

Landslide risk management in Australia 2013 – status of resources available to practitioners

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Abstract

Through its national committee, the Australian Geomechanics Society (AGS) has long recognised the contribution of Landslide Risk Management (LRM) to the wellbeing of the Australian community. As part of a commitment since 1985, the Society recently undertook two initiatives: the 2011 LRM ‘Risky Roadshow’ seminar series conducted throughout the nation; and in 2012 the development of an interactive ‘Education Empowerment’ website specifically directed towards LRM.

The principle objective of these initiatives was to communicate and educate, and thereby empower, landslide practitioners and regulators with knowledge and tools required to implement best practice LRM, as well as to provide information to the general Australian populace regarding landslide risk. These educational resources and tools are based upon the internationally recognised LRM guidelines and commentaries published by AGS in 2000 and 2007. It was appropriate to build upon the guideline outcomes through these recent initiatives to benefit the Australian community.

This paper provides background to the current status of LRM throughout the nation and provides advice on the package of resources available to assist practitioners in conducting landslide risk assessments.

1 Introduction

The Australian Geomechanics Society (AGS) has developed technical papers and guidelines for the management of landslide risk associated with hillside development since 1985. The most recent activities have been: a nationwide ‘LRM Roadshow’ in 2011; which was accompanied by the ‘case histories’ edition of Australian Geomechanics; and the development of an interactive website for empowerment by practitioners, regulators and the general public in landslide risk management matters in 2011 and 2012.

2 How did we get to where we are in 2013?

An abridged history of Landslide Risk Management (LRM) is presented in Table 1, covering the period from 1985 to the present – see also Leventhal et al. (2012). Several significant milestone publications have been produced over the last 28 years during which LRM advanced within Australia (Figure 1), as well as across the globe.

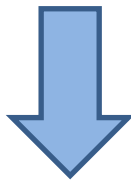
Table 1 Abridged history of the development of LRM within Australia. Briefly, the steps along the way in the development of a meaningful LRM framework for the nation have been as follows

Year	Formative Event
1985	(Walker et al., 1985), as an AGS sub-committee, developed a technical paper on hillside construction in Sydney (over a matter of several months). This has subsequently been recognised as likely to be the first international use of the term 'risk' in association with hillside development.
1993	Sub-committee re-convened to review and update the 1985 paper, and did so as per the conventional AGS approach at the time as volunteers in recognition of shortfalls in the earlier paper inter alia as a consequence of international recognition of risk assessment and risk management.
1997	Thredbo Landslide occurred on 30 July with 18 fatalities and brought to the attention of the Australian public the issues and challenges associated with landslides.
2000	AGS (2000) published (following a seven year gestation from 1993).
2000	Hardcopy of AGS (2000) distributed to each LGA and selected State, Territory and Commonwealth government departments throughout Australia.
2000	Coroner Hand determined his inquiry into the Thredbo landslide. Amongst many recommendations, Coroner Hand strongly recommended the adoption of AGS (2000) by those involved in regulation of hillside construction.
2002	Nationwide 'Risky Roadshow' to promulgate AGS (2000) to practitioners and regulators.
2004	Non-compulsory LRM Guideline developed as a reference document to the Building Code of Australia (BCA).
2005	International Conference on LRM held in Vancouver (Leventhal and Walker, 2005a), followed by distribution to the membership of AGS of modified conference paper (Leventhal and Walker, 2005b) explaining the status of LRM framework at that time and the strategies adopted for implementation of the principles of AGS (2000) into legislative framework.
2005	Landslide Taskforce convened, leading to development of AGS (2007) suite.
2005–2006	Development of proposed NPER (LRM) guideline with details provided to membership of AGS, published in Australian Geomechanics (AGS, 2006) and forwarded by AGS National Committee to the National Engineering Registration Board (NERB) for implementation in government areas where practitioners are required by legislation to demonstrate competence – unfortunately, still waiting for this outcome to be realised.
2006	International workshop on LRM held in Barcelona (by invitation) where Australia represented and contributed to workshop through its leadership in LRM issues. Led to international versions of AGS (2007a and b) published by JTC-1 in 2008.
2007	AGS (2007) published as a suite of guidelines that provide an update of AGS (2000) in recognition of shortcoming therein and improvements in international risk management.
2007	CDROM copy of the suite of AGS (2007) distributed to each LGA and selected state and commonwealth government departments throughout Australia.
2007	Landslide susceptibility issues addressed by revision of Pittwater LGA landslide policy within its building development protocols.
2007	Geoscience Australia published 'Natural Hazards in Australia', with Chapter 8 dealing with landslide risk management with major contribution from AGS.
2007	Hong Kong Landslide Disaster Management workshop on landslide disaster management where Australia represented and contributed to workshop through its leadership in LRM issues.
2008	International guideline and commentary for LRM in land use planning published in international technical press (Fell et al., 2008a and 2008b). These were both significantly based upon AGS (2007a and 2007b).

Year	Formative Event
2010–2011	Contribution to, and ongoing discussions with, Tasmanian Government in regard to provisions in state regional planning schemes for LRM.
2011	Risky Roadshow 2011 to promulgate AGS (2007) to both regulators and practitioners presented by AGS nationwide. Success of the Risky Roadshow 2011 across the nation demonstrated through 479 registrations and request to deliver seminar in Townsville.
2011–2012	Ongoing discussions with Queensland Department of Community Safety in regard to their updating of State Planning Policy 1/03, 'mitigating the adverse impacts of flood, bushfire and landslide', whilst particularly noting that Queensland is the only state government that has legislation that addresses LRM issues within its natural hazard management process.
2011–2012	Development of LRM EE website (launched 2012) to empower regulators, practitioners and the general public.

The suite of papers AGS (2007a to 2007e), known collectively as AGS (2007), is one of those publications. Therein, the methodology of LRM was presented. As depicted in Figure 2, the process builds sequentially, as it logically steps through:

- Risk analysis.
- Risk estimation.
- Risk assessment.
- Risk management.



The specific details of the LRM process are not repeated herein since they are provided within both AGS (2000) and its successor AGS (2007). In addition, presentations are contained within the LRM EE website, to which the reader should refer for guidance.



Figure 1 Significant milestones in technical contributions to LRM in Australia with 'headland' publications provided by the AGS. AGS (2000) and AGS (2007) are downloadable from both the AGS website and the LRM Education Empowerment (LRM EE) website (which is linked from the AGS website)

Figure 2 illustrates that the framework is linked from one step to the next, and develops progressively through the steps.

The technical tools that are at hand for regulators, practitioners, and the general public, to assist in performing, managing and understanding the process include:

1. AGS (2007a and 2007b) – landslide zoning and commentary.
2. AGS (2007c and 2007d) – practice note and commentary.
3. AGS (2007e) – Australian GeoGuides.

These tools can be accessed from both the AGS website and the LRM EE websites, and can be read at or downloaded from both.

Some of the contributory technical papers, guidelines and external processes supporting the LRM process that lead to the LRM framework are illustrated in Figure 3, where the interrelationship of the guidelines, regulator policies and technical papers is depicted diagrammatically.

An example of a particular risk matrix that is recommended by the AGS for qualitative Landslide Risk estimation of loss-of-property is provided in Figure 4. Risk estimation for loss-of-life should be conducted in a quantitative manner to permit assessment through comparison with international and national criteria (which are based upon quantitative measures such as acceptable or tolerable loss-of-life per annum) – specific references and appropriate target risk levels are provided in Section 3.5 of AGS (2007c) and Section C8.2 of AGS (2007d) for discussion on, and background to, this as well as similar discussion in Section 4.2 of AGS (2000) on the logic of this recommendation.

LANDSLIDE RISK ASSESSMENT & MANAGEMENT

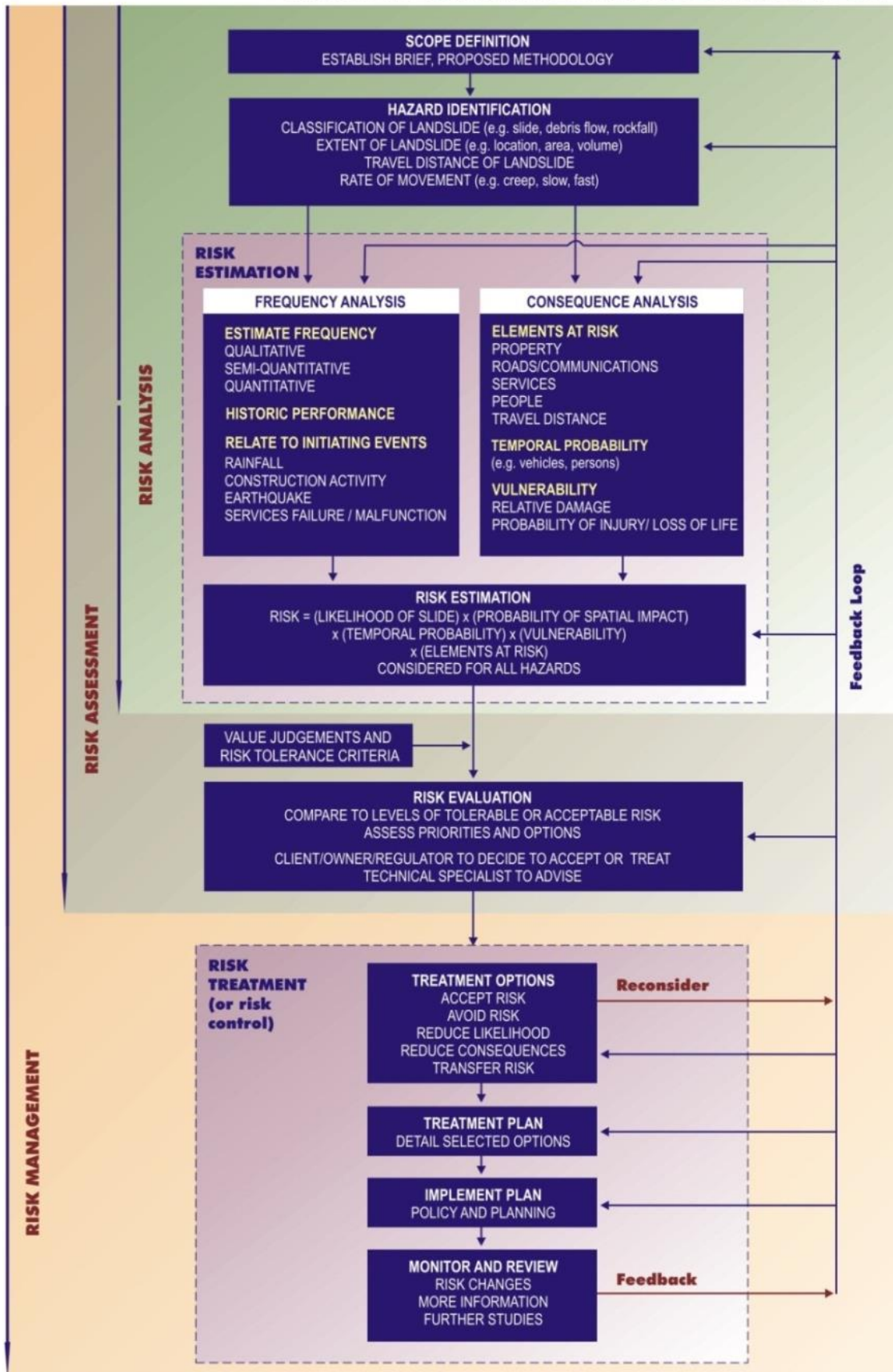


Figure 2 Depiction of the process of LRM

DEVELOPMENT OF SYSTEMATIC AND DEFENSIBLE LANDSLIDE RISK MANAGEMENT PROCESS

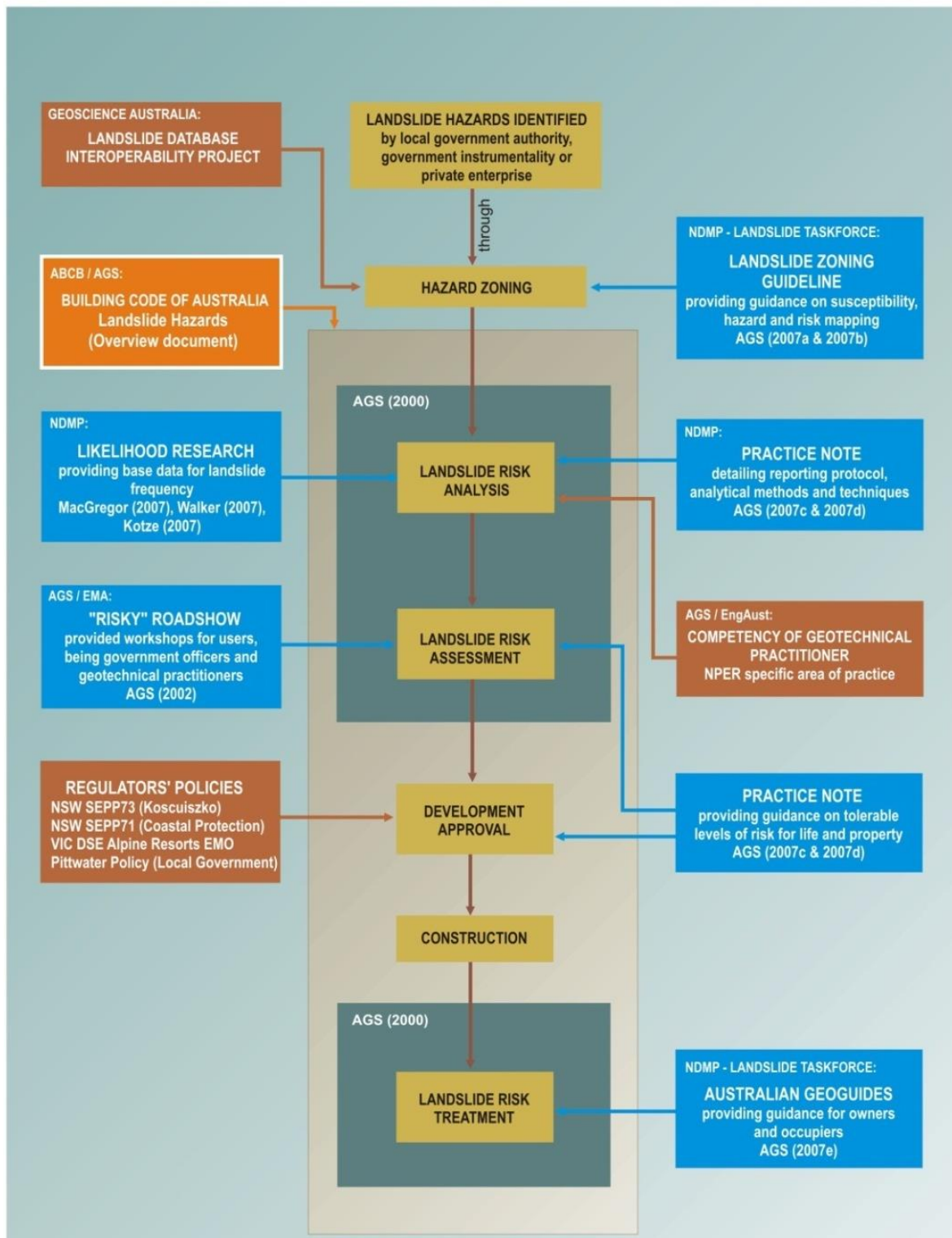


Figure 3 Depiction of the LRM framework illustrating both the framework and the interaction with activities and resources. (Reference should be made to Figure 2 for details of the central spine of the above framework)

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT
QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	Notional Boundary					
10 ⁻¹	5x10 ⁻²	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 ⁻²		100 years		200 years	The event will probably occur under adverse conditions over the design life.	LIKELY
10 ⁻³	5x10 ⁻³	1000 years	2000 years		The event could occur under adverse conditions over the design life.	POSSIBLE
10 ⁻⁴		10,000 years		20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY
10 ⁻⁵	5x10 ⁻⁵	100,000 years	200,000 years		The event is conceivable but only under exceptional circumstances over the design life.	RARE
10 ⁻⁶		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not vice versa.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	Notional Boundary			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%		Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	40%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.
 (3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.
 (4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A - ALMOST CERTAIN	10 ⁻¹	VH	VH	VH	H	M or L (5)
B - LIKELY	10 ⁻²	VH	VH	H	M	L
C - POSSIBLE	10 ⁻³	VH	H	M	M	VL
D - UNLIKELY	10 ⁻⁴	H	M	L	L	VL
E - RARE	10 ⁻⁵	M	L	L	VL	VL
F - BARELY CREDIBLE	10 ⁻⁶	L	VL	VL	VL	VL

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
 (6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level	Example Implications (7)
VH VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

Figure 4 Risk estimation matrix recommended by AGS (2007) for qualitative LRM

The authors specifically draw to the attention of the reader several key items to take-away from the work that has been done over the last three decades:

- A significant library of tools are available to the practitioner to conduct defensible LRM.
- Landslide risk assessments are complex and must be conducted by experienced personnel who are familiar with the methodology, both in the process and the limitations of the appraisal methods.
- An intimate understanding of the geological and geomorphologic processes relevant to a particular project being appraised is a fundamental requirement in the conduct of landslide risk analyses.
- Several methods are available to conduct landslide risk analyses ranging from qualitative to quantitative, though risk of loss-of-life should be conducted employing semi-quantitative or quantitative techniques so that assessment can be linked with internationally recognised criteria.
- A simple understanding of risk, in an engineering context, is that:
 - Risk = likelihood (of an event) × consequence (should that event occur).
 - It is important that engineering reporting does not adopt colloquial usage of the word ‘risk’ which usually means likelihood in a qualitative sense since a hidden (high) consequence is included in the context of this usage. Engineering usage should include an appraisal of both likelihood and consequence for appropriate usage of the term ‘risk’.
- The estimation of likelihood is usually the most difficult part of the risk estimation exercise. Guidance on methods to effect defensible estimates is provided in the Risky Roadshow 2011, for which reference can be made through the LRM EE website.

3 LRM project status in Australia 2013

The status of the most recent Landslide Risk Management activities is:

- The Risky Roadshow 2011 seminar series was successfully conducted nation-wide.
- A special edition of Australian Geomechanics (V46N2 2011) was issued to accompany the Risky Roadshow 2011, within which was presented case histories in the application and use of LRM from throughout the nation. Specific case histories were identified as relevant to each of the Roadshow venues.
- The interactive Education Empowerment website development task was launched just prior to the 11th Australia-New Zealand Geomechanics Conference 2012. It had funding assistance under the National Disaster Mitigation Program (NDMP). The outcomes of the Roadshow 2011 were provided gratis to the project by AGS.

3.1 Nation-wide seminar series (Risky Roadshow, 2011)

The seminar series (see Figure 5) was conducted in five tranches:

- (1) Melbourne – Tuesday, 8 March 2011.
- (1) Hobart – Thursday, 10 March 2011.
- (2) Adelaide – Tuesday, 5 April 2011.
- (2) Perth – Thursday, 7 April 2011.
- (3) Wollongong – Tuesday, 10 May 2001.
- (3) Sydney – Wednesday, 11 May 2011.

- (4) Brisbane – Tuesday, 31 June 2011.
- (4) Newcastle – Wednesday, 1 June 2011.
- (5) Townsville – Monday, 20 June 2011.

The initial planning was for the first four tranches to be conducted but at the request of Townsville Council and local practitioners, an additional tranche at Townsville was conducted.

Each seminar occupied a full day – the morning session focused on regulator requirements and the afternoon session focused on practitioner needs.

The national Roadshow received strong response from practitioners, and variable response from regulators. There were 479 registrations throughout the nation. Feedback forms were distributed at each venue to gauge audience response and to improve the presentations. On average, about 43% of registrants provided feedback. It is fair to say that the feedback was very positive as to the quality and relevance of the presentations. The presentations benefited from this feedback and were progressively modified throughout the program. (The presentations can be viewed through the interactive LRM EE website – see below).

The seminars were presented face-to-face by Bruce Walker and Tony Miner, with support of those activities provided by other members of the LRM sub-committee, Tony Phillips, John Carter and Andrew Leventhal.

3.2 Case histories

Case histories were an important facet of the seminar series and interactive website. The case-histories were published within Australian Geomechanics V46N2 June 2011 (AGS, 2011), as a stand-alone volume recording the use of AGS (2007) in landslide risk management throughout the nation. The case histories were subject to review for consistency by the members of the sub-committee. Selected case histories were presented within the seminars, usually being selected for relevance to the locale of the specific venue, and the case histories are linked to the interactive website. The case histories represent Australia-wide experience, and were published in Australian Geomechanics V46 N1 (AGS, 2011) – see Figure 6.



Figure 5 LRM Roadshow venues with sponsor identification

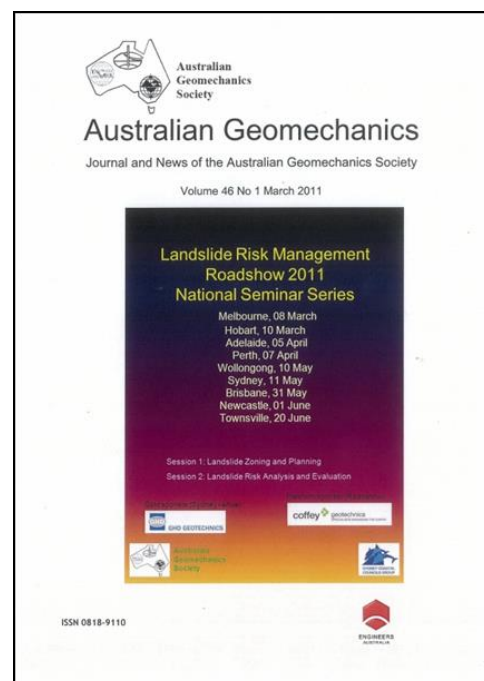


Figure 6 Cover of AG V46 N1 which contained LRM case histories from around the nation

3.3 Education empowerment interactive website

An interactive web-based site was developed to provide LRM education empowerment facilities, particularly based upon Australian experience (Leventhal et al., 2012). The website provides ready access to the facility for practitioners, regulators and the Australian public, as well as accommodating international interest.

Visitors to the site are introduced to LRM through a quiz based process with interactive links to education modules – see a screen-shot of the home page of the website in Figure 7. The outcomes from the 2011 National Roadshow seminars, including the final presentation material and a full copy of the presentations by the speakers, are available interactively. (The seminar that was recorded at Sydney is the basis of the presentation that can be viewed piece-by-piece from the interactive website).

The LRM EE website includes:

- Three web site access points: i) regulators, ii) practitioners, and iii) public.
- Top 10 education elements for each of the streams.
- Links to an entire LRM Risky Roadshow seminar presentation that includes bite-size elements of each of the face-to-face presentations throughout the day of the seminar (based upon the seminar presented in Sydney) with the full complement of PowerPoint slides.

The site is hosted and linked through the AGS website. This affords AGS the ability to update and modify the site as may be appropriate in the future.

The site has attracted over 200 visitors per month (August to December 2012), with visitors from 10 countries.

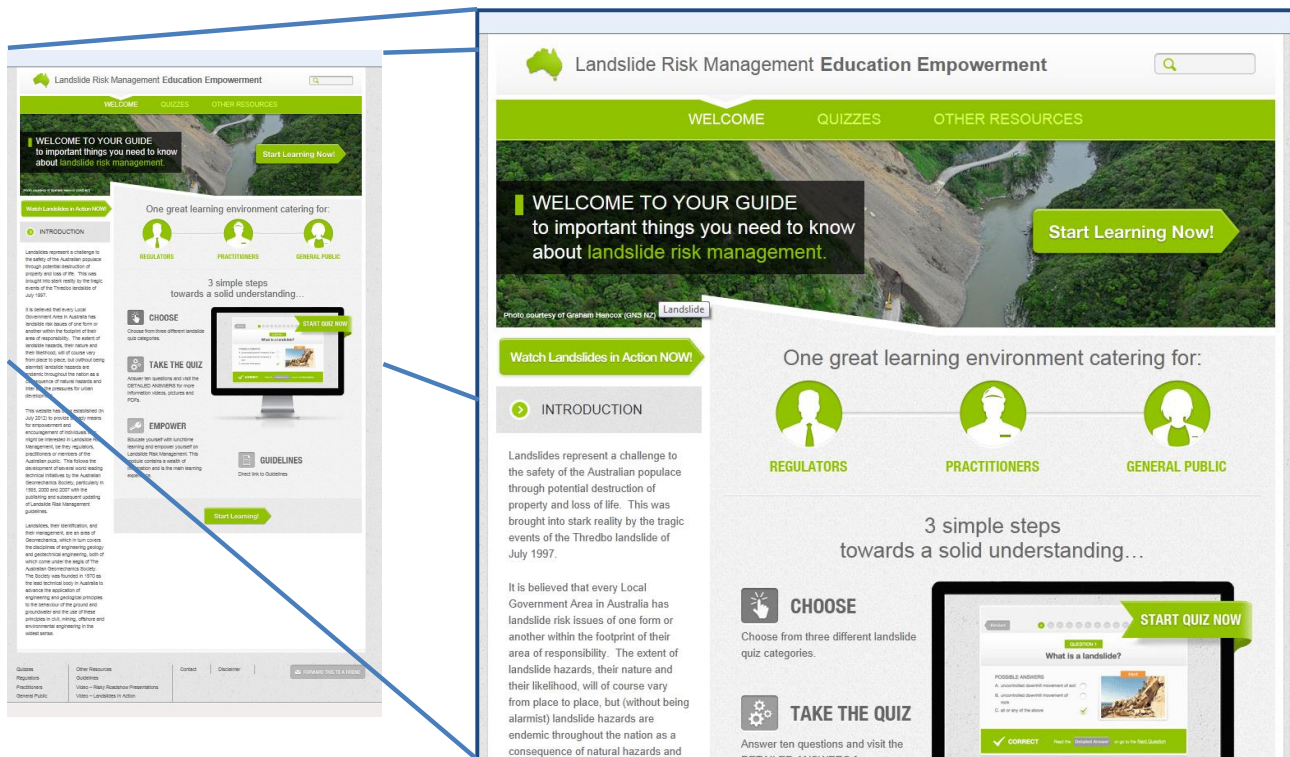


Figure 7 Screen shot of the LRM EE website, accessible through the AGS website www.australiangeomechanics.org

3.4 Other activities

At State Government level, the Department of Community Safety (DCS) of the Queensland Government approached AGS to contribute to the review of their State Planning Policy addressing natural hazards (bushfire, flood and landslide). (It is noted that Queensland is currently the only state with a policy that addresses landslide management (QLD Govt, 2003)). The DCS was establishing a SPP 1/03 Review Landslide Advisory Group, and sought the involvement of AGS in this review. At the time of writing (April 2013), this activity is awaiting to be advanced by the Queensland State Government.

At the Local Government level, the authors are aware of the Local Government Areas and Regulators listed in Table 2 and Table 3 that have adopted LRM (with reference to AGS 2000 or AGS 2007) within natural hazard management policies. It is noted that the interest raised by the LRM Roadshow 2011 offers an opportunity for recognition of the LRM processes (as embedded within AGS (2007)) for incorporation within legislation throughout the nation. The intent of this would be to simplify procedures – through adoption of one protocol nation-wide, rather than a protocol per local government area. This is a potential opportunity for AGS to provide benefit to the broader Australian society, in line with the AGS constitution.

Table 2 Summary of NSW regulators' policies in relation to LRM and geotechnical issues as an example of the type of policies in place (as of 2011)

Regulator	Policy Title	Date	Comment
A: Landslide Risk Management			
NSW Department Infrastructure, Planning and Natural Resources	Kosciusko Alpine Resorts Geotechnical Policy	Undated	The first policy was based on AGS2000. First published in about mid-2003 and after advice from/consultation with GHD-Longmac.
Pittwater Council	Geotechnical Risk Management Policy 2009	2009	First adopted as an 'Interim Policy' in June 2003, with amended versions since then. Based on Kosciusko but with refinements.
Wollongong City Council	Wollongong City Geotechnical Control Plan	12 July 2006	Similar to Pittwater, but with 'local' variations. Supersedes an earlier version from 1990s or earlier as based on Warringah Shire concept.
Gosford City Council	Gosford city Council Development Control Plan No 163 – 'Geotechnical Requirements for Development Applications'	29 February 2003	Prescriptive for report content.
Warringah Shire Council	Draft Local Environment Plan	2009	Draft LEP includes a 'landslide risk map' prepared by Coffey 2006 based on slope angle, and a Geotechnical report addressing LRM to AGS2000 is required for some zones.
Manly Council	Development Control Plan for Landslip and Subsidence 2001	Issued 2001, updated March 2003	Based on AGS2000 and zoning maps prepared by Coffey Geosciences in 1999, using slope angle predominantly.
Baulkham Hills Shire Council	Not sure if a formal policy in general		There is a policy for getting an independent peer review appointed by Council from a panel of peer reviewers for areas of known 'landslide hazard' usually being areas identified by a development suitability zoning study completed in late 1970s.

Regulator	Policy Title	Date	Comment
Wingecarribee Shire (Bowral area)	DCP44 – Requirements for the erection of buildings	Draft 2006, Final/adopted?	Requires 'Geotechnical Risk Assessment' report by suitably qualified consultant. Lists information to be provided. 'Risk' basis not defined.
Ryde City Council	Not sure		Not sure how extensive but is based on zoning maps prepared by Coffey.
Lake Macquarie Shire Council	Not sure		Not sure how extensive but is based on zoning maps prepared by Coffey.
RTA (now Roads and Marine Services)	Guide to Slope Risk Analysis Version 3.1	NSW 2001	RTA system is based on AGS2000 but tailored to suit roads, using a qualitative assessment scheme based on quantitative evaluation of terminology. Primarily considers risk to life, but risk to property also covered.
RailCorp	Geotechnical Risk Assessment and Hazard Management Guidelines TMC401, Version 1.1	Issued December 2009	Qualitative 'ranking' system, appears based on AGS2000, but tailored to suit rail, and primarily based on risk to life.
B: Geotechnical Issues			
Woollahra Municipal Council	Guidelines for preparation of Geotechnical and Hydrogeological Reports	Adopted 9 September 2002	Aimed at issues associated with: development in the alluvial areas with high groundwater levels; temporary excavation support; and effect of vibrations such as from rock excavation.
Ku-ring-gai Council		About 2007	Similar to Woollahra Council.
Mosman Municipal Council	Significant Rock Faces and Retaining Walls Policy	3 April 2007	Limited as per title.
North Sydney Council	Unsure whether formalised		
Clarence River/Maclean Shire Council			Council has considered adopting policy similar to Pittwater.

Table 3 State based LRM regulator policies

State	Regulator	Scheme
Queensland	State Government through Department of Community Safety	Queensland remains the only state in Australia with a state-wide policy for LRM.
	Gold Coast City Council, Townsville, Cairns McKay, Ipswich, Sunshine Coast Regional Council	Constraints Codes and Overlays.
South Australia	Goyder Regional Council, Peterborough	No formal planning instrument, though identified under natural hazards risk assessment.
Tasmania	West Tamar, City of Launceston, City of Hobart, Sullivans Cove, Glenorchy, Kentish, Municipality of George Town	Some provision within Planning Schemes (but variable).
Victoria	Yarra Ranges, Colac Otway Shire, Mornington, Alpine resorts, Baw Baw, Bass, Sth Gippsland, Murrindindi, Bayside, Frankston, Cardinia, Moreland	Erosion Management Overlay.
Western Australia	Stirling	Reference made within planning scheme.

3.5 Applicability to slope instability in open cut mining and civil engineering

There are a number of natural hazards that are relevant to urban, residential, rural and undeveloped property throughout Australia. These include flooding, bush fire, coastal processes, severe storms, flooding, landslides, earthquake and tsunami (Middlemann, 2007). The AGS (2007) suite of guidelines deals with landslide susceptibility, hazard and risk.

Slope instability occurs in many parts of urban and rural Australia (in every local government area across the nation, in one form or the other, in some area of responsibility) and often impacts on housing, roads, railways and other development, and the environment. This has been recognised by many local government councils and government authorities, and thus has led to the requirement by many local government councils for instability assessments prior to permitting building development.

The intent of the LRM guidelines, as expounded in AGS (2000), is:

- To establish uniform terminology.
- To define a general framework for landslide risk management.
- To provide guidance on methods which should be used to conduct the risk analysis.
- To provide information on acceptable and tolerable risks for loss-of-life.

In addition, the aim has been the application widely of LRM to slope engineering using risk assessment processes. This covers both civil engineering and mining situations.

With this pre-amble, it follows that the methodology and principles presented in AGS 2007 can be applied to both civil engineering and mining projects. LRM is one of the many tools available to the designer, constructor, authority and mine operator – for example, the NSW Roads and Traffic Authority (RTA) as it was, Roads and Maritime Services (RMS) as it is now, recognises the risk management approach for their inventory of cuttings and fills, of which there are many thousands throughout the state.

The LRM methodology enables a rationale to be documented for engineering assessment of uncertainties, but with the practitioner's best estimate at that time. By documenting the rationale and factual basis, a defensible assessment is provided which can be readily updated as more data comes to hand. This is implicit in the 'feedback loop' shown on the right hand side of Figure 2. This approach has been recognised

as an issue in mine slope engineering (e.g. as presented by Barry McMahon in the E.H. Davis lecture of 1985 (McMahon, 1985)), not least-wise as a consequence of uncertainty.

Although AGS 2007 is written in the context of ‘landslides’ which are usually thought of as naturally occurring events, the definition of landslide in AGS 2007 (AGS 2007c Appendix B; ‘the term landslide denotes ‘the movement of a mass of rock, debris or earth down a slope’’) is sufficiently general that slopes constructed or formed during civil engineering works (or similar) or by mining, can and should, be included. This would also include temporary works cases. Completion of deterministic analyses (such as Factor of Safety by limit equilibrium analysis) can be used to form part of the methodology for the assessment. Use of sensitivity analyses can assist with evaluation of the likelihood of the event (failure scenario) being considered. Use can also be made of software designed to derive a probability of failure, for example as discussed by Hurley et al. (2012).

Consideration would have to be given to use of appropriate risk criteria for the cases being considered. There is a rational argument for adoption of Tolerable Risk Criteria for mine pit slopes given the management usually associated with such mining, and perhaps for temporary works provided monitoring and reaction plans are included. With appropriate risk management procedures, substantially higher risks may also be justified and accepted by all parties involved. The important aspect here is that the risk assessment, including assumptions and limitations, and risk management requirements are properly documented, discussed and understood and accepted by all parties associated with the assessment process. In the mining context, consequences can include loss of production (such as management of the large scale failures of the Chuquicamata mine east slope of February 1969 and the Bingham Canyon pit slope of April 2013), and business reputation. These two examples appear to have recognised such consequences and hence demonstrate the value of hazard identification, monitoring and implementation of action plans with trigger levels under a risk management program. It is also a reasonable expectation that there are likely to be more funds available for a focused landslide risk appraisal in the mining context.

Though the authors consider that such a process as the one advocated provides a defensible case, should the assessment be found to be incorrect there will inevitably be subsequent scrutiny of a ‘failure event’. Practitioners must be cognisant of the test for negligence (what a similarly skilled practitioner at the same time and same place would have reasonably done and/or concluded) and should document the uncertainties identified and the assumptions made (and/or tested).

All parties need input, though frequently in a civil engineering sense the regulator is ‘the last-man-standing’ in the context of risk transfer, and therefore often will provide the acceptable risk limits applicable to the community it represents – be it home owners, occupants, road users, or the general public. In the mining context, the mine manager is where the ‘buck stops’, though mine regulators may be involved in the approval process.

It should also be noted that risk avoidance is a valid risk management option.

4 Conclusions

A framework for LRM for the nation exists, and tools and training means are available to practitioners. Additionally, guidance is available for regulators for implementation of LRM policies and guidance is also available to the general public. The methodology and principles of LRM can be used for both civil engineering and mining projects provided the rationale is properly documented, understood and accepted by all parties involved.

The success of the 2011 nation-wide LRM Roadshow highlighted the interest and relevance to the general community, regulators and practitioners alike. Significant gains have been made, but on-going work and development, including increased public awareness, recognition by other engineering disciplines of the benefits of cross fertilisation, on-going training and education, together with consistent planning policy across the nation, is still needed.

The national committee of the AGS has determined that the objective of the LRM sub-committee, in delivering a functional LRM framework to the nation, has been achieved, and accordingly this paper is likely to be the final technical update under the current aegis from the national committee.

References

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