Statement of
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before the
House Natural Resources Committee,
Subcommittee on Energy and Minerals
on
Advances in Earthquake Science: the 50th Anniversary of the Great Alaskan Quake
March 27, 2014

Chairman Lamborn, Congressman Holt, Members of the Subcommittee, thank you for this opportunity to discuss the significant advances in earthquake science that have been made in the past 50 years. The U.S. Geological Survey (USGS) is proud to be a partner with our State, university, private-sector, and Federal colleagues in the ongoing research and monitoring that are needed to strengthen the Nation's resilience to earthquakes and other hazards.

The Great Alaska earthquake and its legacy

The magnitude 9.2 Great Alaska Earthquake that struck south-central Alaska on Friday, March 27, 1964, is the largest recorded earthquake in U.S. history and the second-largest earthquake ever recorded. What became known as the “Good Friday” earthquake lasted nearly 5 minutes. To put that in perspective, the shaking lasted about as long as my oral remarks to you today. Alaska’s largest city, Anchorage, sustained heavy property damage—an estimated $2.3 billion in property losses (in 2013 dollars). Tsunamis generated by the earthquake caused deaths and damage as far away as Oregon and California. Altogether the earthquake and subsequent tsunamis resulted in 129 fatalities.

A major leap in scientific understanding followed the 1964 earthquake, including breakthroughs in earth science research, worldwide, that have continued over the past half-century since. At first, geologists did not know how such a huge earthquake could have happened, because the prevailing theories of the day could not explain such a large movement. So they examined the earthquake within the framework of a new theory, plate tectonics, which proposed that the crust of the Earth consists of about a dozen or so major plates that sit on top of the hot mantle below and slowly move past each other or collide. The 1964 Alaska earthquake provided compelling evidence for this theory, including observations that major plate subduction-zone earthquakes produce a pattern of uplift of the coastline and subsidence farther inland from the rupture—a pattern that gradually reverses over time, as continuing plate motion restores the Earth’s surface to its pre-earthquake state. This cyclic pattern was first revealed in U.S. Geological Survey (USGS) studies following the 1964 earthquake.

The 1964 earthquake also demonstrated that secondary faults that spread out or splay upward from the main rupture can accommodate much of the horizontal and vertical movement associated with the sudden plate motion. The resulting uplifts close to shore generated large tsunamis on the Kenai Peninsula near Seward and on Kodiak Island. This kind of secondary faulting likely also intensified near-field tsunami heights during the December 2004 Great Aceh-Andaman Earthquake and tsunami, which killed hundreds of thousands of people.

Catastrophic ground failure in the 1964 Alaska earthquake (and also in the Niigata, Japan, earthquake that same year) provided a new insight into the phenomenon of ‘liquefaction’ of sandy soils caused by earthquake shaking, which poses a major threat to the stability of buildings and other engineered structures. More than $30 million in damage was sustained by the Federally owned Alaska Railroad, from both liquefaction and tsunamis. Parts of the railroad were out of service for nearly 6 months. The 1964 Alaskan and Japanese earthquakes prompted extensive government-funded research by geotechnical engineers in both countries on the physics of liquefaction and implications for the stability of structures. Their findings led to the development of methods now used around the world by civil and structural engineers to ensure the safety of structures in earthquake-prone areas.

Tsunami damage from the 1964 Great Alaska Earthquake was much more widespread than shaking damage, striking both local coasts and ones thousands of miles away. The orientation of the 1964 fault rupture directed the tsunami southeastward toward the coastlines of Washington, Oregon, and California, where it caused extensive flooding and damaged harbors. Sixteen people died and the U.S. west coast sustained millions of dollars in damage. The 1964 earthquake led to the establishment of what is now the NOAA National Tsunami Warning Center (formerly the West Coast & Alaska Tsunami Warning Center).

In 1964, there were no seismic instruments in southern Alaska that were capable of recording the strong ground motions produced by the earthquake. Since then, in cooperation with the University of Alaska, the USGS has installed an extensive earthquake-monitoring network as part of the USGS Advanced National Seismic System (ANSS). The network in Alaska includes hundreds of modern seismic stations, and the city of Anchorage is now the most densely instrumented city in the country. Nationwide, the USGS now supports the operation of more than 2,700 seismic stations, while the Global Seismographic Network (GSN)—a joint program involving the USGS, the National Science Foundation, and the Incorporated Research Institutions for Seismology, IRIS)—provides worldwide coverage, supporting both tsunami warning and basic research in earth science.

The 1964 Alaska earthquake had at least three lasting effects on national earthquake safety policy. First, it showed how disruptive a major earthquake can be to modern society and its infrastructure. Second, it showed the complexity of earthquake effects (ground failures, tsunamis, ground shaking, etc.) that need to be addressed in any national mitigation policy. Third, through the iconic scenes of houses broken apart by landsliding at Anchorage’s Turnagain

Heights, the 1964 disaster demonstrated the importance of considering earthquake effects in urban planning and development. The 1964 Alaska earthquake laid the groundwork for the Earthquake Hazards Reduction Act of 1977, and the resulting National Earthquake Hazards Reduction Program (NEHRP), by forcing recognition that earthquake risk is a national issue. One of the more significant results to come out of this event was promoting earthquake-related research within what was then the U.S. Coast and Geodetic Survey and the USGS. These activities were merged into the USGS in 1972 and became central elements in our Nation's earthquake risk reduction strategy.

In addition to the 50-year milestone of the Great Alaska earthquake, this year marks the 20th anniversary of the Northridge earthquake that struck the greater Los Angeles area in 1994. The Northridge earthquake (M= 6.7) resulted in 57 deaths, thousands injured, and over $20 billion in direct damage. Prior to Hurricane Katrina, this moderate-size urban earthquake was the most costly disaster in U.S. history. It spurred important changes to the current practice of earthquake engineering and risk mitigation worldwide, including changes to building codes for steel structures and wood frame buildings, re-examination of the variability of earthquake motions, and radical modifications to the risk assessment and insurance sectors.

Also this year, the State of Alaska's disaster response exercise, Alaska Shield, commemorates the anniversary of the 1964 Great Alaska Earthquake by considering the effects of that earthquake and resulting tsunami were they to occur now. As a featured component of FEMA's National Exercise Program's Capstone 2014 Exercise, the Alaska Shield exercise offers Federal and State agencies a wide range of simulated activities designed to challenge and provide exceptional training for civilian and military first responders and to test organizational and integration skills at all levels of government. The USGS provided a calibrated, realistic earthquake simulation as the basis for modeling the impacts of a repeat of the 1964 earthquake and tsunami and is participating in the multi-agency response exercise.

In the Alaska Shield scenario, the calculated impacts of the earthquake and tsunami are truly staggering—as they are in many earthquake scenarios to which the USGS has contributed in recent years. Even though it has been two decades since a major earthquake disaster in the United States, the risks are very real, and the resilience of the Nation will be tested when—not if—the next earthquake disaster strikes.

The USGS within NEHRP

The USGS Earthquake Hazards Program (EHP) is the applied Earth science component of the four-agency National Earthquake Hazards Reduction Program (NEHRP, reauthorized by the Earthquake Hazards Reduction Authorization Act of 2004, P.L. 108–360). Led by the National Institute of Standards and Technology (NIST), the other NEHRP partners are the Federal Emergency Management Agency (FEMA) and the National Science Foundation (NSF). Within this partnership, the USGS provides the scientific information and knowledge necessary to reduce deaths, injuries, and economic losses from earthquakes and earthquake-induced tsunamis, landslides, and liquefaction. The USGS is the only Federal agency that routinely and continuously reports on current domestic and worldwide earthquake activity. Through its Advanced National Seismic System (ANSS), the USGS and its university partners monitor and report on earthquakes in all 50 States.

The EHP has four components: monitoring and reporting earthquake activity and crustal deformation; assessing and characterizing earthquake hazards; conducting and supporting targeted research into earthquake causes and effects; and conveying earthquake and safety information for loss reduction. All of these components heavily involve Federal, State, university, and private-sector partners.

Earthquake Monitoring—Delivering Rapid Information for Emergency Response

Within the NEHRP, the USGS has the lead Federal responsibility to provide earthquake advisories and notifications—including, where possible, forecasts and warnings. The USGS provides rapid reports of potentially damaging earthquakes to the White House; the Departments of Defense, Homeland Security (including FEMA), Transportation, Energy, Commerce, and the Interior; State, Tribal, and local emergency managers; numerous public and private critical 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 nearly 400,000 subscribers. The USGS also produces a full suite of situational awareness products, including maps of shaking intensity (ShakeMaps), estimates of facility-specific shaking and potential damage (ShakeCast), and prompt estimates of earthquake fatalities and economic losses (the PAGER product).

The technical foundation that allows the USGS to deliver these products is the ANSS. The Congressional reauthorization of the NEHRP in 2000 established the ANSS to modernize and expand the Nation's seismic monitoring infrastructure in order to improve the delivery of earthquake information to those who need it most. The ANSS consists of a national backbone network, regional networks operated by State and university partners, the USGS National Earthquake Information Center, and sensors installed in buildings, hospitals and bridges, concentrated in high-risk urban areas. Through investments since 2000, ANSS consists of more than 2,700 new and upgraded stations, of a total of 7,100 proposed for full implementation of the ANSS in USGS Circular 1188. These investments have greatly improved the information available for emergency responders, engineering performance studies, and long-term earthquake hazard assessments. A 2005 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.

Assessing the Nation's Earthquake Hazards

Earthquakes are a national challenge, with 75 million people living in moderate to high hazard areas stretched across 39 States. Recent earthquakes in Colorado, Oklahoma, Texas and Virginia have underscored the national nature of earthquake risk. One of the most important achievements that the NEHRP has made is the translation of research into models of the location and expected severity of earthquake shaking nationwide within specified time periods. These models are used to generate maps that are incorporated into the seismic safety elements of building codes and for other purposes. The maps are regularly updated with the best available science, including geologic information about known faults, evidence of prehistoric earthquakes, instrumental and historical earthquake catalogs generated by seismic monitoring, and ground deformation measurements. This year, the USGS will release the latest update of the National Seismic Hazard Maps; the maps and associated data are already seeing use within the engineering community.

The delivery of the updated seismic hazard maps is timed to fit into the development of the next edition of the triennially updated model building codes, a process that involves close cooperation among the USGS, FEMA, NIST, the Building Seismic Safety Council, the American Society of Civil Engineers (ASCE), the International Code Council, and other organizations. The USGS maps are the basis for seismic design maps in the FEMA/NEHRP Recommended Seismic Provisions, the ASCE 7 Standard for Minimum Design Loads, International Building Code, and the International Residential Code; these last two are model codes which have been adopted in almost every State. 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 USGS also works closely with the U.S. Nuclear Regulatory Commission on seismic safety of nuclear power plants, including review of seismic hazard assessments in license applications.

Targeted Research

USGS assessment and monitoring activities are supported by targeted geoscience research, the third major USGS responsibility within the NEHRP partnership. The USGS undertakes world-class research both through our research staff and through grants to and cooperative agreements with universities, State geological surveys, and geotechnical consultants. Proposals for these grants and cooperative agreements are submitted in response to an annual competitive funding opportunity that identifies the scientific problems on which the USGS seeks assistance and progress; each proposal is subjected to a rigorous peer-review process, and awards are made on the basis of merit. USGS-supported research is the bridge between the NSF's investments in fundamental research in science and engineering and more targeted investments that further develop and refine seismic hazard maps and rapid earthquake response products. Ongoing collaboration with the academic community is one of the great strengths of the USGS with regard to earthquake research. Two highly successful examples are the Southern California

Earthquake Center (SCEC), jointly supported by the USGS and NSF, and our decade-long research partnership with the NSF-funded EarthScope facility.

Induced Seismicity. Potentially damaging seismic events can be triggered by disposal of waste fluids from oil and gas production operations by injection into deep underground injection wells. Smaller earthquakes can also be triggered by enhanced geothermal energy production operations and, potentially, by the deep geologic sequestration of supercritical-phase carbon. While the basic geophysical mechanisms are well known, the specific subsurface conditions that are conducive to triggering are not, and it is not yet possible to make site-specific hazard predictions in advance. Thus, there is a need for more data and analysis to relate injection operations to induced seismicity, to connect these events to specific operational parameters and geologic conditions, and to develop monitoring and mitigation plans for decision-makers attempting to minimize seismic risks.

With the support of Congress and the Administration, the USGS is now working with the Department of Energy and the Environmental Protection Agency to undertake this research and working with industry on case studies that will illuminate the physical factors controlling induced earthquakes. Top-priority efforts are to develop methods to forecast whether or not a particular type of injection operation in a specified geologic setting would be likely to induce or trigger earthquakes, to perform comprehensive studies at two carefully selected field sites, and to establish procedures to adapt the National Seismic Hazard Maps to take account of the additional hazard due to earthquakes induced in association with wastewater from the production of oil and gas.

Conveying earthquake hazard and risk to the public

The USGS strives to make earthquake hazards understood through education and outreach products developed in concert with NEHRP, university, and local government partners, including the FEMA-funded National Earthquake Technical Assistance Program (NETAP), the FEMA-supported regional earthquake consortia; the NSF-supported IRIS consortium; and the SCEC university and government consortium. Millions of copies of earthquake preparedness handbooks have been distributed in California, Alaska, Tennessee, 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. Most recently, a version for the Central United States was published for the bicentennial commemoration of the New Madrid sequence of earthquakes, which rocked the U.S. heartland in the winter of 1811-12.

Scenarios have proven to be powerful tools for making earthquake hazards real to people ahead of a disaster. For example, last September the USGS released the SAFRR (Science Application for Risk Reduction) Tsunami Scenario report. A collaboration between the USGS, National Oceanic and Atmospheric Administration, California Geological Survey, and other entities, the document depicts a single realistic outcome of a hypothetical but likely large tsunami, generated by a large Alaskan earthquake and affecting the west coast of the United States, including Alaska and Hawaii. The scenario includes modeling of the earthquake source and tsunami waves, damage and restoration of the built environment, and social and economic impacts. The release was accompanied by a series of workshops held along the California coast, with members of the SAFRR Tsunami Scenario team presenting study results to stakeholders in coastal communities.

Last October, nearly 25 million people across the country and around the world participated in a "Great ShakeOut" earthquake drill. The ShakeOuts, which were started in 2008 through our partnership with SCEC, are an annual opportunity for people in homes, schools, and organizations to practice what to do during earthquakes and to improve preparedness. Since the first event in 2008, with FEMA support, the ShakeOut approach has "gone viral," having been adopted by most States and many countries. The ShakeOuts have led to a number of positive outcomes, including efforts to reduce lifeline vulnerability, retrofit critical structures, improve monitoring systems, and educate residents.

The NEHRP is also working to counter public misperceptions about earthquakes and paths to earthquake loss reduction. For example, there is a common misconception that "building for earthquakes" is very expensive. A recent analysis for NIST by the Applied Technology Council (ATC) evaluated the incremental cost of building to earthquake codes in Memphis, Tennessee. The study calculated that the additional costs of building for earthquakes (by complying with current codes and standards) ranged from just one-half percent to 2.8%, depending on the type of construction. This surprisingly low added cost has important implications nationally, as there are many areas of moderate earthquake risk where seismic building codes have previously been considered the domain of Western States and wrongly supposed to be unaffordable.

Opportunities

Earthquake Early Warning: The next advance in public safety

Modern seismic networks can, in favorable circumstances, provide seconds to a minute or more of warning before the onset of strong shaking, enabling Earthquake Early Warning (EEW). Over the past 11 years, the USGS has invested nearly $10 million in both research and development toward establishing an earthquake early warning capability in California. Funds from the 2009 American Recovery and Reinvestment Act were used in 2010 and 2011 to support the modernization of seismic instrumentation necessary to support the generation of warnings. A test system is operating now; two of the university partners (CalTech and U.C. Berkeley) have been delivering warnings to a small group of test users since January 2011.

However, the current test system is still in the development phase, and considerable additional investment must be made to create a robust and reliable operational warning system. Further work is needed to demonstrate reliability, improve accuracy, establish products for public warning, and expand geographic coverage. The additional funding for EEW that was appropriated by Congress in FY 2014 is being used to complete the R&D phase for the seismic system (an effort that is jointly supported by the Gordon and Betty Moore Foundation) and to improve the operational robustness of the system. The next steps will require expanding coverage throughout California, Oregon, and Washington, fully integrating GPS into the EEW system, and operating the system continuously, 24x7.

A specific, life-saving application of earthquake early warning, not yet realized in the United States, is to provide alerts during post-disaster search-and-rescue (SAR) operations. After a major urban earthquake, SAR teams are always at risk during extended aftershock sequences, when a large aftershock may collapse already damaged buildings and other structures. Once a basic public early warning system is in place, that system can greatly enhance the safety of rescue workers during the operational rescue period, as well as construction workers during the recovery-and-restoration period.

Toward an EarthScope Legacy

EarthScope is a science facility and integrated research program funded by the National Science Foundation, with support contributed by the USGS. It consists of multi-disciplinary observatories that use a wide variety of geophysical instrumentation—seismic, geodetic, imaging and geologic. EarthScope is yielding a comprehensive, time-dependent picture of the North American continent beyond that which any single discipline can achieve. Data obtained from these observatories are allowing scientists to describe how geological forces shaped our landscape and are contributing to the public's understanding of our dynamic Earth.

By the end of 2013, the Transportable Array (TA), a massive array of portable seismometers that is part of the EarthScope facility, had moved into the Eastern United States. Also in 2013, the National Science Foundation began to invest in a cooperative project with USGS and IRIS to operate 150-200 of the TA stations in the East long-term, through at least 2017 if possible. Both NSF and the USGS are investing in this project in 2014: Of the additional funding that was appropriated to the USGS by Congress in FY 2014 for ANSS products and Central and Eastern U.S. monitoring, a portion is being used to extend NSF's investment and, over time, begin to transfer operations of the TA stations to the USGS—that is, making the current resource a permanent feature of the USGS's Advanced National Seismic System and contributing to the broader range of NEHRP objectives.

Conclusion

Giant earthquakes like the one that struck Alaska 50 years ago produce ground shaking of long duration that can trigger soil liquefaction, landslides, and lateral spreading—these occur in predictable locations. Likewise, areas of high tsunami run-up can be estimated in advance. Thus, modern earthquake and tsunami planning scenarios allow emergency responders and community planners much improved visions of what could be expected in a future disaster. Situational awareness tools, such as those provided by ANSS, can expedite response and recovery after such an event occurs. However, rapid earthquake loss assessments are still unacceptably uncertain because of sparse seismic station coverage in many areas (ANSS is only one-third completed), a limited inventory of the built environment, and uncertainly about how buildings and infrastructure respond to extended strong shaking. The next step in public safety—earthquake early warning—is already under development by the USGS and partners, and a test system is operating successfully in California.

I appreciate the opportunity to discuss the vital earthquake research and monitoring that the USGS and our partners are doing. These efforts over the past 50 years have made the Nation and the world safer and stronger. I am confident that the future of earthquake science holds further advances that we can only imagine today.

I would be pleased to answer any questions that you or the other Members may have.

For More Information

The Great Alaska Earthquake of 1964 http://earthquake.usgs.gov/earthquakes/events/alaska1964/

USGS Earthquake Hazards Program http://earthquake.usgs.gov/

The National Earthquake Hazards Reduction Program http://www.nehrp.gov/

FEMA Earthquake Resources http://fema.gov/earthquake

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