STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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Shallow-Landslide Susceptibility Map of the City of Silverton, Marion County, Oregon

2012

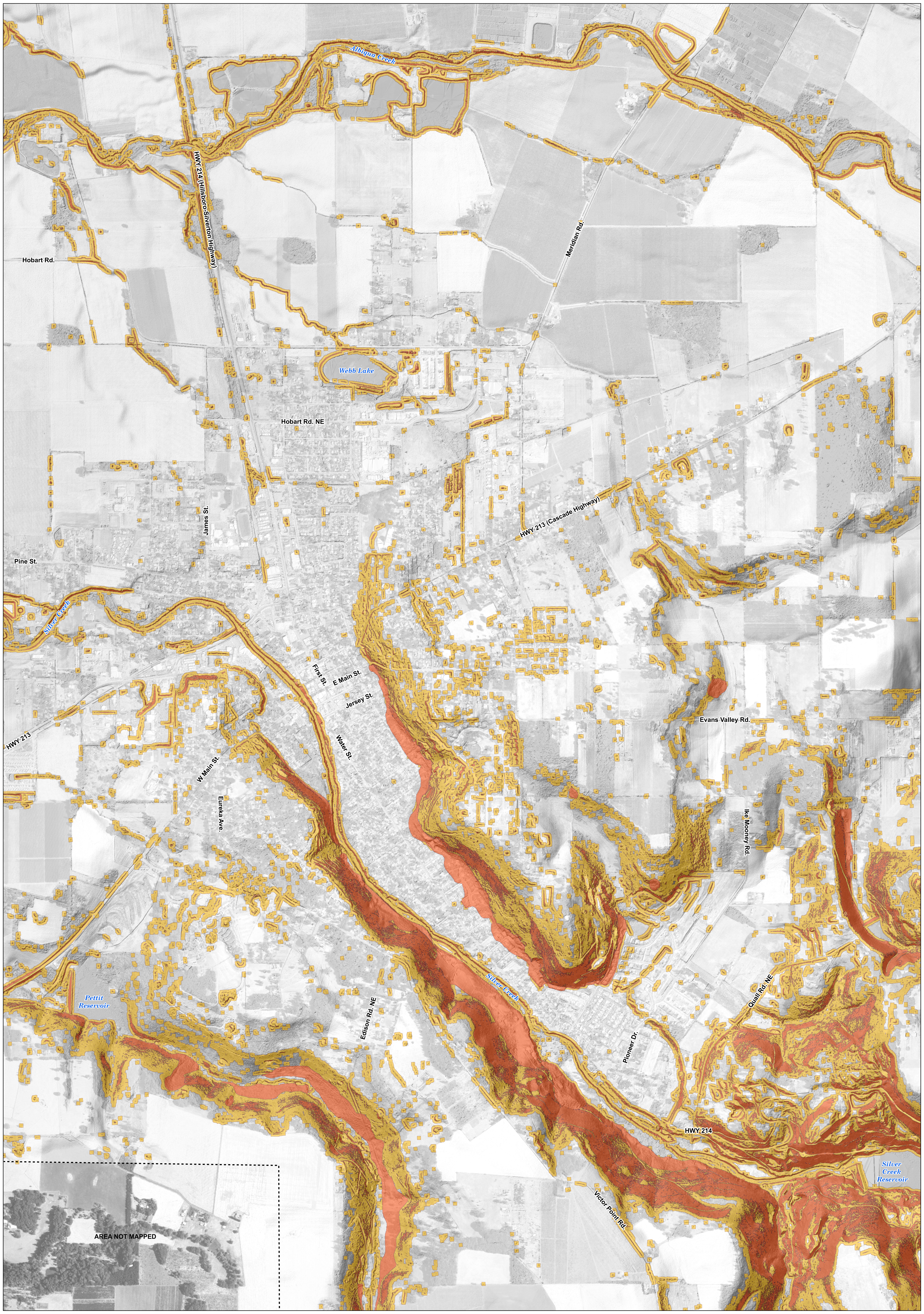
Open-File Report O-12-05

Regional Landslide Hazard Maps of the City of Silverton, Marion County, Oregon

by William J. Burns and Katherine A. Mickelson

Partial funding provided by the City of Silverton (IA No. 41460-11242008)

PLATE 2



EXPLANATION

This map is a shallow-landslide susceptibility map of a portion of this quadrangle. The shallow-landslide susceptibility map identifies landslide prone areas within the region. This susceptibility map is not regulatory, and revisions can happen when new information regarding factors that affect landslide susceptibility is found or future (new) landslides occur. Therefore, it is possible those areas susceptible to shallow-landslides within the map were not identified or that the condition that lead to such susceptibility developed after the map was prepared.

On the basis of several factors and past studies (described in detail in Burns and Madin, 2009), a value (or depth) of 4.5 m (15 ft) is used to divide shallow from deep-landslides. This susceptibility map was prepared by combination of 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 conservative values such as a water table at the ground surface. The landslide inventory data were taken from the complimentary inventory map. 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 aerial photograph (orthorectified) overlain on the lidar-derived digital elevation model. For additional detail on how this map was developed see Burns and others (2012).

This susceptibility map is intended to provide users with relative hazard information regarding shallow-seated landslide susceptibility within the quadrangle. The map is not intended to 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, assist in regional planning, and to reduce risk in areas where moderate and high hazards intersect vulnerable population.

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.

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 landslides.

MODERATE: Moderate susceptibility to shallow landslides.

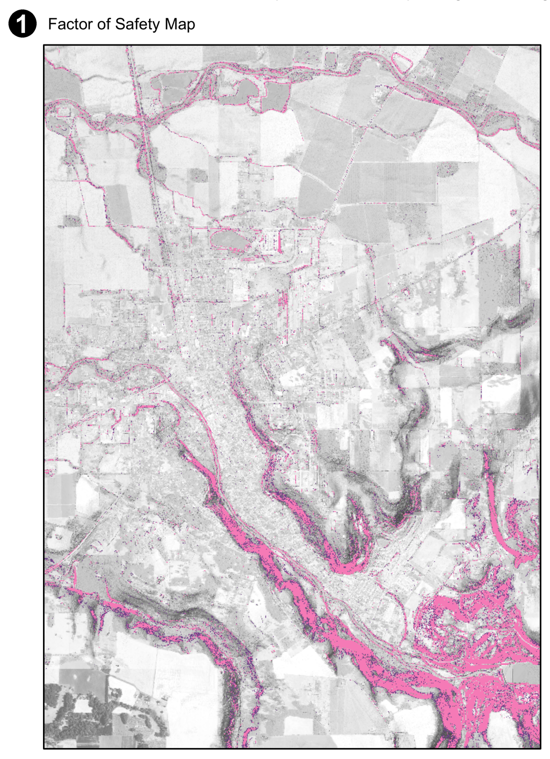
LOW: Low susceptibility to shallow landslides.

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.

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

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

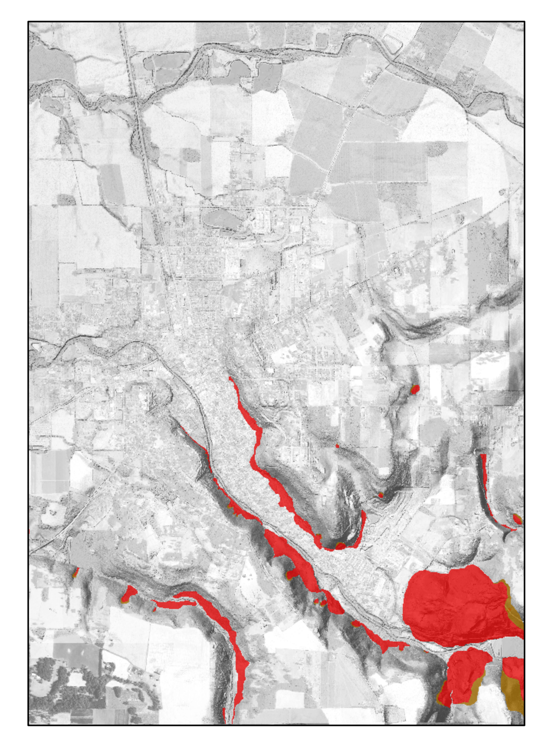
The factor of safety was calculated using the infinite slope equation with conservative parameters. Saturation condition were used so that a "worst case" scenario could be evaluated. Because of limitations related to a grid type analysis, isolated areas with small (less than 4 feet high) elevation change were removed using a standardized process (Burns and others, 2011).

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

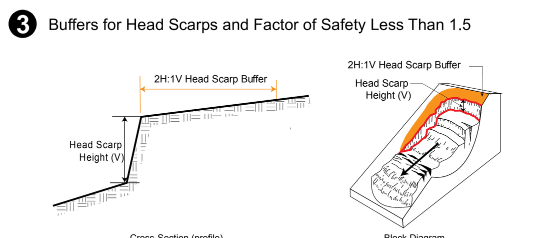


Shallow-Landslide Deposits and Head Scarps Inventory Map: This map is an inventory of existing shallow-landslides in this quadrangle. This inventory map was prepared by compiling all previously mapped landslides from published and unpublished geologic and landslide mapping, lidar-based geomorphic analysis, and review of aerial photographs. Each shallow-landslide was also attributed with classifications for activity, depth of failure, movement type, and confidence of interpretation. The Protocol for Inventory Mapping of Landslide Deposits from Lidar Imagery (Burns and Madin, 2009) was developed with input from many sources, along with years of experience. This map uses color to show different landslide features across the map as explained below.

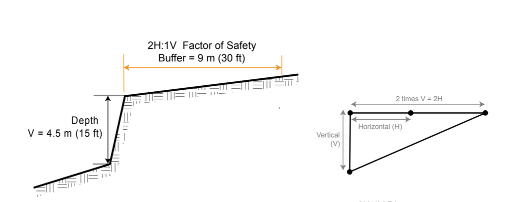
EXPLANATION

- 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. 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 ft) has a 2H:1V buffer equal to 4 m (12 ft)(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-landslide susceptibility protocol was developed with input from many sources, along with 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) 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 sources: a) landslide inventory, b) calculated factor of safety, c) buffers. Factors that can affect the level of detail and accuracy of the final susceptibility map include:
   a. Limitations of the landslide inventory, which are discussed in the Special Paper 42 (Burns and Madin, 2009).
   b. The infinite slope factor of safety calculations are done on one 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. We developed buffers for areas with low factors of safety to try to counter the tendency to underestimate susceptibility. We developed the focal relief method to try to reduce the problem of overestimation of susceptibility due to steep slopes with low relief. However, the overestimation and underestimation of susceptible areas is still likely in some isolated areas.
   c. The 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 values used to make these maps.
3) The susceptibility maps are based on the topographic and landslide inventory data available as of the date of publication. Future changes in topography or the occurrence of 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 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 in the inventory may have been mitigated, reducing their level of susceptibility. Because it is not feasible to collect detailed site-specific information on every landslide, potential mitigation has been ignored.

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 place 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.

REFERENCES

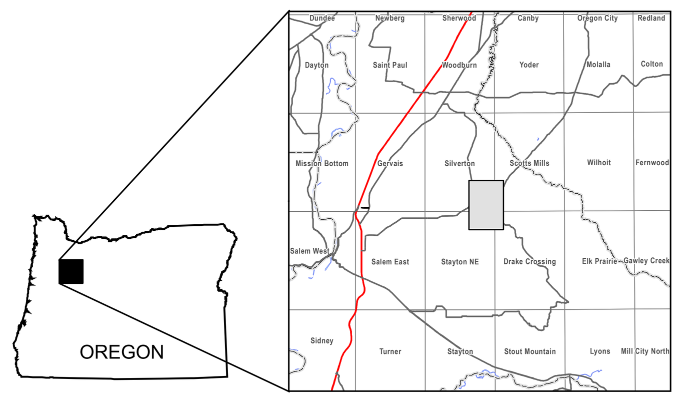
Burns, W. J., and Madin, I. P., 2009, Protocol for inventory mapping of landslide deposits from light detection and ranging (lidar) imagery: Oregon Department of Geology and Mineral Industries Special Paper 42, 30 p., geodatabase template.

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.

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

LOCATION MAP



U.S. Geological Survey 7.5-minute quadrangles and counties are labeled. This map extent shown as gray rectangle.

Base Map:

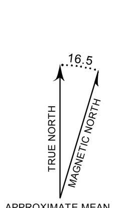
Lidar-derived elevation data are from the Oregon Lidar Consotrium, 2007. Digital elevation model (DEM) consists of a 3-foot square elevation grid that was converted into a hillshade image with sun angle at 315 degrees at a 45 degree angle from horizontal. The DEM is multiplied by 5 (vertical exaggeration) 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.

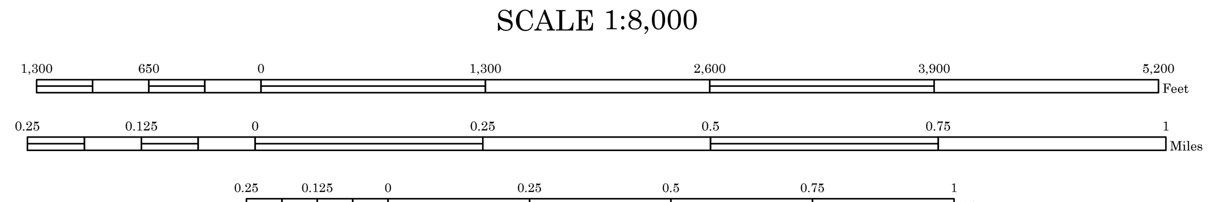
Software: MapInfo Professional 8.0, Esri ArcMap 9.2, Adobe Illustrator CS2.

Source File: Rocks\Publications\Silverton.mxd.



APPROXIMATE MEAN DECLINATION, 2006

SCALE 1:8,000



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

Outside agency review by Rich Barstad, City of Silverton

IMPORTANT NOTICE:

This map depicts existing landslide susceptibility zones on the basis of limited data. The susceptibility zones were created following the methods in the accompanying report (Burns and others, 2012). 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.

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