LANDSLIDE CHAPTER

One of the most common and devastating geologic hazards in Oregon is landslides. Average annual repair costs for landslides in Oregon exceed $10 million and individual severe winter storm losses can exceed $100 million (Wang and others, 2002). As population growth continues to expand and development into landslide susceptible terrain occurs, greater losses are likely to result.

Landslides are typically triggered by periods of heavy rainfall and/or rapid snowmelt. Earthquakes, volcanoes, and human activates may also trigger landslides.

There are 3 main factors that influence an areas susceptibility to landslides: geometry of the slope, geologic material, and water. Certain geologic formations are more susceptible to landslides than others. In general, locations with steep slopes are most susceptible to landslides, and the landslides occurring on steep slopes tend to move more rapidly and are therefore may pose life safety. A full list of acronyms used in this chapter is provided in Appendix 8-B.

El Nino Southern Oscillation and Effects on Landslides

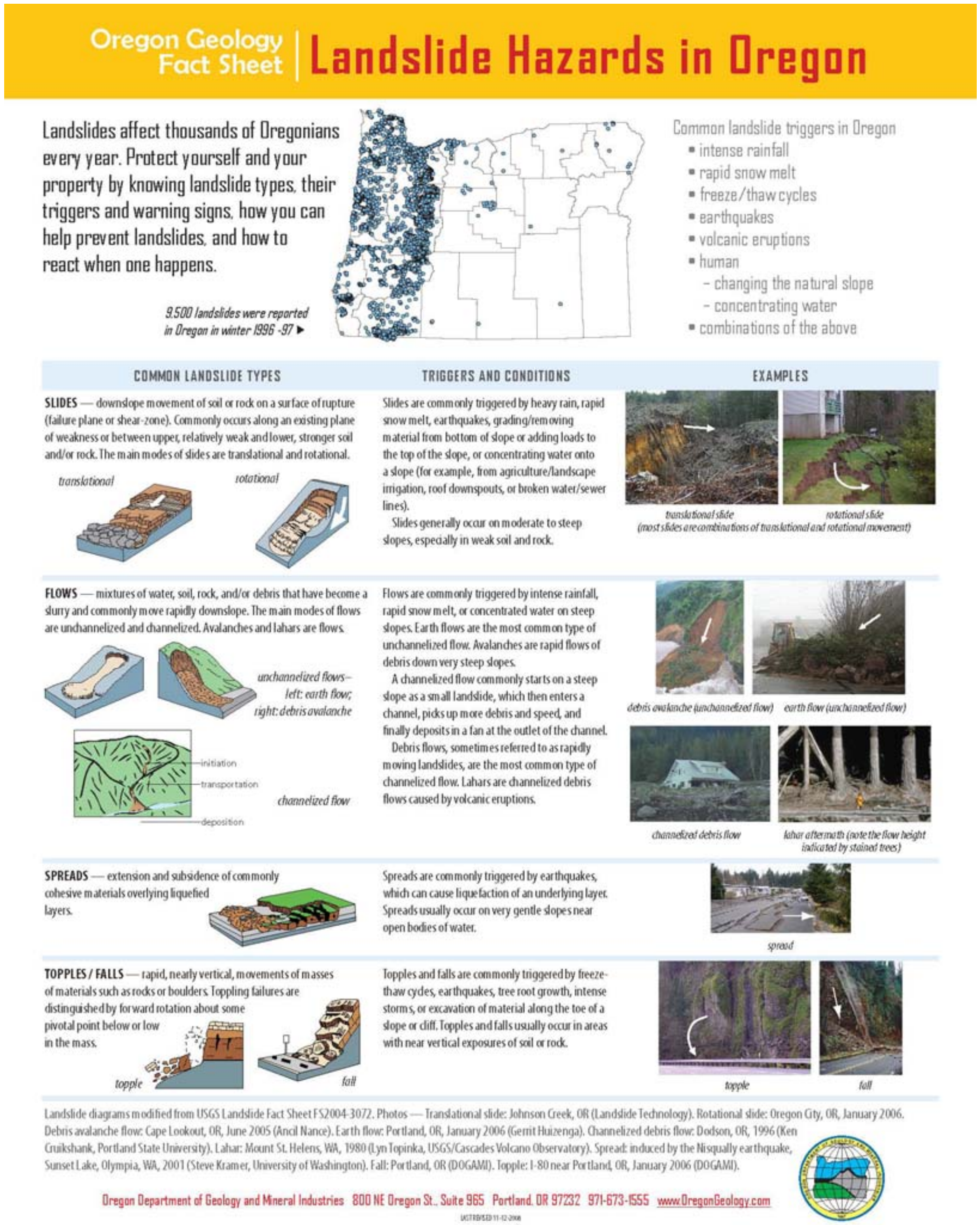
The strongest impacts of intra-seasonal variability on the U.S. occur during the winter months over the western U.S. During the winter this region receives the bulk of its annual precipitation. Storms in this region can last for several days or more and are often accompanied by persistent atmospheric circulation features. Of particular concern are the extreme precipitation events which are linked to flooding and landslide. There is strong evidence for a linkage between weather and climate in this region from studies that have related the El Niño-Southern Oscillation (ENSO) to regional precipitation variability. From these studies it is known that extreme precipitation events can occur at all phases of the El Niño-Southern Oscillation (ENSO) cycle, but the largest fraction of these events occur during La Niña episodes and during ENSO-neutral winters. During La Niña episodes much of the Pacific Northwest experiences increased storminess, increased precipitation and more overall days with measurable precipitation. The risk of flooding and rain-induced landslides (and debris flows) in this region can be related to La Niña episodes.

(NOAA/Climate Prediction Center)
http://www.cpc.noaa.gov/products/intraseasonal/intraseasonal_faq.html#usimpacts

Hazard Analysis/Characterization

The term landslide encompasses a wide range of geologic processes and a variety of nomenclatures that can lend itself to confusion. The general term landslide refers to a range of mass movement including rock falls, debris flows, earth slides, and other mass movements. One very important thing to understand is the fact that all landslides have different frequencies of movements, triggering conditions, and very different resulting hazards.

All landslides can be classified into one the following six types of movements: 1) slides, 2) flows, 3) spreads, 4) topples, 5) falls, 6) complex. Most slope failures are complex combinations of these distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard associated with the landslide, the landslide characteristics, identification methods, and potential mitigation alternatives.



Oregon Geology Fact Sheet | **Landslide Hazards in Oregon**

Landslides affect thousands of Oregonians every year. Protect yourself and your property by knowing landslide types, their triggers and warning signs, how you can help prevent landslides, and how to react when one happens.

9,500 landslides were reported in Oregon in winter 1996 -97 ▶

Common landslide triggers in Oregon
- intense rainfall
- rapid snow melt
- freeze/thaw cycles
- earthquakes
- volcanic eruptions
- human
  - changing the natural slope
  - concentrating water
- combinations of the above

COMMON LANDSLIDE TYPES	TRIGGERS AND CONDITIONS	EXAMPLES
SLIDES — downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone). Commonly occurs along an existing plane of weakness or between upper, relatively weak and lower, stronger soil and/or rock. The main modes of slides are translational and rotational. *translational* *rotational*	Slides are commonly triggered by heavy rain, rapid snow melt, earthquakes, grading/removing material from bottom of slope or adding loads to the top of the slope, or concentrating water onto a slope (for example, from agriculture/landscape irrigation, roof downspouts, or broken water/sewer lines). Slides generally occur on moderate to steep slopes, especially in weak soil and rock.	*translational slide* *rotational slide* *(most slides are combinations of translational and rotational movement)*
FLOWS — mixtures of water, soil, rock, and/or debris that have become a slurry and commonly move rapidly downslope. The main modes of flows are unchannelized and channelized. Avalanches and lahars are flows. *unchannelized flows— left: earth flow; right: debris avalanche* initiation transportation deposition *channelized flow*	Flows are commonly triggered by intense rainfall, rapid snow melt, or concentrated water on steep slopes. Earth flows are the most common type of unchannelized flow. Avalanches are rapid flows of debris down very steep slopes. A channelized flow commonly starts on a steep slope as a small landslide, which then enters a channel, picks up more debris and speed, and finally deposits in a fan at the outlet of the channel. Debris flows, sometimes referred to as rapidly moving landslides, are the most common type of channelized flow. Lahars are channelized debris flows caused by volcanic eruptions.	*debris avalanche (unchannelized flow)* *earth flow (unchannelized flow)* *channelized debris flow* *lahar aftermath (note the flow height indicated by stained trees)*
SPREADS — extension and subsidence of commonly cohesive materials overlying liquefied layers.	Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer. Spreads usually occur on very gentle slopes near open bodies of water.	*spread*
TOPPLES / FALLS — rapid, nearly vertical, movements of masses of materials such as rocks or boulders. Toppling failures are distinguished by forward rotation about some pivotal point below or low in the mass. *topple* *fall*	Topples and falls are commonly triggered by freeze-thaw cycles, earthquakes, tree root growth, intense storms, or excavation of material along the toe of a slope or cliff. Topples and falls usually occur in areas with near vertical exposures of soil or rock.	*topple* *fall*

Landslide diagrams modified from USGS Landslide Fact Sheet FS2004-3072. Photos — Translational slide: Johnson Creek, OR (Landslide Technology). Rotational slide: Oregon City, OR, January 2006. Debris avalanche flow: Cape Lookout, OR, June 2005 (Ancil Nance). Earth flow: Portland, OR, January 2006 (Gerrit Huizenga). Channelized debris flow: Dodson, OR, 1996 (Ken Cruikshank, Portland State University). Lahar: Mount St. Helens, WA, 1980 (Lyn Topinka, USGS/Cascades Volcano Observatory). Spread: induced by the Nisqually earthquake, Sunset Lake, Olympia, WA, 2001 (Steve Kramer, University of Washington). Fall: Portland, OR (DOGAMI). Topple: I-80 near Portland, OR, January 2006 (DOGAMI).

Oregon Department of Geology and Mineral Industries 800 NE Oregon St., Suite 965 Portland, OR 97232 971-673-1555 www.OregonGeology.com

Figure LS-1: Common types of landslides in Oregon.

Visit http://www.oregongeology.org/sub/Landslide/Landslidehome.htm for more information.

These types of movements can be combined with other aspects of the landslide such as type of material, rate of movement, depth of failure, and water content for a better understanding of the type of landslide.

One potentially life threatening type of landslide is the channelized debris flow or "rapidly moving landslide" which are flows that initiate upslope, move into or transport down a steep channel (or drainage) and deposit material, usually at the mouth of the channel. Debris flows are also commonly initiated by other types of landslides that occur on slopes near a channel. They can also initiate within the channel in areas of accelerated erosion during heavy rainfall or snowmelt. Rapidly moving landslides have caused most of the recent landslide related injuries and deaths in Oregon. Debris flows or rapidly moving landslides caused eight deaths in Oregon in 1996 following La Niña storms.

Areas that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. This commonly leads to distinctive geomorphology that can be used to identify landslide areas, although over time the geomorphic expression may become subtle, making the landslide difficult to identify. Other types of landslides tend to occur in the same locations and produce distinctive geomorphology, such as channelized debris flows, which form a fan at the mouth of the channel after repeated events. This is also true for the talus slopes, which form after repeated rock fall has taken place in an area.

Previously impacted areas are particularly important to identify, as they may pose a substantial hazard for future instability and help identify areas that are susceptible to future events. Large, slow moving landslides frequently cause significant property damage, but are far less likely to result in serious injuries. Two examples are the subdivision landslide in Kelso, Washington, and the slide at The Capes development in Tillamook County.

The velocity of landslides varies from imperceptible to over 35 miles per hour. Some volcanic induced landslides have been known to travel between 50 to 150 miles per hour. On less steep slopes, landslides tend to move slowly and cause damage gradually. Debris flows typically start on steep hillsides as shallow landslides, enter a channel, then liquefy and accelerate. Canyon bottoms, stream channels, and outlets of canyons can be particularly hazardous. Landslides can move long distances, sometimes as much as several miles. The Dodson debris flows in 1996 started high on Columbia River Gorge cliffs, and traveled down steep canyons to form debris fans in the Dodson-Warrendale area. Landslide recurrence interval is highly variable. Some large landslides move continuously at very slow rates. Others move periodically during wet periods. Very steeply sloped areas can have relatively high landslide recurrence intervals (10 to 500 years on an initiation site basis). Since debris flows can be initiated at many sites over a watershed, in some cases recurrence intervals can be less than ten years. Slope alterations can greatly affect recurrence intervals for all types of landslides, and also cause landslides in areas otherwise not susceptible. Most slopes in Western Oregon steeper than 30 degrees (~60%) have a risk of rapidly moving landslide activity regardless of geologic unit. Areas directly below these slopes in the paths of potential landslides are at risk as well. Based on the Oregon Department of Forestry Storm Impacts Study, the highest debris flow hazard occurs in Western Lane County, Western Douglas County, and Coos County. The combination of steep slopes and geologic formation (sedimentary rock units) contributes to the increased hazard. The debris flow hazard is also high in much of the Coast Range and Cascade Mountains and in the Columbia River Gorge.

Deep-seated landslides are generally defined as having a failure plane within the regional bedrock unit (generally greater than 15 feet deep), whereas the failure plane of shallow-seated landslides is commonly between the thin soil mantle and the top of the bedrock. Deep-seated landslide hazard is high in parts of the Coast Range. Deep-seated landslides are fairly common in pyroclastic rock units of the Western Cascade Mountains, and in fine-grained sedimentary rock units of the Coast Range. Deep-seated landslides also occur in semi-consolidated sedimentary rocks at or near the Oregon coast particularly around Newport, Lincoln County and Tillamook County, and in the Troutdale Formation around the Portland area.

Infrequent very large landslides and debris flows may occur in any of the larger mountain ranges or in deep gorges throughout Oregon.

During 1996 and 1997, heavier than normal rains caused over 700 landslides within the Portland Metropolitan region, which totaled over $40 million for mitigation (Burns et al., 1998). In the City of Portland, 17 homes were completely destroyed and 64 were badly damaged. There were no serious injuries associated with the landslides in Portland or in other urban areas within Oregon during the 1996 storms. Reported damage costs from the storms were $10 million with 40% of the damage resulting from landslides.

The Oregon Department of Forestry Storm Impacts Study estimated that tens of thousands of landslides occurred on steep slopes in the forests of Western Oregon during 1996. The Oregon Department of Geology and Mineral Industries Slope Failures in Oregon inventoried 9,500 reports of landslides across the state resulting from the 1996 storms. There are a significant number of locations in Oregon that are impacted frequently (every 10 to 100 years) by dangerous landslides. The number of injuries and deaths in the future will be directly related to vulnerability: the more people in these areas, the greater the risk of injury or death.

Identification of Landslide Prone Locations

In order to reduce losses from landslides, areas of landslide hazard must first be identified. The first step in landslide hazard identification is to create an inventory of past (historic and prehistoric) landslides. Once this inventory is created, it can be used to create susceptibility maps which display areas that are likely to have landslides in the future. Once the landslide hazards are identified on inventory and susceptibility maps, the risk can be quantified, mitigation projects prioritized and implemented.

In 2005, DOGAMI began a collaborative landslide research program with the U.S. Geological Survey (USGS) Landslide Hazards Program to identify and understand landslides in Oregon. In order to begin the extensive undertaking of mapping existing landslides throughout Oregon, a pilot project area was selected to compare remote sensing data/images for effectiveness. The remote sensing data sets compared included (Burns, 2007):

1. 30 m (98 ft) digital elevation model (DEM) from the Shuttle Radar Topography Mission
2. 10 m (33 ft) DEM derived from the USGS topographic quadrangles

3. photogrammatic and ground based 1.5 m (5 ft) interval contour data
4. stereo aerial photographs from 1936 to 2000
5. lidar imagery with an average of 1 data point per m^2 (3.2 ft) and with a vertical accuracy of about 5 cm (6 in)

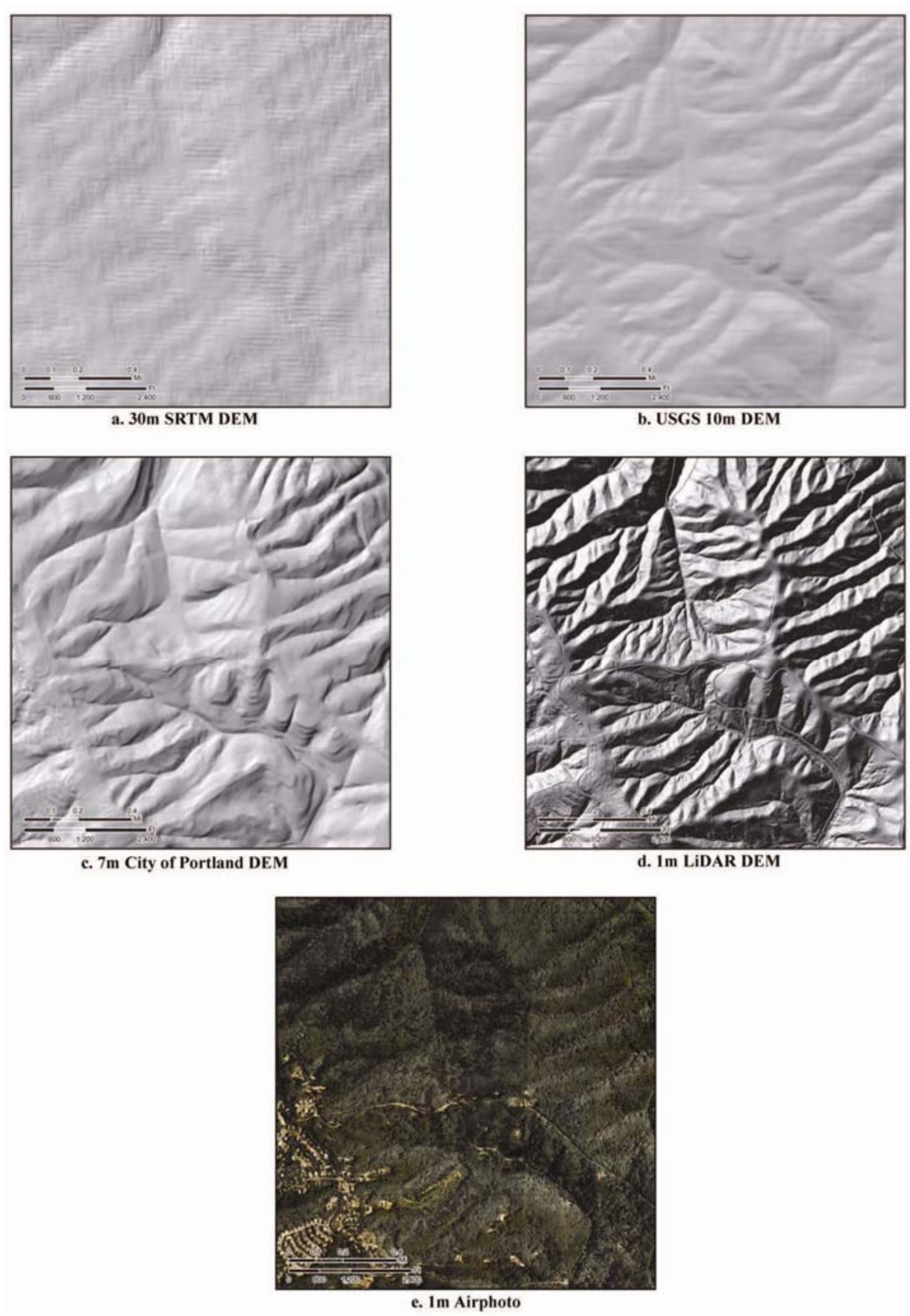


Figure LS-2: Visual comparison of the five (a, b, c, d, e) remote sensing data sets. The air photo is draped over a DEM so that it appears to have the 3-dimensional view provided by a stereo-pair.

Two key findings of the pilot project were: 1) the use of the LIDAR data resulted in the identification of between 3 to 200 times the number of landslides identified using the other data sets and 2) the ease and accuracy of mapping the spatial extent of the landslides identified from lidar data were greatly improved compared to other mapping methods.

When examining the results of the comparison of remote sensing data, several debris flow fans at the mouths of channels or potential channelized debris flow deposits, were identified with serial stereo-pair aerial photos, which did not get identified on the LIDAR derived DEMs. Dense development has taken place in Oregon in the last 40 years, which can mask landslide features, especially if major earthwork has taken place. In most of the populated areas of Oregon, if historic air photos are available, at least one review of (greater than 40 years old) photos should be performed (Burns, 2007).

In order to develop accurate large scale landslide inventory maps, we recommend the following minimal requirements:

1. All previously identified landslides from geologic maps, previous landslide studies, and other local sources should be compiled.
2. The mapper should have experience identifying all types and ages of landslides within the area being studied.
3. Lidar data should be used to identify landslides and accurately locate the extents of previously mapped landslides (from step 1).
4. An orthophoto of similar age to the LIDAR data should be used to minimize the misidentification of man-made cuts and fills as landslides.
5. The mapper should use at least one set of historical stereo-pair aerial photography to locate landslides in the area being studied.
6. Non-spatial data should also be collected at the time of the mapping so that a comprehensive database can be formed. Non-spatial data should generally include confidence of interpretation, movement class, direction of movement, etc. and are described in detail in section 6.0 of this paper.
7. A comprehensive check of spatial (map) and non-spatial data should be developed and implemented including technical review of mapped landslides and field checks where possible.

Step one was accomplished in 2008 with the publication of SLIDO-1. This publication has been updated and again published as SLIDO-2 (Burns and others, 2011).

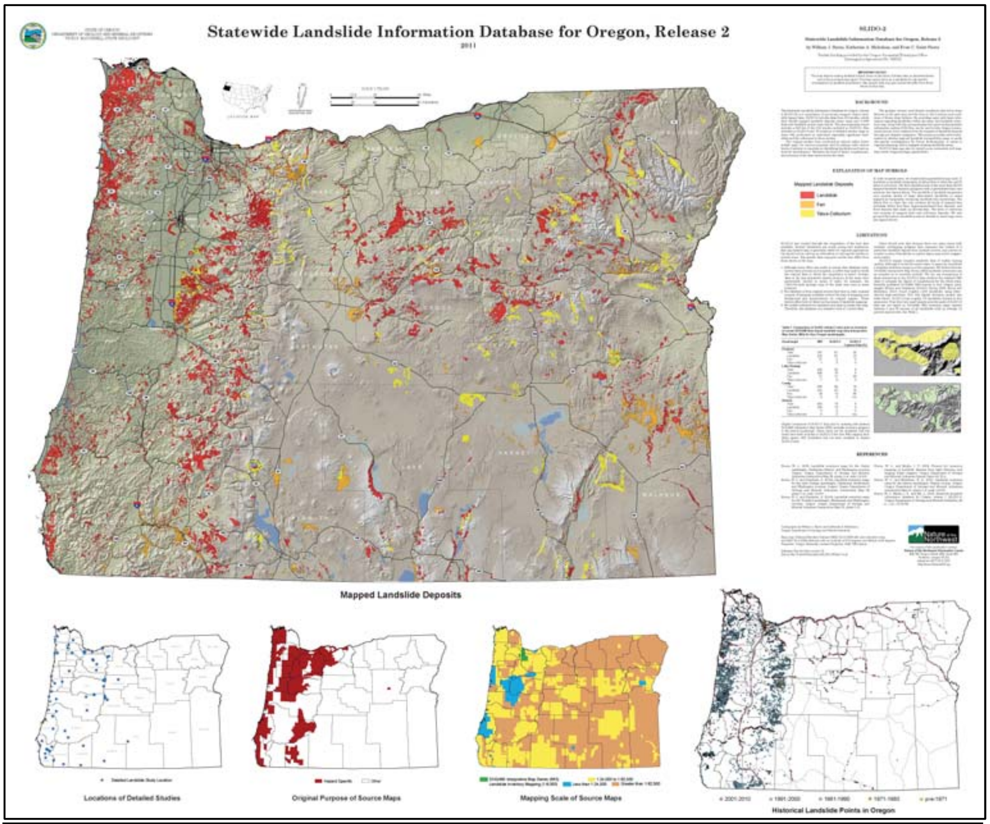


Figure LS-3: Statewide Landslide Information Database for Oregon, Release 2. The resulting SLIDO-2 geodatabase includes 22,542 landslide deposit polygons and landslide-related features from 313 published and unpublished studies, 10,636 historical landslide point locations (including all points from the 1996-97 events), and 72 locations of detailed studies on individual landslides, a significant increase over SLIDO-1.

A protocol was developed by DOGAMI so that we can produce consistent lidar-based landslide inventory maps at an accelerated rate without having to describe how the mapping was done every time a new area is mapped (Burns and Madin, 2009). The results of following this protocol in any particular area include a very detailed database and map of the landslide inventory.

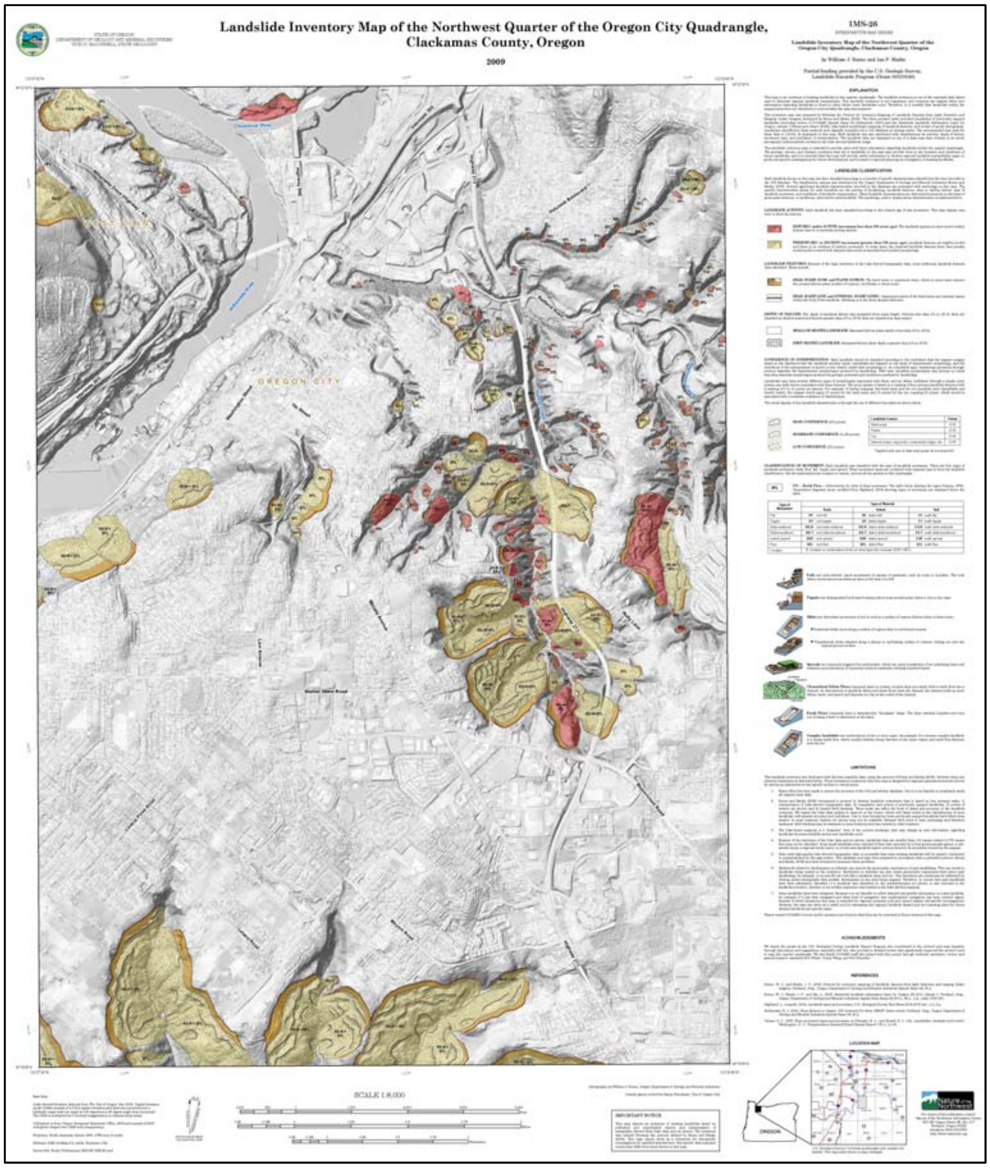


Figure LS-4: Example of a new Lidar-based landslide inventory (Oregon City,OR)

With an accurate landslide inventory in hand, the next step in a complete landslide hazard mapping program is to develop susceptibility maps for common types of landslides. DOGAMI is in progress of completing a shallow landslide, deep landslide, and channelized debris flow susceptibility mapping protocols.

Existing Strategies and Programs

Existing strategies and programs at the state level for this hazard are primarily the responsibility of the Department of Geology and Mineral Industries, Oregon Department of Forestry, and the Department of Land Conservation and Development as summarized below.

Department of Geology and Mineral Industries

DOGAMI conducts hazard assessments, including the identification and mapping of landslide hazards, estimating potential consequences and likelihood of occurrence, and monitoring and assessing potential hazardous geological activity. DOGAMI also provides public education regarding landslide hazards.

Partnership with U.S. Geological Survey National Landslide Hazard Program – DOGAMI has entered into a collaborative partnership with this program, centered around three targeted goals for Western Oregon: 1) develop inventory maps and digital databases of existing deep-seated landslides, 2) develop predictive hazard maps of areas prone to rapidly moving landslides, and 3) develop susceptibility maps of deep-seated landslides for targeted developable areas. This will be conducted in cooperation with local governments and will provide some technical assistance to local governments to facilitate the use and application of this information.

DOGAMI has produced many publications and fact sheets all of which are available through the website at:

http://www.oregongeology.org/sub/Landslide/Landslidehome.htm

Oregon Department of Forestry

ODF regulates forest operations to reduce the risk of serious bodily injury or death from rapidly moving landslides, and assists local governments in the siting review of permanent dwellings on or adjacent to forest lands in *further review areas.*

Landslides and Public Safety Rules – ODF successfully developed permanent forest practice rules to manage risk to public safety from shallow, rapidly moving landslides (Oregon Administrative Rules 629-623-0000 to 0800, see http://arcweb.sos.state.or.us/rules/OARS_600/OAR_629/629_623.html). The permanent rules replaced temporary deferral that affected forest practices in specified areas. The new rules prohibit or limit timber harvestand forest road construction based on the level of associated risk. Following approval by the Board of Forestry, the new rules took effect January 1, 2003.

Department of Land Conservation and Development

DLCD requires local governments to address geologically unstable areas as part of their comprehensive plansthrough Statewide Land Use Planning Goal 7 (Areas Subject to Natural Hazards). DLCD worked with the University of Oregon during 1999 and 2000 to develop a series of *Technical Resources Guides* (TRGs), designed for Oregon cities and counties to assist in planning for, and limiting the effects of threats posed by natural hazards, including landslides. These guides provide policy, planning, and non-regulatory mitigation strategy technical assistance. The landslide TRG may be accessed via either of the following sites:

http://www.oregon.gov/LCD/HAZ/docs/landslides/05_landslide.pdf

http://www.oregonshowcase.org/projects/resourceguide

Debris Flow Warning System

Oregon Department of Forestry meteorologists were responsible for forecasting storms that may trigger debris flows. These forecasts were developed using real time data from telemetered rain gauges and other hydro-meteorological data. Advisories and warnings were issued as appropriate. Information was broadcast over NOAA Weather Radio, the Law Enforcement Data System, and ODOT reader boards.

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LANDSLIDES AND DEBRIS FLOWS ARE POSSIBLE DURING THIS FLOOD EVENT.
PEOPLE...STRUCTURES AND ROADS LOCATED BELOW STEEP SLOPES...IN CANYONS AND NEAR
THE MOUTHS OF CANYONS MAY BE AT SERIOUS RISK FROM RAPIDLY MOVING LANDSLIDES.
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The new and current landslide warning system is run by NOAA National Weather Service. In the current system, landslide warning language is included when a flood watch is issued for a portion of Oregon. Below is an example of the watches issued by NWS.

WESTERN OREGON: ODF has identified three segments of state highways that are of highest concern for debris flow vulnerability. ODOT places warning signs on each end of these three highest hazard areas when conditions may lead to debris flows. In order of concern, the three areas are Oregon Highway 38, milepost 6.5 to milepost 17; Interstate 84, from about milepost 20 to milepost 40; and Oregon Highway 6, milepost 5 to milepost 35.

DOGAMI provides additional information on debris flows to the media and through them to the public. Information is also posted to National Weather Service, ODF, and DOGAMI websites.

Towards Oregon NHMP Goals: #1, 2, and 5

Pre-2012 Oregon NHMP Action Met: LS-LT-2

Lead Agencies: ODF and DOGAMI

Support Agencies: ODOT, OERS/LEDS, OEM

Project Type: Public awareness

Project Start Date: 1997

Project End Date: Ongoing

Years Project Tested: ‘97, ‘98, ‘99, ‘01, ’02, ’03, ’04, 05, 06, 07, 08, 09, 10, 11

Funding Sources: HMGP, ODF, ODOT, others

Activations of the Debris Flow Warning System
(This system no longer exists.)

16-Dec-97 Advisory
Clatsop, Tillamook, Western Yamhill County

24-Nov-98 Advisory
Clatsop to Coos Counties

23-Feb-99 Advisory
Western Oregon north of Highway 20

26-Nov-01 Advisory
Clatsop to Coos Counties

15-Dec-01 Advisory
Northwest Oregon west of the Cascade crest and north of Highway 20

13-Dec-02 Advisory
Curry County and Josephine County west of Highway 199 and south of the Rogue River

31-Jan-03 Advisory
Clatsop, Columbia, Tillamook, and Yamhill counties

13-Dec-03 Advisory
Southern Lincoln, Western Lane, Western Douglas, Coos and Curry counties

29-Jan-04 Warning
Clatsop, Tillamook, Lincoln, Columbia, Washington, Yamhill, and Multnomah County east of Troutdale

Project Benefits: The warning system provides information so that the traveling public can make informed decisions about routes and timing of travel. It also can assist persons living or working in higher hazard areas to make decisions about evacuating those areas until the danger is reduced.

Local Landslide Ordinances

In November 1999, the Oregon Department of Land Conservation and Development (DLCD) awarded a grant to Douglas County to develop a model landslide ordinance for local governments. This grant produced not only the Douglas County model, but also led to several other ordinances.

DOUGLAS, MARION AND POLK COUNTIES, OREGON: The Department of Land Conservation and Development identified the following ordinances as exemplifying the principles of Goal 7 and holds these up as models for local governments in the development of landslide hazard ordinances:

- City of Salem Landslide Hazard Ordinance
- Marion Co. Geologically Hazardous Areas Overlay Zones
- Douglas County Geologic Hazards Overlay Ordinance

Model ordinances are available on the DLCD website: http://www.oregon.gov/LCD/HAZ/landslideslocalgov.shtml

Towards Oregon NHMP Goals: #1, 2, 5, and 6

Pre-2012 Oregon NHMP Action Met: LS-ST-3

Lead Agency: DLCD

Support Agencies: DOGAMI, OEM

Project Type: Land use

Project Start Date: 1999

Project End Date: Ongoing

Years Project Tested: 2001 and ongoing

Funding Source(s): HMGP, state and local funds

Project Benefits: This work provides a factual basis for regulating development in areas at higher risk to geologic hazards, resulting in the siting and/or constructing ofstructures in ways that respect the hazard.

In Salem, concurrent with the mapping effort, a technical advisory committee was formed to advise the city on the preparation of a hazard mitigation plan. In addition, a landslide hazard advisory committee was formed to advise the city, as well as Marion County, on hillside development ordinances.

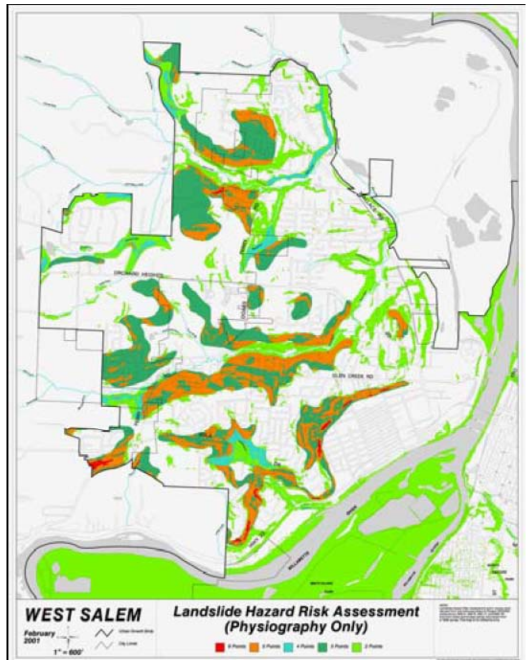

Image above is courtesy of City of Salem

The City of Salem, Marion, and Polk counties participated in a team effort to develop landslide maps and ordinances. This project provides an example of how communities can address risk reduction for geologic hazards. Parts of the South Salem Hills and Eola Hills in West Salem were mapped to characterize landslide types and processes. The areas are partly developed and further development is expected. The size of the South and West Salem slide areas and manifestations of recent movement made these areas of significant concern.

Segmented characterization of the landslide areas provided the opportunity to consider developing different sets of requirements from place to place. The landslide risk relates to other geologic hazards such as streambank erosion and earthquake ground response and lends itself to a multi-hazard risk reduction strategy. Hazard characterization was contracted-out to the private sector and focused-on knowledge of local geology, proper segmentation of slide types, and developing various strategy options to reduce risk in each segment of the slides.

Appendix LS-1: Glossary

Landslides are any detached mass of soil, rock, or debris that moves down a slope or a stream channel.

Landslides are typically subdivided into six categories:

Complex refers to any combination of landslide types.

Flows are rapid to slow mass movement of saturated material moving down a slope. *Debris flows* occur when a landslide moves rapidly downslope as a semi-fluid mass scouring or partially scouring soils from the slope along its path. Debris flows frequently enter channels and usually contain much large woody debris, and move very rapidly. Other *flow* types include earthflows, mudflows, lahars, debris torrents, and creep.

Lateral spreads are failure on very gentle slopes or flat terrain. The failure is usually associated with water-saturated, loose sediment spreading laterally due to liquefaction during earthquakes or human caused rapid ground motion.

Rock falls are masses of rock fragments that break away from a steep slope and travel mostly by free fall, coming to rest at the base of a slope as talus debris.

Rock topples are blocks that have rotated forward and may become a rock fall.

Slides have a distinct zone of weakness that separates the overlying failed material from more stable underlying material. Types of slides include rotational (movement along a curved surface) and translational (movement along a flat surface).

Appendix LS-2: Additional Resources

Burns, S.F.; Burns, W.J.; James, D.H.; and Hinkle, J.C., 1998, "Landslides in Portland, Oregon Metropolitan Area Resulting from the Storm of February 1996: Inventory Map, Database, and Evaluation," published by METRO, Portland, Oregon.

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Burns, W.J. and Mickelson, K.A., 2010. Landslide Inventory Maps for the Oregon City Quadrangle, Clackamas, County, Oregon, Oregon Department of Geology and Mineral Industries, IMS-30, Plates 1, 2, 3

Burns, W.J., Madin, I.P., 2009. Landslide Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (lidar) Imagery, Oregon Department of Geology and Mineral Industries, Special Paper 42

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