Annual Report
of the
National Earthquake Hazards Reduction Program
for Fiscal Year 2008

August 2009


FEMA

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

USGS
science for a changing world

This annual report of the National Earthquake Hazards Reduction Program (NEHRP) for fiscal year 2008 is submitted to Congress by the Interagency Coordinating Committee (ICC) 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 ICC are as follows:

Dr. Patrick D. Gallagher, Acting Chair of the ICC
Deputy Director
National Institute of Standards and Technology
U.S. Department of Commerce

W. Craig Fugate
Administrator
Federal Emergency Management Agency

Dr. Arden L. Bement, Jr.
Director
National Science Foundation

Dr. Peter R. Orszag
Director
Office of Management and Budget
Executive Office of the President

Dr. John P. Holdren
Science Advisor to the President and
Director, Office of Science and Technology Policy
Executive Office of the President

Dr. Suzette M. Kimball
Acting Director
U.S. Geological Survey

Disclaimer 1: Certain trade names or company products are mentioned in the text to specify adequately the experimental procedure and equipment used. In no case does such identification imply recommendation or endorsement by any of the agencies represented on the ICC, nor does it imply that the equipment is the best available for the purpose.

Disclaimer 2: This document provides links to Web sites that may have information of interest to its readers. The agencies represented on the ICC do not necessarily endorse the views expressed or the facts presented on these sites, and they do not endorse any commercial products that may be advertised or available on these sites.

Preface

On a Monday afternoon in May of 2008 an earthquake of magnitude 7.9 struck the eastern portion of Sichuan Province in China. This earthquake left 5 million persons homeless and caused 375,000 injuries. Over 87,000 people are known to be dead or missing. It is estimated that it will be a decade or more before the afflicted area in China is "rebuilt."

Earthquakes can strike without warning and are capable of causing widespread damage and disruption. Fortunately, earthquake disasters can be avoided, but not without sound preparation. Parents can be made confident that schools have been designed to be earthquake safe, and that students have been drilled on personal safety actions. Public officials should be confident that they have made the building stock of their towns and cities earthquake resistant through the adoption and enforcement of appropriate building codes. Emergency response personnel should react to earthquake crises with assurance, steadied by awareness of estimated impacts and by experience gained in scenario exercises. Business owners should be confident that they have taken the steps necessary to ensure employee safety and continuity of operations. Homeowners should be aware of what to expect, reinforce their dwellings, and be prepared to be self sufficient if necessary. It is critical that we have the knowledge and tools to act on these opportunities.

The United States National Earthquake Hazards Reduction Program (NEHRP) is dedicated to providing the knowledge and tools needed to ensure a future in which our people are safe from, and our property and prosperity are resilient to, the impacts of earthquakes. Since 1978, NEHRP has made great strides in public awareness, in hazard assessments, in engineering and geotechnical design and construction methods, in earthquake monitoring and notification, in building code development and adoption, and in response and recovery readiness. Yet the Nation still has vulnerabilities to earthquakes, and much work remains to enable us to seize the opportunities to further reduce and ultimately eliminate this threat.

This document is one of a series of annual reports on the activities and achievements of NEHRP. The achievements described in this report are cast in the framework of the NEHRP strategic plan, thus making it straightforward to measure progress toward the goals and objectives of that plan. These achievements build on the dedication and hard work of a generation of engineers, scientists, and government officials at all levels. We in the NEHRP agencies take pride in these efforts and achievements, and we are resolved to advance this work so that we have the knowledge and tools to keep our children safe in their schools, to make our communities and businesses earthquake resilient, to promote effective emergency response, and to turn homes into havens when earthquakes strike.

Table of Contents

Executive Summary

This document is the annual report of the National Earthquake Hazards Reduction Program (NEHRP) for fiscal year (FY) 2008[1] presented by the NEHRP Interagency Coordinating Committee (ICC). This report, required by Public Law 108–360, describes the activities of the NEHRP agencies during the year and their progress toward reducing the impacts of future earthquakes in the United States. Additionally, this report gives program budgets for FY 2009 and those proposed for FY 2010.

The NEHRP ICC is composed of the Directors of the four NEHRP agencies and the Directors of the White House Office of Science and Technology Policy and Office of Management and Budget. The four NEHRP agencies 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 its Director chairs the ICC.

There were over 3,000 earthquakes registered in the United States in 2008. Notable among these were a magnitude 6.0 event near Wells, NV, on February 21, 2008, and a magnitude 5.4 event in eastern Illinois on April 18, 2008. The latter event was felt in 17 states. Worldwide, the event of greatest impact was in western China, with over 87,000 people known dead or missing. This earthquake caused widespread damage and severe disruption of lifelines and the regional infrastructure. Appendix D gives more detail on these events and others.

The principal accomplishments of NEHRP in 2008 are summarized below:

NEHRP Strategic Plan for Fiscal Years 2009–2013: The NEHRP agencies under the leadership of NIST completed the development, review, and revision of a strategic plan for NEHRP activities. This plan received extensive review by the ICC and by the earthquake professional community of the United States. More than 140 comments were received from individuals, professional societies, and state and federal agencies. The plan received final ICC and interagency clearance in September 2008 and was published the following month.

George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES): NEES is a major initiative by NSF to develop a distributed and interconnected network of laboratory and field facilities to test new and existing design and construction practices, soil response and integrity, and tsunami impacts under realistic earthquake conditions. The

[1] This report covers FY 2008 as defined by the Federal Government, a period that began on October 1, 2007, and ended on September 30, 2008. For convenience and readability "FY" is not repeated in subsequent references to this period, except in budget discussions. Consequently, all references to the year 2008 should be interpreted as FY 2008 unless calendar year 2008 is specified.

construction phase of NEES was completed in 2004 and it has developed into an active research partnership. As of September 2008, through five annual research program solicitations, NSF has funded over 50 research projects to use the NEES facilities to study a wide spectrum of engineering topics related to soil stability, structural response, and safety in earthquakes and tsunamis.

International Codes: The International Code Council recently completed its code change hearings for the 2009 edition of the building codes that serve as the models for codes adopted in the United States. NEHRP representatives provided input on many proposed code changes for the "International Building Code," the "International Existing Building Code," and the "International Residential Code." This involved supporting proposed code changes submitted by FEMA and others that would improve protection against hazards, working to develop some of these proposed changes in cooperation with other proponents, and speaking in opposition to proposed changes that would weaken the code. Overall, NEHRP was successful in introducing and maintaining strong earthquake safety provisions for the building codes.

Earthquake hazards of the Hayward Fault in California's East Bay region: October 21, 2008, marked the 140th anniversary of the 1868 Hayward earthquake, the last damaging earthquake on the Hayward Fault, which runs along the heavily urbanized east side of San Francisco Bay. Geologic studies of the fault reveal that the past five such earthquakes have occurred on average every 140 years. This year, USGS generated a series of products for building public awareness of the significant hazard posed by this fault. USGS organized the 1868 Hayward Earthquake Alliance, a public-private nonprofit organization having over 120 different member organizations focused on promoting earthquake preparedness. About 200,000 schoolchildren from all over the Bay Area participated in a school earthquake drill, and dozens of businesses, organizations, and local governments participated in activities promoting earthquake awareness and preparation.

This report describes these and other accomplishments of NEHRP during 2008. The ICC is proud of these advances that are based on the imaginative thinking, on the technical, engineering, and scientific expertise, and on the hard work of the members of the NEHRP agencies and those they support. Work completed in 2008 will have applications immediately or in the near future in reducing earthquake risk. Work advanced in 2008 has laid a strong foundation for realizing similarly effective outcomes in future years.

Chapter

1

Introduction

1.1 LEGISLATIVE OVERVIEW

The National Earthquake Hazards Reduction Program (NEHRP) is a multiagency program initially authorized by Congress in 1977 and subsequently reauthorized on 2- to 5-year intervals. In 2004 Congress authorized funding to be appropriated for the program through 2009. The four federal agencies with funding authorizations and legislatively mandated responsibilities for NEHRP activities 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).

The reauthorization of NEHRP in 2004 (Public Law 108–360) requires the NEHRP Interagency Coordinating Committee (ICC) to submit an annual report to coincide with the President's annual budget request. This report is transmitted in fulfillment of this requirement to the Committee on Science and Technology and the Committee on Natural Resources of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.[1]

1.2 NEHRP ORGANIZATION AND MANAGEMENT

Previous NEHRP annual reports have discussed in some detail changes in NEHRP organization and management during recent years. The major changes in organization and management can be seen in the shift of lead-agency responsibilities to NIST, in the establishment of the ICC and the Advisory Committee on Earthquake Hazards Reduction (ACEHR), in the development of new strategic and management planning documents, and in the increased cooperation and coordination among the NEHRP agencies.

The roles of the NEHRP agencies, which have not changed within the past 5 years, are described in the paragraphs that follow.

[1] This report covers FY 2008 as defined by the Federal Government, a period that began on October 1, 2007, and ended on September 30, 2008. For convenience and readability "FY" is not repeated in subsequent references to this period, except in budget discussions. Consequently, all references to the year 2008 should be interpreted as FY 2008 unless calendar year 2008 is specified.

Federal Emergency Management Agency

FEMA is responsible for developing effective earthquake risk-reduction tools and promoting their implementation, as well as for supporting the development of disaster-resistant building codes and standards. FEMA's NEHRP activities are led by the Risk Reduction Division of the Mitigation Directorate at FEMA Headquarters and through the FEMA Regions. Organizations that received FEMA support for NEHRP activities in 2008 include states, multistate earthquake consortia, seismic experts from the academic and practitioner communities, and stakeholder groups that access a vast network of expertise in engineering, academics, and public policy.

National Institute of Standards and Technology

NIST serves as the NEHRP lead agency and, in addition, develops, evaluates, and tests earthquake-resistant design and construction practices for implementation in building codes and engineering practice. NEHRP Directorate, Secretariat, and applied research activities are conducted in the Building and Fire Research Laboratory of NIST.

National Science Foundation

NSF supports basic research and research facilities in earth sciences, engineering, and social, behavioral, and economic sciences relevant to understanding the causes and impacts of earthquakes and to developing practical measures to reduce their effects. NSF's NEHRP-related support is carried out primarily through research grants to individual universities, university consortia, and other organizations. These grants are awarded primarily through the agency's Directorate for Engineering and Directorate for Geosciences.

U.S. Geological Survey

USGS operates and supports earthquake monitoring, data analysis, and notification facilities; provides earthquake hazard assessments; and conducts and supports targeted research on earthquake causes and effects. The Earthquake Hazards Program Office at USGS headquarters leads the agency's NEHRP work. USGS research and monitoring activities are conducted by USGS scientists at offices in Albuquerque, NM; Anchorage, AK; Golden, CO; Memphis, TN; Menlo Park and Pasadena, CA; and Seattle, WA, as well as through grants and cooperative agreements with universities, state geological surveys, and other organizations.

Cooperating Organizations

NEHRP agencies support and work with many cooperating organizations, which are described briefly in Appendix A of this report. These organizations are essential in furthering the work of NEHRP in research, development, and implementation. Many of these organizations receive support from multiple NEHRP agencies and other sources with interests common to NEHRP goals.

1.3 NEHRP COORDINATION AND OVERSIGHT

The work of NEHRP is coordinated at the highest level by the Interagency Coordinating Committee (ICC). NEHRP is reviewed and guided by an external advisory panel of nongovernment experts. Working-level NEHRP activities are coordinated by the Program Coordination Working Group (PCWG).

Interagency Coordinating Committee

In 2004 Congress (Public Law 108–360) established the ICC to "...oversee the planning, management, and coordination of the Program." The ICC is composed of the head of each NEHRP agency as well as the Directors of the White House Office of Science and Technology Policy and of the Office of Management and Budget. In addition to program oversight, the ICC is responsible for developing the NEHRP strategic plan, a management plan, an integrated NEHRP budget, and annual reports. The Director of NIST chairs the ICC.

The ICC met in April and August 2008 to address program and policy issues. The ICC also conferred in December 2007 without meeting. These activities focused primarily on the development, review, and content of the "NEHRP Strategic Plan for Fiscal Years 2009–2013." The ICC approved the new strategic plan in August 2008, and it was published in October 2008 after further interagency review. In March 2008, the ICC released its second NEHRP annual report to Congress as required under the 2004 NEHRP reauthorization.

Advisory Committee on Earthquake Hazards Reduction

Congress established the Advisory Committee on Earthquake Hazards Reduction (ACEHR) in 2004 to assess the following:

- Trends and developments in the science and engineering of earthquake hazard reduction.
- The effectiveness of NEHRP in carrying out specified activities.
- The need to revise NEHRP.
- The management, coordination, implementation, and activities of NEHRP.

The ACEHR is composed of leading earthquake professionals who represent a balance of research and practitioner expertise; regional, state, and local interests; and relevant elements of the private sector. The ACEHR met in October 2007 and in April 2008. ACEHR activities at these meetings focused on developing the first ACEHR report to the NIST Director on the effectiveness of NEHRP. The committee released this report in May 2008.[2] The ACEHR report and coordinated

[2] "Effectiveness of the National Earthquake Hazards Reduction Program: A Report from the Advisory Committee on Earthquake Hazards Reduction," May 2008, http://www.nehrp.gov/pdf/2008ACEHRReport.pdf.

NEHRP agency responses can be found at http://www.nehrp.gov/pdf/2008ACEHRReport.pdf and http://www.nehrp.gov/pdf/2008ACEHRReportResponse.pdf.

Program Coordination Working Group

The PCWG is composed of working-level program managers from each NEHRP agency. The PCWG, chaired by NIST, meets monthly to coordinate agency activities, review reporting and planning documents, discuss issues and joint opportunities, and exchange relevant information. NIST maintains the PCWG through support from the NEHRP Secretariat.

The PCWG supports the efforts of the ICC in the preparation of NEHRP annual reports and revised strategic plans. Through the PCWG, the NEHRP agencies sponsored the publication of two Applied Technology Council (ATC) reports covering the 2007 NEHRP existing buildings workshop: "Workshop Proceedings: NEHRP Workshop on Meeting the Challenges of Existing Buildings," ATC–71; and "Prioritized Research for Reducing the Seismic Hazards of Existing Buildings," ATC–73. The PCWG coordinated the agencies' joint activities in sponsoring three 2008 workshops related to priorities identified during the strategic plan development process: performance-based seismic design, a post-earthquake information management system, and earthquake impact scenarios.

1.4 PROGRAM HIGHLIGHTS

Federal Emergency Management Agency

In 2008, FEMA rolled out QuakeSmart, a new initiative to encourage business owners in areas at risk from earthquakes to become aware of their risk, take action to mitigate damage to their businesses, provide greater safety for customers and employees, and speed recovery from earthquakes. The potential benefits to participating businesses are substantial. Business owners can protect their investments and recover more quickly from a disaster, significantly reduce the risk of injury or death for themselves and their customers, and create a more resilient community. The effort began with QuakeSmart community forums in four cities in the Midwest and on the west coast. Regional follow-up events will be held in 2009. Education and public awareness are cornerstones of FEMA's NEHRP work.

A component of FEMA's work identified as a NEHRP strategic priority in the new NEHRP strategic plan is the translation of NEHRP-funded research results into performance-based seismic design (PBSD) guidance and other guidance relating to new and existing buildings. Ultimately, PBSD will enable design professionals to evaluate how a building is likely to perform in an earthquake and will permit the design of new buildings or upgrades to existing buildings with a realistic understanding of the risk of casualties, occupancy interruptions, and economic losses that may occur as a result of future earthquakes. FEMA has completed a draft of "Guidelines for Seismic Performance Assessment of Buildings" and the accompanying "Performance Assessment

Calculation Tool." FEMA also has published "Interim Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components" (FEMA 461), which provides different methodologies for consistently testing the performance of building components.

In 2008, FEMA also supported the release of a new portable electronic application for "Rapid Visual Screening of Buildings for Potential Seismic Hazards" (FEMA 154). ROVER, an acronym for Rapid Observation of Vulnerability and Estimation of Risk, is an open-source program that can be used with handheld electronics, Smart Phones, and GPS devices in the field to gather information as a first step to screening buildings for potential earthquake vulnerability. Training and pilot testing were conducted in 2008 at the University of Utah. USGS also contributed to the pilot test effort. In 2009, FEMA will partner with USGS to test ROVER, and a new post-earthquake screening tool developed by ATC, with the Los Angeles Unified School District.

National Institute of Standards and Technology

New research staff recruitment continued in 2008. One research structural engineer joined NIST in August, and a second such engineer joined NIST in January 2009. Four extramural research projects begun with the NEHRP Consultants Joint Venture (ATC and the Consortium for University Research in Earthquake Engineering) in 2007 continued, while two additional ones were initiated. These projects will contribute to Objective 7 (Develop tools to improve the seismic performance of buildings and other structures) of Goal B and Objective 11 (Support development of seismic standards and building codes, and advocate their adoption and enforcement) of Goal C in the new NEHRP strategic plan. All of the projects are being closely coordinated with FEMA, which has complementary efforts under way.

The NEHRP Secretariat continued its support of ICC, ACEHR, and PCWG activities. The Secretariat focused on developing the revised NEHRP strategic plan, initiating development of a management plan to complement the strategic plan, and providing support to the ACEHR as needed, particularly with preparing its first formal assessment of the program. In preparing the revised strategic plan, the Secretariat conducted a 1-month public feedback period via the NEHRP Web site, http://www.nehrp.gov.

The Secretariat continued its outreach activities, including frequently updating the Web site, developing and posting *SeismicWaves* articles on different aspects of the program, and attending conferences tied to the seismological, engineering, and emergency response communities. Conference attendance included making several invited presentations. The NEHRP Director provided formal testimony to the Senate Homeland Security and Government Affairs Committee's Subcommittee on State, Local, and Private Sector Preparedness during its December 2007 hearing entitled "The New Madrid Seismic Zone—Whose Fault Is It Anyway?" The NEHRP Director led a NEHRP team to Beijing, China, in June 2008 to meet with representatives of the China Earthquake Administration and discuss post-earthquake investigation efforts following the May Sichuan earthquake.

The Secretariat awarded a contract to the National Research Council to analyze the levels of effort required of the NEHRP agencies over a 20-year period to accomplish the broad goals set forth in the revised NEHRP strategic plan. The study should be completed in 2010.

National Science Foundation

As of September 2008, NSF has funded over 50 research projects to use the facilities of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). These awards have supported the study of soil foundation and structure interaction; the seismic performance of foundations, lifelines, and reinforced concrete, masonry, wood, and composite structures; the behavior of steel frames that include innovative bracing schemes; the seismic design of nonstructural systems; seismic risk mitigation of ports and harbors; the seismic performance of bridge systems with conventional and innovative materials; and tsunami generation and impacts on the built environment. The awards are the result of five annual program solicitations and the Small Grants for Exploratory Research program.

In June 2008, NSF released the program solicitation for the competition for the second 5 years of NEES operations entitled "George E. Brown, Jr. Network for Earthquake Engineering Simulation Operations (NEES Ops) FY 2010 – FY 2014."

U.S. Geological Survey

In 2008, USGS publicly released the next-generation national seismic hazard maps following an extensive review process. The maps will be considered for the 2009 edition of "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures." The new maps replace those from 2002, and the release of the updated seismic hazard maps was timed to fit the schedule for the development of the 2012 version of the "International Building Code."

In 2008, USGS and its partners delivered the first-ever statewide earthquake forecast model for California. This model, developed collaboratively with the California Geological Survey and the Southern California Earthquake Center, provides input to the national seismic hazard maps and is being used by the California Earthquake Authority. The latter helped to support the project for the purpose of updating its reinsurance coverage and to evaluate earthquake insurance premiums in the state.

In May 2008, USGS released a scenario describing the expected impacts that a magnitude 7.8 earthquake on the southern San Andreas Fault would have on southern California and the Nation. The predicted fault displacements from the scenario earthquake, as well as established methodologies to predict the shaking levels throughout southern California, enabled scientists, engineers, emergency managers, and the general public to consider in detail the potential impact of a future "Big One" in California. The scenario was developed to be the basis of the November 2008 Golden Guardian emergency management exercise and Great Southern California Shakeout public

preparedness drill, which involved over 5.4 million people and was the largest emergency drill ever undertaken in the United States.

The southern San Andreas Fault scenario was the first major product of the USGS Multi-Hazard Demonstration Project in Southern California initiated during 2007. This project has the goal of linking research results and data with information dissemination to provide an integrated approach to hazards research, warning, and mitigation. This multiyear effort focuses on the eight counties of southern California, where catastrophic losses from natural hazards such as earthquakes, tsunamis, fires, landslides, and floods exceed $3 billion per year. Increased appropriations in 2008 were used to improve delivery of USGS information to support emergency management in southern California and to expand the initiative to high-hazard areas of the Pacific Northwest and Central United States.

1.5 STRUCTURE OF THIS REPORT

As in the previous annual report, the new, recently completed NEHRP strategic plan serves as the framework for this document. The strategic plan defines goals and objectives for the program and standards for the operation of NEHRP facilities, all of which closely track the activities defined by Congress for the program in the 2004 reauthorization. Objectives within each goal define activities, expected results, and outcomes for the 5-year strategic planning period (FY 2009–2013). In this report, NEHRP accomplishments for 2008 are described for each of the strategic plan objectives and for facility operations, continuing to provide a baseline for NEHRP progress as the program enters the implementation phase of the FY 2009–2013 strategic planning cycle. Subsequent annual reports will follow this reporting framework, thus giving a straightforward and simple basis for tracking and evaluating NEHRP yearly performance.

Chapter

2

Program Budgets for FY 2009 and FY 2010

2.1 INTRODUCTION

The program budget for FY 2009 is presented in terms of the funds directed toward or requested for National Earthquake Hazards Reduction Program (NEHRP) goals, as defined in the new NEHRP strategic plan. Each goal is associated with a NEHRP "Program Activity" defined in Public Law 108–360, Section 103(2). This legislation also authorized the development, operation, and maintenance of certain NEHRP facilities: 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 shows the relationships between these congressionally defined activities and the goals set out in the new strategic plan.

Table 2.1—Relationships of NEHRP Strategic Goals to Statutory Program Activities

NEHRP Strategic Goals	NEHRP Program Activities (as defined by Congress in P.L. 108–360)
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.

2.2 NEHRP FY 2009 BUDGETS LISTED BY PROGRAM GOAL

Table 2.2 lists the FY 2009 NEHRP enacted budgets, by program 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 FY 2009 Enacted Budgets

Program Goal	Funds Allocated to Goal ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.2	30.0	11.2	**41.5**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	3.3	3.4		31.5	**38.2**
Goal C: Improve the earthquake resilience of communities nationwide.	5.7	0.5		4.2	**10.4**
Develop, operate, and maintain NEHRP facilities:					
ANSS—USGS				8.8	**8.8**
NEES—NSF			21.8		**21.8**
GSN—NSF and USGS			3.5	5.5	**9.0**
Total:	**9.1**	**4.1**	**55.3**	**61.2**	**129.7**

Notes on Table 2.2:

[1] Budgets are rounded to nearest $0.1M.

[2] The FEMA FY 2009 budget is an allocation from the Department of Homeland Security (DHS) appropriation, which covers program activities but excludes salaries and expenses (S&E) and state grants administered by the FEMA Grants Directorate.

2.3 NEHRP FY 2010 REQUESTED BUDGETS LISTED BY PROGRAM GOAL

Table 2.3 lists the President's requested FY 2010 NEHRP agency budgets by program goal.

Table 2.3—NEHRP FY 2010 Requested Budgets

Program Goal	Funds Allocated to Goal ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.2	31.5	11.4	**43.2**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	3.3	3.4		31.6	**38.3**
Goal C: Improve the earthquake resilience of communities nationwide.	5.7	0.5		4.2	**10.4**
Develop, operate, and maintain NEHRP facilities:					
ANSS—USGS				8.8	**8.8**
NEES—NSF			22.0		**22.0**
GSN—NSF and USGS			3.5	5.5	**9.0**
Total:	**9.1**	**4.1**	**57.0**	**61.5**	**131.7**

Notes on Table 2.3:

[1] Budgets are rounded to nearest $0.1M.

[2] The FEMA FY 2010 budget is an estimated allocation from the Department of Homeland Security (DHS) appropriation, which covers program activities but excludes salaries and expenses (S&E) and state grants administered by the FEMA Grants Directorate.

Chapter

3

NEHRP FY 2008 Activities and Results

The organization of this chapter follows that of the "NEHRP Strategic Plan for Fiscal Years 2009–2013." The strategic plan defines the National Earthquake Hazards Reduction Program (NEHRP) in terms of broad goals and more specific objectives and related strategic priorities. The strategic goals are directly linked to the NEHRP activities defined in Public Law 108–360, Section 103(2). By following the structure of the strategic plan, this report allows the reader to directly assess how accomplishments in 2008 are furthering progress toward our stated objectives. Accomplishments are not categorized by NEHRP agency but rather are cast in terms of collective progress based on cooperative efforts.

3.1 STRATEGIC GOAL A: IMPROVE UNDERSTANDING OF EARTHQUAKE PROCESSES AND IMPACTS

The research supported and undertaken under Goal A provides a strong foundation for the development and implementation of practical earthquake risk-reduction measures pursued under other strategic goals. Strategic Goal A is directly related to the congressionally defined NEHRP program activity "Improve 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." Program accomplishments for 2008 are listed under the four objectives established for Goal A in the strategic plan.

Objective 1: Advance understanding of earthquake phenomena and generation processes

High-performance computer modeling of major earthquakes

The Southern California Earthquake Center (SCEC), a university consortium led by the University of Southern California and supported by the National Science Foundation (NSF) and U.S. Geological Survey (USGS), is studying and applying means to advance seismic hazard research using high-performance computing. In 2008 the PetaSHA Project used high-performance computing concepts and programs to simulate the ground shaking from a magnitude 7.8 earthquake in southern California, see Figure 1. As part of the PetaSHA Project, 40,960 processors on the Blue Gene supercomputer were needed to simulate this event. Much greater computer capacity is required to compute ground shaking at higher frequencies. This new capability will provide simulations of earthquake motions that might cause damage to the large number of small, multistory buildings in southern California.

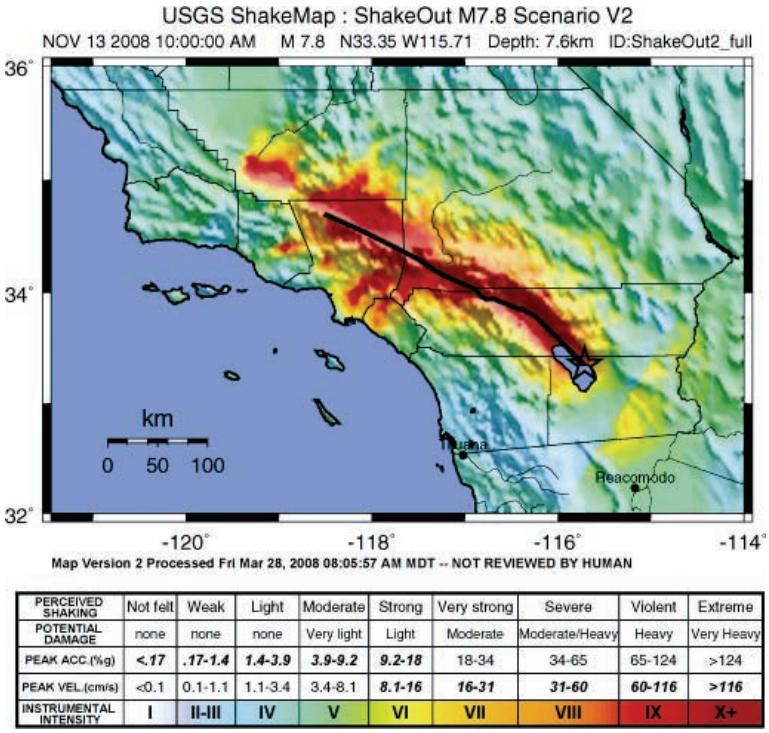

Figure 1. The map shows the effects of a simulated magnitude 7.8 earthquake along the southern San Andreas Fault in California. Red colors indicate areas of extreme shaking and heavy potential damage. Image courtesy of USGS.

SCEC's aim is to use advanced peta-scale computing facilities when they become available in the 2010–2011 timeframe. SCEC's PetaSHA Project has multiple goals to reach simulations of earthquake ground shaking at frequencies up to 10 cycles per second. PetaSHA is involved also in the development of a dynamic rupture platform (DynaShake) that can generate kinematic (descriptive) source characterizations to emulate dynamic source characterizations based on physical principles. The results of DynaShake will be used in validation tests to compare theoretical kinematic earthquake rupture faulting parameters with those observed for earthquakes. Following validation, DynaShake will be used to model several hypothetical large San Andreas Fault earthquakes caused by horizontal slip along a vertical fault plane, as well as a large reverse faulting earthquake caused by vertical slip. PetaSHA will also produce earthquake hazard parameters at 0.5 cycles per second to be applied in the development of a hazard map for Los Angeles.

Tracking tremors in the Pacific Northwest

The documentation of seismic tremor and associated deep, episodic fault slip events in a number of earthquake zones around the world represents one of the most exciting new discoveries in the earth sciences. These phenomena provide new insights into the physics of active, geologic faults and how they relieve accumulated strain. Referred to as ETS (episodic tremor and slip), this remarkable geophysical phenomenon has been particularly well documented in the Cascadia Subduction Zone that threatens the Pacific Northwest and western British Columbia. Deep episodic tremor has also been found beneath the San Andreas Fault in central California and in certain subduction zone settings overseas, including in Japan. "Tremor" refers to seismic waves that radiate from sources at very low amplitudes for long durations, and "slip" refers to slow fault sliding that occurs over many seconds to months, without radiating seismic waves, and is measurable using precise geodetic methods. Research is ongoing to discover the relationship between ETS and the loading of stress onto deep faults that will eventually unleash great earthquakes.

In 2008 USGS, together with the Geological Survey of Canada, NSF's EarthScope program, and UNAVCO Consortium, sponsored an international workshop on ETS. Participants included scientists, engineers, emergency responders, and policy makers. Workshop outcomes included improved coordination among researchers, identification of ways to capitalize on the education and outreach opportunities presented by these phenomena, and consensus interpretations that should improve hazard assessments. Workshop findings have been summarized in the American Geophysical Union's EOS magazine, and reported in detail in a USGS open-file report and in presentations at professional meetings.

Support for fundamental and targeted research in earthquake studies

The Geosciences Directorate's Earth Science Division is NSF's primary long-term funding source for fundamental research related to earthquake processes. As part of their general, semiannual competition, the division's core programs, including the Geophysics, Tectonics, and Continental Dynamics programs, solicit proposals related to seismology, geodesy, rock mechanics, paleoseismology (geologic studies of prehistoric earthquakes), structural geology, and relevant theoretical, modeling, and laboratory projects. Recent outcomes from these programs range from explanatory mechanisms for ETS observed along plate boundaries around the world to insight into the slip differential across the southern San Andreas Fault using interferometric synthetic aperture radar (InSAR) imagery, global positioning systems (GPS), and seismic measurements. This work has substantially improved the description and understanding of the strain building up along major plate boundary faults such as the southern San Andreas Fault and the San Jacinto Fault. Satellite radar images are used to infer slippage on the southern San Andreas Fault system, which has not ruptured in a major earthquake for over 300 years. A list of NSF grants and related abstracts may be found at http://www.research.gov.

USGS annually funds targeted research in earthquake hazards, physical processes, and effects. This assistance adds a significant range of expertise to the USGS Earthquake Hazards Program and leverages support from other federal and state agencies, universities, and the private sector. In 2008, USGS funded over 90 grants and cooperative agreements. The largest funded effort provides multiyear support to SCEC, which is supported jointly with NSF; this cooperative agreement funds micro-grants and workshops that serve to develop a comprehensive understanding of earthquakes in southern California and elsewhere, and to communicate useful knowledge for reducing earthquake risk. All recent USGS grant and cooperative agreement awards and reports that describe research results are available at http://www.earthquake.usgs.gov/research/external.

Objective 2: Advance understanding of earthquake effects on the built environment

The first two studies described on the following pages were undertaken to increase the earthquake resilience of reinforced concrete structures.

Improving the seismic performance of precast concrete structures

Supported by NSF, researchers from the University of Arizona, the University of California San Diego (UCSD), and Lehigh University used the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) outdoor shake table at UCSD in 2008 to simulate the effects of a series of earthquakes on a three-story parking structure. (A shake table is a large platform driven by an electromechanical system to simulate earthquake motions.) This 1-million-pound structure was the largest structure ever tested for seismic performance in the United States, see Figure 2. The tests are part of an investigation to better understand the seismic response of precast concrete floor systems used in building and parking structures.

Figure 2. Test of a half-scale model of a three-story parking garage on the shake table at the University of California, San Diego, Englekirk Structural Engineering Center. The UCSD shake table is an element of the NEES infrastructure, the largest shake table in the United States, and the only outdoor shake table in the world. This study is supported by NSF, NEESinc, the Precast/Prestressed Concrete Institute, and the Charles Pankow Foundation. ©2008 by UCSD Jacobs School of Engineering.

The UCSD shake table subjected the three-story parking structure to a series of simulated seismic events representative of the types of earthquakes that have occurred in different regions of the United States, such as in the Central States, the Pacific Northwest, and southern and northern California. The most severe test subjected the structure to a simulated magnitude 8.0 earthquake.

Because the components of precast concrete structures can be fabricated off site and then assembled into a complete structure in the field, this offers the advantages of reduced construction time and cost. However, the seismic building code for these types of precast buildings is 20 years old. This investigation is pursuing new methods of connecting the structural elements of these buildings using efficient and earthquake-resistant practices. In past earthquakes, individual precast elements pulled apart and failed. This occurred in the collapse of nine parking garages during the Northridge earthquake in Los Angeles in 1994. (Luckily that earthquake occurred in the early morning when the garages were deserted.)

The goals of this research are to provide the necessary fundamental knowledge needed to develop, by 2012, design practices that will allow these buildings to withstand major earthquakes, and to incorporate these practices into building codes across the United States. This cooperative research effort is being supported by the Precast/Prestressed Concrete Institute and its member companies and organizations, the Charles Pankow Foundation, and NSF.

Potential risks associated with connections in modern flat-plate construction

Building frames that consist of horizontal slabs directly supported by columns represent an attractive structural system for use in reinforced concrete construction. In regions of high seismicity, slab-column frames are used in combination with systems that are laterally stiffer and stronger, such as structural walls and moment (shear) resisting frames, which are designed to resist earthquake motions. Although not intended to be part of the lateral force-resisting system, the slab-column frames must be capable of maintaining their gravity load carrying capacity while undergoing earthquake-induced lateral displacements. Results from experimental research and observations after the 1994 Northridge earthquake showed that deformations induced by earthquakes make connections in slab-column or flat-plate frame systems susceptible to shear failures. Connections in most modern flat-plate structures located in earthquake-prone regions feature some sort of steel shear reinforcement (shear studs). This is the case in many recent medium- and high-rise buildings located on the west coast of the United States (e.g., San Francisco, Seattle).

In research supported by NSF, researchers from the University of Michigan and the University of Minnesota, using the unique seismic testing capabilities at the NEES Multi-Axial Subassemblage Testing (MAST) Laboratory at the University of Minnesota, uncovered potential risks associated with some reinforced connections used in flat-plate structures, shown in Figure 3. The NEES MAST laboratory allowed researchers to test large-scale flat-plate connections with more realistic simulated earthquake demands through the application of multidirectional lateral displacements. To evaluate the seismic behavior expected of a typical slab-column connection with shear stud reinforcement, a nearly full-scale slab-column connection subassembly was tested under combined gravity load and multidirectional lateral displacements. Results from the test showed limited connection deformation capacity, as would have been expected if the shear reinforcement had not been present. These results suggest that a reevaluation of current practice for the design of connections in flat-plate construction, as well as an assessment of the vulnerability of modern flat-plate structures located in earthquake-prone regions, are needed.

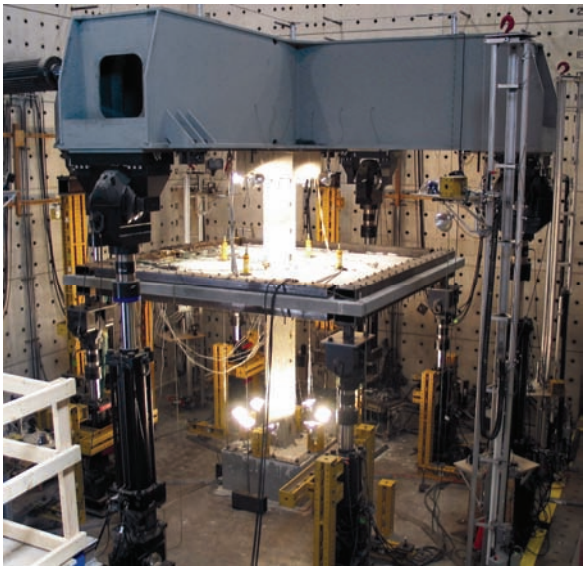

Figure 3. Slab-column connection tested at the NEES MAST facility at the University of Minnesota. ©2007 by MAST Laboratory, Department of Civil Engineering, University of Minnesota.

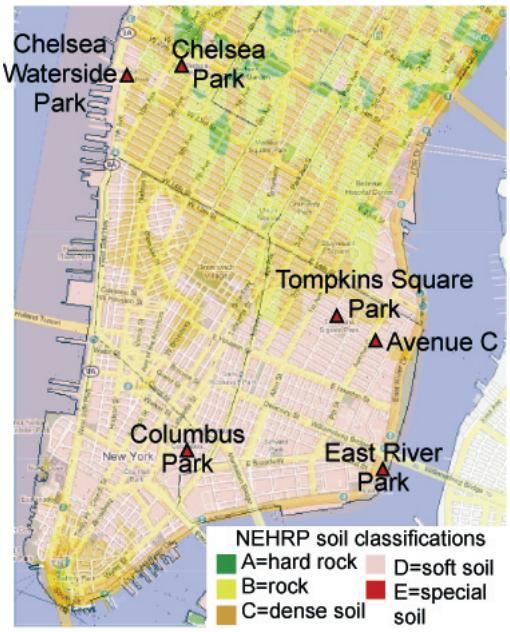

Figure 4. A map of lower Manhattan showing sites where measurements of soil amplifications were made. Image courtesy of USGS.

Following are descriptions of four studies on surface effects of earthquakes: soil amplification of shaking, liquefaction,[1] and landslides.

Non-invasive site characterization in a highly urbanized environment

Research scientists at the Lamont-Doherty Earth Observatory, supported by USGS, applied a new method to determine seismic shear-wave velocities of soil deposits in lower Manhattan (New York City) using ambient noise. Shear-wave velocities in soil deposits are directly related to the degree of amplification of earthquake shaking by these deposits. Using a small array of seismic stations, see Figure 4, and the spatial autocorrelation (SPAC) method, the researchers demonstrated that shear-wave velocity profiles can be determined quickly and inexpensively in a highly urbanized setting. This is the first time that ambient noise or micro-tremor has been used in a metropolitan setting of this type. These results are particularly useful considering that invasive methods of measuring shear-wave velocity are often not practical in the middle of a large city. The quantitative results showing soil shear-wave velocities can be used in the seismic micro-zonation of urban areas.

Understanding liquefaction-induced flow slides during an earthquake

To assess the vulnerability of a site to liquefaction-induced earth slides, it is necessary to predict the residual shear strength (resistance to lateral forces) of liquefied soils. Supported by NSF, researchers at the University of New Hampshire have designed and built a laboratory apparatus for testing the shear strength of liquefied soils over a range of initial soil densities and strain rates. Their experiments have shown that residual shear strength is related to initial density and shear strain rate through a relatively simple relationship. For the clean, uniform fine sands that they tested, residual shear strength increases with relative density up to a relative density of approximately 50 percent, above which the shear strength is essentially constant. Comparisons with residual strengths calculated from field studies show that values from laboratory testing form an upper bound to the calculated field values. These results strongly suggest that the displacement in actual field failures concentrates in one or more thin failure shear bands. These bands expand by

[1] Saturated sands and sandy soils subjected to earthquake shaking experience increased fluid pore pressure and a drastic loss of strength. This phenomenon is called liquefaction. In this state sandy soils behave as heavy fluids, gradually regaining strength as internal water pressures dissipate. As long as the liquefied state persists, the soil will flow down slopes, producing destructive earth flow slides. These flow slides significantly increase the lateral extent of ground failure, and can lead to considerable damage to structures, buried utilities, and roads.

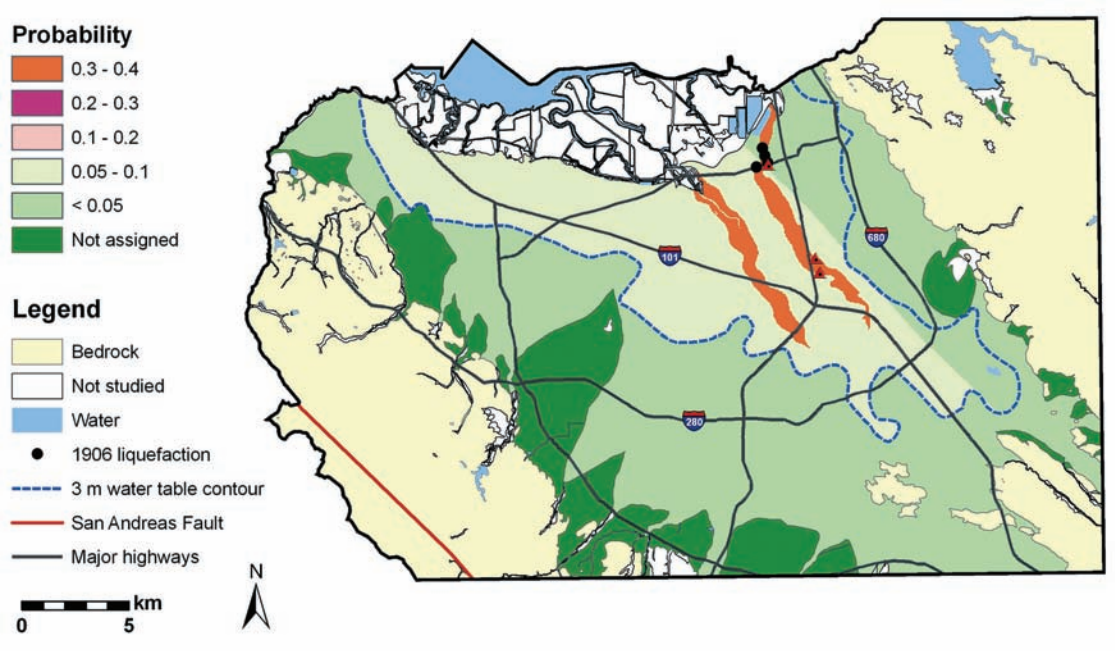

Figure 5. Map showing the variability of liquefaction potential near San Jose, California. Image courtesy of USGS.

water content redistribution within the sliding mass, and thus develop a residual strength corresponding to a relative density lower than that of the mass as a whole. These results may be applied to assessing the liquefaction risk at specific sites.

Liquefaction-potential mapping for earthquake mitigation—San Jose, CA

New liquefaction hazard maps of the greater San Jose area in northern California were released in September 2008. The maps demonstrate the application of a new mapping methodology that is being developed at USGS, enabling regional liquefaction hazard to be portrayed in a probabilistic context. The new methodology also permits the spatial variability of liquefaction hazard to be depicted. Regulatory hazard maps that require real estate developers to address local hazards during development increasingly are being applied by local and state governments. Such regulatory maps for liquefaction hazards, however, rely on methodologies that do not distinguish the variability of the hazard within a broad hazard zone. The San Jose area demonstration maps show the probability of liquefaction for three scenario earthquakes: a magnitude 7.8 earthquake on the San Andreas Fault (like that of 1906), a magnitude 6.7 earthquake on the southern Hayward Fault (like that of 1868), and a hypothetical magnitude 6.9 earthquake on the Calaveras Fault. All of the maps predict higher liquefaction probabilities along the major streams in the Santa Clara Valley as shown in Figure 5. The maps were released as a USGS open-file report, and the extensive subsurface data that were used to develop the maps were made available online.

Mapping the earthquake-induced landslide hazard in Anchorage

In 2008, USGS completed a map portraying seismic landslide hazards in Anchorage, AK. The great 1964 Alaska earthquake triggered widespread landslides in Anchorage that devastated much of the

downtown area and nearby residential developments. Continuing development pressure within the Anchorage "bowl" has increased the need for an updated map showing landslide hazards in future earthquakes. USGS adapted modeling methods first developed after the 1994 Northridge earthquake to be applicable to landslides in Anchorage. USGS researchers worked closely with the Geotechnical Advisory Commission of the Municipality of Anchorage to ensure that the new maps incorporated the most recent data and portrayed hazards in a form that could be used for planning, zoning, and emergency response.

Objective 3: Advance understanding of the social, psychological, and economic factors linked to implementing risk-reduction and mitigation strategies in the public and private sectors

Multihazard research in the social sciences

During 2008, the NSF Directorate for Engineering supported a range of new projects to advance understanding of the social, psychological, and economic factors linked to implementing risk-reduction and mitigation strategies in the public and private sectors. These projects have direct relevance to post-earthquake response and recovery, as well as to other hazards. Researchers at the University of Minnesota are investigating the response of the driving public to the loss of a major traffic artery in Minneapolis following the collapse of the I–35W bridge over the Mississippi River. Based upon equilibrium theory, this investigation examines the evolution of traffic and transportation in the aftermath of the collapse.

Several research projects are being supported to investigate disaster recovery in New Orleans following Hurricane Katrina in 2005. These studies, whose results will be applicable to understanding disaster recovery following earthquakes, include the following:

- A research collaboration among the University at Buffalo, ImageCat, University of British Columbia, University of Delaware, and University of Memphis is using satellite imagery to study the process of disaster recovery in New Orleans.
- Researchers at the University of Illinois at Urbana-Champaign are conducting an in-depth analysis of the recovery planning process in New Orleans following Hurricane Katrina. Both qualitative and quantitative analyses are inherent in this detailed case study.
- Researchers at Johns Hopkins University are examining business recovery in the aftermath of Hurricane Katrina. The approach they are taking is "all-hazard" in nature and has relevance for business recovery from earthquakes. It represents a quantitative analysis of downtime and the various factors that are related to it and how they impact business recovery.

A research team at the University of Southern California is studying the process of data mining social Web sites, such as YouTube, Flickr, and others, to gather information that could be used by humanitarian assistance providers. This innovative research is examining the use of this human reaction information for emergency response and disaster relief, and has relevance for all types of

hazards. Finally, a team of Rice University researchers is studying interdependencies and cascading failures among urban infrastructures.

Objective 4: Improve post-earthquake information management

Learning from Earthquakes and Geo-engineering Extreme Events Reconnaissance programs

The study of the effects and impacts of domestic and foreign earthquakes is essential to improving our national earthquake preparedness. Studies of the geological and seismological effects of earthquakes, of successes and failures in the design and construction of seismic-resistant structures, of the social and economic impacts of earthquakes, and of the effectiveness of emergency response and recovery efforts can be of great help in reducing risk from future earthquakes.

Figure 6. Partially collapsed six-story residential building (with commercial ground floor) in city of Dujiangyan, Sichuan Province, P.R. China. Collapse attributed to several factors, including poorly confined (and possibly nonductile) concrete columns and beams, lack of continuity of prefabricated floor slab diaphragms, and underestimated seismic design levels. Photo taken on August 4, 2008. Image courtesy of the Earthquake Engineering Research Institute. © 2008 by Marshall Lew.

With ongoing support from NSF, the Earthquake Engineering Research Institute (EERI) has maintained the Learning from Earthquakes (LFE) Program for several decades and has sent study teams of structural engineers, geotechnical engineers, and social scientists to the sites of significant earthquakes throughout the world. Reports on team findings are available at http://www.eeri.org/site/projects/learning-from-earthquakes. NSF also provides support for the Geo-engineering Extreme Events Reconnaissance (GEER) Association, which conducts post-earthquake reconnaissance, often together with EERI's LFE teams, as well as investigations of events caused by other natural and man-made hazards. The GEER Association's reports are available at http://research.eerc.berkeley.edu/projects/GEER/. The EERI and GEER investigations, which enable the collection of data and information in a systematic manner, will provide the basic inputs for the Post-Earthquake Information Management System (PIMS) that will be developed by NEHRP in the future.

During 2008 a study was made of the May 12, 2008, earthquake in China, known as the eastern Sichuan or Wenchuan earthquake (magnitude 7.9). This event caused significant damage and many casualties, with over 87,000 persons known dead or missing and 375,000 injured. In August, through NSF support, a team of earthquake researchers, sponsored by EERI and the GEER Association, joined Chinese colleagues in investigating and documenting scientific and engineering effects of this devastating earthquake. The research team included experts in structural, lifelines,

and geotechnical engineering as well as in disaster response and recovery (Figure 6). On October 7, 2008, the EERI–GEER reconnaissance team presented a public technical briefing on the earthquake. A preliminary 12-page reconnaissance report is available at http://www.eeri.org/site/images/eeri_newsletter/2008_pdf/Wenchuan_China_Recon_Rpt.pdf.

Planning for the Post-Earthquake Information Management System (PIMS)

In October 2006, the American Lifelines Alliance (ALA) held a forum attended by more than 50 representatives from the lifelines community to develop a framework for improving the mechanisms for collecting, managing, and archiving data on the performance of the built environment in natural disasters within the United States. With support from the Federal Emergency Management Agency (FEMA), the ALA held a follow-on workshop on July 22–23, 2008, that focused on all of the elements of PIMS. These elements included data collection standards and formats, data management architecture, data retrieval needs, data preservation, system maintenance, and computer hardware requirements. The workshop report, which will be released in 2009, will serve as a foundation for the future development of PIMS.

3.2 STRATEGIC GOAL B: DEVELOP COST-EFFECTIVE MEASURES TO REDUCE EARTHQUAKE IMPACTS ON INDIVIDUALS, THE BUILT ENVIRONMENT, AND SOCIETY AT LARGE

NEHRP activities under Goal B are designed to develop practical and cost-effective methods and measures for earthquake risk assessment and mitigation that build upon the research results obtained under Goal A. Goal B is directly linked to the congressionally defined NEHRP program activity "Develop effective measures for earthquake hazards reduction."

Objective 5: Assess earthquake hazards for research and practical application

Updated national seismic hazard maps

In 2008, after an extensive development and review process, USGS publicly released the next-generation national seismic hazard maps. These maps are being considered for the 2009 edition of the "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures." The maps incorporate new results from earthquake monitoring and research. They replace those from 2002, and their release was timed to fit the schedule for developing the 2012 version of the "International Building Code" (IBC), a process that involves close cooperation among USGS, FEMA, the Building Seismic Safety Council, the American Society of Civil Engineers, the International Code Council, and many other organizations. Earlier versions of the maps have served as the basis for the seismic design maps in the IBC and the "International Residential Code," which have been adopted in almost all states. The maps are also used by insurance companies to set rates for properties in various areas of the country, by civil engineers to estimate the stability and landslide potential of hillsides, by the U.S. Environmental Protection Agency to set construction standards that ensure the safety of waste-disposal facilities, and by FEMA to plan allocation of assistance funds for earthquake education and preparedness.

The next-generation seismic hazard maps were developed using the best available science from internal USGS studies as well as information available from government agencies, academic institutions, and industry. During 2008, USGS also produced a set of engineering design maps that are derived from the new seismic hazard maps for use in construction engineering standards for existing buildings developed by the American Society of Civil Engineers, and ultimately in the IBC. In the near future USGS will produce a variety of specialized products derived from the updated seismic hazard maps, for use by engineers, city planners, and other end users. These products include uniform hazard spectra (showing expected ground shaking as a function of frequency) for a broad range of structures, maps that portray the degree of certainty and resolution of seismic hazard estimates nationwide, and information on the earthquakes most likely to cause strong shaking at a given site of interest. Map graphics are available at http://earthquake.usgs.gov/research/hazmaps/.

California statewide earthquake forecast

In 2008, USGS and its partners delivered the first-ever, statewide earthquake-rupture forecast model for California. This model, developed collaboratively by USGS, the California Geological Survey, and SCEC, provided input for the national seismic hazard maps (see above) and is being used by the California Earthquake Authority to update its reinsurance coverage and to evaluate earthquake insurance premiums in the state. The model was reviewed by a scientific review panel as well as by the National Earthquake Prediction Evaluation Council and the California Earthquake Prediction Evaluation Council. It includes the following innovations:

- The first complete, time-dependent forecast that covers the entire state with a uniform application of methodology, data standards, and treatment of uncertainties.
- More complete analysis and inclusion of paleoseismic (prehistoric) data.
- A more sophisticated analysis of historical seismicity, which revealed a significant over-estimation of earthquake rates in previous models.

Several coordinated information products were released in April 2008 at a widely attended press conference held jointly at SCEC headquarters in Los Angeles and at the Menlo Park offices of USGS in the San Francisco Bay Area. Products included a detailed technical report, a non-technical summary, a USGS fact sheet, an audio "podcast," and numerous supplemental data tables useful for engineers wishing to calculate seismic risk on the basis of the study. Related high-resolution map graphics are available at http://www.scec.org/ucerf/.

Seattle maps used for earthquake hazard mitigation

Using the USGS urban seismic hazard maps released in 2007, the City of Seattle has completed a study of problems posed by earthquake ground motions for unreinforced masonry (URM) buildings. The USGS maps include geological details ranging from local soil conditions at specific sites to the three-dimensional structure of the geology beneath Seattle. They show how forecasted earthquake shaking levels vary across the region at scales useful for urban planning, earthquake response, engineering for major structures, and public education.

Ground motions shown on the USGS maps are particularly high in several parts of Seattle that have a large number of URM buildings. Seattle has a history of such buildings failing during the 1949, 1965, and 2001 earthquakes near Puget Sound. The study identified nearly 1,000 URM buildings, including a public high school, that are at very high risk in the next earthquake. Because only about 15 percent of such buildings have been seismically retrofitted, the city is using the new study to formulate policy to reduce the danger to the population. The mayor of Seattle has characterized the results of the study as defining a public safety issue. Use of the Seattle urban seismic hazard maps to underpin a major local policy decision is a clear indicator of the importance that the development of these maps can have in U.S. cities with high earthquake hazards and risks. The USGS maps are also being used for preliminary design of the new Route 520 bridge across Lake Washington, a multi-billion-dollar structure that represents a critical transportation link for the region.

Multihazard demonstration project

USGS initiated a multihazard demonstration project in southern California during 2007 with the goal of linking research results and data with information dissemination to provide an integrated approach to hazards research, warning, and mitigation. This multiyear effort focuses on the eight counties of southern California, where catastrophic losses from natural hazards such as earthquakes, tsunamis, fires, landslides, and floods exceed $3 billion per year. Partners include state, county, and city government agencies, public and private utilities, industry, academic researchers, FEMA, the National Oceanic and Atmospheric Administration, the U.S. Forest Service, the federal Bureau of Land Management, and local emergency response agencies.

Increased appropriations in 2008 were used to improve delivery of USGS information to support emergency management in southern California and to expand the initiative to high-hazard areas of the Pacific Northwest and Central United States. Activities in southern California focused on the development of a scenario characterizing the impacts of a major event on the southern San Andreas Fault (see Objective 10), and on improving earthquake and related crustal deformation monitoring along the fault. The project also continued work begun in 2007 on a systematic investigation of the earthquake history of the southern San Andreas Fault system in partnership with SCEC. The purpose is to obtain new data to clarify and refine relative hazard assessments for each potential source of a future large earthquake.

In the Pacific Northwest, USGS funds are being used to upgrade the Pacific Northwest Seismic Network operated by the University of Washington, which is a regional network within the USGS Advanced National Seismic System (ANSS). Partial support is also being provided by USGS for light detection and ranging (LIDAR) high-resolution aerial mapping and aeromagnetic data acquisition to map potentially active faults on the eastern edge of the Puget Sound region, for additional ANSS instrumentation to use in landslide monitoring, and for the preparation of models to support a multihazard scenario for Snohomish County in Washington.

USGS support for the Central United States is being used to accelerate development of a seismic hazard map for the St. Louis urban area through work performed by the Missouri Geological

Survey, Missouri Institute of Science and Technology in Rolla, and USGS Mid-Continent Geographic Science Center.

Objective 6: Develop advanced loss-estimation and risk-assessment tools

Development of improved loss-estimation tools: Hazards U.S.–Multihazard (HAZUS–MH)

FEMA has funded the National Institute of Building Sciences (NIBS) to continue development of HAZUS–MH, a nationally applicable, standardized, computer-based, multihazard disaster planning and analysis tool. It can be used to identify sizes and locations of possible threats; estimate resulting damage and disruption; apply supporting data from varied sources; and link with other emergency management and planning tools before, during, and after disasters.

In 2008, FEMA continued to actively promote and support state and local use of HAZUS–MH. As a result, the tool was used to support disaster scenarios for catastrophic planning exercises in the New Madrid region of the central Mississippi Valley and elsewhere, in preparedness training sessions and workshops, and in supporting the operation of HAZUS user groups.

Near real-time earthquake risk analysis with HAZUS and ShakeMap

ShakeMap data, made available by USGS immediately after larger earthquakes, show the intensity and distribution of ground shaking. These data are being used with HAZUS–MH software in California, Utah, Washington, and other states, for near real-time analysis of building and lifeline damage and casualty estimates. FEMA is conducting two demonstration projects in Utah and Washington that use ShakeMaps and HAZUS–MH for earthquake risk assessments and disaster response. Near real-time analyses also can be implemented by state, regional, and local authorities in emergency response exercises to better prepare for future earthquakes.

Risk assessment in the Northeast United States

FEMA continues to support the Northeast States Emergency Consortium (NESEC), which develops activities that combine measures for earthquake risk reduction with measures for the reduction of risks associated with other natural, technological, and man-made disasters in order to advance earthquake hazard mitigation in the Northeast. During 2008 NESEC completed the basic development of the online Hazard-Resistant Building Code Database. This allows the public to determine if their local community has appropriate building code regulations for earthquakes and other hazards. Statewide building code data are currently available to the public, and NESEC continues to work on acquiring community building code tracking data. The Hazard-Resistant Building Code Database is now available at http://www.nesec.org/building_codes/.

During 2008 NESEC continued to operate the NESEC Emergency Management Risk Assessment Center. The purpose of the center is to provide geographic information system (GIS) and HAZUS–MH support to jurisdictions within NESEC that do not have the resources to develop these capabilities in-house. NESEC provides links and information on obtaining GIS software and technical manuals at http://www.nesec.org/resources/.

Objective 7: Develop tools to improve the seismic performance of buildings and other structures

Building standards and codes: The NEHRP Recommended Provisions

The "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures" (NEHRP Recommended Provisions), funded and published by FEMA and developed by the NIBS Building Seismic Safety Council (BSSC), is the primary resource document for the Nation's standards and model building code provisions related to the seismic design of new buildings. This publication also provides a platform for translating NEHRP research results into recommended practices and guidelines. NEHRP agencies and the earthquake community collaboratively contribute to the development of the NEHRP Recommended Provisions. The contributions of USGS primarily relate to seismic hazard and design maps; those of the National Institute of Standards and Technology (NIST) to findings from applied, problem-focused research; those of NSF to research results and new technologies from its funded studies; and those of other earthquake professionals to engineering knowledge and evaluation based on practical experience.

The current edition of the NEHRP Recommended Provisions (FEMA 450), published in 2003, served as the main source for the seismic requirements in the American Society of Civil Engineers (ASCE) standard "Minimum Design Loads for Buildings and Other Structures" (ASCE 7). The national model building codes have adopted ASCE 7 by reference for their seismic safety requirements.

Future editions of the NEHRP Recommended Provisions will emphasize research-to-practice resources and education. NEHRP, through FEMA, has tasked the BSSC to update the document. The nearly completed 2009 edition of the NEHRP Recommended Provisions will feature several significant changes recommended or endorsed by the practitioner community. These include the adoption of the 2008 USGS seismic maps, the approval of several new seismic-resistant systems, the creation of a new section for introducing new information and results, and the complete rewriting of the Commentary section to serve as a training and educational product.

Development of performance-based seismic design (PBSD)

The goal of PBSD is to provide practical assessment and design criteria that enable building owners and regulators to select desired performance levels for new construction or for upgrades of existing buildings that go beyond or differ from current prescriptive building code-based life-safety standards. Although current standards are intended to prevent collapse in an earthquake, they may not prevent damage that is so severe that the building is not useable for its intended function. Ultimately, PBSD will enable evaluations of how a building is likely to perform in a given earthquake, considering uncertainties inherent in both the potential hazard and the actual building response. This will allow the design of new buildings or upgrades for existing buildings with specific performance goals in future earthquakes, such as the reduction of casualties, occupancy and functional interruptions, and economic losses. This project is based on the "Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings"

(FEMA 445). FEMA has contracted with the Applied Technology Council (ATC) to carry out the development work specified in FEMA 445.

The PBSD project is a multiyear effort to develop a new performance assessment methodology and PBSD guidelines for new and existing buildings. FEMA is now in the third year of a 5-year effort to develop the PBSD Performance Assessment Methodology. FEMA has completed approximately 35 percent of the draft "Guidelines for Seismic Performance Assessment of Buildings" and the accompanying "Performance Assessment Calculation Tool," which together provide a methodology to assess individual building performance in future earthquakes. Planned future work extends the performance assessment methodology to develop PBSD procedures and guidelines to assist in the design of buildings to meet desired performance goals.

As part of this project, FEMA has published a new document that provides different methodologies for consistently testing the performance of building components; this publication is entitled "Interim Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components" (FEMA 461). Additional information on the PBSD project may be found at http://www.atcouncil.org/index.php?option=com_content&view=article&id=85&Itemid=54.

In May 2008 NEHRP sponsored the PBSD Missing Pieces workshop, which was conducted by the BSSC to evaluate progress and identify the research that is required to take full advantage of PBSD. Approximately 36 structural and geotechnical practitioners and researchers participated. A full workshop report was published in early 2009.

Quantification of Building Seismic Performance Factors Project

This project is developing and documenting a new methodology for reliably quantifying building system performance and response parameters for use in the seismic design procedures found in model building codes. Structural Response Modification Factors are used in the codes to estimate strength and displacement demands on structural systems that are designed using linear methods but are expected to respond in the nonlinear range. FEMA has published "Quantification of Building Seismic Performance Factors" (90% draft of FEMA P–695, see Figure 7) and conducted two public workshops to introduce design professionals to the proposed new methodology and capture their feedback. NIST is working with FEMA to beta test the new methodology by benchmarking it against performance parameters that have previously been established by the structural engineering community.

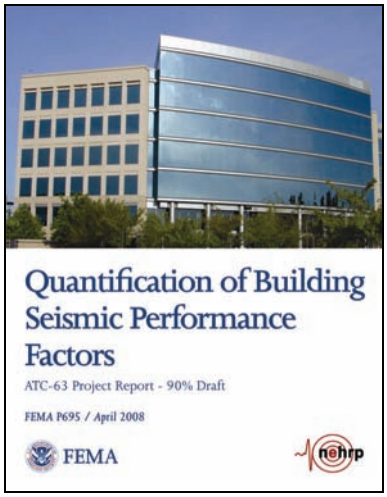

Figure 7. New technical guidance under development by FEMA and NIST. Image courtesy of FEMA.

Rapid observation of vulnerability and estimation of risk

There has been a long-standing need for gathering and classifying information on the seismic risk of buildings before earthquakes, and on building damage after earthquakes, in an electronic format. FEMA addressed this need during 2008 by supporting the release of a new portable electronic application for "Rapid Visual Screening of Buildings for Potential Seismic Hazards" (FEMA 154). The application, named "Rapid Observation of Vulnerability and Estimation of Risk" (ROVER), is an open-source program that can be used with handheld electronic devices, Smart Phones, and GPS units in the field to gather information as a first step in screening buildings for potential earthquake vulnerability. With FEMA support, the ATC and Instrumental Software Technologies conducted ROVER training and pilot testing last spring at the University of Utah's Department of Civil Engineering in Salt Lake City. Participants included Utah engineering students, building officials, a member of the Utah State Legislature, the Salt Lake City fire chief, and the earthquake program manager from the Utah Division of Homeland Security. USGS also contributed to the pilot test effort. In 2009, FEMA will partner with USGS to test ROVER, and a new post-earthquake screening tool based on ATC work, with the Los Angeles Unified School District.

Studying how to meet the challenges posed by existing buildings

The seismic safety of existing buildings remains a major challenge in ensuring the earthquake preparedness of threatened communities. In September 2007, more than 90 earthquake professionals participated in a NEHRP-funded workshop conducted as a joint effort by the ATC and EERI. The purpose of this Meeting the Challenges of Existing Buildings workshop was to identify issues and strategies for the NEHRP agencies to use in strengthening guidance for mitigating the earthquake risk to existing buildings. The workshop report, "NEHRP Workshop on Meeting the Challenges of Existing Buildings, Volume 1" (ATC 71), was published in 2008 and is available for download on the NEHRP Web site (http://www.nehrp.gov). This is the first in a series of reports to be produced as part of the ATC 71 project. This project will draw upon prior work to prioritize research on the problems posed by the seismic safety of existing buildings.

Updating guidance on mitigating nonstructural hazards

Nonstructural damage, such as collapsed false ceilings, overturned bookcases, files, and computer racks, and broken water or gas lines can be a source of significant disruption and of damage sometimes equaling structural building damage. FEMA is updating its guidance on mitigating nonstructural hazards, "Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide" (FEMA 74), which was last published in 1994. In 2008, as a first step in this process, ATC released the "State of the Art and Practice Report" (ATC 69), which will be used as a basis for updating FEMA 74. This report summarizes the current state of knowledge and practice regarding the seismic performance of nonstructural components in buildings, including architectural elements, equipment, building systems (electrical, mechanical, plumbing), and building contents. The information in the report was derived from interviews with architects, engineers, building officials, equipment manufacturers, and contractors practicing in seismically active regions across the United States, and from an extensive search of the literature available on nonstructural seismic design practice and earthquake damage to nonstructural components. The updated version of

FEMA 74 will be produced as an electronic, Web-based document and will be available on the FEMA Web site. The ATC 69 report is available for download at http://www.atcouncil.org.

"Homebuilders' Guide to Earthquake Resistant Design and Construction"

During 2008 FEMA continued to promote use of the "Homebuilders' Guide to Earthquake Resistant Design and Construction" (FEMA 232). This publication includes the latest changes to the "International Residential Code" and the results of the Wood Frame Buildings Project conducted by the Consortium of Universities for Research in Earthquake Engineering. FEMA 232 also presents a series of "above-code" recommendations that have been shown to improve home performance in earthquakes and increase chances of post-earthquake habitability. FEMA is currently working on a Spanish-language version of the guide as well as a CD-based training course based on the guide.

Inauguration of NEHRP "Techbriefs"

During 2008 NEHRP published the first in a series of technical briefs that are designed to help transfer into practice the results of research carried out by the NEHRP agencies and others. The inaugural publication was entitled "Seismic Design of Reinforced Concrete Special Moment Frames: A Guide for Practicing Engineers" (NIST GCR 8-917-1), see Figure 8. Work was also begun on a second Techbrief about the seismic design of steel special moment frames.

Figure 8. The first NEHRP seismic design technical brief, issued in 2008. Image courtesy of NIST.

Seismic design guidance for architects

During 2008 FEMA initiated the development of a training course to accompany "Designing for Earthquakes: A Manual for Architects" (FEMA 454). FEMA 454 explains the principles of seismic design for design professionals who may lack a technical background in engineering and seismology. The publication and training course are targeted to practicing architects, architectural students, and faculty in architectural schools who teach structure and seismic-resistant design.

Objective 8: Develop tools to improve the seismic performance of critical infrastructure

Development of seismic design guidelines for port and harbor facilities

During 2008 NSF awarded a multiyear NEES Grand Challenge research grant to the Georgia Institute of Technology to study the seismic response of unique port and harbor structures (e.g., cranes and piers). NIST initiated a knowledge transfer project to develop seismic design guidelines based on the Georgia Tech work.

Investigation and recommendations for the Kawaihae Harbor Port Facility resulting from the October 2006 earthquake

On October 15, 2006, a magnitude 6.7 earthquake struck the northwest coast of the Island of Hawaii, see Figure 9. This event, known as the Kiholo Bay earthquake, produced bedrock motions in excess of 1g,[2] causing large ground motions and severe damage to port facilities in Kawaihae Harbor, which is located on the coast of Hawaii about 32 kilometers from the earthquake's epicenter. This port, which was forced to close, serves as the point of entry for most of the goods that supply the western side of the island, and is critical to the continued well-being of island residents and businesses. Given the vulnerability of the port to earthquakes and the critical nature of the port to the economic viability of the island, FEMA determined that an evaluation of the damage to the port and an assessment of potential mitigation measures would yield recommendations that would be valuable in reducing the risk of damage during future events.

Figure 9. Kapaau, HI, October 25, 2006 – A repair crew examines the Polou Valley Lookout road, which was closed due to earthquake damage. Image courtesy of FEMA.

The resulting report, published in 2008, documents the investigation and analysis of the damage and the performance of the wharf facilities, and presents associated hazard mitigation guidance developed particularly for Pacific island ports. It was sponsored by the FEMA Region IX Mitigation Division under the Hazard Mitigation Technical Assistance Program, in support of the State of Hawaii Department of Transportation Harbors Division.

The report includes descriptions of the emergency operations efforts, damage, site-response ground motions, and liquefaction, as well as a performance assessment of the three primary piers and waterfront structures. Fundamentals of performance-based engineering are introduced that may be suitable for remote location ports with limited resources. Seismic mitigation guidance addresses several key issues, including the liquefaction of coral soils, unusual attenuation of seismic waves, and clearly graded degrees of structural damage correlated with age of design. The guidance draws on how responders performed emergency measures to provide timely and effective restoration of services at Kawaihae Harbor. The report is aimed at applying limited locally available resources, identifying low-cost mitigation measures, and providing education on concepts of tolerable risk in order to promote realistic and effective means to limit earthquake damage to critical port facilities.

[2] 1g equals the acceleration of gravity. A horizontal acceleration of 1g subjects a structure to a force equal to its weight.

3.3 STRATEGIC GOAL C: IMPROVE THE EARTHQUAKE RESILIENCE OF COMMUNITIES NATIONWIDE

Through activities supported under Goal C, NEHRP agencies work to apply research results developed under Goal A and risk-reduction methodologies developed under Goal B to practical measures that will increase public safety and reduce losses in future earthquakes. Work under this goal includes the monitoring and reporting of seismic activity. Goal C is directly related to the congressionally defined NEHRP program activity "Promote the adoption of earthquake hazards reduction measures by Federal, State, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with a role in planning and constructing buildings, structures, and lifelines."

Objective 9: Improve the accuracy, timeliness, and content of earthquake information products

The accomplishments described under this objective are based on data provided by the regional and national seismic monitoring networks of the Advanced National Seismic System (ANSS) and the Global Seismographic Network (GSN). Both ANSS and GSN facilities are described more fully in section 3.4.

ShakeCast improvements

ShakeCast is a freely available, post-earthquake situational awareness tool. It retrieves earthquake shaking data from the ANSS product ShakeMap, which shows the distribution and intensity of ground shaking immediately following an earthquake. ShakeCast then automatically compares ground shaking intensity measures against data on the location and vulnerability of users' facilities, to generate potential damage assessment notifications, facility damage maps, and other Web-based products for emergency managers and responders. ShakeCast has been widely adopted and is fully operational at the facilities of numerous key lifeline operators in California (e.g., East Bay Metro Utility District, California Department of Water Resources, Los Angeles Metro Water District); in local, state, and federal agencies (e.g., Los Angeles Unified School District, U.S. Department of Homeland Security); and in private organizations (e.g., Travelers Companies, Kaiser Permanente).

Publications about ShakeCast issued in 2008 include a 6-page USGS fact sheet, a cover-featured article in Earthquake Spectra (a publication of EERI), and the comprehensive, 98-page "ShakeCast Manual," all of which are available online. ShakeCast user training was provided in a workshop in northern California and via WebEx for individual ShakeCast users. The California Department of Transportation (Caltrans) chief bridge engineer was recognized by the USGS Director with the 2008 USGS Powell Award (recognizing contributions by non-USGS individuals) for his efforts on ShakeCast development and its deployment at Caltrans throughout the State of California. The ShakeCast system also received the "First Place Award for Technology and Innovation" from the International Association of Emergency Managers.

Caltrans has noted the benefits realized from their ShakeCast deployment during the July 2008 magnitude 5.4 earthquake near Chino Hills, CA: Only one bridge sustained significant damage; this bridge was identified by ShakeCast as the third highest inspection priority among more than 400 bridges assessed.

ShakeCast now accepts pre-earthquake, building seismic vulnerability screening data captured using FEMA's ROVER system. ROVER produces viable ShakeCast input in the course of pre-event building screenings conducted with handheld computers during field inspections.

PAGER update

Prompt Assessment of Global Earthquakes for Response (PAGER) is an ANSS product that helps emergency responders quickly gauge the impact of an earthquake disaster. PAGER provides, within a few tens of minutes after a large earthquake, estimates of the population and cities exposed to potentially damaging shaking worldwide. It also provides maps of the population in the affected region overlaid with shaking intensity contours, and a general description of the vulnerability of exposed buildings. PAGER results and products are automatically posted on the Web and distributed to critical users via e-mail and text messaging. These users include the U.S. Agency for International Development, the White House, the U.S. Department of State, the National Security Council, Thomson Reuters, the United Nations, Mercy Corps, the U.S. Department of Defense, the World Bank, and China's Urban Search and Rescue Teams.

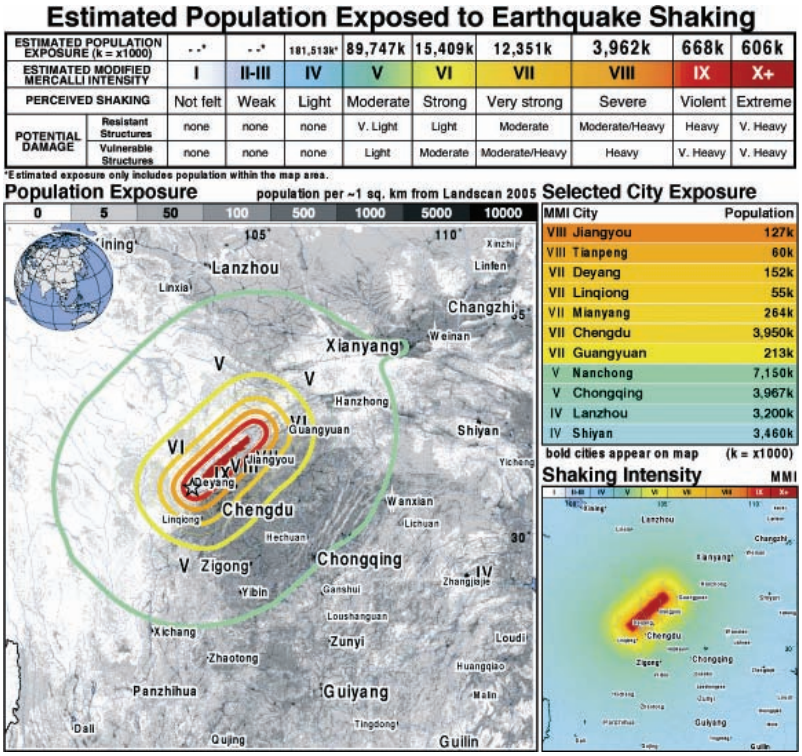

Figure 10. PAGER results for the earthquake in eastern Sichuan showing the area and population impacted. Image courtesy of USGS.

During 2008 the PAGER system generated alerts for about 450 earthquakes. The most notable was the May 12, 2008, eastern Sichuan earthquake in China. Thirty minutes after the earthquake, exposure estimates were sent to critical users indicating that a large-scale disaster had occurred. The PAGER results were used by Chinese authorities as well as by disaster relief organizations to identify the hardest-hit areas even before reports emerged from within the epicentral region. The PAGER maps were reproduced by major media outlets including the New York Times and the BBC.

Figure 10 shows the PAGER results for the Sichuan earthquake. These results were used by government officials and relief organizations in the United States and China, and by many media outlets. It is important to note that in these early results, the region of most damage was estimated to be northeast of the epicenter (star), not in concentric rings around the epicenter. This estimate of the location and degree of greatest damage was based on analyses of seismic waves, which showed the direction of faulting during the earthquake. The human exposure to various degrees of earthquake shaking was based on the seismic analysis and prior knowledge of the population distribution.

In 2008 PAGER development focused on translating the system's exposure calculations into estimates of fatalities. This work spawned a coordinated research effort to collect the necessary information and to develop fatality estimation algorithms, three of which have been implemented and are under internal evaluation.

Continuation of earthquake early-warning technical tests

The concept of earthquake early warning is to detect the occurrence of an earthquake and issue a warning to population centers before the strong seismic shaking arrives. The seismic waves that promulgate strong shaking travel about 3.3 kilometers per second, hence the warning procedures must be automated and reliable.

Technical tests of earthquake early-warning algorithms are continuing, using the ANSS seismic networks in California. Scientists at the California Institute of Technology (Caltech), the University of California, Berkeley, and USGS, working with SCEC, have begun to build an analysis center at SCEC that will gather the test warnings and let researchers know how well the test systems perform. Two of the test methods, called "ElarmS" and "Virtual Seismologist," rely on a network of seismometers across the state to estimate earthquake locations as seismic stations detect primary-wave (P-wave) arrivals, and then to predict the magnitude of the event and the expected shaking intensity. As each second passes, more data become available and earthquake locations, magnitudes, and shaking estimates are refined. If the predicted shaking is severe, the systems issue a warning (not publicly distributed during the test phase). The warning is an estimate of the intensity of shaking at a given location, and the number of seconds until it starts.

Using the current monitoring networks, which are not optimized for early warning, there is enough time to gather the data and generate and transmit enough of a warning to potentially save some lives, even for an earthquake just 15 kilometers or 20 kilometers distant. Because major quakes rupture on long faults radiating severe shaking, early warning systems that rely on first detections at seismic networks could provide millions of people with 10 seconds or more of warning.

The third system being tested should help provide some warning to those located directly above the epicenter of a quake. The "onsite" approach uses a single seismic station, as opposed to multiple stations like the other warnings. Three seconds after detecting a P-wave, instruments analyze the wave, predict the secondary-wave (S-wave) arrival time, and allow a warning to be issued. The most severe earthquake shaking is caused by the S-wave. The system saves a few seconds compared

to other systems, which may be significant in responding to warnings. The dilemma is that there may be more false or missed alarms with this technique, but that may be better than no alarm.

So far, the California tests are encouraging. ANSS data from about 300 seismic stations stream into network centers at Caltech, UC Berkeley, and USGS. Test algorithms process the data and try to detect any earthquakes much faster than has ever been possible before. The results are archived for analysis in a database at SCEC. The test system was exercised by a magnitude 5.4 earthquake that occurred in southern California on July 30, 2008. Despite the fact that only 15 stations are currently processed by the ElarmS-RT algorithm, and that technical transmission issues are delaying some data, the algorithm accurately estimated the earthquake's magnitude. While the location was initially poor, this was due to the sparse station coverage. Once the second and third stations triggered, the location improved substantially. Throughout the entire process, the error in the predicted ground shaking was always small, less than 0.5 intensity units.

Additional support in response to the eastern Sichuan earthquake

In the weeks following the earthquake in China's eastern Sichuan Province, the USGS EROS Data Center coordinated the U.S. Government's response to Chinese requests for satellite imagery of the impacted areas. Additionally, USGS scientists analyzed the changes in the crustal stress field induced by the earthquake to forecast the location of hazardous aftershocks. This analysis was provided to the Chinese government to mitigate further loss of life in the epicentral region.

Geodetic monitoring

Networks of geodetic instruments that measure the permanent deformation of the Earth provide essential information about the massive, slow deformation (strain) of the land surface near faults and the forces that cause earthquakes. USGS is working with universities, local agencies, and the Plate Boundary Observatory (PBO) component of NSF's EarthScope program to conduct geodetic investigations using GPS, to carry out laser-ranging surveys, and to deploy borehole instruments that measure small strain changes.

To address the hazards in the urban Los Angeles region and its environs, USGS operates and distributes data from state-of-the-art, continuously operating GPS stations installed in cooperation with the National Aeronautics and Space Administration's Jet Propulsion Laboratory, the Scripps Institution of Oceanography, and SCEC. These and similar stations in other regions measure changes in the shape of the Earth's surface that help reveal the way stress accumulates on earthquake faults in the region, and how those faults are moving at depth. In addition, USGS is employing a new satellite technology, InSAR, to quickly and accurately produce large aerial maps of pre- and post-earthquake land deformation. USGS supports several university-based geodetic monitoring operations; these awards are listed at http://earthquake.usgs.gov/research/external/networks.php.

Earthquake notification in the Northeast United States

The Northeast States Emergency Consortium, in partnership with the Massachusetts Emergency Management Agency, maintains the multistate Earthquake Hazard Notification System to inform

state emergency management agencies when earthquakes occur. In 2008, the system alerted officials about a dozen seismic events occurring in the Northeast.

Objective 10: Develop comprehensive earthquake scenarios and risk assessments

Earthquake disaster planning in the Central United States

The New Madrid Seismic Zone (NMSZ), located in the Central United States, has the potential to affect eight states, millions of people, and major transportation and lifeline elements that cross the Mississippi and Ohio Rivers. FEMA is supporting a major disaster planning effort in this area, see Figure 11. The states and FEMA Regions involved are Kentucky, Tennessee, Mississippi, and Alabama (Region IV), Illinois and Indiana (Region V), Arkansas (Region VI), and Missouri (Region VII). Multistate, regional preparedness for a disastrous earthquake in this area requires extensive cooperation and coordination between Regions and states in planning and preparedness and in the conduct of response exercises.

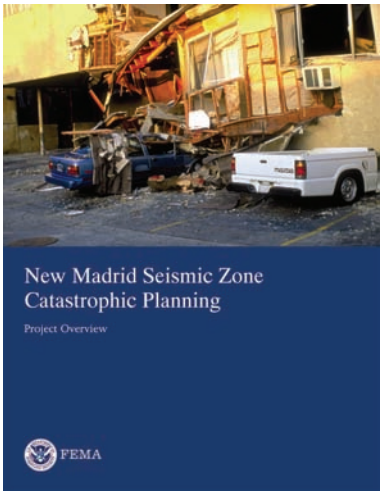

Figure 11. The NMSZ Catastrophic Planning Initiative is under way in the Central United States. Image courtesy of FEMA.

The NMSZ Catastrophic Planning Initiative will provide the first national plan for responding to a major New Madrid earthquake that integrates federal (national and regional), state, and local plans. State and regional planning workshops will lead up to a national TOPOFF[3] exercise planned for 2011.

In 2008, the Region IV HAZUS team supported the NMSZ initiative by completing analyses in support of Tennessee, Kentucky, Mississippi, and Alabama. Workshops in each of the Region IV states actively involved with the NMSZ project also were completed in 2008.

The activities of Region V in 2008 included participating in state and local NMSZ planning workshops in Illinois and Indiana, and maintaining the Region's NMSZ planning working group, in which all Region V divisions participate. Region V also held an NMSZ-based Regional Interagency Steering Committee meeting, participated in a tabletop exercise with the U.S. Army Corps of Engineers and other federal agencies in December 2007, and developed a draft version of the "FEMA V Earthquake Operations and Contingency Plan," dated May 2008.

[3] TOPOFF exercises are the Nation's premier terrorism and disaster preparedness exercises, involving top officials at every level of government as well as representatives from the international community and the private sector.

The State of Missouri, with Region VII staff, worked on a number of NMSZ catastrophic planning activities in 2008. These included the Region VII Public Health and Emergency Preparedness Conference; four catastrophic planning workshops; preparation of the Missouri annex to the Region's earthquake operations plan, which was drafted with regional support; presentations on catastrophic earthquake planning at conferences in Branson, Rolla, and St. Louis; and a tabletop preparedness exercise held at the conference in Rolla in August 2008.

The NMSZ Catastrophic Planning Initiative continues to be an important focus for the Central United States Earthquake Consortium (CUSEC). CUSEC and the Association of CUSEC State Geologists have provided improved baseline maps and other data to maximize the HAZUS models' risk assessment output for the initiative.

Scenario workshop

In September 2008, NEHRP sponsored a workshop on earthquake scenarios that was conducted by EERI and attended by about 74 earthquake professionals. The workshop addressed how to promote the development and use of earthquake scenarios more effectively, and brought professionals who have been involved in developing recent scenarios together with representatives of communities from around the United States that are beginning to consider developing scenarios. EERI will publish an updated and expanded scenario development guide in 2009.

Earthquake scenario for the southern San Andreas Fault

The USGS scenario describing the expected impacts of a magnitude 7.8 earthquake on the southern San Andreas Fault can be used to reduce lifeline vulnerability, retrofit critical structures, improve monitoring systems, plan emergency response activities, and educate citizens. The scenario was developed to be, among other uses, the basis of the November 2008 Golden Guardian emergency management exercise, which was organized by FEMA and the California Offices of Homeland Security and Emergency Services and was the largest emergency response drill ever conducted in California. It was held concurrently with a public preparedness exercise called the Great Southern California ShakeOut that engaged local school districts and businesses to practice earthquake safety drills. The ShakeOut was organized as part of the Dare to Prepare campaign by the Earthquake Country Alliance, a broad public-private coalition of organizations.

USGS researchers led the development of the scenario to produce a realistic example of what a future large earthquake on the San Andreas Fault might look like (see Figure 1). Using the predicted fault displacements from the scenario as well as established methodologies to predict the shaking levels throughout southern California enabled USGS researchers and stakeholders to consider in detail the potential impact of a future "Big One" in California. The total impact of this scenario earthquake was estimated to be approximately 1,800 fatalities and about $200 billion in losses. Among its many findings, this work highlighted significant lifeline vulnerabilities at key transportation arteries that cross the fault. USGS researchers have been in close communication with lifeline operators to discuss the scenario findings and operators' concerns. Maps and images from the scenario can be viewed at http://urbanearth.gps.caltech.edu/shakeout/.

Objective 11: Support development of seismic standards and building codes and advocate their adoption and enforcement

Support for seismic elements of codes and standards applicable to new and existing buildings

NEHRP, through FEMA, supports a group of experts who work with NIBS and the BSSC to submit new or improved design measures, developed under the NEHRP Recommended Provisions, as proposed changes to the Nation's model building codes, including the International Code series of the International Code Council. The BSSC also monitors other proposed changes to the codes and provides testimony during the code change process to help ensure that earthquake-related code provisions are not degraded.

The International Code Council recently completed its code change hearings for the 2009 edition of its model building codes. NEHRP was involved in a significant manner in this process. FEMA staff and contractors provided input on many proposed changes to the "International Building Code," the "International Existing Building Code," and the "International Residential Code." This testimony included supporting code changes submitted by FEMA, supporting proposed code changes where NEHRP worked with the proponents to improve protection against hazards, supporting proposed code changes that other parties submitted that improved protection against hazards, and speaking in opposition to proposed changes that would weaken the code.

FEMA provided testimony regarding the adoption of statewide building codes in Arkansas and Tennessee and worked with the International Code Council to develop code training materials, including an update to the seismic design edition of the popular International Code Council CodeMaster series. The BSSC Code Resource Support Committee is currently updating national seismic design maps for the model codes based on the 2008 USGS national seismic hazard maps.

Objective 12: Promote the implementation of earthquake resilient measures in professional practice and in private and public policies

Earthquake mitigation training

Through 2008 FEMA continued to support the National Earthquake Technical Assistance Program (NETAP) for the development and delivery of training on earthquake mitigation topics for state and local officials and businesses throughout the United States. There was continued demand for NETAP training courses, including "Rapid Visual Screening of Buildings for Potential Seismic Hazards," which is based on the FEMA 154 publication, and "Procedures for Post Earthquake Safety Evaluation of Buildings," which is based on the ATC–20 document. In addition, FEMA provided courses entitled "Earthquake Hazard Mitigation for Nonstructural Elements," which was delivered through a workshop in St. Louis, and "Earthquake Mitigation for Hospitals," which is serving as a model training program for hospitals on nonstructural mitigation and incremental building rehabilitation.

FEMA developed and tested a new training course in 2008, "Seismic Retrofit—One and Two Family Dwellings." Pilot training was held in Fremont, CA, and Portland, OR. The course covered

the effects of earthquakes on one- and two-family dwellings, related retrofit strategies and techniques, and pertinent codes and standards.

In partnership with the U.S. Centers for Disease Control and Prevention, CUSEC developed an "Earthquake Disaster Medicine 101" course that was held in Memphis. The success of this course has led to the development of "Earthquake Disaster Medicine 201," which will be offered in 2009.

FEMA continued to maintain the NEHRP Earthquake Coordinators Web site. This resource provides state and federal earthquake program coordinators with training on earthquake basics, hazards, risks, building techniques, advocacy, partnerships, priorities, and successful activities (http://www.training.fema.gov/emiweb/EarthQuake/welcome.htm).

NEHRP Recommended Provisions: Training and instructional materials

In 2008 FEMA released a compact disc (FEMA 451B–CD) containing a series of training slides and instructional material on the seismic design and construction of new buildings. These materials are based on the NEHRP Recommended Provisions, which serves as the basis for seismic requirements found in model building codes. This CD is a companion product to "NEHRP Recommended Provisions for New Buildings and Other Structures: Design Examples" (FEMA 451 CD).

Earthquake information dissemination and awareness: The Natural Hazards Center

Since 1976, the Natural Hazards Center (NHC) at the University of Colorado has served as a national and international clearinghouse of knowledge concerning the social science and policy aspects of disasters, including earthquakes. In 2008, NSF and seven other federal agencies, including FEMA and USGS, contributed funds to support the NSF grant to the NHC. The center collects and shares research and experience related to preparedness for, response to, recovery from, and mitigation of disasters, emphasizing the link between hazards mitigation and sustainability to both producers and users of research and knowledge on extreme events. The NHC distributes its bimonthly periodical Natural Hazards Observer to more than 15,000 subscribers. This periodical covers current disaster issues; new international, national, and local disaster management, mitigation, and education programs; results from hazards research; relevant political and policy developments; new information sources and Web sites; upcoming conferences; and recent relevant publications. During July 12–15, 2008, the NHC hosted its annual, invitational Hazards Research and Applications Workshop, which involved nearly 400 federal, state, and local emergency officials; representatives of nonprofit, humanitarian organizations; hazards researchers; disaster planners for private industry; and other individuals dedicated to reducing losses from natural hazards. The NHC Web site is at http://www.colorado.edu/hazards/.

Technical seminars on performance-based seismic design

In 2008, with NEHRP support, EERI held the second in a three-part series of technical seminars on PBSD. "Performance-Based Earthquake Engineering for Structural and Geotechnical Engineers: Practical Applications to Deep Foundations: Buildings, Bridges, and Ports" was offered in Seattle (112 attendees), Los Angeles (105 attendees), and San Francisco (115 attendees). Videos of the seminar sessions can be obtained, along with copies of each PowerPoint presentation, from the

EERI Web site (http://www.eeri.org). The videos are made available to the EERI student chapters at universities located throughout North America free of charge.

Earthquake policy development and coordination in the Western United States

The Western States Seismic Policy Council (WSSPC) coordinated with other agencies and organizations in 2008 to host two major conferences on earthquake preparedness issues, both of which were supported by NEHRP (USGS and FEMA). The first conference was held jointly with the International Code Council in Reno, NV, on September 30–October 3, 2007. The second conference was the 2008 National Earthquake Conference: Understanding Earthquakes: From Research to Resilience, held in Seattle on April 22–26, 2008. The national earthquake conference was organized jointly by WSSPC, the Cascadia Region Earthquake Workgroup (CREW), NESEC, CUSEC, EERI, and the Emergency Preparedness for Industry and Commerce Council. WSSPC led the program committee and was responsible for the conference Web site (http://www.earthquakeconference.org), from which conference presentations can be downloaded.

Three policy recommendations were updated by WSSPC and a new recommendation was adopted by the WSSPC membership at the council's annual business meeting in April 2008. The updated policy recommendations related to tsunami preparedness, standard definitions for use in describing earthquake faults, and earthquake monitoring networks. The subject of the new policy recommendation was the importance of inventorying and mitigating unreinforced masonry structures. All of the currently adopted policy recommendations are posted on the WSSPC Web site at http://www.wsspc.org/PublicPolicy/PolicyRecs/index.html.

State earthquake program managers meeting

During 2008 NEHRP supported the application of effective practices and policies for state and local earthquake loss reduction. CUSEC, with FEMA, planned the fourth annual State Earthquake Program Managers Meeting held on April 21, 2008. This meeting is the primary forum at which state-level program managers can exchange information and share experiences, successes, and lessons learned in state-level mitigation planning and implementation.

Objective 13: Increase public awareness of earthquake hazards and risk

Earthquake hazards of the Hayward Fault in California's East Bay region

October 21, 2008, marked the 140th anniversary of the 1868 Hayward earthquake, the last damaging earthquake on the Hayward Fault, which runs along the heavily urbanized east side of San Francisco Bay. Paleoseismic studies of the fault have revealed that the past five such earthquakes occurred 140 years apart on average. In 2008, leading up to the anniversary date, USGS generated a series of products that translate research results into tools for building public awareness of the significant hazard posed by this fault. These products included (1) an 1868 Hayward earthquake ShakeMap showing shaking levels produced throughout the Bay Area by that quake, (2) improved age dating of prehistoric earthquakes on the Hayward Fault, (3) ground motion simulations of Hayward Fault ruptures, and (4) a series of outreach products on the Hayward Fault including a new fact sheet, a guide for touring the Hayward Fault using mass transportation, and a

virtual tour of the 1868 Hayward earthquake. USGS also organized and chaired the 1868 Hayward Earthquake Alliance, a public-private nonprofit organization with more than 120 different member organizations focused on promoting earthquake preparedness. As a result of these efforts about 200,000 schoolchildren from all over the Bay Area participated in a school earthquake drill on the anniversary, and dozens of businesses, organizations, and local governments sponsored and participated in activities promoting earthquake awareness and preparation.

Public Web access to earthquake information

New traffic records were set for the USGS Earthquake Hazards Program (EHP) Web site following the magnitude 7.9 May 12, 2008, Sichuan earthquake and the magnitude 5.4 July 29, 2008, Chino Hills earthquake, the first a large, disastrous event in a moderately populated area in China, and the second a moderate event in a highly populated area of California.

Seismic events worldwide result in a sustained traffic swell to the Web site; for example, the EHP site received a half billion hits in the 30 days following the Sichuan earthquake, see Figure 12. U.S. events, on the other hand, produce a spike of Web traffic within minutes after the earthquake. The Chino Hills earthquake caused peak traffic of 17,730 hits per second just after the earthquake occurred. Many of these hits involved people responding to how the earthquake affected them. These responses are captured in the "Did you feel it" system and are used to generate maps of earthquake effects on humans. The EHP Web site is ranked 3,146 (by amount of traffic) among all worldwide Web sites according to Alexa.com.

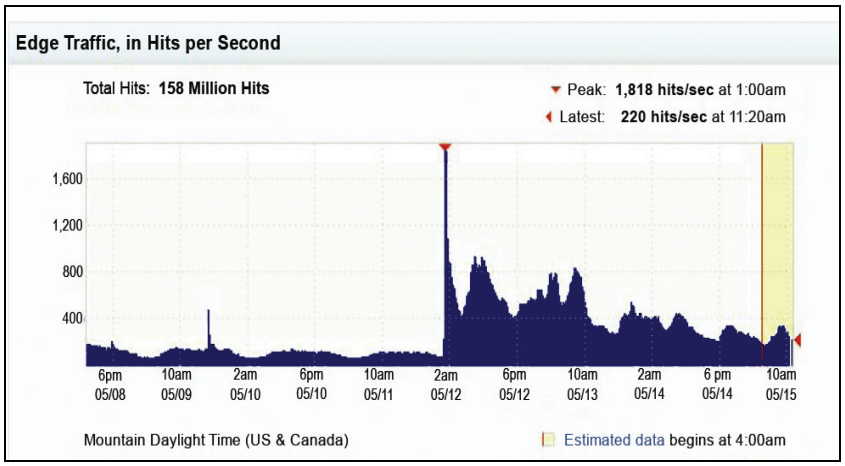

Figure 12. Web traffic at the USGS National Earthquake Information Center immediately following the eastern Sichuan, China, earthquake. Chart courtesy of USGS.

Earthquake Notification Service

The USGS National Earthquake Information Center (NEIC) sends e-mail messages immediately following earthquakes from its Earthquake Notification Service (ENS) to users who have specified criteria for earthquakes of interest. ENS usage continued to increase in 2008. ENS text and pager notifications support a very wide range of user needs and demographics. Currently, there are more than 140,000 subscribers of which 8,800 are using customized notification areas. For example, some users may be interested in receiving notifications only of events occurring in California. There are more than 1,300 users in the military (.mil) domain and over 3,200 in the government (.gov) domain. Most users receive messages via private providers, and most of these are likely to be

individual users. The ENS provides its most rapid notifications to more than 7,000 priority users and more than 2,200 scientists. In a typical day about 170,000 messages go out, 30 new users sign up, and nearly 205 events are processed. These numbers increase dramatically immediately after significant earthquake sequences occur. USGS is continuing efforts to expedite earthquake information processing at NEIC for global events, within ANSS for U.S. events, and with international partners, to automate and expand real-time coverage of events worldwide at lower magnitude thresholds and increased accuracy. ENS statistics from 2007 and 2008 are compared in Table 3.1.

Table 3.1—USGS Earthquake Notification Service

Information Collected	2007	2008
Total subscribers	125,000	140,400
User profiles	200,000	254,500
Customized profiles	3,600	8,800
Military domain	1,000	1,300
Government domain	2,500	3,200
Priority users	2,800	7,000
Scientists	1,000	2,200
New users per day	50	30
Events processed per day	35	205

Assessment of earthquake predictions

The National Earthquake Prediction Evaluation Council is a federal advisory committee established by statute that provides advice and recommendations to the USGS Director on earthquake predictions and related scientific research. The council supports the Director's delegated responsibility under the Stafford Act (Public Law 93–288) to issue timely warnings of potential geologic disasters. In 2008 the council completed its oversight of the construction of the Uniform California Earthquake Rupture Forecast (see Objective 5 above). Council oversight ensured that the forecast, which was released in April, was based on sound scientific data and analyses and received appropriate scientific scrutiny and review.

QuakeSmart initiative

During 2008, FEMA developed and rolled out the QuakeSmart initiative. The goal of QuakeSmart is to build awareness of earthquake risk within the business community and to educate small and emerging businesses on the relatively simple things that they can do to reduce or mitigate the impacts of earthquakes. The benefits of mitigation for businesses are substantial. Not only can business owners protect their investments and recover more quickly from a disaster, they may significantly reduce the risk of injury or death for themselves, their employees, and their customers. This will result in a more resilient community in which future investment is more attractive. The project is a partnership with the Safe America Foundation, a nonprofit venture that focuses on safety and disaster preparedness. In October 2008, FEMA and Safe America conducted a series of QuakeSmart business forums in Emeryville, CA; Reno, NV; Cape Girardeau, MO; and Evansville, IN. These events were hosted by the chambers of commerce in these communities. Regional follow-up events are planned for 2009. QuakeSmart information for businesses is available at http://www.quakesmart.org, see Figure 13.

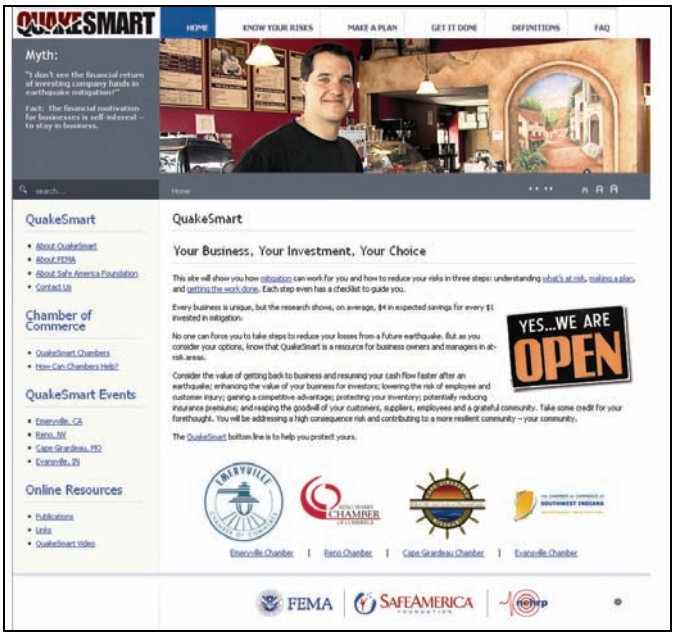

Figure 13. The QuakeSmart Web site offers earthquake risk mitigation information tailored to businesses. Image courtesy of FEMA.

Web sites for public information and outreach

NEHRP maintains a central program Web site at http://www.nehrp.gov. This site provides links to the more specialized sites of the NEHRP agencies. For example, FEMA's earthquake Web site includes sections designed to inform the public, emergency personnel, businesses, and federal, state, and local agencies of ongoing activities in earthquake mitigation. FEMA continues to post NEHRP technical and nontechnical publications on this site at http://www.fema.gov/hazard/earthquake/index.shtm. The USGS Earthquake Hazards Program site (http://earthquake.usgs.gov) provides extensive information about the agency's earthquake-related research and monitoring activities, about its seismic hazard maps and assessments, and about the latest seismic activity worldwide.

Regional awareness—Central United States

CUSEC continued its coordination of and support for earthquake awareness campaigns and programs in Arkansas, Kentucky, Missouri, and Tennessee. This support encompassed town hall meetings, presentations at special events, a meeting of the Central United States Seismic Advisory

Council, displays at the St. Louis Children's Museum, and the Earthquakes Mean Business forum, which was attended by more than 300 business leaders from the St. Louis area.

In August 2008, the Missouri University of Science and Technology hosted a conference entitled "Preparing for a Significant Central U.S. Earthquake: Science Needs of the Response and Recovery Community." Cohosted by USGS, the Mid-Continent Geographic Science Center, and the Geology and Land Survey Division of the Missouri Department of Natural Resources, the conference provided a regional forum for the presentation and exchange of ideas and potential solutions related to preparing for a significant Central United States earthquake similar to the events of 1811–12. More than 300 people attended the conference with heavy representation from emergency management at the local and state levels as well as from professional organizations, the private sector, and the military.

During 2008 CUSEC made significant progress in developing a post-earthquake clearinghouse protocol for the Central United States. At the 2008 National Earthquake Conference, CUSEC unveiled the "Multi-State Post Earthquake Clearinghouse Coordination Plan." The unique regional breadth of the earthquake threat in the Central United States warranted the development of this plan to ensure well-coordinated post-earthquake activities among the research community. The plan also addresses the interaction between research response and emergency management response, an area that has received relatively little attention from state and federal planners.

Regional awareness—New England

NESEC promotes multihazard preparedness and risk reduction among its member states in the Northeast through various media and publications. NESEC News is published quarterly and provides updates on current state emergency management officials, activities, success stories, and resources, as well as multihazard risk information. NESEC also provides links and information about obtaining GIS software and technical manuals on its Web site at http://www.nesec.org/.

NESEC has updated and re-released on DVD its award-winning videos entitled "New England's Next Earthquake: The Writing on the Wall" and "Earthquakes in New England," the latter developed for schoolchildren in kindergarten through grade 5. NESEC re-edited the content, modernized the graphics, and combined these two videos onto a single DVD. This new DVD is available on the NESEC Web site at http://www.nesec.org/video.cfm.

Regional awareness—Pacific Northwest

The Cascadia Region Earthquake Workgroup (CREW) published "Cascadia: Deep Earthquakes 2008," a 28-page report on the serious risk posed by deep earthquakes to the Pacific Northwest and what has been learned from previous events of this type. The report was also published as Open File Report 2008–1 by the Washington Division of Geology and Earth Resources. CREW continued to hold quarterly Multi-Hazard Round Tables at the University of Washington's Department of Urban Design and Planning and Institute for Hazards Mitigation. A notable presentation at the September 2008 round table was "The Wenchuan Earthquake: Practical Implications of Geology (Lessons for the Pacific Northwest)." CREW also participated in

Washington State University's Partners in Emergency Preparedness Conference and continued to support the Pacific Northwest Economic Region's Blue Cascades V emergency response and planning exercise.

Objective 14: Develop the Nation's human resource base in earthquake safety fields

The NSF Undergraduates Program

Programs in NSF's Engineering and Geosciences Directorates provided Research Experiences for Undergraduates (REU) supplements to existing awards to enable undergraduates to be research participants on earthquake and earth science-related projects. During 2008, these supplements enabled undergraduate students to be part of geological research teams; for example, students collected paleomagnetic samples in Patagonia and developed a dynamic digital map of southern Patagonia. This map incorporates the collected paleomagnetic data, photographs of the field areas, information on local and regional geology, and links to published papers and maps. Undergraduates also were sponsored to update the East African Rift tectonic model and participate in GPS field deployments in Uganda in collaboration with a group of German geoscientists. Additionally, undergraduates were supported to gain experience in experimental testing on various NEES research projects using the NEES experimental facilities.

The NSF Early Faculty Career Development (CAREER) Program

NSF's CAREER program provides support for faculty in the early stages of their academic careers to develop both strong research and educational programs. A researcher from the California Institute of Technology was supported in developing a program of multidisciplinary education and research in the mechanics and physics of earthquakes. The awardee has been working with the Pasadena Unified School District and a high school physics teacher to give students an idea of what scientists do and to provide an interesting preview (and application example) of topics in friction and wave propagation that will be covered later in the physics course. A researcher from the University of Southern California, involved in modeling the circulation of the Earth's upper mantle, is being supported through an NSF CAREER award to develop geodynamic and seismological software "modules." These modules will allow a range of students to access research tools for a variety of educational purposes. The goal is to provide different packaging that allows students to use the modules at varying levels of computational difficulty depending on their interest and expertise.

Education of future engineers

In 2008, the NSF Undergraduates Program and FEMA brought students from across the United States to the EERI Annual Meeting in New Orleans. There, the students attended presentations by the Nation's leading professionals and researchers in the earthquake engineering and disaster reduction fields. A high point of each EERI Annual Meeting is the Annual Undergraduate Design Competition, see Figure 14. More than 100 students from 17 teams participated in the 2008 competition, which provided students with an opportunity to learn firsthand about some of the challenges that engineers must deal with in designing seismically resistant buildings. The

Figure 14. Cal Poly's team members (l-r), Robert Thompson, Alan Tonissen, Joseph Thompson, Neda Saeedy, Jeff Stallman, Eduardo Lopez, and Keith Robertson, who placed first in the 2009 Undergraduate Seismic Design Competition. Image © 2009 by Azadeh Alipour.

competition enabled these participants to test their designs on shake tables before the Nation's leaders in earthquake engineering. Over the years, the competition has changed the course of many participants' academic careers, encouraging some of the brightest undergraduates to pursue careers in earthquake engineering and seismic safety.

Funding from FEMA also helps support EERI's 29 student chapters located at universities in the United States, Puerto Rico, Canada, and Mexico.

SCEC ACCESS program

With support from NSF, SCEC's Advancement of Cyberinfrastructure Careers through Earthquake System Science (ACCESS) program is providing a diverse group of students with research experiences in earthquake system science that will advance their careers and encourage their creative participation in cyberinfrastructure (CI) development. The overarching goal of the program is to prepare a diverse, CI-capable workforce for solving the fundamental problems of system science. ACCESS interns will typically be computer science/information technology (CS/IT) students, or geoscience students with experience in CI and IT. In some cases, students majoring in physics, mathematics, multimedia applications, or engineering will also be suitable ACCESS candidates. ACCESS will encourage women and students from under-represented and disadvantaged groups to achieve advanced degrees through CI-related research, and it will guide them toward faculty positions at universities. Topics of research include SCEC computational platform projects, such as the Earthworks Science Gateway, PetaSHA, and the Collaboratory for the Study of Earthquake Predictability. ACCESS has funded five undergraduate and four graduate interns a year since its inception.

Other development programs at the National Science Foundation

NSF supported travel for 40 U.S. scientists and engineers to participate in the 14th World Conference on Earthquake Engineering held in Beijing, China, in October 2008. This conference is a major forum, held every 4 years, which provides an opportunity for the exchange of scientific information and ideas in earthquake engineering. NSF's support enabled U.S. researchers to present technical papers disseminating their research findings and to interact with earthquake engineering researchers from around the world.

An NSF grant award to North Carolina State University supported the third phase of the well-received Enabling Project that was first undertaken in 1994 and repeated in 2002. The goal of the project is to create a critical mass of young investigators to spur the next generation of researchers

in natural hazards and disasters. A nationwide search is conducted to select 16 assistant professors from the fields of engineering, economics, geography, psychology, public health, public policy, sociology, and urban planning. The 16 selected "Enabling Fellows" spend 2 years in a mentoring program involving senior scholars from a broad range of disciplines as mentors. The project includes two workshops, one-on-one mentoring, and research and writing activities.

USGS post-doctoral program

In 2008 USGS continued a program, begun in 2001, of competitive opportunities for post-doctoral research investigations in areas relevant to the agency's various geological programs. Called Mendenhall Fellowships in honor of the agency's fifth Director, these appointments are for 2 years and provide salary and support for research equipment, data, and field work. Since 2001, 16 scientists have received these fellowships to work at USGS centers on research problems in earthquake fields related to the USGS role in NEHRP.

3.4 DEVELOP, OPERATE, AND MAINTAIN NEHRP FACILITIES

Public Law 108–360 requires that NEHRP "develop, operate, and maintain" certain facilities essential to the NEHRP mission. These facilities are the Advanced National Seismic System (ANSS, maintained by USGS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES, maintained by NSF), and the Global Seismographic Network (GSN, maintained by both USGS and NSF). Reports on the activities and status of these facilities during 2008 follow.

Advanced National Seismic System

USGS and its partners are building ANSS to modernize the Nation's seismic monitoring infrastructure. ANSS consists of a national backbone network, regional networks operated by state and university partners, the USGS National Earthquake Information Center (NEIC), and ground- and structure-based instruments concentrated in high-hazard urban areas. Currently about 15 percent deployed, ANSS has already greatly improved information available for emergency responders, engineering performance studies, and long-term earthquake hazard assessments. ANSS has been carefully planned and executed, as reflected by its repeated recognition as the highest-rated information technology major capital investment in the U.S. Department of the Interior. A report by the National Research Council on the costs and benefits of seismic monitoring found that the benefits of fully deploying ANSS outweigh the costs many times over.

To carry out its statutory responsibilities, the NEIC provides rapid reports of potentially damaging earthquakes to the National Command Center, the White House, and the Departments of Defense, Homeland Security (including FEMA), Transportation, Energy, and the Interior, as well as to state and local emergency managers, numerous public and private infrastructure management centers (e.g., railroads, pipelines), the news media, and the public. These earthquake notifications are also delivered as e-mail and text messages to over 100,000 other users. A suite of information products

is available through the USGS Earthquake Hazards Program Web site, which receives an average of 2 million hits per day.

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

Currently, many ShakeMaps are based on models rather than data, due to sparse and heterogeneous monitoring station coverage. As ANSS is more fully deployed and additional sensors are installed, these maps will improve in resolution and accuracy. During 2008, USGS used funds provided by Congress in support of the Multi-Hazard Demonstration Project to deploy ANSS instrumentation along the southern San Andreas Fault. These new sensors will provide critical measurements of ground motions close to a major rupture, improve ShakeMap capability in the fast-growing San Bernardino-Riverside urban corridor, and potentially support implementation of an early-warning system prototype in the future.

USGS directed a significant portion of the $2 million increase provided to its Earthquake Hazards Program in the 2008 congressional appropriations toward ANSS, and will continue to strengthen ANSS as resources allow. Nineteen new stations were added to the system in 2008, in California, Utah, New Jersey, and New York. Building-instrumentation projects were completed in northern and southern California and in Puerto Rico, and a new project was begun in southern California. Purchasing was completed in 2008 for 17 new stations along the southern San Andreas Fault, as part of the Multi-Hazard Demonstration Project in Southern California. A new earthquake processing system was installed at the Hawaii Volcano Observatory, and a Hawaii Integrated Seismic Network was established between USGS and the Pacific Tsunami Warning Center of the National Oceanic and Atmospheric Administration (NOAA). In addition, 15 stations of the Earthscope-USArray Transportable Array (TA) (see section 4.1) are being added to the Pacific Northwest Seismic Network through a grant from the Murdock Trust, along with 3 TA stations from the U.S. Department of Energy's Pacific Northwest Laboratory, and 3 stations acquired by the State of Oregon. Figure 15 shows the growth of ANSS instrument sites since the program began.

To support cooperative activities in regional earthquake monitoring, approximately $6.0 million was provided in 2008 as assistance awards to 15 universities, $3.4 million of which comes from base USGS EHP funds and $2.6 million of which comes from USGS funds targeted for development and maintenance of ANSS. These awards are listed on the USGS Web site at http://earthquake.usgs.gov/research/external/networks.php.

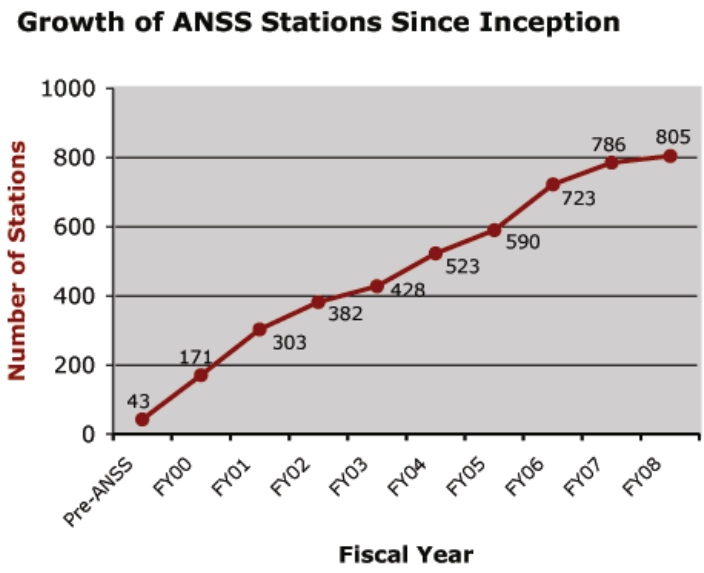

Figure 15. Growth of ANSS stations. Image courtesy of USGS.

George E. Brown, Jr. Network for Earthquake Engineering Simulation

NEES completed its 5-year, $82 million major research equipment and facilities construction in September 2004, focusing on the development of experimental facilities at 15 academic institutions across the United States. Testing resources at these sites include seismic shake tables, geotechnical centrifuges, a tsunami wave basin, large strong-floor and reaction-wall facilities with unique testing equipment, and mobile and permanently installed field equipment. Through the network's CI technology, these 15 experimental facilities are linked via the Internet2 grid, forming the world's first prototype of a distributed "virtual instrument," and can be connected with similar facilities worldwide to harness the best talent globally for earthquake engineering research.

In October 2004 NEES began operations and use of its facilities for research and education, under the management of the NEES Consortium, Inc. (NEESinc), which is located in Davis, CA. NEESinc is a nonprofit organization that works in partnership with the 15 universities to operate the NEES experimental facilities and CI. NEESinc manages NEES as a national, shared-use resource for research and education for the earthquake engineering community, and schedules access to the experimental facilities. NEESinc also provides the system-wide information technology infrastructure of NEES, including repositories for NEES data and simulation tools; manages an education, outreach, and training program; and fosters linkages and partnerships with federal, state, and local government entities, national laboratories, the private sector, and international collaborators. NEESinc will operate NEES through September 30, 2009. During 2008–2009, under program solicitation NSF 08–574, "George E. Brown, Jr. Network for Earthquake Engineering Simulation Operations (NEES Ops) FY 2010 – FY 2014," NSF is conducting a competition to establish a new awardee for operations of the NEES infrastructure for years 6–10 (i.e., October 1, 2009, through September 30, 2014).

NEES provides unique opportunities to pursue the high-priority research outlined in the 2003 National Research Council report, "Preventing Earthquake Disasters—The Grand Challenge in Earthquake Engineering"; to demonstrate the validity of seismic design and rehabilitation concepts; to speed the transfer of research into seismic design guidelines and specifications; and to develop well-informed disaster preparedness and recovery strategies. The NEES infrastructure (experimental facilities and CI) facilitates a variety of innovative experimental approaches that are leading to a better understanding of how the built environment (e.g., buildings, bridges, earth retaining systems, utility systems, coastal regions, and earthen structures and materials) performs during seismic events.

Through five annual program solicitations and the Small Grants for Exploratory Research program, NSF has funded more than 50 research projects to apply the NEES facilities to the study of soil foundation and structure interaction; the seismic performance of foundations, lifelines, and reinforced concrete, masonry, wood, and composite structures; the behavior of steel frames with innovative bracing schemes; the seismic design of nonstructural systems; seismic risk mitigation of ports; and the seismic performance of bridge systems with conventional and innovative materials. Many of these projects have included practitioner and industry partners to help design experimental and analytical investigations and to speed technology transfer.

NEES also provides national resources for developing, coordinating, and sharing new educational programs and materials to train the next generation of the earthquake engineering workforce. During the summer of 2008, NEESinc ran REU programs that gave 22 students the opportunity to work at six NEES experimental facilities (http://www.nees.org). NEESinc also organized the NEES Sixth Annual Meeting, which was held in Portland, OR, from June 18 to 20, 2008. This meeting provided an opportunity for researchers to share experiences, experimental results, and project outcomes that resulted from using the NEES infrastructure. During 2008, the NEES equipment sites also continued to host training workshops for potential users.

Global Seismographic Network

The GSN is a worldwide network of seismic recording stations with standardized instrument design, data formats, and communication protocols. The network is a joint program implemented by USGS through its Albuquerque Seismological Laboratory and by NSF through Incorporated Research Institutions for Seismology and the Institute of Geophysics and Planetary Physics of the University of California.

The NEIC relies on the GSN to fulfill its responsibility for reporting on all significant seismic events worldwide—including, for example, the eastern Sichuan, China, earthquake disaster of May 2008 (see section 4.3). Supplemental funding, received following the Sumatra earthquake and Indian Ocean tsunami of 2004, enabled USGS to modernize NEIC's facilities and establish 24/7 on-site staffing. Those funds also made it possible for USGS and its partners to make considerable strides in enhancing the GSN with new seismic monitoring stations in the Caribbean and improved data telemetry worldwide. These capabilities have, in turn, significantly enhanced our ability to support

NOAA's tsunami warning capabilities, which rely on data from the GSN and other USGS seismic networks.

In 2008, the number of GSN stations increased from 147 to 151. New stations were installed in the Republic of Kiribati on Kanton Atoll and on the Canary Islands of Spain. The station on Wake Island was reinstalled, restoring operations at a site that was destroyed during a 2006 hurricane.

Caribbean Seismic Network expansion (a GSN Affiliate Network)

One of the major accomplishments for the GSN in 2008 was the completion of the Caribbean Seismic Network. Following the 2004 Sumatra-Andaman earthquake, the U.S. Government established an initiative to enhance earthquake and tsunami monitoring in the Caribbean through the installation of seismic stations, tsunami warning buoys, and tide gauges. USGS collaborated with the University of the West Indies Trinidad Seismic Research Unit, the Puerto Rico Seismic Network, and other regional partners to install nine seismic stations in the Caribbean, complementing existing GSN coverage, and completed the last two sites in Jamaica and Turks and Caicos in December 2007. Seven stations were operational at the time of the magnitude 7.4 earthquake in Martinique on November 29, 2007, providing data to the NEIC and the NOAA tsunami warning centers.

"Next Generation" system upgrades

Reaching a major milestone, USGS deployed the first of its "Next Generation" hardware and software upgrades in 2008. New data acquisition systems were deployed at 11 GSN sites, replacing antiquated systems. The systems digitize the ground motions recorded by the seismic sensors and transmit the data to the NEIC for earthquake processing. The Next Generation system rollout comes at a critical time as the current systems operated by USGS have an average age of 14 years and are no longer manufactured.

Chapter

4

Related Activities Supporting NEHRP Goals

Public Law 108–360, the Earthquake Hazards Reduction Program Reauthorization Act of 2004, requires that the annual report to Congress include a description of activities being carried out by the National Earthquake Hazards Reduction Program (NEHRP) agencies that contribute to NEHRP goals but are not officially included in the program. Highlights of these programs and activities are described below.

4.1 EARTHSCOPE

EarthScope is a multidisciplinary science program whose purpose is to explore in unprecedented detail the four-dimensional structure of the North American continent. The program is supported by the National Science Foundation (NSF) in partnership with the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration. The primary EarthScope facilities—the Plate Boundary Observatory (PBO), the San Andreas Fault Observatory at Depth (SAFOD), and USArray—marked the successful completion of their construction in September 2008 and are now proceeding with operations and maintenance. Together, these facilities have installed more than 700 seismometers, 900 continuous global positioning system (GPS) instruments, 50 strainmeters, and 200 magnetolluric instruments. These observatories and instruments, in combination with supporting GeoEarthScope[1] facilities, provide 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 the 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.

[1] GeoEarthScope, a part of the EarthScope Program, includes the acquisition of aerial and satellite imagery and geochronology to examine the strain field beyond the decade time scales available from the PBO geodetic instrumentation.

San Andreas Fault Observatory at Depth

SAFOD is a 3-kilometer-deep hole drilled directly into the San Andreas Fault midway between San Francisco and Los Angeles, near Parkfield, CA. Located in a part of the fault that has ruptured six times since 1857, the hole is providing the first opportunity to observe directly the conditions under which earthquakes occur, to collect rocks and fluids from a fault zone for laboratory study, and to continuously monitor the physical conditions within an active earthquake nucleation zone. Seismic recordings from deep within the boreholes, comprehensive geophysical logs along the entire length of the drill hole, and core, cuttings, and fluid samples have been obtained.

Plate Boundary Observatory

The PBO is a geodetic observatory that measures deformation of the Earth's crust in space and time. It consists of a backbone network of GPS receivers in the western United States and more-focused deployments of GPS receivers and strainmeters in tectonically active areas. While the PBO construction crews have faced challenges in some of the installations—from bears and an active volcano on remote Unimak Island in Alaska to unexpectedly hot geothermal fluids in drill holes in Yellowstone National Park—the resulting network has enabled many new observations of earthquakes and deformation and increased our understanding of earthquake and volcanic hazards. For example, in 2008, PBO instruments recorded a creep event on the San Andreas Fault near Parkfield, CA, an episodic tremor and slip event in the Pacific Northwest, and the large Wells, NV, and Chino Hills, CA, earthquakes. In addition, as part of GeoEarthScope, two light detection and ranging (LIDAR) campaigns were flown to acquire images of fault systems in southern and eastern California (including the San Andreas Fault) and a fold and thrust belt in the Pacific Northwest.

USArray

USArray is a continent-scale network of seismic stations that records earthquakes and explosions to provide a three-dimensional image of the lithosphere and deeper Earth structure. The primary seismic array is a transportable network of seismometers that is rolling across the country, from the western United States to the east coast. Ultimately, it will move to Alaska. This Transportable Array (TA) is installed in a grid-like fashion with approximately 70-kilometer spacing between each of the 400 TA stations. With each station in place for about 2 years, the first 400-station "footprint" on the west coast of the United States was completed in 2008 and the network is now rolling to the east. The easternmost edge of the TA network currently runs through Montana, Wyoming, Colorado, New Mexico, and the Big Bend area of Texas. Site reconnaissance and permitting activities are in full swing for the next swath of stations from North Dakota south to Texas.

For the fourth year in a row, students from local universities were trained to select suitable locations for future seismic stations and successfully identified more than 300 sites in North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. As the seismic network has moved east, some TA stations have been, or are being, acquired for permanent use by organizations in Washington, Oregon, Arizona, Idaho, and Utah. USArray also has a pool of approximately 2,100

portable instruments that can be deployed in more flexible geometries to provide observations of key targets within the footprint of the larger TA. Another component of USArray is the upgrade and installation of about 40 permanent stations across the United States. This network of equally spaced seismometers, which was completed in 2008 and is part of the Advanced National Seismic System (ANSS), will be able to record and detect all earthquakes of magnitude 3.0 and greater that occur within the United States.

4.2 SUBCOMMITTEE ON DISASTER REDUCTION

Many federal agencies play important roles in reducing the effects and impacts of natural hazards. The National Science and Technology Council's Committee on Environment and Natural Resources, through its Subcommittee on Disaster Reduction (SDR), provides coordination for the full spectrum of science and technology contributions to disaster reduction. The SDR is charged with establishing national goals for federal science and technology investments in disaster reduction. In support of this mission, the SDR provides a senior-level interagency forum to leverage expertise, inform policy makers, promote technology applications, coordinate activities, and promote excellence in research and development. NEHRP agencies are all actively involved in SDR activities and serve as the focal point for earthquake-related topics, ensuring coordination between NEHRP and the broader federal enterprise.

In 2008, the SDR released a set of 14 hazard-specific implementation plans to meet the disaster-reduction goals set forth in the report entitled "Grand Challenges for Disaster Reduction," which was issued by the SDR in 2005. NEHRP agencies played a central role in developing the implementation plans for earthquakes and other related hazards, such as landslides and tsunamis, ensuring that the priority activities identified in these plans were well coordinated and consistent with the priorities being developed through the NEHRP strategic-planning process.

4.3 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 wind and seismic effects and on earthquake research. The U.S. sides of these panels are chaired by the National Institute of Standards and Technology (NIST) and USGS, respectively.

U.S.-Japan Panel on Wind and Seismic Effects

In May 2008 the panel conducted its 40th annual joint meeting at NIST headquarters in Gaithersburg, MD. The panel's work involves exchanging guest researchers who perform short-

and long-term joint cooperative research assignments, visiting major public works construction projects that employ innovative civil engineering techniques and research laboratories with unique test and measurement capabilities, and performing joint post-disaster surveys. The panel's accomplishments serve as technical bases for improving seismic design and construction practices by advancing retrofit techniques for bridge structures, addressing shake table modeling and simulation of nonlinear problems, assessing earthquake risks for dams, testing seismic performance guidelines for bridge piers, and jointly conducting full-scale column tests at the National Research Institute for Earth Science and Disaster Prevention's (NIED) Full-Scale Earthquake Testing Facility in Miki, Japan. Other activities have included producing full-scale test data that advance seismic design standards for buildings; advancing technology for repairing and strengthening reinforced concrete, steel, and masonry structures; improving in-situ measurement methods for soil liquefaction and stability under seismic loads; and creating a database comparing Japanese and U.S. standard penetration tests to improve prediction of soil liquefaction.

U.S.-Japan Panel on Earthquake Research

The UJNR Panel on Earthquake Research promotes bilateral cooperation toward a more fundamental understanding of earthquake processes and hazard estimation. The panel promotes basic and applied research to improve our understanding of the causes and effects of earthquakes and to facilitate the transmission of research results to those who implement hazard reduction measures. The scientific cooperation carried out under the aegis of this panel includes joint field work, cooperative data collection, analysis, and dissemination, sharing of research results, and joint publications.

A major focus of joint work over the past 2 years has been the understanding of recently discovered fault slip phenomena that occur deep in fault zones, well below the depths of ordinary earthquakes. These "slow slip events" provide an important new window into the processes that govern strain accumulation in deep fault zones. The large earthquakes in which this deep, built-up strain is suddenly released pose a major hazard to both the United States and Japan.

U.S.-China Cooperation in Earthquake Studies

Following the May 2008 earthquake disaster in Sichuan Province, China, a U.S. delegation of experts in seismology and earthquake engineering led by NIST visited Beijing in June to discuss with their Chinese counterparts potential bilateral information exchange and research cooperation. The delegates included representatives of USGS, the U.S. Department of State, NSF, the Incorporated Research Institutions for Seismology, the Earthquake Engineering Research Institute (EERI), and the Geo-engineering Extreme Events Reconnaissance (GEER) Association. Members of the staff of the China Earthquake Administration hosted the meeting. Chinese participants provided overviews of the information they had collected regarding the Sichuan earthquake. U.S. participants provided overviews of the structure of NEHRP and their organizational capabilities and interests with respect to the earthquake.

A primary focus of the U.S. participants was in organizing near-term joint field investigations in the earthquake-damaged region. Because of complexities in accessing the damaged area, near-term field investigations involving official U.S. participants required further coordination following the June meeting. In discussions related to future cooperation, and in view of the broad participation by Chinese and U.S. agencies in earthquake-related issues, the participants agreed that the existing "Protocol on Earthquake Studies" between China and the United States might be revised to reflect the broader mutual interests and capabilities of the agencies.

During August 3–11, 2008, a team sponsored by EERI and the GEER Association carried out a field investigation in conjunction with Chinese colleagues to document effects of the May 12 Sichuan earthquake. The EERI–GEER team was invited by Professor Zifa Wang, Director of the Institute of Engineering Mechanics–China Earthquake Administration (IEM–CEA). Professor Junwu Dai of the IEM–CEA accompanied the team during the field investigation. Led by Marshall Lew of MACTEC Engineering and Consulting in Los Angeles, the team included experts in structural, lifelines, and geotechnical engineering as well as in disaster response and recovery. Observations of other investigators who visited the earthquake-affected region have also been incorporated into the report prepared by this team. The EERI field investigation was conducted as part of the Learning from Earthquakes Program with funding from NSF. The GEER Association activity was also supported by NSF.

Subsequently, in mid-September 2008, four USGS landslide experts traveled to the earthquake-affected area to work with Chinese colleagues on the evaluation of landslide causes and ongoing hazards. The visit was sponsored by the China Geological Survey. The team succeeded in building strong ties with their Chinese counterparts and, before their trip concluded, signed a conceptual agreement with Chinese scientists for future work focused on capacity building, collaborative hazard assessments, and data exchange.

NEES/E-Defense

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is leveraging and complementing its capabilities through connections and collaborations with large testing facilities at foreign earthquake-related centers, laboratories, and institutions. NSF and the NEES Consortium, Inc. (NEESinc) have developed partnerships to utilize the NEES infrastructure with E-Defense of NIED, which became operational in 2005. To facilitate NEES/E-Defense collaboration, NEESinc and NIED signed a memorandum of understanding in August 2005. In September 2005, NSF and the Japanese Ministry of Education, Culture, Sports, Science, and Technology signed a memorandum concerning cooperation in the area of disaster prevention research. Through such partnerships and joint meetings and workshops, NEES shares its expertise in testing and cyberinfrastructure, provides specialized training opportunities, and coordinates access to its unique testing facilities and central data repository. Five NSF-supported research projects addressing the seismic performance of bridge columns, mid-rise wooden buildings, steel frames, and base-isolated structures will utilize both NEES facilities and E-Defense in the conduct of their projects during the 2008–2010 timeframe.

U.S. Contribution to GEOSS

The Global Seismographic Network, maintained by USGS and NSF, has been designated by the United States as an element of the Global Earth Observation System of Systems (GEOSS). Efforts to build GEOSS are coordinated through the intergovernmental Group on Earth Observations (GEO). The U.S. activities for GEO are coordinated through the U.S. Group on Earth Observations, a subcommittee of the National Science and Technology Council. In 2008 the GEOSS work plan was reorganized, and the task related to improvement and coordination of seismological networks was moved under a new task called "Systematic Monitoring to Support Geohazards Risk Assessment." The new work plan calls for GEOSS members to broaden the scope of this activity to identify and build upon synergies across in-situ observing network types, and to develop a portal that will interlink distributed seismological data centers and provide seamless access to other GEOSS components. Synergies could range from the use of the same best practices and operational approaches, to the use of a common part of the infrastructure for collection and dissemination and co-location of in-situ instruments.

A separate task was developed in the new work plan to develop a "Tsunami Early Warning System of Systems." This task calls for members to support the establishment and continuation of a multihazard, fully operational global tsunami early-warning and mitigation system of systems. These systems promote full and open exchange of publicly funded, unclassified data relevant to tsunami warning and mitigation systems. They also promote the enhancement and development of mechanisms for real-time data sharing, including seismic and sea-level (deep ocean and tide gauge) data. While not directly linked to NEHRP, this task is mentioned here because of its seismic data-sharing goals.

4.4 NEHRP CONTRIBUTIONS TO TSUNAMI SAFETY

Tsunami Hazard Studies

Research on modeling wave run-up and impacts from tsunamis

Researchers at Texas A&M University, Cornell University, the University of Hawaii at Manoa, and the University of Puerto Rico, Mayaguez have developed tsunami models that include three-dimensional vorticity (eddy turbulence). This permits simulation of the large eddies that are commonly observed in harbors during tsunamis, but have not been modeled by traditional tsunami numerical tools. An understanding of how these eddies are generated and evolve should have implications to both harbor design and preparedness plans.

Using experimental data generated from tests in the Oregon State University NEES Tsunami Wave Basin and in University of Hawaii laboratory facilities, the researchers have shown that coral reefs cause the initial long wave (tsunami) to disintegrate into several shorter waves. This transformation and the associated energy dissipation can lead to a significant decrease in run-up and onshore intensity. Their preliminary conclusion regarding the dissipative effect of vegetation is

that both reef and beach vegetation can be effective in wave run-up reduction. By quantifying the roughness coefficient for various types of vegetation, they can provide useful information to researchers and engineers who desire to apply numerical simulations for predicting tsunami and storm-surge inundation on vegetated beaches. Furthermore, the results from the study may serve as a guide to coastal planning, including tree planting.

Guidelines for designing structures for vertical evacuation from tsunamis

The Federal Emergency Management Agency (FEMA) completed the "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis" (FEMA P–646) in 2008. Preparation of this document was jointly funded by FEMA under NEHRP and by the National Oceanic and Atmospheric Administration (NOAA) under the National Tsunami Hazard Mitigation Program. The goal of this project was to develop a design and construction guidance document for special facilities that would allow for vertical evacuation from tsunamis. These are facilities in which those threatened are able to climb above the tsunami water depth. This is a critical issue for several coastal communities along the west coast of the United States that are vulnerable to tsunamis and would not be able to evacuate to high ground for a near-source tsunami, such as one from the Cascadia Subduction Zone. A large near-source tsunami could result in a significant loss of life, and communities are looking for alternatives such as vertical evacuation structures. Oregon and Washington have already expressed interest in using this publication.

Global Training in Seismology and Tsunami Warning

The devastating Indian Ocean tsunami of December 2004 killed 230,000 people and left millions homeless. In response to this tragedy, USGS has partnered with other agencies to provide international training in seismology and tsunami warnings. During 2008, this training was accomplished by specialized courses held in the United States and overseas. These training activities have been coordinated with NOAA, the U.S. Agency for International Development, and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization.

Training was provided at the University of Washington-Seattle, at USGS facilities in Menlo Park, CA, and at the USGS National Earthquake Information Center in Golden, CO. Overseas training courses took place in Indonesia, Thailand, Malaysia, and Mauritius. The participants in these overseas courses are the governmental staff members who are responsible for monitoring earthquake activity and providing rapid and reliable tsunami warnings in their respective countries. The success of these training activities is demonstrated by the newly functional tsunami warning system operating in Jakarta, Indonesia. This warning center sends out e-mail notifications of significant earthquakes within minutes of the occurrence of the earthquake. Public notification systems to communicate tsunami warnings to coastal residents have also been successfully installed and tested in many countries within the greater Indian Ocean basin.

Chapter

5

State Activities to Promote Implementation of Research Results

The Federal Emergency Management Agency (FEMA), through its Mitigation and Preparedness Directorates, supports state and local efforts to reduce their risks to all hazards, including earthquakes. In addition to developing technical assistance and guidance documents, FEMA administers several grant programs, including the all-hazards Pre-Disaster Mitigation (PDM) Grant Program for states and communities; the Hazard Mitigation Grant Program (HMGP), an all-hazards post-disaster grant program; and the Emergency Management Performance Grants Program, which provides grants to states to improve emergency management performance and is administered by FEMA's Preparedness Directorate. With these grants, state and local agencies can fund planning activities and projects to protect their citizens from earthquake hazards. Highlights of successful state, territorial, and local government efforts in support of the National Earthquake Hazards Reduction Program (NEHRP) in 2008 are described below.

Alaska

The Kenai Peninsula Borough, which includes the towns of Homer, Seward, and Seldovia, upgraded its tsunami warning system with HMGP funds. The City of Valdez received "Tsunami Ready" certification, which confirms that the community has established evacuation routes, shelters, 24-hour warning systems, and emergency operations plans for use in the event of a tsunami. A real-time seismic display that includes ShakeMap, seismic data, and tsunami-warning displays was installed in the emergency operations centers of the State of Alaska, Kenai Peninsula Borough, Kodiak Island Borough, Seward, Valdez, Fairbanks North Star Borough, and the Municipality of Anchorage.

Arizona

In June 2008, the Arizona Geological Survey received PDM funds to update seismic hazard information and improve earthquake monitoring. The seismic hazard data will be included in Arizona's hazard risk assessment. The project has support from various state agencies as well as from Arizona State University, the University of Arizona, and Northern Arizona University.

Arkansas

The Arkansas Department of Emergency Management (ADEM) Earthquake Program continues to promote earthquake loss-reduction practices and policies through mitigation, earthquake awareness

and preparedness, and exercises designed to improve response and recovery. As a member of the Central United States Earthquake Consortium (CUSEC), ADEM works closely with CUSEC member states to address the regional risk associated with seismic hazards.

To increase understanding of earthquakes and their effects, several exercises were conducted with the Governor's Office and Cabinet in 2008. ADEM also sponsored a series of training courses that utilized curricula developed by FEMA (ATC–20, "Procedures for Post Earthquake Safety Evaluation of Buildings," and FEMA 154, "Rapid Visual Screening of Buildings for Potential Seismic Hazards"). Three workshops trained 79 engineers in the qualification procedures needed to identify potentially hazardous buildings in their communities after an earthquake or catastrophic disaster and to conduct damaged-building inspections. As part of the New Madrid Seismic Zone (NMSZ) Catastrophic Planning Initiative, ADEM is conducting follow-up workshops in 34 counties projected to have the most damage. These workshops build on the earthquake planning template developed in 2007 for the earthquake annexes to county emergency operations plans.

The Arkansas Geological Survey recently produced the first statewide Soil Site Classification Map of Arkansas. This map will be incorporated into an updated version of the 1999 CUSEC State Geologists Soil Site Class Map and will provide valuable information to Hazards U.S.–Multihazard (HAZUS–MH) software users when they plan earthquake scenarios. The Arkansas Geological Survey also is developing a series of seismicity maps. These maps include an NMSZ map and an Enola Swarm area map, both of which have informational summaries of earthquake history in these regions. Individual county seismicity maps are in production for the 48 counties in Arkansas that have had recorded seismicity.

California

The "2007 State of California Multi-Hazard Mitigation Plan" has been approved by FEMA and has been designated an Enhanced State Mitigation Plan.

On March 26, 2008, California conducted the first "live code" tsunami communications test in state history in Humboldt County. This test used tsunami event-notification codes that activated the Emergency Alert System and caused a message to appear on television screens announcing that "The National Weather Service has issued a tsunami warning for Humboldt County." The purpose of this test was to assure that the final stage in the tsunami warning system functioned properly and could be relied upon in an actual tsunami emergency. California also initiated work on a second generation of tsunami inundation maps for coastal California. These maps take advantage of new scientific research on seismic sources as well as improved modeling and data.

California participated in the development of a detailed earthquake scenario for the southern San Andreas Fault, a magnitude 7.8 event that was used for the Golden Guardian exercise in November 2008 and served as a fundamental component of southern California's ShakeOut earthquake preparedness campaign. State officials promoted the use of new real-time seismic information

technologies, including ShakeMap, ShakeCast, the California Integrated Seismic Network Display, and HAZUS–MH.

The California Seismic Safety Commission Earthquake Investigations Team visited Japan in November 2007. The team met with government agencies and emergency management groups and observed damage and recovery efforts related to the July 2007 Niigata earthquake. A report on lessons learned in the investigation was presented to the commission in February 2008.

The commission began partnering with Seccion Amarilla Spanish Yellow Pages in spring 2007. Seccion is the largest distributed Spanish business directory in California. The commission provided three full pages of emergency seismic safety information for the front of the directory at a substantial discount and participated in directory distributions in Los Angeles, San Francisco, and Sacramento.

California recently adopted a national standard, "Seismic Rehabilitation of Existing Buildings" (ASCE 41–06), as a retrofit regulation for public schools and state-owned buildings (effective January 1, 2008). California has also adopted retrofit regulations for hospitals and unreinforced masonry buildings.

Almost 2,200 state-maintained bridges were determined to need seismic retrofitting as of January 2007. Of these, all but eight have been retrofitted. In addition, 699 of 1,235 local bridges have been retrofitted. One locally owned toll bridge (Golden Gate Bridge) is in the process of being retrofitted.

With the "My Hazards" interactive Web site, users can view earthquake, flood, and fire hazard information for any location in California. Links to explanations of the hazards and regulatory zones are provided. Equally important, the site provides links to specific mitigation activities to reduce users' risks from hazards in their areas. The California Office of Emergency Services partnered with the California Resources Agency to effectively use technology as an outreach tool. Data and information from the California Geological Survey, the U.S. Geological Survey (USGS), the California Department of Forestry and Fire Protection, and FEMA were compiled for this project.

California began work on an inventory data improvement project for HAZUS–MH in support of the 2008 Golden Guardian exercise and other planned mitigation activities and exercises. The scope of work includes HAZUS–MH loss estimates for a magnitude 7.8 earthquake on the San Andreas Fault affecting the counties of Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura. The estimates will incorporate detailed seismic hazard information recently developed by the USGS Multi-Hazard Demonstration Project in Southern California and the Southern California Earthquake Center, as well as newly developed, vastly improved building inventory data and information on construction patterns throughout the eight-county area. The resulting earthquake loss estimates will provide California with a more accurate quantification of potential risks in terms of economic risk and population impacts.

Illinois

In May 2008, the Governor of Illinois announced the creation of the Illinois Seismic Safety Task Force to enhance state earthquake mitigation measures. The group will include members from several state agencies as well as public, private, and academic sectors.

With PDM funds, Illinois has begun to develop mitigation plans for 16 counties and 1 municipality in high-risk earthquake zones in southern Illinois.

The "State of Illinois Standard State Mitigation Plan Update," which was approved by FEMA in November 2007, has a detailed earthquake risk assessment featuring comprehensive seismic loss modeling performed by the Mid-America Earthquake Center.

Work continued on the new high school for the City of Waterloo Community School District (Monroe County) with enhanced or "code plus" earthquake resistance incorporated into the building design. The increased costs of constructing the school buildings with "code plus" earthquake-resistant features were funded in part under an HMGP grant.

As part of the NMSZ Catastrophic Planning Initiative, three workshops were conducted in Illinois to focus on state and local response issues. The workshops covered objectives for each area and the results highlighted strengths as well as gaps in earthquake response capabilities. As a result of the workshops, several workgroups will continue to address the identified capabilities and improve on those areas where additional planning is needed.

Following the April 18, 2008, magnitude 5.2 earthquake, the state emergency operations center was activated and regional staff coordinated with local officials to conduct damage surveys. The Illinois Department of Transportation implemented its procedures for road and bridge inspections.

Illinois maintains an earthquake link on http://www.Ready.Illinois.gov. This Web site provided information to the public after the April 18 earthquake. A mitigation calendar was also published that includes a month on earthquake mitigation.

Indiana

Indiana conducted six earthquake planning workshops during 2008. More than 500 people representing about 200 local, state, federal, and private-sector agencies and organizations attended the workshops. A comprehensive "Workshop Results Document" was prepared that addressed the discussions relating to each workshop topic. Indiana also conducted three district-level earthquake planning workshops focused on counties and local jurisdictions. More than 350 local government representatives attended these workshops and a "Workshop Results Document" was produced for each of these sessions. From information gathered at all of the workshops, Indiana's first "Catastrophic Earthquake Response Plan" was drafted. This document will be completed by December 2008.

An HMGP project grant was awarded to Vanderburgh County and the City of Evansville for anchoring and tie-downs of modular homes for wind and seismic bracing.
Indiana completed its "Standard State Mitigation Plan Update." The plan features an earthquake risk assessment as part of the hazard assessment. Indiana also improved its outreach materials and is in the process of revising an earthquake safety and mitigation video for the general public.

Kentucky

The Kentucky Earthquake Council held its first meeting in several years. This was a significant step in organizing and revitalizing earthquake mitigation efforts throughout Kentucky. Since then, two meetings of the Kentucky Earthquake Technical Workgroup have also been held, with an average of 30 high-level participants from state agencies attending.

The Kentucky Earthquake Program accomplished many goals in 2008 and has set goals for 2009. A full-scale Kentucky National Guard exercise took place in Areas 1–3 of western Kentucky and involved a New Madrid earthquake scenario. Guardsmen, emergency managers, and the Civil Air Patrol all took part in the exercise. Local agencies also participated in selected counties.

Areas 1, 4, and 12 in Kentucky participated in the Spills of National Significance (SONS) '07 exercise, which also focused on a New Madrid earthquake scenario. Shell Oil set up a federal portion of the SONS exercise in Paducah, which included local play. This proved to be very successful.

The FEMA Tier I Exercise that is being planned to test the catastrophic plan has also been a priority for Kentucky. The Kentucky Office of Homeland Security and the Kentucky Division of Emergency Management have worked with CUSEC on this initiative. The exercise, scheduled for 2011, is an important part of the ongoing disaster planning process in the state.

Missouri

Two earthquake presentations conducted as part of the Missouri State Emergency Management Agency Conference reached more than 100 participants. The Missouri Seismic Safety Commission issued its "Strategic Plan for Earthquake Safety in Missouri" in December 2007.

The St. Louis Science Center's Earthquake Awareness Day activities were attended by about 350 participants. An "Earthquake Mitigation for Hospitals" poster was presented at the St. Louis Science Center and the New Madrid Earthquake Conference at Rolla.

Preparations were under way for Missouri's 2009 Earthquake Awareness Month observance. More than eight outreach, awareness, and education events are scheduled, with requests pending for two FEMA National Earthquake Technical Assistance Program (NETAP) training courses in "Nonstructural Earthquake Mitigation" and "Earthquake Mitigation for Hospitals/Healthcare Facilities." During 2008 about 130 persons received NETAP training in Missouri.

Nevada

The State of Nevada assisted local communities impacted by the February 21, 2008, Wells earthquake and the April 25, 2008, Mogul earthquake by answering technical questions about the events, distributing "Living with Earthquakes in Nevada" into the affected areas (including more than 1,000 copies in the Mogul-Somersett area before that earthquake), and conducting an early assessment and documentation of the impacts of the earthquakes. In partnership with FEMA, the state also distributed 75,000 copies of "Living with Earthquakes in Nevada" in the Reno Gazette-Journal while state residents were still thinking about the 2008 quakes.

Meetings of the Nevada Earthquake Safety Council served as forums for technical presentations and discussions on earthquake-hazard and risk-mitigation topics, including the earthquakes that occurred in Reno in 1914; USGS Fault and Fold Database accuracy and use; the 2008 Wells earthquake; the 2008 Mogul-Somersett quake; the Nevada Earthquake Sequence; earthquake hazards of unanchored propane tanks; an introduction to the new Nevada Division of Emergency Management facility; problems with use of the USGS Quaternary Fault and Fold Database in Nevada; deliberations and policy recommendations at the Western States Seismic Policy Council (WSSPC) annual meeting; deliberations and proceedings of the 2008 National Earthquake Conference; and updates on recent earthquakes in Nevada and around the world.

The Nevada Bureau of Mines and Geology hosted the 2007 WSSPC annual meeting in Reno and cosponsored the 2008 Seismic Hazard Summit—Southern Nevada Region, held in Las Vegas. State officials are also developing an infrastructure database for HAZUS–MH in Nevada and finalizing the Quaternary Fault Map of Nevada. Other state activities included participation in the Vigilant Guard response exercise based on a major Reno-Carson City urban corridor earthquake scenario and the distribution of free "Earthquakes in Nevada and How to Survive Them" brochures and earthquake epicenter maps.

The Nevada Educational Seismic Network held workshops for teachers as part of an effort to bring earthquake science and awareness to the next generation. Students and teachers have direct access to earthquake information with seismometers in schools, and earthquake awareness is spread through school administrators, who make decisions on school seismic hazard mitigation, as well as through parents and others.

New Mexico

"Rockin' Around New Mexico" is a summer geology workshop for teachers conducted by the New Mexico Bureau of Geology and Mineral Resources. The workshop features in-class instruction and field experiences to explore geology in a unique location of the state each year. The 2008 session was located in Socorro and at the Sevilleta National Wildlife Refuge and focused on earthquakes and soils in the Rio Grande Rift. Rockin' 2008 was sponsored by the New Mexico Department of Homeland Security and Emergency Management, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, New Mexico Mining Association, and New Mexico Geological Society.

The 3-day workshop began with an overview of local geology within the Rio Grande Rift and its relevance to the region between Albuquerque and Socorro. The participants received hands-on field and laboratory instruction about the relationships between earthquakes, magma bodies, and soils in determining landscape dynamics and stability in New Mexico. Field work emphasized the development of soils in arid and semiarid settings and how soil information is used to derive paleoseismic histories of faults and in particular normal faults. Laboratory activities included describing distinctive soil characteristics such as texture, structure, color, and calcium carbonate content.

On the second morning, teachers examined tilted fault blocks of the Rio Grande Rift that are spectacularly exposed in San Lorenzo Canyon, and how the local geology determines the occurrence of springs. In the laboratory, an overview of rift structures placed the deformation features seen in the morning in the broader context of the rift and the underlying Socorro Magma Body. During a hike on the third day, participants studied evidence for episodic movement of the Cliff Fault near the Sevilleta National Wildlife Refuge Educational Laboratory, where understanding of semiarid soils may be applied to understanding stability and fault offset. Earthquake safety drills and other lessons from FEMA's earthquake preparedness publications for students and teachers were demonstrated, followed by discussions of emergency preparedness measures that should be in place in the event of a damaging earthquake.

Oregon

In an effort to increase school safety, the Oregon Department of Education launched Quake Safe Schools, a Web site that provides public awareness information on the earthquake hazards in Oregon and rankings of seismic safety at each school. About 2,100 schools were assessed by using FEMA's rapid visual screening technique based on seismic zone, building structure, building irregularities, original construction date, and soil type. The Web site allows communities, parents, and school boards to learn more about earthquake hazards and how they relate to school safety.

South Carolina

As part of National Preparedness Month, the South Carolina Emergency Management Division (SCEMD) distributed the "South Carolina Earthquake Guide" for the first time in newspapers in Charleston and surrounding areas. The guide contains information on the history of earthquakes in the state, advice on how to prepare for an earthquake, and what to do should an earthquake occur.

The new South Carolina Earthquake Education and Preparedness Program was established at the College of Charleston. A center of excellence for South Carolina on earthquakes, earthquake education, and earthquake preparedness, the new program is located in the College of Charleston's Department of Geology and Environmental Geosciences. In addition to developing and maintaining outreach and education programs, the center will host workshops for diverse audiences.

South Carolina's Earthquake Awareness Week observance was held November 4–10, 2008. In support of the week, a governor's proclamation was issued, news releases were disseminated, earthquake literature was mailed to county emergency managers and school administrators, and a "Drop, Cover, and Hold" drill was held with schools. The drill was announced over the National Oceanic and Atmospheric Administration's weather radio broadcasts. For the first time, four counties achieved 100 percent school participation in the drill. A total of 63,504 students and 7,893 staff practiced procedures that could save their lives in the event of an earthquake.

SCEMD developed an earthquake brochure for schools, which helps schools to develop action plans for school earthquake safety programs. The brochure was distributed through local emergency managers to public and private schools for use during Earthquake Awareness Week. The brochure also was added to the SCEMD Web site.

SCEMD continues to work with 46 counties to update and maintain the HAZUS–MH infrastructure database covering medical facilities, airports, communication facilities, power plants, emergency facilities (police, fire, emergency management, and emergency medical services), schools, potable water systems, and waste water systems. SCEMD is serving as a beta testing state for FEMA's HAZUS–MH-related Comprehensive Data Management System (CDMS) and CDMS Web Portal.

Utah

Utah has taken important steps to reduce the vulnerability of schools to damaging earthquakes, as well as to address the vulnerability of its unreinforced masonry (URM) building stock. HAZUS–MH has played an important role in these initiatives. The software has sharpened the focus on the vulnerability of schools in this region to damaging earthquakes. Specifically, HAZUS–MH has been used to estimate losses and potential casualties from scenario earthquakes in a region that is among the most susceptible in the United States to seismic activity.

The Wasatch Front region of Utah is an extremely active seismic zone that experiences approximately 700 earthquakes per year. Although many of these temblors are less than magnitude 3.0, a magnitude 7.0 earthquake will occur roughly once every 350 years along the central portion of the Wasatch Fault. The last large earthquake along the fault occurred between 400 and 600 years ago.

The Wasatch Front is home to Utah's most populous counties, including Salt Lake, Utah, and Davis. More than 80 percent of Utah's population is located in areas subject to large earthquakes. Although Utah has been a national leader in incorporating seismic design into modern building codes, the seismic threat was not widely recognized in Utah until the mid-1970s. As a result, many (±185,000) of the buildings in the area are URM structures, which are brick and mortar structures that are not reinforced by steel, and which tend to be brittle and inflexible during earthquake events.

FEMA considers the Wasatch Front to be a high-hazard area. FEMA, in partnership with the State of Utah, has conducted studies of the region using HAZUS–MH to estimate damages and losses. HAZUS–MH was used to model losses from a magnitude 7.0 event, providing estimates for three different times of day: 2 a.m., 2 p.m., and 5 p.m. For this study, HAZUS–MH estimated that a daytime event would cause more than 6,000 deaths. The model estimates that 80 percent of the severe casualties in the scenario earthquake would be caused by URM buildings. HAZUS–MH predicts that casualties from schools would total approximately 1,100. The model estimates that of the 765 schools in this 17-county region, 205 would be moderately damaged and 38 would sustain major damage.

HAZUS–MH findings and supporting analysis have drawn attention once again to the vulnerability of URM structures to damaging earthquakes in the Wasatch Front. In light of these findings, Joint Resolution 7, passed by the Utah legislature in February 2008, states that "a major seismic event could result in catastrophic loss of life, property and business in the state" and calls for a statewide inventory of public URM buildings. The joint resolution also references the important role of the Utah Seismic Safety Commission in providing technical and scientific support for this critically important initiative.

Appendix

A

Cooperating Organizations Receiving NEHRP Support

This appendix includes brief descriptions of organizations that carry out work related to NEHRP activities described in this report. The descriptions do not include the many academic institutions to which NEHRP provides support for individual research grants and cooperative agreements. For each organization that is described, a link to its Internet Web site is provided.

Applied Technology Council

The Applied Technology Council (ATC) 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 not be available from any single organization. Funding for ATC projects is obtained from government agencies and from the private sector. (http://www.atcouncil.org)

Cascadia Region Earthquake Workgroup

The Cascadia Region Earthquake Workgroup (CREW) is a coalition of private and public representatives working together to increase the ability of Cascadia Region communities in British Columbia, California, Oregon, and Washington to reduce the effects of earthquake events. Established in 1996, CREW provides an essential link among the Federal Government, local government, private industry, and citizens to promote NEHRP goals. (http://www.crew.org)

Central United States Earthquake Consortium

The Central United States Earthquake Consortium (CUSEC) is a partnership of the Federal Government and the states of Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee, the states most affected by earthquakes in the New Madrid Seismic Zone. Established in 1983, the mission of CUSEC is to reduce deaths, injuries, property damage, and economic losses resulting from earthquakes in the Central United States. (http://www.cusec.org)

Consortium of Universities for Research in Earthquake Engineering

The Consortium of Universities for Research in Earthquake Engineering (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. (http://www.curee.org)

Earthquake Engineering Research Institute

The Earthquake Engineering Research Institute (EERI) is a national, nonprofit technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. The objectives of EERI are to reduce earthquake risk by advancing the science and practice of earthquake engineering; to improve understanding of the impact of earthquakes on the physical, social, economic, political, and cultural environment; and to advocate comprehensive and realistic measures for reducing the harmful effects of earthquakes. (http://www.eeri.org)

Incorporated Research Institutions for Seismology

The Incorporated Research Institutions for Seismology (IRIS) is a National Science Foundation (NSF) supported university research consortium dedicated to exploring the Earth's interior through the collection and distribution of seismographic data. IRIS partners with the U.S. Geological Survey in the operation of the Global Seismographic Network, which provides data for global seismological research and is one of the primary data sources used by the USGS National Earthquake Information Center 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. USArray (part of the NSF-funded EarthScope project) includes permanent stations that have contributed to the Advanced National Seismic System 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 the Advanced National Seismic System, U.S. regional networks, and other NEHRP programs. (http://www.iris.edu)

National Institute of Building Sciences

Congress chartered the National Institute of Building Sciences (NIBS) in 1974 as an independent, nongovernmental, 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 program 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. (http://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 is involved in developing the 2009 "NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures," and in working with the Federal Emergency Management Agency (FEMA) on practical building code applications of these provisions. (http://www.bssconline.org)

Natural Hazards Center

The NSF-supported Natural Hazards Center (NHC), headquartered at the University of Colorado at Boulder, continues to be the world leader in the dissemination of research information, awards, findings, and applications to the hazard and disaster research and management communities. The NHC accomplishes its work through four major activities: information dissemination, annual workshops, information services, and research. The majority of the center's work is supported by an NSF grant, but the NHC also receives contributions from other agencies and sources. (http://www.colorado.edu/hazards/)

NEES Consortium, Inc.

NEES Consortium, Inc. (NEESinc) is located in Davis, CA. It is a nonprofit organization that works in partnership with the 15 universities that operate the experimental facilities and cyberinfrastructure of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). NEESinc manages NEES as a national, shared-use resource for research and education for the earthquake engineering community, and schedules access to the network's experimental facilities. NEESinc also provides the system-wide information technology infrastructure of NEES, including repositories for NEES data and simulation tools; manages an education, outreach, and training program; and fosters linkages and partnerships with federal, state, and local government entities, national laboratories, the private sector, and international collaborators. (http://www.nees.org)

Northeast States Emergency Consortium

The Northeast States Emergency Consortium (NESEC) receives significant funding from FEMA to support the common mission of working with federal, state, and local partners to promote multihazard preparedness and risk reduction in support of NEHRP goals. Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont form NESEC. (http://www.nesec.org)

Southern California Earthquake Center

During 2008, the Southern California Earthquake Center (SCEC) was in the second year of its third phase, SCEC3, a 5-year program funded by NEHRP partners NSF and USGS. The main goal of SCEC is to produce a physics-based understanding of earthquake phenomena in southern California through the integrative study of tectonics, active fault systems, fault zone processes, fault rupture, and ground motions. The center's long-term research goals address four basic science areas: earthquake source physics, fault system dynamics, earthquake forecasting and predictability, and ground motion prediction. SCEC has developed a substantial computational resource for earthquake research, coordinated through a community modeling environment that allows researchers to share knowledge and data for hypothesis formulation and testing and model prediction. SCEC scientific accomplishments have been incorporated into practical products, such as the USGS national seismic hazard maps and the new seismic attenuation relations developed by the Next Generation Attenuation Project, which is managed by the Lifelines Program of the PEER Center. (http://www.scec.org)

Western States Seismic Policy Council

The Western States Seismic Policy Council (WSSPC) is a regional earthquake consortium funded primarily by FEMA and USGS. WSSPC members are the state geological survey and emergency management directors of 13 western states (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming); 3 U.S. territories (American Samoa, Guam, and the Northern Mariana Islands); a Canadian territory (Yukon Territory); and a Canadian province (British Columbia). The mission of WSSPC is to develop seismic policies and share information to promote programs intended to reduce earthquake losses. (http://www.wsspc.org)

Appendix

B

NEHRP Management Chronology FY 2008

Table B.1 provides a brief chronology of NEHRP management activities during fiscal year 2008.

Table B.1—Chronology of FY 2008 NEHRP Management Activities

Date	Event
October 15, 2007	PCWG Meeting
October 23–24, 2007	ACEHR Meeting
November 13, 2007	PCWG Meeting
December 18, 2007	PCWG Meeting
January 3, 2008	PCWG Meeting
February 12, 2008	PCWG Meeting
March 12, 2008	PCWG Meeting
March 24, 2008	Annual report for FY 2007 submitted to Congress
April 3, 2008	ICC Meeting
April 10–11, 2008	ACEHR Meeting
May 8, 2008	PCWG Meeting
May 21, 2008	ACEHR Meeting (Conference Call)
May 25, 2008	First ACEHR report submitted to Director of NIST
June 26, 2008	PCWG Meeting
July 25, 2008	PCWG Meeting
August 22, 2008	ICC Meeting
August 25, 2008	PCWG Meeting
September 30, 2008	PCWG Meeting

ACEHR—Advisory Committee on Earthquake Hazards Reduction

ICC—Interagency Coordinating Committee on Earthquake Hazards Reduction

PCWG—Program Coordination Working Group

Appendix

C

List of Acronyms

ACCESS	Advancement of Cyberinfrastructure Careers through Earthquake System Science
ACEHR	Advisory Committee on Earthquake Hazards Reduction
ADEM	Arkansas Department of Emergency Management
ALA	American Lifelines Alliance
ANSS	Advanced National Seismic System
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BSSC	Building Seismic Safety Council
Caltech	California Institute of Technology
Caltrans	California Department of Transportation
CAREER	Early Faculty Career Development Program
CDMS	Comprehensive Data Management System
CI	Cyberinfrastructure
CREW	Cascadia Region Earthquake Workgroup
CS/IT	Computer Science/Information Technology
CUREE	Consortium of Universities for Research in Earthquake Engineering
CUSEC	Central United States Earthquake Consortium
DHS	U.S. Department of Homeland Security
EERI	Earthquake Engineering Research Institute
EHP	Earthquake Hazards Program
ENS	Earthquake Notification Service
ETS	Episodic Tremor and Slip
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
GEER	Geo-engineering Extreme Events Reconnaissance Association
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System
GPS	Global Positioning System; Global Positioning Satellites
GSN	Global Seismographic Network
HAZUS–MH	Hazards U.S.–Multihazard
HMGP	Hazard Mitigation Grant Program
IBC	International Building Code
ICC	Interagency Coordinating Committee

IEM–CEA	Institute of Engineering Mechanics–China Earthquake Administration
InSAR	Interferometric Synthetic Aperture Radar
IRIS	Incorporated Research Institutions for Seismology
LFE	Learning from Earthquakes Program
LIDAR	Light Detection and Ranging
MAE Center	Mid-America Earthquake Center
MAST	Multi-Axial Subassemblage Testing Laboratory
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEESinc	NEES Consortium, Inc.
NEHRP	National Earthquake Hazards Reduction Program
NEIC	National Earthquake Information Center
NESEC	Northeast States Emergency Consortium
NETAP	National Earthquake Technical Assistance Program
NHC	Natural Hazards Center
NIBS	National Institute of Building Sciences
NIED	National Research Institute for Earth Science and Disaster Prevention
NIST	National Institute of Standards and Technology
NMSZ	New Madrid Seismic Zone
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
PAGER	Prompt Assessment of Global Earthquakes for Response
PBSD	Performance-Based Seismic Design
PCWG	Program Coordination Working Group
PDM	Pre-Disaster Mitigation Grant Program
PEER Center	Pacific Earthquake Engineering Research Center
PIMS	Post-Earthquake Information Management System
REU	Research Experiences for Undergraduates
ROVER	Rapid Observation of Vulnerability and Estimation of Risk
SCEC	Southern California Earthquake Center
SCEMD	South Carolina Emergency Management Division
SDR	Subcommittee on Disaster Reduction
SONS	Spills of National Significance
SPAC	Spatial Autocorrelation
TA	Transportable Array
UCSD	University of California San Diego
UJNR	U.S.-Japan Cooperative Program on Natural Resources
URM	Unreinforced Masonry
USGS	U.S. Geological Survey
WSSPC	Western States Seismic Policy Council

Appendix

D

Significant Earthquakes of FY 2008

This appendix gives a chronology of significant earthquake activity worldwide during the period from October 1, 2007, through September 30, 2008.

February 21, 2008. Wells, NV. Magnitude 6.0. This was the largest earthquake to occur in the contiguous United States during the year. The earthquake was felt throughout northeastern Nevada, southern Idaho, and western Utah and had numerous aftershocks. No lives were lost, three people were injured, and more than 20 buildings were heavily damaged.

April 18, 2008. Eastern Illinois. Magnitude 5.4. This earthquake occurred in the Wabash Seismic Zone of the Central United States. Although it caused only minor damage to buildings in East Alton, Mount Carmel, and West Salem, it caused widespread concern throughout the Central United States. It was felt in parts of 17 states, from Minnesota to Mississippi and from Nebraska to North Carolina. This event is a reminder that earthquakes occur in the Central United States and that when they do they affect a much larger region than do quakes of the same magnitude in the Western United States.

May 12, 2008. China. Magnitude 7.9. This earthquake struck the eastern region of Sichuan Province with deadly consequences, including over 69,000 known fatalities and more than 18,000 persons missing and presumed dead. There were more than 375,000 casualties and at least 45.4 million people were affected by this earthquake. The event also triggered many landslides, which buried large sections of towns and their inhabitants. This was the deadliest earthquake worldwide since a magnitude 7.6 event killed approximately 80,000 people in Pakistan in 2005.

June 13, 2008. Japan. Magnitude 6.9. This event struck northern Honshu killing 12 and injuring over 300. It damaged some 350 structures and caused numerous landslides and the disruption of several rail transportation lines. Instrument recordings of the ground shaking in this event showed some of the largest acceleration values ever registered from an earthquake. Ground acceleration is directly related to the force exerted on nearby structures.

July 29, 2008. Chino Hills, CA. Magnitude 5.4. This earthquake occurred near the town of Chino Hills, about 80 kilometers east of Los Angeles. It was widely felt in southern California but caused only minor injuries and damage. Most of the structures in the Chino Hills area are relatively new and well suited to withstand earthquake shaking. The high volume of telephone use following the shock overloaded provider capacity and disrupted service.