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Mister Chairman and Members of the Subcommittee, thank you for holding this hearing on the hazards earthquakes pose here and abroad. The work of the U.S. Geological Survey (USGS) Earthquake Hazards Program is predicated on the belief that 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 earthquakes and other natural hazards. The magnitude-7.9 earthquake that struck the densely populated Sichuan province in China earlier this month was a sobering reminder of the impact that earthquakes can have on vulnerable populations.

The USGS strives 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 delegated 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), which is led by the National Institute of Standards and Technology and also includes the Federal Emergency Management Agency (FEMA) and the National Science Foundation (NSF). In collaboration with Federal partners, plus State and local governments and universities, the USGS reports on earthquake size, location, and shaking intensity; develops regional and national hazard assessment maps and related products; supports targeted research to improve our monitoring and assessment capabilities; and builds public awareness of earthquake hazards. The USGS is committed to translating research results into actions that can reduce earthquake losses.

Assessing the Nation's Earthquake Hazards

Last month's magnitude-5.2 earthquake near the Illinois-Indiana border underscores the fact that earthquakes are a national hazard, not a "West Coast problem." Although damage was limited due to the small size of the earthquake, it was felt over a very broad area. Over 36,000 people from 16 states and the Canadian province of Ontario completed on-line surveys on the USGS "Did You Feel It?" website describing what they experienced in that event. Earlier in the year, a magnitude-6 earthquake struck the town of Wells, Nevada, causing extensive damage to older, brick buildings that were not built to withstand earthquake shaking. The city of Reno, Nevada is currently experiencing a swarm of earthquakes, the largest being magnitude-4.7. Even the Nation's Capital was rattled by an earthquake this month, when a magnitude-2 earthquake struck northern Virginia and was widely felt across the metropolitan Washington, D.C. area.

Earlier this month, the USGS released the latest update of the National Seismic Hazard Maps, which estimate probabilities of large earthquakes and the ground shaking to be expected if those earthquakes occur. These maps show that earthquakes are a serious threat in 46 states. The maps are the culmination of a multi-year process to incorporate the best available science, including geologic information about faults, evidence of prehistoric earthquakes, instrumental and historical earthquake catalogs generated by seismic monitoring, and ground deformation measurements.

The release of the updated seismic hazard maps is timed to fit into the development of the next generation of building codes, a process that involves close cooperation among the USGS, FEMA, the Building Seismic Safety Council, the American Society of Civil Engineers, the International Code Council, and many other organizations. Earlier versions of the 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 maps are also used by insurance companies to set rates for properties in various areas of the country, by civil engineers to estimate the stability and landslide potential of hillsides, by the U.S. Environmental Protection Agency to set construction standards that ensure the safety of waste-disposal facilities, and by FEMA to plan the allocation of assistance funds for earthquake education and preparedness.

The changes in earthquake ground shaking estimates in the new maps compared to previous versions released in 1996 and 2002 are due principally to the incorporation of new models on the strength of earthquake shaking near faults, and the manner in which that shaking decreases with distance. The expected shaking has gone up in western Washington and Oregon due to new ground-motion models for the offshore Cascadia subduction zone. Also because of new models, ground motion estimates in the Central and Eastern United States are about 10 - 25 percent lower. These models also show that ground motion estimates in most of California, Utah, Nevada, Arizona, Idaho and western Montana are as much as 30 percent lower for shaking that affects taller multi-story buildings. For those same areas, ground motion estimates remain nearly the same for shaking that affects structures of one or a few stories.

Urban Hazard Maps

Complementing the national maps, urban seismic hazard maps provide more detailed information on local site conditions for use in engineering and planning. Urban seismic hazard maps have been released in the past two years for Memphis and Seattle, with others being developed for the St. Louis and Evansville (Indiana) areas. Those maps show how forecasted earthquake shaking levels vary at scales useful for urban planning, earthquake response planning, engineering guidance for major structures, and public education. Such maps require detailed mapping of surficial geology and knowledge of subsurface geology in order to incorporate the local effects into estimates of shaking. Developing these maps would not be possible without significant involvement of local and regional scientists, engineers, emergency managers, and the business community.

New seismic hazard maps of the City of Seattle combine state-of-the-art modeling techniques and detailed information about near-surface materials that affect shaking strength, and display the variation in expected earthquake shaking with unprecedented resolution. Demand for these maps has been high. For example, the Washington Department of Transportation is using them in preliminary design of the new Route 520 bridge across Lake Washington.

Earthquake Forecast for California

Key to understanding the earthquake hazard is forecasting the probability of large events, and nowhere is that more important than California where high hazard is combined with a huge population at risk. Last month, the USGS combined forces with the Southern California Earthquake Center (SCEC) and the California Geological Survey, with support from the California Earthquake Authority, to deliver the first-ever statewide earthquake rupture forecast.

The new study determined the probabilities that different parts of California will experience earthquake ruptures of various magnitudes. The new statewide probabilities are the result of a model that comprehensively combines information from seismology, earthquake geology, and geodesy (precisely measuring movements of the Earth's surface as faults are loaded towards failure).

According to the forecast, California is virtually certain – *more than a 99% chance* – of having a magnitude 6.7 or larger earthquake within the next 30 years. Such earthquakes can be deadly, as shown by the 1989 magnitude 6.9 Loma Prieta and the 1994 magnitude 6.7 Northridge earthquakes. The likelihood of a major earthquake of magnitude 7.5 or greater in the next 30 years is 46% –and such an earthquake is most likely to occur in the southern half of the state. The most likely sources of magnitude- 6.7 earthquakes are the San Andreas Fault and the Hayward-Rodgers Creek Fault.

USGS scientists are working with regional partners to raise awareness about the hazards posed by both the San Andreas and Hayward-Rodgers Creek Faults. The Bay Area will mark the 140th anniversary of the 1868 Hayward earthquake on October 21 and 22, 2008. Emergency management offices for the 10 San Francisco Bay Area counties will conduct a response drill based on a Hayward Fault earthquake scenario. Although the 1868 earthquake was one of the most damaging earthquakes in Bay Area history, few residents know about its impact, or the likely effects of its impending repeat. The USGS and its partners have developed a wide array of scientific and educational products, similar to those developed for the earthquake preparedness campaign linked to the centennial commemoration of the 1906 San Francisco earthquake, to increase the level of preparedness and resilience in the Bay area.

Using Scenarios to Better Understand What is at Risk

Scenarios are a tool that details the likely consequences of a damaging earthquake and have been used successfully in the Pacific Northwest and in the Central United States to raise awareness of earthquake hazards. In order to make the hazard posed by the Southern San Andreas Fault more understandable to the public, the USGS and its partners have developed a scenario that describes the impacts that a magnitude-7.8 earthquake on this fault would have on the region. The southern San Andreas Fault has generated earthquakes of this size on average every 150 years – and on a portion of the fault that ruptures in the scenario, the last earthquake happened more than 300 years ago. Information in the scenario can be used to reduce lifeline vulnerability, retrofit critical structures, improve monitoring systems, plan emergency response, and educate our citizens.

This scenario is a product of the USGS Multi-Hazards Demonstration Project in Southern California, a community-focused initiative in which dozens of partner organizations are working with the USGS to understand the long-term impacts of a devastating earthquake, including its long-term impacts on the complicated social and economic interactions that sustain southern California society.

Seismologists and computer scientists modeled the ground shaking that would occur in this earthquake. Engineers and other professionals used this estimated ground shaking to produce a realistic picture of this earthquake's damage to buildings, roads, pipelines, and other infrastructure. From these damages, social scientists projected casualties, emergency response, and the impact of the scenario earthquake on southern California's economy and society. The scenario considers the impacts not just from the earthquake shaking but also from associated fires, landslides and other related hazards.

The scenario will be the basis of an emergency response exercise, the Great Southern California ShakeOut, in November 2008. Plans are underway to include a significant public component to the exercise, engaging local school districts and businesses to practice earthquake safety drills. The public exercise is being organized as part of a major Dare to Prepare campaign by the Earthquake Country Alliance, a broad public-private coalition of organizations. By identifying the consequences of a major earthquake in southern California, the scenario is intended to help the public identify what they can change *before* the earthquake to avoid catastrophic impact *after* the inevitable earthquake occurs. The scenario emphasizes that a catastrophic earthquake in southern California would have national impact due to the tremendous transportation hub that the ports and distribution corridors represent.

The total impact of this scenario earthquake is estimated to be approximately 1,800 fatalities and about $200 billion in losses. Both those numbers would be considerably higher without mitigation measures that have been put in place over the last few decades by State agencies, utilities, and private owners. To put this in perspective, the fatalities from the 7.9 Sichuan earthquake are approximately 34,000 and rising. The major losses for this earthquake scenario come from damage to older buildings built to earlier standards; damage to non-structural elements and building contents; damage to lifelines and infrastructure crossing the fault; business interruption from damaged infrastructure, especially water systems; and fire losses following the earthquake.

Duration of strong shaking will be an important contributor to damage in any earthquake as large as the earthquake defined by the scenario. Shaking lasts a long time because it takes about 100 seconds for a fault this long to rupture and because some of the waves get trapped and reverberate in sedimentary basins, where population is concentrated. Damage from surface rupture is most serious where lifelines (roads, railroads and utilities) cross the fault. Many of these crossings are concentrated within a few mountain passes and the disruption to these lifeline corridors has a major economic impact. Disrupted lifelines include fiber optic cables, petroleum and natural gas pipelines, railroads, aqueducts, and overhead electric power transmission lines.

The scenario also includes a number of large aftershocks, whose shaking can damage already weakened structures, necessitate evacuations, endanger rescue workers, and undo efforts to restore and rebuild. Southern California is unfortunately well situated for major fires to be generated following earthquakes. The number of ignitions that will create fires large enough to call the fire department can be extrapolated from previous earthquakes and depends upon the number of households at different levels of seismic shaking. This leads to an estimate of 1,600 ignitions of which 1,200 will be too large to be controlled by one fire company. In areas of dense wood frame construction, these fires if not controlled will grow quickly to involve tens or hundreds of city blocks.

Another way that the USGS works to make earthquake hazards understood is through education and outreach products developed in concert with Federal agency, university, and local government partners, including the FEMA-supported regional earthquake consortia, the NSF-supported IRIS Consortium, and SCEC, which is jointly supported by the NSF and the USGS. Millions of copies of earthquake preparedness handbooks have been distributed in California, Alaska, and many other states. As part of an effort to reach underserved populations, both the southern California and Bay Area versions of *Putting Down Roots in Earthquake Country* have been translated into Spanish, and a shortened version of the Bay Area *Putting Down Roots* has been translated into a number of Asian languages and distributed through Asian-language newspapers.

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 was 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.

To carry out its statutory responsibility, 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 also 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.

In an effort to modernize the Nation's seismic monitoring infrastructure, the USGS and its partners are building the Advanced National Seismic System (ANSS). The ANSS consists of a national backbone network, regional networks operated by State and university partners, the USGS National Earthquake Information Center (NEIC), 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 ANSS has been carefully planned and executed, as reflected by its repeated rating as the highest-rated information technology major capital investment in the Department of the Interior. A report by the National Research Council on the costs and benefits of seismic monitoring found that the benefits of fully deploying ANSS outweigh the costs many times over.

The ANSS has enabled dramatic changes in the way that earthquake information is conveyed and is central to improving the use of USGS data within the engineering community. Products such as ShakeMap showing the distribution of intense shaking are made available directly after a potentially damaging earthquake to provide emergency managers with greater situational awareness than was possible before. Systems such as ShakeCast and California Integrated Seismic Network (CISN) Display push information directly to critical users and, in the case of ShakeCast, allow them to directly estimate potential damage to facilities. When coupled with FEMA's HAZUS software, ShakeMap helps support loss estimation. ShakeMap is now available as part of the newest release of Google Earth, along with real-time feeds of USGS earthquake information and links to the USGS website.

Currently, many ShakeMaps are based on models rather than data, due to sparse and heterogeneous station coverage. Similarly, sparse seismic station coverage and incomplete data exchange delayed analysis and reporting of last week's northern Virginia earthquake (by more than an hour). As the ANSS is deployed and additional sensors are installed, these maps will improve in resolution and accuracy. In the current fiscal year, the USGS is using funds provided by Congress to support the Multi-Hazards Demonstration Project to deploy ANSS instrumentation along the southern San Andreas Fault. These new sensors will provide critical measurements of ground motions close to a major rupture, improve ShakeMap capability in the fast growing San Bernardino-Riverside urban corridor, and potentially support implementation of an early warning system prototype in the future.

The NEIC has responsibility for reporting not only on domestic earthquakes but on all significant seismic events worldwide. To carry out this mandate, NEIC relies on the Global Seismographic Network (GSN), which the USGS has developed in partnership with the NSF and the IRIS consortium of universities. Supplemental funds following the Sumatra earthquake and Indian Ocean tsunami enabled the USGS to modernize NEIC facilities and establish 24/7 onsite staffing. Those funds also made it possible for the USGS and its partners to make considerable strides in enhancing the GSN with new seismic monitoring stations in the Caribbean and improved data telemetry worldwide. These capabilities have, in turn, significantly enhanced our ability to support NOAA's tsunami warning capabilities, which rely on data from the GSN and other USGS seismic networks.

Last fall, 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. In the case of the Sichuan earthquake earlier this month, PAGER results were distributed within 30 minutes of the event, indicating several million people had been exposed to severe shaking and tens of millions to very strong shaking that was likely to damage buildings. 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.

Targeted Research

Both USGS assessment and monitoring activities depend on the targeted geoscience research that is the third major USGS responsibility within the NEHRP partnership. External research supported by the USGS through grants and cooperative agreements to universities, State geological surveys, and geotechnical consultants augments the USGS' internal research capabilities. This targeted research is awarded on the basis of merit, and provides a bridge from the NSF's investments in fundamental research to generate critical advances in understanding that underpin development of the national and urban seismic hazard maps and rapid earthquake response products. One of the great strengths of the USGS in the earthquake arena is our ongoing research collaboration with the academic community and our important research partnership with the NSF's EarthScope facility.

The ability to characterize the earthquake hazard in regions like the Pacific Northwest where active faults are poorly exposed has been revolutionized by high-resolution Lidar topographic imaging, which can reveal fault scarps that are hidden beneath vegetation. Since Lidar acquisition began in 2000 in Puget Sound, the USGS has used this data to document recent surface deformation on seven major crustal faults. The USGS, using funding for the Multi-Hazards Initiative, is beginning Lidar acquisition in eastern Washington over the portions of the area thought to be the location of a magnitude-7 earthquake.

In the resurgent research area of earthquake prediction, the USGS has a special responsibility under NEHRP legislation to review the validity of predictions and their policy implications. The congressionally established National Earthquake Prediction Evaluation Council advises USGS in this arena. The council met last year to consider the implications of seismic tremor and so-called "slow" earthquakes for increasing the risk of a major subduction-zone earthquake, such as that which threatens the Pacific Northwest coast. Detection of these phenomena has been made possible by advances in geodesy and other observational capabilities. The council is in the process of establishing guidelines for what constitutes a valid prediction with testability being a major criterion. For that reason, the USGS is pleased that SCEC has undertaken a Collaboratory for the Study of Earthquake Predictability to serve as a level playing field in which hypotheses can be rigorously tested and reviewed.

Mission Aligns with Broad National Goals

The work of the USGS Earthquake Hazards Program – monitoring, assessment, research – is well aligned with the recently completed USGS science strategy, entitled *Facing Tomorrow's Challenges*, which recognizes natural hazards as one of our primary mission areas. The strategy calls for progress in three areas, emphasizing that partnerships are integral to all three:

- Building a robust monitoring and communications infrastructure;
- Expanding and fine-tuning our assessments of hazards and risks; and
- Improving forecasting through better understanding of physical processes.

The program also supports government-wide priorities set by the National Science and Technology Council's Subcommittee on Disaster Reduction (SDR), which has identified a set of *Grand Challenges for Disaster Reduction* that, if met, would significantly enhance societal resilience to disasters. With representation from 22 Federal departments and agencies, the Subcommittee is charged with establishing clear national goals for science and technology investments in disaster reduction, promoting interagency cooperation in risk assessment and other activities supporting disaster reduction. The grand challenges are: 1) provide hazard and disaster information where and when it is needed; 2) understand the natural processes that produce hazards; 3) develop hazard mitigation strategies and technologies; 4) recognize and reduce vulnerability of interdependent critical infrastructure; 5) assess disaster resilience using standard methods; and 6) promote risk-wise behavior.

In order to meet these challenges, SDR has developed a set of plans identifying the priority science and technology implementation actions needed for all major types of hazards. These documents are helping to shape sustained U.S. Government science and technology investments in disaster reduction and also can serve as a blueprint for international cooperation. Activities of the USGS Earthquake Hazards Program are highlighted as priority implementation actions in the earthquake implementation plan.

A draft NEHRP strategic plan that has been released for public comment identifies scenario development and full ANSS deployment as strategic priorities for the partnership.

The 2002 re-authorization of NEHRP established a committee to provide advice and guidance to the USGS Earthquake Hazards Program. Consisting of representatives from academic institutions, state government, and the private sector, the Scientific Earthquake Studies Advisory Committee provides outside guidance to the program. The committee's 2007 report to Congress and the USGS recommends additional investment in the ANSS, endorses the Multi-Hazards Demonstration Project in southern California and encourages its expansion nationally, encourages additional work into the episodic tremor and slip phenomenon, and cautions on a dwindling scientific workforce.

Conclusion

Infrequent, damaging earthquakes can be among the costliest natural disasters. While there is still much to learn about earthquakes, what we do know underscores the need for greater preparedness and mitigation in order to build a more resilient society. As a science agency, the USGS relies on a broad array of partnerships to move toward those goals.

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