Report of the
Scientific Earthquake Studies Advisory Committee
of the Department of the Interior
to the Director of the United States Geological Survey

2005

The Scientific Earthquake Studies Advisory Committee (SESAC) of the Department of the Interior is issuing this annual report to the Director of the United States Geological Survey (USGS) for submission to Congress. The report describes the Committee's activities of the past year and addresses policy issues and matters relating to the participation of the USGS in the National Earthquake Hazards Reduction Program (NEHRP). We believe this report (and previous years' reports) will be particularly useful to the NEHRP Advisory Committee on Earthquake Hazards Reduction currently being established.

SESAC MANDATE

The Scientific Earthquake Studies Advisory Committee was appointed and charged, through Public Law 106-503, to advise the Director of the United States Geological Survey on matters relating to that agency's participation in the National Earthquake Hazards Reduction Program. The charge includes review of the USGS Earthquake Hazard Program's roles, goals, and objectives, assessment of its capabilities and research needs, guidance on achieving major objectives, and establishment of performance goals.

ACTIVITIES OF THE COMMITTEE DURING 2005

The SESAC met three times:

1. Meeting in Reston, January 11 and 12. Objective: Review the overall direction of the USGS Earthquake Hazards Program for the current year and for the future, with emphasis on defining opportunities for future growth and strategies for balancing program needs against increasing resource limitations.
2. Meeting in Menlo Park, April 13 and 14. Objective: Review the direction of the USGS Earthquake Hazards Program in the Western United States, with emphasis on the creation, communication, and use of seismic hazard analyses in the region.
3. Meeting in Seattle, September 27, 28, and 29. Objective: Review the direction of the USGS Earthquake Hazards Program in the Pacific Northwest, with emphasis on tsunami hazard mitigation.

REVIEW OF THE USGS EARTHQUAKE HAZARDS PROGRAM

The various accomplishments of, issues pertaining to, and opportunities for the USGS Earthquake Hazards Program identified and reviewed at our January, April, and September meetings are discussed below.

Five-Year Plan Review

The USGS provided the SESAC the September 2004 draft of the Earthquake Hazards Program's Five-Year Plan for 2004-2008. This draft of the plan was initiated in January 2003, presented to the USGS executive leadership team for review in January 2004, presented to the White House Office of Management and Budget (OMB) in September 2004, and given to the Committee for discussion at its January 11-12, 2005 meeting. Shortly after the January 2005 meeting, SESAC members submitted comments regarding the plan to the USGS. The USGS intends to consider these comments in the final version, which they hope to complete by the end of 2005. In mid-September 2005, the USGS met with OMB to discuss finalization of the plan.

The SESAC finds the September 2004 draft Five-Year Plan to be a good one. It sets five-year goals for the three key elements of the program (national and regional earthquake hazard assessment; earthquake monitoring, notification, and information; and research on earthquake physics and effects). In addition, this new plan sets five-year goals for a fourth element that had not been clearly articulated in previous program plans—earthquake safety policy. The plan includes a set of prioritized tasks, which can only be accomplished if funding for the USGS Earthquake Hazards Program is significantly increased to the levels authorized by Congress for the National Earthquake Hazards Reduction Program (NEHRP).

The SESAC looks forward to seeing the final version of the Five-Year Plan. Substantive comments we have about the September 2004 draft follow.

- A priority for the Committee in 2006 will be to scrutinize the USGS's intention reflected in the draft Five-Year Plan to become involved in risk assessment activities and earthquake safety policy. In the interim, we feel it wise for the USGS to work with the Federal Emergency Management Agency (FEMA) and the National Institute of Standards and Technology (NIST) to assure the geological products (probabilistic seismic hazard maps, fault maps, ShakeMaps, information on liquefaction hazards, landslide hazards, and local basin effects) of the USGS and other organizations can be and are properly integrated into HAZUS and other loss-estimation methods.
- The USGS must recognize that to do a thorough job of assessing earthquake hazards, detailed (1:24,000-scale and sometimes larger) earthquake hazard maps are needed, including probabilistic ground-shaking maps; liquefaction-, landslide-, and fault-rupture-hazard maps; and three-dimensional models of seismic velocities at shallow depths (for geotechnical engineering applications) and at greater depths (for predicting amplification resulting from basin effects). Such maps are critical for hazard assessments and consequent earthquake-risk mitigation. FEMA's view is such mapping is the responsibility of the USGS, but the USGS has not aggressively tried to build the level of program funding to produce the detailed maps that are needed across the country, even in the highest hazard areas. There are two possible solutions to this problem: (1) the USGS obtains a dramatic increase in its budget to handle the need for detailed hazard maps, or (2) the USGS strongly informs FEMA, NIST, and others they do not

have the resources to adequately cover the needs for detailed maps; therefore, the production of these maps should be a legitimate and required component of mitigation, thereby making funds available through FEMA's pre-disaster mitigation program and post-disaster Stafford Act relief.

- Maintaining an active research program on earthquake occurrence, physics, and effects is vital to the overall objectives of the USGS Earthquake Hazards Program. Many of the advances in earthquake hazard assessments, monitoring, and notification now put into practice were made possible by research supported through the National Earthquake Hazard Reduction Program. The Five-Year Plan properly focuses on developing physics-based understanding of earthquake nucleation, propagation, and arrest, as well as the transmission of seismic waves and their impacts on the built environment. The real question for the Earthquake Hazards Program is whether the program will have the personnel and resources to address the crucial tasks identified. At present, Element III (Research on Earthquake Physics, Occurrence and Effects) represents only 20 percent of the overall program. Given the increasing public expectations for 24/7 monitoring and notification, there is a danger the research component will wither under flat or declining budgets. The Earthquake Hazards Program cannot afford to become solely a monitoring entity, *hoping* the vital research needed to improve hazard assessments and earthquake forecasting will be accomplished by other agencies or academia. It is imperative the program receives funding to continue to support and coordinate internal and external research.
- A major component of the Earthquake Hazards Program, internally and through cooperative agreements with universities, private sector partners, and others, is regional earthquake monitoring. At present, there is effective cooperation between regional networks, but much more must be done to move toward a fully integrated national network. Earthquake parameters, including location and magnitude, need to be standardized across network boundaries. Seismic data, including waveforms, must be uniformly available. Finally, given the budgetary environment, the USGS cannot afford to duplicate efforts in each of the regional networks, including those supporting volcano monitoring. There has been considerable progress in this area, particularly in California with the development of the California Integrated Seismic Network (CISN), but the USGS and its partners must do more to ensure uniform availability and quality of data products. For example, the USGS needs to develop a data center for parametric information from ANSS products, and must develop standardized software for use by regional networks and make its adoption a requirement for USGS support. The USGS has invested a great deal in its array systems and there is a foundation to build on, but it is not articulated in the Five-Year Plan.
- The December 26, 2004 Sumatra earthquake and Indian Ocean tsunami highlighted the need for the Five-Year Plan to better reflect the Earthquake Hazard Program's role in working with NOAA for tsunami warning and hazard mitigation. The plan lacks adequate discussion of the role of earthquake monitoring and related research in effective tsunami warning. Furthermore, developing a 24/7 earthquake monitoring and reporting capability is listed as a

lesser priority (3). Given the supplemental funding provided following the Indian Ocean disaster, we understand this will be upgraded and the change should be reflected in the final plan.

- An issue that needs to be adequately addressed in the Five-Year Plan is the importance of geodesy in earthquake physics. What should be the role of the USGS in geodetic monitoring, given the key advances and opportunities for partnering with Earth Scope and NASA? In the past, the USGS led the world in geodetic survey monitoring of active faults. Existing GPS networks operated cooperatively by the USGS and others are being folded into the Plate Boundary Observatory framework. InSAR measurements are contributing to mapping crustal strain as well as earthquake deformations. A logical role for the USGS is to provide comprehensive maps of strain accumulation in space and time, as is being done for Southern California, and to integrate these data into physical models of the fault loading processes.

Earthquake Hazards Program in the Western United States

In April, the SESAC met in Menlo Park, California. The primary focus of the meeting was research conducted by the USGS Earthquake Hazards Program in the Western U.S. Additional discussions centered on the proposed USGS regional reorganization, and the recently announced emphasis on a Natural Hazards Initiative.

The Committee heard a detailed summary of the state of planning for the regional restructuring of the USGS, the Director's reasons for enacting a restructure, the options currently on the table, and the potential impacts of these options for the management and financial health of the Geologic Discipline and the Earthquake Hazards Program. SESAC members expressed concern a reorganization would impede the success of the Earthquake Hazards Program. It cannot be assumed it will be business as usual after a reorganization, particularly if the favored zip-code plan is put in place. We recommended the USGS maintain a process-oriented focus and assure that national monitoring is not compromised by a regionalized management structure. We understand the financial challenges and hope the reorganization will not increase the burden; the Earthquake Hazards Program's biggest challenge is having the money and people to take advantage of opportunities.

The FY 2007 Natural Hazards Initiative design team in Menlo Park reported receiving $300 million worth of research proposals. Risk assessment requires earthquake-engineering expertise and there was discussion as to how to incorporate this capability. A significant component in the initiative will be partnerships. The Committee felt it was imperative to include the development of strategies for potentially catastrophic urban disasters in the U.S.

The SESAC reviewed the activities of the Crustal Deformation Project, which are managed out of Menlo Park. Key reasons for monitoring crustal deformation, using GPS and InSAR, are to: (a) estimate fault slip rates for input to earthquake probability assessments and National Strong Ground Motion Maps; (b) map and model co-seismic,

post-seismic and inter-seismic deformation; (c) search for and constrain potential precursory deformation; and (d) obtain process-based understanding of the earthquake deformation cycle (needed to accomplish (a), (b), and (c)).

The Earthquake Processes and Occurrences (EQPRO) Project reported on two large projects they participate in that cross both mega-project and internal/external USGS program borders: the Rupture Dynamics part of the 1906 Project (a collaborative effort led by the San Francisco Bay Area program, with heavy participation by the Earthquake Effects Projects, the Earth Surfaces Processes Team, and external researchers); and the Hayward Fault Project (a collaborative effort led by the Earthquake Physics and Faulting Project, with heavy participation by EQPRO, the Earth Surfaces Processes Team, and external researchers). We felt the activities of the Hayward Fault Project need to be applied to more faults in the San Andreas fault system and in the Pacific Northwest.

Work of the Physics of Earthquakes and Faulting Project involving borehole studies, heat-flow research, and laboratory research was presented. There are extensive collaborations with universities, the Southern California Earthquake Center (SCEC), and international partners to leverage USGS assets and resources. The USGS has made obvious contributions to crustal processes and earthquake research (Byerlee's law, rate/state friction, mechanics of induced seismicity, Coulomb stress transfer/earthquake triggering models).

The activities of the Golden-based Earthquake Effects Project were summarized, emphasizing: (a) three-dimensional velocity model-building and scenario ground-motion prediction in the Santa Clara Valley; (b) comparison of alternative shallow shear-wave velocity measurement techniques and site response calculations; (c) calculation of time histories of ground motion, kinematic, and dynamic models; and (d) landslide susceptibility maps for Alaska. The Committee engaged USGS staff in an extensive discussion of how the science flow fits with the development of attenuation functions used in hazard maps. We would like to see better coordination between ground-motion modeling at the various centers and more national coordination.

The research encompassed by the Western Region Earthquake Effects MegaProject includes: (a) rupture dynamics and radiated energy; (b) ground motion regressions; (c) aftershock and site response deployments; (d) active source refraction and reflection; (e) Northern California ShakeMap; (f) liquefaction studies and sampling; and (g) landslide studies. An important aspect of this work is collaboration with Pacific Earthquake Engineering Research Center's (PEER) New Generation Attenuation Project. Additional discussions centered on a Bay Area three-dimensional model, several seismic imaging experiments, and a Parkfield dense-array analysis of the main shock rupture.

Stress-interaction calculations have been performed by the Menlo Park and Golden teams to estimate the effects of the magnitude 9.0 and magnitude 8.7 Sumatra earthquakes on the state of stress of other faults in the region. Faults of concern include the Sumatra fault, a strike-slip fault that traverses northern Sumatra and Banda Aceh and is capable of magnitude 7.5 earthquakes, and portions of the subduction interface off the west coast of

Sumatra. Preliminary geodetic and other data suggest that at least two substantial fault patches are primed for failure. An array of ten strong-motion stations is being installed and funds from the U.S. Agency for International Development are being sought to defray the cost of installing and maintaining the stations. The recorded ground motions will be valuable in studying similar tectonic environments in the U.S., such as Cascadia and Alaska.

A detailed time-line of the National Earthquake Information Center (NEIC) actions and response to the Sumatra earthquake was presented, along with perspectives on how the existing technology, practices, and interagency agreements factored into the response. Advances are underway at the NEIC, including testing of a new, integrated software and hardware system called *Hydra* that will include an advanced analyst interface and improved algorithms for rapid phase determination and event characterization.

April 18, 2006 will mark the centennial of the San Francisco earthquake and fire, the great natural disaster of the 20th century in the United States. The Menlo Park office is playing a major role in preparations that include an impressive lineup of activities that commemorate the event, review the progress made in earthquake risk reduction, and set the agenda for managing earthquake risk in the 21st century. Many of the activities are being coordinated through the 135 members of the 1906 Earthquake Centennial Alliance (http://1906centennial.org/). This partnership of business, government, museums, media, educational institutions, and professional societies is sponsoring scores of public activities leading up to the centennial. The 100th Anniversary Conference Commemorating the 1906 San Francisco Earthquake will be held in San Francisco on April 18-22, 2006. This joint meeting of the Earthquake Engineering Research Institute, Seismological Society of America and Disaster Resistant California and 55 cosponsoring organizations, including the USGS, will assemble government, business, engineering and scientific professionals to learn from the past, assess the present, and prepare for the future (http://www.1906eqconf.org/index.htm). For one week, these institutions will be focused on integrating mitigation efforts to create disaster resistant communities in all earthquake vulnerable areas.

Earthquake Hazards Programs in the Pacific Northwest

In September, the SESAC met in Seattle, Washington. The USGS's earthquake hazard reduction activities there include geologic and geophysical research and monitoring, primarily from the Seattle USGS office. They participate in collaborative regional seismic monitoring of the Washington/Oregon region by the Pacific Northwest Seismic Network (operated by the University of Washington) and a strong business-community partnership program with the Cascadia Region Earthquake Workgroup (CREW), and share tsunami research and warning capabilities with the Seattle National Oceanic and Atmospheric Administration (NOAA) office. The Committee particularly noted the significant collaboration of the community in geology, engineering, and emergency management efforts exemplified by CREW. The credibility of the local experts is enhanced by the participation of the USGS, NOAA, and university experts in state, county, and city government earthquake hazard activities and briefings. The Committee

recognized the Pacific Northwest hazards programs are effectively tied to the national program and efforts are required to insure this continues.

A presentation of geologic mapping of active and regional tectonic features focused on the Seattle region. The project demonstrated the value of LIDAR imagery for detailed analysis of the Seattle fault and surrounding area of Puget Sound. Seismic refraction and reflection of crustal structure were employed to map subsurface structures, particularly the geometry and extent of the Seattle fault and the extent of the surrounding sedimentary basins. Ground-motion assessments by the USGS have been very successful in the Puget Sound area. Using data from the magnitude 6.8 Nisqually (near Tacoma) earthquake of February 2001, recorded by the ANSS broadband seismic stations and accelerometers, and numerical modeling associated with sedimentary basins verified this important method. Earthquake scenarios developed for the Puget Sound region illustrate that populated areas could be significantly impacted by large events due to the amplification of strong ground motions. Additional hazards in the area are landslides triggered by earthquakes and other sources in over-steepened slopes, particularly along the coastline of Puget Sound. The USGS needs to improve collaboration with the Washington Department of Natural Resources on the joint objective of natural hazard mapping.

The Oregon Department of Geology and Mineral Industries summarized related seismic hazard studies in the Portland area. The Oregon group is partnering with the USGS for advancing hazard assessment in that region and implementing ANSS monitoring. The USGS has begun to strengthen ties to the Oregon Department of Geology and Mineral Industries in natural hazard mapping in Oregon. This activity needs to be continued, with additional commitment of USGS support for Oregon earthquake hazard assessment.

The USGS demonstrated strong ties to community programs. Efforts have been made to engage the business community and assist them in implementing earthquake risk mitigation activities; successful examples include Starbucks, Microsoft, and Boeing. The Pacific Northwest Seismic Network operates a modern, digital seismic monitoring network that materially benefits the State of Washington. We note, however, that unfortunately, the State of Washington's contribution to this effort is very limited. We urge the USGS to become more engaged with the academic community to help the researchers in science and engineering become more user-focused so the needs of the communities at risk will be addressed and research results can be effectively applied in risk reduction activities.

The clear goals of earthquake loss reduction must continue to be communicated by the USGS in understandable terms to local decision makers. Effective communication (bottom-up approach) to decision makers addressing community needs has been very effective in the region, especially through ties to CREW. This approach achieves local buy-in for loss reduction activities and is highly commended by the Committee. The Elementary Edition K-6 educational booklet, *How the Smart Family Survived a Tsunami*, and the DVD *Run to High Ground*, by the Washington State Military Department, Emergency Management Division, developed to help children prepare for tsunamis, are fine examples of how complex scientific issues can be explained to the public.

Another exemplary report is the Earthquake Engineering Research Institute's *Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault.* This report was accomplished through broad collaborative efforts among various professional organizations (the American Society of Civil Engineers, Seattle, the Structural Engineers Association of Washington, the University of Washington, the Washington Emergency Management Division, the Cascadia Region Earthquake Workgroup, the Federal Emergency Management Agency, and the US Geological Survey).

The implementation of the FEMA's Project Impact in Seattle has been a tremendous success. Project Impact was a nationwide program of pre-disaster mitigation that was a casualty of FEMA's downsizing; however, the 2001 Nisqually earthquake kept the program alive in Seattle. As is the case with most of the USGS's work in the Pacific Northwest, additional funding is needed so USGS scientists can work closely with the Project Impact disaster mitigation activities.

The tsunami hazard is of particular importance to the Pacific Northwest because major subduction-zone earthquakes are possible in the coastal areas of Washington, Oregon, California, and Alaska. The relatively short warning time of only a few minutes, up to 20 minutes, in Washington, Oregon, and California specifically highlights the need for full implementation of ANSS and additional broadband seismic station information, incorporated with real-time NOAA tsunami forecasting. The Committee was particularly impressed with the timely publication by the USGS of *Local Tsunami Hazards in the Pacific Northwest from the Cascadia Subduction Zone Earthquake*, only eight days after the December 26, 2004 Sumatra earthquake and Indian Ocean tsunami, illustrating the high level of tsunami awareness in the Pacific Northwest.

Significant progress in the Pacific Northwest has been accomplished toward improved tsunami awareness, the development of hazard maps and reports, and proposed risk reduction measures. Interagency collaboration on tsunami hazard mitigation exists between the USGS, NOAA, the Washington Emergency Management Division, Clallam County Emergency Management Division, and the Quileute Tribal Council. Such ties among state, local, and tribal agencies must be continued. Additionally, the USGS and NOAA (particularly the National Weather Service) need to increase collaboration to improve real-time transfer of tsunami-generating earthquake information and tsunami warnings. This must include access to the real-time earthquake information developed by the National Earthquake Information Center (NEIC), which will be communicated more effectively with the 24/7 operation of the NEIC, beginning January 2006. The USGS NEIC team needs to work closely with the National Weather Service to implement corrective measures to avoid recurrence of the unacceptable June 14, 2005 tsunami warning, which was ineffective and informed the public of nonexistent threats.

Site-specific and highly reliable instrumentation is needed near the Cascadia tsunami source so that communities along the Pacific Coast where destructive tsunamis have the potential to strike within 5 to 20 minutes after the earthquake can be notified immediately that a tsunami has been initiated and is moving toward the coast. The USGS must work with local and state agencies in this effort to incorporate timely monitoring information

on earthquake occurrence. The emergency management community must engage the structural engineering community in their tsunami protection efforts. The committee noted that some poles for mounting tsunami-warning instrumentation and certain evacuation structures were not earthquake or tsunami resistant. Funding agencies need to designate resources to support the efforts to create tsunami-ready communities. The efforts so far have only begun to make the public aware that potential catastrophic earthquakes and tsunami threats exist. Effective educational programs will help to ensure rapid response and recovery.

EarthScope Opportunities for the USGS Earthquake Hazards Program

EarthScope is expanding seismic and geodetic observational capabilities that will provide key information for the USGS earthquake research and monitoring goals. In the past three years, EarthScope has begun to populate USArray, a mobile seismic array, and the Plate Boundary Observatory network of Global Positioning System receivers and strain meters. The resulting information is vital to understanding the structure, evolution, and crustal deformation of North America, as well as providing data on earthquake and volcano processes. Additionally, components of existing western United States GPS networks, initially funded under NSF and other grants, are being transferred and coordinated into the overall Plate Boundary Observatory. These stations will provide important geodetic coverage on active fault zones and tectonic deformation of the entire western U.S.

The USGS is regarded as a partner with EarthScope in its operations and research; however, the USGS does not have the resources to take full advantage of EarthScope activities and data. To do its job, the USGS needs to fully exploit EarthScope instrumentation. The Committee reiterates its 2004 recommendations that the USGS become a more integral participant in EarthScope by

- Continuing to support USGS scientists and provide technical support in the San Andreas Fault Observatory at Depth project
- Incorporating data from the seismic and geodetic arrays into USGS monitoring systems
- Involving USGS scientists more broadly in use of EarthScope data
- Actively seeking collaborative research with university scientists in research and hazard topics of common interest.

The EarthScope USArray provides seismic data that complement the ANSS data, as well as providing additional information for several USGS-funded regional seismic arrays. The Plate Boundary Observatory provides important information on the rate at which strain is accumulating in earthquake prone regions. These efforts materially benefit the USGS earthquake monitoring and research objectives, especially at a time when resources are limited. The SESAC will concentrate on the USGS Earthquake Hazards Program's relationship with EarthScope at their next meeting in January 2006.

USGS Regional Reorganization

During its meetings this year, the SESAC received reports on the ongoing USGS planning process for reorganization of its regional management structure. At the January meeting in Reston, the Committee was briefed by then-Director Chip Groat on his goals for the reorganization, in particular, improving the interaction between external partners and pushing decision-making out to the field to enhance responsiveness to partner needs. At the April meeting in Menlo Park, the Committee was briefed on the progress in the planning process.

At both meetings, the Committee members emphasized the importance of retaining a national vision for USGS earthquake hazards activities and maintaining strong linkages between the regional offices (such as Pasadena, Seattle, and Memphis) and the program office in Reston and the team leadership in Menlo Park and Golden. Without these linkages, the ability of program-supported scientists to share resources and apply their experiences in other regions would be adversely affected. The Committee feels the leaders of the Earthquake Hazards Program, the Western Region Earthquake Hazards Team, and the Central Region Geologic Hazards Team have been successful at maintaining these linkages and being responsive to regional partner needs, in particular through the efforts of regional coordinators who form the program's internal council, along with coordinators focused on monitoring and research topics. Whatever form restructuring takes, the Committee feels strongly that it should not hinder the current management system, which is working well.

Working Group on California Earthquake Probabilities

A new Working Group on California Earthquake Probabilities has been established recently, in partnership with the Southern California Earthquake Center, the California Geological Survey, and the California Earthquake Authority (CEA) (the State's earthquake insurance provider and rate-setting organization). The Committee notes that such partnerships strengthen the USGS Earthquake Hazards Program in several tangible ways. They marshal new resources (the Working Group will receive $1.75 million directly from CEA) and expand the pool of expertise (the Working Group will include SCEC's academic scientists). Most importantly, they coordinate and integrate efforts to produce useful products for regional hazard assessment and risk reduction.

This project will combine new information on earthquake occurrence with the best-available forecasting methods to construct a uniform earthquake rupture forecast for all California. It will build on previous Working Group studies (the latest published in 2002) and will be tightly coordinated with the 2007 revisions to the National Seismic Hazard Maps.

National Earthquake Prediction Evaluation Council (NEPEC)

The Committee continues to strongly urge the USGS to reconstitute the National Earthquake Prediction Evaluation Council (NEPEC) as soon as possible. There is

renewed scientific interest in earthquake prediction, which is likely to intensify given the increased awareness of natural hazards following the recent tsunami and hurricane disasters. A number of research groups are working in this area, and their efforts are being reported in the popular press. Currently no mechanism exists for the Director of the USGS to meet the statutory responsibility to evaluate and respond to scientific earthquake predictions. A reconstituted NEPEC would establish the means to evaluate predictions at the national level and to inform decision makers of the scientific credibility of earthquake prediction methods.

Natural Hazards Initiative

The SESAC strongly encourages the USGS, the Secretary of the Interior, the Office of Management and Budget, and Congress to move forward vigorously with the Natural Hazards Initiative in the USGS fiscal year 2007 budget. The apocalyptic Sumatra earthquake in December 2004 and the ensuing tsunami serve as stark reminders of our vulnerability to earthquakes and their associated hazards. Geologic and historical evidence indicates that in 1700, an earthquake of similar magnitude (estimated to be 9+) along the Cascadia subduction zone devastated coastal areas of northern California, Oregon, Washington, and British Columbia, causing a comparable tsunami and extensive ground shaking. The geologic record further indicates that such an earthquake has occurred at least seven times in the past in the Pacific Northwest, and that it will happen again, perhaps soon. Tsunamis from distant earthquakes can be detected hours before they strike our shores, but a tsunami caused by a local event, such as the 1700 earthquake along the Pacific Northwest coast, would take only minutes to strike our coastline.

Although devastating landslides usually are caused by storms, landslides of even greater scale frequently are triggered by earthquakes. Earthquake hazard maps, particularly in urban areas, will reduce risks through improvements in building design and practice and through land-use planning that recognizes landslides and other geologic hazards. These maps include probabilistic ground-shaking maps, landslide-hazard maps, liquefaction-hazard maps, and fault-rupture-hazard maps.

As was recognized in Project Impact, hardening the built environment for the predominant natural hazard in an area has the effect of reducing exposure to many other hazards. Major earthquakes are particularly challenging in this regard, because they are sudden events that are unpredictable in the short time frames in which emergency responders could mobilize. Recent experiences and loss-estimation models indicate that urban earthquakes can kill thousands of people and cause tens to hundreds of billions of dollars of economic losses. Cities throughout the country (including ones in Alaska, California, Nevada, New York, Missouri, Oregon, South Carolina, Tennessee, Utah, and Washington) face significant risk from earthquakes. These risks can be reduced through planning, mitigation, and emergency response. Recent events have caused natural hazards to come to the fore, and the Committee believes the USGS, through its Natural Hazards Initiative, has a major growth opportunity to take the leadership in creating a disaster-resistant country.

There is an exponential exposure to hazards—in two years it will be worse than it is today due to population growth and urbanization. Post-Katrina and Rita, we recognize the next big one will come. Natural disasters will be a national discussion for the next year or so, and the USGS should do everything it can do ensure the government is thinking broadly about catastrophic events that break the system—disasters at the largest scale for which we are not prepared to respond in time to save lives and protect property. The cornerstone of effective risk reduction is understanding and defining the hazard, and the USGS Earthquake Hazards Program provides the key elements—scientific understanding, hazard assessment, and real-time earthquake monitoring.

Large-scale computational capability is absent in the USGS and would be important to this effort. Increasingly, what the USGS does so well is synthesize large data sets, and it needs to increase its modeling capabilities to accomplish this important work. There is concern the USGS is being bypassed because it does not have the computers needed. If a greatly enhanced computational ability is seriously considered, code verification, maintenance, and quality assurance also will need to be funded.

The USGS is effective in disseminating information that can reduce the aftereffects of a catastrophic event, but it needs the budget to do so. The Natural Hazards Initiative could provide the necessary increases to the USGS budget to address earthquake, tsunami, landslide, and other hazards. Leadership and partnerships have to be strengthened because NEHRP currently is ineffective. The hazard reduction program in the U.S. cannot fall through the cracks as it did during Katrina. Catastrophic events will occur on the San Andreas system, the Cascadia subduction zone, Utah's Wasatch fault, and the New Madrid fault in the Midwest, and we need to be better prepared. The U.S. cannot afford to sustain continued major losses from natural hazards.

In our past three annual reports, the SESAC raised concerns that the level of support for the Advanced National Seismic System (ANSS) was woefully inadequate to meet program goals. Although funding in FY 2005 was below the amount authorized by Congress, the Committee was pleased to see a 19 percent increase in the appropriation for ANSS this year (from $4.4 million in FY 2004 to $5.25 million in FY 2005). In addition, ANSS received $2.95 million in supplemental funding in support of the President's tsunami warning initiative, an increase that will continue in FY 2006. Because the supplemental funds are narrowly targeted at those aspects of ANSS that support improved tsunami response, the need remains for improved support of the entire ANSS program.

The supplemental funds will be used to implement round-the-clock (24/7) operations at the National Earthquake Information Center (NEIC), complete the replacement of the legacy earthquake event processing system at NEIC, and improve the distribution of earthquake intensities and tsunami warnings to a variety of users. With these upgrades, NEIC will dramatically reduce the response time for issuing earthquake alerts, achieve improvements in the accuracy and efficiency of locating earthquakes, and expand the number of standard products it generates.

In our 2004 report, we recommended the USGS pick up the costs of long-term maintenance of the backbone ANSS stations that NSF is purchasing and installing as part of the USArray element of the EarthScope facility. The Committee is pleased to see that the USGS is following that recommendation and collaborating with NSF on this important aspect of the ANSS.

The Committee was pleased to learn that NEIC had developed a partnership with the Air Force Technical Applications Center (AFTAC) to improve real-time monitoring and notification of global earthquakes. Data from both the AFTAC arrays and the seismic stations in the International Monitoring System of the Comprehensive Nuclear Test Ban Treaty Organization will be incorporated into NEIC operations. In return, NEIC is now sending email notifications of magnitude 6.0 or larger earthquakes to AFTAC; these are then broadcast to U.S. military response facilities worldwide.

The National Research Council (NRC) recently completed its study on the economic benefits of improved seismic monitoring. The NRC's 2005 report, *Improved Seismic Monitoring—Improved Decision Making: Assessing the Value of Reduced Uncertainty*, concluded that

> *Full deployment of the ANSS offers the potential to substantially reduce earthquake losses and their consequences by providing critical information for land-use planning, building design, insurance, warnings, and emergency preparedness and response. In the committee's judgment, the potential benefits far exceed the costs—annualized building and building-related earthquake losses alone are estimated to be about $5.6 billion, whereas the annualized cost of the improved seismic monitoring is about $96 million, less than 2 percent of the estimated losses. It is reasonable to conclude that mitigation actions—based on improved information and the consequent reduction of uncertainty—would yield benefits amounting to several times the cost of improved seismic monitoring.*

The NRC, while noting the difficulty in quantifying benefits of the ANSS, demonstrated:

> *It is possible, by using a series of assumptions, to determine a "ball-park" figure for earthquake losses that could be avoided by using improved seismic monitoring information as the basis for implementing improved performance-based earthquake engineering design. These assumptions relate to the value of the built environment within the U.S., the cost of seismic rehabilitation and the number of existing buildings that need strengthening, and the annual expected loss from earthquakes compared with reduced losses when higher seismic design standards based on information from improved monitoring are applied. These calculations indicate a total loss avoided of more than $140 million per year, based on an estimate of reduced earthquake losses together with estimates of savings in construction costs that would accrue from the implementation of performance-based engineering design in those regions where improved seismic monitoring indicates the seismic design standards can be reduced.*

The SESAC wholeheartedly endorses the NRC report. Full funding for the ANSS is a key element in reducing the risk from the inevitable damaging earthquakes that will strike the United States. As the report states,

> *The United States should rank arresting the future growth of seismic risk and reducing the nation's current seismic risk as highly as other critical national programs that need persistent long-term attention, and it should make the necessary investment to achieve these goals.*

A magnitude 8 earthquake in California (or a well-placed magnitude 7) is the apotheosis of a class of extreme disasters that will break the system. Catastrophes in this class include hurricanes the size of Katrina, terrorist attacks the size of 9/11, and tsunamis the size of Sumatra. An earthquake of this magnitude has not hit California since 1906, but it certainly will, most likely soon. Earthquake scenarios have been prepared for high-hazard areas such as Northern and Southern California, Seattle, and Salt Lake City, but they need to updated and expanded to all high-hazard areas of the country. To understand what a catastrophic event will involve, we propose a demonstration project to form a model for the others. We propose the USGS undertake a complete analysis of the consequences of two catastrophic earthquakes—one in the San Francisco Bay Area and one in Southern California. This analysis has a head start because many pieces have been completed or are currently underway. We propose the USGS integrate the complete picture, from rupture on the fault, wave propagation into buildings and other structures, the response of all levels of our infrastructure, the emergency response, and continuing to the full recovery of our society.

The purpose of this exercise would be to identify where and when the breaking points for an extreme earthquake disaster in California will be, so steps to prevent such breakage might be taken. A coherent response by local, state, and federal agencies will require "vertical integration" of preparatory actions, emergency response, and recovery programs upward through all three levels of government. Such integration is currently lacking and best achieved by planning for the most extreme disasters. To accomplish this goal, we need to rebuild our capacity for managing the earthquake problem. The federal earthquake program employs half the staff it did in 1981. California's earthquake preparedness and mitigation program has shrunk from 30 people 10 years ago to 2 people today. We need to develop an integrated program in which scientists, engineers, and emergency managers work together to develop a comprehensive response program. Many people need to be involved, including the relevant agencies at the local, state, and federal level, academic researchers, and private industry.

We estimate to mobilize the necessary resources will require $10 million a year for two years. The lessons learned in this demonstration project will be applicable to all national extreme disasters. As the 1906 earthquake and fires and Hurricane Katrina demonstrated, decisions made by politicians in the critical hours following the disaster are not always the best. The time to understand and formulate the response is now.

RECOMMENDATIONS

We believe there are three especially important and high-priority recommendations for the USGS Earthquake Hazards Program at this time.

1. The SESAC strongly encourages the USGS, the Secretary of the Interior, the Office of Management and Budget, and Congress to move forward vigorously with the Natural Hazards Initiative in the USGS fiscal year 2007 budget. Recent events have spotlighted natural hazards, and the Committee believes the USGS, through its Natural Hazards Initiative, has a major growth opportunity to take the leadership in creating a disaster-resistant country. We recommend the USGS undertake a complete analysis of the consequences of catastrophic earthquakes in the San Francisco Bay Area and in Southern California and integrate the complete picture, from rupture on the fault, wave propagation into buildings and other structures, the response of all levels of our infrastructure, the emergency response, and continuing to the full recovery of our society. The purpose of this exercise would be to identify where and when the breaking points for an extreme earthquake disaster in California will be. The lessons learned in this demonstration project would be applicable to all national extreme disasters.
2. In support of the above recommendation, the Committee continues to strongly recommend to the Director of the USGS that full funding of the ANSS at the level authorized in the current NEHRP legislation be appropriated. The USGS must make a commitment to work through the Department of the Interior and the Office of Management and Budget to ensure this objective is met. Full deployment of the ANSS offers the potential to substantially reduce earthquake losses and their consequences by providing critical information for land-use planning, building design, insurance, warnings, and emergency preparedness and response. A 2005 report by the National Research Council reiterates that the potential benefits far exceed the costs
3. The Committee reemphasizes the USGS must reestablish the National Earthquake Prediction Evaluation Council to serve as the forum to review predictions and resolve scientific debate prior to public controversy or misrepresentation, so decision makers are not mislead by unfounded short-term earthquake predictions. The Committee encourages the USGS to support an active NEPEC equipped with adequate resources to perform this role.