WASATCH FRONT FORUM

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NO. 1

EARTHQUAKE HAZARDS PROGRAM

The Wasatch Front Forum is published quarterly by the Utah Geological Survey. Information, contributions, questions, and suggestions concerning future issues may be sent to the Editor at the address listed below:

Janine L. Jarva, Editor, UGS, 2363 South Foothill Drive, Salt Lake City, UT 84109-1491, (801) 467-7970, fax 801-467-4070.

Gary E. Christenson, Associate Editor, UGS, 2363 South Foothill Drive, Salt Lake City, UT 84109-1491, (801) 467-7970.

Brian A. Cowan, Associate Editor, FEMA, 500 C. Street, S.W., Room 501, Washington, D.C. 20472, (202) 646-2821.

William J. Kockelman, Associate Editor, USGS, 345 Middlefield Road, MS 922, Menlo Park, CA 94025, (415) 329-5158.

Susan J. Nava, Associate Editor, University of Utah Seismograph Stations, 705 WBB, Salt Lake City, UT 84112, (801) 581-6274

James L. Tingey, Associate Editor, CEM, 1110 State Office Building, Salt Lake City, UT 84114, (801) 538-3400.

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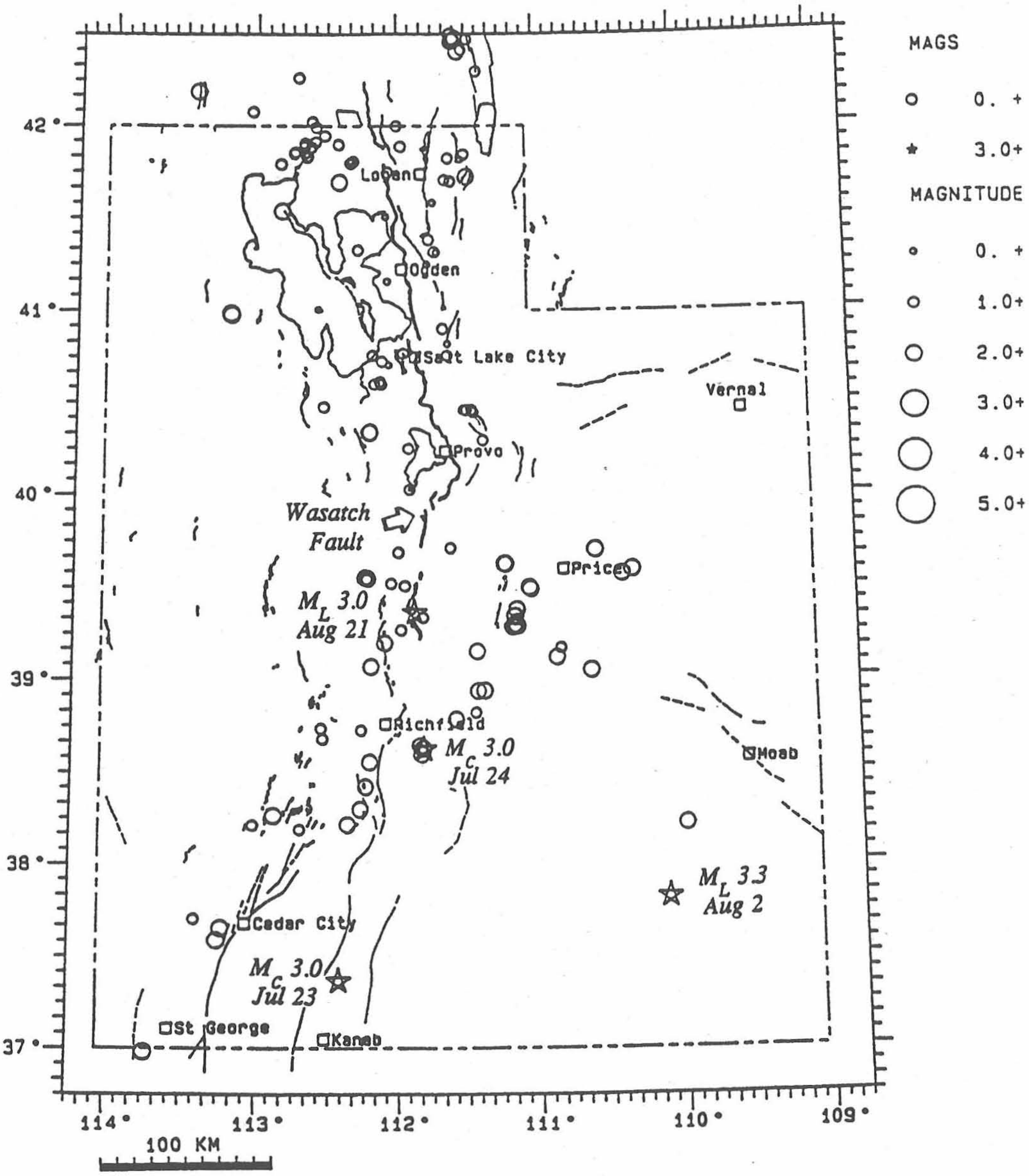
EARTHQUAKE ACTIVITY

IN THE UTAH REGION

July 1 - September 30, 1991

Susan J. Nava
University of Utah Seismograph Stations

During the three-month period July 1 through September 30, 1991, the University of Utah Seismograph Stations located 132 earthquakes within the Utah region (see epicenter map below). The total includes four earthquakes in the magnitude 3 range, specifically labeled on the epicenter map, and 60 in the magnitude 2 range. (Note: Magnitude indicated here is either local magnitude, M_L, or coda magnitude, M_C. All times indicated here are local time, which was Mountain Daylight Time.)



Large and/or Felt Earthquake			
● Mc 3.0	July 23	10:00 p.m.	6 miles SE of Alton (see N of Kanab)
● Mc 3.0	July 24	5:16 a.m.	9 miles NNE of Koosharem (see SE of Richfield)
● ML 3.3	Aug 2	1:59 p.m.	37 miles W of Blanding (see SW of Moab)
● ML 3.0	Aug 21	7:47 a.m.	10 miles NNW of Fayette (see N of Richfield)

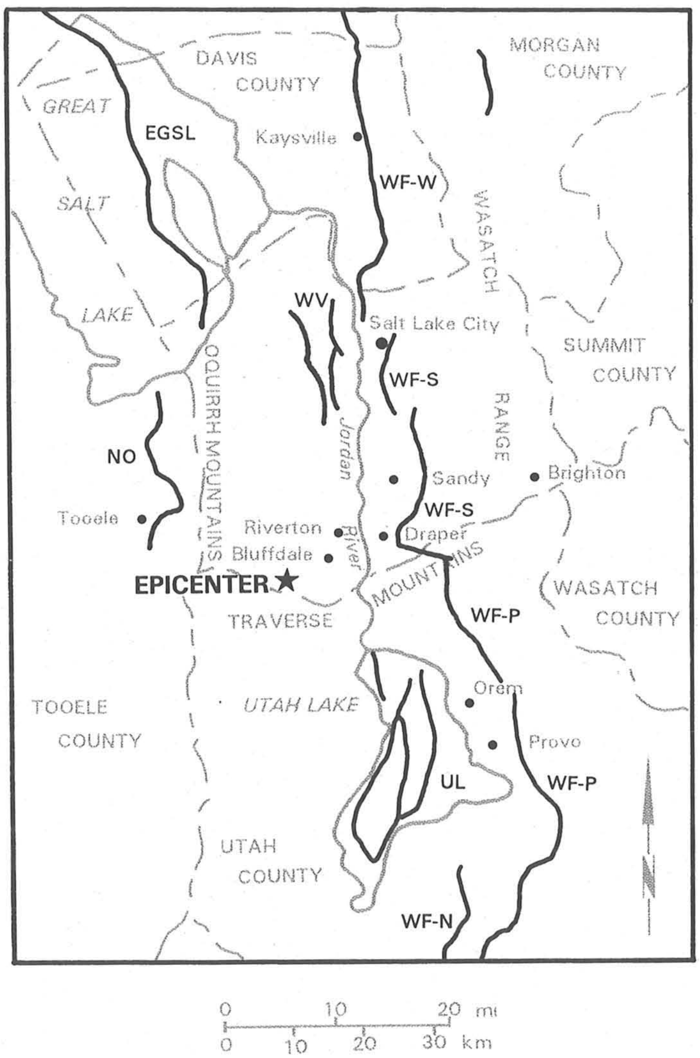
Additional information on quakes within the Utah region is available from the University of Utah Seismograph Stations.

EARTHQUAKE SHAKES SOUTHERN SALT LAKE VALLEY

by Gary E. Christenson and Susan S. Olig
Utah Geological Survey

At 7:42 a.m. on the morning of Monday, March 16, 1992, Salt Lake and northern Utah Valleys were shaken by a magnitude 4.2 earthquake. It was reported felt from Kaysville in Davis County to Orem in northern Utah Valley, and from Brighton in the Wasatch Mountains to Tooele, west of the Oquirrh Mountains (Susan J. Nava and Jim Tingey, verbal communications, March 31, 1992). Shaking was strongest in the southern Salt Lake Valley (Bluffdale, Riverton, Draper, Sandy), where news reports indicated some foundation and building cracks, sidewalk and patio cracks, and at least one report of falling bricks dislodged from a chimney. Most other reports were of rattling dishes, swaying of hanging objects, and rocking motions. Shaking was of very short duration, and in many cases was a single jolt.

The epicenter was located in the western Traverse Mountains near Camp Williams (figure 1). Early reports from the U.S. Geological Survey's worldwide seismic network indicated a



WF-W: Wasatch fault-Weber segment
WF-S: Wasatch fault-Salt Lake City segment
WF-P: Wastch fault-Provo segment
WF-N: Wasatch fault-Nephi segment
EGSL: East Great Salt Lake fault zone
WV: West Valley fault zone
NO: Northern Oquirrh fault zone
UL: Utah Lake faults

Figure 1. Location of the M_L 4.3 March 16, 1992 earthquake (40° 27.90' N, 112° 2.60' W) from the University of Utah Seismograph Stations and faults with evidence for displacement during the last 30,000 years (from compilation in preparation by Suzanne Hecker).

magnitude of 4.8, but later reports from the University of Utah Seismograph Stations' (UUSS) local network downgraded the magnitude to 4.2. They calculated a focal depth of 12.3 km (7.7 mi). Jim Pechmann and Gerard Schuster at the University of Utah had deployed 10 accelerometers in the Salt Lake Valley last fall under a 2-year grant from the National Science Foundation to look at low-strain (weak) earthquake ground motion in the valley. Records from these instruments are being retrieved and analyzed, and will hopefully yield information regarding ground motions in the valley. The level of ground shaking was too small to trigger any of the U.S. Geological Survey strong-motion instruments in the valley.

There are no mapped Quaternary faults in the epicentral area. Because of the relatively great focal depth, it is possible the earthquake was on the west-dipping Wasatch fault (assuming a fault dip of 29 to 35 degrees). If so, it is near the boundary between the Salt Lake and Provo segments of the fault. A preliminary focal mechanism determined by the UUSS indicates normal slip on either a northwest-striking plane dipping 38 degrees west or a north-northwest-striking plane dipping 56 degrees east (J.C. Pechmann, verbal communication, 1992). The west-dipping plane is consistent with the geometry of the Wasatch fault zone at this location.

The earthquake was generally too small to expect any significant geologic effects other than local rock falls and stream-bank caving. Utah Geological Survey (UGS) teams were dispatched to the epicentral area within a couple hours of the earthquake to search for possible geologic effects. The Traverse Mountains were combed for rock falls, landslides, and ground cracks, and the Jordan River and other areas of shallow ground water were searched for evidence of liquefaction. Nothing was found, as might be expected, but a later investigation by Kimm M. Harty (UGS) of a reservoir on the Jordan River at about 9400 South (20.0 km [12.4 mi] north of the epicenter) that was drained the morning of the earthquake turned up possible evidence of liquefaction in freshly exposed reservoir sediments. Many small holes, some surrounded by cones of sediment were found in the organic, silty, bottom sediment. Possible origins of these features include earthquake-induced liquefaction, expulsion of trapped gases, and de-watering of sediment following rapid draining of the reservoir. The investigation concluded that a combination of these processes, including liquefaction, probably formed the features.

Although this was not a large or damaging earthquake, it should yield some valuable ground-shaking information. It also served as an opportunity for many private companies and government agencies to test their emergency response and notification plans, which will now be revised and improved as necessary. Finally, it has served as a gentle reminder to everyone that we live in earthquake country, that earthquakes occur without warning, and that we must be prepared for the inevitable, large, damaging earthquake that will one day hit the Wasatch Front.

LEGISLATURE APPROVES FUNDING FOR STRONG-MOTION INSTRUMENTS

by Gary E. Christenson
Utah Geological Survey

As reported in the last issue of the Wasatch Front Forum, the 1992 Legislature considered a request from the Utah Geological Survey (UGS) and Department of Natural Resources for funding to buy strong-motion instruments. This request was approved, and an on-going appropriation from general funds of $75,000/year was added to the UGS base budget. The funding begins July 1, 1992. Additional one-time supplemental funds of $250,000 were also recommended by the Energy and Natural Resources Committee of the Legislature, but were not appropriated.

Although $75,000/year is a relatively modest amount, given the $1.6 million estimated by the Utah Policy Panel on Earthquake Instrumentation (UPPEI) for a minimum strong-motion program, this money will provide: (1) needed impetus to formally develop a cooperative program among the various groups involved in strong-motion instrumentation, and (2) seed money with which to pursue outside funding sources, both federal and private. The philosophy, goals, and make-up of the state strong-motion program will be determined over the next several months by the UGS and other groups. After that, technical data needed to select sites will be collected and compiled, sites and instruments will be chosen, and permission to install instruments obtained from site owners. It is projected that the first instruments will probably not be deployed until mid-1993 because of the extensive up-front planning needed. However, once the initial planning is done, deployment should proceed relatively quickly. We estimate that it will take about 20 years to achieve the minimum UPPEI-recommended program. However, this can be accelerated if additional funding is acquired.

This funding for strong-motion instrumentation is only a small fraction of that needed for modern earthquake instrumentation in Utah. The strong-motion program will eventually provide engineers with strong-motion records for use in designing earthquake-resistant structures, but the program will not provide information regarding earthquake size, location, and focal mechanism. For the last 3 years, the University of Utah Seismograph Stations, Utah Division of Comprehensive Emergency Management, and UGS have been actively pursuing funding for a more comprehensive program to upgrade all earthquake instrumentation, but have had little success because of the high price tag (about $3 million). While this $75,000 represents an important first step, it is just that. We will continue to strive to upgrade all components of Utah's aging earthquake-instrumentation program.

EPICENTER ACTIVITIES

by Bob Carey
Utah Division of
Comprehensive Emergency Management

The Earthquake Preparedness Information Center (EPICenter) is currently engaged in four projects dealing with seismic issues that are related to public concerns. These projects include 1) a study of the effects of changing the Uniform Building Code Seismic Zone from 3 to 4 on the Wasatch Front, 2) a booklet for Utah residential structure seismic improvement, 3) a study of potential hazards and damage associated with earthquake-related fault rupture and liquefaction in Salt Lake County, and 4) a new brochure on earthquake awareness and preparedness.

The study on the proposed change to the Uniform Building Code Seismic Zone map will objectively detail and address the conclusions regarding specific qualitative and quantitative impacts of the potential zone change. Topics to be covered in the study include: specific economic impacts on development and the housing trades; impacts on architects, engineers, developers, realtors, and the other construction trades; impacts on new building costs covering various building types; impacts on the change of use, renovation, or rehabilitation of existing buildings covering various building types; impacts on the resale value of existing buildings; impacts on new housing and other building starts; impacts on homeowners insurance including earthquake insurance rates; and the subjective and objective attitudes of people who may be impacted by such a change.

The Utah Residential Structure Seismic Improvement Guide will be written for use by homeowners, contractors, architects, engineers, and others involved in improving the earthquake resistance of dwellings. The Guide will specifically look at unreinforced masonry homes built between about 1906 to 1965. The Guide will briefly explain building dynamics related to earthquake forces and details specific techniques for improving seismic resistance in residential structures. It will contain numerous, clearly illustrated diagrams and pictures showing how these techniques can be applied.

The study of potential hazards and damage associated with earthquake-related fault rupture and liquefaction in Salt Lake County is a cooperative effort between the EPICenter and the University of Utah. The study will delineate possible hazard boundaries and mitigation strategies for a potential Richter magnitude 6.0 or larger earthquake using Geographic Information Systems techniques. The study will focus on the effects of fault rupture and liquefaction, studying how, why, and where these phenomena will occur and determine the extent of potential damage.

The EPICenter is overhauling it's awareness and preparedness document. The updated version will be in color with more illustrations and diagrams. The first draft of this document is nearing completion and after the review process is scheduled for distribution in September of this year.

GPS STUDY IN SALT LAKE VALLEY

by Bill Hardman
University of Utah

The University of Utah Department of Geology and Geophysics is initiating a project to measure deformation along the Wasatch fault in Salt Lake Valley using high-precision Global Positioning System (GPS) satellite surveying. Using state-of-the-art equipment and processing techniques, it will be possible to achieve three-dimensional millimeter-level precision with GPS. These new GPS results will be compared to conventional triangulation networks (established in 1933 and 1962) and laser triangulation measurements (established in 1972) in order to determine long-term strain rates for the Wasatch fault. The field measurement campaign will run from May 2-22, 1992 and will include participants from University Navstar Consortium (UNAVCO), the Utah Geological Survey, the Utah Division of Water Rights (Dam Safety section) and the Utah Department of Transportation.

USU/SALT LAKE COUNTY QUAKE VIDEO WINS AWARD

by Janine L. Jarva
Utah Geological Survey

The Utah Chapter of the American Planning Association has given an Award of Merit for Information Technology to three Utah State University (USU) faculty members and two Salt Lake County professionals for their videotape entitled "Earthquake Awareness and Hazard Mitigation." USU participants in the program were sociologist Gary Madsen, civil and environmental engineer Loren Anderson, and producer Steve Soulier from the Instructional Technology Department. Salt Lake County geologist Craig Nelson and Jerold Barnes, Director of the Salt Lake County Planning Division, were the other participants in preparing the video.

The 23-minute video presents much general information on earthquake hazards as well as specific information on hazards in Salt Lake County. It was created as a joint project of Utah State University and the Salt Lake County Planning Division with grant funds from the U.S. Geological Survey's National Earthquake Hazard Reduction Program. Technical production costs amounted to approximately $6,000 (a typical video program usually runs about $1,000 per minute). It represents the first local government earthquake education video in the United States. It is also the first collaborative effort to integrate information about planning, geological, engineering, and sociological aspects of Wasatch Front earthquake hazards. This innovative use of information technology has succeeded in translating complex technical information into an easy-to-understand format to educate and inform Utah citizens about earthquake hazards and risk in their own backyards.

The video explains why earthquakes occur and where they occur in the western United States. The program also discusses potential earthquake hazards and the types of damage that are likely to occur. It provides suggestions for how to reduce the risks, including building to code standards, strengthening existing structures, planning and zoning to control building in high-hazard zones, and preparing individually for earthquakes.

By helping people understand earthquake hazards and how they are likely to be affected, this program helps bridge the gap between "what will happen" and "what I can do about it." A better understanding by the public of the potential impacts posed by earthquake hazards means better acceptance and support of natural-hazard ordinances and promotion of responsible land-use policies as well as promoting personal preparedness.

The Salt Lake County Planning Division ((801) 468-2061) keeps 10 copies of the video available for free checkout by the public. Over

2,500 viewers in the past year including local government officials, members of community councils, individuals from school classes at all education levels, church groups, and neighborhood organizations have had an overwhelmingly positive response to the video. Interest in earthquakes and support for public policy steps such as building code and zoning improvements was found to be surprisingly high in a survey of Salt Lake County residents and community leaders conducted as part of the project (see WFF, 1989, v. 5, no. 4, p. 7-10 and WFF, 1988, v. 5, no. 1, p. 5-6.).

Because Utah has earthquake hazards over much of the state, not just in Salt Lake County, Drs. Madsen and Anderson obtained funds to produce a more generic version of the video, useful in communities throughout Utah. This video is available from the Utah Geological Survey as Public Information Series 10, Earthquake Awareness and Risk Reduction in Utah (see WFF, 1990, v. 7, no. 2, p. 5 for review.). Its cost is $6.00 plus $2.50 for shipping (Utah residents must add 6.25 % sales tax). Bulk discounts are available. For more information, call UGS at (801) 467-7970.

ATWOOD HONORED WITH JOHN WESLEY POWELL AWARD

by Janine L. Jarva
Utah Geological Survey

Each year the U.S. Geological Survey (USGS) presents the John Wesley Powell award to persons or groups outside the Federal Government for voluntary actions that result in significant gains or improvements in the efforts of the USGS to provide "earth science in the public service."

Genevieve Atwood, former Director of the Utah Geological Survey, received the 1990 Powell Award for Achievement in State Government. In a letter to Genevieve from Dallas Peck, Director of the USGS, she was cited for several significant accomplishments: "First, your role in the formation of the Utah Seismic Safety Advisory Council and your contributions to the successful completion of its work in a 4-year period led to the adoption of improved seismic safety policies in Utah. Second, your advice and council as a participant in our workshops and as a member of our Earthquake Advisory Panel were of great benefit to the National Earthquake Hazards Reduction Program. Third, as testimony of your management ability and scientific leadership, the cooperative 5-year program, which had the ambitious goal of assessing the earthquake hazards along the Wasatch Front and translating the results for use by planners, emergency managers, and engineers, has become a model for all to emulate. This exceptionally successful program was marked by: . . . trenching to determine earthquake recurrence intervals; a county geologist program; close collaboration with the Division of Comprehensive Emergency Management, University of Utah, Utah State University, our Office of Earthquakes, Volcanoes, and Engineering, and others; brown bag seminars; annual workshops; awards; improved instrumentation; and legislation. Finally, because of your vision and influence, Utah is now in an excellent position to be a leader during the 1990's in the International Decade for Natural Disaster Reduction and to take advantage of the unique opportunities this program will provide to deepen understanding of the scientific and social aspects of natural disaster reduction."

In appreciation for and in recognition of Genevieve's leadership of the Utah Geological Survey in cooperative programs with the USGS, the USGS presented her with the John Wesley Powell Award for State Government Achievement. Congratulations Genevieve!

A GIS-BASED ASSESSMENT OF EARTHQUAKE CASUALTY RISK: SALT LAKE COUNTY, UTAH

by Philip C. Emmi and Carl A. Horton
University of Utah

The purpose of this paper is to demonstrate a particular application in the general quest for techniques with which to model the interaction between geophysical and cultural systems. The particular application involves an assessment of risk to property, life and limb due to the earthquake ground shaking hazard affecting Salt Lake County Utah (population = 725,600). Salt Lake County is located on the Wasatch Front and the Wasatch Fault. It is at risk from over twenty-two different fault segments, each capable of an earthquake large enough to do damage to the urbanized areas of the County. At issue are the magnitudes and spatial distributions of losses due to earthquake ground shaking that can be expected probabilistically over short, intermediate and long exposure periods. Findings are based on five items of information - a microzonation of the earthquake ground shaking hazard, a building inventory with data on the value and structural frame type of taxable residential and commercial buildings, damage functions defining the seismic performance of buildings by frame type as a function of ground shaking intensity, data on the density of residential and employee populations, and earthquake casualty functions defining the risk to life and limb as a function of the degree of damage sustained by occupied buildings. The method of analysis is through the algebraic combination of digital map layers within a vector-based geographic information system. Triangular irregular network models originally generated at a 1:100,000 scale show expected distributions of casualties. Policy implications for seismic risk mitigation are also addressed. Research funding was provided by the U.S. Geological Survey through the national Earthquake Hazards Reduction Program.

ELEMENTS OF RISK ASSESSMENT

Hazards occur with potentially definable probabilities. Their impacts on humans and their cultural artifacts are central to an assessment of risk. Risk is a blanketing phenomenon: mathematically, it is represented by a curved surface in three-dimensional space whose x-, y-, and z-axes are defined by the three conceptual components of a probabilistic risk assessment detailed in Figure 1. The z-axis defines event intensities, such as the intensities of earthquake ground shaking or the intensities of structural damage, to which a target site is subject. Of course, high intensity events occur with lower probabilities than do low intensity events. The x-axis defines the length of the time period over which one wishes to regard a target site or population as being exposed. The longer the exposure period, the greater the probability of loss beyond negligible magnitudes. The y-axis defines the probabilities with which various event intensities are exceeded. Low intensity events are exceeded with higher probabilities than are high intensity events.

A probabilistic assessment of risk requires the simultaneous treatment of exposure period, event intensities, and exceedance probabilities. Thus, technical statements of risk are made by referring to a specific event intensity to which a target site or population is exposed with a standard probability of that intensity being exceeded over a given exposure period. In earthquake risk assessment, a practice has been established to refer to the intensities of events that have a 10 percent chance of being exceeded over 10-year, 50-year, and 250-year exposure periods.

For graphic representation, the three-dimensional phenomenon of risk is depicted in two-dimensional space by representing event intensities as a family of curves. Then exceedance probabilities for a given event intensity can be represented as a simple function of exposure time. Several functions are used to describe the relationship for each of several event intensities defined over a relevant range from low to high intensity (Figure 2).

For any given event intensity and exposure period, an exceedance probability can be found by reference to the appropriate risk curve. However, in practice, technical statements of risk are cast the other way around; that is, the 10 percent exceedance probability is presented as a standard and then one seeks to find the event intensities which have a 10 percent chance of being exceeded over 10-, 50-, and 250-year exposure periods. It is, nonetheless, useful to recall that when one refers to a given event intensity for which there is a 10 percent chance of exceedance over, say, a 10-year period that one is simultaneously referring to all probabilities on the risk curve for that intensity of event including, as is shown on Figure 2, a 50 percent chance of exceedance over a 70-year period and a 92 percent chance of exceedance over a 250 year period.

The short (10-year) exposure period is useful when thinking about personal and private

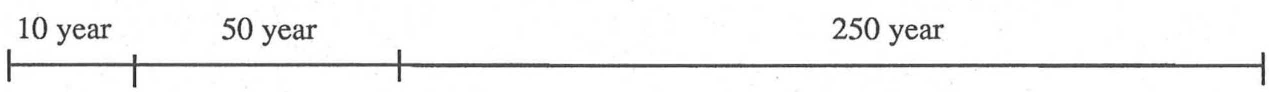
Ground Shaking Intensity

The severity of the event is measured using the Modified Mercalli Intensity Scale (MMI). This is a non-instrumental scale based on human perception and observations of structural damage and geophysical change.

I- Generally not felt
II- Felt on upper floors of buildings
III- Felt by most persons indoors
IV- Dishes, windows and doors are disturbed.
V- Small or unstable objects overturn.
VI- Felt by all, heavy objects moved, walls may crack.
VII- Considerable damage to poorly built structures, chimneys broken.
VIII- Chimneys fall, walls may deform. Heavy damage to poorly built structures, slight damage to others.
IX- Well designed structures deformed, frame buildings shift, underground pipes are broken.
X- Most masonry and frame structures detstroyed.
XI- Few if any masonry structures remain, damage is great to wood frame structures, bridges are destroyed.
XII - Near complete destruction.

Exposure Periods

The exposure periods of 10, 50, and 250 years are used. These periods roughly correspond to those one would want to consider when concerned with the internal contents of buildings (10 years), the structural integrity of ordinary buildings (50 years), and the integrity of lifelines, critical facilities and buildings housing hazardous materials.



Exceedance Probabilty

Since the timing and intensity of hazardous events cannot be accurately predicted, the timing and intensity of events can only be expressed in terms of the liklihood of their occurence. The exceedance probability is the liklihood that an event of a given intensity or greater will occur within a given exposure period. In seismology, it is customary to identify the event intensities which has a 10% exceedance probability over 10, 50 and 250 year exposure periods. Combining event intensity, exposure period and exceedance probability results in statements of the following format: At the Salt Lake International Airport, there is a 10% chance of ground shaking exceeding an intensity of X over a 50 year exposure period; correspondingly, there is a 90% chance that intensities will fail to exceed X over any 50 year period.

Figure 1. Conceptural components for an assessment of earthquake ground shaking intensities.

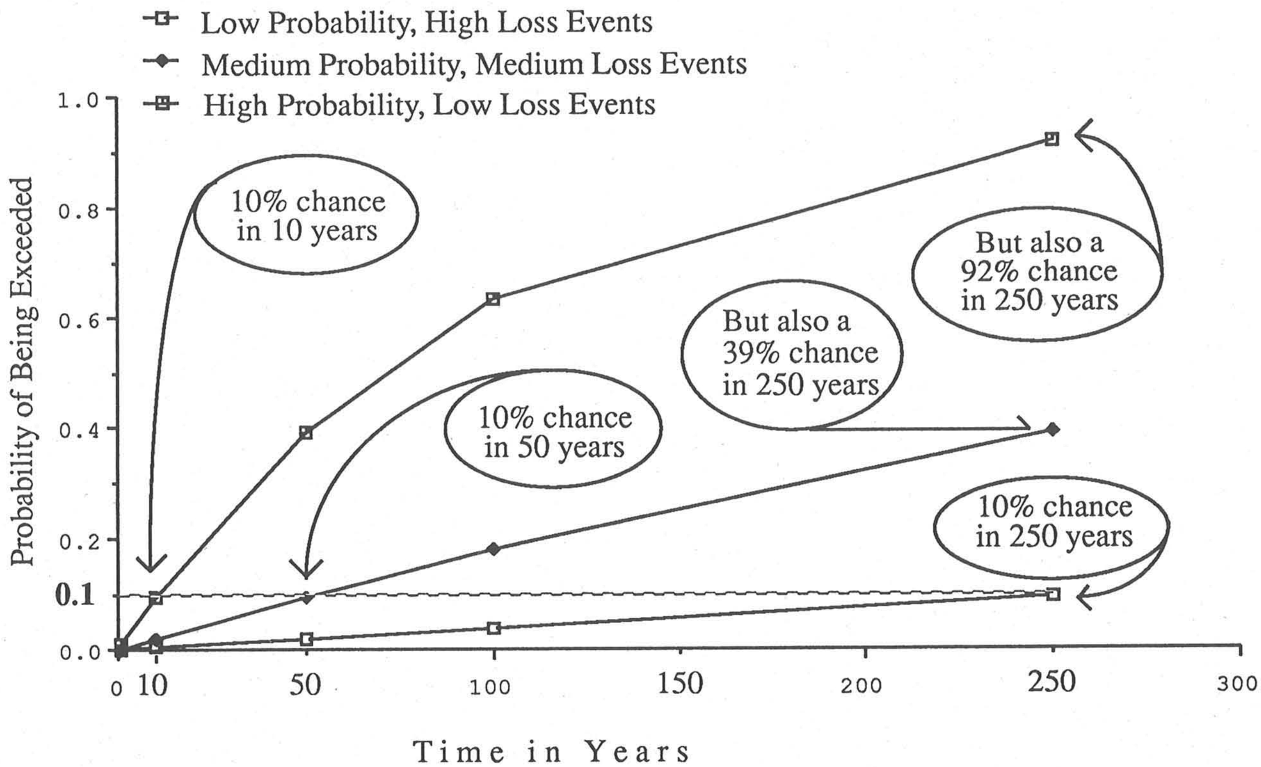


Figure 2. A family of equations describing the probabilities with which losses of different magnitudes might occur as a function of the length of the exposure period.

responses to earthquake hazards or about the internal contents of structures. The intermediate (50-year) period is useful when thinking about the structural integrity of most ordinary structures and about possible public policy responses. The longer (250-year)exposure period is useful when thinking about the design of high occupancy structures, critical facilities, hazardous facilities and lifelines. All three exposure periods are useful when thinking about issues of liability and earthquake hazard insurance.

DATA AND METHODS

Findings on risk to property are based on three items of information -- a mapping of the earthquake ground shaking hazard, a building inventory providing data on the value and structural frame type of taxable residential and commercial buildings, and damage functions defining the seismic performance of structures as a function of ground shaking intensity. A probabilistic assessment of the ground motion hazard in Salt Lake County for short, intermediate, and long exposure periods was taken from Emmi (1990). Damage functions were drawn from Report #13 of the Applied Technology Council (ATC-13, Rojahn, 1985). An inventory of residential and commercial buildings was developed for this study with data from property files maintained by the Salt Lake County Office of Tax Administration (Salt Lake County Data Processing, 1987).

Emmi's (1990) assessment of the ground shaking hazard for Salt Lake County is based on studies of seismic faults in the region and a probabilistic assessment of the acceleration which events on these faults could impart to bedrock underlying parts of Salt Lake County (Young et al, 1987). To this data were added estimates of the degree to which different soils throughout the Salt Lake Valley might modulate or amplify seismic energy moving from bedrock through depositional material. Ground shaking intensities (measured on the Modified Mercalli Intensity Scale) with a 10 percent chance of being exceeded over a 10-year period were found to vary from an intensity VI near the Lake Bonneville benches on the lower slopes of the Wasatch and Oquirrh Mountains to an intensity VIII+ on fine silts and clays of the Quaternary flood plain and delta complex at the valley center. Ground shaking intensities with a 10 percent chance of being exceeded over a 50-year period range from intensity VIII above the benches to X at the valley center. Ground shaking intensities with a 10 percent chance of being exceeded over a 250-year period range from intensity VIII+ above the benches to XI at the valley center.

Two separate building inventories were maintained -- one for residential structures and one for taxable commercial structures. Data on all residential structures in the County is maintained on tape in digital format. Each record refers to a single parcel of land. The spatial location of each parcel is identified by reference to a Sidwell code number which defines a parcel's location by township, range, section, quarter-section, block, and parcel number. Data on the quarter-section location, age, and value (measured as reconstruction cost new) for each of 158,790 residential dwellings in the study area was extracted from the master tape.

Data on the larger-class and smaller-class exterior wall types, as well as the number of wall sections, was also noted. This data was used in conjunction with the expertise of local structural engineers and building officials to classify dwellings into one of four structural frame types (Reaveley, 1988). The four structural frame types include wood frame, reinforced masonry, unreinforced masonry with a load-bearing frame, and unreinforced masonry. To protect the confidentiality of parcel-level data and to prepare the data for representation within a vector-based GIS, each parcel record was combined into a longer record where the common characteristic was each parcel's quarter-section location. These records were then entered into a GIS and linked by location to a digital map of the quarter-sections within the study area.

Commercial structures refer to taxable, privately held structures in commercial and industrial use. The only data on the 11,840 commercial structures in our study area which is maintained in machine-readable format is their Sidwell location. All other information is kept by the County Assessor on paper records. Thus, only a sample of the commercial structure records were used. The sample size was in excess of 2,000 records for a sampling ratio of 0.17. A stratified random sample design with 100 percent sampling of major commercial centers was used. Outside major commercial centers, a sample size of at least seven records per quarter-section was maintained. Sample data was extracted from records on the quarter-section location, frame type, age, replacement value, and use. This data was used to classify each structure into one of six frame types, each of which is recognized in ATC-13 (Rojahn, 1985). The six frame types included wood, light metal, reinforced masonry, braced steel, ductile concrete, and unreinforced masonry. For each quarter-section location, data on sample size and sampled structure values by ATC frame type was merged with data on the number of commercial structures per quarter-section. Sampling ratio for each frame type and location were computed, and estimates were made of the total value of structures by frame type at each location.

Also residing in the GIS were maps of the study area showing ground shaking intensities with a 10 percent chance of being exceeded over 10-, 50-, and 250-year exposure periods. This data was added to the residential and the commercial property inventories. Then selected were the damage function data provided in tabular form by Rojahn (1985) for those structure types found in the data inventory: these were fit statistically to continuous functional relationships, typically second-order polynomial equations. Structural replacement value data, ground shaking intensities, and seismic damage functions were used to compute the expected loss by location for each frame type within each exposure period. For each exposure period, the results for each frame type were added together to yield data and maps on the total magnitude and spatial variation in expected loss to residential and commercial structures from seismically induced ground shaking (Figure 3).

In addition to damage functions, ATC-13 provides tabular data on rates of major and minor injuries and loss of life as a function of the percentage of building replacement value lost. This data, together with our assessments of structural loss, was used to assess the risk to life and limb. The first step was to convert ATC's tabular data to a suite of continuous mathematical functions. Here, the mathematical form is typically a second-order polynomial of a double logarithmic transformation.

The amounts of expected structural damage to commercial and residential buildings was known, but, to be useful, functions on injury and loss of life require data on the number of employees occupying commercial buildings and the number of residents occupying dwelling units. Data by traffic zone was used to develop thematic map layers composed of residential and employee populations (Wasatch Front Regional Council, 1990). Uniform densities within zones were assumed. A geometric intersection function was used to combine population density data with property damage assessments. The resulting map contained over 5,000 distinct records with an attached data structure sufficient to permit calculation by polygon of the densities with which commercial and residential structures are occupied and the mean damage factor for each type of structure. This data was sufficient to calculate, in conjunction with seismic casualty functions, the volume, density, and spatial distribution of injuries and loss of life due to ground shaking. These numbers were computed as values with 10 percent exceedance probabilities over 10-, 50-, and 250-year exposure periods (Figure 4).

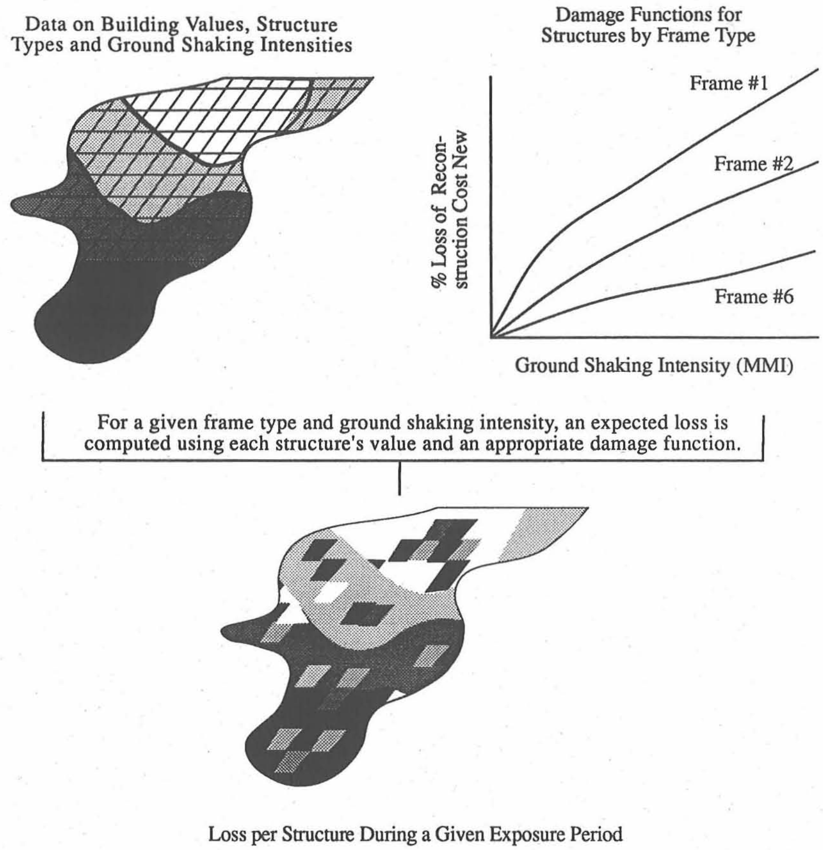


Figure 3. Estimated losses to residential and commercial structures.

FINDINGS

The replacement value of the residential structures in the study area equals $6.14 billion. The comparable figure for taxable commercial structures in $4.51 billion. There are an estimated 158,790 residential structures and 11,840 commercial structures in the study area. The degrees of loss due to the ground shaking hazard that have a 10 percent chance of exceedance over 10-, 50-, and 250-year exposure periods are shown in the Figure 5. The upper graph expresses degrees of loss as a percentage of the total value of the taxable residential and commercial stocks. The lower graph expresses loss in dollars of damage averaged per structure.

Variation in expected loss by structural frame type and location is considerable. Losses to favorably located wood frame, light metal, and braced steel structures are expected to remain below 10 percent even over the longer 250-year exposure period. Comparable figures for unfavorably located, unreinforced masonry structures and non-ductile concrete structures are put at 79 percent and 48 percent respectively. Variation in average loss to residential structures by frame type for each exposure period is shown in Figure 6. Figure 7 shows comparable data for commercial structures. These two charts point to the importance of unreinforced masonry (URM) structures as a significant source of risk to property. Among residential structures, URMs represent 18 percent of the value of the stock but equal between 45 and 39 percent of expected residential stock loss over the three different exposure periods. Among commercial structures, URM's represent 22 percent of the value of the commercial stock but equal between 71 and 61 percent of expected commercial stock loss over the three different exposure periods. Loss to URMs is a higher proportion of total loss over shorter exposure periods because the less seismically vulnerable buildings in the stock do not begin to show significant damage until subject to the greater degrees of ground shaking only expected over longer exposure periods. These findings suggest that important gains in seismic safety could be had by focusing efforts on unreinforced masonry structures.

The residential population in the study area numbers 725,621 persons. While in dwellings, the residential population risks injury and loss of life due to the effects of ground shaking on the structural integrity of dwellings. The degree of damage to the residential stock having a 10 percent exceedance probability over a 10-year exposure period is consistent with 45 or more major injuries and 14 or more fatalities (if, at the time, the residential stock is fully occupied). Over a 50-year exposure period, these figures increase to 690 or more major injuries and 200 or more dead. Over a 250-year exposure period, these figures reach 2,300 or more major injuries and 640 or more dead.

The density of casualties among the residential population is largely a function of the degrees of damage to residential properties, residential occupancy densities, and casualty rates sustained at various damage intensities. Data on the degrees of damage to the residential stock with a ten percent chance of being exceeded over a 50-year exposure period have been used, together with residential population data and seismic casualty functions, to show where major injuries are expected to concentrate. Figure 8 shows a three-dimensional perspective of this data

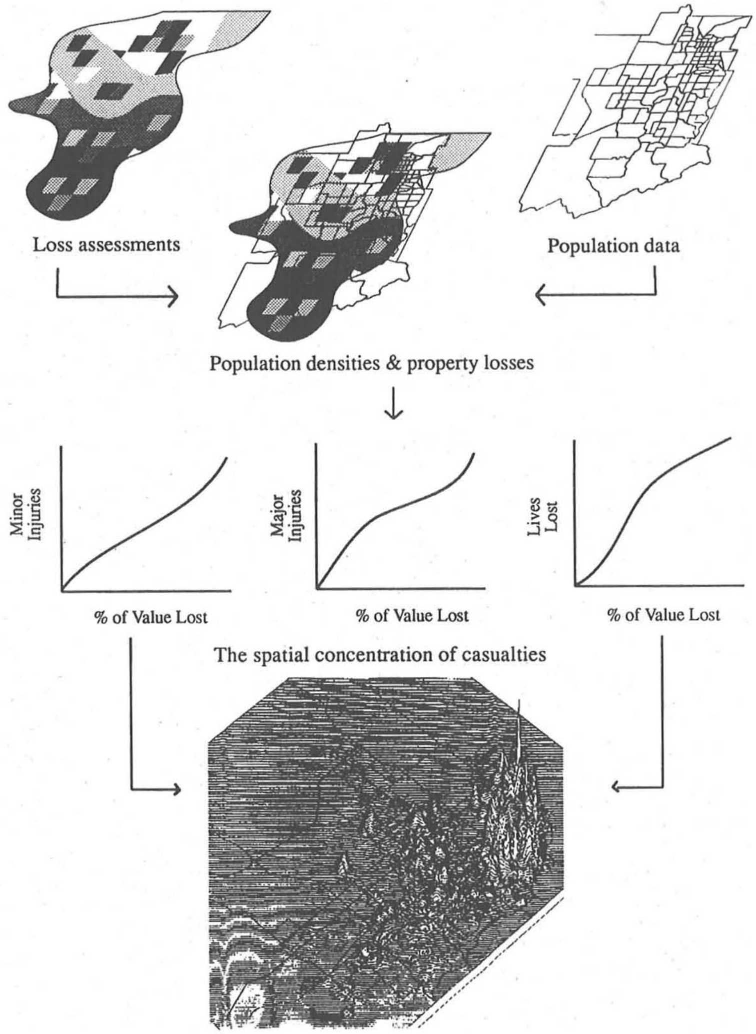


Figure 4. Using population and property loss data to estimate casualties due to earthquake ground shaking.

looking northwest from a high oblique angle. Clearly, injuries are concentrated in the northeast quadrant of Salt Lake City. Secondary clusters are shown in Murray, Rose Park, and Kearns. Though not shown, the relative patterns of spatial clustering for injuries and for loss of life to the residential population over 10- and 250-year exposure periods are nearly identical to those represented in Figure 8.

Forty-six percent of the residential population, or 331,230 persons, are employed. Assume that the non-taxable portions of the commercial stock performs seismically like their nearby taxable portions. Then the degree of damage to the commercial stock having a 10 percent exceedance probability over a 10-year

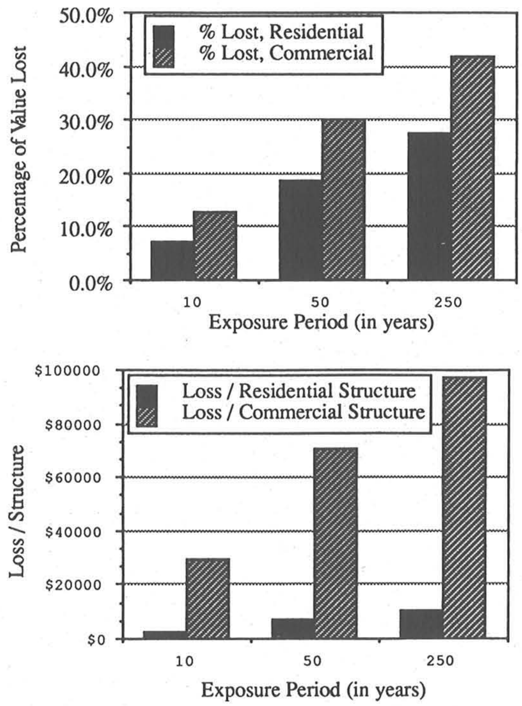


Figure 5. The degree of loss to property having a 10% chance of being exceeded over three different exposure periods.

exposure period is consistent with 80 or more major injuries and 20 or more deaths (if one assumes the commercial stock is fully occupied by the local employee population). Over a 50-year exposure period, these figures increase to 1,500 or more major injuries and 410 or more dead. Over a 250-year exposure period, these figures reach 4,700 or more major injuries and 1,300 or more dead.

These numbers are roughly two times the comparable figures for residential populations. These larger numbers are due to the greater intensities of ground motion to which our major commercial districts are subject. They are also due to the poorer seismic performance of many larger commercial buildings, especially older URMs. They are further due to the greater densities with which commercial buildings are occupied. These three factors outweigh the fact that the employee population is about one-half the residential population. The result is a greater risk to employee populations than to residential populations.

The density of injuries and loss of life

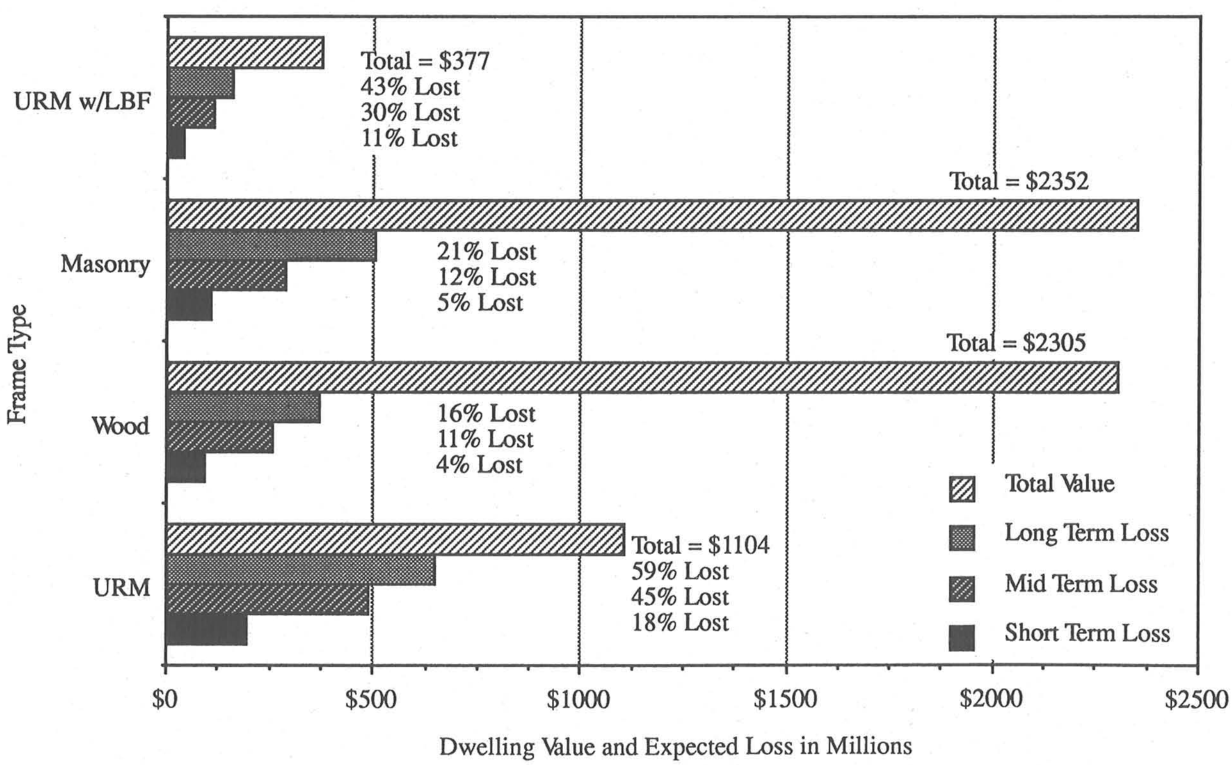


Figure 6. Expected losses to dwellings by frame type and exposure period.

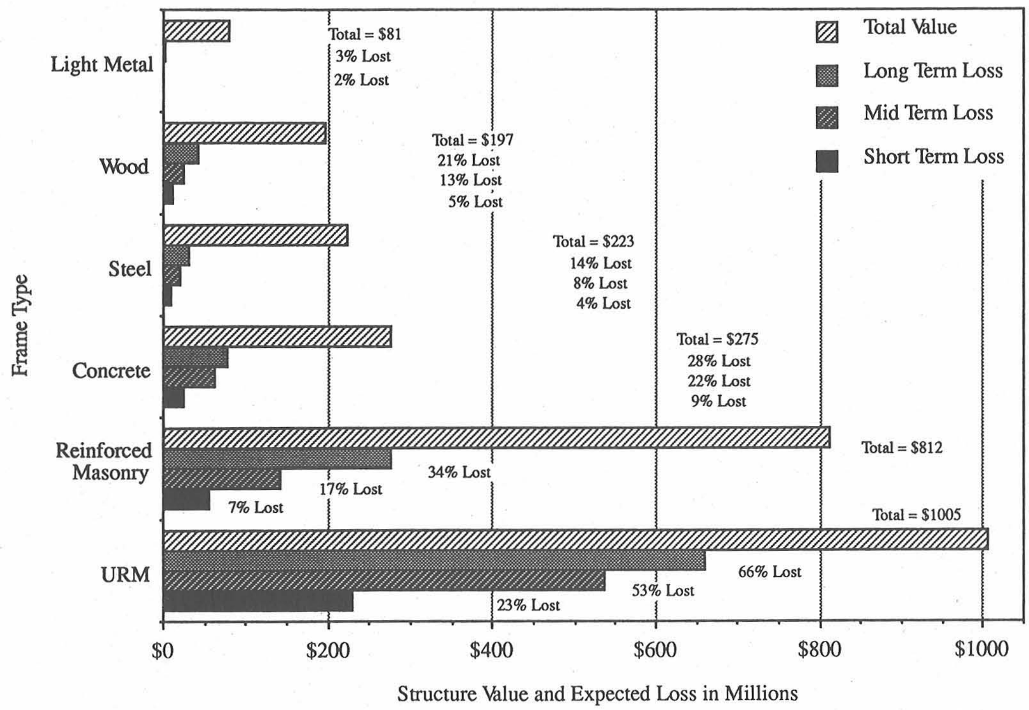


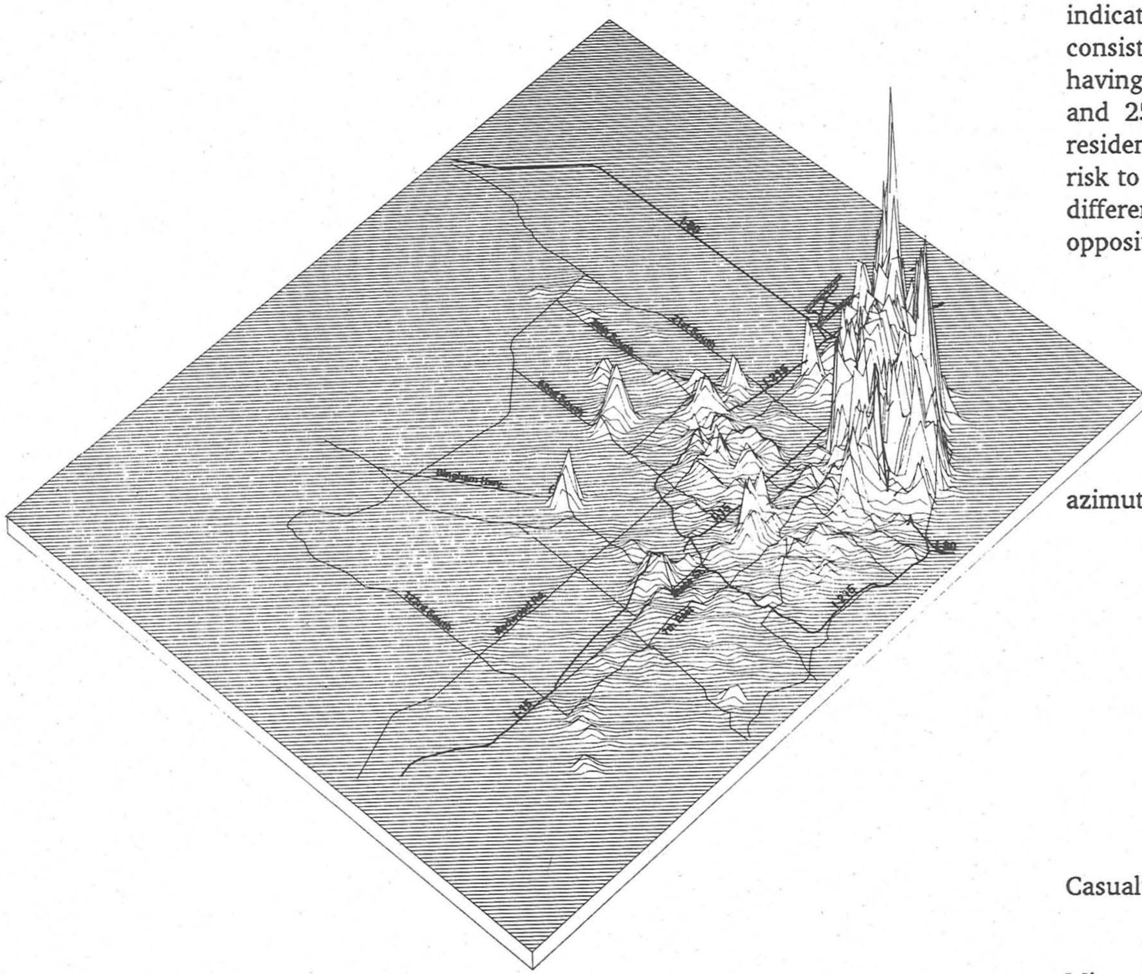
Figure 7. Expected losses to commercial structures by frame type and exposure period.

among the employee population is a function of the intensities of loss to commercial structures, the densities with which these structures are occupied, and the rates with which injuries and loss of life are sustained. Data on the degrees of damage to commercial structures having a ten percent chance of being exceeded over a 50-year exposure period has been used, together with employee population data and seismic casualty functions, to show where major injuries might concentrate. Figure 9 uses the same three-dimensional perspective used in Figure 8, but the vertical exaggeration is much lower (30 vs 600). Injuries are overwhelmingly concentrated in the Central Business District of Salt Lake City. Secondary clusters are aligned southward along State Street and east of the International Airport. Since the relative spatial distribution of injuries and loss of life is almost totally independent of the length of the exposure period, Figure 9 serves as a measure of the density of casualties to employee populations for both shorter and longer exposure periods.

An assessment of risk to both residential and employee populations is needed to incorporate consideration of the daily cycle of use to which residential and commercial structures are put. A probabilistic assessment of risk to the general population can be found by combining information on risk to each population with data on the intensity with which they each use residential and commercial structures. First, divide the population of 725,621 residents into two groups - 331,230 employees and 394,391 non-employees. (Assume that risk to students is similar to the risk to residential, non-employee populations while present in educational buildings.) Refer to Table 1 for assumptions about the proportion of time members of each group spend in commercial structures, residential structures, or in neither such structure. Then the risk to which both populations are subject is given by the weighted sum of the following four terms: 1) the risk to employees while in commercial structures, 2) the risk to non-employees while in commercial structures, 3) the risk to employees while in residential structures, and 4) the risk to non-employees while in residential structures. The resulting assessment of risk is given in Table 2.

MITIGATION POLICY OPTIONS

Preliminary implications of research results for hazard mitigation policies include implications for the existing stock and implications for future additions to the stock. Implications regarding the existing stock are



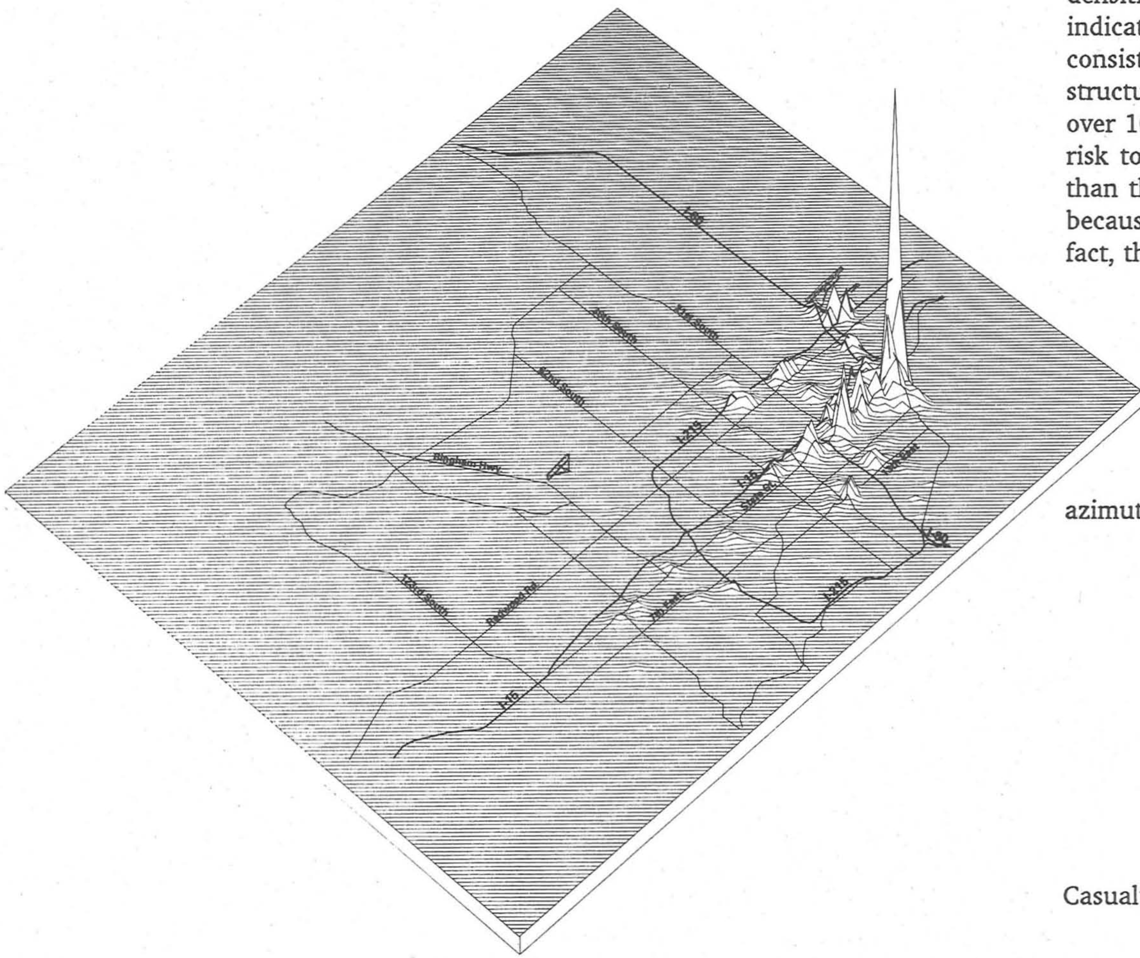
Casualty loss densities are consistent with data on expected damage to residential structures, residential occupancy densities, and seismic casualty rates. The table below indicates the casualty losses to residential populations consistent with the expected damage to residential structures having a 10 percent chance of being exceeded over 10, 50, and 250 year exposure periods. Note that the risk to residential populations shown here appears larger than the risk to employee populations shown in Figure 9 because of differences in the vertical exaggeration when, in fact, the opposite is true.

azimuth = 315° altitude = 60° vertical exaggeration = 600

Casualties to residential populations by exposure period.

	10 year	50 year	250 year
Minor Injuries	470	4,720	12,700
Major Injuries	45	690	2,300
Loss of Life	14	200	640

Figure 8. Concentrations of casualties to residential populations due to earthquake ground shaking: Salt Lake County, Utah.



Casualty loss densities are consistent with data on expected damage to commercial structures, employee occupancy densities, and seismic casualty rates. The table below indicates the casualty losses to employee populations consistent with the expected damage to commercial structures having a 10 percent chance of being exceeded over 10, 50, and 250 year exposure periods. Note that the risk to employee populations shown here appears smaller than the risk to residential populations shown in Figure 8 because of differences in the vertical exaggeration when, in fact, the opposite is true.

azimuth = 315° altitude = 60° vertical exaggeration = 30

Casualties to employee populations by exposure period.

	10 year	50 year	250 year
Minor Injuries	640	8,000	20,500
Major Injuries	80	1,500	4,700
Loss of Life	20	410	1,300

Figure 9. Concentrations of casualties to employee populations due to earthquake ground shaking: Salt Lake County, Utah.

Table 1. Assumptions about building occupancy.

Building Type	Population Category	
	Workers	Non-Workers
Commercial	35%	15%
Residential	55%	75%
Neither	10%	10%

Table 2. Expected casualties losses.

Category of Loss	Length of the Exposure Period		
	10 Years	50 Years	250 Years
Minor Injuries	644	7300	18901
Major Injuries	70	1245	4476
Loss of Lives	21	351	1093

drawn from results on the magnitude of and spatial variation in expected losses to property, life, and limb. Findings help define whether and in what manner the risk of loss from ground shaking constitutes a public concern.

Clearly, the magnitudes of loss to residential structures over intermediate and longer exposure periods are high enough to constitute a public concern, but what of the loss expected over the shorter exposure period? Expected losses to residential structures are, on the average, low enough ($3,014 per structure) to be an essentially private concern. However, the variation in loss among units by location and frame type is large enough to call into question this general conclusion. A more carefully drawn interpretation would hold that the losses to well-built dwellings in favorable locations are low enough to be considered essentially private concerns but that the losses to less well-built units in susceptible locations are large enough to merit a public response. For selected dwelling types in selected locations, the risk from ground shaking constitutes a public concern even in the short run. Comparable implications hold for commercial structures and for the risk of injury and loss of life.

The magnitudes of expected loss suggest that a public program of risk identification is in order. Such a program would help identify potentially hazardous buildings and clarify the responsibility for risk reduction and remedial action.

Earthquake insurance is a problem. Expected losses are often too high for self-insurance to work. The need for information about insurance options is great enough to warrant a program of public education about risk and insurance options. Ambiguities about tort liability also warrant a program of public education. Education programs could complement ongoing earthquake safety programs conducted by the Utah State Division of Comprehensive Emergency Management.

The large magnitudes of expected loss also imply the possibility of substantially reduced loss through policies promoting structural retrofits for seismically vulnerable buildings. Such policies are already in effect in Salt Lake City. Similar regulations responding to variation in both risk and the seismic performance of existing structures are needed in other local jurisdictions.

County population is projected to increase by 42 percent over the next twenty years. The number of dwelling units is projected to increase by 56 percent over the same period. The opportunity exists to reduce the local population's exposure to seismic risk through hazard mitigation policies applied to new construction. Salt Lake County's recent Natural Hazard Ordinance is a step in the right direction. It embodies principles that need to be used in the design of similar ordinances for all municipal jurisdictions in the County: it defines hazard areas by their relative degree of intensity, and it exacts a differing degree of scrutiny and commensurate mitigation measures depending upon the degree of risk associated with the proposed class and density of land use. Adopting natural hazard ordinances county-wide, perfecting hazard mitigation policy instruments, and establishing guidelines for their implementation constitutes an important part of the challenge to local public policy making.

The risk, the burden of response, and the possibilities for implementation are shared between the public and private sectors. Public/private cooperation is essential for clarifying the extent of risk, for sharing in the cost of mitigation, and for developing the tools for mitigation policy implementation. Public policies governing taxes, infrastructure location, land use planning, and building regulation can be utilized in ways that incrementally reduce exposure to seismic risks. Private-sector insurance and lending policies can also respond to the magnitude and spatial variation in seismically related risks. The evolution of tort liability can define with increasing clarity the distribution of responsibilities in the event of a damaging earthquake. Coordinating land use policies with local tax policies, infrastructure location decisions, building regulations, and insurance and lending policies are also important. Advances on each of these fronts are needed to develop an effective response to the risks detailed above.

ACKNOWLEDGEMENT

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REDUCING EARTHQUAKE HAZARDS IN UTAH: THE CRUCIAL CONNECTION BETWEEN RESEARCHERS AND PRACTITIONERS

By William J. Kockelman
U.S. Geological Survey

[This is the seventh and final excerpt from the publication entitled "Reducing Earthquake Hazards in Utah: The Crucial Connection Between Researchers and Practitioners" to be reprinted in the Forum (see WFF, v.6, no.1-2, p. 16-25, 1990; v.6, no. 3-4, p. 9-17, 1990; v. 7, no. 1, p. 6-13, 1990; v. 7, no. 2, p. 7-19, 1990; v. 7, no. 3, p. 9-17, 1991; and v. 7, no. 4, p. 8-20, 1992). Although the full paper will be included in USGS Professional Paper 1500-A, "Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah" currently in press, the editors felt the information to be timely and relevant enough to reprint herein. The complete paper is available as USGS Open-File Report 90-217 until the Professional Paper is released. Questions can be directed to Bill Kockelman at (415) 329-5158. Ed.]

EVALUATION AND REVISION

The last component in Utah's comprehensive earthquake-hazard reduction program is evaluating the effectiveness of the reduction techniques and revising them, if necessary. See figure 1 (see WFF, v. 6, no. 1-2, p. 17). Evaluating and revising the entire program as well as the other components -- studies, translation, and transfer -- may also be undertaken.

The evaluation component was included as a task in the national earthquake-hazard reduction program by Wallace (1974) and as recommendations of the California Joint Committee on Seismic Safety (1974) advisory groups. Evaluation has been emphasized in a review of ten cities' efforts to manage floodplains (Burby and others, 1988, p. 9), in the comprehensive tasks of a national landslide-hazard reduction program (U.S. Geological Survey, 1982, p. 44), and in the recommendations of the NEHRP Expert Review Committee (1987, p. 81-85).

In Utah, evaluation is included in the abbreviated recommendations for earthquake-risk reduction by the Utah Seismic Safety Advisory Council (1981), as an active item from a governor's conference on geologic hazards (Utah Geological and Mineral Survey, 1983), and as a task in the Utah work plan.

Importance

The effectiveness of each hazard-reduction technique varies with the time, place, and persons involved. Therefore, it is prudent to include a continuing systematic evaluation as part of any program for earthquake-hazard reduction. An inventory of uses made of the information, reports of interviews with the users, and an analysis of the results and responses will also result in identifying new users, innovative uses, as well as any problems concerning the research information, its translation, transfer, and use. The evaluation will be helpful, even necessary, to those involved in funding, producing, translating, transferring, and using the research information as well as managing a comprehensive program.

Performing the studies and then translating and transferring the research information is expensive and difficult because of the limited number of scientists and geotechnicians -- national, state, local, university, corporate, and consulting -- particularly when aligned with the needs of communities throughout the United States. The adoption and enforcement of an appropriate hazard-reduction technique is time-consuming, and requires many skills -- planning, engineering, legal, and political -- as well as strong and consistent public support.

Scarce financial and staff resources must be committed; necessarily persistent and difficult actions must be taken to enact a law, adopt a policy, or administer a reduction program over a long period of time. To discover later that the hazard-reduction technique selected is ineffective, unenforced, or its cost is greatly disproportionate to its benefits is not only disheartening but may subject those involved to criticism and withdrawal of financial support!

Few systematic evaluations have been made of natural-hazards reduction techniques, including earthquake-hazards reduction techniques. To my knowledge, no rigorous studies of the benefits-to-costs have been conducted. However, a few intensive evaluations have been made for flood, landslide, and other reduction techniques and programs which may be applicable to earthquakes.

The following examples of various evaluations are presented for introductory proposes. Their findings and recommendations, although beyond the scope of this report, will be helpful to Utahans in their selection of the most appropriate transfer and reduction techniques.

Evaluation of Reduction Techniques

Several reduction techniques (list 2) have been evaluated, problems identified, and improvements suggested; examples follow:

- o Preparing and implementing local seismic safety elements by the California Seismic Safety Element Review Committee (1985).
- o Lending, appraising, and insuring policies of the 12 largest home mortgage lenders in California by Marston (1984).
- o Disclosing surface fault rupture hazards to real-estate buyers in Berkeley and Contra Costa County by Palm (1981).

- o School earthquake safety and education project in Seattle and community outreach education centers at Memphis State University and Baptist College in Charleston, South Carolina, by Bolton and Olson (1987b).
- o Strengthening, redeveloping, abandoning, or demolishing unreinforced masonry-bearing-wall buildings in the cities of Long Beach, Santa Ana, and Los Angeles by Alesch and Petak (1986).
- o Strengthening masonry-bearing-wall buildings in the City of Los Angeles after the 1987 Whittier Narrows earthquake by Deppe (1988).
- o Retrofitted highway bridges after the 1986 earthquake in Palm Springs by Mellon (1986).
- o Mapping investigating, and regulating surface-fault-rupture zones by Hart (1986).

Translation and Transfer Techniques

Several translation and transfer techniques (list 4) have been evaluated, problems identified, and recommendations made; some examples follow:

- o Announcing earthquake prediction and forecast information by Turner and others (1981).
- o Disseminating earthquake education material to public and private schools by Bolton and Olson (1987a).
- o Disseminating earthquake-hazards information to public officials and private sector representatives in Charleston, South Carolina, by Greene and Gori (1982).
- o Using earth-science information in cities, counties, and selected regional agencies in the San Francisco Bay region by Kockelman (1975, 1976b, 1979), Kockelman and Brabb (1979), and Perkins (1986).
- o Translating and transferring information in the U.S. Geological Survey by Bates (1979) and O'Kelley and others (1982).
- o Conducting a workshop on preparing for and responding to a damaging earthquake in the eastern United States by Tubbesing (1982, p. 57-59).
- o Adopting ordinances based on guidelines and model ordinances developed and transferred by the Southeastern Wisconsin Regional Planning Commission (1987, p. 24).

Evaluation of Programs

Several earthquake-hazard reduction programs have been evaluated, problems identified, and revisions suggested; examples follow:

- o Community seismic safety programs before, during and after the 1983 Coalinga, California, earthquake by Tierney (1985).
- o Planning and implementing seismic-hazard mitigation in Alaska by Selkregg and others (1984).
- o Use of earthquake-hazard information for enlightenment, decisionmaking, and practice in California, Washington, Utah, South Carolina, Massachusetts, Idaho, Puerto Rico, Kentucky, Alaska, Missouri, U.S. Virgin Islands, and the eastern, western, and central United States by Hays (1988a).
- o National Earthquake-Hazards Reduction Program in the United States by the NEHRP Expert Review Committee (1987).
- o Effectiveness of the geology and planning program in Portola Valley, California, by Mader and others (1988, p. 55-61).
- o San Francisco Bay Region Environmental and Resources Planning Study by Arthur D. Little, Inc. (1975) and Brown (1975).
- o Land use and reconstruction planning after the 1971 San Fernando, 1964 Alaska, and 1969 Santa Rosa earthquakes by Mader and others (1980).
- o Seismic safety policies of local governments by Wyner and Mann (1983).
- o Structure design and behavior investigation after over 200 earthquakes by members of the Earthquake Engineering Research Institute (Scholl, 1986).

Various Evaluations in Utah

Several reduction and transfer techniques and programs in Utah have been evaluated, problems identified, and revisions suggested; examples follow:

- o Awareness and reduction of earthquake hazards by Perkins and Moy (1988, p. 9-19).
- o Multi-hazard mitigation project for Ogden and Weber County by Olson and Olson (1985).

- o Hazardous building abatement and sensitive lands development ordinances for Provo by May and Bolton (1986).
- o County Hazards Geologist Program by Christenson (1988).
- o Earthquake knowledge, risk perception, and mitigation priorities in Salt Lake County by Madsen (1988).
- o Adequacy of engineering geologic reports by Nelson and others (1987).
- o Perception of earthquake risk and support for regulations by Emmi (1987).

Reduction Techniques for Other Hazards

Several reduction techniques for other natural hazards have been evaluated, problems identified, and improvements suggested. Their evaluation methods, findings, and recommendations may be applicable to earthquake hazards; examples follow:

- o Disclosing hurricane-flood-hazards information to prospective home buyers in Florida by Cross (1985).
- o Providing state financial incentives for flood-hazard reduction to local governments by Burby and Cigler (1983).
- o Subsidizing flood insurance for property owners and their lenders by Miller (1977), Burby and French (1981, p. 294), and Kusler (1982, p. 36, footnote 55).
- o Notice, watch, and warning system for a potential 1978 Pillar Mountain landslide Kodiak by Saarinen and McPherson (1981).
- o Warnings for the 1980 Mount St. Helens volcano eruption by Saarinen and Sell (1985).
- o Planning and engineering response and recovery to 1982 debris flows at Love Creek (Santa Cruz County) and Inverness (Marin County) by Blair and others (1985).

Evaluation Methods

There are numerous methods for evaluating the effectiveness of an earthquake-hazard reduction program and its components -- studies, translation, transfer, and reduction. The above examples of evaluation indicate that these methods vary widely because of the human and financial resources available, the region involved, and the evaluator's interest, experience, and commitment. A thorough discussion of these methods is beyond the scope of this report, however, the following four will illustrate different levels of rigor:

1. Soliciting comments and suggestions from the producers, translators, transfer agents, and users of the research information.
2. Inventorying the documents where research information is cited and conducting systematic interviews with the users as to the types of information needed, used, problems with it, and improvements desired.
3. Comparing losses experienced in several areas having similar hazards and operating under the same type of reduction technique, but where different levels of requirements, administration, or enforcement are in effect.
4. Collecting and comparing the benefits and costs -- public and private -- of several different reduction techniques before and after a damaging earthquake in a jurisdiction where the geologic and tectonic environments are uniform.

The phrase "public and private costs" is used here to mean all direct and indirect costs and losses such as market value declines, road and utility repairs, emergency response activities, real-property damages, personal-property losses, deaths, injuries, tax revenue losses, industrial production losses, commerce interruption, and traffic delays. If it is demonstrated that the cost of a reduction technique is substantially less than the cost of anticipated damage we may conclude a favorable benefit-cost ratio for the use of the reduction technique.

The following will introduce the reader to several methods which address various topics and have different levels of rigor.

- o Use of earth-science products by city, county, and selected multicounty organizations by Kockelman (1975, p. 20-26; 1976b, p. 16-20; 1979, p. 27-31).
- o Natural-hazard reduction plan appraisal and cost/benefit analysis by Lohman and others (1988, p. 183-201).
- o Economics of landslide mitigation strategies by Bernknopf and others (1985)
- o Methods of cost-benefit analysis for different building codes and for upgrading existing structures by Pate and Shah (1980).
- o Testimony on the costs and housing impacts

of unreinforced masonry building rehabilitation before a state agency (Boswell, 1987).
- Benefit-cost ratios for reconstructing over 1,350 state-owned buildings by H.J. Degenkolb Associates (1981).

Comment

These examples of evaluation vary as to topic, area affected, type of technique, evaluator, and comprehensiveness. What they all have in common is a critical look at the success or failure of a program or of the translation, transfer, or reduction techniques used.

Even if adequate earthquake-hazard research information is available, presented in a language understandable by nontechnical users, effectively transferred, and properly used as is being done in Utah, the lasting effectiveness of each earthquake-hazard reduction technique (list 2) depends upon many other factors, usually outside the control of the researcher, engineer, planner, or decisionmaker. For example:

- Continued awareness and interest by the public.
- Careful revision (if needed) of enabling legislation by the state legislature.
- Accurate site investigations by qualified geologists and geotechnical engineers.
- Conscientious administration of regulations by plan-checkers, inspectors, and other building officials.
- Sustained support of inspection and enforcement officials by political leaders and their constituents.
- Consistent enforcement by government inspectors and attorneys.
- Judicious adjustment of regulations by administrative appeal bodies.
- Skillful advocacy by public regulators and plaintiffs, and proper interpretation by the courts.
- Genuine concern for individual, family, and community safety by real-estate buyers, developers, insurers, and lenders.

A consultant and expert witness, who is a former state geologist and former president of a state board of registration for geologists and geophysicists, reports in Slosson and Havens 1985) on his experience during the past 25 years:

> ... many of the problems and losses related to damage from earthquakes ... are directly or indirectly attributable to government's (local, state, and/or federal) inability and/or failure to enforce existing policies, codes, or regulations.

The benefits of evaluation and revision cannot be restated often enough, namely: to avoid an unconscionable waste of taxpayers' money and an usually irreparable loss of program managers' credibility.

CONCLUSION

The reduction of casualties, damages, and interruptions in Utah require that appropriate earthquake research be conducted and used by planners, engineers, and decisionmakers. A major part of any effective earthquake-hazard reduction program must be dedicated to the translation of research information and its transfer to nontechnical users as is being done in Utah.

The selection of earthquake areas or processes for study and performing the necessary scientific and engineering studies are only the first steps in any earthquake-hazard reduction program. If the information prepared is inadequate, inappropriate, not translated, not transferred, or not used, earthquake losses will increase; public and private monies will be wasted; and demands will be made on Federal, state, and local governments agencies for disaster relief and costly reconstruction.

Usually, public planners, engineers, and decisionmakers give most of their attention and resources to problems that are perceived to be serious or pressing. A 1977 study of 6 sites of varying political environments and attitudes toward seismic safety was conducted by Atkisson and Petak (1981, p. I39). They found at that time that the "seriousness attributed to earthquakes ... was consistently low in all sites." See figure 23. With the exception of floods (10th in Salt Lake City) and earthquakes (10th in Los Angeles), natural hazards at all sites were considered least serious -- 13 to 18 on the list of serious problems.

Recently, Perkins and Moy (1988, rpt. 3, table 4, p. 15) asked 15 city managers and county administrators in Utah to indicate what earthquake-

PROBLEM SERIOUSNESS SCORES IN THE SIX SITES

	CA		LA		MA		BOSTON		UTAH		SLC	
	X	RANK	X	RANK	X	RANK	X	RANK	X	RANK	X	RANK
INFLATION	7.6	1	6.6	4	7.5	4	7.1	5	7.2	1	7.5	1
POLLUTION	7.2	2	7.5	1	6.0	8	4.4	13	5.7	3	6.7	2
UNEMPLOY.	7.0	3	7.0	3	8.6	1	7.6	2	4.2	8	4.5	9
CRIME	6.9	4	5.9	8	7.3	5	7.3	4	5.5	4	5.6	3
WELFARE	6.9	5	7.1	2	8.2	2	7.4	3	5.9	2	5.0	6
EDUCATION	6.2	6	6.3	5	5.4	11	7.0	6	4.1	9	4.3	11
DRUGS	6.0	7	6.0	7	6.1	7	6.6	8	5.1	5	4.9	7
TRAFFIC	5.7	8	6.2	6	5.1	12	6.5	9	3.8	10	4.7	8
HOUSING	5.5	9	5.7	9	6.4	6	6.4	10	4.8	7	5.5	4
FIRES	5.3	10	4.2	14	6.0	9	5.9	11	3.4	12	3.7	12
TOO LITTLE GROWTH	5.0	11	5.0	12	7.8	3	7.7	1	3.7	11	3.3	14
RACE	4.7	12	4.4	13	5.4	10	6.9	7	2.6	16	3.4	13
QUAKES	4.6	13	5.5	10	1.2	18	1.3	18	3.2	15	1.2	16
PORNOGRAPHY	4.1	14	5.3	11	4.0	14	5.4	12	5.0	6	5.1	5
FLOODS	3.3	15	2.8	15	4.5	13	2.2	15	3.3	13	4.5	10
TOO MUCH GROWTH	2.5	16	1.6	16	1.3	17	1.3	16	3.3	14	3.0	15
HURRICANES	1.3	17	1.0	17	3.1	15	2.3	14	1.0	17	1.2	17
TORNADOES	1.1	18	1.O	18	1.5	15	1.3	17	1.0	18	1.0	18
X =	5.05		4.95		5.30		5.26		4.04		4.17	

Figure 23. Rankings by key public and private decisionmakers as to the relative seriousness of 18 state and local issues for 3 states and 3 cities from Atkisson and Petak (1981, table I-9, p. I-40).

hazard reduction techniques had been adopted in the past five years. According to Perkins (oral commun., 1989), 13 responded: all 13 had adopted at least one technique; nine had adopted a technique primarily for reasons of earthquake safety, and four of these had adopted four or more techniques. Obviously, Utahans are not only more aware of the earthquake hazard but are continuing to take appropriate actions.

The effective use of research information in Utah depends upon: (1) the users' interest, capabilities, and experience in hazard-related activities; (2) enabling legislation authorizing State and local hazard-reduction activities; (3) adequate detailed information in a readily usable and understandable form; and (4) the use of effective transfer techniques. These four elements exist in Utah. All that remains is for Utahns to continue to adopt appropriate reduction techniques and enforce them over many years.

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July 8-16, 1992, Developments in dynamic soil-structure interaction, NATO Advance Study Institute, held in Antalya, Turkey. For more information contact R.W. Clough, Department of Civil Engineering, UC Berkeley, Berkeley, CA 94720, (415) 642-2618, fax 415-643-5264.

July 19-25, 1992, Tenth World Conference on Earthquake Engineering, held in Madrid, Spain, one week prior to the 1992 Olympics in Barcelona, Spain. The official language of the conference will be English. Abstract deadline is April, 1991 and the deadline to receive papers is May, 1992. Individuals wishing to receive the first, and subsequent, announcement circulars should request them from 10WCEE, Steering Committee, c/o Tilesa, Londres 39 - 1 B, 28028 Madrid, Spain.

August 24 - September 3, 1992, International Geological Congress, held in Kyoto, Japan. The 1992 congress will include sessions on the IDNDR, remote sensing of natural hazards, evaluation of seismic hazards, prediction and reduction of geologic hazards, and hazard mapping. Abstracts were due December 1, 1991. For a conference circular with information on abstract submission and registration, contact the Secretary General, 29th IGC, P.O. Box 65, Tsukuba, Ibaraki 305, Japan, 81/298/54-3627, FAX 81/298/54-3629.

October 3-9, 1992, Association of Engineering Geologists Annual Meeting, held in Long Beach, California. For information contact John Byer, Kovacs-Byer, Inc., 11430 Ventura Boulevard, Studio City, CA 91604, (818) 980-0825.

October 26-29, 1992, Geological Society of America Annual Meeting, held in Cincinnati, Ohio. Abstracts are due July 8, 1992 and should be submitted to the Abstracts Coordinator, GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301. For general information about the annual meeting, contact GSA Meetings Department at the same address, (303) 447-2020.

April 19-21, 1993, ASCE Structures Congress '93, Structural engineering - leadership in natural hazard mitigation, held in Irvine, California. For information, contact R. Villaverde, Secretary, Steering Committee, Structures Congress '93, Department of Civil Engineering, University of California at Irvine, Irvine, CA 92717.

June 1-6, 1993, Third International Conference on Case Histories in Geotechnical Engineering, held in St. Louis, Missouri. One of the themes of this conference will be geotechnical earthquake engineering. Abstracts were due by February 28, 1992. For further information on the conference or the call for papers, contact Shamsher Prakash, Conference Chairman, III CHGE, 308 Civil Engineering, University of Missouri-Rolla, Rolla, MO 65401, (314) 341-4489, fax 314-341-4729.

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