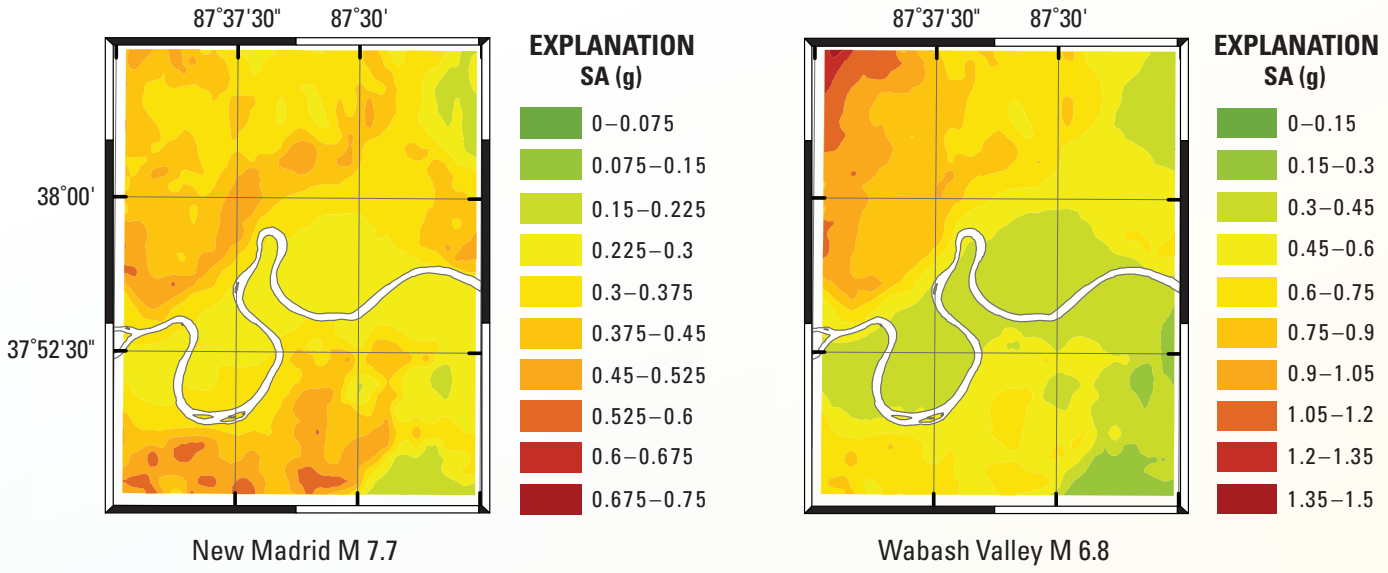

Figure 2. Scenario-based ground motion maps. These maps show the expected ground motions at a period of 0.2 seconds for two scenario earthquakes: a M 7.7 New Madrid earthquake and a M 6.8 Wabash Valley earthquake. (M, magnitude; SA, spectral acceleration; g, acceleration of gravity)

Liquefaction-Potential Maps

The third product produced by the EAEHMP is a set of liquefaction-potential maps (fig. 3). These maps were generated for the two scenario earthquakes described above. Results indicate the degree to which liquefaction is likely at sampled sites across the region; results also indicate the severity of the potential ground deformation. For example, sites with a liquefaction potential of 5 or greater are likely to experience liquefaction, while sites with liquefaction potential greater than 12 are likely to see lateral spreading (substantial lateral movement of the land). Values for the liquefaction-potential index are high along the Ohio River, where the soil profiles are predominantly sand. Values away from the river in the uplands are lower, owing to the predominance of clay. For the Wabash Valley scenario, major liquefaction would be expected in the downtown Evansville area.

Like the scenario-based ground-motion maps, liquefaction-potential maps can be useful to emergency management in preparing for earthquakes. But, like the probabilistic maps, they can also help public officials make decisions about new development and locating critical infrastructure.

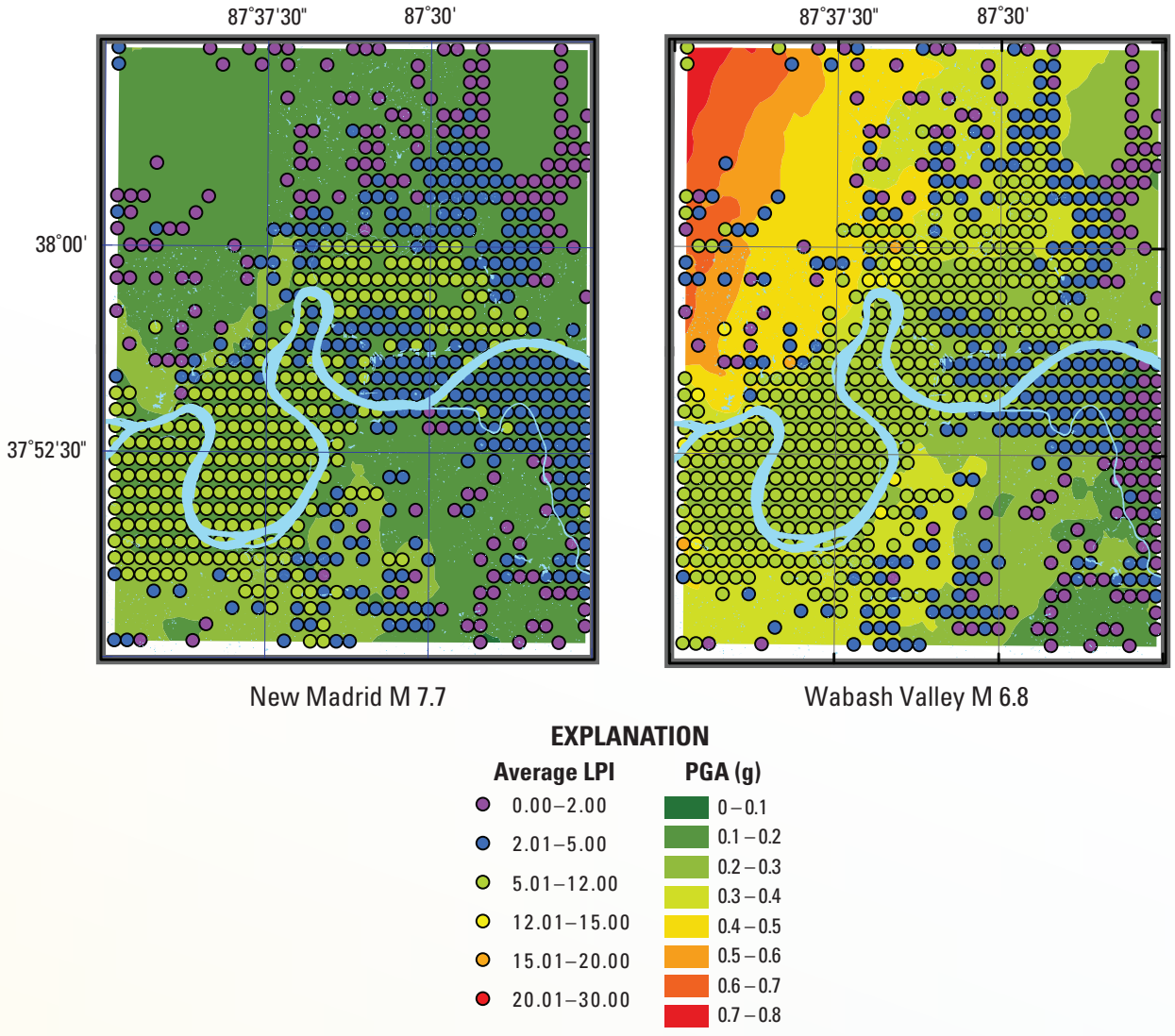

Figure 3. Liquefaction potential index (LPI) maps. These maps show the mean liquefaction potential index from two scenario earthquakes: a M 7.7 New Madrid earthquake and a M 6.8 Wabash Valley earthquake. A LPI value of 5 means that there is a surface expression of liquefaction. A value of 12 indicates lateral spreading. (PGA, peak ground acceleration; g, acceleration of gravity)

Acknowledgments

The Evansville seismic-hazard maps are a collaborative effort among the USGS and several regional partners including: Purdue University; the Center for Earthquake Research and Information at the University of Memphis (CERI); the State Geologic Surveys of Kentucky, Illinois, and Indiana; the Southwest Indiana Disaster Resistant Community Corporation; and the Central U.S. Earthquake Consortium State Geologists.

Partners:

Purdue University
Center for Earthquake Research and Information at the University of Memphis
Kentucky Geological Survey
Illinois State Geological Survey
Indiana Geological Survey
Southwest Indiana Disaster Resistant Community Corporation
Central U.S. Earthquake Consortium State Geologists

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Evansville Hazard Mapping Reports:

Probabilistic Maps: *http://pubs.usgs.gov/of/2011/1231/*
Scenario Maps: *http://pubs.usgs.gov/of/2011/1260/*
Liquefaction Maps: *http://pubs.usgs.gov/of/2011/1203/*

Evansville Hazard Mapping website:

http://earthquake.usgs.gov/regional/ceus/urban_map/evansville/

Earthquake Hazards Program:

http://earthquake.usgs.gov/
For more information on seismic hazard assessments, see:
United States National Seismic Hazard Maps, *http://pubs.usgs.gov/fs/2008/3017/*
Urban Seismic Hazard Mapping for Memphis, Shelby County, Tennessee, *http://pubs.usgs.gov/fs/2005/3142/*
St. Louis Area Earthquake Hazards Mapping Project, *http://pubs.usgs.gov/fs/2007/3073/*