Slope Engineering for Mountain Roads

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It is recommended that reference to all or part of this book should be made in one of the following ways:

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Slope Engineering for Mountain Roads

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Foreword

This book is special in that it has made a significant advance in coalescing engineering, geology and geomorphology into one orderly and comprehensive volume which can be read and enjoyed by an engineer with a lack of knowledge of geology and geomorphology, or a geologist with a lack of engineering and geomorphology. The book, I believe, is the first, or at least one of the first, fully cohesive engineering geology texts, unlike many predecessors which are only a partially successful integration between the disciplines of engineering and geology. The latter principally reflect the discipline of the authors and even when one is a geologist and one an engineer, the joins are often patently visible. Not so with this book.

How has this come about?

Firstly, the authors are a team of practising engineers, geologists and geomorphologists, not academics, nor a working party, nor a conference of themed papers, but employees of a major consulting practice with decades of successful hands-on experience in the subject. As such, it is not teaching geology to engineers, or engineering to geologists: it is a book that integrates the planning, design, construction and maintenance of mountain roads in wet mountainous environments – mainly the humid tropics and subtropics.

Secondly, it is the example set by the excellent manual, 'Principles of low cost road engineering in mountainous regions', Transport Research Laboratory, UK, Overseas Road Note No. 16 (1997). This also drew heavily upon the knowledge and experience of the consulting engineers, Scott Wilson UK, earlier pioneering publications on mountain roads in Nepal, and academic leaders such as Professors Brunsden, Cooke, Doornkamp and Jones who, in the 1970s and 80s, were largely responsible for creating the broader framework in Britain of modern engineering geomorphology and visualizing its power as a tool in assisting engineering.

These two factors provided knowledge and set the scene for a wider-scoped new book some fifteen years later.

The driving force for the new book, albeit with considerable help from many others (see Acknowledgments), is Dr. Gareth Hearn, one of UK's leading second generation of engineering geomorphologists who mainly work in industry and have inherited the mantle of the original academic pioneers. He has been supported in this role by Tim Hunt: a geotechnical engineer with considerable experience in mountain road engineering.

Good road engineering in wet mountains is a matter of achieving efficiently that which is practical. There are, as far as I am aware, no substantive codes yet written, especially for wet mountain road engineering. Eurocodes used or discussed in the book and the current vogue of geotechnical modelling are often not the realistic way forward for mountain slope design because of the difficulty in obtaining hard field geo-data about mountain slopes. Each situation is a risk judgement. What factor of safety should be used on a mountain where a huge lump of the landscape could fall before, during or after the engineering works? What is the limit of what can be built in mountain terrain? The book has navigated its way through these problems. I like it very much. It is heading towards developing a mountain road philosophy but there is still quite a long way to go yet to writing a Wet-Mountain Slope Code but it has made significant headway.

What else do I like about the book? From its perceptive description of mountains and landslides, mountain roads and their feasibility, planning, site investigation, detailed design and construction to subsequent road and slope management, its logical structure is well written for tropical situations and remote areas which commonly have only limited infrastructure support. There are many case studies interwoven with the text, largely drawn from the firsthand experience of the authors. References are numerous and relevant and lead to wider reading. Figures, tables and annotated photographs abound and considerably strengthen the book, especially as colour is comprehensively used and is particularly helpful in illustrating multi-coloured tropical soils. Each photograph has been carefully selected to support and illustrate the associated subject matter. Text boxes are used to supplement engineering and geological points without disturbing the theme of the main text. All in all, a readable, valuable and authoritative volume. The authors, Scott Wilson, the Department for International Development (DFID) and the Geological Society Publishing House are to be congratulated.

Professor P. G. Fookes, F. R. Eng.
Winchester, UK
August 2011

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Most of the illustrations contained herein are taken from projects carried out in the humid tropics and subtropics, although some examples are given from areas outside these zones in order to illustrate a particular aspect. The editor and URS Scott Wilson Ltd would like to thank the following for appointing them to carry out the work illustrated in this book:

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How to use this book

This book covers the design, construction and maintenance of mountain roads in the humid tropics and subtropics and focuses on slope stability aspects. It concentrates on low-cost, low-volume roads, but many of the techniques described are equally applicable to higher road classifications.

The book is split into four parts.

Part A. Landslides and mountain roads
Part B. Site investigation
Part C. Design and construction
Part D. Slope management

An Index and a Glossary of Terms are also provided. References quoted are listed at the end of each Section. Note that references are only indicative, that is, they do not represent a comprehensive listing. The reader should carry out their own literature searches if a more comprehensive bibliography is required.

Part A describes and illustrates the background to landslide and slope instability problems affecting roads in hilly and mountainous areas of the humid tropics and subtropics. Basic considerations of hazard and risk are discussed.

Part B contains a description and review of techniques of site investigation, ranging from desk study, through field mapping to ground investigation and monitoring.

Part C provides practical advice on a range of issues that relate to the design and construction of alignments, slopes, retaining structures, drainage and erosion protection works.

Part D focuses on slope inspections, works prioritization and emergency management during road maintenance and operation.

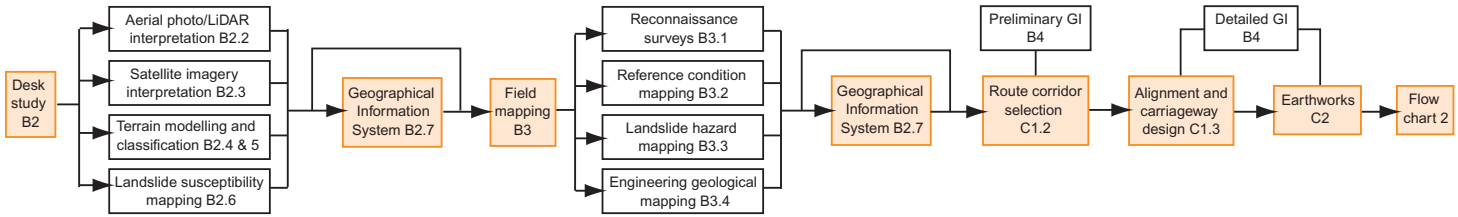
Most practitioners will probably not wish to read this book cover to cover, but prefer to focus on aspects most immediately relevant to them. Consequently, Activity Flow Charts 1–4 have been prepared. These flow charts provide summary recommendations of the activities that should be undertaken when:

- designing new roads to minimize slope instability (Flow chart 1);
- forming new slopes during road construction and road improvement (Flow chart 2);
- maintaining slopes during road operation (Flow chart 3); and
- responding to slope and retaining wall failures that occur during road operation (Flow chart 4).

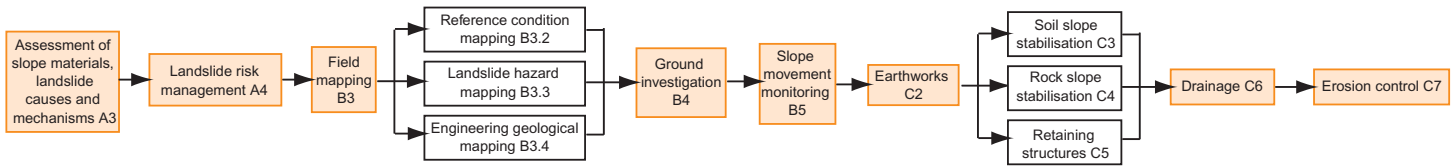
The relevant sections of this book, where each activity is described, are indicated in the flow charts. Project phasing and construction procurement are not referred to in the flow charts, and are discussed in Section A2.

Each of the disciplines of geology and civil engineering, including their various specializations and subdivisions such as geomorphology, engineering geology, geotechnical engineering and hydrology, for example, offers techniques and skills that can contribute variously to the design, construction and maintenance of mountain roads. Multidisciplinary teams are most common on large and complex construction projects but guidance may be required in compiling these teams, or in seeking the advice of a specialist following an instability event during road operation for example. Consequently, Table 1 shows the broad range of tasks that each of these specialists might ordinarily undertake. However, there will be much variation and many exceptions according to training and experience, and each situation will require careful team selection. The definitions of the various specialists listed in Table 1 are provided in the Glossary.

Flow chart 1: Design of new roads to minimise slope instability



Flow chart 2: Design and construction of new slopes (for new road construction and road improvement)



Flow chart 3: Maintenance of existing slopes

Flow chart 4: Slope or retaining wall failure during road operation

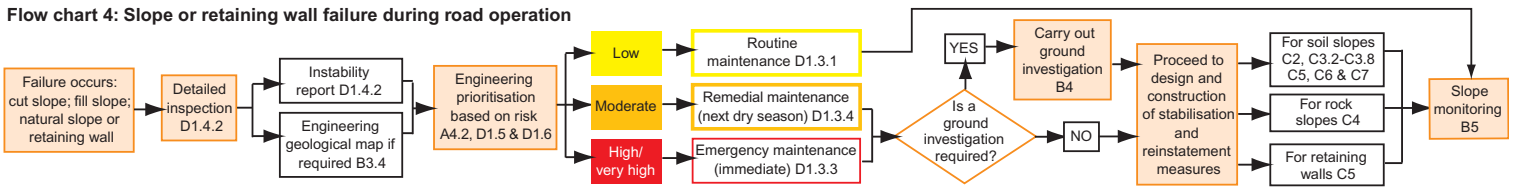


Table 1. *Common specialist skill sets for the assessment of terrain and slope stability and the design of mountain roads*

Specialist	*Terrain classification (B2.4 & 2.5)*	*Landslide mapping*		*Identifying areas of future instability*	*Ground investigation (B4)*			*Slope stability assessment & analysis*		*Design of engineering works*						
		From remote sensing (B2.2 & B2.3)	*From field observation (B3.4)*	*From remote sensing & field observation (B2.6 & B3.3)*	*Planning*	*Supervising*	*Interpreting*	*Soil slopes (C3.2)*	*Rock slopes (C4.2)*	*Alignment (C1)*	*Earthworks (C2)*	*Soil slope stabilisation (C3.3–C3.8)*	*Rock slope stabilisation & protection (C4.3 – C4.5)*	*Retaining walls (C5)*	*Drainage (C6)*	*Erosion protection (C7)*
Geologist	Some skills likely	Some skills possibly	Some skills possibly	Some skills possibly	Some skills possibly	Some skills possibly	Some skills possibly	Skills unlikely	Some skills likely	Some skills possibly	Some skills possibly	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely
Geomorphologist	Main skill fields	Main skill fields	Main skill fields	Main skill fields	Some skills likely	Some skills possibly	Some skills possibly	Some skills possibly	Some skills possibly	Some skills likely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Some skills possibly	Skills unlikely
Engineering geologist	Some skills likely	Some skills likely	Main skill fields	Main skill fields	Main skill fields	Main skill fields	Main skill fields	Main skill fields	Main skill fields	Some skills likely	Some skills likely	Some skills likely	Main skill fields	Some skills likely	Some skills possibly	Some skills possibly
Geotechnical engineer	Skills unlikely	Skills unlikely	Some skills possibly	Some skills possibly	Some skills likely	Some skills likely	Main skill fields	Main skill fields	Some skills possibly	Some skills possibly	Main skill fields	Main skill fields	Some skills possibly	Main skill fields	Some skills likely	Some skills possibly
Civil engineer (roads & structures)	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Main skill fields	Some skills likely	Some skills likely	Some skills likely	Some skills likely	Some skills likely	Some skills likely
Drainage engineer	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Main skill fields	Main skill fields
Bio-engineer/forester	Skills unlikely	Skills unlikely	Some skills possibly	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Some skills likely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Skills unlikely	Some skills likely	Main skill fields

Key: ■ (black) Main skill fields; (stippled) Some skills likely; (grey) Some skills possibly; (light grey) Skills unlikely