August 13, 2014

2014 Oso, Washington, Landslide

GEER Association Report No. GEER-036

Explanation of Landslide Classification and Frequency Estimates

This note is intended to provide clarification on terminology regarding classification of the 2014 Oso Landslide and on how the order-of-magnitude estimate of the frequency of large landslides was inferred based on available data.

Landslide Classification

In the classification of Cruden and Varnes (1996), the long runout portion of the Oso Landslide would be classified as a debris flow, whereas in the Hungr et al. (2001) classification it would be a debris avalanche, as it was not confined to an established channel. Given that Stage 1 of the landslide (involving zones E and F) was unconfined, and noting the blocky structure of zone E and the preservation of portions of the original ground surface, we prefer to describe zone E as a debris avalanche rather than a debris flow. However, we prefer the term debris flow for the deposits in zone F given its fluidity and completely reworked character. While we noted that our Stage 1 involved an initial slide that transitioned to a debris flow, the gradational contact between zones E and F further favors describing the Stage 1 deposit as a debris avalanche/debris flow.

Landslide Frequency

The data available to support an estimate the frequency of large landslides in this relatively small portion of the valley consists of a single radiocarbon-dated landslide (at around 6000 calendar years ago) in the portion of the valley covered by Haugerud's (2014) relative age mapping from which we can infer about 15 large landslides into three relative age Classes B, C, and D, with two additional landslides in the most recent age Class A representing recently active slides that did not extend far into the valley. An absolute constraint on the age of the landslides in this valley segment is the depositional age of about 15,000 years for the glacial sediments forming the Whitman Bench, into which the N. F. Stillaguamish River incised prior to those landslides.

An average frequency of landsliding in this valley can be calculated from these data in several ways. For example, it is reasonable to think that some landslides may have occurred close together in time, such as during or after extreme seasonal or event precipitation. In addition, it is likely that not all of the landslides shown on Haugerud's (2014) map ran out completely across the valley bottom. However, the distal portions of many of the landslide deposits are truncated and apparently have been eroded and removed either by river erosion or subsequent landsliding. Hence, we considered several ways to estimate landslide frequency.

An estimate of the landslide frequency can be calculated by assuming that the 15 large landslides in age Classes B-D depicted on the Haugerud map are no older than 6000 years, which would result in a landslide frequency of one per 400 years (6000/15). This estimate does not account for the fact that the other age Class D landslides could be older than the one dated, and conversely does not account for any "missing" landslides that have been eroded from this valley segment or otherwise completely concealed. In contrast, assuming that all 15 landslides post-date the approximately 15,000-year depositional age of the Whitman Bench would produce an estimated frequency of one every 1000 years (15,000/15).

However, such simple average landslide frequencies do not account for the temporal distribution of the slides, and it is possible that all of the landslides portrayed on the map occurred in several discrete episodes. Using four episodes based on Haugerud's relative age classes results in a 1500-year frequency considered over the 6000 year calendar age of the single dated age Class D landslide (6000/4), and a 3,750 year frequency if considered over the past 15,000 years (15,000/4). However, discounting Haugerud's (2014) age Class A, which were recent landslides that clearly did not run out across the valley, to consider three episodes would result in average frequencies of one every 2,000 years (6000/3) and 5,000 years (15,000/3), respectively, when considered over 6,000- and 15,000-year time spans.

Finally, including the 2014 Oso Landslide, direct physiographic and stratigraphic evidence suggests that two landslides ran out over the valley bottom in the past. The large slide to the west of the 2014 Oso Landslide (i.e., the large landslide in Haugerud's age class B) is presumed to be younger than the radiocarbon dated 6000-year landslide from age Class D. Together with the 2014 landslide, this would imply a 3000-year frequency for such events (6000/2). The laterally extensive undated, alluvium-buried landslide deposit, shown beneath Steelhead Lane on the Dragovich et al. (2003) map of the Mount Higgins 7.5-minute quadrangle, is younger than 15,000 years, which together with the other two discussed immediately above would result in 3 valley-spanning landslides in 15,000 years, or an average frequency of one every 5,000 years (15,000/3).

We emphasize that the best way to get a better understanding of the temporal distribution of landslides is to date more of them. However, if we take the upper and lower bounds of the range of estimates discussed here, we can constrain the frequency of large landslides in this portion of the valley to between 400 and 5000 years. Hence, we conclude that an order of magnitude estimate of the frequency of large landslides in this valley segment spans the upper half of once per century to the lower half of once per millennium, which we generalized to an order-of-magnitude estimate of once every 300 to 3,000 years given that 3 is essentially halfway between 1 and 10 on a log scale.

References Cited

Cruden, D. M., and Varnes, D. J., 1996, Landslide types and processes, in *Landslides: Investigation and Mitigation*, Turner, A. K., and Shuster, R. L., eds., Transportation Research Board, Special Report 247, pp. 36-75.

Dragovich, J. D., Stanton, BV. W., Lingley, W. S., Jr., Briesel, G. A., and Polenz, M., 2003, *Geologic Map of the Mount Higgins 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington*, Washington Division of Geology and Earth Resources, 1:24,000 scale, Open File Report 2003-12.

Haugerud, R. A., 2014, *Preliminary Interpretation of Pre-2014 Landslide Deposits in the Vicinity of Oso, Washington*, U.S. Geological Survey Open-File Report 2014-1065, U.S. Geological Survey, Reston, *http://dx.doi.org/10.3133/ofr20141065*.

Hungr, O., Evans, S. G., Bovis, M., and Hutchinson, J. N., 2001, Review of the classification of landslides of the flow type, *Environmental and Engineering Geoscience*, v. 7, p. 221-238.