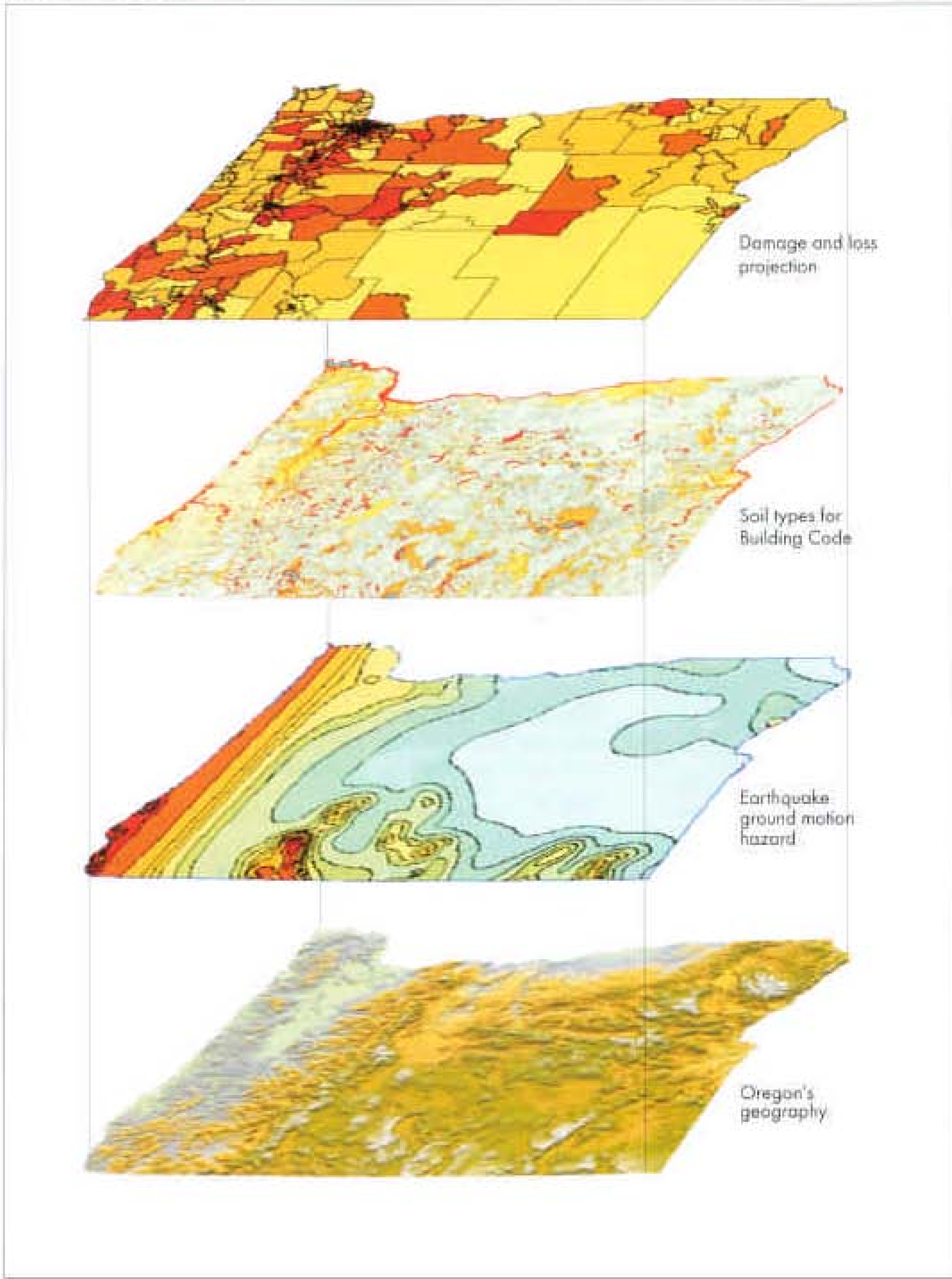
OREGON GEOLOGY

published by the
Oregon Department of Geology and Mineral Industries

VOLUME 60, NUMBER 6 NOVEMBER/DECEMBER 1998



IN THIS ISSUE:

Oregon earthquakes: Preliminary estimates of damage and loss

Oregon Schools Seismic Safety Project

Tillamook County Hospital honored for seismic strengthening technology

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(ISSN 0164-3304)

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Published bimonthly in January, March, May, July, September, and November by the Oregon Department of Geology and Mineral Industries. (Volumes 1 through 40 were entitled *The Ore Bin*.)

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Style is generally that of U.S. Geological Survey publications. (See USGS Suggestions to Authors, 7th ed., 1991, or recent issues of *Oregon Geology*.) Bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Include names of reviewers in the acknowledgments.

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Cover illustration

Four maps are shown that make up individual layers of the GIS-based analysis associated with the damage and loss assessment discussed in the article beginning on page 123. Highest hazard is indicated by most intensely red coloring.

Klamath Falls—five years after the earthquakes

Klamath County and the Oregon Department of Geology and Mineral Industries (DOGAMI) sponsored a commemorative celebration on October 30, five years after the earthquakes that shook the region on September 20, 1993. The event took place at the new Klamath County Government Center and Courthouse, a structure that had suffered damage in 1993 but has been rebuilt and expanded since. Among the participants were the three County Commissioners, Chairman Bill Garrard, Steve West, and Al Switzer and representatives of DOGAMI, county government, organizations related to emergency management, the local engineering community, the Federal Emergency Management Agency, Oregon Emergency Management, and the U.S. Geological Survey.

Remembering the experience of the 1993 quakes and what has been achieved in recovering from them served as a basis for looking to the future of this region, which will certainly have earthquakes again.

After a morning meeting moderated by Klamath County Emergency Manager Bill Thompson, an afternoon field trip led the participants to an example of a fault exposure within the urban boundary of the City of Klamath Falls; to Modoc Point, where the danger of earthquake-induced landslides is particularly obvious; and to Ponderosa Middle School, where ground subsidence related to both geothermal groundwater extraction and faulting has caused damage to buildings.

DOGAMI is currently involved in several earthquake-related activities in the Klamath Falls area. In concert with county, state, and federal agencies, the department is creating earthquake hazard maps for Klamath County; damage and loss assessments and a slope stability assessment for the county; and a partial building inventory that especially targets unreinforced masonry (URM) structures. □

U.S. POSTAL SERVICE STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION

Publication title: OREGON GEOLOGY, no. 600040; filing date 9-25-98. Published bimonthly, 6 issues per year, annual subscription price $10. Address of publication office, publisher's business office, editor, and owner: State Office Building, 800 NE Oregon St., #28, Portland, OR 97232-2162. Publisher and owner: Oregon Department of Geology and Mineral Industries; editor: Klaus K.E. Neuendorf. No bondholders. Circulation during last 12 months/of single issue, respectively: Net press run 2,500/2,500; paid circulation est. 50/50; mail subscriptions 1,192/1,184; total paid circulation 1,242/1,234; free distribution 169/169; free distribution outside the mail 318/314; total free distribution 487/483; total distribution 1,729/1,1717; not distributed 793/763; return 0/0; total 2,500/2,500; percent paid and/or requested circulation 72/72. I certify that the statements made by me above are correct and complete.

Klaus K. Neuendorf, Editor

Oregon earthquakes: Preliminary estimates of damage and loss

by Yumei Wang, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Oregon is especially vulnerable to earthquake hazards because of its location on the Pacific "Ring of Fire" and its plate-tectonic setting. To better understand public needs that involve earthquake hazards and the health, safety, and welfare of the state's population, the Oregon Department of Geology and Mineral Industries (DOGAMI) has conducted earthquake damage and loss estimation studies for Oregon. Results from this study can be used to help increase earthquake awareness, stimulate mitigation and risk reduction action (e.g., strengthening facilities), support and set policies and legislation, and develop emergency response plans.

This paper reviews the modeling of estimated damage and losses for (1) a magnitude 8.5 (M8.5) subduction zone earthquake off the coast of Oregon and (2) 500-yr return interval probabilistic ground motions for the entire state. The two data sets included detailed geologic information contained in a statewide Uniform Building Code (UBC) soil map.

Results from the statewide estimates show that Oregon is unprepared for earthquake hazards. A large subduction zone earthquake will cause over ten billion dollars of building damage alone. Losses from the 500-yr ground motions are almost three times the amount of the subduction zone earthquake. Most of the damage costs are located in western Oregon, where the expected ground motions and population density are higher than in eastern Oregon.

BACKGROUND

Recent earthquakes have caused damage in Oregon, and future damaging earthquakes are inevitable. Damage and losses from recent worldwide earthquakes have devastated local communities due to the vulnerable developments in those areas. The earthquakes of Kobe, Japan (1995, M6.9); Northridge, California (1994, M6.7); and Loma Prieta, California (1989, M7.1), caused about 100, 42, and 10 billion dollars, respectively, in direct economic losses.

Oregon has numerous potential earthquake sources that can produce strong ground shaking and damage to the communities. The Cascadia subduction zone fault, which lies just offshore, can produce a M8.5 earthquake or perhaps even larger (Yamaguchi and others, 1997). Inland faults, such as the Mount Angel fault that triggered the M5.6 Scott Mills ("Spring Break") quake in 1993 and the West Klamath Lake fault zone that, during the same year, triggered the two Klamath Falls main shocks of magnitudes 5.9 and 6.0, are examples of crustal earthquake sources. About 30 and 10 million dollars in damage were inflicted by the Scotts Mills and Klamath Falls earthquakes, respectively. As a result of growing awareness of earthquake hazards in Oregon, steps are being taken to better understand and prepare for the threat of a large-magnitude Cascadia subduction zone earthquake as well as for inland earthquakes. The present study is one such example. Another example is that more stringent building code requirements have been adopted. In 1993, the Seismic Zone designation for western Oregon was raised from 2B to 3 in the Uniform Building Code (UBC); in October 1998, the central and south coast area was raised from Zone 3 to Zone 4.

Balancing the public safety benefits with limited funds can be more effective with a better understanding of the economics at stake, that is, the possible damage and losses. With these estimated losses, planners and policy makers have useful information to guide public policy issues to reduce future loss of life and property. Various interest groups can reduce the possible impact in specific areas by targeting information in the predicted damage and loss estimates. Although loss estimations have inherent uncertainties and limitations, the results can be viewed as important information. Both regional and local mitigation can be implemented based on these results. For example, this work may help formulate state legislation that focuses on improving the state's building inventory database and furthering the state's risk reduction efforts. Or, this work may help instigate or substantiate the seismic evaluation or strengthening of older school buildings in a local school district.

METHOD

The damage and loss estimates for future earthquake ground shaking were obtained using HAZUS97 software produced by the Federal Emergency Management Agency (FEMA) (National Institute of Building Sciences, 1997; Risk Management Solutions, Inc., 1997). HAZUS97 has recently become available to the public and operates through a geographic information system (GIS) to display earthquake hazard information, inventory data, and estimated losses in the form of both maps and tables. This software was developed through a cooperative agreement between FEMA and the National Institute of Building Sciences (NIBS). Risk Management Solutions, Inc., of Menlo Park, California, developed the software under the oversight of a panel of recognized experts in their respective fields. The software was calibrated with past earthquakes and pilot-tested in two communities in the nation, one of them Portland, Oregon The estimates discussed here are only samples of the possible types of damages and losses that can be modeled with this software.

The method involves modeling an earthquake source and attenuation relationships or ground motions, determining the damage based on fragility curves, which indicate the probable degree of damage, and then quantifying the losses on the basis of the inventory database. The procedure yields quantitative estimates of losses in terms of direct costs for repair and replacement of damaged buildings, direct costs associated with loss of function (e.g., loss of business revenue, relocation costs), casualties, displacement of people from residences, and removal of debris generated. In addition, functionality losses for emergency and essential facilities and components of transportation and utilities are quantified.

In HAZUS97, the ground motions are characterized by spectral response based on a standard spectrum shape, peak ground acceleration (PGA), and peak ground velocity (PGV). Elastic response spectra (5-percent damping) are used to characterize ground shaking. The spectra have the same standard shape defined by a PGA value at zero period, spectral response at a 0.3-second period in the acceleration domain, and spectral response at a 1.0-second period in the velocity domain. The shape is adjusted for site amplification and distance from the source to the site.

Building damage is estimated by applying fragility curves, capacity curves, building type, seismic design level, and ground response. Owing to the limited amount of building inventory data and the regional approach of this method, model groups of buildings (or population groups) are evaluated on a census tract basis. Single buildings at specific locations are not evaluated. The damage functions include (1) building fragility curves that describe the probability of reaching or exceeding different damage states at a given peak building response; and (2) building capacity ("pushover") curves that are used with damping-modified demand spectra to determine peak building response. The damage state probabilities are used as inputs to estimate induced physical damage and direct economic and social loss, such as casualties, monetary losses, and shelter needs. For this study, all buildings were placed at low seismic design level.

Loss estimates are based on (1) structural repair costs depending on extent of damage, model building types and occupancy classes; (2) nonstructural repair costs for all occupancy classes, both acceleration-sensitive damage (from the shock waves themselves) and drift-sensitive damage (from the structure's deformation in response to the shock waves); (3) value of building contents as a percentage of building replacement value for all occupancy classes; (4) contents damage as a function of damage state; (5) annual gross sales or production for agricultural, commercial, and industrial occupancy classes; (6) business inventory as a percentage of gross annual sales for agricultural, commercial and industrial occupancy classes; and (7) business inventory damage as a function of damage state for agricultural, commercial and industrial occupancy classes. A large amount of default economic data is included in the method to develop the direct economic losses.

Study region and source data

The study region is the state of Oregon, with a population of just over 3 million people. The highest population concentration is in the western part of the state, especially in the Willamette Valley.

HAZUS97 evaluates the study region by census tracts. Oregon has a total of 727 census tracts. HAZUS97 includes numerous databases from a variety of sources, including information on geography, demographics, economics, buildings, and lifelines. Demographics and residential buildings are obtained from the 1990 data of the United States Census Bureau. Nonresidential data, such as commercial and industrial structures, are obtained from 1995 reports by Dunn and Bradstreet. HAZUS97 estimates a total building exposure (i.e., replacement value, not market value) of about $160 billion for the state.

The soil map (see second map from top on cover illustration) includes the six soil categories defined in the 1997 Uniform Building Code (UBC) (Wang and others, 1998). UBC soil types were estimated on the basis of published digital regional geologic and agricultural soil maps, previously mapped material properties, and shear-wave velocities measured on the unit or similar units. In order to conduct the HAZUS97 analyses, soil profile type S_F (soil requiring site-specific evaluation) has been reclassified into type S_E (soft soil). Also, the soil map is modified within HAZUS97 to a census tract basis for analyses of most buildings.

Except for the soil data, this study has relied on the HAZUS97 default databases. Therefore, the results provide relative, not absolute, estimates of losses. Statistical uses, for example at the county level, are appropriate.

Earthquakes modeled

Two earthquake types were evaluated: (1) a (deterministic) M8.5 Cascadia subduction zone earthquake and (2) 500-yr return interval probabilistic bedrock ground motions.

M8.5 Cascadia earthquake

The M8.5 earthquake is produced by a rupture along the Cascadia margin that lies generally parallel to Oregon's coastline. The M8.5 model assumes a rupture length of 480 km and a hypocentral (or focal) depth of 10 km. The fault is modeled as a low-angle reverse (or thrust) fault with an equal bi-directional rupture pattern (i.e., a rupture extending equally in both directions from the center of the quake). For this model, we used the Project 97 Pacific Northwest attenuation relationship available in HAZUS97, which is based on earlier work by Frankel and others (1996). This relationship applies to rock sites and uses 50 percent each of (1) the attenuation curves for deep and subduction zone earthquakes by Youngs, Chiou, Silva and Humphrey (1997) and (2) the attenuation curves by Sadigh, Chang, Abrahamson, Chiou, and Power (1993). Attenuation ("lessening") relationships are used to calculate the peak ground acceleration (PGA) which decreases with distance from the earthquake.

After the PGA is calculated, deterministic ground motions (spectral responses) are calculated from algorithms stored in HAZUS97 relational databases. Those values are then amplified by factors based on local soil conditions as determined by the soil map described earlier. The ground motions in the general building damage analyses are computed at the centroid (the mathematical "middle") of a census tract.

Output ground motions for PGA (Figure 1), peak ground velocity (PGV), and spectral acceleration (S_A), spectral velocity (S_V), and spectral displacement (S_D) at periods of 0.3 and 1.0 seconds are provided on a census track basis. The maps include soil influence and thus represent motions at the ground surface.

500-yr return interval ground motions

The ground motions modeled are taken from the U.S. Geological Survey (USGS) earthquake ground motion hazard map with a 10-percent probability of exceedance in 50 years (Frankel and others, 1996; see cover illustration, second layer from bottom). This map represents single median ground motions for the region over the next 475-year period, commonly referred to as the "500-year" return interval. These probabilistic ground motions include peak ground acceleration (PGA), peak ground velocity (PGV), and spectral velocity (S_V) at 0.3 seconds and 1.0 seconds.

The USGS probabilistic maps, which were used as the basis for design value maps of the 1997 *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (Building Seismic Safety Council, 1997), show the ground motion levels with specified probabilities of being exceeded in a 500-yr return interval. Ground shaking motions with a 500-yr return interval are equivalent to a 10-percent probability of being exceeded in 50 years or, in other terms, an annual frequency of exceedance of 0.002. The probabilistic approach incorporates all fault sources capable of generating earthquake ground shaking and includes earthquake wave propagation from the sources to include all areas

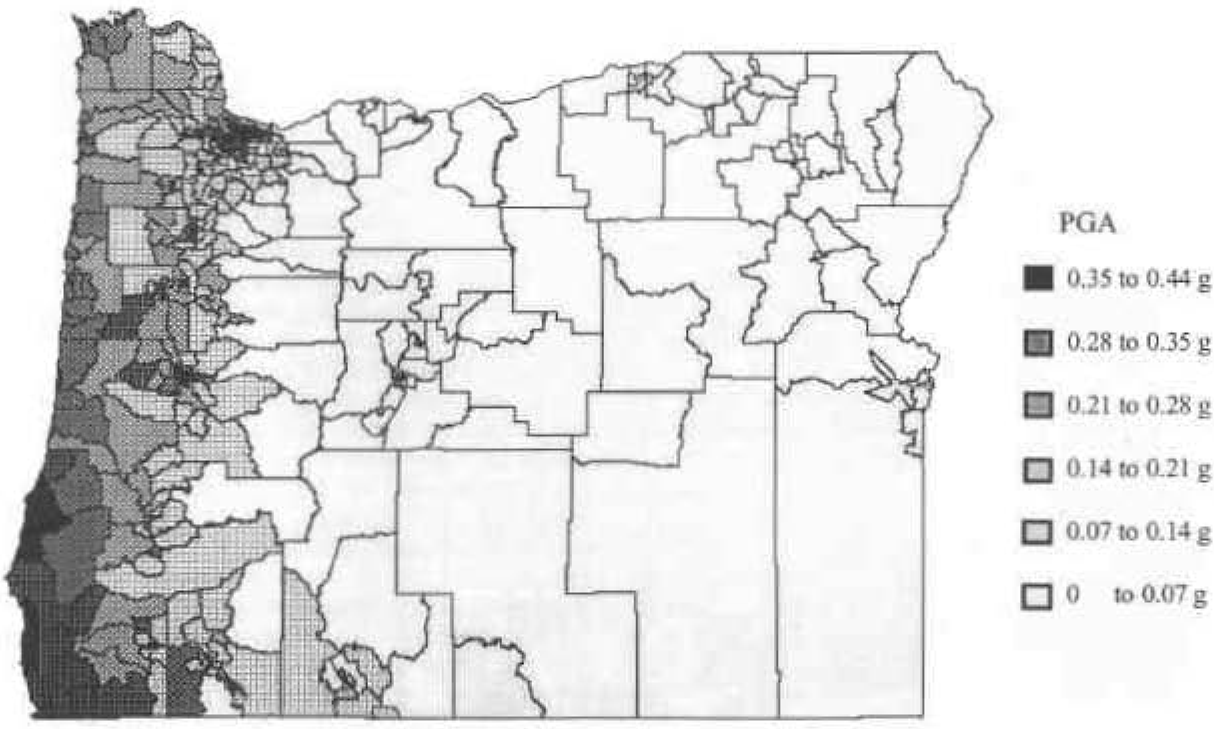


Figure 1. Peak ground acceleration (PGA) for M8.5 Cascadia subduction zone earthquake on census tract basis. Convention of yellow-to-red coloring for progression from least to most dangerous rendered here as light-to-dark shading.

of Oregon. Thus, for each given site, the ground motion levels (peak ground accelerations) for all the earthquake locations and magnitudes in the vicinity are represented. Probabilistic maps provide an equal representation of likelihood of various levels of ground motions across the state.

Output ground motions for PGA (Figure 2); PGV; and S_A, S_V and S_D at periods of 0.3 and 1.0 seconds are provided on a census track basis. These maps include soil influence and thus represent motions at the ground surface.

The damage and loss estimate from the 500-yr model does not represent a single earthquake occurrence nor does it provide an uppermost estimate of losses. This is because the 500-yr map does not represent a single earthquake event. Also, smaller earthquakes that produce lower levels of ground shaking and are not represented on the probabilistic map are expected to occur and produce additional damage and loss not estimated in this study. Thus, if all expected earthquakes were included, the cumulative losses over the next 500 years would be higher than the estimated losses reported in this study.

Discussion of method

From a user's standpoint, HAZUS97 is a powerful tool to assess earthquake losses. A user can obtain a sense of the order of magnitude of damage and loss for the items reported in Figures 3 and 4, such as casualties and building losses.

HAZUS97 has a number of limitations. A notable example of a limitation is that HAZUS97 evaluates most building losses on a census tract basis. However, many geologic hazards are not easily portrayed and represented by a single census tract value. Other geology-related limitation examples are, e.g., that user-supplied ground motion models are not able to incorporate user-specified soil maps and that certain specifics of fault ruptures, such as fault dip and oblique senses of motion, cannot be modeled.

One significant limitation is that the default inventory database is incomplete. Thus, the estimated losses are necessarily in error. For example, although there are numerous unreinforced masonry structures (URMs) in Oregon, the currently available default building database does not include any URMs. Thus, the reported damage and loss estimates may seriously under-represent the actual threat. In studies that incorporate URMs in the inventory, the death and injuries toll is likely to increase significantly due to the nature of catastrophic failure of URMs.

Other examples of incomplete building inventory involve schools and emergency facilities. A simple case study for Klamath County shows the default inventory

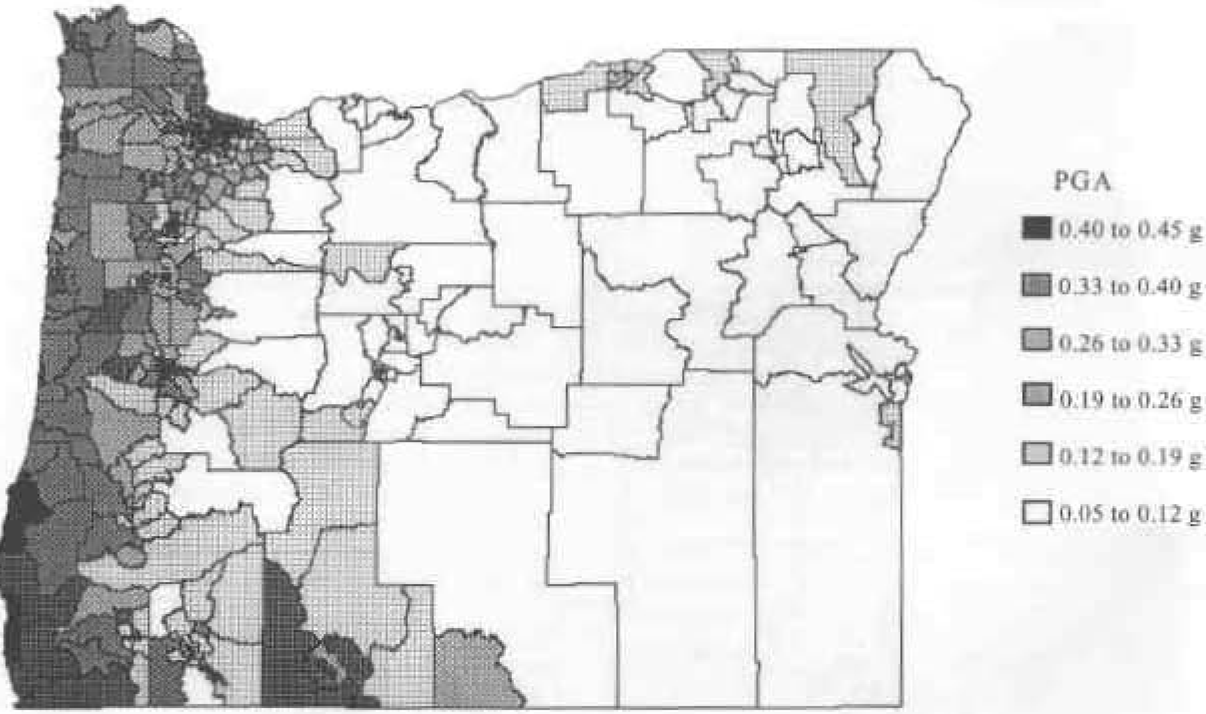


Figure 2. Peak ground acceleration (PGA) for 500-yr return interval ground motions on census tract basis. Convention of yellow-to-red coloring for progression from least to most dangerous rendered here as light-to-dark shading.

to have eight schools and five emergency facilities. The actual count is 34 schools and 35 emergency facilities (William Thompson, Klamath County Emergency Services, personal communication, 1998). For emergency facilities, a simple statewide assessment was made. The default database includes 438 emergency facilities, whereas the assessment shows 792. Thus, assuming the counts were approximated in a similar manner, the default database underestimated the emergency facility count by almost a factor of two. An underrepresentation of schools and emergency facilities could produce erroneously results, especially involving damage and functionality. The default lifeline inventory also appears to be seriously incomplete and requires user input to achieve a sense of damage and loss values.

HAZUS97 has several programming errors, which are being corrected in later versions. One example is obtaining a probability of 1 when summing the computed damage states for buildings by building type in the summary reports. Also, the summary reports, at times, failed to print the results from several counties. In addition, conducting successive runs without creating a new scenario is problematic in that previously calculated numbers are reported as the new calculations. A related problem seems to arise with the export function for individual study regions.

RESULTS

The statewide results from the two modeled earthquakes, the M8.5 Cascadia earthquake (referred to below briefly as "the M8.5") and the probabilistic 500-yr return interval ground motions (referred to below briefly as "the 500-yr") are summarized in Figures 3 and 4, respectively. Estimates include social losses (deaths and injuries, displaced households, short-term shelter needs) (Figures 3a and 4a), monetary building losses (Figures 3b and 4b) and number of buildings damaged (Figures 3c and 4c). Also discussed below are the functionality of emergency facilities, schools, transportation systems (highway and airport economic loss and bridges damage state and functionality), and communication facilities; and the debris generated.

The method used generates estimated loss results for both the direct physical damage and the direct economic loss resulting from damage to the inventory in the study region. Damage and loss results are reported for each census tract and may be viewed as maps or tables produced by HAZUS97. Additional information from this study, such as summary tables on a county basis, ground motion maps, and other information that is not discussed in this text can be found in Wang (1998). Certain results from the 500-yr ground motion model are not provided here, because they are not appropriately applied to real-world conditions: they cannot be experienced in a single event. Thus, for example, the functionality of schools, emergency facilities, transportation systems, and the like is not reported for the probabilistic model.

Social losses

Social losses including casualties, displaced households, and short-term shelter needs are reported below. The census data are used to help estimate these losses.

Deaths and injuries

Deaths and injuries are estimated at 7,700 and 24,600 for the M8.5 and 500-yr, respectively (Figures 3a and 4a). These values are divided into four severity levels: Severity 1 is described as "Injuries requiring only basic medical aid but no hospitalization"; severity 2 is described as "Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life-threatening status"; severity 3 is described as "Injuries that pose an immediate life-threatening condition if not treated adequately and expeditiously. The majority of these injuries are a result of structural collapse and subsequent collapse [trapping -*ed.*] or impairment of the occupants." Severity 4 is described as "Instantaneously killed or mortally injured."

For the M8.5, about 6,300 are estimated at severity 1; 1,200 at severity 2; 200 at severity 3, and 100 at severity 4. For the 500-yr, about 19,700 are estimated at severity 1; 3,800 at severity 2; 600 at severity 3; and 500 at severity 4.

For both models, estimated casualties are highest for a 2 p.m. earthquake. These casualties can be attributed mostly to damages of commercial and industrial buildings. The number of casualties varies depending upon time of day of the earthquake, building type, occupancy class, and traffic pattern. Casualties in residential buildings are higher at 2 a.m. and 5 p.m. earthquake events.

Displaced households

The displaced households are estimated at 17,300 and 47,400 for the M8.5 and 500-yr, respectively (Figures 3a and 4a).

Short-term shelter needs

The short-term shelter needs are estimated at 12,400 and 32,700 for the M8.5 and 500-yr, respectively (Figures 3a and 4a).

Buildings

Building damage

States of structural and acceleration-sensitive and drift-sensitive nonstructural damage to the general building stock are generated for each occupancy class and for each building type according to five damage states: None, Slight, Moderate, Extensive, and Complete. Reported values include: (1) building damage by count by general occupancy, (2) building damage by general occupancy, and (3) building damage by building types for low seismic design level.

(1) *Building damage by count by occupancy class.* For the M8.5, the building damage by count of buildings is estimated at 717,000, 130,000, 75,000, 35,000, and 19,000 for damage states None, Slight, Moderate, Extensive, and Complete, respectively. From these damage state results, about 885,000 buildings are estimated to be green-tagged (i.e., the building has been inspected, and there are no restriction on use or occupancy), 55,000 are estimated to be yellow-tagged (i.e., off limits to unauthorized personnel), and 37,000 are estimated to be red-agged (i.e., unsafe, not to be entered or occupied) (Figure 3b).

For the 500-yr, the building damage by count of buildings is estimated at 425,000, 253,000, 182,000, 75,000, and 41,000 for damage states None, Slight, Moderate, Extensive, and Complete, respectively. From these results, about 769,000 buildings are estimated to be green-tagged, 129,000 are estimated to be yellow-tagged, and 79,000 are estimated to be red-tagged (Figure 4b).

(2) *Building damage by percent by occupancy class.* For the M8.5, building damage by general occupancy is estimated at 51, 11, 13, 9, and 5 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively. For the 500-yr, building damage by general occupancy is estimated at 24, 13, 19, 18, and 16 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively.

(3) *Building damage by percent by building type.* For the M8.5, the building damage by building types assuming low seismic design levels for all buildings were estimated at 41, 10, 15, 12, and 7 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively. For the 500-yr, the building damage by building types assuming low design levels for all buildings were estimated at 18, 10, 19, 20, and 19 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively.

Direct economic losses to buildings

The total direct economic losses to buildings are estimated at $11.8 and $31.6 billion for the M8.5 and 500-yr, respectively. These losses include both capital stock losses and income losses.

For the M8.5, capital stock losses are $2.03 billion for structural damage, $4.31 billion for nonstructural damage, $0.95 billion for contents, and $0.03 billion for inventory damage. Income losses are $1.21 billion for relocation, $1.35 billion for capital-related loss, $1.20 billion for wages, and $0.73 billion for rental income (Figure 3c).

For the 500-yr, capital stock losses are $5.05 billion for structural damage, $12.22 billion for nonstructural damage, $2.76 billion for contents, and $0.06 billion for inventory damage. Income losses are $3.04 billion for relocation, $3.76 billion for capital-related loss, $2.94 billion for wages, and $1.80 billion for rental income (Figure 4c).

Essential facilities

In HAZUS97, police stations, fire stations, and emergency operation centers are considered to be essential facilities. These are facilities that provide services to the community and should be functional after an earthquake.

The functionality of emergency facilities and schools is estimated for the day following the earthquake. For the M8.5, functionality of 65 percent for emergency facilities and 66 percent for schools is estimated. As mentioned above, because the 500-yr ground motions cannot be experienced in a single event, the functionality of essential facilities for the entire state is not reported.

Transportation

Transportation include highway, railway, light rail, bus, port, ferry, and airport systems. Selected results are provided for highways, including major and urban roadways and bridges; airports, which consists of control towers, runaways, terminal buildings, parking structures, fuel facilities, and maintenance and hangar facilities; and bridges.

Direct economic loss for transportation

For the M8.5, the direct economic loss is estimated at $0.37 billion for highways and $0.12 billion for airports. For the 500-yr, the direct economic loss is estimated at $1.26 billion for highways and $0.32 billion for airports.

Damage states and functionality for bridges

For the M8.5, the highway bridge damage is estimated at 67, 21, 9, 1, and 7 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively. The estimated functionality on the day of the earthquake is 72 percent. For the 500-yr, the highway bridge damage is estimated at 31, 32, 26, 4, and 6 percent for damage states None, Slight, Moderate, Extensive, and Complete, respectively.

Utilities

Utility systems include potable water, wastewater, oil, natural gas, electric power, and communication systems. Results are provided for the communication systems, which consist of broadcasting stations from the default inventory. For the M8.5, the estimated functionality for communication systems is 71 percent.

Debris

The total amount of debris generated is estimated for the M8.5 at 9.3 million tons and for the 500-yr at 23.3

(Continued on page 131)

Figure 3. Cascadia M 8.5 damage and loss estimates: (a) Social losses for individuals and households. (b) Number of buildings by damage tags: green tag = building has been inspected, no restrictions on use or occupancy; yellow tag = off limits to unauthorized personnel; red tag = unsafe, not to be entered or occupied. (c) Direct economic losses to buildings.

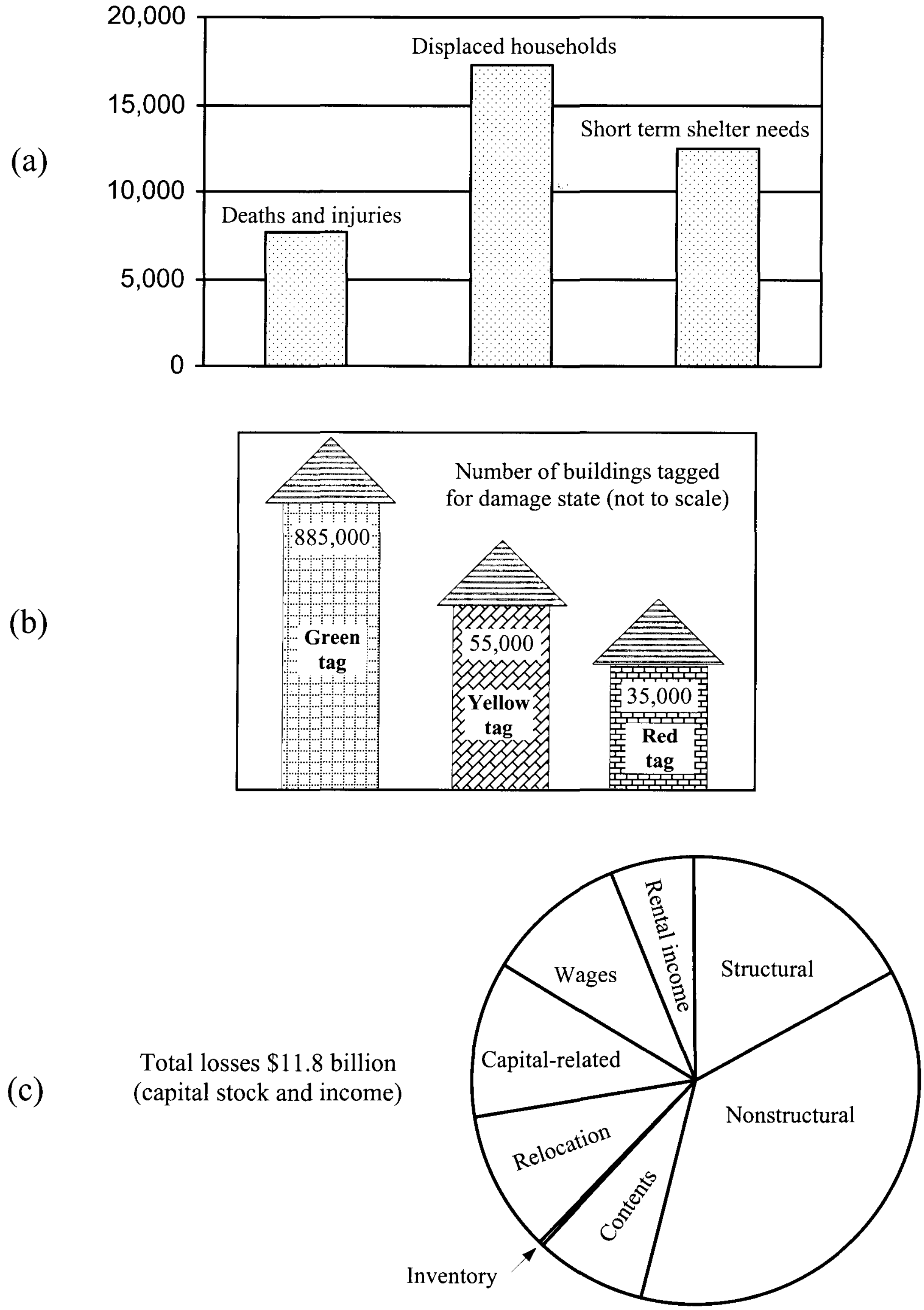
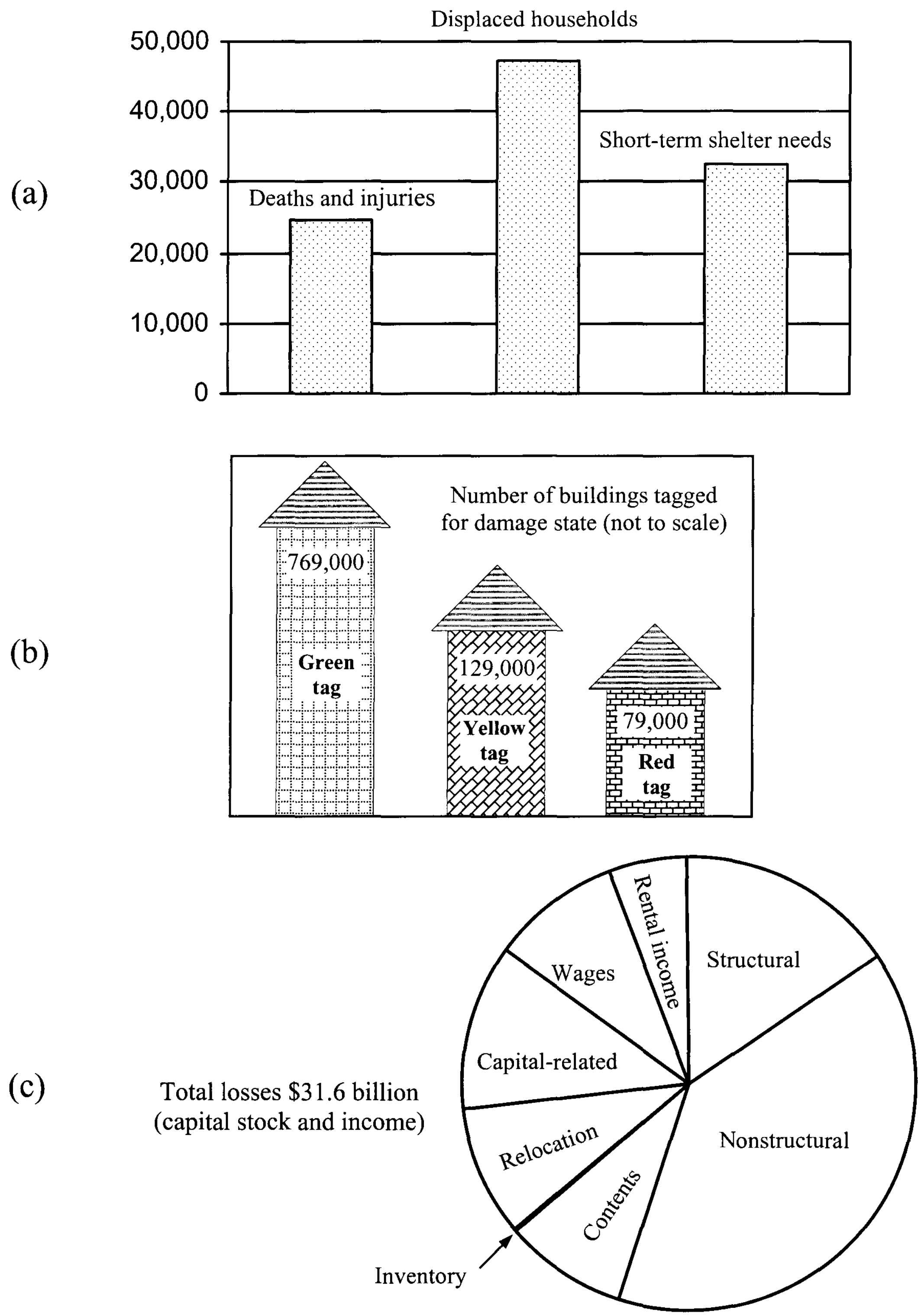


Figure 4. 500-year return interval damage and loss estimates: (a) Social losses for individuals and households. (b) Number of buildings by damage tags: green tag = building has been inspected, no restrictions on use or occupancy; yellow tag = off limits to unauthorized personnel; red tag = unsafe, not to be entered or occupied. (c) Direct economic losses to buildings.



(Continued from page 128)
million tons. The debris is categorized under two types: The first type of debris is easily movable with bulldozers and includes brick, wood, glass, building contents, and other materials. The second type of debris falls in large pieces, such as steel members or reinforced concrete elements.

SUMMARY

The preliminary results from this study suggest that there is a serious risk in Oregon from both a M8.5 Cascadia event and 500-yr probabilistic ground motions. Studies of the M8.5 event indicate that over 10 billion dollars of building damage and about 7,000 casualties or more will be inflicted. The 500-yr ground motion studies indicate losses of more than 30 billion dollars, which is considerably higher than the M8.5 model. The 500-yr study produces higher losses because the modeled hazards span the entire state (i.e., offshore subduction zone and local inland earthquakes). Results from this study can be used to help increase earthquake awareness, stimulate mitigation and risk reduction action (e.g., strengthening facilities), support and set policies and legislation, and develop emergency response plans.

FUTURE STUDIES

Future studies for Oregon may involve evaluating additional earthquake scenarios, specialized hazards (e.g., tsunami inundation, liquefaction, and slope stability), and expanded inventory data and focused study regions, such as counties. Inventory data may include unreinforced masonry structures, which are currently not included in the default database, or a more accurate inventory of schools or emergency facilities. Development of a more complete inventory would provide more accurate inventory damage and loss estimates.

ACKNOWLEDGMENTS

Special thanks are extended to Stuart Nishenko of FEMA and Jawhar Bouabid of Risk Management Solutions, Inc., for their thoughtful reviews. My sincere appreciation goes to John D. Beaulieu of DOGAMI and William M. Elliott of the City of Portland for their support of this study. Thanks also to Klaus Neuendorf and Neva Beck for their assistance in producing this paper. Research was supported by State of Oregon funds.

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Hells Canyon subject of new book

Islands & Rapids. A geologic story of Hells Canyon, is an exciting new book by retired U.S. Geological Survey geologist Tracy Vallier. It is published by Confluence Press, Lewis-Clark State College, Lewiston, Idaho.

Vallier's book tells the geologic history of the region but also serves as a field guide and entertains the reader with natural and human history and the author's own reminiscences. It has four maps and many photographs.

The book sells for $25 and can be purchased from the Nature of the Northwest Information Center. See back cover of this issue for ordering information. ☐

Oregon Schools Seismic Safety Project

by Eugene L. Trahern[1], P.E., Linda Lawrance Noson[2], and Dan E. Wermiel[3]

INTRODUCTION

The purpose of this project was to assist in the development of a statewide earthquake vulnerability analysis of Oregon schools and to use the results to prepare a mitigation planning methodology for use by school facilities personnel. Western Oregon has approximately 1,200 public schools in 173 districts. Historic earthquake activity, including recent damaging earthquakes in the Scotts Mills and Klamath Falls communities, and the results of earthquake studies by the Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Geological Survey (USGS), and other scientists indicate that western Oregon is an area of high earthquake hazard. Schools located in western Oregon are potentially vulnerable to earthquake-induced damage and associated human and economic losses.

The Oregon School vulnerability project was to be carried out in three phases: (1) develop a general screening tool to assess school earthquake vulnerability, (2) complete data analysis and validate study data collected in the general survey using detailed studies of representative districts, and (3) develop a methodology to assist school facility planners in the management of school mitigation projects. This report focuses on the progress made in phase 1. The Oregon Emergency Management and the Federal Emergency Management Agency provided funding for the completion of phase 1. Phases 2 and 3 were not funded.

[1] Seismic Program Manager, Coughlin Porter Lundeen; work performed while at Dames & Moore.

[2] Senior Project Scientist, AGRA Earth & Environmental, Inc., work performed while at Dames & Moore.

[3] Geologist, Oregon Department of Geology and Mineral Industries

Figure 1. Earthquake damage at Molalla High School from the Scotts Mills ("Spring Break") earthquake, March 25, 1993.

BACKGROUND

The extensive Oregon public awareness program on regional earthquake hazards and their potential impact on buildings, combined with the recent occurrence of several damaging Oregon earthquakes, have raised concerns about the potential vulnerability of Oregon school buildings to earthquake damage. The building standards used to design schools and other buildings in Oregon and other parts of the country have changed over time as new information on regional earthquake hazards and the response of buildings to earthquake shaking has been developed. Oregon schools built before 1991 used earthquake design standards below those required in Oregon today. Schools built before about 1952 were unlikely to have used any earthquake design measures. Figure 2 shows changes in the Uniform Building Code (UBC) seismic zone map from 1946-1998 (see Technical Note). A survey of school buildings was needed to identify the level and the distribution of vulnerability among Oregon Communities.

The screening tool to collect data to be used in the vulnerability assessment was developed as a means to manage costs. The Oregon Department of Education estimated that it would take $1.2 million dollars to collect data on school buildings if one were to use standard building inventory techniques. A less expensive approach to identify areas of particular concern was desired. The screening tool developed relies on local

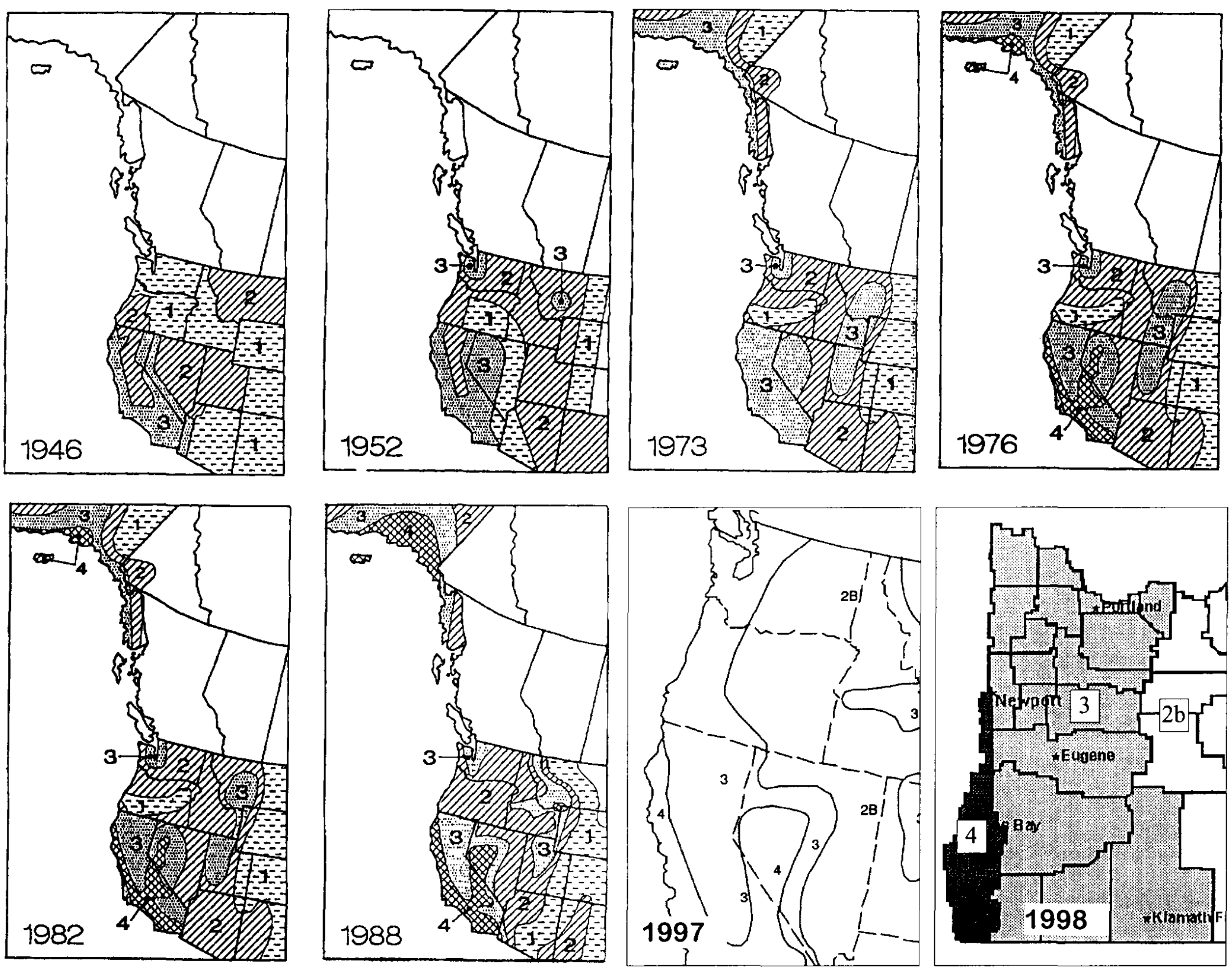

Figure 2. Diagrams showing history of Uniform Building Code zoning for the West Coast. Partially modified from International Conference of Building Officials (1997) and earlier issues of that series, except for 1998 diagram, which shows the western portion of the seismic zone map of Oregon, taken from Structural Engineering Committee (1998), as adopted by the Oregon Building Codes Division, Department of Consumer and Business Services. All eastern counties not shown here are included in Seismic Zone 2b (white); most of western Oregon is assigned to Seismic Zone 3 (light shade); and "all that land which lies westerly of Range 10 West of the Willamette Meridian from the north line of Coos County to the northerly line of Township 10 South (just south of Otter Rock), and all of Coos and Curry Counties" are included in Seismic Zone 4 (dark shade).

Technical Note

The Uniform Building Code (UBC) sets design standards adopted by most communities in the western United States. UBC earthquake design standards vary according to (1) the amount of ground shaking expected to occur in an area and (2) the distance of buildings to the fault or faults that may cause the shaking. The modern UBC defines five seismic zones based on these criteria, ranging from the highest level of ground shaking and nearest faults (Zone 4) to the lowest level (Zone 0). The Oregon State Building Code Agency assigned western Oregon to Seismic Zone 3 in 1991 as did the UBC in 1994.

district personnel to provide information to an initial survey questionnaire.

A "risk management" approach to the project was utilized to initially identify and analyze loss exposures. "Risk management" is defined herein to mean the process of making and implementing decisions that will minimize adverse effects of accidental and business losses on an organization. Terminology for risk managers differs depending upon the interested stakeholders, but generally for engineers, earth scientists, and other earthquake professionals, **hazard** refers to the earthquake itself and **risk** refers to the potential damages and losses caused by an earthquake and combines **hazard**, **vulnerability**, and **exposure**. **Vulnerability** refers to the degree of loss or damage to particular structures, or segments of society. **Exposure** refers to the items at risk (life, property, business interruption, etc.).

Risk management approach to mitigation and preparedness

Seismic mitigation by structural engineers most commonly means strengthening or otherwise improving the building's response to earthquakes in order to obtain a better building performance. A broader risk management perspective would define mitigation as those actions taken to implement risk-control measures that will be completed before the earthquake occurs. This definition includes traditional strengthening projects (retrofit), new design standards, maintenance procedures to improve building conditions, real-estate purchasing criteria, and occupancy criteria to reduce exposure, e.g., using older buildings for storage rather than for classroom use.

Emergency preparedness actions to develop an effective and rapid response capability to be implemented when an emergency occurs, may also help reduce the severity of losses by limiting the amount of additional damage and injury that may occur after the earthquake or during aftershocks.

Mitigation and preparedness are complementary loss-reduction strategies that are a part of any comprehensive risk control program.

A problem facing the school districts is that of funding costly building upgrades or replacement structures. Any program developed to reduce earthquake risk should identify those strategies that provide the "biggest bang for the buck".

STUDY METHODOLOGY

A seven-step process (Figure 3) is intended to screen out facilities of lower risk and direct funds to those in need. For individual buildings, a small number of buildings at an individual school site or for a small school district, step 2 is often undertaken to evaluate each building. With 1,200 public school buildings located throughout western Oregon, this task would be costly and time consuming. Thus, this project focused on the initial screening in step 1 (general questionnaire). The results of this step were to support the development of a methodology for school facilities personnel to use in preparing a seismic mitigation plan.

The Oregon Department of Education provided a directory of school facilities in Oregon. This information was used to develop a database of contact information for each school district located in seismic zone 3. Critical building information required to screen the vulnerability of school buildings and to develop an overall mitigation plan was not available from the state. Oregon school facility construction and funding is carried out at the school district level. Thus, the first task was to develop a survey questionnaire that could be filled out by facility personnel in each school district. The results of the survey would then be assembled in a database for prioritizing the school buildings.

Questionnaire

The general questionnaire developed was a nine-page document used to collect information on the vulnerability of the building structures, the exposure or value at risk (occupancy, use, historical value), and the opportunity for potential upgrades. The following items give a general indication of the types of information requested:

- General school district information (name, city, enrollment, etc.).
- General school information (name, address, contact person, enrollment, etc.).
- Building vulnerability/construction (construction date, type of structural system, number of stories, size/square footage, shape, deterioration, upgrades, etc.).
- Site (settlement, slopes, landslides, soil conditions, etc.).
- Building documents (availability of drawings or previous studies).
- Historic registry or value.
- Mitigation opportunities (schedule for demolition, repair, reroofing, etc.).
- Environmental risks (natural gas, asbestos, chemicals, etc.).

STEP 1 **Develop Seismic Mitigation Plan and Perform Initial Screening**	Agency facility managers complete their surveys Set program goals and objectives Define exemptions (filter exclusions) Perform initial screening Costs based on typical retrofit costs ($/sq. ft.) for building type Highest evaluated buildings of Step 1 are sent to Step 2
STEP 2 **General Structural Assessment**	Seismic Program Structural Engineer: ATC-21 approach plus Modify structural ranking Completes plan review of existing drawing Brief building field observation Evaluates buildings Costs based on typical costs for identified deficiencies Highest evaluated Step 2 buildings are sent to Step 3
STEP 3 **Detailed Structural Evaluation**	Population Consultant Structural Engineer: Prepares structural analysis of selected buildings Prepares evaluation report Highest Step 3 buildings sent to Step 4 Costs based on engineer's analysis and identified deficiencies
STEP 4 **Cost Analysis (Cost)**	Consultant Structural Engineer prepares Schemes and Structural Estimate Benefit-cost ratio (BCR) prepared for: Part 1: Structural retrofit only (Structural BCR) Part 2: Structural retrofit plus (Total BCR) Fire and life safety Asbestos and other hazards Access All of Step 4 buildings are sent to Step 5
STEP 5 **Recommendation (Report)**	Final report Recommendations made for projects to be included in budget
FOLLOWING BUDGET APPROVAL:	
STEP 6 **Detailed Design**	
STEP 7 **Implementation**	

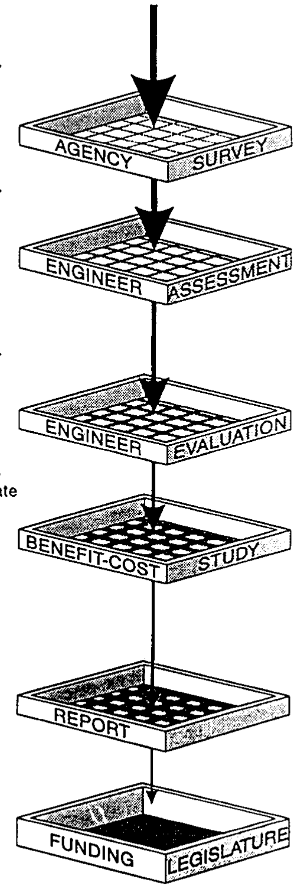

Figure 3. Summary description of seven-step procedure to assess school earthquake vulnerability and act on it.

- Past earthquake damage.
- Occupancy (occupancy, hours, etc.).
- Building function (school use, nonstudent use, plans for community shelter).
- Relocation (alternate sites).
- Comments on completing the survey.

The questionnaire was sent out to 173 school districts in western Oregon. Responses were received and logged for 93 districts (55-percent response). Data entry using Microsoft Access and preliminary data analysis was completed for approximately 20 percent of the districts surveyed. Late responses and the termination of funding for the project prevented the input and analysis of the remaining data.

Screening/ranking methodology

Initial results for the completed questionnaires were screened using a methodology and ranking system previously developed for the City of Seattle buildings. The informal prioritization method shown in Figure 4 utilizes a weighted point-ranking system based on the structural risk (exposure, vulnerability, and hazards), function rank, opportunity, and historic value.

PRELIMINARY RESULTS

Examples of the results are displayed graphically in Figures 5 and 6. As noted above, data entry was not completed for all of the responses received, data were not verified, and the informal prioritization method was not modified to account for items specific to the project such as benchmark years of local construction. However, preliminary results of the data can indicate some interesting trends.

THE NEXT STEP AND BEYOND:

In order to complete the Step 1 initial screening and data collection, which will assist in developing the mitigation plan, several tasks should be completed as follows:

1. Complete Oregon school vulnerability study.

- Complete data entry (late responses), review building

(Continued on page 137)

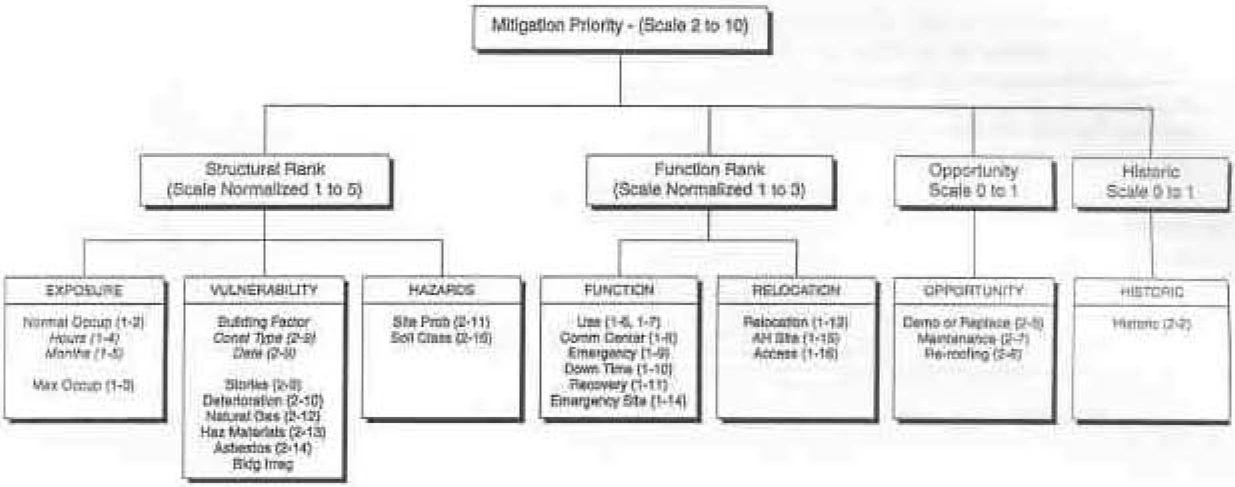

Figure 4. Schematic representation of informal Prioritization Method developed for buildings of the City of Seattle

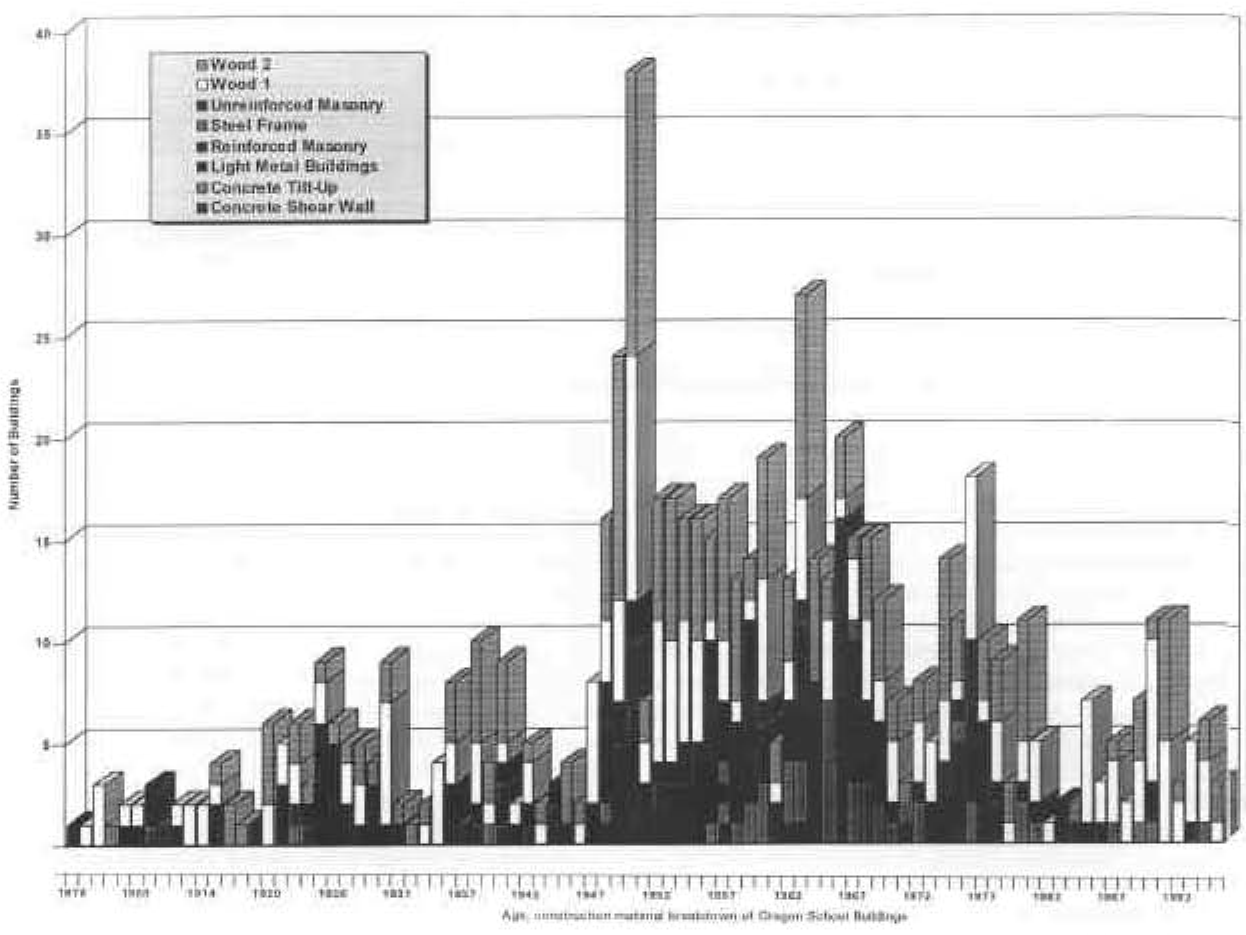

Figure 5. Number of surveyed Oregon schools by age, also indicating construction type.

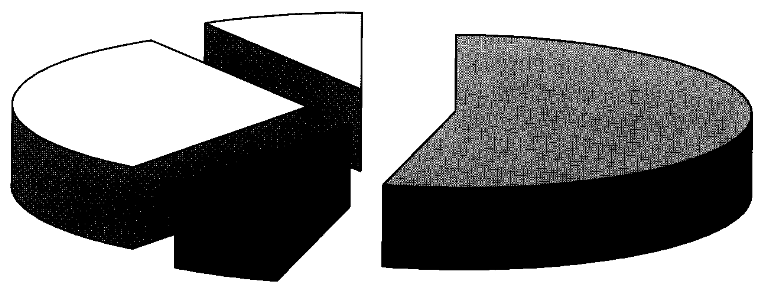

Figure 6. Distribution of surveyed schools according to vulnerability category: very high, high, moderate, and low.

(Continued from page 135)

surveys, confirm missing/confusing data, modify responses as needed (e.g., construction dates of 1996 and unreinforced masonry are not feasible).

- Establish weighted functions to sort collected data into mitigation priorities, including benchmark years showing dates when critical earthquake design requirements were adopted, buildings to be exempted from the program, etc.
- Complete database design.
- Complete Oregon school vulnerability study by sorting weighted database by selected mitigation parameters. Determine vulnerability groupings by schools and districts.
- Report findings.

2. Prepare risk-based mitigation methodology.

- Conduct field evaluations of four to five representative school districts to verify vulnerability study.
- Revise database and mitigation weighting functions as appropriate.
- Prepare mitigation planning methodology based on the results, including criteria, district qualifications and ranking procedures.

3. Develop and deliver mitigation planning workshops.

- Topics to include overall vulnerability of the Oregon schools, approaches for seismic screening and evaluation of school buildings, cost estimation, integrated school planning models, criteria for State mitigation program.

SUMMARY

A general questionnaire was developed and completed to assist in the identification of earthquake exposures and the associated risk to western Oregon schools. Returned data were not complete nor were they standardized. However, several interesting trends can be concluded. In order to reduce the potential risk to the Oregon school system, a combination of mitigation and planning should be performed. Step 1 information can assist in prioritizing funding for both the mitigation and planning process. Proper evaluation of the needs of public schools in Oregon with respect to seismic design will require additional professional survey work with standardized procedures.

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Structural Engineering Committee, 1998, Seismic zonation for the Oregon coast.: Final report submitted to the Building Codes Structures Board, February 12, 1998 (for Oregon Building Codes Division), p. 9. □

Seismic risk reduction efforts in Tillamook honored by WSSPC

Tillamook County General Hospital (photo below) has received an "Award in Excellence" for new technology from the Western States Seismic Policy Council (WSSPC).

With the award, the multi-state Council recognized the successful efforts of the County to improve the structural safety of the hospital from the destructive effects of earthquakes. The goal was to strengthen the facility so that it would allow immediate occupancy after a 500-year return interval earthquake.

In the course of renovating and expanding the hospital facilities, fluid viscous dampers were installed in "dynamic" braces (example in photo on right) that will dissipate shaking energy. The improved elastic design exceeds the required standards of Seismic Zone 3. It actually satisfies Seismic Zone 4 standards, which are required only in areas along the southern Oregon coast.

The fluid damper technology itself is a century old. However, its use in Tillamook is the first time in history that it is applied to a "fixed-base" hospital, i.e., a hospital with a base not already specially designed to ride out earthquakes.

The use of this approach made construction of additional shear walls unnecessary and kept construction-related disturbance of the hospital to a minimum.

For a description of the project, see Craig Keller, 1998, "When in doubt, damp it out": Connections (a publication of the Structural Engineers Association of Oregon), April 1998, p. 5–6. □

BOOK REVIEW

by Gregory J. Retallack, Department of Geological Sciences, University of Oregon, Eugene, OR 97403: e-mail gregr@darkwing.uoregon.edu.

The Oligocene Bridge Creek flora of the John Day Formation, Oregon, by Herbert W. Meyer and Steven R. Manchester. Berkeley, University of California Press, University of California Publications in the Geological Sciences 141, October 1997, 195 p., including 75 plates, $50.00.

The Bridge Creek flora is one of the most famous fossil assemblages in Oregon, and its investigation extends back into prehistory. Fossil leaves from one of the localities for this fossil flora (Iron Mountain) have been found in archaeological excavations of a Native American campsite dating back some 1,460 years (Ashwill, 1987; Aikens, 1993). Oregon's pioneer paleontologist, Thomas Condon, while a congregational missionary at The Dalles, first made collections for scientific study in 1865, from the main locality near Bridge Creek, currently in the Painted Hills Unit of the John Day Fossil Beds National Monument (Clark, 1989). He sent his specimens to authorities on the east coast, and they were illustrated in classical monographs of fossil floras of the western United States. These fossils have continued to attract collectors ever since, especially the popular site behind Wheeler County High School in Fossil, Oregon. Despite a number of signs around Fossil, the town is not known for dinosaurs, which are scarce in Oregon, but for these fossil leaves of early Oligocene age (33–32 Ma).

The best known of the Bridge Creek fossils is the dawn redwood (*Metasequoia*), which has been nominated (though not approved) as Oregon's state fossil. This distant relative of the coast (*Sequoia*) and giant redwoods (*Sequoiadendron*) of California was once abundant in Oregon, but has been extinct here since the late Miocene (5 Ma). *Metasequoia* fossils were known long before small populations were discovered still living in China. *Metasequoia* is now a popular ornamental plant. There is a splendid example planted beside Cascade Hall on the University of Oregon campus. It was grown from a seedling brought to Oregon by Ralph Chaney, the Berkeley paleobotanist, on the occasion of his visit for the Condon lecture in 1948. Although it has been widely assumed that he collected the seeds during his visit to China, he was unsuccessful in collecting seeds during his winter visit, and grew his seedlings from seed independently purchased from the Chinese by E.D. Merrill of Harvard's Arnold Arboretum. Our fine *Metasequoia* tree near Cascade Hall is appropriately enough under the gaze of a nearby bronze bust of Thomas Condon, who became a foundation professor of Natural Sciences at the University of Oregon in 1876.

The Bridge Creek flora has been described and featured in paleontological and paleoecological studies by a variety of authors since its nineteenth century discovery. At last Meyer and Manchester have assembled a coherent and well illustrated revision of this important fossil flora that should be of interest to paleontologists both professional and amateur, as well as to botanists, paleoclimatologists, and geologists. Picture-matching to identify fossils is made easy by an extensive selection of unretouched photographs on 75 plates. Also offered is an extensive listing of current identifications of specimens in previously published studies of the flora.

In the relentless give and take of taxonomic revision, some familiar old names have been changed. *"Celtis"* leaves for example are now referred to *Plafkeria*, and *"Tremophyllum"* to *Cedrelospermum*. The old and widely-used species name *Metasequoia occidentalis* has technical problems, and Meyer and Manchester recommend calling these common fossils just plain *Metasequoia* (species indeterminate). Meyer and Manchester now recognize 125 species in the flora, a higher diversity than previously suspected. Many of the additional genera are unfamiliar conifers such as *Calocedrus*, *Tetraclinis*, *Folkeniopsis*, and *Keteleeria*. There also are newly-recognized dicots of tropical affinities, such as *Parrotia* and *Fothergillia*.

The Bridge Creek flora has featured prominently in discussions of the mid-Tertiary climatic cooling, or "Paradise lost" in Don Prothero's (1994) memorable allusion. The early Oligocene Bridge Creek flora is the oldest known flora of temperate climatic affinities, following tropical floras of the Eocene. In discussing this climatic shift, Meyer and Manchester note that newly recognized diversity and taxa of tropical affinities undermine its reputation as a dicot flora of temperate climatic affinities, but not by much. The climatic affinities of the flora still reveal substantial cooling compared with the Eocene floras of the underlying Clarno Formation. Mean annual temperature during Oliocene time estimated from the various Bridge Creek floras was 8°–10°C, with likely winter frost. Little regard is given to other climatic parameters, such as seasonality and lowered precipitation, or to the rapidity of the climatic shift, all currently better revealed by fossil soils (Retallack and others, 1996). Such additional climatic parameters and likely paleoaltitudes can be revealed by fossil floras with appropriate computer-analysis (Wolfe and others, 1998). Clearly there is more to learn from the Bridge Creek flora, but Meyer and Manchester have set a high standard for the description of this important step in the evolution of modern North American vegetation.

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DOGAMI PUBLICATIONS

Released September 1, 1998

Mist Gas Field Map, 1998 edition, Open-File Report O–98–01, 1 map sheet, scale 1:24,000, 33 p. text, $6.

The map of the Mist Gas Field in Columbia and Clatsop Counties that has been published by the Oregon Department of Geology and Mineral Industries since 1981 has been updated over its 1997 edition and released as Open-File Report O–98–01. The release includes the map and a production summary for the years 1993 through 1997.

The annually updated *Mist Gas Field Map* shows the field divided into quarter sections. It displays location, status, and depth of all existing wells and serves as a basis for locating any new ones. It also shows the area and wells that are used for storage of natural gas. The production summary includes well names, revenue generated, pressures, production, and other data. The map and accompanying data are useful tools for administrators and planners, as well as explorers and producers of natural gas.

The *Mist Gas Field Map* is available both as the usual paper copy and, on request, in digital form (price $25). It is offered in three different CAD formats (.DGN, .DWG, and .DXF), all on one 3½-inch high-density diskette formatted for DOS, for use by different software systems. Using a digitized version allows customizing the map to suit individual needs.

A cumulative report of past production at the Mist Gas Field between 1979 and 1992 is available in a separate release under the title *Mist Gas Field Production Figures* as DOGAMI Open-File Report O–94–6 (price $5).

Released October 9, 1998

Geology and mineral resources map of the Rio Canyon quadrangle, Jackson County, Oregon, by Frank R. Hladky. Geological Map Series GMS–108, scale 1:24,000, 12 p. text, $6.

The Rio Canyon quadrangle is dominated by Grizzly Peak, an ancient volcano that has been deeply eroded by the headwaters of Antelope Creek. The *Geology and Mineral Resources Map of the Rio Canyon Quadrangle, Jackson County, Oregon* and accompanying report reveal many newly discovered facets of the area's geology over about 50 million years of geologic history.

The earth is a dynamic system, and at a certain scale its surface literally changes from day to day. The changes can either add to the surface ***(deposits)*** or scour it down ***(erosion)***. Deposits are made, for instance, by events like volcanic eruptions leaving volcanic rocks behind or by streams overflowing their banks and leaving sedimentary flood deposits. Such events can be easily read in the geologic record of the Rio Canyon quadrangle.

In the map area, the oldest rocks are in the sedimentary Payne Cliffs Formation. Between about 37–50 million years ago, (we can't be more precise than that) a large braided river system carried material from the Siskiyou Mountains, depositing it during flood events. Toward the end of this period, some of the earliest Cascade Range volcanism began; it happened to start in or near the Rio Canyon quadrangle. This volcanism continued for 8 million years.

When the early Cascade volcanic activity stopped, it was followed by 20 million years of uplift and ***erosion***. During this period, the ground rose just as slowly as streams were able to erode rock. The net result was that for most of this 20 million year period, there aren't any deposits of rock to tell the story.

Besides volcanism and uplift, adjacent Bear Creek valley has been greatly influenced by massive landslides shown on the new map. Although we do not have precise dates, these slides are geologically recent (within a couple of million years) and may have been triggered by earthquakes, either from the offshore Cascadia subduction zone or from crustal earthquakes like those felt in Klamath Falls in 1993.

An important application of geologic mapping is to better understand groundwater resources. In the Rio Canyon quadrangle, the production of wells depends on the degree of fracturing and hardness of the rocks. Highly fractured, rigid rocks (as in many volcanic areas) tend to produce larger quantities of water than softer rocks. In areas underlain by the soft sediments of the Payne Cliff Formation, well production is often less than in the volcanic rocks.

Chemical analyses of the groundwater show that

(Continued on page 142)

Index to OREGON GEOLOGY, volume 60, 1998

Numbers refer to issue and first page of entry. Subject entries cross-referenced to author entries (in parentheses).

(Continued from page 140)
high levels of arsenic are found in wells in sedimentary strata east of Bear Creek valley. This report ties high levels of arsenic, mercury and base metals (copper, zinc, and lead) to silicic tuffs at nearby Shale City, just east of the map.

Mapping of mineral resources is another reason for geologic mapping. It appears the only mineral occurring in economic quantities in the area is crushed rock. Other resources have been prospected but not developed.

Emergency plan and drills prepare ODOT for "the real thing"

District 4 gets the call just after noon. Benton County has declared an emergency. An 8.5 earthquake has jolted the Corvallis area, and the damage is extensive. A major landslide on Highway 20 has traffic blocked—emergency responders can't get through. ODOT [Oregon Department of Transportation] crews are quickly dispatched to the scene. Kevin Bryan, District 4 incident response coordinator, immediately heads for the county's Emergency Operations Center where he will monitor ODOT's response efforts throughout the disaster. More reports come in. A derailed train spills diesel fuel into the Mary's River—the Harrison Street Bridge has collapsed—there's another landslide. Suddenly, a 7.1 aftershock rocks the area. And the calls keep coming.

Luckily, this earthquake was only a drill. Recently, ODOT, along with a host of other response agencies, schools and businesses participated in a five-hour emergency exercise staged by Benton County. The drill provided valuable training for ODOT, Bryan reported.

"We tested our equipment, our response time, and, most importantly, our thinking," he said. "During real emergencies, we need to react quickly—drills like this help us prioritize our actions."

According to ODOT Emergency Response Planner Rose Gentry, ODOT will increasingly participate in multiagency drills statewide, so crews can hone and test their emergency response skills. Gentry chairs ODOT's 10-member Emergency Preparedness Committee, made up of employees appointed by the Maintenance Leadership Team. Committee members, who meet monthly in Redmond, have just completed a rigorous internal and external review of its draft operations plan.

"Once Director Crunican approves the plan, we will then distribute copies throughout ODOT and to state and county agencies—probably in October," said Gentry.

ODOT's emergency preparedness training will begin statewide early next year, and when it's completed, the agency will accelerate its participation in external emergency drills.

"Our goal is to continually practice our skills so we are prepared for any emergency," said Gentry. "We want to make good use of our operations plan, not just store it on a shelf." (Written by Jayne Stewart, strategic communications coordinator, 503/986-4329.)

—From *Transcript* (ODOT newsletter), v. 6, no. 10 (October 1998), p.5. ☐

AVAILABLE PUBLICATIONS
OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

BULLETINS	Price	☑
103 Bibliography (8th supplement, 1980-84). 1987	8.00	
102 Bibliography (7th supplement, 1976-79). 1981	5.00	
101 Geologic field trips, W. Oregon/SW Washington. 1980	10.00	
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