New lakes in deglaciating high-mountain areas
Current and future risks from impact waves by rock/ice-avalanches

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1 High-mountain lakes in a changing environment

Over the past few decades glaciers in Switzerland as in most other regions worldwide have experienced fast retreat due to climate change. Ongoing warming is expected to reduce glacier areas in Switzerland by about a further 75% by the first half of this century. The retreat of glaciers is and will be causing important changes in high-mountain environments with effects on downstream and low-land areas. Particularly essential are aspects of hazards, risks and water resources. The management of existing and new glacier lakes that form due to continued glacier retreat pose several challenges to research and practice and require an interdisciplinary approach. GIS-based models (Frey et al. 2010, Paul and Linsbauer, in press) show that numerous overdeepenings will appear on the exposed glacier beds, which are considered as potential sites of lake formation. In many cases these newly forming lakes will be situated in an over-steepened and destabilized topography and therefore are prone to impact waves from landslides. The risk that they might burst out and endanger infrastructure, residential areas and persons further downvalley is increasing with further lake formation and glacier recession.

1.1 Embedding of the PhD and research questions

The PhD is part of the project ‘New lakes in deglaciating high-mountain areas: climate-related development and challenges for sustainable use (NELAK)’ within NRP 61 ‘sustainable water management’ and contributes a comprehensive study on risk analysis with respect to impact waves from rock/ice-avalanches into existing and newly forming lakes in deglaciating high-mountain regions and the associated potential glacier floods. In order to realistically and reasonably deal with the rapidly changing situation, the following key questions need to comprise:

- How can the hazard potentials be systematically analysed and anticipated - for present as well as for future conditions (involving changes in climate, ice conditions, lake formation and landscape evolution)?
- How can the vulnerability of the population and infrastructure be assessed and reduced especially in view of future conditions?
- Which levels of probabilities and associated risks have to be expected? What levels of risk are acceptable/unacceptable?
- Which priority has to be given to threats evolving from new lakes in deglaciating high-mountain regions in comparison with other natural hazards?
- Which sort of solutions (prevention, intervention, reconstruction) can be applied under which circum-stances? How can the most appropriate solution or combination of solutions be assessed on the basis of an integral action planning?

The aim is to provide a practice-oriented, straightforward and easy–manageable framework to decision-makers in order to facilitate the assessment process of the risks evolving from high-mountain lakes. Priority is thereby given to an integral, holistic point of view instead of profound investigation on detailed questions. The full integration of future conditions (e.g. glacier vanishing, landscape evolution and lake formation as a consequence of climate change) will provide long-lasting results that will also be highly relevant on an international level and thus strengthen the Swiss science in this field.
2 Research Plan

In order to answer the generally formulated research questions in 1.1, a three-part approach was established (Fig. 1).

![Fig. 1: The three parts of the PhD-approach.](image)

2.1.1 Local scale approach

A multi-hazard approach to evaluate and estimate the danger of a particular high-mountain lake will be elaborated. The assessment scheme will consider the whole process chain, starting with the triggering mechanism and ending with the impact on populated areas. The aim is to determine crucial characteristics of the hazard processes involved and to find models, which fit into the assessment scheme. The delimitation of the hazard processes to be analysed is as follows:

- Rockfall
- Wave propagation
- Dam breach
- Outburst flood

The research questions and methods to be applied are as follows:

How can the different hazard processes be linked in order to generate intensity maps?

1. What input parameters does the model require? What is the output of the model? Can the results of the model serve as input for the following model?
   - Literature review

2. Is it the information that is required for the hazard assessment?
   - Literature review

3. Is it possible to generate the required information?
   - Reconstructing a lake outburst in Peru using the most suitable models. Calibration of the assessment scheme.

4. Is it possible to apply the scheme to a lake not bursted out yet?
   - Application of the assessment scheme to a lake not bursted out.

2.1.2 Regional scale approach

The risks resulting from high-mountain lakes in the Swiss Alps will be compared among each other, while existing lakes are as much included in the analysis as future ones. The delimitation of the analysis is as follows:

- Region = Swiss Alps
New lakes in deglaciating high-mountain areas

- Process = rock/ice-fall induced outburst floods
- Points in time = today, middle of the 21st century, end of the 21st century

The research questions and methods to be applied are as follows:
Comparing the risks resulting from high-alpine lakes in Switzerland amongst each other, where are the highest risks?

5. Which potential detachment zones above lakes are the most susceptible to slope failures?
   ➔ Analysis of the areas that feature the topographic potential to reach a lake (Serraino 2011) regarding it's susceptibility to failure (Fischer, in prep.).

6. Which lakes provide the biggest hazard potentials?
   ➔ Analysis of the lakes regarding their volume and the slope of a potential outburst flood until the damage potential (Paul and Linsbauer, in press).

7. Where is the biggest damage potential located?
   ➔ Application of a landuse allocation model (Walz 2006) to the Swiss Alps and implementation of driving forces of a sustainable settlement development (Perlik et al. 2008).

2.1.3 Management

In order to meet the requirements of the applied holistic approach, two aspects of integral management will be addressed in a qualitative manner:

- Integral risk management: comparison of the risks from high-mountain lakes to other (natural) hazards.
- Integral lake management: link the risks from high-mountain lakes to potential opportunities they provide (e.g. hydropower, tourism).

3 Literature


