



Reducing risks from hazardous glacier lakes in the Cordillera Blanca (Peru): Six decades of experience and perspectives for the future

Cesar Portocarrero (1), Alejo Cochachin (2), Holger Frey (3), Cesar González (4), Wilfried Haeberli (3), and Christian Huggel (3)

(1) Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña, Huaraz, Peru, (3) University of Zurich, Department of Geography, Zurich, Switzerland, (2) Unidad de Glaciología y Recursos Hídricos, Autoridad Nacional de Agua, Huaraz, Peru, (4) CARE Peru, Huaraz

Outbursts from glacier lakes at various spatial and temporal scales have had marked geomorphological effects in many mountain ranges. In many glacierized Andean mountain regions substrates of human settlements made out of flood and debris-flow deposits are testimonies of such events. Examples in the Cordillera Blanca, Peru, are the towns of Caraz, Carhuaz or parts of Huaraz. Continued glacier shrinking since the end of the Little Ice Age caused the formation or enlargement of numerous lakes. The outburst of Laguna Palcacocha, destroying the centre of Huaraz and causing more than 1800 losses of life in December 1941, marked the beginning of systematic risk reduction work in Peru. Corresponding efforts included glacier and lake inventories, hazard assessments, definition of high-risk situations, and completion of engineering work for lake-level lowering in more than 30 cases. The latter comprises outlet reinforcements on morainic dams as well as artificial tunnels in bedrock thresholds. This work has been remarkably efficient as documented in the latest case of the Laguna Huallacocha (Carhuaz-Ancash), where the earlier made installations withstood the erosive power of an impact wave from an ice avalanche in 2015. In the case of the Laguna 513, the impact wave and far-reaching flood caused by a rock/ice avalanche from Nevado Hualcán in April 2010 showed that the risk had been essentially reduced by the preventive lake-level lowering in the early 1990s but not to zero.

Risk assessments, planning, construction and non-structural risk reduction efforts continue. Work is in progress to increase the safety of Laguna Palcacocha where extensive assessments and model calculations had been carried out. Risks related to rock/ice avalanches into lakes from steep icy slopes and related to de-buttressing processes as well as long-term permafrost degradation increases. Based on morphological indications and numerical modelling (GlabTop) an inventory of possible future lakes likely to form with continued atmospheric warming and glacier retreat has been compiled. The possibility of monitoring the stability of slopes around lakes using satellite-based radar interferometry techniques has been tested in the case of Laguna Parón and a number of other lakes. Hence risk reduction measures applied to critical glacier lakes is based on rigorous science and research progress.

For the future it is essential to integrate risk reduction with water resource management because shrinking glaciers reduce water availability during the dry season when various economic sectors depend on melt water. First experiences with development of multi-purpose projects combining risk and water resource management have shown the associated scientific, technical, social and legal challenges. A multi-disciplinary process involving multiple institutions and actors is necessary to secure sustainable development in the Andes of Peru, and related experiences are valuable for other high-mountain regions as well.