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ADVANCES IN EARTHQUAKE SCIENCE: 50TH ANNIVERSARY OF THE GREAT ALASKAN QUAKE

U.S. HOUSE OF REPRESENTATIVES, COMMITTEE ON NATURAL RESOURCES, SUBCOMMITTEE ON ENERGY AND MINERAL RESOURCES

ONE HUNDRED THIRTEENTH CONGRESS, SECOND SESSION

HEARING CONTENTS:

OPENING STATEMENT:

Honorable Doug Lamborn *[view PDF]*
Chairman, House Subcommittee on Energy and Mineral Resources

WITNESSES:

Dr. William Leith *[view PDF]*
Senior Science Advisor for Earthquake and Geologic Hazards, U.S. Geological Survey

Dr. Lisa Grant Ludwig *[view PDF]*
President-Elect, Seismological Society of America
Graduate Director, Program in Public Health, University of California, Irvine

Dr. John Vidale *[view PDF]*
Director, Pacific Northwest Seismic Network
Professor, Department of Earth and Space Sciences, University of Washington

Dr. Reginald DesRoches *[view PDF]*
School of Civil & Environmental Engineering, Georgia Institute of Technology

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Opening Statement of

Chairman Doug Lamborn

Subcommittee on Energy & Mineral Resources

On Thursday, March 27, 2014

1324 Longworth House Office Building Subcommittee Oversight Hearing on

"Advances in Earthquake Science: 50th Anniversary of the Great Alaskan Quake"

Today marks the fiftieth anniversary of the Good Friday Great Alaska Earthquake. It was a massive 9.2 magnitude quake making it the second largest earthquake ever recorded with 'modern' seismic equipment, and the largest in the US.

Technically, the earthquake occurred in the Aleutian Trench 'subduction zone' – although at the time the earthquake occurred 'subduction zone' was not a part of the geologic lexicon. The rupture occurred along a 580 mile stretch of the fault and lasted between 4 and 5 minutes. The earthquake caused the greatest amount of vertical uplift ever measured, almost 34 feet, and Southern Alaska moved more than 65 feet seaward. The earthquake also caused the largest tsunami to ever hit the west coast of the United States and Canada with the largest wave, 222 feet high, hitting Valdez at Shoup Bay.

In all, the earthquake and ensuing tsunamis and landslides, caused 129 fatalities in Alaska, Oregon, and California. More than 70 percent of the deaths were actually a result of the tsunamis and not the actual quake.

The town of Valdez was destroyed and 30 people lost their lives, many of them children that had come down to the dock to meet the freight ship Chena that was delivering the first fresh fruits and vegetables of the year. As tradition would have it the Chena crew would toss fruit to the children that had come to meet the ship.

Two crew members were filming the festivities when the earthquake hit – they captured the destruction on film.

The Great Alaskan Earthquake is one of the most studied natural disasters. The Federal response was significant not only in economic relief and reconstruction but also research.

Geologists from the USGS were some of the first geoscientists on site conducting field mapping, surveys, and taking core samples. Their findings were published in a series of six professional papers and The National Academy of Sciences published eight volumes of scientific research.

Research on the quake made significant contributions to the emerging theory of 'Plate Tectonics'.

Today earth scientists recognize that the earthquake resulted from the convergence of the North American Plate overriding the Pacific Plate where it is being subducted into the earth's mantle along the Aleutian trench.

According to the USGS, knowledge gained from the research conducted on the Alaska quake has provided the geologic framework for assessing the earthquake and tsunami hazards at convergent plate margins around the world.

Many other contributions to earthquake science and hazard reduction were also made that provided geoscientists with tools they could use to identify other plate boundaries that have had major ruptures in the past and are susceptible to future ruptures such as the Cascadia structure in the Pacific Northwest.

Hazards caused by movement on secondary fault structures, a better understanding of liquefaction, a better understanding of earthquake hazards in general, and tsunami hazards assessments and warnings.

As was evident in the Great Alaska quake and others that we have experienced in 50 years since, death and destruction from the Tsunamis can be greater and more widespread than damage caused by the shaking and the tsunami can happen thousands of miles for the epicenter of the earthquake.

In recent years, massive earthquakes and tsunamis have wracked devastation across Indonesia, Japan, Chile and Haiti. But in each of these massive movements of the earth, there are lessons.

Earthquakes in Haiti and Chile while nearly the same size cause massive differences in deaths and damage. Much of the difference is the direct result of efforts to establish standards and mitigation of earthquake hazards.

In Japan, the early warning system allowed the Japanese transit system to shut down every train so not a single derailment occurred as a result of the Honshu quake.

Today we are here to remember those who lost their lives in the Great Alaska Quake. We are to remind ourselves that we cannot be compliant in protecting against hazards and remind ourselves that the advancement of science depends on our vigilance.

I would like to thank our witnesses for being here today. I look forward to hearing their thoughts on advances in earthquake science over the past fifty years.

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Statement of
Dr. William Leith
Senior Science Advisor for Earthquake and Geologic Hazards
U.S. Geological Survey
U.S. Department of the Interior
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

<u>Earthquake Early Warning: The next advance in public safety</u>

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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TESTIMONY OF DR. LISA GRANT LUDWIG
PRESIDENT-ELECT OF THE SEISMOLOGICAL SOCIETY OF AMERICA
PROFESSOR OF PUBLIC HEALTH, UNIVERSITY OF CALIFORNIA, IRVINE
BEFORE THE SUBCOMMITTEE ON ENERGY AND MINERAL RESOURCES
COMMITTEE ON NATURAL RESOURCES
U.S. HOUSE OF REPRESENTATIVES
THURSDAY MARCH 27, 2014

Chairman Lamborn, Ranking Member Holt, and Members of the Subcommittee, thank you for inviting me to testify on "Advances in Earthquake Science: 50th Anniversary of the Great Alaskan Quake". As a Professor at University of California Irvine, I am one of millions of US residents who lives with earthquake risk every day. Today I speak primarily as President-Elect of the Seismological Society of America (SSA), which was founded after the devastating 1906 San Francisco earthquake and is now the largest and most respected society of seismologists in the world. The core purpose of SSA is to advance seismology and the understanding of earthquakes for the benefit of society.

My message is threefold:

- In the 50 years since the Great Alaskan Earthquake, there has been a scientific revolution in understanding of earthquakes.
- Federal investment in science has been directly responsible for tremendous advances in understanding earthquakes and the threat they pose to society.
- This investment has yielded valuable returns that benefit society by helping us to become an earthquake resilient nation.

Let me begin with the Great Alaskan Earthquake on Good Friday 1964. I've heard the stories many times from extended family. Donna Grant was shopping in downtown Anchorage when the earthquake struck. As buildings collapsed in front of her and chasms opened in the street, she grabbed a parking meter and "hung on for dear life". The shaking lasted for nearly 5 minutes and she had time to think: it was the beginning of World War III and the end of the world as she knew it. Her experience is important because it illustrates the link between earthquake science and national security. When downtown Anchorage was collapsing around her, neither Donna Grant nor anyone else, knew it was caused by a megathrust earthquake due to subduction of the Pacific plate beneath North America. In 1964, the World-Wide Seismographic Network (WWSN), which had been emplaced for monitoring nuclear weapons testing in the cold war, was also collecting earthquake data, and this data was critical to the breakthrough discovery of plate tectonics.

We now know that she experienced the most powerful recorded earthquake in U.S. history and the second largest of all time. The Alaskan earthquake was so large, at Magnitude 9.2, that seismologists had to develop a new scale to measure it. The earthquake generated a tsunami with peak height of 220 feet in Valdez Alaska, which affected the entire west coast and Hawaii, causing significant damage. The recent, widely televised Japanese tsunami in 2011 provides a vivid illustration of the devastation that can follow a major subduction zone earthquake, and the need to protect our nation from similar future events.

The development of plate tectonics, a product of seismic monitoring and geological studies, also provided a powerful tool for identifying areas that are most susceptible to earthquakes. The greatest concentration of earthquakes, and the greatest earthquake hazard, occurs at the plate boundaries. These plate boundaries have been imaged by seismologists, and mapped by geologists. Modern seismic instruments and sophisticated digital data processing methods allow the locations of earthquakes of all sizes to be precisely determined. The methods and technology are similar to ultrasound instruments commonly used in medical imaging and diagnosis. The earthquake locations reveal the presence of active faults within the Earth's crust. Some faults that reach the surface, such as the San Andreas fault in California, can be further investigated by geologists, or paleoseismologists, to determine their past earthquake history, and their potential to produce future earthquakes. For example, research on the San Andreas fault conducted by myself and others, has shown that the average time between surface-rupturing earthquakes is about a century. These findings are a call to action. The last two "Big Ones" on the San Andreas fault, in 1906 and 1857 in northern and southern California, respectively, occurred more than a century ago, so it is important to prepare for the next one. I have become so concerned about the implications for my own community that I joined UC Irvine's Program in Public Health to work on protecting health and safety in addition to conducting earthquake science research.

Earthquakes are not just a California problem. Research in paleoseismology, the study of prehistoric earthquakes using geologic methods and advanced dating techniques such as high resolution radiocarbon dating, has revealed much about the potential for large earthquakes in many seismically active regions. In Alaska, huge earthquakes similar to the 1964 quake have occurred, on average, hundreds of years apart. Similar research along the coast of Washington, Oregon and northern California has shown that large subduction zone earthquakes have occurred every few centuries, and the last great earthquake on the Cascadia subduction zone occurred in 1700.

The old saying "those who ignore history are condemned to repeat it" should not apply to earthquake hazard in the US because we now know, as a direct result of federally supported research and seismic monitoring, that we have a significant earthquake problem. We also have the scientific knowledge and technological tools to develop an earthquake resilient nation. We know the areas that are most likely to be affected, and the type of earthquakes that are most

likely to occur. For example, many researchers are working on simulating earthquakes and developing scenarios that can be used for planning and preparation. Advanced computing technologies and access to supercomputers have enabled calculation of expected shaking from earthquakes on the San Andreas fault, the Cascadia subduction zone, and other important fault zones. The Great Southern California ShakeOut earthquake preparedness exercise which started in 2008 to prepare for the "Big One" on the San Andreas fault, has expanded into annual earthquake preparedness drills throughout seismically active areas of the US, and the world, with approximately 25 million participants last year. Earthquake data collected by the USGS, university researchers, and others, are used for development of National Seismic Hazard Maps which are incorporated into building codes for earthquake-resistant design.

Unfortunately, earthquakes cannot be prevented. We can trigger them, but we cannot stop them. In my opinion, we must protect ourselves from this natural terrorist beneath our feet. Congress is our first line of defense, through support of a real-time Earthquake Early Warning (EEW) system, continued funding of the Advanced National Seismic System (ANSS), and reauthorization of the National Earthquake Hazard Reduction Program (NEHRP) with appropriation of funds at levels that reflect the significant threat that earthquakes pose to our national security. EEW is a proven technology for alerting communities in advance of strong shaking, and EEW systems have already been deployed in Japan and other countries, but not yet in the U.S. Created by Congress in 1977, NEHRP has provided the resources and leadership that have led to significant advances in understanding the risk earthquakes pose and the best ways to counter them. Through NEHRP, the federal government and university partners have engaged in seismic monitoring, mapping, research, testing, engineering and related activities for building code development, mitigation, and emergency preparedness. NEHRP has served as the backbone for protecting U.S. citizens, their property and the national economy from the devastating effects of large earthquakes. Although NEHRP is well known for its research programs, it is also the source for hundreds of new technologies, maps, design techniques, and standards that are used by design professionals every day to mitigate risks and save lives, protect property, and reduce adverse economic impacts.

NEHRP makes Americans safer and our Nation more secure and financially stronger by implementing the results and insight from research in the earth and behavioral sciences, public policy, and engineering. NEHRP was reauthorized by Public Law 108-360 in 2004. However, this authorization expired in October of 2009, a few months before the devastating Haiti earthquake. As Chairman Lamborn pointed out in his statement on March 9, 2011 "...earthquakes can and do kill hundreds of thousands of people, in the case of Haiti a magnitude 7 earthquake killed over 230,000 people." The tragedy in Haiti was surprising to many outside the community of earthquake scientists, but it was well known among seismologists that Haiti is on a seismically active plate boundary and susceptible to earthquakes. Such knowledge is powerful if it is acted upon. I am here today to tell you that federal investment in earthquake science has given us the

knowledge we need to protect ourselves from the type of tragedy we saw in Haiti. But in science, as in life, you get what you pay for. It is in the best interest of our nation to invest in earthquake science and to continue working toward our common goal of becoming an earthquake resilient nation.

I would like to close by expressing my sincere thanks to the committee for inviting me to testify about this important and urgent problem.

Written testimony of
John E. Vidale, Ph.D.
Director, Pacific Northwest Seismic Network
Professor, Department of Earth and Space Sciences, University of Washington
Washington State Seismologist

Hearing on:
Advances in Earthquake Science: 50th Anniversary of the Great Alaskan Quake

Before the United States House Committee on Natural Resources,
Subcommittee on Energy and Mineral Resources

March 27th, 2014

Good morning Chairman Lamborn, Ranking Member Holt and members of the subcommittee. I appreciate the opportunity to speak to you this morning about our nation's earthquake history, the progress we have made in blunting the dangers posed by earthquakes, and a proposed path forward to safeguard the future of our nation, specifically the West Coast. In particular, I would like to address the situation in the Pacific Northwest, where a major earthquake will one day occur that is much like the 1964 Great Alaska earthquake. My name is John Vidale. I am the Washington State Seismologist, and a Professor in the University of Washington's College of the Environment, and director of the Pacific Northwest Seismic Network. I am responsible for reporting on significant seismic events in Washington and Oregon, and work with city planners, engineers and emergency managers to mitigate seismic hazard, and conduct basic earthquake research.

Background: Great subduction earthquakes

While many earthquakes are great in the sense of tragic to the public, only those with magnitude bigger than 8 receive the title "great" from the experts. This lofty status leaves out, for example, the deadly Haiti quake of 2010 (M7.0), the earthquake that leveled Christchurch in 2011 (M6.3), and even the 1906 San Francisco earthquake (M7.8).

The 1964 earthquake in Alaska that we are discussing is even one step larger, an M9, with vastly wider reach and nearly unimaginable power. These M9 earthquakes threaten only two places in the US – Alaska and the Pacific Northwest coast – and only the Pacific Northwest is heavily populated and industrialized.

The M9 coming to the Pacific Northwest might not come for centuries or it might come tomorrow, but it is overripe. More than 300 years after the last great earthquake, we are within its likely window of recurrence, and we know that enough energy has already built up as strain in the rocks around the fault to power an M9. When it comes, the severely shaken region will extend from northern California up the coast to Canada, including the entire coastlines of Oregon and

Washington. An M9 would wallop the Willamette Valley and the Puget Sound, devastating the urban populations and menacing the economic well-being of Portland and Seattle.

To address this devastation, I would like to highlight two special opportunities; earthquake early warning and seafloor monitoring, and discuss why the Cascadia subduction zone needs to be a special focus, and argue the strong motivation to strengthen the National Earthquake Hazard Reduction Program.

Earthquake early warning (EEW) for the West Coast

One new advance in earthquake research is the development of Earthquake Early Warning systems (EEW). These use seismometers and GPS monitors to recognize an earthquake within a few seconds, then broadcast a warning that shaking is coming to vulnerable areas. The system requires delicate instruments, fast communications, and well-tested evaluation and notification protocols, but in essence it is very simple and well established; it is not rocket science. These warnings will be disseminated to the public via text messages and other public emergency broadcast systems.

Our opinion at the Pacific Northwest Seismic Network (PNSN) is that high-performance EEW for the US West Coast is at most 5 years away, and once it is here, its value will be clear to all. An EEW system would provide several key advantages that help to mitigate earthquake risks and public apprehension. In terms of life safety, an early warning will stop trains to prevent derailments, abort airport take-offs and landings, halt surgeries, allow for bridges to clear, shutdown elevators, open critical doors, warn schools and the population in general, and allow for faster tsunami warnings.

In the private sector, companies can mitigate losses by battening down factories, fortifying and shifting computer operations, and shutting off pipelines.

Emergency responders can jump-start emergency operations while mass communications still work, and maps of predicted devastation can be more quickly and effectively disseminated.

The sooner it is implemented, the sooner we can reassure the people and corporations that we are taking all prudent steps to reduce earthquake vulnerability. The longer EEW has been in operation and proven to work, the broader will be the range and effectiveness of the mitigation steps it enables.

An EEW system is ideally suited for the impending M9 on the Pacific Northwest coast. The earthquake will rupture along more than 600 miles of coastline, with the ground breaking for four to six minutes or more.

Depending on whether the earthquake starts near or far from critical spots like Portland or Seattle, we expect one to five or more minutes of warning time prior to

the arrival of the severe shaking. We would also gain valuable extra minutes and accuracy in tsunami warnings.

Many other countries exposed to earthquakes have already built EEW systems, including Mexico, Korea and Romania. Japan is spending upwards of $1 billion on their monitoring and warning system, and China and Taiwan hundreds of millions of dollars. Active systems in Japan and Mexico have already demonstrated the practicality of these systems. The 2011 M9 Tohoku earthquake provided clear evidence of strong benefits of EEW for both preparing for shaking and very quick warning of tsunami risk.

The USGS has made a detailed implementation plan for EEW for the entire West Coast, finding that $16.1 million per year would build and operate a system, providing warning for the most dangerous regional faults. In the meantime, the regional seismic networks run from Caltech, UC Berkeley, and the University of Washington have been experimenting with prototype EEW systems.

The next step - monitoring of the seafloor

In the Pacific Northwest, the performance of the EEW system would be greatly bolstered by adding seismic instrumentation offshore, on the seafloor, where the unfolding magnitude 9 earthquake could be most quickly and accurately observed. This information would increase the warning time and make warnings more accurate. The offshore instruments would also watch for long-term signs of tectonic unrest, and accelerate scientific research and hazard mitigation.

The technology for ocean bottom seismometers and water pressure sensors is well established. By attaching these instruments to a cable system, the data would reach processing centers immediately. Methods for recording long-term seafloor motion under the sea, such as GPS, are more difficult to implement, and are the subject of instrument development.

Again, Japan is now spending close to $1 billion to monitor on the seafloor their faults that generate great earthquakes; we should do likewise. Japan is partly motivated by the observation that during the 2 days before their great earthquake, unusual motions of the seafloor were seen, and could only be seen with seafloor instruments. The University of Oregon, Oregon State University, and the University of Washington have scientists and technicians who are experts in these issues, and are poised to move us forward.

Important to devote adequate attention to Cascadia

The annual expected loss from all earthquakes in Oregon and Washington is $1 billion a year, a large fraction of the total exposure for the United States. The discovery of the risk is recent, with the seismogenic nature of the Cascadia Fault first appreciated in the 1990's, and the dangers of the Seattle Fault and other activity along the I-5 corridor from Vancouver to Portland coming even more

recently. We do not have the many-decades history of study enjoyed by the San Andreas system and some fault systems farther east. Worse, much of the evidence is hidden in forests or under miles of ocean, or wiped clean by the glaciers that have scoured the Pacific Northwest landscape. Our most frequent strong earthquakes are tens of miles deep, tied to no fault at the surface that can be mapped.

The USGS should devote **sufficient resources to identify and quantify earthquake risk in the Pacific Northwest**. The largest earthquake scientists expect in the Pacific Northwest will be 30 times more energetic than the largest anticipated earthquake in California. Our problem is not simply an extension of San Andreas faulting, and needs more devoted study within the region.

A strong NEHRP (National Earthquake Hazard Reduction Program) is imperative

One lesson from recent earthquakes is that research into earthquake hazard is not yet complete. Each earthquake has come with a deadly and expensive surprise. 1996 Kobe brought fire and liquefaction of port facilities, 2004 Sumatra and 2011 Japan disobeyed geological wisdom in important ways, 2011 Japan also uncovered poorly designed reactors, 2011 Christchurch unexpectedly knocked out New Zealand's second largest city with downtown liquefaction.

Our cities in America have not been tested since the relatively mild 1994 Northridge earthquake. The next major event that occurs beneath one of our cities will surely present a nasty surprise, and continued investment in earthquake mitigation research through the USGS (US Geological Survey) and NEHRP will pay dividends many times over.

Reauthorization of NEHRP is needed to assure continued effort to characterize poorly understand hazards. The funding level should be high enough to accommodate new developments such at earthquake early warning and seafloor monitoring. The level should be at least at high as the previous levels, most recently set in 2010. We should not make the mistake of forgetting about the earthquake threat because it has been 20 years since the last urban US earthquake.

Summary

The Great Alaska Earthquake of 1964 is a forerunner of an eventual plate boundary earthquake in the Pacific Northwest. To responsibly prepare, we should build an earthquake early warning system, design and emplace seafloor monitoring, maintain a vigorous earthquake science and engineering effort within the Pacific Northwest, and this also requires a re-authorized strong NEHRP program.

Reginald DesRoches, Ph.D.
Karen and John Huff Chair and Professor
School of Civil & Environmental Engineering
Georgia Institute of Technology

Committee on Natural Resources, Subcommittee on Energy and Mineral Resources

Hearing on

"Advances in Earthquake Science: 50th Anniversary of the Great Alaskan Quake."

The 1964 magnitude 9.2 Alaska earthquake will forever be remembered for its size (the largest earthquake ever recorded in the US), duration (over 4 minutes of strong shaking) and the widespread damage (impacting 50,000-100,000 square miles, 131 casualties, and economic losses of $2.5 billion in today's dollar). The 50 years following this earthquake has marked an unprecedented period of great progress in our understanding of earthquakes and how to build to minimize the impact of earthquakes. As a result, we are much more prepared, much safer and much more resilient; however, more can be done to protect our infrastructure. Below, I highlight the areas where we have seen significant progress in the last 50 years.

Building Codes & Design

Building codes were woefully inadequate at the time of the 1964 Alaska Earthquake. Buildings that were designed and built 50 years ago would likely sustain damage in a moderate to large earthquake. Although building codes are updated frequently, some of the most significant changes have occurred after major earthquakes identified or emphasized structural deficiencies. The 1971 San Fernando and 1994 Northridge earthquakes were two such landmarks in terms of building codes.

Advances in structural dynamics by the late 1960s encouraged structural engineers to consider not only seismic forces, but also the movement or "ductility" a structure must undergo in an earthquake. Ductility - the ability to bend without breaking – was recognized as the key to earthquake resistant design. Buildings without ductility can exhibit brittle failures resulting in building collapse. Studies and lab tests by researchers demonstrated that good detailing – for example, the placement of steel reinforcement in the right quantity and location - was critical and could provide sufficient ductility in concrete structures.

Retrofitting

A large percentage of the built infrastructure was designed and constructed prior to the introduction of modern seismic codes which were introduced in the early-to-late 1970s. These structures are highly vulnerable to damage or destruction in earthquakes. Seismic

retrofit (or rehabilitation) strategies have been developed to reduce the vulnerability of homes, buildings, and other infrastructure exposed to earthquakes. Coupled with the development of retrofit systems was the development and use of earthquake protection systems (isolators, energy dissipators). These systems offer vastly improved performance over conventional design for buildings and bridges, not just life-safety but continued functionality.

Significant efforts from the research community have been focused on developing and testing effective retrofit approaches on buildings, bridges, and other infrastructure types. These studies have been instrumental in developing new approaches for retrofit and improving existing approaches. Many of the approaches for retrofitting used today were developed using National Earthquake Hazards Reduction Program (NEHRP) resources.

Seismic retrofitting of vulnerable structures is critical to reducing risk. It is important for protecting the lives and assets of building occupants and the continuity of their work. On the whole, communities with retrofitted structures are less likely to sustain significant loss-of-life or injuries, will be more resilient and will recover from earthquakes more rapidly. Businesses that use retrofitted buildings are more likely to survive damaging earthquakes and to sustain shorter business interruptions.

Seismic Design and Retrofitting Works!

The impact of the improvements to building codes and retrofitting technologies could be seen in the 1987 Whittier Quake, 1991 Sierra Madre Quake, 1992 Landers Quake, 1989 Loma Prieta, and 1994 Northridge Quake. Los Angeles city officials say that more than 200,000 people were living in retrofitted brick buildings when the Northridge Quake hit. Not a single death or injury was reported from more than 37,000 units in 1,300 strengthened buildings. The structures that were built or strengthened under the new, stricter code experienced limited damage, while those structures that had not been retrofitted suffered greater damage.

Public Policies

Significant progress has been made in the area of public policy as it relates to earthquakes. Public policies regarding performance of hospitals, emergency operations centers, city halls, and schools didn't exist 50 years ago. The lack of safety of another class of existing structures became a prominent policy consideration following the 1971 San Fernando Earthquake. Several hospitals, including the Veteran Administration and the Olive View Hospitals, collapsed in the earthquake; 44 people died at the VA hospital alone. As a result, the 1973 California State Alquist Hospital Safety Act mandated that new hospital structures have higher seismic safety standards.

California Senate Bill 1953, passed in 1994, required that acute care facilities built before 1973 (including approximately 474 buildings) be upgraded to certain standards. According to the legislation, by 2008, these structures should not pose a significant threat to life; by

2030, hospitals are to be retrofitted to a level capable of providing services to the public after disasters.

Education and Training

In 1964, the only earthquake engineers were in California, Japan and Mexico. Now, earthquake engineering is taught all over the country, including schools in states that are not traditionally thought of as being in a seismic zone, such at Georgia Tech. In fact, just this week, researchers at Georgia Tech are conducting one of the largest seismic retrofit studies ever conducted right in the middle of downtown Atlanta - to develop and validate cost effective retrofits for unsafe reinforced concrete buildings. This project, along with hundreds of others, would not be possible without the continued support of the National Earthquake Hazards Reduction Program, specifically the Network for Earthquake Engineering Simulation (NEES)Program. The NEES Program has made a number of unique studies a reality. From large scale testing of the California levee system to testing of buried pipelines, the NEES program has provided the research community with the opportunity to test a range of systems in a fashion that we could not even imagine 50 years ago.

Finally, I would like to reiterate that we still have more work to do to prepare for the impact of earthquakes. There exists thousands of vulnerable buildings and critical infrastructure systems in areas moderate-to-high seismic zones. Identifying and finding cost-effective retrofit approaches before an earthquake strikes is critical. However, the American people are safer, and our cities more resilient socially and economically, than we were 50 years ago. This is a direct result of NEHRP-funded research, knowledge transfer, and education/outreach programs.

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is a shared-use network that features 14 advanced experimental equipment sites and field stations. They are linked by a robust cyberinfrastructure, the NEEShub at nees.org, which includes a central data repository, simulation, and collaborative capabilities. Sponsored by the National Science Foundation (NSF), NEES is dedicated to the mitigation of earthquake and tsunami risks. Researchers, educators, students, practitioners, academic institutions, partnering organizations, and funding agencies collaborate through NEES to advance and disseminate mitigation knowledge and strategies.

NEEScomm, the NEES operation, cyberinfrastructure, and education and outreach headquarters at Purdue University, is dedicated to serving the community through effective stewardship, deploying robust user-requirements driven cyberinfrastructure, and providing leadership in network-wide education and outreach activities.

The NEES program is authorized by Act of Congress under the National Earthquake Hazards Reduction Program (NEHRP). NEEScomm is supported by the National Science Foundation, Dr. Joy M. Pauschke, NSF Program Coordinator, through cooperative agreement number: CMMI-0927178.

Visit http://nees.org for more information.

National Earthquake Hazards Reduction Program

The National Earthquake Hazards Reduction Program (NEHRP) was established by the U.S. Congress when it passed the Earthquake Hazards Reduction Act of 1977, Public Law (PL) 95–124. At the time of its creation, Congress' stated purpose for NEHRP was "to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." In establishing NEHRP, Congress recognized that earthquake-related losses could be reduced through improved design and construction methods and practices, land use controls and redevelopment, prediction techniques and early-warning systems, coordinated emergency preparedness plans, and public education and involvement programs.

Since NEHRP's creation, it has become the Federal government's coordinated long-term nationwide program to reduce risks to life and property in the United States that result from earthquakes. Since NEHRP's 1977 beginnings, Congress has periodically reviewed and reauthorized NEHRP (1980, 1981, 1983, 1984, 1985, 1988, 1990, 1994, 1997, 2000, and 2004.) While changes have occurred in program details in some of the reauthorizations, the four basic NEHRP goals remain unchanged:

- Develop effective practices and policies for earthquake loss reduction and accelerate their implementation.
- Improve techniques for reducing earthquake vulnerabilities of facilities and systems.
- Improve earthquake hazards identification and risk assessment methods, and their use.
- Improve the understanding of earthquakes and their effects.

In its initial NEHRP authorization in 1977, and in subsequent reauthorizations, Congress has recognized that several key Federal agencies can contribute to earthquake mitigation efforts. Today, there are four primary NEHRP agencies:

- Federal Emergency Management Agency (FEMA) of the Department of Homeland Security
- National Institute of Standards and Technology (NIST) of the Department of Commerce (NIST is the lead NEHRP agency)
- National Science Foundation (NSF)
- United States Geological Survey (USGS) of the Department of the Interior