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Structural controls on the 2007 Chehalis Lake landslide, British Columbia, Canada

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The Chehalis Lake landslide occurred on 4 December 2007 at the northwest end of Chehalis Lake in British Columbia, Canada. The source area is located at the intersection of the main valley slope and the northern sidewall of a prominent gully. The failed rock mass appears to have initially slid into the gully, where it was redirected by the gully sidewall toward the lake. Approximately 3 Mm^3 of fragmented rock entered the lake and generated a displacement wave that destroyed three local campgrounds and removed forest on the opposite shore of the lake to a maximum height of approximately 30 m. Fortunately, the recreational sites were unoccupied at the time of the landslide; otherwise there would have been loss of life.

The landslide is located near an intrusive contact between late Jurassic andesite and middle to early Cretaceous quartz diorite. The landslide occurred at a time when rain was falling on snow. A cold period between 30 November and 2 December, during which snow fell at Chehalis Lake, was followed by warming and rainfall on 3 and 4 December. Runoff and infiltration probably increased pore water pressures in the fractured rock mass and reduced the effective friction angle along discontinuity surfaces.

We assessed the rock mass quality using the Geological Strength Index (GSI) chart. The range in GSI values is 50-60, corresponding to a very blocky rock mass with good surface conditions. Field estimates of the intact rock strength indicate that both the quartz diorite and andesite are strong to very strong rocks ($\sim$100 MPa). A geotechnical consulting company conducted a preliminary assessment of the landslide and concluded that the failure surface was a pervasive planar structure, in part a fault with a gouge zone a few centimetres thick.

We used field measurements, terrestrial digital photogrammetry, and an airborne-LiDAR digital elevation model to further characterise the failure surface and five sets of planar discontinuities. The discontinuity orientation data were used to perform kinematic, surface wedge limit equilibrium, and three-dimensional distinct element analyses. The results from these stability analyses suggest that: i) the presence, orientation, and high persistence of a discontinuity set dipping obliquely downslope was critical to the development of the failure surface; ii) planar sliding was the dominant failure mechanism; iii) the mobilized effective friction angle along the discontinuities must have been less than 30^o for the landslide to initiate; iv) a steeply dipping discontinuity set striking perpendicular to the slope and associated with a fault, although of little importance to the overall stability of the slope, controlled the volume and extent of the failed rock mass.

This study highlights the importance of three-dimensional topography on the landslide initiation and subsequent transport. The Chehalis Lake landslide was kinematically confined on one side but free on the other. This geometry and the orientation of the failure plane caused the rock mass to initially move toward the gully instead of directly down the slope. These results are significant because a two-dimensional slope stability analysis would not have been able to model this failure mechanism.