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Shallow Landslide Susceptibility Map of the Bull Run Watershed

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Surficial and Bedrock Engineering Geology, Landslide Inventory and Susceptibility, and Surface Hydrography of the Bull Run Watershed, Clackamas and Multnomah Counties, Oregon

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PLATE 2

EXPLANATION

This shallow landslide susceptibility map identifies landslide-prone areas that are defined following the protocol of Burns and others (2012).

On the basis of several factors and past studies (described in detail by Burns and Madin [2009]), a depth of 15 ft (4.5 m) is used to divide shallow from deep landslides. We preapred this shallow susceptibility map by combining three factors: 1) calculated factor of safety (FOS), 2) landslide inventory data, and 3) buffers, as described below. We calculated the FOS by using conservative values such as having the water table at the ground surface. We used landslide inventory data from the corresponding inventory map (Plate 1). The combinations of these factors comprise the relative susceptibility hazard zones: high, moderate, and low, as shown by the Susceptibility Hazard Zone Matrix below. The landslide susceptibility data are displayed on top of a base map that consists of the lidar-derived digital elevation model.

SHALLOW LANDSLIDE SUSCEPTIBILITY CLASSIFICATION

Each landslide susceptibility hazard zone shown on this map has been developed according to a number of specific factors. The classification scheme was developed by the Oregon Department of Geology and Mineral Industries (Burns and others, 2012). The symbology used to display these hazard zones is explained below.

Shallow Landslide Susceptibility Zones: This map uses color to show the relative degree of hazard. Each zone is a combination of several factors (see Hazard Zone Matrix, below).

HIGH: High susceptibility to shallow landslides.

MODERATE: Moderate susceptibility to shallow landslides.

LOW: Low susceptibility to shallow landslides.

Shallow Landslide Susceptibility Hazard Zone Matrix

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 Deposits & Head Scarps	included	—	—
3 Buffers	2H:1V (head scarps)	2H:1V (FOS less than 1.5)	—

1 Factor of Safety (FOS)

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.

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

A slope with a FOS > 1 is theoretically a stable slope because the shear strength is greater than the shear stress. A slope with a FOS < 1 is theoretically an unstable slope because the shear stress is greater than the shear strength. A critically stable slope has a FOS = 1. Because of the inability to know all the conditions present within a slope, most geotechnical engineers and engineering geologists recommend that slopes with a FOS < 1.5 be considered potentially unstable (Turner and Schuster, 1996; Cornforth, 2005).

We calculated the FOS by using the infinite slope equation with conservative parameters. Saturated conditions were used so that a "worst case" scenario could be evaluated. Because of limitations related to a grid type analysis, we removed isolated areas with small (less than 4 ft [1.2 m] high) elevation change by using a standardized process (Burns and others, 2012).

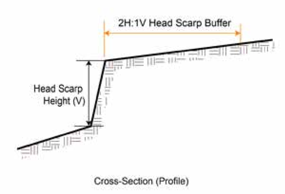
2 Landslide Inventory

An inventory of all existing landslides in this area is shown on Plate 1. We prepared this inventory map by compiling all previously mapped landslides from published and unpublished geologic and landslide mapping, analyzing lidar-based geomorphology, and reviewing aerial photographs. We also attributed each landslide with classifications for activity, depth of failure, movement type, and confidence of interpretation. We created the inventory by using the protocol developed by Burns and Madin (2009). We extracted the shallow landslides from the inventory and used these to create this shallow landslide susceptibility map.

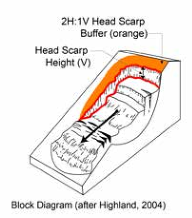
3 Buffers for Head Scarps and Factor of Safety Less Than 1.5

Buffer for Head Scarps: This buffer was applied to all head scarps from the landslide inventory. 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 6 ft (2 m) has a 2H:1V buffer equal to 12 ft (4 m).

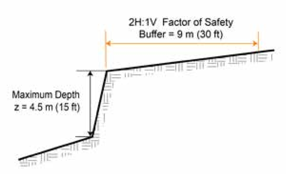
Buffer for Factor of Safety Less Than 1.5: This buffer was applied to all areas with a calculated FOS less than 1.5. The buffer consists of a 2:1 horizontal to vertical distance (2H:1V). For example, if the maximum depth for shallow landslides is 15 ft (4.5 m), then the 2H:1V buffer would equal 30 ft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



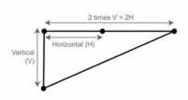
Cross-Section (Profile)



Block Diagram (after Highland, 2004)



Cross-Section (Profile)



2H:1V Diagram

LIMITATIONS

Several limitations are worth noting and include the following.

1) Every effort has been made to ensure the accuracy of the GIS and tabular database, but it is not feasible to completely verify all of the original input data.

2) The shallow landslide susceptibility maps are based on three primary components: a) calculated factor of safety, b) landslide inventory, and c) buffers. Factors that can affect the level of detail and accuracy of the final susceptibility map include the following:

a) Factor of safety calculations are strongly influenced by the accuracy and resolution of the input data for material properties, depth to failure surface, depth to groundwater, and slope angle. The first three of these inputs are usually estimates (material properties) or conservative limiting cases (depth to failure surface and groundwater), and local conditions may vary substantially from the estimated values used to make these maps.

b) Limitations of the landslide inventory are discussed by Burns and Madin (2009).

c) Infinite slope factor of safety calculations are done on one grid cell at a time without regard to adjacent grids. The results may underestimate or overestimate the level of stability for a certain area. We developed buffers for areas with low factors of safety to counter the tendency to underestimate susceptibility. We developed the focal relief method to reduce the problem of overestimation of susceptibility due to steep slopes with low relief. However, overestimation and underestimation of susceptible areas are still likely in some isolated areas.

3) The susceptibility maps are based on the topographic and landslide inventory data available as of the date of publication. Future new landslides may render this map locally inaccurate.

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

5) Some landslides in the inventory may have been mitigated, thereby reducing their level of susceptibility. Because it is not feasible to collect detailed site-specific information on every landslide, potential mitigation has been ignored.

REFERENCES

Burns, W.J., and Madin, I.P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (lidar) imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p., geodatabase template.

Burns, W.J., Madin, I.P., and Mickelson, K.A., 2012, Protocol for shallow-landslide susceptibility mapping: Oregon Department of Geology and Mineral Industries Special Paper 45, 32 p.

Cornforth, D.H., 2005, Landslides in practice: Investigation, analysis, and remedial/preventative options in soils: Hoboken, N.J., John Wiley and Sons, Inc., 596 p.

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

Turner, A.K., and Schuster, R.L., eds., 1996, Landslides: Investigation and mitigation: Transportation Research Board, National Research Council, Special Report 247, 673 p.

NOTICE

ABOUT THIS PUBLICATION

The Bull Run Watershed (BRW) is the primary drinking water supply for the City of Portland and several suburbs and is cooperatively managed by the Portland Water Bureau and the U.S. Forest Service. The watershed is located 25 miles (40 km) east of downtown Portland on the western slopes of the Cascade Range. The BRW is a surface water collection system, so the risk of landslide impact directly to the water and the infrastructure is relatively high. Because landslides are one of the most widespread and damaging natural hazards in Oregon, it is important to map and assess the risk in the BRW. The purpose of this study is to assist the Portland Water Bureau in understanding the landslide hazard better and thus increase their ability to reduce future risk. The study publication consists of a text report, five map plates, and three geodatabases.

Generalized Surficial Engineering Geology

Quaternary (<2 Ma) Surficial Deposits

- alluvial deposits
- cinders (Aschoff Buttes)
- landslide deposits (deep)
- glacial till, outwash, and colluvium

Quaternary to Middle Miocene (~2-17 Ma) Soil Weathered In Place

- residual soil on volcaniclastic rock
- residual soil on sedimentary rock
- residual soil on igneous rock

- water

Additional Map Symbols

- Summit
- Primary Paved Road
- Primary Gravel Road
- Secondary Road or Non-Bull Run Road
- Stream
- Lake / Reservoir

16.5°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2014

SCALE 1:24,000

4,000 2,000 0 4,000 8,000 12,000 16,000 Feet

0.75 0.375 0 0.75 1.5 2.25 3 Miles

0.75 0.375 0 0.75 1.5 2.25 3 Kilometers

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Source Data:
Lidar data from DOGAMI Lidar Data Quadrangles LDQ-2010-45121-D7-Bull Run Lake, LDQ-2010-45121-D8-Hickman Butte, LDQ-2010-45121-E7-Wahtum Lake, LDQ-2010-45121-E8-Tanner Butte, LDQ-2010-45122-D1-Brightwood, LDQ-2010-45122-D2-Bull Run, LDQ-2009-45122-D3-Sandy, LDQ-2010-45122-E1-Multnomah Falls, and LDQ-2010-45122-E3-Washougal.

Roads, streams, and waterbodies from the City of Portland and the Oregon Department of Geology and Mineral Industries (2013). Additional physical and cultural locations from the Geographic Names Information System, U.S. Geological Survey (2013).

Projection:
North American Datum 1983, HARN Oregon Statewide Lambert International Feet

Cartography:
Daniel E. Coe (principal) and William J. Burns