

STATE OF OREGON  
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES  
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# Landslide Inventory Map of the Southwest Quarter of the Washougal Quadrangle, Multnomah County, Oregon, and Clark County, Washington

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INTERPRETIVE MAP SERIES

Landslide Inventory Maps of the Washougal Quadrangle,  
Multnomah County, Oregon, and Clark County, Washington

by William J. Burns, Katherine A. Mickelson, and Serin Duplantier

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## PLATE 3

### EXPLANATION

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

This inventory map was prepared by following the Protocol for Inventory Mapping of Landslide Deposits from Light Detection and Ranging (Lidar) Imagery developed by Burns and Madin (2009). The three primary tasks included compilation of previously mapped landslides (including review of the Statewide Landslide Information Layer for Oregon, release 2 (Burns and others, 2011), lidar-based morphologic mapping of landslide features, and review of aerial photographs. Landslides identified by these methods were digitally compiled into a GIS database at varying scales. The recommended map scale for these data is 1:5,000, as displayed on this map. Each landslide was also attributed with classifications for activity, depth of failure, movement type, and confidence of interpretation. The landslide data are displayed on top of a base map that consists of an aerial photograph (orthorectified) overlaid on the lidar-derived hillshade image.

This landslide inventory map is intended to provide users with basic information regarding landslides within the quarter quadrangle. The geologic, terrain, and climate conditions that led to landslides in the past may provide clues to the locations and conditions of future landslides, and it is intended that this map will provide useful information in developing regional landslide susceptibility maps, to guide site-specific investigations for future developments, and to assist in regional planning and mitigation of 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 (Burns and Madin, 2009). Several significant landslide characteristics recorded in the database are portrayed with symbology 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 displays uses color to show the activity.

- HISTORIC and/or ACTIVE (movement less than 150 years ago):** The landslide appears to have moved within historic time or is currently moving (active).
- PREHISTORIC or ANCIENT (movement greater than 150 years ago):** Landslide features are slightly eroded and there is no evidence of historic movement. In some cases, the observed landslide features have been greatly eroded and/or covered with 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 ZONE and FLANK ZONES:** The head scarp or uppermost scarp, which in many cases exposes the primary failure plane (surface of rupture), and flanks or shear zone.
- HEAD SCARP LINE and INTERNAL SCARP LINES:** Uppermost extent of the head scarp and internal scarps within the body of the landslide. Hatching is in the down-dropped direction.

**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 landslide was classified according to the confidence that the mapper assigns based on the likelihood that the landslide actually exists. Landslides are mapped on the basis of characteristic morphology, and the confidence of the interpretation is based on how clearly visible that morphology is. As a landslide ages, weathering (primarily through erosion) degrades the characteristic morphology produced by landsliding. With time, landslide morphologies may become so subtle that they resemble morphologies produced by geologic processes and conditions unrelated to landsliding. Landslides may have several different types of morphologies associated with them, and we define confidence through a simple point system (see table below) associated with these features. The point system is based on a ranking of four primary landslide features with a ranking of 0 to 10 points per feature. For example, if during mapping, the head scarp and toe of a landslide were identifiable and clearly visible, the mapper would apply 10 points for the head scarp and 10 points for the toe, equaling 20 points, which would be associated with a moderate confidence of identification.

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

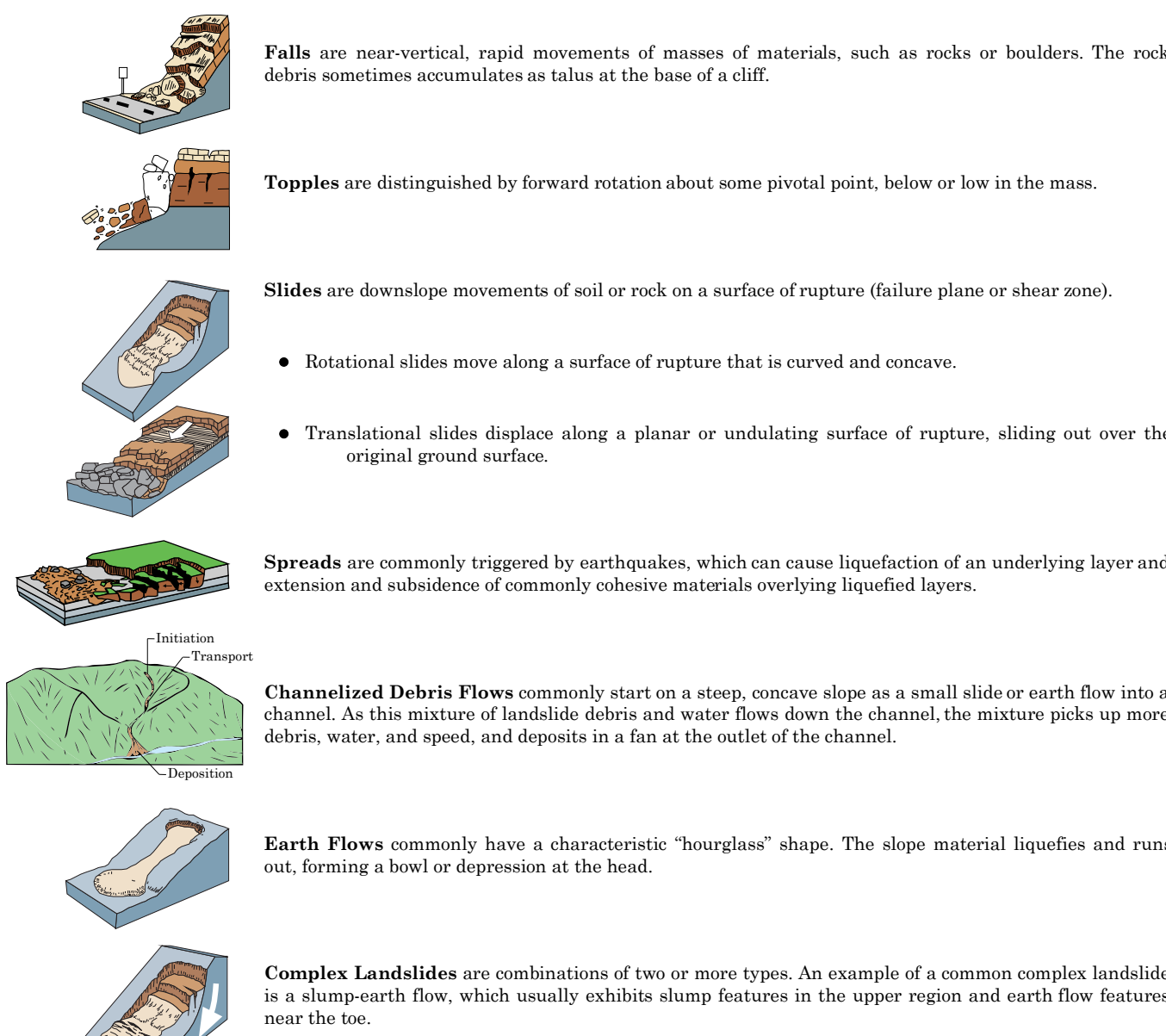
Confidence	Line Style	Points
HIGH CONFIDENCE (≥30 points)	Solid line	Head scarp 0-10 Flanks 0-10 Toe 0-10
MODERATE CONFIDENCE (11-29 points)	Dashed line	Internal scarps, sag points, compression ridges, etc. 0-10*
LOW CONFIDENCE (≤10 points)	Dotted line	

**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 quadrangle.

EFL	EFL - Earth Flow
	Abbreviation for class of slope movement. The table below displays the types (Varnes, 1978).

Generalized diagrams (some modified from Highland, 2004) showing types of movement are displayed below the table.

Type of Movement	Rock	Debris	Soil
Fall	RF rock fall	DF debris fall	EF earth fall
Topple	RT 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	EET earth spread
Flow	RFL rock flow	DFL debris flow	EFL earth flow
Complex	C complex or combinations of two or more types (for example, ESR + EFL)		



### LIMITATIONS

This landslide inventory was developed with the best available data, using the protocol of Burns and Madin (2009). However there are inherent limitations as discussed below. These limitations underscore that this map is designed for regional applications and should not be used as an alternative to site-specific studies in critical areas.

- Every effort has been made to ensure the accuracy of the GIS and tabular database, but it is not feasible to completely verify all original input data.
- Burns and Madin (2009) recommend a protocol to develop landslide inventories that 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 checking. These tasks can affect the level of detail and accuracy of the landslide inventory. We expect the lidar data quality to improve in the future, which will likely result in the identification of more landslides with greater accuracy and confidence. Due to time limitations, previously mapped landslides have likely been missed. In 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 other locations.
- The lidar-based mapping is a "snapshot" view of the current landscape that may change as new information regarding landslides becomes available and as new landslides occur.
- 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. Some small landslides were included if they were reported by a local governmental agency, a site-specific study, a regional study report, or a local area landslide expert, and are found to be accurately located by the mapper.
- Even with high-quality lidar-derived topographic data, it is possible that some existing landslides will be missed, overlooked, or misinterpreted by the map author. This database and map were prepared in accordance with a published protocol (Burns and Madin, 2009) and were reviewed to minimize these problems.
- Earthwork related to development on hillside can remove the geomorphic expressions of past landsliding. This can result in landslides being missed in the inventory. Earthwork on hillside 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 in the lidar-derived mapping.
- 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. Again, 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 landslide site-specific maps.

Please contact DOKAMI if errors and/or omissions are found so that they can be corrected in future versions of this map.

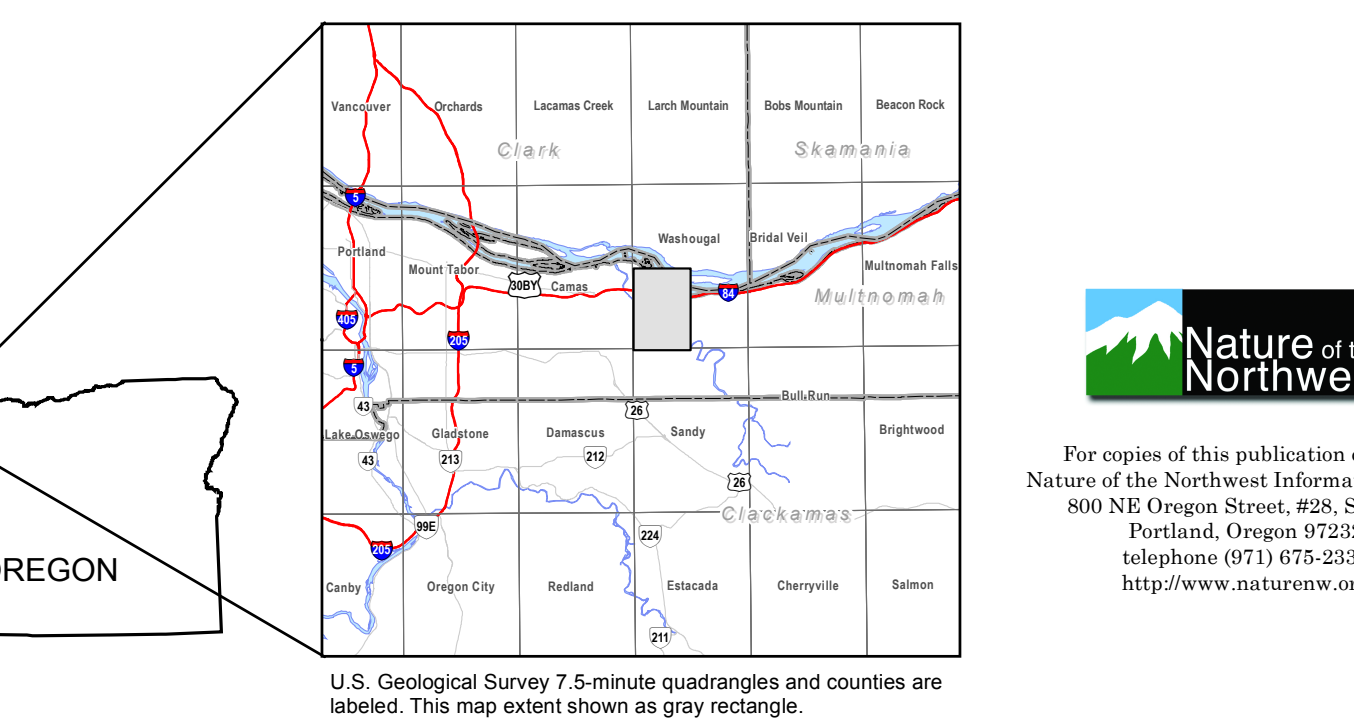
### ACKNOWLEDGMENTS

We thank U.S. Geological Survey Landslide Hazard Program staff, especially Jeff Coe, and DOKAMI staff Bob Witter, Yvonne Wang, and Deb Schaeffer, who provided detailed reviews that significantly improved the protocol and the map template for this series.

### REFERENCES

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### LOCATION MAP



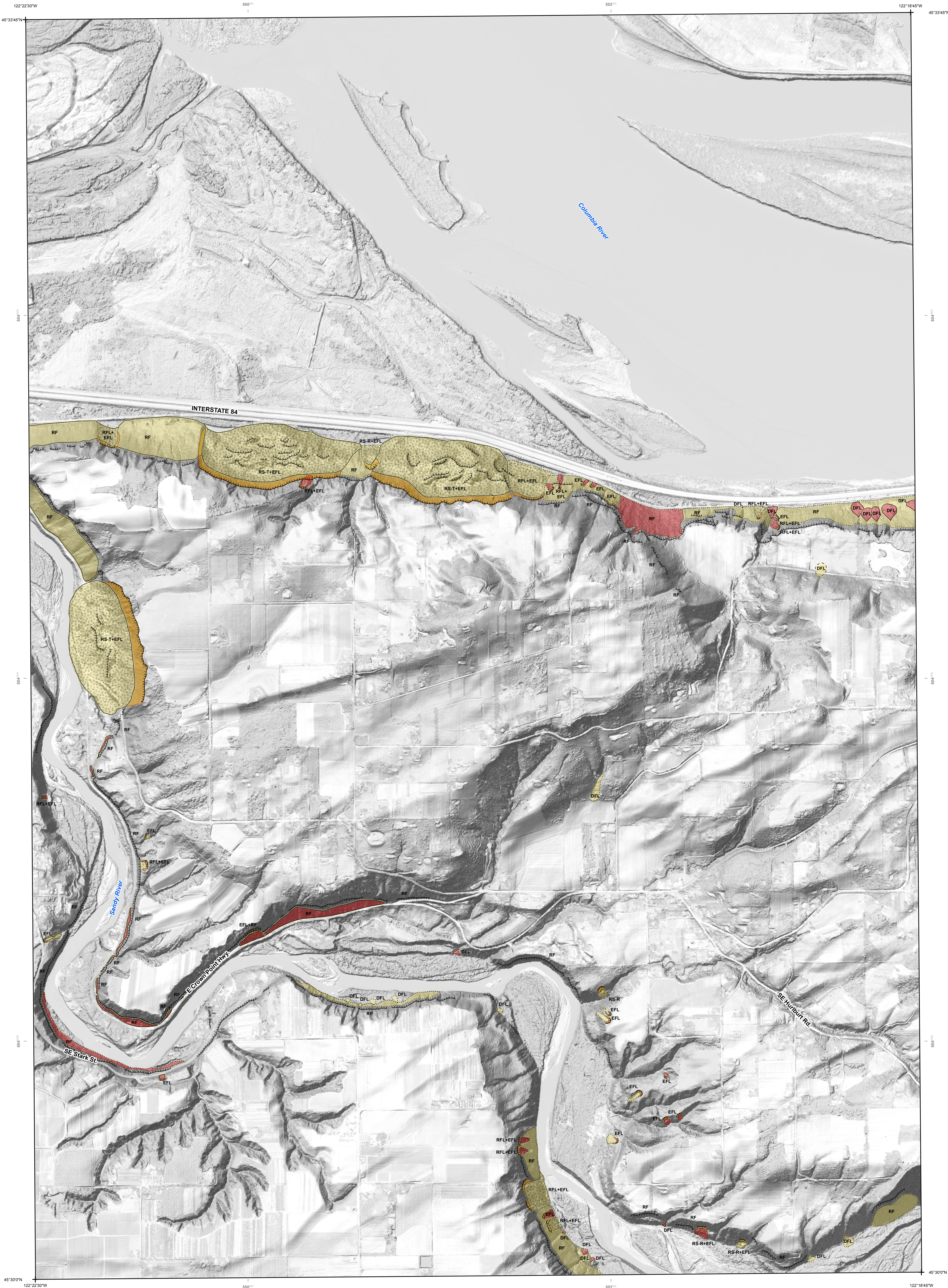
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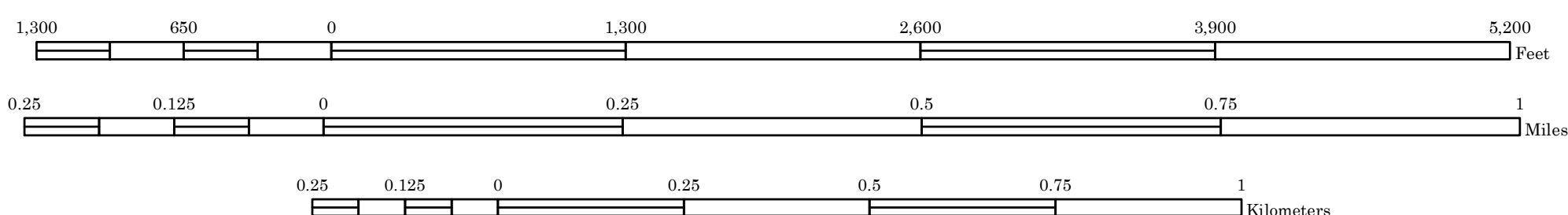
This map benefited from comments by Adam Barber and other Multnomah County staff.  
This map also benefited from internal review and comments by Ian Madin, DOKAMI Chief Scientist.

### IMPORTANT NOTICE

This map depicts an inventory of existing landslides based on published and unpublished reports and interpretation of topography derived from lidar data and air photos. The inventory was created following the protocol defined by Burns and Madin (2009). 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.



SCALE 1:8,000



Base Map:  
Lidar data from DOKAMI Lidar Data Quadrangle LDQ-2009-0512253 Washougal and Clark County, Washington, 2002. Digital elevation model (DEM) consists of a 3-foot square elevation grid that was converted into a hillshade map with an angle of 31.5 degrees at a 40 degree angle from horizontal. The DEM was multiplied by 5 (vertical exaggeration) to enhance slope areas.

2005 orthophoto imagery is from Oregon Geospatial Enterprise Office and is draped over the hillshade map with transparency.

Projection: North American Datum 1983, UTM zone 10 North.

Software: Esri ArcMap 10, Adobe Illustrator CS2.

Source File: Project\USGS Portland Landslide\Washougal.mxd

APPROXIMATE MEAN DECLINATION, 2009