

Introduction

River valleys in areas of high relief are at a high risk of slope failure¹. On March 22, 2014 a massive landslide occurred in Washington State near Oso along the Stillaguamish River, destroying a community and killing 43 residents. The landslide was particularly devastating for a number of reasons. Although the volume of this slide ($8 \times 10^6 \text{ m}^3$) was similar to others that had been previously recorded in western Washington, its mobility was unprecedented¹. This high mobility made the slide particularly destructive: the slide crossed the river and travelled over 1km to bury the community. Due to its high mobility it has been classified as a debris avalanche flow.



Figure 1: Photo of Oso slide taken on 29 March taken by Spc. Samantha Ciaramitaro - <http://www.dvidshub.net/image/1209676/oso-mudslide>.

Using the factors that led to the characteristics of the Oso slide, this study examines landslide risk in the region around Oso along the Stillaguamish River. Factors such as slope, surface geology, and proximity to a cut bank were considered to evaluate two high risk sites downstream from the Oso slide. Each site was evaluated for its reach angle, which can be used to estimate mobility and subsequent level of devastation².

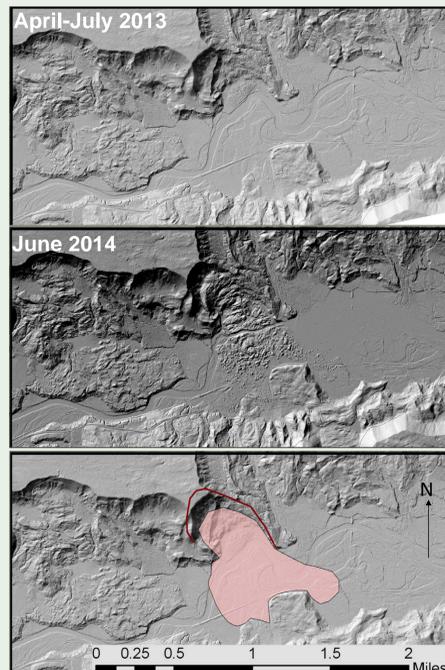


Figure 2: LIDAR images of the 2014 Oso slide region. Bottom image shows lateral extent of slide⁴.

Methods

LIDAR images from the Puget Sound LIDAR consortium were used³. One set of LIDAR images were collected between 4/29/13 and 7/24/13 before the landslide occurred. The second set were taken by the Washington State Department of Transportation in June 2014 after the landslide. Shapefiles of old scarps were sourced from a study by Haugerud, 2014⁴ and subsurface geology data is from Washington State Department of Natural Resources⁵.

Hazard Assessment

Geology

The region is characterized by glacial deposits, including glaciolacustrine units. Glaciolacustrine deposits are composed of clay and silt, which provide a slip face for the slide. First, a 500 ft buffer was created around the river, then an intersection function was run on the river and glaciolacustrine deposits. Figure 3 shows the regions along the river at highest risk for slope failure due to underlying

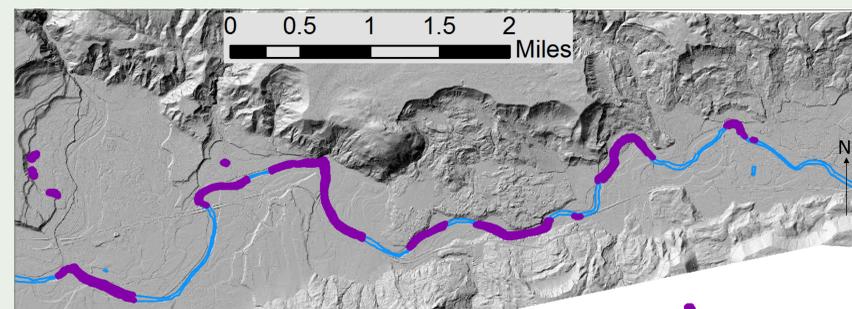


Figure 3: Pre-landslide LIDAR with clay risk overlay (purple) and the Stillaguamish River (blue)

Slope

The steepness of slope has an influence on the shear stresses in the hillside⁶. Steeper slopes have a higher frequency of failure and subsequent flow⁶. In this study, a slope map was created from LIDAR data. Regions with slopes greater than 20 degrees were selected. A 500 ft buffer was placed around the river and an intersection was run on the two layers. Figure 4 shows the regions along the river at highest risk for slope failure due to steepness

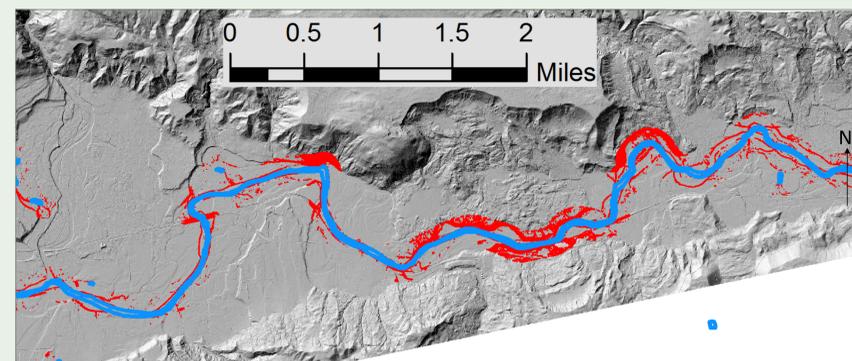


Figure 4: Pre-landslide LIDAR with slope risk overlay (red) and the Stillaguamish River (blue)

¹Iverson, R.M., George, D.L., Allstadt, K., et al., 2015, Landslide mobility and hazards: implications of the 2014 Oso disaster: Earth and Planetary Science Letters, v. 412, no. 0, p. 197-208.

²Corominas, Jordim 1996, The Angle of Reach as a mobility index for small and large scale landslides: Canadian Geotechnical Journal, v. 33, p. 260-271.

³<http://pugetsoundlidar.ess.washington.edu>

⁴<http://pubs.usgs.gov/of/2014/1065/>

⁵http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/gis_data.aspx

⁶Guzzetti, F., Carrara, A., Cardinali, M., and Reichenbach, P., 1999, Landslide hazard evaluation: a review of current techniques and their application in a multi-scale study, Central Italy: Geomorphology, v. 31, no. 1-4, p. 181-216.

Combined Evaluation

The geology and slope hazard maps were overlaid to evaluate locations with the highest landslide risk (fig. 5). Transects were made of the regions with the highest risk from the highest elevation on the hill to the valley floor through the areas of greatest hazard.

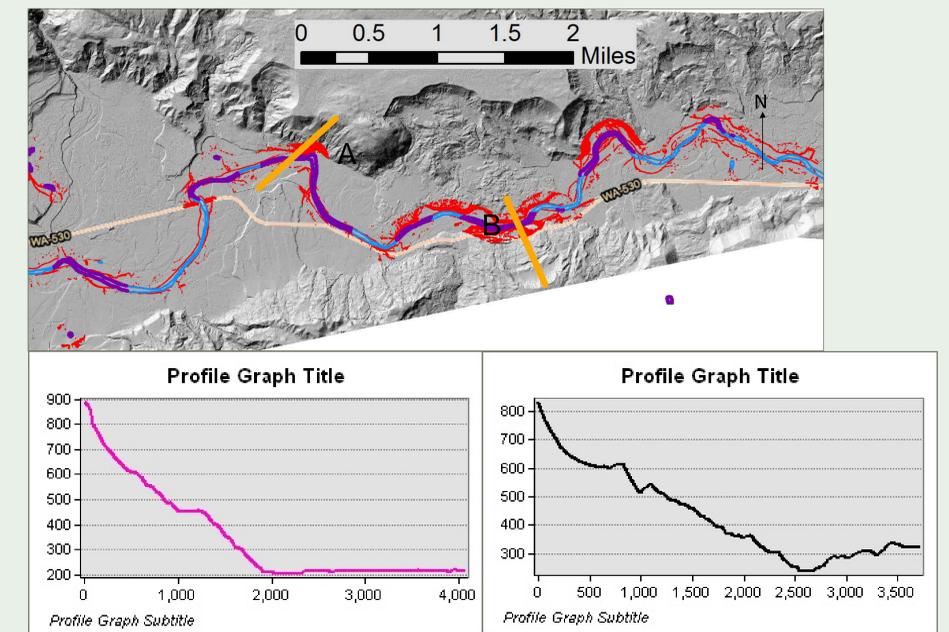


Figure 5: Combined risk analysis of the Oso region showing the areas at highest risk of slide due to underlying geology and slope. Transects are shown in orange. Below are profile views of two transects indicated in orange in figure 4. Profile of transect A is on the left, profile of transect B is on the right.

Mobility Analysis

The mobility of a landslide can be estimated from its reach angle². The reach angle is the ratio between the vertical drop, H , and the horizontal distance, L , travelled by the landslide. A landslide with a lower reach angle tend to be larger and more mobile than those with high reach angles². Here, H/L was estimated by taking a transect of the highest risk areas. H/L for transect A is $900/2000$, or 0.45; H/L for transect B is $650/2600$, or 0.25.

Conclusion

Two areas of the Stillaguamish River near Oso, Washington were evaluated for landslide risk based on subsurface geology and slope angle. Reach angle, or H/L , gives a sense of mobility of the slide was measured on two transects in the high risk areas. The reach angle indicates that a slide in the transect B region is likely to be more devastating than a slide in the transect A region.