Section 8
Landslide
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Why are Landslides a threat to Portland?

Landslides are a serious geologic hazard that impacts nearly every U.S. state. Nationally, landslides cause 25 to 50 deaths each year and can pose a serious threat to human life.[1] The best estimates of the direct and indirect costs of landslide damage in the United States range between $1 billion to $2 billion annually.[2] In Oregon, a significant number of locations are at risk to dangerous landslides. Landslides have had an impact in Portland; they have created a number of problems in and around the City's hills. Although not all landslides result in private property damage, many impact transportation corridors, fuel and energy conduits, and communication facilities. [3]

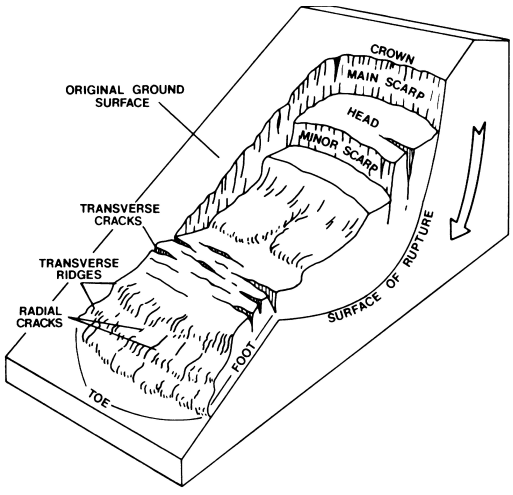
Landslides can be broken down into two categories: rapidly moving and slowly moving. Rapidly moving landslides (debris flows and earth flows) present the greatest risk to human life; persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Rapidly moving landslides have also caused most of the recent landslide-related injuries and deaths in Oregon. A rapidly moving debris flow in Douglas County killed five people during the storms of 1996. Slow moving landslides can cause significant property damage but are less likely to result in serious human injuries. An example occurred in Kelso, Washington in 1998: 60 homes were destroyed by reactivated slow-moving landslides that caused $25 million in damages.

Landslide Characteristics

What is a Landslide?

Landslides are downhill or lateral movements of rock, debris, or soil mass. The size of a landslide usually depends on the geology and the triggering mechanism. Processes and conditions that can trigger slope failures include intense rainfall, earthquake shaking, volcanic eruption, and rapid snowmelt. Human alterations can also increase the potential for slope instability and can also trigger specific failures.[4] Landslides initiated by rainfall tend to be smaller, while those initiated by earthquakes may be very large.

Figure 8-1. Rotational Slide

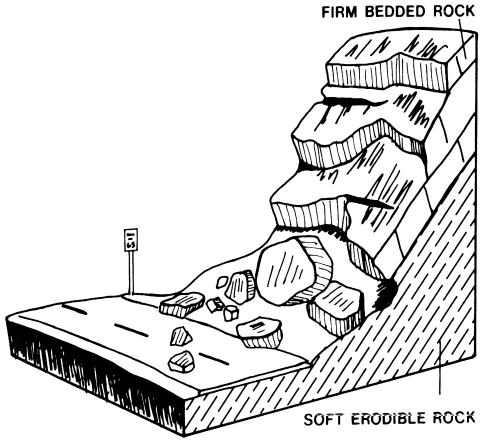


Slides associated with volcanic eruptions are typically large and can include as much as one cubic mile of material. Slides caused by erosion occur when ditches or culverts beneath hillside roads become blocked

with debris. If the ditches are blocked, run-off from slopes is inhibited during periods of precipitation. This causes the run-off water to collect in soil and will, and in some cases, cause a slide. Usually the slides are small (100 – 1,000 cubic yards), but some have been known to be quite large.

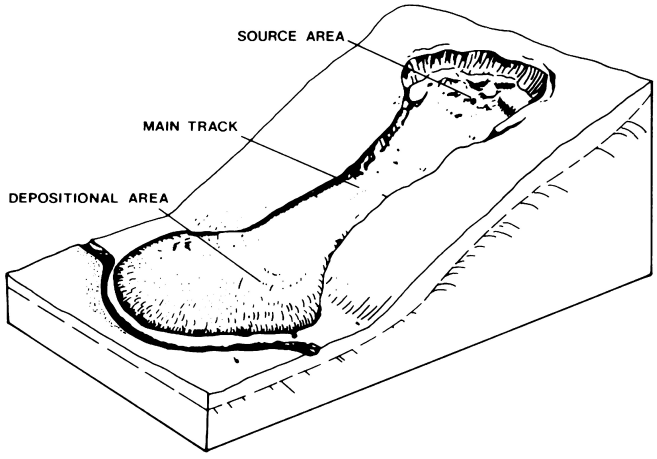
Landslides can vary greatly in the volume of rock and soil involved; the length, width, and depth of the area affected; the frequency of occurrence; and the speed of movement. Some of the characteristics that determine the type of landslide are the slope of the hillside, moisture content, and the nature of the underlying materials. Landslides are given different names depending on the type of failure and their composition and characteristics. Types of landslides include, but are not limited to, slides, rock falls, and flows.

Figure 8-2. Rock Fall



Source: *Planning for Natural Hazards: The Oregon Technical Resource Guide*, DLCD

Figure 8-3. Earthflow



Source: *Planning for Natural Hazards: The Oregon Technical Resource Guide*, DLCD

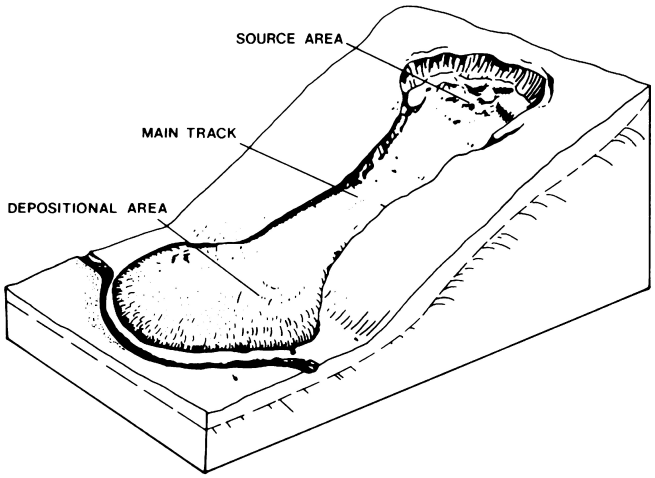
Slides move in contact with the underlying surface. These movements include rotational slides where sliding material moves along a curved surface and translational slides that occur along flat surfaces. These slides are generally slow moving and can be deep. Slumps are small, rotational slides that are generally shallow (See Figure 8-1). Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage but are far less likely to result in serious injuries than rapidly moving landslides.[5]

Rock falls (see Figure 8-22) occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations (such as those along highways) where the road has been cut through bedrock can cause falls. These slides are fast moving and materials free-fall or bounce down the slope. The total volume of material involved is generally small, but individual boulders or blocks of rock can be large and can cause significant damage.

Flows (see Figure 8-3) are landslides in which soil and rock breaks up and flows like a plastic or liquid. They are often categorized as debris flows or earth flows. Debris flows normally occur when a landslide moves downslope as a semi-fluid mass scouring, or partially scouring, soils from the slope along its path. Debris flows are typically fast-moving and also tend to increase in volume as they scour out the channel.[6] Debris flows often occur during heavy rainfall, can move rapidly for large distances, and generally occur in stream valleys and on the fans at the edges of valleys. One dramatic example of a debris flow in Oregon is the Dodson debris flow that occurred in 1996. This debris flow started high on the Columbia Gorge cliffs and traveled far down steep canyons to form debris fans at Dodson.[7] In fact, I-84 was closed for several days as a result of the flow. As a landslide slows down, debris material falls out and is deposited. Debris fans are the depositional areas of debris flows. They are typically found at the base of steep hill slopes and at mouths of steep canyons.[8] Earth flows are slower landslides occurring on saturated slopes with weak soils. Earthquakes often trigger earth flows.

Landslides are typically triggered by periods of heavy rainfall or rapid snowmelt but earthquakes, volcanic activity, and excavations might also trigger them. Certain geologic formations are more susceptible to landslides than others. Human activities, including development on or near steep slopes, can increase susceptibility to landslide events. In general, landslides on steep slopes are typically more dangerous because they can occur with little warning and their movements can be very rapid.

What locations are at risk from landslides and debris flows?



Locations at risk from landslides or debris flows include areas with one or more of the following conditions:

- On or close to steep hills;
- Steep road-cuts or excavations into steep slopes;
- Existing landslides or places of known historic landslides (such sites often have tilted power lines, trees tilted in various directions, cracks in the ground, and irregular-surfaced ground);
- Steep areas where surface runoff is channeled, such as below ground in culverts, V-shaped valleys, canyon bottoms, and steep stream channels;
- Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons, large boulders (2 to 20 feet diameter) perched on soil near fans or adjacent to creeks; and
- Occurrences of logjams in streams.[1]

Landslide Conditions

Although landslides are a natural geologic occurrence, their severity and their impacts on people can be increased by human activities. Grading for road construction and development can increase slope steepness. Grading and construction can also decrease a slope's stability by adding weight to the top of the slope, removing support at the base of the slope, and increasing water content. Other human activities affecting landslides include excavation, drainage and groundwater alterations, and changes in vegetation.[9]

Natural Conditions

Natural processes can cause landslides or re-activate historical landslide sites. Steep, concave-shaped slopes with larger drainage areas appear to be more susceptible to landslides than other landforms. Rainfall-initiated landslides tend to be smaller but occur frequently while earthquake-induced landslides may be very large but are less frequent. Landslides are particularly common along stream banks, reservoir shorelines, large lakes, and the seacoasts. The removal of material supporting the shoreline by currents and waves or undercutting during construction at the base of a slope produces countless small slides each year. Seismic tremors can also trigger landslides on slopes historically known to have landslide movement. Earthquakes can cause additional failure (lateral spreading) on gentle slopes above steep streams and riverbanks. Landslides associated with volcanic eruptions can include volumes of more than one cubic mile of material. All soil types can be affected by conditions that trigger landslides.

Many of the natural hazards definitions found in this plan come from existing state resources, including the *Planning for Natural Hazards: Technical Resource Guide,* the *Oregon State Natural Hazards Plan,* and FEMA-adopted local plans. For more information on existing resources for natural hazards and mitigation planning in the state of Oregon, please visit www.OregonShowcase.org.

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading of these slopes can result in some slopes that are steeper than the pre-existing natural slopes. Since slope steepness is a major factor in landslides, these steeper slopes can be at an increased risk for landslides. Additionally, the added weight of fill placed on slopes can result in an increased landslide hazard. Small landslides can be fairly common along roads in either the road cut or the road fill. Landslides that occur below new construction sites are often indicators of impacts stemming from excavation. A slope, when cut, is undermined. Without support, the soil/earth material may collapse and move.

Drainage and Groundwater Alterations

Water (either storm water or a natural drainage) flowing through or over the ground can trigger landslides. For proper drainage, water must either infiltrate into the ground, drain into a mechanized system, or run off to another area. Drainage can be affected naturally by the geology

and topography of an area or by man-made activities such as excavation and grading (described above). Any activity that increases the amount of water flowing onto slopes can increase the potential of landslides. Channels, streams, ponding, and erosion on slopes are all indicators of potential slope problems. They can also be created by man-made activities.

Ineffective storm water management—including water retention facilities that direct water onto slopes—and excess runoff can cause erosion and generate landslides. Development that results in an increase in the amount of impervious surfaces impairs the land's ability to absorb water and may redirect the run-off into other areas. Unabsorbed water concentrates and gains speed and volume. As a result, more landslides could occur. Broken or leaking water or sewer lines can also be problematic as well as lawn irrigation and minor alterations to small streams in landslide prone locations. Road and driveway drains, gutters, downspouts, and other constructed drainage facilities can concentrate and accelerate flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.[10]

Changes in Vegetation

Vegetation is an important factor when discussing landslide trigger mechanisms. Vegetation plays a complex role in maintaining slope stability. Removing vegetation from very steep slopes can increase landslide hazards. The *Storm Impacts Study* conducted by the Oregon Department of Forestry found that landslide hazards in three out of four steeply sloped areas were highest for a period of 10 years after timber harvesting.[11] Areas that have experienced wildfire and land clearing for development may have long periods of increased landslide hazard. In addition, woody debris in stream channels (both natural and man-made from logging) may increase the severity of impacts from debris flows.[12] Woody debris in streams provides excellent habitat and other benefits.

Development

Development sites with the greatest risk from landslides are those located against the base of very steep slopes, in confined stream channels (small canyons), and on fans (rises) at the mouth of these confined channels. While home development sites at the base of slopes do not cause landslides, they do put residents and property at risk of landslide impacts. The simplest mitigation measure for this situation is to locate the home out of the impact area or construct debris flow diversions for homes at risk (as diversions simply redirect the damaging material to another location, they can exacerbate the problem.) Three development-related actions that can put people at risk include:[13]

1. **Creating Steeper Slopes**. Excavation practices, sometimes aggravated by drainage, can reduce the stability of otherwise stable slopes. These failures commonly affect only a small number of

homes. Without these excavation practices, there is little risk of landslides in areas not prone to landslide movement.

2. **Development on or Adjacent to Existing Landslides**. Existing landslides are generally at risk of future movement regardless of excavation practices. Excavation and drainage practices can further increase risk of landslides. In many cases, there are no development practices that can completely assure stability. Homeowners and communities in these situations accept some risk of future landslide movement.
3. **Development on Gentle Slopes**. Development on gentle slopes can be subject to landslides that begin a long distance from the development.

The extent to which new residents, long-time homeowners, and developers are informed about the risks associated with landslides is a key factor in landslide location and occurrence. Developers who are uninformed about geological materials and processes may contribute to conditions that trigger landslide activity or increase susceptibility to landslide hazards.[14]

Community Landslide Issues

Landslides can affect utility services, transportation systems, and critical lifelines. In addition to the immediate damages and loss of service that communities may suffer, the disruption of infrastructure, roads, and critical facilities may also have a long-term effect on the economy. Utilities including potable water, wastewater, telecommunications, natural gas, and electricity are all essential to the community. Loss of electricity has the most widespread impact on the whole community and can even affect other utilities. For example, even landslide movements as small as an inch or two increase the potential for natural gas pipelines to break.[15]

Roads

Roads are subject to closure during landslide events. Since many Portland residents are dependent on roads for commuting to work, delays and detours generated by a landslide event will likely have an economic impact on residents and businesses. To evaluate the benefit of landslide mitigation activities for roads, the City should consider the number of vehicle trips per day over the identified section of road, the increase in travel time the detour around a road closure will cause, and whether the road is used for commercial traffic or emergency access.[16] Bridges are a critical part of road connections that may suffer extensive damage in landslide events.

Landslide Hazard Assessment

Hazard Identification

Hazard identification, the first phase of a hazard assessment, involves an estimation of the geographic extent of the hazard, its intensity, and

its probability of occurrence.[17] This process usually produces a hazard map. Hazard maps can provide detailed information in a clear format and can assist in policy and land use decisions. Landslides in the Portland area occur primarily in four areas.[18] Severe weather events produced more than 700 landslides throughout Portland in 1996. More than half of the slides occurred in the Portland West Hills where weak, silt-rich soils become easily saturated and fail, resulting in earthflows. A second area of concern includes the steep slopes along the Willamette River such as Oaks Bottom and Swan Island. These landslides tend to be thin but numerous, and many are human-caused when garbage and yard debris are dumped over the edges of the slopes. In southeast Portland, reactivation of ancient landslides is a large problem on deposits of the fine-grained Troutdale Formation sediments. The fourth landslide prone area includes the steep creeks along the Columbia and north Willamette Rivers where debris flows occur. Examples are Dodson in the Columbia Gorge and Germantown Road in northwest Portland.

Landslides are common in Portland because the area has steep slopes, abundant precipitation, and in some areas, weak soils. Portland's two most famous landslides have occurred in the West Hills and were reactivated by construction activity. The Washington Park Landslide was reactivated in 1895 when the City built two new reservoirs. This phenomenal landslide has since slowed to four centimeters per year. The Children's Museum, World Forestry Center, and the Oregon Zoo also are built on a large landslide that was reactivated in 1957 by the widening of Highway 26 which also reactivated the slide area; this landslide is now stabilized.

While recent landslide events in Portland have not been rapidly moving debris flows, the potential for their occurrence exists. However, debris flows have caused most of the recent landslide-related injuries and deaths in Oregon.[19] They have been the catalyst for the creation of state law and the impetus for large mapping project undertaken by the Oregon Department of Forestry (ODF) and the Oregon Department of Geology and Mineral Industries (DOGAMI).

Metro and Portland State University have also generated a map documenting Landslide Locations (1996-1997) and Zones of High Landslide Potential in the Portland Metropolitan Region. The Portland study area has been subject to major and minor landslides. Hundreds of landslides (as many as 700) were recorded during the February and December 1996 flood events. In general, landslide recurrence intervals are highly variable. Some large landslides are continuous and slow moving. Others are triggered by acute conditions and occur sporadically.

Large-scale natural events typically occur infrequently while small-scale natural events occur more frequently. Frequency varies depending on the location of an event as well as the surrounding geology, climate, hydrology, and vegetation. Given the complex variables involved in triggering landslide events, it is unrealistic to expect to predict a specific date and time when that event will occur. Though these factors

may suggest the likelihood of future events, even this likelihood will remain largely a function of climate, rainfall, and soil conditions.[20] Without specific interventions, landslide events are likely to continue to occur at rates that are similar to those experienced in the past.

Vulnerability Assessment

Vulnerability assessment is the second phase of a hazard assessment. It combines the information generated through landslide identification with an inventory of the existing development exposed to landslide hazards. Vulnerability assessments help predict how different types of property and population groups will be affected by a hazard.[21] The optimal method for doing this analysis at the county or jurisdiction level is to use parcel-specific assessment data on land use and structures.[22] Data that includes known landslide and debris flow locations can be used to assess the population and total value of property at risk from future landslide occurrences.

This plan uses the results of a pilot study conducted for the Hazard US – Multi-Hazard software program. HAZUS-MH applies engineering and scientific risk calculations that have been developed by hazard and information technology experts to provide defensible damage and loss estimates; these methodologies are accepted by FEMA and provide a consistent framework for assessing risk across a variety of hazards and locations. Landslide data from the HAZUS-MH software package was supplemented with local data for critical facilities and hazard areas. Inventory data were superimposed over the hazard areas to enable GIS queries to estimate the quantity of assets at risk (population, structures, critical facilities, etc.)

Approximately 66,400 people (28,800 households) are potentially exposed to landslides in the Portland area. Special needs populations (the elderly and low income populations) are not disproportionately impacted. More than $8.8 billion dollars in commercial and residential property is exposed[1] to the impact from landslides. Some critical facilities are exposed to landslides; 46% of potable water treatment plants, 30% of hospitals, and 18% of fire stations in Portland are exposed.

More detailed results of the HAZUS-MH study for landslides follows. They provide an overall summary description of the jurisdiction's vulnerability to the hazards and address the impacts of the hazards on the jurisdiction. Additionally, they identify the extent of the hazard and document previous occurrences of landslide events in the Portland metropolitan area. A complete risk assessment for landslides is included in *Risk Assessment Pilot Project Results for DMA 2000 Plan.*

[1] Estimated exposure to a hazard is different than an estimated loss. However, when data were not adequate to estimate loss, exposure (or at-risk inventory) was estimated as a first step to evaluating the risk.

Multnomah County Hazard Analysis

Summary of Risk Factors

Severity Score	High	**Period of occurrence:**	Fall, Winter, and Spring
History (2)	20	**Probability of event(s):**	Occasional
Vulnerability (5)	50	**Warning time:**	Hours to days
Maximum Threat (10)	100	**Major contributor(s):**	Topographic characteristics, terrain, and water saturation
Probability (7)	70	**Cause injuries?**	Yes, and risk of death
Total Score	240	**Potential facilities shutdown?**	30 days or more

Table 8-1. Historic Landslides for Portland (1996-2002) (DOGAMI 2002b)

Historic Landslide Type	Number of Occurrences in the City of Portland
Debris Flow	13
Debris Slide	56
Earth Flow	168
Earth Flow / Debris Flow	3
Earth Flow / Rockfall	1
Rockfall	11
Rockfall / Earth Flow	2
Rockfall / Mudflow	1
Slump	49
Slump – Earth Flow	89
Slump – Earth Flow / Debris	7
Slump – Earth Flow / Rockfall	1
Slump / Debris Flow	1
Translational (horizontal movement)	1

LANDSLIDE HAZARD PROFILE

Background and Local Conditions

Landslides are part of the natural, on-going process of smoothing topographical high points. Landslides occur when gravitational forces associated with slide mass exceed the resistance produced by the material holding that mass in place. Landslides are downhill or lateral movements of soil and rock that can include rock falls, slides, slumps, lateral spreading, earth and mudflows, and settlement. Landslides can result from ground saturation after intense or prolonged rainfall, erosion associated with surface water runoff, improper or poorly designed drainage systems or slopes, vegetation removal by land clearing, and shocks or vibrations from earthquakes. After wildland fires, landslides are more likely because resistance forces produced by roots associated with trees, shrubs, and grass are reduced. Many hillsides in the Portland/Vancouver PMSA are unstable and vulnerable to landslides and mudflows. Landslides associated with rainfall tend to be relatively smaller; earthquake-induced landslides may be much larger. The pilot project focuses on rain-induced landslides.

Historic Frequency and Probability of Occurrence

The Portland study area has been subject to major and minor landslides. Hundreds of landslides (as many as 800) were recorded during the February and December 1996 flood events. In general, landslide recurrence intervals are highly variable. Some large landslides are continuous and slow moving. Others are triggered by acute conditions and occur sporadically. Table 8-1 lists the types and number of landslides in the City of Portland from 1996 to 2002.

Severity

Existing mitigation and emergency directives for this risk in the Portland area evidence the high risk of this hazard. For example, the State of Oregon has a Debris Avalanche Action Plan that directs state agencies to seek solutions to reduce the loss of life from debris flow and landslides. The Multnomah County Hazard Analysis considered this hazard a high risk. Similarly, this hazard is considered a severe risk based on the Multnomah County hazard analysis and data reviewed by the risk assessment team as part of this project.

Historic Losses and Impacts

Hundreds of landslides occurred during the February and December 1996 flood events and accounted for 20 percent ($13 million) of the $64 million in damages associated with the February 1996 storms. During those events, 17 homes were completely destroyed and 64 were badly damaged due to landslides (Oregon OEM 2000). During the 1996 landslides, eight deaths were recorded statewide. During a March 1972 landslide, three motorists were injured in a mud and rockslide on Interstate 5 near Portland. Losses for the State of Oregon generally average less than one or two lives per year and between $1 million and $10 million annually (Oregon Department of Land Conservation and Development [LCD] 2003).

Designated Hazard Areas

Although the total area of land subject to a high potential for landslides is small, the consequences are serious when structures, roads, or lifeline systems are affected. Many hillsides in the study area are unstable and subject to slides and flows. Landslide losses most likely will increase because city-wide development is occurring on and near increasingly less stable land.

According to a study of the February 1996 storm, changes to slopes through cutting or filling increased the risk of landslides in 76 percent for the inventoried landslide areas in the Metro region (Burns and others 1998). The study also found that there are four dominant landslide areas: the West Hills Silt Soil Province; the debris flows in the Valley Bottoms Province along the Columbia River; the steep bluffs along Rivers Province on the Willamette and Clackamas Rivers, and the fine-grained Troutdale Formation Province (which was not analyzed for this pilot study). It is important to note that hazard maps only provide a general indication of landslide hazards. Figure 3-4 shows the dominant landslide hazard areas in the Portland study area as well as the locations of the 1996 landslides.

Mitigation Plan Goals and Public Priorities

The mitigation plan goals and action items are derived from review of regional and national natural hazard mitigation plans and planning literature and guidance from the Portland Natural Hazards Mitigation Plan Steering Committee. The goals for the City of Portland Natural Hazards Mitigation Plan are broad based to include all of the identified hazards addressed in the plan. Goals for the mitigation plan address five categories:

1. Identify risk level and evaluate Portland's vulnerability to natural hazards.
2. Implement activities to protect human life, property, and natural systems.
3. Promote public awareness, engage public participation, and enhance partnerships through education, outreach, and coordination of a diverse and representative group of the City's population.
4. Establish a disaster resilient economy.
5. Build and support the capacity and commitment to continuously reduce vulnerability to hazards.

Existing Mitigation Activities

Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies or organizations.

City Programs

Bureau of Development Services (BDS)

BDS has geotechnical engineering staff to review all building permits for new development in landslide-prone areas. As part of these building permit reviews, BDS can require geotechnical engineering or engineering geology reports to address landslide concerns. In addition, the Zoning Code requires geotechnical engineering/engineering geology reports to be submitted for land use review applications in some situations. In a land use review application, the land use planning staff and the geotechnical staff review the submitted reports to ensure that applicable approval criteria are met. Some of the relevant city code provisions include:

- Title 24, Chapter 70, covering grading and excavation work.
- Title 10, Erosion and Sediment Control, review erosion control plans for all development requiring a permit where ground is disturbed and inspect all of these sites for compliance.
- Title 33, Chapter 632 on Sites in Potential Landslide Hazard Areas. Potential Landslide Hazard Areas are shown on the city's Potential Landslide Hazard Area Map. This zoning code applies

to properties proposed for land division. BDS reviews geotechnical engineering and engineering geology reports submitted by applicants. The approval criterion ensures that lots are created where development can occur with the least likelihood of causing landslides on the site or adjacent properties.

- Title 33, Chapter 430, Environmental Zones. This chapter regulates development within environmental zones, which often include steep slopes. There are two types of environmental zones, the Environmental Protection Overlay Zone and the Environmental Conservation Overlay Zone. In the protection zones, new development is allowed only when there is a public need or benefit. Conservation zones allow only limited urban development. Tree removal requires a permit and replanting of the site is required to mitigate for impacts.

Bureau of Planning

The City of Portland Comprehensive Plan includes policies that relate to landslide hazards both implicitly and explicitly. These include:

- 8.13 Natural Hazards – Control the density of development in areas of natural hazards consistent with the provisions of the City's Building Code, Chapter 70, the Floodplain Ordinance and the Subdivision Ordinance.
- 8.16 Uplands Protection – conserve significant upland areas and values related to wildlife, aesthetics and visual appearance, views and sites, slope protection, and groundwater recharge. Encourage increased vegetation, additional wildlife habitat areas, and expansion and enhancement of undeveloped spaces in a manner beneficial to the city and compatible with the character of surrounding urban development.
- 8.16 B. Slope Protection and Drainage – Protect slope from erosion and landslides through the retention and use of vegetation, building code regulations, erosion control measures during construction, and other means.

Capital Improvement Plan

The City of Portland's Capital Improvements Program (CIP) is a dynamic document that is reviewed by a CIP development team who prioritizes projects to be scheduled into a 5-year citywide projected budget. Each bureau submits their projects after reviewing them through weighted criteria. Some landslide mitigation projects might be considered as part of the capital improvement plan.

Portland Office of Transportation (PDOT)

PDOT's importance in mitigation has been very under estimated. They coordinate the clearance of roads after a disaster, keep the street network free from cracks or sluffs, and maintain knowledge of the below and above surface infrastructure. If areas of greatest risk are identified prior to a disaster, mitigation efforts can be planned or response routes

changed to accommodate the lack of thoroughfare due to the landslide effects.

The following programs are some of PDOT's projects that keep roads open and businesses operating.

- PDOT has a pavement maintenance system that tracks the condition of the city streets. In areas of potential landslides, PDOT monitors for cracks in the road. For example, Willamette Blvd had significant cracks. PDOT prioritized the road and did a grinding and asphalt overlay this year to seal the cracks to prevent water from infiltrating the top of the slope.
- PDOT uses the emergency routes identified in either the Snow and Ice Plan or the Seismic Response Plan. These pre-identified routes help to ensure that routes are restored to service.
- PDOT will put up barriers in areas that are prone to rock slides or debris falling. If a slope is considered to be a threat, the bureau may contact a geotech engineer for additional analysis, and a city engineer will make a final determination. Survey crews may set markers to evaluate whether a slope is stable. The area in question is then periodically measured. Once a site is identified at being at risk for a landslide, the bureau will consider a number of physical options including gabion baskets or rock screening to stabilize the slope.
- The Bureau's storeroom keeps several landslide mitigation products in stock including geotech fabric or visqueen. The fabric can be stapled onto an unstable slope to keep additional material from sliding. The fabric may contain seeds that would then serve to revegetate the hillside.
- The bureau tracks weather predictions annually to better prepare for potential events.
- Drainage and street design standards aim to minimize impacts of run off and channel water away from the top of slopes.

Bureau of Environmental Services (BES)

BES's work for ecosystem restoration and stabilization has many similarities to natural hazard mitigation. The natural systems are what make Portland and the region livable. With the increased development in the Portland Metro area, our natural habitat is at risk and being depleted. Ecological protection and mitigative actions go hand in hand to strengthen the endangered terrain, habitat, and wildlife. The following are actions taken by BES to secure this asset:

- Standards are being developed for the pump stations. Some sewers have been moved within the West Hills to avoid landslide problems. Developers are currently required to keep new sewers out of inaccessible areas even if they must build a pump station to make the system work.

- The Downspout Disconnection Program targets homes in the eastside Combined Sewer Overflow (CSO) area, assesses each home individually according to safety standards, and exempts pockets of properties within the target area due to steep slopes and other concerns. A change in the standard of sump installation has extended the placement of the sump from 200 ft from the edge of the slope to 500 feet from the edge of the slope; sometimes a pump is not installed at all.
- Watershed planning projects have been completed which revegetate slopes and repair stream banks. Onsite stormwater management has reduced overflow to creeks. BES has erosion control requirements and an erosion control inspector for CIP projects. The Stormwater Section of Operations and Maintenance has done 12-18 pilot projects with ditches along steep roadways that have included construction of swales with inlets to carry water to a safe location, use of perforated pipe to accept and carry excess water, and creation of swales with paving up the embankment. The purpose is to prevent erosion at the toe of the slope, allow less water to collect in ditches along the road, and prevent destabilization of the slopes.
- The third version of the Stormwater Management Manual has been completed. It requires developers of sites in the West Hills and deep SE hills (SE 162nd) to assess slope using a topographic map and submit a geotechnical report for any new development. Staff reviews the proposals. The Manual contains descriptions of stormwater facility types for use by all new development projects. The facilities have specific design standards that include % slope and soil type. In areas prone to slides, BES has specifications for pipe materials and joints.
- The Watershed Revegetation Program is managing more than a thousand acres. Projects have included stabilizing the slope along N Willamette Blvd where two major fires occurred in the past few years.
- Emergency permitting procedures have been developed for repairs and mapping has been developed of landslide hazard areas.

Landslide Coordination Committee

The Landslide Coordination Committee was established after the 1996 landslides. It consists of staff representing the Bureau of Development Services, the Portland Office of Transportation, the Bureau of Maintenance, the Bureau of Environmental Services, the Parks and Recreation Bureau, the Water Bureau, and Risk Management. It meets primarily in the fall through spring months to review landslide occurrences within the City, communicate details of the landslide event, and coordinate review, permitting, and mitigation activities. The group has developed a procedure for quickly alerting members by email with pertinent information on a landslide occurrence so that each bureau can

determine actions that need to be taken. The group has also developed a procedure for processing landslide repair projects in environmental zones.

Water Bureau

The Water Bureau is an active partner in landslide mitigation. Since a 1996 report indicated that the Water Bureau should "Continue to mitigate landslide hazards to the conduits from Bull Run" the following mitigation projects have been conducted:

- Horizontal drains were installed at the Ditch Camp slide to mitigate ground movement. Since installation of the drain ground movement has nearly stopped.
- Two intertie facilities have been constructed (Larsons 2001, Hudson 2004). These intertie facilities allow the isolation of a section of conduit in case of damage by a landslide.
- The approach channel on Dam #2 was lined with a geomembrane to reduce leakage into the teardrop area. The teardrop area was formed after a landslide in 1995 severely damaged the conduits.
- The landslide in the teardrop area was repaired with a rock buttress. Damaged conduits were repaired and the bridge over the Bull Run River was rebuilt.
- The slide at Bowman's bridge was repaired with a rock fill buttress.
- Ten (10) vibrating wire piezometers have been installed to monitor the groundwater levels in the teardrop area.
- A landslide assessment was completed along the entire conduit corridor (2003). Additional monitoring equipment has been installed in the areas identified as having the highest landslide hazards (13 inclinometers and 6 piezometers).
- Over 50 inclinometers are installed throughout the Water Bureau system. These are monitored on a consistent basis.
- Six piezometers were installed in the Washington Park landslide area to monitor groundwater levels in the slide mass (2004).
- An annual assessment report of the landslide conditions in the system is completed.

Portland Office of Emergency Management (POEM)

Emergency Operation Center (EOC)

The Emergency Operations Center is an established facility from which command and control of events needing multi-disciplinary coordination occurs. The EOC is located out of the flood plain and away from landslide or earthquake fault line territory; although some think proximity to major transportation routes poses a risk, others deem it an advantage for accessibility.

State Programs

Statewide Planning Goal 7: Areas Subject to Natural Hazards

Goal 7 is one of the Statewide Planning goals established by the Oregon Legislature in 1973 to guide land use patterns throughout the State. Goal 7 requires local agencies to inventory hazard areas and adopt comprehensive plans that reduce risk to people and property from natural hazards.

Debris Avalanche Action Plan

Governor John Kitzhaber met with directors of state agencies after the 1996 storm events to develop a plan to address rapidly moving landslides (also known as debris flows). The plan, the Debris Avalanche Action Plan, was issued on March 4, 1997.

The governor's plan included specific recommendations that should be taken by state and local governments. For example, the plan directed LCDC to review Goal 7 and directed DOGAMI to support legislation requiring full disclosure of hazards on property on all property transactions. The plan directed DOGAMI to examine the conflict between resource (farm land and forest land) and residential use of steeply sloped land. In addition, Senate Bills (SB) 1211 and 12 prescribed work for DOGAMI. The Oregon Department of Forestry (ODF) and Oregon State University (OSU) were jointly directed by the plan to examine factors that might contribute to debris flows. In response, they specifically mapped rainfall intensity in Western Oregon.[23]

Senate Bill 1211

SB 1211, approved in 1997, required the establishment of a task force, the Joint Interim Task Force on Landslides and Public Safety; the Task Force was created as a direct response to the 1996 storm events that impacted all of Oregon. The Interim Task Force identified five areas to amend state statutes, and recommended that LCDC make changes to Goal 7 during the 1999-2001 biennium. Also of interest is the direction by the Interim Task Force to change the disclosure provisions of the statutes. Oregon Revised Statute (ORS) 105.465 describes a property seller's responsibility to disclose landslide hazard information to buyers.[24]

The provisions of SB 1211 include:

- Allowing the Oregon State Forester to prevent timber harvest or road construction in or below areas identified by the Department of Forestry as "high risk sites" and where homes or highways are in precarious locations.
- Allowing road officials to close roads that pose risk to human life because of landslides.

- Requiring State agencies and local officials to develop and distribute information about hazards of construction on sites that are vulnerable to landslides.
- Establishing a 10-member Task Force on Landslides and Public Safety to assess the problem and develop a solution. It includes legislators and representatives from state natural resource agencies, boards of commissions, local government, and the public.

Oregon State Senate Bill 12/Debris Flow Mapping

More changes to existing regulations occurred in 1999 when the Oregon legislature approved SB 12 (codified in ORS 195.250-195.275 and ORS 527.630-527.710). SB 12 directed DOGAMI to establish maps of hazard areas, termed "further review areas," in which jurisdictions would apply more restrictive development ordinances to protect life and property. The DOGAMI report that corresponds to the maps of hazard areas described the most hazardous areas as mountainous terrain, particularly drainage channels and depositional fans. The DOGAMI report explicitly states that one goal of the State of Oregon is to protect citizens' lives and property. The DOGAMI report also describes that the map can "help to assess the risk and prioritize risk-reduction activities." According to SB 12, rapidly moving landslides present the greatest risk to people in those areas and mitigation for these types of landslides is limited. One of the most common types of rapidly moving landslides, a debris flow, is the primary focus of SB 12. DOGAMI attempted to characterize the geographic extent and location of rapidly moving landslides; the DOGAMI Map includes the estimated runout of a debris flow path. [25]

The Oregon legislature passed HB 3375 and it became effective on January 1, 2004. It eliminated portions of the state statute that were passed as SB 12. Specifically, HB 3375 eliminated mitigation measures (ORS 195.263), development rights and recording (ORS 195.266 and 195.270), and the moratorium on development (ORS 195.275).

Oregon Department of Forestry (ODF)

The Oregon Department of Forestry has developed a preliminary overview of debris flows (rapidly moving landslides) prone areas in western Oregon. Their debris flow maps include the general locations subject to naturally occurring debris flows and include the initiation sites and locations along the paths of potential debris flows (confined stream channels and locations below steep slopes). These maps do not consider the effects of management-related slope alterations (drainage and excavation) that can increase the hazard, nor do they consider very large landslides that could possibly be triggered by volcanic or earthquake activity. Areas identified in these maps are not to be considered "further review areas" as defined by Senate Bill 12 (1999).[26] In April 2000, the Board of Forestry adopted six guiding principles to guide development of the forest practice rules to meet the SB 12 requirements.

Information used to develop the ODF Debris Flow maps include:

- Based on US Geological Survey Data, digital elevation models at 30-meter resolution were used to derive slope steepness and then to develop polygons for assigned hazards. Note that actual slopes are steeper than these digitally elevated models.
- Mapped locations of Tyee soil formation and similar sedimentary geologic units.
- Oregon Department of Forestry *Storm Impacts and Landslides of 1996* study; debris flow initiation and path location data.
- Stream channel confinement near steep hill slopes based on US Geological Survey Digital Raster Graphics.
- Historical information on debris flow occurrence in western Oregon (from Oregon Department of Forestry, US Forest Service, DOGAMI, Bureau of Land Management, and the Oregon Department of Transportation).
- Fan-shaped land formations below long, steep slopes.
- Areas of highest intensity precipitation do not appear to be correlated with known areas of high and extreme debris flow hazard, so precipitation intensity was *not* used to develop risk (hazard) ratings.[27]

Prohibition of Certain Forest Operations

As part of the requirements of Senate Bill 12, ODF is currently deferring certain forest operations on landslide-prone sites above homes and roads. The Department's policy is that timber harvesting or road construction operations will be prohibited on land where landslides or debris flows pose a significant threat to human safety. Exceptions for salvage or other purposes are considered on an individual basis but have been infrequent in keeping with the goal of preventing significant risks to human life.[28]

Debris Flow Warning System

The debris flow warning system was initiated in 1997 and involves collaboration between ODF, DOGAMI, the Oregon Department of Transportation (ODOT), local law enforcement, NOAA Weather Radio, and local media.

ODF meteorologists are responsible for forecasting storms that may trigger debris flows. Information is broadcast over NOAA Weather Radio and on the Law Enforcement Data System. DOGAMI provides additional information on debris flows through the media. ODOT provides warning signs to motorists in landslide-prone areas during high-risk periods.[29]

Landslide Brochure

With the goal of reaching homeowners, DOGAMI developed a landslide public outreach brochure, "Landslides in Oregon: Protect Yourself and Your Property" in cooperation with several other state agencies. Forty

thousand copies were printed in November 1997 and were distributed widely to building codes officials, county planners, local emergency managers, field offices of natural resource agencies, banks, real estate companies, insurance companies, and other outlets. The brochures are available from DOGAMI, OEM, ODF, and the Department of Land Conservation and Development (DLCD).[30]

Oregon State Building Code Standards

The Oregon Building Codes Division adopts statewide standards for building construction that are administered by state and local municipalities throughout Oregon. The One- and Two-Family Dwelling Code and the Structural Specialty Code contain provisions for lot grading and site preparation for the construction of building foundations.

Both codes contain requirements for cut, fill, and sloping of the lot in relationship to the location of the foundation. There are also building setback requirements from the top and bottom of slopes. The codes specify foundation design requirements to accommodate the type of soils, the soil bearing pressure, and the compaction and lateral loads from soil and ground water on sloped lots. The building official has the authority to require a soils analysis for any project where it appears the site conditions do not meet the requirements of the code or can require that special design considerations be taken. ORS 455.447 and the Structural Code require a seismic site hazard report for projects that include essential facilities such as hospitals, fire and police stations, emergency response facilities, and special occupancy structures such as large schools and prisons.[31]

Landslide Mitigation Action Items

The landslide mitigation action items provide direction on specific activities that the City of Portland can undertake to reduce risk and prevent loss from landslide events. Each action item includes an estimate of the timeline for implementation. Short-term action items (ST) are activities that state agencies may implement with existing resources and authorities. Long-term action items (LT) require new or additional resources and/or authorities.

Short-term Action Items

ST-LS#1: Develop a comprehensive landslide map for the City of Portland to identify hazard areas and improve communication with the public.

Key Issues Addressed

- For hazard area maps to be useful, they must be mapped accurately and at an appropriate scale to be incorporated into land use decisions. In addition, public outreach is needed to provide the public with information about the potential risk.

Ideas for Implementation

- Partner with DOGAMI to fund LIDAR imaging work and use it to map landslides.
- Collect all landslide hazard maps with City of Portland information so that these maps can be analyzed, evaluated, and a determination made as to how each map can and should be used. The collected maps could be scanned into GIS to be used as individual layers or combined into a composite map. A comprehensive landslide hazard map could be developed for the City.

General Comments

- Mapping of landslide hazards was identified in the 1996 *Flood and Landslide Hazard Mitigation Plan*, Recommendation #4.

Information about existing maps:

- The *Potential Landslide Hazard Map* officially applies to all land use applications. It shows landslide hazard areas as slight, moderate, or severe. The geographic area covered by this map, because it is an older map, does not match the current boundaries of the City's planning jurisdiction (which includes the City and the unincorporated urban areas of Multnomah County).

- The Landslide Hazard Area Map (adopted June 1, 2002) applies to new land divisions but not to other land use applications.
- Rapidly moving landslide maps are available on the City of Portland web page at www.portlandmaps.com, but they are still draft maps. Final maps will be need to be developed in partnership with DOGAMI, but funding is not available to do this work.
- A small portion of Portland was included in a recent LIDAR study partially funded by the Bureau of Environmental Services. USGS and DOGAMI have just begun to analyze data to map landslide hazard areas. Additional funding is required to develop LIDAR coverage for the entire city to map landslides.

Coordinating Organization:	Bureau of Development Services
Internal Partners:	Planning Bureau, Water Bureau, Bureau of Environmental Services, Portland Department of Transportation, Bureau of Maintenance, Parks Department
External Partners:	Department of Geology and Mineral Industries (DOGAMI)
Level of Immediate Capability:	Medium
Estimated Timeline:	5 + years
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards. Promote public awareness, engage public participation, and enhance partnerships through education, outreach and coordination of a diverse and representative group of the City's population.

ST-LS#2: Continue to maintain and improve internal City communications to facilitate coordination of landslide mitigation activities.

Key Issues Addressed

- Maintain and improve internal procedures that inform responsible staff in affected bureaus of responsibilities associated with landslide mitigation.
- Study and consider expanding the current scope of activities of the landslide coordination committee to develop and recommend policies and procedures that better prevent and mitigate landslide events.

Ideas for Implementation

- Add to the existing landslide coordination committee meeting discussions the possibility of additional areas of discussion related to landslide hazards. Gain these additional areas of discussion by considering input and participation by other key staff members and outside interested parties with the intent of landslide event prevention and improving internal procedures. Items to consider:
- Guidance and technical support on design of development on potentially hazardous sites.
- Information exchange with potentially affected parties, both internal and external.
- Review and consider improvements to existing public information practices all aimed at informing the public/designers/builders in best development practices in landslide areas.
- Establish and maintain an improved relationship with regional, state, and federal agencies equipped to respond to landslide events.

General Comments

- The Landslide Coordinating Committee could be a good place to begin. It is comprised of representatives from multiple city bureaus that oversee programs or policies that mitigate or prepare for and respond to landslides. Currently, they work to assure that all of these efforts are coordinated, to improve the efficiency of response and recovery from any event.

Coordinating Organization:	Bureau of Development Services
Internal Partners:	Bureau Of Environmental Services, Portland Department Of Transportation, Bureau Of Maintenance, Bureau of Water, Parks and Recreation, Risk Management
External Partners:	public
Level of Immediate Capability:	High
Estimated Timeline:	on-going
Plan Goals Addressed:	Build and support the capacity and commitment to continuously become less vulnerable to hazards.

ST-LS#3: Improve property owner awareness of the importance of proper maintenance of private drainage systems.

Key Issues Addressed

- Improve public awareness of maintenance responsibilities of drainage systems to reduce the impact that these systems have on landslide events.

Ideas for Implementation

- Provide continuing public outreach to property owners on how to maintain their systems.

General Comments

- Maintaining a private drainage facility keeps the facility at its optimum capacity, reducing the likelihood of water saturating the facility to saturate the earth outside of the facility and increasing the possibility of a landslide
- PCC 17 defines the responsibilities of city and property owners for improved and unimproved streets.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Bureau of Maintenance
External Partners:	Residents, property owners
Level of Immediate Capability:	Medium
Estimated Timeline:	Ongoing
Plan Goals Addressed:	Promote public awareness, engage public participation, and enhance partnerships through education, outreach and coordination of a diverse and representative group of the City's population.

ST-LS#4: Mitigate Portland's water supply infrastructure from landslide hazards.

Key Issues Addressed

- The Portland water supply system delivers water from reservoirs in the Cascade foothills to downtown Portland. The water infrastructure passes through areas with significant landslide hazards.
- To improve the overall system reliability, mitigation projects need to be undertaken that reduce the vulnerability of the facilities to landslide hazards.

Ideas for Implementation

- Construct inter-ties between conduits to allow rerouting of water in times of need
- Harden or bury the conduit crossing at the Sandy River Crossing.
- Conduct a conduit condition survey
- Undertake a proactive landslide monitoring program in areas of high landslide hazard
- Harden or bury the conduits at the exposed/trestle locations
- Increase the capacity of the Groundwater Pump Station
- Develop design standards for new facilities that reduce their risk to landslide hazards
- Categorize how hazards identified from LIDAR survey effect water infrastructure

General Comments

- One intertie has already been completed, with another currently under construction.
- Significant elements of a landslide monitoring system are in place. An annual landslide condition report is prepared that outlines the state of the system relative to landslide hazards from the previous season. Additions to the system will be installed as conditions mandate.
- The last conduit condition survey was done in Conduit #3 in 1987.
- Design has begun to mitigate approximately half of the exposed conduit locations. Construction is anticipated to begin in 2005 and last 2 years.
- Increased capacity at the Groundwater Pump Station allows for greater redundancy of the Bull Run system if it is taken out of service due to a landslide event. Additional wells and associated pipeline are being designed and constructed.
- Once the LIDAR survey is complete, it will be used to assess vulnerability of Water Bureau facilities.

Coordinating Organization:	Bureau of Water
Internal Partners:	none
External Partners:	none
Level of Immediate Capability:	High
Estimated Timeline:	On-going
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

ST-LS#5: Acquire land or apply conservation easement for long term and permanent mitigation of risk.

Key Issues Addressed

- Some areas in the City may be such high risk they should not be developed. If there is not development, the City could avoid the provision of infrastructure in high-risk areas.
- Undeveloped land would also provide benefits including wildlife habitat, and valuable open space, and reduced erosion.

Ideas for Implementation

- Identify areas at high risk for landslides and consider acquisition and management as natural area parkland when resources are available and acquisition meets objectives of park system.
- Compare the location of high risk areas to areas the City has identified as high quality habitat and water quality protection areas so as to maximize the benefits achieved.
- Continue to work on watershed assessments to identify other relevant issues.

General Comments

- Implementation would occur as willing sellers chose to sell their landslide prone properties.
- This action was identified in the 1996 Flood and Landslide Hazard Mitigation Plan.

Coordinating Organization:	Bureau of General Services
Internal Partners:	Bureau of Planning, Parks and Recreation, Bureau of Development Services, Bureau of Environmental Services, Risk Management
External Partners:	Metro, non-profit land trusts
Level of Immediate Capability:	Medium (interest and institutional capability are high, funding is low)
Estimated Timeline:	2-3 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

ST-LS#6: Initiate more operations and maintenance pilot projects along roads that inform the development of standards for managing stormwater in ditches in landslide prone areas.

Key Issues Addressed

- Utilize maintenance techniques to supplement landslide mitigation efforts already being implemented

Ideas for Implementation

- As opportunity arise, implement alternative stormwater ditch designs to mitigate landslide prone roadsides.

General Comments

- One technology that can be piloted is a swale that is filled with permeable material and a perforated pipe.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Bureau of Maintenance
External Partners:	public
Level of Immediate Capability:	High
Estimated Timeline:	on-going
Plan Goals Addressed:	Promote public awareness, engage public participation, and enhance partnerships through education, outreach and coordination of a diverse and representative group of the City's population.

ST-LS#7: Complete a study of the West Hills drainage system that addresses the cumulative effects of development in the area.

Key Issues Addressed

- Many landslides have occurred in the West Hills.
- Development continues to occur with drainage addressed site by site, but little is known about the cumulative impacts of development. A study that identifies weaknesses in the overall system is needed.

Ideas for Implementation

- Assess/inventory drainage patterns and facilities
- Identify drainage facilities are that are used but not municipally controlled
- Assess the potential for the development of new drainage facilities to increase landslide risks
- Review the 1995 On-Site Drainage Design Manual for the West Hills

General Comments

- The study will be complex and difficult to do.
- The study should be coordinated with other watershed health activities

Coordinating Organization:	Bureau of Environmental Services, Planning and Modeling and Engineering Services
Internal Partners:	Bureau of Planning, Bureau of Development Services (Site Development)
External Partners:	Office of Neighborhood Involvement
Level of Immediate Capability:	Low (no funding, though staff capability exists)
Estimated Timeline:	3-5 years, dependent on funding
Plan Goals Addressed:	Identify risk level and evaluate Portland's vulnerability to natural hazards.

ST -LS#8: Continue development of standards for small pump stations as an alternative to gravity sewers in inaccessible or high risk areas.

Key Issues Addressed

- As much as possible, sewers should be kept out of landslide prone areas to assure continuity of service and to protect public health.

Ideas for Implementation

- If necessary, require a small pump station for slide prone areas for development.

General Comments

- Small pump stations are another tool to help the engineer avoid slide prone areas with the sewer utility.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Bureau of Development Services
External Partners:	none
Level of Immediate Capability:	High
Estimated Timeline:	within one year
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

Long-term Action Items

LT-LS#9: Review the effectiveness of regulations related to development in identified landslide hazard areas.

Key Issues Addressed

- Existing regulations limit development in identified landslide hazard areas, but may not fully achieve the goal of protecting life and property.

Ideas for Implementation

- Discuss and determine what is acceptable risk for development in landslide hazard areas. Involve all bureaus in the discussion of whether the existing regulations are achieving goals of the natural hazard mitigation plan.
- Develop a landslide hazard map using the best available scientific information. This map should be used as a reference in policy discussions.

- Bureaus other than Bureau of Development Services could have approval criteria or standards for applicants if they are in a landslide prone area. All bureaus should review the need for approval criteria or standards.
- The Zoning Code has provisions that allow exceptions to minimum density requirements when a site is within an environmental zone, a Landslide Hazard Area, or a flood hazard area. Consider changing the Zoning Code provisions in the base zones to state that if the site is within a Landslide Hazard Area, the maximum density should be zero.
- Research how revegetation can address landslide prevention and contribute to stability on steep slopes and incorporate this into design practices and requirements. This should include: (1) literature review; (2) inventory and map natural areas with high landslide potential for vegetation needs; and (3) update revegetation operating procedures.

General Comments

- On-going implementation of existing regulations will occur through the existing development review process.
- The city requires geotechnical engineering or engineering geology reports for building permits on steep lots.
- City bureaus could use additional time to review applications for development in these areas to give full consideration to the effects of constructing utilities and other facilities in these areas.
- It may take 1-2 years to research how revegetation can help to prevent landslides and contribute to stability on steep slopes.

Coordinating Organization:	Bureau of Development Services (Land Use Services and Site Development), Bureau of Planning
Internal Partners:	Bureau of Planning, Bureau of Environmental Services
External Partners:	Department of Geology and Mineral Industries, Oregon Department of Forestry, United States Geological Survey
Level of Immediate Capability:	Medium
Estimated Timeline:	3-5 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

LT-LS#10: Update the Bureau of Environmental Services Sewer and Drainage Facilities Design Manual.

Key Issues Addressed

- There is a need to address the issue of where construction of sewers will be allowed and the type of materials and construction methods that are not acceptable in slide-prone areas.
- Clarify when it might be appropriate to use a small pump station.

Ideas for Implementation

- Determine appropriate design standards for both new pipes and rehabilitated pipes that consider risk, service level and construction methods in identified high-risk landslide areas.
- Establish pipe materials and joint specification standards for use in landslide prone areas.
- Consider options to gravity flow systems such as pump stations in areas subject to landslides.
- Add into the Design Manual a section for sewer designs in landslide-prone areas

General Comments

- City staff, developers and consultants use the Design Manual to assist in the design of drainage and sanitary sewer systems.

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	
External Partners:	none
Level of Immediate Capability:	Medium
Estimated Timeline:	5 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

LT-LS#11: Employ alternate construction methods such as trenchless construction on City projects to reduce the impact that development can have in landslide prone areas.

Key Issues Addressed

- Design of sewers should take into account the risk of landslides due to the construction methods used.

Ideas for Implementation

- Train City design staff in appropriate design methods for landslide prone areas.

General Comments

- Alternative methods of construction (such as trenchless methods) can minimize the disturbance to the soil surface thereby minimizing the risk of a slide in that area. Bureau staff will work toward recommending this more often (as appropriate).

Coordinating Organization:	Bureau of Environmental Services
Internal Partners:	Staff in Bureau of Environmental Services
External Partners:	none
Level of Immediate Capability:	Medium
Estimated Timeline:	3-5 years
Plan Goals Addressed:	Implement activities to protect human life, property and natural systems.

Landslide Resource Directory

City Resources

Portland State University, Department of Geology

Portland State University conducts research and prepares inventories and reports for communities throughout Oregon. Research and projects conducted through the Department of Geology at Portland State University include an inventory of landslides for the Portland metropolitan region after the 1996 and 1997 floods and a subsequent susceptibility report and planning document for Metro in Portland.

Contact: Portland State University, Department of Geology
Address: 17 Cramer Hall; 1721 SW Broadway, Box 751, Portland, OR 97207
Phone: 503- 725-3389
Website: http://www.geol.pdx.edu

Portland Office of Emergency Management (POEM)

Coordination of plan development, training, exercise and equipment procurement and or distribution. Emergency Management is responsible for updating plans as codified by Title 15 of the City Code and in alignment with federal and state standards.

Contact: Director
Address: 1001 SW 5th Ave. Suite 650
Phone: 503- 823-4375
Website: www.portlandonline.com
Email: Ascarrunz@ci.portland.or.us

Portland Bureau of Development Services

This department houses both the permit center and the engineering section that regulate development in landslide prone areas.

Address: 1900 SW 4th Ave
Phone: 503.823.7526 (Development Services Center)
Website: www.bds.ci.portland.or.us/dsc/dscmain.htm

Plans and Codes

City of Portland Flood & Landslide Hazard Mitigation Plan; October 1996; Portland Bureau of Buildings; Commissioner Gretchen Kafoury;

Master Slide List August 6, 1996;

Articles/ Public Outreach

Planning for Natural Hazards, Landslide Technical Resource Guide; Oregon DLCD & Community Planning Workshop; July 2000

Landslides in Portland, Oregon Metropolitan Area Resulting from the Storm of February 1996; Inventory Map, Database and Evaluation; Burns, Burns, James & Hinkle, Dept. of Geology, PSU; August 27, 1998

February 1996 Flooding, Landslide and Stream Erosion in the State of Oregon; FEMA DR-1099-OR; Prepared by the Interagency Hazard Mitigation Team;

Relationship between rainfall and debris flows in western Oregon; Oregon Geology, Volume 62, Number 2, March/April 2000;

Forestry, landslides, and public safety: an issue paper prepared for the Oregon Board of Forestry. Oregon Department of Forestry.

Homeowner's Landslide Guide, For hillside flooding, debris flows, erosion and landslide control; Oregon Emergency Management; FEMA Region X (pamphlet)

Map of rapidly moving landslide hazards for Western Oregon: GIS outputs and summary report (draft and final), Hofmeister, Jon R., Miller, Daniel J., Mills, Keith A., and Beier, Ann E., 2002,

Landslides in Oregon; DOGAMI, Oregon Department of Forestry and Oregon Emergency Management (pamphlet)

State Resources

Department of Land Conservation and Development (DLCD)

Oregon's Department of Land Conservation and Development administers a natural hazards program to assist local governments in meeting statewide Planning Goal 7: Areas Subject to Natural Disasters and Hazards. Activities relating to landslide mitigation include:

- Distribution of model ordinances through which hazards can be mitigated. DLCD advises local governments on which ordinance best meets their needs;
- Reviewing local land use plan amendments for consistency with state landslide programs and regulations and providing direct technical assistance;
- Providing a liaison between pertinent local, state, and federal agencies. DLCD representatives serve on a variety of commissions and ad hoc committees which deal with natural hazards;
- Adopting and amending statewide planning goals and administrative rules relating to natural hazards.

Contact: State Floodplain Manager, Natural Hazards Program Manager
Address: 635 Capitol Street NE, Suite 150
Phone: (503) 373-0050
Fax: (503) 378-6033
Website: http://www.lcd.state.or.us/hazards.html

Oregon Department of Forestry (ODF)

The mission of the Oregon Department of Forestry is to serve the people of Oregon through the protection, management, and promotion of a healthy forest environment, which will enhance Oregon's livability and economy for today and tomorrow. ODF regulates forest operations to reduce the risk of serious injury or death from rapidly moving landslides related to forest operations and assists local governments in the siting review of permanent dwellings on and adjacent to forestlands in further review areas.

Contact: Oregon Department of Forestry, Northwest Oregon
Address: 801 Gales Creek Road, Forest Grove, Oregon 97116-1199
Phone: (503) 359-7448
Website: http://www.odf.state.or.us

Oregon Department of Forestry Debris Flow Warning Page

The ODF debris flow warning page provides communities with up-to-date access to information regarding potential debris flows. As the lead agency, ODF is responsible for forecasting and measuring rainfall from storms that may trigger debris flows. Advisories and warnings are issued as appropriate. Information is broadcast over NOAA weather radio and on the Law Enforcement Data System. DOGAMI provides additional information on debris flows to the media that convey the information to the public. ODOT also provides warnings to motorists during periods determined to be of highest risk for rapidly moving landslides along areas on state highways with a history of being most vulnerable. Information is available on the ODF website at www.odf.state.or.us.

Oregon Department of Geology and Mineral Industries (DOGAMI)

DOGAMI is an important agency for landslide mitigation activities in Oregon. Some key functions of DOGAMI are development of geologic data, development of maps, and regulation of mining and drilling for geological resources. The agency also provides technical resources for communities and provides public education on geologic hazards. DOGAMI provides data and geologic information to local, state, and federal natural resource agencies, industry, and private groups.

Contact: DOGAMI
Address: 800 NE Oregon Street, Suite 965, Portland, Oregon 97232
Phone: (503) 731-4100
Fax: (503) 731-4066
Website: http://sarvis.dogami.state.or.us
Email: info@naturenw.org

Nature of the Northwest

Oregon Department of Geology and Mineral Industries and the USDA Forest Service jointly operate the Nature of the Northwest Information Center. The Center offers a selection of maps and publications from state, federal, and private agencies.

Contact: The Nature of the Northwest Information Center
Address: 800 NE Oregon Street #5, Suite 177**,** Portland, Oregon 97232

Phone: (503) 872- 2750
Fax: (503) 731-4066
Website: http://www.naturenw.org
Email: Nature.of.Northwest@state.or.us

Oregon Department of Transportation (ODOT)

ODOT provides warnings to motorists during periods determined to be of highest risk for rapidly moving landslides along areas on state highways with a history of being most vulnerable to rapidly moving landslides. ODOT also monitors for landslide activity and responds to slide events on state highways.

Contact: ODOT Transportation Building
Address: 355 Capitol St. NE, Salem, OR 97310
Phone: (888) 275-6368
Website: http://www.odot.state.or.us

Oregon State Police (OSP)-Office of Emergency Management (OEM)

OEM coordinates state resources for rapid and effective response to rapidly moving landslide and other landslide-related emergencies. The Oregon Emergency Response System (OERS) of OEM is a key player in the dissemination of debris flow advisories and warnings. OEM chairs a group that develops and measures landslide hazard mitigation strategies. OEM also administers the FEMA Hazard Mitigation Grant Program, which provides a source of funding for implementing hazard mitigation projects. OEM also works with other state agencies to develop information for local governments and the public on landslide hazards.

Contact: Oregon Emergency Management
Address: 595 Cottage Street NE
Phone: (503) 378-2911
Fax: (503) 588-1378
Website: http://www.osp.state.or.us/oem

Federal Resources

Federal Emergency Management Agency, landslide fact sheet

FEMA's website contains information on strategies to reduce risk and prevent loss from landslides and debris flows.

Contact: Federal Regional Center, Region 10
Address: 130-228th St. SW, Bothell, WA 98021-9796
Phone: (425) 487-4678
Website: http://www.fema.gov/library/landslif.htm

Natural Resource Conservation Service (NRCS)

The NRCS produces soil surveys. These may be useful to local governments who are assessing areas with potential development limitations including steep slopes and soil types. They operate many programs dealing with the protection of natural resources.

Contact: NRCS, Oregon Branch
Address: 101 S.W. Main Street, Suite 1300, Portland, OR 97204

Phone: (503) 414-3200
Fax: (503) 414-3103
Website: http://www.or.nrcs.usda.gov

US Geological Survey, National Landslide Information Center (NLIC)

The NLIC website provides good information on the programs and resources regarding landslides. The page includes information on the National Landslide Hazards Program Information Center, a bibliography, publications, and current projects. USGS scientists are working to reduce long-term losses and casualties from landslide hazards through better understanding of the causes and mechanisms of ground failure both nationally and worldwide.

Contact: National Landslide Information Center
Phone: (800) 654-4966
Website: http://landslide.usgs.gov

Additional Resources

American Planning Association (APA)

The APA's research department embarked on a program to bring together solutions from multiple disciplines into a single source. It will help serve local planning efforts in identifying landslide hazards during the planning process so as to minimize exposure to landslide risks. The APA's website highlights planning efforts to reduce risk and loss from landslides.

Contact: Principal Investigator, Landslides Project
Address: Research Department, American Planning Association
122 S. Michigan Ave., Suite 1600
Chicago, Illinois 60603-6107
Phone: (312) 431-9100
Fax: (312) 431-9985
Website: http://www.planning.org/landslides
Email: landslides@planning.org

American Red Cross

The American Red Cross is a volunteer-led humanitarian organization that provides relief to victims of disasters and helps people prevent, prepare for, and respond to emergencies. The Oregon Trail Chapter was chartered as a Red Cross unit in 1917. The chapter serves the residents of Clackamas, Columbia, Multnomah, Washington, Yamhill, and Tillamook counties. The Oregon Trail Chapter provides a variety of community services which are consistent with the Red Cross mission and meet the specific needs of this area including disaster planning, preparedness, and education.

Contact: American Red Cross, Oregon Trail Chapter
Address: P.O. Box 3200, Portland, OR 97208-3200
Phone: (503) 284-1234
Fax: (503) 284-4247
Website: http://www.redcross-pdx.org
http://www.redcross.org/services/disaster/keepsafe/volcano.html
Email: info@redcross-pdx.org

Institute for Business & Home Safety (IBHS)

IBHS was created by the insurance industry to reduce damage and losses caused by natural disasters. Their website provides educational resources and on-line publications for insurers, businesses, and homeowners who are interested in taking the initiative to minimize future damages and losses.

Contact: Institute for Business and Home Safety
Address: 1408 North Westshore Boulevard - Suite 208 - Tampa, FL 33607
Phone: (813) 286-3400
Fax: (813) 286-9960
E-mail: info@ibhs.org
Website: http://www.ibhs.org/ibhs2

State of Washington, Department of Ecology

The Washington State Department of Ecology has a landslide website with tips for reducing risk, identifying warning signs, and using hazard maps.

Contact: Department of Ecology
Address: PO Box 47600, Olympia, WA 98504-7600
Website: http://www.ecy.wa.gov/programs/sea/landslides
Email: hshi461@ecy.wa.gov

Publications

Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000).

Produced by the Community Planning Workshop for the Department of Land Conservation and Development, this is a natural hazards planning and mitigation resource for Oregon cities and counties. It provides hazard-specific resources and plan evaluation tools. The document was written for local government employees and officials. The Technical Resource Guide includes a natural hazards comprehensive plan review, a hazard mitigation legal issues guide, and five hazard-specific technical resource guides that cover flooding, wildfires, landslides, coastal hazards, and earthquakes. You can write, call, fax, or go on-line to obtain this document.

Contact: Natural Hazards Program Manager, DLCD
Address: 635 Capitol St. NE, Suite 200, Salem, OR 97301-2540
Phone: (503) 373-0050
Fax: (503) 378-6033
Website: http://www.lcd.state.or.us/hazards.html

Mileti, Dennis, *Disasters by Design: A Reassessment of Natural Hazards in the United States* (1999) Joseph Henry Press.

This book offers a way to view, study, and manage hazards in the United States that will help foster disaster-resilient communities, higher environmental quality, inter- and intragenerational equity,

economic sustainability, and an improved quality of life. The volume provides an overview of what is known about natural hazards, recovery, and mitigation; reveals how research findings have been translated into policies and programs; and advances a sustainable hazard mitigation research agenda.

Olshansky, Robert B., *Planning for Hillside Development* (1996) American Planning Association.

This document describes the history, purpose, and functions of hillside development and regulation and the role of planning, and provides excerpts from hillside plans, ordinances, and guidelines from communities throughout the US.

Olshansky, Robert B. & Rogers, J. David, *Unstable Ground: Landslide Policy in the United States* (1987) Ecology Law Quarterly.

This is about the history and policy of landslide mitigation in the US.

Public Assistance Debris Management Guide (July 2000) Federal Emergency Management Agency

The Debris Management Guide was developed to assist local officials in planning, mobilizing, organizing, and controlling large-scale debris clearance, removal, and disposal operations. Debris management is generally associated with post-disaster recovery. While it should be compliant with local and county emergency operations plans, developing strategies to ensure strong debris management is a way to integrate debris management within mitigation activities. The Guide is available in hard copy or on the FEMA website.

Contact: FEMA Distribution Center
Address: 130 228th Street, SW, Bothell, WA 98021-9796
Phone: (800) 480-2520
Website: http://www.fema.gov/r-n-r/pa/dmgtoc.htm

USGS Landslide Program Brochure. National Landslide Information Center (NLIC), United States Geologic Survey

The brochure provides general information in simple terminology on the importance of landslide studies and a list of databases, outreach, and exhibits maintained by the NLIC. The brochure also includes information on the types and causes of landslides, rockfalls, and flows.

Contact: USGS- MS 966, Box 25046
Address: Denver, Federal Center, Denver, CO 80225
Phone: (800) 654-4966
Web: http://geohazards.cr.usgs.gov/

Landslide Endnotes

[1] Mileti, Dennis, *Disasters by Design: A Reassessment of Natural Hazards in the United States* (1999) Joseph Henry Press, Washington D.C.
[2] Brabb, E.E., and B.L Harrod. (Eds) *Landslides: Extent and Economic Significance. Proceedings of the 28th International Geological Congress Symposium on Landslides.* (1989) Washington D.C., Rotterdam: Balkema.
[3] *USGS Landslide Program Brochure,* National Landslide Information Center, United States Geologic Survey.
[4] Hofmeister, Jon R., Miller, Daniel J., Mills, Keith A., and Beier, Ann E., 2002, Map of rapidly moving landslide hazards for Western Oregon: GIS outputs and summary report (draft and final).
[5] Interagency Hazard Mitigation Team, *State Hazard Mitigation Plan* (2000) Oregon State Police – Office of Emergency Management.
[6] Ibid.
[7] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 5.
[8] Hofmeister, Jon R., Miller, Daniel J., Mills, Keith A., and Beier, Ann E., 2002, Map of rapidly moving landslide hazards for Western Oregon: GIS outputs and summary report (draft and final).
[9] Ibid.
[10] *Homeowner's Guide for landslide control, hillside flooding, debris flows, soil erosion,* (March 1997).
[11] *Storm Impacts and Landslides of 1996 Final Report* (1999) Oregon Department of Forestry.
[12] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 5.
[13] Ibid.
[14] *The Citizens' Guide to Geologic Hazard* (1993) American Institute of Professional Geologists, American Institute of Professional Geologists.
[15] *Regional All Hazard Mitigation Master Plan for Clackamas County* (February 1998) Goettel & Associates.
[16] Ibid.
[17] Burby, R. (Ed.) *Cooperating with Nature* (1998) Washington D.C.: Joseph Henry Press.
[18] Hofmeister, Jon R., Miller, Daniel J., Mills, Keith A., and Beier, Ann E., 2002, Map of rapidly moving landslide hazards for Western Oregon: GIS outputs and summary report (draft and final),
[19] Interagency Hazard Mitigation Team, *State Hazard Mitigation Plan* (2000) Oregon State Police – Office of Emergency Management.
[20] Sears, Tricia, June 2003, The sometimes discordant fusion of science and policy: an example of a land use planning study of a hazard area in Dodson and Warrendale, Oregon, 137 p.
[21] Burby, R. (Ed.) *Cooperating with Nature.* (1998) Washington D.C.: Joseph Henry Press.
[22] Ibid
[23] Sears, Tricia, June 2003, The sometimes discordant fusion of science and policy: an example of a land use planning study of a hazard area in Dodson and Warrendale, Oregon, 137 p.
[24] Sears, Tricia, June 2003, The sometimes discordant fusion of science and policy: an example of a land use planning study of a hazard area in Dodson and Warrendale, Oregon, 137 p.
[25] Sears, Tricia, June 2003, The sometimes discordant fusion of science and policy: an example of a land use planning study of a hazard area in Dodson and Warrendale, Oregon, 137 p.
[26] *Western Oregon Debris Flow Hazard Maps: Methodology and Guidance for Map Use* (1999) Department of Geology and Mineral Industries/Oregon Department of Forestry.
[27] Ibid.
[28] Ibid.
[29] Ibid.
[30] Ibid.
[31] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Chapter 5.