Landslide risk management for Australia

Andrew Leventhal and Geoff Withycombe overview Australia's world-class landslide risk management guidelines.

Abstract

The Australian Geomechanics Society published a suite of guidelines in 2007 that are recognised nationally and internationally as world-leading practice. The three documents are supplemented by two commentaries to collectively provide advice to the Australian public, government regulators responsible for the management of landslide risk, and geotechnical practitioners who conduct assessments of landslide risk. As a consequence, these contribute to safer communities and therefore a reduction in the costs of disasters.

This paper discusses the development of the guidelines and their applications in land use planning, risk assessment, risk management and the transfer of knowledge to practitioners, regulators and the broader Australian public. The paper also provides a brief overview of the status of Landslide Risk Management in Australia.

The Landslide Zoning guideline for land use planning has been the template for an international version which was published in late 2008 jointly by the three international technical societies representing geomechanics interests worldwide.

Introduction

The application of Landslide Risk Management in Australia has advanced in several significant ways over the last two and a half decades and is now embedded in regulation in New South Wales and Victoria in a number of Local Government Areas (these particular areas being where residential development is susceptible to landslides) and State Government instrumentalities in each state.

Background to landslide activities

The Australian Geomechanics Society (AGS) (Walker et al., 1985) introduced the concept of risk into hillside residential development. Indeed, it is fair to say that this was the introduction of the concept of risk into the residential development (through the building approval process) within Australia. Pleasingly, it was rapidly accepted and adopted by Local Government Areas within critical metropolitan areas of Sydney and Melbourne.

Fell (1995) presented a keynote address on the style, mechanics and distribution of landslides within southeastern Australia. Excluding mining activity, he concluded that: most landslides in Australia are in soil and weathered rock reflecting the deeply weathered profile over much of the country; most landsliding is restricted to a few geological environments; the vast majority of sliding is reactivation of existing natural instability; many soils are fissured, and shear strengths between residual and fully softened are appropriate; many sedimentary rock and tertiary sediment slides occur where low residual strength soils and rocks are present; much instability is rainfall related, and landslide activity has increased through clearing of vegetation.

Cyclic weather patterns can produce much of the landslide activity. For example, principally as a result of a La Nina-driven extended period of rainfall, from 1988 to 1990 widespread instability affected significant lengths of the Main Northern Rail Line and over 100 sites on the South Coast Rail Line in NSW - these latter requiring closure of the Line in 1989 to affect treatment of landslide issues. In addition, precedent rainfall of 0.5m to 0.6m depths over periods of 3 to 6 months have been recognised by many researchers and practitioners as triggers for deep-seated landsliding, particularly in the NSW coastal Illawarra region, and presumably similarly elsewhere throughout the nation. On the other hand, short intense rainfall events tend to produce surface erosion and debris flow landslides, as was the case in Wollongong in 1998.

In terms of awareness, most of the Australian populace would be familiar with the landslide in the Kosciusko ski resort village of Thredbo in 1997 that demolished two accommodation lodges and resulted in the death of 18 people. The landslide involved the rapid collapse of a fill embankment that had previously supported the Alpine Way above the village. The fatalities were the subject of a Coronial Inquiry (Hand, 2000) who determined that the failure was intimately linked to saturation of the failed mass through rupture of a water supply pipeline.

Photo courtesy of NSW Police.

This landslide of 30 July 1997 at Thredbo claimed 18 lives as a consequence of the destruction of two ski lodges by a failure of the road embankment fill of the Alipne Way.

In 2000, the AGS published a technical paper on landslide risk management concepts and guidelines (AGS, 2000). Since it had been recognized that the 1985 advice (Walker et al., 1985) had become outdated through improvements within the practice of risk assessment and risk management, both within Australia and internationally. Updated advice to geotechnical practitioners and regulators was provided in AGS (2000). Within his determination of the Thredbo Inquiry, Coroner Hand (*ibid*) recommended "that the Building Code of Australia and any local code dealing with planning, development and building approval procedures, be reviewed and, if necessary, amended to include directions which require relevant consent authorities to take into account and to consider the application of proper hillside building practices and geotechnical considerations when assessing and planning urban communities in hillside environments". He further recommended that "AGS (2000) be taken into account in undertaking this exercise".

An outline of the framework for landslide risk management process is provided in Figure 1.

Most landslide risk assessments for domestic development could be conducted then in accordance with the principles and guidelines within AGS (2000). Such assessments were frequently performed as qualitative assessments for risk to property, with a quantitative (or perhaps more correctly, semi-quantitative) assessment of risk to life. Some Local Government Councils operate with acceptable risk levels of "Moderate" for property and 1 x 10^{-5} per annum (alternatively, using scientific notation, as 1E-5pa) for risk to life within the domestic development setting, whilst others set acceptable risk levels of "Low" or "Very Low" for property and 1E-6pa for risk to life.

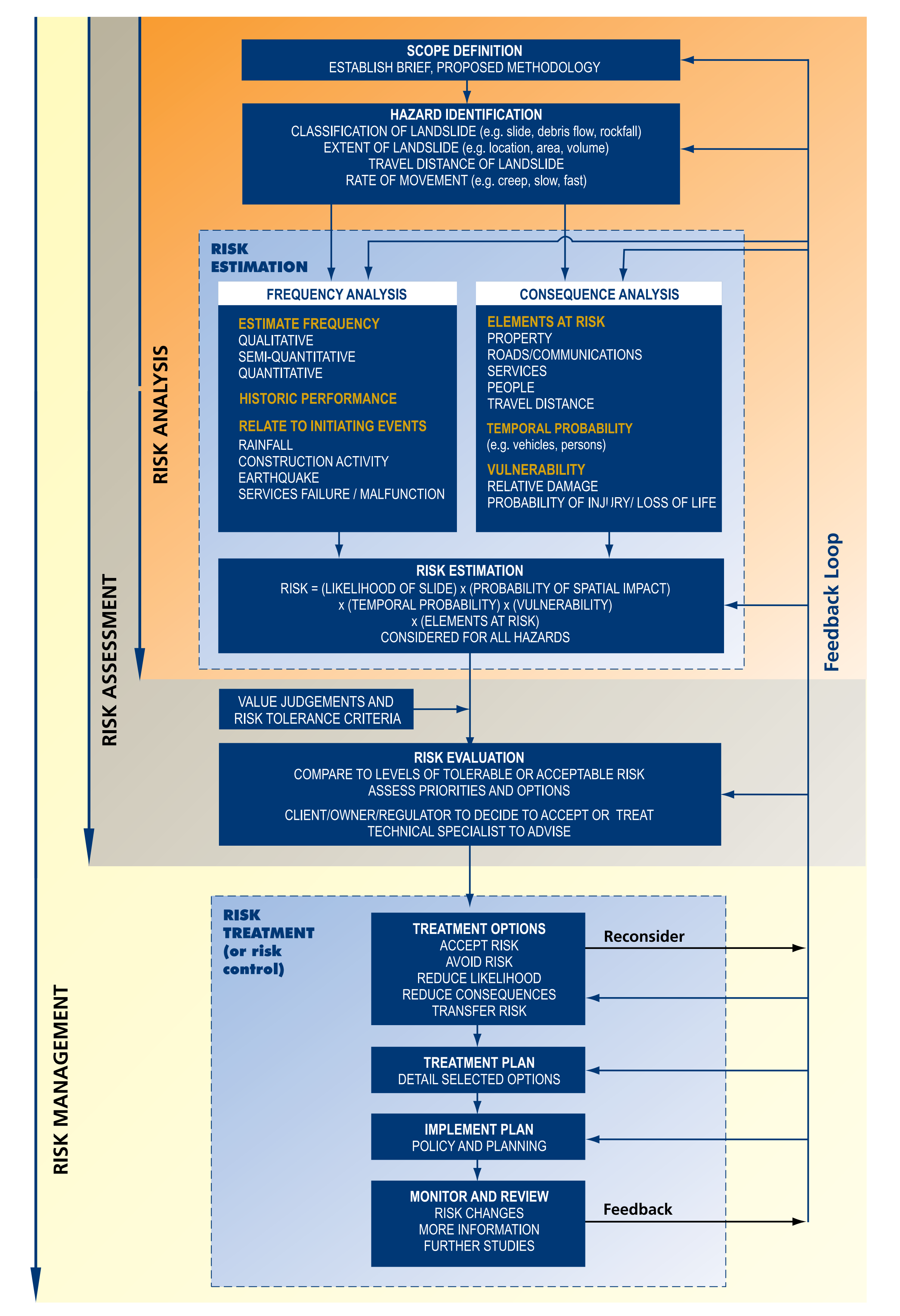
AGS (2000) has been integrated within planning instruments by Local Government Areas such as: Pittwater Council (in the northern beaches area of metropolitan Sydney), Wollongong City Council (in the Illawarra area on the south coast of NSW), Shire of Yarra Ranges (outer metropolitan Melbourne in Victoria); Colac-Otway (in rural Victoria); and State Government instrumentalities such as the NSW Dept of Planning for Kosciuszko National Park (which covers the alpine ski resorts of New South Wales – including Thredbo) and the Victorian Alpine Resorts.

A discussion of the status of adoption of Landslide Risk Management around the Australian Governments is provided within the appendix of Leventhal & Kotze (2008). Therein, it is noted that:

(a) Nationally. For residential development, the Building Code of Australia requires every site to be classified in accordance with AS2870, which is an Australian Standard that deals with the identification and management of reactive clays – not landslide risk. AS2870 permits classification of a site as Class P for circumstances not covered by identified reactive clay scenarios. Such Class P situations, whilst perhaps mainly intended for sites with a significant presence of fill or soft soils, could also include landslide hazard and/or landslide risk. This classification to cover the presence of landslide hazard, however, is perhaps relatively tenuous, and to the authors' knowledge has not been tested.

    The guideline for landslide hazards (ABCB, 2006), developed by AGS for the Australian Building Codes Board (ABCB), is a companion document to the Building Code of Australia and has introduced the concept of risk management for landslide issues. Currently, this guideline is an advisory (rather than mandatory) document.

Figure 1. Landslide Risk Assessment and Management. Flowchart demonstrating the Landslide Risk Management Process.



(b) The regulations for each State and Territory are quite varied, few recognise the issue of Landslide Risk Management and there is intermittent reference only to AGS (2000).

Quantitative landslide risk assessments have been conducted for particular major infrastructure projects - such as the Bethungra Spiral on the Main Southern Rail Line between Sydney and Melbourne (Moon et al. 1996) and for Lawrence Hargrave Drive (Wilson et al., 2005). The scale of the projects has permitted undertaking of these quantitative studies. A study by MacGregor et al. (2007) provided data to assist performance of quantitative assessments at a domestic residential development scale for geomorphic settings comparable to Pittwater Local Government Area.

In 1998, a major storm event led to 140 separate landslide events (fortunately with no attributed fatalities) throughout the Illawarra Region on the South Coast of NSW - i.e. within the Local Government Area of Wollongong City Council. The commendable actions during this emergency were recognised by an award from Emergency Management Australia. An outcome of the actions undertaken during the event was the development of a Landslide Action Plan (Wollongong City Council, 1999).

Key Points:

- The Thredbo landslide, with its unfortunate loss of life, led to a wide appreciation throughout Australia of the hazards to both life and property posed by landslides.
- Regulators were put on notice by the Coroner of the Thredbo landslide of the desirability to include assessment of landslide hazards in the building development process in hillside areas prone to instability.
- Tools such as the guidelines produced by the Australian Geomechanics Society exist to assist regulators and practitioners in this process.

Landslide risk management guidelines and commentaries

The development of three guidelines and their commentaries was funded under the 2004-2005 funding round of the National Disaster Mitigation Program. The application was sponsored by the Sydney Coastal Councils Group. The outcomes were three guidelines and two commentaries on Landslide Risk Management (See Table 1).

Table 1: List of guidelines and commentaries in Australian Geomechanics V42(1).

Guideline Title	Abbreviated Title	Reference	Intended Users
"Guideline for landslide susceptibility, hazard and risk zoning for land use planning", Australian Geomechanics, Vol 42 No 1, March 2007.	Landslide Zoning Guideline	AGS (2007a)	Regulators, Geotechnical Practitioners
"Commentary on guideline for landslide susceptibility, hazard and risk zoning for land use planning", Australian Geomechanics, Vol 42 No 1, March 2007.	Commentary on Landslide Zoning Guideline	AGS (2007b)	As above
"Practice Note guidelines for landslide risk management", Australian Geomechanics, Vol 42 No 1, March 2007.	Practice Note 2007	AGS (2007c)	Geotechnical Practitioners, Regulators
"Commentary on Practice Note guidelines for landslide risk management', Australian Geomechanics, Vol 42 No 1, March 2007.	Practice Note Commentary	AGS (2007d)	As above
"Australian GeoGuides for slope management and maintenance", Australian Geomechanics, Vol 42 No 1, March 2007.	Australian GeoGuides	AGS (2007e).	General Public, Regulators, Geotechnical Practitioners

The Australian Geomechanics Journal.

Copies of the guidelines and commentaries are available for download from the Australian Geomechanics Society's website: www.australiangeomechanics.org [from the home page use the link "Download the Landslide Risk Management documents", and then download from AGS (2007)]. Note that copies of AGS (2000) are also downloadable from the same webpage.

The **Landslide Zoning Guideline** provides guidance in the methods of Landslide Zoning to government regulators (officers of local government and state government instrumentalities) and geotechnical practitioners. Such characterisation contributes to the planning process in areas of landslide hazard. The associated **Commentary** provides background to the guideline.

The **Practice Note Guideline** and **Commentary** provide guidance both to practitioners in the performance of project specific landslide risk assessment and management, and also to government officers in interpretation of the reports they receive. The Practice Note can be used an external reference document for legislative requirements and supersedes the recognised industry "standard" on Landslide Risk Management in Australia – AGS (2000). AGS (2000) remains as a complementary commentary and reference document. The Practice Note provides a means for uniformity in the quality of assessment and reporting and, as such, will promote confidence in the planning and risk management process regarding landslide hazards.

The Practice Note provides:

i. a revised risk to property matrix to address shortcomings identified in usage – see Appendices B, C and D herein;

ii. recommendation for the adoption of criteria for tolerable risk to life;

iii. the introduction of Importance Levels and linked criteria for tolerable risk to property – see Appendices A and C herein;

iv. the introduction of a suite of model sign-off forms, linked to recommendations from risk assessments, to improve the linkages between assessment, design and construction. This provides a management tool in the Landslide Risk Management process;

v. further explanation of the risk equation and method of calculation, together with further examples and references; and

vi. guidance on the contents of a Landslide Risk Management report.

The **Australian GeoGuides** for slope management and maintenance provide owners, occupiers and the broader public with guidance on management and maintenance of properties subject to landslide hazard.

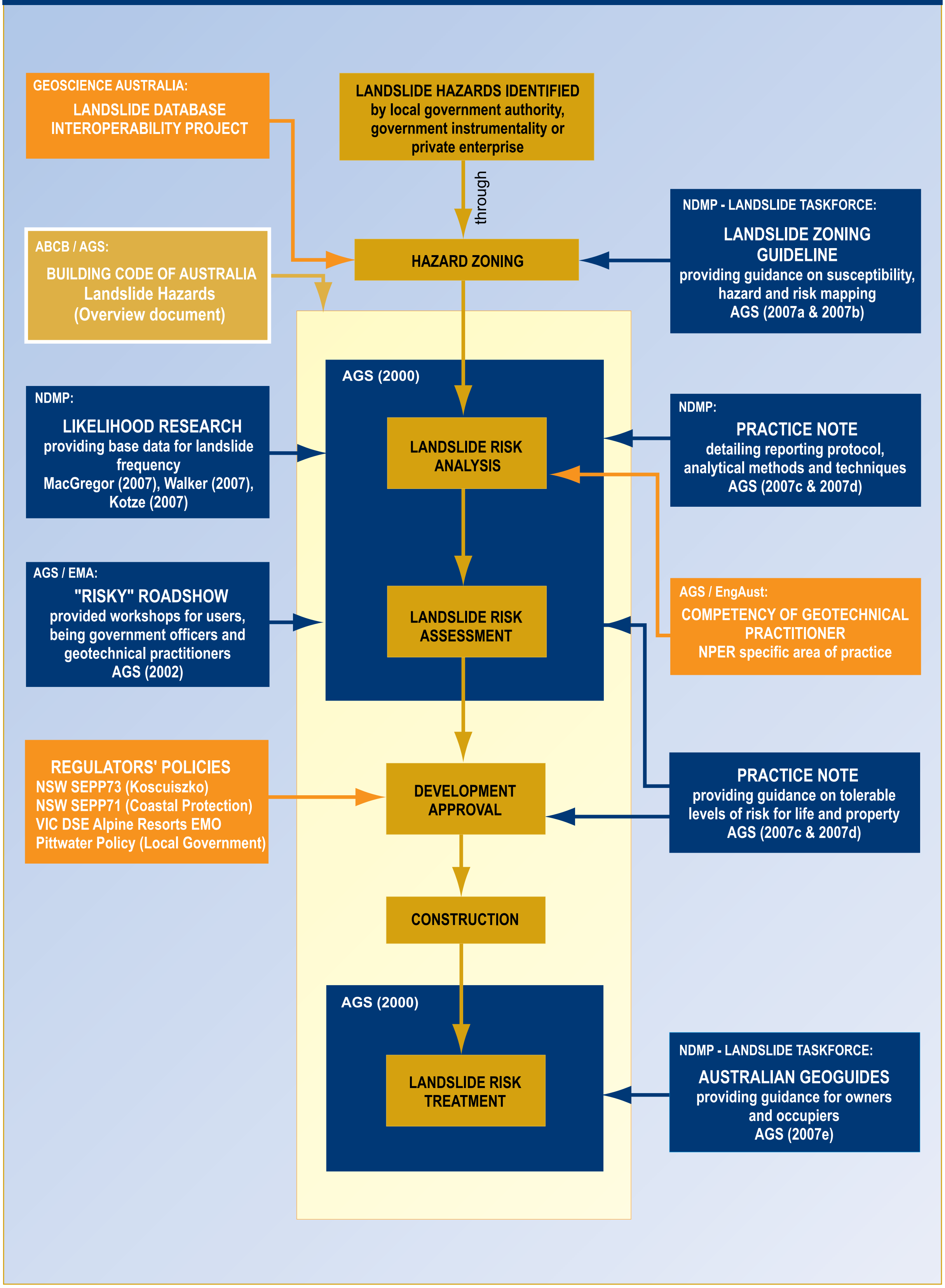
Project Outcomes

The suite of guidelines and the Australian GeoGuides benefit the general community and Local Government regulators through achieving safer, more sustainable, communities in relation to their exposure to landslide risk. The guidelines also reduce risk to the community through improved planning and slope management practices – key requisites of the Natural Disaster Mitigation Program funding. These guidelines link with the risk management practices presented in AGS (2000) [as enhanced by the Practice Note], and the Building Code of Australia Guideline (ABCB, 2006).

This suite of aforementioned guidelines contributes significantly to completion of the Landslide Risk Management framework for Australia described in Leventhal (2007) and Leventhal et al. (2007). A diagram depicting the Landslide Risk Management framework, and the manner that the suite of project outcomes interacts with the framework is provided at Figure 2. A project sheet that briefly explains this National Disaster Mitigation Program-funded project and its outcomes is available from the Sydney Coastal Councils Group.

As part of an undertaking to notify relevant parties of the outcomes of the project, CD ROMs containing copies of the guidelines and commentaries were distributed to each Local Government Council throughout Australia.

Figure 2. Development of systematic and defensible landslide risk management process.



It is noted that the use of Importance Levels, as defined in the Building Code of Australia, has enabled a move from strictly residential domestic development to a wider range of structures - e.g. from buildings which need to withstand a rapid onset natural emergency (such as cyclone shelters) to those that do not (perhaps such as farmyard structures). An explanation of Importance Levels and a copy of the discussion contained within the Practice Note Commentary (AGS 2007d) are provided herein in Appendix A.

Target risk levels

Philosophically, there are a number of parties involved in setting acceptable or tolerable risk levels – namely: the owner of the property in question; the occupier of the property; members of the public that may be impacted in the event of a landslide; and the regulator responsible for approval of the development. Pragmatically, however, the regulator is the party who must determine the risk levels given its responsibility to manage hazards at the local community level. In most instances, that will be the Council of a Local Government Area or a State instrumentality.

In AGS (2007c & 2007d), adoption of *tolerable risk* criteria was recommended.

The AGS suggests that for most development in existing urban areas criteria based on Tolerable Risks levels are applicable because of the trade-off between the risks, the benefits of development and the cost of risk mitigation. Tolerable risk levels for property are one class higher than provided in Appendix C (e.g. *Moderate* where *Low* is acceptable). Consideration should be given by regulators to adopting Tolerable risk to property for *Existing Slope* and *Existing Development* situations in a similar vein to the recommended differentiation for risk to life. The recommended *Tolerable loss of life* risk values for the person *most at risk* for different situations are shown in Table 1 of the Practice Note (and are included in Appendix D herein).

It is recommended in AGS (2007d) that risks be assessed only for the *person most at risk*, and not for the *average person* as suggested in AGS (2000). ANCOLD (2003) reported that the *person most at risk* is always controlled, and that *average risks* were difficult to define and determine.

The recommended values are higher for *existing slopes* than for *new slopes*. This is in keeping with ANCOLD (2003) and general literature on risk tolerability which indicates that persons tolerate risks from existing hazards more than for newly constructed ones. Where development modifies an existing slope, the *new slope* criteria should be applied in accordance with the definitions given for the situation in Table 1 of the Practice Note.

Regulators may decide to apply *acceptable risk* criteria for high consequence cases, such as schools, hospitals and emergency services in recognition of the importance of these structures and as a way of covering societal risk concerns. This is also reflected in the recommended criteria for property loss for different Importance Levels of structures.

The community may tolerate higher risks from natural hazards than man-made hazards (IUGS 1997).
Such a consideration by the regulator may result in some natural hazards being tolerated in the face of exceptional expenditure to reduce the risk to tolerable levels.
An example of this may be the risks associated with boulder falls from natural cliff lines in a bush reserve adjacent to existing residential development.
If the regulator and potentially affected owners were not aware of the circumstances, then prior to the landslide risk assessment they would have been *uninformed*. Adoption of such tolerable risks should be made on the basis of an appropriate landslide risk assessment and appraisal of the risk mitigation options.

It is recognised in AGS (2007d) that the recommended criteria are higher than required by NSW Department of Planning (2002). However, those criteria apply to development such as chemical plants which can be sited in locations where the low risks can be achieved. Urban development is within designated areas, the land owner has no option but to develop at the nominated site (if practical) so the trade-off between risk levels, cost of development and risk mitigation have to be considered. This is a similar situation to dams and is part of the reason ANCOLD have adopted tolerable risk criteria.

Societal Risk may be measured against the ANCOLD (2003) recommended values as given in Figure 4 of Leroi et al. (2005). Reference should be made to ANCOLD (2003) when carrying out such assessments.

International activities

The Landslide Zoning guideline and its Commentary provided the template for international versions. Published in the *International Journal of Engineering Geology*, the international guideline and commentary were modified from the AGS version under the aegis of the Joint Technical Committee JTC-1 on Landslides and Engineered Slopes (Fell et al., 2008 & 2008a, on behalf of JTC-1). JTC-1 exists through the collaboration of the three international bodies within the geotechnical arena - the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), the International Society for Rock Mechanics (ISRM) and the International Association of Engineering Geologist (IAEG). The international adoption of the Australian-developed guideline and commentary reflects well upon the pedigree of the documents.

Other current activities in Australia

The Department of Mineral Resources, Tasmania, is one of the few, if not the only, state government instrumentalities in Australia involved in landslide susceptibility mapping on a regional scale (1:25,000). (The mapping program of Wollongong City is a Local Government undertaking). Mineral Resources Tasmania, in its undertaking to provide an assessment of landslide susceptibility of major urban areas, has continued its mapping programme with the publishing of susceptibility mapping for Launceston, which complements earlier work around Hobart. Deterministic GIS modeling techniques were employed to produce predictive susceptibility maps. Mazengarb (2007) reported the status of this work, which aligns with the guideline AGS (2007a). The outcomes are being used by relevant Councils, to identify the need for detailed assessment in response to development applications.

Mapping of landslide susceptibility and hazard mapping has continued within the Wollongong city boundaries through a combination of support from the Wollongong City Council (local government) and university sponsored research. This undertaking previously was also supported by NSW State Government road and rail transport instrumentalities. Flentje (2007) reports trialling an extension of the program into the broader Sydney Basin through the use of GIS methods.

Landslide hazard and susceptibility mapping was completed for Local Government land use planning within Pittwater Council's area of responsibility in the northern beaches area of metropolitan Sydney in 2007 (Leventhal & Kotze, 2007). Landslide likelihood is one of the most important input parameters to Landslide Risk Analysis, and research into this in the Pittwater area was also reported this year (MacGregor et al., 2007). This was supported by the work on rainfall analysis (Walker, 2007) and on recorded rockfall frequency (Kotze, 2007).

Geoscience Australia (2007) undertook an assessment of risk analysis requirements for natural hazards throughout Australia. The study was conducted for the Council of Australian Governments and covers tropical cyclones, flood, severe storm, bushfire, earthquake, tsunami and landslide hazards. As a consequence of the development of the practice of landslide risk management within Australia, a significant contribution was made to the landslide chapter by members of the AGS Landslide Taskforce. The landslide chapter deals with: hazard identification; costs of landslides; potential influence of climate change; roles and responsibilities; and discusses information gaps. The information gaps identified include: the development of landslide inventories (a matter being addressed by Geoscience Australia through its Landslide Inventory Interoperability Project); support for regional susceptibility mapping; and support of the need for systematic and standardized landslide risk assessments throughout the nation (as is now possible through AGS 2007c for example). The "Natural Hazards in Australia" project (Geoscience Australia, *ibid.*) promotes the AGS (2007) suite to government at all levels throughout Australia.

Key Points:

- A framework for landslide risk management which can be adopted throughout Australia has been developed by the Australian Geomechanics Society.
- Regulators such as the Councils of local government areas are the bodies appropriate to manage the landslide risk management process, with policy and resource support from other levels of government.
- The determination of acceptable or tolerable risk to life and risk to property must reside with the regulator, who acts in the best interests of its local community.
- There is an overall national benefit for a universal approach to landslide risk management, thereby providing surety to all those involved in the process that best practice is in operation.

Recognition of the contribution by AGS to landslide risk management

The value of the guidelines to the Australian populace has been recognised by the Civil College of Engineers Australia through the award of the Warren Medal in 2007 to the principal authors of the guidelines. [The Warren Medal is awarded annually by the Civil College of Engineers Australia for the best paper in the discipline of civil engineering.]

In November 2008, the suite of guidelines was recognised with High Commendation in the Australian Safer Communities Awards 2008. These Awards are sponsored by Emergency Management Australia (EMA).

The judges noted that:

> "The award is for a suite of six world-leading papers on landslide risk management published in March 2007 and for the development of a framework for Landslide Risk Management in Australia. The papers are intended to be of value to regulators, geotechnical

practitioners and the general public interested in land use planning. Copies of the papers have been widely distributed to local government authorities and state and territory instrumentalities across the country. The two specific elements of the national disaster mitigation project were Landslide Hazard Zoning and Slope Management. The framework is anticipated to have significant implications for national disaster mitigation, as recognised by state and federal governments."

Key Point:

- The landslide risk management framework and guidelines developed by the Australian Geomechanics Society has been recognised both nationally and internationally as world-leading practice.

Future work

Future tasks include:

(i) Modifications to regulations within existing legislation are required to incorporate the AGS (2007) suite. This will initially involve Pittwater Council, Wollongong City Council, Kosciuszko National Park, Victorian Alpine resorts erosion management plan (under which landslide risk management is covered) and the Shire of Yarra Ranges and Shire of Colac-Otway in Victoria. Both Pittwater and Yarra Ranges are in the process of implementation.

(ii) Formulation of a Development Control Plan-format for the performance of Landslide Risk Management within the building approval process, and particularly for it to be suited to the NSW Planning standard template which is under government consideration.

(iii) Introduction of an Australia-wide / state-wide profroma for conducting Landslide Risk Management for the advantage of both regulators and practitioners, and hence of benefit to the general public. Whilst recognizing that there are landslide hazards of one form or the other in virtually every local government area of Australia, the aim is for one process rather than several hundred variations.

(iv) Continued transfer of information through education empowerment of landslide risk management to regulators and pracftitioners, involving workshops and teaching materials (pending funding).

(v) Developments of landslide inventory, susceptibility and hazard zoning through demonstration projects to determine the viability of these tools to assist regulators (pending funding).

Conclusions

A major initiative completed in 2007 was to develop a suite of guidelines and commentaries (AGS 2007). The generation of these risk management tools provides the means for the understanding and application of landslide risk management throughout the nation for the benefit of the Australia populace.

This paper provides the summary of the state of Landslide Risk Management within Australia.

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Appendix A
IMPORTANCE LEVEL

Extract from Building Code of Australia (as reported in Appendix A of AGS 2007c)

Importance Level – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason per se of the Importance Level.

Importance Level of Structure	Explanation	Examples (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
1	Buildings or structures generally presenting a low risk to life and property (including other property).	Farm buildings. Isolated minor storage facilities. Minor temporary facilities. Towers in rural situations.
2	Buildings and structures not covered by Importance Levels 1, 3 or 4.	Low-rise residential construction. Buildings and facilities below the limits set for Importance Level 3.
3	Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds.	Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250. Buildings and facilities for colleges or adult education facilities with a capacity greater than 500. Health care facilities with a capacity of 50 or more residents but no having surgery or emergency treatment facilities. Jails and detention facilities. Any occupancy with an occupant load greater than 5,000. Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4. Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.
4	Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials.	Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgery facilities. Emergency service facilities: fire, rescue, police station and emergency vehicle garages. Utilities required as back-up for buildings and facilities of Importance Level 4. Designated emergency shelters. Designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries.

(from BCA Guidelines)

Appendix B

Extract from AGS (2007c, Appendix C) –
An example of qualitative landslide risk assessment matrix.

See Appendix C of AGS (2007c) for details of the assessment of likelihood and consequence for landslide hazards, together with description of the risk levels.

Qualitative Risk Analysis Matrix – Level of Risk to Property.

LIKELIHOOD			**CONSEQUENCES TO PROPERTY (with indicative approximate cost of proportional damage)**				
DESCRIPTOR		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:

1. Refer to Appendix C (AGS, 2007c) for examples of qualitative measures of likelihood and consequences which contribute to that table, and descriptions of risk level implications that are outputs of the table.
2. Cell A5 may be subdivided such that a consequence of less than 0.1% is Low Risk.
3. When considering a risk assessment, it must be clearly stated whether it is for existing conditions or with risk control measures (that may not necessarily be implemented at the time of assessment).

Appendix C

Extract from AGS (2007d)

Copy of Table C10 from Commentary to AGS LRM Practice Note 2007

AGS suggested Acceptable Qualitative Risk to Property Criteria.

Importance Level of Structure (Note 1)	Suggested Upper Limit of Acceptable Qualitative Risk to Property (Note 2)	
	Existing Slope (Note 3) / Existing Development (Note 4)	New Constructed Slope (Note 5) / New Development (Note 6) / Existing Landslide (Note 7)
1	Moderate	Moderate
2	Low	Low
3	Low	Low
4	Very Low	Very Low

Notes:

1. Refer to Appendix A, Practice Note (AGS 2007c)
2. Based on Appendix C, Practice Note (AGS 2007c)
3. "Existing Slopes" in this context are slopes that are not part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
4. "Existing Development" includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
5. "New Constructed Slope" includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).
6. "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0 m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope / Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.
7. "Existing Landslides" have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of "public safety".

Appendix D

Recommendations for acceptable and tolerable risk in AGS (2007c) and AGS (2007d) for importance Level 2 Structures and for the person-most-at-risk.

Situation	Acceptable Risk		Tolerable Risk	
	Risk to Property	Risk to Life	Risk to Property	Risk to Life
New slopes, new development or existing landslide	LOW or VERY LOW	10^{-6} per annum	MODERATE, LOW or VERY LOW	10^{-5} per annum
Existing slopes or existing development	LOW or VERY LOW	10^{-5} per annum	MODERATE, LOW or VERY LOW	10^{-4} per annum

Note 1: AGS (2007c) Table 1 for risk to life, AGS (2007d) Table C10 for risk to property.

Note 2: For other than single residential dwellings of Importance Level 2, societal risk criteria may apply.

This table combines recommendations from AGS (2007c) and AGS (2007d). The table refers to structures of Importance Level 2 potentially at risk from landslides related to both (i) new slopes or new development and (ii) existing landslides.

Risk values identified as "tolerable" include an implication of an order of magnitude higher risk than an "acceptable" level, this being a trade-off between the risks, the benefits of development and the cost of risk mitigation borne by society.

About the authors

Andrew Leventhal was National Chairman of the Australian Geomechanics Society (AGS) in 2002 & 2003 and is currently responsible to the AGS National Committee for matters associated with landslide risk management. This is in the context of a voluntary position in the professional society. He held the office of President of the Sydney Division of Engineers Australia in 200 & also 2001. He is a Senior Principal Geotechnical Engineer with GHD Geotechnics.

Geoff Withycombe is the Executive Officer of the Sydney Coastal Council Group (SCCG). The Sydney Coastal Councils Group was established in 1989 to promote co-ordination between member councils on environmental and natural resource management issues relating to the sustainable management of the urban coastal environment. The Group consists of 15 councils adjacent to Sydney marine and estuarine environments and associated waterways.

Andrew may be contacted at Andrew.Leventhal@ghd.com.au