DISCUSSION "LANDSLIDE RISK MANAGEMENT CONCEPTS AND GUIDELINES"

(AUSTRALIAN GEOMECHANICS, VOLUME 35, NO 1, MARCH 2000, PP 49 TO 52)

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1 INTRODUCTION

Coffey Geosciences Pty Ltd has many years of experience of landslide risk assessment and management and continue to do a great deal of work in this area. The paper entitled "Landslide risk management concepts and guidelines" (Landslide Paper) published in the last edition of Australian Geomechanics will have implications for us, other practitioners, clients, owners and regulators and those affected by landslide risk. The Landslide Paper defines landslides as "the movement of a mass of rock, debris or earth down a slope". This broad definition, which includes falls, topples, slides, flows and spreads from both natural and artificial slopes, means that many geotechnical professionals get involved in slope risk management at some time.

We are currently in the process of preparing notes for internal distribution on landslide risk management and the Landslide Paper and, in these notes, we intend including examples of how they can be applied. During this process it has become clear that some of our experienced practitioners have concerns about some aspects of the Landslide Paper and how it might be interpreted in practice.

The purpose of this letter is to contribute to a constructive debate by highlighting and discussing the strengths of the Landslide Paper, raising and discussing areas of concern and summarising what we think are important issues. We have also included four example case histories which show how short simple reports can be consistent with risk management principles and the concepts and guidelines in the Landslide Paper.

2 SOME OF THE STRENGTHS OF THE LANDSLIDE PAPER

The following comments highlight some of the strengths of the Landslide Paper.

2.1 INTRODUCES RISK MANAGEMENT PRINCIPLES

We see the introduction of risk management principles as the major strength of the Landslide Paper. Applied to slopes the principles can be interpreted as answering the following questions:

- What are the issues and who cares? (SCOPE DEFINITION).
- What might happen? (HAZARD IDENTIFICATION).
- How likely is it? (LIKELIHOOD).
- What damage or injury might result? (CONSEQUENCE).
- How important is it? (RISK EVALUATION).
- What can be done about it? (RISK TREATMENT).

In our experience applying risk management principles encourages people to plan, work and report more effectively because they understand the wider context of the job. In particular, this often involves giving more attention to consequences and treatment options than has sometimes happened in the past. All the examples attached are consistent with risk management principles. The risk management steps are highlighted against the relevant paragraphs in Example 1.

2.2 RAISES THE ISSUE OF LOSS OF LIFE

The Landslide Paper makes it clear that risk of loss of life should be considered. Recognising potential hazards, which can cause loss of life, is the first step. The record of deaths in Australia shows that the following hazards/situations can lead to fatality:

- Sheltering near very steep cliffs, overhangs (or even caves) during rain.
- Dislodging boulders while climbing.
- Fast debris flows from steep natural slopes.
- Fast debris flows from loose fills.
- Slower debris flows or slides which trap people in buildings or cars and bury them.
- Sudden failure of temporary cut slopes (eg, slide of trench or basement excavation).

Slow moving earth or debris slides seldom lead to death because people have time to get out of the way.

Example 2 is a situation where a significant risk of loss of life was recognised and immediate action was taken to reduce the risk.

2.3 PROVIDES USEFUL REFERENCE MATERIAL

The inclusion of the landslide risk management terms in Appendix A and other landslide terms in Appendix B will encourage a more uniform approach. Other appendices provide useful references and background material.

3 CONCERNS ABOUT THE LANDSLIDE PAPER

The following comments highlight some concerns on the Landslide Paper raised by experienced practitioners. Although some of the concerns are related to emphasis, perception, interpretation and presentation we feel there is value in raising and discussing the issues as they may also be of concern to other practitioners.

3.1 LACK OF EMPHASIS ON GEOLOGY

In our opinion there is a lack of emphasis on the geological and geomorphological skills needed to understand landslide hazards. In the majority of cases, the most difficult and time consuming issue in landslide risk management is recognising, understanding and explaining the hazards. In our experience the best work on understanding landslide risk is usually carried out by engineering geologists with knowledge and experience of landslides and an understanding of risk management principles. Such geologists usually have a good understanding of uncertainty and are less likely to quantify unrealistically than people with little geological knowledge. All too often, in our experience, people start arguing about numbers (eg. factor of safety or probability of failure) when a better contribution to the landslide risk management process would be to put more effort into understanding and explaining the particular geological processes at the site in question.

3.2 OVER-EMPHASIS ON QUANTIFICATION

Where realistic, some form of quantification based on understanding the hazard helps decision making. The attached examples, although simple are partly quantitative. In our opinion the level of risk quantification implied in the Landslide Paper is inappropriate for the majority of jobs. In conjunction with the lack of emphasis on geology discussed above there is a danger that the Landslide Paper may give the impression that a quantified risk assessment, however unrealistic, is better than the judgement of an experienced practitioner who has the knowledge and wisdom to understand the limitations of quantification in that particular situation. The quality of a landslide risk assessment is related to the extent that the hazards are recognised, understood and explained which is not necessarily related to the extent to which they are quantified. The level of quantification shown in the examples will be adequate in many cases.

The Landslide Paper recommends that risk for loss of life should be quantified. In our experience that is not always necessary. Sometimes when risk of loss of life is identified as an issue in an initial study it is possible to take immediate steps to reduce the risk without the need for further assessment. In some situations where uncertainty remains, the client/owner/regulator or those affected may be happy to make a decision on the basis of the initial qualitative or semi-quantitative assessment. In other situations, where quantifying the likelihood of loss of life involves a great deal of uncertainty and subjective judgement, recognising and explaining the uncertainty and making cautious judgements may be more helpful to the decision making process than unrealistic attempts at quantification.
As explained in the Landslide Paper there can be many direct and indirect consequences of a landslide. Fully understanding and quantifying the consequences of a landslide will seldom, if ever be achievable. Often, we will not have the knowledge or expertise to estimate some of the direct costs, let alone the consequential costs. We are usually engaged by the client/owner/regulator because of our knowledge of the hazard. Our major role is to understand and

explain the consequences. The client/owner/regulator may wish to attempt to quantify the cost of some of the direct consequences but in our experience, in many cases they will be willing to make value judgements on risk acceptability and treatment options on the basis of the assessor's description of possible consequences.

3.3 THE LANDSLIDE PAPER IS TOO PRESCRIPTIVE

There is a recommendation in the Landslide Paper to "follow the guidelines" and encouragement to use particular terms and a complex risk matrix. The first sentence of Section 3.5.3 of the Landslide Paper (page 62) states that "risk for loss of life should be quantified..." and there are other similar statements elsewhere. As explained above, there are many circumstances when it may be reasonable to make decisions about risk without quantifying the risk of loss of life. In our opinion each case should be judged on it merits. Unrealistic attempts to quantify the risk of loss of life with inadequate knowledge may be quite misleading.

In our opinion the Landslide Paper is too prescriptive and we do not agree with all the recommendations. We believe that the best way to advance the practice of landslide risk management in Australia is to encourage a constructive debate on the Landslide Paper and the publication of case histories.

3.4 THE APPLICABILITY OF THE EXAMPLE TERMS AND RISK MATRIX IN APPENDIX G

Appendix G provides examples of some qualitative terms and shows how they may be linked to a risk matrix. The text of the Landslide Paper recommends the terms in Appendix G and the frequent cross-references to this appendix lend it authority.

We have reservations about Appendix G because it is an example that represents a particular situation. It will not be applicable to many jobs because:

- It includes specific description of consequences which may not be relevant to the job.
- It includes very specific risk level implications that are unlikely to be generally applicable. The amount of investigation required, and cost of treatment is not necessarily related to the level of risk. For example, as explained on page 64 of the Landslide Paper, if the high risk is associated with a single large boulder it may be easy to remove the boulder and reduce the risk without further investigation.
- The use of dual terms in the qualitative risk analysis matrix effectively creates eight risk levels (without including low risk which does not appear on the matrix). This complexity is unlikely to be required.

Users of Appendix G also need to recognise that it is not possible to make a qualitative judgement as to likelihood, and to use this judgement to assign a probability. The first step in the process is to make a quantitative assessment of the probability of landsliding, and then assign a qualitative likelihood description based on this information.

More fundamentally, we caution about the over use of risk matrices. As shown in the attached examples risk matrices are not essential to the risk assessment and management process. Trying to fit a relatively simple job to a pre-defined matrix can result in unnecessarily complex and clumsy reporting. At worst it could encourage an unthinking cookbook approach instead of understanding the particular site and the clients concerns and clear and simple reporting.

Risk matrices are of value where many risks have to be compared. In such cases, it can be useful to develop risk analysis matrices in conjunction with others (clients/owners/regulators/other practitioners) to help rank risks, set priorities and develop a uniform approach to decision making. If we do contribute to the development of a risk matrix we have to remember that consequence ranking and risk ranking are value judgements. We have to try to avoid the tendency (identified in a recent British government report on risk) for "experts throughout the decision making process to substitute their own value judgements for those of the stakeholders".

We recognise that the above discussion points out the limitations of Appendix G without offering an alternative. We encourage the profession to publish examples or partial examples of case histories where risk matrices have been used to assist decision making. Examples which have a track record of being accepted by clients/owners/regulators/those affected by the risk and, if quantified, explain how indicative probability was assessed will be particularly useful references.

4 SUMMARY

The quality of a landslide risk assessment has always been and remains primarily dependent on the extent that the hazards are recognised and understood. Where dealing with natural slopes this requires good geological and geomorphological skills and knowledge of landslide types and landslide behaviour, experience and judgement. Developing a sound geotechnical model and understanding failure mechanisms are of prime importance. This means that the quality of the assessment is usually related to the quality and experience of the people carrying out the work and the time and effort spent trying to understand the hazard.

Realistic quantification based on knowledge, insight and understanding of the particular site, the region and the hazards in question with open acknowledgement of the uncertainty and judgement involved helps the decision making progress. Unrealistic quantification based on poor understanding of the hazard will be meaningless and misleading, will not contribute to good decision-making and should be avoided.

The Landslip Paper appears to be primarily addressed to skilled geotechnical engineers and engineering geologists who have the experience and wisdom to apply the principles outlined. It is not in our view in a form that is readily assimilated by other potential audience categories, such as local government, developers, owners and the like. Once this debate has proceeded to a resolution it may be appropriate to prepare a separate document to clearly outline the recommended processes to clients.

The strengths of the Landslide Paper discussed above, in particular the application of risk management principles should help improve slope risk management. We look forward to hearing other opinions on the Landslide Paper and landslide risk management in Australia.

example reports

The following examples show how short, simple reports can be consistent with risk management principles and the Landslide Paper. It is not necessary to attach appendices to these reports although it may have been useful to include sketch maps and sections. Although the examples are simple they may be regarded as partly quantitative as they provide some indication of the likelihood of the hazard. Fuller attempts at quantification (sometimes using spreadsheets to manipulate assessed probabilities) although useful in some circumstances will not be required for the majority of jobs.

EXAMPLE 1 – ROCK FALLS
(COMMENT: This example illustrates each step involved in risk management.)

Mr Smith parks his car in an old quarry. Recently some rocks fell from the quarry face and landed near the car. Mr Smith asked us to advise him on the rock fall risk to his car.	(SCOPE DEFINITION)
The quarry face is 10 m high and slopes at 70°. The face consists of slightly weathered high strength sandstone. The bedding dips at 80° into the face and there are short joints orthogonal to bedding. No persistent defects were observed that could contribute to overall slope failure but toppling of individual blocks up to 0.5 m across is possible and has occurred in the past.	(HAZARD IDENTIFICATION)
The quarry face is about 30 years old. Rock falls on the quarry floor and discussion with local residents indicate that there are on average 3 to 10 rock falls a year (between 0.1 m and 0.5 m across). About 1 in 3 of the rock falls reach the car park (ie, 1 to 3 per year).	(LIKELIHOOD–QUANTIFIED)
If a rock fall reaches the car park while the car is parked there may be some damage to the front of car (eg, a broken headlight or a dent to the bonnet). The car is there about 50% of the time.	(CONSEQUENCES)
Mr Smith did not want to take the risk of having his car damaged. We	(RISK EVALUATION)

advised him that a fence would stop the rock falls reaching the car or he could park elsewhere. Barring down some obvious loose rocks would reduce (but not eliminate) the likelihood of rock falls. (RISK TREATMENT reducing the consequence, avoiding the risk, reducing the likelihood)

Mr Smith chose to park elsewhere. (CLIENT DECISION)

EXAMPLE 2 – temporary slopes
(COMMENT: This is a short letter but it includes all the steps discussed in the previous example.)

Jones Construction Pty Ltd has cut a vertical slope 3 m high in stiff clay at a building site in the city. There is a footpath and buried services at the top of the slope. The council asked us to advise them on the risk to the footpath and services.

We advised the council that (based on similar experience elsewhere) sudden failure of the slope could occur at anytime which could cause the footpath to collapse and disrupt the services. We also pointed out that the slope collapse could injure or kill anybody working below the slope.

The council immediately passed our advice on to Jones Construction Pty Ltd. Both parties agreed that the risk was unacceptable and temporary support for the slope was installed.

EXAMPLE 3 – ROAD CUTTINGS ON MAJOR HIGHWAY (PARTIAL EXAMPLE)
(COMMENT: For a single cut slope use of a risk matrix is probably unnecessary. However if there are many cuts the matrix will help rank risks and establish priorities for slope treatment.)

Table 1 is an example of a simple qualitative risk matrix. In this table there are four divisions of relative likelihood, three divisions of relative consequence and six levels of relative risk. As the main purpose of the matrix is to rank risk in order to help set priorities for risk treatment we have used numbers to describe the risk level. Injury and loss of life issues were also considered (not shown here).

LIKELIHOOD	**CONSEQUENCES**		
	Severe	**Moderate**	**Minor**
High	1	2	3
Medium	2	3	4
Low	3	4	5
Very Low	4	5	6
Numbers (1 to 6) are the risk levels			

TABLE 1 Qualitative risk assessment matrix

An example of a job involving landslide risk to a major highway using the Table 1 risk matrix is summarised on Table 2. In this example the client may decide to take no action for Cutting 14.

	WHAT MIGHT HAPPEN	**HOW LIKELY**	**WHAT DAMAGE**	**RISK RANKING**
A	**Small debris flow** Rock fragments and soil may be washed off slope during intense rain. Individual flows generally less than 1 m^3.	**High** Likely to occur several times in first winter after construction and during locally intense rain in subsequent years.	**Minor** Debris may block gutter. Soil, small rock fragments (generally less than 100 mm across) may reach carriageway	3
B	**Small rock fall** Toppling and wedge failures up to 3 m^3 on left hand side.	**Medium** Assuming good quality construction may occur on average every 3 to 10 years (based on performance of	**Minor** Most debris likely to be retained in the gutter. Some rock fragments may reach carriageway.	4

		existing cuts).		
C	**Large rock fall** Wedge failure up to 10 m^3 left hand side where persistent defects.	**Low** May occur due to stress release or mechanical weathering (eg, root jacking). Annual probability judged to be less than 0.1 (1 in 100).	**Moderate** Some debris likely to reach highway and may block one lane. Damage to vehicle could result in vehicles running into debris or debris hits vehicle.	4
D	**Overall collapse** Overall failure of whole slope on combination of persistent defects.	**Very low** No defects or combination of defects recognised that could contribute to such a failure. Annual probability judged to be less than 0.0001 (1 in 10000)	**Severe** Debris could block entire highway. Vehicles could be damaged and traffic disrupted for several days.	4

Table 2 Risk assessment for cutting 14

EXAMPLE 4 – HAZARD ZONING

(COMMENTS: The example uses some relative hazard terms, which were used in an existing hazard zoning scheme and development control system. The basis of the ranking terms was explained in the hazard zoning scheme and the council; other practitioners and residents had accepted their use.)

Mrs Brown wants to extend her house. The house is located on a steep slope (escarpment) underlain by weathered basalt of Tertiary age. Previous hazard zoning in the region has been used as a basis for development controls. The basalt escarpment has been zoned as a high hazard area. Existing landslides (mainly debris slides and slow debris flows in colluvium) affect about 10% of the basalt escarpment in the region and it was judged that new landslides could occur on some of the unfailed slopes. The local council usually only allows further development in the area if a site specific assessment results in a downgrading of the hazard rating.

There are 20 lots on the basalt escarpment where Mrs Brown lives. We observed recent or active landslides on six of these lots including one of the lots next to Mrs Brown's house. Local records and aerial photographs indicate that some of the landslides have moved several times in the previous 50 years. An investigation report by another consultant indicated that soil strength material occurred to a depth of at least 6 m at one of the landslides. The borelogs did not distinguish between colluvium, residual soil and extremely weathered basalt. The landslides occur on slopes of 15° and 22°.

The overall slope on Mrs Brown's property is about 25°. Site observations (under the house and in the cutting for the garage) revealed that slightly weathered basalt underlies residual soil at shallow depth. Behind the house (where the extension is planned) there were low outcrops of basalt. Long grass, shrubs and the effects of landscaping largely hid the outcrops. The outcrops were undisturbed. No open joints or infilled seams were observed.

On the basis of the site specific assessment we advised the council that it was very unlikely that a landslide would affect Mrs Brown's property. In accordance with criteria agreed with the council this resulted in a downgrading of the hazard rating to low. The council allowed Mrs Brown to extend her house.

(DISCUSSION: *The example shows that a purely statistical approach based on the occurrence of landslides on the basalt escarpment would have been misleading. The landslide hazard on Mrs Brown's property is very much less than the average hazard elsewhere on the escarpment. While it was not possible to quantify the probability of a landslide on Mrs Brown's property it is clearly very low.*

Ackowledgments

A number of senior geotechnical engineers and engineering geologists within Coffey have provided valuable input to this paper. Their contribution is gratefully acknowledged.