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Modeling a Glacial Lake Outburst Flood Process Chain: The Case of Lake Palcacocha and Huaraz, Peru

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One of the consequences of recent glacier recession in the Cordillera Blanca, Peru, is the risk of Glacial Lake Outburst Floods (GLOFs) from lakes that have formed at the base of retreating glaciers. GLOFs are often triggered by avalanches falling into glacial lakes, initiating a chain of processes that may culminate in significant inundation and destruction downstream. This paper presents simulations of all of the processes involved in a potential GLOF originating from Lake Palcacocha, the source of a previously catastrophic GLOF on December 13, 1941, 1800 people in the city of Huaraz, Peru. The chain of processes simulated here includes: (1) avalanches above the lake; (2) lake dynamics resulting from the avalanche impact, including wave generation, propagation, and run-up across lakes; (3) terminal moraine overtopping and dynamic moraine erosion simulations to determine the possibility of breaching; (4) flood propagation along downstream valleys; and (5) inundation of populated areas. The results of each process feed into simulations of subsequent processes in the chain, finally resulting in estimates of inundation in the city of Huaraz. The results of the inundation simulations were converted into flood intensity and hazard maps (based on an intensity-likelihood matrix) that may be useful for city planning and regulation. Three avalanche events with volumes ranging from 0.5-3 x 106 m3 were simulated, and two scenarios of 15 m and 30 m lake lowering were simulated to assess the potential of mitigating the hazard level in Huaraz. For all three avalanche events, three-dimensional hydrodynamic models show large waves generated in the lake from the impact resulting in overtopping of the damming-moraine. Despite very high discharge rates (up to 63.4 x 103 m3/s), the erosion from the overtopping wave did not result in failure of the damming-moraine when simulated with a hydro-morphodynamic model using excessively conservative soil characteristics that provide very little erosion resistance. With the current lake level, all three avalanche events result in inundation in Huaraz, and the resulting hazard map shows a total affected area of 2.01 km2, most of which is in the high-hazard category. Lowering the lake has the potential to reduce the affected area by up to 35% resulting in a smaller portion of the inundated area in the high-hazard category.