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Glacial hazards and the development of risk management protocols

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The recession of glaciers worldwide has received huge media coverage over the last few years in association with the issue of climate change. Our understanding of the links between changing climate and glacier response has developed significantly as has the technology by which to monitor glaciers and associated lakes. For example, there have been step changes, particularly in remote-sensing techniques, over the last decade that have facilitated the large scale assessment of glacial hazards for entire countries down to the scale of detailed study of particular glacial lakes. Glaciological processes have been identified such that our understanding of supra-glacial lake formation on debris-covered glaciers has improved substantially – from climate processes, negative mass balance, and glacier down wasting to stagnation of ice flow. There are still significant issues unresolved, such as mechanisms of thermokarst degradation; en-glacial hydrological processes; and how to identify where a moraine dam could fail, the processes of breach formation and the consequential effects on the form of the ensuing flood.

Despite this, the management of glacial hazards in a broader context has not developed much. There are still substantial issues concerning the validation of hazard assessments scientifically and the adoption of appropriate protocols by the responsible government agencies in order to manage the ensuing risks. The media are still headlining potential catastrophes and causing alarm among local communities. The so-called Palcacocha fiasco in the Cordillera Blanca, Peru, in April 2003 and the Imja Tsho media flurry of May 2008 in Nepal are but two recent examples. How can scientific organisations and government agencies work together to create objective risk management procedures and avoid mass hysteria in situations where significant hazards are identified?

There has also been an increased awareness that glacial hazards are not restricted to the Andes or Himalayas and attention has been turning rightly to include many other glacierised mountain environments (e.g. Tien Shan Mountains, Pamirs, Karakorum, Caucasus Mountains, the Alps in Europe, the Rockies in north America, and within Scandinavia, to name but a few). While there are similarities in development of hazards in these regions there are undoubtedly differences in how these should be assessed and managed.

Rightly, there has been a great deal of development of tools for the assessment of glacial *hazards*, particularly from the mid-1990s. However, there must be more use of the concept of glacial lake 'systems' to identify all the available physical components (triggers and thresholds) that exist within a particular location. More recently attention has also been paid to the assessment of *risk* through mapping potential vulnerability but while the risks can be identified to varying degrees, little thought is being given to the *management* of those risks, including the consequences of temporal changes. Mitigation without a thorough risk assessment or sufficient understanding of the local glacial lake system has led to significant loss of life, such as at Quebrada los Cedros in Peru in October 1950. Localised mitigation at Raphstreng Tsho in Bhutan in 1996-98 has possibly increased the potential for a major GLOF from the adjacent Thorthormi Tsho through a lack of consideration of the glacial lake systems present.

With the advent of Geographical Information Systems (GIS) there is a possibility that the glaciological constraints on hazard assessment will be reduced by using *generalised* rules of analysis that look for statistical solutions to applied search rules. It is important, therefore, that GIS analytical techniques include and benefit from the scientific understanding that is being developed from a wide variety of disciplines and provide co-ordinated methods of risk assessment. Similarly, Multi-Criteria Analysis should be further developed to incorporate a wider range of constituents for overall decision making purposes. These various analytical methods should be used within agreed protocols for the management of those risks. A possible framework for doing this is being developed and will be presented for discussion.