



**REYNOLDS
GEO-SCIENCES**

Independent Geological Consultants



Development of glacial hazard and risk minimisation
protocols in rural environments

Guidelines for the management of glacial hazards
and risks

November 2003

Report No: R7816

Reynolds Geo-Sciences Ltd
Unit 17, Mold Business Park,
Wrexham Road,, Mold
Flintshire, CH7 1XP, UK

Tel: +44 (0)1352-756196
Fax: +44 (0)1352-759353
E-mail: rgsl@geologyuk.com
Web: www.geologyuk.com





Notice:

The intellectual property rights represented by the documents contained herein are vested in Reynolds Geo-Sciences Ltd and are protected under UK law. The use of the technical detail by third parties without the express permission of Reynolds Geo-Sciences Ltd and without due recompense is not permitted under any circumstances.

The copyright of the document herein belongs to Reynolds Geo-Sciences Ltd and all rights are protected.

© Reynolds Geo-Sciences Ltd, November 2003, all rights reserved.

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. This is under the Knowledge and Research (KaR) scheme in grant R7816 Development of Glacial Hazard and Risk Minimisation Protocols in Rural Environments. The views expressed are not necessarily those of the DFID.

Cover picture: Collage of images from the study regions for the project. Clockwise from top left (1) the terminus of Imja Glacier entering Imja Tsho, Nepal; (2) Laguna Llaca, Cordillera Blanca, Peru; (3) the end-moraine breach and flood sediments of an outburst from Sabai Tsho, Nepal, in 1998.



Guidelines for the management of glacial hazards and risks

EXECUTIVE SUMMARY

Glacial hazards, such as ice avalanches and floods from glacial lakes, threaten communities and commercial activities in many mountain ranges of the world. The threat to economic development of some of the world's poorest countries has already been highlighted by several catastrophic events in recent decades. Furthermore, within the current and predicted scenario of a warming climate it is expected that the frequency, and in some cases the magnitude, of glacial hazards will increase. Despite the damages and associated costs experienced from past events, there remains little guidance on procedures of hazard and vulnerability assessment. It is clear that guidance is required given that donors, project financiers and/or insurers increasingly require a risk assessment for new development projects.

A structured approach to the management of glacial hazards and their associated risks is set out within this document. The work is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. It draws upon three years of research into techniques of glacial hazard assessment and socio-economic vulnerability analysis and is aimed at assisting governments in the planning and implementation of risk reduction strategies. The guidance notes are aimed at increasing the objectivity and independence of the risk assessment process. Intended users of the notes include both technical personnel and non-specialists involved in the assessment or management of glacial hazards.

Following the introduction and definitions of some key terms, a review of glacial hazards is provided as background information (Chapter 3). This includes a summary of the types of glacial hazards and a consideration of the relation to climatic change. The economic importance of glacial hazards is explained with reference to the costs associated with past events in Nepal and Peru, and in terms of projected costs of the loss of a mature hydropower plant, which could amount to \$500 million. Finally within Chapter 3, the needs for risk guidelines are emphasised as the nature of hazard and vulnerability changes and more people become involved in this increasingly important subject area.

A risk management framework is outlined in Chapter 4, incorporating elements of *hazard identification and assessment, vulnerability assessment, risk estimation, risk evaluation, and risk control*. The rest of the document is dedicated to the discussion of each of these phases, with reference to practical examples and published literature. First, issues of project planning, including structure and choice of methods, and operational guidance for elements of site investigation and data management are provided in Chapter 5. Chapter 6 contains guidance on the assessment of risk, including new schemes for the assessment of moraine-dammed lake hazard and for the mapping of physical vulnerability to lake outbursts.

Finally, risk management options are discussed in Chapter 7, ranging from the employment of engineering methods to reduce hazards at source or to contain their runouts further down valley, through to, for the first time, a consideration of methods to reduce aspects of social vulnerability. Regional and national risk management issues and examples of international co-ordination initiatives are provided as guidance to senior planners and political figures involved in strategic management.

More detailed guidance for some of the specific site investigation techniques used within risk assessment studies is provided in a series of self contained notes in the Appendix.

Note on distribution:

This document is available to government agencies, educational establishments, research institutions, NGOs and other non-profit making organisations in countries eligible for British aid. Free copies can normally be addressed to individuals under official titles, not by names. Post and packaging will normally be charged in addition. This report can also be purchased by organisations and individuals not eligible to receive free copies. Please contact:

Reynolds Geo-Sciences Ltd
Unit 17, Mold Business Park, Wrexham Road, Mold, Flintshire CH7 1XP, UK
Tel: +44(0)1352 756196; Fax: +44(0)1352 759353
Email: rgsl@geologyuk.com; Web: www.geologyuk.com



Guidelines for the management of glacial hazards and risks

CONTENTS:

EXECUTIVE SUMMARY

1	<u>INTRODUCTION</u>	1
2	<u>DEFINITIONS</u>	1
3	<u>GLACIAL HAZARDS</u>	2
	3.1 <u>Types of glacial hazard</u>	2
	3.2 <u>Glacial hazards and climate change</u>	4
	3.3 <u>Economic consequences and the threat to development</u>	5
	3.4 <u>The need for glacial risk management guidelines</u>	5
4	<u>A FRAMEWORK FOR GLACIAL RISK MANAGEMENT</u>	7
5	<u>SITE INVESTIGATION AND DATA MANAGEMENT</u>	8
	5.1 <u>Purpose of site investigation</u>	8
	5.2 <u>Scope of site investigation</u>	8
	5.3 <u>Planning an investigation</u>	10
	5.4 <u>Investigation techniques</u>	11
	5.5 <u>Data management</u>	13
	5.6 <u>Quality Assurance</u>	13
	5.7 <u>Health and Safety</u>	14
	5.8 <u>Regulatory and political aspects</u>	14
6	<u>GLACIAL RISK ASSESSMENT</u>	14
	6.1 <u>Introduction</u>	14
	6.2 <u>Glacier/lake inventory compilation</u>	15
	6.3 <u>Glacial hazard assessment</u>	15
	6.3.1 <u>Factors affecting hazard</u>	15
	6.3.2 <u>Event volumes and discharges</u>	17
	6.3.3 <u>Runout distances</u>	18
	6.3.4 <u>Determining probability</u>	19
	6.3.5 <u>Early recognition of hazards</u>	19
	6.3.6 <u>A hazard assessment scheme for moraine-dammed lakes</u>	20
	6.4 <u>Vulnerability assessment</u>	21
	6.4.1 <u>Factors affecting physical vulnerability from lake outbursts</u>	22
	6.4.2 <u>A physical vulnerability mapping scheme for lake outbursts</u>	23
	6.4.3 <u>Assessing aspects of human vulnerability</u>	24
7	<u>RISK MANAGEMENT</u>	26
	7.1 <u>Introduction</u>	26
	7.2 <u>Hazard reduction</u>	26
	7.3 <u>Alternative measures of hazard reduction</u>	27
	7.4 <u>Vulnerability reduction</u>	28
	7.4.1 <u>Vulnerability reduction by engineering methods</u>	28
	7.4.2 <u>Vulnerability reduction by social methods</u>	28
	7.5 <u>Regional and national risk management strategies</u>	30
	7.6 <u>International co-ordination initiatives</u>	31
	Acknowledgements	32
	References	32

Appendix - Guidelines for techniques used within glacial hazard and risk assessments



- A1 Guidelines for engineering geological descriptions**
- A2 Guidelines for engineering geological mapping**
- A3 Guidelines for slope stability analysis in risk modelling**
- A4 Guidelines for the use of geophysical methods in the assessment of glacial hazards**
- A5 Guidelines for geomorphological mapping in glacial hazard and risk assessment**