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OPEN-FILE REPORT O-98-4

Using Earthquake Hazard Maps

A Guide for Local Governments In the Portland Metropolitan Region

By
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for
Metro
Portland, Oregon

1998

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Prepared for Metro
Portland, Oregon

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October 1998

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Regional Services
Creating livable communities

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GSL Properties
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This guidebook is based on research supported by the U.S. Geological Survey (USGS) Department of the Interior, under USGS award number 1434-HQ-97-GR-03159. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Government.

Contents

1. Introduction

Earthquakes come without warning. As the ground beneath our feet begins to tremble, we lose the most fundamental basis for a sense of safety – solid ground. Earthquakes are frightening and destructive, but we are not totally at their mercy. The message of this guide is that by learning about earthquake hazards and transforming knowledge into action, we can greatly reduce the impacts of inevitable future earthquakes in the Portland metropolitan region.

1.1. Purpose of Guide

This guide, prepared with support from the U.S. Geological Survey, explores how local governments can use earthquake hazard maps prepared for the Portland metropolitan region by the Oregon Department of Geology and Mineral Industries (DOGAMI) to reduce damage in earthquakes. It is addressed to local government staff and elected and appointed officials who regulate the use and development of land and construction of buildings and prepare for and manage disaster response and mitigation. The guide focuses on local government actions, but recognizes that all levels of government, businesses, community organizations, households and individuals play roles in reducing a community's vulnerability to earthquakes.

This guide continues work, also supported by the U.S. Geological Survey, in which a Metro committee worked with staff and consultants to develop recommendations in the report, *Using Earthquake Hazard Maps for Land Use Planning and Building Permit Administration.* This guide builds on the recommendations in the prior report, adding considerable detail about mitigation approaches and providing numerous examples from the Metro region that show actual and potential uses of the earthquake hazard maps and data. It describes the relationship of earthquake hazard mitigation to Oregon's statewide planning goals, local comprehensive planning, the Oregon structural specialty code, emergency management requirements, hazard mitigation planning and Metro's growth management planning.

This guide does not include hard and fast rules for using earthquake hazard maps. Such rules are unrealistic given the wide range of possible applications and local conditions. Instead, the guide presents possible approaches to using the maps and data for specific local government functions: comprehensive planning and zoning, review of subdivision applications, site-specific seismic investigations, public facilities and utilities planning, redevelopment and seismic retrofit programs, and emergency management. The examples are provided to show exactly how the maps were or could be used in real-life situations. The purpose is to stimulate local government officials to consider what they can do to reduce earthquake hazards in carrying out their day-to-day tasks.

1.2. EARTHQUAKE HAZARDS

Earthquakes are an Oregon problem. In the language of plate tectonics, western Oregon sits next to the Cascadia subduction zone where the Juan de Fuca Plate is diving under the North American Plate in a process capable of generating infrequent, but very large earthquakes. In addition, the western part of the state is underlain by a large and complex system of faults that can produce more frequent, moderate earthquakes such as the recent Loma Prieta and Northridge earthquakes in California and the Kobe earthquake in Japan. The Portland metropolitan region has been shaken in the past and will be shaken in the future.

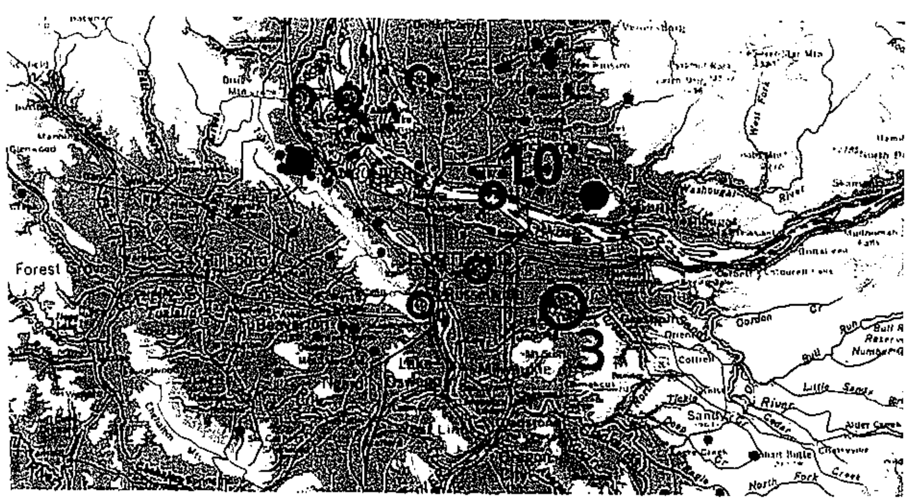
Earthquakes are a complex of hazards – ground shaking, surface fault rupture, slope failure and ground failure resulting from liquefaction. Surface fault rupture is not a potential hazard in the Portland region, but amplified ground shaking, slope failures, and liquefaction are all expected.

1.2.1. Amplified Ground Shaking

Earthquakes generate shaking in bedrock that is then transmitted through the soil to the ground surface. Some soils dampen the ground motion while others amplify it, causing unusually strong or prolonged shaking that can be very damaging to structures. Areas where ground shaking is likely to be amplified usually can be safely developed with careful attention to building design and construction.

1.2.2. Slope Instability

Slope instability or landsliding is a potential problem in areas with hilly terrain, including both steep and gentle slopes, and along riverbanks. Earthquake shaking can trigger landslides on slopes that are otherwise stable; however, the less stable a slope is under non-earthquake conditions, the more susceptible it is to failure in an earthquake. Landslides are very damaging to structures built on or below slopes that fail, but such damage can often be prevented if the hazard is clearly identified and taken into account prior to development.



Map shows epicenters of earthquakes striking the Portland region from 1872-1993. The most significant earthquakes were M 5.5 in 1887, M 5.2 in 1962 and M 5.6 in 1993. The region also felt the 1949 and 1965 Puget Sound earthquakes. In addition to moderate earthquakes like these, the Portland region will one-day experience a very large earthquake originating in the Cascadia subduction zone.

1.2.3. Liquefaction

Liquefaction is a phenomenon in which certain soils below the water table lose strength when shaken and become like a liquid. Liquefaction alone does not cause damage, but if the "liquefied" soil can flow, the ground surface may settle or spread apart, damaging structures, roads and utility lines. Liquefaction is most likely to occur in sandy soils in areas with high ground water tables along rivers, creeks, lakes and other bodies of water or in areas with hydraulically placed sand fills. The effects of liquefaction are generally more severe when the liquefiable layers are thick.

One of the most damaging effects of liquefaction is lateral spreading. When the underlying soils liquefy, the ground surface may move sideways and settle unevenly, breaking into blocks with fissures between them. Lateral spreading is very damaging to structures and especially to highways, railroads, bridges, and buried lifelines such as those carrying water, sewage, storm water, electricity, and communications.

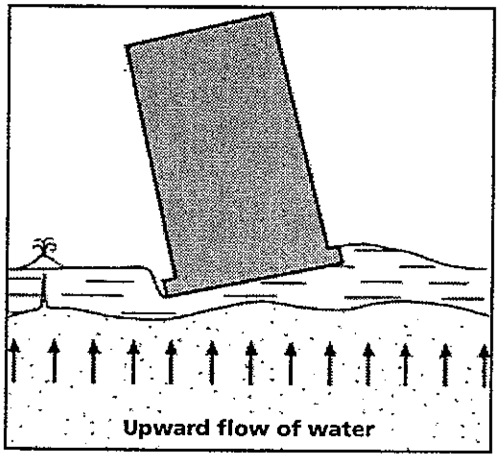
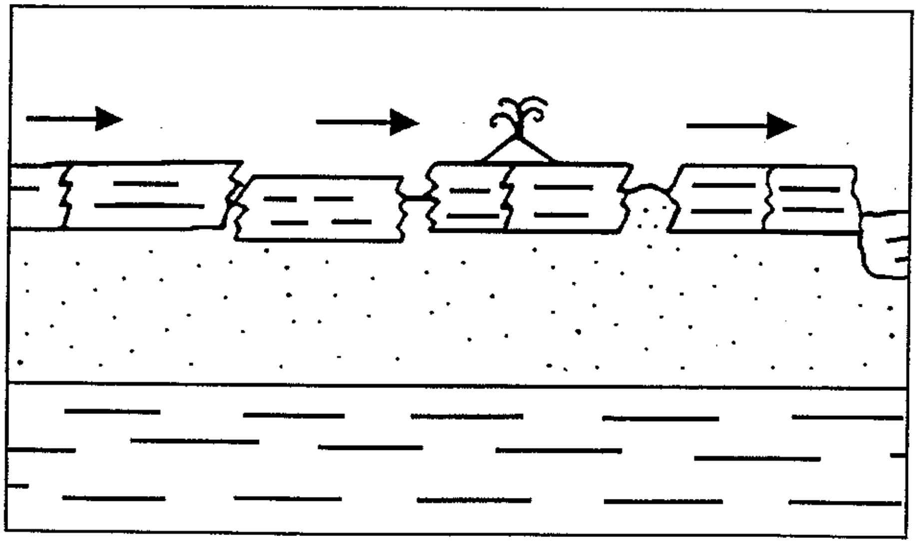


Diagram shows effects of liquefaction. The potential is present in layers of sandy soil between clays. The soils must be saturated to liquefy, thus the potential also requires a high ground water table. Failure occurs only when the liquefied material is free to flow.

1.3. EARTHQUAKE HAZARD MAPS FOR THE METRO REGION

Earthquake hazards are the subject of a series of maps prepared by the Oregon Department of Geology and Mineral Industries (DOGAMI) with funding from the U.S. Geological Survey and Federal Emergency Management Agency.

The data for all the maps were collected at a scale of 1:24,000 and are entered into Metro's Regional Land Information System. Metro can print on order any of the maps in color at scales as large as 1:24,000. The information is not detailed enough for use at scales larger than 1:24,000 and the maps are not suitable to make judgments about individual properties. However, they can be used to indicate where additional hazards information is needed before development decisions are made.



Lateral spreading can result from liquefaction. The ground splits into blocks that move sideways and settles unevenly. It is especially damaging to infrastructure such as roads, utility lines and pipelines.

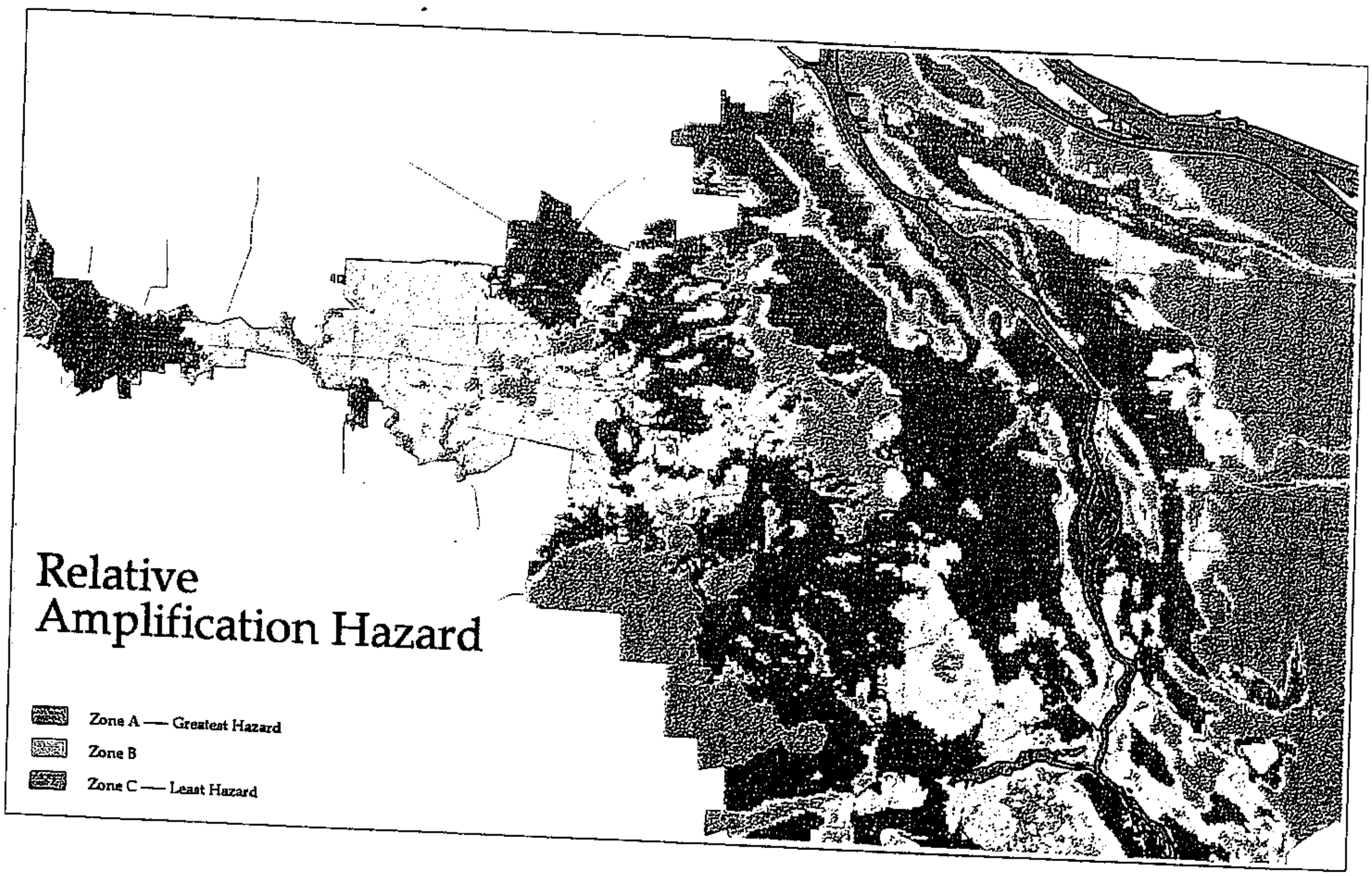
The hazard mapping is generally "conservative," meaning that the maps show areas expected to be hazardous during the worst of several possible scenario earthquakes and under the most adverse subsurface conditions expected for the area. Also, when the information is not definitive for an area, it is assigned to the most severe of the probable hazard categories. The hazard designations are "relative." Thus "high hazard" does not mean total destruction or any particular level of damage in an area; it means the area is likely to have more damage than those designated as moderate or low hazard.

1.3.1. Relative Ground Shaking Amplification Maps

The relative ground shaking amplification map shows areas where soils may amplify peak ground acceleration leading to particularly strong or prolonged ground shaking in an earthquake. Scientists judge that peak accelerations at bedrock will be quite uniform throughout the region, but where deep, soft soils overlie the bedrock, the peak ground accelerations at the ground surface can be much higher than at bedrock. The potential for amplified ground shaking is high throughout much of the western half of the region, particularly in river valleys with deep alluvial soils.

Because most earthquake damage is caused by ground shaking, the areas with amplified ground shaking would likely experience more damage than areas without significant amplification.

Map shows relative ground shaking amplification in the Portland metropolitan region. In the areas shown in pink, the hazard is rated "3", the highest potential for ground shaking amplification. Much of the urbanized land in the region is in this high hazard category. Careful attention to building design and construction is needed here.



1.3.2. Relative Slope Instability Hazard Maps

Not surprisingly, the relative slope instability hazard map shows that the hilly parts of the region are most likely to have landslides in an earthquake. Most of Portland's hillsides have some potential for slope failure with the potential generally increasing as slope angle and the thickness of the soil mantle increase.

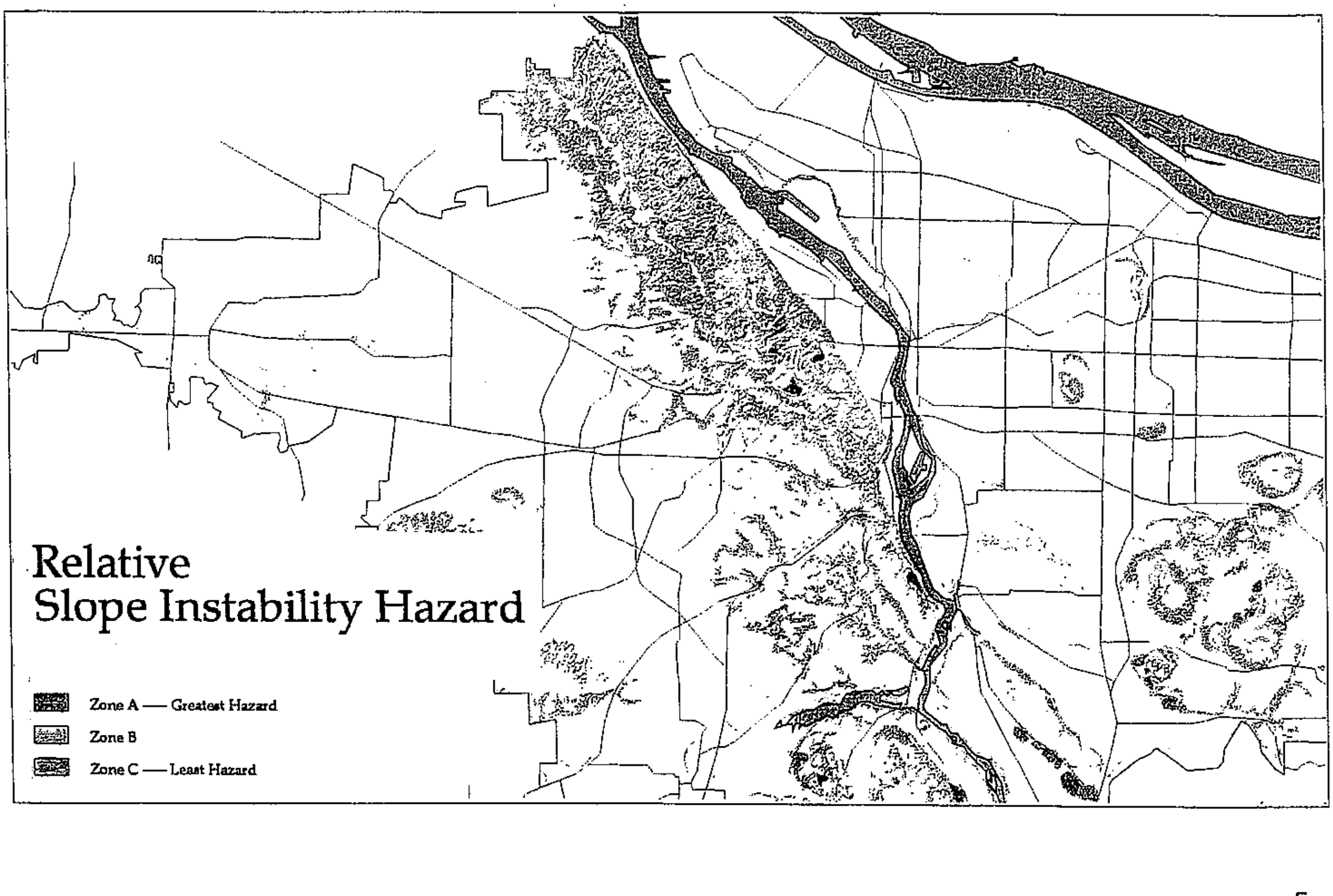
1.3.3. Relative Liquefaction Hazard Maps

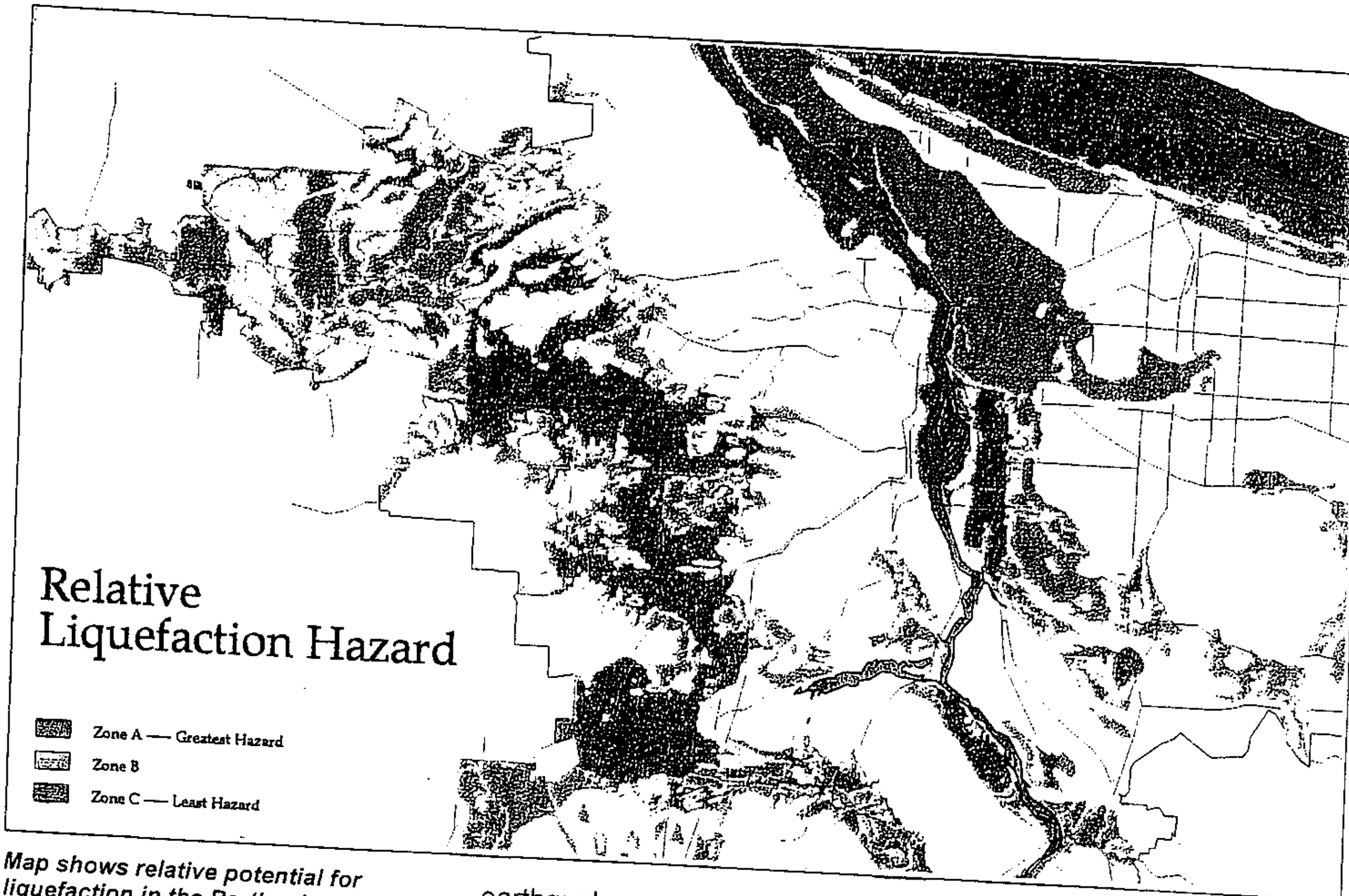
The relative liquefaction hazard map shows that areas along the Columbia, Willamette and Tualatin rivers are those most likely to have damage from liquefaction-induced ground failures. These areas have a combination of thick soil layers and ground water close to the surface, spelling a high likelihood of liquefaction failure in an earthquake. Much of the area between the rivers has moderate liquefaction potential because of seasonally high ground water levels.

1.3.4. Relative Earthquake Hazard Maps (REHM)

The hazards depicted on the three maps of individual hazards are additive. A given location can experience a combination of them. Recognizing this, DOGAMI has created a composite of the three hazard maps called the Relative Earthquake Hazard Map (REHM). This map shows at a glance where the effects of an earthquake are likely to be most severe. The REHM was created for use by people with little or no technical knowledge of

Map shows relative slope instability in the Portland metropolitan region. The most unstable areas are shown in pink and rated as high hazard. These areas are concentrated in the hills to the west of the Willamette River. In these areas, careful siting of structures, site preparation, building design and construction can reduce potential damage.





Map shows relative potential for liquefaction in the Portland metropolitan region. The areas most susceptible to liquefaction are shown in pink and rated as high hazard. Areas along the Columbia, Willamette and Tualatin rivers and west of the hills are most likely to have damage from liquefaction-induced ground failures. Attention to site preparation and foundation design can reduce damage in these areas.

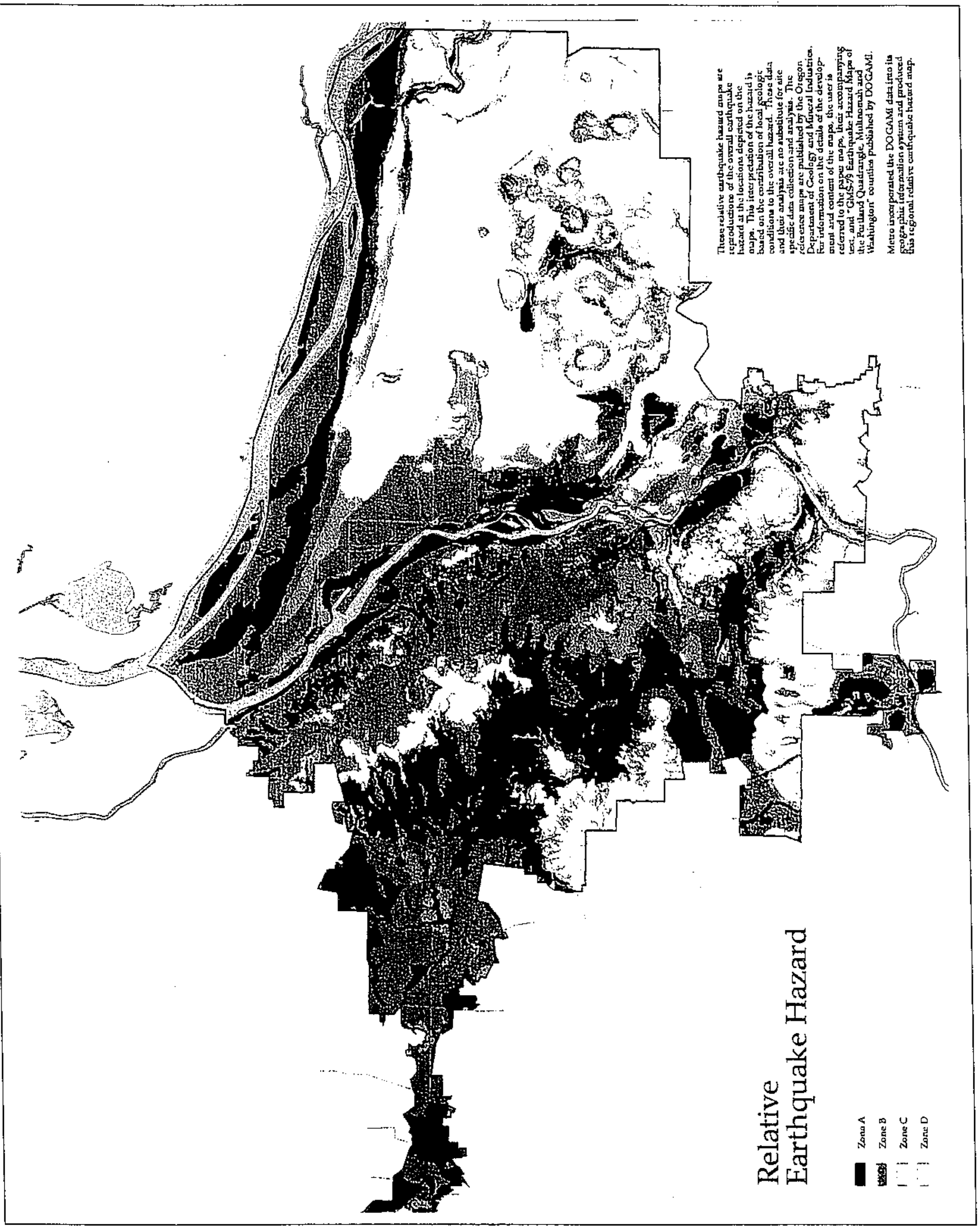
earthquakes and their effects. It shows four zones arranged in order from Zone A (red), the most hazardous, to Zone D (pale yellow), the least hazardous.

Because liquefaction and slope instability usually do not both occur in the same areas, a maximum of two hazards – either slope instability or liquefaction together with ground shaking amplification can be present at any given site. High slope instability and high or moderate ground motion amplification combine to form the red zones in the hillsides; high liquefaction susceptibility and high or moderate ground motion amplification combine to form the red zones near the rivers.

1.4. Using Maps to Reduce Earthquake Impacts

People and institutions are not powerless over earthquakes. With information about the hazards, they can act to reduce risks to people and damage to buildings. Most damage in earthquakes is caused by ground shaking – the earthquake hazard depicted on the map of relative ground shaking amplification. This hazard is addressed primarily by building codes. Generally speaking, if a building is located on ground that is not subject to liquefaction or slope failure, it can be designed and constructed to remain intact under expected levels of ground shaking.

When a building site is susceptible to liquefaction or landslide, site-specific seismic investigations and structural analysis can guide the design and construction of site modifications and buildings. Or, perhaps, the hazardous site or portion of a site can



The relative earthquake hazard map (REHM) for the Portland metropolitan region. The map is a composite of the maps shown above. Zone A, shown in red, contains the land most hazardous in an earthquake. To be in zone A, an area must be rated 3 for at least one hazard and at least 2 for one or two others. Much land along the rivers and in the western part of the region is red.

be avoided altogether. Many responses to earthquake hazards are appropriate; public officials, developers and property owners need to balance the cost of options to reduce losses with other environmental, economic and social concerns.

The REHM is a logical first stop in learning about earthquake hazards in the region. It is an excellent educational tool, conveying the message that the Portland region is indeed earthquake country, and that some areas are more hazardous than others. The REHM alerts people that a hazard may be present at a site. This is a signal to review the individual hazard maps to determine which hazards may be present and their severity. By indicating areas where heavy damage can be expected, the REHM helps focus emergency management and mitigation efforts.

The individual hazard maps are useful when it is important to know what hazard or hazards may be present at a site and their relative severity. Because different actions are appropriate to reduce damage from different earthquake hazards, these maps often provide a better basis for specific mitigation actions than the REHM. Effective ways for local governments to use both the REHM and the individual hazard maps are described in Section 3 of this guide.

1.5. Organization of Guide

The next section of this guide discusses state and regional requirements and programs that provide the context for local government uses of the earthquake hazard maps. This is followed by discussions of uses of the maps by local governments for comprehensive planning and zoning; review of subdivision applications; site-specific seismic hazard evaluations; planning, siting and design of public facilities and utilities; redevelopment and seismic retrofit; and emergency management. Examples of how the maps are being used, or realistically could be used, are incorporated into the discussion of each topic. Sources for additional information are found at the end of the document.

2. State and Regional Context for Local Use of Earthquake Hazard Maps

2.1. State Requirements for Comprehensive Planning

Oregon's land-use statutes require cities and counties to adopt comprehensive plans and implement regulations that are consistent with statewide planning goals. Cities and counties must submit their plans and regulations for approval by the Oregon Department of Land Conservation and Development (DLCD). The department's approval is called "acknowledgment."

Once comprehensive plans and ordinances are acknowledged, Oregon law deems many land development decisions to be "ministerial" and, therefore, not subject to discretion. When someone applies to develop a parcel, the major decisions have already been made. Local government officials review the application to ensure that it complies with the adopted plan and land use regulations. This gives property owners considerable assurance that a project will be approved quickly if it is designed in accord with plans and regulations.

Every 4-10 years, local comprehensive plans are subject to "periodic review" to ensure they are achieving statewide planning goals. The process is initiated when DLCD sends a letter to the jurisdiction indicating the subjects that must be considered during periodic review. The review consists of evaluating the existing plan and regulations, developing a work program to correct any deficiencies, and revising the plan. The evaluation and work program are sent to DLCD for approval prior to undertaking revisions. The department could easily require local governments to use the earthquake hazard maps during periodic review of their comprehensive plans.

The entire local comprehensive planning process is geared to meeting the 19 statewide goals. DLCD has issued brief guidelines to help local governments apply most of the goals. In addition, the Oregon Land Conservation and Development Commission has adopted administrative rules for some goals specifying in detail the requirements for consistency.

Local governments are most likely to use the earthquake hazard maps in addressing Goal 7, *Areas Subject to Natural Disasters and Hazards*. Earthquake hazards are also pertinent to goals 5, 10, 11, 12 and 14. These goals are listed in Table 1 and the potential use of earthquake hazard maps in meeting each is described in the following sections.

Goal 7: Areas Subject to Natural Disasters and Hazards

To protect life and property from natural disasters and hazards.

Developments subject to damage or that could result in loss of life shall not be planned nor located in known areas of natural disasters and hazards without appropriate safeguards. Plans shall be based on an inventory of known areas of natural disaster and hazards.

Areas of natural disasters and hazards are areas that are subject to natural events that are known to result in death or endanger the works of man, such as stream flooding, ocean flooding, ground water, erosion and deposition, landslides, earthquakes, weak foundation soils and other hazards unique to local or regional areas.

2.1.1. Goal 7: Areas Subject to Natural Disasters and Hazards

Goal 7 is "to protect life and property from natural disasters and hazards." The full text is in the sidebar. The guidelines state that "proposed developments should be keyed to the degree of hazard and to the limitations on use . . ." (Guideline A.1)

The guidelines specifically note flooding, but not earthquake hazards. However, Guideline B.2 states, "When locating developments in areas of known natural hazards, the density or intensity of the development should be limited by the degree of the natural hazard."

Goal 7 provides the essential authority, indeed responsibility, for local governments to inventory and respond to natural hazards, including earthquake hazards, in their comprehensive plans and land use regulations. The guidelines are not specific and no administrative rules have been issued to further guide local efforts in conforming to this goal.

Table 1. STATEWIDE PLANNING GOALS

Goal 5. Open Space, Scenic and Historic Areas and Natural Resources	To conserve open space and protect natural and scenic resources.
Goal 7. Areas Subject to Natural Disasters and Hazards	To protect life and property from natural disasters and hazards.
Goal 10. Housing	To provide for the housing needs of citizens of the state.
Goal 11. Public Facilities and Services	To plan and develop a timely, orderly and efficient arrangement of public facilities and services to serve as a framework for urban and rural development.
Goal 12. Transportation	To provide and encourage a safe, convenient and economic transportation system.
Goal 14. Urbanization	To provide for an orderly and efficient transition from rural to urban land use.

However, DLCD is now preparing administrative rules with specific requirements. Such rules could specify that local governments use the earthquake hazard maps for the Metro region and for other areas in Oregon to identify areas subject to earthquake hazards. The rule could also indicate appropriate responses to identified hazards. Through such a mechanism, Oregon cities and counties would have to incorporate strategies to reduce seismic risk in their comprehensive plans.

2.1.2. Goal 5: Open Spaces, Scenic and Historic Areas and Natural Resources

Goal 5 requires an inventory of the location, quality and quantity of natural resources including wetlands and watersheds, fish and wildlife habitats, waterways, historic sites and other lands desirable for open space or in need of preservation.

The state goal expects that the resources inventoried will be preserved unless there is a conflict in uses. "Where conflicting uses have been identified, the economic, social, environmental and energy consequences of the conflicting uses shall be determined and programs developed to achieve the goal."

Lands with earthquake hazards often coincide with lands with resource values. For example, wetlands are often subject to liquefaction and watersheds and wilderness areas may be prone to landslides. Open space uses on these lands not only preserve resources, but also mitigate potential hazards.

2.1.3. Goal 10: Housing

Goal 10 is "to provide for the housing needs of citizens of the state." To do this, local governments are expected to inventory "buildable lands" – lands in "urban and urbanizable areas that are suitable, available and necessary for residential use." In analyzing suitability, local governments may consider potential damage from natural hazards, including earthquakes. Rules issued to implement Goal 10 allow an extension of a city's urban growth boundary (UGB) if the city precludes development of hazardous lands within its UGB.

2.1.4. Goal 11: Public Facilities and Services

Goal 11 is "to plan and develop a timely, orderly and efficient arrangement of public facilities and services to serve as a framework for urban and rural development." Under this goal, cities or counties are to adopt public facilities plans describing the water, sewer, transportation, power generation and distribution facilities "to support the land uses . . . within an urban growth boundary containing a population greater than 2,500."

Lifelines are particularly vulnerable to interruption by earthquakes. The earthquake hazard maps can be used in selecting locations for these and other facilities and establishing design parameters consistent with the exposure to earthquake hazards.

2.1.5. Goal 12: Transportation

Goal 12 is "to provide and encourage a safe, convenient and economic transportation system." A safe transportation system is one that can withstand the onslaught of natural hazards, including earthquakes, with a minimum of disruption. The earthquake hazard maps can be used to identify potential earthquake hazards to be considered in locating and designing transportation facilities.

2.1.6. Goal 14: Urbanization

Goal 14 is "to provide for an orderly and efficient transition from rural to urban land use." To do this, local governments are required to establish urban growth boundaries (UGBs) that clearly separate urban from rural land. Sufficient land should be included within the UGB to accommodate projected needs for housing, employment, commercial and public facilities and services. Local governments are wise to consider earthquake hazards in determining lands to be included within the UGB, considering the potential for both safe development and access. As noted in the discussion of Goal 10, administrative rules specifically permit expansion of the UGB to compensate for hazardous land within the UGB withheld from housing development.

2.2. Oregon Structural Specialty Code

The state building code is comprised of specialty codes: plumbing, electrical, mechanical, elevator, boiler and pressure vessel, and structural. All building in Oregon must be done according to the state code. Cities choose to enforce all or part of the code in their jurisdictions. If they choose not to enforce parts of the code, the counties may assume the responsibility. The state also maintains a building code staff that handles plan check and inspection in areas of the state where neither a city nor a county assumes the function. Building officials, plan examiners and inspectors are all certified by the state. Building permit fees finance code enforcement.

Most earthquake safety provisions are in the Oregon Structural Specialty Code (OSSC), which is the most recent Uniform Building Code (UBC) including amendments added by the state.

State and regional officials meet to discuss potential uses of earthquake hazard maps.

Until 1989, state amendments placed all of Oregon in Seismic Risk Zone 2 and required less reinforcing for small masonry buildings than the UBC. In 1989, the small masonry building amendment was deleted and the Seismic Risk Zone was changed to 2B for all of Oregon except a section near the California border that was placed in Zone 3. In 1993, the map was changed again to add most of western Oregon to Zone 3 with more stringent seismic provisions than Zone 2 or 2B.

In 1994, the legislature amended Section 2905 of the OSSC to require seismic site hazard investigations" for "essential facilities, hazardous facilities, major structures and special occupancy structures." For these facilities, the code states that "Prior to the design of new structures . . . or new significant additions . . . the site shall be evaluated . . . for vulnerability to seismic geologic hazards." The evaluation is to be done by "an especially qualified engineer or engineering geologist." The Oregon Revised Statutes (ORS) 455.447 describes geotechnical reports and seismic site hazard reports. Seismic site hazard reports are to be reviewed by a professional with qualifications at least equal to those of the preparer.

For structures not in one of the listed categories, the local building official may require an especially qualified engineer to determine the engineering properties of the soil. Thus, for specific buildings, local building officials must require a site investigation and for non-listed buildings they have discretion to require an investigation. The earthquake hazard maps are an important tool in exercising this discretion.

The Appendix to Chapter 33 of the UBC covering grading and hillside development is not adopted by the state, but local governments may adopt it or other provisions to regulate hillside development. If adopted by local governments, Appendix 33 gives building officials the discretion to require geotechnical or engineering geologic investigations of sites whenever they determine there is a need for geologic information. Section 106.3.2 of the OSSC also gives local building officials additional authority to require geotechnical reports.

2.3. Emergency Management

The Oregon Office of Emergency Management (OEM) directs all counties and cities that elect to participate in preparing emergency management plans. These plans outline the tasks, procedures and departmental responsibilities for responding to disasters and initiating recovery. The plans include annexes for the disasters and hazards the jurisdiction is most likely to face. Most do not now include earthquake annexes, but with the availability of the earthquake hazard maps, and increasing awareness of the risks, OEM expects earthquake annexes to become more common.

OEM maintains a general hazard mitigation plan with annexes for specific hazards or disasters. In March 1997, the governor directed OEM to form a permanent hazard mitigation team with representatives from 18 state agencies. As its first task, this team undertook a study of rain-induced landslides. Later efforts will include identifying ways to reduce earthquake damage.

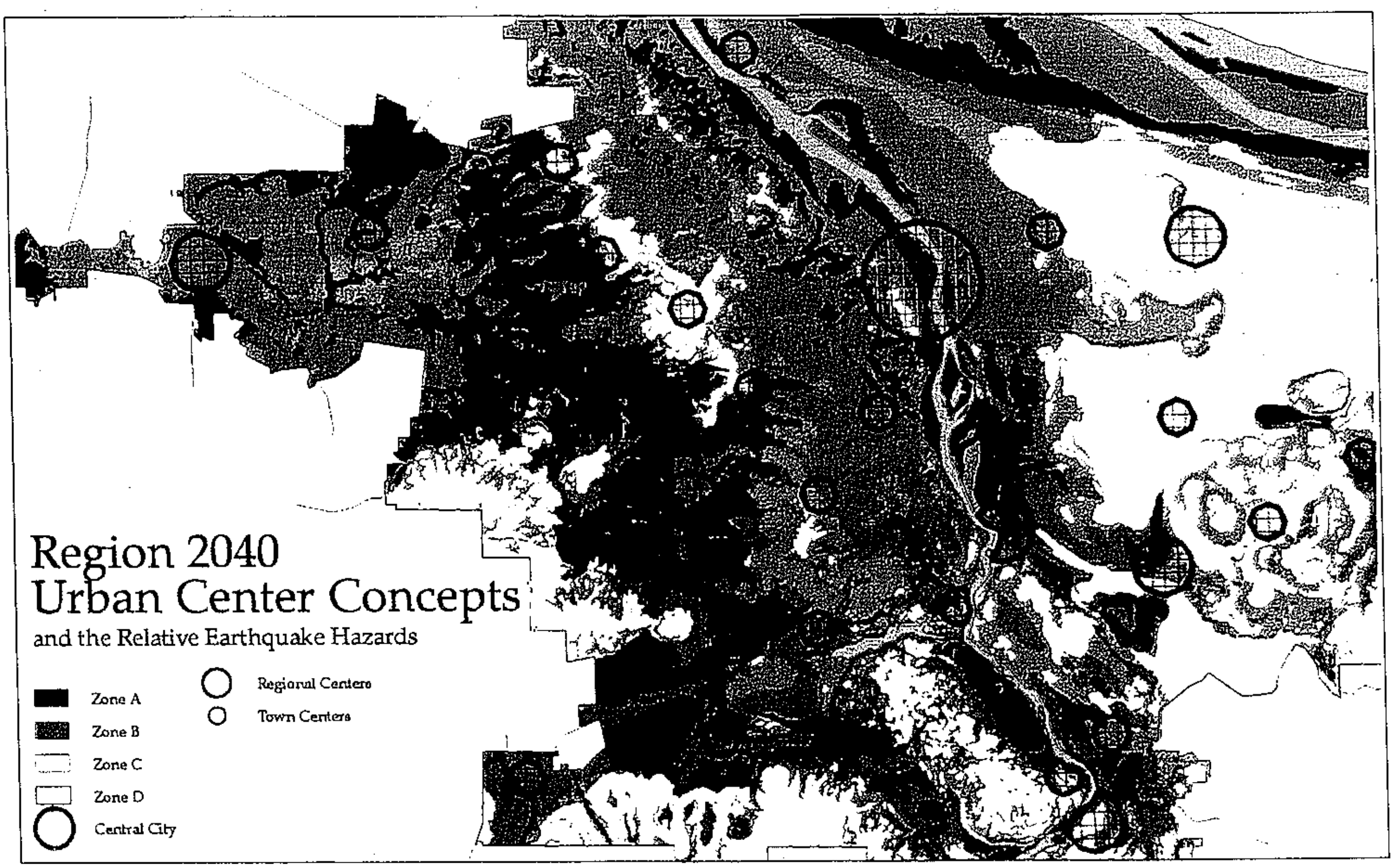
Under current Federal Emergency Management Agency (FEMA) procedures, states are responsible for preparing hazard mitigation plans after declared disasters to evaluate all the hazards in the disaster area and set forth actions to reduce the impact of future disasters. Failure to complete and implement a hazard mitigation plan could jeopardize eligibility for disaster assistance in future disasters. The earthquake hazard maps could be used to help identify mitigation projects. OEM is already using the earthquake hazard maps to create scenarios for training exercises for emergency responders.

2.4. Metro Growth Management Planning

Metro is a true regional government, formed in 1978, with a charter approved by the voters of the Portland region and an elected council and executive officer. Its activities are guided by the *Regional Framework Plan*, adopted in December 1997, consolidating planning documents approved over the years by the Metro council. The *Regional Framework Plan* does not directly regulate local actions. However, it provides the framework for functional plans that may contain specific requirements affecting local planning. At this time (1998), the Metro council has not adopted any functional plans.

Some of the regional and town centers planned to accommodate the region's growth are located in earthquake hazard areas as shown on the REHM. With the earthquake hazards information, local governments can now make decisions about future growth considering earthquake hazards along with other factors.

Metro's *2040 Growth Concept* was hammered out prior to the



Regional Framework Plan. It defines how the region will grow and designates regional and town centers where population and commercial activity will be concentrated. By fostering fairly dense development in these centers, residents of the region hope to avoid the sprawl that plagues many metropolitan areas. The land beyond the regional and town centers is to remain in forest or agricultural uses and the land between them in open space and low density residential uses.

The *Growth Concept* was adopted before earthquake hazard maps were available for the entire region so earthquake hazards were not considered in evaluating growth centers. However, since the adoption of the growth concept by the Metro Council, the staff has created an overlay showing the centers and relative earthquake hazards.

The map shows that several centers are located in areas with higher than average risk of damage from earthquakes. Knowing this, Metro and the region's local governments could consider several options to adjust future development to earthquake risk levels.

- Amend the plan to reallocate future growth (density) from the regional and town centers with high hazard to centers in safer locations.
- Recommend site-specific investigations prior to local approval of development in regional and town centers with high risk.
- Review and, if needed, recommend stricter building code standards in centers with high risk. This would probably entail amendment of the Oregon Structural Specialty Code.
- Review the location and design of new infrastructure and public facilities in areas with high risk.

Metro also works with local governments to ensure that the urban growth boundary (UGB) for the region contains sufficient land to accommodate urban growth for 20 years. Pursuant to statewide planning Goal 10 on housing, Metro maintains an inventory of "buildable land" within the UGB. As noted above, buildable land is vacant residential land "that is not severely constrained by natural hazards or subject to resource protection measures."

A major improvement in earthquake safety could result if Metro retained a geologist or geotechnical engineer to assess the hazard data and maps when it updates its buildable land inventory.

Metro has a regional land-use information system (RLIS) containing a wealth of spatial information for the region – parcel data, zoning, urban development and natural resources. RLIS also contains the earthquake hazard maps for the region and information on the seismic vulnerability of most buildings in the region with the exception of single family homes. Vital systems and critical facilities are also included in the inventory. These data are available to local governments in several forms – paper, electronic (Internet) and on a CD-ROM called MAD-GIS (Metro Area Disaster Geographic Information System).

The data on seismic vulnerability of buildings is especially useful for mitigation planning and emergency response in developed areas. Metro has compiled an inventory of every non-residential building and every residential building more than two stories in height. The buildings are classified by 23 different factors including address, year built, use, occupancy and structural type. Buildings are assigned to one of 11 structural types that are differentiated according to expected seismic performance. The building data may be combined with the hazard maps to assess the vulnerability of the existing structures in the Metro region to earthquake damage. Using damage ratios keyed to structure type and geologic conditions, estimates of earthquake losses can be calculated. The ability to combine building data and hazard maps helps policymakers set priorities for retrofit of hazardous buildings, define redevelopment needs and priorities, and construct realistic earthquake damage scenarios for emergency response training.

2.5. Natural Hazards Mitigation Plan

At the time this report was published, a regional natural hazards mitigation plan was being prepared by Metro with the help of a consultant team. Its purpose is to identify potential hazard mitigation measures for the region to reduce the impacts of future natural disasters – floods, landslides, earthquakes, severe weather, volcanic activity and other hazards. The project is part of the hazard mitigation planning process required by FEMA after the flood and landslide disaster in February 1996. The hazard mitigation suggestions in this guide may help local governments implement parts of the forthcoming hazard mitigation plan.

3. Local Use of Earthquake Hazard Maps

Local governments determine what gets built where and how and, therefore, are critical to seismic risk reduction. State goals and programs and regional policies provide the context, but the most important decisions remain with cities and counties. Local governments will find many applications for the earthquake hazard maps. Table 2 lists several important local government functions and assesses the usefulness of each of the maps for each function.

Table 2. USES OF EARTHQUAKE HAZARD MAPS BY LOCAL GOVERNMENTS

Function	Maps			
	Relative Earthquake Hazard	Relative Ground Shaking Amplification	Relative Liquefaction Hazard	Relative Slope Instability
Comprehensive planning & zoning	✓✓	✓	✓✓✓	✓✓✓
Review subdivision applications	✓	✓	✓✓✓	✓✓✓
Site-specific seismic hazard evaluation	✓✓	✓✓	✓✓✓	✓✓✓
Siting and design of public facilities and utilities	✓+	✓+	✓✓+	✓✓✓
Redevelopment and seismic retrofit	✓✓	✓✓	✓✓+	✓✓✓
Emergency management	✓✓✓	✓✓✓	✓✓✓	✓✓✓

✓	**Limited usage**
✓✓	**Moderate usage**
✓✓✓	**Extensive usage**

Local governments will find the maps showing relative slope instability and liquefaction potential highly useful for comprehensive planning and zoning and review of subdivision applications. All four maps are moderately or highly useful to indicate sites where site-specific seismic investigations should be required and setting priorities for redevelopment projects and seismic retrofit programs. The liquefaction and landslide hazard maps are particularly useful for siting and design of public facilities and utilities. Emergency managers will find all four maps highly useful creating public education programs, earthquake hazard mitigation programs, response plans and scenarios for training exercises. Uses of the maps for all these purposes are described below with examples drawn from the Portland metropolitan region.

3.1. Comprehensive Planning and Zoning

As noted in the previous section, every city and county must prepare a comprehensive plan consistent with Oregon's statewide planning goals. Local comprehensive plans are submitted to the Land Conservation and Development Commission (LCDC) for acknowledgment and revised every four to seven years to recognize changes in state and regional requirements, information and local conditions. Although local governments have considerable latitude in complying with the state goals, success in the acknowledgment process depends on carefully collecting and analyzing data pertinent to land use. State guidelines and administrative rules require inventories of a jurisdiction's natural features, including lands subject to natural hazards. Information on natural features is typically assembled on maps and analyzed with other information to determine future land uses that are then shown on the comprehensive plan map. The earthquake hazard maps can be readily used in this analysis along with maps of floodplains, landslides, topography, wetlands and other physical characteristics that influence land use.

A geographic information system (GIS) is a significant aid in this analytic process. It allows local governments to efficiently and systematically combine spatial data from a variety of sources. This ability to layer information allows analysts to see in one glance the net effect of all the factors influencing land use decisions in a given area, while at the same time retaining the ability to explore the influence of the individual factors. The data used to create the earthquake hazard maps are available from Metro and can be incorporated into a GIS.

Guidelines

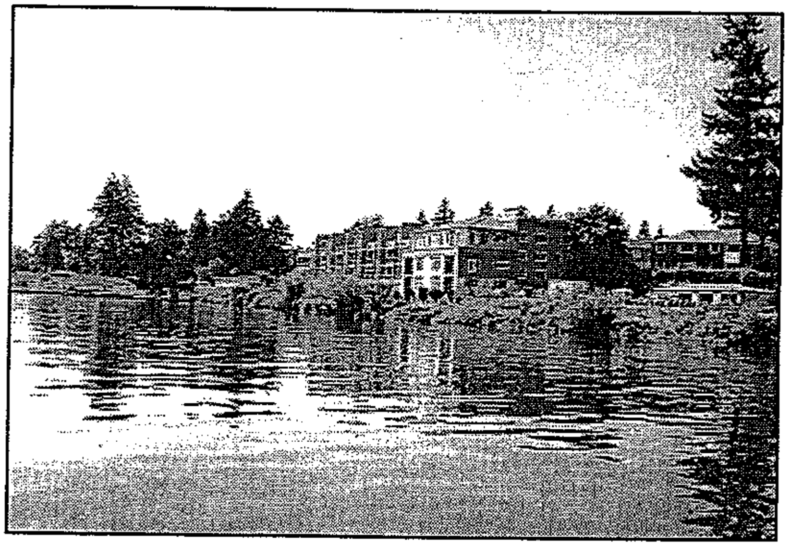
- ***Use the earthquake hazard maps, along with other information, in determining land uses and urban growth boundaries.***
- ***During periodic review of comprehensive plans, review and revise, if needed, the uses for lands shown as hazardous on the earthquake hazard maps.***
- ***Incorporate the earthquake hazard maps into local GIS, if available.***

Most comprehensive plans in the Metro region were completed before the earthquake hazard maps were available. As they come due for periodic review, planners can use the earthquake hazard maps in the analysis of physical characteristics affecting land use. For this purpose, the component maps will be most useful. In general, ground shaking hazards are best mitigated by adopting and enforcing appropriate building code standards and giving careful attention to design and construction. Restrictions on land use are rarely justified because of the potential for strong ground shaking. However, restrictions may be indicated for potential landslides, liquefaction and other ground failure hazards that can be triggered by earthquake ground shaking. Maps showing the distribution of potential ground failure hazards are usually the most useful to include in the land use analysis.

The example below describes the comprehensive plan of the City of Lake Oswego and shows how the earthquake hazard maps could be used by the city in preparing its plan. The example demonstrates that considering earthquake hazards will not complicate the land use analysis and will probably not result in significant land use changes. It is likely to strengthen the rationale for low-density uses or open space preservation in specific areas where earthquake hazards coincide with other hazards or natural features warranting protection.

3.1.1. Example: Lake Oswego Comprehensive Plan

Lake Oswego is a city of about 35,000 people in Clackamas County eight miles south of Portland. The city grew rapidly in the 1970s and 1980s – more than 60 percent of the housing units were constructed after 1970. Little vacant, buildable land remains within the city limits. New building will result from annexation, some redevelopment of older areas and infill projects. The community has a mix of housing densities, commercial areas and some industrial uses. It contains about twice as many employed residents as jobs so that many people commute to jobs elsewhere. The city households have relatively high incomes with a 1989 median household income of $51,499 compared with $35,419 for Clackamas County and $27,250 for Oregon. Rents and house values are also high relative to the county and state.

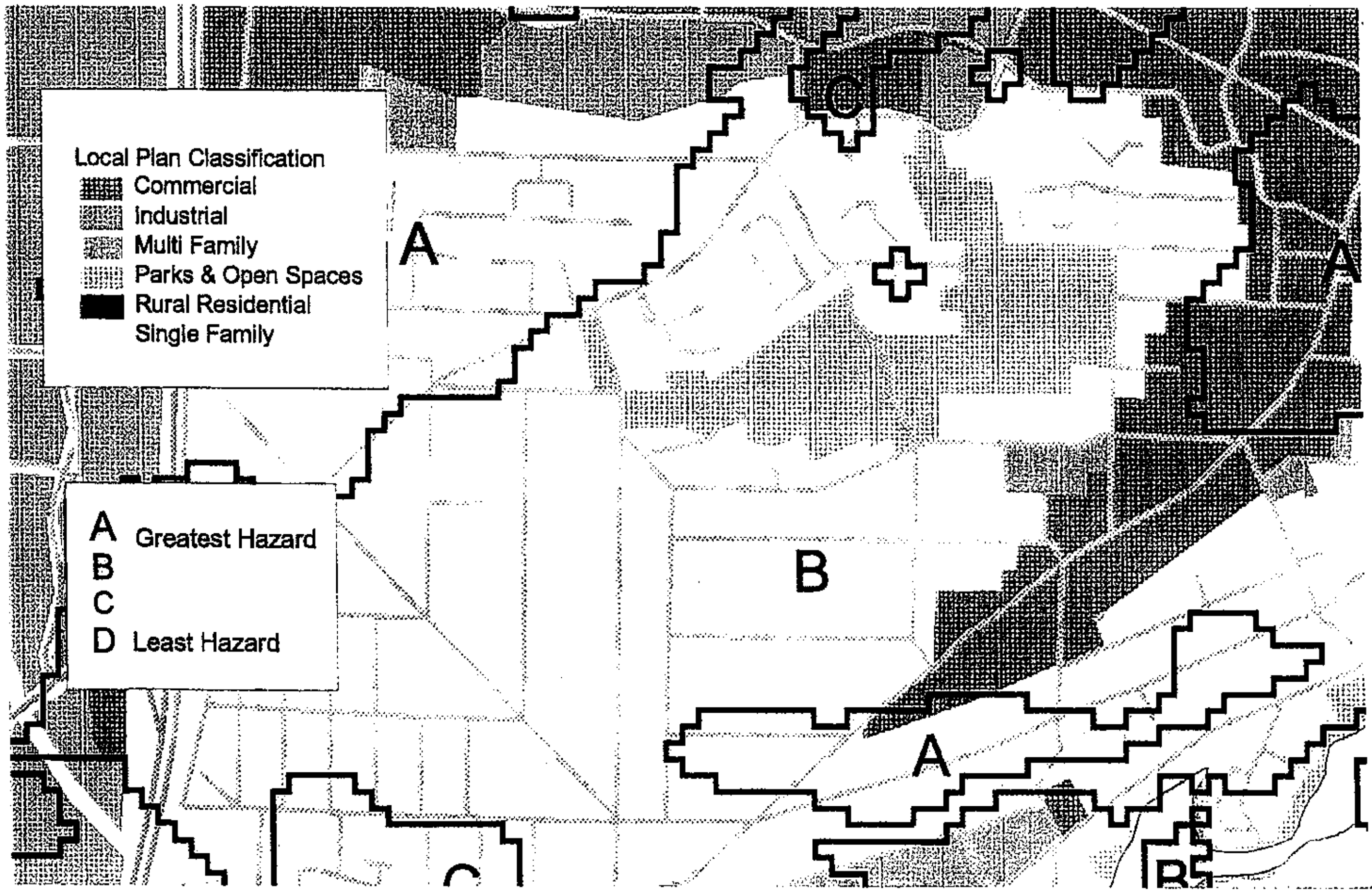


The City of Lake Oswego is located south of Portland and west of the Willamette River on Lake Oswego. This photo shows the lake from near the city center.

Like many Oregon cities, Lake Oswego has a comprehensive plan with a chapter for each relevant state goal – in this case Goal 13. The analysis and policy framework in the *Lake Oswego Comprehensive Plan* permits the easy use of the earthquake hazard maps as another factor in determining the city's land-use pattern, particularly in designating open spaces. The city's plan draws on an inventory of "sensitive lands" – wetlands, stream corridors and tree groves. The sensitive lands meeting criteria for protection are placed in an overlay zone – the Resource Protection (RP) district for wetlands and stream corridors or the Resource Conservation (RC) district for tree groves. The two resource overlay district boundaries are shown on the comprehensive plan and zoning maps, but the official regulatory delineations are in the *Sensitive Lands Atlas*, a bound volume of maps at a scale of 1" = 200' maintained at city hall.

Areas with earthquake hazards are not explicitly included in the sensitive lands inventory or the resource overlay districts; however, they easily could be and the result would be to strengthen the case for resource protection. The following map shows hazard zones on the REHM for a portion of the city. As can be seen, the RP and RC overlay districts contain most of these hazard areas. Thus, considerable earthquake hazard mitigation is inherently a part of open space planning in Lake Oswego. Considering earthquake hazards as well as resource values in drawing the boundaries of the overlay zones could enhance this approach to mitigation.

The Lake Oswego comprehensive plan treats hazards more directly in the chapter on Goal 7, *Natural Disasters and Hazards*.



Lake Oswego's Comprehensive Plan places selected wetlands, stream corridors and tree groves in resource protection and conservation overlay districts. The resources in these areas are to be protected from development.

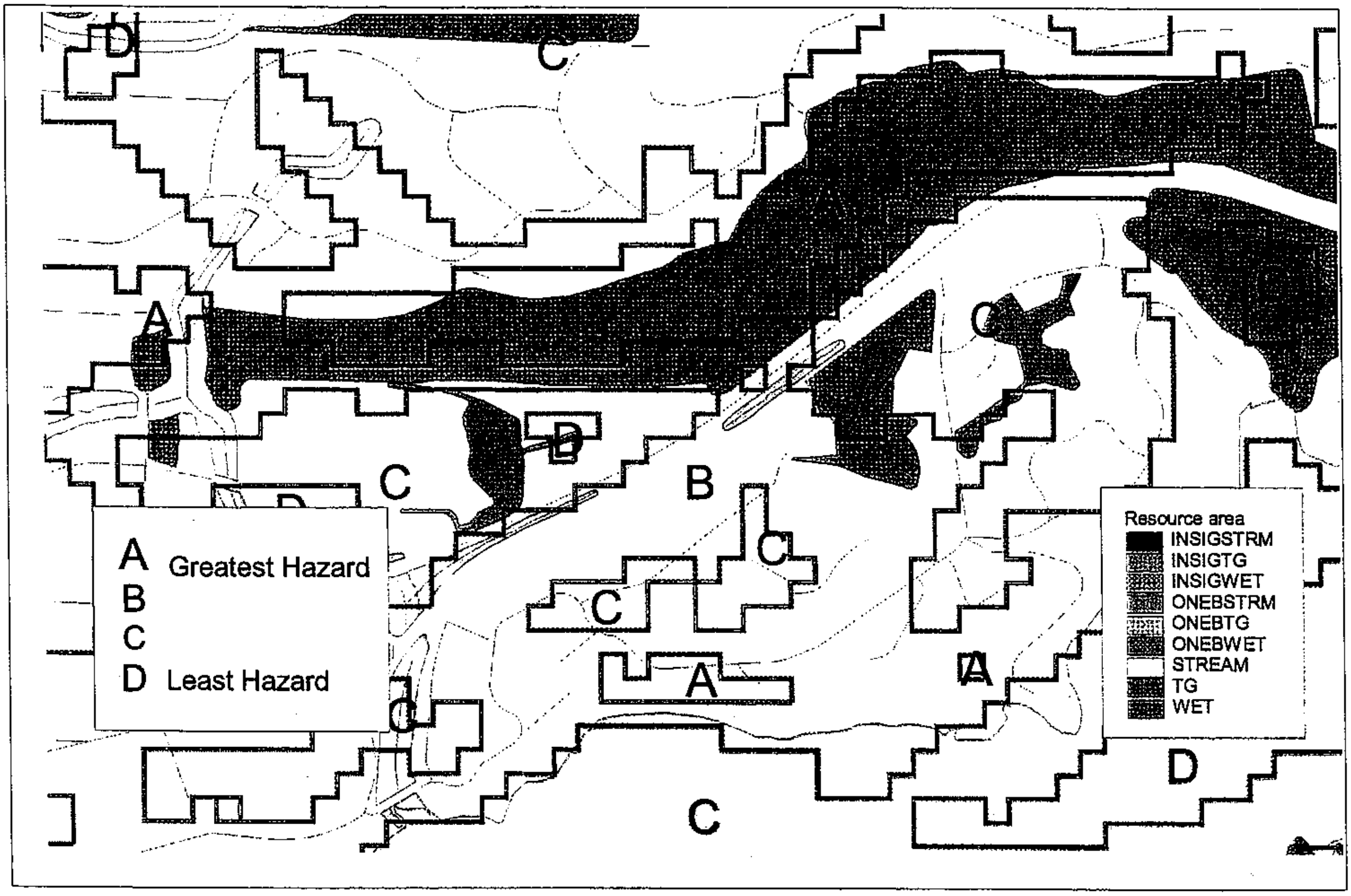
The chapter is divided into three sections: (1) flood hazards, (2) earthquake hazards and (3) landslides, erosion and unstable soils.

The provisions on flood hazards are the most specific, responding to the requirements of the National Flood Insurance Program. Land use is addressed by including stream corridors and wetlands in the Resource Protection overlay zone and by allowing development density within the flood fringe to be transferred to higher portions of a site. Recommended action measures include encouraging land acquisition within the flood plain for conveyance and storage of floodwaters and for open space and passive recreation.

In the section on landslides, erosion and unstable soils, the Lake Oswego plan notes that landslide hazards are identified in the Lake Oswego Physical Resources Inventory (LOPRI) of March 1976 and weak foundation soils are identified in the Soil Conservation Service Soils Survey. The city uses these maps in applying policies and regulations.

Land-use policies include:

- Regulate density and intensity of land use in areas with the potential for unstable soils, known or potential landslide hazards and soil erosion hazard areas, in accord with the degree of hazard.



This map shows the resource districts superimposed on the REHM. Most high hazard areas are in one of these zones where development is carefully controlled. The city is unwittingly, but wisely, managing its hazardous lands as it protects and conserves its natural resources.

- Require that land identified with a potential for high erosion hazard will be maintained in open space, unless appropriate evidence demonstrates that engineering can effectively overcome soil and slope limitations.
- Allow development density proposed on steep slopes and on lands with unstable soils to be transferred to stable portions of the site when these areas are preserved as open space.

An important action measure is to reduce the intensity of development permitted by zoning, when needed, to eliminate or reduce erosion, landslide or unstable soil hazards.

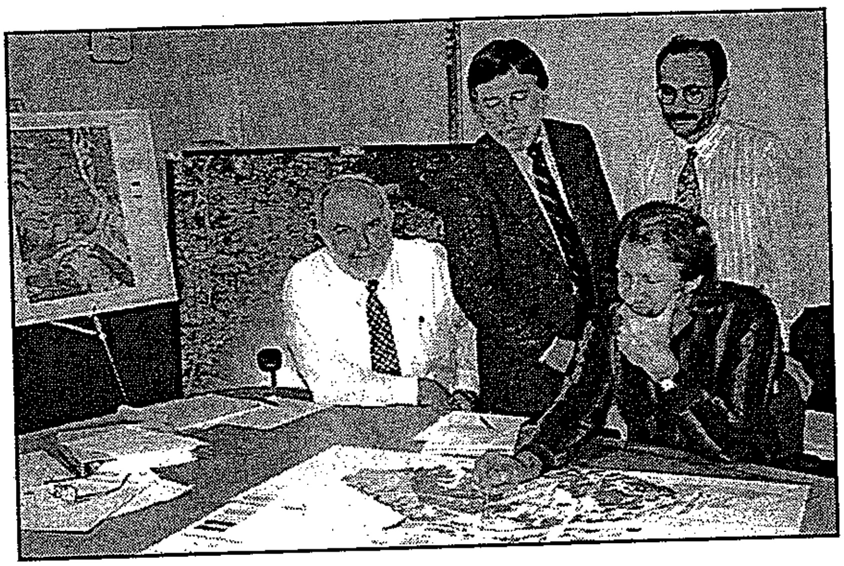
This park on the north shore of Lake Oswego is on land with potential for liquefaction. Park and open space uses provide public benefit while also reducing potential earthquake damage.

Under earthquake hazards, one policy and one action measure directly address land uses in earthquake hazard areas:

- Enact regulations governing the location of structures and land uses, as new seismic information becomes available.

- Use DOGAMI's inventory of relative earthquake hazards in the Lake Oswego area to determine areas that will likely experience the greatest effects from any earthquake. This information can be used in refining the Emergency Operations Plan and determining relative damage potential of various locations.

At the time the plan was adopted in 1994, DOGAMI had not completed the earthquake hazard maps covering Lake Oswego. With the maps now available, the policy and implementing action could be strengthened. In fact, the city will find that most of the areas shown on the DOGAMI liquefaction and landslide potential maps are already regulated as sensitive lands or landslide, erosion, or weak foundation soil areas. The DOGAMI maps will help the city fine-tune and reinforce its existing system of planning and regulation in hazardous areas.



City of Lake Oswego staff members look over the map of landslides used for policies to prevent landslide damage.

The landslide and weak soil map used by Lake Oswego is prepared at a scale of 1" = 800' – the same scale as its comprehensive plan map. The DOGAMI maps were prepared at the scale of 1" = 2,000' and should not be enlarged beyond this scale. Thus, Lake Oswego is unlikely to switch from the Soil Conservation Service map to the DOGAMI maps for its planning program. However, the city could use the earthquake hazard maps to check for hazards not shown on the Soil Conservation Service map. In doing this, staff needs to recognize that soils maps only provide information about the top 6 feet or so of soil. The earthquake hazard maps contain information at much greater depth and provide explicit interpretations about expected performance in an earthquake.

Communities will find the DOGAMI maps an excellent starting point in treating earthquake hazards in their comprehensive plans. With the maps, they can institute policies and action programs similar to those adopted by Lake Oswego to protect sensitive hillsides, wetlands and stream corridors as community resources while at the same time protecting their residents from dangers associated with living and working in these often hazardous areas.

3.2. REVIEW OF SUBDIVISION APPLICATIONS

The subdivision of land determines the number and configuration of lots as well as the location of roads and utility lines serving the lots. Careful land division is a powerful way to reduce future earthquake damage. Earthquake hazards are more easily addressed before a lot is created than afterwards. Once a lot is created and sold, local governments find it difficult, if not impossible, to deny owners the right to build. It is very important that all lots have buildable areas relatively free of hazards, accessible through stable lands and served by utilities that can remain operational after an earthquake. The earthquake hazard maps can be used in reviewing subdivision applications to avoid creating lots that may subsequently prove difficult to develop safely.

Guidelines

- ***Use the earthquake hazard maps to determine when seismic hazard evaluations are needed before land is subdivided.***
- ***Before new lots are created, use the earthquake hazard maps to help assess the vulnerability of the lots, access and utility lines in the event of an earthquake.***

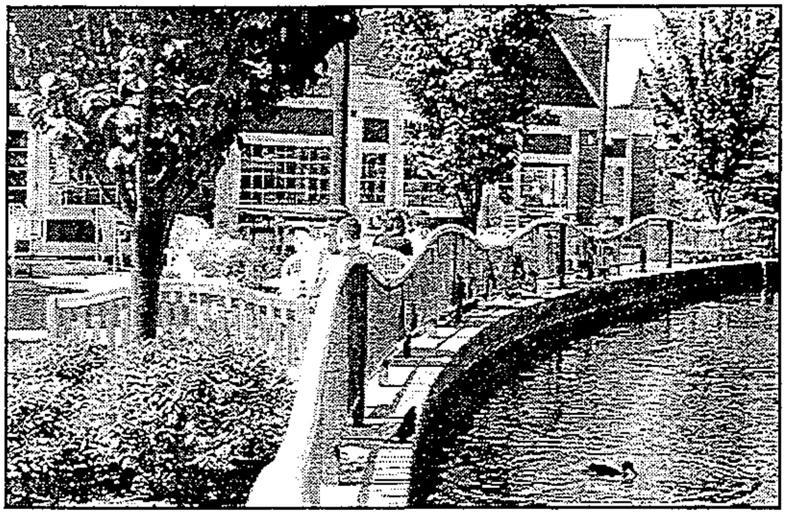
Chapter 92 of the *Oregon Revised Statutes* establishes procedures for the partition and subdivision of land in the state. Under this law, subdivisions must be consistent with acknowledged comprehensive plans and local governments are required to adopt their own standards and procedures which may include, among other items, requirements for "securing safety from fire, flood, slides, pollution or other dangers." (ORS 92.044(a)(B)). Earthquake hazards could be considered "other dangers."

A critical need at the time of subdivision is sufficient information to identify potentially unsafe lots before they are created. The earthquake hazard maps are not detailed enough to identify unsafe lots, but they do identify large areas with potential hazards. In these areas, engineering geology and geotechnical investigations should be required prior to subdivision so that sufficiently detailed information can be considered in drawing lot boundaries, locating roads, and designing utilities and public facilities. Such investigations would focus on landslide and liquefaction hazards because these are the earthquake hazards that most affect the safety of subdivisions and subdivision improvements.

Current practice among local governments in the Metro region varies considerably. A few defer the whole question of geotechnical reports until the building permit stage after the land has been subdivided and the roads and other site improvements constructed. This may limit options and increase costs for hazard mitigation. Often it is more effective and less expensive, for example, to avoid an unstable hillside than to stabilize it. On the other hand, some cities require geotechnical reports early in the subdivision process so that the information can be used in designing the subdivision. If the information from the preliminary studies indicates potential problems, detailed reports may also be required for individual lots before actual construction.

3.2.1. Example: City of Tualatin

The availability of the earthquake hazards maps is beginning to change practice in the region. An example is the City of Tualatin. Tualatin, with a 1990 population of about 15,000, is located southeast of Portland on the Tualatin River. The city is almost entirely within a "red zone" on the REHM because of thick alluvial soils that amplify ground shaking and have the potential to liquefy. Small areas also have low to moderate potential for landslides.



In the last decade, Tualatin has grown rapidly, completing major projects such as Tualatin Common, shown above, designed to become a new city center.

In Tualatin, a development application is reviewed and approved by the other departments and planning commission, and then comes to the building division for building permits. Soils and geology are not usually considered until the building permit stage.

At this point in the approval process, the building division may recommend soils or geotechnical studies when the importance of the structure or knowledge of potential hazards indicates a need. The purpose is to be sure site improvements and foundation design are appropriate for the site. Staff members in other divisions sometimes object to requiring reports, viewing them as an unnecessary burden on the applicant especially because reports are not required by the state.

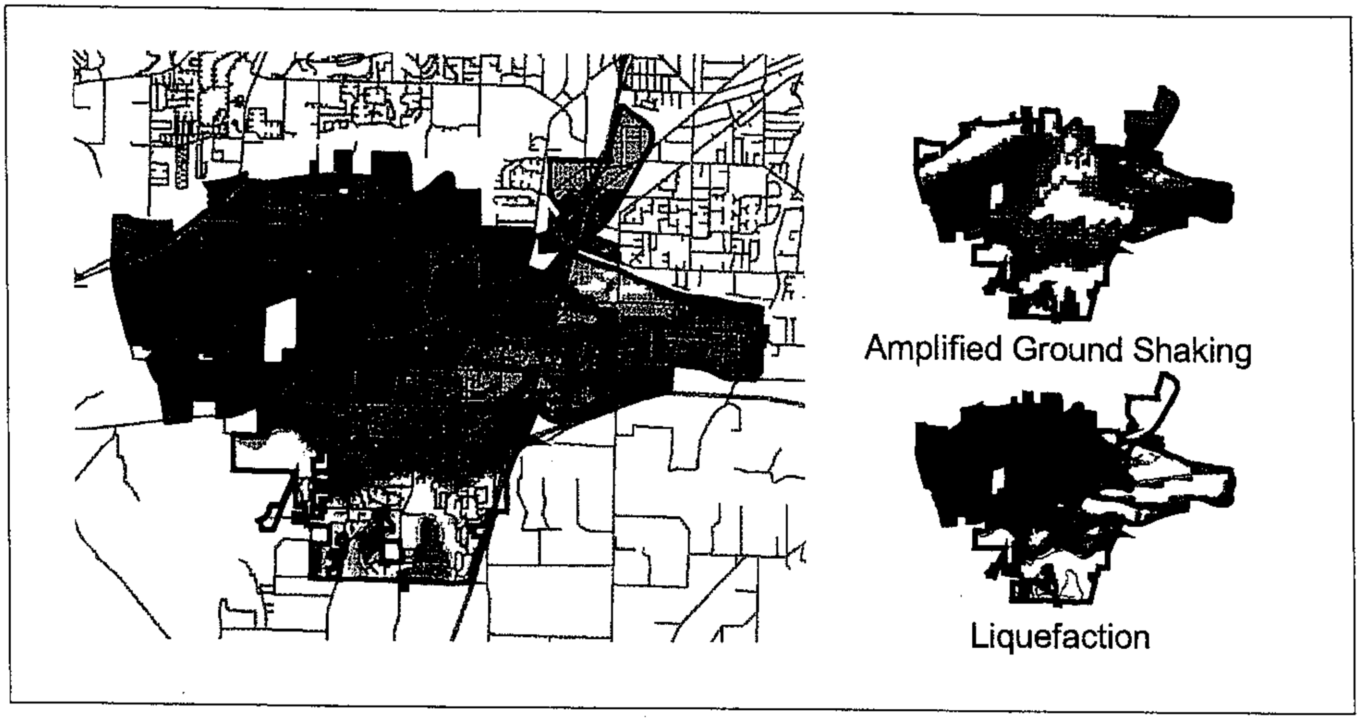
Geotechnical reports are reviewed by the building staff and approved by the building official, none of whom are geotechnical engineers. Several projects have been redesigned on the basis of the information contained in soils or geology reports.

The city is fortunate in that it has a building division plans examiner with an interest in earthquake safety. This plans examiner attended a Metro earthquake awareness class and, since that time, has required project designers to state in their building permit applications the site's earthquake hazard zone (A, B, C or D) and category of slope instability, ground shaking amplification, and liquefaction (1, 2, or 3). This information helps him determine what topics should be covered in soils or geotechnical reports, if required.

Plans examiner in Tualatin reviewing relative liquefaction hazard map.

The plans examiner was interested in the earthquake hazards maps as soon as they were released for the Tualatin in 1996. Using the maps was difficult because to view the city's entire area required four quadrangle maps. He requested funding from the engineering division for an engineering technician to produce a single map covering just Tualatin from Metro's GIS database.

The relative earthquake hazard map for Tualatin is now on the wall in the building division where it is attracting much interest. In the year or so since Tualatin has had the maps, public awareness of earthquake hazards seems to have increased. The building department now receives calls inquiring about earthquake

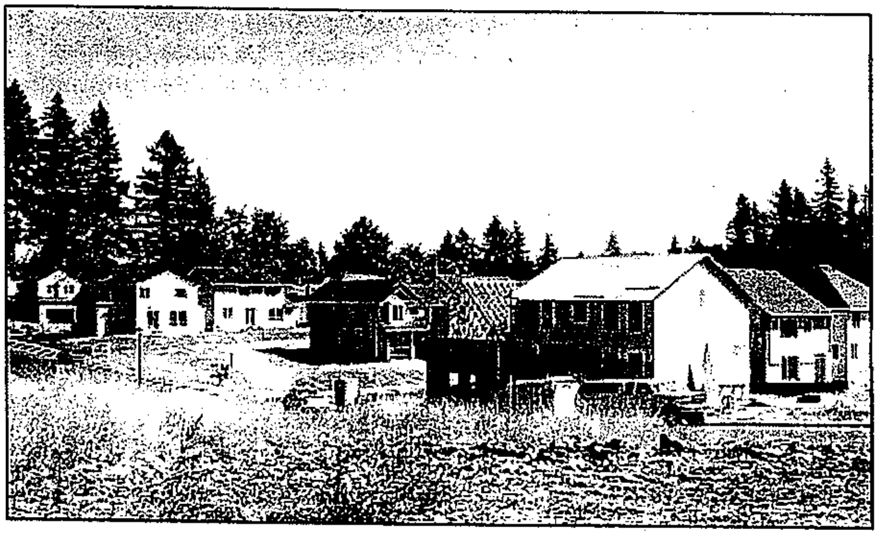


The City of Tualatin is almost all in Zone A (high hazard) on the REHM because of the potential for both amplified ground shaking and liquefaction.

hazards. This is an important indication that a change in procedures is on the horizon.

Now with maps showing the entire city and growing public awareness, the plans examiner hopes Tualatin will improve its subdivision procedures to incorporate standard practice in requiring geotechnical information. Specifically, he would like to see the city:

- Establish policy guidance for requiring and reviewing soils and geotechnical reports.
- Require preliminary soils and geology reports before subdivisions are designed. This would relieve some of the burden that now rests solely on the building division to ensure acceptably safe development.
- Require permits for grading and excavation and geotechnical



This subdivision created 83 lots in an area with both unstable slopes and potential liquefaction. A geotechnical report was done prior to grading and construction of improvements, but the report did not evaluate earthquake hazards. Subdivision applications in areas like this should be accompanied by an engineering geology and geotechnical report reviewed for adequacy by a qualified professional retained by the city.

reports, if needed, before building permits are issued.

- Require that reports be done by licensed geotechnical engineers and/or engineering geologists.
- Charge applicants a fee to pay for qualified professional review of reports submitted with subdivision applications.
- Add space for listing earthquake hazard zones on the cover sheet for the structural calculations. Now just the UBC zone is called for.

These excellent ideas are consistent with the approaches suggested in the following section addressing local requirements for site-specific seismic hazard evaluations in considerable detail. This next section discusses important features of provisions to require geotechnical and engineering geology reports that can be incorporated into subdivision, zoning, building or other regulations governing land development.

3.3. SITE-SPECIFIC SEISMIC HAZARD EVALUATIONS

One of the most effective ways to use the earthquake hazard maps in regulating land use is to require site-specific seismic hazard evaluations prior to approving subdivisions and development in zones with potential earthquake hazards. As noted in the previous section, the maps are not detailed enough to evaluate hazards on an individual building site or in a small area. Nor is the detail sufficient to say that a given site should not be developed solely because of the presence of earthquake hazards. The zones indicate **relative** not **absolute** hazards and the **potential** not the **certainty** of a hazardous condition.

The earthquake hazard maps do, however, provide an effective early warning that hazardous conditions may be present. The prudent response to this warning is to obtain more information to determine the actual presence or absence of hazards. This is done through site investigations by qualified geotechnical engineers and engineering geologists.

Table 3 summarizes seismic hazard investigation recommendations in the MACMED report, *Using Earthquake Hazard Maps for Land Use Planning and Building Permit Administration*, adopted by the Metro Council. The table defines the need for site investigations for each type of land use (grouped according to vulnerability to earthquake damage), each hazard zone, and each of four earthquake performance objectives. Table 3 also identifies facilities, regardless of location, for which the Oregon Specialty Structural Code now requires investigations.

TABLE 7: SITE SPECIFIC SEISMIC HAZARD INVESTIGATION REQUIREMENTS BASED ON RELATIVE EARTHQUAKE HAZARD MAP

LAND USE GROUP	LAND USES (a)	Facilities Affected by OSSC	HAZARD ZONES & INVESTIGATION REQUIREMENTS: Greatest	High	Moderat	Least
Potential Catastrophe	Large dams					
if Damaged	Nuclear plants					
	Facilities using/storing large qt. of haz. mat.	X				
High-Occupancy with	Day care centers < 250 kids					
Involuntary or Dependen	Day care centers > 250 kids	X				
Occupants	Schools K-12 < 300 students					
	Schools K-12 > 300 students	X				
	Convalescent homes < 50 persons					
	Convalescent homes > 50 persons	X				
	Jails and detention facilities	X				
Essential for Emergency	Fire & police stations					
Response	Garages for emergency vehicles					
	Water tanks					
	Structures housing fire suppresants					
	Govt. communications centers					
	Emergency response centers					
	Hospitals					
	Medical bldg. with surgical services					
Critical to functioning	Large power plants					
of the Metro Region	Power intertie					
	Sewage treatment plants					
	Water plants	X				
	Regional highways and bridges and tunnels					
	Regional rail lines					
	Airports					
	Port facilities					
	Major communications facilities	X				
	Telephone exchanges	X				
	Radio and TV stations					
High Occupancy	Buildings > 10 stories	X	3	3	2	1
	Public & private Colleges < 500 occupants		3	3	2	1
	Public & private Colleges > 500 occupants	X	3	3	2	1
	Public assembly places w/ > 300 capacity	X	3	3	2	1
	Hotels/motels >50 rms >60,000' >10 stories	X	3	3	2	1
	Major industries and employers		3	3	2	1
	Apartments > 25 units		3	3	2	1
	Buildings w/ > 150 employees		3	3	2	1
Important Local Impacts	Facilities using/storing small qt. of haz. mat.	X	3	3	2	1
If Damaged	Small dams that would cause flooding		3	3	2	1
	Gas stations		2	2	2	1
	Highways, streets, and bridges		2	2	2	1
	Utility lines, substations, and gas mains		3	3	2	1
	Water & sewer mains		3	3	2	1
	Industries/business important to economy		2	2	2	1
	Health care clinics		2	2	2	1
	Co-generation power plants		3	3	2	1
Moderate Occupancy	Buildings w/ 4 to 10 stories	X	3	3	2	1
	Apartment 9 to 25 units (b)		3	3	2	1
	Buildings w/ 50 to 150 employees		3	3	2	1
	Bldgs w/50-150 employees >60k'>10 stories	X	3	3	2	1
	Public assembly places: 50 to 300 capacity		3	3	2	1
	Hotels/motels <50 rms <60,000' <10 stories		3	3	2	1
Low Occupancy	Apartment Building with 2 to 8 units (b)		2	2	1	1
	Buildings with < 50 employees (b)		2	2	1	1
	Buildings with 1 to 3 stories (b)		2	2	1	1
	Public assembly places with < 50 capacity(b)		2	2	1	1
	Single-family houses (c)		2	2	1	1
	Manufactured Dwelling (c)		2	2	1	1

KEY TO SITE INVESTIGATION REQUIREMENTS

4 = Site investigation with panel peer review required

3 = Site investigation required unless other data suggest otherwise

2 = Site investigation not automatically required. Local govt may require if desired

1 = Site investigation not required.

EARTHQUAKE PERFORMANCE OBJECTIVES

Fully Functional (Acceptable risk is near zero)

Immediate Occupancy (Acceptable risk is very low)

Damage Control (Acceptable risk is low)

Substantial Life-Safety (Acceptable risk is moderate)

CURRENT STATE REQUIREMENT

X = Facilties required to have seismic site hazard study by the Oregon Structural Specialty Code (OSSC)

FOOTNOTES

(a) The land uses are guidelines and could change as unique facilities and land uses are developed.

(b) Discretion should be applied so that unneccesary site investigations are not required for smaller buildings within this categories. Guidelines to determine when investigations are needed should be established.

(c) Site investigation required if stipulated in a subdivision approval or other development approval of the planning agency.

Engineering Geologist

A geologist studies earth materials and natural earth processes (e.g., earthquakes, landslides, sedimentation) and functions as an earth historian, who uses the geologic record as a basis to forecast future occurrences of geologic processes. An engineering geologist uses the knowledge of past and potential events to identify and characterize geotechnical problems that could affect the location, design, construction and maintenance of structures and engineering works.

Geotechnical Engineer

A geotechnical engineer is a civil engineer who considers the effects of earth materials and geologic processes on structures. Geotechnical engineers use information provided by engineering geologists in analyzing the effects of geologic conditions on proposed structures and in designing structures to effectively address the geologic conditions. Thus, the geotechnical engineer mitigates the constraints identified by the engineering geologist through analysis and design of engineering works.

This geologist has just read a bore hole. Sometimes, subsurface investigation is needed to obtain sufficient information about site conditions to ensure safe development.

Using the table as a general guide, cities and counties can adopt ordinances to require seismic hazard evaluations of individual properties. Such ordinances, normally administered by building departments, need to include at least the following provisions:

- Purposes of the ordinance.
- Adoption of composite and/or individual hazard maps as the official maps of earthquake hazards for the jurisdiction.
- Adoption of matrices relating seismic site investigation requirements to hazard categories found on the hazard map.
- Procedures for review by qualified geotechnical engineers or engineering geologists of geologic and geotechnical reports submitted by project applicants.
- Procedures to resolve technical differences between engineering geologists and geotechnical engineers representing applicants and those representing the city or county.
- Methods to refine the maps on the basis of new information from geologic and geotechnical studies.
- Procedures for inspection by geotechnical engineers during site preparation and construction.
- Funding for the cost of administering investigation requirements, including review of reports by qualified engineers, through charges to developers.

3.3.2. Procedures for Requiring Seismic Hazard Evaluations

Ordinances to require seismic hazard evaluations establish the framework for detailed procedures for requiring, reviewing, and applying the results of site-specific seismic hazard evaluations. Exact procedures will vary from jurisdiction to jurisdiction, but some issues, such as those discussed in this report, will always need to be addressed.

Determining the Need for Investigations

Table 3 is a good guide to determine when a seismic hazard evaluation is needed, but other information and maps should also be used, when available, to make the decision. Basically seismic hazard evaluations should be required for new development or major modification to structures located in moderate and high hazard categories. Reports may also be required in low hazard categories if local officials determine hazard conditions may be present.

Type of Investigation

In the ideal situation, a project applicant meets with staff of the building and/or planning department before submitting an application to determine project requirements, including whether or not a seismic hazard evaluation will be needed and, if so, what kind of investigations are needed and who should do them. For this purpose, the individual hazard maps are useful because the investigation requirements vary with the type of hazard suspected at a site. Table 4 lists the type of investigations that would normally be required in each of the hazard zones shown on the maps of relative slope instability, liquefaction potential and ground shaking amplification.

Table 4. TYPES OF GEOLOGIC INVESTIGATIONS BY HAZARD ZONE

Hazard	Relative Hazard Severity Zone	Type of Investigation Needed
Slope Instability	3 high	• engineering geology and geotechnical engineering
	2 moderate	• engineering geology and geotechnical engineering
	1 low	• geotechnical engineering only (unless geotechnical engineer or city recommend engineering geologist)
Liquefaction	3 high	• engineering geology and geotechnical engineering
	2 moderate	• geotechnical engineering
	1 low	• geotechnical engineering
Amplification	3 high	• engineering geology and geotechnical engineering
	2 moderate	• geotechnical engineering
	1 low	• geotechnical engineering

Steps in a Site Investigation

If an evaluation is needed, the applicant will be asked to retain a qualified engineering geologist and/or geotechnical engineer to conduct a site investigation. The engineering geologist or geotechnical engineer will usually meet with city staff to establish the scope of the evaluation. Table 5 lists the steps in a typical investigation. When the investigation is complete, the report is then submitted to the planning or building department along with a planning or building permit application.

Table 5. STEPS IN A SITE INVESTIGATION

Steps	**Investigative Tasks**	**Professional Responsibility** primary/secondary
Recognition	• Review available maps and analysis of aerial photographs. • Conduct field reconnaissance and geologic mapping. • Identify geologic hazards.	• engineering geologist ↓
Characterization	• Conduct detailed geologic mapping and profiling. • Prepare preliminary geologic cross sections. • Select strategic locations and depth requirements for subsurface exploration. • Collect subsurface samples for testing. • Test subsurface samples.	• engineering geologist ↓ • engineering geologist/geotechnical engineer • geotechnical engineer
Risk Assessment	• Synthesize office, field and laboratory test data. • Evaluate hazards (low, moderate, high). • Analyze potential hazards numerically. • Determine risk associated with specific land use.	• engineering geologist/geotechnical engineer • engineering geologist • geotechnical engineer/engineering geologist • engineering geologist/geotechnical engineer
Mitigation	• Decide tolerable risk considering client needs, local ordinances and codes. • Develop and evaluate mitigation alternatives. • Disclose limitations associated with design options	• engineering geologist/geotechnical engineer • geotechnical engineer/engineering geologist ↓

Independent Peer Review of Reports

The city or county arranges for impartial review of the report by a qualified professional to ensure that all geologic issues are identified and resolved. The mere fact that another professional will review reports can raise the standard of care exercised by report preparers. Reports should be reviewed for completeness, accuracy, consistency with available earthquake hazard maps, and appropriateness of design recommendations.

Few jurisdictions have staff members qualified to critically review the submitted reports. Most rely on review by qualified consulting engineering geologists and geotechnical engineers retained by the local government. The reviewers must be objective, familiar with local geologic conditions and community planning and building regulations, and have the courage to stand by decisions that are frequently controversial. They are usually restricted from performing geotechnical work for applicants in the community where they are reviewing geotechnical reports.

The depth or extent of the geologic/geotechnical review can vary depending on the community's development philosophy. Some communities ask the reviewer to simply verify that the applicant's consultants have performed a complete investigation exhibiting the usual standard of care. Other communities ask reviewers to critically evaluate the conclusions of the applicant's consultants. In this case, the reviewer actually inspects each site, reviews aerial photography, asks for more data or supplemental analyses, and performs other tasks as needed to independently verify the consultant's conclusions and recommendations.

Experts

Engineers and geologists rely upon each other to evaluate hazards and minimize society's risk from geologic processes. An engineering geologist identifies the geologic hazards and their associated risks to society (typically to structures), and the geotechnical engineer uses that information to reduce risk through analysis and design. In seismic hazard analysis, for example, an engineering geologist would identify the potential earthquake threat in terms of earthquake size, location and the probability of occurrence in a given time period. The engineering geologist would also predict the frequency and magnitude of ground motion at the site from subsurface geology and distance from potential earthquake sources. The geotechnical engineer would incorporate the geologist's estimates of frequency and magnitude of ground motion into analysis and design of an appropriate foundation for the proposed structure.

Resolving Differences Among Experts

Disputes between the applicant's and the community's geologic experts may arise during the review. It is important to fully resolve seismic hazard issues prior to planning approval to avoid major changes to the locations of structures or methods or extent of construction activities after the planning department approves the project.

Geology is not an exact science, and well-qualified professionals can disagree on geologic interpretation and what needs to be done. Such disagreements can trouble public officials who may feel they are in unfamiliar territory. Usually, the first need in such situations is additional site studies. More detailed information can eliminate or greatly reduce professional differences. If significant differences remain, it helps to have a policy or procedure for making decisions. The most common approaches are:

- Adopt a policy stating that the community will support the judgment of the professional it has retained to represent the public interest in the safety of the project unless there are strong reasons to do otherwise.
- Establish a procedure to bring in either a third qualified professional or a committee of qualified professionals to resolve the issue.
- Establish a formal or informal mediation process involving those involved in the project.

Guidelines

- ***Adopt policies to acquire additional seismic hazard information before development of areas shown as potentially hazardous on the earthquake hazard maps.***
- ***Establish procedures to require site-specific seismic hazard evaluations.***
- ***Seek qualified engineering geologists and geotechnical engineers to review geotechnical reports submitted by applicants for development permits.***

Carrying out the Recommendations

Geotechnical design criteria are usually included as part of the seismic hazard evaluation or in a separate geotechnical engineering report submitted prior to planning approval. However, some geotechnical issues involving design details in the final development plans may not be fully resolved at the planning level, but should be resolved prior to issuance of building and grading permits.

Once permits are issued and construction is under way, the developer's geotechnical engineer inspects site grading, foundations, drainage facilities, retaining walls and other mitigation structures to be sure they are done according to the approved plans. The prior work is of no value if the grading and construction do not conform to the plans. Usually, local governments require an "as built" report from the developer's geotechnical engineer certifying that the project was built as approved.

3.3.2. Example: The City of Portland Site Investigation Procedures

Most cities and counties in the Metro region do not routinely require site investigations other than soils studies. An exception is the City of Portland, where practice is similar to the process outlined in the previous section. As in most cities, the Portland Planning Bureau reviews a development application for consistency with the comprehensive plan and land-use regulations, and the Portland Bureau of Buildings reviews it for compliance with the building code and issues the permits needed for actual construction. The Bureau of Building uses the earthquake hazard maps (along with other maps) in deciding when to require geotechnical or engineering geology reports on a proposed development site and what information needs to be included in the reports. For this purpose, the individual hazard maps are most useful; the composite REHM is not used. The bureau may require reports, as noted above, under several provisions of the Oregon Structural Specialty Code as well as under its own excavation and grading regulations adopted many years ago.

The bureau has had a geotechnical engineer on staff for 18 years. The engineer is consulted about the need for geotechnical reports and reviews the reports submitted to the department to ensure they adequately cover the identified issues and that the recommendations can effectively solve the problems described. If necessary, usually because of controversy about a project, the bureau retains consultants to review reports.

Here a geotechnical engineer inspects an excavation for a foundation. Adequate monitoring of construction is an important part of good procedures for site-specific geotechnical investigations.

In the event of differences of opinion between the staff geotechnical engineer and the applicant's consultant, the bureau asks the applicant's consultant for clarification. If this doesn't resolve the issue, the bureau has an appeals process in place.

Several local geotechnical consultants form a volunteer committee that meets as needed to resolve disputes.

The building permit fee covers the entire cost of administering the process of obtaining and reviewing geotechnical and engineering geology reports. In Portland, permit fees are set to cover the cost of services. In other cities and counties, fees are established by state statute and a vote is now needed to raise them. However, in the Metro region, there is so much construction that current fees are ample to cover costs.

The information acquired through the Portland requirements is rarely used to prevent development; rather it is used to guide site preparation and the design of foundations and buildings. An example of the process at work occurred in the review of an application to construct several large single-story tilt-up buildings just south of the Columbia River in an industrial area. The building site was just outside the area covered by the earthquake hazard maps available at that time; however, by extrapolation the Bureau of Buildings assumed it was in a "red zone" with high liquefaction potential and high to moderate ground shaking amplification.

The bureau required a site investigation that found loose silty sands capable of liquefying during a design-level earthquake and causing ground settlement of up to eight inches. This meant that the buildings could not be founded on conventional shallow spread footings. The design team decided to support the buildings on piles driven to a dense gravel layer and to interconnect the pile caps with reinforced concrete tie beams. So designed, the foundation is expected to withstand the settlement anticipated in an earthquake.

3.4. Planning, Siting and Designing of Public Facilities and Utilities

Guidelines

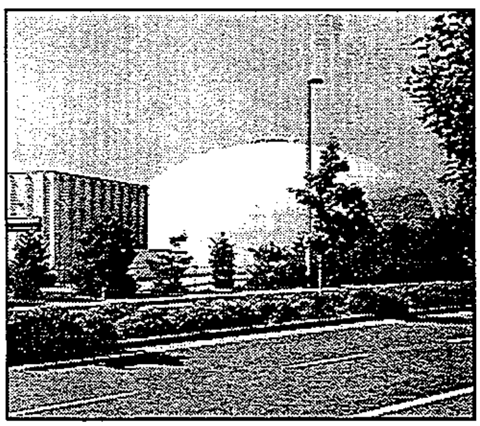
- ***Using the earthquake hazard maps, identify potential hazards to be addressed in selecting the sites and designing public facilities and utilities.***
- ***Use the earthquake hazard maps to help guide retrofit projects and emergency preparedness efforts.***

Certain public facilities, transportation routes and utility lines are essential to the functioning of modern communities. At the most basic level, land use plans and, particularly subdivision regulations, should consider the vulnerability of public facilities and utilities to damage from earthquakes. Areas slated for future urban growth should be served by roads and utility lines that will stay operational in the event of an earthquake.

For example, it may be possible to build houses safely on a ridgetop, but not possible to access them without passing through unstable terrain. If the problem is identified prior to building, it may be feasible to transfer the houses to another portion of the site that can be safely accessed.

Certain facilities, such as schools, hospitals, fire and police stations, emergency operations centers are essential for emergency response and should be located and designed with special care. Communities and utility companies need to know the seismic vulnerability of these facilities and take appropriate steps to keep the risk within acceptable limits. This is done most easily in the planning stages for new facilities. Project locations and construction designs can then be chosen to minimize potential for service disruptions when an earthquake strikes.

Reducing risk in existing facilities is more difficult. Here, the tasks are to identify vulnerability and establish priorities for retrofit or abandonment and relocation. The following example of a seismic vulnerability study prepared for the Portland Water Bureau illustrates an approach to using earthquake hazards information to assess the vulnerability of a critical public utility.



The City of Portland pumps water to a storage tank from a series of wells along the south side of the Columbia River as backup water in case the main supply is disrupted. The earthquake hazard maps show the site highly susceptible to liquefaction in an earthquake. This essential facility could be out of service after an earthquake.

3.4.1. Example: Assessing Water System Vulnerability to Earthquake Damage

The Portland Water Bureau has responded to the growing body of information about the region's earthquake hazards by initiating an assessment of the seismic vulnerability of its water system including sources, storage, distribution, operations and maintenance. Most of Portland's water comes from the Bull Run River and is stored in the Powell Butte reservoir. The conduits leading from the Bull Run to the reservoir cross the Sandy River on an old bridge and are vulnerable to damage in earthquakes, floods and other natural disasters.

Ground water from a series of wells along the south side of the Columbia River is Portland's alternative source of water. The ground water is pumped from the wells to a two million gallon storage tank and from there to the Powell Butte reservoir from which it can enter the city's distribution system. The earthquake hazard maps show that the well sites, storage tank, pumping station and pipes to the reservoir are all in areas subject to potential liquefaction and lateral spreading. The city faces the possibility of losing both its main and alternative sources of water in an earthquake.

In 1996, the bureau commissioned the engineering firm, Dames and Moore, to evaluate the seismic vulnerability of the alternative ground water supply system. The engineers gathered records of subsurface borings in the area, including those used by DOGAMI in preparing the relative earthquake hazard maps, and made additional borings. The results confirmed the presence of significant liquefaction and lateral spreading potential, however, the hazard was not as great as depicted on the maps. Yet, even so, when the information was viewed along with data on how the facilities were constructed, the possibility of system loss in even a moderate earthquake was found to be high.

Portland's emergency water supply is delivered to the reservoir through these conduits on a bridge crossing the Sandy River. The bridge is also susceptible to damage from liquefaction and lateral spreading.

The study defined two levels of retrofit of the major system elements: (1) take care of the most serious deficiencies and life-safety hazards and (2) improve the chances that the system would remain functional after a major earthquake. The city has laid out the elements of capital improvement projects to start the retrofit work, but before starting, decided to look at the system from a multihazard perspective. A major study is now under way to assess the vulnerability of the entire water system to earthquakes, floods, volcanic eruptions and a variety of other natural and manmade perils. Once this study has been completed and a mitigation program developed, establishing priorities based on a balancing of the risks and the costs to avert them, the city will move ahead with modifications to the system.

The Dames and Moore study recommends three measures to mitigate earthquake damage to water pipelines:

- Construct a new redundant pipeline between the ground water pump station and an existing 42-inch pipeline west of Blue Lake "in an alignment well away from the levee in a corridor where minimal lateral spreading is anticipated."
- Develop emergency response capabilities to quickly restore damaged pipelines.
- Improve the pipeline at the locations where the most severe lateral spreading is likely to occur.

These three recommendations express, in a specific case, generic options to mitigate damage to lifelines and other infrastructure:

- Locate lifelines where hazards are the least severe.
- Provide redundancy if a primary line is at risk.
- Prepare to respond to damage.
- Strengthen the line, provide flexible connections and the ability to shut off vulnerable segments.

3.5. Redevelopment and Seismic Retrofit

Guidelines

- ***Consider earthquake hazards in selecting sites for redevelopment and take the opportunity to create safer land uses and buildings while achieving other redevelopment objectives.***
- ***Use the earthquake hazard maps, along with structural and other information, to help prioritize buildings and facilities for seismic retrofit.***

In an ideal world, decision makers would evaluate earthquake hazards before making land-use decisions. Seismic safety would be incorporated into the location and design of buildings and infrastructure and the resulting level of seismic risk would have been consciously chosen based on the careful balancing of the costs and benefits. This ideal is rarely achieved. Most of the buildings in the Portland region were constructed before earthquake hazards mapping was completed for the region and before seismic standards were included in the building code. What can be done to prevent excessive damage to existing development in an earthquake?

Remember that earthquake risk depends on two factors: land susceptible to strong ground shaking or ground failure and buildings susceptible to earthquake damage because of age, type of construction, occupancy, or condition. The earthquake hazard maps provide needed information about hazardous lands. Metro's Regional Land Information System also provides information about vulnerable buildings gathered from an inventory of all buildings in the region except single family houses. By combining the maps with the building inventory, it is possible to evaluate the vulnerability of specific areas of a community to earthquake damage. Areas with concentrations of vulnerable buildings in red or orange zones on the REHM would be particularly prone to damage. These areas can logically be targeted for urban renewal projects or seismic retrofit programs.

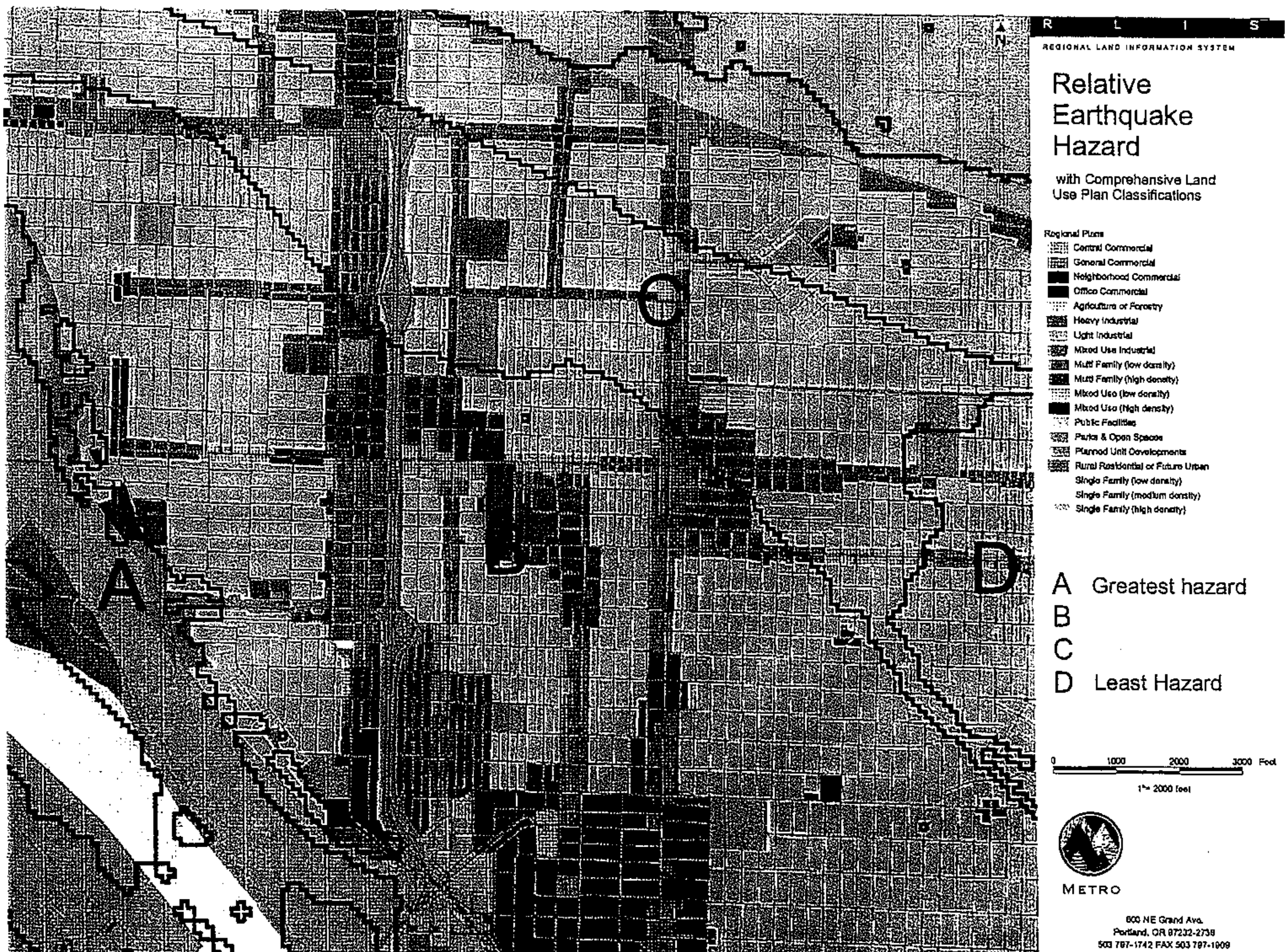
The link between earthquake hazard mitigation and redevelopment is strong. Earthquakes are often particularly damaging in old sections of a city. These are the same areas targeted for redevelopment. The worst case of missing the boat is for a community to invest in rehabilitation of a deteriorating area without also investing in seismic strengthening. Buildings rehabilitated cosmetically, but not structurally, have been lost in most California earthquakes including the Whittier (1987), Loma Prieta (1989) and Northridge (1994). The lesson is clear: projects to renovate old buildings, particularly those constructed of unreinforced masonry, should include seismic strengthening, if needed.

3.5.1. Example 1: Redevelopment Planning in the Albina Community in Portland

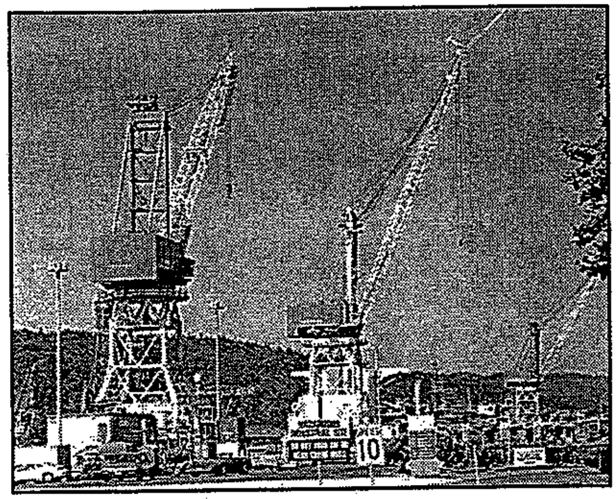
In 1993, the City of Portland adopted a community plan for the Albina district north and northeast of downtown. The purpose of the plan is to "combat the loss of employment base, disinvestment and dilapidation . . ." The plan includes the vision statements and policies worked out by neighborhood associations for eleven neighborhoods in the district. The planning area includes significant areas in Hazard Zones A and B on the relative earthquake hazards map: waterfront land on the Columbia River west of the airport and extending south to about the railroad tracks, the Swan Island/Mocks Landing area on the Willamette River and scattered areas in Zone B. Land in Zone A has high potential for liquefaction and a high or moderate potential for amplified ground shaking. Land in Zone B has a high potential for liquefaction and moderate potential for amplified ground shaking.

The waterfront area contains the north Portland Harbor and a combination of industrial uses and golf courses. Swan Island is a major ship repair yard with ancillary uses.

The Albina planning area includes parts of the Columbia and Willamette waterfronts and the neighborhood north of the convention center. This is the community plan map with an overlay showing the earthquake hazard zones from the REHM. Part of the area is in hazard zones A and B, primarily because of potential liquefaction.



Efforts to redevelop the area include this mixed use complex on Martin Luther King, Jr. Boulevard. Apartments top ground floor commercial space.



Expansion or renovation of the Port of Portland facilities at Swan Island would provide an opportunity to consider land use or structural changes to improve earthquake safety.

The scattered areas in Zone B are primarily single-family residential neighborhoods with some neighborhood and highway commercial areas.

Much of the planning area for the Albina community plan is in an "enterprise zone." In this zone, Portland offers incentives for development to stimulate economic activity. The area also includes an extension of the Oregon Convention Center Urban Renewal Area along Martin Luther King Jr. Boulevard and Alberta Street. Public improvements planned for the urban renewal area include a new police station and design improvements along Martin Luther King Jr. Boulevard.

The Albina plan recommends creation of a special zoning district to be applied to the Swan Island shipyards to ensure the continued economic viability of this important source of employment for Portland and especially for the Albina community, while at the same time protecting the riverbank.

The earthquake hazard maps could be used in planning for the shipyards, perhaps by adding greenbelts along parts of the Willamette encompassing some of the more hazardous lands. As in comprehensive planning, the presence of hazards becomes a factor to be combined with other considerations in making land use decisions and setting priorities for change.

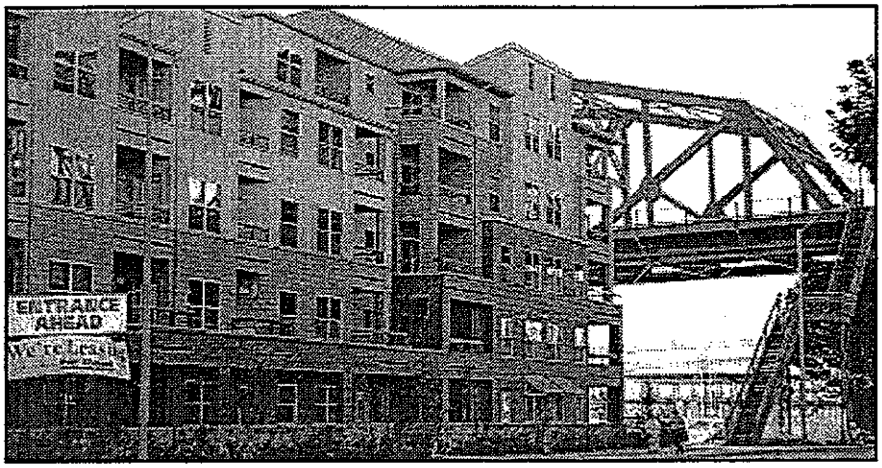
3.5.2. Example 2: Redevelopment of Vacant Land

The Portland Development Commission (PDC) is Portland's redevelopment agency. Formed in the 1960s during the heyday of federally-subsidized urban renewal, PDC has its own commission appointed by the mayor.

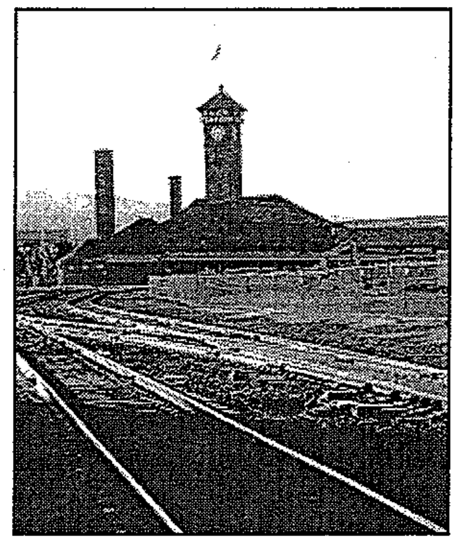
In 1987, PDC purchased Union Station, constructed in 1895, and about 30 acres of adjacent railroad yards in downtown Portland. PDC contracted to remove unused tracks and clear the site and then selected GSL Properties as a partner to develop seven acres of the site as the cornerstone of a new River District.

From the beginning, PDC and GSL Properties recognized that the site is beset by soils problems and earthquake hazards. The REHM places it in Zone B because of the potential for liquefaction and amplified ground shaking. The hazards are compounded by the fact that the site is composed of unengineered fill placed in the late 1800s and also shows evidence of contamination from the prior uses.

GSL Properties proposed a design with about 550 apartments and townhouses and a small amount of retail space constructed on a podium supported by pilings resting on bedrock up to 170 feet below the ground surface. In an earthquake, the entire structure would stay anchored to the bedrock in spite of liquefaction or other ground failure. The design was approved by the city and the developer sought bids. However, because of their large number and depth, the pilings proved to be so costly that support for the structure had to be substantially redesigned.



The railroad yard on Naito Parkway between the Steel and Broadway bridges is the site of a major mixed-use project intended to stimulate redevelopment of the river front in downtown Portland. The project is designed to contend with unengineered fill and potentially liquefiable soil.



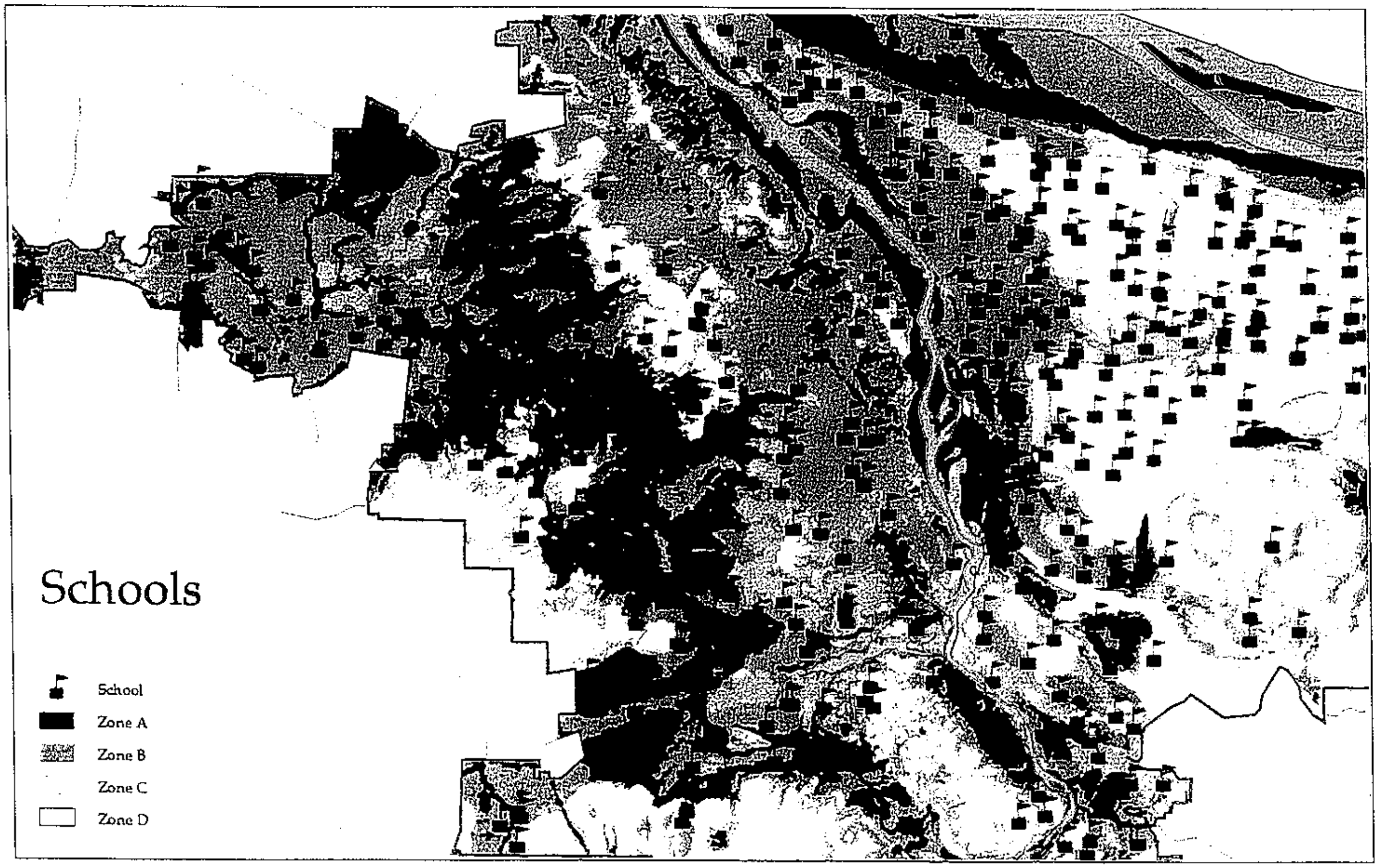
The new design, which was under review by the city when this report was published, divides the same building mass into several separate buildings. Three townhouse and two apartment buildings will be constructed at grade on mat foundations engineered to essentially float and stay in one piece in the event of ground failure.

The other two apartment buildings will be constructed over a two-level parking garage in the center of the site. The parking garage will have one level at grade and one level below grade and will rest on driven grout friction piles (Geopiers). The piles will not rest on bedrock but are designed to prevent up and down movement. With the exception of the parking structure, all buildings will be wood frame.

The new design is less costly, is expected to perform well in an earthquake, and is less massive than the original design – a good example of how earthquake safety and other objectives can coincide.

3.5.3. Example 3: Retrofit Priorities for Portland Schools

Because earthquakes occur relatively infrequently, public actions to reduce earthquake losses are often a hard sell. Actions to improve the safety of public schools, however, may be an exception. Few people are willing to expose the community's children to the risk of being crushed in a collapsed school building. Portland voters approved a bond issue in November 1995 that includes $40 million for the seismic retrofit of public schools. This is the first phase in a program that is expected to



Many public schools in Portland are in areas subject to earthquake hazards – amplified ground shaking, liquefaction and slope instability. Many are also constructed of unreinforced masonry that typically does poorly in earthquakes. The school district uses this information to help select schools for seismic retrofit.

cost $200-$250 million and take seven years to complete.

An early task of Portland Public Schools was to determine priorities for the retrofit program. The school district turned to Metro for a custom map of the City of Portland showing the relative earthquake hazards zones and all public schools. District staff then reviewed the building inventory and identified construction type, use, number of occupants and number of stories of each school facility.

The information was compiled in a matrix, which was then used to assign priorities. Unreinforced masonry (URM) buildings were considered highest priority for retrofit. Among these, the ones in earthquake hazard zones A and B were selected for work in the first phase of the program (1996-97) and those in earthquake hazard zones C and D were scheduled for Phase II. The district plans to complete between 30 and 50 buildings a year.

3.6. Emergency Management

Mitigation can greatly reduce the damage that will occur when an earthquake strikes, but it cannot eliminate it altogether. Cities and counties in the region still need to be prepared to respond effectively to an earthquake disaster. Knowing this, the emergency management agencies in the region have found many uses for the earthquake hazard maps in programs to educate the public about earthquakes, train emergency workers and reduce the damage from future earthquakes.

The REHM, with its bright red, orange and yellow hazard zones, is a perfect tool for public education. The red zones stand out clearly and people invariably react to the map by looking to see if the places they live and work are in a red zone. The map is a beginning point in a process of education that starts with awareness of the potential for an earthquake and continues with practical suggestions about personal actions to reduce risk.

The state requires each county to prepare an emergency management plan. Although not mandated by the state, some cities prepare their own plans. Typically annexes are prepared for each type of disaster anticipated. Most plans do not now include annexes for earthquakes, but the state Office of Emergency Management is preparing guidelines for earthquake annexes. Counties with earthquake hazards, as shown on the REHM, will be expected to prepare earthquake annexes to their local plans. The earthquake hazard maps will be the starting point in this endeavor.

In addition to being useful in training for response, the maps provide an essential foundation for mitigation planning both before and after a disaster. Under FEMA's new emphasis, mitigation planning is an increasingly important function of emergency management agencies. Congress requires hazard mitigation planning in the aftermath of a disaster as a condition for receiving disaster assistance funds (Stafford Act). Local emergency management agencies find themselves increasingly working with other local departments and agencies as an advocate for mitigation programs.

Guidelines

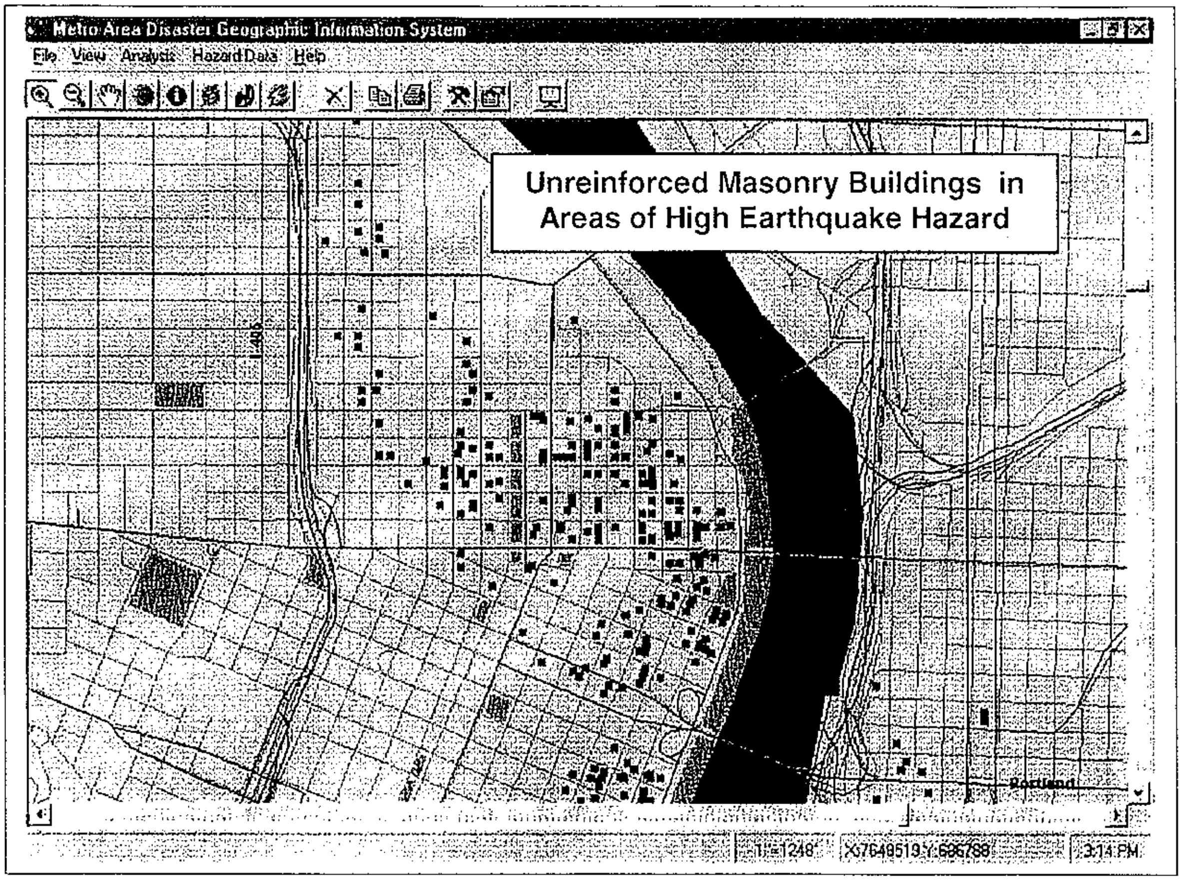
- ***Use the earthquake hazard maps to explain the region's earthquake vulnerability to the public.***
- ***Use the earthquake hazard maps to help create realistic scenarios for emergency planning and training exercises.***
- ***Consider vulnerability to earthquake damage in addressing hazardous material siting, storage, transport and use.***

3.6.1. Example 1: Public Education

The Washington County emergency management agency uses the REHM in training and public outreach programs to increase preparedness and response capability. The REHM is an important visual aid in training emergency responders and their families. The agency also uses it in presentations to the staffs, teachers, and PTA at the elementary schools and staff at hospitals and nursing homes. These people need to know what to expect in an earthquake and what to do afterward to help the special populations in their care. The agency manager describes the REHM as an "excellent tool for educating the public . . . to the hazards that exist in the area. We find them very educational and very captivating."

3.6.2. Example 2: Earthquake Response Planning

Cities and counties are participating in earthquake response planning being coordinated by Metro. The earthquake hazard maps are key elements of the process. For example Metro is working with cities and counties in the region to plan for post-disaster debris removal. The REHM is used both to identify areas where concentrations of debris are likely to occur and select sites for the disposal of debris.



One emergency management function is to plan for the removal and disposal of debris after a disaster. The MAD GIS software can be used to predict areas where debris may be concentrated after an earthquake.

Metro is also working with cities and counties to identify emergency transportation routes for evacuation and delivery of emergency aid. The earthquake hazard maps help identify where transportation facilities are likely to be damaged – critical data for the study.

3.6.3. Example 3: Hazard Mitigation at Hazmat Sites

The Portland Fire Bureau has been assessing the presence of hazardous materials in potential liquefaction zones as depicted on the relative liquefaction hazard map. As part of this effort the agency persuaded the management of a chlorine plant to retrofit its facility and change procedures to reduce the risks of a chlorine escape in an earthquake. The company spent $100 million to upgrade equipment and reduced the amount of chlorine stored on site at any one time by piping it directly to railroad cars and moving it off site quickly rather than piping it to storage tanks. The maximum amount of chlorine stored on site has been reduced from 600 tons to 90 tons.

4. Guidelines

The following lists summarize the main guidance provided in Section 3.

4.1. Comprehensive Planning and Zoning

- Use the earthquake hazard maps, along with other information, in determining land uses and urban growth boundaries.
- During periodic review of comprehensive plans, review and revise, if needed, the uses for lands shown as hazardous on the earthquake hazard maps.
- Incorporate the earthquake hazard maps into local GIS, if available.

4.2. Review of Subdivision Applications

- Use the earthquake hazard maps to determine when seismic hazard evaluations are needed before land is subdivided.
- Before new lots are created, use the earthquake hazard maps to help assess the vulnerability of the lots, access and utility lines in the event of an earthquake.

4.3. Site-Specific Seismic Hazard Evaluations

- Adopt policies to acquire additional seismic hazard information before development of areas shown as potentially hazardous on the earthquake hazard maps.
- Establish procedures to require site-specific seismic hazard evaluations.
- Seek qualified engineering geologists and/or geotechnical engineers to review geotechnical reports submitted by applicants for development permits.

4.4. Planning, Siting and Designing Public Facilities and Utilities

- Using the earthquake hazard maps, identify potential hazards to be addressed in the selecting sites and designing public facilities and utilities.
- Use the earthquake hazard maps to help guide retrofit projects and emergency preparedness efforts.

4.5. Redevelopment and Seismic Retrofit

- Consider earthquake hazards in selecting sites for redevelopment and take the opportunity to create safer land uses and buildings while achieving other redevelopment objectives
- Use the earthquake hazard maps, along with structural and other information, to help prioritize buildings and facilities for seismic retrofit.

4.6. Emergency Management

- Use the earthquake hazard maps to explain the region's earthquake vulnerability to the public.
- Use the earthquake hazard maps to help create realistic scenarios for emergency planning and training exercises.
- Consider vulnerability to earthquake damage in addressing hazardous material siting, storage, transport and use.

5. Appendix: Sources of Information

Using Earthquake Hazard Maps for Land Use Planning and Building Permit Administration, Report of the Metro Advisory Committee for Mitigating Earthquake Damage. Metro, May 1996

MAD GIS CD-ROM, Metro Area Disaster Geographic Information System, GIS Tools for Emergency Management Planning: Mitigation, Preparedness, Response and Recovery. Metro, December 1997

Look Before You Build, Geologic Studies for Safer Land Development in the San Francisco Bay Area, U.S. Geological Survey Circular 1130. Tyler, Martha Blair, 1994

Earthquakes in Washington and Oregon Map, 1872-1993. Goter, Susan K., 1994

Oregon Structural Specialty Code

Guidelines for Engineering Geology Reports

Regional Natural Hazards Mitigation Plan

Oregon Statewide Planning Goals

DOGAMI, Maps and report explaining methods and uses

DOGAMI CD-ROM