



Towards a GLOF hazard map for the city of Huaraz, Cordillera Blanca, Peru

Holger Frey (1), Christian Huggel (1), Rachel E Chisolm (2), César Gonzales (3), Alejo Cochachin (4), and César Portocarrero (5)

(1) University of Zurich, Department of Geography, Zurich, Switzerland (holger.frey@geo.uzh.ch), (2) The University of Texas at Austin, Center for Research in Water Resources, Austin, United States, (3) CARE Peru, (4) Autoridad Nacional del Agua, Unidad de Glaciología y Recursos Hídricos, Huaraz, Peru, (5) Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña (INAIGEM), Huaraz, Peru

Huaraz, with 120,000 inhabitants, is the largest city at the foot of the Cordillera Blanca Mountain Range, Peru, and is located at the confluence of the Quillcay River with the main Santa River. Three moraine dammed glacier lakes are located in the headwaters of the Quillcay catchment, which pose a potential threat of glacier lake outburst floods (GLOFs) to Huaraz: Laguna Cuchillacocha (2.5 x 10⁶ m³), Laguna Tullparaju (12 x 10⁶ m³), and Laguna Palcacocha (17 x 10⁶ m³). The latter burst out in 1941, causing one of the deadliest GLOFs known in history, with about 2000 casualties and destroying a third of the city of Huaraz.

Currently, the presence of these lakes within potential runout distances of possibly very large ice or rock/ice-avalanches, combined with the large damage potential in the city of Huaraz, some 20 km downstream of the lakes and further potentially endangered infrastructures such as the city of Trujillo, large-scale irrigation projects and hydropower plants along the Santa River poses a high-risk situation, despite lake safety systems at all three lakes were constructed in the last century. At Laguna Palcacocha, temporary measures, such as syphoning and a permanent supervision by a team of observers are undertaken at Laguna Palcacocha. For the future, more permanent measures are planned, including non-structural measures, such as a sensor-based early warning system for the entire catchment.

In this framework, a preliminary GLOF hazard map for the entire Quillcay catchment has been developed, based on physically-based numerical modeling. For each of the three lakes, three scenarios of different magnitudes and related probabilities were modeled. For each case, a series of models was used to simulate each part of the chain of interacting processes. The eventual GLOFs were simulated with FLO₂D for Palcacocha and RAMMS for Tullparaju and Cuchillacocha. Small, medium and large scenarios were merged for all three lakes, in order to come up with a single hazard map for the entire catchment. Inundation heights were first translated into intensities, and then intensities were converted into hazard levels, according to the probability of the scenario, which resulted in the preliminary hazard map.

This map is currently used for informing the population and for the planning of further mitigation actions. For the development of the final hazard map, more detailed simulations in the urban area of Huaraz are needed, combined with field mapping to adjust the map to local conditions and peculiarities. Related efforts are ongoing, in close collaboration with local institutions and authorities. Besides the scientific challenges for the development of such a hazard map, the institutional aspect for the official approval and legal validation is a major challenge that needs to be tackled.