MULTI-HAZARD MITIGATION PLAN

FOR

CORVALLIS, OREGON

November 19, 2007

EXECUTIVE SUMMARY

This Multi-Hazard Mitigation Plan for the City of Corvallis, Oregon covers each of the major natural and some of the human-caused hazards that pose risks to the City. The primary objectives of this Mitigation plan are to reduce the negative impacts of future disasters on the community: to enhance life safety, increase public awareness, protect natural systems, and build partnerships. This Mitigation Plan is a planning document, not a regulatory document.

This mitigation plan meets FEMA's planning requirements by addressing hazards, vulnerability and risk. Hazard means the frequency and severity of disaster events. Vulnerability means the value, importance, and fragility of buildings and infrastructure. Risk means the threat to people, buildings and infrastructure, taking into account the probabilities of disaster events. Adoption of a mitigation plan is required for communities to remain eligible for future FEMA mitigation grant funds.

The Corvallis Hazard Mitigation Plan is a living document which will be reviewed at least annually and updated periodically. The continuing active participation of citizens, agencies, and other Corvallis stakeholders is an essential part of the process of keeping the Corvallis Hazard Mitigation current. Comments, suggestions, corrections and updates are encouraged from all interested parties throughout the life of the Plan.

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1.0 INTRODUCTION

1.1 What is a Mitigation Plan?

The City of Corvallis is subject to a wide range of natural and human-caused hazards, including: floods, winter storms, landslides, wildland/urban interface fires, earthquakes, dam failures, hazardous material spills, and many others. The impact of a hazard event on a community may be minor - a few inches of water in a street - or it may be major - with damages reaching millions of dollars.

There have been several recent events, all of which resulted in Presidential Disaster Declarations for Benton County, with significant damages and impacts in Corvallis:

- The flooding in February 1996 affected many portions of Corvallis. A combination of rain, warmer temperatures causing snow melt, and then more rain caused flooding in the southern part of Corvallis and southern Benton County. Shelters were opened, some families were evacuated by boat, and massive sandbagging efforts were conducted to save governmental and private structures. This winter storm also brought numerous landslides and resulted in the closure of a lifeline transportation route for about 24 hours.
- The winter storm in December 2003 and January 2004 struck the Pacific Northwest and rapidly developed into a full-blown snowstorm in elevations as low as 500 feet. There was significant snow fall and freezing rain across the county, including Corvallis, with widespread impacts in Benton County. Freezing rain fell along the coast and throughout the Willamette Valley causing widespread ice accumulations. Critical services within the county were disrupted, with about 10,000 consumers without electricity for 3 to 4 days. Local governments were closed, and the local hospital discharged non-critical patients due to an increase in patient admissions that were related to the storm. Emergency snow removal was conducted to keep primary roads open. Transport of emergency workers by Search and Rescue groups kept care facilities and medical facilities operational. One person died as a result of the power outage.
- The windstorm in December 2005 primarily affected electric utilities, with significant damage to Consumers Power Inc. which supplies Corvallis, resulting in widespread power outages in many Benton County locations.
- The flooding in December 2005 and January 2006 affected many of the smaller streams and the Mill Race in Corvallis, with road closures and damage to some residential properties.

This Mitigation Plan addresses all levels of natural hazard events and some human-caused hazards as well. The Plan includes minor events such as winter storms or localized storm water flooding that may happen in some locations almost every year and localized events such as landslides or mudslides. The plan also includes larger events such as major floods, earthquakes, or major wildland/urban interface fires that may affect large numbers of residents in Corvallis, with very high levels of damages and losses, albeit with much lower probabilities of occurrence.

Mitigation simply means actions that reduce the potential for negative impacts from future disasters. Mitigation actions reduce future damages, losses and casualties. The Corvallis mitigation plan has several key elements.

1. Each hazard that may impact Corvallis significantly is reviewed to determine the probability (frequency) and severity of likely hazard events.
2. The vulnerability of Corvallis to each hazard is evaluated to determine the likely extent of physical damages, casualties, and economic impacts.
3. A range of mitigation alternatives are evaluated to identify those with the greatest potential to reduce future damages and losses in Corvallis, to protect facilities deemed critical to the community's well being, and that are desirable from the community's political and economic perspectives.

1.2 Why is Mitigation Planning Important for Corvallis?

Effective mitigation planning will help the residents of Corvallis deal with natural and anthropogenic (human-caused) hazards realistically and rationally. That is, it will help identify specific locations in Corvallis where the level of risk from one or more hazards may be unacceptably high and then find cost effective ways to reduce such risk. Mitigation planning strikes a pragmatic middle ground between unwisely ignoring the potential for major hazard events on one hand and unnecessarily overreacting to the potential for disasters on the other hand.

Furthermore, the Federal Emergency Management Agency (FEMA) now requires each local government entity to adopt a multi-hazard mitigation plan to remain eligible for future pre- or post-disaster FEMA mitigation funding. Thus, an important objective in developing this plan is to maintain eligibility for FEMA funding and to enhance Corvallis's ability to attract future FEMA mitigation funding.

The Plan is specifically designed to help Corvallis gather the data necessary to compete successfully for future FEMA funding of mitigation projects. FEMA requires that all FEMA-funded hazard mitigation projects must be "cost-effective" (i.e., the benefits of a project must exceed the costs). Benefit-cost analysis is thus an important component of mitigation planning, not only to meet FEMA requirements, but also to help evaluate and prioritize potential hazard mitigation projects in Corvallis, regardless of whether funding is from FEMA, state or local government or from private sources.

Hazard mitigation planning is applicable to Corvallis as a whole, including the entire population and all of the built environment of buildings (residential, commercial, and public) and infrastructure (transportation and utility systems). However, for mitigation planning purposes and for implementation of mitigation actions, facilities designated as critical for the well being of residents of Corvallis are given a higher priority. A summary of the types of critical facilities in Corvallis is given below in Table 1.1. A listing of specific critical and important facilities in Corvallis is given in Table 1.2. Maps of critical facilities in Corvallis are shown in Figures 1.1 and 1.2, with FEMA-mapped floodplains also shown for reference.

Table 1.1
Types of Critical Facilities in Corvallis

Category	Critical Functions	High Priority	Medium Priority
Emergency Services	*Facilities critical for immediate emergency response, including life safety*		
Fire Stations		YES	
Police Stations		YES	
Ambulance Services		YES	
Emergency Operations Centers		YES	
Emergency Shelters			YES
Medical Facilities	*Facilities providing direct patient care, including hospitals, clinics, and nursing homes*		
Hospitals and Urgent Care Facilities		YES	
Other Medical Facilities			YES
Special Needs Populations	*Facilities housing people that may need assistance is evacuation from emergencies*		
Elderly Housing		High occupancy facilities	Low occupancy facilities
Schools (K-12)		YES	
Schools (Higher Education)		YES	
Jails		YES	
Utilities			
Water	Facilities for treatment and distribution of potable and irrigation water	Major treatment plants, water transmission lines, major reservoirs,	Smaller reservoirs and pumping plants
Wastewater	Facilities for pumping and treatment of wastewater	Treatment plants and pumping plants	
Electric Power	Facilities for generation, transmission and distribution of electric power	High voltage substations and transmission lines	Other substations and transmission lines, trunk distribution lines
Telecommunications	Facilities for transmission, switching and distribution of telephone traffic	PSAPs (911 centers) and Central Offices (switching)	Trunk lines
Natural Gas	Facilities for transmission and distribution of natural gas		Transmission lines and compressor stations
Dams	Facilities to impound water for flood control, power generation and water supply	Major dams upstream of population centers	Smaller dams and dams not upstream of population centers
Transportation Systems			
Roadways	Necessary for emergency response, public safety and disaster recovery	Major highways, arterials, and bridges on such roads	Secondary roads and bridges
Air, rail, and water transport	These transport modes are of secondary importance for Corvallis	Not at this time	Not at this time
Hazmat Facilities	Facilities that manufacture, store, use, or transport hazardous materials	Sites with large inventories of hazardous materials	Sites with smaller inventories of hazardous materials

Table 1.2
Corvallis Critical and Important Facilities

City Buildings and Facilities	
	City Hall
	Fire Stations 1, 2, 3, 4, 5 and 6
	Public Works Maintenance Facility
	Corvallis Public Schools
	Corvallis Senior Center
	Madison Building
	Majestic Theater
	Corvallis Municipal Airport
City Water System	
	Taylor Water Treatment Facility
	Rock Creek Water Treatment Facility
	Marys River Bridge Crossings (Water Transmission Pipes)
	Water Reservoirs
	Water Pump Stations
City Wastewater System	
	Wastewater Treatment Facility
	Wastewater Lift Stations
Benton County Buildings	
	Law Enforcement Building
	Benton County Courthouse
	Benton County Public Works
	Benton County Health Department
Medical and Care Facilities	
	Good Samaritan Hospital
	Samaritan Heart of the Valley
	OSU Health Center
	Regent Retirement Residence
	Corvallis Manor
	Conifer House Nursing Home
	Boyter's Golden Horizon Inc.
	Stoney Brook Assisted Living
	West Hills Assisted Living Community
	Corvallis Caring Center
Utility Systems	
	Consumers Power Inc.
	Pacific Power
	US West
	Northwest Natural Gas.

Important Facilities

City Buildings and Facilities	
	Parks and Recreation Admin Building
	Parks and Recreation Maintenance Compound
	City Hall Annex
	Transit Mall
	Art Center
Other Facilities	
	Group Shelters

Figure 1.1
Critical Facilities in Corvallis and FEMA-Mapped Floodplain Boundaries

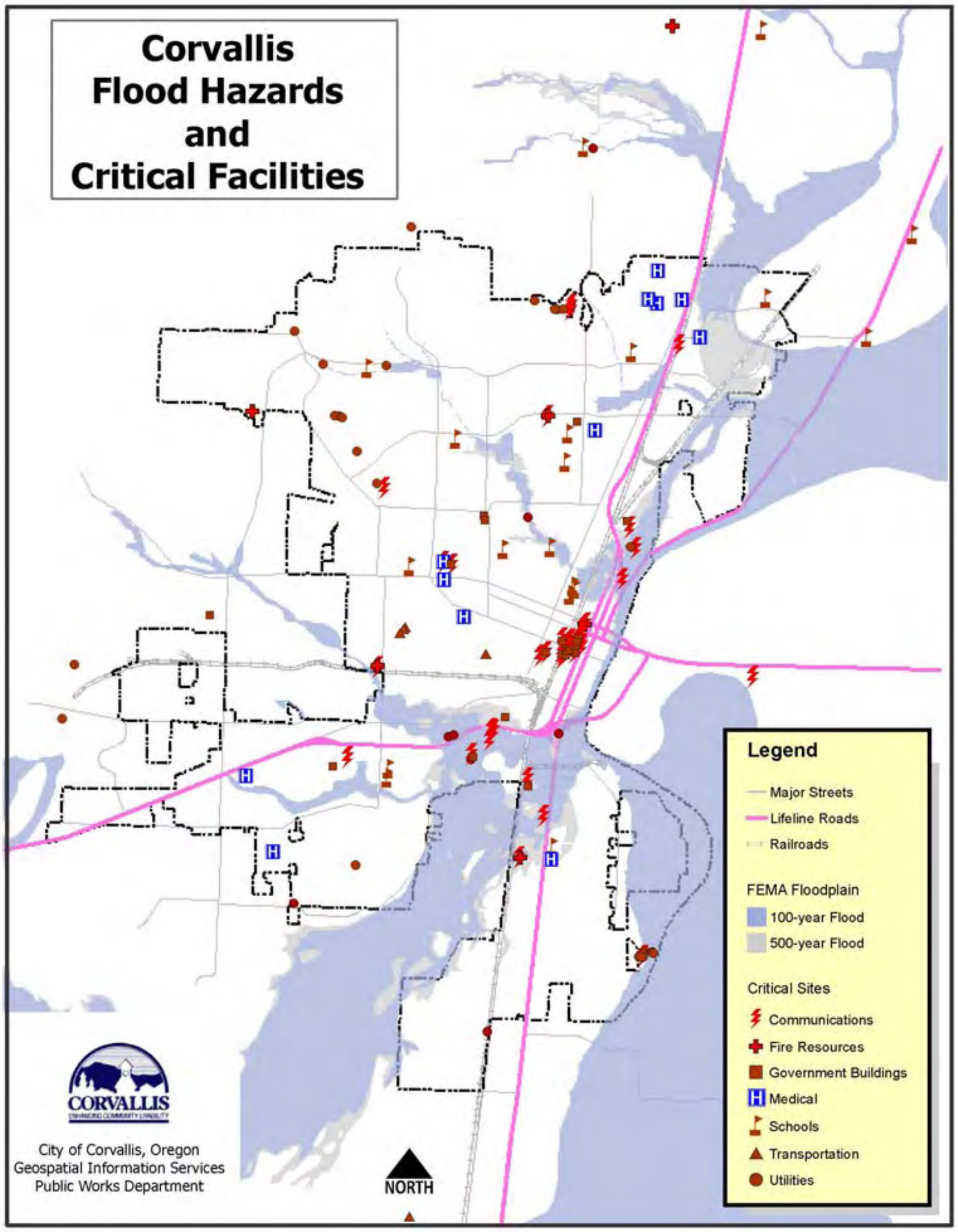
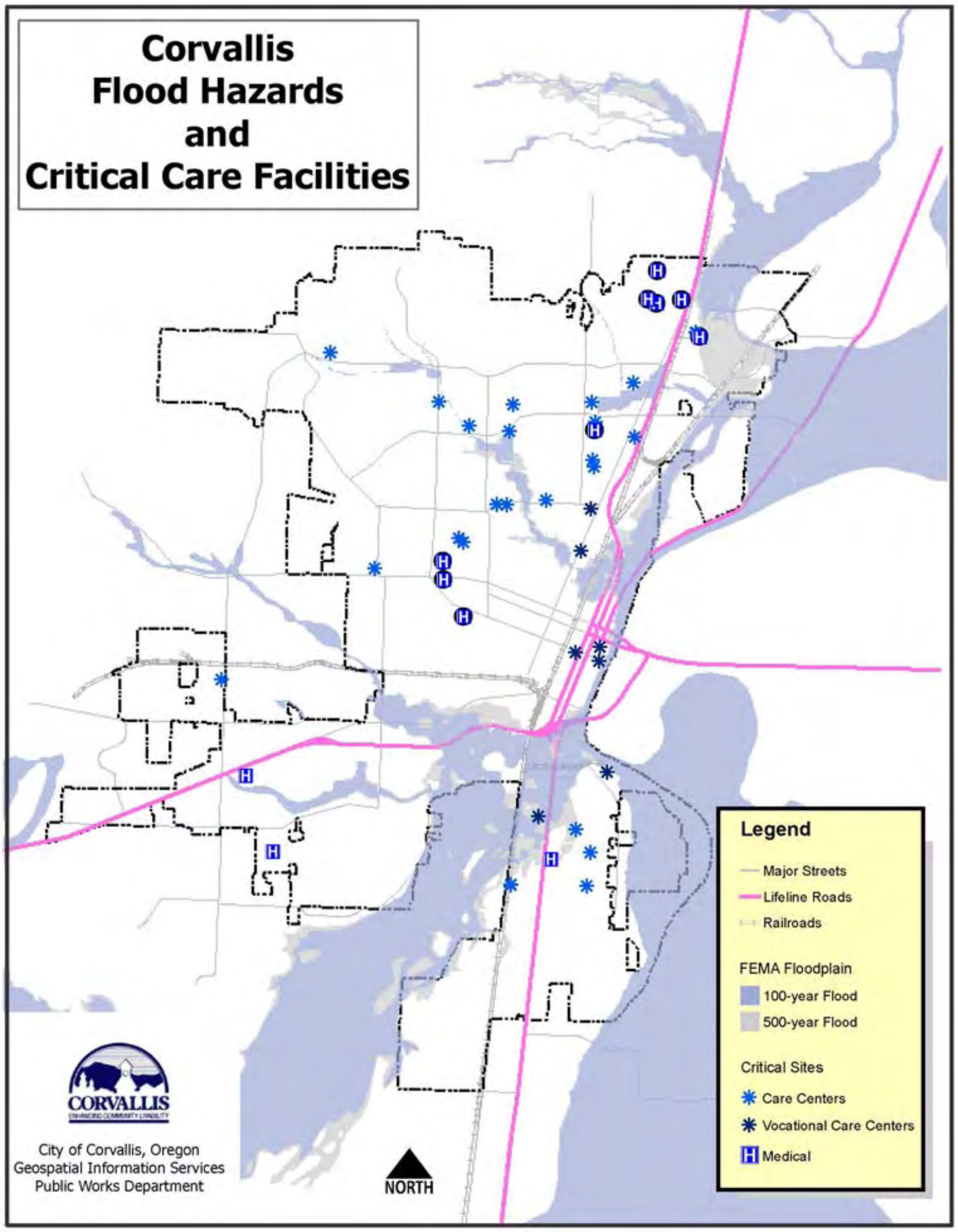


Figure 1.2
Care Facilities in Corvallis and FEMA-Mapped Floodplain Boundaries



1.3 The Corvallis Mitigation Plan

This Corvallis Mitigation Plan is built is upon a quantitative assessment of each of the major hazards that may impact Corvallis, including their frequency, severity, and areas of the City likely to be affected. The hazards addressed include: floods, severe winter storms (including windstorms), landslides, wildland/urban interface fires, earthquakes, volcanic eruptions, dam failures, and utility and transportation disruptions.

The Corvallis Mitigation plan includes a quantitative assessment of the vulnerability of buildings, infrastructure, and people to each of these hazards, to the extent possible with existing data. The plan also includes an evaluation of the likely magnitude of the impacts of future disasters on Corvallis.

These reviews of the hazards and the vulnerability of Corvallis to these hazards are the foundation of the mitigation plan. From these assessments, high hazard areas where buildings, infrastructure, and/or people may be at high risk are identified whenever possible. These high risk situations then become priorities for future mitigation actions to reduce the negative impacts of future disasters on Corvallis.

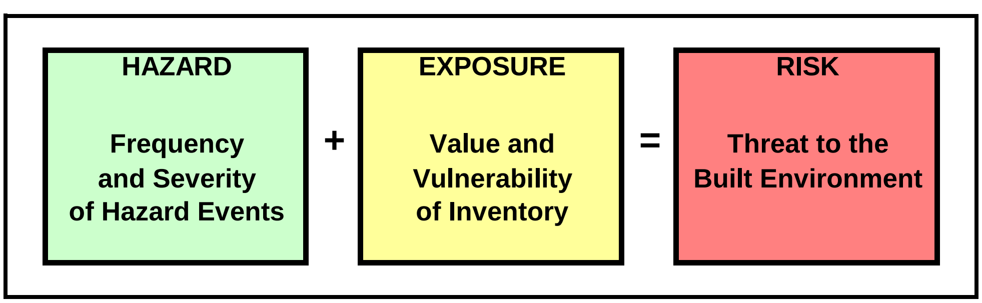
The Corvallis Mitigation Plan deals with hazards realistically and rationally and also strikes a balance between suggested physical mitigation measures to eliminate or reduce the negative impacts of future disasters and enhancements in land use planning to reduce the potential for negative impacts of disasters on new development. Finally, the plan suggests better emergency planning to help prepare the community to respond to and recover from disasters for which physical mitigation measures are not possible or not economically feasible.

1.4 Key Concepts and Definitions

The central concept of mitigation planning is that mitigation reduces risk. **Risk** is defined as the threat to the built environment posed by the hazards being considered. That is, risk is the potential for damages, losses and casualties arising from the impact of hazards on the built environment.

The extent of risk depends on the combination of **hazard** and **exposure** as shown in Figure 1.3 below.

Figure 1.3
Hazard and Exposure Combine to Produce Risk



Thus, there are four key concepts that govern hazard mitigation planning: hazard, exposure, risk and mitigation. Each of these key concepts is addressed in turn.

HAZARD refers to natural or anthropogenic events that potentially may cause damages, losses or casualties (e.g., floods, winter storms, landslides, earthquakes, hazardous material spills, etc.). Hazards are characterized by their frequency and severity and by the geographic area affected. Each hazard is characterized differently, with appropriate parameters for the specific hazard. For example, floods may be characterized by the frequency of flooding, along with flood depth and flood velocity. Winter storms may be characterized by the amount of rainfall in a 24-hour period, by the wind speed, by the amount of snow or ice associated with a storm. Earthquakes may be characterized by the severity and duration of ground motions and so on.

A hazard, by itself, may not result in any negative impacts on a community. For example, a highly flood-prone five acre parcel may typically experience several shallow floods per year, with several feet of water expected in a 50-year flood event and more than six feet of water expected in a 100-year flood event. However, the parcel may be wetlands adjacent to a tidal marsh that floods daily, with no development (structures or infrastructure) on the parcel. In this case, the frequent flooding does not have any negative impacts on the community. Indeed, in such circumstances, the very frequent flooding (i.e., high hazard) may be beneficial in providing wildlife habitat.

The important point here is that hazards do not produce risk, unless there is vulnerable inventory exposed to the hazard. In the context of mitigation planning, “inventory” means simply people, buildings, or infrastructure exposed to damages from one or more natural or manmade hazards.

EXPOSURE is the quantity, value and vulnerability of the built environment (inventory of buildings and infrastructure) in a particular location subject to one or more hazards. Inventory is described by the number, size, type, use, and occupancy of buildings and by the infrastructure present. Infrastructure includes roads and other transportation systems, utilities (potable water, wastewater, natural gas, electric power), telecommunications systems and so on.

Inventory varies markedly in its importance to a community and thus varies markedly in its importance for hazard mitigation planning. Some types of facilities, “critical facilities,” are especially important to a community, particularly during disaster situations. Examples of critical facilities include police and fire stations, hospitals, schools, emergency shelters, 911 centers, and other important buildings. Critical facilities may also include infrastructure elements that are important links or nodes in providing service to large numbers of people such as a potable water source, an electric power substation and so on. “Links” are elements such as water pipes, electric power lines, telephone cables that connect portions of a utility or transportation system. “Nodes” are locations with important functions, such as pumping plants, substations, or switching offices.

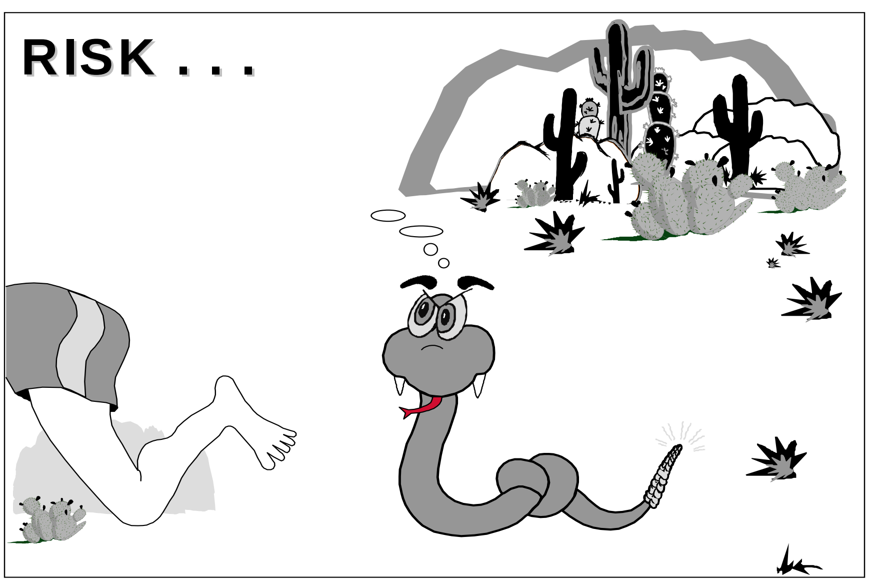
For hazard mitigation planning, inventory is characterized not only by the quantity and value of buildings or infrastructure present but also by its vulnerability to each hazard under evaluation. For example, a given facility may be vulnerable to flood damages and earthquake damages or to flood damages only or to earthquake damages only. Depending on the hazard, different measures of vulnerability must be used.

RISK is the threat to the built environment (buildings and infrastructure) and people - the potential for damages, losses and casualties arising from hazards. Risk results from the combination of Hazard and Exposure. That is, when the geographic areas affected by one or more hazards contain people, buildings, and infrastructure vulnerable to damage from the hazard(s). For mitigation planning, evaluation of risk generally emphasizes the built environment and people. However, risk also includes the potential for environmental damage.

Risk is the potential for future damages, losses or casualties. A disaster event happens when a hazard event is combined with vulnerable inventory (that is when hazard event strikes vulnerability inventory exposed to the hazard). The highest risk in a community occurs in high hazard areas (frequent and/or severe hazard events) with large inventories of vulnerable buildings or infrastructure.

However, high risk can also occur with only moderately high hazard, if there is a large inventory of highly vulnerable inventory exposed to the hazard. For example, seismic hazard is lower in Oregon than in the seismically active areas of California. However, for some buildings, seismic risk in Oregon may be comparable to or even higher than seismic risk in California, due to the very recent adoption in Oregon of seismic design standards commensurate with current understanding of seismic hazards in Oregon. Much of the building inventory in Oregon is vulnerable to earthquake damages because older buildings were generally designed and built to much lower seismic standards than currently required in Oregon. Conversely, a high hazard area can have relatively low risk if the inventory is resistant to damages (e.g., elevated to protect against flooding or strengthened to minimize earthquake damages).

Figure 1.4
Risk Results from the Combination of Hazard and Exposure



MITIGATION means actions to reduce the risk due to hazards. Mitigation actions reduce the potential for damages, losses, and casualties in future disaster events. Repair of buildings or infrastructure damaged in a disaster is not mitigation because repair simply restores a facility to its pre-disaster condition and does not reduce the potential for future damages, losses, or casualties. Hazard mitigation projects may be initiated proactively - before a disaster, or after a disaster has already occurred. In either case, the objective of mitigation is always to reduce future damages, losses or casualties.

A few of the most common types of mitigation projects are shown below in Table 1.3.

Table 1.3
Common Mitigation Projects

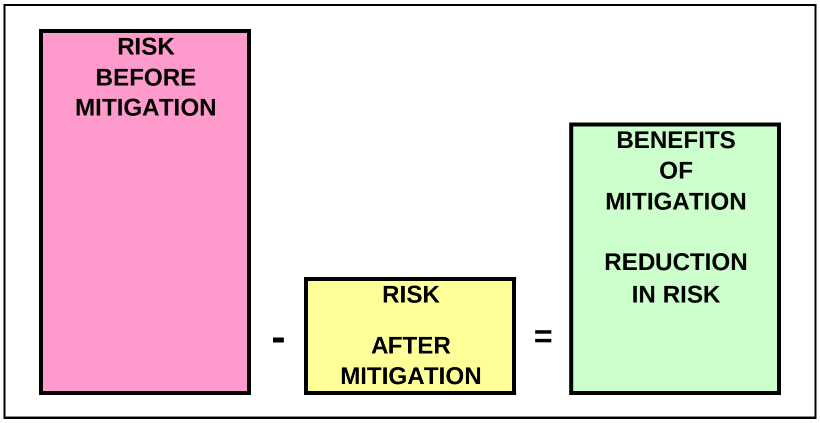
Hazard	Mitigation Project
Flood	Build or improve levees or flood walls
	Improve channels for flood control
	Improve drainage systems and culvert capacities
	Create detention ponds for storage
	Relocate, elevate or floodproof flood-prone structures
	Acquire and demolish highly flood-prone structures
Winter Storms	Add emergency generators for critical facilities
	Improve redundancy of utility systems
	Trim trees to reduce failures of utility lines
Earthquakes	Upgrade seismic performance of buildings
	Upgrade seismic performance of infrastructure
Landslides	Remediate slide conditions
	Relocate utility lines or structures
Wildland/Urban Interface Fires	Increase fire safe construction practices
	Vegetation (fuel load) control
General	Enhance emergency planning and mutual aid
	Expand public education programs

The mitigation project list above is not comprehensive and mitigation projects can encompass a broad range of other actions to reduce future damages, losses, and casualties.

1.5 The Mitigation Process

The key element for all hazard mitigation projects is that they reduce risk. The benefits of a mitigation project are the reduction in risk (i.e., the avoided damages, losses, and casualties attributable to the mitigation project). In other words, benefits are simply the difference in expected damages, losses, and casualties before mitigation (as-is conditions) and after mitigation. These important concepts are illustrated below in Figure 1-5.

Figure 1.5
Mitigation Projects Reduce Risk



Quantifying the benefits of a proposed mitigation project is an essential step in hazard mitigation planning and implementation. Only by quantifying benefits is it possible to compare the benefits and costs of mitigation to determine whether or not a particular project is worth doing (i.e., is economically feasible). Real world mitigation planning almost always involves choosing between a range of possible alternatives, often with varying costs and varying effectiveness in reducing risk.

Quantitative risk assessment is centrally important to hazard mitigation planning. When the level of risk is high, the expected levels of damages and losses are likely to be unacceptable and mitigation actions have a high priority. Thus, the greater the risk, the greater the urgency of undertaking mitigation actions.

Conversely, when risk is moderate both the urgency and the benefits of undertaking mitigation are reduced. It is neither technologically possible nor economically feasible to eliminate risk completely. Therefore, when levels of risk are low and/or the cost of mitigation is high relative to the level of risk, the risk may be deemed acceptable (or at least tolerable). Therefore, proposed mitigation projects that address low levels of risk or where the cost of the mitigation project is large relative to the level of risk are generally poor candidates for implementation.

The overall mitigation planning process is outlined in Figure 1.6 on the following page.

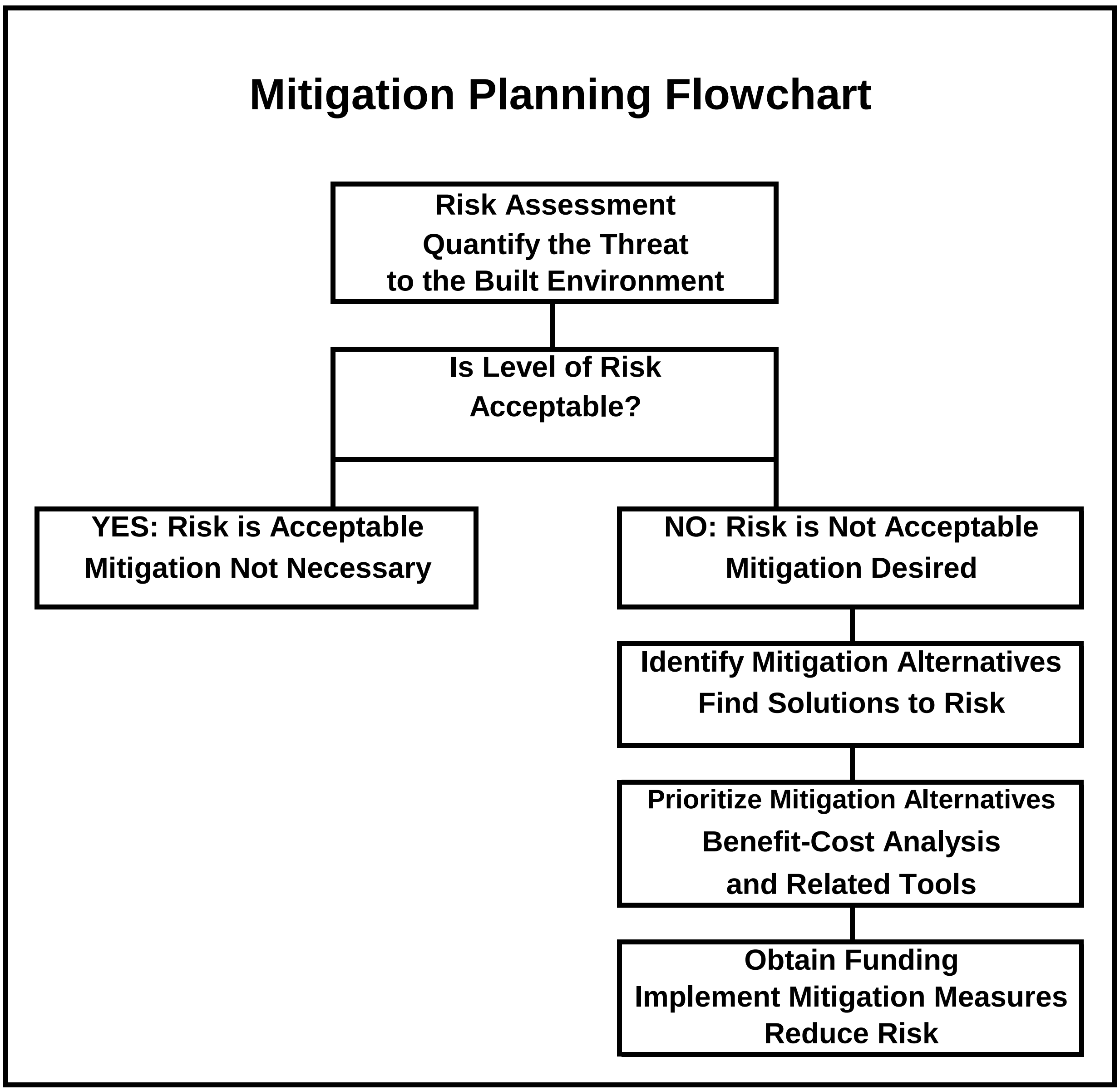
The flow chart below outlines the major steps in Hazard Mitigation Planning and Implementation for Corvallis.

The first steps are quantitative evaluation of the hazards (frequency and severity) impacting Corvallis and of the inventory (people, buildings, infrastructure) exposed to these hazards. Together these hazard and exposure data determine the level of risk for specific locations, buildings or facilities in Corvallis.

The next key step is to determine whether or not the level of risk posed by each of the hazards impacting Corvallis is acceptable or tolerable. Only the residents of Corvallis can make this determination. If the level of risk is deemed acceptable or at least tolerable, then mitigation actions are not necessary or at least not a high priority.

On the other hand, if the level of risk is deemed not acceptable or tolerable, then mitigation actions are desired. In this case, the mitigation planning process moves on to more detailed evaluation of specific mitigation alternatives, prioritization, funding and implementation of mitigation measures. As with the determination of whether or not the level of risk posed by each hazard is acceptable or not, decisions about which mitigation projects to undertake can be made only by the residents of Corvallis.

Figure 1.6
The Mitigation Planning Process



1.6 The Role of Benefit-Cost Analysis in Mitigation Planning

Communities that are considering whether or not to undertake mitigation projects must answer questions that don't always have obvious answers, such as:

What is the nature of the hazard problem?

How frequent and how severe are hazard events?

Do we want to undertake mitigation measures?

What mitigation measures are feasible, appropriate, and affordable?

How do we prioritize between competing mitigation projects?

Are our mitigation projects likely to be eligible for FEMA funding?

Benefit-cost analysis is a powerful tool that can help communities provide solid, defensible answers to these difficult socio-political-economic-engineering questions. **Benefit-cost analysis is <u>required</u> for all FEMA-funded mitigation projects, under both pre-disaster and post-disaster mitigation programs. Thus, communities seeking FEMA funding must understand benefit-cost analysis.** However, regardless of whether or not FEMA funding is involved, benefit-cost analysis provides a sound basis for evaluating and prioritizing possible mitigation projects for any natural hazard.

Benefit-cost analysis software, technical manuals and a wide range of guidance documents are available from FEMA at no cost to communities. A Benefit-Cost Analysis Toolkit CD which contains all of the FEMA benefit-cost materials is available from FEMA. The publication ***What is a Benefit? Draft Guidance for Benefit-Cost Analysis*** is particularly recommended as a general reference for benefit-cost analysis. This publication includes categories of benefits to count for mitigation projects for various types of buildings, critical facilities, and infrastructure and has simple, standard methods to quantity the full range of benefits for most types of mitigation projects.

The principles of benefit-cost analysis are briefly summarized in the Appendix at the end of the Corvallis Hazard Mitigation Plan.

1.7 Hazard Synopsis

To set the overall context of hazard mitigation planning, we briefly review the major hazards that impact Corvallis. Different parts of Corvallis vary in topography, climate, population, development patterns and so on. Similarly, the impact of many hazards on communities in Corvallis varies with location within the City. Some hazards affect the entire City, while some hazards have only localized potential consequences.

Floods. Portions of Corvallis have areas of flood plains mapped by FEMA. These include areas along the Willamette River, as well as areas along smaller tributary creeks. There are over 3,000 buildings located within the footprint of these FEMA-mapped floodplain. Furthermore, other portions of Corvallis, outside of the mapped floodplains, are also subject to significant, repetitive flooding from local storm water drainage.

Winter Storms. All of Corvallis is subject to the effects of winter storms, including wind, rain, snow and ice, as well as secondary effects such as power outages.

Landslides. Portions of the hilly areas of Corvallis, especially the in the hilly portions of North Corvallis, are subject to landslides or debris flows (mudslides), which may affect buildings, roads, and utilities.

Wildland/Urban Interface Fires. Parts of Corvallis are subject to the risk of wildland fires, including the hilly forested areas of North Corvallis. As a result, many residential areas bordering or impinging into forested areas near the edges of the developed areas of Corvallis may have high levels of risk from wildland/urban interface fires.

Earthquakes. All of Corvallis is subject to the impacts of earthquakes, including not only major earthquakes on the Cascadia Subduction Zone off the Oregon coast, but also smaller crustal earthquakes within western Oregon.

Volcanic Hazards. All of Corvallis is subjected, to a minor degree, to volcanic hazards from eruptions in the Cascades (e.g., Mount Hood, the Three Sisters). For Corvallis, the impacts of volcanic events are likely to be only minor ash falls, with perhaps some impact on public water supplies from ash causing high turbidity in drinking water supplies.

Dam Failures. Many heavily populated portions of Corvallis along the Willamette River are in the inundation areas from dam failures. While dam failures are highly unlikely, the consequences of failure would be high.

Disruption of Utility and Transportation Systems. All of Corvallis is also subject to disruption of utility and transportation systems from winter storms and other natural hazards, as well as from anthropogenic causes.

In evaluating these natural or human-caused hazards, it is important to recognize that the risk to Corvallis (i.e., the potential for damages, economic losses, and casualties) varies markedly from one hazard to another. As discussed in more detail in Section 1.4, risk depends on the combination of the frequency and severity of hazard events and on the value and vulnerability of infrastructure, buildings, and people to each potential hazard. Risk is thus always probabilistic in nature. Some hazard events, such as winter storms, happen every year to at least some extent. Other hazard events, such as major earthquakes may happen only once every few hundred years. However, the level of risk from earthquakes is high, even though the frequency of occurrence is low, because the potential consequences (damage, economic losses, and casualties) are very high.

The relative risk posed to Corvallis by each of the 8 hazards covered in this mitigation plan is summarized below in Table 1.4.

Table 1.4
Relative Risk to Corvallis

Hazard	Risk
Earthquake	High
Flood	High
Dam Failure	High
Winter storms (Severe weather)	Moderate
Wildand/Urban Interface Fires	Moderate
Disruption of Utility and Transportation Systems	Moderate
Landslides	Low
Volcanic Eruptions (Ash Falls)	Low

In summary, there are many natural and human-caused hazards which affect all or large portions of Corvallis.

The remaining chapters of this mitigation plan include the following.

Chapter 2 provides a brief community profile for Corvallis.

Chapter 3 documents the community involvement and public process involved in developing this mitigation plan.

Chapter 4 outlines the mitigation plan goals, mitigation strategies, and action items.

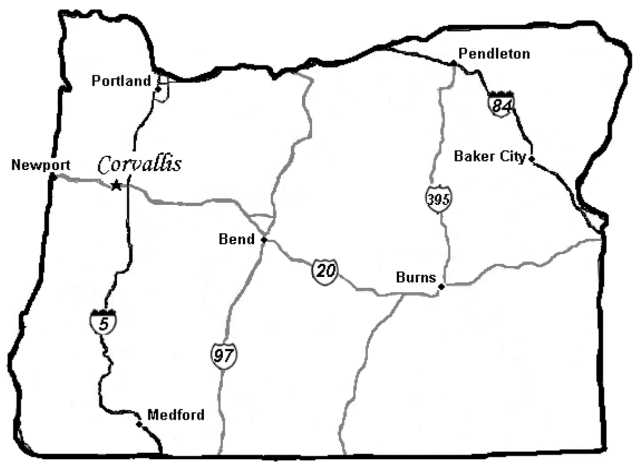
Chapter 5 documents the formal process of plan adoption, implementation, and maintenance.

Chapters 6 through 13 cover each of the major hazards addressed in this mitigation plan, including: floods, winter storms, landslides, wildland/urban interface fires, earthquakes, volcanic hazards, dam safety, and disruption of utility and transportation systems.

2.0 COMMUNITY PROFILE: CITY of CORVALLIS, OREGON

2.1 Geography and Climate

Corvallis, Oregon is a compact city located along the Willamette River in western Oregon, covering about 14 square miles. The geography of Corvallis includes gentle hills and flat topography. The City has flood prone areas along the Willamette River and its tributaries and smaller areas that are subject to wildland/urban interface fire and landslide risks.



The climate for Corvallis is moderate. Mean daily temperatures range from highs of about 81 degrees and lows of about 51 degrees in July and August to highs of about 46 degrees and lows of about 33 or 34 degrees in December and January (Corvallis, Oregon State University weather station data). The average annual rainfall is about 43 inches. Average monthly precipitation varies from about 6 to seven inches in November through January to about 0.4 inch in July. It rarely snows in Corvallis, and most snow melts on the same day it falls.

2.2 Population and Demographics

Originally founded as the City of Marysville in 1851, the City was renamed Corvallis in 1853, and incorporated as one of Oregon's oldest cities in January 1857. Oregon State University is a land, sea, sun, and space grant institution, one of only two institutions of higher education in the United States to hold all four titles. OSU, first chartered as Corvallis College in 1868, currently covers 400 acres of land in and around Corvallis. Student enrollment in the 2006-2007 academic year was over 19,300, with more than 3,500 in graduate programs.

Corvallis is a medium-sized city with a 2000 decennial census population of 49,332. Portland State University estimates the 2006 population was 53,900. Corvallis is the largest city in Benton County, with about two-thirds of the County's population living in

Corvallis. As a result, Corvallis remains the heart of both the Willamette Valley and Benton County.

More detailed population and demographic data for Corvallis from the 2000 census are shown below, along with similar data for Oregon. The age and ethnicity categories in Table 2.1 below intentionally include overlapping subsets of categories for planning purposes.

Table 2.1
Corvallis Demographic Data (2000 Census Data)

Demographic Data	City of Corvallis	Oregon
Age		
Under 5 years	5.1%	6.5%
Under 18 years	19.2%	24.7%
18 years and over	80.2%	75.3%
18 years to 65 years	70.2%	62.5%
65 years and over	10.0%	12.8%
Ethnicity of Households		
White	87.1%	86.6%
Black or African American	1.1%	1.6%
American Indian or Alaska Native	0.8%	1.3%
Asian	5.6%	3.0%
Native Hawiian and Pacific Islander	0.3%	0.2%
Other or two or more races	5.1%	7.3%
Hispanic or Latino (of any race)	5.4%	8.0%
Language spoken at Home		
English Only	88.3%	87.9%
Language other than English	11.7%	12.1%
Speak English less than very well	4.9%	5.9%
Spanish	4.6%	6.8%
Other Indo-Eurpoean languages	2.6%	2.6%
Asian and Pacific Island languages	3.9%	2.4%

2.3 Employment and Economics

Corvallis is a regional center for higher education, industrial technology, engineering, research, commerce, and health care. Corvallis is the home of Oregon State University, the state's leading research university. In a 2002, USA Today list, Corvallis ranked fourth in the number of patents issued by location, reflecting the impact of both Oregon State University and the research done at the Hewlett-Packard complex located in Corvallis. In 2004, the Harvard Business Review ranked Corvallis 15th (tied with Atlanta) in its Creativity Index, which looks at Technology, Talent, and Tolerance. In 2005, Expansion Management selected Corvallis as a "Five-Star Knowledge Worker Metro Area," the highest rating achievable, and in 2006 Corvallis was named number two on the National Science Foundation’s list for percentage of scientists in the population.

The City of Corvallis and Benton County have maintained a strong employment base, even as Oregon has had the highest unemployment rate in the United States for the last several years. Benton County consistently holds the state's lowest unemployment rate; in December 2006, Benton County's seasonally adjusted unemployment rate was 4.3% while the state was at 5.4%. The top ten employers in Corvallis as of the most recent compilation by the Corvallis-Benton Chamber Coalition are shown below in Table 2.2:

Table 2.2
Largest Employers in Corvallis

	Number of Employees
Oregon State University	7,393
Hewlett Packard	3,440
Good Samaritan Hospital	1,800
Corvallis School District 509-J	749
Holiday Tree Farm	700
Corvallis Clinic	600
City of Corvallis	440
Benton County	379
CH2M Hill	378
Summit Information Systems	310

Selected economic data for Corvallis from the 2000 census are summarized in Table 2.3 below. Corresponding data for Oregon are also shown for reference.

Table 2.3
Selected Economic Data (2000 Census Data)

Demographic Data	City of Corvallis	Oregon
Population 16 years and older	47,917	3,472,867
In labor force	62.1%	65.2%
Employed	58.5%	61.0%
Unemployed	3.4%	4.2%
Not in Labor Force	37.9%	34.8%
Commuting to Work		
Drove alone	68.0%	73.2%
Carpooled	9.6%	12.2%
Public transportation	2.1%	4.2%
Walked	9.8%	3.6%
Other means (including bicycles)	6.8%	1.9%
Worked at home	3.6%	5.0%
Housing Data		
Homeownership rate	53.4%	64.3%
Housing units in multi-unit structures	43.3%	23.1%
Incomes and poverty levels		
Median household income	$52,742	$40,916
Per capita money income	$19,968	$20,940
Families below the poverty level	8.6%	7.9%
with children under 18 years	12.0%	12.4%
with children under 5 years	15.3%	16.6%

2.4 Housing in Corvallis

Housing demographic data from the 2000 census are summarized below. The data reflect the impact of Oregon State University in the city; OSU provides housing on campus for fewer than 4,000 of the 19,000 student population, with the vast majority of students living off campus in rental housing units.

Table 2.4
Corvallis Housing Data

Demographic Data	City of Corvallis	Oregon
Total Housing Units	24,218	1,452,709
Occupied units	22,869	1,333,723
Vacant units	1,349	118,986
Vacancy percentage	5.6%	8.2%
Owner-occupied units	48.7%	53.5%
Renter-occupied units	51.3%	38.2%

The age distribution of Corvallis housing stock is shown below. Age of housing stock is relevant for mitigation planning purposes because older construction is less likely to conform to current building codes for fire and earthquake safety standards and are less likely to conform to flood plain management regulations. For example, 42% of Corvallis housing stock was built before 1960, with nine percent built before 1940.

Table 2.5
Corvallis Housing Stock by Year Built

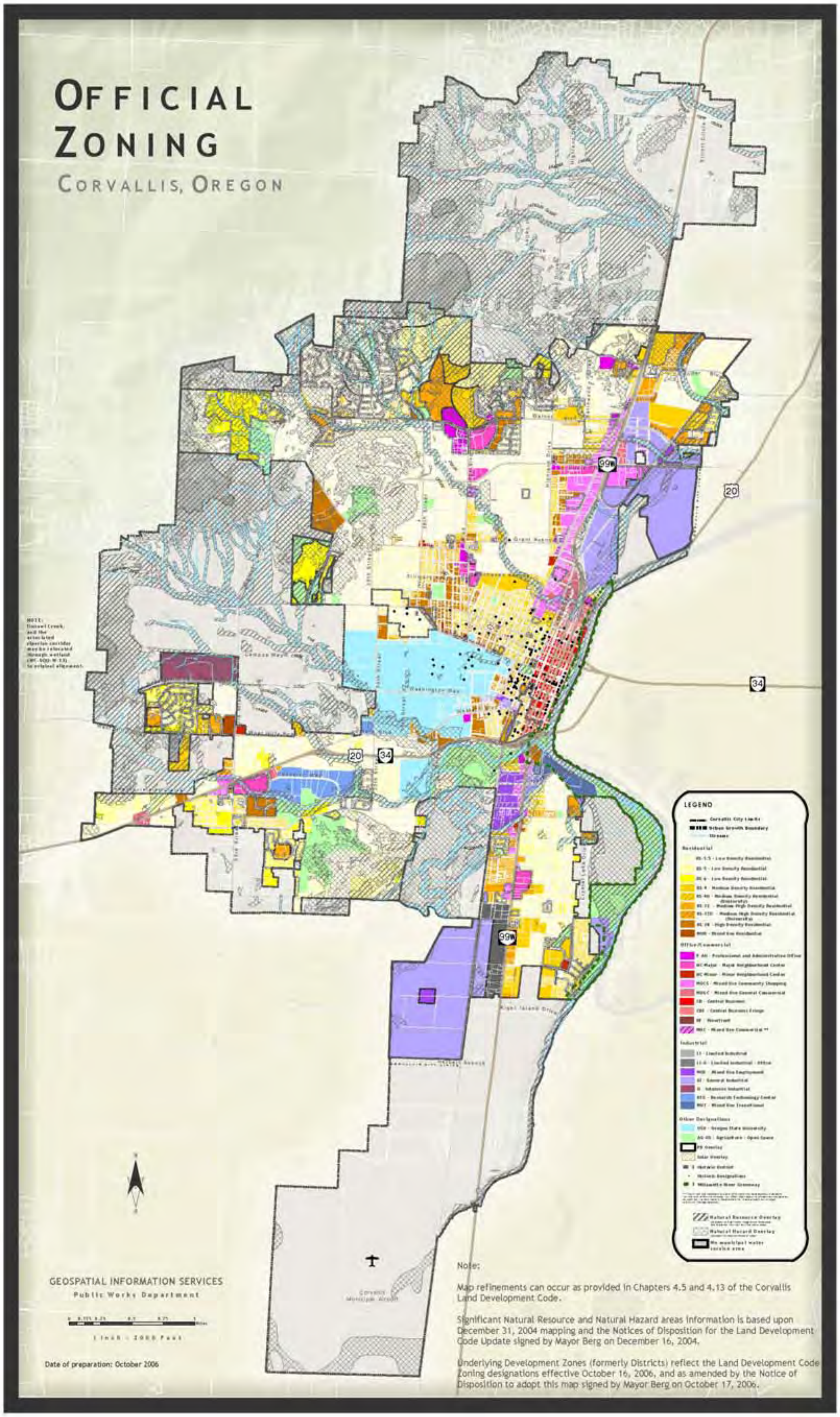
Corvallis Housing Stock by Year Built

Demographic Data	City of Corvallis
1990 - March 2000	18.7%
1980 - 1989	9.6%
1970 - 1979	29.3%
1960 - 1969	15.4%
1940 - 1959	18.0%
1939 or earlier	9.0%

2.5 Land and Development

Land use and development patterns in the City of Corvallis are documented by the zoning map show below as Figure 2.1.

Figure 2.1
Corvallis Zoning Map



2.6 Regulatory Context

2.6.1 Overview

Oregon land use laws require land outside Urban Growth Boundaries (UGBs) to be protected for farm, forest, and aggregate resource values. For the most part, this law limits the amount of development in the rural areas. However, the land use designation can change from resource protection in one of two ways:

- The requested change could qualify as an exception to Statewide Planning Goals, in which case the city must demonstrate to the State that the change meets requirements for an *exception*. These lands, known as *exception lands,* are predominantly designated for residential use.

- Resource land can also be converted to non-resource use when it can be demonstrated to Corvallis that the land is no longer suitable for farm or forest production.

Local and state policies currently direct growth away from rural lands into UGBs, and, to a lesser extent, into rural communities. If development follows historical development trends, urban areas will expand their UGBs, rural unincorporated communities will continue to grow, and overall rural residential density will increase slightly with the bulk of rural lands kept in farm and forest use. The existing pattern of development in the rural areas, that of radiating out from the urban areas along rivers and streams is likely to continue. Most of the “easy to develop” land is already developed, in general leaving more constrained land such as land in the floodplains or on steep slopes to be developed in the future, perhaps increasing the rate at which development occurs in natural hazard areas.

2.6.2 Oregon Statewide Planning Goal 7

Oregon State Planning Overview

Since 1973, Oregon has maintained a strong statewide program for land use planning. The foundation of that program is a set of 19 statewide planning goals that express the state's policies on land use and on related topics, such as citizen involvement, land use planning, and natural resources.

Most of the goals are accompanied by "guidelines," which are suggestions about how a goal may be applied. Oregon's statewide goals are achieved through local comprehensive planning. State law requires each city and city to adopt a comprehensive plan and the zoning and land-division ordinances needed to put the plan into effect. The local comprehensive plans must be consistent with the statewide planning goals. Plans are reviewed for such consistency by the state's Land Conservation and Development Commission (LCDC). When LCDC officially approves a local government's plan, the plan is said to be "acknowledged." It then becomes the controlling document for land use in the area covered by that plan.

Goal 7

Goal 7: Areas Subject to Natural Disasters and Hazards has the overriding purpose to "protect people and property from natural hazards". Goal 7 requires local governments to adopt comprehensive plans (inventories, policies and implementing measures) to reduce risk to people and property from natural hazards. Natural hazards include floods, landslides, earthquakes, tsunamis, coastal erosion, and wildfires.

To comply with Goal 7, local governments are required to respond to new hazard inventory information from federal or state agencies. The local government must evaluate the hazard risk and assess the:

a. frequency, severity, and location of the hazard;
b. effects of the hazard on existing and future development;
c. potential for development in the hazard area to increase the frequency and severity of the hazard; and
d. types and intensities of land uses to be allowed in the hazard area.

Local governments must adopt or amend comprehensive plan policies and implementing measures to avoid development in hazard areas where the risk cannot be mitigated. In addition, the siting of essential facilities, major structures, hazardous facilities and special occupancy structures should be prohibited in hazard areas where the risk to public safety cannot be mitigated. The state recognizes compliance with Goal 7 for coastal and riverine flood hazards by adopting and implementing local floodplain regulations that meet the minimum National Flood Insurance Program (NFIP) requirements.

Goal 7 provides local jurisdictions with the following guidelines for planning and implementation:

In adopting plan policies and implementing measures for protection from natural hazards local governments should consider:

a. the benefits of maintaining natural hazard areas as open space, recreation, and other low density uses;
b. the beneficial effects that natural hazards can have on natural resources and the environment; and
c. the effects of development and mitigation measures in identified hazard areas on the management of natural resources.

Local governments should coordinate their land use plans and decisions with emergency preparedness, response, recovery and mitigation programs. Given the numerous waterways and forested lands throughout Corvallis, special attention should be given to problems associated with river bank erosion and potential for wild land/urban interface fires.

Goal 7 guides local governments to give special attention to emergency access when considering development in identified hazard areas, including:

a. Consider programs to manage stormwater runoff as a means to address flood and landslide hazards,

b. Consider non-regulatory approaches to help implement the goal,

c. When reviewing development requests in high hazard areas, require site specific reports, appropriate for the level and type of hazards. Site specific reports should evaluate the risk to the site, as well as the risk the proposed development may pose to other properties.

d. Consider measures exceeding the National Flood Insurance Program..

Corvallis Compliance With Goal 7

The City evaluates emergency access when considering development. For the most part (with few acceptations), developers are required to build dwellings near the roadway in part to provide easier access for emergency vehicles. Larger development proposals must include a stormwater management plan for stormwater discharge and development cannot alter an existing waterway. In conformance with NFIP regulations, Corvallis requires that new development in mapped floodplains be at least one foot above the base flood elevation, reducing the risk of flood damage.

2.7 Community Rating System

Jurisdictions that regulate new development in their floodplains are able to join the National Flood Insurance Program (NFIP). In return, the NFIP provides federally backed flood insurance for properties in participating areas. Corvallis participates in the NFIP program and 414 flood insurance policies are held within Corvallis, per NFIP data as of August 31, 2007.

The Community Rating System (CRS) is a part of the NFIP. The CRS reduces flood insurance premiums to reflect what a community does above and beyond the NFIP's minimum standards for floodplain regulation. Community participation in the CRS is voluntary. Corvallis does participate in CRS with a current rating of 7, which results in a 15% discount for flood insurance in Special Flood Hazard Areas (SFHAs, as defined by FEMA) and a 5% discount in areas outside SFHAs.

If Corvallis achieved a higher CRS rating, residents would obtain greater discounts (up to 45% for the highest rating) for flood insurance and, more importantly, the level of flood risk in Corvallis would be reduced.

The objective of the CRS is to reward communities for what they are doing, as well as to provide an incentive for new flood protection activities. The reduction in flood insurance premium rates is provided according to a jurisdiction's CRS classification, which is dependent upon the number of points awarded the jurisdictions for flood reduction activities implemented. To apply, a jurisdiction submits documentation that shows what it is doing and that its activities deserve at least 500 points. By participating in the CRS program, a jurisdiction not only reduces the risk of loss due to flood damage but policy holders gain up significant reductions in flood insurance premiums.

There are 18 floodplain management activities credited by the CRS organized under four series:

1. Public Information,
2. Mapping and Regulations,
3. Flood Damage Reduction, and
4. Flood Preparedness.

All but two of the 18 management activities are optional. The two required activities are the elevation certificate and repetitive loss requirements. Following are the 18 activities from which a jurisdiction can receive CRS credits. The City Practice comments are verbatim from the 2006 ISO CRS Rating Survey.

1. **Elevation Certificates**: This activity provides credit for maintaining records of flood data and elevations of new, substantially improved and substantially damaged buildings on FEMA's elevation certificate form. Using the FEMA elevation certificate form for all construction after applying for the CRS is required of all jurisdictions under the program. Maintaining records prior to applying for the CRS is optional.

   City Practice: Community Development maintains elevation certificates for new and substantially improved buildings. Copies of elevation certificates are available upon request. Elevation certificates are also kept for post-FIRM buildings.

2. **Map Information**: This activity credits assisting the public in reading and understanding Flood Insurance Rate Maps (FIRMs) in response to requests from the public. This service must be publicized and records kept of its use.

   City Practice: Credit is provided for furnishing inquirers with flood zone information from the community's latest Flood Insurance Rate Map (FIRM), publicizing the service annual and maintaining records.

3. **Outreach Projects**: Credit is provided for advising people every year of the flood hazard, the availability of flood insurance, and/or flood protection methods. Credit points are based on two factors: the type of outreach project and the topics covered by each project.

   City Practice: A community brochure is mailed to all properties in the community on an annual basis. An outreach brochure is mailed annually to all properties in the community's Special Flood Hazard Area (SFHA)>

4. **Hazard Disclosure**: Various ways of telling people that a property is in a floodplain are credited under the CRS. No credit is given if the information is provided only if a person asks. The disclosure information must be volunteered or appear on a document, such as a Multiple Listing Service

printout, fact sheet, or offer to purchase contract, that house hunters see before they have committed to buying or renting the property.

City Practice: Credit is provided for state and community regulations requiring disclosure of flood hazards.

5. **Flood Protection Information:** This activity's credit points are provided for two approaches to providing detailed flood-related information to residents: through a local public library or through a local governments website. Both locations can contain a great deal of information and both offer alternatives for people who are hesitant or unable to go to a planning office or talk to a local official. Credit is available for either approach or both.

   City Practice: Documents related to floodplain management are available in the reference section of the Corvallis-Benton County Library.

6. **Flood Protection Assistance**: The objective of this activity is to provide interested property owners with general information that responds to their needs. Providing construction plans or specifications that should be prepared by an architect or engineer is not necessary. This activity must be publicized annually in a newsletter, telephone book, or other outreach project that reaches everyone in the community or everyone in the floodplain. The publicity must meet the same criteria as an outreach project that is credited. The assistance office need not be local staff if other agencies have agreed to answer inquiries. Assistance can be provided by a combination of offices to secure a range of expertise. This activity does not give credit for floodplain ordinance enforcement activities normally conducted by a building department, like providing base flood elevations, making site visits, and/or reviewing plans to ensure that they comply with the building code.

   City Practice: The community provides technical advice and assistance to interested property owners and annually publicizes the service.

7. **Special Hazard Areas**: FEMA and many states and communities have long recognized that the mapping and regulatory standards of the NFIP do not adequately address all of the flood problems in the country. There are many special local situations in which flooding or flood-related problems do not fit the national norm. Therefore, there are situations in which the NFIP's floodplain management criteria do not adequately protect property from flood damage. To encourage local jurisdictions to address these hazards, the CRS provides credit for mapping, preserving open space, and regulating new development in areas subject to the following eight special hazards:

   - Uncertain flow paths—alluvial fans, moveable bed streams and other floodplains where the channel moves during a flood.

- Closed basin lakes—lakes that have a small or no outlet that may stay above flood stage for weeks, months, or years.
- Ice jams—flooding caused when warm weather and rain break up a frozen river. The broken ice floats downstream until it is blocked by an obstruction, such as a bridge or shallow area, creating a dam.
- Land subsidence—lowering of the land surface caused by withdrawal of subsurface water or minerals or by compaction of organic soils.
- Coastal dunes and beaches.
- Mudflow hazards—a river, flow, or inundation of liquid mud down a hillside, usually as a result of a dual condition of loss of brush cover, and the subsequent accumulation of water on the ground preceded by a period of unusually heavy or sustained rain.
- Coastal erosion—areas subject to the wearing away of land masses caused primarily by waves on the oceans, Gulf of Mexico, and the Great Lakes.
- Tsunamis—large ocean waves caused by an underwater earthquake or volcano.

City Practice: No comments in the ISO survey.

8. **Additional Flood Data:** "Flood data" include base flood elevations and delineation of floodways and coastal velocity zones. This activity credits (1) studies conducted outside the SFHA, (2) studies conducted in the SFHA where base flood elevations were not shown on the FIRM, (3) restudying an area shown on the FIRM where the new study produced higher base flood elevations and (4) studies that were conducted to higher standards than the normal FEMA mapping criteria. No credit is provided unless (1) the flood study has been adopted by the jurisdiction for regulatory purposes and (2) the study either meets or exceeds the criteria in *Flood Insurance Study Guidelines and Specifications for Study Contractors*.

   City Practice: Credit is provided for conducting and adopting flood studies for areas not included on the flood insurance rate maps and that exceed minimum mapping standards.

9. **Open Space Preservation**: This activity credits preserving vacant land in the floodplain as open space, i.e., as areas where there will be no buildings and no filling. The areas must be *preserved* as open space either through public ownership or by development regulations that prohibit buildings and filling. The areas can be public parks, private preserves, playing fields, golf courses, or other uses provided that the owner documents that the land will stay as open space. The open space must not be federal land and it must not be water (i.e., not a lake or river). There must be no buildings on the land, although parcels larger than 10 acres may have one building that is a necessary appurtenance to open space use, such as a restroom facility, ranger's cabin, or bleachers. Open space is not credited in FIRM Zones A99 or AR.

City Practice: Credit is provided for preserving approximately 33.48 acres in the special flood hazard areas as open space.

10. **Higher Regulatory Standards**: This activity provides credit for regulations that require new development to be protected to one or more standards stricter than the NFIP's minimum requirements.
    - Floodplain management regulations that require freeboard for all new buildings and substantial improvements (i.e., all new buildings (and their furnaces, utilities, ductwork, etc.) must be elevated or floodproofed to a level at least 1 foot above the base flood elevation).
    - Adopt and enforce the soil testing and compaction requirements of the Standard, Uniform, National, or International Building Codes (also known as the Southern, ICBO, BOCA, and I-Codes).
    - Regulations that require ALL improvements, modifications, additions, and reconstruction projects to an existing building to be counted cumulatively over a period of at least five years.
    - Establish a threshold for substantial improvements at less than 50%.
    - Prohibit or restrict critical facilities in the floodplain.
    - Regulations that prohibit fill in the floodplain (not just in the floodway) or that require compensatory storage.
    - Regulations that prohibit activities in the floodplain that are hazardous to public health or water quality or that require that new floodplain developments avoid or minimize disruption to shorelines or stream channels and their banks.
    - Regulations that prohibit or restrict building enclosures, including breakaway walls, below the base flood elevation.
    - Regulations are mandated by state law.
    - Building Code Effectiveness Grading Schedule of class 6 or better. Add points if the community has adopted either the International Residential Code or the International Building Code (50 points if your community adopted both codes).
    - All proposed development projects in the floodplain and the certificates of occupancy for such projects are reviewed by a Certified Floodplain Manager (CFM).
    - Manufactured home parks in the floodplain where the base flood elevation is more than 3 feet deep, require that newly placed manufactured homes be elevated above the base flood elevation.
    - Map or otherwise designate the community's coastal AE Zone (i.e., the coastal SFHA that is not mapped as V Zone) and require that all new buildings in the coastal AE Zone meet the requirements for buildings in V Zones and for openings in A Zones.

City Practice: Credit is provided for enforcing regulations that require freeboard for new construction and substantial improvement, foundation protection, natural and beneficial functions and state mandated regulatory standards. Credit is also provided for a Building Code Effectiveness Grading Schedule (BCEGS) Classification of 2/2.

11. **Land Development Criteria**: This section credits regulatory provisions that encourage developers to avoid the floodplain or to minimize the amount of construction in the floodplain. The areas designated for this credit cannot be the same as the areas designated for open space credit under the open space criteria.

    City Practice: No comment in the ISO survey.

12 **Flood Data Maintenance**: Credit is provided for keeping the community's floodplain maps and elevation reference marks more current, useful, or accurate in order to improve local regulations, planning, disclosures, and property appraisals.

    City Practice: Credit is provided for maintaining and using digitized maps in the day to day management of the floodplain. Credit is also provided for establishing and maintaining a system of elevation reference marks.

13. **Stormwater Management**: This activity credits regulating new development in the watershed (not just the floodplain) to minimize the adverse impacts of stormwater runoff on downstream flooding and water quality.

    City Practice: The community enforces regulations for freeboard in non-SFHA zones, soil and erosion control, and water quality..

14. **Repetitive Loss Requirements**: Repetitive loss requirements are mandatory for any jurisdiction with at least one repetitive loss property. A repetitive loss property has had two or more claims of at least $1,000 paid by the NFIP over a 10-year period since 1978. A jurisdiction with 10 or more repetitive loss properties must review and describe its repetitive loss problem, undertake an outreach project, and prepare a floodplain management plan.

    City Practice: No comments in the ISO survey.

15. **Floodplain Management Planning**: The CRS provides credit for preparing, adopting, implementing, evaluating, and updating a comprehensive floodplain management plan. The CRS does not specify what activities a plan must recommend, but it credits plans that have been prepared according to a standard 10-step planning process. The 10-step CRS process is consistent with hazard mitigation planning regulations, pursuant to the Disaster Mitigation Act of 2000 (44 *CFR* 201.6).

    City Practice: No comments in the ISO survey.

16. **Acquisition and Relocation**: Credit is provided for acquiring, relocating, or otherwise clearing buildings out of the floodplain. This activity credits any approach as long as an insurable building is removed from the path of flooding. Credit is not provided for structural flood control projects that result in revisions to floodplain boundaries. Acquisition and relocation

credit is provided only if the property qualifies for preserved open space. CRS credit is provided only for acquisition or relocation projects undertaken after the date of the community's initial FIRM. Credit is provided only if the lot is still vacant, even if a new building was built to flood protection standards. Credit is provided only for removing the main building on a lot, not for removing garages, sheds, or other accessory structures.

City Practice: No comments in the ISO survey.

17. **Drainage System Maintenance:** Under this activity, a local government receives credit for defining its drainage system, inspecting it, removing debris, correcting drainage problem sites, and regulating dumping in the system. For the purposes of this activity, a jurisdiction's drainage system consists of all natural and human-made watercourses, conduits, and storage basins that must be maintained in order to prevent flood damage to buildings (including repetitive loss properties) from smaller, more frequent storms. In some areas, this will include streets, roadside ditches, underground storm sewers, and inlets, as well as open channels and detention and retention basins. The defined drainage system must also cover those areas having repetitive loss properties, where the cause of the losses was due to local drainage problems or smaller, more frequent storms.

City Practice: All of the community's drainage systems are inspected regularly throughout the year and maintenance is performed as needed by the Corvallis Public Works Department. Records are being maintained for both inspections and required maintenance. Credit is also given for an ongoing Capital Improvements Program.

18. **Flood Warning Program:** Credit is provided for a program that provides timely identification of impending flood threats, disseminates warnings to appropriate floodplain occupants, and coordinates flood response activities. The local government must have a flood threat recognition system that identifies an impending flood in order to receive credit under this activity.

City Practice: Credit is provided for a program that provides timely identification of impending flood events, disseminates warnings to appropriate floodplain residents, and coordinates flood response activities.

2.9 Regulatory Context: Summary Comments

Sections 2.6 to 2.8 above reviewed regulatory programs and issues related to hazard mitigation planning. The state land use planning requirements, Goal 7, and the CRS regulations are all regulatory programs. That is, these programs impose legal requirements and restrictions on development that are intended to provide for public safety and to minimize the future impacts of disaster events on Corvallis.

In contrast, this Hazard Mitigation Plan is not a regulatory document. That is, a Hazard Mitigation Plan is intended to educate the public about hazards and to encourage prudent practices but it does <u>not</u> mandate practices or regulate development. However, a Hazard Mitigation Plan is closely related so some regulatory processes in the sense that greater awareness about and better data on hazards may subsequently lead to changes in regulations.

An important objective of developing a Hazard Mitigation Plan is to start the long term process of acquiring better data on hazards, vulnerability and risk in Corvallis. Acquiring better data may eventually lead to more regulation of identified high hazard areas. However, better data with higher spatial resolution may also result in reclassifying areas tentatively mapped as being in potential hazard areas as, in fact, not being in hazard areas. For example, the spatial resolution of mapping of potential landslide areas or areas subject to liquefaction in earthquakes is generally low. More refined mapped of such hazards is likely to reduce the areas designated as being potentially subject to these hazards.

3.0 PUBLIC PROCESS

3.1 Overview

City of Corvallis has a strong history of mitigation planning and involving citizens and community partners in many of its planning activities.

Public participation allows a range of public interests to participate and express their ideas, thoughts, and opinions on matters that are important to their way of life. As government stewards of the people, City of Corvallis Government has an obligation to solicit and receive the view of its citizenry. Additionally, the State of Oregon and FEMA have requirements to receive public input during the development of Land Use Plans and flood mitigation plans, respectively.

Corvallis' mitigation planning activities began well before the City initiated development of the Corvallis Hazard Mitigation Plan, including the City's':

- Active participation in the development of the FEMA-approved Benton County Hazard Mitigation Plan. Three of the 15 Benton County Mitigation Plan Steering Committee members represented the City of Corvallis, with representatives from the Corvallis Fire, Public Works, and Community Developments. In addition, several more of the Steering Committee represented other Corvallis-based organizations, including Good Samaritan Regional Medical Center, Oregon State University, ODOT, and CH2M Hill.
- Active and ongoing focus on implementing Oregon's Goal 7.
- Participation in the National Flood Insurance Program, including the Community Rating System.
- Long history of considering natural hazards for land use and zoning planning.

The City of Corvallis was also a charter member of the Benton County Emergency Management Council (BCEMC). BCEMC has been exceptionally active in planning for and responding to disasters events. BCEMC has received numerous awards including being named Outstanding Regional Task Force by FEMA, two Exemplary Practices Awards from Oregon Emergency Management, and an Excellence Award from the Western States Seismic Policy Council. BCEMC was one of the few initial organizations granted Project Impact Community status and funding. Many BCEMC members played an active role in the development of the Corvallis Hazard Mitigation Plan.

Corvallis also played a major role in Benton County's unusually active and successful Project Impact mitigation programs. For Benton County overall, $300,000 in Project Impact funding was leveraged with other grant funds and over $6.5 million in related community projects for a total of over $7.2 million in hazard assessment, education/ outreach and mitigation activities. Many of these projects were in the City of Corvallis, including seismic risk assessment for public schools, nonstructural seismic mitigation in public schools and other facilities, including the Corvallis Senior Center. The City of

Corvallis' effort included over $5.5 million in mitigation projects, including Dixon Creek flood mitigation, Willamette River bank stabilization, and stormwater system upgrades.

The involvement of the public throughout the plan development process has resulted in a Corvallis Hazard Mitigation Plan that includes the concerns and ideas of individuals, organizations, and other agencies and reflects these concerns and ideas in the Goals, Objectives, Strategies and Action Items within the plan.

3.2 Corvallis Hazard Mitigation Plan Steering Committee

A 13-member Steering Committee was formed from City departments with a vested interest in mitigation planning, along with one Benton County Representative. Members of this committee included:

Bob Fenner	City of Corvallis Public Works Department
Jim Mitchell	City of Corvallis Public Works Department
Steve Rogers	City of Corvallis Public Works Department
Tom Penprase	City of Corvallis Public Works Department
John Olson	City of Corvallis Public Works Department
Jerry Smith	City of Corvallis Public Works Department
Nancy Brewer	City of Corvallis Finance Department
Ken Gibb	City of Corvallis Community Development Department
Dan Carlson	City of Corvallis Community Development Department
Roy Emery	City of Corvallis Fire Department
Julie Conway	City of Corvallis Parks and Recreation Department
Carolyn Rawles-Heiser	City of Corvallis Library Department
Mary King	Benton County Emergency Management

3.3 Documentation of Corvallis Mitigation Plan Meetings

Meeting #1 September 6, 2007: Public Meeting
5:00 to 7:00 PM, Main Meeting Room Downtown Corvallis Fire Station

The first public meeting was advertised by three notices in the Corvallis Gazette-Times: one notice on Sunday August 28th and two notices on September 6th, as well as by an extensive e-mail notification list. The meeting notice was also posted on the City of Corvallis website in the "What's New" Section:

Public Notice

The City of Corvallis is seeking input on the development of a Pre-Disaster Mitigation Plan. A public meeting will be held 5:00 pm - 7:00 pm on Thursday, September 6, 2007, in the main meeting room of Fire Station 1, 400 NW Harrison Blvd. This meeting will introduce the planning process to develop a local hazard mitigation plan, detail the purpose and key elements of the Plan, and gather public comment on the needs to be included in the Plan. Topics to be discussed include a review of the major hazards posing risk to Corvallis such as earthquake, flood, wildland/urban interface fires; identify goals, objectives, and *mitigation action items; identify data and data sources needed for the plan; and outline the steps and schedule to submit the plan to the Federal Emergency Management Agency. For more information, contact the Public Works Department at 541-766-6916.*

The purpose of the meeting, as documented by the meeting notice above and by the meeting handouts was to:

1) Review the context of a local hazard mitigation plan – what it is, what is included, why it is important to Corvallis ("Corvallis" in the broadest sense of public entities, private entities, and residents).
2) Review the major hazards posing risk to Corvallis: earthquake, flood, wildland/urban interface fires, etc., drawing on the Benton County Plan.
3) Present first cut Corvallis-specific goals, objectives and action items to provoke thinking and discussion from the stakeholders.
4) Identify Corvallis-specific data needed for the Corvallis plan, and identify the sources of such data.
5) Outline the steps and schedule necessary to submit the Corvallis Hazard Mitigation Plan to the Federal Emergency Management Agency (FEMA) as soon as possible.

The meeting was attended by 12 people, with very active discussions taking up two full hours. The meeting attendance list is included at the end of this chapter.

Meeting #2, September 7, 2007: City Staff and Other Stakeholders
9:00 to 11:00 AM, Madison Building Meeting Room

The second meeting was held the morning after the first meeting, primarily for City of Corvallis staff, but with other community stakeholders also present. The purpose and scope of this meeting was very similar to the first public meeting as documented above, with a more detailed focus on assigning data collection efforts for Corvallis-specific data to specific Corvallis staff.

The meeting was attended by 13 people, with very active discussions taking up two full hours. The meeting attendance list is included at the end of this chapter.

Meeting #3, October 15, 2007: City Staff and Other Stakeholders
9:00 AM to 12:00 Noon, Madison Building Meeting Room

The third meeting focused on refining Corvallis-specific mitigation priorities and action items, for each of the natural hazards considered in the Corvallis Hazard Mitigation Plan.

The meeting was attended by 14 people, with very active discussions taking up three full hours. The meeting attendance list is included at the end of this chapter.

Meeting #4: October 15, 2007: Public Meeting
5:00 to 7:00 PM, Madison Building Meeting Room

This meeting was advertised, as was the first Public Meeting on September 6, but multiple notices in the Corvallis Gazette-Times and by notices on the City of Corvallis website. Draft Hazard Mitigation Plan chapters and maps were posted on the City of Corvallis website to facilitate review and comment by all stakeholders.

The meeting was attended by 5 people and focused mostly on seismic issues, which were of most concern for the audience. The meeting attendance list is included at the end of this chapter.

Corvallis Hazard Mitigation Plan: Attendance Lists for Meetings

Meeting #1 September 6, 2007: Public Meeting

Peggy Pierson, Benton County Emergency Management
Mary King, Benton County Emergency Management
LueAnn Belknap, Linn Benton Food Share
Jim Mitchell, Corvallis Public Works Transportation Division Mgr.
Diane Merten
Roy Emery, Corvallis Fire Chief
Robert Fenner, Corvallis Public Works Buildings and Fleet Supervisor
John Olson , Corvallis Public Works Utility Services Supervisor
Sanja Tripathi
Kevin Harding, Hewlitt Packard
Brian Leeper
Ed Pieterick

Meeting #2, September 7, 2007: City Staff Meeting

Gary Boldizsar, Corvallis Police Chief
Nancy Brewer, Corvallis Finance Director
Jim Mitchell, Corvallis Public Works Transportation Division Mgr
Karen Emery, Corvallis Division Mgr for Parks & Recreation
Ellen Vollmert, Corvallis Assistant City Mgr.
John Olson, Corvallis Public Works Collections and Storm Supervisor
Mike Fegles, Corvallis Development Services Supervisor
Roy Emery, Corvallis Fire Chief
Jerry Smith, Corvallis Public Works Communications and GIS Supervisor
Carolyn Rawles-Heiser, Corvallis Library Director
Steve Rogers, Corvallis Public Works Director
Robert Fenner, Corvallis Public Works Buildings & Fleet Supervisor
Ken Gibb, Corvallis Community Development Director

Meeting #3, October 15, 2007: City Staff and Other Stakeholders

John Olson, Corvallis Public Works Utility Services Supervisor
Al Warde, Corvallis Public Works Utility Services Supervisor
Brian Rigwood, Corvallis Public Works Utility Supervisor
Kevin Harding, Hewlitt Packard
Sanja Tripathi
Nancy Brewer, Corvallis Finance Director
Steve Rogers, Corvallis Public Works Director
Steve Deghetto, Corvallis Parks Maintenance Supervisor
Roy Emery, Corvallis Fire Chief
Dan Henslee, Corvallis Police
Robert Fenner, Corvallis Public Works Buildings and Fleet Supervisor
Jim Mitchell, Corvallis Public Works Transportation Division Mgr.

Mary King, Benton County Emergency Supervisor
Ken Gibb, Corvallis Community Development Director

Meeting #4: October 15, 2007: Public Meeting

Jim Mitchell, Corvallis Public Works Transportation Division Mgr.
Robert Fenner, Corvallis Buildings and Fleet Supervisor
Ellen Volmert, Corvallis Assistant City Manager
Roy Emery, Corvallis Fire Chief
Name, American Legion/Veterans of Foreign Wars

4.0 MISSION STATEMENT, GOALS, OBJECTIVES and ACTION ITEMS

4.1 Overview and

The overall purpose of the Corvallis Hazard Mitigation Plan is to reduce the impacts of future natural or human-caused disasters on Corvallis. That is, the purpose is to make Corvallis more disaster resistant and disaster resilient, by reducing the vulnerability to disasters and enhancing the capability to respond effectively to and recover quickly from future disasters.

Completely eliminating the risk of future disasters in Corvallis is neither technologically possible nor economically feasible. However, substantially reducing the negative impacts of future disasters is achievable with the adoption of this pragmatic Hazard Mitigation Plan and ongoing implementation of risk reducing action items.

Incorporating risk reduction strategies and action items into the city's existing programs and decision making processes will facilitate moving Corvallis toward a safer and more disaster resistant future. This mitigation plan provides the framework and guidance for both short- and long-term proactive steps that can be taken to:

- Protect life safety,
- Reduce property damage,
- Minimize economic losses and disruption, and
- Shorten the recovery period from future disasters.

In addition, the Corvallis Hazard Mitigation Plan is intended to meet or contribute towards meeting various regulatory requirements, including:

1. FEMA's (Federal Emergency Management Agency) mitigation planning requirements so that Corvallis remains eligible for pre- and post-disaster mitigation funding from FEMA,
2. Oregon Emergency Management's mitigation planning evaluation criteria, and
3. Oregon's Goal 7 natural hazard planning guidelines.

Meeting these regulatory requirements is an essential step to facilitate implementation of mitigation measures and in making progress towards achieving the primary mission, goals and objectives summarized below.

The Corvallis Hazard Mitigation Plan is based on a four-step framework that is designed to help focus attention and action on successful mitigation strategies: Mission Statement, Goals, Objectives and Action Items.

- **Mission Statement.** The Mission Statement states the purpose and defines the primary function of the Corvallis Hazard Mitigation Plan. The Mission Statement is an action-oriented summary that answers the question "Why develop a hazard mitigation plan?"
- **Goals.** Goals identify priorities and specify how Corvallis intends to work toward reducing the risks from natural and human-caused hazards. The Goals represent the guiding principles toward which the City's efforts are directed. Goals provide focus for the more specific issues, recommendations and actions addressed in Objectives and Action Items.
- **Objectives.** Each Goal has Objectives which specify the directions, methods, processes, or steps necessary to accomplish the plan's Goals. Objectives lead directly to specific Action Items.
- **Action Items.** Action items are specific well-defined activities or projects that work to reduce risk. That is, the Action Items represent the steps necessary to achieve the Mission Statement, Goals and Objectives.

4.2 Mission Statement

The mission of the Corvallis Hazard Mitigation Plan is to:

> **Proactively facilitate and support city-wide policies, practices, and programs that make Corvallis more disaster resistant and disaster resilient.**

Making Corvallis more disaster resistant and disaster resilient means taking proactive steps and actions to:

- Protect life safety,
- Reduce property damage,
- Minimize economic losses and disruption, and
- Shorten the recovery period from future disasters.

4.3 Mitigation Plan Goals and Objectives

Mitigation plan goals and objectives guide the direction of future policies and activities aimed at reducing risk and preventing loss from disaster events. The goals and objectives listed here serve as guideposts and checklists as agencies, organizations, and individuals begin implementing mitigation action items in Corvallis.

Corvallis's mitigation plan goals and objectives are based broadly on the goals established by the State of Oregon Natural Hazards Mitigation Plan, and are consistent with goals and objectives in the Benton County Hazard Mitigation Plan. However, the specific priorities, emphasis and language are Corvallis's. These goals were developed with extensive input and priority setting by agencies, the mitigation plan steering committee, stakeholders and citizens from Corvallis.

Goal 1: Reduce the Threat to Life Safety

Objectives:

A. Enhance life safety by minimizing the potential for deaths and injuries in future disaster events.

B. Enhance life safety by maximizing the access of emergency services to all parts of the city.

Goal 2: Protect Critical Buildings, Facilities, and Infrastructure

Objective:

A. Implement activities or projects to protect critical facilities and infrastructure in both the public- and private-sectors.

Goal 3: Enhance Emergency and Essential Services

A. Seek opportunities to enhance, protect, and integrate emergency and essential services.

B. Strengthen emergency operations plans and procedures by increasing collaboration and coordination among public agencies, non-profit organizations, business, and industry.

Goal 4: Reduce the Threat to Property

Objectives:

A. Identify buildings and infrastructure at high risk from one or more hazards.

B. Use GIS mapping of hazards and inventory to identify and highlight at risk buildings, facilities and infrastructure.

C. Conduct risk assessments for critical buildings, facilities and infrastructure at high risk to determine cost effective mitigation actions to eliminate or reduce risk.

D. Encourage home- and business-owners to evaluate and mitigate risk to their properties.

Goal 5: Create a Disaster-Resistant and Disaster-Resilient Economy

Objectives:

A. Develop and implement activities to protect economic well-being and vitality while reducing economic hardship in post disaster situations.

B. Reduce insurance losses and repetitive claims for chronic hazard events.

C. Work with State and Federal partners to reduce short-term and long-term recovery and reconstruction costs.

D. Expedite pre-disaster and post-disaster grants and program funding.

Goal 6: Increase Public Awareness, Education, Outreach, and Partnerships

Objectives:

A. Coordinate and collaborate, where possible, risk reduction outreach efforts with both public and private organizations.

B. Develop and implement risk reduction education programs to increase awareness among citizens, local, county, and regional agencies, non-profit organizations, business, and industry.

C. Promote insurance coverage for catastrophic hazards

D. Strengthen communication and coordinate participation in and between public agencies, citizens, nonprofit organizations, business, and industry.

Goal 7: Vigorously Seek Funding Sources for Mitigation Actions

Objectives:

A. Explore both private and public (local, state and federal) funding sources for mitigation actions.

B. Consider financial and tax incentives to encourage private sector mitigation actions in Corvallis.

4.3 Corvallis Hazard Mitigation Plan Action Items

The Mission Statement, Goals and Objectives for Corvallis, as outlined above, are achieved via implementation of specific mitigation action items. Action items may include refinement of policies, data collection to better characterize hazards or risk, education, outreach or partnership-building activities, as well as specific engineering or construction measures to reduce risk from one or more hazards at specific locations within Corvallis.

Action items identified and prioritized during the development of the Corvallis Hazard Mitigation Plan are summarized in the following tables.

Individual action items may address a single hazard (such as flood, earthquake, or windstorm) or they may address two or more hazards concurrently. The first group of action items is for multi-hazard items that address more than one hazard, followed by groups of action items for each of the eight hazards considered in this plan , as addressed in Chapters 6 to 13.

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Multi-Hazard Mitigation Action Items								
Short-Term #1	Establish a formal role for the Corvallis Hazard Mitigation Steering Committee to develop a sustainable process to encourage, implement, monitor, and evaluate citywide mitigation actions	Public Works, Community Development, Fire	Ongoing	X	X	X	X	X
Short-Term #2	Identify and pursue funding opportunities to implement mitigation actions	Public Works, Community Development	Ongoing	X	X	X	X	X
Short-Term #3	Participate in public and private sector partnerships to foster hazard mitigation activities	Public Works, Community Development, City Manager's Office	Ongoing					X
Short-Term #4	Develop separate detailed inventories of at-risk public and private buildings and infrastructure and prioritize mitigation actions	Public Works, Community Development	1-2 Years	X	X	X	X	
Long-Term #1	Develop education programs aimed at mitigating the risk posed by hazards	Emergency Management, Capital Planning and Development	Ongoing					X
Long-Term #2	Integrate the Mitigation Plan findings into planning and regulatory documents and programs as appropriate	Public Works, Community Development, Fire	Ongoing	X	X	X	X	X
Long-Term #3	Integrate hazard, vulnerability and risk Mitigation Plan findings into enhanced Emergency Operations planning.	Public Works, Fire, Police	Ongoing	X	X	X	X	X
Long-Term #4	Update website to include mitigation activities, opportunities, and success stories	Emergency Management, Planning, Information Services	Ongoing					X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Flood Mitigation Action Items: Within FEMA-Mapped Floodplains								
Short-Term #1	Inventory critical facilities (if any) within mapped floodplains or other high flood risk areas and identify mitigation options if such facilities are identified.	Public Works, Community Development	Ongoing	X	X	X	X	
Short-Term #2	Survey elevation data for buildings within mapped floodplains, evaluate flood risk quantitatively, and explore mitigation options with property owners.	Public Works, Community Development	Ongoing	X		X	X	X
Flood Mitigation Action Items: Outside of FEMA-Mapped Floodplains								
Short-Term #1	Complete the inventory of locations in Corvallis subject to frequent storm water flooding	Public Works, Community Development	Ongoing	X	X	X	X	X
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works	Ongoing	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Winter Storms Mitigation Action Items								
Short-Term #1	Inventory and remove hazardous trees in City right of way	Public Works, Parks	Ongoing	X	X	X	X	
Short-Term #2	Complete an inventory of locations in Corvallis subject to frequent storm water flooding or repetitive tree fall problems from wind/ice	Public Works, Parks	Ongoing	X	X	X	X	X
Short-Term #3	Enhance tree trimming efforts especially for transmission lines and trunk distribution lines and consider tree trimming ordinance	Public Works, private utilities	Ongoing	X	X	X	X	X
Short-Term #4	Encourage property owners to trim trees near service drops to individual customers	Public Works	Ongoing	X		X	X	X
Short-Term #5	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	Public Works, Benton County Emergency Management, Community Development and private owners	1-2 Years	X	X			X
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works	Ongoing	X	X	X	X	X
Long-Term #2	Consider upgrading electric lines and poles to improve wind/ice loading, undergrounding critical lines, and adding interconnect switches to allow alternative feed paths and disconnect switches to minimize outage areas	Private utilities	5 Years	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Landslide Mitigation Action Items								
Short-Term #1	Complete a detailed inventory of locations where critical facilities and infrastructure are subject to landslides	Public Works, Community Development	1-5 Years	X	X	X	X	X
Long-Term #1	Consider landslide mitigation actions for slides seriously threatening critical facilities, other buildings or infrastructure	Public Works, Community Development	5 Years	X	X	X	X	X
Long-Term #2	Limit future development in high landslide potential areas	Community Development	Ongoing	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Wildland/Urban Interface Fire Mitigation Action Items								
Short-Term #1	Identify specific parts of Corvallis at high risk for urban/wildland interface fires because of fuel loading, topography and prevailing construction practices	Fire	1-2 Years	X	X	X	X	X
Short-Term #2	Identify evacuation routes and procedures for high risk areas and educate the public	Fire	Ongoing	X	X	X		X
Short-Term #3	Develop Corvallis Wildfire Protection Plan	Fire	1-2 Years	X	X	X	X	X
Long-Term #1	Encourage fire-safe construction practices for existing and new construction in high risk areas	Fire, Community Development	Ongoing	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Earthquake Mitigation Action Items								
Short-Term #1	Complete seismic retrofits for City Hall and the Marys River bridge crossings for water transmission lines, both of which are critical facilities for Corvallis, urgently requiring retrofit	Public Works	1-2 Years	X	X	X	X	
Short-Term #2	Complete seismic retrofit for North Hill 1st Level East Reservoir	Public Works	1-2 Years	X	X	X	X	
Short-Term #3	Complete seismic vulnerability analyses of critical facilities with significant seismic vulnerabilities, including fire, police, medical, and other emergency communication/response facilities	Public Works, community partners	1-5 Years	X	X	X	X	X
Short-Term #4	Complete seismic vulnerability analyses for lifeline utility and transportation systems, including: water, wastewater, natural gas, electric power, telecommunications and bridges	Public Works, ODOT, private utilities	1-5 Years	X	X	X	X	X
Short-Term #5	Support/steer a project using outside support/consultants to complete an inventory of public, commercial and residential buildings that may be particularly vulnerable to earthquake damage	Public Works, Community Development	2-5 years	X	X	X	X	X
Short-Term #6	Educate homeowners about structural and non-structural retrofitting of vulnerable homes and encourage retrofit	Public Works, Community Development	Ongoing	X		X	X	X
Long-Term #1	Obtain funding and retrofit critical public buildings and lifeline utility and transportation facilities with significant seismic vulnerabilities	Public Works, ODOT, private utilities	10 years	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Volcanic Hazards Mitigation Action Items								
Short-Term #1	Update public emergency notification procedures for ash fall events	Public Works, Fire, Police, City Manager's Office	1-2 Years	X	X			X
Short-Term #2	Update emergency response planning for ash fall events	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Evaluate capability of water treatment plants to deal with high turbidity from ash falls and upgrade treatment facilities and emergency response plans to deal with ash falls	Public Works	1-2 Years	X	X	X	X	X
Short-Term #4	Prepare/pre-script public messages about protection from and disposing of volcanic ash	Public Works, Fire, Police						X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Dam Safety Mitigation Action Items								
Short-Term #1	Prepare high resolution maps of the dam failure inundation areas and update emergency response plans, including public notification and evacuation routes.	Public Works, City Manager's Office, Benton County Emergency Management	1-2 Years	X	X			X
Short-Term #2	Encourage the Corps of Engineers to undertake a though seismic risk evaluations for dams upstream of Corvallis and to make seismic and/or flood improvements as necessary	Benton County Emergency Management	Ongoing	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Utility and Transportation System Disruption Mitigation Action Items								
Short-Term #1	Educate and encourage residents to maintain several days of emergency supplies for power outages or road closures	Public Works, Fire, Police, Benton County Emergency Management	Ongoing	X	X			X
Short-Term #2	Review and update emergency response plans for disruptions of utilities or roads	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #4	Write procedures for maintaining water supply during extended power outages	Public Works	1-2 years		X		X	

5.0 PLAN ADOPTION, MAINTENANCE and IMPLEMENTATION

5.1 Overview

For a hazard mitigation plan to be effective, it has to be implemented gradually over time, as resources become available, continually evaluated and periodically updated. Only through developing a system which routinely incorporates logical thinking about hazards and cost-effective mitigation into ongoing public- and private-sector decision making will the mitigation action items in this document be accomplished effectively. The following sections depict how Corvallis has adopted and will implement and maintain the vitality of the Corvallis Hazard Mitigation Plan.

5.2 Plan Adoption

FEMA approval of the Plan was received on **….TBD…..** FEMA approval means that Corvallis's Hazard Mitigation Plan meets national standards and that the City will continue to be eligible for hazard mitigation funding from FEMA's Hazard Mitigation Grant Program, the Pre-Disaster Mitigation Program and the Flood Mitigation Assistance Program.

The Corvallis Hazard Mitigation Plan was adopted by the Corvallis City Council on **….TBD……**, making this the effective date of the plan.

Corvallis has the necessary human resources to ensure the Plan continues to be an active planning document. City staff have been active in the preparation of the plan, and have gained an understating of the process and the desire to integrate the plan into the Corvallis Comprehensive Plan Land Use Plan. In 2006 the City of Corvallis was included in the Benton County's Hazard Mitigation Plan. The City of Corvallis is required by the Oregon Director of Emergency Services to develop a Multi- Hazard Plan for the City of Corvallis. The Plan will provide the City, private business and the public information on how to minimize potential hazard risks in the City. The city has experienced several disasters, flooding, earthquakes of minimal size and winter storms. Through this linkage, the plan will be kept active and be an ongoing working document.

Recent major high-profile disasters, including hurricanes on the Gulf Coast and the earthquake/tsunami in Indonesia, have raised public awareness about disasters. These events, and the growing understanding of the threats posed to Corvallis from various national and anthropogenic hazards, have kept the interest in hazard mitigation planning and implementation alive at the City Council level, at the city staff level, among private sector entities and among the citizens of Corvallis.

5.3 Implementation

Coordinating Body

The Corvallis Hazard Mitigation Planning Committee will ensure the successful implementation of the plan. Members of Community Development, Public Works, Fire, Police, Parks and Recreation, Library, Finance, and City Council will coordinate the implementation of the plan and be responsible for periodically monitoring, evaluating and updating the plan. The city will continue to provide staffing to accomplish this. Consistent staffing allows for well-organized meetings and will ensure that the right people are involved at the meetings. The existing active interest in mitigation and emergency planning that exists within Corvallis will help to ensure the successful implementation of the plan.

Integration of the Hazard Mitigation Plan into Ongoing Programs, Policies, and Practices

The mission statement, objectives, goals and action items outlined in Chapter 4 of the Corvallis Hazard Mitigation Plan provide a strong framework and guidance for the identified mitigation priorities for Corvallis. However, the Mitigation Plan is a guidance document, not a regulatory document; and thus implementation of the objectives, goals and action items can be accomplished most effectively by fully integrating this guidance into ongoing city-wide programs, policies and practices.

The City of Corvallis government structure includes a mayor and city council as well as numerous departments, boards and commissions, as outline in Figure 5.1 on the following page. Many, indeed most, of the governmental entities have functions which overlap with awareness of or education and outreach about hazards posing risk to Corvallis and and/or to implementation of hazard mitigation actions in either/or the public and private sectors.

The City of Corvallis currently addresses statewide planning goals and legislative requirements through its comprehensive land use plan, capital improvement plans, and implementation of building codes. The Hazard Mitigation Plan provides a series of action items – many of which are closely related to the objectives of these existing City programs. To the extent possible, Corvallis will work to incorporate the recommended mitigation action items into existing programs and procedures. These action items will help the City address various other statewide requirements, such as land-use planning Goal 7, which was developed to protect life and property from natural disasters and hazards through planning strategies that restrict development in areas of known hazards.

Figure 5.1
Structure of Corvallis Government

Mayor

City Council

Departments and Divisions:

- City Manager's Office
- Finance
- Parks and Recreation
- Public Works
  - Administration
  - Engineering
  - Transportation
  - Utilities
- Fire
- Police
- Community Development
  - Development Services
  - Planning
  - Housing
  - Administration
- Corvallis-Benton County Public Library

Boards, Commissions and Committees[1]:

- Airport Commission
- Budget Commission
- Capital Improvement Program Commission
- Citizens Advisory Commission on Civic Beautification and Urban Forestry
- Citizens Advisory Commission on Transit
- Committee for Citizen Involvement
- Core Services Committee
- Corvallis-Benton County Library Board
- Downtown and Economic Vitality Plans Implementation Commission
- Historic Resources Commission
- Housing and Community Development Commission
- Land Development Hearings Board
- Open Space Advisory Board
- Parks, Natural Areas, and Recreation Board
- Planning Commission
- Riverfront Commission
- Watershed Management Advisory Commission

[1] related to hazards and planning

Goal 7 requires that local governments base development plans on inventories of known areas of natural disasters and hazards and that the intensity of development should be limited by the degree to which the natural hazard occurs within the areas of proposed development. The City's Planning Department will be responsible for land use reviews, and assuring compliance with the zoning codes. The department will be able to use the resources and actions identified in this plan as an avenue to update statewide land-use planning Goal 7: Natural Hazards element of the City's comprehensive plan and to integrate mitigation into existing zoning and planning documents when applicable.

Additionally, the City is also responsible for issuing building permits and promoting compliance with city-adopted construction codes. After the adoption of this Hazard Mitigation Plan, the Development Services Division will review the city's adopted building code to ensure it is sufficient to support its goals and objectives. In addition, the Development Services Division will promote safe building practices in an effort to have structures more resistant to the impacts of all hazards.

This integration of the Plan with ongoing activities will continue for other plans and projects within the City. As development plans come into the Planning Division, reviewers will need to keep in mind potential hazard mitigation actions that may need to be implemented. The adopted building codes for the City include many standards that mitigate potential hazard damage. The City stays current in adoption of upgraded codes, ensuring that the new construction activities will meet the highest standard available for hazards such as floods and seismic.

Capital improvement planning that occurs in the future will also contribute to the goals in the Hazard Mitigation Plan. Various City Departments, including Finance, Public Works, Community Development and Parks and Recreation, develop Capital Improvement Programs (CIPs) and review them on an annual basis. The Hazard Mitigation Planning Committee will work with these departments to identify any relevant action items from Hazard Mitigation Plan and work to incorporate such actions into the appropriate sections of the City's CIP's.

Within six months of formal adoption of the City's Hazard Mitigation Plan, the procedures listed above will be incorporated into the process of existing planning mechanisms at the City level. The meetings of the Hazard Mitigation Planning Committee will provide an opportunity for committee members to report back on the progress made on the integration of mitigation planning elements into City planning documents, policies, procedures, and programs.

Cost Effectiveness of Mitigation Projects

As Corvallis and other entities, public or private, within the City consider whether or not to undertake specific mitigation projects or evaluate how to decide between competing mitigation projects, they must answer questions that don't always have obvious answers, such as:

What is the nature of the hazard problem?

How frequent and how severe are hazard events?

Do we want to undertake mitigation measures?

What mitigation measures are feasible, appropriate, and affordable?

How do we prioritize between competing mitigation projects?

Are our mitigation projects likely to be eligible for FEMA funding?

Corvallis recognizes that benefit-cost analysis is a powerful tool that can help communities provide solid, defensible answers to these difficult socio-political-economic-engineering questions. Benefit-cost analysis is <u>required</u> for all FEMA-funded mitigation projects, under both pre-disaster and post-disaster mitigation programs. Thus, communities seeking FEMA funding must understand benefit-cost analysis. However, regardless of whether or not FEMA funding is involved, benefit-cost analysis provides a sound basis for evaluating and prioritizing possible mitigation projects for any natural hazard. Thus, Corvallis will use benefit-cost analysis and related economic tools, such as cost-effectiveness evaluation, to the extent practicable in prioritizing and implementing mitigation actions. See the Benefit-Cost Appendix at the end of the Corvallis Hazard Mitigation Plan for details on the benefit-cost analysis process.

5.4 Plan Maintenance

Periodic Monitoring, Evaluation and Updating

The Corvallis Hazard Mitigation Plan will be monitored and evaluated annually and updated at least every five years. As the community gradually implements the action items within the Plan, remaining action items may evolve or priorities may change. The hazards that exist in Corvallis will continue to exist, but the conditions within the community, such as the population and development patterns, will undoubtedly continue to change. As such changes occur gradually over time, the Plan will be regularly monitored, evaluated, and updated to ensure that it remains up-to-date and retains its vitality and relevance.

Local, state and federal agencies will conduct or refine studies that may lead to new or better information on specific hazards. For example, flood plan maps are periodically updated and new studies may better define landslide or debris flow areas or areas subject to liquefaction during earthquakes. The new information will need to be incorporated not only into the Hazard Mitigation Plan but also into other documents, such as the Comprehensive Plan.

Changes in the priorities of citizens of Corvallis may also affect the effectiveness of the Plan. Community values are regularly monitored through the Comprehensive Plan update process. As the Comprehensive Plan is implemented and updated, the Hazard Mitigation Plan will be reviewed as well.

The Hazard Mitigation Planning Committee will meet at least annually to review and evaluate the Plan. This will be the opportunity to incorporate new information into the Plan and remove outdated items and completed actions. This will also be the time to recognize the success of the community in implementation of action items. All revisions of the Plan will be taken to the City Council for formal acknowledgement as part of Corvallis's Plan maintenance and implementation program. The Hazard Mitigation Planning Committee will also have lead responsibility for the formal updates of the plan every five years.

Continued Public Involvement and Participation

Implementation of the mitigation actions identified in the Plan must engage the community. The participation that led to the Plan was the result of existing community networks, and these networks will continue to participate as the community-wide mitigation activities identified in the plan are implemented. Some projects can be done at the volunteer level, and others will require technical expertise. The stakeholders in the planning process will become project partners, as needed, on specific items.

There are many organizations within the City that have common interests and concerns, including hazard mitigation. Organizations such as Benton County, Good Samaritan Hospital, Benton County Emergency Services, Hewitt Packard, Corvallis Chamber Commerce and various other large and small businesses will be important partners in the implementation of the Plan over time. Successful completion of high priority mitigation action items will require ongoing project planning with active participation from all stakeholders.

Corvallis has a proven history of involving, and continues to involve, multiple partners in planning and mitigation work. These partnerships with local, state, and federal partners have resulted in comprehensive plans and projects that could not have been completed by any agency alone. This cooperation is also demonstrated by the broad-based makeup of the Hazard Mitigation Planning Committee.

Corvallis is dedicated to involving the public directly in the ongoing monitoring, evaluating and updating of the Hazard Mitigation Plan. Copies of the Plan will be posted on the City's website, which will also contain an email address and phone number to which people can direct their comments and concerns about hazard mitigation issues and priorities.

Public meetings will also be held after each annual evaluation or when deemed necessary by the Hazard Mitigation Planning Committee, The meetings will provide the public a forum at which they can express their concerns, opinions, or ideas about the Plan. The representatives from Public Works, Community Development and Fire Department will maintain public involvement and advertise for the public meetings through existing community organizations such as. The City's represenatives will be responsible for using City resources to publicize the annual public meetings and maintain public involvement, to include the City's website, informational posters, City newsletter, email distribution lists, and local newspapers.

STAPLE/E Approach

Corvallis will also use the STAPLE/E methodology developed by the State of Oregon: "State of Oregon's Local Natural Hazard Mitigation Plan: An Evaluation Process". Using STAPLE/E criteria, mitigation activities can be evaluated quickly in a systematic fashion based on the Social, Technical, Administrative, Political, Legal, Economic, and Environmental (STAPLE/E) considerations and opportunities for implementing particular mitigation action items in the City. The STAPLE/E approach is helpful for doing a quick analysis of mitigation projects. Most projects that seek federal funding and others often require more detailed Benefit/Cost Analyses.

The following are suggestions for how to examine each aspect of the STAPLE/E Approach.

Social: Planning Division staff, local non-profit organizations, or local planning groups can help answer these questions.

- Is the proposed action socially acceptable to the community?
- Are there equity issues involved that would mean that one segment of the community is treated unfairly? (Or one segment more favorably?)
- Will the action cause social disruption?

Technical: Public Works, Engineering and Development services Division staff can help answer these questions.

- Will the proposed action work?
- Will it create more problems than it solves?
- Does it solve a problem or only a symptom?
- Is it the most useful action in light of other goals?

Administrative: Elected officials can help answer these questions.

- Is the action implementable?
- Is there someone to coordinate and lead the effort?
- Is there sufficient funding, staff, and technical support available?
- Are there ongoing administrative requirements that need to be met?

Political: City Council members and planning officials can help answer these questions.

- Is the action politically acceptable?
- Is there public support both to implement and to maintain the project?

Legal: Include legal counsel, land use planners, and risk managers in this discussion.

- Who is authorized to implement the proposed action?
- Is there a clear legal basis or precedent for this activity?
- Are there legal side effects? Could the activity be construed as a taking?
- Is the proposed action allowed by the comprehensive plan, or must the comprehensive plan be amended to allow the proposed action?
- Will the City be liable for action or lack of action?
- Will the activity be challenged?

Economic: City Economic Development staff, civil engineers, Building Department, and the County Assessment and Tax Assessor Office can help answer these questions.

- What are the costs and benefits of this action?
- Do the benefits exceed the costs?
- Are initial, maintenance, and administrative costs taken into account?
- Has funding been secured for the proposed action? If not, what are the potential funding sources (public, non-profit, and private)?
- How will this action affect the fiscal capability of the City?
- What burden will this action place on the tax base or economy?
- What are the budget and revenue effects of this activity?
- Does the action contribute to other goals, such as capital improvements or economic development?
- What benefits will the action provide? (This can include dollar amount of damages prevented, number of homes protected, credit under the CRS, potential for funding under the HMGP or the FMA program, etc.)

Environmental: Environmental groups, land use planners, public works, and natural resource managers can help answer these questions.

- How will the action impact the environment?
- Will the action need environmental regulatory approvals?
- Will it meet local and state regulatory requirements?
- Are endangered or threatened species likely to be affected?

6.0 FLOOD HAZARDS

Corvallis is subject to flooding from several different types of flood sources, including:

1) over bank flooding from the Willamette River and the Marys River,
2) over bank flooding from numerous smaller creeks which are tributaries to the above rivers, and
3) local storm water drainage flooding.

Flooding on streams and rivers within Corvallis generally results from large winter storms from the Pacific, which often result in simultaneous flooding on many rivers and streams in an affected area. However, because of geographic variations in rainfall amounts and differences in drainage areas, slopes, and other watershed characteristics, the severity of flooding in any given rainfall event often varies significantly from stream to stream and location to location. Historically, most major floods in Corvallis have occurred in the months of December, January and February, although flooding in other months is certainly possible.

6.1 Historical Floods in Corvallis

Historically, flooding has occurred in Corvallis throughout the recorded history of the area, ever since the first European settlers arrived in the area in the mid-1800s.

The FEMA Flood Insurance Studies for Corvallis (August 5, 1986) and for Albany (July 7, 1999) have a brief history of major historical floods in Corvallis. Major floods on the Willamette River occurred in 1861, 1890, 1901, 1909, 1923, 1964, 1972, and 1974. Lesser floods occurred in 1943, 1945, 1946, 1948, 1953, 1961, and 1977.

The 1861 was the greatest flood event along the Willamette. Without flood control measures, the 1964 flood would have been the greatest flood of the 20th century; however, flood control measures greatly reduced the peak flood discharge and flood elevations and thereby greatly reduced areas affected by the flood. Even so, extensive flooding occurred in North Albany, South Corvallis and other areas along the river.

Flooding potential along the Willamette River has been substantially reduced by the 11 major flood control reservoirs on the Willamette with about 1.7 million acre feet of flood control storage. Despite the reduction in flood potential from construction of the dams, portions of Corvallis continue to have a significant level of flood risk from the major rivers as well as from the numerous streams running through Corvallis. The dams on the Willamette have not reduced flood risk on the Marys River or on the smaller streams.

6.2 The 1996 Flood

The most recent significant flood event in Corvallis occurred in February 1996. Unusually heavy rains over the four-day period from February 5th to February 8th 1996 resulted in significant flooding on numerous rivers and streams throughout western Oregon. In Corvallis, flood impacts continued for several days after the end of heavy rainfall.

The following narratives about the 1996 flood are from: T**he Cascades West Region of Oregon and the February Flood of 1996: A Regional Flood Recovery Plan for Benton, Lane, Lincoln, and Linn Counties** (November 1996).

The already saturated ground caused the rain to flow into the creeks and soon overflow their banks in the north and south ends of Corvallis. 147 people were rescued by rubber raft in north Corvallis on Tuesday Feb 6. The situation continued to worsen throughout the county, but specifically in the City of Corvallis. The Marys River (Philomath/Corvallis) and overtopped their banks and isolated homes and motorists, prompting more rescues throughout Tuesday and Wednesday. The Willamette River in Corvallis came within 6 inches of flood stage, but did not flood. However, it affected the Marys River, which could not feed into the Willamette and discharge their flood waters.

Shelters were established in Corvallis. Dixon, Oak and Squaw Creeks overflowed their banks, and storm runoff flooded many streets. The Marys River and Mill Race also overflowed their banks and affected south Corvallis. The sewer and storm drains were over capacity and sewage contaminated much of the water. The main north-street through town was closed at 8 pm, after many vehicles were stalled in the high water. Drainage ditches overflowed onto the highway and flooded homes and businesses in south Corvallis. Sandbagging attempts kept some of the water at bay, but not all of it. On Thursday morning, south Corvallis was cut off from the rest of the city. As the day worsened, the bridges over the Willamette (Hwy 34/20) were closed. The waters continued to back up into basements and began to flood key facilities (Pacific Power control station and Corvallis Law Enforcement Building). On Friday, the waters crested and shuttles were used to bring residents to and from south Corvallis. Cost estimates of the flood for the City of Corvallis totaled $465,091.

6.3 Flood Hazards and Flood Risk: Within Mapped Floodplains

6.3.1 Overview

FEMA Floodplain Maps show areas where the Federal Emergency Management Agency (FEMA) has determined that a flood hazard exists. Nearly all communities in Corvallis have at least some portion of the mapped hazard areas, or floodplains, within their jurisdiction. The FEMA-mapped floodplains in Corvallis are summarized below in Table 6.1 from the FEMA Flood Insurance Studies (FIS) for Corvallis. Each FIS includes a summary of historical flood experience along with quantitative data on stream discharges (volume of water flowing in the river or stream) and flood elevations.

For the most part, the FEMA-mapped floodplains in Corvallis include only areas along the larger rivers and streams, which also have significant concentrations of development and population. Throughout Corvallis, there are many other localized areas that have significant flood risk but are not included in the FEMA mapped floodplains because the streams are too small and/or because the flood-prone population is too small. Furthermore, there are additional localities within Corvallis were flooding occurs because of local storm water drainage, rather than overbank flooding from rivers and streams. Such, local storm water drainage areas are not mapped by FEMA. Thus, evaluation of flood hazards in Corvallis must consider not only the FEMA-mapped floodplains, but also the other localized areas of repetitive flooding or high flood risk outside of the mapped floodplains (see Section 6.4).

Table 6.1
FEMA-Mapped Floodplains in Corvallis

Flood Insurance Study	Flood Sources with Detailed Studies[1]	Flood Sources with Approximate Studies[1]
Corvallis (July 2, 1984)		
	Willamette River	Sequoia Ditch
	Marys River	North Fork Squaw Creek[2]
	Millrace and Millrace Overflow	South Fork Squaw Creek[2]
	Steward Slough	Oak Creek
	Dixon Creek	North Fork Dixon Creek
	South Fork Dixon Creek	South Fork Dixon Creek
	Squaw Creek[2]	Unnamed tributary to Dixon Creek
	South Fork Squaw Creek	
	Oak Creek	

[1] Detailed and approximate studies include specific portions of the reaches along these flood sources as listed in each Flood Insurance Study.

[2] Subsequent to the FEMA Flood Insurance Study, Squaw Creek has been renamed Dunawi Creek.

FEMA Flood Insurance Rate Maps (FIRMs) for the above mapped areas show flood plain details such as the 100-year and 500-year flood plain boundaries. For Corvallis, there are six FIRMs (effective date January 3, 1985), which are the most recent maps.

FEMA-mapped floodplains in Corvallis include:

1) a broad swath of the lowlands along the reach of the Willamette River, and
2) bands along the smaller FEMA-mapped rivers and creeks in Corvallis.

A synopsis of these FEMA mapped flood-prone areas in Corvallis is given below in Table 6.2.

Table 6.2
Synopsis of FEMA-Mapped Flood-Prone Areas in Corvallis

FIRM Maps	Flood Source	Geographic Area
Corvallis (6 FIRMs)		
	Willamette River	band along the west bank of the river, extending to or near 1st Street, with wider flood-prone areas in the vicinity of Marys River and the Millrace and in the vicinity of Dixon Creek
	Dixon Creek, including North and South Forks	Narrow bands along these creeks, extending to a wider band downtown in vicinity of Polk and Buchanan to the Willamette River
	Sequoia Ditch	Area in vicinity of Sycamore Ave., Sequoia Ave. and 9th St. and area along Circle Blvd, east of the railroad tracks
	Steward Slew	area in northeast Corvallis west of Canterbury, south to Plymouth Circle and Sherwood Way and west to the railroad tracks
	Oak Creek	Area north of Highway 20/34 west of 27th Street
	Marys River	Areas north and south of Highway 20/34
	Squaw Creek, including North and South Forks[1]	narrow bands along these creeks, extending to the Marys River
	Mill Race and Marys River	Area between Marys River and Millrace, east of the railroad tracks, south to vicinity of Tunison Ave.

[1] Subsequent to the FEMA Flood Insurance Study, Squaw Creek has been renamed Dunawi Creek.

An important caveat in interpreting the FEMA floodplain maps (and the synopsis above) is that there are additional areas of Corvallis, not within the mapped floodplains, that are also at flood risk. These flood-prone areas are discussed later in this chapter (Section 6.4).

Full details of the FEMA-mapped flood plains in Corvallis are shown on the six FIRMs referenced above. The following maps give an overview of these mapped flood-prone areas. Figure 6.1 shows a city-wide overview of floodplains while Figures 6.2 through 6.6 show more localized areas. For full details of the FEMA-mapped floodplains in Corvallis see the FEMA FIRM maps.

From an overlay of Corvallis GIS data with the FEMA floodplain maps, it has been determined that there are 1679 buildings in Corvallis whose footprint is within the mapped 100-year floodplain and an additional 1439 buildings whose footprint is above the 100-year floodplain, but within the 500-year floodplain. Thus, in total, there are over 3100 buildings in Corvallis that may be at significant flood risk. These building data include a few greenhouses, miscellaneous structures, and buildings under construction.

These data do not consider the elevation of the structures. Many of these structures may be within the floodplain, but with first floor elevations above the flood levels. More detailed quantitative flood risk assessment for these buildings requires elevation data.

Figure 6.1
FEMA Mapped Floodplains in Corvallis

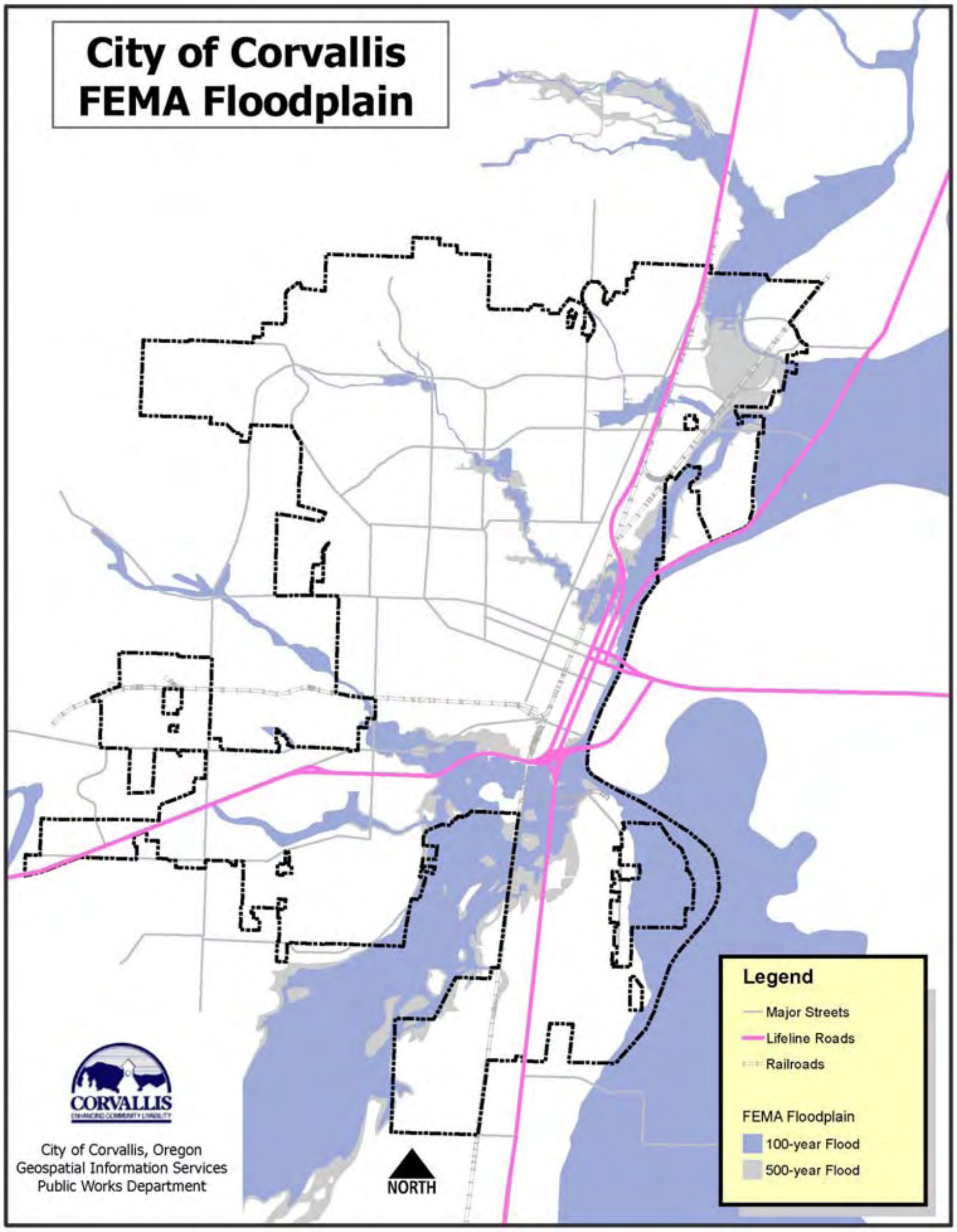


Figure 6.2
Downtown Corvallis FEMA Floodplain
(with Critical Facilities also shown)

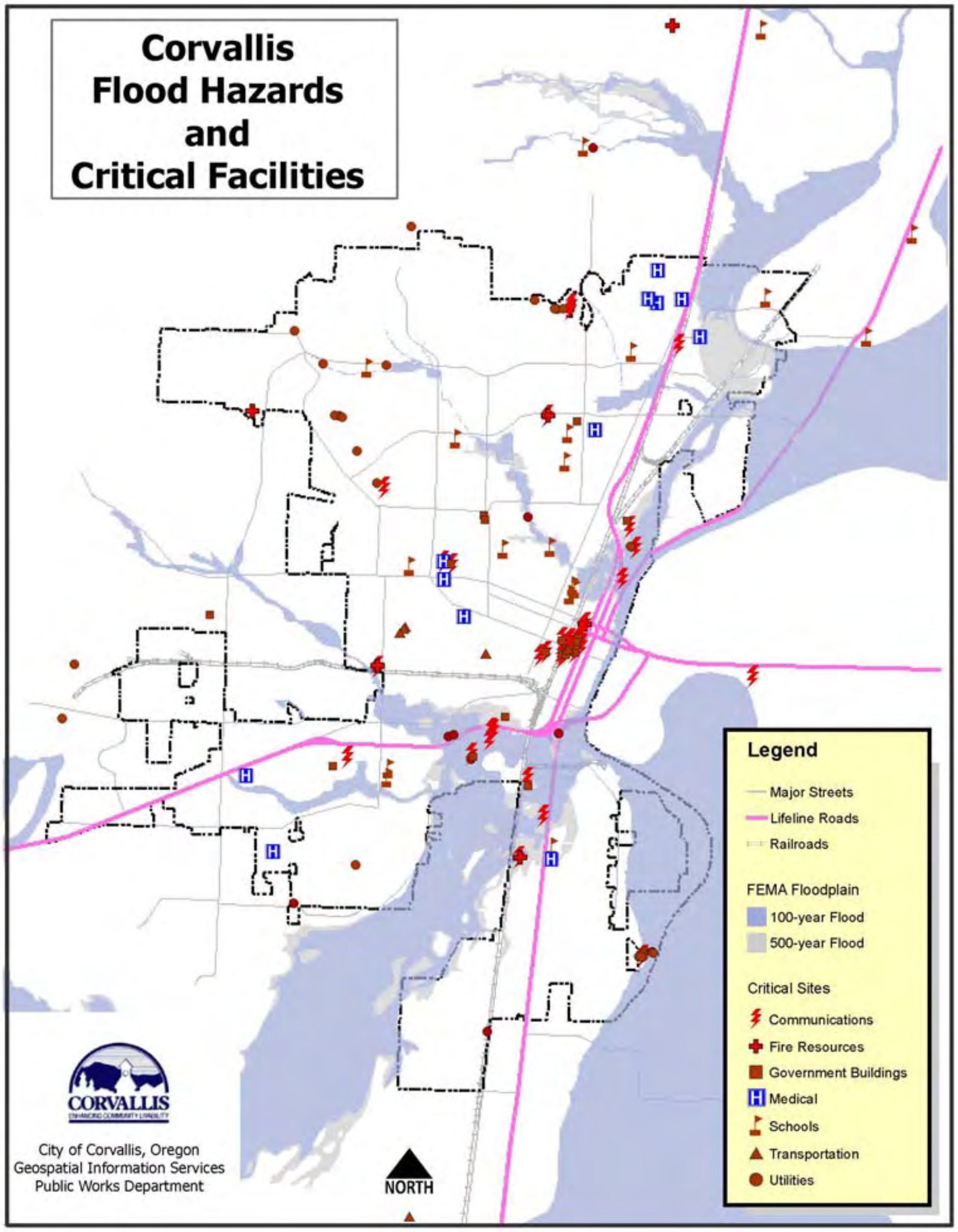


Figure 6.3
Central Downtown Area with FEMA Floodplain and 1996 Flood Boundaries

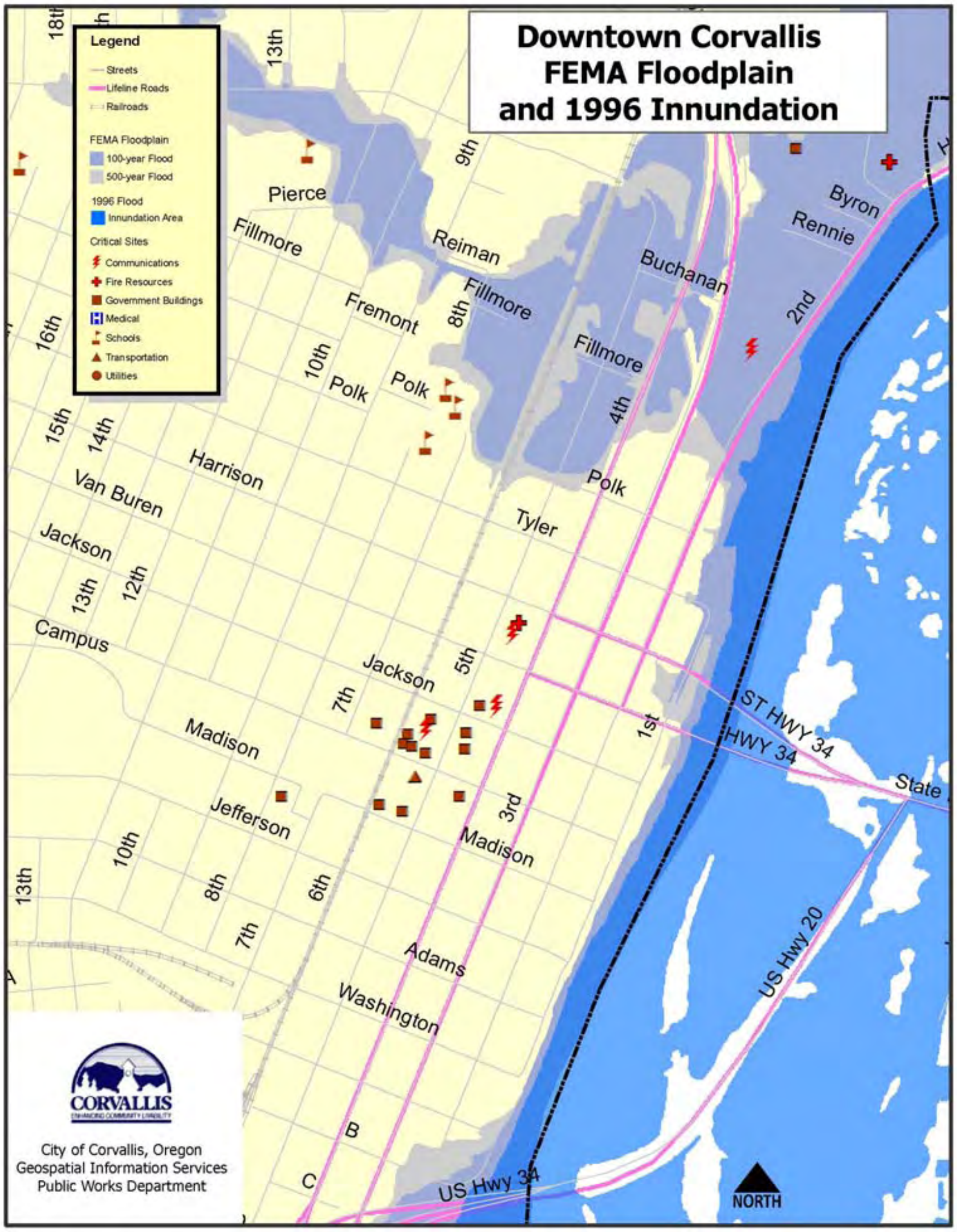


Figure 6.4
North Corvallis FEMA Floodplain

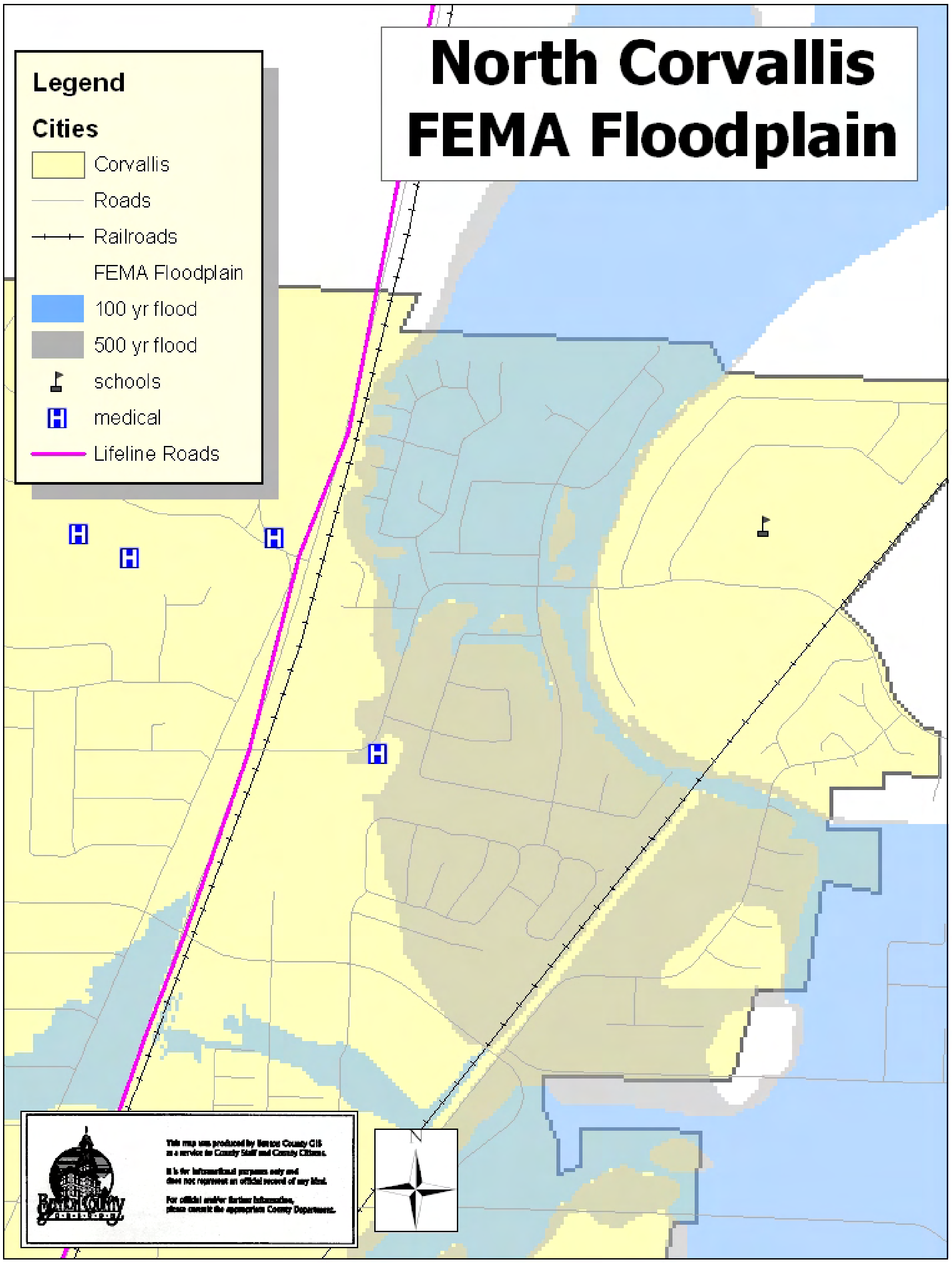


Figure 6.5
Dixon Creek FEMA Floodplain

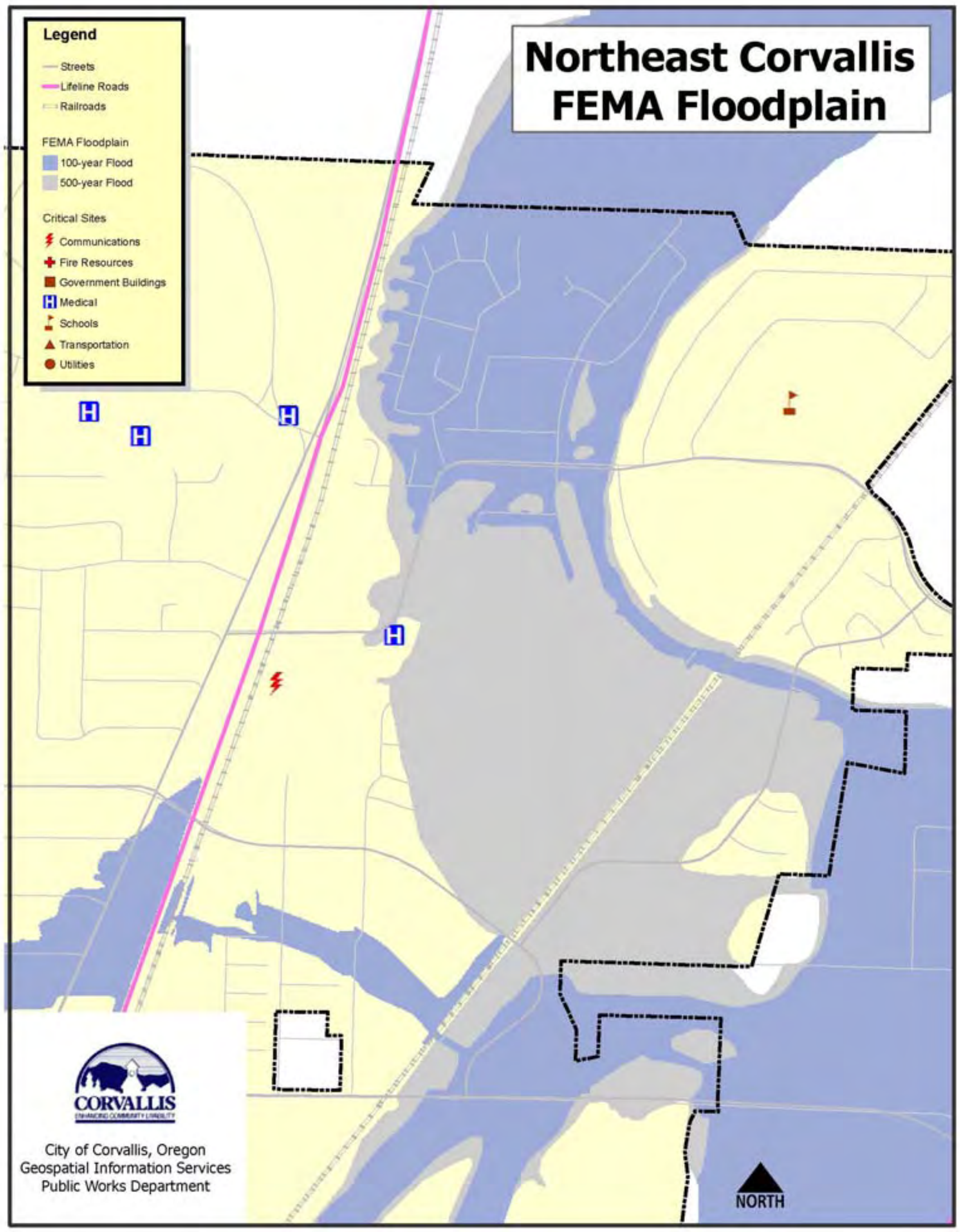
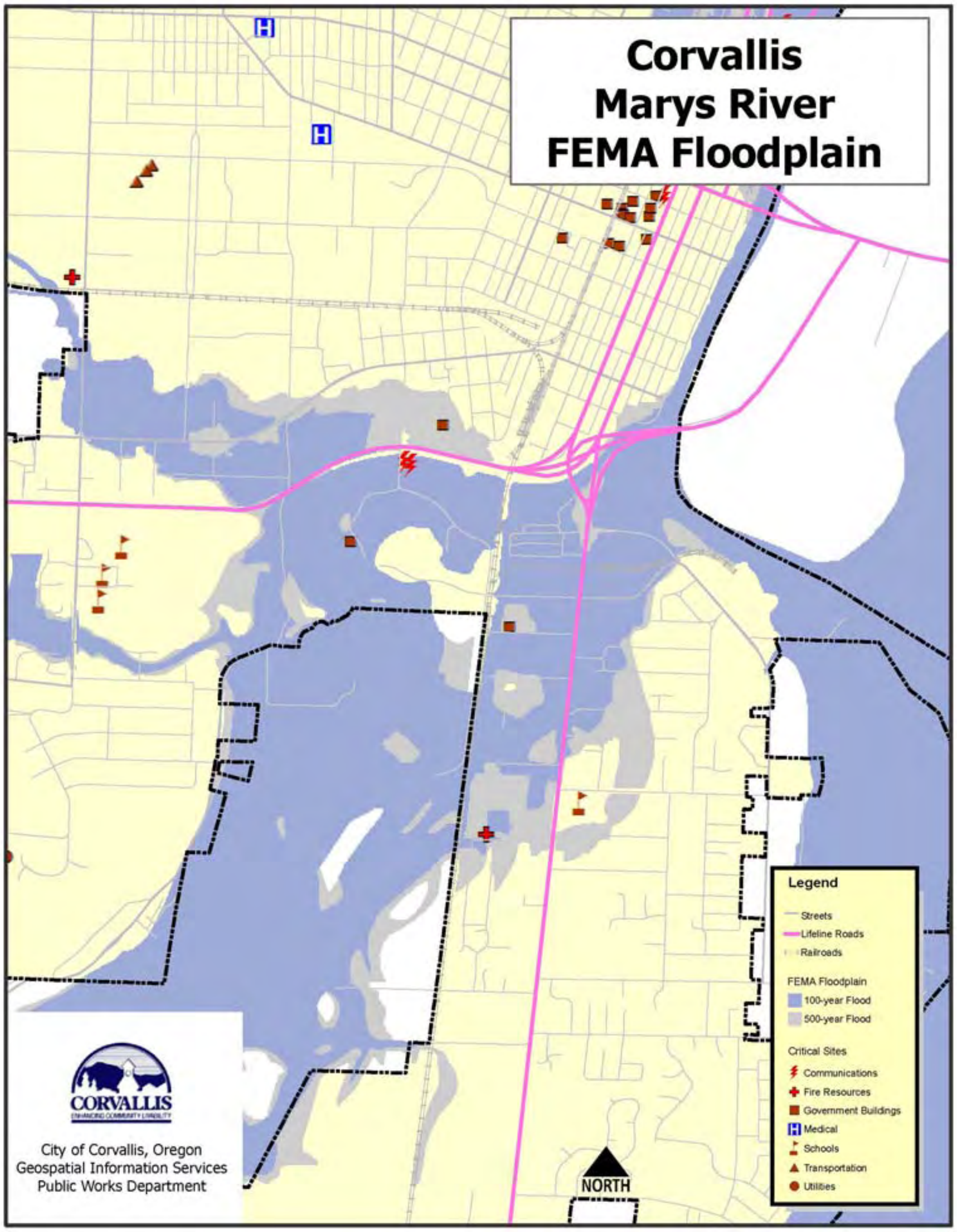


Figure 6.6
Marys River FEMA Floodplain



6.3.2 Flood Hazard Data

For mapped floodplain areas, the flood hazard data included in the Flood Insurance Study (FIS) allow quantitative calculation of the frequency and severity of flooding for any property within the floodplain. Such calculations are very important for mitigation planning, because they allow the level of flood risk for any structure to be evaluated quantitatively. The example below illustrates these concepts.

For example, for the Willamette River between the westbound and eastbound Highway 34 Bridges, the 1999 FEMA FIS for Albany includes the following data:

Table 6.3
Flood Hazard Data
Willamette River at Highway 34

Flood Frequency (years)	Discharge (cfs)	Elevation (feet)
10	107,000	214.2
50	153,000	218.3
100	177,000	219.8
500	246,000	222.9

The stream discharge data shown above are from the table on page 12 of the FIS for Corvallis, for the Willamette River stream gage at Highway 34 Stream discharge means the volume of water flowing down the river and is typically measured in cubic feet of water per second (cfs). The flood elevation data are from the Flood Profile Graph 01P in the FIS. Flood elevation data vary with location along the reach of the river and thus separate flood elevation data points must be read from the graph at each location along the river. The flood elevation data above for the Willamette River are at the Highway 34 Bridge.

Quantitative flood hazard data, such as shown above, are very important for mitigation planning purposes because they allow quantitative determination of the frequency and severity (i.e., depth) of flooding for any building or other facility (e.g., road or water treatment plant) for which elevation data exist. For example, a building located in Corvallis near the Highway 34 Bridge (cf. Table 6.3 above), with a first floor elevation of 214 feet is expected to flood about once very 10 years, on average. 50-year, 100-year, and 500-year flood events would result in about 4.2 feet, 5.8 feet and 7.9 feet of water above the first floor, respectively. Thus, such a structure would demonstrably be at significantly high flood risk. However, another structure in the same vicinity with a first floor elevation of 220 feet would still be at flood risk, albeit at a much lower level of risk, with flooding reaching the first floor only about once every 100 years, on average.

Such quantitative flood hazard data also facilitate detailed economic analysis (e.g., benefit-cost analysis) of mitigation projects to reduce the level of flood risk for a particular building or other facility.

6.3.3 Interpreting Flood Hazard Data for Mapped Floodplains

The level of flood hazard (frequency and severity of flooding) is not determined simply by whether the footprint of a given structure is or is not within the 100-year floodplain. A common error is to assume that structures within the 100-year floodplain are at risk of flooding while structures outside of the 100-year floodplain are not. Some importance guidance for interpreting flood hazard is given below.

A. Being in the 100-year floodplain does not mean that floods happen once every 100 years. Rather, a 100-year flood simply means that the probability of a flood to the 100-year level or greater has a 1% chance of happening every year.

B. Much flooding happens outside of the mapped 100-year floodplain. First, the 100-year flood is by no means the worst possible flood. For example, for flooding along the Willamette River in Corvallis, the 500-year flood is about three feet higher than the 100-year flood (cf. data in Table 6.3 above). Thus, floods greater than the 100-year event will flood many areas outside of the mapped 100-year floodplain. Second, many flood prone areas flood because of local storm water drainage conditions. Such flood prone areas have nothing to do with the 100-year floodplain boundaries.

C. The key determinant of flood hazard and flood risk for a structure or other facility is the relationship of the elevation of the structure or facility to the flood elevations for various flood events. Thus, homes with first floor elevations below or near the 10-year flood elevation have drastically higher levels of flood hazard and risk than other homes in the same neighborhood with first floor elevations near the 50-year or 100-year flood elevation.

The FEMA FIRM maps use a variety of nomenclature to describe different types of flood-prone area and flood plain classifications have changed over time. For reference, definitions of some important flood plain terms commonly used on FIRMs are given below.

The FEMA floodplain maps include the following types of flood-prone areas:

1. **Zone AE**, within the 100-year floodplain, with base flood elevation (100-year flood) and detailed flood hazard data. On older FIRMs, numbered A-Zones (A1 to A30) have similar flood information.

2. **Zone A**, within 100-year flood plain, but without base flood elevation or detailed flood hazard data.

3. **Zone AH**, flood depths of 1 to 3 feet (usually areas of ponding), base flood elevations determined.

4. **Zone AO**, flood depths of 1 to 3 feet (usually sheet flow on sloping terrain).

5. **Zone A99**, to be protected from 100-year flood by Federal flood protection system under construction, no base flood elevations determined.

6. **Zone X (shaded)**, areas of 500-year flood, areas of 100-year flood with average depths less than 1 foot or with drainage areas less than 1 square mile, and areas protected by levees from 100-year flood. On older FIRMS, Zone B areas have similar meaning.

7. **Zone X (unshaded)**, areas outside 500-year flood plain.

8. **Zone D**, areas in which flood hazards are undetermined.

6.3.4 Caveats for Corvallis Flood Insurance Study

The Flood Insurance Studies (FIS) for Corvallis were published in 1984. Flood hazard conditions often change with time as channels and watersheds evolve with increasing development and other changes. Over time, the accuracy of a FIS typically diminishes with time and any FIS should be redone periodically to ensure that data are accurate and up to date for flood zoning and mitigation planning purposes.

In many cases, increasing development within watersheds (which increases runoff), and gradual accumulation of sediment and debris in channels results in higher flood levels with time. In other cases, however, improvements in storm water management or channel improvements may results in lower flood levels.

Simply because an FIS is old, does not necessarily mean that a FIS is obsolete or inaccurate. However, the older a study is, the more likely it is that channel or watershed conditions have changed over time. Therefore, as time passes, care should be taken in interpreting and using data from the FIS, especially in reaches of rivers or streams where substantial channel changes are documented or flood control measures have been added.

FEMA has recognized that may FIS's are old and is in-process with a nationwide map modernization program which is intended to update all of the FIS's and FIRMs and map additional areas. However, this map modernization program will not be completed for several years at the earliest. Meanwhile, the existing FIS's and FIRMs for Corvallis are generally the best available flood data.

6.4 Flood Hazards and Flood Risk: Outside of Mapped Floodplains

The discussion above in Section 6.3 above applies only to the limited portions of Corvallis that are within the FEMA-mapped floodplains of the major rivers and portions of some of the smaller streams. For mitigation planning purposes, it is very important to recognize that flood risk for a community is not limited only to areas of mapped floodplains. Other portions of Corvallis outside of the mapped floodplains may also at relatively high risk from over bank flooding from streams too small to be mapped by FEMA or from local storm water drainage.

Some areas of Corvallis outside of mapped floodplains may also subject to repetitive, damaging floods from local storm water drainage, separate from overbank flooding from creeks too small to be mapped. In many cases, local storm water drainage flooding occurs along unnamed gullies or simply in low spots. There are probably numerous such flood prone sites in Corvallis; some of these sites may have experienced repetitive flooding over many years. Unlike FEMA-mapped floodplains for larger rivers and creeks, areas subject to storm water drainage are not systematically mapped.

The storm water management system in Corvallis includes nine storm water detention facilities, about 160 miles of storm water pipes, 4,872 catch basins and 2,499 manholes. The City also maintains about 14 miles of urban streams (open drainageways).

Most storm water drainage systems, including those in Corvallis, are designed to handle small to moderate size rainfall events. Storm water systems are sometimes designed to handle only 2-year or 5-year flood events, and are rarely designed to handle rainfall events greater than 10-year or 15-year events.

For local rainfall events that exceed the collection and conveyance capacities of the storm water drainage system, some level of flooding inevitably occurs. In many cases, local storm water drainage systems are designed to allow minor street flooding to carry off storm waters that exceed the capacity of the storm water drainage system. In larger rainfall events, flooding may extend beyond streets to include yards. In major rainfall events, local storm water drainage flooding can also flood buildings. In extreme cases, local storm water drainage flooding can sometimes result in several feet of water in buildings, with correspondingly high damage levels.

6.5 Inventory Exposed to Flood Hazards in Corvallis

Critical facilities such as emergency communications, fire stations, police stations, medical care facilities are, by definition, particularly important to a community. Similarly, key transportation and utility infrastructure are also particularly important to a community. One important action item for Corvallis Hazard Mitigation Plan is to compile an inventory of such critical facilities that are at high risk for each hazard, including floods. A list of critical facilities located within the FEMA-mapped 100-year or 500-year floodplains is given below in Table 6.4. These facilities are also shown in

Figure 6.7. Transportation routes in or near Corvallis which are subject to flooding are shown Figure 6.8 following the critical facilities map.

Table 6.4
Critical Facilities in Corvallis within 100-Year and 500-Year Floodplains

Public Buildings		
	1205 - 1245 NE 3rd St.	Public Works
	1205 - 1245 NE 3rd St	Fire Dept. Drill Tower
	365 SW Tunison Ave.	Fire Station
	1310 SW Avery Park Drive	Parks
	360 SW Avery	Benton County
	1315 SW E Ave	Corvallis School District
Utility Facilities		
	3140 SE Clearwater Dr.	Corvallis Water Treatment
	900 NE 2nd St.	AT&T Telephone
	1221 SW 15th St.	KLOO/KFAT Radio Transmitter
	Hwy 20 & Garden Ave	Northwest Natural Gas
	5 locations	Corvallis Wastewater Lift Stations
	6 locations	Fiber optics communications
Care Facilities		
	1780 SW 3rd St.	Vocational Care
	165 NE Conifer	Residential Care
	1940 SE Stone St.	Residential Care

Figure 6.7
Critical Facilities in Corvallis within 100-Year and 500-Year Floodplains

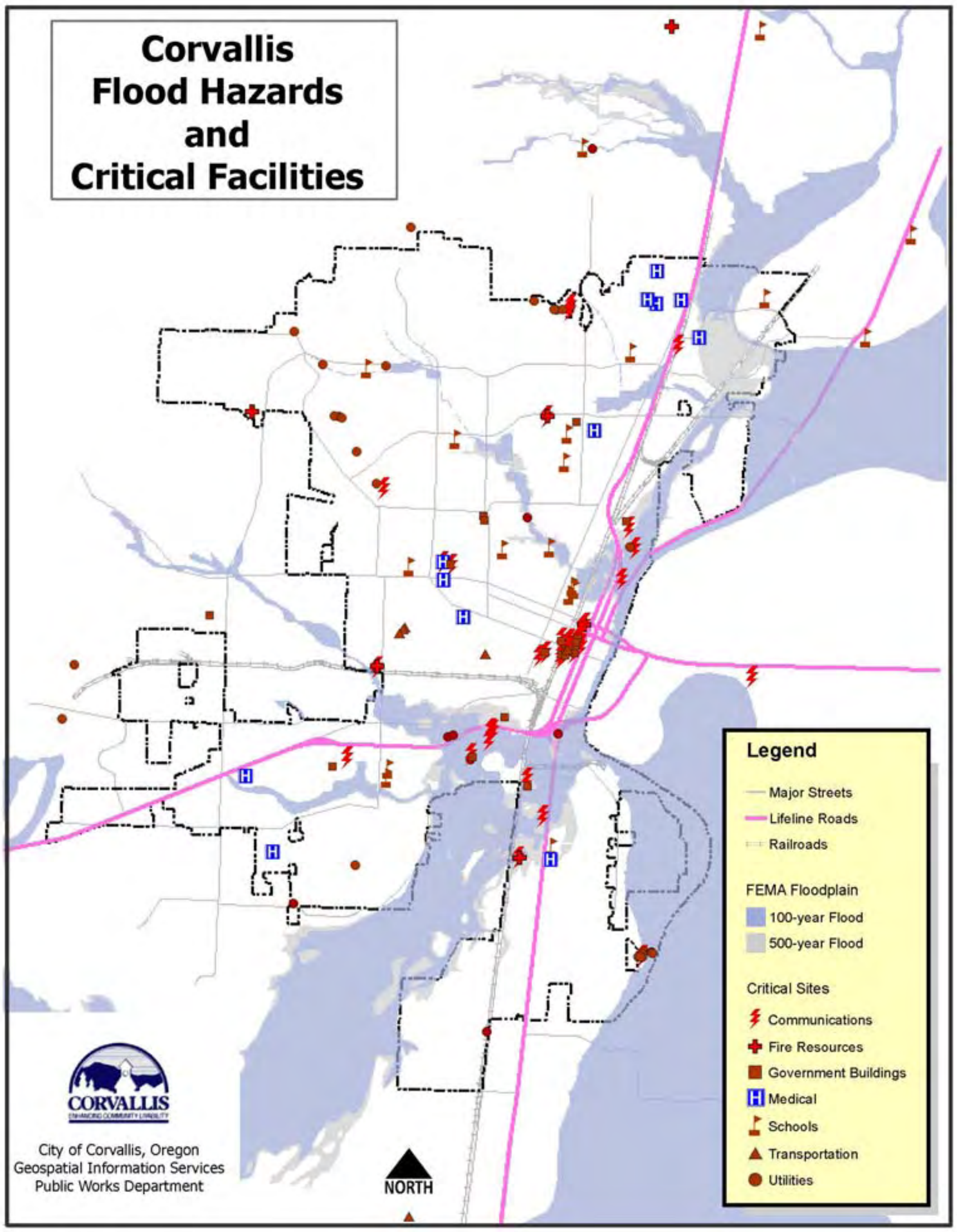
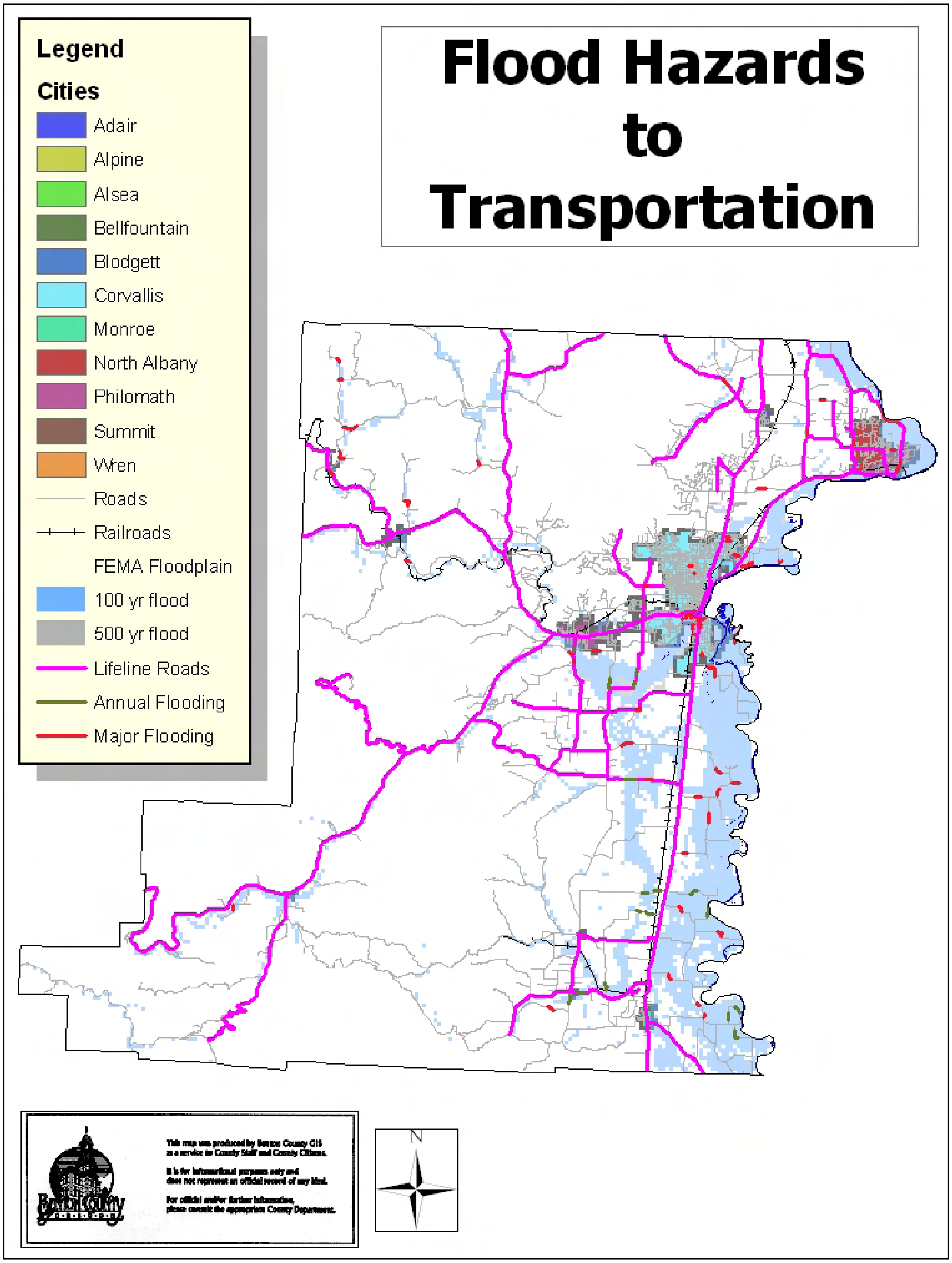


Figure 6.8
Flood Hazards to Transportation Routes



To quantify the level of flood hazard for buildings, other facilities or infrastructure, within mapped floodplains, it is necessary to determine the elevations of these structures. Only by determining the elevation of each potentially flood-prone structure, can the level of flood hazard (frequency and severity of flooding) be calculated accurately. Similarly, acquiring elevation data for additional structures within the 500-year flood plain as well as for structures in other flood-prone areas outside of mapped floodplains would greatly increase the accuracy of hazard, inventory, and vulnerability assessments for floods in Corvallis. Compiling and interpreting such elevation data, especially for critical facilities is encouraged as a high priority action item.

The best structure elevations (first floor elevations) are those determined accurately by surveying. Flood insurance certificates generally include survey elevation data. Absent survey data, however, useful estimates of elevations for structures can often be made by reference to elevations of nearby structures or public infrastructure with surveyed elevation data. In addition to elevation data, quantifying the level of risk faced by these structures requires basic data about each structure, including building data (square footage, number of stories, with or without basement), and information on the type and importance of function (residential, commercial, public).

As noted above, many localized areas of Corvallis, outside of the mapped floodplains, may also be subject to relatively high levels of flood risk. To quantify the level of flood risk posed by these areas, historical data should be systematically compiled to include documentation of the frequency and severity of flooding. Severity of flooding can include dollar estimates of past damages, if available, and/or simple narratives reporting whether the flooding in a given area is limited to minor street and yard flooding only, or whether flooding is severe enough to produce road damages, road closures, or damages to other infrastructure or buildings as well.

6.6 Flood Loss Estimates and Flood Risk

6.6.1 Flood Loss Estimates

The FEMA Q3 digital flood maps for Corvallis show the geographic areas within mapped floodplains for 100-year and 500-year flood events. The geographic extent of these mapped flood plains is tabulated below in Table 6.5.

Table 6.5
100-year and 500-year Floodplain Data for Corvallis

County	Area (sq. miles)	Area in 100-year floodplain (sq. miles)	Percentage in 100-year floodplain	Area in 500-year floodplain (sq. miles)	Percentage in 500-year floodplain[1]
Corvallis	14.19	1.62	11.42%	0.628	4.43%

[1] Areas and percentages in 500-year floodplain are areas beyond those in the 100-year floodplain.

For Corvallis, about 11.42 % and 4.43% of the total area of the city are located within the 100-year and 500-year floodplains, respectively. Thus, for Corvallis, nearly 16% of the city's area is within the FEMA-mapped floodplains.

Rough estimates of the magnitude of potential flood losses in Corvallis can be made from estimates of the number of buildings located within mapped-floodplains.

To estimate the approximate level of damages in a major flood affecting many of the flood-prone properties in Corvallis, we assume that a 100-year flood affects about 75% of the buildings within the mapped 100-year flood plain, or about 1259 buildings. We assume 75%, rather than 100% because some of these buildings are likely to be sufficiently elevated above grade that they will experience minimal or no damages in a 100-year flood event.

Estimated damages per flooded building are shown below in Table 6.6.

Table 6.6
Rough Estimate of Damage per Building for 100-Year Flood

Category	100-Year Flood
Average Building Replacement Value	$200,000
Average Contents Value	$45,000
Flood depth above first floor	2 feet
Building damage (22%)	$44,000
Contents damage (33%)	$15,000
Other damages	$4,000
Displacement costs	$4,000
Total Damages and Losses	$67,000

These estimates are based on an average building replacement value of $200,000 ($100/sf for 2,000 sf), with an average contents value of $54,000 (30% of building replacement value, a typical FEMA assumption for benefit-cost analysis of residential flood mitigation projects). For an assumed flood water depth of 2 feet above the first floor, building and contents damage percentages are estimated as 22% and 33%, of building replacement value and contents replacement value, respectively, using typical FEMA values for one-story structures without basements. Other damages, including damages to yards, vehicles, and outbuildings are estimated roughly at $4,000 per structure. Displacement costs for temporary housing are estimated roughly at $4,000 per structure. With these input data/assumptions, estimated damages and losses total about $67,000 per flooded building. The above estimates assume mostly residential buildings with some commercial buildings also experiencing first floor flooding.

For the 1259 flooded buildings, the total flood losses are estimated roughly as shown below in Table 6.7. These rough estimates, about $150,000,000 in flood damages and losses, should not be interpreted literally, but rather simply as an approximate measure of the order of magnitude of flood damages and losses that might be experienced in a major flood event in Corvallis. The estimated amounts for infrastructure damages and economic losses are based roughly on typical amounts (vs. building damages) in past flood events. Actual damages and losses in any specific major flood may be more than or less than these estimates, depending on the severity of the specific flood event, as well as on the actual building elevations for buildings identified as being within the footprint of the 100-year floodplain.

Table 6.7
Total Flood Losses

Category	Estimate
Building and Contents per Table 6.7	$84,353,000
Infrastructure Damages[1]	$42,176,500
Economic Losses[2]	$21,088,250
Total Damages and Losses	$147,617,750

[1] Infrastructure damages estimated roughly as 50% of building and contents damages.

[2] Economic losses to the community estimated roughly as 25% of building and contents damages.

The above estimates assume that all of the 100-year floodplains in Corvallis are affected by a 100-year flood, which may or not actually occur. Finally, these estimates of potential flood damages are for the FEMA-mapped floodplains only. Although the FEMA-mapped floodplains include much of the flood-prone inventory of buildings and infrastructure in Corvallis, there may be additional flood-prone areas outside of the mapped floodplains.

For a 500-year flood, similar estimates were made, assuming that 90% of the structures in the 100-year floodplain have an average of 3 feet of water and that 75% of the structures in the 500-year floodplain have an average of 1 foot of water. The estimated total damages and economic losses are about $300,000,000. The higher damage estimate for the 500-year flood arises from more building being flooded and from higher water depths. The same caveats as noted above for the 100-year flood estimates also apply to the 500-year estimates.

Similar approximate flood damage and loss estimates can be made using loss estimation calculation tools such as FEMA's HAZUS-MH loss estimation software. However, making more accurate flood loss estimates for Corvallis would require more detailed data as discussed below in the following section.

6.6.2 Techniques for More Accurate Flood Loss Estimates

More accurate flood loss estimates for specific areas of Corvallis can be made by obtaining more detailed inventory information, including elevations of flood prone structures. Then, the economic impacts of floods can be estimated more completely using the approaches outlined below.

For most residential structures and many similar commercial and public structures, the likely amount of building damage from floods of any given depth can be estimated approximately using FEMA depth-damage tables. These depth damage tables are derived from Federal Insurance Administration flood insurance claims data for several million properties and thus represent typical damage levels for typical structures. Although actual damages will vary somewhat from structure to structure, depending also on flood conditions such as duration, velocity, and degree of contamination, these typical values represent a good starting point to estimate flood damages for typical structures and thus to help quantify the level of flood risk.

In estimating flood losses or evaluating flood risk (for a structure or a whole community) it is very important to recognize that the economic impact of floods includes not only damages to buildings and contents but other economic impacts as well, including:

1. damages to yards, vehicles, and outbuildings (not in depth damage data above),
2. displacement costs for temporary quarters while repairs are made,
3. loss of business income,
4. loss of public services.

In some cases, these economic impacts of floods can be a significant fraction of building and contents damages, or even larger, especially for critical facilities or critical infrastructure. FEMA's publication *What is a Benefit? Draft Guidance for Benefit-Cost Analysis* provides an excellent primer, along with typical values and simple economic methods, to place monetary values on the loss of function of buildings, critical facilities, roads and bridges, and utility systems.

6.7 Flood Insurance Data for Corvallis

The National Flood Insurance Program (NFIP) maintains a database of all flood insurance policies in the United States. NFIP data for Corvallis indicate 414 flood insurance policies in place as of August 31, 2007.

Three of these structures are on FEMA's national repetitive loss list, which means that they had two or more claims of $1,000 or more within a 10-year time period. However, because these claims data do not consider the severity or frequency of the flood events causing the flood loss claims, the repetitive loss list is not mathematically rigorous. For example, some properties on the list may have simply been unlucky and have experienced two flood events with low probabilities (e.g., 100-year or greater events) within a short time period. Thus, the properties on the repetitive loss list may be at relatively high flood risk or they may not.

For reference, we note that the Corvallis GIS data indicate that there are 1679 buildings with footprints within the 100-year floodplain and 1439 additional buildings with footprints within the 500-year floodplain. Overall, these data indicate over 3100 flood-prone buildings in Corvallis, of which only about 13% (414) have flood insurance. This low insurance rate probably reflects the absence of major flooding in

Corvallis in recent years. However, this low insurance rate poses risks for Corvallis because the absence of insurance will impede recovery after a major flood event.

6.8 Summary of Flood Risk for Corvallis

The flood hazard, vulnerability and risk data, estimates and analyses presented above are summarized in the following table.

Table 6.8
Summary of Flood Risk for Corvallis

Question	Commentary
What is the source and type of the flood problem?	
a. overbank flooding from Willamette and Marys Rivers and numerous smaller streams	About 15% of Corvallis is within FEMA-mapped floodplains.
b. storm water drainage flooding	Affects limited portions of Corvallis
What is the geographic area affected by the flooding?	
a. FEMA-mapped floodplains	See Floodplain maps on pages 6-5 to 6-8.
b. areas outside of FEMA-mapped floodplains	Affects limited portions of Corvallis
What inventory of buildings and infrastructure are at risk?	
a. Buildings	GIS data indicate that 1679 buildings have footprints within the 100-year floodplain with an additional 1439 buildings within the 500-year floodplain.
b. Critical facilities	See listing in Table 6.5
b. Roads and other infrastructure	As demonstrated by the 1996 flood, major highways to/from Corvallis, including Highways 20 and 34, and many secondary roads are subject to closure during flood events.
How frequent is the flooding problem?	
a. roads	Minor road closures occur frequently with major floods affecting key highways
b. buildings	Quantitative determination of frequency of flooding expected requires elevation data for buildings
How serious is the flooding problem?	
a. frequent flooding (annual or every few years)	Minor flooding affects limited portions of Corvallis
b major floods (25-year, 50-year, 100-year etc. events)	100-year and 500-year flood events could result in approximately $150,000,000 and $300,000,000 in damages and losses, respectively.

6.9 Common Flood Mitigation Projects

Potential mitigation projects to reduce the potential for future flood losses cover a wide range of possibilities.

For either major rivers or the creeks, it would be theoretically possible to reduce future flood losses by building levees or floodwalls. In practice, however, such projects are often very expensive and have a host of environmental and other regulatory hurdles.

For the smaller creeks, channel improvements to improve water conveyance capacity and removal of flow-restriction obstructions may be desirable. Another possibility for some of the smaller creeks would be to construct detention ponds upstream to temporarily store water during high rainfall periods. Detention ponds are basically leaky dams, designed to be dry during normal conditions. Detention ponds typically have restricted outlets with controlled flow rates. Thus, during periods of high inflow into the pond, water is stored temporarily and then gradually released. The effect of detention ponds is to lower peak discharge values and thus to lower peak flood elevations.

For areas of Corvallis subject to flooding from storm water drainage, various storm water drainage system improvements may be desirable. Typical improvements include upgrades to the size of drainage ditches or storm water drainage pipes and upgrades to pumping capacity (for pumped portions of drainage systems). Another possibility for some areas may be construction of local detention ponds.

For critical facilities at low elevations with high flood risk, such as the water and wastewater treatment plants, construction of berms or floodwalls to protect the facilities may be desirable.

For residential, commercial or public facilities at high flood risk, elevation of structures or, for structures at very high flood risk, acquisition and demolition are potential mitigation options. Elevation and acquisition (especially) are expensive mitigation options that are generally not cost-effective unless the levels of flood hazard and flood risk are rather high. That is, these mitigation options are most attractive for structures deep in the flood plain (i.e., with first floors below the 10-, or 20-, or 30-year flood elevations). For structures outside of mapped floodplains, elevation or acquisition would likely be cost-effective only for structures with a strong history of major, repetitive flood losses.

For structures near the fringe of the 100-year flood plain, near the 100-year flood level, or with some history of repetitive flood losses, various small-scale flood loss reduction measures such as elevation of furnaces and utilities may be desirable.

The following table contains flood mitigation action items from the master Action Item table in Chapter 4.

Table 6.11
Flood Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Flood Mitigation Action Items: Within FEMA-Mapped Floodplains								
Short-Term #1	Inventory critical facilities within mapped floodplains or other high flood risk areas, identify and implement appropriate mitigation options	Public Works, Community Development	Ongoing	X	X	X	X	
Short-Term #2	Survey elevation data for buildings within mapped floodplains, evaluate flood risk quantitatively, and explore mitigation options with property owners.	Public Works, Community Development	Ongoing	X		X	X	X
Flood Mitigation Action Items: Outside of FEMA-Mapped Floodplains								
Short-Term #1	Complete the inventory of locations in Corvallis subject to frequent storm water flooding	Public Works, Community Development	Ongoing	X	X	X	X	X
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works	Ongoing	X	X	X	X	X

7.0 WINTER STORMS

7.1 Overview

Winter storms affecting Corvallis are generally characterized by a combination of heavy rains and high winds, sometimes with snowfall, especially at higher elevations. Heavy rains can result in localized or widespread flooding, as well as debris slides and landslides. High winds commonly result in tree falls which primarily affect the electric power system, but which may also affect roads, buildings and vehicles. This chapter deals primarily with the rain, wind, snow and ice effects of winter storms. Larger scale flooding is addressed in Chapter 6. Debris flows and landslides are addressed in Chapter 8.

For completeness, we also briefly address other weather events in this chapter, including severe thunderstorms, hail, lightning strikes and tornadoes. The frequency, severity, and impacts of such weather events are generally minor for Corvallis, compared to winter storm effects (see Section 7.5).

Winter storms can affect the area directly, with damage within Corvallis, or indirectly, with damage outside the area but affecting transportation to/from the area and/or utility services (especially electric power). Historically, Corvallis has often been subject to both direct and indirect impacts of winter storms.

The winter storms that affect Corvallis are typically not local events affecting only small geographic areas. Rather, the winter storms are typically large cyclonic low pressure systems moving from the Pacific Ocean and that thus usually affect large areas of Oregon and/or the whole Pacific Northwest.

Historical winter storm data complied by the Portland Office of the National Weather Service (www.wrh.noaa.gov/Portland/windstorm.html) list the following major winter storm events with substantial wind damage in Oregon:

1. February 7, 2002
2. December 12, 1995
3. November 13-15, 1981
4. March 25-26, 1971
5. October 2, 1967
6. March 27, 1963
7. October 12, 1962
8. November 3, 1958
9. December 21-23, 1955
10. December 4, 1951
11. November 10-11, 1951
12. April 21-22, 1931
13. January 20, 1921
14. January 9, 1880.

The website referenced above has informative narrative summaries of each winter storm event, including wind speed data and damage reports. Similar summaries of historical wind storm data have been compiled by Wolf Read at Oregon State University (http://oregonstate.edu/~readw/). This OSU website has a vast archive of historical winter storm data for Oregon.

The specific severity and impacts of the major historical winter storm events listed above varied significantly with geographic location within Oregon. However, in terms of sustained wind speeds and damage levels, the 1880 and 1962 storms stand out as the most severe such events for Oregon.

7.2 Rain Hazard Data

Severe winter storms in Corvallis often include heavy rainfall. The potential impact of heavy rainfall depends on both the total inches of rain and the intensity of rainfall (inches per hour or inches per day). In the context of potential flooding, "rainfall" also includes the rainfall equivalent from snow melt. Flash floods, which are produced by episodes of intense heavy rains (usually 6 hours or less) or dam breaks are rare in Corvallis (and western Oregon as a whole) but do represent a potential meteorological hazard.

Large drainage basins, such as that for the Willamette River typically have response times of several days: the total rainfall amounts (plus snow melt) over periods of several days or more are what determines the peak level of flooding along large rivers. Smaller rivers may have response times of several hours up to a day or so. Smaller, local drainage basins have even shorter response times and levels of peak flooding may be governed by rainfall totals over a period of an hour to a few hours.

However, for the Willamette River, there are numerous large multi-purpose dams and thus the usual natural correlation between rainfall events and flood levels does not completely apply. Rather, flooding along such rivers is heavily governed by water release patterns from the dams. For the major rivers, dam operating characteristics and capacities are included in the flood modeling for FEMA-mapped floodplains (see Chapter 6).

Corvallis annual rainfall data are shown in Table 7.1 below two representative locations. As shown below, there are substantial variations in annual rainfall from year to year.

Table 7.1
Corvallis Rainfall Data

Location	Average Annual Precipitation (inches)	Lowest Annual Precipitation (inches)	Highest Annual Precipitation (inches)	Period of Record
Corvallis	40.96	23.68 (1930)	73.21 (1996)	1889-2004

Data for Corvallis (OSU) weather station from Western Regional Climate Center website: www.wrcc.dri.edu

The rainfall data shown in Table 7.1 give general overview of the potential for winter storm flooding in Corvallis, but whether or not flooding occurs at specific sites depends heavily on specific local rainfall and local drainage conditions.

Statistical rain fall data for Corvallis are shown in Table 7.2 with these data taken from the NOAA maps shown in Chapter 7 of the Benton County Hazard Mitigation Plan. Table 7.2 shows the 24-hour rainfall amounts for various return periods: 2-years, 25-years, and 100-years. The frequency of rainfall events is interpreted in the same manner as the frequency of flood events. Thus, a 2-year rainfall event simply means that such rainfalls have a 50% chance of happening in any given year. A 25-year or 100-year rainfall event mean simply that such rainfalls have a 4% or 1% chance, respectively, of happening in any given year.

Table 7.2
24-Hour Precipitation Totals for Various Return Periods

Corvallis	Map Contour Band (inches)	Approximate Value (inches)
2-Year 24-Hour Rainfall	<3	2.5
25-Year 24-Hour Rainall	<4	3.5
100-Year 24-Hour Rainall	<5	4.5

These 24-hour precipitation maps provide useful information for evaluating the potential for localized flood impacts from winter storms. The 24-hour precipitation totals are a reasonable measure of flood risk for small drainage basins. Longer duration precipitation totals govern flooding on larger rivers, but such flooding is already included in the modeling behind FEMA's floodplain mapping and covered by the discussion of flood hazards in Chapter 6.

The rainfall totals shown in Table 7.2 are high enough to generate significant potential localized flooding problems. However, whether or not localized flooding does occur depends on specific local drainage conditions. For example, 3" of rain in one area may cause no damage at all, while 3" of rain in a nearby area may cause road washouts and flooding of buildings.

For Corvallis, identification of specific sites subject to localized flooding during winter storms is based on historical occurrences of repetitive flooding events during past winter storm events. The flood-prone sites in Corvallis identified in Chapter 6 Floods are for combination of overbank flooding from streams and rivers and from local storm water drainage flooding. See Table 6.5 and the maps of Flood Hazards to Critical Facilities and Transportation in Chapter 6.

Additional sites in Corvallis with a history of repetitive flood problems are shown below in Table 7.3; this list is representative but not complete, there may other repetitive loss sites as well.

Table 7.3
Repetitive Flood Sites in Corvallis

Location	Notes
Law Enforcement Building	Police Dept, regional communications, county mainframe computer
Dixon Creek between Buchanan Ave. and Circle Blvd.	30 homes threatened
Avery Dr., south to the Mill Race	several homes and businesses threatened, lifeline blocked

7.3 Wind Hazard Data

Wind speeds associated with winter storms vary depending on meteorological conditions, but also vary spatially depending on local topography. For Corvallis, the wind hazard levels are generally lower than those experienced at higher elevations in the western part of Benton County.

A regional overview of wind hazards is shown by the wind data maps in Chapter 7 of the Benton County Hazard Mitigation Plan. Wind speed data for Corvallis are shown in Table 7.4 below for 2-year and 50-year return periods.

Table 7.4
Corvallis Wind Hazard Data

Return Period	Sustained Wind Speeds (miles/hr)	Peak Gust Wind Speeds (miles/hr)
2-year	37	48
50-year	62	81

These data are sustained wind speeds for the standard meteorological data height of 10 meters (about 39 feet) above ground level. Peak gusts are commonly 30% or so higher than the sustained wind speeds. Of course, extreme wind events, with return periods greater than 50 years will have higher wind speeds.

For Corvallis, the 2-year wind speeds are too low to cause widespread substantial wind damage. However, there may be localized wind damage, especially at sites where local wind speeds are higher or where there are especially exposed locations, such at the boundary between clear cut and forested areas.

For Corvallis, the 50-year wind speeds are high enough to cause widespread wind damage. Damage may be severe at particularly exposed sites. Thus, for most locations in Corvallis winter storms with significant direct wind damage are not likely every year or every few years, but perhaps once every decade or so, on average, with major wind storm events happening at intervals averaging every few decades.

7.4 Snow and Ice Hazard Data for Corvallis

Winter storms can also involve ice and snow, most commonly at higher elevations than Corvallis, but sometimes in the Willamette Valley as well. The most likely impact of snow and ice events on Corvallis are road closures limiting access/egress to/from some areas, especially roads to higher elevations. Winter storms with heavy wet snow or high winds and ice storms may also result in power outages from downed transmission lines and/or poles.

Average annual snowfalls in Corvallis are generally low as shown below in Table 7.5.

Table 7.5
Snowfall Data for Corvallis

Location	Average Annual Snowfall (inches)	Lowest Annual Snowfall (inches)	Highest Annual Snowfall (inches)	Period of Record
Corvallis	6.10	0.00	51.90 (1949-50)	1889-2004

Data for Corvallis (OSU) weather station from Western Regional Climate Center website: www.wrcc.dri.edu

Since 1889, there have been nine years with 20" or more of snow in Corvallis, as shown below in Table 7.6.

Table 7.6
Significant Snowfall Events for Corvallis

Corvallis			
Year	**Annual Snowfall (inches)**	**Peak Snowfall Month**	**Peak Monthly Snowfall (inches)**
1892-3	21.0	January	17.0
1908-9	23.0	January	23.0
1915-6	25.6	January	22.4
1919-20	20.0	December	20.0
1942-3	20.0	January	18.0
1949-50	51.9	January	51.9
1968-9	27.7	January	24.0
1970-1	27.5	January	15.3
1991-2	26.3	February	15.0

Data for Corvallis (OSU) weather station from Western Regional Climate Center website: www.wrcc.dri.edu

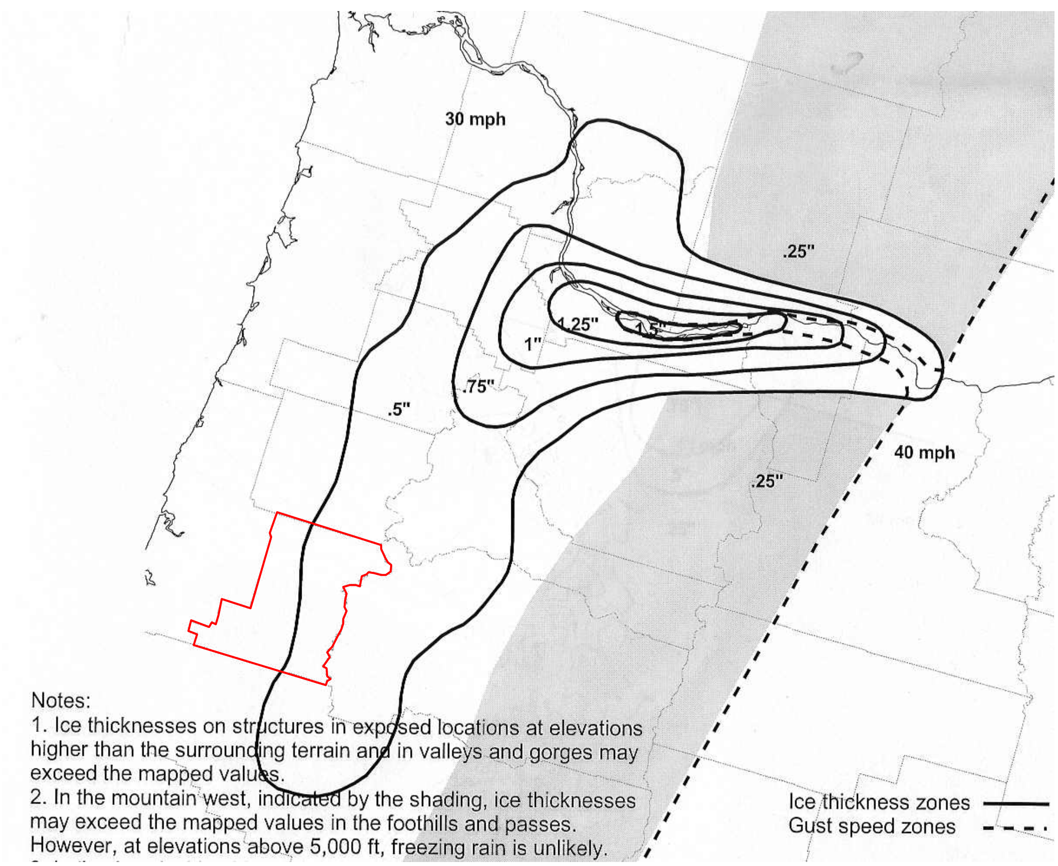
In addition to snow events, Corvallis is also subject to ice storm and freezing rain events. Ice storms and freezing rain are fairly common, especially along the Willamette River Valley when cold air near the ground coincides with warm moist air at higher altitudes.

The National Climatic Data Center (NCDC) database shows two ice storm or freezing rain events for Corvallis between 1993 and 2004. Both of these were relatively minor events with increased traffic accidents due to ice on the roads, with few other damages. Website addresses for NCDC and the state and county storm event database are: www.ncdc.noaa.gov and http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms, respectively.

Probabilistic ice storm data showing ice thicknesses with return periods from 50 years to 400 years are given in a recent report by the American Lifelines Alliance (Extreme Ice Thicknesses from Freezing Rain, 2004). The 50-year return period ice thickness map (Figure 7.1 below) shows about 0.5" of ice for Corvallis, with ice thickness decreasing westward from the Willamette River Valley. 100-year and 400-year ice thicknesses for Corvallis are about 0.75" and 1.0", respectively.

For Corvallis, ice thicknesses in 50-year or more severe events are high enough (0.5" or greater) to cause substantial damage, especially to trees and utility lines.

Figure 7.1
50-Year Ice Thickness from Freezing Rain



7.5 Other Severe Weather Events

The National Oceanic and Atmospheric Administration (NOAA), which includes the National Weather Service, also includes the National Climatic Data Center (NCDC). The NOAA and NCDC websites have a vast amount of historical information on severe weather events throughout the United States. These databases can also be searched by State and County to obtain more localized information. Website addresses are: www.noaa.gov and www.ncdc.noaa.gov, for NOAA and NCDC, respectively. The state and county storm event database can be found at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms. Unless otherwise referenced, all of the storm event data below for Corvallis are from the state and county storm event database referenced above.

Severe Thunderstorms and Hail Events

The NCDC database lists 6 thunderstorm and high wind events in Benton County since 1982. Damage was reported in only one thunderstorm event on May 1, 1998 in Corvallis; this event included numerous tree falls and damage to at least one building. Most thunderstorm events in Corvallis are typically too minor to be recorded as significant storm events. Nevertheless, thunderstorm events in Corvallis can occasionally cause locally high winds with tree falls which may affect roads, utility lines, and buildings.

The NCDD data base listed two hail events for Benton County : April 2, 2001 in Corvallis and Albany. No damage reports were available. Hail events certainly occur in Corvallis, generally during summer months. However, hail damage is generally minor and few practical mitigation alternatives are applicable to hail, other than taking shelter and moving vehicles to garages when possible.

Lightning

Nationwide, lightning is the number two weather related killer nationwide, second only to floods. NOAA data show that lightning causes about 90 deaths per year, with at least 230 injuries (NOAA Technical Memorandum NWS SR-193, 1997). Lightning injuries appear to be systematically underreported and thus the actual injury total is most likely significantly higher.

For Oregon, casualties from lightning are very low, with totals of only 7 deaths and 19 injuries reported over a 35 year period (NOAA). Thus, the level of risk posed by lightning strikes in Corvallis, while not zero, is very low. For Benton County, the NCDD data base does not list any major lightning events.

Public education about safe practices during electrical storms is the only available mitigation measure to reduce casualties from lightning. Lightning strike damage to buildings or infrastructure is generally relatively minor and few practical mitigation alternatives are applicable to lightning, other than installing lightning arrestors on critical facilities subject to lightning damage.

Tornadoes

Tornadoes also occasionally occur in Oregon. However, Oregon is not among the 39 states with any reported tornado deaths since 1950. A compilation of historical tornadoes in Oregon by the national weather service (http://nimbo.wrh.noaa.gov/ Portland/tornado.html) includes 64 tornadoes statewide, with only one tornado in Benton County. The NCDC data base lists a small tornado about 15 miles west of Albany on June 1, 1997 and a funnel cloud (which did not touch down) west of Corvallis on May 29, 1996.

Climate and weather conditions in Oregon and specifically in Corvallis make the occurrence of major tornadoes unlikely. The most practical mitigation actions for tornadoes are public warnings and taking shelter to minimize the potential for deaths and injuries.

7.6 Winter Storm Risk Assessment

Winter storm flooding and wind impacts may affect both infrastructure and buildings. Localized flooding from winter storms very commonly affects the transportation system, especially roads. Severe winter storms will result in numerous road closures due either to washouts or due to depth of water on road surfaces. Such localized flooding also affects buildings located in the flooded areas. Additional road closures are likely in some events from landslides/mudslides as well as from snow/ice storms.

Wind impacts from winter storms arise primarily from tree falls, which may affect vehicles and buildings, to some extent, but whose primary impact is often on utility lines, especially electric power lines. Widespread wind damages may result in widespread downing of trees or tree limbs with resulting widespread downage of utility lines. Such tree-fall induced power outages affect primarily the local electric distribution system, because transmission system cables are generally less prone to tree fall damage because of design and better tree-trimming maintenance. In severe wind storms, direct wind damage or wind driven debris impacts on buildings cause building damages, especially for more vulnerable types of construction such as mobile homes.

As discussed above in Section 7.1, both winter storm flood hazards and winter storm wind hazards have highly localized impacts. The location and severity of such impacts depend very strongly on specific local conditions. Therefore, it is difficult to make regional risk assessment or loss estimates from mapping the hazards and overlaying the inventory: such a risk assessment simply requires too much detailed data which are not yet available.

An alternative approach is to document the severity and locations of winter storm flood and wind damage from the pattern historical events. For more quantitative risk assessment of localized flooding and wind damages arising from winter storms, the best approach is to systematically gather data on sites of repetitive damages due to localized flooding or wind damages. By documenting (and mapping using GIS) the sites of repetitive damage events, along documentation of the type and cost of damages and losses, the most seriously impacted sites can be clearly identified. Clearly, such repetitive loss sites with significant damages are likely candidates for mitigation actions.

The probable impacts of winter storms on Corvallis are summarized below in Table 7.7.

Table 7.7
Probable Impacts of Winter Storms on Corvallis[1]

Inventory	Probable Impacts
Portion of Corvallis Affected	Entire city may be affected by road closures or loss of electric power; otherwise direct damages to buildings and infrastructure are likely to be localized and relatively minor
Buildings	Isolated minor damage from tree falls, some buildings affected by flood damage in major storms, especially in the storm water drainage problem areas identified in Section 6.3
Streets within communities	Minor road closures due to tree falls and flooding; limited impact because of short detour routes within communities
Roads within and to/from Corvallis	Potential closures of some roads and major highways due to snow, debris flows or landslides, localized flooding and tree falls
Electric Power	Loss of electric power may be localized due to tree falls on local distribution lines or affect larger areas if tree falls affect transmission lines
Other Utilities	Generally minor or no impacts on other utilities from winter storms
Casualties	Small potential for casualties (deaths and injuries) from tree falls, contact with downed power lines, or traffic accidents.

[1] These winter storm impacts include localized flooding and the effects of wind, snow, and ice.

7.7 Mitigation of Winter Storm Impacts

Potential mitigation projects for winter storms may address any of the aspects of such storms, including floods, winds, and landslides (see Chapter 8). See also Chapter 13 for additional discussion of the disruptions to utility and transportation systems.

For winter storm flooding, the mitigation measures discussed in Chapter 6 (Floods) for local storm water drainage flooding are exactly the mitigation measures for the flood aspects of winter storms. Common mitigation projects include: upgrading storm water drainage systems, construction of detention basins, and structure-specific mitigation measures (acquisition, elevation, flood proofing) for flood-prone buildings. For roads subject to frequent winter storm flooding, possible mitigation actions include elevation of the road surface and improved local drainage. For utilities subject to frequent winter storm flooding, possible mitigation actions include improved local drainage, elevation or relocation of the vulnerable utility elements to non-flood prone areas nearby.

For wind effects of winter storms, the most common and most effective mitigation action is to increase tree trimming effects, because a high percentage of wind damage to utilities, buildings, vehicles, and people arises from tree falls. Trimming of trees subject to falling on utilities, buildings, vehicles, and people is an effective mitigation measure. However, economic, political and esthetic realities place limits on tree trimming as a mitigation action. Future wind storm damage in Corvallis could be almost eliminated by cutting down all large trees along roads or in populated areas. Obviously, such an extreme mitigation measure is neither practical nor desirable for many reasons.

Effective tree trimming mitigation programs focus on limited areas where tree falls have a high potential to result in major damages and economic losses. High priority areas include examples such as the following:

1) Transmission lines providing electric power to the area,
2) Major trunk lines providing the backbone of the electric power distribution system within the area
3) Distribution lines for electric power to critical facilities in the area,
4) Specific circumstances where falling of large trees poses an obvious threat to damage buildings and/or people or close major transportation arteries.

Mitigation measures for snow and ice are limited, although tree trimming efforts, discussed above under wind, also reduce the impact of snow and ice on trees, roads, and utility lines. For the most part, dealing with snow and ice storms are primarily issues of emergency planning, response and recovery.

Similarly, few mitigation measures appear practical for Corvallis for other types of severe weather, including severe thunderstorms, hail, lightning, and tornadoes. For such weather events, public education about safe practices and emergency planning, response and recover appear to be the most useful pragmatic actions.

The following table contains winter storm mitigation action items from the master Action Item table in Chapter 4.

Table 7.8
Winter Storm Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Winter Storms Mitigation Action Items								
Short-Term #1	Inventory and remove hazardous trees in City right of way	Public Works, Parks	Ongoing	X	X	X	X	
Short-Term #2	Complete an inventory of locations in Corvallis subject to frequent storm water flooding or repetitive tree fall problems from wind/ice	Public Works, Parks	Ongoing	X	X	X	X	X
Short-Term #3	Enhance tree trimming efforts especially for transmission lines and trunk distribution lines and consider tree trimming ordinance	Public Works, private utilities	Ongoing	X	X	X	X	X
Short-Term #4	Encourage property owners to trim trees near service drops to individual customers	Public Works	Ongoing	X		X	X	X
Short-Term #5	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	Public Works, Benton County Emergency Management, Community Development and private owners	1-2 Years	X	X			X
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works	Ongoing	X	X	X	X	X
Long-Term #2	Consider upgrading electric lines and poles to improve wind/ice loading, undergrounding critical lines, and adding interconnect switches to allow alternative feed paths and disconnect switches to minimize outage areas	Private utilities	5 Years	X	X	X	X	X

8.0 LANDSLIDES

8.1 Landslide Overview and Definitions

The term “landslide” refers to a variety of slope instabilities that result in the downward and outward movement of slope-forming materials, including rocks, soils and artificial fill. Four types of landslides are distinguished based on the types of materials involved and on the mode of movement. These types of landslides are illustrated in Figures 8.1 to 8.4 and described below.

> **Rockfalls** are abrupt movements of masses of geologic materials (rocks and soils) that become detached from steep slopes or cliffs. Movement occurs by free-fall, bouncing and rolling. Falls are strongly influenced by gravity, weathering, undercutting or erosion.
>
> **Rotational Slides** are those in which the rupture surface is curved concavely upwards and the slide movement is rotational about an axis parallel to the slope. Rotational slides usually have a steep scarp at the upslope end and a bulging “toe” of the slid material at the bottom of the slide. . Rotational slides may creep slowly or move large distances suddenly.
>
> **Translational Slides** are those in which the moving material slides along a more or less planar surface. Translational slides occur on surfaces of weaknesses, such as faults and bedding planes or at the contact between firm rock and overlying loose soils. Translational slides may creep slowly or move large distances rather suddenly.
>
> **Debris Flows** (also called debris torrents) are surficial movements in which loose soils, rocks and organic matter combine with entrained water to form slurries that flow rapidly downslope or within a stream channel. They may travel hundreds to thousands of feet.

All of these types of landslides may cause road blockages by dumping debris on road surfaces or road damages if the road surface itself slides downhill. Utility lines and pipes are prone to breakage in slide areas. Buildings impacted by slides may suffer minor damage from small settlements or be completely destroyed by large ground displacements or by burial in slide debris. Also, as evidenced by 1996 winter storms in Oregon, landslides may also result in injuries or fatalities.

There are three main factors that determine susceptibility (potential) for landslides:

1) slope steepness,
2) soil/rock characteristics or landform shape, and
3) subsurface water.

Loose, weak rock or soil is more prone to landslides than is more competent rock or dense, firm soils. For landslides, the term competent rock means solid, coherent rock with good bearing strength that is less prone to landslides. Finally, water saturated soils or rock with a high water table are much more prone to landslides because the water pore pressure decreases the shear strength of the soil and thus increases the probability of sliding.

Figures 8.1 to 8.4
Major Types of Landslides

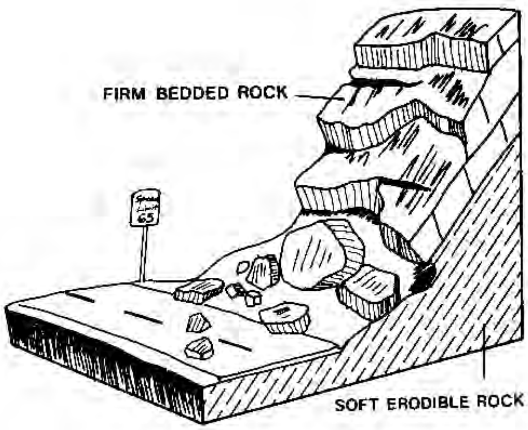


Fig. 8-1. Rockfall

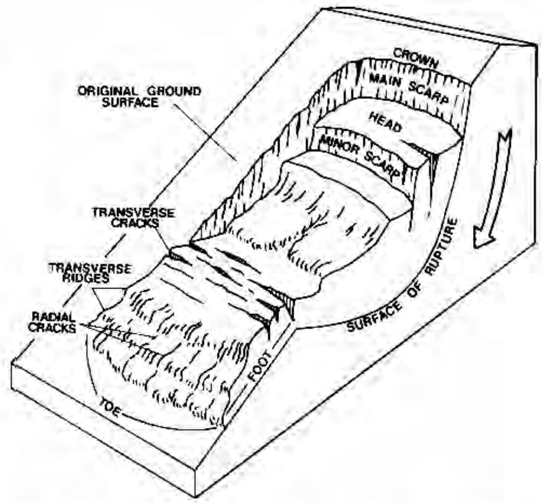


Fig. 8-2. Rotational Landslide

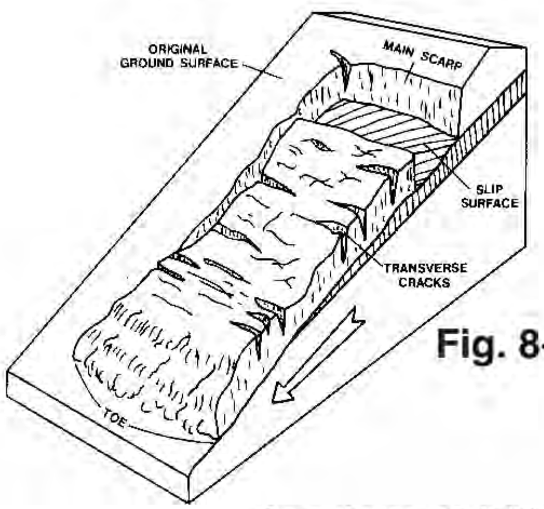


Fig. 8-3. Translational Landslide

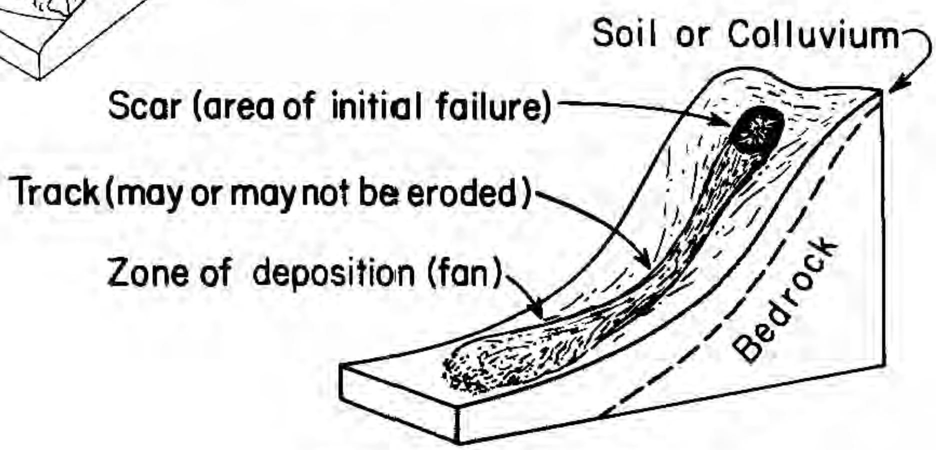


Fig. 8-4. Debris Flow

The water content of soils/rock is a major factor in determining the likelihood of sliding for any given slide-prone location. Thus, the vast majority of landslides happen during rainy months, when soils are saturated with water. However, landslides may happen at any time of the year. In addition to landslides triggered by a combination of slope stability and water content, landslides may also be triggered by earthquakes. Areas prone to seismically triggered landslides are generally similar to those prone to ordinary (i.e., non-seismic) landslides. As with ordinary landslides, seismically triggered landslides are more likely to occur when soils are saturated with water.

Debris flows and landslides are a very common occurrence in hilly areas of Oregon, and may occur in hilly portions of Corvallis. Many landslides occur in undeveloped areas and thus may go unnoticed or unreported. For example, DOGAMI conducted a statewide survey of landslides from four winter storms in 1996 and 1997 and found 9,582 documented landslides, with the actual number of landslides estimated to be many times the documented number. For the most part, landslides become a problem only when they impact developed areas and have the potential to damage buildings, roads, or utilities.

8.2 Landslide Hazard Assessment for Corvallis

Overall, the risk of landslides in Corvallis is relatively low. Areas subject to landslides are mostly limited to hilly portions of North Corvallis and a few other locations and along localized portions of river or stream channel banks. The following maps show landslide or debris flow hazard areas in or near Corvallis, prepared by various agencies. The maps use different criteria for hazard areas and thus differ somewhat in their details. All are included to give the broadest perspective on potential landslide or debris flow hazard areas in or near Corvallis.

Figures 8.5 and 8.6 are landslide hazard and landslide runout hazard maps prepared by Corvallis GIS. Landslide runout hazard areas are subject to debris flows.

Figure 8.7 shows earthquake-induced landslide hazard areas for Benton County, which indicates no mapped high- or moderate-hazard areas within Corvallis. Hazard areas for other types of landslides are generally similar to the earthquake-induced landslide hazard areas.

Figure 8.8 shows active landslide areas for the North Corvallis area, with about two dozen active slide areas outside city limits. Several of these active slide areas include developed residential areas. There is also one very small active slide area within city limits, in a developed residential area.

Figure 8.9 shows debris flow hazard areas for North Corvallis. This map is an excerpt from the map of debris flow hazards for North Corvallis, Adair and North Albany, prepared by the Oregon Department of Forestry and the Oregon Climate Service which is included in Chapter 8 of the Benton County Hazard Mitigation Plan. There are significant areas with moderate or high debris flow hazards. All of these areas are outside of the Corvallis city limits, but do impinge on developed areas north of the City.

Figure 8.5
City of Corvallis Landslide Hazard Areas

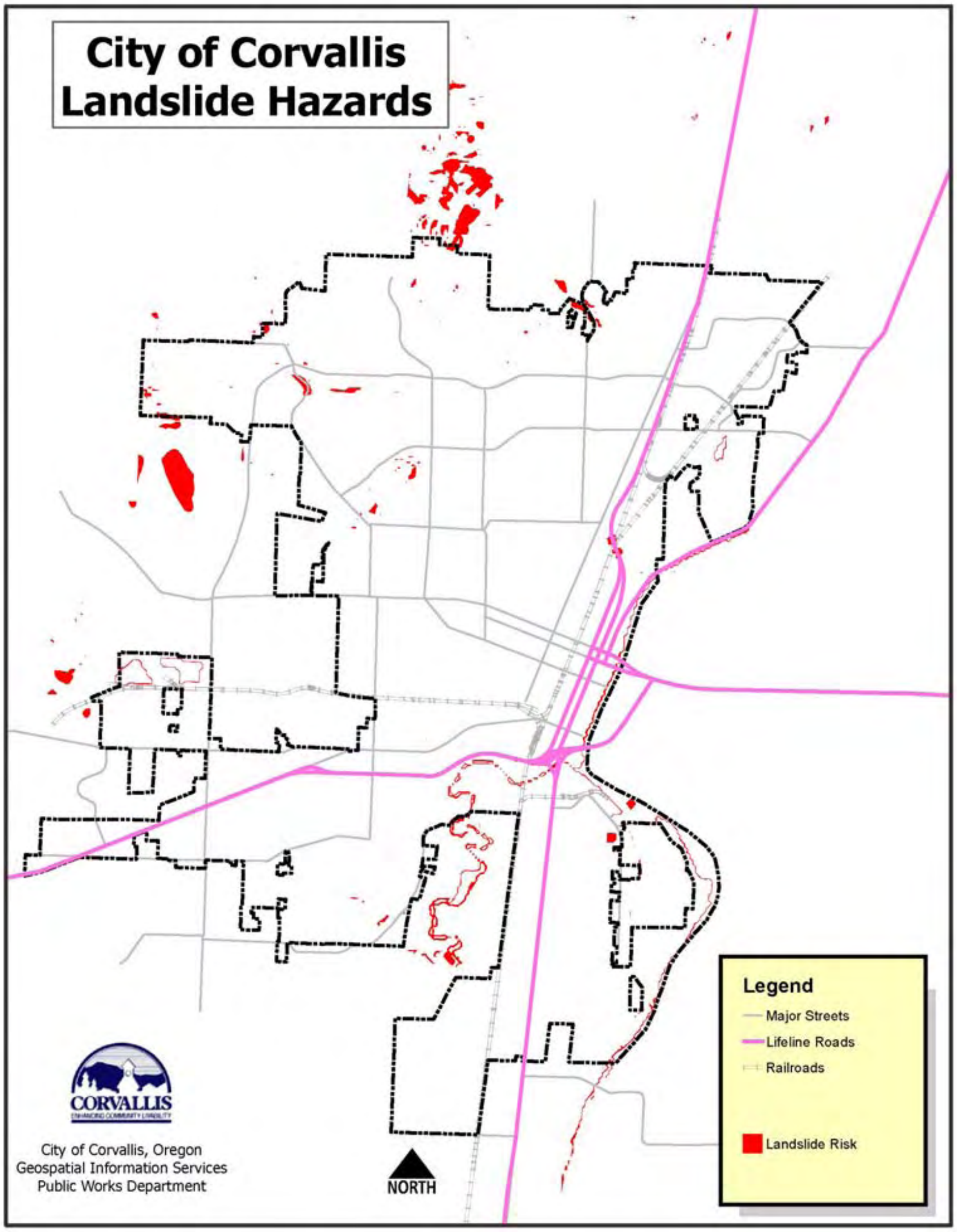


Figure 8.6
Landslide Runout Hazard Map for Corvallis

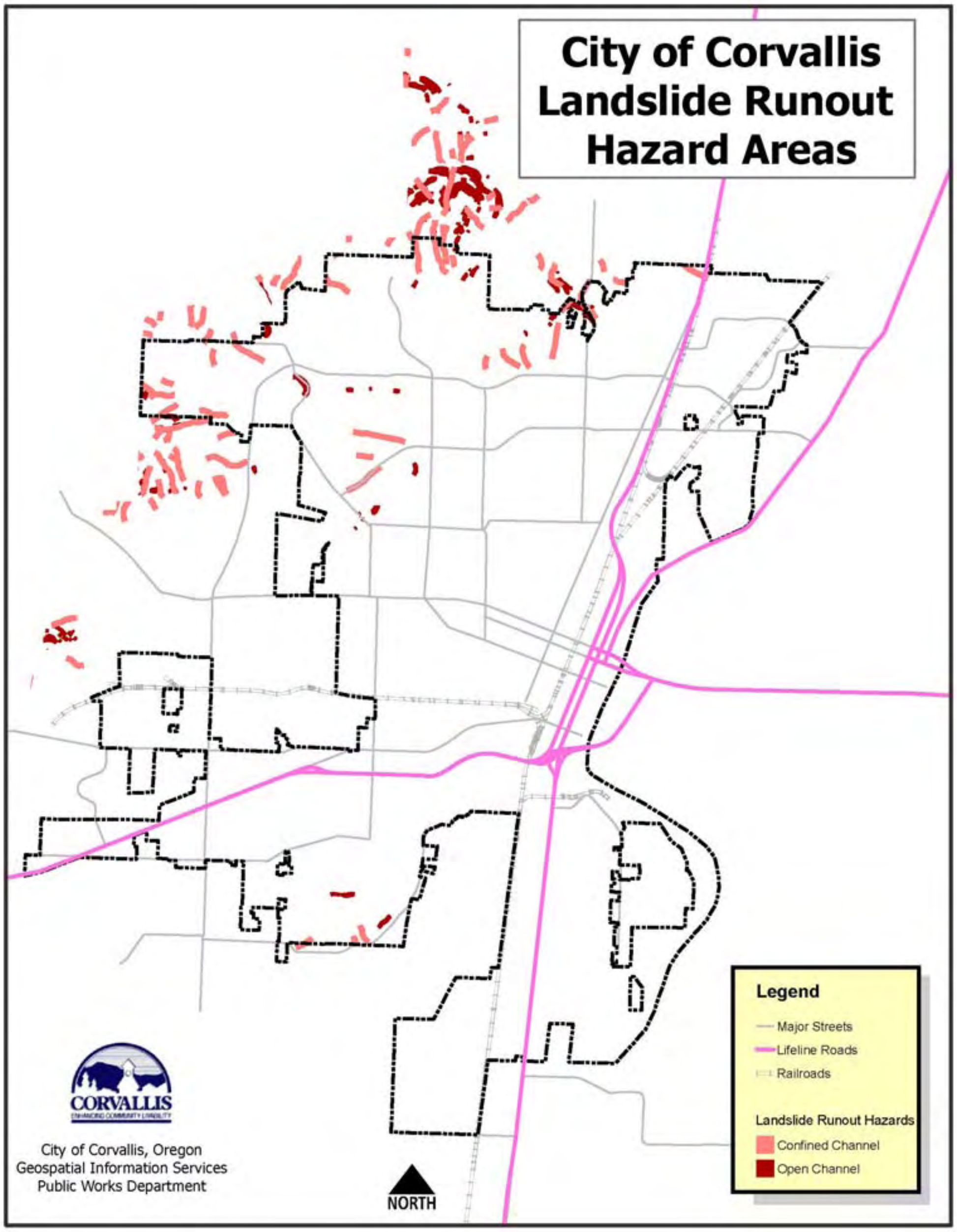
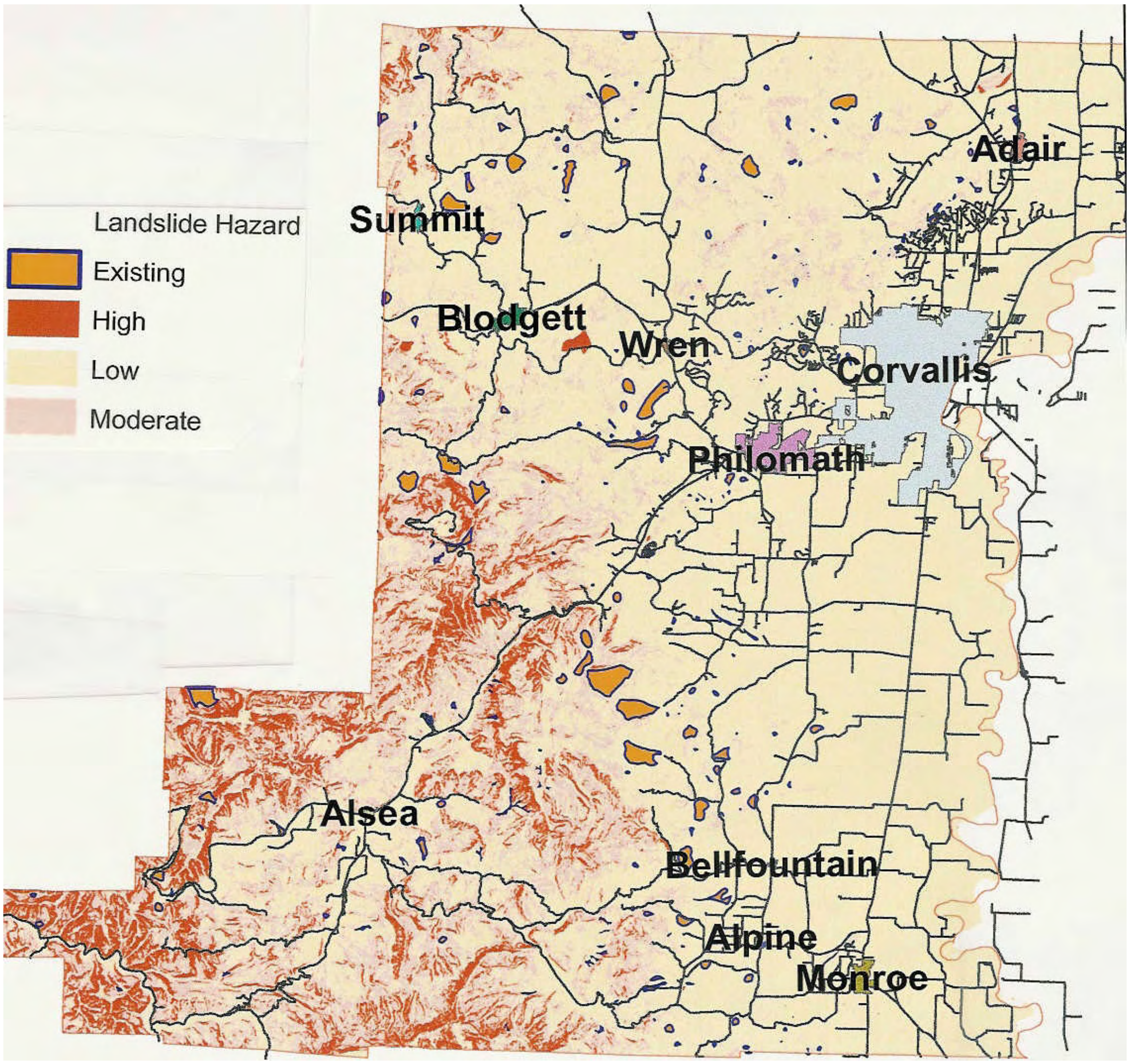
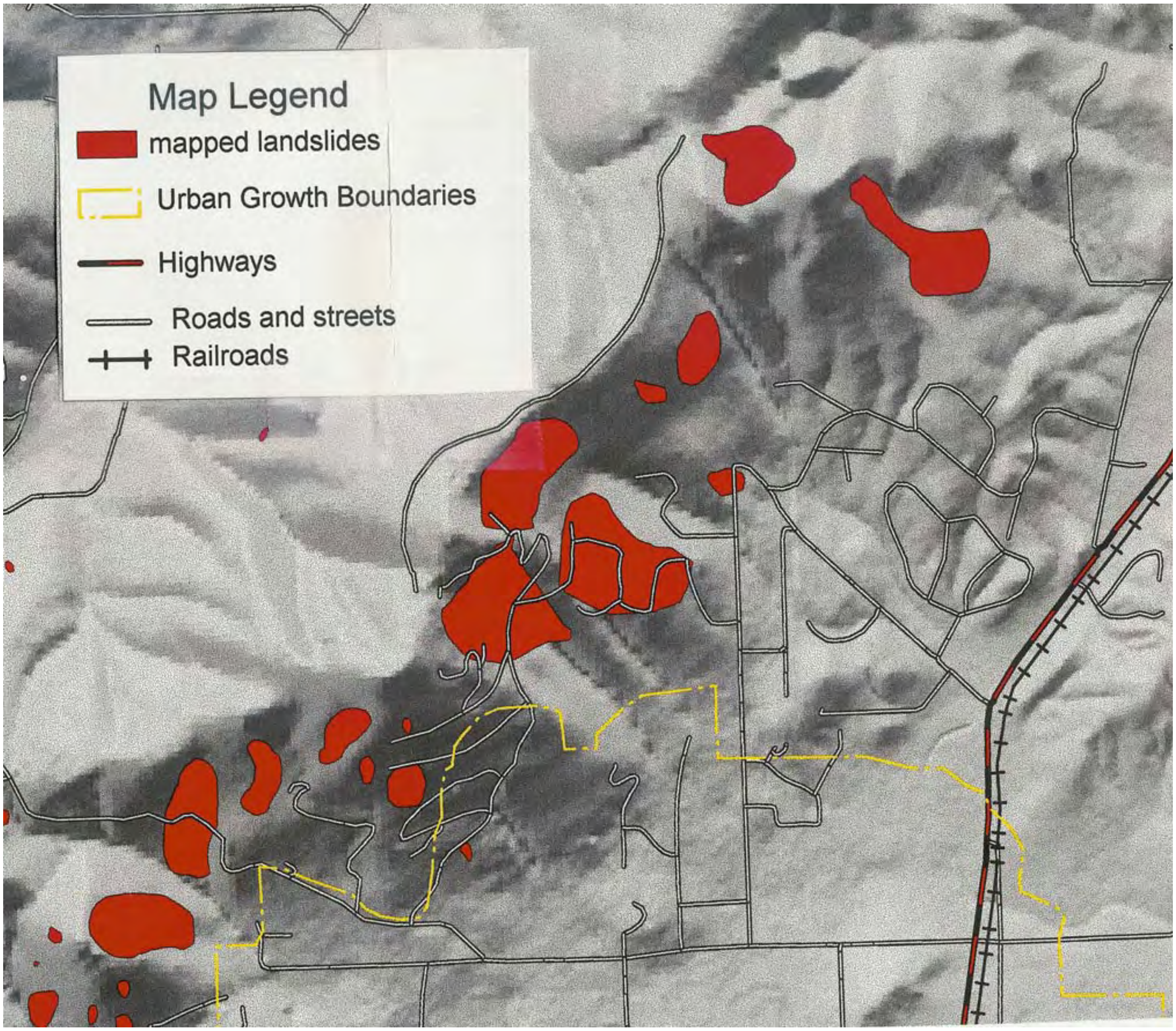


Figure 8.7
DOGAMI Earthquake-Induced Landslide Hazard Map for Benton County[1]



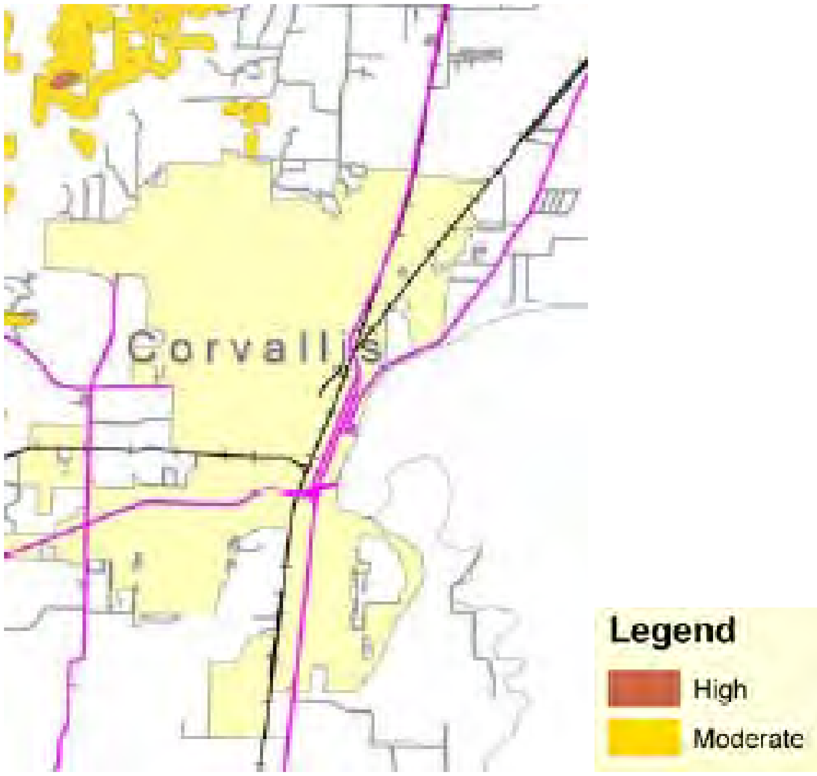
[1]Preliminary Earthquake Hazard and Risk Assessment and Water-Induced Landslide Hazard in Corvallis, Oregon. (Zhenming Wang, Gregory Graham, and Ian Madin, DOGAMI, Open File Report O-01-05, 2001)

Figure 8.8
DOGAMI Preliminary Map of Active Slide Areas in North Corvallis Area[1]



Preliminary Landslide Hazard Map of the Corvallis-Philomath Urban Areas, Corvallis, Oregon (Ian Madin, DOGAMI).

Figure 8.9
Debris Flow Hazard Areas: North Corvallis and Vicinity



8.3 Landslide Risk Assessment for Corvallis

The potential impact of debris flows and landslides on Corvallis are summarized below in Table 8.1.

Table 8.5
Potential Impacts of Debris Flows and Landslides on Corvallis

Inventory	Probable Impacts
Portion of Corvallis affected	Landslide prone areas in Corvallis include parts of North Corvallis, a few other areas, and portions of river and stream bank areas.
Buildings	Buildings subject to landslides include a few residential buildings in the North Corvallis area.
Streets within communities	Minor road closures possible from landslides; limited impact because of generally short detour routes within communities.
Roads within and to/from Corvallis	Minimal risk for highways in immediate vincinity of Corvallis. Highways through the coast range or Cascades are subject to closures from landslides.
Electric power	Very minor otential for localized loss of electric power due to landslides affecting power lines in portions of North Corvallis.
Other Utilities	Potential outages of water, wastewater and natural gas from pipe breaks from landslides. Probable impacts are very localized.
Casualties	Landslides that impact buildings or roads could result in a small number of casualties (deaths and injuries).

8.4 Mitigation of Landslide Risk

In terms of public safety there are two broad types of landslides to be concerned about: 1) those that can be sometimes be solved by engineering methods (such as road fill failures and slow moving landslides, and 2) those that can typically only be solved through prudent location of buildings, roads, and utilities (debris flows, debris torrents). It is important to make this distinction to understand that some landslide problems do not lend themselves to engineering solutions.

Mitigation of landslide risks is often quite expensive. In some cases, slope stability can be improved by addition of subsurface drainage to reduce pore water pressure, by construction of appropriate debris dams, retaining walls or by other types of geotechnical remediation. In some cases, buildings can be hardened to reduce damages. An alternative mitigation strategy for already built buildings or infrastructure with high potential for landslide losses is to relocate the facilities outside of known slide areas.

Mitigation of landslide risk can also be accomplished by effective land use planning to minimize development in slide-prone areas. Generally, such land use planning requires rather detailed geotechnical mapping of slide potential so that high hazard areas can be demarcated without unnecessarily including other areas of low slide potential.

The impacts of slide damage on road systems can also be partially addressed by identifying areas of high slide potential or of repetitive past slide damages so that alternative routes for emergency response can be pre-determined.

The following table contains landslide mitigation action items from the master Action Items table in Chapter 4.

Table 8.2
Landslide Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Landslide Mitigation Action Items								
Short-Term #1	Complete a detailed inventory of locations where critical facilities and infrastructure are subject to landslides	Public Works, Community Development	1-5 Years	X	X	X	X	X
Long-Term #1	Consider landslide mitigation actions for slides seriously threatening critical facilities, other buildings or infrastructure	Public Works, Community Development	5 Years	X	X	X	X	X
Long-Term #2	Limit future development in high landslide potential areas	Community Development	Ongoing	X	X	X	X	X

9.0 WILDLAND/URBAN INTERFACE FIRES

Fire has posed a threat to mankind since the dawn of civilization. Fires may cause significant damage to property and may also result in deaths and injuries. For the purposes of mitigation planning, we consider three types of fires: structure fires, wildland fires, and wildland/urban interface fires.

> Structure fires are fires in urban, suburban or rural areas where structures (and contents) are the primary fire fuel. Structure fires predominantly affect residential and other ordinary buildings. However, structure fires may also affect other types of structures, including bulk fuel storage or hazmat facilities. Fires affecting these types of facilities may be particularly hazardous to both firefighters and nearby residents. Fires on pipelines and transportation fires (road, rail, air) generally have similar characteristics to fires at hazmat sites or structures.
>
> Wildland fires are fires where vegetation (grass, brush, trees) is the primary fire fuel.
>
> Wildland/urban interface fires are fires where the fire fuel includes both structures and vegetation. Wildland/urban interface fires are basically wildland fires that burn into developed areas.

The emphasis of this chapter is on wildland/urban interface fires because such fires are natural disasters that may affect large developed areas and large numbers of people. Thus, wildland/urban interface fires are of special concern for mitigation planning. Most structure fires are limited to one structure. Structure fires involving bulk fuel, hazardous materials, pipelines, and transportation fires have many similarities in response strategies and impacts to the more general discussion of Hazmat Incidents, as discussed in Chapter 14. Wildland fires, by definition, affect wildlands with generally limited impacts on developed areas.

Chapter 9 of the Benton County Hazard Mitigation Plan includes useful background information on various types of fires. For conciseness, this background information is not repeated here.

9.1 Wildland/Urban Interface Fires

9.1.1 Overview

Wildland/urban interface fires are fires where the fuel load consists of both vegetation and structures. In Oregon, including Benton County and Corvallis, as elsewhere in the United States, recent patterns of development have lead to increasing numbers of homes built in areas subject to wildland fires. Development in areas subject to wildland fires may pose high levels of life safety risk for occupants as well as high levels of fire risk for homes and other structures.

Urban or suburban areas may have a significant amount of landscaping and other vegetation. However, in such areas the fuel load of flammable vegetation is not continuous, but rather is broken by paved areas, open space and areas of mowed, often irrigated, grassy areas with low fuel loads. In these areas, the vast preponderance of all significant fires are single structure fires. The combination of separations between buildings, various types of fire breaks, and generally low total vegetative fuel loads make the risk of fire spreading much lower than in wildland areas. Furthermore, most developed areas in urban and suburban areas have water systems with good capacities to provide water for fire suppression and organized fire agencies who typically respond quickly to fires, with sufficient personnel and apparatus to control fires effectively. Thus, in such areas the risk of a single structure fire spreading to involve multiple structures is generally quite low.

Areas subject to wildland/urban interface fires have very different fire hazard characteristics. The defining characteristic of the wildland/urban interface area is that structures are built in areas with essentially continuous (and often high) vegetative fuel loads. In other words, structures are built in areas subject to wildland fires. When wildland fires occur in such areas, they tend to spread quickly and structures in these areas may, unfortunately, become little more than additional fuel sources for wildland fires. The siting of homes has also changed over time. Historically pioneering families built their homes in low lands, close to water and the fields they intended to work, while during the last 30 years or so, rural homes have increasingly been built in locations chosen because of the view or other amenities. Thus, many newer homes are in locations more difficult to defend against wildland fires.

The fire risk to structures and occupants in wildland/urban interface areas is high not only because of the high vegetative fuel loads but also because fire suppression resources are typically much lower than in urban or suburban areas. Homes in wildland/urban interface areas are most commonly on wells rather than on municipal water supplies. Thus, the availability of water for fire suppression is often severely limited. Less availability of water resources makes it more likely that a small wildland fire or a single structure fire in an urban/wildland interface area will spread before it can be extinguished.

Furthermore, because many developments in interface areas have relatively low populations and are some distance from population centers, the availability of firefighting personnel and apparatus is generally lower than in more populated areas and response times are typically much longer. The longer typical response times arise in part because of greater travel distances and, thus, greater travel times, but also because most fire agencies in lower population density areas are entirely or largely composed of volunteer staff. Response times from volunteer staff fire agencies are typically longer than response times for career staff agencies, where fire stations are commonly staffed continuously. In some cases, narrow winding roads also impede access by fire fighting apparatus. As with water supplies, the lower availability of fire fighting personnel and apparatus and the longer response times increase the probability that a small wildland fire or a single structure fire in an urban/wildland interface area will spread before it can be extinguished.

Residents in many wildland/urban interface areas also face high life safety risk. High life safety risk arises because of the high fire risk, especially from large fires that may spread quickly and block evacuation. Life safety risk in interface areas is often exacerbated by limited numbers of roads (in the worst case only one access road) that are often narrow and winding and subject to blockage by a wildland fire.

Life safety risk in interface areas is also often exacerbated by homeowners' reluctance to evacuate homes quickly. Instead, homeowners often try to protect their homes with whatever fire suppression resources are available. Such efforts generally have very little effectiveness. For example, the water flow from a garden hose is too small to meaningfully impact even a single structure fire (once the structure is significantly engulfed by flames) and is profoundly too small to have any impact on a wildland fire. Unfortunately, home owners who delay evacuation in well meant but misguided attempts to save their homes often place their lives in grave jeopardy by delaying evacuation until it may be impossible.

Major fires in the urban/wildland interface have the potential for enormous destruction and very high casualties. For example, the October 20, 1991 East Bay Fire in Oakland California burned 1,600 acres with 25 fatalities, 150 injuries, and over 3300 single-family homes and 450 apartment units destroyed. Total damages were over $1.5 billion. This fire was fueled by very high vegetative fuel loads and occurred on an unusually hot, dry, windy day. The fire spread extremely quickly, with over 800 homes engulfed by fire within the first hour, and completely overwhelmed initial fire suppression efforts.

In October 1991, rural counties near Spokane Washington experienced 92 separate fires that burned about 35,000 acres and 114 homes. Between October 25 and November 3, 1993, 21 major wildland fires broke out in California. These fires burned over 189,000 acres and destroyed over 1,100 structures with 3 fatalities and hundreds of injuries. The worst wildland/urban interface fire in United States history as far as casualties are concerned occurred in 1871 in Peshtigo, Wisconsin. This fire burned over 1.2 million acres and killed over 1,200 people. In 2003, a series of wildland/urban interface fires in southern California (San Bernardino area) burned over 750,000 acres and destroyed over 3,000 homes. These few examples dramatically illustrate the potential for disasters in the urban/wildland interface area.

9.1.2 Historical Data for Wildland Fires in Oregon

The Oregon Department of Forestry website (www.odf.state.or.us) has a table of the most important historical fires in Oregon over the past 150 years. Of the 12 major fires, the five largest fires all occurred between 1848 and 1868. The two largest fires, the 1868 Coos Bay fire and the 1849 Siletz fire consumed 988,000 and 800,000 acres of wildland, respectively. The next four largest fires occurred between 1933 and 1945, with each fire consuming between 240,000 and 180,000 acres. The most recent fire listed, the 1987 Silver Fire burned 97,000 acres. None of these major fires occurred in Benton County. More recent major fires include the 2002 Biscuit Fire that burned nearly 500,000 total acres (with about 471,000 acres in Oregon and nearly 29,000 acres in California) and the 2003 B&B Complex fire that burned 90,769 acres.

The Oregon Department of Forestry website (www.odf.state.or.us) has several categories of wildland fire data listed, including: numbers of forest fires and numbers of acres burned in Oregon forest lands. However, these ODF data are <u>only</u> for ODF-responsibility lands and do not include forest lands where primary fire suppression responsibility is federal or local. These data provide one measure of wildland fire data for Oregon. For ODF responsibility lands in Oregon as a whole, the 10-year average number of wildland fires is 1,062. Since 1986, the largest number of acres burned in one year was 99,060 in 2002, while the lowest number of ODF-responsibility acres burned in one year was 1,410 in 1997. For the entire state of Oregon, both the number of fires and the acres burned are higher than these ODF data alone.

9.2 Wildland/Urban Interface Fire Risk for Corvallis

An overview perspective on wildland/urban interface fire risk for Corvallis and vicinity is provided by the vegetation map of Benton County, which is shown in Figure 9.1.

Most of the vegetated areas in Benton County are classified as Douglas Fir – Western Hemlock, with areas of Douglas Fir – Broadleaf Deciduous, and areas of Douglas Fir – Oregon White Oak and Oregon White Oak – Douglas Fir. Along the Willamette River Valley there are areas of Cottonwood-Willow Riparian, and Pasture Riparian Bottomland, and Agricultural lands with these classifications being as per the Atlas of Oregon.

Vegetation Codes for Benton County Include:

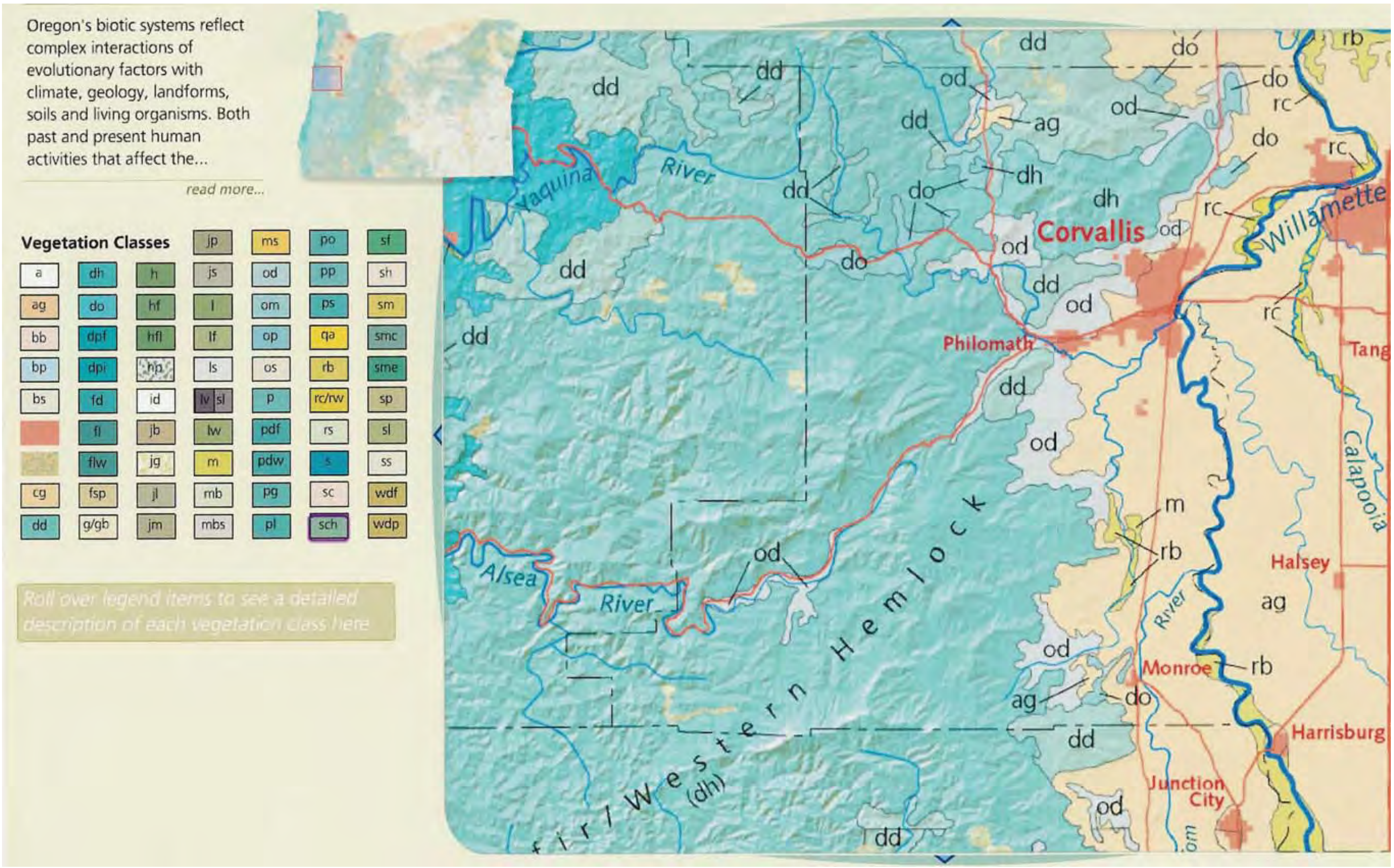
dd	Douglas fir – broadleaf deciduous,
dh	Douglas fir – western hemlock,
do	Douglas fir – Oregon white oak,
od	Oregon white oak – Douglas fir,
m	Marsh,
rc	Cottonwood – willow riparian,
rb	Pasture – riparian bottomland, and
ag	agricultural.

As shown on Figure 9.1, Corvallis is bordered on the north and northwest sides by forested areas, classified as Oregon white oak – Douglas fir (classification “od” on the map). On the east, south and southwest sides, Corvallis is bordered by agricultural lands (classification “ag” on the map) with low potential for wildland/urban interface fires.

The three primary factors governing the level of hazard for wildland fires or wildland/ urban interface fires are: fuels (type and load), weather and topography. For Corvallis, the fuel load in the nearby forested areas to the north and northwest of the city is generally high and relatively continuous across large geographic areas. Because of historical logging activities, much of the forest is composed of relatively young trees, with a high density of trees per acre. Such forests may pose a higher fire hazard than do old growth forests with fewer, larger trees.

Topography contributes to fire hazard because fires spread much more quickly up steep slopes. Weather is very important in governing the level of fire hazard. Rainfall amounts and patterns contribute to the level of fuel load and also to moisture levels in vegetation. During fires, temperature, humidity and wind speed are major factors governing the rate of spread of wildland fires and thus major factors governing the ease or difficulty with which a given fire is likely to be contained.

Figure 9.1
Vegetation Cover in Benton County (Atlas of Oregon)



Developments in wildland/urban interface areas face a range of levels of fire risk, depending on a number of factors. Developments that have all of most of the following attributes are at the highest level of risk:

1) High vegetative fuel loads, with a high degree on continuity of fuel load (i.e., few significant firebreaks). Risk may be particularly high if the fuel load is grass, brush and smaller trees, subject to being at very low moisture levels in short duration drought periods.

2) Higher slopes, which cause fires to spread more rapidly than in flatter terrain.

3) Limited fire suppression capacity, including limited water supply capacity for fire suppression purposes, limited fire fighting personnel and apparatus, and typically long response times for fire alarms.

4) Limited access for fire fighting apparatus and limited evacuation routes for residents at risk.

5) Construction of structures to less than fully fire-safe practices, and

6) Lack of maintenance of firebreaks and defensible zones around structures.

Fire protection services for Corvallis and adjacent areas are provided by three local fire agencies:

Corvallis Fire Department,
Corvallis RFPD, and
Philomath Fire District.

Specific geographic areas identified by the Corvallis Fire Department and the Corvallis RFPD as being at risk for wildland/urban interface fires are summarized in Table 9.1 (from Benton County Hazard Mitigation Plan).

Table 9.1
Areas of Special Concern for Wildand/Urban Interface Fires

Corvallis **Geographic Area of Concern**	**Narrative of High Risk Situation**	**High Vegetative Fuel Loads**	**Poor Vegetation Clearance Around Structures**	**Non-Firesafe Construction Practices**	**Steep Topography**	**Limited Access/Egress**	**Limited Water Supplies**	**Distance/Time from Fire Dept**
Crescent Valley / Vineyard Mountain	Area of high value homes from 10 to 40 years old in forested area in the Corvallis RFPD	X	X	X	X	X	X	
Oak Creek	West of Corvallis along Oak Creek for about 5 miles	X	X	X	X	X	X	X
Skyline West	Northwest of Corvallis off Ponderosa Drive in forested area with areas of heavy underbrush. Many homes have brush adjacent to structure and combustible roofing.	X	X	X	X	X	X	

Wildland/urban interface fire risk for at risk neighborhoods near the city boundaries on the north and northwest sides is increased by:

1) Inadequate water supply for fire suppression in many areas,
2) Lack of defensible space around structures or fire breaks,
3) Inadequate road system with steep grades, narrow streets, lack of secondary access routes, no turnarounds or turnarounds on long dead end streets, and
4) Prevalence of non-fire rated construction with combustible roofing and exterior wall covering materials, with open decks and eves.

The Skyline West subdivision is of particular concern to the Corvallis Fire Department because this is a forested residential area with areas of heavy underbrush. Many homes have brush adjacent to structures and combustible roofing. Fire risk is compounded by the steep topography in parts of this area and by limited or nonexistent water supplies sufficient for controlling a major fire. The only access/egress to Skyline West is via NW Ponderosa Avenue. Thus, timely evacuation in the event of a major fire and restricted access for fire fighting apparatus are both problematic.

An aerial view of the Skyline West subdivision showing the heavy vegetative fuel loads in close proximity to structures is shown below in Figure 9.2.

Figure 9.2
Skyline West Subdivision

The potential impacts of wildland/urban interface fires on Corvallis are summarized below in Table 9.2.

Table 9.2
Potential Impacts of Wildland/Urban Interface Fires on Corvallis

Portion of Corvallis affected	Highest risk areas are residential areas bordering heavily vegetated wildland areas in the north and northwest parts of Corvallis along with adjacent portions of Benton County.
Buildings	Small wildland/urban interface fires could affect a few residential buildings. Larger fires could effect entire neighborhoods and extreme events (cf. Oakland Hills 1991 fire) could affect hundreds of buildings
Streets within communities	Minor road closures possible from fires; limited impact because of short detour routes within communities.
Roads within and to/from Corvallis	Potential closures of major highways due to fires, especially roads west of Corvallis.
Electric power	Potential for localized loss of electric power due to fires affecting power lines in or near Corvallis
Other Utilities	Generally minor or no impacts on other utilities from fires, except for possible loss of telephone service due to fires affecting phone poles/lines.
Casualties	Potential for deaths and injuries in major wildland/urban interface fires, especially if evacuations are not completed expeditiously.

9.3 Mitigation Strategies

This section outlines suggested strategies for reducing the level of risk to both property and life safety in wildland/urban interface development areas that may be at high risk from wildland/urban interface fires. The suggested mitigation strategy has four elements:

1) reduce the probability of fire ignitions,
2) reduce the probability that small fires will spread,
3) minimize property damage, and
4) minimize the life safety risk.

Reduce the probability of fire ignitions

Efforts to reduce the probability of fire ignitions should focus on manmade causes of ignition through a combination of fire prevention education, enforcement, and other actions. Fire prevention education actions could include efforts to heighten public awareness of fire dangers, especially during high danger time periods and better education about fire safe practices, such as careful disposal of smoking materials, and adhering to restrictions on burning of rubbish and debris. Fire prevention enforcement action could include strict enforcement of burning restrictions and vigorous investigation and prosecution of arson cases. An important physical action to reduce the probability of ignitions is to maintain or upgrade tree-trimming operations around power lines to minimize fires starting by sparking from lines to vegetative fuels.

Reduce the probability that small fires will spread.

Possible mitigation actions to reduce the probability that small fires will spread include enhancement of water supply and fire suppression capabilities for high risk areas, expansion of existing firebreaks, creation of new firebreaks and expanding defensible spaces around structures in wildland/urban interface areas. Geographical area specific pre-emergency planning by jurisdiction should also be conducted to help optimize fire response strategies.

Minimize Property Damage

The education and action items discussed above may help to reduce future property damages by reducing the number of fire ignitions and by reducing the probability that a small fire will spread. In addition, specific fire safe building practices should be implemented (if not yet implemented) or enforced vigorously (if not yet vigorously enforced). Fire safe building practices have two main elements: first, design of structures, and second, creation of defensible spaces around structures.

The USFA (www.usfa.fema.gov) and other organizations have many sources of information about fire safe practices in the wildland/urban interface. For example, the National Fire Protection Association (NFPA) has an excellent "Firewise" communities program with an excellent, highly informative website (www.firewise.org). The firewise website can also be reached from the main NFPA website (www.nfpa.org). The Firewise website has very informative publications and videos for local officials and homeowners to help understand, evaluate, and improve the fire safety of structures at risk from wildland/urban interface fires. Similar information is also available at the FireFree site by the Safeco Insurance Company: (www.safeco.com/safeco/about/giving/firefree.asp)

The NFPA Firewise construction and firewise landscaping checklists are particularly recommended as concise summaries of the primary fire-safe designs and practices for homeowners at risk from wildland/urban interface fires.
The NFPA's Firewise Construction Checklist, makes the following main recommendations (among others):

1) site homes on as level terrain as possible, at least 30 feet back from cliffs or ridge lines,

2) build homes with fire-resistant roofing materials, such as Class-A asphalt shingles, slate or clay tiles, concrete or cement products, or metal.

3) build homes with fire-resistant exterior wall cladding, such as masonry or stucco,

4) consider the size and materials for windows; smaller panes hold up better than larger ones, double pane and tempered glass windows are more fire resistant than single pane windows; plastic skylights can melt and allow access for burning embers,

5) prevent sparks and embers from entering vents by covering vents with wire mesh no larger than 1/8", box eaves, and minimize places to trap embers on decks and other attached structures, and

6) keep roofs, eaves, and gutters free of flammable debris.

The NFPA's Firewise Landscaping Checklist includes the following main recommendations (among others), based on a four-zone planning concept around the house:

1) Zone 1 should be well irrigated area of closely mowed grass or non-flammable landscaping materials such as decorative stone, at least 30' in all directions around the home,

2) Zone 2 should be a further irrigated buffer zone with only a limited number of low-growing, fire-resistant plants,

3) Zone 3, further from the house, can include low growing plants and well-spaced, well-pruned trees, keeping the total vegetative fuel load as low as possible, and

4) Zone 4 is the natural area around the above three landscaped zones. This area should be thinned selectively, with removal of highly flammable vegetation and removal of ladder fuels that can spread a grass fire upwards into tree tops.

Minimize Life Safety Risk

The mitigation actions above may help to minimize life safety risk by helping to reduce the number of ignitions, by reducing the probability that small fires will spread, and by encouraging more fire-safe practices of building construction and fire-safe landscaping. These practices are meritorious for reducing the fire hazards to structures. However, they may also give homeowners a false sense of life safety security. A false sense of security may encourage people to stay in homes at risk during wildfires, rather than evacuating immediately at the first fire warning.

The most important action to minimize life safety risk during wildland/urban interface fires is immediate evacuation. However, evacuations must be directed by the responsible fire agencies to ensure both egress for residents and access for fire apparatus and personnel. Uncontrolled evacuations can sometimes block access and thus potentially increase fire spread. Thus, reducing life safety risk requires public education and emergency planning to encourage and expedite warnings and evacuations (voluntary or mandatory).

Life safety risk during wildland/urban interface fires is exacerbated by limited evacuation routes. Improving evacuation roads (widening, straightening) and, most importantly, providing as many alternate evacuation routes as possible can significantly reduce evacuation times and lower the probability that residents seeking to evacuate may be trapped by fire-blocked routes.

The following table contains wildland/urban interface fire mitigation action items from the master Action Item table in Chapter 4.

Table 9.3
Wildland/Urban Interface Fire Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Wildland/Urban Interface Fire Mitigation Action Items								
Short-Term #1	Identify specific parts of Corvallis at high risk for urban/wildland interface fires because of fuel loading, topography and prevailing construction practices	Fire	1-2 Years	X	X	X	X	X
Short-Term #2	Identify evacuation routes and procedures for high risk areas and educate the public	Fire	Ongoing	X	X	X		X
Short-Term #3	Develop Corvallis Wildfire Protection Plan	Fire	1-2 Years	X	X	X	X	X
Long-Term #1	Encourage fire-safe construction practices for existing and new construction in high risk areas	Fire, Community Development	Ongoing	X	X	X	X	X

10.0 EARTHQUAKES

Historically, awareness of seismic risk in Oregon has generally been low, among both the public at large and public officials. This low level of awareness reflected the low level of seismic activity in Oregon, at least in recent historical time. However, over the past several years, awareness of seismic risk in Oregon has significantly increased. Factors in this increased awareness include the 1993 Scotts Mills earthquake in Clackamas County, widespread publicity about possible large magnitude earthquakes on the Cascadia Subduction Zone, and recent changes in Seismic Zonation in the Oregon Building Code which increased seismic design levels for new construction in western Oregon.

Before reviewing the levels of seismic hazard and seismic risk in Corvallis, we first present a brief earthquake “primer” that reviews some basic earthquake concepts and terms.

10.1 Earthquake Primer

In the popular press, earthquakes are most often described by their Richter Magnitude (M). Richter Magnitude is a measure of the total energy released by an earthquake. In addition to Richter magnitude, there are several other measures of earthquake magnitude used by seismologists, but such technical details are beyond the scope of this discussion. The Scotts Mills (Oregon) earthquake was M = 5.6, while the Northridge (California) earthquake was about M = 6.7. Great earthquakes, for example, on the San Andreas Fault or on the Cascadia Subduction Zone, may have magnitudes of 8 or greater.

It is important to recognize that the Richter scale is not linear, but rather logarithmic. A M8 earthquake is not twice as powerful as a M4, but rather thousands of times more powerful. A M7 earthquake releases about 30 times more energy than a M6, while a M8 releases about 30 times more energy than a M7 and so on. Thus, great M8 earthquakes may release thousands of times as much energy as do moderate earthquakes in the M5 or M6 range.

The public often assumes that the larger the magnitude of an earthquake the “worse” the earthquake. Thus, the “big one” is the M8 earthquake and smaller earthquakes (M6 or M7) are not the “big one”. However, this is true only in very general terms. Larger magnitude earthquakes affect larger geographic areas, with much more widespread damage than smaller magnitude earthquakes. However, for a given site, the magnitude of an earthquake is NOT a good measure of the severity of the earthquake at that site. Rather, the intensity of ground shaking at the site depends on the magnitude of the earthquake <u>and</u> on the distance from the site to the earthquake. An earthquake is located by its epicenter - the location on the earth’s surface directly above the point of origin of the earthquake. Earthquake ground shaking diminishes (attenuates) with distance from the epicenter. Thus, any given earthquake will produce the strongest ground motions near the earthquake with the intensity of ground motions diminishing with increasing distance from the epicenter.

Thus, for a given site, a smaller earthquake (such as a M6.5) which is very close to the site could cause greater damage than a much larger earthquake (such as a M8) which is quite far away from the particular site.

However, earthquakes at or below M5 are not likely to cause significant damage, even locally very near the epicenter. Earthquakes between about M5 and M6 are likely to cause some damage very near the epicenter, with the extent of damage typically being relatively minor (e.g., the 1993 Scotts Mills earthquake). Earthquakes of about M6.5 or greater can cause major damage (e.g., the Northridge earthquake), with damage usually concentrated fairly near the epicenter. Larger earthquakes of M7+ cause damage over increasingly wider geographic areas with the potential for very high levels of damage near the epicenter. Great earthquakes with M8+ can cause major damage over wide geographic areas. For example, a M8+ on the Cascadia Subduction Zone could affect the entire Pacific Northwest from British Columbia, through Washington and Oregon, and as far south as Northern California.

The intensity of ground shaking varies not only as a function of M and distance but also depends on soil types. Soft soils may amplify ground motions and increase the level of damage. Thus, for any given earthquake there will be contours of varying intensity of ground shaking. The intensity will generally decrease with distance from the earthquake, but often in an irregular pattern, reflecting soil conditions (amplification) and possible directionality in the dispersion of earthquake energy.

There are many measures of the severity or intensity of earthquake ground motions. A very old, but commonly used, scale is the Modified Mercalli Intensity scale (MMI), which is a descriptive, qualitative scale that relates severity of ground motions to types of damage experienced. MMIs range from I to XII.

More useful, modern intensity scales use terms that can be physically measured with seismometers, such as the acceleration, velocity, or displacement (movement) of the ground. The most common physical measure, and the one used in this Mitigation Plan, is Peak Ground Acceleration or PGA. PGA is a measure of the intensity of shaking, relative to the acceleration of gravity (g). For example, 1.0 g PGA in an earthquake (an extremely strong ground motion) means that objects accelerate sideways at the same rate as if they had been dropped from the ceiling. 10% g PGA means that the ground acceleration is 10% that of gravity and so on.

Damage levels experienced in an earthquake vary with the intensity of ground shaking and with the seismic capacity of structures. Ground motions of only 1 or 2% g are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low. Ground motions below about 10% g usually cause only slight damage. Ground motions between about 10% g and 30% g may cause minor to moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse. Ground motions above about 30% g may cause significant damage in well-designed buildings and very high levels of damage (including collapse) in poorly designed buildings. Ground motions above about 50% g may cause high levels of damage in many buildings, even those designed to resist seismic forces.

10.2 Seismic Hazards for Corvallis

Earthquakes in Western Oregon, and throughout the world, occur predominantly because of plate tectonics - the relative movement of plates of oceanic and continental rocks that make up the rocky surface of the earth. Earthquakes can also occur because of volcanic activity and due to other geologic processes.

The Cascadia Subduction Zone is a geologically complex area off the Pacific Northwest coast from Northern California to British Columbia. In simple terms, several pieces of oceanic crust (the Juan de Fuca Plate, Gorda Plate and other smaller pieces) are being subducted (pushed under) the crust of North America. This subduction process is responsible for most of the earthquakes in the Pacific Northwest as well as for creating the volcanoes in the Cascades. Figure 10.1 shows the geologic (plate-tectonic) setting for Oregon.

There are three source regions for earthquakes that can affect Corvallis:

1) “interface” or “subduction zone” earthquakes on the boundary between the subducting oceanic plates and the North American plate,

2) “intraslab” or “intraplate” earthquakes within the subducting oceanic plates, which are also known as “Benioff Zone” or deep zone earthquakes, and

3) “crustal” earthquakes within the North American Plate.

The geographic and geometric relationships of these earthquake source zones are shown in Figure 10.2

The “interface” earthquakes on the Cascadia Subduction Zone may have magnitudes of 8 or greater, with probable recurrence intervals of 500 to 800 years. The last major earthquake in this source region probably occurred in the year 1700, based on current interpretations of Japanese tsunami records. Such earthquakes are the great Cascadia Subduction Zone earthquake events that have received attention in the popular press. These earthquakes typically occur about 20 to 60 kilometers (12 to 40 miles) offshore from the Pacific Ocean coastline. Ground shaking from such earthquakes would be very strong near the coast and moderately strong ground shaking would be felt throughout Corvallis.

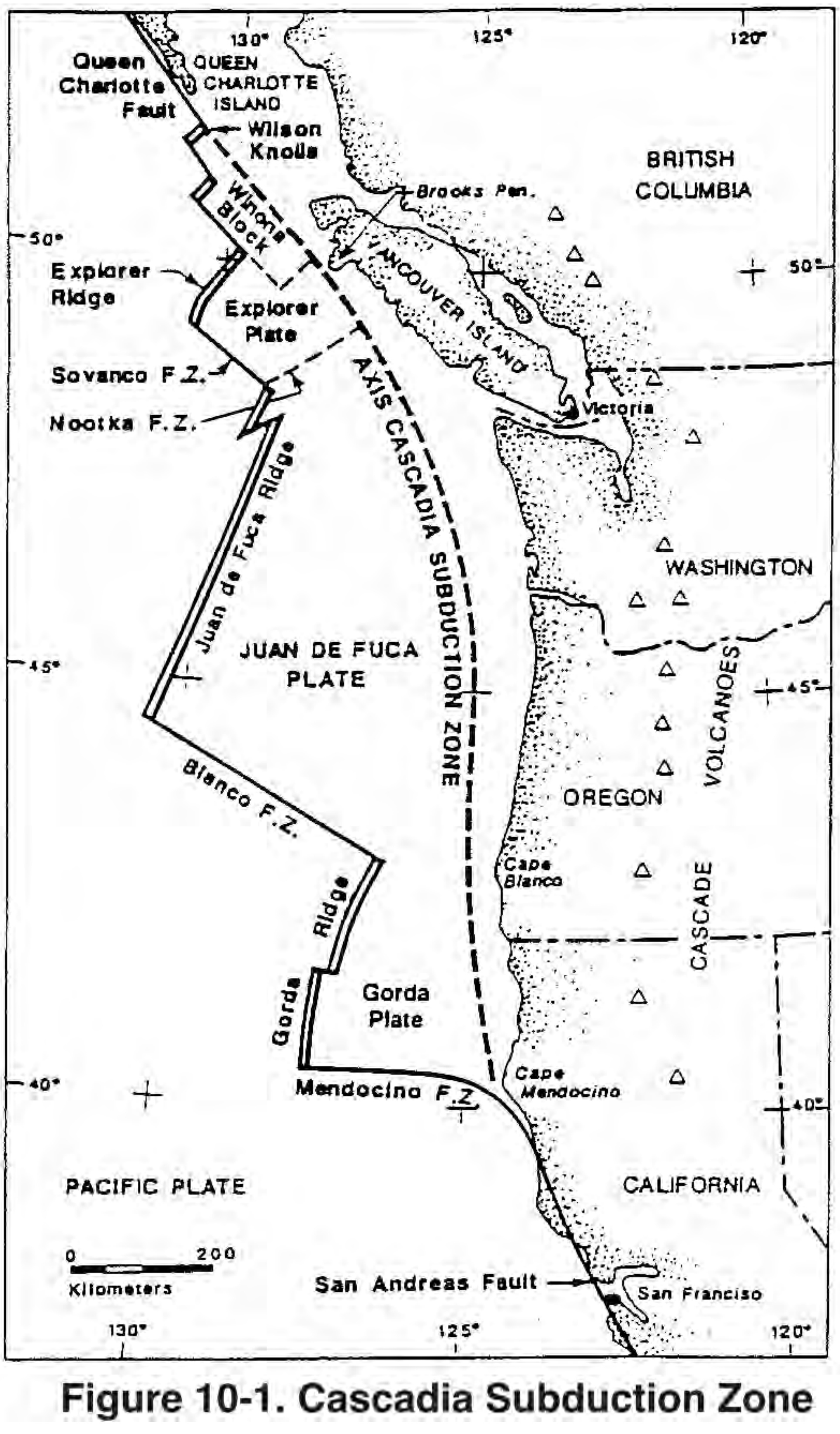


Figure 10-1. Cascadia Subduction Zone

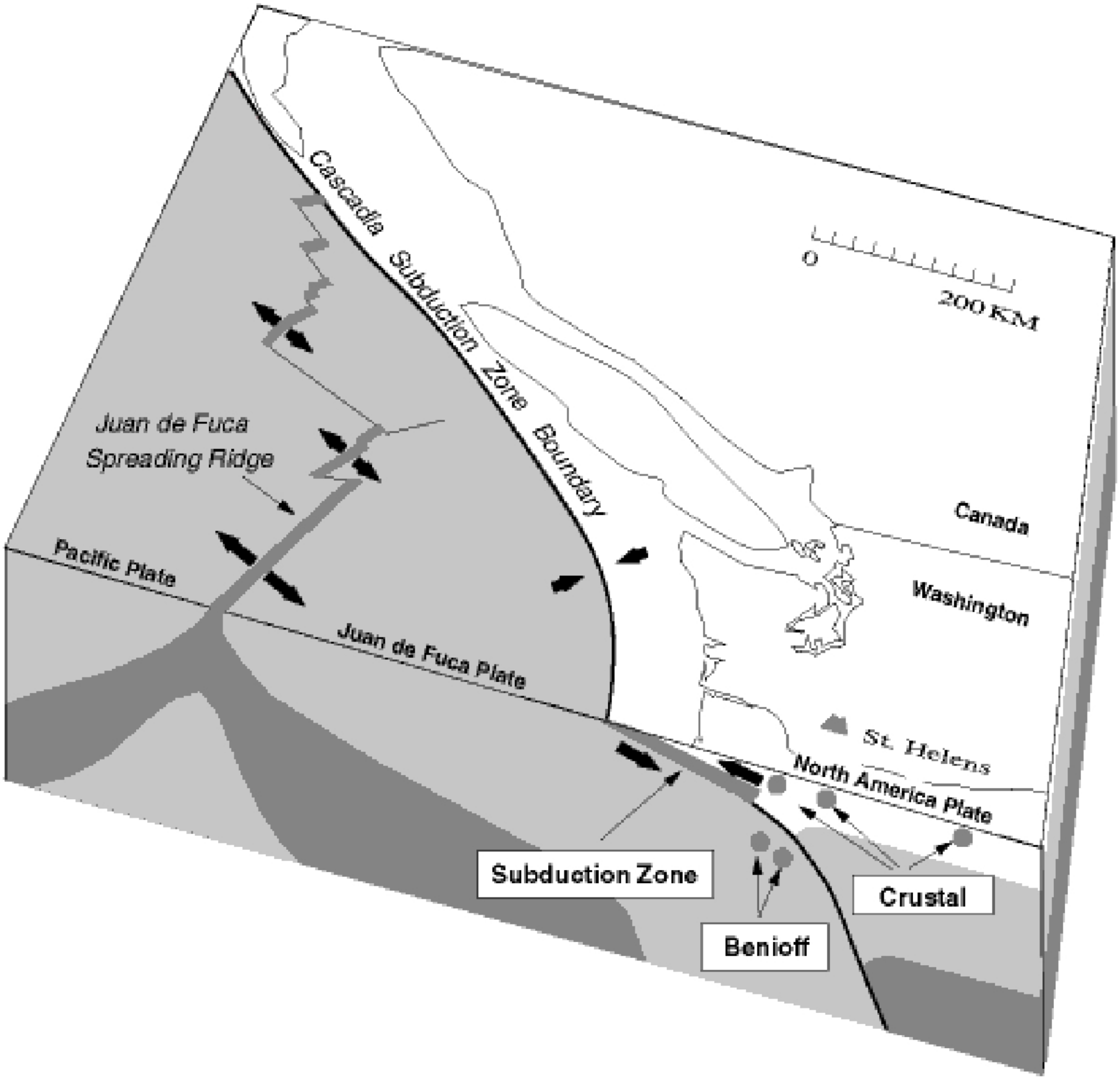


Figure 10.2
Earthquake Source Zones

The “intraslab” earthquakes, which are also called “intraplate” or “Benioff Zone” earthquakes, occur within the subducting oceanic plate. These earthquakes may have magnitudes up to about 7.5, with probable recurrence intervals of about 500 to 1000 years (recurrence intervals are poorly determined by current geologic data). These earthquakes occur quite deep in the earth, about 30 or 40 kilometers (18 to 25 miles) below the surface with epicenters that would likely range from near the Pacific Ocean coast to about 50 kilometers (30 miles) inland. Thus, epicenters from these types of earthquakes could be located in Lincoln County or western Benton County. Ground shaking from such earthquakes would be very strong near the epicenter and moderately strong ground shaking would be felt throughout all of Benton County, with the level of shaking decreasing towards eastern Benton County.

“Crustal” earthquakes within the North American plate are possible on faults mapped as active or potentially active as well as on unmapped (unknown) faults. The only mapped fault in Benton County is the Corvallis Fault, which runs in a SW to NE direction through northwest Corvallis. The Corvallis Fault and two other nearby faults, the Owl Creek Fault east of Corvallis and the Mill Creek Fault north of Albany, are shown on Figure 10.3.

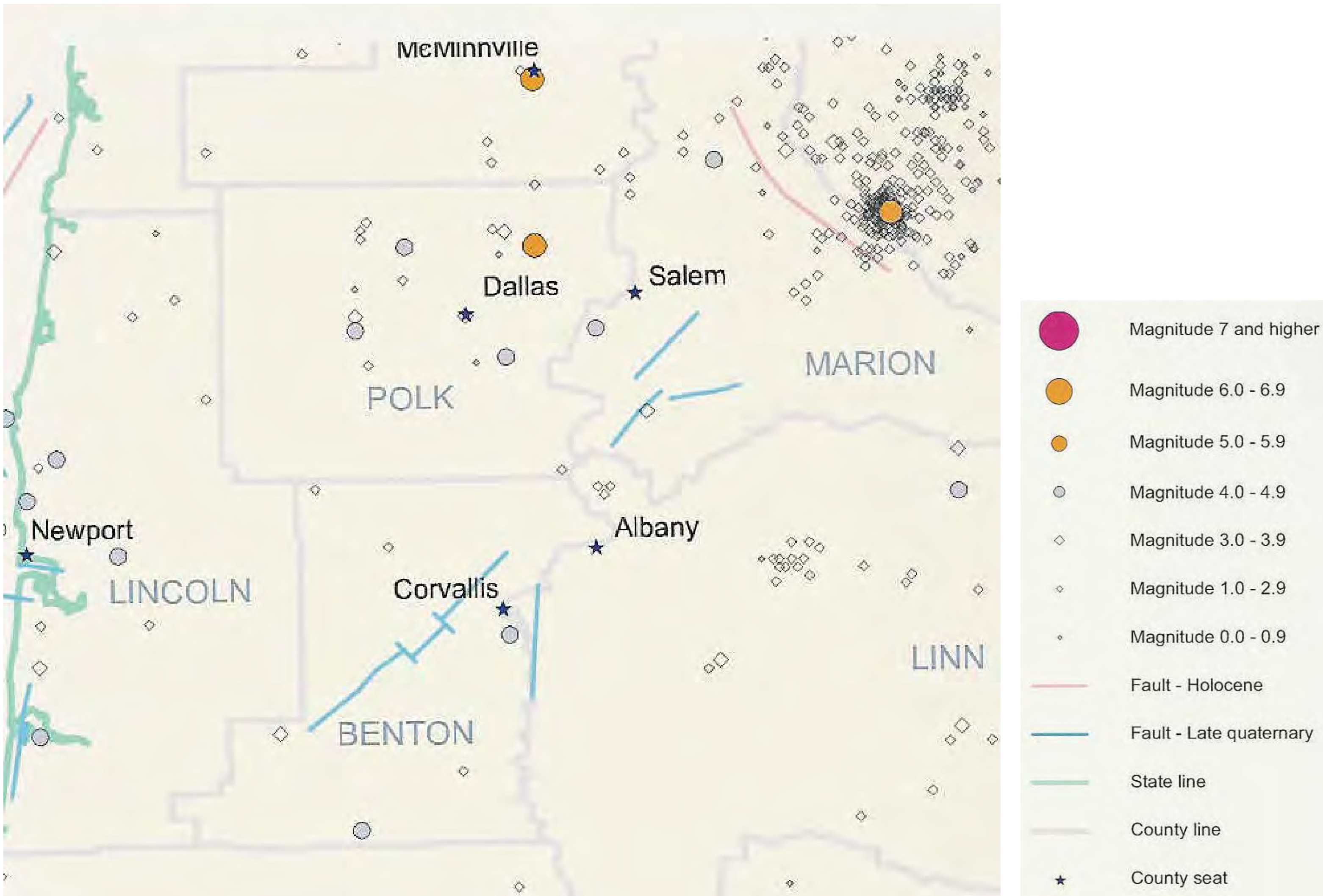
The USGS fault classifications for the above faults are Class B for the Corvallis Fault and Class A for the Owl Creek Fault and the Mill Creek Fault. For the Corvallis Fault, the classification means that the fault exists but that there is no evidence or equivocal evidence for movements during the Quaternary geologic time period (the last 1.6 million years). For the Owl Creek and Mill Creek Faults, the classification means that there has apparently been movement within the past few hundred thousand years, but not within the past 10,000 years. Thus, the risk from earthquakes on these faults appears very low.

Historically observed crustal earthquakes in Oregon from 1841 to 2002 are shown in Figure 10-3 (DOGAMI, Map of Selected Earthquakes for Oregon, 1841 through 2002, Open-File Report 03-02, 2003). During this time period, only six small earthquakes have occurred in Benton County as shown on Figure 10.3. Larger earthquakes in nearby counties are also shown.

However, based on the historical seismicity in Western Oregon and on analogies to other geologically similar areas, small to moderate earthquakes up to M5 or M5.5 are possible almost anyplace in Western Oregon, including almost anyplace in Benton County. Such earthquakes would be mostly much smaller than the Scotts Mills earthquake up to about the magnitude of that 1993 earthquake. The possibility of larger crustal earthquakes in the M6+ range cannot be ruled out. However, the probability of such events is likely to be very low.

Because the probability of large crustal earthquakes (M6 or greater) affecting Benton County is low and because any damage in smaller crustal earthquakes is likely to be minor and very localized, crustal earthquakes are not considered significant for hazard mitigation planning purposes. Therefore, our analysis focuses on the larger, much more damaging earthquakes arising from the Cascadia Subduction Zone.

Figure 10-3
Earthquake Epicenters from 1841 to 2002



The characteristics of the subduction zone earthquakes affecting Corvallis are summarized in Table 10.1 below. The maximum magnitudes are estimated from the length and width of the mapped fault plane or from similar earthquakes elsewhere in the Pacific Northwest (for the intraslab earthquakes). Recurrence intervals are based on current best estimates.

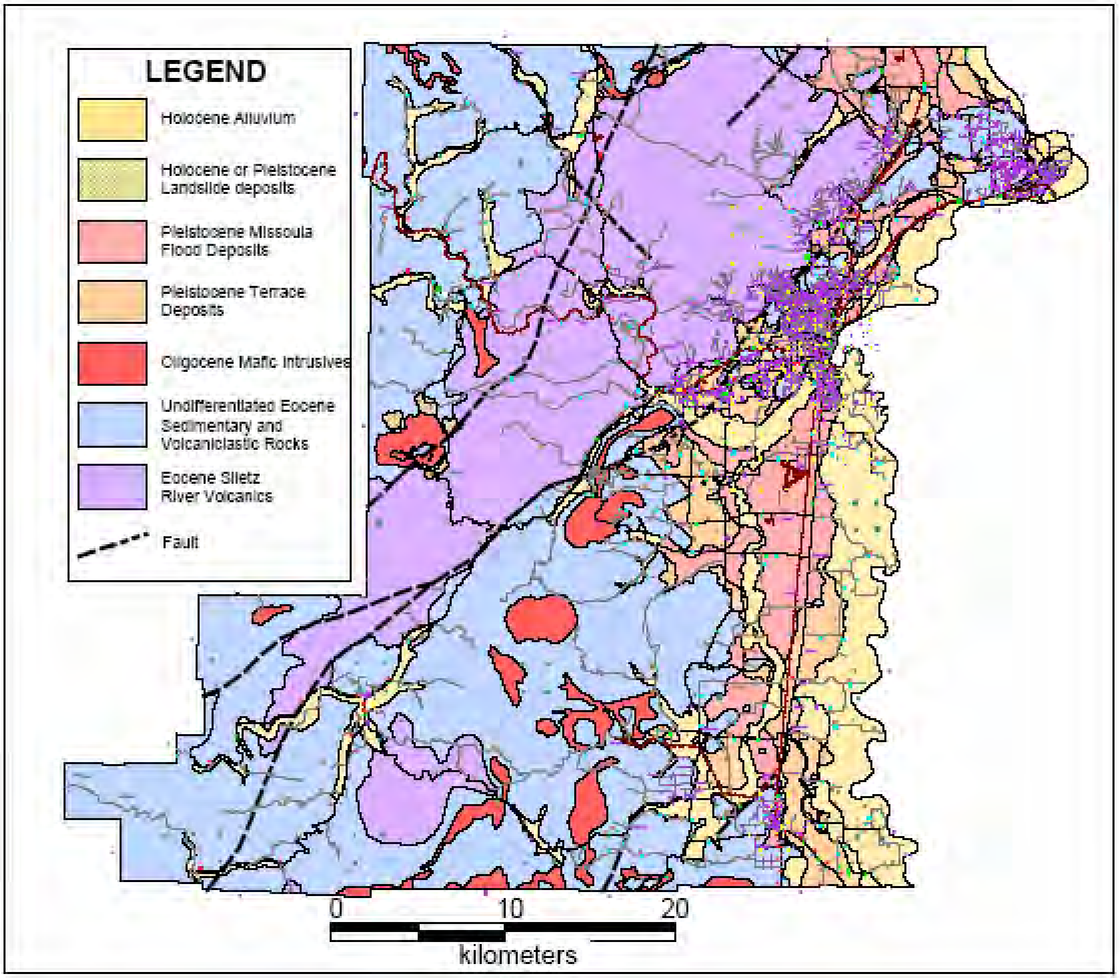
Table 10.1
Seismic Sources Affecting Corvallis

Fault	Maximum Magnitude	Probable Recurrence Interval (years)
Cascadia Subduction Zone (interface earthquake)	8.5	500 to 800
Cascadia Subduction Zone (intraslab earthquake)	7.5	500 to 1000

In addition to these large earthquakes, the Cascadia Subduction Zone also experiences smaller earthquakes such as the M6.8 Nisqually earthquake near Olympia Washington which occurred on February 28, 2001. The Nisqually earthquake was an intraslab earthquake which occurred at a depth of 52 kilometers (about 30 miles). Other relatively recent similar Cascadia Subduction Zone earthquakes include the M7.1 Olympia earthquake in 1949 and the M6.5 Seattle-Tacoma earthquake in 1965. These earthquakes killed 15 people and resulted in over $200 million in damages (1984 dollars, www.dnr.wa.gov). Similar earthquakes are possible in Western Oregon, including Benton County.

The following figure shows a generalized geologic map of Benton County and includes the Corvallis Fault and other mapped faults. The mapped faults within or near Benton County are relatively small and not very active. Thus, seismic hazard for Corvallis arises predominantly from major earthquakes on the Cascadia Subduction Zone. Smaller, crustal earthquakes in or near Benton County could be locally damaging, but would not be expected to product widespread or major damage.

Figure 10.4
Geologic Map of Benton County[1]



[1] Preliminary Earthquake Hazard and Risk Assessment and Water-Induced Landslide Hazard in Benton County, Oregon. Zehnming Wang, Gregory Graham, and Ian Madin, DOGAMI Open File Report O-01-05, 2001.

10.3 Other Aspects of Seismic Hazards in Corvallis

Most of the damage in earthquakes occurs directly because of ground shaking which affects buildings and infrastructure. However, there are several other aspects of earthquakes that can result in very high levels of damage in localized sites: liquefaction, landslides, dam failures and tsunamis.

10.3.1 Soil Effects

Liquefaction is a process where loose, wet sediments lose strength during an earthquake and behave similarly to a liquid. Once a soil liquefies, it will tend to settle and/or spread laterally. With even very slight slopes, liquefied soils tend to move sideways downhill (lateral spreading).

Settling or lateral spreading can cause major damage to buildings and to buried infrastructure such as pipes and cables.

In general, areas of high liquefaction potential largely follow river and stream drainage channels, marshy areas and areas near lakes. In addition, similar soil conditions may occur in areas where lakes or streams existed in the past but have now been filled in by natural or human-caused processes.

In earthquakes, liquefaction, settling or lateral spreading does not occur in all such areas or in all earthquakes. However, in larger earthquakes with strong ground shaking and long duration shaking, liquefaction is likely in many of these high liquefaction potential areas. Settlements of a few inches or more and lateral spreads of a few inches to several feet are possible. Even a few inches of settlement or lateral spreading is likely to cause significant to major damage to affected buildings or infrastructure.

For Benton County, DOGAMI has prepared county-wide maps of areas known or likely to be affected by these soils effect (Preliminary Earthquake Hazard and Risk Assessment and Water-Induced Landslide Hazard in Benton County Oregon, Open File Report O-01-05, 2001). This DOGAMI publication includes maps of areas subject to liquefaction, amplification of earthquake ground motions, and earthquake induced landslides.

These maps are based on available data and should not be over interpreted to represent exact locations of soils subject to liquefaction. Not all areas within given bins of liquefaction potential may be as classified: some areas may have higher potential and some areas may have lower potential. Detailed site-specific geotechnical studies are necessary to determine the level of liquefaction, settlement or lateral spread hazard at any specific location. The DOGAMI map (Open File Report O-01-05) showing areas in or near Corvallis with moderate or high liquefaction potential is shown in Figure 10.5. A more detailed Corvallis map showing areas with liquefaction potential is shown in Figure 10.6.

10.3.2 Landslides

Earthquakes can also induce landslides, especially if an earthquake occurs during the rainy season and soils are saturated with water. The areas prone to earthquake-induced landslides are largely the same as those areas prone to landslides in general. As with all landslides, areas of steep slopes with loose rock or soils are most prone to earthquake-induced landslides. Areas with steep slopes and loose rock or soils that are prone to water-induced landslides or debris flows are also subject to earthquake-induced landslides. For reference, see the landslide and debris flow hazard maps in Chapter 8 Landslides.

10.3.3 Dam Failures

Earthquakes can also cause dam failures in several ways. The most common mode of earthquake-induced dam failure is slumping or settlement of earthfill dams where the fill has not been properly compacted. If the slumping occurs when the dam is full, then overtopping of the dam, with rapid erosion leading to dam failure is possible. Dam failure is also possible if strong ground motions heavily damage concrete dams. In a few cases, earthquake-induced landslides into reservoirs have caused dam failures. Earthquake-induced dam failures are addressed in more detail in Chapter 12 which covers dam failures that could affect Corvallis.

Figure 10.5
DOGAMI Liquefaction Potential Map for Corvallis and Vicinity

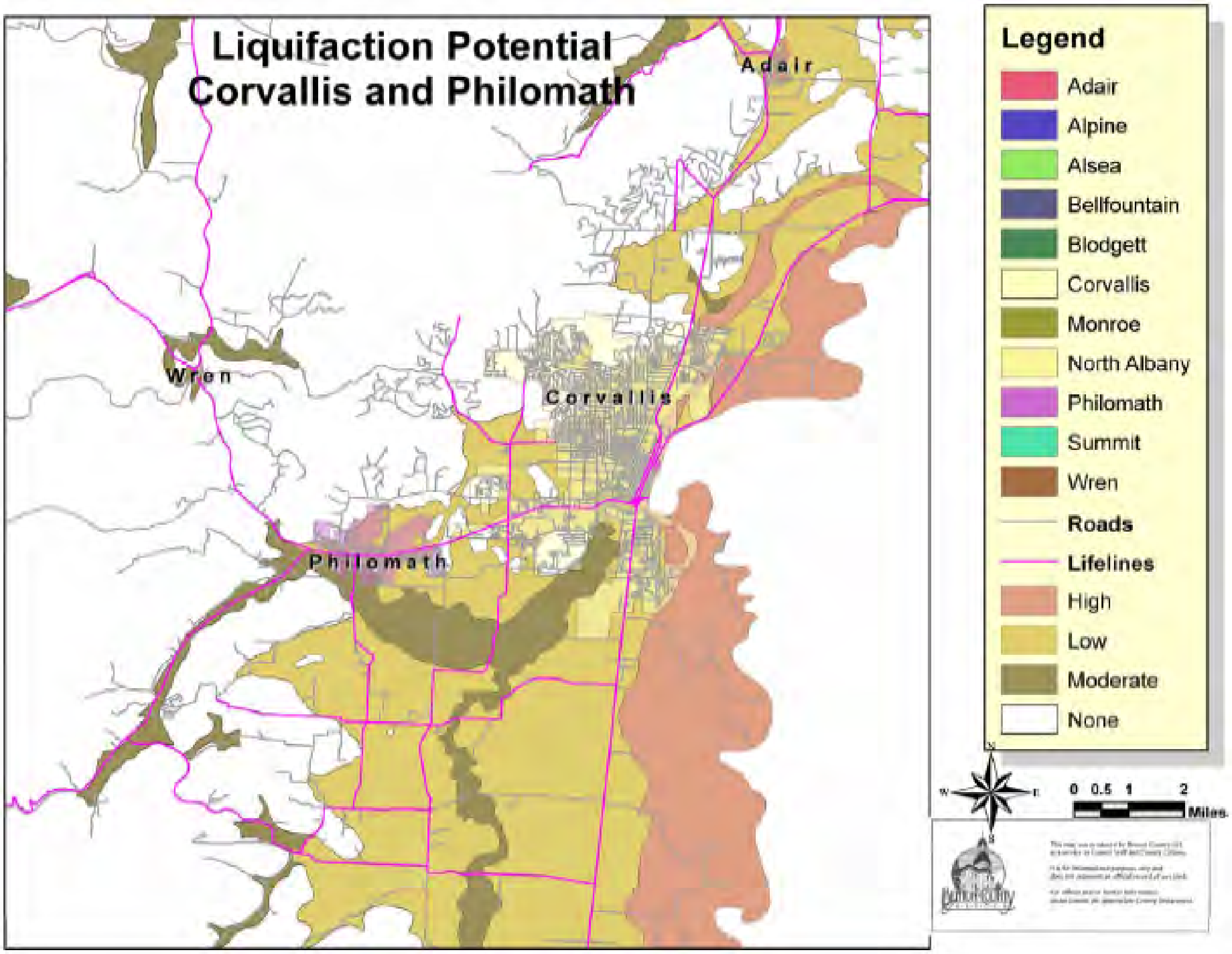


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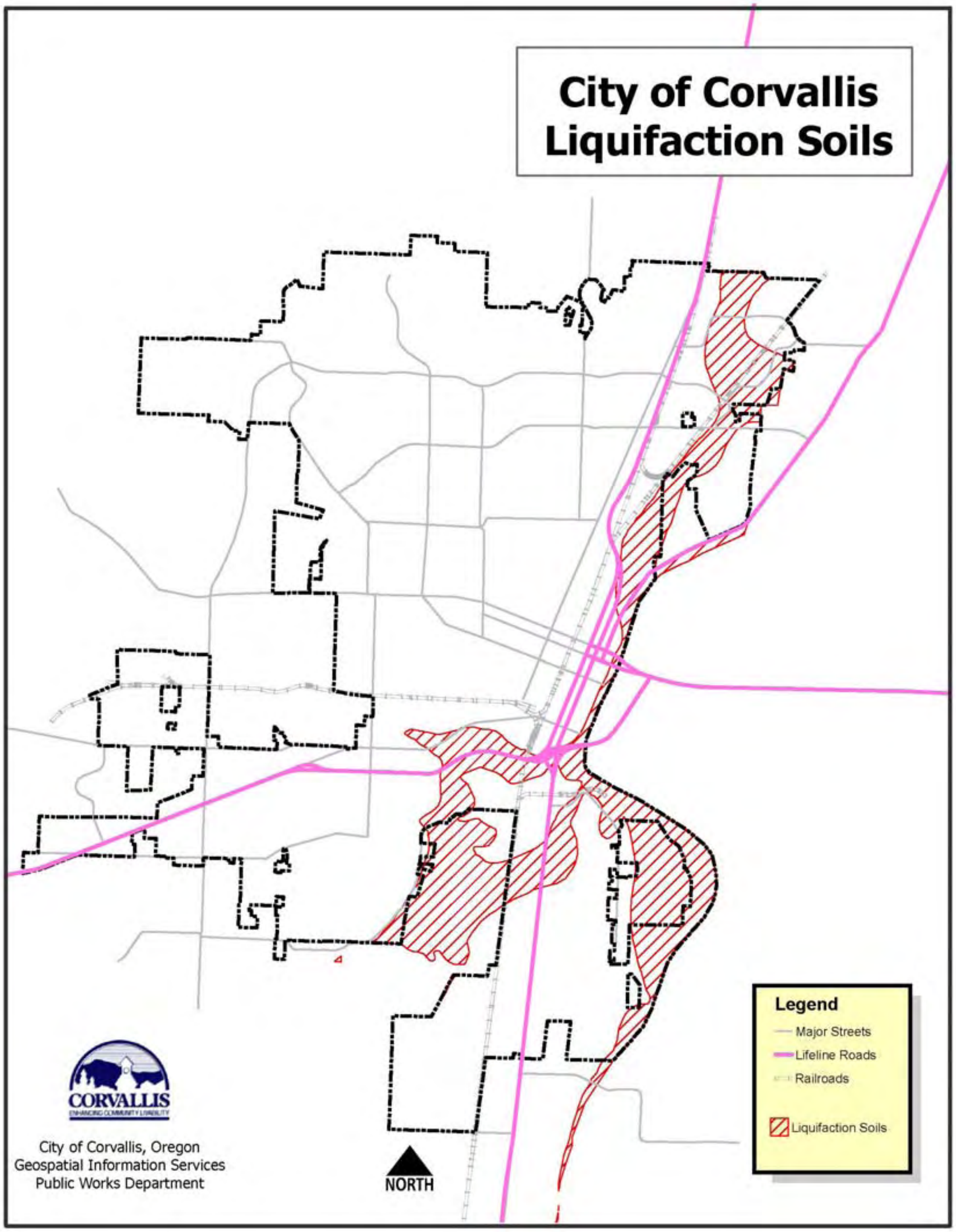
Figure 10.6
Areas within Corvallis with Soils Subject to Liquefaction



10.3.4 Tsunamis and Seiches

Tsunamis, which are often incorrectly referred to as "tidal waves," result from earthquakes which cause a sudden rise or fall of part of the ocean floor. Such movements may produce tsunami waves, which have nothing to do with the ordinary ocean tides. In the open ocean, far from land, in deep water, tsunami waves may be only a few inches high and thus be virtually undetectable, except by special monitoring instruments. These waves travel across the ocean at speeds of several hundred miles per hour. When such waves reach shallow water near the coastline, they slow down and can gain great heights.

Tsunamis affecting the Oregon coast can be produced from very distant earthquakes off the coast of Alaska or elsewhere in the Pacific Ocean. For such tsunamis, the warning time for the Oregon coast would be at least several hours. However, interface earthquakes on the Cascadia Subduction Zone can also produce tsunamis. For such earthquakes the warning times would be very short, only a few minutes. Because of this extremely short warning time, emergency planning and public education are essential before such an event occurs.

For Corvallis, not being on the coast, there are no impacts from tsunamis.

Another earthquake related phenomenon is "seiches" which are waves from sloshing of inland bodies of waters such as lakes, reservoirs, or rivers. In some cases, seiches have caused damages to shorefront structures and to dams. However, for the Corvallis the potential for seiches of sufficient magnitude to cause significant damage to upstream dams appears low.

10.4 Risk Assessment for Scenario Earthquakes

For regional planning purposes, FEMA's HAZUS-MH (Hazards U.S. Multi-Hazard) software can be used to make estimates of county-wide damages in Benton County from two scenario earthquakes. HAZUS is an extensively peer-reviewed nationally-applicable loss estimation methodology which draws heavily on census and other nationally-available data on buildings and infrastructure.

The two scenario earthquakes considered include: a) a M8.5 Cascadia Subduction Zone Interface Earthquake and b) a M7.5 Cascadia Subduction Zone Intraplate (Benioff Zone) Earthquake. The earthquake loss estimates shown below were calculated in 2001 for Phase Two of the Regional All Hazard Mitigation Master Plan for Benton, Lane, and Linn Counties, using a methodology very similar to HAZUS.

For each of these scenario earthquakes, building damage estimates for Benton County are approximately $400 million. Injuries were estimated to be about 600 for daytime earthquakes and about 160 to 170 for nighttime earthquakes. Deaths were estimated to be about 12 for daytime earthquakes and about 1 for nighttime earthquakes. Casualties are much lower for nighttime earthquakes, because most of the population is in mostly wood-frame residential buildings, which typically have lower casualty rates than many other types of structures. Summary results are shown below in Tables 10-2 and 10-3.

10.4.1 M8.5 Cascadia Subduction Zone Interface Earthquake

The estimated impacts of this earthquake on the building stock in Benton County are summarized below in Table 10.2. The percentage of damage in Corvallis vis-à-vis all of Benton County will be higher than Corvallis' percentage of Benton County's population because most of the larger, older, more seismically vulnerable buildings in Benton County are in Corvallis. Thus, we estimate that approximately 80% of the building damage, deaths, and injuries and other earthquake impacts in Benton County are likely to occur in Corvallis.

Table 10.2
M8.5 Cascadia Subduction Zone Interface Earthquake

Loss Estimate	Benton County	Corvallis
Building Damage	$420,000,000	$336,000,000
Percent Damage[1]	11.40%	15.00%
Daytime Deaths	12	10
Daytime Injuries	646	517
Nighttime Deaths	1	1
Nighttime Injuries	170	136
Heavily Damaged Residential Buildings[2]	1,711	1,369
Estimated number of people needing emergency shelter[3]	3,422	2,738

[1] Percent damage is relative to building replacement value.
[2] Heavily damaged buildings are those in the extensive or complete damage states.
[3] Of the total displaced people, perhaps 1/3 will need public emergency shelter, with the rest finding shelter with relatives, friends, or in commercial lodgings.

The direct loss estimates shown above are for the building stock only. Including the direct damages to contents, infrastructure and direct economic impacts from loss of function, the total direct economic impacts of these scenario earthquakes may be about double the estimates shown above

For such an earthquake, a substantial fraction of the larger buildings in the area will be damaged, including many essential service facilities, such as major medical facilities, fire and police stations, schools, and emergency shelters.

Utility systems will be significantly damaged, including damaged buildings and damage to utility infrastructure, including water and wastewater treatment plants and equipment at high voltage substations (especially 230 kV or higher which are more vulnerable than lower voltage substations). Buried pipe systems will suffer extensive damage with approximately one break per mile in soft soil areas. There would be much lower rate of pipe breaks in other areas. Restoration of utility services will require substantial mutual aid from utilities outside of the affected area. Expected outages of utility and transportation systems may include approximately:

Water: 10 days with no water to about 25% of customers in urban areas, 20 days to restore water service to 99% of customers,

Wastewater: loss of function at treatment plant is likely, perhaps for up to several days

Natural gas: similar to water service, in areas served by natural gas distribution systems,

Electric power: widespread outages for 8 to 24 hours, local outages in rural areas up to 72 hours,

Phone systems: system overload for about 72 hours, most customers have normal service after 72 hours, similar situation with cellular customers,

Highways: about 10 days to make emergency repairs, about 3 to 5% of bridges in complete damage state.

10.4.2 M7.5 Cascadia Subduction Zone Intraplate Earthquake

The estimated impacts of this earthquake on the building stock in Benton County are summarized below in Table 10.3.

Table 10.3
M7.5 Cascadia Subduction Zone Intraplate Earthquake

Loss Estimate	Benton County	Corvallis
Building Damage	$398,000,000	$318,000,000
Percent Damage[1]	10.80%	14.00%
Daytime Deaths	11	9
Daytime Injuries	602	482
Nighttime Deaths	1	1
Nighttime Injuries	157	126
Heavily Damaged Residential Buildings[2]	1,853	1,482
Estimated number of people needing emergency shelter[3]	3,706	2,965

[1] Percent damage is relative to building replacement value.
[2] Heavily damaged buildings are those in the extensive or complete damage states.
[3] Of the total displaced people, perhaps 1/3 will need public emergency shelter, with the rest finding shelter with relatives, friends, or in commercial lodgings.

The direct loss estimates shown above are for the building stock only. Including the direct damages to contents, infrastructure and direct economic impacts from loss of function, the total direct economic impacts of these scenario earthquakes may be about double the estimates shown above

In addition to building damages, utility systems (electric power, water, wastewater, natural gas) and transportation systems (bridges, pipelines) are also likely to experience significant damage. These types of damage and economic impacts are likely to be similar to those summarized above for the M8.5 Interface earthquake.

The potential impacts of major earthquakes on Corvallis are summarized below in Table 10.4.

Table 10.4
Potential Impacts of Major Earthquakes on Corvallis

Inventory	Probable Impacts
Portion of Corvallis affected	Entire City of Corvallis and surrounding areas.
Buildings	Many buildings will have no damage or light to moderate damage, with heavy damage concentrated in vulnerable buildings (wood frame buildings with cripple walls, unreinforced masonry, etc.). Total building damage estimated to be about $300 million.
Streets within Corvallis	Minor road damage possible in areas of soft soils. Many bridges may have significant damage, 3% to 5% may be in complete damage state.
Roads to/from Corvallis	Minor road damage possible in areas of soft soils. Many bridges may have significant damage, 3% to 5% may be in complete damage state.
Electric power	Widespread outages for about 8 to 24 hours. Outlying areas may have outages up to 72 hours.
Water utilities	About 10 days with no water to about 25% of customers in urban areas, about 20 days to restore water service to 99% of customers. Failure of the major water transmission lines on the Marys River bridge crossings would result in almost complete loss of water to Corvallis, with a high likelihood of long duration water outages.
Other Utilities	Loss of function to wastewater treatment plant. Natural gas system damages and outages similar to water systems. Phone systems (land and cellular) will have system overload for about 72 hours, then most customers will have normal service.
Emergency Shelter Needs	Approximately 3,000 people may need emergency shelter.
Casualties	About 10 deaths for daytime earthquake or about 1 death for nighttime earthquake. Daytime injuries about 500; nighttime injuries about 130.

The above summary of potential impacts is for major earthquakes on the Cascadia Subduction Zone, as shown above in Tables 10.2 and 10.3. Smaller earthquakes would have substantially smaller impacts on Corvallis than shown above.

In addition, there is a low probability that a major earthquake could result in substantial damage or failure of the major dams upstream of Corvallis (cf. Chapter 12 Dams).

10.5 Earthquake Risk Assessment: Technical Guidance

For planning purposes, it is sometimes useful to consider three levels of earthquake risk assessment.

> A Level One Risk Assessment means that nationally available data are used. For example, FEMA's HAZUS loss estimation software uses national data and HAZUS risk assessments for a community are Level One. The risk assessments presented in the previous section were Level One Assessments.
>
> A Level Two Risk Assessment is a more refined evaluation using local data such as soil maps, assessor's records, local building code history and so on to more accurately reflect local conditions than when using only national data. Level Two Assessments are generally more accurate than Level One Assessments, but still rely on generalized, typical data, rather than building specific data.
>
> A Level Three Risk Assessment is building- or facility-specific, using detailed data for each facility. A Level Three Risk Assessment cannot be done for an entire community, but rather is typically done for a single building or a few buildings or other facilities that may be particularly vulnerable or for which mitigation of seismic hazards is a high priority.

10.5.1 Level Two Risk Assessment

The Level One earthquake loss estimates presented above are based on census-tract level data. For a given community, a more accurate loss estimate could be obtained by incorporating Level Two local data into the loss calculations. Such data could include:

1) better inventory data,
2) spatial distribution of inventory within census tracts,
3) overlay of soils information with inventory to identify areas subject to amplification, liquefaction, settling and displacements, and
4) refinement of building fragility curves to reflect local inventory.

Such Level Two loss estimates would be more accurate than the Level One assessments presented above. However, the Level One estimates probably provide accurate enough estimates of the approximate magnitude of losses for emergency planning purposes. Furthermore, conducting a Level Two loss estimate would require very intensive data collection and processing efforts, without providing enough detail for specific mitigation projects. Therefore, Level Two risk assessments may not be as useful for Corvallis as the Level Three Assessments suggested below.

10.5.2 Level Three Risk Assessment

The potential damages and losses from earthquakes affecting Corvallis are very high. However, the probability of such earthquakes is relatively low and many types of buildings, such as wood frame homes, are generally expected to perform reasonably well in earthquakes. Therefore, widespread mitigation of seismic hazards is probably not called for in the case of most ordinary or typical buildings. That is, seismic mitigation actions are probably necessary only for a small percentage of the total building stock in Corvallis.

Furthermore, buildings constructed since the early 1990s generally meet current seismic design requirements and will generally perform fairly well in future earthquakes. Similarly, new buildings will be built in accordance with current Seismic Zone 3 requirements and thus the seismic capacity of the building stock in Corvallis will gradually improve over time as the existing stock is gradually replaced and/or upgraded.

However, for some types of buildings which are more vulnerable or more important than typical buildings, seismic retrofit may be highly desirable. Prime candidates for possible seismic retrofits include:

- any buildings that are substantially more vulnerable than typical buildings (e.g., unreinforced masonry buildings),
- buildings on soft soil sites subject to amplification of ground motions and/or liquefaction, and
- essential service facilities such as major medical facilities, police and fire stations, schools, emergency shelters and key governmental facilities including City Hall, Public Works shops and other government facilities important for post-earthquake response and recovery efforts.

Specific buildings may be substantially more vulnerable than typical buildings because of their structural system. Examples of vulnerable building types include: unreinforced masonry, precast concrete frame, concrete or steel frame with unreinforced masonry infill walls, concrete moment resisting frame, and precast concrete tiltup walls.

Buildings may also be substantially more vulnerable than typical buildings because of their design characteristics. Examples include buildings with soft first stories (taller than other stories and/or with large expanses of windows without shear walls) and buildings with major configurational irregularities, as well as wood frame buildings with cripple wall foundations or with sill plates not bolted to the foundation. Thus, we suggest that Level Three risk assessments focus primarily on such buildings, especially for essential service facilities.

A Level Three assessment provides a building-specific evaluation, more accurate than generic assessments based on typical buildings. Ideally, a Level Three assessment would include a site specific seismic hazard analysis, taking into account soil conditions, and a building-specific evaluation of the seismic vulnerability of each building under evaluation.

In addition to buildings, there are other critical facilities which may be vulnerable to seismic damage, including utility and transportation system infrastructure. Minimizing earthquake damage to such facilities is particularly important to a community because loss of function of critical utility or transportation system infrastructure may have a very large economic impact on the community. Facilities that should have a high priority for Level Three Risk Assessments include: electric power substations (especially high voltage substations), water and waste-water treatment plants, water reservoirs, bulk fuel storage tanks and hazmat storage tanks, dams and bridges. For utilities in general, non-structural mitigation measures are often very cost-effective and should have a high priority.

For buildings, utilities and other important facilities, the seven-step Mitigation Planning methodology outlined in Chapter 1 is appropriate. For prioritizing between mitigation projects, the principles of benefit-cost analysis apply to mitigation projects for all hazards, including seismic hazard mitigation. FEMA has software available to conduct such analyses of prospective earthquake hazard mitigation projects.

10.6 Other Earthquake Risk Comments for Corvallis

A “windshield” survey means a quick, preliminary seismic risk evaluation of a building or other facility, based on readily observable external attributes. A windshield survey may literally be done from a vehicle, but more commonly includes a quick walk around inspection. Conclusions drawn from such preliminary evaluations must be interpreted carefully as giving only a general indication of the probable level of seismic risk posed by the building or facility.

The following comments are based on a very limited windshield type survey of Corvallis’ building stock.

Overall, a majority of the building inventory in Corvallis is residential, with most residential structures being wood frame buildings. In general, wood frame buildings perform well in earthquakes, with a few notable exceptions. Wood frame buildings with the following characteristics are generally substantially vulnerable to major seismic damage:

1) sill plates not bolted to foundation,
2) cripple wall perimeter systems, and
3) buildings on steep slopes, partially supported on “stilts.”

Cripple wall perimeter systems are short wooden walls which raise the first floor elevation above grade by typically about 2 to 4 feet. Unbolted sill plates and cripple wall construction are common in pre-WW2 construction. Visual inspection and the general vintage of building stock in Corvallis suggest that there are likely significant numbers of buildings in Corvallis with cripple wall foundations or with unbolted sill plates. About 9% of the residential building stock in Corvallis pre-dates 1940.

Unreinforced masonry buildings are also subject to major damage in earthquakes. Corvallis has at least several dozen masonry buildings (most commercial or industrial in the older downtown area) which may be unreinforced or reinforced masonry. Some of these buildings may be highly vulnerable to earthquake damage and thus should have a high priority for detailed evaluation, especially those buildings with high occupancies or important functions.

A detailed inventory of wood frame buildings with the above noted seismic deficiencies and inventory of unreinforced masonry buildings would be useful to further quantify the level of risk posed by such structures in Corvallis.

10.7 Earthquake Hazard Mitigation Projects: General Examples

There are a wide variety of possible hazard mitigation projects for earthquakes. The most common projects include: structural retrofit of buildings, non-structural bracing and anchoring of equipment and contents, and strengthening of bridges and other infrastructure components.

The seismic hazard (frequency and severity of earthquakes) is moderate in the Corvallis. However, the risk (potential for damages and casualties) may be fairly high because some buildings and infrastructure may be highly vulnerable to earthquake damages. The risk assessment methodology outlined above for earthquakes provides the basis for identifying the high risk facilities that then become the primary targets for mitigation.

Structural retrofit of buildings should not focus on typical buildings, but rather on buildings that are most vulnerable to seismic damage. Priorities should include buildings on soft soil sites subject to amplification of ground motion and/or liquefaction and especially on critical service facilities such as hospitals, fire and police stations, emergency shelters, and schools.

Non-structural bracing of equipment and contents is often the most cost-effective type of seismic mitigation project. Inexpensive bracing and anchoring may protect very expensive equipment and/or equipment whose function is critical such as medical diagnostic equipment in hospitals, computers, communication equipment for police and fire services and so on. For utilities, bracing of control equipment, pumps, generators, battery racks and other critical components can be powerfully effective in reducing the impact of earthquakes on system performance. Such measures should almost always be undertaken before considering large-scale structural mitigation projects.

The strategy for strengthening bridges and other infrastructure follows the same principles as discussed above for buildings. The targets for mitigation should not be typical infrastructure but rather specific infrastructure elements that have been identified as being unusually vulnerable and/or are critical links in the lifeline system. For example, vulnerable overpasses on major highways would have a much higher priority than overpasses on lightly traveled rural routes.

For reference, a detailed analysis of a seismic retrofit project for a building (Monroe High School) is included in the Appendix to Chapter 10 of the Benton County Hazard Mitigation Plan.

The following table contains earthquake mitigation action items from the master Action Item table in Chapter 4.

Table 10.5
Earthquake Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Earthquake Mitigation Action Items								
Short-Term #1	Complete seismic retrofits for City Hall and the Marys River bridge crossings for water transmission lines, both of which are critical facilities for Corvallis, urgently requiring retrofit	Public Works	1-2 Years	X	X	X	X	
Short-Term #2	Complete seismic retrofit for North Hill 1st Level East Reservoir	Public Works	1-2 Years	X	X	X	X	
Short-Term #3	Complete evaluations and implement seismic retrofits for important City buildings, including Fire Stations #2, #3, and #4, Majestic Theater, Madison Building, Municipal Court, City Hall Annex and the Senior Center.	Public Works	2-5 years	X	X	X	X	
Short-Term #4	Complete seismic vulnerability analyses of critical facilities with significant seismic vulnerabilities, including fire, police, medical, and other emergency communication/response facilities	Public Works, community partners	1-5 Years	X	X	X	X	X
Short-Term #5	Complete seismic vulnerability analyses for lifeline utility and transportation systems, including: water, wastewater, natural gas, electric power, telecommunications and bridges	Public Works, ODOT, private utilities	1-5 Years	X	X	X	X	X
Short-Term #6	Support/steer a project using outside support/consultants to complete an inventory of public, commercial and residential buildings that may be particularly vulnerable to earthquake damage	Public Works, Community Development	2-5 years	X	X	X	X	X
Short-Term #7	Educate homeowners about structural and non-structural retrofitting of vulnerable homes and encourage retrofit	Public Works, Community Development	Ongoing	X		X	X	X
Long-Term #1	Obtain funding and retrofit critical public buildings and lifeline utility and transportation facilities with significant seismic vulnerabilities	Public Works, ODOT, private utilities	10 years	X	X	X	X	X

11.0 VOLCANIC HAZARDS

11.1 Overview

The Cascades, which run from British Columbia through Washington and Oregon into northern California, contain more than a dozen major volcanoes and hundreds of smaller volcanic features. In the past 200 years, seven of the Cascade volcanoes in the United States have erupted, including: Mt. Baker, Glacier Peak, Mt. Rainier, Mount St. Helens, Mt. Hood, Mt. Shasta, and Mt. Lassen.

Over the past 4,000 years (a geologically very short time period) there have been three eruptions of Mt. Hood, four eruptions in the Three Sisters area, and two eruptions in the Newberry Volcano area and minor eruptions near Mt. Jefferson, at Blue Lake Crater, in the Sand Mountain Field (Santiam Pass), near Mt. Washington, and near Belknap Crater. During this time period, the most active volcano in the Cascades has been Mount St. Helens with about 14 major eruptions and many smaller eruptions.

Many other volcanoes are deemed active or potentially active. The Smithsonian Institution's Global Volcanism Project lists 20 active volcanoes in Oregon and 7 in Washington. These volcanoes are listed below in Tables 11.1 and 11.2

Table 11.1
Active Volcanoes in Oregon

Volcano	Type	Last Eruption
Mt. Hood	Stratovolcano	1866
Mt. Jefferson	Stratovolcano	950 main volcano inactive for >10,000 years
Blue Lake Crater	Crater	1490 BC
Sand Mountain Field	Cinder cones	1040 BC?
Mt. Washington	Shield volcano	620 main volcano inactive
Belknap Field	Shield volcanoes	460?
North Sister Field	Complex volcano	350
South Sister	Complex volcano	50 BC?
Mt. Bachelor	Stratovolcano	5800 BC
Davis Lake	Volcanic field	2790 BC?
Newberry Volcano	Shield volcano	620 crater formation 300,000 to 500,000 years ago
Devils Garden	Volcanic field	unknown
Squaw Ridge Lava Field	Volcanic field	unknown
Four Craters Lava Field	Volcanic field	unknown
Cinnamon Butte	Cinder cones	unknown
Crater Lake	Caldera	2290 BC Crater formation about 7,700 years ago
Diamond Craters	Volcanic field	unknown
Saddle Butte	Volcanic field	unknown
Jordan Craters	Volcanic field	1250 BC
Jackies Butte	Volcanic field	unknown

Table 11.2
Active Volcanoes in Washington

Volcano	Type	Last Eruption
Mt. Baker	Stratovolcano	1880
Glacier Peak	Stratovolcano	1700 $\pm$ 100
Mt. Rainier	Stratovolcano	1825 (?)
Mt. Adams	Stratovolcano	950 AD (?)
Mount St. Helens	Stratovolcano	1991 (eruptions started in 1980)
West Crater	Volcanic field	5760 BC (?)
Indian Heaven	Shield volcanoes	6250 BC $\pm$ 100

On a longer geological time scale, volcanic activity in the Cascades has been very widespread. A DOGAMI report on prehistoric and historic volcanic eruptions in Oregon (see website below) notes that over 3,000 large and small volcanoes have erupted over the past five million years, in the Cascades as a whole. Within historical times, between 1843 and 1860 there were a series of 21 eruptions in the Cascades and there is some scientific speculation that the Northwest may be entering another period of volcanic activity.

A great deal of general background information on Oregon and Washington volcanoes and on volcanoes in general is available on several websites, including the following.

Table 11.3
Volcano Websites

Institution	Website
Smithsonian Institution (Global Volcanism Project)	www.volcano.si.edu/gvp
United States Geological Survey (USGS) - general site	www.usgs.gov
USGS Cascades Volcano Observatory (Vancouver, WA)	http://vulcan.wr.usgs.gov
DOGAMI	www.oregongeology.com

The numerous volcanoes of the Cascades differ markedly in their geological characteristics. The largest volcanoes are generally what geologists call composite or stratovolcanoes. These volcanoes may be active for tens of thousands of years to hundreds of thousands of years. In some cases, these large volcanoes may have explosive eruptions such as Mount St. Helens in 1980 or Crater Lake about 7,700 years ago. The much more numerous sites of volcanic activity are generally what geologists call mafic volcanoes. This type of volcano is typically active for much shorter time periods, up to a few hundred years, and generally forms small craters or cones. Mafic volcanoes are not subject to large explosive events.

11.2 Volcanic Hazard Types

In Oregon, awareness of the potential for volcanic eruptions was greatly increased by the May 18, 1980 eruption of nearby Mount St. Helens in Washington which killed 57 people. In this eruption, lateral blast effects covered 230 square miles and reached 17 miles northwest of the crater, pyroclastic flows covered six square miles and reached 5 miles north of the crater, and landslides covered 23 square miles. Ash accumulations were about 10 inches at 10 miles downwind, 1 inch at 60 miles downwind, and ½ inch at 300 miles downwind. Lahars (mudflows) affected the North and South Forks of the Toutle River, the Green River, and ultimately the Columbia River as far as 70 miles from the volcano. Damage and reconstruction costs exceeded $1 billion.

Volcanic eruptions often involve several distinct types of hazards to people and property, as well evidenced by the Mount St. Helens eruption. Major volcanic hazards include: lava flows, blast effects, pyroclastic flows, ash flows, lahars, and landslides or debris flows. Some of these hazards (e.g., lava flows) only affect areas very near the volcano. Other hazards may affect areas 10 or 20 miles away from the volcano, while ash falls may affect areas many miles downwind of the eruption site.

Lava flows are eruptions of molten rock. Lava flows for the major Cascades volcanoes tend to be thick and viscous, forming cones and thus typically affecting areas only very near the eruption vent. However, flows from the smaller mafic volcanoes may be less viscous flows that spread out over wider areas. Lava flows obviously destroy everything in their path.

Blast effects may occur with violent eruptions, such as Mount St. Helens in 1980. Most volcanic blasts are largely upwards. However, the Mount St. Helens blast was lateral, with impacts 17 miles from the volcano. Similar or larger blast zones are possible in future eruptions of any of the major Cascades volcanoes.

Pyroclastic flows are high-speed avalanches of hot ash, rock fragments and gases. Pyroclastic flows can be as hot as 1500 ^{o}F and move downslope at 100 to 150 miles per hour. Pyroclastic flows are extremely deadly for anyone caught in their path.

Ash falls result when explosive eruptions blast rock fragments into the air. Such blasts may include tephra (solid and molten rock fragments). The largest rock fragments (sometimes called “bombs”) generally fall within two miles of the eruption vent. Smaller ash fragments (less than about 0.1”) typically rise into the area forming a huge eruption column. In very large eruptions, ash falls may total many feet in depth near the vent and extent for hundreds or even thousands of miles downwind.

Lahars or mudflows are common during eruptions of volcanoes with heavy loading of ice and snow. These flows of mud, rock and water can rush down channels at 20 to 40 miles an hour and can extend for more than 50 miles. For some volcanoes, lahars are a major hazard because highly populated areas are built on lahar flows from previous eruptions.

Landslides or debris flows are the rapid downslope movement of rocky material, snow and/or ice. Volcano landslides can range from small movements of loose debris to massive collapses of the entire summit or sides of a volcano. Landslides on volcanic slopes may be triggered by eruptions or by earthquakes or simply by heavy rainfall.

11.3 Volcanic Hazards for Corvallis

Several of the active volcanoes in Oregon and Washington (See Tables 11.1 and 11.2) are located relatively near Corvallis, including Mount St. Helens and Mt. Hood. Approximate distances from Corvallis to three relatively nearby volcanoes are shown below in Table 11.4.

Table 11.4
Distances from Corvallis

Volcano	Distance (miles)
Mount St. Helens	112
Mt. Hood	92
Three Sisters	80

Among these relatively nearby volcanoes, Mount St. Helens is the most active. Mt. Hood and the Three Sisters are definitely active.

Corvallis is approximately 80 miles from the Three Sisters, and further away from the other volcanoes. We review the volcanic hazards posed by the Three Sisters the nearest active volcano that may affect Corvallis.

Awareness of potential volcanic activity at the Three Sisters has been raised because of the recent discovery of an uplift (bulge) on the west side of South Sister. In May 2001, the USGS announced that it had detected a slight swelling or uplift of the west side of South Sister. This bulge, which occurred between 1996 and 2000, covers an area about 9 to 12 miles in diameter, with a maximum bulge in the center of about 4 inches. The cause of this uplift (bulge) is most likely intrusion of a small amount of magma (molten rock) deep under the surface, probably at a depth of about 4 miles.

This observation confirms that South Sister is still an active volcano, but needs to be interpreted cautiously. For comparison, a bulge was also observed on the north side of Mount St. Helens in the months prior to the May 18, 1980 eruption. However, the Mount St. Helens bulge was 450 feet high and growing at a rate of 5 feet per day prior to the eruption. Thus, the South Sister bulge of 4 inches is certainly not an indication of an imminent eruption.

The UGSG analysis of Volcano Hazards in the Three Sisters Region, Oregon was published in 1999 (Open-File Report 99-437). The main conclusions are summarized in the following paragraphs.

The Three Sisters area includes two large composite volcanoes (Middle and South Sister). Large composite volcanoes in the Cascades (e.g., Mt. Hood, Mt. Jefferson, Newberry Volcano, Crater Lake) are often active for hundreds of thousands of years and are subject to sometimes explosive eruptions (e.g., Mount St. Helens in 1980). Hazards from eruptions of composite volcanoes include all of the hazards listed above in Section 11.2.

Between the major composite volcanoes, the crest of the Cascades is built up of hundreds of “mafic” volcanoes. Mafic volcanoes typically erupt for a few weeks to a few centuries, although some can be nearly as large as the composite volcanoes. Prominent mafic volcanoes in the Three Sisters area include North Sister, Mount Bachelor, Belknap Cater, Black Butte, and Mount Washington. Mafic volcanoes often form broad fields of volcanic vents such as in the Sand Mountain Field near the Santiam Pass, north of the Three Sisters.

Mafic volcanoes typically erupt less explosively than do composite volcanoes, so that impacts of eruptions are less widespread. Most mafic eruptions in the Three Sisters areas have produced tephra deposits and lava flows that typically traveled 3 to 9 miles from the vents and rarely 9 to 12 miles from the vents. Tephra deposits rarely exceed 4 inches in thickness at distances 6 miles from the vent.

Belknap Crater, about 1,500 years old, is one of the youngest mafic volcanoes in the Cascades. The Sand Mountain field, a cluster of cones and lava flows west of Santiam Pass, was formed during three eruptive periods between about 2,000 and 4,000 years ago.

The USGS study of Volcano Hazards in the Three Sisters Region includes three hazard zones: proximal hazards, distal hazards, and a regional lava flow hazard zone.

> **The proximal hazard zone** is limited to the immediate area around the Three Sisters and is an oval area about 8 miles (east-west) by 10 miles (north-south). The proximal hazard area is the area subject to the most intense volcanic hazards including lava flows, tephra flows, pyroclastic flows, landslides and debris flows and lahars. Fortunately, this area is predominantly wilderness with very low population.
>
> **The distal hazard zones** are river valleys extending away from the proximal hazard zone that are subject to landslides, debris flows and lahars. The distal hazard zone has three levels for areas subjected to lahars (and other flows) of varying sizes. Areas subjected to lahars include Squaw Creek into Sisters, Tumalo Creek into Bend, the valley between Sparks Lake and Crane Prairie Reservoir, and the McKenzie River (and tributaries) west of the Three Sisters.
>
> **The regional lava flow hazard** zone includes a band about 30 to 40 miles wide covering the entire crest of the Cascades. Locations throughout this zone, which includes Sisters, Bend, and the Santiam Pass, are subject to lava flows from mafic volcanism could occur anywhere in this entire zone.

None of these Three Sisters volcanic hazard zones impact Corvallis directly.

Thus, the extent of volcanic hazards for Corvallis appears largely limited to the possibility of minor ash falls from eruptions at Three Sisters or at other locations in the Cascades (e.g., Mount St. Helens). In all but the most extreme events, ash falls in Corvallis are likely to be minor with an inch or less of ash likely. Volcanic events in the Three Sisters area or in the Santiam Pass area (Sand Mountain volcanic field) could also close eastbound Highway 20 and thus affect transportation to/from Corvallis, at least to a very limited extent.

However, to a much lower extent, volcanic activity at Three Sisters could affect Corvallis in several ways:

1) Depending on the volume of volcanic ash ejected by an eruption and on prevailing wind directions at the time of eruption, various thicknesses of ash falls may affect Corvallis. Possible impacts of ash falls include:

a) Clean-up and debris removal,

b) Possible respiratory problems for at-risk population such as elderly, young children or others with respiratory problems,

c) Possible impacts on public water supplies drawn from surface waters, including degradation of water quality (high turbidity) and possible increased maintenance requirements at water treatment plants, and

d) Possible electric power outages from ash-induced short circuits in distribution lines, transmission lines, and substations.

2) Debris flows, landslides, and lahars into the river valleys near the Three Sisters may affect the McKenzie River and the Willamette River downstream and thus also affect public water supplies downstream.

The following maps show probabilistic data on ash fall in western Oregon, taking into account all of the active volcanoes (USGS Open File Report 9-437, Plate 1, 1999). Interpolating between the map contours of Figure 11.5, the annual probability of 1 centimeter (about 0.4 inch) or more of volcanic ash is about 1/5000 in Corvallis. In other words the return period for such ash falls are about 5,000 years for Corvallis.

Interpolating between the map contours of Figure 11.6, the annual probability of 10 centimeters (about 4 inches) or more of volcanic ash is less than 1/10,000. In other words the return period for such ash falls are greater than 10,000 years for Corvallis.

Figure 11.5
Annual Probability of 1 Centimeter (about 0.4 inch) or More of Volcanic Ash

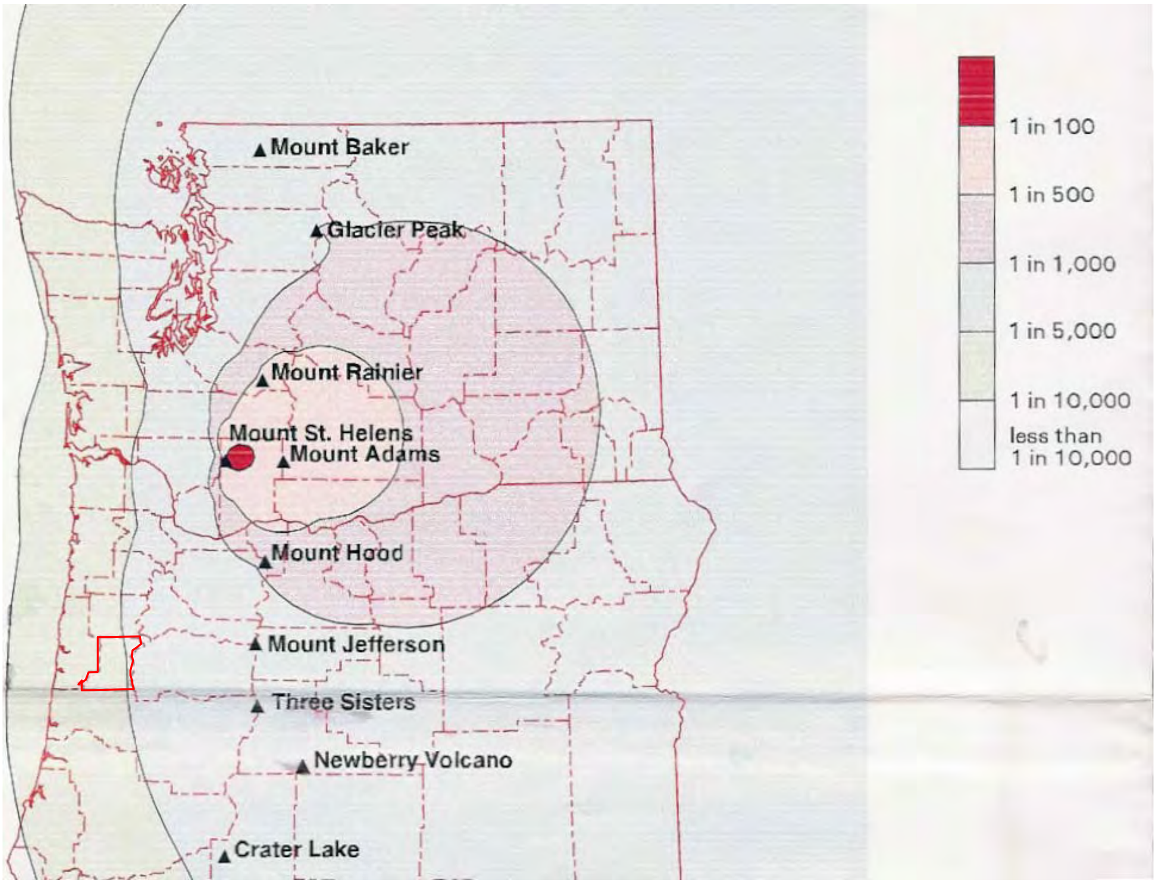
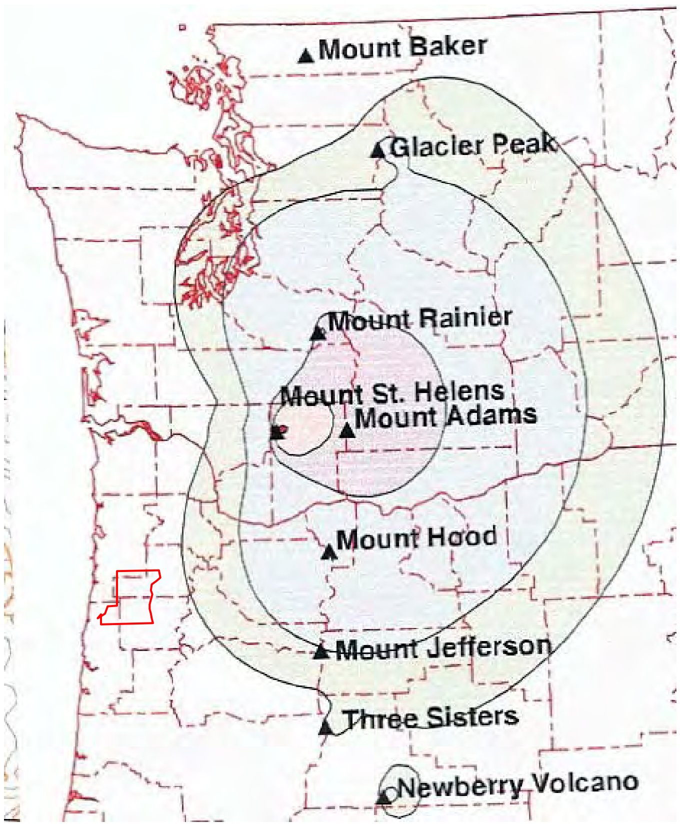


Figure 11.6
Annual Probability of 10 Centimeters (about 4 inches) or More of Volcanic Ash
(same scale as Figure 11.5 above)



The low probabilities of significant ash falls (i.e., long return periods) arise because ash falls in Corvallis require volcanic eruptions producing ash and wind directions that deposit ash westward from the volcanoes.

For the 2004 eruptions of Mount St. Helens (and presumably for future eruptions of Mount St. Helens and other volcanoes in the Cascades), NOAA has real time volcanic ash forecasts, taking into account eruption locations and wind directions. These forecasts are available at: http://www.arl.noaa.gov/ready/vaftadmenu

To see specific ash forecasts for Mount St. Helens, click on "Hypothetical Eruptions" and then select St. Helens and the desired forecast time frame to view the projections.

The probable impacts of potential volcanic eruptions on Corvallis are summarized below in Table 11.7.

Table 11.7
Probable Impacts of Potential Volcanic Eruptions on Corvallis

Inventory	Probable Impacts
Portion of Corvallis Affected	Entire City of Corvallis and surrounding region may be affected by ash falls from some eruptions.
Buildings	Negligible impact, other than minor cleanup required
Streets within Corvallis	Negligible impact, other than minor cleanup required
Roads to/from Corvallis	Negligible impact, other than minor cleanup required
Electric Power	Temporary power outages possible from short circuits caused by ash falls
Other Utilities	Negligible impact, other than minor cleanup required for most utilities. Potential to impact water treatment plants which may require additional maintenance to deal with high turbidity water
Casualties	Some potential for health impacts, especially for frail people with respiratory problems.

11.4 Mitigation of Volcanic Hazards

Mitigation of volcanic hazards is predominantly in the areas of monitoring volcanic activity, warnings and evacuation, and emergency response. That is, there are few, if any, practical physical measures to mitigate the direct impacts of volcanic activity.

The USGS actively monitors volcanic activity in the Cascades via networks of seismic sensors (which can detect earthquakes related to magma movements) as well as very accurate ground surface measurements, such as that which has detected the very small bulge on South Sister. The USGS also has a volcanic warning system with several levels of alert as a potential eruption becomes more likely and more imminent.

For the Cascades, the USGS volcano warning system (www.usgs.gov) has three levels. Level One (Volcanic Unrest) means anomalous conditions that could be indicative of an eventual volcanic eruption. Level Two (Volcanic Advisory) means that processes are underway that have a significant likelihood of culminating in hazardous volcanic activity, but when the evidence does not indicate that a life- or property-threatening event is imminent. Level Three (Volcano Alert) means that monitoring or evaluation indicate that precursory events have escalated to the point where a volcanic event with attendant volcanologic or hydrologic hazards threatening to life and property appears imminent or is underway.

For Corvallis, which is located well outside of any of the likely direct hazard zones for any Cascades volcanic events, mitigation for volcanic activity is likely a low priority. In the event of a minor ash fall, public warnings directing people (especially those with respiratory problems) to remain indoors, and minor cleanup are most likely the only necessary responses for most volcanic effects impacting Corvallis. In addition, water treatment plants should be evaluated to ensure that they can handle possible high turbidity events from volcanic ash falls into water supplies.

The following table includes the volcanic hazards mitigation action items from the master Action Items table in Chapter 4.

Table 11.8
Volcanic Hazards Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Volcanic Hazards Mitigation Action Items								
Short-Term #1	Update public emergency notification procedures for ash fall events	Public Works, Fire, Police, City Manager's Office	1-2 Years	X	X			X
Short-Term #2	Update emergency response planning for ash fall events	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Evaluate capability of water treatment plants to deal with high turbidity from ash falls and upgrade treatment facilities and emergency response plans to deal with ash falls	Public Works	1-2 Years	X	X	X	X	X
Short-Term #4	Prepare/pre-script public messages about protection from and disposing of volcanic ash	Public Works, Fire, Police						X

12.0 DAM SAFETY

12.1 Overview of Dams

Dams are manmade structures built to impound water. Dams are built for many purposes including water storage for potable water supply, livestock water supply, irrigation, or fire suppression. Other dams are built for flood control, recreation, navigation, hydroelectric power or to contain mine tailings. Dams may also be multifunction, serving two or more of these purposes.

The National Inventory of Dams, NID, which is maintained by the United States Army Corps of Engineers, is a database of approximately 76,000 dams in the United States. The NID does not include all dams in the United States. Rather, the NID includes dams that are deemed to have a high or significant hazard potential and dams deemed to pose a low hazard if they meet inclusion criteria based on dam height and storage volume. Low hazard potential dams are included only if they meet either of the following selection criteria: 1) exceeds 25 feet in height and 15 acre-feet of storage, or 2) exceeds 6 feet in height and 50-acre feet of storage. There are many thousands of dams too small to meet the NID selection criteria. However, these small dams are generally too small to have significant impacts if they fail and thus are generally not considered for purposes of risk assessment or mitigation planning.

This NID potential hazard classification is solely a measure of the probable impacts if a dam fails. Thus, a dam classified as High Potential Hazard does not mean that the dam is unsafe or likely to fail. The level of risk (probability of failure) of a given dam is not even considered in this classification scheme. Rather, the High Potential Hazard classification simply means that there are people at risk downstream from the dam in the inundation area, if the dam were to fail. The NID potential hazard classification system for dams is as summarized below in Table 12.1.

Table 12.1
NID Hazard Potential Classification for Dams[1]

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, or Lifeline Losses
Low	None expected	Low and generally limited to dam owner
Significant	None expected	Yes
High	Probable, one or more expected	Yes, but not necessary for this classification.

Dams assigned the low hazard potential classification are those where failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the dam owner's property.

Dams assigned to the significant hazard potential classification are those where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities. Significant hazard potential dams are often located in predominantly rural or agricultural areas.
Dams assigned to the high hazard potential classification are those where failure or

mis-operation will probably cause loss of human life. Failure of dams in the high classification will generally also result in economic, environmental or lifeline losses, but the classification is based solely on probable loss of life.

Of the dams in the NID, nearly 60% are privately owned. In addition to the dams in the NID, there are many thousands of dams too small to meet the selection criteria for the NID. Most of these small dams are also privately owned.

The NID is available online through several links at FEMA and the United States Army Corps of Engineers. However, since September 11, 2001, access is somewhat restricted. Basic NID information and links to the database are available at http://crunch.tec.army.mil/nid/webpages/nid.cfm

12.2 Dam Primer

In the simplest terms, dams are impervious structures that block the flow of water in a river or stream and thereby impound water behind the dam. Dams have been built for thousands of years from a wide range of materials, including earth, stone, masonry, wood, and concrete. Large modern dams are almost always embankment dams (built primarily from soil, rock, or mixtures) or concrete dams.

Large modern dams almost always have control mechanisms such as gated spillways or outlet pipes for releasing water in a controlled fashion. Typically, dams are operated to smooth natural variations in water flow. During high water flow periods, water is stored behind a dam, while in low water flow periods, water is released to increase flows. Controlled releases typically result in lower peak (flood) flows and higher minimum flows than in uncontrolled streams. The specific patterns of water storage and release vary from dam to dam, depending on the primary purpose(s) of the dam and on a wide variety of economic, regulatory and environmental considerations.

12.2.1 Dam Nomenclature and Types of Dams

Modern dams, whether embankment dams or concrete dams, are typically constructed on a foundation, which may be concrete, natural rock or soils, or compacted soils. Dams are usually constructed along a constricted part of a river valley to minimize cost. Dams are also connected to the surrounding natural valley walls, which become the abutments of the dam structure itself.

Embankment dams are commonly termed earthfill or rockfill dams, depending on the primary material used in their construction. Historically, a wide range of earth and rock materials have been used to construct embankment dams, with various construction techniques including hydraulic fill and compaction. Embankment dams are broad flat structures, typically at least twice as wide at the base as their height. In cross section, embankment dams are typically trapezoidal, with a wide flat base, sloping slides and a narrower flat top.

Depending on the permeability of the materials used in an embankment dam, impervious layers may be added to the upstream side of the structure or in the center core of the structure. Embankment dams are subject to erosion by running water. Thus, modern embankment dams always have erosion-resistant materials used in the water release and control mechanisms of the dam. Typically, concrete spillways with concrete or steel gates are used to control releases. Many dams also have outlet pipe systems with concrete or steel pipes as part of the water release control system.

Modern concrete dams fall into two major classes: gravity dams and arch dams. Concrete gravity dams are designed on principles similar to embankment dams. Concrete gravity dams are broad structures, generally triangular in shape with a flat base, a narrow top, a flat upstream side and a broad sloping downstream side. Much of these dams' capacity to impound water arises from the weight of the dam. Typically, gravity dams are keyed into bedrock foundations and abutments to increase the stability of the dam.

Concrete arch dams rely primarily on the strength of concrete to impound water. Concrete arch dams are much thinner in cross section than concrete gravity dams and are always convex on the upstream side and concave on the downstream side because concrete is much stronger in compression than in tension. With this arch design, the pressure of impounded water compresses the concrete and makes the dam stronger. Like concrete gravity dams, concrete arch dams are also keyed into bedrock foundations and abutments to provide stability. A less common variation of a concrete arch dam is a concrete buttress dam. Buttress dams are arched or straight dams with additional strength provided by buttresses perpendicular to the long axis of the dam.

An excellent introduction to dam nomenclature and descriptions of types of dams is given in the FEMA publication: Dam Safety: An Owner's Guidance Manual.[3] For further details, the reader is referred to this publication and the references therein.

12.2.2 Dam Failure Modes

Dam failures can occur at any time in a dam's life; however, failures are most common when water storage for the dam is at or near design capacity. At high water levels, the water force on the dam is higher and several of the most common failure modes are more likely to occur. Correspondingly, for any dam, the probability of failure is much lower when water levels are substantially below the design capacity for the reservoir.

For embankment dams, the most common failure mode is erosion of the dam during prolonged periods of rainfall and flooding. When dams are full and water inflow rates exceed the capacity of the controlled release mechanisms (spillways and outlet pipes), overtopping may occur. When overtopping occurs, scour and erosion of either the dam itself and/or of the abutments may lead to partial or complete failure of the dam. Especially for embankment dams, internal erosion, piping or seepage through the dam, foundation, or abutments can also lead to failure. For smaller dams, erosion and weakening of dam structures by growth of vegetation and burrowing animals is a common cause of failure.

For embankment dams, earthquake ground motions may cause dams to settle or spread laterally. Such settlement does not generally lead, by itself, to immediate failure. However, if the dam is full, relatively minor amounts of settling may cause overtopping to occur, with resulting scour and erosion that may progress to failure. For any dam, improper design or construction or inadequate preparation of foundations and abutments can also cause failures. Improper operation of a dam, such as failure to open gates or valves during high flow periods can also trigger dam failure. For any dam, unusual hydrodynamic (water) forces can also initiate failure. Landslides into the reservoir, which may occur on their own or be triggered by earthquakes, may lead to surge waves which overtop dams or hydrodynamic forces which cause dams to fail under the unexpected load. Earthquakes can also cause seiches (waves) in reservoirs that may overtop or overload dam structures. In rare cases, high winds may also cause waves that overtop or overload dam structures.

Concrete dams are also subject to failure due to seepage of water through foundations or abutments. Dams of any construction type are also subject to deliberate damage via sabotage or terrorism. For waterways with a series of dams, downstream dams are also subject to failure induced by the failure of an upstream dam. If an upstream dam fails, then downstream dams also fail due to overtopping or due to hydrodynamic forces.

An excellent review of the common mechanisms for dam failures is given in the FEMA publication: Dam Safety: An Owner's Guidance Manual.[3] For further details, the reader is referred to this publication and the references therein.

A National Research Council study[4] of dam failures in the United States and Western Europe from 1900 to 1969 compiled historical data on the observed probability of failure as a function of type of dam. Dam failures are quite common in the United States. For example, FEMA data from Tropical Storm Alberto (1994) show 230 dam failures in the State of Georgia from this single event.[5] Fortunately, most dam failures are of small dams where the failure poses little or no risk to life safety and only minor, localized property damage. Most failures are of dams that are too small to be included in the NID database or dams in the NID Low Hazard Potential Category.

However, in the United States between 1960 and 1997 there were 23 dam failures that caused at least one death, with total fatalities from these 23 failures estimated at 318 people.[5] Since 1874, there have been six dam failures in the United States which killed over 100 people.[2] The worst dam failure, in terms of casualties, was the 1889 Johnstown Pennsylvania dam failure which killed over 2,200 people. Three of the high fatality dam failures occurred in the 1970s: Black Hills, South Dakota, Big Thompson River, Colorado, and Buffalo Creek, West Virginia. These three failures alone resulted in an estimated 514 deaths.[2] (Note: the published death statistics in this paragraph from these two FEMA sources are inconsistent, but these differences are not significant for the present purposes).

12.3 Oregon Dam Data

The National Inventory of Dams (NID) lists 812 dams in Oregon. Of these NID dams, 9 are in Benton County. The statistical breakdown of these dams by NID Potential Hazard Categories is shown below in Table 12.2. For Oregon, there are 128 dams in the High Potential Hazard Category.

Table 12.2
Numbers of Dams by NID Potential Hazard Categories

NID Hazard	Oregon	Benton County
High	128	1
Significant	151	1
Low	521	4
Undetermined	12	3
Total	812	9

There is only one dam in Benton County in the High Potential Hazard Category, the North Fork Dam in Philomath which is the reservoir for Corvallis' Rock Creek Water Treatment plant and is owned by the City of Corvallis. Information on this dam is shown below in Table 12.3.

Table 12.3
NID High Potential Hazard Dams in Benton County

County	Dam Name	River	City	NID Height (feet)	NID Storage (acre feet)
Benton	North Fork Dam	North Fork Rock Creek	Philomath	83	305

However, Corvallis is also potentially at risk from dams upstream along the Willamette River and its tributaries, including 9 dams in Lane County which are in the High Potential Hazard Category. These 9 dams, all of which are federally owned and operated are listed individually in Table 12.4 below.

Table 12.4
NID High Potential Hazard Dams
Affecting Benton County

County	Dam Name	River	City	NID Height (feet)	NID Storage (acre feet)
Lane	Cottage Grove	Coast Fork Willamette River	COTTAGE GROVE	103	50,000
Lane	Dexter	Middle Fork Willamette River	EUGENE	117	29,900
Lane	Fall Creek	Fall Creek	SPRINGFIELD	205	125,000
Lane	Dorena	Row River	COTTAGE GROVE	154	131,000
Lane	Lookout Point	Middle Fork Willamette River	EUGENE	276	477,700
Lane	Blue River Dam	Blue River	SPRINGFIELD	312	89,000
Lane	Hills Creek	Middle Fork Willamette River	OAKRIDGE	341	356,000
Lane	Cougar	South Fork McKenzie River	SPRINGFIELD	519	219,000
Lane	Fern Ridge	Long Tom River	EUGENE	49	121,000

All of these NID High Potential Hazard dams are upstream Corvallis and thus have a potential impact on the city.

12.4 Dam Failure Hazard Assessment: Corvallis

A 1987 report[6] on Dam/Levee Failure by the Oregon Emergency Management Division lists 51 historical dam failures in Oregon from 1896 through the 1980s. As of the time of this report, no dam failure fatalities had been recorded in Oregon. However, the potential for dam failure fatalities certainly exists in Oregon and in Corvallis, albeit with a low probability of occurrence.

To evaluate the level of risk posed by dams in Corvallis, we consider primarily dams in the NID high potential hazard classification. Dams in the significant and low potential hazard categories do not pose a life safety threat and the risk of property damage is minimal or low.

Additional data on the ten NID high potential hazard dams potentially affecting Corvallis are given below in Tables 12.5 and 12.6. As shown below, the North Fork Dam and all of the Corps dams do have EAPs.

Table 12.5
Additional Data on NID High Potential Dam in Benton County

County	Dam Name	River	NID Storage (acre feet)	Date Built	Dam Type	EAP	Owner
Benton	North Fork Dam	North Fork Rock Creek	305	1960	RE	Yes	Corvallis

Table 12.6
Additional Data on NID High Hazard Potential Dams Affecting Benton County

County	Dam Name	River	Storage (acre feet)	Date Built	Dam Type	EAP	Owner
Lane	Cottage Grove	Coast Fork Willamette	50,000	1942	RE	Y	Corps
Lane	Dexter	Middle Fork Willamette	29,900	1955	RE	Y	Corps
Lane	Fall Creek	Fall Creek	125,000	1965	ER	Y	Corps
Lane	Dorena	Row River	131,000	1949	RE	Y	Corps
Lane	Lookout Point	Middle Fork Willamette	477,700	1953	RE	Y	Corps
Lane	Blue River Dam	Blue River	89,000	1968	RE	Y	Corps
Lane	Hills Creek	Middle Fork Willamette	356,000	1962	RE	Y	Corps
Lane	Cougar	South Fork McKenzie	219,000	1964	ER	Y	Corps
Lane	Fern Ridge	Long Tom	121,000	1941	RE	Y	Corps

The NID dam type classification includes the following types of dams:

RE rockfill/earthfill embankment dams, primarily rockfill (fill >3” size)
ER rockfill/earthfill embankment dams, primarily earthfill (fill <3” size)

These dams were completed between 1941 and 1968. All dams are rockfill/earthfill embankment dams. All dams are operated by the US Army Corps of Engineers and all have emergency operations plans in place. All Corps dams are maintained on a regular schedule and undergo regular inspections, with major re-inspections every five years. Furthermore, the Corps is highly experienced in the construction, operation, and maintenance of dams.

As noted previously, the NID classification as High Potential Hazard means only that there is probable loss of life if one of these dams fails. The NID classification contains no information whatsoever about the safety or lack of safety of a given dam and no information about the probability of failure.

For embankment dams, as discussed above**,** the most common failure modes are overtopping, foundation failures, and seepage through the dam. For concrete dams, the most common failure modes are overtopping and foundation failures. Under normal or flood conditions, failure of the Corps operated dams appears highly unlikely. Failure is perhaps possible, however, in extreme flood events well above the design basis, especially if the reservoirs were close to full at the onset of flooding. The spillway capacities could be exceeded with a potential for overtopping failures.

There are, however, two other circumstances that may pose significant threats to any of these dams: landslides and earthquakes.

> A major landslide into a reservoir, whether triggered by seismic activity or not, could result in a large surge wave that could result in dam failure from a combination of overtopping and hydrodynamic forces.
>
> A major earthquake, either a Cascadia Subduction Zone earthquake, or a smaller, interplate or intraplate earthquake in Western Oregon, could cause sufficient damage to these dams to pose a risk of failure.

12.5 Dam Risk Assessment

Each of these major dams which pose a potential life safety hazard for Benton County are operated by the United States Army Corps of Engineers. The Portland District of the Corps, Geotechnical Engineer Branch, Concrete and Dam Safety Section has safety responsibilities for these dams. A variety of dam safety related information is also available on the Portland District's web site at www.nwp.usace.army.mil. Under the Corps normal dam operating practices, dams are inspected annually, with a more complete evaluation every five years on a rotating schedule.

12.5.1 Flood Damage to Dams

All of the Corps dams were designed and built with specific flood capacities. Current dam designs are based on Standard Project Floods. Standard Project Floods, as defined in the Corps Engineer Manual 1110-2-1411 (March 1, 1965) are floods resulting from the Standard Project Storm. In turn, the Standard Project Storm is defined, somewhat imprecisely, as the most severe flood-producing rainfall-snowmelt, depth-area-duration event that is considered "reasonably characteristic" of the

drainage basin. Discussions with Corps staff in the Portland District Office indicated that the Standard Project Flood is approximately a 500-year flood event.
The Corp dams' discharge design levels include the combination of spillway discharge capacity and reservoir outlet pipe discharge capacity. As an example, for the Hills Creek Dam, the Standard Project Flood is 64,500 cubic feet per second. The maximum controlled discharge capacity of the dam is 151,760 cubic feet per second, or nearly two and one-half times the Standard Project Flood discharge. These data are included on the Hills Creek Project, Emergency Response Flowchart[7]. At discharges beyond the maximum controlled discharge capacity of the dam, the dam would be overtopped, discharges would be uncontrolled, and there would be a high probability of damage to the dam, with some potential for dam failure. The large margin of safety in the discharge capacity of the dam suggests that the Hills Creek Dam likely has the capacity to withstand floods at least as large as a 1,000 year flood event without expected damage.

12.5.2 Earthquake Damage to Dams

All of these dams were designed and built in the 1940s to 1960s. Seismic design considerations were thus significantly lower than current seismic design considerations. A summary tabulation of the seismic design basis and inspection history of these dams is given below in Table 12.7 (Corps of Engineers, Portland District Office, March, 2001).

Table 12.7
Seismic Design, Evaluation and Inspection Data
Corps of Engineers Dams

Dam	Date of Last Seismic Evaluation	Seismic Design Basis		Date of Last Periodic Inspection
		Original	Current	
Cottage Grove	1981	None	0.21 g	1997
Dexter	1981	0.10 g	0.21 g	1996
Fall Creek	1981	0.10 g	0.21 g	1999
Dorena	1981	none	0.21 g	1997
Lookout Point	1981	0.10 g	0.21 g	1999
Blue River	1994	0.10 g	0.24 g	1996
Hills Creek	2000	0.10 g	0.22 g	1999
Cougar	1994	0.10 g	0.24 g	1997
Fern Ridge	2001	none	0.35 g	2000

As shown in Table 12.7, the Corps has conducted at least preliminary seismic evaluations of all of these dams. However, some of these evaluations were conducted in the 1980s and thus do not reflect current understanding of the seismic hazard in Oregon or current state-of-the-art seismic evaluation engineering principles. The Corps has an ongoing regular inspection program and an ongoing seismic evaluation program. Presumably, updated seismic evaluations of these dams will be completed over the next few years.

Seismic considerations were completely absent in the design of two of these dams:

Dorena and Fern Ridge. The others were explicitly designed or probably designed to ground shaking levels of 0.10 g, which is the maximum seismic design level for any of the Corps dams in western Oregon. In contrast, the current Corps seismic design levels for dams at these sites (i.e., if new dams were to be built today) would be 0.21 g to 0.24g for the dams in eastern Lane County and 0.35 g for Fern Ridge . Thus, current seismic design requirements are for levels of ground shaking about two times higher than the probable design levels for most of these dams and about three times higher for Fern Ridge.

Seismic evaluations of dam safety are a highly technical, highly specialized art. Separate evaluations must be done for each dam. The evaluation requires a detailed analysis of the design and construction of the dam, an analysis of the current condition of materials and components, geotechnical analysis of the foundation and site, and a site-specific seismic hazard analysis. For emergency planning purposes, a seismic evaluation should include the probabilities of failure for a scenario earthquake such as a large magnitude event on the Cascadia Subduction Zone.

12.5.3 Loss Estimates (Preliminary)

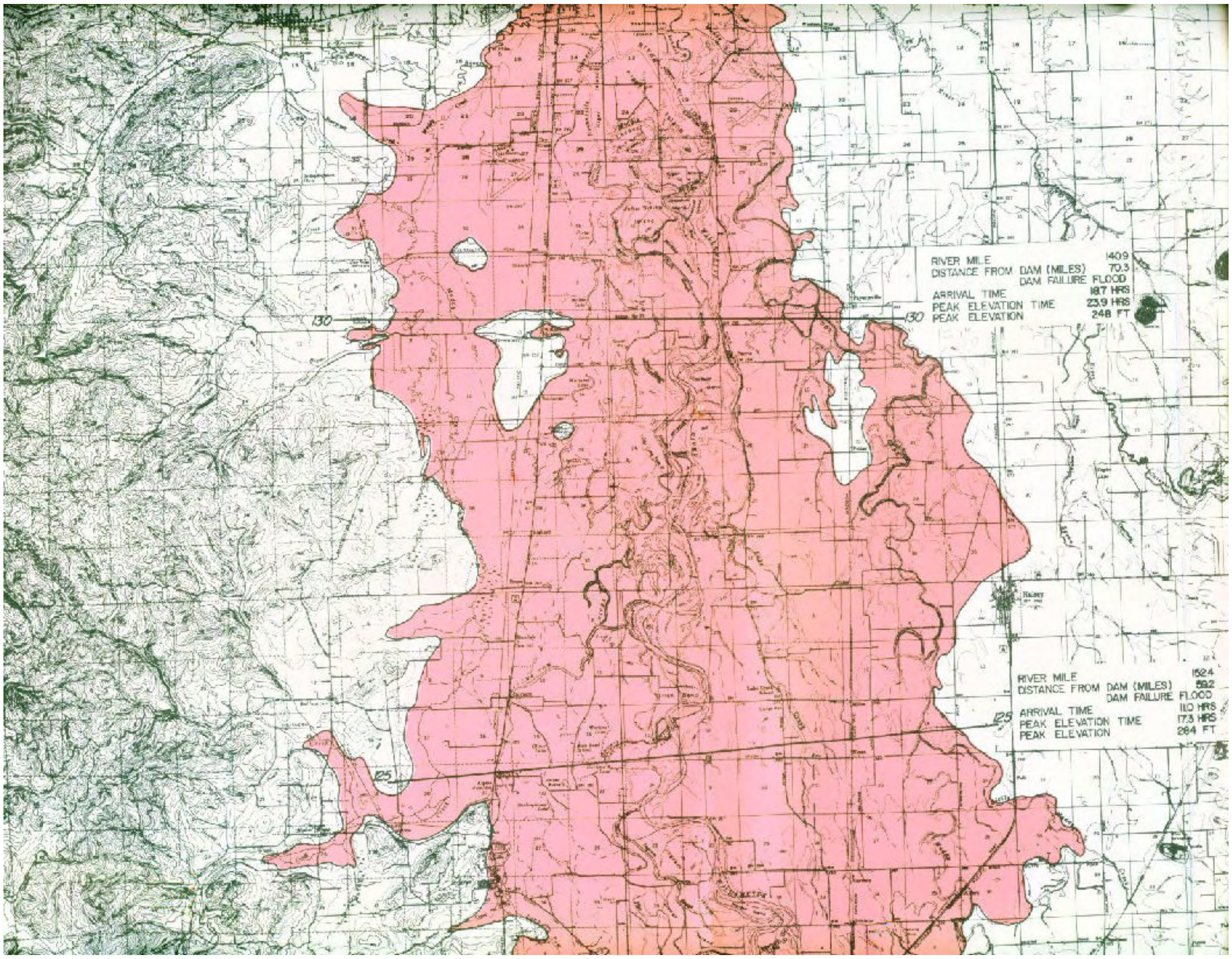
Detailed loss estimates for possible failures of these dams are beyond the scope of this mitigation plan. However, we note that in 1987 the Oregon Emergency Management Division[6], estimated that a completely catastrophic failure of the Hills Creek Dam, an extremely unlikely event, could require the evacuation of over 250,000 people with damages in excess of $10 billion. Adjusting these 1987 estimates for inflation and for population growth suggests that damages could easily exceed $20 billion. Detailed casualty estimates have not been made for catastrophic dam failures affecting Corvallis. However, given the large inundation areas, high water depths, and the logistical difficulties in evacuating thousands of people to safe ground, it is not difficult to imagine that a truly catastrophic dam failure could potentially result in several hundred deaths, in the worst case scenario.

An important aspect of potential dam failures upstream from Corvallis is that warning times from dam failure to flood arrival times in Corvallis are generally quite long, 12 hours or more.

The probability of catastrophic failure of these dams is impossible to estimate with any accuracy, from present data. Almost certainly, the probability is less than 0.1% per year (less than once in 1,000 years, on average) and perhaps substantially less. However, the consequences of failure are so high that careful evaluation is certainly warranted.

Each of the Corps dams upstream from Corvallis has studies showing inundation areas if dams were to fail catastrophically. Generally, these inundation maps show inundation flood boundaries for dam failures under extreme flood conditions and are thus an upper bound for inundation areas under other conditions (e.g., earthquake induced dam failure under non-flood conditions). As an example, a portion of the inundation area mapped along the Willamette River is shown below in Figure 12.1.

Figure 12.1
Sample Dam Inundation Area Map



The probable impacts of potential dam failures on Corvallis are summarized below in Table 12.8.

Table 12.8
Probable Impacts of Potential Dam Failures on Corvallis

Inventory	Probable Impacts
Portion of Corvallis affected	Direct impacts limited to mapped inundation areas for very unlikely complete dam failures at the same time as extreme flood events. More likely dam failure events would have significantly smaller inundation areas.
Buildings	Heavy damage in inundation areas, if dam failure occurs.
Streets within Corvallis	Damage and closures in inundation areas, if dam failure occurs.
Roads to/from Corvallis	Damage and closures in inundation areas, if dam failure occurs.
Electric power	Damage and loss of service in inundation areas, if dam failure occurs.
Other Utilities	Damage and loss of service in inundation areas, if dam failure occurs.. Potential for major damage to water and wastewater treatment plants in extreme events.
Casualties	Potential for casualties (deaths and injuries) in extremely unlikely major dam failures, depending on warning time available and effectiveness of evacuations.

12.6 Mitigation Strategies

Possible dam failures affecting Corvallis are very low probability events, but the potential casualties and economic impacts are high. The combination of low probability but large impacts makes analysis of such situations difficult from both a technical and a public policy perspective. The evaluation is difficult technically because it requires detailed engineering analysis of each dam and careful probabilistic risk analysis. As always, communication with the public must be non-alarmist, but factual, realistic and informative.

Recommendations

1. The first step in mitigation planning for dam safety is emergency planning. Emergency planners in Benton County should obtain copies of the inundation maps for each of the major dams to familiarize themselves with the areas of potential flooding. Inundation maps which are available from the USACE only as paper copies should be scanned or otherwise entered into the Corvallis GIS mapping system. For emergency planning, the estimated flood depths and the time periods from dam failure are particularly important. Flood depths and flood times both vary markedly with distance downstream from the dam locations. For emergency planning, key elements include community emergency notification procedures and evacuation planning (routes and traffic control). Because of the very large numbers of potential evacuees, training seminars and scenario exercises are strongly recommended.

2. All major dams have Emergency Action Plans. These plans should be reviewed to ensure that they are complete and up to date. Emergency planning officials in each county should be fully informed of the detailed consequences of the potential failure of each dam.   Public notification and evacuation plans should be updated and tested. For some types of dam failures, for example, those due to extreme floods, there may be some warning time. Decision making procedures, protocols, and procedures for issuing watches, warnings, and evacuation notices should be reviewed and updated and coordinated among all responsible federal, state, and local agencies.

3. Because of the age of these dams, the seismic design basis is significantly below current seismic design requirements. Preliminary seismic evaluations have been done but without sufficient detail to evaluate the probabilities of dam failures. Because of the extreme consequences of potential failure of one or more of these dams, we recommend that detailed seismic evaluations be conducted for all of these dams.

References

1. FEMA, Federal Guidelines for Dam Safety: Hazard Potential Classification Systems for Dams, FEMA 333, October 1998.

2. FEMA, Multihazard Identification and Risk Assessment, A Cornerstone of the National Mitigation Strategy, Chapter 20, Dam Failures, 1997.

3. FEMA, Dam Safety: An Owner’s Guidance Manual, FEMA 145, August 1987.

4. National Research Council, Safety of Existing Dams, Evaluation and Improvement, National Academy Press, 1983.

5. FEMA website (www.fema.gov), National Dam Safety Program webpage.

6. Oregon Emergency Management Division, Dam/Levee Failure, Statewide Hazard Analysis, March, 1987.

7. Hills Creek Lake Project, Emergency Response Flowchart, Distributed January 2000, United States Army Corps of Engineers, Portland District, 5 pages.

The table on the following page contains dam safety mitigation action items from the master Action Items table in Chapter 4.

Table 12.9
Dam Safety Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Dam Safety Mitigation Action Items								
Short-Term #1	Prepare high resolution maps of the dam failure inundation areas and update emergency response plans, including public notification and evacuation routes.	Public Works, City Manager's Office, Benton County Emergency Management	1-2 Years	X	X			X
Short-Term #2	Encourage the Corps of Engineers to undertake a though seismic risk evaluations for dams upstream of Corvallis and to make seismic and/or flood improvements as necessary	Benton County Emergency Management	Ongoing	X	X	X	X	X

13.0 DISRUPTION OF UTILITY AND TRANSPORTATION SYSTEMS

The previous chapters dealt with each of the major natural hazards impacting Corvallis including floods, severe weather events, landslides, wildland/ urban interface fires, earthquakes and volcanic hazards. These chapters evaluated each of the hazards and the risk arising from the hazards as they impact the buildings, infrastructure and people of Corvallis.

Each of these hazards may result in not only damage to buildings but also damage to and disruption of utility and transportation systems. Mitigation projects may be implemented to reduce or avoid such damage and disruptions and a few examples were discussed in the previous chapters. Evaluating the potential damage and disruption of utility and transportation systems from each natural hazard is an important part of the risk assessment for each locality affected by a natural hazard.

However, disruption of utility and transportation systems may have impacts on the affected community which are far broader than the direct damage and corresponding direct loss of service. In this sense, disruption of utility and transportation systems may be viewed almost as a hazard. As for other hazards, the probability, duration, and extent of such outages can be assessed and the impacts (risk) associated with such outages can be quantified. Among the major utilities, loss of electric power generally has the most widespread impact on other utilities and on the community as a whole. Therefore, this chapter deals with electric power outages in somewhat more detail than for the other utility and transportation systems.

13.1 Transportation Systems

Streets, roads, and highways are subject to closure during flood events because of high water levels on road surfaces. This type of closure may occur during either a major flood event on the larger rivers and streams in Corvallis and surrounding areas or during severe weather events as a result of localized flooding on smaller drainage systems. In major floods or major winter storms, such road closures may be widespread. If flow velocities are low, then such closures are usually due primarily to water depth and there is generally little damage to the road system; reopening the road simply requires waiting for the water level to drop and then cleaning up mud and debris on the road surface.

However, if flow velocities are higher then erosion of the road surface or undermining of the road may occur. This type of damage is most common in hilly areas with relatively steep slopes and occurs most often on smaller roads rather than on major highways. Reopening such roads often requires repair of the damaged road surface.

The flood of February 1996 provided ample evidence of the impact of flooding on roads. For example, in Corvallis, there were many flood-caused road closures. These closures included most of the major highways east and south of the city and numerous secondary roads.

For Corvallis, Chapter 7 (Winter Storms) identified some of the most problematic areas where major arteries and other roads have been repeatedly affected by winter storms (primarily localized flooding).

Some sites of road closures are difficult to mitigate without large scale flood control projects. However, mitigation is possible at many locations with high potential for road closures. Common measures include raising the road surface to reduce the probability of water overtopping the road or improving local drainage (e.g., culvert upsizings).

Risk assessments for road closures must include a measure of the importance of the road for transportation as well as an evaluation of the direct physical damages to the road. In many cases, the disruption of transportation has a larger economic impact that the direct physical damages.

To evaluate and prioritize hazard mitigation projects for roads, we suggest three measures of the relative importance of a road:

1) number of vehicle trips per day,
2) detour time around a road closure, and
3) road use as primary access/egress, including emergency vehicles.

The number of vehicle trips per day is an obvious measure of the importance of a road. All other factors being equal, a road with 500 trips per day is more important than a road with 50 trips per day and thus should have a higher priority for mitigation projects. However, a better measure of the importance of a road is obtained if the detour time is also considered. If traffic loads were equal, a mitigation project on a road where a closure required a one hour detour would have a higher priority than a road where a closure only required a five minute detour. More accurately, it is the combination of traffic load and detour time that provides a measure of the impact of road closure. The product of number of trips per day and the detour time gives a measure of the number of vehicle-hours of delay that result from a closure. Consider the following example:

Table 13.1
Calculation of Vehicle-Hours of Delay from Road Closures

Road	Trips per Day	Detour Time (hours)	Vehicle-Hours of Delay per day of Closure
A	500	0.10	50
B	100	1.00	100

In this example, Road A has fives times the traffic of Road B, but because the detour time is much longer for a closure on B than on A, the number of vehicle-hours of delay is greater on Road B than on Road A. On this basis, mitigation of the hazard causing the closure would have a higher priority on Road B than on Road A.

The number of vehicle hours of delay is a proxy for the economic impact of the closure. The current FEMA value (for benefit-cost analysis purposes) for the economic impact of lost time due to road closures is $32.23 per vehicle hour of delay (What is a Benefit?, FEMA 2001). This value is based on national average wage and benefits level and national average vehicle occupancy data, along with the assumption that an hour of leisure time is worth the same to a person as an hour of work (a common economic assumption). Then, for example, 100 vehicle hours of delay per day has an estimated economic impact of $3,223 and so on. For the vast majority of roads, with "typical" traffic loads, using an economic value of $32.23 per vehicle per hour of delay provides a reasonable measure of the economic impact of road closures. Although FEMA has not yet updated the 2001 value for road closures to the equivalent current value, the corresponding 2007 value would be about $37.67, taking into account inflation over the past six years.

Everything else being more or less equal, roads which serve as primary access/egress routes and/or serve many emergency vehicles may be given a higher priority for mitigation.

For completeness, we note that roads are networked systems and a more accurate analysis of the relative priority of mitigation projects to reduce road closures should consider the network characteristics of a local road system. However, network analysis is complex, requires specialized expertise and is expensive. Network analysis may be justified for very expensive projects, such as a multi-million dollar relocation of a bridge to reduce the potential for flood washouts. However, the simple three parameter prioritization methodology suggested above is probably sufficient for evaluation of most small to medium sized mitigation projects.

Other transportation systems (rail, air, ports, ferry) are also subject to disruption due to the impacts of hazards. The analysis of such systems is roughly similar to that discussed above, but mitigation projects for such systems are encountered far less frequently than are mitigation projects for roads. Moreover, most such projects are not directly applicable to or a low priority for Corvallis and are thus not considered further.

13.2 Utility Systems - Overview

Evaluation of hazard mitigation projects for utility systems have some commonalities between systems that we briefly review before addressing each major utility system in turn.

Utility systems such as potable water, wastewater, natural gas, telecommunications, and electric power are all networked systems. That is, they consist of nodes and links. Nodes are centers where something happens - such as a pumping plant, a treatment plant, a substation, a switching office and the like. Links are the connections (pipes or lines) between nodes.

Risk assessments for utility systems are similar to risk assessments for buildings, in that the inventory of utility components is overlaid on the hazard map and the vulnerability of utility components is evaluated for the hazards impacting the utility. A major difference arises, however, because of the networked nature of utilities. As a simple example, consider an electric utility which suffers damage to 10% of its transmission lines. The extent of service outage might be essentially zero if there are redundant lines with sufficient capacity to handle the demand for electric power. Or, the extent of service outage might be 100% if the damaged lines provide the sole power feed for a community. Thus, the operating characteristics and network characteristics (especially the amount of redundancy) must be considered.

> **In conducting risk assessments or evaluating hazard mitigation projects for utility systems, the networked nature of such systems must be considered. The extent or lack of redundancy for particular elements in a system profoundly affects the extent to which a given level of damage results in system outages.**

The general procedure for conducting a risk assessment or evaluating a hazard mitigation project for a networked utility system is outlined below in six steps.

1) Overlay utility system components with hazard maps,

2) Estimate the vulnerability of each component to impacts from each hazard,

3) From the estimated amount of damage to the system and the system's network operating characteristics, estimate the extent and duration of service outage,

4) From the damage estimates and the resources available, estimate the restoration time,

5) From the service outage (number of customers and duration) estimate the economic impacts of such loss of service, and

6) If a mitigation project is being evaluated estimate the reduction in direct damages and the reduction in service interruption attributable to mitigation project.

An important caveat for conducting risk assessments or evaluation of hazard mitigation projects for networked utility systems is that specialized expertise is often required. The analyst must thoroughly understand the operating characteristics of utility system components and their vulnerability to each hazard as well as thoroughly understand the network operating characteristics of the system as a whole. In the absence of sufficient experience and expertise risk assessments or evaluation of hazard mitigation projects may produce inaccurate and misleading results.

> **CAVEAT: conducting risk assessments or evaluation of hazard mitigation projects of networked utility systems often requires specialized expertise to produce meaningful results.**

For reference, a detailed discussion of how to evaluate seismic hazard mitigation projects for water systems is given in the American Society of Civil Engineers monograph "***Guidelines for the Seismic Upgrade of Existing Water Transmission Facilities***," (J. M. Eidinger, editor, 1999; chapter by K. A. Goettel "Seismic Upgrades of Water Transmission Systems: When Is It Worth It?"). Very similar principles apply to evaluating hazard mitigation projects for other utility systems for any type of hazard.

The following sections briefly review utility systems with emphasis on identifying the system components which are most vulnerable to damage and loss of service from hazards covered in this Mitigation Plan: flooding, winter storms, landslides and earthquakes. Such components are thus logical targets for high priority mitigation projects whenever important components are subject to the hazards.

13.3 Potable Water Systems

Water treatment plants are often located in flood prone areas and are subject to inundation when raw water enters the filters, sedimentation or flocculation basins, resulting in loss of capability to treat incoming raw water properly. Water system control buildings and pump stations may also be subject to flood damages. Public or private water systems with wells as the water source are subject to outages when flood waters contaminate well heads; this is a common problem for smaller water systems.

For Corvallis, neither the Taylor nor Rock Creek Water Treatment Plants are within the mapped 100-year floodplains, although they could experience flooding in events significantly larger than a 100-year flood.

Water transmission or distribution pipes are rarely damaged by flood waters, unless there are soil settlements or major erosion, because the lines are sufficiently pressurized (for water quality) to prevent intrusion of flood waters. Water transmission or distribution pipes are, however, subject to breakage when they cross landslide areas or in earthquakes. Water treatment plants are also subject to earthquake damages to the building and to process and control equipment.

Water systems, including Corvallis's water systems, are also highly vulnerable to electric power outages. Many water systems include pumped storage systems where water is pumped to storage tanks which are typically located 60 to 200 feet above the elevation of water system customers. Such tanks generally contain no more than 1 or 2 days of storage beyond typical daily usage (for reasons of water quality). Thus, electric power outages of more than 1 or 2 days may result in loss of potable water due to the inability of pumping plants to pump water. The most logical mitigation projects to minimize such outages are to provide back-up generators at key pumping plants or to provide quick connects so that portable generators (if available) can be quickly installed. Water treatment plants are also subject to outages due to loss of electric power.

For Corvallis, both water treatment plants have one commercial power source (CPI or PP&L). The Rock Creek plant has sufficient generator capacity to operate without commercial power. However, the generator at the Taylor plant provides only minimal backup power and the facility cannot operate without commercial power. This limitation poses significant risk to Corvallis for any events which result in prolonged power outages. Four of the critical booster stations have on-site generators with enough capacity to operate the pumps. All of the other booster stations are pre-wired for quick connection of portable generators in the event of loss of commercial power.

For the Corvallis water system, seismic upgrades have been done for both water treatment plants and most of the reservoirs. Water pipes almost inevitably suffer damage in earthquakes regardless of their materials, although older cast-iron pipes typically have higher failure rates than ductile iron, welded steel or PVC pipes. Upgrades of pipes are rarely feasible from an economic perspective for seismic reasons alone, except for critical locations for transmission pipes where failure may result in prolonged outages for many customers. Critical locations include bridge crossings, liquefaction areas, and landslide areas and any other areas where the probability of failure is high.

Common mitigation projects for water systems include flood protection for treatment plants, providing back-up power, seismic upgrades for treatment plants and critical transmission lines and moving pipes from active landslide areas.

The most critical mitigation projects for the Corvallis water system are:

1) Seismic upgrades for the critical water transmission lines at the Marys River 3rth Street and 15th Avenue bridge crossings,
2) Seismic retrofit for the North Hills 1st Level East 5 million gallon reservoir, and
3) Adequate backup power at the Taylor Water Treatment Plant.

13.4 Wastewater Systems

Wastewater systems are often highly vulnerable to flood impacts. Rising water may cause collection pipes to backup and overflow. Intrusion of storm water into collection systems may result in flows that exceed treatment plant capacities, resulting in release of untreated or only partially treated flows. Treatment plants are often located in flood plains, at low elevations, to facilitate gravity flow. However, such locations also facilitate flood damages. Wastewater treatment plans may be inundated, resulting in full or partial plant shutdown or plant bypass with corresponding release of untreated or only partially treated flows.

Lift stations and treatment plants are also subject to loss of function due to electric power outages, with resulting overflows or releases. Collection pipes are also subject to breakage due to landslides. However, such impacts are not particularly common, since most wastewater collection systems are in more urbanized areas with only selected areas subject to slides. Wastewater pipes are, however, subject to breakage in earthquakes. Wastewater treatment plants are also subject to earthquake damages to the building and to process and control equipment.

The Corvallis Wastewater Reclamation Plant is located within the 100-year floodplain. A seismic evaluation and retrofit have been completed. The plant's electric power is provided by two PP&L feeds, which provides some redundancy. There are two very small generators at the plant, which provide only minimal power. The plant cannot operate without commercial power. All but one of the wastewater lift stations have on-site backup generators with enough capacity to operate the pumps.

Common mitigation projects for wastewater systems include flood protection for wastewater treatment plants, providing back-up power for nodes such as lift stations, moving collection pipes from active landslide areas, and seismic upgrades for treatment plants.

The most critical mitigation projects for the Corvallis wastewater system are:

1) Improved flood protection for the Wastewater Reclamation Plant, and
2) Adequate backup power at the Wastewater Reclamation Plant

13.5 Natural Gas Systems

Natural gas transmission and distribution pipes are not usually affected by flooding, because the pipes are pressurized. However, compressor stations may be subject to inundation damage or loss of electrical power to run electrical and mechanical equipment.

Transmission and distribution pipes are also subject to rupture in slide areas and in earthquakes. Buried utility pipes are very subject to failure in small ground movements. Movements as small as an inch or two are often sufficient to break the pipes, especially for older cast-iron pipe which is more brittle than welded steel or polyethylene pipe. Possible mitigation actions include pipe upgrades for a few critical locations and nonstructural seismic mitigation for control equipment.

13.6 Telecommunications Systems

Telephone (land lines and cellular) systems, broadcast radio and TV systems, and cable TV systems may all be vulnerable to damages and services outages from hazards. However, in general, such systems have proved to be somewhat less vulnerable to service outages than other utility systems. System nodes (broadcast studios, switching offices and such) are subject to flooding if located in flood-prone areas. However, because of the importance of such facilities, few are located in highly flood-prone sites.

Similarly, few such facilities are likely to be located in landslide prone areas. Cellular towers in hilly areas, however, may be more subject to landslide hazards.

Buried communications (copper and fiber optic) and cable television cables are usually flexible enough to accommodate several feet of ground movement before failure. Thus, while major landslides may rupture such cables, minor settlements or small slides are not nearly as likely to impact such cables as they are to break buried gas or water pipes. Thus, such lines typically perform relatively well in earthquakes.

Above ground communications and cable television cables are subject to wind-induced failures from tree falls and pole failures. However, such failures are a less common than failures of electric power lines. The better performance of communications cables arises in part because the electrical cables are always highest on the poles, thus a falling branch is usually first resisted by the power cables. Also, because the voltage levels in communications cables are much lower than those in power cables, the communication cables are not subject to “burn down” or shorting if wind-swayed cables touch each other or get too close.

Some telecommunications facilities are subject to failure as a result of loss of electric power. However, key facilities almost always have backup battery power and/or generators. Therefore, telecommunications facilities are generally much less vulnerable to outages from loss of electric power than are water or wastewater systems.

Possible mitigation projects for telecommunications systems include flood proofing of important nodes, adding back-up power, relocating facilities out of active slide areas and seismic retrofits.

For Corvallis, the most critical telecommunications element is probably the telephone central office (switching facility) serving the city. If the telephone central office has not had recent seismic evaluations for both the building’s structural and nonstructural components, then such an evaluation and retrofit (if necessary) would be a high priority.

13.7 Electric Power Systems

Overview

The electric power system is central to the functioning of a modern society. The impacts of loss of electric power are large: residential, commercial and public customers are all heavily dependent on electric power for normal functioning. Furthermore, as discussed above, other utility systems, especially water and wastewater systems, are heavily dependent on electric power for normal operations. Loss of electric power, therefore, may have large impacts on affected communities, especially if outages are prolonged.

Electric power for Corvallis is provided by Pacific Power and by Consumers Power. Electric power systems have somewhat complex operating characteristics, which are briefly summarized here. Electric power systems have three main parts: generation, transmission, and distribution.

Generation is the production of electric power. Generating plans can be hydroelectric, fossil fuel (oil, gas, or coal), nuclear, or various renewable fuels (wind, solar, biomass, etc.). Most of the electric power consumed within Corvallis is produced elsewhere and transmitted via high-voltage transmission lines into the county. The Bonneville Power Administration (BPA) is the primary source of power for Corvallis. BPA’s power comes from hydroelectric facilities (57%) operated by the Corps of Engineers or the

Bureau of Reclamation, from a nuclear plant (3%), from interchanges and wheeling (37%) of power transmitted by BPA but not owned by BPA and from other sources (3%). Through the Pacific Interties (high voltage AC or DC transmission lines) power is moved back and forth between California, the Pacific Northwest and western Canada.

The transmission system is a network of high voltage lines (500 kV and 230 kV) and substations which transmit power between generation plants and the local distribution system. The distribution system is a network of lower voltage lines and substations which carries power from transmission system substations to neighborhoods and eventually to individual customers.

Power Outages in Corvallis: Wind and Ice Storm Events

Power outages in Corvallis are may result from disruption of the transmission lines carrying power from outside Corvallis or from damage to the local distribution lines within Corvallis. The generating plant system has sufficient redundancy so that failures of one or more plants do not usually lead to significant power outages. However, because of the absence of generating capacity within Corvallis, major disruptions in the transmission system would result in substantial curtailment of available power. A major ice storm in the Columbia River area could conceivably results in failure of most of the 500 kV transmission lines feeding Corvallis.

Furthermore, a severe ice storm with 2" to 4" of ice over much of Corvallis could result in failure of most 500 kV and 230 kV transmission lines to and within Corvallis. Such a failure, which is unlikely, but certainly not impossible (see Chapter 7), would probably entail widespread power outages in Corvallis for at least 2 to 5 days.

The most frequent power outages, however, are due to failure of the local subtransmission or distribution system lines. Winter storms are the most frequent cause of significant electric power outages, with wind being the primary culprit. Electric distribution lines, the low voltage lines that deliver power to neighborhoods, are the most vulnerable electric system component in winter storms. Failures most commonly result from tree falls or from "burn downs" when wind-swayed cables touch or get too close to each other and short circuit. Distribution system failures may also be due to utility pole failures. Distribution lines may also fail due to ice loading in excess of design specifications or from landslides or debris flows or flooding which knock out utility poles.

Once a portion of a power distribution circuit fails, all customers in all or part of the circuit lose power, pending on the circuits design. The duration of the power outage depends on the number of outages and the number of repair crews available for repairs. A typical power utility repair crew (2 or 3 people with a cherry picker) can restore power to a distribution circuit with common types of damage in 1 or 2 hours after arriving at the damage site.

Electric transmission lines (110 kV and higher) are less vulnerable to winter storm damage because of more robust design specifications. These lines are usually higher above the ground and much less prone to tree branches falling on lines. Furthermore, because of the higher voltage (compared to distribution lines), power utilities must diligently pursue tree trimming programs to avoid flashovers from lines being too close to trees. Nevertheless, transmission lines do sometimes fail due to large tree falls, rapid growth of trees near lines, unusually high winds or heavy ice loads.

Corvallis is subject to outages of electric power primarily due to line failures. One possible failure mode would be the transmission lines that feed Corvallis from the north. More common failure modes would be failures of the trunk distribution lines within Corvallis and failures of distribution circuits or service drops from distribution lines to individual buildings. The local failures are most likely due to tree falls during wind storm events.

Mitigation projects to reduce the frequency and duration of electric power systems include: augmenting tree trimming programs and hardening lines and poles in locations where ice loading or wind effects result in repeated outages. In some cases, adding connections to improve redundancy of power feed paths and adding disconnect switches to minimize areas affected by any given failure are also worthwhile. In addition to such "hard" mitigation possibilities, there are also "soft" or planning mitigation projects. For example, enhancing mutual aid agreements with nearby utilities can reduce the duration of major outages by increasing the number of crews and equipment for making repairs. Other planning/logistics measures such as ensuring that adequate supplies of parts and equipment are available may also reduce the duration of future outages.

For Corvallis, augmenting tree trimming programs, especially for the transmission lines and the trunk distribution lines is probably the most effective mitigation measure. In selected locations upgrading lines and poles to better withstand loads from trees, wind and ice may also be appropriate. If there are key links in the systems that are highly prone to repetitive failures, undergrounding of limited portions of such links may also be appropriate.

Power Outages in Corvallis: Earthquakes

Electric power systems are also subject to outages in earthquakes, primarily from damage to substation equipment and distribution system transformers, rather than from failures of lines and poles.

The seismic vulnerability of the Bonneville Power System, which supplies much of the power for Corvallis is currently undergoing detailed study. More locally, the seismic vulnerability of the CPI and PP&L substations and other components supplying power to Corvallis is largely unknown. CPI has indicated that the distribution system has been evaluated throughout their six county service area, with upgrades budgeted and prioritized. Upgrades made in the Corvallis area include substations, transformers, control systems, distribution lines and transmission lines. However, detailed information about specific upgrades is not available. The extent to which PP&L has made similar evaluations and upgrades is unknown.

13.8 Impacts on Corvallis and Mitigation Action Items

The probable impacts of disruption of transportation and utility systems on Corvallis, which were summarized above, are also covered in each of the other hazard Chapters (6 -12, 14 and 5). Each of these chapters includes an impacts table which summarizes probable impacts on roads, bridges, and utility systems. A generalized summary of the probable impacts of utility disruptions and road closures on Benton Count is given in Table 13.2 below.

Table 13.2
Probable Impacts of Utility Disruptions and Road Closures

Inventory	Probable Impacts
Portion of Corvallis affected	Impacts may be localized for damage to local utility distribution systems or street closures, or effect the entire city for damage to transmission lines or closures of major highways to/from Corvallis
Buildings	Negligible impacts to buildings, but loss of utilities may substantially affect function of buildings
Streets within Corvallis	Some incidents may include temporary street closures
Roads to/from Corvallis	Some incidents may include temporary road closures
Electric power	Some incidents may include temporary loss of electric power in localized parts of Corvallis or for the entire County. Duration of disruptions can range from an hour to up to a probable maximum outage of 1 or 2 days for most wind/ice events. Longer outages are possible for extreme wind/ice events or for major earthquakes.
Water	Failure of the major water transmission lines on the Marys River bridge crossings would result in almost complete loss of water to Corvallis, with a high likelihood of long duration water outages. Prolonged power outages would also result in widespread water outages.
Wastewater	Power outages affecting the treatment plant would result in nearly complete loss of treatment capability.
Natural Gas	Localized loss of service from pipe breaks in earthquakes is expected.
Telecommunications	Prolonged power outages would likely affect some modes. Seismic damage to the Corvallis telephone central office might impact nearly all telephone communications.
Casualties	Low potential for direct casualties, but some incidents such as loss of electric power during cold weather may require evacuations and displacement of people (especially fragile or special needs population) to temporary shelters.

The following table contains action items for mitigation of disruptions of utility and transportation systems, from the master Action Items table in Chapter 4. See also the mitigation action items for Winter Storms (Chapter 7) which includes action items related to tree trimming efforts to reduce storm effects on the electrical distribution systems within Corvallis.

Table 13.3
Mitigation Action Items for Disruption of Utility and Transportation Systems

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Partnerships
Utility and Transportation System Disruption Mitigation Action Items								
Short-Term #1	Educate and encourage residents to maintain several days of emergency supplies for power outages or road closures	Public Works, Fire, Police, Benton County Emergency Management	Ongoing	X	X			X
Short-Term #2	Review and update emergency response plans for disruptions of utilities or roads	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #4	Write procedures for maintaining water supply during extended power outages	Public Works	1-2 years		X		X	

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Multi-Hazard Mitigation Action Items								
Short-Term #1	Establish a formal role for the Corvallis Hazard Mitigation Planning Committee to develop a sustainable process to encourage, implement, monitor, and evaluate citywide mitigation actions	Public Works, Community Development	Ongoing	X	X	X	X	X
Short-Term #2	Identify and pursue funding opportunities to implement mitigation actions	Public Works, Community Development	Ongoing	X	X	X	X	X
Short-Term #3	Develop public and private sector partnerships to foster hazard mitigation activities,	Public Works, Community Development, City Manager's Office	Ongoing					X
Short-Term #4	Develop detailed inventories of at-risk buildings and infrastructure and prioritize mitigation actions	Public Works, Community Development	1-2 Years	X	X	X	X	
Long-Term #1	Develop education programs aimed at mitigating the risk posed by hazards	Emergency Management, Capital Planning and Development, Economic Development	Ongoing					X
Long-Term #2	Integrate the Mitigation Plan findings into planning and regulatory documents and programs	Public Works, Community Development, Fire	Ongoing	X	X	X	X	X
Long-Term #3	Integrate hazard, vulnerability and risk Mitigation Plan findings into enhanced Emergency Operations planning.	Public Works, Fire, Police	Ongoing	X	X	X	X	X
Long-Term #4	Update website to include mitigation activities, opportunities, and success stories	Emergency Management, Planning, Information Services						X
Long-Term #5	Develop a speaker's bureau to provide information on mitigation activities, opportunities, and success stories	Public Works, Community Development, Fire, Citizen Corps programs						X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Flood Mitigation Action Items: Within FEMA-Mapped Floodplains								
Short-Term #1	Inventory critical facilities (if any) within mapped floodplains or other high flood risk areas and identify mitigation options if such facilities are identified.	Public Works, Community Development	Ongoing	X	X	X	X	
Short-Term #2	Survey elevation data for buildings within mapped floodplains, evaluate flood risk quantiatively, and explore mitigation options with property owners.	Public Works, Community Development	Ongoing	X		X	X	X
Flood Mitigation Action Items: Outside of FEMA-Mapped Floodplains								
Short-Term #1	Complete the inventory of locations in Corvallis subject to frequent storm water flooding	Public Works, Community Development	Ongoing	X	X	X	X	X
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works, Community Development	Ongoing	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Winter Storms Mitigation Action Items								
Short-Term #1	Complete an inventory of locations in Corvallis subject to frequent storm water flooding or repetitive tree fall problems from wind/ice	Public Works, Community Development	Ongoing	X	X	X	X	X
Short-Term #2	Enhance tree trimming efforts especially for transmission lines and trunk distribution lines and consider tree trimming ordinance	Public Works, private utilities	Ongoing	X	X	X	X	X
Short-Term #3	Encourage property owners to trim trees near service drops to individual customers	Public Works	Ongoing	X		X	X	
Short-Term #4	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	TBD: need local input here	1-2 Years	X	X			
Long-Term #1	For locations with repetitive flooding and significant damages or road closures, determine and implement mitigation measures such as upsizing culverts or storm water drainage ditches	Public Works	Ongoing	X	X	X	X	X
Long-Term #2	Consider upgrading electric lines and poles to improve wind/ice loading, undergrounding critical lines, and adding interconnect switches to allow alternative feed paths and disconnect switches to minimize outage areas	Private utilities	5 Years	X	X	X	X	X
Long-Term #3	Encourage new developments to include underground power lines	Community Development	ongoing	X	X	X	X	X
Earthquake Mitigation Action Items								
Short-Term #1	Complete seismic retrofit of City Hall and the Mary's River crossing for the 24" water transmission line, both of which are critical facilities for Corvallis, urgently requiring retrofit	Public Works	1-2 Years	X	X	X	X	
Short-Term #2	Complete inventory of public, commercial and residential buildings that may be particularly vulnerable to earthquake damage	Public Works, Community Development	1-5 years	X	X	X	X	X
Short-Term #3	Complete seismic vulnerability analyses of critical facilities with significant seismic vulnerabilities, including fire, police, medical, and other emergency communication/response facilities	Public Works	1-5 Years	X	X	X	X	X
Short-Term #4	Complete seismic vulnerability analyses for lifeline utility and transportation systems, including: water, wastewater, natural gas, electric power, telecommunications and bridges	Public Works, ODOT, private utilities	1-5 Years	X	X	X	X	X
Short-Term #5	Educate homeowners about structural and non-structural retrofitting of vulnerable homes and encourage retrofit	Public Works, Community Development	Ongoing	X		X	X	X
Long-Term #1	Obtain funding and retrofit critical public buildings and lifeline utility and transportation facilities with significant seismic vulnerabilities	Public Works, ODOT, private utilities	10 years	X	X	X	X	X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Landslide Mitigation Action Items								
Short-Term #1	Complete the inventory of locations where critical facilities, other buildings and infrastructure are subject to landslides	Public Works, Community Development	1-2 Years	X	X	X	X	X
Long-Term #1	Consider landslide mitigation actions for slides seriously threatening critical facilities, other buildings or infrastructure	Public Works, Community Development	5 Years	X	X	X	X	X
Long-Term #2	Limit future development in high landslide potential areas	Community Development	Ongoing	X	X	X	X	X
Hazard	**Action Item**	**Coordinating Organizations**	**Timeline**	**Mitigation Plan Goals Addressed: Life Safety**	**Critical Facilities and Emergency Services**	**Protect Property**	**Disaster Resilient Economy**	**Public Education, Outreach, Parnerships**
Wildland/Urban Interface Fire Mitigation Action Items								
Short-Term #1	Identify specific parts of Corvallis at high risk for urban/wildland urban interface fires because of fuel loading, topography and prevailing construction practices	Fire	1-2 Years	X	X	X	X	X
Short-Term #2	Identify evacuation routes and procedures for high risk areas and educate the public	Fire	Ongoing	X	X	X		X
Short-Term #3	Develop Corvallis Wildfire Protection Plan	Fire	1-2 Years	X	X	X	X	X
Long-Term #1	Encourage fire-safe construction practices for existing and new construction in high risk areas	Fire, Community Development	Ongoing	X	X	X	X	X
Hazard	**Action Item**	**Coordinating Organizations**	**Timeline**	**Mitigation Plan Goals Addressed: Life Safety**	**Critical Facilities and Emergency Services**	**Protect Property**	**Disaster Resilient Economy**	**Public Education, Outreach, Parnerships**
Volcanic Hazards Mitigation Action Items								
Short-Term #1	Update public emergency notification procedures for ash fall events	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #2	Update emergency response planning for ash fall events	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Evaluate capability of water treatment plants to deal with high turbidity from ash falls and upgrade treatment facilities and emergency response plans to deal with ash falls	Public Works	1-2 Years	X	X	X	X	X
Short-Term #4	Prepare/pre-script public messages about protecting from and disposing of volcanic ash	Public Works, Fire, Police						X

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed: Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Dam Safety Mitigation Action Items								
Short-Term #1	Prepare high resolution maps of the dam failure inundation areas and update emergency response plans, including public notification and evacuation routes.	Public Works, TBD	1-2 Years	X	X			X
Short-Term #2	Encourage the Corps of Engineeris to undertake a though seismic risk evaulations for dams upstream of Corvallis and to make seismic and/or flood improvements as necessary	TBD: need local input here	Ongoing	X	X	X	X	X
Short-Term #3	Conduct a thorough study of levee/dike systems protecting Corvallis for both earthquake and flood vulnerabiilty, including impacs of failure on protected structuresm and implement mitigation measures as necessary	TBD: need local input here	1-2 Years	X	X	X	X	X
Hazard	**Action Item**	**Coordinating Organizations**	**Timeline**	**Mitigation Plan Goals Addressed: Life Safety**	**Critical Facilities and Emergency Services**	**Protect Property**	**Disaster Resilient Economy**	**Public Education, Outreach, Parnerships**
Utility and Transportation System Disruption Mitigation Action Items								
Short-Term #1	Educate and encourage residents to maintain several days of emergency supplies for power outages or road closures	Public Works, Fire, Police	Ongoing	X	X			X
Short-Term #2	Review and update emergency response plans for disruptions of utilities or roads	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #3	Ensure that all critical facilities in Corvallis have backup power and emergency operations plans to deal with power outages	Public Works, Fire, Police	1-2 Years	X	X			X
Short-Term #4	Write procedures for maintaining water supply during extended power outages	Public Works	1-2 years		X		X	
	NOTE: topics below NOT included in Corvallis Hazard Mitigation Plan at this time							
Hazard	**Action Item**	**Coordinating Organizations**	**Timeline**	**Mitigation Plan Goals Addressed: Life Safety**	**Critical Facilities and Emergency Services**	**Protect Property**	**Disaster Resilient Economy**	**Public Education, Outreach, Parnerships**
Hazmat Incident Mitigation Action Items								
Short-Term #1	Ensure that first responders have readily available site-specific knowledge of hazardous chemical inventories in Corvallis	Oregon State Fire Marshal, Fire, Police, Public Works, Water, businesses with hazardous materials inventory	1 year	X	X			X
Short-Term #2	Enhance emergency planning, emergency response training and equipment to address hazardous materials incidents.	Oregon State Fire Marshal, Fire, Police, Public Works, Water, businesses with hazardous materials inventory	Ongoing	X	X			X
Short-Term #3	Encourage owners of sites with significant quantities of hazardous materials and of sites with Extremely Hazardous Materials to evaluate and upgrade seismic bracing/anchoring for hazardous materials storage systems.	Oregon State Fire Marshal, Fire, Police, Public Works, Water, businesses with hazardous materials inventory	Ongoing	X	X			

Hazard	Action Item	Coordinating Organizations	Timeline	Mitigation Plan Goals Addressed				
				Life Safety	Critical Facilities and Emergency Services	Protect Property	Disaster Resilient Economy	Public Education, Outreach, Parnerships
Terrorism Mitigation Action Items								
Short-Term #1	Enhance emergency planning, emergency response training and equipment to address potential terrorism incidents.	Emergency Management, OCEM, Law Enforcement agencies, Fire Service agencies, Citizen Corps programs	Ongoing	X	X	X	X	X
Long-Term #1	Upgrade physical security detection and response capability for critical facilities, including water systems and for any high-profile facilities such as major high tech facilities and sites with large quantities of hazardous materials	Emergency Management, Fire, Facilities Maintenance, Water, industrial/business hazmat users	5 Years	X	X	X	X	X

Appendix 1
Principles of Benefit-Cost Analysis

Benefit-cost analysis is the tool that provides answers to a central question for hazard mitigation projects: **"Is it worth it?"** If hazard mitigation were free, individuals and communities would undertake mitigation with robust enthusiasm and the risks from hazards would soon be greatly reduced. Unfortunately, mitigation is not free, but often rather expensive. For a given situation, is the investment in mitigation justified? Is the owner (public or private) better off economically to accept the risk or invest now in mitigation to reduce future damages? These are hard questions to answer! Benefit-cost analysis can help a community answer these difficult questions.

In the complicated real world of mitigation projects, there are many factors which determine whether or not a mitigation project is worth doing or which of two or more mitigation projects should have the highest priority. Consider a town which has two flood prone neighborhoods and each neighborhood desires a mitigation project. The two neighborhoods have different numbers of houses, different value of houses, different frequencies and severity of flooding. The first neighborhood proposes storm water drainage improvements at a cost of $3.0 million. The second neighborhood wants to elevate houses at a cost of $3.0 million. Which of these projects should be completed? Both? One or the Other? Neither? Which project should be completed first if there is only funding for one? Are there alternative mitigation projects which are more sensible or more cost-effective than the proposed projects?

Such complex socio-political-economic-engineering questions are nearly impossible to answer without completing the type of quantitative flood risk assessment and benefit-cost analysis discussed below.

In determining whether or not a given mitigation project is worth doing, the level of risk exposure without mitigation is critical. Consider a hypothetical $1,000,000 mitigation project. Whether or not the project is worth doing depends on the level of risk before mitigation and on the effectiveness of the project in reducing risk. For example, if the before mitigation risk is low (a subdivision street has a few inches of water on the street every couple of years or a soccer field in a city park floods every five years or so) the answer is different than if the before mitigation risk is high (100 or more houses are expected to have flooding above the first floor every 10 years or a critical facility is expected to be shut down because of flood damages once every five years).

All well-designed mitigation projects reduce risk (badly designed projects can increase risk or simply transfer risk from one community to another). However, just because a mitigation project reduces risk does not make it a good project. A $1,000,000 project that avoids an average of $100 per year in flood damages <u>is not</u> worth doing, while the same project that avoids an average of $200,000 per year in flood damages <u>is</u> worth doing.

The principles of benefit-cost analysis are briefly summarized here. The benefits of a hazard mitigation project are the reduction in future damages and losses, that is, the avoided damages and losses that are attributable to a mitigation project. To conduct benefit-cost analysis of a specific mitigation project the risk of damages and losses must be evaluated twice: before mitigation and after mitigation, with the benefits being the difference.

The benefits of a hazard mitigation project are thus simply future damages and losses which are avoided because a mitigation action was implemented.

Because the benefits of a hazard mitigation project accrue in the future, it is impossible to know exactly what they will be. For example, we do not know when future floods or other natural hazards will occur or how severe they will be. We do know, however, the probability of future floods or other natural hazards (if we have appropriate hazard data). Therefore, the benefits of mitigation projects must be evaluated probabilistically and expressed as the difference between annualized damages before and after mitigation. The following simplified example illustrates the principles of benefit-cost analysis; more details are given in the examples in the Appendices.

To illustrate the principles of benefit-cost analysis, we consider a hypothetical single family home in the town of Acorn, with the home located on the banks of Squirrel Creek. The home is a one story building, about 1500 square feet on a post foundation, with a replacement value of $60/square foot (total $90,000). We have flood hazard data for Squirrel Creek (stream discharge and flood elevation data) and elevation data for the first floor of the house. Therefore, we can calculate the annual probability of flooding in one-foot increments, as shown below.

Table A1.1
Damages Before Mitigation

Flood Depth (feet)	Annual Probability of Flooding	Scenario Damages and Losses Per Flood Event	Annualized Flood Damages and Losses
0	0.2050	$6,400	$1,312
1	0.1234	$14,300	$1,765
2	0.0867	$24,500	$2,124
3	0.0223	$28,900	$673
4	0.0098	$32,100	$315
5	0.0036	$36,300	$123
Total Expected Annual (Annualized) Damages and Losses			**$6,312**

Flood depths shown above in Table A1.1 are in one foot increments of water depth above the lowest floor elevation. Thus, a “3" foot flood means all floods between 2.5 feet and 3.5 feet of water depth above the floor. We note that a “0" foot flood has, on average, damages because this flood depth means water plus or minus 6" of the floor; even if the flood level is a few inches below the first floor, there may be damage to flooring and other building elements because of wicking of water.

The Scenario (per flood event) damages and losses include expected damages to the building, content, and displacement costs if occupants have to move to temporary quarters while flood damage is repaired.

The Annualized (expected annual) damages and losses are calculated as the product of the flood probability times the scenario damages. For example, a 4 foot flood has slightly less than a 1% chance per year of occurring. If it does occur, we expect about $32,100 in damages and losses. Averaged over a long time, 4 foot floods are thus expected to cause an average of about $315 per year in flood damages. Note that the smaller floods, which cause less damage per flood event, actually cause higher average annual damages because the probability of smaller floods is so much higher than that for larger floods. With these data, the house is expected to average $6312 per year in flood damages. This expected annual or "annualized" damage estimate does not mean that the house has this much damage every year. Rather, in most years there will be no floods, but over time the cumulative damages and losses from a mix of relatively frequent smaller floods and less frequent larger floods is calculated to average $6312 per year.

The calculated results in Table 1.10 are the flood risk assessment for this house for the as-is, before mitigation situation. The table shows the expected levels of damages and losses for scenario floods of various depths and also the annualized damages and losses.

The risk assessment shown in Table A1.2 shows a high flood risk, with frequent severe flooding which the owner deems unacceptable. Therefore he explores mitigation alternatives to reduce the risk: the example below is to elevate the house 4 feet.

Table 1.11
Damages After Mitigation

Flood Depth (feet)	Annual Probability of Flooding	Scenario Damages and Losses Per Flood Event	Annualized Flood Damages and Losses
0	0.2050	$0	$0
1	0.1234	$0	$0
2	0.0867	$0	$0
3	0.0223	$0	$0
4	0.0098	$6,400	$63
5	0.0036	$14,300	$49
			$112

By elevating the house 4 feet, the owner has reduced his expected annual (annualized) damages from $6312 to $112 (98% reduction) and greatly reduced the probability or frequency of flooding affecting his house. The annualized benefits are the difference in the annualized damages and losses before and after mitigation or $6312 - $112 = $6200.

Is this mitigation project worth doing? Common sense says yes, because the flood risk appears high: the annualized damages before mitigation are high ($6,312). To answer this question more quantitatively, we complete our benefit-cost analysis of this project. One key factor is the cost of mitigation. A mitigation project that is worth doing at one cost may not be worth doing at a higher cost. Let's assume that the elevation costs $20,000. This $20,000 cost occurs once, up front, in the year that the elevation project is completed.

The benefits, however, accrue statistically over the lifetime of the mitigation project. Following FEMA convention, we assume that a residential mitigation project has a useful lifetime of 30 years. Money (benefits) received in the future has less value than money received today because of the time value of money. To take the time value of money into account, we need to do what is known as a "present value calculation." We compare the present value of the anticipated stream of benefits over 30 years in the future to the up-front out-of-pocket cost of the mitigation project.

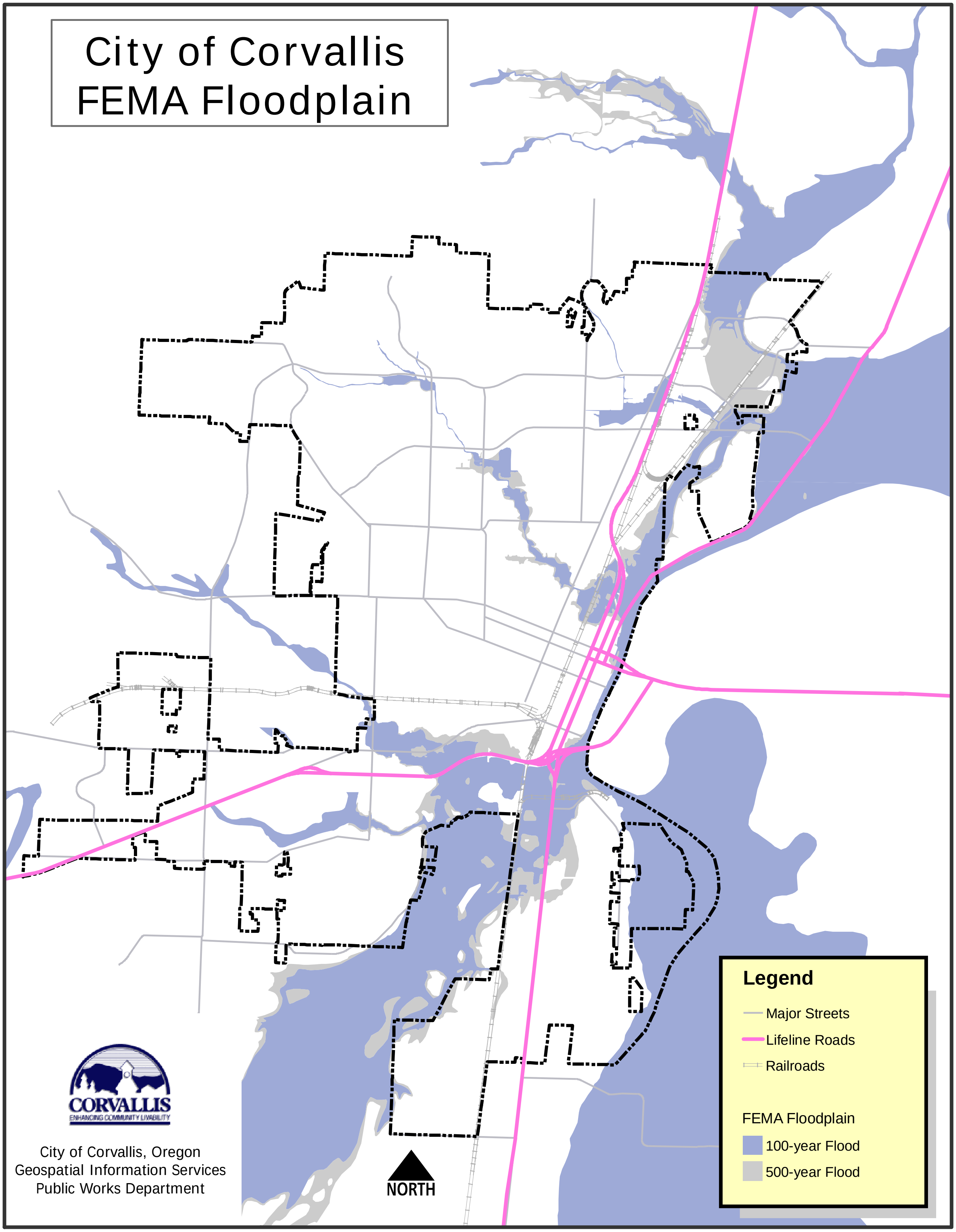
A present value calculation depends on the lifetime of the mitigation project and on what is known as the discount rate. The discount rate may be viewed simply as the interest rate you might earn on the cost of the project if you didn't spend the money on the mitigation project. Let's assume that this mitigation project is to be funded by FEMA, which uses a 7% discount rate to evaluate hazard mitigation projects. With a 30-year lifetime and a 7% discount rate, the "present value coefficient" which is the value today of $1.00 per year in benefits over the lifetime of the mitigation project is 12.41. That is, each $1.00 per year in benefits over 30 years is worth $12.41 now. The benefit-cost results are now as follows.

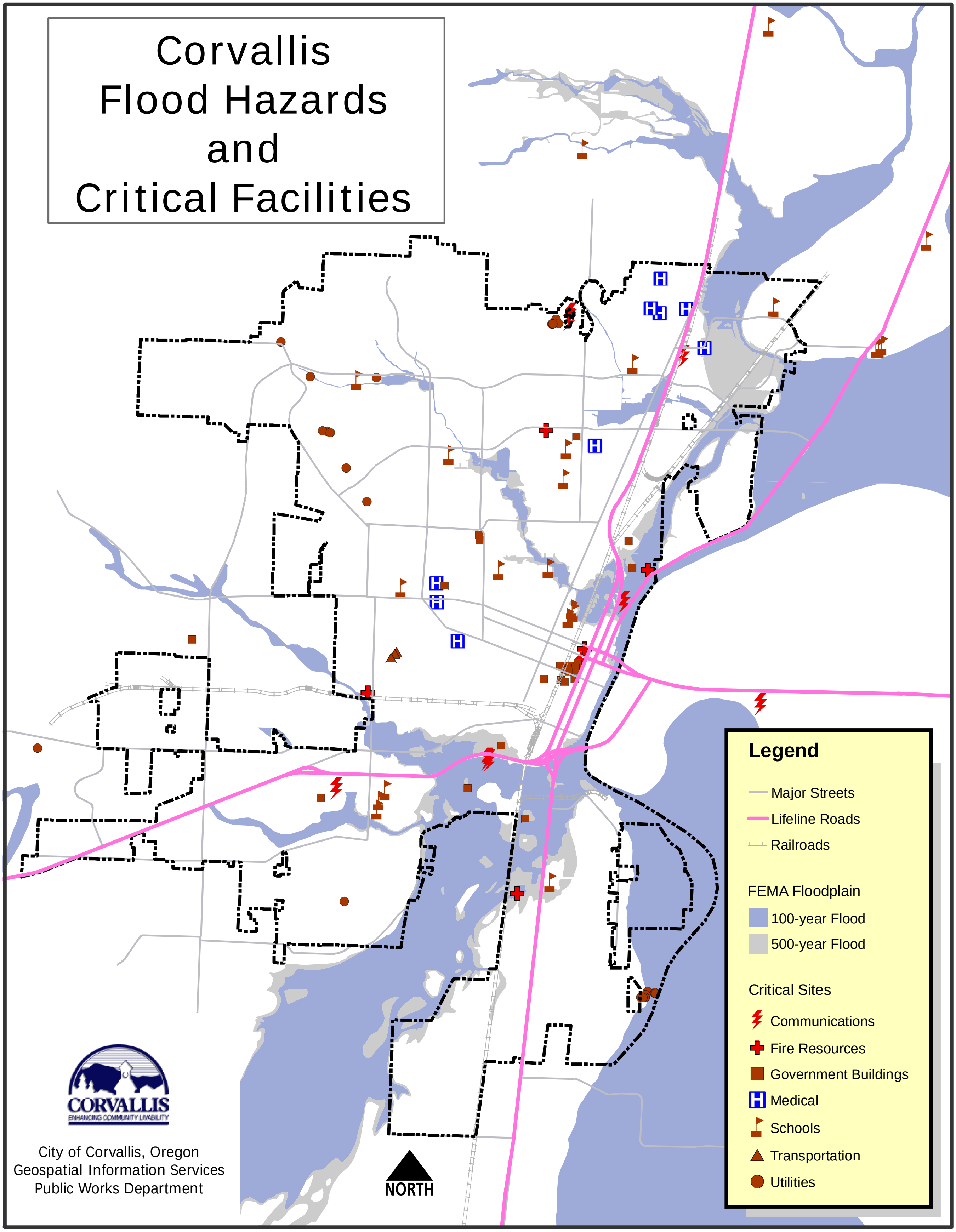
Table A1.3
Benefit-Cost Results

Annualized Benefits	$6,200
Present Value Coefficient	12.41
Net Present Value of Future Benefits	$76,942
Mitigation Project Cost	$20,000
Benefit-Cost Ratio	3.85

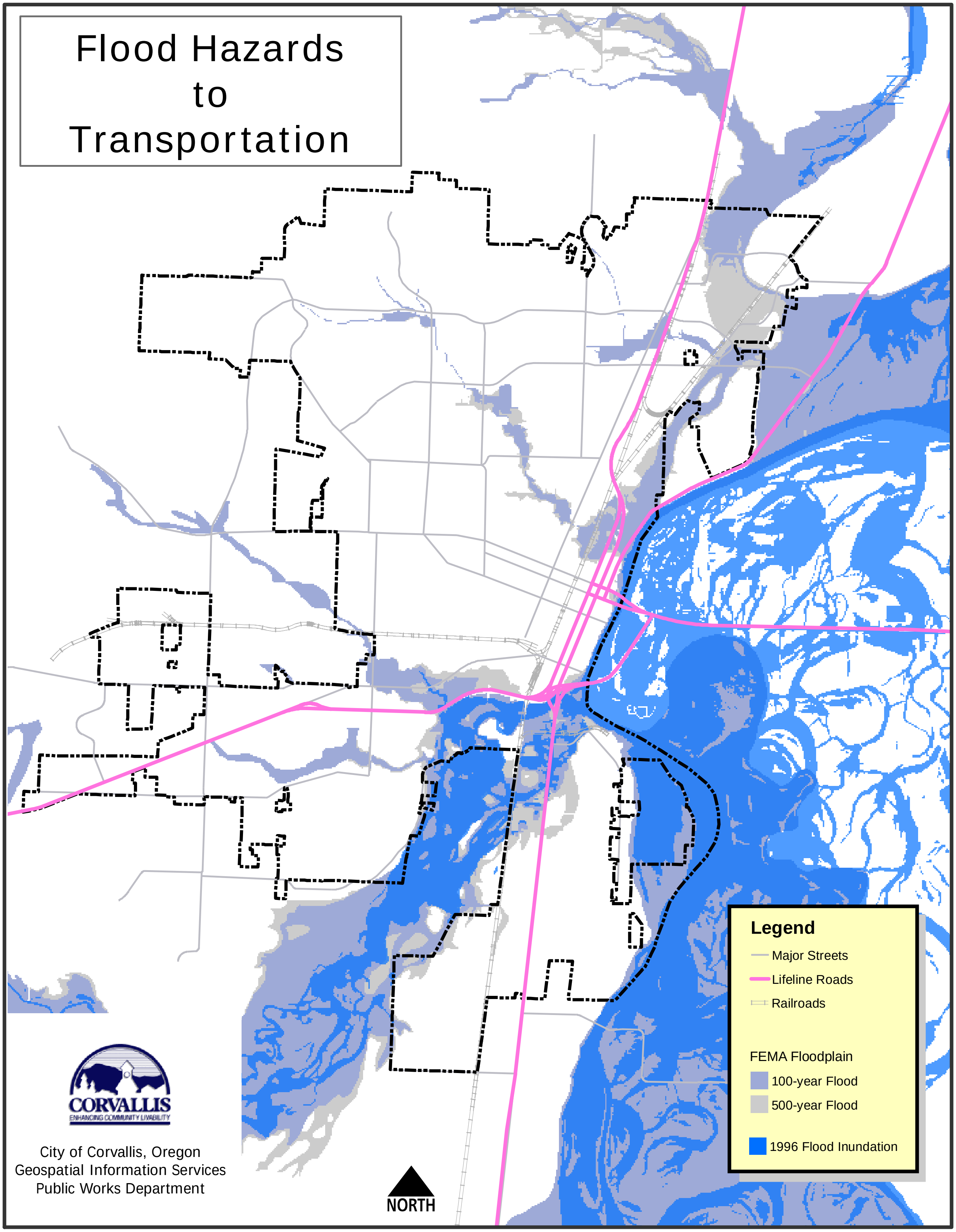
These results indicate a benefit-cost ratio of 3.85. Thus, in FEMA's terms the mitigation project is cost-effective and eligible for FEMA funding. Taking into account the time value of money, which is essential for a correct economic calculation, results in lower benefits than if we simply multiplied the annual benefits times the 30 year project useful lifetime. Economically, simply multiplying the annual benefits times the lifetime would ignore the time value of money and thus gives an incorrect, spurious result.

The above discussion of benefit-cost analysis of a flood hazard mitigation project is intended to illustrate the basic concepts. Very similar principles apply to mitigation projects for earthquakes or any other natural hazards. The role of benefit-cost analysis in prioritizing and implementing mitigation projects in Corvallis is addressed in Chapter 4 (Plan Goals, Mitigation Strategies and Action Items) and in Chapter 5 (Plan Adoption, Maintenance and Implementation).

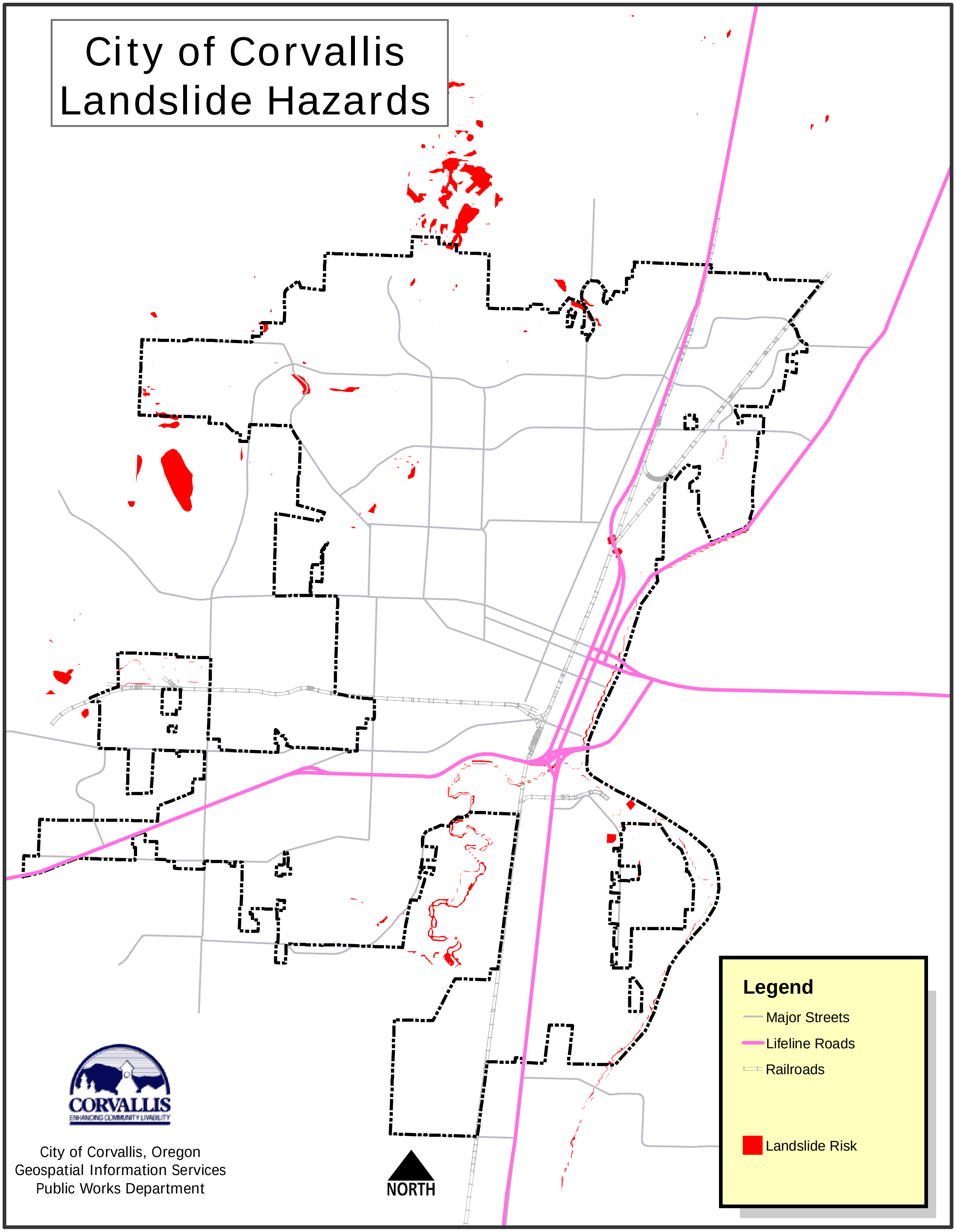

City of Corvallis
FEMA Floodplain
Legend
Major Streets
Lifeline Roads
Railroads
FEMA Floodplain
100-year Flood
500-year Flood
NORTH
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department

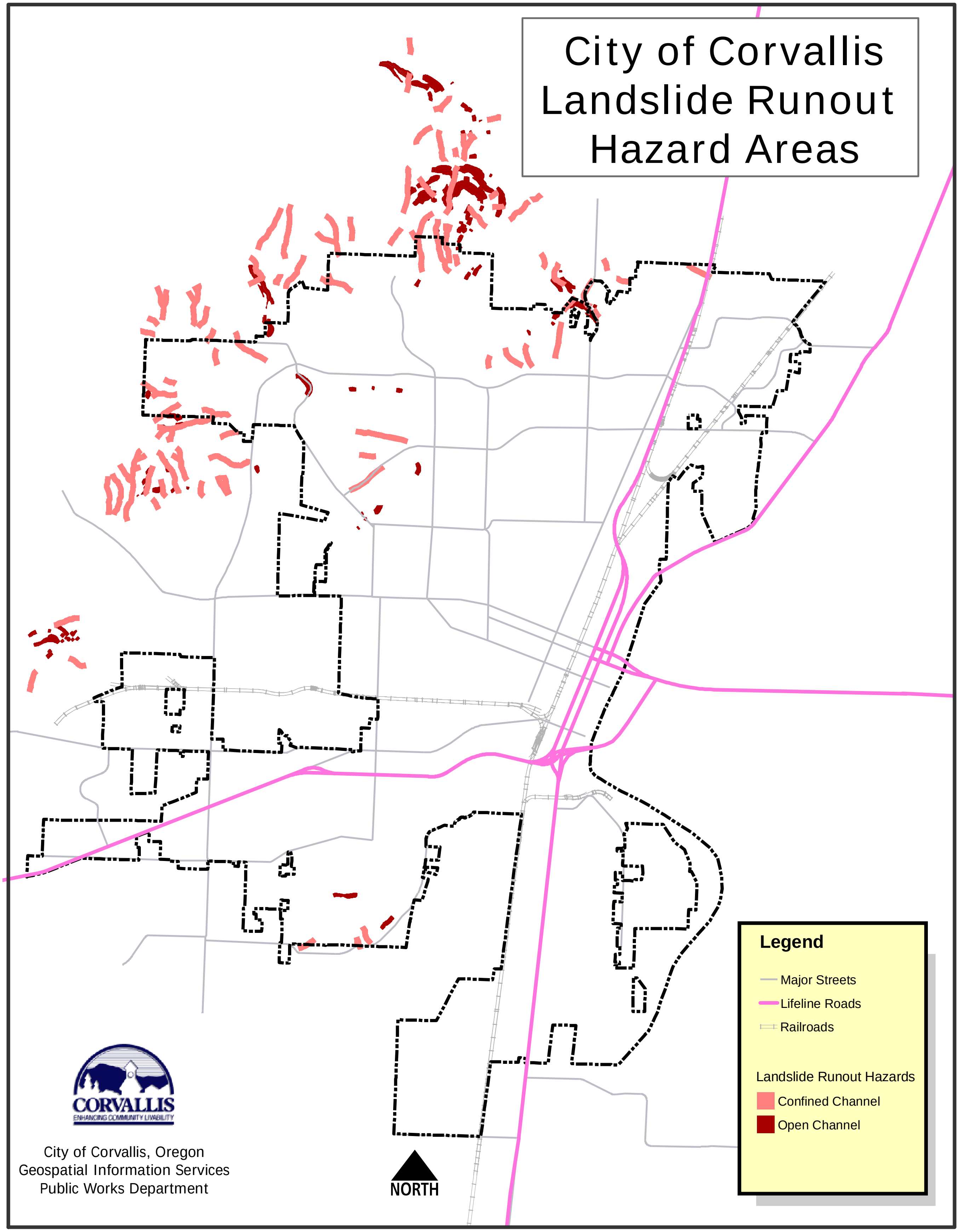


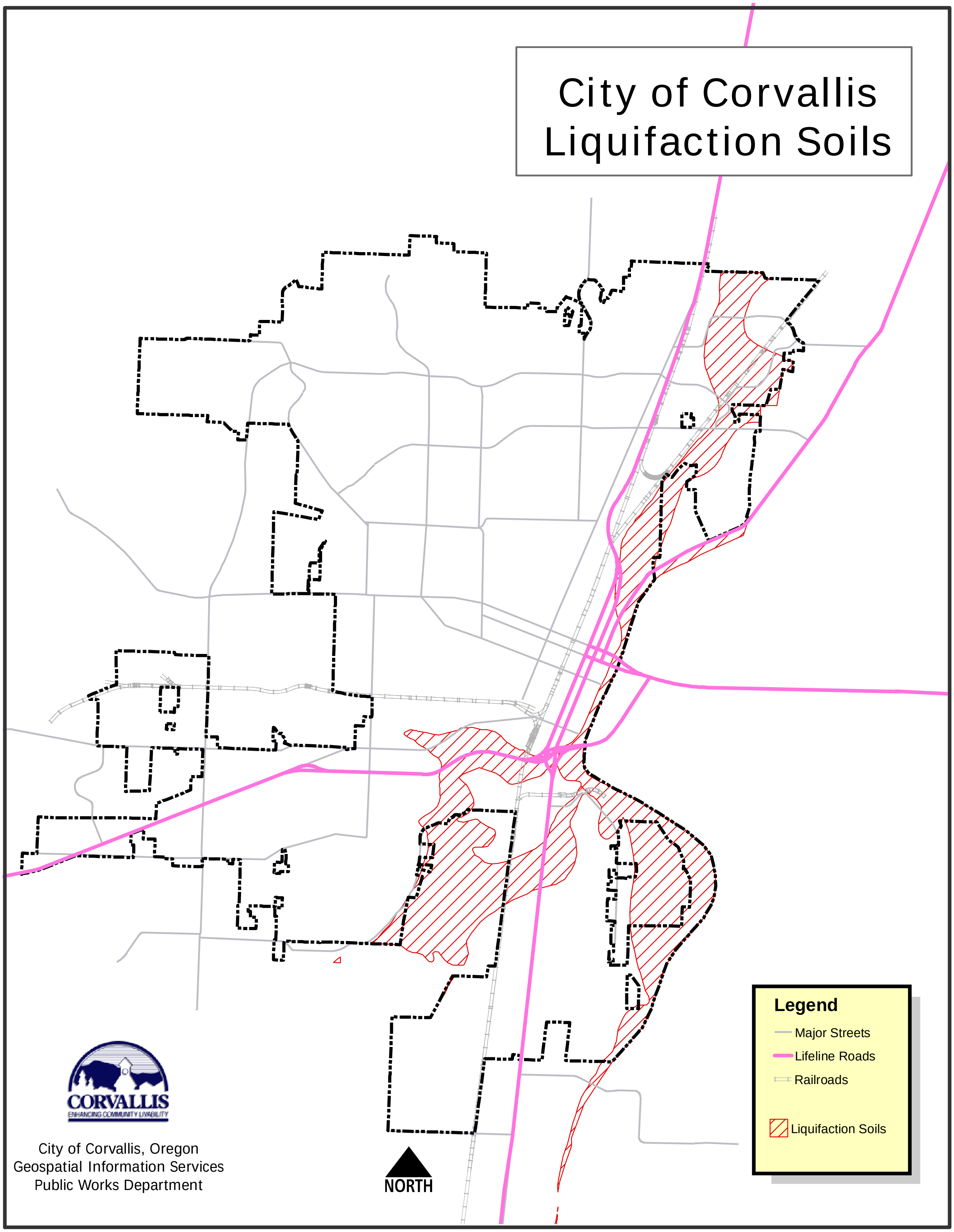
Corvallis
Flood Hazards
and
Critical Facilities
Legend
Major Streets
Lifeline Roads
Railroads
FEMA Floodplain
100-year Flood
500-year Flood
Critical Sites
Communications
Fire Resources
Government Buildings
Medical
Schools
Transportation
Utilities
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department
NORTH



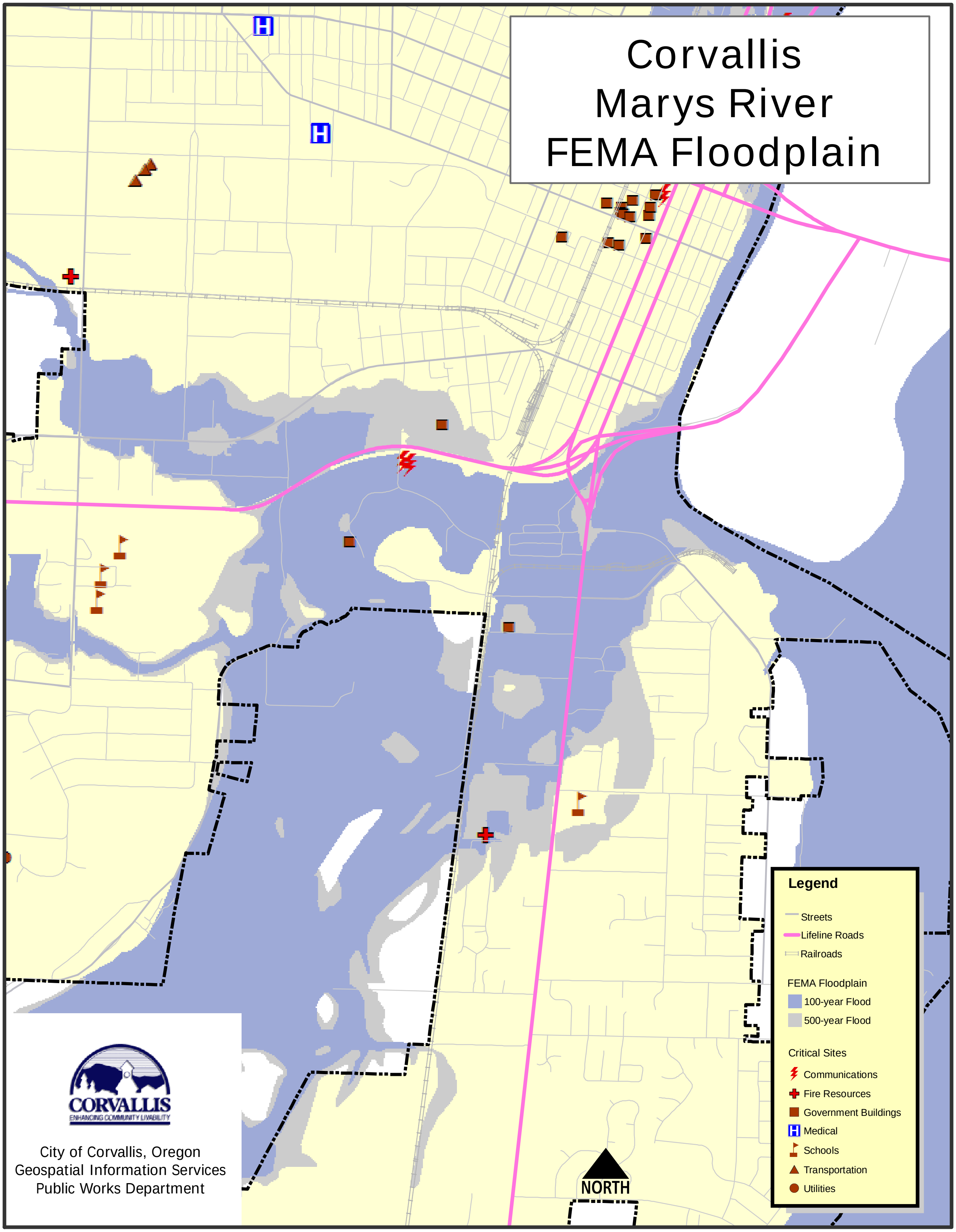
Flood Hazards
to
Transportation
Legend
Major Streets
Lifeline Roads
Railroads
FEMA Floodplain
100-year Flood
500-year Flood
1996 Flood Inundation
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department
NORTH

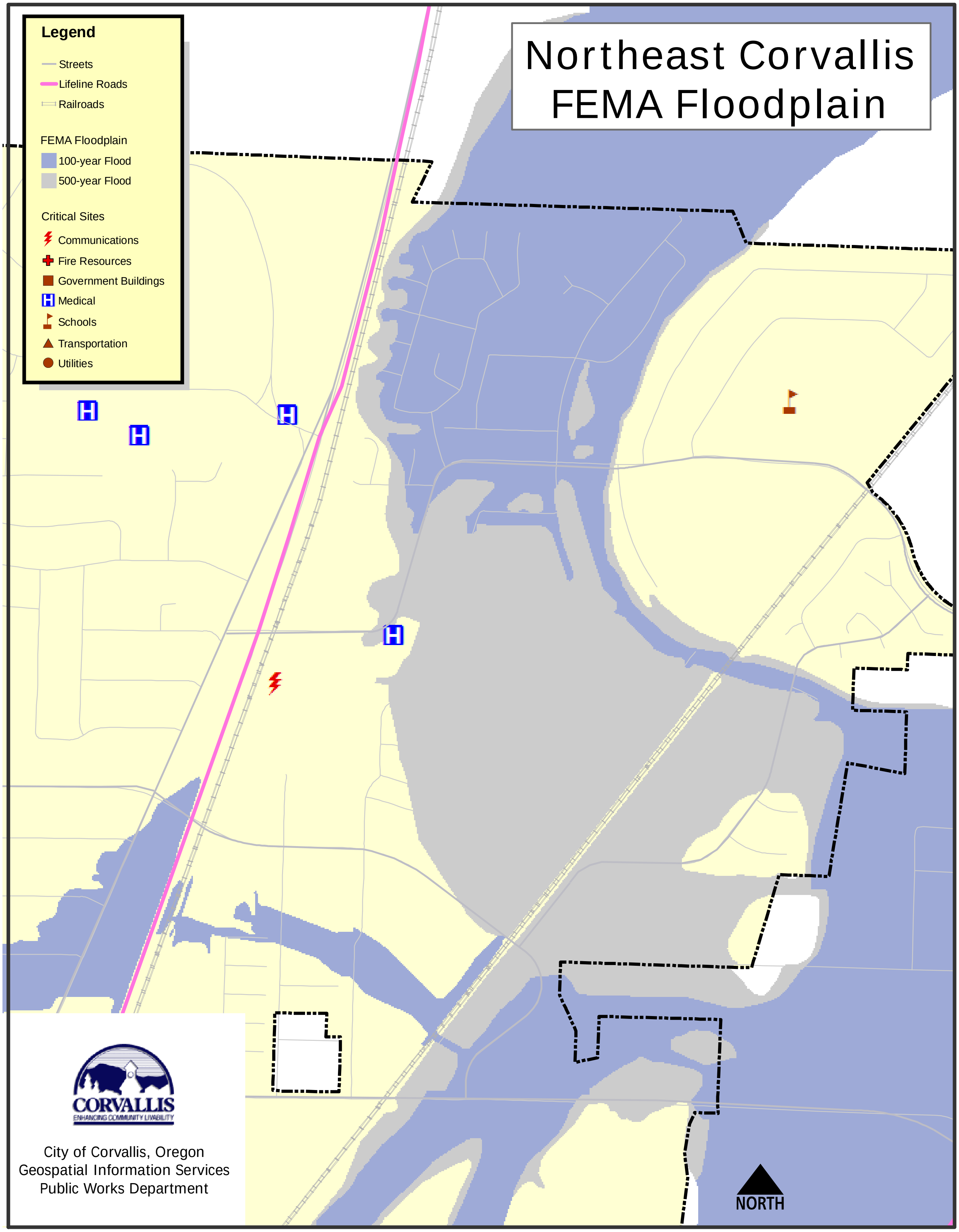

City of Corvallis
Landslide Hazards
Legend
Major Streets
Lifeline Roads
Railroads
Landslide Risk
NORTH
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department


City of Corvallis
Landslide Runout
Hazard Areas
Legend
Major Streets
Lifeline Roads
Railroads
Landslide Runout Hazards
Confined Channel
Open Channel
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department
NORTH

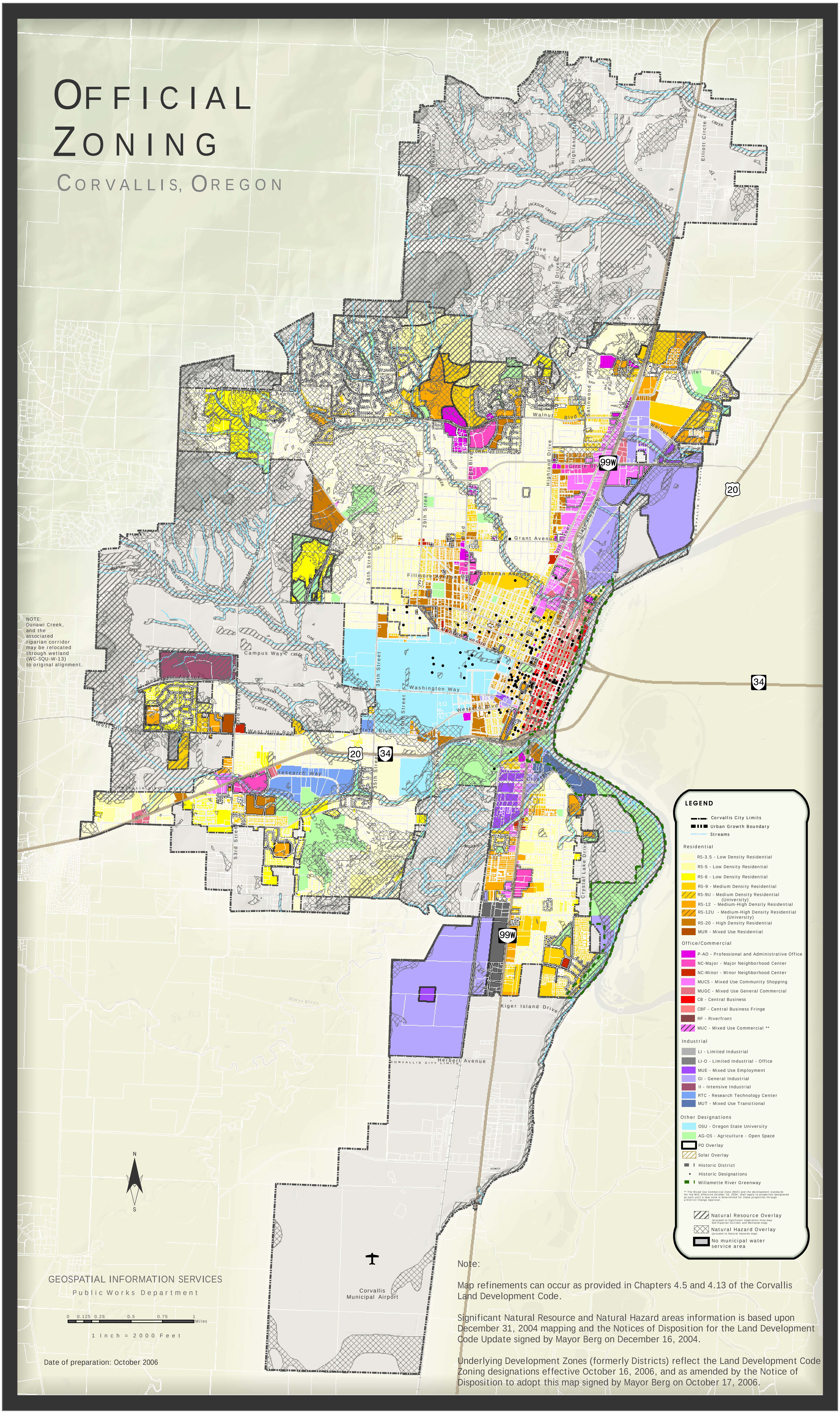


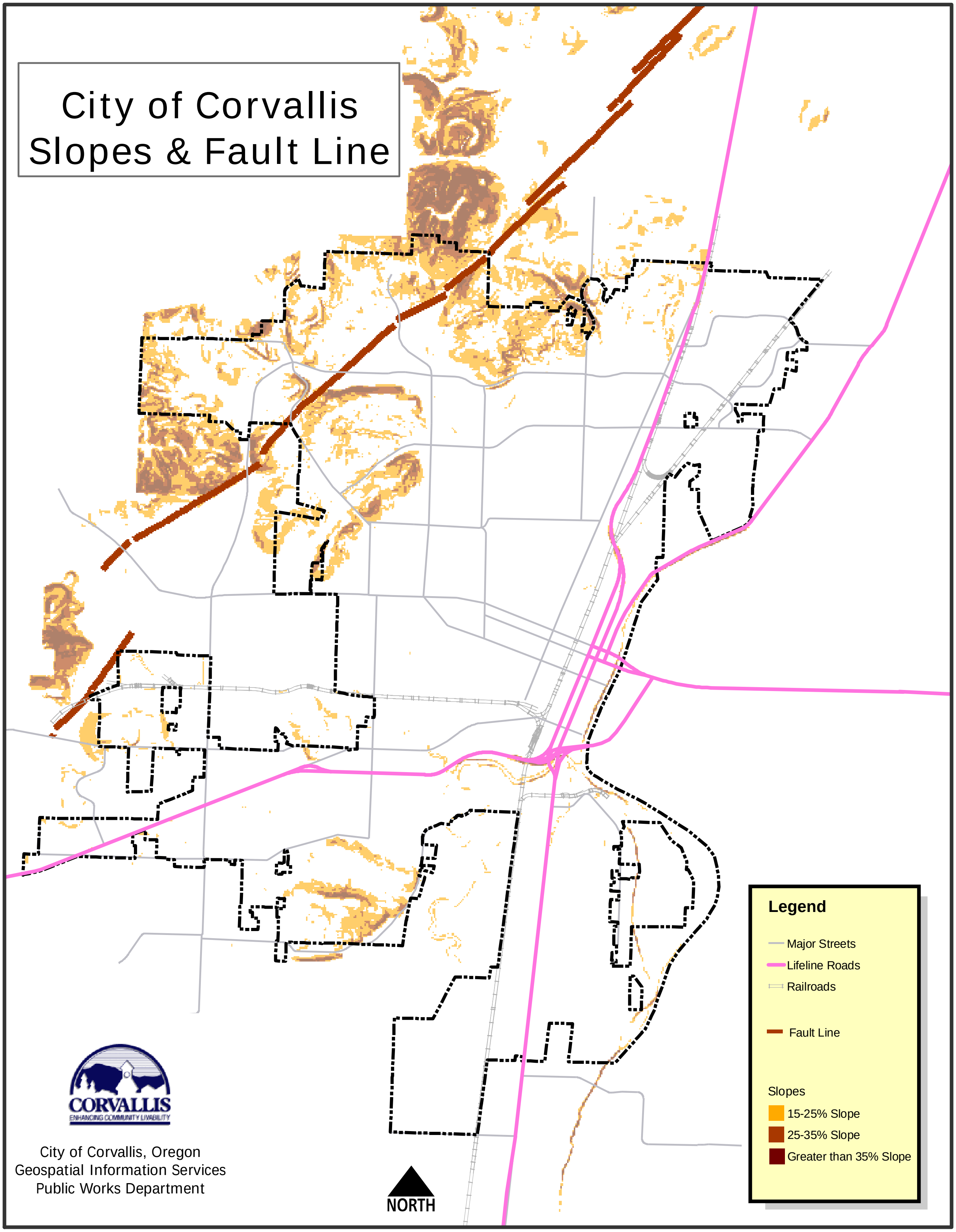
City of Corvallis
Liquifaction Soils
Legend
Major Streets
Lifeline Roads
Railroads
Liquifaction Soils
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
NORTH
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department


Corvallis
Marys River
FEMA Floodplain
Legend
Streets
Lifeline Roads
Railroads
FEMA Floodplain
100-year Flood
500-year Flood
Critical Sites
Communications
Fire Resources
Government Buildings
Medical
Schools
Transportation
Utilities
NORTH
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department



Northeast Corvallis FEMA Floodplain
Legend
Streets
Lifeline Roads
Railroads
FEMA Floodplain
100-year Flood
500-year Flood
Critical Sites
Communications
Fire Resources
Government Buildings
Medical
Schools
Transportation
Utilities
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department
NORTH


OFFICIAL ZONING
CORVALLIS, OREGON
NOTE: Dunawi Creek, and the associated riparian corridor may be relocated through wetland (WC-SQU-W-13) to original alignment.
LEGEND
Corvallis City Limits
Urban Growth Boundary
Streams
Residential
RS-3.5 - Low Density Residential
RS-5 - Low Density Residential
RS-6 - Low Density Residential
RS-9 - Medium Density Residential
RS-9U - Medium Density Residential (University)
RS-12 - Medium-High Density Residential
RS-12U - Medium-High Density Residential (University)
RS-20 - High Density Residential
MUR - Mixed Use Residential
Office/Commercial
P-AO - Professional and Administrative Office
NC-Major - Major Neighborhood Center
NC-Minor - Minor Neighborhood Center
MUCS - Mixed Use Community Shopping
MUGC - Mixed Use General Commercial
CB - Central Business
CBF - Central Business Fringe
RF - Riverfront
MUC - Mixed Use Commercial **
Industrial
LI - Limited Industrial
LI-O - Limited Industrial - Office
MUE - Mixed Use Employment
GI - General Industrial
II - Intensive Industrial
RTC - Research Technology Center
MUT - Mixed Use Transitional
Other Designations
OSU - Oregon State University
AG-OS - Agriculture - Open Space
PD Overlay
Solar Overlay
Historic District
Historic Designations
Willamette River Greenway
** The Mixed Use Commercial Zone (MUC) and the development standards for the MUC effective October 16, 2004, shall apply to properties designated as such until a new zone is determined for these properties through a District Change Approval.
Natural Resource Overlay
(proceed to Significant Vegetation Area map and Riparian Corridor and Wetlands map)
Natural Hazard Overlay
(proceed to Natural Hazards map)
No municipal water service area
Walnut Blvd
Circle Blvd
Grant Avenue
Fillmore Ave
Buchanan Avenue
Campus Way
Washington Way
West Hills Road
Research Way
29th Street
35th Street
36th Street
53rd Street
Highland Drive
Crystal Lake Drive
Kiger Island Drive
Herbert Avenue
Elliott Circle
99W
20
34
Corvallis Municipal Airport
N
S
GEOSPATIAL INFORMATION SERVICES
Public Works Department
0 0.125 0.25 0.5 0.75 1 Miles
1 Inch = 2000 Feet
Date of preparation: October 2006
Note:
Map refinements can occur as provided in Chapters 4.5 and 4.13 of the Corvallis Land Development Code.
Significant Natural Resource and Natural Hazard areas information is based upon December 31, 2004 mapping and the Notices of Disposition for the Land Development Code Update signed by Mayor Berg on December 16, 2004.
Underlying Development Zones (formerly Districts) reflect the Land Development Code Zoning designations effective October 16, 2006, and as amended by the Notice of Disposition to adopt this map signed by Mayor Berg on October 17, 2006.


City of Corvallis
Slopes & Fault Line
Legend
Major Streets
Lifeline Roads
Railroads
Fault Line
Slopes
15-25% Slope
25-35% Slope
Greater than 35% Slope
CORVALLIS
ENHANCING COMMUNITY LIVABILITY
City of Corvallis, Oregon
Geospatial Information Services
Public Works Department
NORTH