
# Annual Report
# of the
# National Earthquake Hazards Reduction Program
# for Fiscal Year 2011

**September 2012**




This report about the National Earthquake Hazards Reduction Program (NEHRP) during fiscal year 2011 is submitted to Congress by the Interagency Coordinating Committee of NEHRP, as required by the Earthquake Hazards Reduction Program Reauthorization Act of 2004 (42 U.S.C. 7701 et. seq., as amended by Public Law 108–360).

**The members of the Interagency Coordinating Committee are as follows:**

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# Executive Summary

This is the annual report of the National Earthquake Hazards Reduction Program (NEHRP) for fiscal year (FY) 2011,[1] presented by the NEHRP Interagency Coordinating Committee (ICC). This report, required by Public Law 108–360, describes the 2011 activities of the NEHRP agencies, and their progress toward reducing the impacts of future earthquakes in the United States. The report also lists program budgets for FY 2012 and those proposed for FY 2013.

The four Federal agencies participating in NEHRP are the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). NIST serves as the NEHRP lead agency and the Director of NIST chairs the ICC. Within NEHRP, the participating agencies have distinct roles and responsibilities that are mutually dependent and supportive.

The NEHRP ICC is composed of the Administrator of FEMA, the Directors of NIST, NSF, and USGS, and the Directors of the White House Office of Science and Technology Policy and Office of Management and Budget.

Significant activities and accomplishments of NEHRP in 2011 are outlined briefly below.

## National Research Council Study on Implementation of NEHRP Strategic Plan

In March 2011, the National Research Council of the National Academy of Sciences completed a study and released a report entitled "National Earthquake Resilience: Research, Implementation, and Outreach" (2011).[2] The study was conducted by an independent group of experts representing the fields of earth sciences, engineering, social sciences, and public earthquake safety policy. The study report endorses the NEHRP strategic plan[3] and presents a 20-year road map for implementing the plan and achieving the NEHRP vision of national earthquake resilience. The report identifies 18 specific task elements required to improve national earthquake resilience, and independently estimates the annual costs of implementing the road map. The study and report were sponsored by NIST pursuant to its role as NEHRP lead agency.

## Earthquake Hazards in the Central United States

NEHRP used the bicentennial anniversary of a series of major earthquakes that occurred in 1811–1812 near New Madrid in southeastern Missouri to promote public awareness of and preparedness

[1] This report covers FY 2011 as defined by the Federal Government, a period that began on October 1, 2010, and ended on September 30, 2011. For convenience and readability "FY" is not repeated in subsequent references to this period, except in budget discussions. Consequently, all references to the year 2011 should be interpreted as FY 2011 unless calendar year 2011 is specified.

[2] www.nehrp.gov/pdf/NRC2011.pdf.

[3] NEHRP, "Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009–2013," October 2008.

for earthquake hazards in the central United States. In November 2010, the NEHRP Advisory Committee on Earthquake Hazards Reduction (ACEHR) held a meeting in Memphis, TN, to review earthquake hazards assessments and preparedness in the region. ACEHR was briefed by Federal, regional, State, and local officials with a focus on issues involving the development, adoption, and implementation of seismic safety elements in building codes. The committee prepared a report on its findings and recommendations for the ICC. In May 2011, FEMA led a National Level Exercise (NLE–11) to test emergency response procedures for large earthquakes in the central United States. Although this was not a NEHRP exercise, it was based on hazard and impact assessments developed by NEHRP and specifically tailored for use in the exercise.

### Earthquake Preparedness and Mitigation Training

During 2011, FEMA developed two new training courses on "Earthquake Basics" and on "Home and Business Earthquake Safety and Mitigation" designed, respectively, to explain earthquake hazards to a broad audience and to provide instruction on structural and nonstructural steps that can be taken to mitigate earthquake risk. To address the earthquake threat to schools, FEMA produced a series of webinars on "Incremental Seismic Rehabilitation of School Buildings (K–12): Providing Protection to People and Buildings." In March 2011, FEMA conducted a workshop on "Earthquake Building Rating Systems" to introduce architects, engineers, and code officials to the technical issues involved in evaluating the seismic safety of various building types. Finally, FEMA organized and conducted a series of seminars in Puerto Rico on the application of building codes newly adopted in the commonwealth.

### Earthquake Early Warning

In 2011, in cooperation with universities in California and Washington, USGS continued developing and began testing a prototype earthquake early warning system in California. The purpose of this system is to detect the occurrence of a large earthquake near its source and immediately broadcast a warning of imminent strong ground shaking to more distant areas. A warning issued a few tens of seconds in advance of shaking could allow schools, hospitals, critical facilities, lifeline operators, and the general public to take precautionary actions. The prototype system will be tested over the next few years under operational conditions.

### Significant Earthquakes of 2011

NEHRP agencies and cooperating institutions and individuals observed and studied three significant earthquakes in 2011, events which renewed their sense of purpose in relation to NEHRP:

- **Tohoku, Japan**—The magnitude 9.0 (M9.0) earthquake and resulting tsunami that struck off the coast of Japan on March 11, 2011, are likely to have caused the greatest economic loss in history due to a natural disaster.[4] The earthquake-induced tsunami also caused the

[4] "The Effects of the Great Japan Earthquake on Japan's BoP Statistics," a Central Bank of Japan presentation delivered to the International Monetary Fund Committee on Balance of Payments Statistics during the committee's meeting of October 24–26, 2011, reported economic losses in the impacted areas of Japan at $310 billion, with 15,811 dead and 4,035 people missing (www.imf.org/external/pubs/ft/bop/2011/11-18.pdf).

failure of a nuclear power plant, which has prompted a complete reexamination of the use of nuclear power in Japan. This chain of events has emphasized the need to consider the impacts of cascading events in disaster response planning and preparedness.

- **Christchurch, New Zealand**—An M6.1 earthquake, 30,000 times less powerful than the Japan event, struck New Zealand on February 21, 2011. This earthquake was a direct hit on the town of Christchurch, causing major damage to the downtown area and significant loss of life. This event demonstrated that a relatively common earthquake of M6.0 can have very serious consequences if it strikes the center of a city that is perhaps not as resilient as it could have been.

- **Virginia, United States**—On August 23, 2011, an M5.8 earthquake occurred in a rural area of central Virginia. Although no widespread damage resulted, the event was felt by over 30 million persons throughout most of the eastern United States, causing concern and societal disruption, and triggered a many-month shutdown of the North Anna nuclear power plant. If this earthquake had, like the Christchurch event, struck in the center of a city such as Richmond, VA, or had been a few tenths of a magnitude unit larger, the consequences would have been much greater and more widespread.

The activities of NEHRP in 2011, discussed more fully in the body of this report, are presented with some sense of pride and accomplishment. Nevertheless, the lessons learned or emphasized from foreign and domestic earthquakes during this period are daunting and sobering reminders of the remaining work needed in the United States to ensure safety in and resilience to future earthquakes.

## Section 1
# Introduction

The National Earthquake Hazards Reduction Program (NEHRP) is a multiagency program established by Congress "to reduce the risks of life and property from future earthquakes in the United States." The four Federal agencies participating in NEHRP are the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). NIST serves as the lead agency for NEHRP.

NEHRP was initially authorized by Congress in 1978. Since then, Congress has periodically reauthorized the program, generally at 2- to 5-year intervals. The latest reauthorization of NEHRP (Public Law 108–360) authorized funding for the four participating agencies through fiscal year 2009. Both the House of Representatives and the Senate are considering NEHRP reauthorizations. Pending the passage of new reauthorizing legislation, the NEHRP agencies continue to perform their duties as outlined in Public Law 108–360.

That law requires that the NEHRP Interagency Coordinating Committee (ICC), which directs the program, submit an annual report on NEHRP budgets and activities. The ICC submits this annual report, covering 2011,[5] pursuant to that requirement.

Previous NEHRP annual reports provide detail on the organizational structure of NEHRP and agency roles and responsibilities. That information, as well as much greater detail regarding NEHRP, is provided at www.nehrp.gov. This NEHRP annual report for 2011 provides information on NEHRP budgets, 2011 statutory program activities, State activities promoting implementation of research results, and related non-NEHRP activities that support NEHRP goals.[6] This report and prior NEHRP annual reports are available at www.nehrp.gov/about/reports.htm.

Two very noteworthy earthquakes that held lessons for the United States occurred early in 2011. First, on February 21, the magnitude 6.3 (M6.3) South Island, New Zealand, earthquake devastated the city of Christchurch, which has a building stock resembling that of many U.S. cities. The Christchurch disaster provides insights about building and lifeline performance that are applicable to the United States. Second, on March 11, the M9.0 Great Tohoku earthquake and resulting tsunami struck the northeast coast of Japan. The resulting losses of life and property were tragic. There again are insights for the United States, particularly with respect to the potential for a similar devastating

[5] This report covers FY 2011 as defined by the Federal Government, a period that began on October 1, 2010, and ended on September 30, 2011. For convenience and readability "FY" is not repeated in subsequent references to this period, except in budget discussions. Consequently, all references to the year 2011 should be interpreted as FY 2011 unless calendar year 2011 is specified.

[6] FEMA-related activity information in this report was extracted from "The National Earthquake Hazards Reduction Program: FEMA Accomplishments in Fiscal Year 2011," issued by FEMA in April 2012.

earthquake and tsunami event in the Cascadia Subduction Zone, off the coastlines of the States of Washington and Oregon. While this 2011 report does not dwell on these two earthquakes, the NEHRP agencies initiated studies of them that will impact NEHRP activities in 2012 and beyond. Appendix C provides a brief summary of the notable earthquakes that occurred in 2011.

## Section 2
# Program Budgets

Public Law 108–360 requires that NEHRP annual reports include, for each agency participating in the program and for each program "activity" defined in the legislation, a program budget for the current fiscal year (i.e., the year following that covered in the report) and a proposed program budget for the next fiscal year. The "Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009–2013," published in October 2008 (www.nehrp.gov/pdf/strategic_plan_2008.pdf), defined three major goals for the program that encompass all but one of the program activities defined in Public Law 108–360. The remaining activity, which concerned the development, operation, and maintenance of NEHRP facilities, was incorporated directly into the strategic plan. Table 2.1 shows the relationships between the congressionally defined program activities and the goals and activities that are included in the strategic plan.

Program budgets for the current fiscal year (FY 2012) are presented in table 2.2, which shows the funding that each participating agency is directing toward the goals and activities specified in the strategic plan. Table 2.3 identifies the agency funding requested or anticipated for NEHRP in FY 2013. Funds budgeted for the development, operation, and maintenance of NEHRP facilities are allocated among the Advanced National Seismic System (ANSS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network (GSN).

**TABLE 2.1—*Relationships of NEHRP strategic goals to statutory program activities***

| NEHRP Strategic Goals | Statutory Program Activities* |
|---|---|
| **Goal A:** Improve understanding of earthquake processes and impacts. | Improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines, through interdisciplinary research that involves engineering, natural sciences, and social, economic, and decision sciences. |
| **Goal B:** Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large. | Develop effective measures for earthquake hazards reduction. |
| **Goal C:** Improve the earthquake resilience of communities nationwide. | Promote the adoption of earthquake hazards reduction measures by Federal, State, and local governments, and others. |
| Develop, operate, and maintain NEHRP facilities. | Develop, operate, and maintain ANSS, NEES, and the GSN. |

* As defined by Congress in Public Law 108–360.

## 2.1 NEHRP FY 2012 Budgets by Strategic Goal Area

Table 2.2 lists the FY 2012 NEHRP budgets, by strategic goal, for the following NEHRP agencies: Federal Emergency Management Agency (FEMA), National Institute of Standards and Technology (NIST), National Science Foundation (NSF), and U.S. Geological Survey (USGS).

**TABLE 2.2—*NEHRP agency budgets for FY 2012***

| Strategic Goal | FY 2012 Funds Allocated to Goal ($M)[1] | | | | |
|---|---|---|---|---|---|
| | FEMA[2] | NIST[3] | NSF[4] | USGS[5] | **Total** |
| **Goal A:** Improve understanding of earthquake processes and impacts. | 0.1 | 0.3 | 49.7 | 10.9 | **61.0** |
| **Goal B:** Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large. | 4.0 | 3.1 | | 19.5 | **26.6** |
| **Goal C:** Improve the earthquake resilience of communities nationwide. | 3.7 | 0.7 | | 16.9 | **21.3** |
| Develop, operate, and maintain NEHRP facilities: | | | | | |
| ANSS—USGS | | | | 7.8 | **7.8** |
| GSN—NSF and USGS | | | 3.5 | 5.3 | **8.8** |
| **Total:** | **7.8** | **4.1** | **53.2** | **60.4** | **125.5** |

Notes on table 2.2:

[1] Budgets are rounded to the nearest $0.1 million.

[2] The FEMA FY 2012 budget is an allocation from the U.S. Department of Homeland Security (DHS) appropriation that covers NEHRP activities but excludes employee salaries and expenses (S&E).

[3] The NIST FY 2012 budget is an allocation from the NIST appropriation that covers all NEHRP-related activities, including the NEHRP Lead Agency role and Earthquake Risk Reduction R&D activities.

[4] The NSF FY 2012 budget is an allocation from the NSF appropriation that covers NEHRP activities but excludes Agency Operations and Award Management (AOAM). The NSF budget includes support for the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).

[5] The USGS FY 2012 budget is a line item in the USGS appropriation that covers NEHRP activities.

## 2.2 NEHRP FY 2013 Budget Requests by Strategic Goal Area

Table 2.3 lists the FY 2013 NEHRP planning budgets for each agency by strategic goal. These figures are based on agency submissions included in the President's FY 2013 budget request to Congress.

**TABLE 2.3—*NEHRP agency budget requests for FY 2013***
***(See notes 2-5 below for explanation of agency NEHRP "budget requests")***

| Strategic Goal | FY 2013 Funds Requested or Anticipated for NEHRP Goals ($M)[1] | | | | |
|---|---|---|---|---|---|
| | FEMA[2] | NIST[3] | NSF[4] | USGS[5] | **Total** |
| **Goal A:** Improve understanding of earthquake processes and impacts. | 0.1 | 0.3 | 49.7 | 12.0 | **62.1** |
| **Goal B:** Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large. | 3.3 | 3.1 | | 21.1 | **27.5** |
| **Goal C:** Improve the earthquake resilience of communities nationwide. | 3.1 | 0.7 | | 17.4 | **21.2** |
| Develop, operate, and maintain NEHRP facilities: | | | | | |
| ANSS—USGS | | | | 8.4 | **8.4** |
| GSN—NSF and USGS | | | 3.5 | 5.5 | **9.0** |
| **Total:** | **6.5** | **4.1** | **53.2** | **64.4** | **128.2** |

Notes on table 2.3:

[1] Budgets are rounded to the nearest $0.1 million.

[2] The FEMA FY 2013 budget is a planned allocation from the U.S. Department of Homeland Security (DHS) appropriation that covers NEHRP activities but excludes salaries and expenses (S&E).

[3] The NIST FY 2013 budget is a planned allocation from the NIST appropriation that covers all NEHRP-related activities, including the NEHRP Lead Agency role and Earthquake Risk Reduction R&D activities.

[4] The NSF FY 2013 budget is a planned allocation from the NSF appropriation that covers NEHRP activities but excludes Agency Operations and Award Management (AOAM). The NSF budget includes support for the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).

[5] The USGS FY 2013 budget is a line item in the USGS appropriation that covers NEHRP activities.

# Section 3
# Statutory Program Highlights

This section briefly highlights major accomplishments of the National Earthquake Hazards Reduction Program (NEHRP) during 2011. Highlights of research, implementation, and outreach are presented under the relevant goal or activity from the current NEHRP strategic plan. As shown earlier in table 2.1, these goals and activities are directly related to the NEHRP activities defined by Congress in Public Law 108–360. In addition, major statutory program leadership and facility operation highlights are presented.

## 3.1 Goal A: Improve Understanding of Earthquake Processes and Impacts

### 2011 National Research Council Workshop on Grand Challenges in Earthquake Engineering Research

At the end of fiscal year (FY) 2014, the National Science Foundation (NSF) will complete 10 years of support for facility operations and research at the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). To provide input for NSF's future planning of earthquake engineering research infrastructure beyond FY 2014, NSF engaged the National Research Council (NRC) to organize a community workshop on the Grand Challenges for earthquake engineering research and on the experimental facilities needed to address these challenges. This workshop was held on March 14–15, 2011, in Irvine, CA, and assembled 37 experts in earthquake engineering, materials science, social sciences, and cyberinfrastructure. The attendees identified 13 high-priority Grand Challenges in basic earthquake engineering research and 14 networked earthquake engineering experimental capabilities and cyberinfrastructure tools required to address these challenges.[7]

### NSF RAPIDs for 2011 New Zealand and Japan Earthquakes

NSF responded in the aftermath of the February 2011 New Zealand earthquake and the March 2011 Tohoku, Japan, earthquake, subsequent tsunami, and nuclear power plant crisis by alerting the research community, through two "Dear Colleague Letters," to the availability of the Rapid Response Research (RAPID) funding mechanism. NSF RAPID grants support activities having a severe urgency due to time constraints affecting the availability of, or access to, data, facilities, or specialized equipment. Such activities include quick-response research on natural or anthropogenic disasters. Collaborating with the agency's Office of International Science and Engineering and Directorate for Computer and Information Science and Engineering, the NSF Directorate for Engineering supported more than 30 RAPID awards, many with collaborators from the affected countries, to collect perishable data from these events on geotechnical, structural, and lifelines

[7] National Research Council, "Grand Challenges in Earthquake Engineering Research: A Community Workshop Report," available at http://books.nap.edu/catalog.php?record_id=13167.

performance; emergency preparedness, response, and relief; and tsunami generation, run-up, and impacts on the natural and built environments.

### Advancing Multi-side Real-time Hybrid Simulation

Real-time hybrid simulation (RTHS) is an emerging experimental technique for seismic testing that can fully capture strain, damping, and inertial effects by computing each numerical integration time step of an experiment in real time. In RTHS, the dynamics of the testing system and numerical integration scheme are critical to ensuring the stability of the test and accuracy of the end results. The major challenge with geographically distributed, or multi-site, RTHS is the accommodation of large communication time delays associated with sending data over long distances—including over the Internet.

NSF-supported research, conducted by a research team from the University of Connecticut, Lehigh University, and the University of Illinois at Urbana-Champaign (UIUC), successfully demonstrated for the first time a new computational framework for conducting geographically distributed RTHS tests, using multiple equipment sites in NEES. This real-time "hybrid test" included two controllable, magneto-rheological fluid dampers, one located at the NEES site at Lehigh and the second at the NEES site at UIUC, that were implemented to reduce the seismic response of a simulated three-story building model. The tools developed and validated through this new testing technique will facilitate future advanced experimentation, leveraging multiple geographically distributed equipment sites, such as shake table and large-scale test facilities, within NEES, and allowing researchers to conduct larger and more complex experimental verification of seismic protective systems, more rapidly advancing the state of knowledge and acceptance of new concepts in seismic hazard mitigation.

### Mitigating Liquefaction

Soil liquefaction is an important seismic hazard that has caused extensive damage to buildings, bridges, dams, wharves, and lifelines in past earthquakes. Buildings founded on sand that liquefies during an earthquake will experience sudden loss of support, which can result in significant and irregular settlement of the building that, in turn, causes cracking of foundations and structural damage. The 2011 Christchurch, New Zealand, earthquakes caused significant liquefaction, leading to pipeline fractures that left residents without running water or sewer services.

With NSF support, researchers at the University of California (UC), Davis, and Lafayette College, through experimentation using the NEES geotechnical centrifuge at UC Davis, developed a new method that uses a natural biological process to stabilize liquefaction-prone sandy soils. Naturally existing bacteria are used to transform soil into a sandstone-like material that resists damage from liquefaction, thereby increasing building and human safety during earthquakes. This process is termed "microbially-induced calcite precipitation" (MICP). MICP, at the micro-scale, facilitates the precipitation of calcite on sand grains, particularly at particle-particle contacts. The calcite effectively cements particles together, increasing their stiffness and strength, while also reducing their compressibility and permeability. This project has opened the door to a new field, called Bio-

Mediated Soil Improvement, in which natural biological processes are being harnessed to improve the engineering properties of soil.

### Adaptive Seismic Protection System

An NSF-supported research team, led by Rice University in partnership with several other academic institutions and industry, has created an innovative adaptive seismic protection system combining fluid viscous dampers and a new device called the Negative Stiffness Device (NSD). The NSD system, tested in a three-story building on the shake table at the University of Buffalo NEES laboratory, essentially "mimics" structural weakening known to reduce damaging seismic forces and displacements, but without inelastic excursions and permanent deformations. When the NSD is coupled with supplemental dampers for displacement control, the main structural system experiences reduced accelerations, reduced displacements, and reduced base shear. Incorporating NSDs significantly reduces the amount of energy transmitted to a structure so that it suffers little or no damage and remains serviceable even after a strong earthquake. Since the NSD is a passive device and has components made of mild steel, it is very cost-effective and easy to install. The system can be used in new buildings as well as for retrofit situations. The NSD is the first practical negative stiffness device implementable in large structures (a patent application is in progress).

### Studies of Earthquakes and Earthquake Hazards in the Eastern United States

On August 23, 2011, a magnitude 5.8 earthquake struck near Louisa, VA, about 75 miles southwest of Washington, DC. This earthquake was the largest to occur in the Eastern United States over the last century. It is estimated that the earthquake was felt by over 30 million people from Georgia to southeastern Canada, causing minor damage in the immediate epicentral area and to buildings and monuments in Washington, DC. In addition, the earthquake caused the shutdown of the North Anna nuclear power plant in Louisa County, VA.

The Virginia earthquake provided an excellent case study for examining the causes and effects of earthquakes in the Eastern United States. The National Institute of Standards and Technology (NIST) and Federal Emergency Management Agency (FEMA) conducted a damage survey of the epicentral area focusing on damage to school buildings. NSF and the U.S. Geological Survey (USGS) immediately sent field teams with portable seismometers to the area to record aftershocks in the immediate vicinity of the main shock. Analysis of the recorded data provided very accurate locations of the aftershocks and their depth below the surface. The results outlined a planar surface in three dimensions clearly characteristic of a fault plane. This is the first time in the study of eastern U.S. seismicity that an earthquake could be unequivocally associated with movement on a causal fault. Field studies and geological and geophysical surveys continue in 2012.

NSF supported awards to the Geotechnical Extreme Events Reconnaissance (GEER) Association, headquartered at UC Berkeley, to Cornell University, and to the Virginia Polytechnic Institute and State University to investigate the earthquake.[8] The quick-response GEER investigation found

[8] The GEER report is available at http://geerassociation.org/GEER_Post%20EQ%20Reports/Virginia_USA_2011/Cover_Virginia_2011.html.

minor liquefaction and slumping along some streams, minor separation of approach abutments from bridge bents, rockfalls, and slope movements in marginally stable slopes, all primarily in the epicentral region. Although few ground failures were found, GEER investigators observed correlation between geotechnical conditions and structural damage, especially in the National Capital Region. Soil amplification in soft sediments overlying hard rock influenced damage and shaking intensity patterns, as did the underlying geologic structure associated with the Appalachian Mountains and the strike of regional geologic faulting.

### Induced Seismicity

During 2011, USGS began studies, with collaborators from State agencies and academia, of localized earthquake swarms near Trinidad, CO, Prague, OK, and Guy, AR. These swarms of earthquakes appear to be coincident in time and space with actions related to the pumping or injection of fluids into deep wells. In most cases these wells are related to the recovery of gas and petroleum or the disposal of wastewater associated with these activities. On August 23, 2011, a magnitude 5.3 earthquake occurred near an injection site in southern Colorado and on February 27, 2011, a magnitude 4.7 earthquake occurred near an injection site in central Arkansas. In early March, injection operations at two Arkansas disposal sites were discontinued.

The current hypothesis is that the injected fluids migrate into nearby faults that are highly stressed but inactive due to the pressure of the overlying rock. The injected fluids increase the pore pressure along the fault surface thus reducing the effects of the overburden pressure and tectonic stresses. The reduction of the effective stress allows shear stresses to dominate and results in slippage along the fault causing earthquakes. USGS continues to study this problem with the goals of understanding the specific factors that affect the earthquake hazard at a particular injection site, and informing the development of pumping protocols that will allow gas and oil operations to continue while minimizing the risk of triggering earthquakes.

### United States-Japan Cooperative Testing at E-Defense

In August 2011, two NSF-supported NEES research projects led by the University of Nevada, Reno, used Japan's National Research Institute for Earth Science and Disaster Prevention Earth-Defense (E-Defense) shake table facility in Miki, Japan, to test different base isolation concepts and the performance of nonstructural systems in a five-story, steel moment frame building. The tests involved full-scale proof-of-concept validation of design approaches for new seismic isolation and protective systems (triple pendulum bearings and lead rubber bearings and sliders), identification of performance limits for extreme motions to accelerate the adoption of these systems, and collection of full-scale response data for nonstructural building components (interior wall partition systems, ceilings, piping, concrete cladding panels, and enclosed furnished rooms).

Also through NSF support, researchers from UC Los Angeles collaborated with E-Defense researchers and a University of Tokyo Earthquake Research Institute faculty member to provide additional sensors to measure displacements and calculate strains for two reinforced concrete, full-scale, four-story buildings in tests conducted in December 2010 at E-Defense. The added

instrumentation provided valuable data on the response and behavior of special reinforced-concrete shear walls and unbonded post-tensioned walls under U.S. design requirements; these data can be used for future modeling studies of dynamic, three-dimensional responses.[9]

### Improved Ground-Motion Prediction Equations

Seismic hazard maps and related planning tools rely on accurate calculation of the ground motions to be caused by potential future earthquakes. During 2011, USGS participated in large, collaborative efforts to develop improved equations and procedures that will lead to more accurate prediction of the ground shaking produced by earthquakes in North America. Ground-motion prediction equations for the western United States, developed in 2008, are being updated for delivery in 2012, using new ground-motion recordings from recent earthquakes, in a project led by the Pacific Earthquake Engineering Research Center (PEER). For the eastern United States, where earthquakes are more rare, work is under way to gather all available earthquake shaking records, including those from the August 2011 magnitude 5.8 earthquake in Virginia, to underlie improved hazard assessments. The results for the eastern United States should be completed in 2013.

### First Recording of Episodic Tremor Accompanied by Small Earthquakes

Researchers at the University of Washington, supported by NSF, used multiple arrays (groups of seismometers) to successfully record a moderate episode of seismic tremor that occurred in March 2010 near the west coast of North America. Episodic tremor and slip (ETS) is a newly discovered interaction between tectonic plates where the motion between the plates is not characterized by discrete earthquakes but rather by an episode of continuing rumble (tremor) accompanied by permanent deformation (slip) that can be identified using the global positioning system (GPS), strainmeters, and tiltmeters. Recording a moderate tremor episode allowed this group to detect that a handful of small earthquakes accompanied the tremor. They concluded that the slow slip stressed the tectonic plate plunging beneath North America enough to cause this activity. These are the first earthquakes that have been shown to be triggered by ETS. Researchers plan to follow up this work with the ultimate goal of ascertaining the likelihood that ETS triggers dangerous earthquakes.

### Aftershock Recording and Data Analysis of New Zealand Earthquakes

A University of Wisconsin (UW) project supported by NSF involved installing nine portable seismometers in the vicinity of the September 4, 2010, magnitude 7.1 Darfield earthquake on the South Island of New Zealand. This was a cooperative international effort between UW-Madison and Victoria University-Wellington (VUW). The instruments supplemented five temporary VUW instruments and three permanent New Zealand instruments in the area and recorded the first 4 months of aftershocks following the Darfield earthquake. This array of portable instruments provided the data necessary to determine more accurately the locations and depths of aftershocks that outlined the three-dimensional geometry of the geologic fault that gave rise to the main shock. The aftershock locations formed a narrow east-west band, and were all between 12 and 17 kilometers in depth. Near Christchurch, approximately 20 miles to the west of Darfield, aftershocks were more numerous, broadly distributed, and shallower, with most from 8 to 13 kilometers deep,

[9] See http://peer.berkeley.edu/publications/peer_reports/reports_2011/webPEER-2011-104-WALLACEetal.pdf.

similar to the depth of the February 22, 2011, magnitude 6.3 earthquake that struck near and heavily damaged Christchurch. Data recorded at the temporary stations are being used to better understand the temporal and spatial distribution of earthquakes in this sequence of earthquakes.

NSF also supported two RAPID awards to UC San Diego and Duke University to deploy sensors, data acquisition systems, and personnel from the NEES facility at UC Los Angeles to Christchurch, New Zealand in July and September 2011. The purpose was to gather quantitative data on the shaking of modern buildings during strong aftershocks of the 2010 and 2011 earthquakes. High-resolution monitoring systems were installed in damaged buildings, uniquely recording building responses to many large aftershocks. The projects targeted damaged precast-concrete buildings and a base-isolated building. The two precast-concrete buildings are of interest because they are similar to U.S. precast-concrete buildings; both are recently constructed and had moderate earthquake damage. The base-isolated structure is the very new Christchurch Women's Hospital. The data generated from its response to aftershocks will be used to assess its response and compare its actual behavior with the modeling assumptions used in its seismic design.

### Studies of Extensive, Earthquake-Induced Ground Failures in Peru

Researchers in the NSF-supported GEER Association deployed a reconnaissance team in August 2007 to investigate the ground failure effects of a magnitude 8.0 earthquake that shook the coastal region of central Peru. The city of Pisco suffered considerable damage, and the civil infrastructure in the entire region was significantly affected. From a geotechnical perspective, the Pisco earthquake was most significant for the amount of soil liquefaction and landsliding observed in the epicentral area. The observations of the GEER team highlighted the fact that earthquake impacts extend over vast areas and have unique spatial signatures that are a function of regional-scale factors such as geologic setting, ground motion intensity, and land use patterns.

Advancements in the field of remote sensing, combined with new opportunities in information management and spatial analysis, provide a promising new direction for earthquake studies. An existing NSF award is supporting research at the University of Arkansas that employs remote sensing, subsurface geotechnical investigations, and traditional reconnaissance information to collect, process, interpret, and digitally archive ground failure events identified in Peru by the GEER team. In particular, landslides in the epicentral area and a massive lateral spread complex on a marine terrace in Canchamaná were extensively documented. Post-earthquake satellite images were compared with pre-event imagery and were subjected to complex image processing using a detailed DEM model derived from a stereo pair of images from the GeoEye-1 satellite, which was specifically tasked by the research team to obtain post-earthquake imagery. Image processing was conducted by the Center for Advanced Spatial Technologies at the University of Arkansas.

Results indicate that the observed deformations were not "lateral spreading" in the truest sense, since the movements did not extend all the way to the free face at the land-ocean contact. Rather, the movements seemed to be concentrated in areas with slightly higher slope angles. The research team proposes the term "lateral slumping" to describe this phenomenon. Lateral slumping appears to be a slope-type failure triggered by liquefaction of underlying soils and driven by static shear

stresses from very small slope angles (i.e., less than 3 percent on average) without a nearby open face. The team believes that lateral slumping should be considered in ground failure analyses for future earthquakes because traditional lateral spreading and slope stability analyses would not typically be performed for the circumstances documented in this work. The study also identified only a weak correlation between landslide intensity and peak ground acceleration. The researchers speculate that the high levels of ground shaking across the study area largely exceeded the seismic stability thresholds of susceptible slopes. Hence ground-shaking intensity was more closely tied to earthquake-induced permanent displacement, rather than to displacement initiation.

### Planning for Multidisciplinary Research on Community Resilience

An NSF-supported workshop held in June 2011 brought together hazard researchers, sociologists, engineers, planners, architects, anthropologists, economists, geographers, and seismologists to discuss concepts for a proposed resilience research network to study disasters, tentatively named Creating a More Resilient America. The goal of the network is to provide long-term, systematic data collection—for longitudinal analysis and modeling of vulnerability and resilience through time—at nodes strategically located in regions subject to disasters such as flooding, hurricanes, and earthquakes.[10]

## 3.2 Goal B: Develop Cost-Effective Measures to Reduce Earthquake Impacts on Individuals, the Built Environment, and Society at Large

### Research in Support of Performance-Based Seismic Design

As related in previous NEHRP annual reports, leading structural engineers project that substantial research is needed to facilitate full implementation of performance-based seismic design (PBSD), which is a NEHRP strategic priority. The NEHRP agencies continue to support research and knowledge transfer efforts that support PBSD. Work continued in 2011 on the "Guidelines for Seismic Performance Assessment Methodology for Individual Buildings" (FEMA P–58) and the accompanying Performance Assessment Calculation Tool. When it is completed in FY 2012, this performance assessment methodology will allow designers to assess the seismic performance of proposed or existing individual buildings in future earthquakes. These products represent the first phase of the development of PBSD guidelines for new and existing buildings. Other PBSD-related work continued at both FEMA and NIST.

### Publication of Seismic Design and Construction Guidelines

While NEHRP moves ahead with efforts to develop and refine PBSD, the NEHRP agencies recognize that the vast majority of U.S. buildings will continue to be designed using the prescriptive provisions of national model building codes. So, NEHRP continues its long-standing commitment to developing and publishing seismic design and construction guideline documents for design professionals.

[10] The workshop report is available at http://archone.tamu.edu/hrrc/camra/report.pdf.

### *Continued evolution of "NEHRP Recommended Provisions"*

In June 2011 FEMA completed and published "Quantification of Building Seismic Performance Factors: Component Equivalency Method" (FEMA P–795), which builds on the previously released "Quantification of Building Seismic Performance Factors" (FEMA P–695). FEMA P–795 is being considered for adoption as an Acceptance Criteria resource by the International Code Council Evaluation Service. Accompanying these FEMA publications is a newly released report, "Evaluation of the FEMA P–695 Methodology for Quantification of Building Seismic Performance Factors" (NIST GCR 10–917–8). The "seismic performance factors" addressed in these documents are numerical coefficients that have been developed by experts to permit the designers of typical, regular buildings to approximate with acceptable accuracy the dynamic earthquake behavior of such structures using static linear models that are simpler to implement than the more complex nonlinear models used in PBSD.

As noted in earlier reports, FEMA released its latest edition of the "NEHRP Recommended Seismic Provisions for New Buildings and Other Structures" (FEMA P–750)[11] in 2009. This publication has been referenced in the subsequent development of new seismic regulations for national model building codes and standards. To help practitioners understand the basis for these regulations, FEMA published "Earthquake-Resistant Design Concepts: An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures" (FEMA P–749) in December 2010.

### *Reducing the risks of nonstructural earthquake damage*

During the recent earthquakes in New Zealand, Chile, Japan, and Virginia, and earlier earthquakes in California, Washington, and other parts of the United States, nonstructural failures have accounted for most damage and injuries. Businesses, schools, hospitals, and other organizations have had to spend significant time and dollars for the cleanup and repair necessitated by nonstructural failures (the nonstructural components of buildings include architectural, mechanical, electrical, and plumbing systems, as well as furniture, fixtures, equipment, and other contents). Such failures can also impede safe evacuation, delay rescues, and cause additional hazards. In January 2011 FEMA completed "Reducing the Risks of Nonstructural Earthquake Damage" (FEMA E–74), an electronic publication that replaced earlier print editions of the title. FEMA E–74 describes the sources and types of nonstructural earthquake damage and presents effective methods and guidance for minimizing future injuries and property losses from nonstructural risks. It is available on the FEMA website at www.fema.gov/plan/prevent/earthquake/fema74/index.shtm. FEMA also initiated the development of two training courses that are based on FEMA E–74.

### *Continued publication of NEHRP "Techbriefs"*

NEHRP released three new volumes in its series of "Techbriefs," which are concise publications designed to help transfer research results into practice. The latest volumes are "Nonlinear Structural Analysis for Seismic Design" (NIST GCR 10–917–5), "Seismic Design of Composite Steel Deck and Concrete-Filled Diaphragms" (NIST GCR 11–917–10), and "Seismic Design of Cast-in-Place

[11] For the sake of brevity, this publication is hereinafter referred to as the NEHRP Recommended Seismic Provisions.

Concrete Special Walls and Coupling Beams" (NIST GCR 11–917–11). NEHRP also began efforts to produce two more Techbriefs for release in FY 2012.

### Application Tools for the National Seismic Hazard Assessments

In 2011, USGS scientists and engineers worked to expand the application of the agency's 2008 national seismic hazard maps through the development of web-based tools for use by engineers. These tools provide site-specific anticipated ground shaking parameters for designing structures in accordance with (1) the NEHRP Recommended Seismic Provisions, (2) the American Society of Civil Engineers (ASCE) standard, updated in 2010, entitled "Minimum Design Loads for Buildings and Other Structures" (ASCE 7–10), and (3) the 2012 International Building Code. The inputs required of the user are a site location (e.g., address or latitude and longitude) and its soil classification. The user receives the design parameters needed for earthquake resistant construction at that specific site without having to extrapolate from a map and compute the effects of various soil conditions. These tools have proven very popular with practicing design and construction engineers.

### Hazard Maps for Urban Areas

USGS completed major products during 2011 for a detailed seismic hazard study of the area in and around Evansville, IN, as part of the Tri-State (Evansville) Project. These products included reports on liquefaction hazards, a probabilistic seismic hazard assessment (including site effects), and regional earthquake scenarios. Partners in the Evansville project include the State geological surveys of Indiana, Kentucky, and Illinois, the Southwest Indiana Disaster Resistant Community Corporation, the Central United States Earthquake Consortium (CUSEC), and Purdue University.

### Seismic Hazard in the Sacramento River Delta

The Sacramento/San Joaquin Delta is an inland delta at the western extent of the Great Central Valley. Fresh water for about half of California flows through the delta. About 1,100 miles of earthen levees were built around swampy islands starting after the Civil War to reclaim these lands for farming. Although the levees have had isolated failures over the years, they are at risk for a catastrophic failure (defined as having as many as 50 individual failures at once) from local and regional earthquakes. A failure of this scale would likely result in salt water from San Francisco Bay contaminating the water in the delta and fouling the water supply for half the population of California. USGS, in partnership with California's Department of Water Resources, has undertaken a coordinated suite of monitoring and research activities to determine the seismic hazard affecting the delta. A small array of seismometers has been deployed to measure the shaking response of levees to near and distant earthquakes. The results will be used to develop a three-dimensional framework of the delta's underlying sediment layers, and to characterize the levee soils. USGS seismologists also monitored the shaking response of a full-scale model levee constructed by university engineers. USGS geologists placed trenches across several nearby faults to determine their histories of earthquake activity. A significant new finding is that two faults previously believed to be separate, may actually have failed together in the past. A repeat of such an earthquake could have considerably greater impact on the delta than is considered in the current California seismic hazard model.

## 3.3 Goal C: Improve the Earthquake Resilience of Communities Nationwide

### ShakeOut!

Goals for the annual ShakeOut earthquake preparedness drills include shifting the culture about earthquakes and increasing earthquake preparedness, by exposing participants to consistent and frequent information about what to do—information delivered in many forms and from many sources. ShakeOut also provides participants with the opportunity to see others like themselves getting prepared, and to talk about preparedness with their family, friends, and coworkers. In October 2010, 7.9 million people participated in the Great California ShakeOut and it is estimated that more than 2 million people participated in the Great Central U.S. ShakeOut in 2011. FEMA provided partial financial support for these activities, as well as assistance from staff located in the agency's regional offices. ShakeOut events, which were originated in 2008 by the Earthquake Country Alliance for California, are the largest earthquake drills in U.S. history. USGS, in cooperation with the Southern California Earthquake Center (SCEC), has developed scenario earthquakes for ShakeOut events and has provided multimedia materials for use in the exercises.

### National Earthquake Response Exercise Based on Central U.S. Scenario Earthquakes

The National Level Exercise 2011 (NLE–11), conducted during May 16–20, 2011, and coordinated by FEMA, tested disaster response efforts involving all levels of government. The exercise scenario was that of a series of large earthquakes in the New Madrid Seismic Zone (NMSZ), with impacts to eight States and four FEMA regions. Although this event was not a NEHRP activity per se, it was based on years of NEHRP earthquake hazard and impact assessments focused on the central United States. The earthquake scenarios were provided by USGS, giving the exercise a credible scientific foundation. USGS also took advantage of this unique opportunity to forge and strengthen ties with partnering agencies, demonstrate important USGS capabilities and science products, and test USGS response activities and coordination mechanisms in the wake of a domestic disaster.

### Earthquake Outreach Tour

The NMSZ Earthquake Outreach Tour was held on February 7–11, 2011. Tour events were jointly hosted by FEMA's headquarters and Region VII offices, CUSEC, the Institute for Business and Home Safety, States located within the NMSZ, and other partners. The theme of the week-long tour was "Identify Your Risk, Make a Plan, and Take Action," which is also the motto for FEMA's QuakeSmart program. Along with other FEMA senior leadership, FEMA Administrator Craig Fugate attended and spoke at tour events on February 11. The tour included five forums held in five separate NMSZ communities, and concluded on February 11 at St. Louis University with the "Earthquakes: Mean Business" seminar. During the tour, more than 5,000 FEMA publications were distributed and more than 500 people were briefed on how to identify, plan for, and mitigate their seismic risks.

### Building Code Adoption Tracking

One of the most effective ways to reduce seismic risks in local communities is to adopt and implement appropriate seismic-resistant building codes. To track code adoption by local

communities, FEMA, with contractor support, maintains the Building Code Adoption Tracking system, which uses the Building Code Effectiveness Grading Schedule from the Insurance Services Organization, a private company that monitors building code adoption and implementation nationwide. At the end of FY 2011, 48 percent of communities in the United States participating in the tracking system had adopted building codes that adequately address natural hazards, including seismic hazards (some States do not participate in the tracking system). This metric highlights the connection between the adoption and enforcement of disaster-resistant building codes and reductions in the losses suffered by communities during disasters. Efforts are under way to determine whether a methodology can be developed that may allow FEMA to quantify these benefits in a more meaningful way.

### Citizen's Earthquake Safety Handbook for the Central United States

During 2011 USGS published "Putting Down Roots in Earthquake Country: Your Handbook for the Central United States." This booklet, which USGS prepared in cooperation with FEMA, CUSEC, the CUSEC State Geologists, and SCEC, provides information to residents of the Central States about the threat of earthquakes in that area, particularly around the NMSZ, and explains how to prepare for, survive, and recover from such events. It explains why residents of this region need to be concerned about earthquakes and describes what to expect during and after an earthquake. Much is known about the threat of earthquakes in the central United States, including where they are likely to occur and what can be done to reduce losses from future earthquakes, but not enough has been done to prepare for future earthquakes. The handbook describes preparations that can be undertaken by individual residents before an earthquake occurs to increase their safety and protect their property.

### QuakeSmart

Following disasters, local businesses are often not prepared to resume operations, which is critical to a community's ability to recover. FEMA created the QuakeSmart program to help local businesses mitigate earthquake losses and resume operations after a quake strikes. In 2011, FEMA released several QuakeSmart products and conducted a number of QuakeSmart activities. The products included a user-friendly, clear, and technically sound package of interactive guidance and tools that can help businesses reduce the potential for injuries, damage, and financial losses from an earthquake. "QuakeSmart: Earthquake Mitigation Toolkit for Businesses" (FEMA P–811DVD) takes users through the three-step QuakeSmart process: Identify Your Risk; Make a Plan; and Take Action! QuakeSmart activities included successful partnerships established among FEMA, FEMA-supported regional earthquake consortia, local chambers of commerce, and businesses in the NMSZ for the Earthquake Outreach Tour and ShakeOut events. The QuakeSmart website (www.fema.gov/earthquake-publications/quakesmart-toolkit-welcome) continued to provide valuable information on earthquake risk mitigation and related FEMA resources.

### Undergraduate Education

The NEES Research Experience for Undergraduates (NEESreu) program, led by Purdue University, is a dynamic 10-week summer research program for upper division undergraduate students

interested in civil engineering, computer science/engineering, electrical engineering, and other fields related to the testing of seismic risk mitigation measures. Each NEESreu participant is paired with a faculty advisor, joins a NEES research team, and participates in research and enrichment activities, including attending the NEES Annual Meeting and the Young Researchers' Symposium. In 2011, 29 NEESreu students joined faculty mentors in NEES research facilities at UC San Diego; UC Los Angeles; UC Santa Barbara; Lehigh University; Oregon State University; UIUC; the University of Nevada, Reno; and the University of Auckland, New Zealand. Students' papers detailing the results of their individual research projects are available at http://nees.org/neesreuprogramsummer2011.

The Pacific Earthquake Engineering Research Center, located at UC Berkeley, coordinates an NSF-supported Research Experiences for Undergraduates (REU) site that focuses on the theme of engineering earthquake-resilient communities. In 2011, PEER supported 11 summer REU students who conducted research projects in structural engineering, geotechnical engineering, and urban planning and public policy at three research sites: UC Davis, the University of Washington, and UC Berkeley.

The Southern California Earthquake Center is very active in the earth science education community, participating in organizations such as the National Association of Geoscience Teachers, the Coalition for Earth System Education, and local and national science educator organizations. In addition, SCEC supports three student intern programs: Summer Undergraduate Research Experiences (SURE), Undergraduate Studies in Earthquake Information Technology (USEIT), and Advancement of Cyberinfrastructure Careers through Earthquake System Science (ACCESS). Since 2002, 150 students have participated in the SURE program, 167 students in the USEIT program, and 29 students in the ACCESS program.

### ROVER: New End-to-End Software for Managing Seismic Risk

FEMA teamed with the Applied Technology Council (ATC) and private-sector partners to create a new tool to screen and evaluate buildings for seismic risk. Available online and on CD-ROM, the Rapid Observation of Vulnerability and Estimation of Risk (ROVER) software automates two international standard paper-based methodologies: "Rapid Visual Screening of Buildings for Potential Seismic Hazards" (FEMA 154) and "Procedures for Post-earthquake Safety Evaluation of Buildings" (ATC–20). With the automation now provided by ROVER, inspectors no longer need to juggle papers, clipboard, and camera, and managers no longer need to transcribe paper forms. ROVER also shares data with two other tools used to manage seismic risk: HAZUS–MH, developed for FEMA by the National Institute of Building Sciences, and ShakeCast, software created by USGS.

### Earthquake Early Warning

Working during 2011 with funding received through the American Recovery and Reinvestment Act of 2009, USGS replaced many of the older seismic recording instruments in California that had slow data transmission rates. The modern replacements have enabled existing systems to provide much timelier earthquake alerts and will support the development of a prototype capability to deliver

automated warnings after an earthquake occurs but before strong ground shaking arrives at sites away from the epicenter. Even a few seconds of advance warning may be useful for enabling schoolchildren to seek refuge under their desks; utilities to rebalance electricity distribution and possibly shut off gas lines; hospitals to start auxiliary power systems; public transit systems to reduce speeds; fire stations to open their doors; and other targeted uses. Since 2006, USGS has worked with the consortium of universities that operate the Advanced National Seismic System (ANSS) California Integrated Seismic Network to test early-warning algorithms. In 2009, USGS began the second phase of this partnership, which involves building a prototype statewide earthquake alerting system. This development work will be accelerated by a grant provided in 2012 by the Gordon and Betty Moore Foundation of $6 million over 3 years to three west coast universities ($2 million to each) for work with USGS toward a prototype early warning system. Any developments in earthquake warning coming from ANSS investments in California will be propagated nationwide as ANSS is more fully implemented.

## National Practitioner Training Activities

### *New earthquake training courses*

FEMA developed two new earthquake training courses in 2011: "Earthquake Basics: Science, Risk, and Mitigation" (IS–325), and a train-the-trainer course, "Home and Business Earthquake Safety and Mitigation" (FEMA P–909). Earthquake Basics is a 30-minute independent study course that presents non-technical information on earthquake science, risk, and mitigation and discusses techniques for structural and nonstructural earthquake mitigation. This course is targeted to many audiences, including home owners, business owners, the private sector, government workers at all levels, first responders, nonprofit organizations, volunteers, and community-based organizations. "Home and Business Earthquake Safety and Mitigation" provides training on structural and nonstructural earthquake mitigation, with the intent of creating a cadre of trainers with the ability to provide basic knowledge on earthquakes and the simple steps that can be taken to mitigate seismic risk in homes and businesses.

### *Webinars on school safety*

Many school buildings located across the Nation and the U.S. territories are vulnerable to earthquakes. This vulnerability could potentially result in deaths and injuries among students, teachers, and staff; damaged or collapsed buildings; damaged or destroyed furnishings, equipment, and building contents; and disrupted educational programs and school operations. FEMA has produced a series of webinars based on its publication "Incremental Seismic Rehabilitation of School Buildings (K–12): Providing Protection to People and Buildings" (FEMA 395), that show participants how to assess earthquake risks, develop plans for reducing and managing these risks, secure nonstructural elements of school facilities, and apply "incremental seismic rehabilitation" to school buildings.

### *National Earthquake Technical Assistance Program*

FEMA's National Earthquake Technical Assistance Program (NETAP) supports the development of training curricula on earthquake mitigation topics and provides courses for State and local officials and businesses throughout the United States. Demand for the following courses continued to be very high during 2011: FEMA 154; ATC–20; "Earthquake Hazard Mitigation for Hospitals" (FEMA P–767); and "Reducing the Risks of Nonstructural Earthquake Damage" (FEMA E–74).

### *Workshop on a rating system for the earthquake performance of buildings*

In March 2011, FEMA sponsored a workshop on earthquake building rating systems. Invitees included finance and insurance sector representatives, building owners, building managers, public officials, architects, engineers, and code officials. Topics addressed at the workshop included the following: the objectives to be met by a system designed to rate the earthquake performance of buildings; communicating seismic risk to non-engineers; using a rating system to spur action aimed at reducing seismic risk; and linkages to and lessons from existing green building rating systems. As a result of recommendations generated at this workshop, FEMA agreed to update and nationalize a product for conducting simplified seismic assessments of detached, single-family, wood-frame buildings (known as ATC–50) that was originally developed for the City of Los Angeles after the 1994 Northridge earthquake. The updated version, which will be known as FEMA P–50 and will be available in 2012, will include updated "Seismic Retrofitting Guidelines for Detached Single-Family Dwellings" (FEMA P–50–1).

### *Puerto Rico seismic code training*

FEMA organized and conducted, with support from the Building Seismic Safety Council, three seminars on Puerto Rico's newly adopted earthquake building codes in 2011. The seminars, held in three separate localities on the island, were cosponsored by the Puerto Rico Institute of Civil Engineers and Land Surveyors and the Puerto Rico Planning Board with funding from FEMA's Community Assistance Program.

## Publication of Earthquake Resistant Design Concepts Guide

An important aspect of NEHRP's strategic goal C is encouraging design and construction practices that address the earthquake hazard and minimize the associated risk to life and property. Helping design and construction practitioners to understand the basis for the seismic regulations in the Nation's building codes and standards is a key to successfully implementing such practices. In 2011, FEMA published "Earthquake-Resistant Design Concepts: An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures" (FEMA P–749). This guide provides a non-technical and readily understandable explanation of the intent and requirements of the seismic design criteria found in the Nation's building codes and standards and serves as a companion document for the NEHRP Recommended Seismic Provisions.

## Updated Catalog of FEMA Earthquake Resources and Directory of Partners

In December 2010, FEMA published an updated "Catalog of FEMA Earthquake Resources" (FEMA P–736A and FEMA P–736A CD). The catalog includes a list of FEMA's earthquake-related

training courses and materials along with an annotated list of the agency's earthquake publications. It was distributed at many events in 2011, including the Earthquake Engineering Research Institute Annual Conference, the 2011 Structural Engineers Association of California Annual Conference, and the National Earthquake Program Managers (NEPM) meeting. The version available on compact disc (FEMA P–736A CD) includes PDF copies of some of the more popular FEMA publications, such as "Are You Ready? An In-depth Guide to Citizen Preparedness" (IS–22), the "Earthquake Safety Guide for Homeowners" (FEMA 530), and the "Earthquake Home Hazard Hunt Poster" (FEMA 528).

FEMA also updated its "Directory of FEMA Earthquake Partners," an online resource that facilitates the agency's earthquake-related partnership efforts by providing contact information for more than 300 organizations and individuals involved in earthquake mitigation.

## 3.4 NEHRP Statutory Activity: Program Leadership

In performing statutory program management, coordination, and oversight functions during 2011, the NEHRP Interagency Coordinating Committee (ICC)[12] met one time, the Advisory Committee on Earthquake Hazards Reduction (ACEHR)[13] met four times, and the working-level Program Coordination Working Group met eight times. All program leadership activities are supported by the NEHRP Secretariat.

### New Madrid Bicentennial

For one of its meetings, ACEHR met in Memphis, TN, at the Center for Earthquake Research and Information. This meeting signaled ACEHR's support for activities that would occur in 2011 and 2012 in commemoration of the 1811 and 1812 New Madrid earthquakes and for activities that improve earthquake preparedness in the central United States. Following this meeting, ACEHR issued its "New Madrid Bicentennial Statement."[14] The NEHRP agencies responded to the statement with activities that were described in subsequent NEHRP "SeismicWaves" newsletter articles.[15]

### ICC Responses to ACEHR Recommendations

ACEHR also delivered numerous recommendations and observations on NEHRP in 2010 and 2011. In December 2011, the Director of the NIST Engineering Laboratory, who is the Designated

[12] The ICC is composed of the Directors/Administrators of the four NEHRP agencies and the Directors of the Office of Management and Budget and the Office of Science and Technology Policy of the Executive Office of the President.

[13] The ACEHR is composed of 16 nationally recognized leading earthquake practitioners who are not Federal agency employees and who are appointed to three year terms of service.

[14] See www.nehrp.gov/pdf/ACEHR_bicentennial.pdf .

[15] See www.nehrp.gov/pdf/SeismicWavesMay11.pdf and www.nehrp.gov/pdf/SeismicWavesJun11.pdf.

Federal Official (DFO) for ACEHR, provided feedback from the ICC on ACEHR's recommendations. The full text of this feedback is available on the NEHRP website.[16]

### NEHRP Secretariat Operations

During 2011 the NIST NEHRP Secretariat continued to provide support and leadership for addressing earthquake safety and risk reduction issues nationwide. NIST served as the primary point of contact and as a source of technical expertise for the U.S. House of Representatives Committee on Science, Space, and Technology, Subcommittee on Technology and Innovation during the NEHRP reauthorization process. The Director of NEHRP testified at a hearing on Earthquake Risk Reduction held by the subcommittee on April 7, 2011. The NEHRP Secretariat supported a major study by the NRC to develop a 20-year road map that will support implementation of the goals of the NEHRP strategic plan. The NRC released the study report in March 2011,[17] and the NEHRP agencies are analyzing it for guidance in future program planning.

## 3.5 NEHRP Statutory Activity: Develop, Operate, and Maintain NEHRP Facilities

Public Law 108–360 requires NEHRP to "develop, operate, and maintain" certain facilities essential to the NEHRP mission. These facilities are the Advanced National Seismic System (ANSS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network (GSN). Highlighted below are activities related to these facilities that NEHRP carried out during 2011.

### Advanced National Seismic System

The USGS ANSS effort is an initiative to expand and improve the performance and integration of national, regional, and urban seismic monitoring networks in the United States. The system consists of a national "backbone" network, the National Earthquake Information Center (NEIC), 14 partner-operated regional networks located in areas of moderate-to-high seismic activity, and the "National Engineering Strong Motion Project" for monitoring earthquake shaking in structures.

By the end of FY 2011, ANSS was 30 percent complete with 2,158 modern seismic stations, the 24x7 operational center at the NEIC, and 1,164 motion recorders in buildings and other structures. American Recovery and Reinvestment Act funding, allocated by USGS in 2009 to ANSS modernization, resulted in significant progress toward modernizing older stations and upgrading communications and data centers in 2010 and 2011.

ANSS is now capable of detecting almost all felt earthquakes in the United States (except in remote areas of Alaska) and the NEIC provides reports within minutes of their occurrence. The NEIC provides information on potentially damaging earthquakes to the National Command Center; the White House; the Departments of Defense, Homeland Security (including FEMA), Transportation,

[16] See www.nehrp.gov/pdf/ACEHRMeetingSummaryDec2011.pdf.

[17] National Research Council, "National Earthquake Resilience: Research, Implementation, and Outreach," The National Academies Press, Washington, DC, 2011. Available at www.nehrp.gov/pdf/NRC2011.pdf.

Energy, and the Interior; State offices for disaster services; numerous public and private infrastructure management centers (e.g., railroads and pipelines); the news media; and the public. Rapid earthquake notifications are delivered by e-mail and text message to over 250,000 users, and a suite of earthquake information products such as ShakeMaps, Did You Feel It? maps, and technical data is available on the website of the USGS Earthquake Hazards Program, which typically receives more than two million hits every day. USGS also provides near-real-time data to the National Oceanic and Atmospheric Administration's (NOAA) tsunami warning centers, supporting tsunami monitoring in the Pacific Rim and alerting in Alaska, Hawaii, Washington, Oregon, California, and U.S. territories in the western Pacific Ocean.

A 2005 cost-benefit study of ANSS by the NRC concluded that the economic benefits of the improved national system outweigh its costs by approximately 10 to 1. The quantitative economic benefits in just one benefit area (performance-based seismic design) exceed the cost of deploying the entire system.

### Regional Earthquake Monitoring

As part of ANSS, USGS and cooperating universities operate regional seismic networks in areas of high seismicity. Data from regional seismic networks are used to monitor active faults and ground shaking with much greater detail and accuracy than is possible with the national-scale network. Each region has appropriate local data processing capabilities and regional data are contributed to a national ANSS catalog of earthquakes. ANSS regional networks serve as State or local distribution points for information about earthquakes to the public, local and State agencies, and other regional interests. The regional data centers also relay earthquake data in real time to the USGS NEIC, as well as to other regional networks. The centers provide information about regional earthquake hazards and risks and about accepted mitigation practices, and those centers located at universities provide training and research facilities for students. During 2011, USGS partners in the ANSS regional monitoring effort were the California Institute of Technology; Columbia University; the University of Montana; Saint Louis University; the University of Nevada, Reno; the University of Alaska, Fairbanks; UC Berkeley; UC San Diego; the University of Memphis; the University of Oregon; the University of South Carolina; the University of Utah; Boston College; and the University of Washington.

### Global Seismographic Network

The GSN provides high-quality seismic data to support earthquake alerts, tsunami warnings, hazard assessments, national security (through nuclear test treaty monitoring), earthquake loss reduction, and research on earthquake sources and the structure and dynamics of the Earth. The GSN is a joint program supported by USGS and NSF and implemented by USGS, the Institute for Geophysics and Planetary Physics at the University of California, and the Incorporated Research Institutions for Seismology (IRIS), a university consortium sponsored by NSF. The network currently (2011) consists of 150 globally distributed stations, and USGS is responsible for the operation and maintenance of 100 of these stations.

USGS tasks related to the GSN include maintaining and upgrading station facilities, monitoring and maintaining network telecommunications, troubleshooting problems, providing major repairs, conducting routine service visits to network stations, training station operators, providing direct financial aid in support of station operations at those sites lacking a host organization, and ensuring data quality and completeness.

Because of its real-time data delivery, the GSN has become a critical element of continuous USGS hazard warning activities. Ninety-seven percent of GSN stations transmit real-time data continuously to the USGS NEIC in Golden, CO, where they are used, along with data from other networks, to rapidly determine the locations, depths, magnitudes, and other parameters of earthquakes (and other seismic events) worldwide. All GSN data are available to the public and scientists around the world via the IRIS Data Management Center. Data from the GSN are used extensively for basic and applied research on earthquakes, Earth structure, and other geophysical problems in studies conducted and supported by USGS and other agencies such as NSF, the U.S. Department of Energy, and the U.S. Air Force.

During 2011, USGS made significant progress in its so-called "next generation" upgrades, replacing the datalogger computers and electronics in a joint effort with IRIS to refurbish and standardize the network. The equipment for these upgrades was purchased with economic stimulus funds allocated by both USGS and NSF.

### NEES Operations Award to Purdue University

NEES began operations of its facilities and cyberinfrastructure in 2004 under an NSF award to the NEES Consortium, Inc., to enable research and innovation in earthquake and tsunami loss reduction, create an educated workforce in hazard mitigation, and conduct broader outreach and lifelong learning activities. In 2009, following a merit review re-competition process, NSF selected Purdue University to lead, manage, operate, and maintain NEES during FY 2010–2014.

NEES consists of a managing headquarters (known as NEEScomm) located at Purdue University; 14 state-of-the-art earthquake engineering and tsunami experimental facilities located at and locally operated by universities across the United States; the NEEShub cyberinfrastructure framework; and the NEES Academy for education, outreach, and informal science education, which is powered by NEEShub.[18] The 14 NEES experimental facilities are located at Cornell University; Lehigh University; Oregon State University; Rensselaer Polytechnic Institute; University at Buffalo, The State University of New York; UC Berkeley; UC Davis; UC Los Angeles; UC San Diego; UC Santa Barbara; UIUC; the University of Minnesota, Twin Cities; the University of Nevada, Reno; and the University of Texas at Austin. These facilities include single (outdoor), dual, and triple shake tables; geotechnical centrifuges with in-flight biaxial shakers and robotic tools; a tsunami wave basin; laboratories for testing large-scale structures, soil-foundation-structure interaction systems, and lifeline systems; mobile geotechnical and structural field-testing equipment; and two permanently instrumented field sites in southern California.

[18] Information about NEES is available at www.nees.org.

NEEShub, which is based on HUBzero technology previously developed at Purdue University, seamlessly integrates the 14 facilities and their telepresence capabilities, a publicly accessible, curated data repository, web-based collaborative tools, access to leading-edge computing resources, and open-source computational tools. Using Internet2, the NEES cyberinfrastructure enables hybrid testing methods (coupled computational and physical simulations) as well as multisite hybrid simulation.

The NEES Academy provides a community resource for educational materials, online learning, and outreach across the age spectrum. It supports outreach to the profession, providing a mechanism to bridge theories to practice and the needs of practice to research priorities. Faculty and staff at the NEES facilities support ongoing local outreach efforts, such as K–12 camps, museum exhibits, and informal science education. NEEScomm organizes an annual meeting that brings together both NSF-supported researchers using the NEES infrastructure and the distributed NEES operations team to discuss research findings, sharing of NEES experimental and cyberinfrastructure resources, and effective methods for education and outreach in earthquake engineering. Quake Summit 2011 was organized by NEEScomm and MCEER, which is located at the University at Buffalo, as a joint NEES-MCEER annual meeting and was held on June 9–11, 2011, in Buffalo, NY.

## Section 4

# State and Territory Activities to Promote Implementation of Research Results

The FEMA Earthquake Hazards Reduction State Assistance Program (implemented through cooperative agreements) is a FEMA responsibility under Public Law 108–360, which directs the agency to support State efforts to mitigate seismic risks and reduce future losses from earthquakes. Under the program, FEMA provides funds each year to eligible States and U.S. territories with high seismic risk. The funds can be used to support a range of eligible activities: (1) developing seismic mitigation plans; (2) preparing inventories and conducting seismic safety inspections of critical structures and lifelines; (3) updating building codes, zoning codes, and ordinances; (4) increasing earthquake awareness and education; and (5) encouraging the development of multistate groups for such purposes.

In 2011, FEMA awarded $1.795 million to 33 States and territories. This support is being used to strengthen earthquake risk-reduction efforts that are both traditional and innovative. Traditional uses include preparing and distributing information for the public that describes seismic hazards within a State as well as recommended preparedness and mitigation strategies and resources. Program funds also are helping States to train personnel in the use of FEMA's HAZUS-MH earthquake risk-assessment software; update State and county hazard mitigation and preparedness plans; support detailed, geologic seismic-hazard mapping in at-risk regions; cosponsor earthquake awareness and mitigation conferences; and review the adequacy of building codes and land use regulations in relation to seismic safety.

Following are selected examples of State and territory activities that involved FEMA support in 2011, listed in alphabetical order by State and territory. More detailed information regarding these activities may be found in the April 2012 FEMA document "The National Earthquake Hazards Reduction Program: FEMA Accomplishments in Fiscal Year 2011."

### Alabama

Alabama participated in the Great Central U.S. ShakeOut, which was added to the earthquake curriculum for the 6th grade and involved the business community through local chambers of commerce. Alabama also participated in NLE–11; a "hot wash" was held by officials after the exercise and outreach items were distributed to generate awareness of the earthquake risk throughout Alabama.

### Alaska

Alaska identified three communities affected by the 1964 Alaska earthquake and tsunami and developed interactive kiosks to educate their citizens and visitors about the risks they could face.

Kodiak, AK initiated a seismic risk assessment with the support of Alaska Homeland Security, the University of Alaska, Fairbanks, and the Alaska Seismic Safety Commission.

### American Samoa

American Samoa joined the FEMA earthquake State assistance program in FY 2010. Its 2011 focus was public outreach and education, including an initiative to develop and implement a public awareness campaign that was carried out primarily through advertising earthquake risks in local newspapers.

### Arizona

Arizona has two primary programs under way: the operation of 10 broadband seismometers, and public outreach and awareness. The seismometer data are being provided to counties in Arizona to assist in their earthquake awareness and planning activities. Outreach and awareness successes include television, radio, YouTube, blog-based, and print messaging.

### Arkansas

Arkansas supported a wide range of activities in 2011: updates to the Earthquake Program website of the Arkansas Department of Emergency Management; work with CUSEC for the Great Central U.S. ShakeOut; a "Public Earthquake Home Mitigation Workshop" at Ace Hardware in Conway; entry into an agreement with Radio Disney for a public awareness campaign; the creation and airing of an earthquake awareness television public service announcement; an "Earthquake 101" presentation for a teacher in-service workshop in Little Rock; earthquake awareness, response, and mitigation presentations for primary- and secondary-school counselors (more than 600 people attended 15 presentations); and the delivery of multiple FEMA 154 and ATC–20 training courses.

### California

California continued developing the California Integrated Seismic Network monitoring system; participating in earthquake-early-warning research and development; completing and exercising the Southern California Catastrophic Earthquake Response Plan; providing scenario technical assistance for California's Golden Guardian exercises; updating the "Guide and Checklist for Non-Structural Hazard Mitigation for California Schools"; rolling out an innovative social media campaign and the associated PBS documentary "Totally Unprepared"; and preparing the California Enhanced Hazard Mitigation Plan.

California also supported the California Earthquake Country Alliance (ECA) "whole community" collaboration among earthquake education stakeholders and ECA's product, the Great California ShakeOut. ShakeOut drills have spread to 10 other States and territories as well as to New Zealand, Japan, and developing nations through the Aga Kahn Development Network.

### Georgia

Georgia completed an earthquake response plan and an earthquake preparedness guide. The State also emphasized earthquake preparedness via Great Central U.S. ShakeOut activities; "Preparedness

Piggy" videos; ReadyGeorgia; Georgia Emergency Management Agency website enhancements; an earthquake preparedness brochure; church bulletin inserts; and an NLE–11 support workshop. Schools were the primary audience for the ShakeOut campaign, with about 94,000 students participating in drills.

### Guam

Guam developed new outreach materials for schools, tourists, and residents; conducted "Drop, Cover, and Hold On" drills; completed a hazard mitigation plan; conducted FEMA 154 and ATC–20 training classes; and conducted the 2011 Great Guam ShakeOut, for which some materials were translated into Japanese.

### Hawaii

In 2011, earthquake assistance funds were used in Hawaii for technical assistance, earthquake information products, exercises, promotion of building code adoption, implementation of a "Post and Pier" project via a web-based expert system, and teacher training workshops. Hawaii is also assessing regional hazards by conducting GIS mapping of soil types for Maui County and mapping landslide areas.

### Idaho

Idaho held the Great Idaho ShakeOut in October 2011. The State also developed a high school curriculum based on "Putting Down Roots in Earthquake Country: Your Handbook for Earthquakes in Idaho," and conducted soil classification mapping, planning initiatives, and exercises.

### Illinois

Illinois registrants for the Great Central U.S. ShakeOut 2011 numbered more than 490,000. Two ATC–20 courses were held in southern Illinois, which now has 218 trained inspectors in the CUSEC database. A group of architectural, engineering, and building inspection professionals from State government and the private sector continues to develop a framework for training, equipping, and deploying safety inspection teams.

### Maine

Maine used its 2011 earthquake assistance funds to provide business owners and managers with education on seismic risk and risk-reduction activities; update the State database of critical facilities; enable a Level 2 risk assessment in HAZUS-MH; and continue outreach and awareness activities.

### Missouri

Missouri prepared for the 2011 Great Central U.S. ShakeOut with numerous outreach and education activities, particularly those targeted to schoolchildren. Missouri also participated in NLE–11 and collaborated with the S.A.V.E. Coalition on ATC–20 training and other projects. The Missouri State Seismic Safety Commission was very involved in February's Earthquake Awareness Month activities. The Missouri Department of Natural Resources conducted "The Earth Moves under Our Feet" event at the Onondaga Cave State Park and earthquake mitigation events at the Bootheel Youth

Museum. The Bloomfield Elementary School used assistance funds to secure its nonstructural hazards.

### Nevada

Nevada held the 2011 Great Nevada ShakeOut on the same day as the Great California ShakeOut. SCEC was very helpful in organizing the event. Other activities included the completion of a project on soil classifications in Clark County by the Nevada Seismological Laboratory, upgrading seismic stations in Nevada with funds provided by USGS, and improving the State's coordination with the California Integrated Seismic Network. Nevada also is updating its epicenter map, including historical earthquakes.

### New Mexico

New Mexico conducted seismic vulnerability assessments using HAZUS-MH for 64 essential facilities (fire stations, emergency operations centers, police stations, hospitals, and schools) located in eight counties in the Belen to Taos corridor.

### New York

New York has about 20,000 State-owned buildings, but has limited information on the risk to these buildings posed by earthquakes and other hazards. To better understand the risk to State-owned buildings and to advance the "State Multi-Hazard Mitigation Plan," New York supported a multiagency task force and an associated working group that have been developing a State building inventory plan.

### Oklahoma

The Oklahoma Office of Emergency Management (OEM) completed educational workbooks through the Newspaper in Education program and preparedness advertisements that appeared in the Daily Oklahoman newspaper. During the Annual Emergency Management Conference in August 2011, the OEM distributed earthquake brochures and staff from the Oklahoma Geological Survey made presentations on the earthquake hazard in the State. The OEM website continues to be updated with earthquake information and now has a section on "Earthquake Safety." An Oklahoma-specific webpage was created within the Great Central U.S. ShakeOut website to provide up-to-date information on earthquake hazards, earthquake drills, and preparing homes and businesses for earthquakes. Jones School participated in the ShakeOut, along with representatives from the OEM, local emergency management agencies, FEMA Region VI, and FEMA's headquarters.

### Oregon

Oregon held the first Great Oregon ShakeOut as a pilot project in one county in 2011. Its success has resulted in plans for a statewide "Drop, Cover, and Hold On" drill in 2012. Two ATC–20 classes were held, along with an ATC–45 class. In Clackamas County, NETAP training (FEMA P–767) was held at a local hospital. The Cascadia Road Show held more than 10 public education events that were attended by more than 1,000 people. Oregon continues to work with its local and Federal partners in planning for a magnitude 9.0 Cascadia Subduction Zone earthquake and tsunami.

### Puerto Rico

Puerto Rico successfully adopted the latest model building codes in 2011. With this adoption, coupled with community education and implementation of risk reduction projects, Puerto Rico is on its way to building safer and more resilient communities. In support of the code adoption, FEMA provided experts who conducted workshops for local building code officials, architects, engineers, surveyors, and floodplain managers. Other training classes included FEMA–154; FEMA P–767; "Seismic Rehabilitation Training for One- and Two-Family Wood-Frame Dwellings" (FEMA 593); ATC–20; and ROVER. There was also a Puerto Rico Police Academy workshop that focused on what to do before, during, and after an earthquake. The Puerto Rico Emergency Management Agency (PREMA) conducted an earthquake preparedness campaign, which ran through June 2011 and included a LANTEC 2011 exercise for a magnitude 7.6 earthquake. PREMA, NOAA, and other organizations participated in the exercise, which was designed to improve tsunami warning systems.

### South Carolina

South Carolina has focused much of its work on increasing education about and awareness of the earthquake risk through the use of Internet social media, promotional videos, speaking engagements, and letters to schools and emergency management agencies. Bookmarks were used to encourage registrations for the Great Central U.S. ShakeOut, which soared from 40,000 to more than 100,000 after the 2011 Tohoku earthquake in Japan. South Carolina also conducted workshops for local governments on seismic risk and mitigation; developed an exhibit on the 1886 Charleston earthquake; performed HAZUS training; produced a "Drop, Cover, and Hold On" video; reactivated the South Carolina Seismic Safety Commission; conducted ATC–20 and FEMA–154 training attended by more than 350 participants; supported printing and distribution of updated seismic hazard maps; and carried out seismic vulnerability assessments. Other activities related to updating the South Carolina earthquake plan, the State's supporting role in NLE–11, regional and county earthquake exercises, operation of the South Carolina Seismic Network, and partnerships with colleges, universities, and other organizations.

### Texas

Outreach was conducted in numerous communities in El Paso County during 2011, where earthquake awareness and all-hazard community preparedness materials were distributed to residents through meetings in "colonia" border settlements. There also were several presentations by the "Promotoras," a subchapter of Project Vida, in and around the City of El Paso and in rural areas of El Paso County. Regional outreach included training provided to members of the Rio Grande Council of Governments First Responders Preparedness Planning Group in Marfa, TX. Officials with the City of Marfa have expressed an interest in receiving more in-depth and site-specific earthquake awareness training.

### Utah

Older unreinforced masonry (URM) buildings pose extreme risks to life safety in earthquake-prone areas. In Utah, there are many URM buildings. In 2011, Utah conducted rapid visual screenings of schools using ROVER, updated the "Utah Guide for the Seismic Improvement of Unreinforced

Masonry Dwellings," developed a flyer about the guide, and published exercise scenarios and "Putting Down Roots in Earthquake Country: Your Handbook for Earthquakes in Utah." The State also conducted scenario activities aided by HAZUS-MH and ShakeMaps, tools that were developed with FEMA and USGS support.

### Vermont

Vermont hosted nonstructural mitigation training based on FEMA E–74, combined with training by the State Geologist on the earthquake risk to critical facilities, for the owners of those facilities. The State Geologist also is a member of the "HAZUS/ShakeMap Earthquake Scenario Project" working group for New England.

### Virgin Islands

Television public service announcements on earthquakes and tsunamis were created and aired in 2011. Earthquake and tsunami presentations also were conducted at public and private schools, non-governmental organizations, churches, community centers, and home-owner associations.

### Washington

The Washington State Earthquake Program continued to identify methods to reduce risk and implement practical mitigation measures for deficient school structures. The Washington State Seismic Committee (SSC) initiated the "School Seismic Safety Pilot Project" to assess the seismic vulnerabilities of school district buildings in the Walla Walla and Aberdeen school districts, two areas with known earthquake faults. This effort produced a model process that could help the State and its cash-strapped school districts target hazard mitigation funds to those buildings most at risk. The SSC initiated a multiyear planning effort, "The Resilient Washington State Initiative," by engaging stakeholders who will assist the SSC in assessing current vulnerabilities to seismic hazards, in examining critical interdependencies between and across sectors, in establishing performance metrics for restoration of services and infrastructure, and ultimately, in providing a blueprint for long-term risk reduction policy implementation to improve Washington's resilience to earthquakes and other disasters. The effort will include the development of more effective seismic mitigation policies and recommendations for legislation and policy changes to improve statewide seismic safety. It will facilitate implementation of seismic risk reduction policies across Washington, with the goal of making the State truly resilient in 50 years.

For many years, the Washington State Emergency Management Division has conducted regularly scheduled "Drop, Cover, and Hold On" drills for citizens, schools, responders, businesses, and others. The ShakeOut name and brand has now been incorporated into this effort, and will debut in Washington State in October 2012. With Washington joining the ShakeOut participants, the entire west coast of the United States will be participating in simultaneous, annual earthquake drills that improve public safety and reduce personal vulnerability to earthquake hazards. Also in 2011, Washington initiated the Cascadia Subduction Zone earthquake planning efforts in coordination with FEMA Region X. State officials continue to work with FEMA and other local and Federal partners in planning for a magnitude 9.0 Cascadia Subduction Zone earthquake and tsunami.

# Section 5
# Related Non-NEHRP Activities That Support NEHRP Goals

Public Law 108–360 requires that NEHRP's annual reports to Congress include a description of activities being performed by the NEHRP agencies that contribute to NEHRP goals but are not included in the program. Highlights of these activities are described below.

## Interagency Committee on Seismic Safety in Construction

Through the NEHRP Secretariat, the Interagency Committee on Seismic Safety in Construction continued working with the Building Seismic Safety Council to produce updated, recommended standards for seismic safety in existing federally owned and leased buildings. The final draft of the new standards neared completion in 2011, and a new standards document will be issued in FY 2012.

## EarthScope

EarthScope is a multidisciplinary earth science program aimed at exploring in unprecedented detail the four-dimensional structure, dynamics, and evolution of North America. EarthScope is supported by NSF in partnership with USGS and the National Aeronautics and Space Administration (NASA). The EarthScope Facility, successfully completed in September 2008, comprises three core components: the San Andreas Fault Observatory at Depth (SAFOD), the Plate Boundary Observatory (PBO), and the United States Seismic Array (USArray). By the end of 2011, more than 1,100 permanent GPS stations, 1,400 seismic stations, 84 strainmeters, 354 magnetotelluric stations, and 26 tiltmeters were installed as part of the EarthScope Facility.

The EarthScope Facility, and more broadly the EarthScope program, provides a framework for broad, integrated studies of fault properties and earthquake processes, and for the analysis of seismic and volcanic hazards, fluids, and magma in the crust and mantle, plate-boundary processes, large-scale continental deformation, continental structure and evolution, and deep-Earth structure. EarthScope has developed a cyberinfrastructure to integrate, distribute, and analyze the diverse data sets collected by the facilities. In addition, the EarthScope Education and Outreach Program is actively engaging the general public, educators, and students to teach them about EarthScope science and to promote science literacy.

### EarthScope: SAFOD

The San Andreas Fault Observatory at Depth is a 3-kilometer deep hole drilled directly into the San Andreas fault, midway between San Francisco and Los Angeles near Parkfield, CA. SAFOD is providing the first opportunities to observe directly the conditions under which earthquakes occur and to collect rocks and fluids from the fault zone for laboratory study. SAFOD also includes a long-term observatory intended to continuously monitor the physical conditions within an active

earthquake nucleation zone. Data collected by SAFOD are providing unique insights into the physical and material conditions within a zone of active faulting. Analysis of the SAFOD core is well under way. In the past 2 years, more than two dozen papers have been published using SAFOD core, including information on the roles of different minerals and fault fluids in earthquake and faulting processes.

### EarthScope: PBO

The Plate Boundary Observatory is a geodetic observatory designed to study the three-dimensional strain field resulting from deformation across the active boundary zone between the Pacific and North American plates in the western United States. The PBO includes 1,200 GPS stations, 80 strainmeters, and 79 seismic stations. Its regional-scale geodetic network has provided surprising new information on the Pacific-North American plate boundary, showing, for example, that extension in the Basin and Range Province is not uniform, as was once widely believed, but instead is focused near its western and eastern edges. In addition, PBO GPS measurements are being used to understand the distribution of soil moisture and snow depth, key inputs to climate models, across the western United States, and vegetation greenness, a measure of the health of the environment and of environmental response to drought.

### EarthScope: USArray

The United States Seismic Array is a continent-scale seismic and magnetotelluric observatory designed to provide a foundation for integrated studies of continental lithosphere and deep Earth structure over a wide range of scales. The USArray consists of four major components:

- A Reference Network of permanent seismic stations that forms part of ANSS
- A Transportable Array[19] of about 400 seismic stations
- A Flexible Array pool of approximately 2,100 portable seismic instruments for use in experiments proposed by individual scientists
- A Magnetotelluric Array with permanent and transportable instruments

## Subcommittee on Disaster Reduction

The Subcommittee on Disaster Reduction (SDR) is an element of the President's National Science and Technology Council and facilitates national strategies for reducing disaster risks and losses that are based on effective use of science and technology. Mitigating natural and technological disasters requires a solid understanding of science and technology, rapid implementation of research information into disaster reduction programs and applications, and efficient access to diverse

[19] The Transportable Array is a rolling network of seismometers, moving from west to east across the United States, with stations spaced every 70 kilometers. The first stations were installed in 2004 in California, and the installation of the first Atlantic coast stations is planned for 2012. To date, approximately 1,370 Transportable Array stations have been deployed.

information available from both public and private entities. Chartered in 1988, the SDR provides a unique Federal forum for information sharing; the development of collaborative opportunities; the formulation of science- and technology-based guidance for policy makers; and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks.

Representatives of NEHRP participate in SDR meetings and provide briefings on program developments. The SDR serves as a forum for NEHRP agencies to reach out to and coordinate with other Federal agencies doing work related to NEHRP goals and objectives.

## International Activities

### U.S.-Japan Cooperative Program on Natural Resources

In 1964, the United States and Japan established the U.S.-Japan Cooperative Program on Natural Resources (UJNR) to promote bilateral cooperation in research and data exchange. Today, the UJNR involves 18 U.S. agencies and 10 Japanese agencies. The NEHRP agencies play important roles in the UJNR panels on earthquake research and on wind and seismic effects. The U.S. sides of these panels are chaired by USGS and NIST, respectively.

#### *UJNR Panel on Earthquake Research*

The eighth joint meeting of the UJNR Panel on Earthquake Research was held in Nagaoka, Japan in October 2010. The 21 members of the U.S. delegation to the meeting included representatives from USGS, NIST, NASA, SCEC, and UNAVCO, 8 early-career scientists supported by NSF and USGS, as well as the Director of NEHRP. The technical sessions focused on the earthquake cycle, episodic tremor and slow slip, strong-motion prediction and seismic hazards, early warning and rapid assessment of earthquakes and tsunamis, and studies of recent earthquakes. A field trip was also held to the epicentral region of the 2004 Niigata Chuetsu earthquake, and to the Kashiwazaki Nuclear Power Plant, the world's largest, that was damaged by the 2007 Niigata Chuetsu Oki earthquake. The next meeting of the panel is planned for the United States in October 2012.

#### *UJNR Panel on Wind and Seismic Effects*

As previously reported in the 2010 NEHRP annual report, there were about 2 years of limited interaction with Japan related to this panel. Accompanied by various U.S. agency representatives, NIST hosted an organizational meeting in San Francisco with leaders of Japan's Building Research Institute and Public Works Research Institute to review this UJNR relationship. Following this, the Japan side hosted a panel meeting in Tsukuba in late August 2011. Following this meeting, Japan side members hosted the U.S. side members on visits to some of the more heavily damaged areas from the 2011 Great Tohoku earthquake. As 2011 came to a close, U.S. agencies looked for ways to reduce travel commitments for UJNR while maintaining important bilateral relationships.

### U.S.-China Cooperation in Earthquake Studies

Cooperation between the United States and China in earthquake studies continued in 2011. In December 2010, the NEHRP agencies and a representative of the Nuclear Regulatory Commission

hosted a visit with representatives of the Institute of Engineering Mechanics, China Earthquake Administration. The two sides exchanged data regarding their future research plans.

### NEES Sharing Results and Facilities with Foreign Interests

NSF's "Memorandum Concerning Cooperation in the Area of Disaster Prevention Research" with Japan's Ministry of Education, Culture, Sports, Science, and Technology enables U.S. researchers to use both NEES facilities and Japan's E-Defense shake table, the world's largest, to investigate the seismic performance of large- to full-scale geotechnical and structural innovations. To enable this collaboration and joint use of facilities and data sharing, Purdue University, through the NEES operations award from NSF, has established a partnership with the National Research Institute for Earth Science and Disaster Prevention, which operates the E-Defense shake table facility. Annual workshops are organized, through an NSF award to UC Berkeley, to coordinate the NEES/E-Defense collaborative research program in earthquake engineering. The most recent meeting was held in August 2011 at the E-Defense shake table facility at the Hyogo Earthquake Engineering Research Center in Miki, Japan, and researchers from Japan and the United States discussed collaborative research in high performance reinforced concrete structures, base isolation and vibration control, and geotechnical engineering (underground construction). As part of NEES operations for fostering additional international collaborations, Purdue has also formalized partnerships with the Port and Airport Research Institute in Japan and with the Canadian Seismic Research Network, which is headquartered at McGill University in Montreal, Quebec, Canada.

## Appendix A

# Cooperating Organizations Receiving NEHRP Support

During 2011, NEHRP provided partial support in the form of either contracts or financial assistance for the following organizations, either directly or through recipients, to advance NEHRP goals and objectives. This listing does not include the many academic institutions to which NEHRP provides financial assistance through individual research grants and cooperative agreements. For each organization that is presented, a link to its Internet website is provided.

### Applied Technology Council (ATC)

The Applied Technology Council is a nonprofit corporation established in 1973 through the efforts of the Structural Engineers Association of California. ATC's mission is to develop and promote state-of-the-art, user-friendly engineering resources and applications for use in mitigating the effects of natural and other hazards on the built environment. ATC also identifies and encourages needed research and develops consensus opinions on structural engineering issues in a nonproprietary format. Project work is conducted by a wide range of highly qualified consulting professionals, thus incorporating the experience of many individuals from academia, research, and professional practice who would otherwise not be available from any single organization. Funding for ATC projects is obtained from government agencies and from the private sector. (www.atcouncil.org)

### Consortium of Universities for Research in Earthquake Engineering (CUREE)

CUREE is a nonprofit organization, established in 1988, which is devoted to the advancement of earthquake engineering research, education, and implementation. CUREE's membership, comprising some two dozen universities and many associated faculty members, works to identify new ways that research can solve earthquake problems; to collect and synthesize information and make it easily accessible; to establish national and international hazard research relationships; to perform earthquake engineering and related research; to manage research consortia and cooperative programs; and to educate experts, practitioners, students, and the public. (www.curee.org)

### Earthquake Engineering Research Institute (EERI)

EERI is the Nation's leading technical society dedicated to the reduction of risk from earthquakes and is recognized as an authoritative voice for earthquake risk reduction information in the United States. A significant activity for EERI is supporting Federal agencies in implementing their unique NEHRP responsibilities.

With support from FEMA, EERI annually produces a technical seminar program to improve the knowledge of practicing engineers. The seminar program for 2011, presented in San Francisco, Seattle, and Los Angeles, was "Seismic Design and Performance of Nonstructural Elements." Leading national authorities from practice and academia discussed nonstructural element performance in recent earthquakes, NEES research on nonstructural performance, current code

requirements, the new edition of "Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide" (FEMA E–74), and implementing new requirements for equipment seismic certification. The total number of attendees in all sessions was 235. The seminar was recorded and is now available for downloading on the EERI website.

Each year, EERI issues at least one new oral history with FEMA support. These important publications help preserve the historical record of earthquake science and engineering and are critical to providing a sense of history to those active in the earthquake field as well as young people considering it as a career. In 2011, EERI published an oral history of William A. Anderson, a scholar-pioneer in the field of sociology. His oral history offers insight into his roles as a supportive colleague and an architect of the current U.S. science and engineering research infrastructure. Dr. Anderson's oral history is the first on a social scientist.

The 2011 NEHRP FEMA/EERI professional fellowship recipient published his research on "Earthquake Ground Motion Simulation Using Novel Machine Learning Tools," which was conducted in association with the California Institute of Technology's Earthquake Engineering Research Laboratory. The recipient developed a novel method of model-independent probabilistic seismic hazard analysis and ground motion simulation, which was verified using previously recorded data and machine learning.

A Ph.D. candidate in public policy at UC Berkeley was the 2010–2011 NEHRP-FEMA Graduate Fellow in Earthquake Hazard Reduction. Her work focuses on the beliefs and behavior of people and organizations that are in a position to make critical preparedness choices for their communities. Her dissertation evaluates a 2005 Berkeley, CA, law addressing the soft-story wood-frame apartment building problem, and examines influences on building owners' seismic safety investment decisions. It is the first study to compare the relative roles of individual characteristics, social influences, and economic factors on mitigation choices. The findings are relevant to other jurisdictions struggling with how to reduce seismic vulnerabilities in their existing building stocks.

EERI's Student Leadership Council organizes and manages the Annual Undergraduate Seismic Design Competition. The competition is a hands-on learning experience and always an exciting component of EERI Annual Meetings. In February 2011, approximately 250 undergraduate students from 25 teams took part in the largest competition to date. (www.eeri.org)

### Incorporated Research Institutions for Seismology (IRIS)

IRIS is an NSF-supported university research consortium dedicated to exploring the Earth's interior through the collection and distribution of seismographic data. IRIS partners with USGS in the operation of the GSN, which provides data for global seismological research and is one of the primary data sources used by the USGS NEIC in tracking global earthquake activity. The IRIS Program for Array Seismic Studies of the Continental Lithosphere loans portable seismograph systems for national and international field investigations, including many that have contributed to studies of earthquakes and Earth structure under NEHRP. The IRIS Education and Outreach Program enables audiences beyond seismologists to access and use seismological data and research

for educational purposes. The IRIS United States Seismic Array (part of the NSF-funded EarthScope project) includes permanent stations that have contributed to the USGS ANSS as well as portable stations that are systematically collecting data from across the continental United States. Data collected by all of these IRIS programs are assessed, archived, and distributed by the IRIS Data Management System, along with data contributed from numerous national and international sources, including ANSS, U.S. regional networks, and other NEHRP programs. (www.iris.edu)

### National Institute of Building Sciences (NIBS)

Congress chartered the National Institute of Building Sciences in 1974 as an independent, non-governmental, nonprofit organization. NIBS balances public and private expertise to mobilize uniquely authoritative support for the public interest in building sciences, engineering, construction, and technology. NIBS involves the national building community in shaping its programs and priorities through its Consultative Council; other councils address specific issues in security and disaster preparedness, facility performance and sustainability, and information resources and technologies. (www.nibs.org)

Since 1979, the Building Seismic Safety Council (BSSC) of NIBS has provided a national forum for improving earthquake-resistant design and construction, benefiting both the building community and the public in general. Supported by some 65 voting member organizations, the BSSC has been involved in developing the 2009 NEHRP Recommended Seismic Provisions and in working with FEMA on practical building code applications of these provisions. (http://bssc.nibs.org/)

### Natural Hazards Center

NSF, USGS, and other Federal agencies support the Natural Hazards Center at the University of Colorado at Boulder, to advance and communicate knowledge on hazard mitigation and disaster preparedness, response, and recovery. Using an all-hazards and interdisciplinary framework, the center fosters information sharing and integration of activities among researchers, practitioners, and policy makers from around the world; supports and conducts research; and provides educational opportunities for the next generation of hazards scholars and professionals. The 36th Annual Natural Hazards Research and Applications Workshop, held July 9–12, 2011, in Broomfield, CO, brought together researchers and practitioners from many disciplines for face-to-face discussions on how society deals with hazards and disasters. (www.colorado.edu/hazards/)

### Southern California Earthquake Center (SCEC)

The Southern California Earthquake Center, headquartered at the University of Southern California, was founded in 1991 with a mission to gather data on earthquakes in southern California and elsewhere, to integrate information into a comprehensive and physics-based understanding of earthquake phenomena, and to communicate that understanding to society at large as useful knowledge for reducing earthquake risk. A community of over 600 scientists from 16 core institutions, 47 participating institutions, and elsewhere participates in SCEC. SCEC also partners with a large number of other research, education, and outreach organizations in many disciplines.

During 2011, the center was in the fifth year of its third phase, SCEC3, a 5-year program funded by NEHRP partners NSF and USGS.

To support its community of participating organizations, SCEC engages in information technology research that will revolutionize our methods of doing collaborative research and distributing research products online. In addition, the SCEC Communication, Education, and Outreach Program offers student research experiences, web-based education tools, classroom curricula, museum displays, public information brochures, online newsletters, and technical workshops and publications. (www.scec.org)

## Regional Earthquake Consortia

### *Cascadia Region Earthquake Workgroup (CREW)*

CREW is a coalition of private- and public-sector representatives working together to improve the ability of communities throughout the Cascadia Region (northern California, Oregon, Washington, and British Columbia) to reduce the effects of earthquakes and related hazards such as tsunami. Since the mid-1990s, CREW has created several publications, including scenarios, post-disaster recovery guides, and other educational materials accessible on CREW's website. CREW is composed mostly of volunteer representatives who help foster linkages between scientists, businesses, and government agencies on earthquake resilience.

In 2011, CREW hosted three webinars attended by emergency managers from all levels of government and by business partners, engineers, and the general public, to provide lessons learned from historical events for future mitigation and preparedness activities. Topics included "Post-Disaster Reconnaissance of Tohoku," "Tsunami Vertical Evacuation Lessons Learned from Japan," and "Lessons Learned from the Christchurch, New Zealand Earthquake." CREW also hosted a forum and panel discussion on "Benefit/Cost Analysis" that identified the basics behind such analysis from an economist's viewpoint and presented challenges and opportunities related to enhancing benefit/cost analysis for community seismic mitigation projects.

CREW continues to support its partners in any earthquake-related efforts that occur in their State or Province. In 2011, CREW supported Washington State's earthquake resilience planning efforts, British Columbia's ShakeOut 2011, and FEMA Region X for the Cascadia regional planning efforts and the Evergreen Quake Exercise series. (www.crew.org/)

### *Central United States Earthquake Consortium (CUSEC)*

CUSEC, in partnership with FEMA and NEHRP, was established in 1983 and includes 8 member States and 10 associate States represented in FEMA Regions IV, V, VI, and VII. The CUSEC Board of Directors includes the heads of the emergency management agencies of the eight member States (Alabama, Arkansas, Illinois, Indiana, Kentucky, Missouri, Mississippi, and Tennessee) and an ex officio member representing the Association of CUSEC State Geologists.

In 2011, CUSEC sponsored numerous awareness and education projects. These included the development and distribution of brochures, newsletters, and pamphlets; Earthquake Awareness Week activities; town hall meetings; working with State and local groups to encourage adoption of building codes; and bicentennial observances of the 1811–1812 New Madrid earthquakes. For the bicentennial, CUSEC participated in the kick-off event in St. Louis on February 11, 2011, and was involved in associated events throughout the course of the year. CUSEC coordinated and sponsored the Great Central U.S. ShakeOut, which engaged more than 3 million participants across 11 States. CUSEC was honored by the White House for its efforts through President Obama's Champions of Change program, and received FEMA's "Individual and Community Preparedness Award" for the ShakeOut program. CUSEC's partnership with the St. Jude Children's Research Hospital's Dream Home program is a highlight of its bicentennial activities and its efforts to demonstrate seismic risk reduction measures.

Mitigation activities in 2011 included sponsoring nonstructural training for schools, hospitals, and child care facilities and FEMA 154 training at various locations; promoting the adoption of building codes; applying research results via workshops; and post-earthquake clearinghouse planning. CUSEC also focused on multistate response and recovery coordination with other groups. Activities in this area included the creation or improvement of catastrophic earthquake response plans for all eight CUSEC States at the local and State level and the validation of those plans through NLE–11. CUSEC was involved in two groundbreaking efforts in connection with NLE–11. One was a first-ever "Resource Allocation" workshop that identified necessary resource requirements and developed an understanding of national capabilities, including those in the private sector. In the other effort, CUSEC States served as a model and real-world test of the U.S. Department of Homeland Security's "Virtual USA" project. This allowed the CUSEC States to share data and information dynamically among themselves and with the Federal Government, by effectively linking differing operating systems.

In 2011, CUSEC created EQProgram.net as an online resource for State earthquake program managers to use in their efforts to better prepare their States and the Nation for earthquakes. The website, which serves as an online tool for information exchange, document sharing, news distribution, and collaboration among the managers, is maintained and hosted by CUSEC. (www.cusec.org/)

### *Northeast States Emergency Consortium (NESEC)*

NESEC was established in 1991 and is located in Wakefield, MA. It develops, promotes, and coordinates comprehensive all-hazards emergency management activities throughout the Northeast. This includes all phases of emergency management: preparedness, response, recovery, and mitigation. NESEC's work is a vital component of the planning and response activities undertaken to ensure the safety and welfare of the more than 40 million people living in the region. Members of NESEC include Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.

Activities and initiatives in 2011 included participating in the production of ShakeMaps and HAZUS-MH studies for 11 earthquakes in the Northeast; a Level 2 HAZUS-MH earthquake loss estimation study for the City of Boston; facilitating building code awareness through an online zip code application; reformatting and modernizing, using GIS, the results of a study funded by FEMA in 1992 on "Seismic Provisions of State/Local Building Codes"; and developing a URM building inventory and mitigation strategy, which should help in raising awareness of these earthquake-vulnerable buildings and their locations across the northeast United States. (www.nesec.org/)

### *Western States Seismic Policy Council (WSSPC)*

WSSPC was established in 1979. The 39 members of WSSPC include the directors of the geological surveys and emergency management agencies from 13 Western States, British Columbia, Yukon, American Samoa, Guam, and the Northern Mariana Islands, and representatives from 7 seismic councils and commissions. Affiliate members include private corporations, local governments, nonprofit organizations, universities, and individuals who share the common goal of reducing losses from earthquakes.

WSSPC develops policy recommendations via three standing committees: the Basin and Range Province Committee; the Tsunami Hazard Mitigation Committee; and the Committee for Engineering, Construction, and Building Codes. In 2011, a "Safe Schools Initiative" was started to focus on progress being made by the States in assessing and mitigating vulnerable schools. WSSPC also developed five policy recommendations related to identifying and mitigating URM buildings; assessing fault activity in the interior Western States; an earthquake emergency handbook for first responders and incident commanders (a recommendation based on the 2008 Wells, NV earthquake experience); earthquake monitoring networks; and public education on mitigation and warning procedures for distant and local tsunamis. Other policy subjects include earthquake early warning, the safety of new and existing school buildings, earthquake scenarios, and managing post-earthquake information.

WSSPC's Tsunami Hazard Mitigation Committee prepared a white paper titled "Tsunami Hazard Mitigation and Preparedness: A Perspective from State and Territory Tsunami Programs in the High Tsunami Risk Pacific Region." The report highlights the importance of the States' outreach and education efforts in preparing coastal communities for great earthquakes followed by locally generated tsunamis.

Other activities included the WSSPC Awards in Excellence program; conferences and workshops, including the earthquake early warning workshop and a nonstructural mitigation workshop held in conjunction with the NEPM meeting; seismic council and commission meetings; annual State reporting on earthquake program activities; and outreach through the WSSPC website and quarterly newsletter. (www.wsspc.org)

## Appendix B
# List of Acronyms

| | |
|---|---|
| ACCESS | Advancement of Cyberinfrastructure Careers through Earthquake System Science |
| ACEHR | Advisory Committee on Earthquake Hazards Reduction |
| ANSS | Advanced National Seismic System |
| ASCE | American Society of Civil Engineers |
| ATC | Applied Technology Council |
| BSSC | Building Seismic Safety Council |
| CREW | Cascadia Region Earthquake Workgroup |
| CUREE | Consortium of Universities for Research in Earthquake Engineering |
| CUSEC | Central United States Earthquake Consortium |
| DFO | Designated Federal Official |
| ECA | Earthquake Country Alliance |
| E-Defense | Earth-Defense |
| EERI | Earthquake Engineering Research Institute |
| ETS | Episodic tremor and slip |
| FEMA | Federal Emergency Management Agency |
| FY | Fiscal year |
| GEER | Geotechnical Extreme Events Reconnaissance |
| GPS | Global Positioning System |
| GSN | Global Seismographic Network |
| ICC | NEHRP Interagency Coordinating Committee |
| IRIS | Incorporated Research Institutions for Seismology |
| MICP | Microbially-induced calcite precipitation |
| NASA | National Aeronautics and Space Administration |
| NEES | George E. Brown, Jr. Network for Earthquake Engineering Simulation |
| NEESreu | NEES Research Experience for Undergraduates |
| NEHRP | National Earthquake Hazards Reduction Program |
| NEIC | National Earthquake Information Center |
| NEPM | National Earthquake Program Managers |
| NESEC | Northeast States Emergency Consortium |
| NETAP | National Earthquake Technical Assistance Program |
| NIBS | National Institute of Building Sciences |
| NIST | National Institute of Standards and Technology |

| | |
|---|---|
| NLE–11 | National Level Exercise 2011 |
| NMSZ | New Madrid Seismic Zone |
| NOAA | National Oceanic and Atmospheric Administration |
| NRC | National Research Council |
| NSD | Negative stiffness device |
| NSF | National Science Foundation |
| OEM | Oklahoma Office of Emergency Management |
| PBO | Plate Boundary Observatory |
| PBSD | Performance-based seismic design |
| PEER | Pacific Earthquake Engineering Research Center |
| PREMA | Puerto Rico Emergency Management Agency |
| RAPID | Rapid Response Research |
| REU | Research Experiences for Undergraduates |
| ROVER | Rapid Observation of Vulnerability and Estimation of Risk |
| RTHS | Real-time hybrid simulation |
| SAFOD | San Andreas Fault Observatory at Depth |
| SCEC | Southern California Earthquake Center |
| SDR | Subcommittee on Disaster Reduction |
| SSC | Washington State Seismic Committee |
| SURE | Summer Undergraduate Research Experiences |
| UC | University of California |
| UIUC | University of Illinois at Urbana-Champaign |
| UJNR | U.S.-Japan Cooperative Program on Natural Resources |
| URM | Unreinforced masonry |
| USArray | United States Seismic Array |
| USEIT | Undergraduate Studies in Earthquake Information Technology |
| USGS | U.S. Geological Survey |
| UW | University of Wisconsin |
| VUW | Victoria University-Wellington |

## Appendix C
# Notable Earthquakes of 2011

This appendix summarizes notable earthquake activity worldwide during the period from October 1, 2010, through September 30, 2011. The selected earthquakes are listed in chronological order.

### February 14, 2011: Central Arkansas, Magnitude 4.7

The earthquake was located near the towns of Guy and Greenbrier and was part of an earthquake swarm in the area that began in 2009. This swarm was located in the vicinity of deep well fluid injection activities. Following this earthquake the Arkansas Oil and Gas Commission ordered the suspension of pumping activities in nearby wells. The earthquake caused little damage but was widely felt in central and northern Arkansas and in southern Missouri.

### February 21, 2011: Christchurch, New Zealand, Magnitude 6.1

This earthquake struck during the early afternoon (local time) about 3 miles from the center of Christchurch. It was the largest in a series of earthquakes that began with a magnitude 7.0 event on September 30, 2010, near Darfield, about 30 miles to the west. Because of its proximity to the center of Christchurch, the impacts of the February earthquake were much greater than those of the Darfield event. It resulted in the deaths of 182 people, and significant numbers of people suffered injuries. Much of the loss of life was the result of the catastrophic collapse of a multistory office structure, the Canterbury Television (CTV) building, where 115 people died. Ground failures, liquefaction, and subsequent flooding also caused significant losses, particularly to buried lifelines. Total economic losses are estimated to be between $15 and $20 billion.

### March 11, 2011: Near East Coast of Honshu, Japan, Magnitude 9.0

The Great Tohoku earthquake was the largest earthquake to impact a modern, industrialized country in recent history. Although the ground shaking damage from this offshore earthquake was not unusually severe, the ensuing tsunami exceeded anticipated heights and caused widespread damage and loss of life along the northeastern Honshu coastline. At least 15,000 people were killed, over 4,600 are missing, more than 5,300 were injured, and approximately 131,000 were displaced. At least 332,300 buildings, 2,100 roads, and 50 bridges along the east coast of Honshu from Chiba to Aomori were destroyed or damaged by the earthquake and tsunami. Most casualties and damage occurred in Iwate, Miyagi, and Fukushima, from the tsunami that had a maximum run-up height of over 120 feet in some locations. The tsunami damaged nuclear power facilities near Fukushima, causing some release of radioactive material. The total economic loss in Japan was initially estimated at $300 billion, but this loss estimate is expected to rise, making the economic losses from this event the largest from any natural disaster to date.

### August 23, 2011: Central Virginia, Magnitude 5.8

This earthquake was the largest in the eastern United States in over 100 years. It was felt by approximately 30 million people from southern Canada to northern Georgia and as far west as Illinois. Moderately heavy damage occurred in the rural region of Louisa County southwest of the town of Mineral. Schools were particularly hard hit, primarily with nonstructural damage. Widespread light to moderate damage occurred from central Virginia to southern Maryland, including in the Washington, DC area where many iconic monuments and buildings suffered minor damage. Minor damage was also reported in parts of Delaware, southeastern Pennsylvania, and southern New Jersey. A nuclear power plant at North Anna, VA was shut down for several months. The locations of aftershocks following this earthquake clearly define a three-dimensional planar surface, indicative of a buried geologic fault. This is the first time that an earthquake in the eastern United States has been associated unambiguously with a specific geologic feature.