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E A R T H Q U A K E H A Z A R D S P R O G R A M

SALT LAKE COUNTY ADOPTS NATURAL HAZARDS ORDINANCE!

by Craig Nelson, Salt Lake County Geologist
Salt Lake County Public Works - Planning Division

The Board of County Commissioners approved the Natural Hazards Ordinance on May 31st, granting final approval for implementation of guidelines for development within areas subject to geologic hazards. The purpose of this ordinance is to help minimize the effects of natural hazards on the public's health, safety, and property. The ordinance provides development standards based on proposed land use for three potential hazards: surface fault rupture, liquefaction potential, and snow avalanche. Other hazards, such as rockfall and landslide, may be included when maps delineating "special study areas" are completed. In addition, a formal disclosure procedure is now in effect that will provide pertinent hazards information to real-estate buyers. These provisions apply only to new construction within the unincorporated portion of Salt Lake County.

Although geologic hazard information has been available in the past, before enactment of the ordinance there were no consistent methods for requiring site-specific studies to identify hazards and make recommendations for avoidance or mitigation. The ordinance also provides for review of each development to insure that potential hazards have been appropriately dealt with.

Approval of the Natural Hazards Ordinance culminates nearly a decade of preparation by Jerold Barnes, Salt Lake County Planning Director. The public hearing before the County Commission was preceded by a lengthy draft revision process where comments and suggestions were received from the public, the technical community, and government officials. Support for adoption of the Natural Hazards Ordinance was received from the Salt Lake League of Women Voters, the United Association of Community Councils, Salt Lake County Fire and Flood Control & Highway Divisions, the Utah Geological and Mineral Survey and many private citizens.

Adoption and implementation of an ordinance that addresses potential geologic hazards places Salt Lake County at the forefront of responsible land-use planning in Utah. This ordinance now provides an excellent model for use by other local governments. Both County and Planning Commissioners are to be congratulated for taking a farsighted, pro-active position on geologic hazards. For more information please contact Craig Nelson at Salt Lake County Public Works - Planning Division, 2001 South State Street, #N3700, Salt Lake City, Utah 84190-4200, (801) 468-2061.

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DEADLINES FOR FUTURE ISSUES

SUMMER 1989 . . . . . JULY 15, 1989
AUTUMN 1989 . . . . . OCTOBER 15, 1989
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AN EARTHQUAKE MAY MEAN BIG LAWSUITS FOR UTAH'S CITIES AND COUNTIES

by Jeanne B. Perkins, Association of Bay Area Governments Earthquake Program Manager and
Kenneth K. Moy, Moy and Lesser, Association of Bay Area Governments Legal Counsel

What IS the potential liability of local governments for injuries and losses in an earthquake? What is the impact of liability on local government decisionmaking? Is liability acting as an incentive to earthquake hazard reduction programs? Are there practical ways to promote safety and reduce liability exposure? These are the questions asked by a two-year research project funded by the National Science Foundation (NSF). In addition to a thorough legal analysis, the Association of Bay Area Governments (ABAG) conducted a written survey of local government employees in the states of Utah, California, Alaska, and Washington. Lengthy in-person interviews were conducted in the Salt Lake area, as well as in California, and the Puget Sound area of Washington.

The Extent of Local Government Liability in Utah

Local governments CAN be held liable for some losses.

Partly because of their regulatory role, local governments traditionally have been protected by *sovereign immunity*, a concept derived from the English legal system. It is based on the notions that (a) the "King can do no wrong," and (2) the lawmaker cannot be prosecuted under laws created by it. Although this immunity has been reduced in recent years, certain actions of local governments will continue to be immune from liability as courts balance the need of governments to govern against the need to compensate innocent victims of government negligence.

The Utah Governmental Immunity Act (the "Act"), as amended, U.C.A. Sections 63-30-1 et seq. provides that all governmental entities are immune from tort liability, except as otherwise provided in the Act. The Act waives immunity for: "defective, unsafe or dangerous condition of any highway, road, street, alley, crosswalk, culvert, tunnel, bridge, viaduct or other structures located thereon" (U.C.A. Section 63-30-8) and "dangerous or defective condition of any public building, structure, dam, reservoir or other public improvement (except latent defective conditions)" (U.C.A. Section 63-30-9). With certain exceptions, some of which are noted below, all governmental entities are liable for the negligence of their employees acting within the scope of employment (U.C.A. Section 63-30-10). The most important areas in which the Act retains immunity are (a) discretionary functions; (b) issuance, denial or revocation of a permit or license; (c) failure to inspect or negligent inspection of private property; and (d) emergency medical assistance, firefighters, hazardous materials handling and emergency evacuations.

The legal defense that earthquakes are an *act of God* will no longer work in most circumstances. In the legal sense, an *act of God* is a natural event causing damage over which people have no control. Although in one sense an earthquake is beyond our control, the facts are that earthquakes have and will occur in Utah and scientists are gaining increased knowledge about them and their processes. Earthquakes and the damage resulting from earthquakes may be foreseeable and under some circumstances the losses can be mitigated, at least partially. Therefore, the *act of God* defence to tort liability may work in only two very limited situations: (1) if the earthquake was of such type or size as to be unforeseeable and the local government did not act negligently with respect to dealing with a foreseeable earthquake; or (2) if the earthquake was foreseeable, and the local government took all *reasonable* actions to prevent harm, but nonetheless damage still occurred.

Some Key Legal Concepts

A tort is a civil (as opposed to criminal) wrong, other than a breach of contract, for which courts award damages. There are four elements of a tort:

1. a pertinent duty must be imposed on the local government;
2. the local government must have violated that duty;
3. the victim must have been injured or suffered damages; and
4. there must be a casual connection between the local government's negligence and the harm suffered by the victim.

The usual standard by which a defendant's actions are judged in order to determine whether it has violated a duty is *negligence*. The concept of *negligence* is usually based on the rule of *reasonableness*. How would a reasonable person have acted under similar circumstances? Could the injury or loss have been foreseen? What was the apparent magnitude of the risk? What were the relative costs and benefits of action vs. inaction?

The *discretionary immunity* applies to basic policy decisions which have a planning, rather than an operational character. For example, a city council's decision to enact a law requiring landowners to disclose geologic and soils conditions prior to selling the property or building on it would be immune as a discretionary function. The city manager's decision to waive the requirement may or may not be immune, depending on the language of the ordinance, the factors used to make the decision, and the state in which he is located. The clerk who issues a building permit without requiring the disclosure document is not immune under the discretionary function theory. The higher the level of the decisionmaker in the governmental chain of command,

the more likely that this immunity applies. Thus, the "who" and "how" of a decision can be as important as the decision itself.

It is important to understand the role of *judges and juries* in a jury trial. Questions of fact (concerning whether something is factually true or untrue or whether something did or did not occur) are the exclusive province of the jury except under extreme circumstances. Questions of law (requiring that the law be interpreted or applied) are the exclusive province of the judge. However, it is the jury that decides, as a matter of fact, whether or not it would have been reasonable to do more, thereby determining, as a matter of law, that negligence exists.

Liability Varies With the Circumstances

The most likely sources of liability in Utah are injuries or damages caused by the "dangerous condition" of government property--its hospitals, city halls, jails, and public works. The risk of being held liable is increased if the government had actual or constructive knowledge of those conditions. In most situations, the injured party will rely on traditional tort analysis in establishing liability. Immunity retained for "latent defects" appears to be no more than a restatement of general tort principles.

Utah's local governments have much less potential liability for injuries on private property than on public property. As noted above, local governments in Utah are immune from liability for most actions relating to the issuing of permits and the inspection of private property. A possible, but unlikely source of potential liability rests on a literal reading of the Act.

Given the language of U.C.A. Section 63-30-10, one can argue that a local government's failure to take action on a code violation, if such violation is not related to the status of a permit or license and is not uncovered during an inspection, is not covered by the statutory immunity. This theoretical basis for liability resulting from negligent inspections and permit issuance has not been confirmed by court decisions.

However, because of the extensive immunities in Utah law, the theory of *inverse condemnation* may be used when public property or public actions are involved in damaging private property. For purposes of this discussion, inverse condemnation derives from the constitutional requirement that a local government cannot "take" private property without "just compensation." Where government ACTION results in such damage to property that it is useless or greatly diminished in value, a court may rule that the action is a "taking" that must be compensated. Whether **Utah** recognizes an action for inverse condemnation is not clear. Several inverse condemnation suits based on local governments' handling of the 1983 rains and resulting flood and mudslide damages were on appeal before the Utah Supreme Court in 1988.

The Utah statute provides immunity for public entities and their employees in most emergency response situations. In the unusual circumstances where the statutory immunity is not available, the public entity may be liable for the non-discretionary acts of its employees.

In Utah, the issuance of an earthquake warning is probably immune either under the provisions of state statutes or the discretionary immunity function.

The Impact of Liability on Local Government Decisionmaking

Based on a written questionnaire and in-person interviews with local government staff in four states, we arrived at several conclusions about the effects of liability on motivating earthquake mitigation programs.

Even though a higher risk of earthquakes and earthquake events can trigger the initiation of programs, this is an incomplete picture of the motivation process. Local government staff in the four state area ranked ten factors motivating earthquake hazard reduction programs in their jurisdiction. The top five (in order) were:

1. leadership of a staff member or elected official;
2. the need to maintain local government functions;
3. concern for potential liability;
4. improved public safety; and
5. a state or federal government requirement.

The top four (in order) for Utah were:

1. improved public safety;
2. the need to maintain local government functions;

3./4.an active risk management program; and

3./4.leadership of a staff member or elected official.

Concern for potential liability was tied for fifth in Utah.

In both the four state area and in Utah, liability was ranked even higher among those with most types of "active" earthquake programs. In particular liability was listed first in Utah (and tied for first in the four-state area) among those that had canceled or significantly changed a project due to earthquake concerns or policies. It was listed first very few times when compared to the other top motivators; it achieved its high ranking because it is pervasive. There is no single motivator for earthquake programs; the motivators are as diverse as the jurisdictions themselves.

Over 90% of those surveyed in the four-state area believe that the law is at least sometimes uncertain. Half of these feel that this uncertainty is having little or no effect on their jurisdiction, a quarter feel that it encourages aggressive programs, and a quarter feel that it discourages programs. Managers from jurisdictions which have the most comprehensive earthquake mitigation programs are more likely to believe that this uncertainty is encouraging action. On the other hand, only 74% of those in Utah felt that the law was uncertain.

Managers from jurisdictions with active earthquake programs do NOT see significantly more or less liability exposure than the entire group surveyed. Thus, **there is no indication that any major change in rules governing liability or immunity would result in more active earthquake programs.** A general concern for liability, rather than how they perceived their degree of

liability exposure, appears to motivate earthquake hazard reduction programs. About 2/3 of those surveyed reported concern for liability for earthquake hazards within their jurisdictions, double the number of ten years ago.

Jurisdictions with "active" earthquake programs tend to be self-insured with active risk management programs. However, project staff concluded that the existence of active risk management programs and active earthquake programs are the result of a progressive top management and stable elected bodies promoting safety awareness, rather than risk management somehow "causing" the earthquake program to be more active.

Promoting Safety While Coping with Liability -- Some Advice for Local Governments

As a result of the findings from this study, the following are recommendations for local government to promote public safety and cope with liability.

1. Local governments should comply with any statutory or mandatory duties imposed by the state or federal governments.
2. A program should be developed to inspect, repair and maintain the city's or county's public buildings and facilities.
3. Your local government's risk manager is useful as an ally in promoting increased earthquake safety of all public facilities and buildings.
4. Local government staff should NOT assume that liability exposure exists for any mitigation program involving private property. Ask advice from your legal counsel.
5. Immunity from liability exists for almost any emergency situation. However, emergency staff should understand when the emergency is over and normal liability rules apply.
6. Act to promote the safety and welfare of the people in your community. If you act reasonably, your liability exposure can be minimized.

For More Information

This article highlights the finding of a research project described in an ABAG report, Liability of Local Governments for Earthquake Hazards and Losses: A Guide to the Law and its Impacts in the States of California, Alaska, Utah, and Washington ($12.00). In addition a companion document subtitled Background Research Reports ($15.00) contains the background legal research, summaries of case law and statutes, and the results of the survey of local government behavior. The reports can be ordered from Association of Bay Area Governments, P.O. Box 2050, Metro-Center-Eighth and Oak Streets, Oakland, CA 94604, (415) 464-7900.

LEGISLATIVE STUDY OF EARTHQUAKE INSTRUMENTATION NEEDS IN UTAH

by Walter J. Arabasz
University of Utah Seismograph Stations

On February 4, 1989, leaders of the state's earthquake program (including representatives of the Utah Geological and Mineral Survey, the University of Utah Seismograph Stations, and the Utah Division of Comprehensive Emergency Management) briefed state legislators on the earthquake threat in Utah and on the general needs of Utah's earthquake program. Subsequently, Representative Ray Nielsen of Sanpete County filed a resolution, as part of a master study resolution (H.J.R. No 34) at the end of the 1989 General Session, to study "earthquake instrumentation needs of Utah." Legislative study will be undertaken during the summer of 1989 for reporting to the 1990 General Session.

Existing earthquake-related instrumentation in Utah is out-of-date and seriously inadequate for meeting the state's needs--for earthquake monitoring, hazard identification and mitigation, defensive engineering design, and emergency response and public safety.

The primary instrumentation needs of the state are judged to include:

- modernization of the University of Utah's state seismic network;
- instruments to record damaging strong ground motions and other needed data as part of a coherent state program of strong-motion studies for earthquake engineering;
- communications equipment for alarm systems and rapid transfer of earthquake information between seismological recording centers and public safety officials during an earthquake emergency; and
- instruments for precise measurement of changes in the ground surface that may occur before large earthquakes.

In practice, legislative study now presupposes that the state's instrumentation needs can be clearly specified and prioritized, that there is expert agreement, and that careful consideration will have been given to cost effectiveness and the state's best interests. A task force to formulate an objective, expert view about what's needed in Utah in terms of instrumentation-scope, priority, urgency-is being planned by Genevieve Atwood and Walter Arabasz.

SUMMARY OF EARTHQUAKE REPORTS IN PROGRESS

by Gary E. Christenson
Utah Geological and Mineral Survey

The Utah Geological and Mineral Survey (UGSM), Utah Division of Comprehensive Emergency Management (CEM), and University of Utah Seismograph Stations (UUSS) are all involved in producing a variety of earthquake-related products directed toward non-earth scientists and non-technical users. All will incorporate information from the "consensus document" which summarizes the results of the 5-year USGS NEHRP and is scheduled for completion this summer. The targeted users for the products vary, as do the areas and topics covered and level of detail and type of explanatory information included. The products are listed below to inform Forum readers of what to expect in the next few years in terms of user-oriented publications.

As a part of its statewide geologic hazards map series, the UGMS is producing an earthquake hazards map of the state at a scale of 1:750,000. This map will include a short text which will explain in general terms the various earthquake hazards (surface faulting, ground shaking, liquefaction, slope failure, various types of flooding, and tectonic subsidence), and the map will depict to the extent possible the distribution, severity, and probability of occurrence of each hazard statewide. It will incorporate information from other maps in the UGMS hazard map series such as the Quaternary fault map (see v. V, no. 2, p. 10, Wasatch Front Forum), shallow ground water map (UGMS Map 110), and dam failure inundation map (UGMS Map 111), as well as recent work by Matt Mabey and Les Youd on liquefaction severity. The map is targeted for use by state, local government, and other planners who need a general knowledge of the distribution and severity of earthquake hazards, primarily to determine and prioritize where they need more detailed information prior to development to ensure that loss reduction measures are implemented where necessary.

The Utah Division of Comprehensive Emergency Management and UGMS are presently working on a handbook, principally for use by local governments, to help them evaluate the earthquake risk in their communities. The UGMS is preparing a summary and explanation of the hazards and directory of information sources, and Utah CEM is developing a method for inventorying community assets and determining approximate losses and reconstruction costs. The product will be in the form of a handbook(s) which can be used by a community to perform its own evaluation. Once completed, workshops and other educational programs will be conducted to aid interested communities in using the handbook(s) and performing the evaluation. The handbook(s) is chiefly directed toward Wasatch Front communities which have relatively detailed information regarding earthquake hazards.

The University of Utah Seismograph Stations (Walter Arabasz) and Don Mabey have a grant from the USGS to prepare a "showpiece" book describing earthquakes and the earthquake hazards of Utah in a popularized publication for the general public. It will be a well-illustrated, professionally-designed book which will discuss where earthquakes occur in Utah and how they're recorded, summarize general geologic and seismologic aspects of earthquake occurrence, and discuss earthquake hazards and damage. The intent of the book is to appeal to (1) the general public (who must encourage and support elected and appointed officials to make decisions on implementing earthquake hazard-reduction measures), (2) teachers and students, and (3) decisionmakers themselves.

All of these products are in progress at various stages of completion. It is anticipated that all will be available within the next 1-2 years, and anyone wishing further information is encouraged to contact the agencies and workers listed above.

UNSUNG EARTHQUAKE MITIGATION PROJECTS

by Jim Tingey
Utah Division of Comprehensive Emergency Management

Over the past several years while geologists, seismologists, engineers, and emergency planners have been basking in the dim limelight of the National Earthquake Hazard Reduction Program in Utah, many other unsung earthquake mitigation workers have performed notable work. The reasons for their shyness can only be speculated but we at the Forum can no longer allow them to live in obscurity. Good work must be acknowledged and what greater reward than your name in the indelible ink of the "Wasatch Front Forum."

Recent projects which qualify for mention include the seismic upgrading of the State Office Building directly behind the Capitol in Salt Lake City. While a thorough asbestos abatement program is underway, structural steel is being incorporated into the framework of the building to provide lateral bracing and thus more seismic resistance. Jim Bailey of E.W. Allen & Associates Engineering said that this work will bring the frame of the building up to 100 percent of 1988 UBC specifications. E.W. Allen is also involved in retrofitting the Old Main Building on the Utah State University Campus in Logan.

The recently completed Evans and Sutherland Computer Simulation Facility in Research Park, which was engineered by Reaveley Engineering, incorporating the

latest seismic base isolation design and the retrofitted City and County Building, stand as significant, national examples of progressive seismic construction.

Our local utility companies, notably Mountain Fuel Supply and US West, have also been active in risk analysis and earthquake mitigation activities which for the most part go unmentioned.

In order to recognize earthquake mitigation practices in Utah and to learn from Utah's hazard reduction champions, please contact the Forum or Jim Tingey at 801-584-8370 with any information on "Unsung" earthquake mitigation heroes and activities.

UTAHNS SUBMIT MICROZONATION PROPOSAL TO NSF

by Gary E. Christenson
Utah Geological and Mineral Survey

At the Fifth Annual Workshop on Earthquake Hazards and Risk along the Wasatch Front, Loren Anderson discussed the need for a Utah microzonation project (see discussion in Wasatch Front Forum, v. V, no. 2, p. 4). Loren and Genevieve Atwood (UGMS) have now submitted a proposal to the National Science Foundation for funding to start a three-year microzonation/implementation project along the Wasatch Front. As stated in the proposal:

> "The goal of the Utah Microzonation/Implementation Project is to devise a set of microzonation standards, create a set of microzonation products, and implement earthquake hazard reduction strategies by a team approach to the research. The study area will include Salt Lake, Utah, Weber, and Davis Counties, the most populous counties of the Wasatch Front, Utah. "

Loren would be principal investigator and project manager. Genevieve is co-principal investigator, and the proposed project consists of a resource team, review team, and international liaison group. The resource team includes technical experts and information users from state and local government agencies, professional groups, universities, and private industry representing a variety of disciplines including planning, engineering, earth science, emergency response, and building inspection. This group will provide the local experience needed to carry out the project. The review team consists chiefly of outside experts with experience in microzonation projects elsewhere, and the liaison group will start the technology transfer to others internationally once the project is nearly complete.

The proposal was submitted to NSF in early May. Anyone wishing further information should contact Loren Anderson or Genevieve Atwood.

THREE UTAH AGENCIES HOST PLANNING COMMITTEE FOR NATIONAL EARTHQUAKE EDUCATION CONFERENCE

By Deedee O'Brien
Utah Museum of Natural History

The National Center for Earthquake Engineering Research (NCEER) and the Federal Emergency Management Agency (FEMA) are co-sponsoring a national conference entitled Disaster Preparedness: The Place of Earthquake Education in Our Schools scheduled for July 10 & 11, 1989, in Buffalo, New York. The planning committee for this conference includes people currently involved in earthquake education around the country. Utah is represented by Deedee O'Brien, Teacher Workshop Coordinator for the Utah Museum of Natural History (UNMH). Jim Tingey, Emergency Response Planner for Utah Division of Comprehensive Emergency Management (CEM), will be a speaker at the conference.

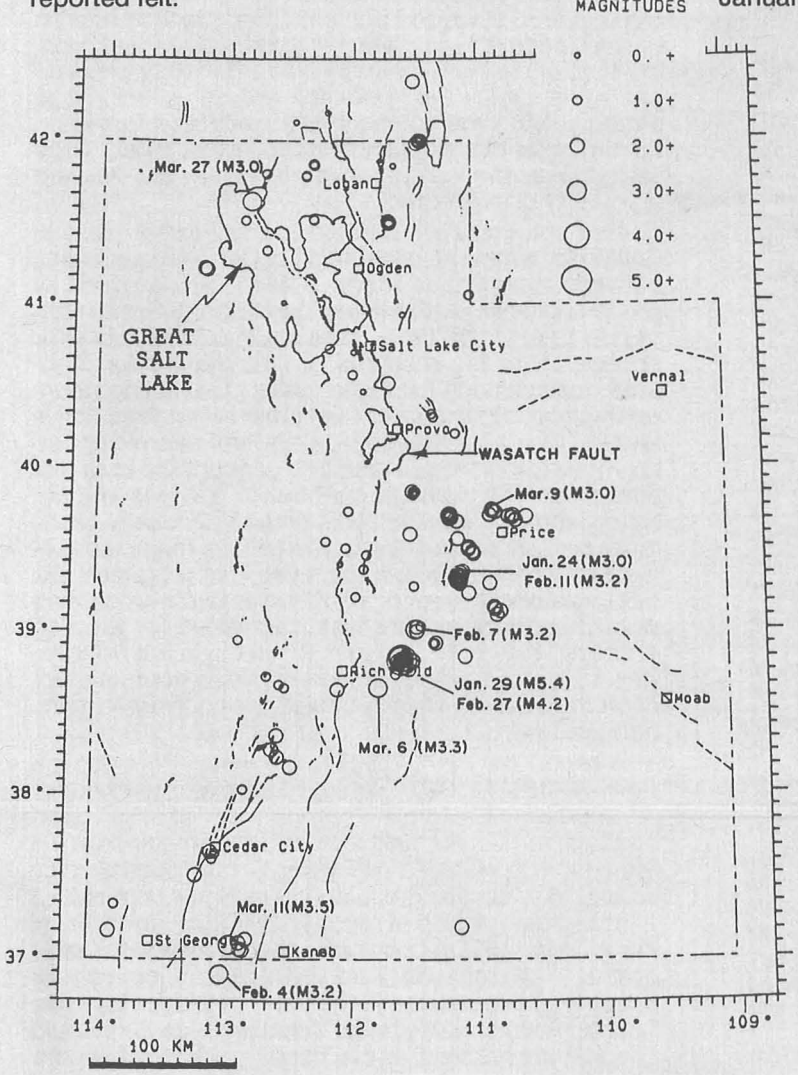
The conference planning committee recently met in Salt Lake City to finalize the conference agenda and to learn first hand about Utah's earthquake hazard and earthquake education situation. They were co-hosted by the Museum, Comprehensive Emergency Management and the Utah Geological & Mineral Survey (UGMS). In attendance were Katharyn Ross (NCEER), Andrea Dargush (NCEER), Rodney Doran (SUNY at Buffalo), Linda Noson (FEMA District 10 - Seattle), Dan Cicirello (Emergency Services, Arkansas), Marilyn MacCabe (FEMA), and Joyce Blueford (Math/Science Nucleus, CA). In addition, local experts were invited to the meeting as advisors. They included Genevieve Atwood (UGMS), Dale Baker (U of U faculty, Education Studies), Bill Case (UGMS), Frank DeCourten (UMNH), Joyce Marsing (State PTA), Sue Nava (University of Utah Seismograph Stations), Sharon Sauter (elementary teacher, Oquirrh Elementary School), Marianna Sullivan (principal, Libbie Edwards Elementary School), and Jim Tingey (CEM).

UTAH EARTHQUAKE ACTIVITY

January 1 - March 31, 1989

by Susan J. Nava
University of Utah Seismograph Stations

During the three-month period January 1 through March 31, 1989, the University of Utah Seismograph Stations located 207 earthquakes within the Utah region (see accompanying epicenter map). Of these earthquakes, 111 had a magnitude (either local magnitude, M_L, or coda magnitude, M_c) of 2.0 or greater, ten had a magnitude of 3.0 or greater, and nine were reported felt.



The largest earthquake during the report period was a shock of M_L5.4 on January 29 at 09:06 PM MST, 26 km southeast of Salina, in north-central Sevier County. The Salina earthquake was felt widely in central and northern Utah (maximum Modified Mercalli Intensity V to VI), and in northern Arizona, western Colorado and southwestern Wyoming. The largest aftershock of the January 29 Salina earthquake was an M_L4.2 event that occurred on February 27 at 08:13 AM MST, that was felt in four counties. During the report period, 51 earthquakes associated with the Salina sequence have been located.

Eight other earthquakes of magnitude 3.0 and greater occurred in the Utah region during the report period: an M_c3.0 event on January 24 at 04:37 PM MST, located 15 km west of Huntington; an M_c3.2 event on February 4 at 05:26 AM MST, located 50 km southwest of Kanab; an M_c3.2 event on February 7 at 04:49 AM MST, which was felt in Manti; an M_c3.2 event on February 11 at 01:37 PM MST, located 11 km west of Huntington; an M_L3.3 event on March 6 at 12:41 AM MST, which was felt in Koosharem and Glenwood; and M_c3.0 event on March 9 at 07:33 AM MST, located 10 km east of Helper; an M_c3.5 event on March 11 at 11:30 PM MST, which was felt in Springdale, Rockville, and Colorado City, Arizona; and an M_L3.0 event on March 27 at 04:41 AM MST located 25 km west of Promontory. Four additional earthquake were reported felt in Utah during the report period: an M_L2.7 event on February 2 at 09:15 PM MST, which was felt in Beaver; an M_L2.8 shock on February 3 at 07:04 AM MST which was felt in Salina and Ephraim; an M_L2.7 event on February 3 at 11:08 AM MST, which was felt in Helper and Manti; and an M_L2.5 event on March 5 at 11:51 PM MST, which was felt in the West Desert, and in Wendover, Nevada.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations.

PROBABILITIES OF LARGE EARTHQUAKES OCCURRING IN CALIFORNIA ON THE SAN ANDREAS FAULT

A statement published in the early 1980's indicated that there was a 50 percent chance of a large and damaging earthquake in southern California during the subsequent 30 years. However, since new data on prehistoric earthquakes and slip-rates for several areas in California have become available since that time, the National Earthquake Prediction Evaluation Council (NEPEC) recommended the formation of a working group, the Working Group on California Earthquake Probabilities, to evaluate the earthquake threat to southern California and to review and assess the likelihood of a great earthquake in southern California during the next few decades. The Working Group included: D.C. Agnew, University of California, San Diego; C.R. Allen, California Institute of Technology; L.S. Cluff, Pacific Gas and Electric Company; J.H. Dieterich, U.S. Geological Survey; W.L. Ellsworth, U.S. Geological Survey; R.L. Keeney, University of Southern California; A.G. Lindh, U.S. Geological Survey; S.P. Nishenko, U.S. Geological Survey; D.P. Schwartz, U.S. Geological Survey; K.E. Sieh, California Institute of Technology; W. Thatcher, U.S. Geological Survey; and R.L. Wesson, U.S. Geological Survey. The results of this distinguished working group's review and synthesis is published as U.S. Geological Survey Open-File Report 88-398, from which the Executive Summary below was taken. It should be of interest to Forum readers even though its focus is the San Andreas fault. The assignment of levels of reliability for conditional probabilities of each fault segment studied, is worthy of particular note and would be very useful information if the technique could be applied to the Wasatch fault. As new data are continually being gathered relevant to long-term forecasts for specific segments of major faults in California, it is expected that the conclusions of this document will need to be revised and updated every few years. Open-File Report 88-398, 62 p. can be obtained for $9.75 (paper copy) or $4.00 (microfiche) from the USGS Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225, (303)236-7476. Ed.

Executive Summary

Because of increased public interest and concern about expected losses from future earthquakes in California, the National Earthquake Prediction Evaluation Council recommended that the probability of occurrence of large (magnitude 7 or greater) earthquakes in California be evaluated. In response to this recommendation, the U.S. Geological Survey formed the Working Group on California Earthquake Probabilities.

The Working Group met several times during the summer and fall of 1987 and winter of 1988 to review and assess the state of knowledge that would allow calculation of earthquake probabilities on specific fault segments. The scope of the evaluation was limited to assessing the probabilities for large earthquakes resulting from slip on the major faults of the San Andreas fault system. The evaluations were based on a probability model that assumes increase of probability with elapsed time since the previous major earthquake on the fault segment. To determine time-dependent probabilities, the faults were divided into their recognizable segments, and the potential for a future large earthquake on the segment was calculated based on the time that has elapsed since the most recent large earthquake, and fault parameters such as slip rate and amount of displacement.

Although there are numerous other active faults in California, almost all capable of moderate earthquakes between magnitudes 6 and 7 and some capable of producing large earthquakes, the Working Group concluded that, at this time, there are insufficient data for application of the methods of time-dependent probability calculations for these faults. Estimating future earthquake occurrence for the other recognized active faults is best approached by long-term seismic potential models that do not take into account the length of time since the previous earthquake and assume the hazard remains constant with time. Individually, these faults present a lesser threat than do the major faults of the San Andreas system, because their long-term slip rates, historical rates of earthquake occurrence, and size of earthquakes are less than those for the San Andreas. However, because these faults are not considered in our analysis, the probabilities computed for each region of California should be considered minimum values.

A report by the Federal Emergency Management Agency (FEMA, 1980) stated that a major earthquake in southern California, comparable to the great earthquake of 1857, has a probability greater than 0.5 in the next 30 years. The Working Group found that the earthquake hazard on the southern San Andreas fault is at least as high as that reported by FEMA. In addition, the Working Group concluded that somewhat smaller events, of magnitude 7 to 7 1/2 are of concern in southern California and in the San Francisco Bay area. Such events occurring near population centers could pose severe hazards, as discussed in the FEMA report.

The time interval chosen for the probability calculations was 30 years, 1988 to 2018, although similar calculations using the same models were performed for 5-year, 10-year, and 20-year intervals, as well. To dis-

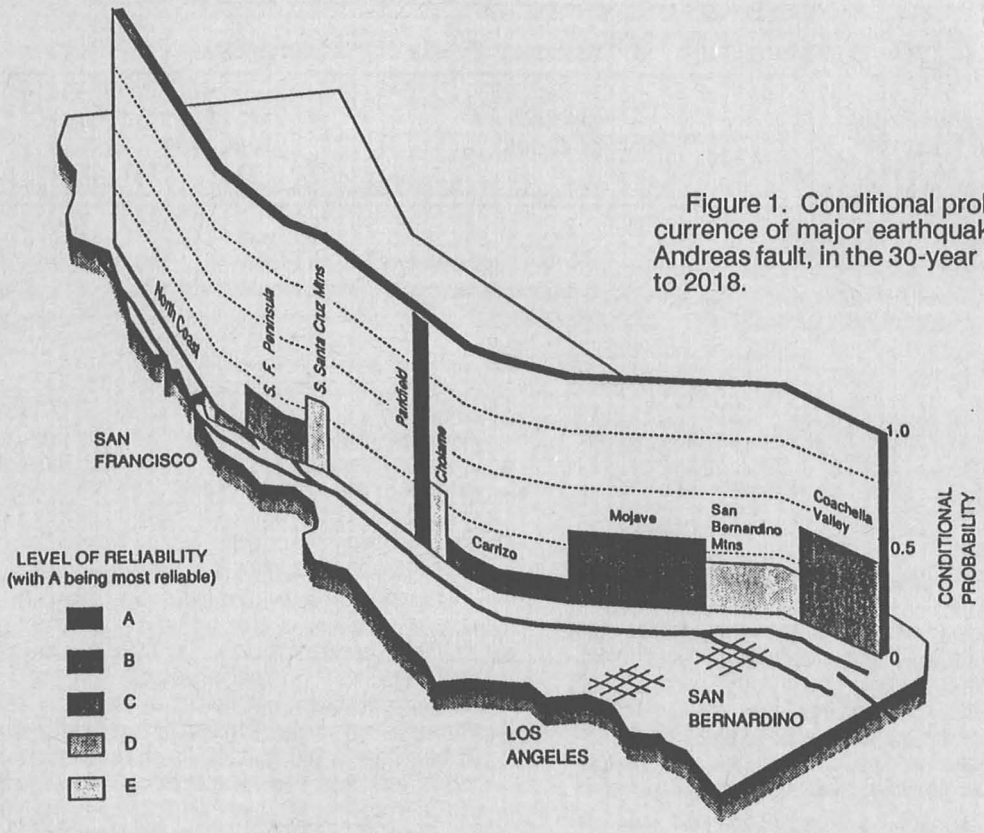


Figure 1. Conditional probability for the occurrence of major earthquakes along the San Andreas fault, in the 30-year interval from 1988 to 2018.

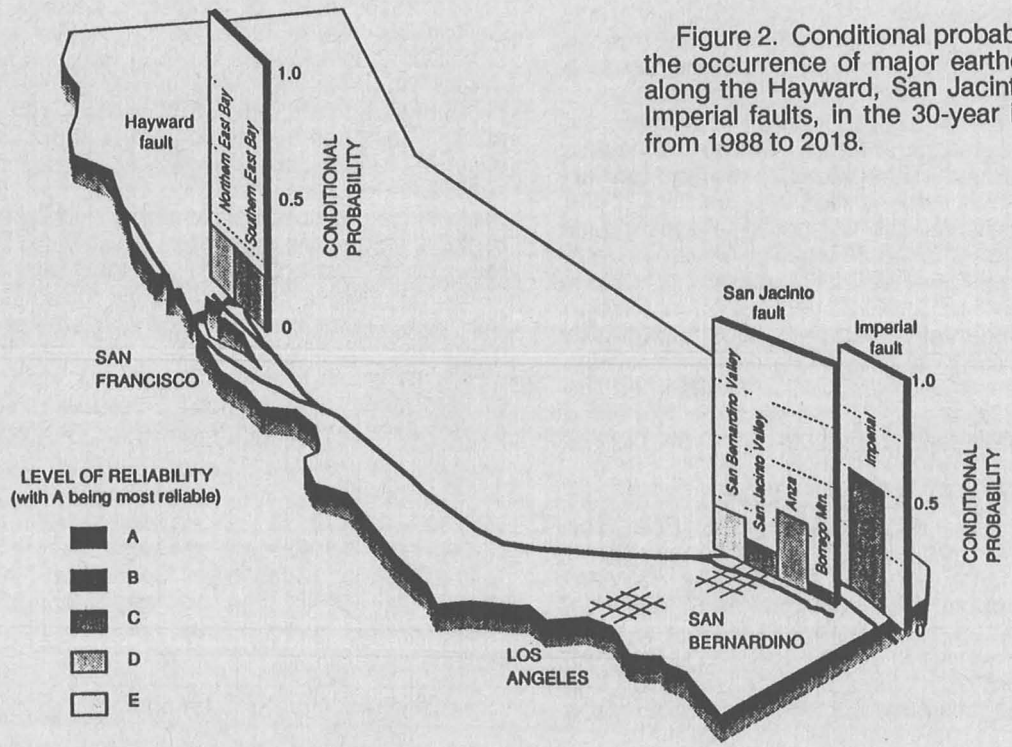


Figure 2. Conditional probability for the occurrence of major earthquakes along the Hayward, San Jacinto, and Imperial faults, in the 30-year interval from 1988 to 2018.

Probability of One or More Large Earthquakes on Faults of the San Andreas Fault System					
Geographic Region or Fault	Expected Magnitudes	Probability for Intervals Beginning 1/1/88			
		5 y	10 yr	20 yr	30 yr
San Francisco Bay Area	7	0.1	0.2	0.3	0.5
Southern San Andreas Fault	7.5-8	0.1	0.2	0.4	0.6
San Jacinto Fault	6.5-7	0.1	0.2	0.3	0.5

tinguish fault segment models based on relatively good data from those based on poor or incomplete data, each segment was given a level of reliability rating from A to E, with A being most reliable.

The results of the Working Group's evaluations, judgments, analyses, and assessments are summarized on figures 1 and 2.

Within a region containing more than one fault segment, the total probability of the occurrence of at least one large earthquake is, for many applications, of greater interest than the probabilities for individual segments. The results of aggregating the individual probability values to forecast the probability of a large earthquake in three regions is summarized in the above table.

- The 30-year probability of large earthquakes is highest in southern California. We have identified the 100-km-long Coachella Valley segment as having the highest probability (0.4) of producing an earthquake of magnitude 7 in the next 30 years. A major earthquake has not occurred there since about AD 1680. The Mojave segment, part of the source region of the great 1857 earthquake, has a 30-year probability of 0.3.
- Evaluation of the southern San Andreas fault depends critically on the future behavior of the San Bernardino Mountains segment. If the San Bernardino Mountains segment slips independent of the adjacent segments, the expected magnitude of earthquakes on the southern San Andreas fault would be about 7, with a total probability of at least one such event in the next 30 years of 0.7. If the San Bernardino Mountains segment slips along with either the Mojave segment to the north or the Coachella Valley segment to the south, then the resulting earthquake would approach the size of the 1857 earthquake, and have a 30-year probability of 0.6.
- The probability of large earthquakes within the next 30 years along fault segments in the San Francisco Bay Area is also significant. The total probability for all fault segments evaluated is 0.5. The Hayward fault has produced two earthquakes in historical time, in 1836 and 1868; both had estimated magnitudes approaching 7. The Northern East Bay segment of the Hayward fault, the Southern East Bay segment of the Hayward fault, and the San Francisco Peninsula segment of the San Andreas fault each have a probability of 0.2 of an earthquake of magnitude 7 in the next 30 years. The 30-year probability of a great earthquake along the North Coast segment, extending north from the San Francisco Peninsula, is less than 0.1.
- Fewer data are available about the recurrence of large earthquakes along five separate segments of the San Jacinto fault. During the course of the Working Group's deliberations, the magnitude 6.6 1987 Superstition Hills earthquake occurred on one of these segments. The Working Group estimated a probability of 0.5 for the four remaining segments combined, for the occurrence of earthquakes of about magnitude 7 within the next 30 years. The segment of the San Jacinto fault having the highest probability is the Anza segment (0.3). The others are: San Bernardino Valley segment, 0.2; San Jacinto Valley segment, 0.1; and the Borrego Mountain segment, less than 0.1.

The assessment of long-term seismic hazard on California's major faults is an active and rapidly developing field. New data and improvements in the model on which the assessments are based will probably lead to revision and refinement in the probabilities assigned here to segments of the San Andreas system. In addition, alternate interpretations of fault segmentation may also lead to somewhat different probabilities at specific locations. However, the total regional values are much less sensitive to the detailed recurrence characteristics of individual segments. These cumulative values are quite robust and support the main conclusion of our study, that the probability of major earthquake on the San Andreas in southern California within the next 30 years is high, about 0.6; this probability approaches 0.5 both in the San Francisco Bay Area, and along the San Jacinto fault.

MEETINGS AND CONFERENCES

August 7-11, 1989, Fifth Chilean conference on seismicity and earthquake engineering held in Santiago, Chile. For information, contact 5th CCSEE, Department of Structural Engineering, Catholic University of Chile, Casilla 6177, Correo 22, Santiago, Chile.

August 8-11, 1989, Fifth international conference on structural safety and reliability (ICOSSAR '89), held at the Ramada Renaissance in San Francisco, California. Every aspect of structural safety and reliability will be covered. New developments as well as state-of-the-art and novel applications of reliability principles in all types of structural systems will be discussed. ICOSSAR "89 will emphasize the safety and performance requirements of critical engineering systems under the threat of natural and man-made hazards. Issues of risk analysis and risk acceptance pertaining to the safety of major technological systems will also be part of the conference. For information, contact ICOSSAR Secretariat, c/o ASCE, 345 East 47th Street, New York, NY 10017, Attention: Elizabeth Yee, (212) 705-7544.

August 13-18, 1989, Twelfth international conference on soil mechanics and foundation engineering, held in Rio de Janeiro, Brazil. For information, contact Professor R. Seed, Department of Civil Engineering, 440 Davis Hall, University of Californai, Berkeley, CA 94720.

August 21-22, 1989, First international seminar on siesmic base isolation of nuclear power facilities, held at the Auditorium of Pacific Gas and Electric Company, San Francisco, California. For more information, contact Y.W. Chang, Argonne National Laboratory, (312) 972-4680, or F. Tajirian, Bechtel, (418) 768-0401.

September, 1989, International conference on reinforced and prestressed prefabricated concrete structures in seismic areas, held in Iasi, Romania. For information, contact Prof. A. Negoita, Polytechnical Institute, Bd. Karl Marx 38, 6600 Iasi, Romania.

September 4-9, 1989, Make no little plans, the 1989 conference of the Association of Preservation Technology will be held in Chicago, Illinois. APT is an international association of preservationists, restoration architects, engineers, landscape architects, materials scientists, conservators, archaeologists, craftsmen, and others involved in preservation. Session topics include stabilization and repair, materials conservation, craftsmanship in preservation, preserving what's new, landscape restoration, and preservation project management. For further information, contact the Association for Preservation Technology, c/o Small Homes Council, 1 East St. Mary's Road, Champaign, IL 61820, (217) 333-1801.

September 4-9, 1989, Fourth international symposium on analysis of seismicity and seismic risk, sponsored by the International Association of Seismology and Physics of the Earth's Interior (IASPEI), held at the Castle of Bechyne, south of Prague, Czechoslovakia. For information contact the Organizing Committee of the Symposium (RNDR. Zdenka Schenkova CSC) Geophysical Institute of the Czechoslovak Academy of Sciences, Bocni II. c.p. 1401, 141 31 Praha 4 - Sporilov, Czechoslovakia.

September 13-16, 1989, Reconstruction after urban earthquakes: an international agenda to achieve safer settlements in the 90's, sponsored by the National Center for Earthquake Engineering Research, at the Hyatt Regency Hotel in Buffalo, New York. The purpose of this conference is to develop an international agenda of activities to help ensure timely and organized reconstruction efforts following earthquakes. The conference is the first in a series of international meetings that NCEER will hold biannually over the next ten years to discuss issues of recovery and reconstruction following natural disasters. All are being organized in conjunction with the United Nation's proclamation of the 1990's as the International Decade for Natural Disaster Reduction (IDNDR). Reconstruction experts from around the world will examine issues such as the financing of reconstruction, aseismic building technologies, building code enforcement and the role of cultural background in housing reconstruction. Topics will include: research, knowledge data bases, information dissemination, land use and zoning, repair costs, funding resources, and the role of insurance and reinsurance. Separate plenary sessions will review the reconstruction processes of several international earthquake disasters including Anchorage, Alaska (1964); Mexico City, Mexico (1985); and Leninakan, U.S.S.R. (1988). The program will be attended by government officials and representatives of private industry that are involved in the planning, decision making and implementation of the reconstruction process, as well as members of the academic and research communities. The issues of earthquake reconstruction and pre-disaster planning are important aspects of reducing the potential for long-term secondary disaster following earthquakes. This conference is seen as a vital step in improving planning, reconstruction efforts and earthquake awareness throughout the United States and world. For additional information contact Jelena Pantelic or Merna Seaman at NCEER, State University of New York at Buffalo, Red Jacket Quadrangle, Buffalo, NY 14261, (716) 636-3391.

September 18-19, 1989, Preventive care of historic photographs and negatives, the Utah Preservation Consortium's second annual preservation

workshop, will be held at the Museum of Fine Arts Auditorium at the University of Utah, Salt Lake City, Utah. The workshop will be conducted by Debbie Hess Norris, instructor of photographic conservation in the Art Conservation Program at the University of Delaware and Winterthur Museum. It is open to the general public. For further information, contact Randy Silverman, 6216 HBLL, Brigham Young University, Provo, UT 84602, (801) 561-5516.

September 26-29, 1989, Second U.S.-Japan workshop on liquefaction, large ground deformation, and their effects on lifeline facilities, co-sponsored by NCEER and several Japanese institutes, in Buffalo and Ithaca, New York. The workshop is part of an integrated program to address the problems of large ground deformations during earthquakes, establish case history documentation, and develop comprehensive guidelines for siting, analysis, design, and countermeasures to mitigate the effects of large earthquake-induced ground deformations on lifeline facilities. Bilateral position papers will be published and serve as a framework for collaborative work in developing guidelines of practice. The guidelines will be issued as a consensus document on engineering practice of lifelines for large ground deformations. For additional information, contact NCEER at (716) 636-3391 or Thomas O'Rourke, Cornell University, Ithaca, NY 14853-3501, (607) 255-6470.

October 1-6, 1989, Association of Engineering Geologists annual meeting "Engineering geology of mountain and plain", held in Vail, Colorado. Technical program topics will include: engineering geophysics, earthquake hazards and fault assessment, and earthquake engineering. Symposia will include engineering geology problems of large landslides and hazard reduction for mountain development. Short courses will cover landslide mitigation techniques and ground water contaminant transport modeling. For information, contact Michael W. West, Technical Program Chairman, Michael W. West and Associates, Inc., 290 Bank Western Building, 8906 West Bowles Avenue, Littleton, CO 80123, (303) 972-1537.

October 8-11, 1989, American Society of Civil Engineers 1989 convention, held at the New Orleans Marriott Hotel, New Orleans, Louisiana. For information, contact ASCE, 345 East 47th Street, New York, NY 10017, (212) 705-7436.

October 16-20, 1989, Fourth international seminar, earthquake prognostics: hazard assessment, risk evaluation, loss reduction, and earthquake insurance, organized by the Institute of Seismology, State Seismological Bureau of China, and Earthquake Prognostics Research Group, Berlin, Federal Republic of Germany, to be held in Beijing, China. For more information, contact Prof. Wu Yilin, Secretary; Head, Crustal Deformation Department; Institute of Seismology, State Seismological Bureau of China; Xiao Hong Shan, Wuhan, China. Tel: (86 27) 8144626 or Prof. Andreas Vogel, Chairman; Head, Department of Mathematical Geophysics; Free University of Berlin; Podbielskiallee 60, D-1000 Berlin 33. Tel: (49 30) 838 63 68.

October 23-26, 1989, Fourth international conference on soil dynamics and earthquake engineering, held in Mexico City, Mexico. The objectives of this conference are to provide a forum for the presentation and discussion of new and advanced ideas in soil dynamics and earthquake engineering, and to encourage and enhance the role of mechanics, geology, and seismology in these areas. The conference provides an opportunity for the presentation of the work of applied mathematicians, scientists, and engineers involved in solving problems in the field of earthquake and geotechnical engineering. Focus topics include: the 1985 Mexican earthquake, probabilistic methods, engineering seismology, ground motion, site response, soil properties, soil dynamics, soil liquefaction, implications for seismic codes from lessons learned in the 1985 Mexican earthquake, soil structure interaction, piles, dams and structural dynamics. For further information, contact either Prof. A.S Cakmak, Department of Civil Engineering, Princeton University, Princeton, NJ 08544, (609) 452-4601; or Prof. I. Herrera, Instituto de Geofisica, Universidad Nacional, Autonomo de Mexico, Apartado Postal 22-582, 14000 Mexico, D.F., (905) 548-5892.

October 29 - November 1, 1989, Society for Risk Analysis annual meeting, held at the Nikko Hotel, San Francisco, California. This conference will include a special "super-session" on earthquake risk. For more information, contact the Society for Risk Analysis, 8000 Westpark Drive, Suite 400, McLean, VA 22101, (703) 790-1745.

October 30 - November 2, 1989, Buildings and earthquakes: technology, planning and implementation, co-sponsored by NCEER, the International Council for Building Research, Studies and Documentation, Working Commission W-73 on Natural Disasters Reduction (CIB W-73), the Ministry of Construction (MOC) of the People's Republic of China, and the National Science Foundation, will take place in Knuming, People's Republic of China. The symposium will focus on technology issues: health, building performance, building design/codes, the construction process, and hazard/risk/vulnerability; planning issues: preparedness planning, economic and social considerations; implementation issues: code and construction enforcement/regulation, institutional and management considerations. Published proceedings from the symposium will be made available. For more information, contact Jelena Pantelic, Assistant Director, NCEER, at (716) 636-3391.

November 16-19, 1989, Eighth national congress on seismic engineering and Seventh national congress

on structural engineering, held in Acapulco, Mexico. For information, contact Sociedad Mexicana de Ingenieria Sismica A.C., Camino Santa Teresa No. 187, Col Bosques del Pedregal, 14020 Mexico, D.F., telephone 573-80-11 ext. 141 and Sociedad Mexicana de Ingenieria Estructural, A.C., Av. Nuevo Leon No. 54-2 Piso, Col. Condesa, 06140, Mexico, D.F., telephone 553-85-68 amd 553-55-96.

April 9-11, 1990, Structural Stability Research Council's 1990 annual technical session and meeting, held at the Marriott Pavilion Hotel, St. Louis, Missouri. For further information, contact the Secretary, SSRC, Fritz Engineering Laboratory #13, LeHigh University, Bethlehem, PA 18015.

May 20-24, 1990, Fourth U.S. national conference on earthquake engineering, sponsored by the Earthquake Engineering Research Institute, NCEER, NSF, USGS, FEMA, ASCE, and NIST, held at the Palm Springs Resort Radisson and Convention Center in Palm Springs, California. The purpose of this conference is to address recent advances in earthquake engineering and earthquake preparedness and to respond to the needs of the future by providing a safer seismic environment. The participants at this meeting will discuss both the state-of-the-art in seismic risk reduction through earthquake engineering as well as the most current approaches to earthquake preparedness. Future trends and needs will also be addressed. For additional information, contact Dee Czaja, 4NCEE Office, Civil Engineering Department, University of California, Irvine, CA 92717, (714) 856-8693.

September 11-16, 1990, Ninth European conference on earthquake engineering, held in Moscow, USSR. This conference will provide an opportunity for earthquake specialists to acquaint conference participants with recent work on seismic hazards and to take part in discussions on developing trends in research and design. Sessions are planned to examine seismic risk and the development of seismic codes and standards; design of seismic-resistant buildings; strong ground motion and soil/structure interaction; experimental methods for testing structures; earthquake response of structures; engineering analysis of structural damage after stong earthquakes; repair and strengthening of structures after earthquakes; low-cost housing in seismic regions; reliability of lifelines in earthquakes; prediction of building behavior in earthquakes; lessening seismic risk in populated areas; and social and economic aspects of earthquake engineering. For information, contact 9ECEE Organizing Committee, Gosstroy USSR, Pushkinskaya 26, IO3828, Moscow, USSR.

March 11-15, 1991, Second international conference on recent advances in geotechnical earthquake engineering and soil dynamics, held in St. Louis, Missouri. Abstracts (500 words) are due by November 1, 1989. For more information, contact Shamsher Prakash, Conference Chairman, Civil Engineering, University of Missouri-Rolla, Rolla, MO, 65401, (314) 341-4489 or -4461.

August 21-23, 1991, Fourth international conference on seismic zonation, sponsored by the Earthquake Engineering Research Institute, will be held at Stanford University in Palo Alto, California. The conference will provide a stae-of-the-art assessment of the advances in seismic zonation integrating earth sciences, engineering, planning, social sciences, and public policy. It will emphasize results pertinent to disaster mitigation on local, regional and national scales at locations throughout the World. The recent tragic earthquakes in Mexico City (1985) and Armenia (1988) have emphasized the importance of using zonation techniques to reduce earthquake damage. These events raise numerous social science and public policy issues as well. Lessons learned from these events have led to multidisciplinary advances pertinent to reduction of life and property losses in future earthquakes. For further information, contact the Earthquake Engineering Research Institute, 6431 Fairmont Avenue, Suite 7, El Cerrito, CA 94530-3624, (415) 525-3668.

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