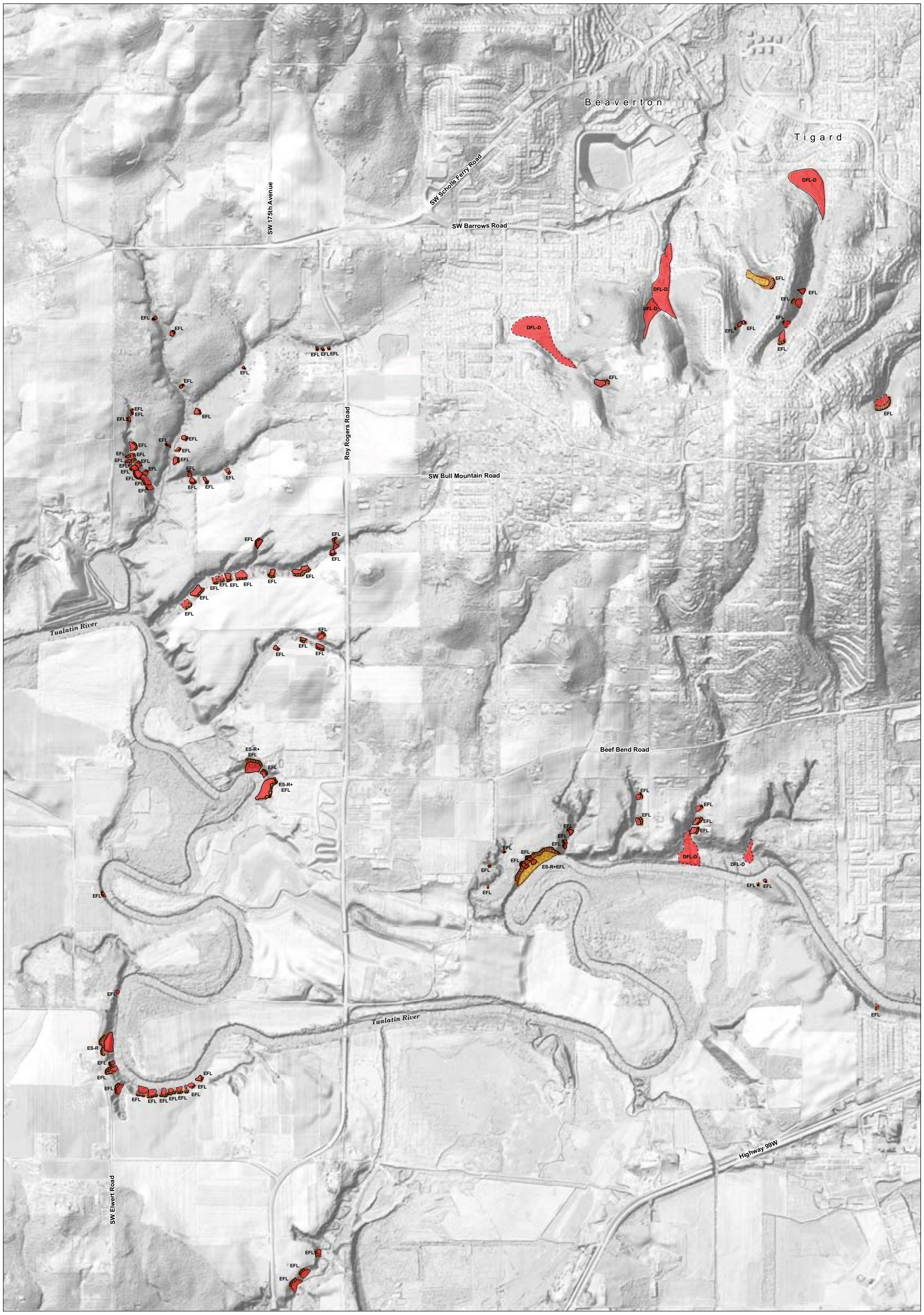
Facsimile of PLATE 1, Landslide Inventory Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon, DOGAMI OPEN-FILE REPORT O-08-09, Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
VICKI S. McCONNELL, STATE GEOLOGIST

Landslide Inventory Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon

2008



Base Map:

Elevation data from Oregon Lidar Consotrium, 2007. Digital elevation model (DEM) consists of a 3-foot by 3-foot elevation grid with hillshade sunangle at 315 degrees at a 45 degree angle from horizontal. Orthophoto is from Oregon Geospatial Enterprise Office, 2005 and consists of 2005 orthophoto draped over DEM with transparency.

Projection: North American Datum 1983, UTM zone 10 north

Software: MapInfo Professional 8.0, ESRI ArcMap 9.2, Adobe Illustrator CS2

Source File: Rocks\Publications\O-08-09\Plate_1.mxd

SCALE 1:8,000

1,300 650 0 1,300 2,600 3,900 5,200 Feet

0.25 0.125 0 0.25 0.5 0.75 1 Miles

0.25 0.125 0 0.25 0.5 0.75 1 Kilometers

Cartography by William J. Burns, Oregon Department of Geology and Mineral Industries

Outside agency review by Paul Schaefer, Washington County

IMPORTANT NOTICE
This map depicts existing landslides on the basis of limited data. The hazard zones were created following the protocol defined by Burns and Madin (2008). This map cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on this map.

OPEN-FILE REPORT O-08-09

Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon

by William J. Burns

Partial funding provided by Washington County (Project 100075, PO 141319)

PLATE 1

EXPLANATION

This map is an inventory of existing landslides in this area. The landslide inventory is one of the essential data layers used to delineate regional landslide susceptibility. This landslide inventory is not regulatory; revisions can happen when new information regarding landslides is found or new landslides occur. Therefore, it is possible that landslides within the map area were not identified or occurred after the map was prepared.

This inventory map was prepared by compiling all previously mapped landslides (published geologic and landslide mapping), analyzing lidar-based geomorphology, and reviewing aerial photographs. Landslides identified by these methods were digitally compiled into a GIS database at a scale of 1:1,500. The recommended map scale for these data is 1:8,000, as displayed on this map. Each landslide was also attributed with classifications for activity, landslide features, depth of failure, confidence of interpretation, and movement type. The landslide data are displayed on top of a base map that consists of an orthorectified aerial photograph overlain on the lidar-derived digital elevation model.

This landslide inventory map is intended to provide users with basic information regarding landslides within the area. The geologic, terrain and climatic conditions that led to slope failures in the past may provide clues to locations and conditions of future slope failures, and it is intended that this map will provide useful information to develop regional landslide susceptibility maps, to guide site-specific investigations for future developments, to assist in regional planning, and to mitigate existing landslides.

LANDSLIDE CLASSIFICATION

Each landslide shown on this map has been classified according to a number of specific characteristics identified at the time recorded in the GIS database. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (DOGAMI) (Burns and Madin, 2008). Several significant landslide characteristics recorded in the database are portrayed with symbols on this map. The specific characteristics shown for each landslide are the activity of landsliding, landslide features, deep or shallow failure, type of landslide movement, and confidence of landslide interpretation. These landslide characteristics are determined primarily on the basis of geomorphic features, or landforms, observed for each landslide. The symbology used to display these characteristics is explained below.

LANDSLIDE ACTIVITY: Each landslide has been classified according to the relative age of last movement. This map uses color to show the activity.

ACTIVE or HISTORIC (movement < 100 years): The landslide appears to be currently moving or to have moved within historic time.

DORMANT – YOUNG (movement 100-10,000 years – Holocene): Landslide features are fresh to slightly eroded, but there is no evidence of historic movement.

DORMANT – MATURE (movement > 10,000 – Pleistocene and earlier): The observed landforms related to the landslide have been greatly eroded or covered with Pleistocene or earlier alluvial deposits that result in smoothed and subdued morphology.

LANDSLIDE FEATURES: Because of the high resolution of the lidar-derived topographic data, some additional landslide features were identified. These include:

HEAD SCARP: The uppermost scarp, which in most cases exposes the primary surface of rupture.

HEAD AND INTERNAL SCARPS: Scarps within the body of the landslide.

DEPTH OF FAILURE: The depth of landslide failure was estimated from scarp height. Failures less than 4.5 m (15 ft) deep are classified as shallow-seated, and failures greater than 4.5 m (15 ft) deep are classified as deep-seated.

SHALLOW-SEATED LANDSLIDE: Estimated failure plane depth is less than 4.5 m (15 ft).

DEEP-SEATED LANDSLIDE: Estimated failure plane depth is greater than 4.5 m (15 ft).

CONFIDENCE OF INTERPRETATION: Each mapped landslide is classified according to a "confidence" that the mapper assigns to it, and can be regarded as a measure of the likelihood that the landslide actually exists. Landslides are mapped on the basis of characteristic landforms, and the confidence of interpretation is based on the presence or absence of those landforms. As a landslide ages after its last movement, erosion removes or covers the landforms that formed by landsliding. With time, these distinctive landforms become so subtle that they resemble landforms produced by geologic processes and conditions unrelated to landsliding.

Because most landslides, with the exception of channelized debris flow transport zones and deposit zones, rock falls, and topples, have several different types of geomorphic features associated with them, a good way to define certainty is through a simple point system associated with these features. For example, if the head scarp and toe of a landslide are only features identifiable during mapping, the mapper applies 30 points for the head scarp and 30 points for the toe, equaling 60 points, which is associated with a good certainty of identification.

The visual display of this confidence of interpretation is through the use of different line styles as shown below.

EXCELLENT (> 80% confidence, ≥ 90 points)

GOOD (60%–80% confidence, 60–89 points)

MODERATE (40%–60% confidence, 30–59 points)

FAIR (20%–40% confidence, 11–29 points)

POOR (< 20% confidence, ≤ 10 points)

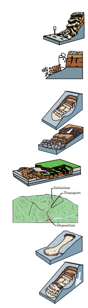
Landslide Feature	Points
Head scarp	30
Flanks	30
Toe	30
Internal scarps, sag ponds, compression ridges, etc.	10*

*Applied only once so that total points do not total more than 100

CLASSIFICATION OF MOVEMENT: Each landslide was classified with the type of landslide movement. There are five types of landslide movement: slide, flow, fall, topple, and spread. These movement types are combined with material type to form the landslide classification. Not all combinations are common in nature, and not all are present in this area.

Example: EFL — **EFL - Earth Flow** – Abbreviation for class of slope movement. Table below displays all types. Generalized diagrams displaying types of movements are shown below table (some modified from Highland, 2004).

	Type of Material		
Type of Movement	Rock	Coarse Soils	Fine Soils
Fall	RF rock fall	DF debris fall	EF earth fall
Topple	RP rock topple	DT debris topple	ET earth topple
Slide-rotational	RS-R rock slide-rotational	DS-R debris slide-rotational	ES-R earth slide-rotational
Slide-translational	RS-T rock slide-translational	DS-T debris slide-translational	ES-T earth slide-translational
Lateral spread	RSP rock spread	DSP debris spread	ESP earth spread
Flow	RFL rock flow	DFL-I debris flow-initiation DFL-T debris flow-transport DFL-D debris flow-deposition	EFL earth flow
Complex	C complex or combinations of two or more types (for example, ES-R + EFL)		



Falls are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.

Slides are downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone).

- Rotational slides move along a surface of rupture that is curved and concave.
- Translational slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.

Channelized Debris Flows commonly start on a steep, concave slope as a small slide or earthflow into a channel. As this mixture of landslide debris and water flows down the channel, it picks up more debris and water, as well as speed, and deposits material in a fan at the outlet of the channel.

Earth Flows commonly have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.

Complex Landslides are combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibits slump features in the upper region and earth flow features near the toe.

LIMITATIONS

The landslide inventory mapping protocol was developed with input from many sources and people, along with expertise gained from years of experience. Several limitations are worth noting and underscore that any regional hazard map is useful for regional applications but should not be used as an alternative to site-specific studies in critical areas.

1. Although it is possible to check for errors in the GIS and tabular database, it is not feasible verify all original input data.
2. As discussed above, the protocol to develop landslide inventories is based on four primary tasks: 1) interpretation of lidar-derived topographic data, 2) compilation and review of previously mapped landslides, 3) review of historic air photos, and 4) limited field check. These tasks can affect the level of detail and accuracy of the landslide inventory. We expect lidar data quality will improve in the future, which will likely result in identification of more landslides with greater accuracy and confidence. Because of time limitations some previously mapped landslides have likely been missed. For some locations, historic air photos may not be available. Because field work is time consuming and therefore expensive, field checking may be extensive in some locations and very limited in some remote locations.
3. The GIS database is a "snapshot" view of the current data; new information regarding landslides may be found and new landslides may occur.
4. Because of the resolution of the lidar data and air photos, landslides that are smaller than 100 square meters (1,075 square feet) may not be identified. Small landslides were included if they are provided by a local governmental agency, a site- or area-specific study report, or a local area landslide expert, and are found to be accurately located.
5. It can be expected that the geological interpreter will not recognize some landslides as a result of lidar data and air photo quality, scale, vegetation, or other characteristics. A mapper's experience level and experience with landslides in the immediate area also affect the quality of the inventory map. To limit these problems, this map was developed following the lidar-based landslide inventory mapping protocol developed by Burns and Madin (2008) and has undergone peer review.
6. Earthwork related to development on hillsides can remove the geomorphic expressions of past landsliding. This can result in landslides being missed in the inventory. Earthwork on hillsides can also create geomorphic expressions that mimic past landsliding. For example, a cut and fill can look like a landslide scarp and toe. This limitation can sometimes be addressed by viewing aerial photographs that predate development in the area being mapped. Therefore, to ensure that past landslides have been adequately identified, if a landslide was identified on the predevelopment air photos, it was included in the landslide inventory, whether or not surface expression was located on the lidar-based map.
7. Some landslides have been mitigated. Because it is not feasible to collect detailed site-specific information on every landslide, for example if it has been mitigated and what level of mitigation was implemented, mitigation has been omitted.

Because of these limitations this map is intended for regional purposes only and cannot replace site-specific investigations. However, the map can serve as a useful tool for estimating the regional landslide hazard and as a starting point for future detailed site-specific maps. Please contact DOGAMI if errors and/or omissions are found so that they can be corrected in future versions of this map.

Acknowledgements: Funding for this project was provided through a grant by Washington County Land Use and Transportation, Planning Division, with additional funds from the State of Oregon. We thank DOGAMI staff who helped work on this project through technical assistance, review, and general aid.

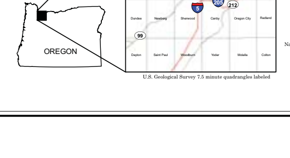
REFERENCES

Burns, W. J., and Madin, I. P., 2008 manuscript in preparation, Lidar-based landslide inventory mapping protocol, Oregon Department of Geology and Mineral Indutries

Highland, L., compiler, 2004, Landslide types and processes, U.S. Geological Fact Sheet 2004-3072 (ver. 1.1), 4 p.

Wiegers, M, O., 2006, Landslide inventory map of the Morgan Hill quadrangle, Santa Clara County, California: California Geological Survey, Landslide inventory map series.

LOCATION MAP



U.S. Geological Survey 7.5 minute quadrangles labeled

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Facsimile of PLATE 2, Shallow-Seated Landslide Susceptibility Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon, DOGAMI OPEN-FILE REPORT O-08-09, Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
VICKI S. McCONNELL, STATE GEOLOGIST

Shallow-Seated Landslide Susceptibility Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon

2008

Base Map:

Elevation data from Oregon Lidar Consortium, 2007. Digital elevation model (DEM) consists of a 3-foot by 3-foot elevation grid with hillshade sunangle at 315 degrees at a 45 degree angle from horizontal. The DEM is multiplied by 5 (vertical exaggeration) to enhance slope areas. Orthophoto is from Oregon Geospatial Enterprise Office, 2005 and consists of 2005 orthophoto draped over DEM with transparency.

Projection: North American Datum 1983, UTM zone 10 north

Software: MapInfo Professional 8.0, ESRI ArcMap 9.2, Adobe Illustrator CS2

Source File: Rocks\Publications\IPlate_2.mxd

SCALE 1:8,000

1,300 650 0 1,300 2,600 3,900 5,200 Feet

0.25 0.125 0 0.25 0.5 0.75 1 Miles

0.25 0.125 0 0.25 0.5 0.75 1 Kilometers

Cartography by William J. Burns, Oregon Department of Geology and Mineral Industries

Outside agency review by Paul Schaefer, Washington County

IMPORTANT NOTICE
This map depicts landslide susceptibility zones on the basis of limited data. The susceptibility zones were created following the protocol defined by Burns (2008). This map cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on this map.

OPEN-FILE REPORT O-08-09

Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon

by William J. Burns

Partial funding provided by Washington County (Project 100075, PO 141319)

PLATE 2

EXPLANATION

The map depicts susceptibility to shallow-seated landslides for this area. For the purpose of this map, shallow-seated landslides are defined as those with a depth to the failure plane of less than 4.5 m (15 ft) (Burns, 2008). This susceptibility map is not regulatory. When new information regarding factors that affect landslide susceptibility becomes available or when new landslides occur, the map may be updated. Therefore, it is possible that susceptible areas within the map area were not identified and that landslides occurred after the map was prepared.

This shallow-seated susceptibility map was prepared by combining three factors: 1) calculated factor of safety (FOS), 2) landslide inventory data, and 3) buffers of the previous two factors. The factor of safety was calculated using a water table at the ground surface. The landslide inventory data were taken from the accompanying inventory map (Plate 1). The combinations of these factors comprise the relative susceptibility hazard zones: high, moderate, and low. The landslide data are displayed on top of a base map that consists of an orthorectified aerial photograph overlain on the lidar data derived digital elevation model. For additional detail on how this map was developed, see Burns (2008) or the accompanying text report.

This susceptibility map is intended to provide users with relative hazard information regarding shallow-seated landslide susceptibility within this area. The map cannot replace site-specific engineering geologic and geotechnical investigations. It is intended that this map will provide useful information to guide regional and site-specific investigations for future developments, to assist in regional planning, and to reduce risk in areas where moderate and high hazards intersect vulnerable population.

SHALLOW-SEATED LANDSLIDE SUSCEPTIBILITY CLASSIFICATION

Each landslide susceptibility hazard zone shown on this map was developed according to a classification scheme that uses a number of specific factors. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (DOGAMI) (Burns, 2008). The symbology used to display these hazard zones is explained below.

Landslide Susceptibility Zones: This map uses color to show the relative degree of hazard. Each zone is a combination of several factors.

HIGH: High susceptibility to shallow-seated landslides.

MODERATE: Moderate susceptibility to shallow-seated landslides.

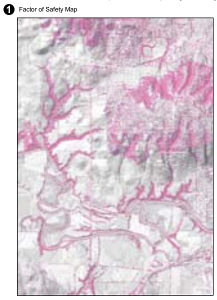
LOW: Low susceptibility to shallow-seated landslides.

Hazard Zone Matrix Table

Contributing Factors*	Final Hazard Zone		
	High	Moderate	Low
1 Factor of Safety (FOS)	less than 1.25	1.25 - 1.5	greater than 1.5
2 Landslide Inventory	included	—	—
3 Buffers	2H:1V (head scarps)	2H:1V (FOS less than1.5)	—

*See explanation of corresponding contributing factors below.

1 Factor of Safety Map



Factor of Safety (FOS) Map: The mechanics of slope stability can be divided into two forces: driving forces and resisting forces. These forces are a function of the material properties and the geometry of the slope. These two forces oppose each other, and slope stability can be thought of as their ratio.

$$\text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

Thus a ratio greater than 1 indicates a stable slope because the resisting forces are greater than the driving forces. A ratio less than 1 indicates an unstable slope because the driving forces are greater than the resisting forces. A critically stable slope has a ratio equal to roughly 1. Because all the conditions present within a slope cannot be accounted for, Senneset (1996) recommends that slopes with a factor of safety of less than 1.5 be considered potentially unstable.

The factor of safety was calculated using the infinite slope equation. Conservative parameters and saturated water conditions were used so that a "worst case" scenario could be evaluated. This map uses color to show the change in the factor of safety across the map as explained below.

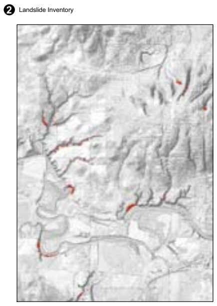
EXPLANATION

Factor of Safety less than 1.25

Factor of Safety between 1.25 and 1.5

Factor of Safety greater than 1.5

2 Landslide Inventory



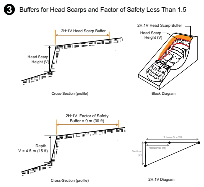
Landslide Inventory: This map is an inventory of existing landslides in this quarter quadrangle (see accompanying landslide inventory map, Plate 1). This inventory map was prepared by compiling previously mapped landslides from published geologic and landslide mapping, analyzing lidar-based geomorphology, and examining aerial photographs. Each landslide was also attributed with classifications for activity, landslide features, depth of failure, confidence of interpretation, and movement type (Burns and Madin, 2008). The map uses color to show different landslide features across the map as explained below.

EXPLANATION

Landslide Deposits

Landslide Head Scarps

3 Buffers for Head Scarps and Factor of Safety Less Than 1.5



Buffer for Head Scarps: This buffer was applied to all head scarps from the landslide inventory (Plate 1). The buffer consists of a 2:1 horizontal to vertical distance (2H:1V). This buffer is different for each head scarp and is dependent on head scarp height. For example, a head scarp height of 2 m (6.5 ft) has a 2H:1V buffer equal to 4 m (13 ft) (Block diagram modified after Highland, 2004).

Buffer for Factor of Safety Less Than 1.5: This buffer was applied to all areas with a calculated FOS less than 1.5. The buffer consists of a 2:1 horizontal to vertical distance (2H:1V). The maximum depth for shallow-seated landslides is 4.5 m (15 ft), the 2H:1V buffer equals 9 m (30 ft).

LIMITATIONS

The shallow-seated landslide susceptibility map was developed following an established protocol (Burns, 2008) with input from many sources, along with expertise gained from years of experience. Several limitations are worth noting and underscore that this hazard map is useful for regional applications but should not be used as an alternative to site-specific studies in critical areas.

1) Although it is possible to check for errors in the GIS and tabular database, it is not feasible verify all original input data.

2) As discussed above, the protocol to develop shallow-seated landslide susceptibility maps is based on three primary factors: a) calculated factor of safety, b) landslide inventory, and c) two buffers. These factors can affect the level of detail and accuracy of the final susceptibility map. For example:

   a. The landslide inventory data have limitations that are discussed in the lidar-based landslide inventory mapping protocol (Burns and Madin, 2008).

   b. Calculation of the factor of safety has two limitations worth noting:

      i. One of the limitations of the use of the infinite slope equation for regional stability analysis is due to the nature of the type of analysis, called grid based analysis. In this type of analysis, the calculations are done on an individual grid cell at a time without regard for the adjacent grids. The results sometimes underestimate or overestimate the level of stability for a certain area. To reduce underestimation of potentially unstable areas), buffers were developed. However, overestimation of potentially unstable areas remains a problem. The primary result that is overestimation is likely due to the high resolution of the lidar-derived DEM. Very small areas (even as small as 3 ft by 3 ft) are identified as potentially unstable. For example, in areas of otherwise low relief, noise in the lidar topographic data due to low vegetation or other factors may introduce very small areas of apparent moderate hazard where there is actually none. These areas should be verified in the field as necessary.

      ii. The second limitation to the factor of safety calculations is the accuracy and resolution of the input data (geology, depth to failure surface, groundwater, and slope angle). All four datasets can have substantial effects on the final calculations.

   c. The two buffers can lead to underestimation or overestimation of the potentially unstable areas.

3) The GIS database is a "snapshot" view of the current data; new information regarding landslides may be found and new landslides may occur.

4) Because the lidar-based digital elevation model (DEM) is only a model of elevation, it does not distinguish elevation changes that may be due to the construction of structures like retaining walls. Because it would require extensive field work to locate all of these existing structures and remove them or adjust the material properties in the model, they have been included as a conservative approach and therefore must be examined on a site-specific basis.

5) Some landslides and slopes have been mitigated. Because it is not feasible to collect detailed site-specific information on every landslide or slope (for example if it has been mitigated and what level of mitigation was implemented) mitigation has been omitted.

Because of these limitations this map is intended for regional purposes only and cannot replace site-specific investigations. However, the map can serve as a useful tool for estimating the regional landslide hazard and as a starting point for future detailed site-specific maps. Please contact DOGAMI if errors and/or omissions are found so that they can be corrected in future versions of this map.

Acknowledgements: Funding for this project was provided through a grant by Washington County Land Use and Transportation, Planning Division, with additional funds from the State of Oregon. We thank DOGAMI staff who helped work on this project through technical assistance, review, and general aid.

REFERENCES

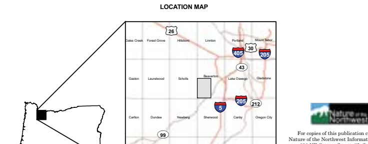
Burns, W. J., 2008 manuscript in preparation, Lidar-based shallow-seated landslide susceptibility mapping protocol, Oregon Department of Geology and Mineral Industries

Burns, W. J., and Madin, I. P., 2008 manuscript in preparation, Lidar-based landslide inventory mapping protocol, Oregon Department of Geology and Mineral Industries

Highland, L., compiler, 2004, Landslide types and processes, U.S. Geological Survey Fact Sheet 2004-3072 (ver. 1.1), 4 p.

Senneset, K., 1996. Landslides, Proceedings of the Seventh International Symposium on Landslides: Trondheim, Norway, A.A. Balkema, p. 337–380.

LOCATION MAP



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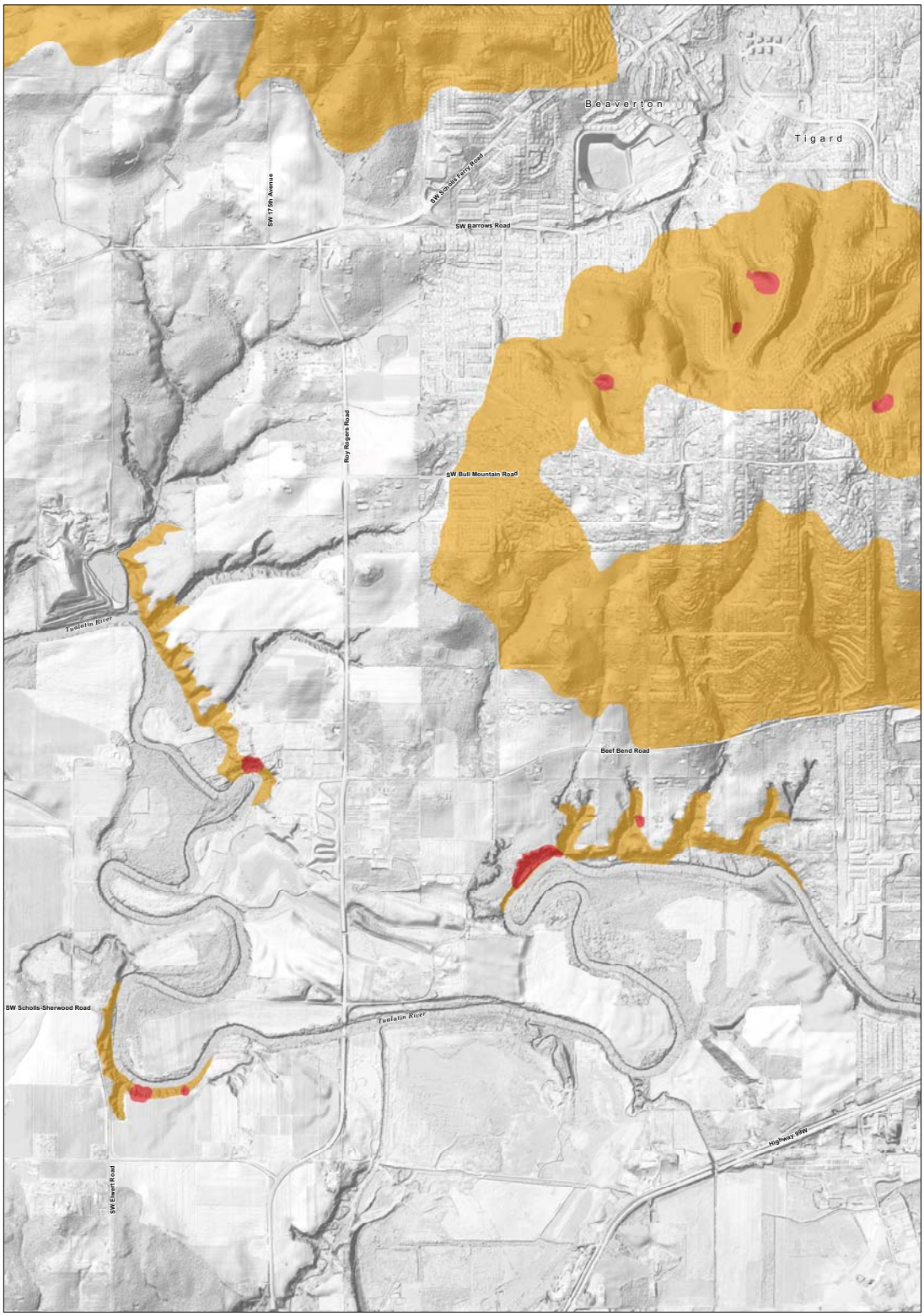
Facsimile of PLATE 3, Deep-Seated Landslide Susceptibility Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon, DOGAMI OPEN-FILE REPORT O-08-09, Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon.

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
VICKI S. McCONNELL, STATE GEOLOGIST

Deep-Seated Landslide Susceptibility Map of the Southwest Quarter of the Beaverton Quadrangle, Washington County, Oregon

2008



Base Map:

Elevation data from Oregon Lidar Consortium, 2007. Digital elevation model (DEM) consists of a 5-foot by 5-foot elevation grid with hillshade example at 315 degrees azimuth, 45 degrees angle of illumination. DEM tiles were from Oregon Geospatial Enterprise Office, 2003 and consists of 2003 orthophoto draped over DEM with transparency.

Projection: North American Datum 1983, UTM zone 10 north

Software: MapInfo Professional 8.0, ESRI ArcMap 9.2, Adobe Illustrator CS2

Source File Rocks: Publications/O-08-09/Plate_3.mxd

SCALE 1:8,000

1,200 400 0 1,200 2,400 3,600 4,800 Feet

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Cartography by William J. Burns, Oregon Department of Geology and Mineral Industries

Outside agency review by Paul Schaefer, Washington County

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OPEN-FILE REPORT O-08-09

Regional Landslide Hazard Maps of the Southwest Quarter of the Beaverton Quadrangle, West Bull Mountain Planning Area, Washington County, Oregon

by William J. Burns

Partial funding provided by Washington County (Project 100075, PO 141319)

PLATE 3

EXPLANATION

The map depicts susceptibility to deep-seated landslides for this area. For the purposes of this map, deep-seated landslides are defined as those with a depth to the failure plane of greater than 4.5 m (15 ft) (Burns, 2008). This susceptibility map is not regulatory. When new information regarding factors that affect landslide susceptibility becomes available or when new landslides occur, the map may be revised. However, it is possible that susceptible areas within the map area were not identified and that landslides sustained after the map was prepared.

This deep-seated susceptibility map was prepared by combining three factors: 1) landslide inventory data (shown on Plate 1), 2), head scarp buffers, and 3) geologic units and slope angles. The combination of these factors comprise the relative susceptibility hazard zones shown on this map. The landslide inventory was created using a lidar-based geomorphic mapping approach. The lidar was acquired from orthorectified aerial photograph overlaids on a lidar data derived digital elevation model. For additional detail on how this map was developed, see Burns (2008) or the accompanying text report.

This susceptibility map is intended to provide users with relative hazard information regarding deep-seated landslide susceptibility within this area. The map cannot replace site-specific engineering geologic and geotechnical investigations. It is intended that this map will provide useful information to guide regional and site-specific investigations for future developments, to assist in regional planning, and to reduce risk in areas where moderate and high hazards intersect vulnerable population.

DEEP-SEATED LANDSLIDE SUSCEPTIBILITY CLASSIFICATION

Each landslide susceptibility hazard zone shown on this map was developed according to a classification scheme that uses a number of specific factors. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (DOGAMI) (Burns, 2008). The symbology used to display these hazard zones is explained below.

Landslide Susceptibility Zones: This map uses color to show the relative degree of hazard. Each zone is a combination of several factors.

HIGH: High susceptibility to deep-seated landslides.

MODERATE: Moderate susceptibility to deep-seated landslides.

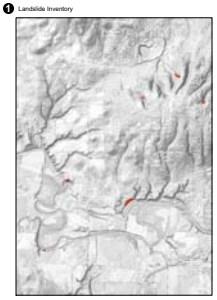
LOW: Low susceptibility to deep-seated landslides.

Hazard Zone Matrix Table

Contributing Factors*	Final Hazard Zone		
	High	Moderate	Low
1 Landslide Inventory	included	—	—
2 Head Scarp Buffers	included	—	—
3 Geologic Units and Slope Angles	—	included	included

*See explanation of corresponding contributing factors below.

1 Landslide Inventory



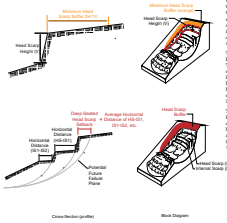
Landslide Inventory: This map displays a subset of the landslide inventory containing only the deep-seated landslide deposits and head scarps in this area (see accompanying landslide inventory map, Plate 1). The inventory was prepared by compiling previously mapped landslides from published geologic and landslide mapping; analyzing lidar-based geomorphology; and examining aerial photographs. Each landslide was also attributed with information for the type of failure features, confidence of interpretation, depth of failure, and movement type (Burns and Madin, 2008). The map uses color to show different landslide features across the map as explained below.

EXPLANATION

Deep-Seated Landslide Deposits

Landslide Head Scarps

2 Head Scarp Buffers



Buffer for Head Scarps: This buffer was applied to all head scarps from the landslide inventory. In most cases the first buffer results in the minimum buffer distance and the second buffer (described below) results in the maximum buffer distance. In all cases the greater of the two values was used.

The first buffer consists of a 2:1 horizontal to vertical distance (2H:1V). This buffer is different for each head scarp and is dependent on the scarp height. For example, a head scarp height of 2 m (6.5 ft) has a 2H:1V buffer equal to 4 m (13 ft) (Black diagram modified after Highland, 2004).

The second buffer is different for each head scarp and is dependent on the average of the horizontal distance between internal scarps. For example, an average horizontal distance of 50 m (164 ft) has a 2H:1V buffer equal to 100 m (328 ft).

3 Geologic Units and Slope Angles

Geologic Units and Slope Angles: This map is a generalized geologic map that depicts areas where slope angles is greater than 10 degrees. This map uses color to show different geologic units and slope angles across the map.

Using educated judgment, the author combined three collection to create this hazard zone contributing factor:

1) Susceptible geologic units are those that have been the most active landslides in the inventory.

2) Relative proximity to identified deep-seated landslides from the inventory.

3) Slope angles greater than 10 degrees.

The results of this third contributing factor were used to create the boundary between moderate and low hazard zones for deep-seated landslide susceptibility.

EXPLANATION

Landslide Deposits (from landslide inventory)

Landslide deposit

Geologic Units (from best available geologic map)

Qal - Recent alluvium

Ql - Loess

Qff - Quaternary alluvium

Tcr - Columbia River Basalt

Slope Angle (degrees) (derived from lidar DEM)

Greater than 10

LIMITATIONS

The deep-seated landslide susceptibility map was developed following an established protocol that incorporates several types of data (Burns, 2008). Several limitations are worth noting and underscore that this regional hazard map is useful for regional applications but should not be used as an alternative to site-specific studies in critical areas.

1) Although it is possible to check for errors in the GIS and tabular database, it is not feasible to completely verify all original input data.

2) As discussed above, the protocol to develop deep-seated landslide susceptibility maps is based on three primary factors: a) landslide inventory, b) head scarp buffers, and c) additional factors. These factors can affect the level of detail and accuracy of the final susceptibility map. Because the maps are based on a subjective combination of factors, all of which have inherent uncertainty, the resultant hazard zones also have uncertainty. For example:

   a) The landslide inventory data have limitations that are discussed in the lidar-based landslide inventory mapping protocol (Burns and Madin, 2008).

   b) Calculation of head scarp buffers is limited based on head scarp height (first buffer) and an average of the horizontal widths of previous or downslope blocks (second buffer). It is assumed that most large deep-seated landslides have the potential to fail retrogressively upslope; however, this is not always the case.

   c) Using educated judgment, the author combined three collections: susceptible geologic units, slope angles greater than 10 degrees, and relative proximity to identified deep-seated landslides to create the third hazard zone matrix factor. Because this estimate is based on visual overlap of these collections, the accuracy and resolution of the output data can be substantially overestimated or underestimated.

3) The GIS database is a "snapshot" view of current data; new information regarding landslides may be found and new landslides may occur.

4) Because the lidar-based digital elevation model (DEM) is only a model of elevation, it does not distinguish elevation changes that may be due to the construction of structures like retaining walls. Because it would require extensive field work to locate all of these existing structures and determine the stability of each individual structure, these potential structures have been assumed to be slopes as a conservative approach and therefore must be examined on a site-specific basis.

5) Some landslides and slopes have been mitigated. Because it is not feasible to collect detailed site-specific information on every landslide or slope (for example, if it has been mitigated and what level of mitigation was implemented), mitigation has been omitted.

Because of these limitations this map is intended for regional purposes only and cannot replace site-specific investigations. However, the map can serve as a useful tool for estimating the regional landslide hazard and as a starting point for future detailed site-specific maps. Please contact DOGAMI if errors and/or omissions are found so that they can be corrected in future versions of this map.

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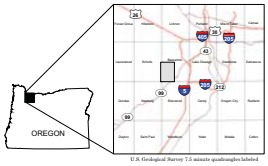
REFERENCES

Burns, W. J., and Madin, I. P., 2008 manuscript in preparation, Lidar-based landslide inventory mapping protocol, Oregon Department of Geology and Mineral Industries.

Burns, W.J., 2008 manuscript in preparation, Lidar-based deep-seated landslide susceptibility mapping protocol, Oregon Department of Geology and Mineral Industries.

Highland, L., compiler, 2004, Landslide types and processes, U.S. Geological Survey fact sheet 2004-3072 (ver. 1.1), 4 p.

LOCATION MAP


OREGON
26
Portland
Salem
Eugene
Medford
Bend
Pendleton
Klamath Falls
Lakeview
Burns
Ontario
Baker
Enterprise
La Grande
Hermiston
Coos Bay
Roseburg
Grants Pass
Ashland
Klamath Falls
Lakeview
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Enterprise
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Portland
Salem
Eugene
Coos Bay
Roseburg
Medford