Some landslide risk zoning schemes in use in Eastern Australia and their application

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ABSTRACT Landslide risk zoning schemes in use in Eastern Australia have developed with mixed terminology to describe the probability and the consequences of landsliding. The terms "hazard" and "risk" have been interchanged. The zoning schemes have also been influenced by the lack of insurance to cover damage due to landsliding, and have generally made inadequate allowance for the situation where loss of life is possible. It is suggested that some standardisation of terms and approach is needed, and steps taken to introduce landslide insurance.

1 INTRODUCTION

Since 1984, the author has been involved in the development of several landslide risk zoning schemes in New South Wales and Victoria. These are:

- Joint author of the Australian Geomechanics Society "Classification of Risk of Slope Instability" (Walker et al, 1985)
- Project leader for geotechnical zoning studies of the Lake Macquarie City Council area (Newcastle, NSW) in 1984 (Coffey and Partners, 1984, Fell and Flentje, 1991 and Flentje, 1991).
- Review consultant (with D.H. Stapledon) of landslip risk assessment, Mooroolbark (in the Shire of Lillydale), Victoria (Coffey and Partners, 1987)
- Review consultant (with M. Ervin) for classification of risk of slope instability in the Shire of Lillydale, Victoria (Coffey Partners International, 1990)
- Project team member for development of guidelines for management of lands subject to landsliding in the Richmond and Tweed River catchments, NSW (MacGregor, McManus and Fell, 1990 and MacGregor and McManus, 1992)
- Review consultant (with D.H. Stapledon) for classification of landslide risk due to debris flow in the Montrose area (Shire of Lillydale), Victoria.

This involvement has seen a development of the approach taken to landslide risk zoning in these studies, all of which (except the Richmond-Tweed study) are in urban areas, and involve relatively large scale mapping. It has also highlighted the confusion in terminology used in such studies, the influence of the user (often a council) on the scheme, and the influence of liability and insurance matters.

The paper sets out to share some of these experiences, and discusses future directions such schemes might take.

2 DEFINITIONS OF HAZARD AND RISK

The terms "hazard" and "risk" are poorly defined in landslide zoning schemes. This is possibly forseeable, because when one refers to the Oxford Pocket Dictionary one finds the following:

	Hazard	—	chance, danger, risk
and	Risk	—	chance of bad consequences, exposure to chance of injury or loss

ie. that the terms are interchangeable.

The concepts of hazard and risk are well developed in dam engineering, and are used in selection of design floods for spillways and other features. ANCOLD (1983) give the following definitions:

Hazard	—	relates to the potential damage or loss of life in the event of a dam failure, or misoperation of the dam or its facilities
Risk	—	relates to an evaluation of the probability of failure accuracy.

ANCOLD (1983) gives three grades of hazard which are based on US Corp of Engineers criteria:

"Low" hazard
Rural areas where no residences are threatened and economic loss downstream would be minimal, such as farm buildings, limited damage to agricultural land, minor roads, etc

"Significant" hazard
Rural areas where a few residences would be threatened and economic loss would be appreciable, including possible damage to secondary roads, minor railways, or relatively important public utilities

"High" hazard
Where more than a few residences would be threatened, or where loss of human life is liable to be more than a few persons, or where economic loss would be appreciable, such as possible serious damage to extensive community, industrial, commercial or agricultural facilities, highways, primary roads, main railways, important public utilities.

Varnes (1984), in a UNESCO review of principles and practice of landslide hazard zonation, cautions that the terms hazard and risk do not have universally similar meanings and proposes that the United Nations Organisation UNDRO (Office of the United Nations Disaster Relief Coordinator) and UNESCO definitions be used. These are:

Natural hazard (H) means the probability of occurrence within a specified period of time and within a given area of a potentially damaging phenomenon

Vulnerability (V) means the degree of loss to a given element or set of elements at risk (see below) resulting from the occurrence of a natural phenomenon of a given magnitude. It is expressed on a scale from 0 (no damage) to 1 (total loss)

Specific risk (R_s) means the expected degree of loss due particular natural phenomenon. It may be expressed by the product of H times V

Elements at risk (E) means the population, properties, economic activities including public services, etc at risk in a given area

Total risk (R_t) means the expected number of lives lost, persons injured, damage to property, or disruption of economic activity due to a particular natural phenomenon, and is therefore the product of specific risk (R_s) and elements at risk (E). Thus:

$$R_t = (E)(R_s) = (E)(H \times V)$$

The terms hazard and risk are interchanged compared to the ANCOLD (1983) definitions. Varnes does not, however, define what low, medium, high etc total risk would be.

Hunt (1984), who discusses rating of hazard and risk in some detail, gives the following definitions:

Hazard — refers to the slope failure itself in terms of its potential magnitude and probability of occurrence

Risk — refers to the consequences of failure on human activities.

These are consistent with Varnes (1984) definitions.

Magnitude is further defined in terms of the volume of material which may fail, the velocity of movement during failure, and the land area which may be affected. Risk is related to property damage and potential for loss of life. The degree of hazard and risk is classified as shown in Table 1.

For the purposes of discussion, the Hunt definitions will be adopted for the remainder of this paper.

3 AUSTRALIAN LANDSLIDE ZONING SCHEMES

In 1985 the Sydney Group of the Australian Geomechanics Society established a subcommittee to develop a risk classification for slope instability in the Sydney basin, and to provide guidelines for hillside construction. The classification was not a zoning scheme, but it was expected that most practitioners would adopt the risk classification when working in the Sydney basin (including Sydney, Newcastle, Gosford, Wollongong). Table 2 presents the risk classification.

It should be noted that:

- the classification was developed for the whole of the Sydney basin, which includes a diverse range

Table 1. Landslide hazard and risk degree (Hunt, 1984).

HAZARD DEGREE	RISK DEGREE
No Hazard: A slope is not likely to undergo failure under any forseeable circumstances.	The rating basis for risk is the type of project and the consequences of failure. No Risk: The slope failure will not affect human activities.
Low Hazard: A slope may undergo total failure (as compared with partial failure) under extremely adverse conditions which have a low probability of occurrence (for examples, a 1000-year storm or a high-magnitude earthquake in an area of low seismicity), or the potential failure volume and area affected are small even though the probability of occurrence is high.	Low Risk: An inconvenience easily corrected, not directly endangering lives or property, such as a single block of rock of small size causing blockage of a small portion of roadway and easily avoided and removed.
Moderate Hazard: A slope probably will fail under severe conditions which can be expected to occur at some future time, and a relatively large volume of material is likely to be involved. Movement will be relatively slow and the area affected will include the failure zone and a limited zone downslope (moderate displacement).	Moderate Risk: A more severe inconvenience, corrected with some effort, but not usually directly endangering lives or structures when it occurs, such as a debris slide entering one lane of a roadway and causing partial closure for a brief period until it is removed.
High Hazard: A slope is almost certain to undergo total failure in the near future under normal adverse conditions and will involve a large to very large volume of materials, or a slope may fail under severe conditions (moderate probability), but the potential volume and area affected are enormous, and the velocity of movement very high.	High Risk: Complete loss of a roadway or important structure, or complete closure of a roadway for some period of time, but lives are not necessarily endangered during the failure. Very High Risk: Lives are endangered at the time of failure by, for example, the destruction of inhabited structures or a railroad when there is no time for a warning.

Table 2. Australian Geomechanics Society Sydney Group classification of risk of slope instability (Walker et al, 1985).

RISK OF INSTABILITY	EXPLANATION	IMPLICATIONS FOR DEVELOPMENT
VERY HIGH	Evidence of active or past landslips or rockface failure; extensive instability may occur.	Unsuitable for development unless major geotechnical work can satisfactorily improve the stability. Extensive geotechnical investigation necessary. Risk after development may be higher than usually accepted.
HIGH	Evidence of active soil creep or minor slips or rockface instability; significant instability may occur during and after extreme climatic conditions.	Development restrictions and/or geotechnical works required. Geotechnical investigation necessary. Risk after development may be higher than usually accepted.
MEDIUM	Evidence of possible soil creep or a steep soil covered slope; significant instability can be expected if the development does not have due regard for the site conditions.	Development restrictions may be required. Engineering practices suitable to hillside construction necessary. Geotechnical investigation may be needed. Risk after development generally no higher than usually accepted.
LOW	No evidence of instability observed; instability not expected unless major site changes occur.	Good engineering practices suitable for hillside construction required. Risk after development normally acceptable.
VERY LOW	Typically shallow soil cover with flat to gently sloping topography.	Good engineering practices should be followed.

Table 3. Lake Macquarie City Council geotechnical zoning (Fell and Flentje, 1991).

ZONE	DESCRIPTION
NEWCASTLE COAL MEASURE SEQUENCE	
ZONE T1 >15° slopes COAL & CLAYSTONES	Steep slopes, greater than 15°, with known coal seams and/or tuffaceous claystones present that may affect the site.
ZONE T2 >15° slopes NO COAL or CLAYSTONES	Steep slopes, greater than 15°, without known coal seams and/or tuffaceous claystones present that may affect the site.
ZONE T3 5° - 15° slopes COAL & CLAYSTONES	Moderate slopes, between 5° and 15°, with known coal seams and/or tuffaceous claystones present that may affect the site.
ZONE T4 5° - 15° NO COAL or CLAYSTONES	Moderate slopes, usually between 5° and 15°, without known coal seams and/or claystones present that may affect the site.
ZONE T5 <5° slopes COAL & CLAYSTONE	Gentle slopes, less than 5°, with known coal seams and/or tuffaceous claystones present that are not expected to affect the site.
NARRABEEN GROUP	
ZONE T1A >15° slopes CLAYSTONES	Steep slopes, greater than 15°, with known or inferred claystones-shale intervals present that may affect the site.
ZONE T2A >15° slopes NO CLAYSTONES	Steep slopes, greater than 15°, without known or inferred claystones-shale intervals present that may affect the site.
ZONE T3A 5° - 15° slopes CLAYSTONES	Moderate to gentle slopes, between 5° and 15°, with known or inferred claystones-shale intervals present that may affect the site.

of sedimentary rock environments, including shale, sandstone, interbedded siltstone and sandstone, and coal measure rocks

- the "risk" classification explanations are a mixture of hazard, ie. probability of occurrence, risk, ie. the implications of failure, and method, ie. statements of evidence of instability
- there is no mention of potential for loss of life.

The AGS classification has been widely accepted by practitioners and councils. Some practitioners have modified the classification to remove the "very low" classification, partly motivated by concern of professional liability. The classification has been instrumental in educating councils to the concept of risk classification, and has led to a reduction in demands to pronounce a site "stable", with all the associated legal implications.

3.2 Lake Macquarie City Council geotechnical zoning

In 1984 Lake Macquarie City Council implemented a geotechnical zoning scheme, based on a study by Coffey and Partners (1984). This followed several landslide incidents, which resulted in significant cost to Council in investigations and remedial works. The zoning was revised in 1991 (Fell and Flentje, 1991 and Flentje, 1991) to account for additional geotechnical information available from 600 consultant's reports to Council, and elsewhere prepared from 1984 to 1991. The Council area is underlain by the Newcastle Coal Measures and Narrabeen group sedimentary rocks. Much of the instability in the area relates to the presence of tuffaceous claystone, and/or coal seams. Table 3 summarizes the recommended 1991 zoning classifications.

It has been recommended that the AGS risk classification be adopted for all sites requiring assessment. Assessment will be required

- for all zones when new subdivisions are being developed
- for zones T1, T2, T3, T1A, T2A and T3A when building applications and minor subdivisions are being assessed. This is necessary because conditions alter locally and require individual assessment.

For zone T4, Council officer's inspection only is recommended, with good construction practice for hillside development to be followed (based on the table in Walker et al but with some quantification on depths of cuts and heights of fills). Unless major site changes are proposed, zone T5 is to be developed following "normal engineering practices". As part of the 1991 study detailed geological maps at 1:4000 scale (some 1:10,000 and 1:25,000) have been prepared, to show the location of coal seams. These will be made available to practitioners, and will be a valuable guide to areas of potential instability, given the strong relationship between instability and the presence of claystone and nearby coal seams. The slope boundaries were delineated on experience of instability, but it should be noted that large scale instability is often associated with low slope angles — 6° to 10°.

The LMCC geotechnical zoning is not strictly a landslide hazard/risk zoning, except in so far as zones T4 and T5 are concerned. It is left to the practitioner assessing the site to classify the hazard/risk. Efforts to convince Council and local consultants that a clearer definition between hazard and risk was desirable were unsuccessful, because they felt that the AGS classification was working satisfactorily.

3.3 Shire of Lillydale landslip risk classifications

In 1987 the Shire of Lillydale had a relatively small area in Mooroolbark assessed for landslide/hazard risk by Coffey and Partners Pty Ltd (1987).

This study was in a subdivision, and the area was zoned into very high, high, medium and low risk according to the AGS classification. The area was underlain largely by basalt, and there was evidence of instability in some areas. Arising out of this, and a study in 1988 of freehold land in the Upper Yarra and Dandenong Ranges (Coffey and Partners, 1988), the Council engaged Coffey and Partners to zone the whole of their Shire. This is reported in Coffey Partners International Pty Ltd (1990) and Lillydale Council (1990), and in Olds and Wilson (1992).

The hazard/risk classification was based on the AGS classification, but modified to exclude very high and very low categories because it was impracticable to differentiate them from high and low respectively with the limited amount of detailed investigation being used. It was also amended to describe the likelihood of landsliding, and the damage potential. The risk classification, development controls and damage potential are shown in Table 4.

The zone boundaries were based on geology (which included basalt, volcanics, and sedimentary), slope angle, evidence of instability, and geomorphologic and geologic similarity to known unstable areas. Low and medium risk areas were differentiated into Lb (basalt) and L (other) and M1, M2, based on geology and slope angle.

Development controls and site assessment procedures were developed and made available to the public in Shire of Lillydale (1990). These are summarised in Table 5.

The building development controls were based on those in Walker et al (1985), with quantification on heights of cuts and fills, and some amplification on disposal of waste water. It can be seen that in this classification, "risk (explanation)" is equivalent to Hunt's (1984) "hazard degree", and "damage potential" is equivalent to "risk degree".

It is a genuine zoning scheme, in that it allows routine controls to be implemented for a large part of the Shire without reference to a geotechnical assessment, and even then, imposes quite tight control on development.

The descriptive terms are general and probability is not quantified, which is not unreasonable given the large area involved and the intensity of investigation possible. The classification does not specifically refer to potential for loss of life, but this was identified in two areas, one of which has been further studied — ie. the Montrose debris slide area which is discussed below.

Table 4. Shire of Lillydale landslide risk and damage potential classification (Coffey and Partners International, 1990 and Lillydale Shire Council, 1990).

Risk Zone	Explanation	Damage Potential Extent	Damage Potential Probability
Exempt	Instability is improbable		
Low Low-basalt	Landslip is very unlikely Landslip is very unlikely but caution is warranted	Slight	Very low
Medium 1	Landslip is unlikely	Slight	Low
Medium 2	Landslip is unlikely but higher risk than M1	Moderate	Very low
High	There is some risk of landslip	Severe Large severe	High Moderate

Table 5. Shire of Lillydale landslide risk zones, assessment and development methods.

Risk Zone	Assessment Requirements	Development Controls
Exempt	No stability assessment	Good engineering practice
Low	Confirm risk classification at same time as classification of site reactivity	Good hillside practice
Low-basalt	Assessment by geotechnical practitioner	Good hillside practice
Medium 1	Confirm risk classification at same time as classification of site reactivity	Good hillside practice
Medium 2	Geotechnical assessment and where necessary, geotechnical investigations	Minimum Good hillside practice
High	Detailed geotechnical studies, visual assessment alone insufficient	No building development until risk downgraded by investigation and/ or remedial works

3.4 Richmond and Tweed River catchments, guidelines for management of lands subjected to landsliding.

This study, which is reported in MacGregor, McManus and Fell (1990) and MacGregor and McManus (1992) is different to the others in that rural areas are involved, and the objectives were to develop guidelines for implementation by Soil Conservation Service of NSW officers. It is also significantly different in that being rural land, the objective is not to produce an environment with "zero" risk of landsliding, but rather to limit it to ensure farming is not disrupted, land is not degraded with respect to its farming potential, and that erosion which could cause river siltation is controlled.

3.5 Shire of Lillydale — debris flow risk zoning at Montrose

As part of the study discussed in section 3.3, it was recognised that a large debris flow or avalanche had occurred off the western slope of Mt Dandenong in 1891. This had flowed about 1km from the base of the mountain. The area is now partly developed as suburban housing. It was realised that if such an event was to occur now, there was a high probability that lives would be lost. Coffey Partners International were engaged to carry out further investigations of the area and to prepare a zoning classification of debris flow hazard/risk. This is described in Coffey Partners International (1991) and Moon, Olds and Wilson (1992).

The study involved some significant features additional to that for the general landslip classification study for Lillydale Shire described in section 3.3. These included:

- delineation of potential source areas for debris, flow paths and deposition zones
- quantification of the size of potential debris flows, the probability of occurrence and, to a lesser extent, the damage potential
- consideration of development control alternatives.

Figure 1 shows part of the zoning map of the area. Tables 6, 7 and 8 the risk zones, assumed recurrence interval, and the damage potential.

Because of the intensity of the investigations carried out, there are no "assessment requirements" relating to debris flow, but the area is covered by the landslip risk zones described in Table 5, so will also be classified in that respect. The Coffey Partners International (1991) report presents a matrix of development control options, giving varying degrees of conservatism which the Council may adopt. This includes reference to the possible need to evacuate some areas, allow no further development, restrict development, and inform the residents of the risk.

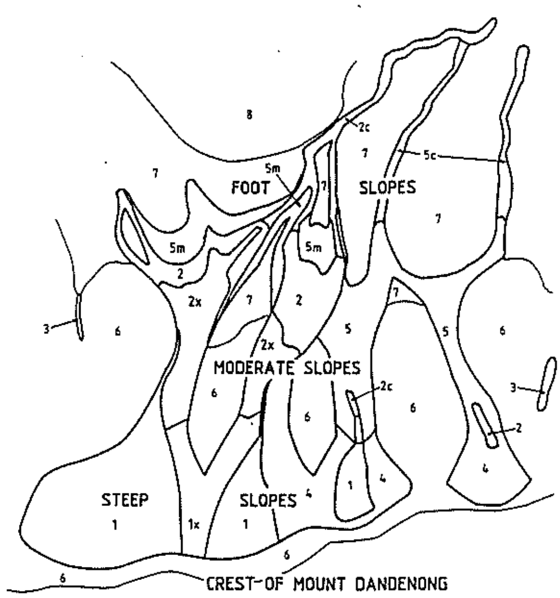

Figure 1. Part of debris flow risk zoning at Montrose (adapted from Coffey Partners International (1991).

At the time of writing this paper the author had not been requested to review the final report (although earlier drafts had been reviewed), and Lillydale Council had not decided which option to adopt.

It will be noted that considerable judgement has to be exercised in such a zoning study:

- to determine the magnitude of likely debris flow volumes
- to determine flow paths and distances
- assessing the recurrence intervals of events (in this case a historic event assisted, as did evidence of instability in the source areas).

However, the outcome is a zoning which allows rational decision making based on the best available methods and data.

4 DISCUSSION

There are some issues which arise from these reports:

a) There is a need to reach some standard terminology on what is meant by hazard and risk. It is the author's view that it will be necessary to adopt a dual scheme, similar to Hunt (1984), which uses hazard degree to describe the probability and magnitude of the event, and risk degree to describe the likely impact on human activities if the landslide occurred, or the Lillydale zoning approach which uses risk category to describe the probability and magnitude of the event, and damage potential to describe the likely impact on human activities if the landslide occurred.

   It is the author's view that hazard and risk are interchangeable words in many person's minds, so any adopted standard should only include one of them. This would favour use of "hazard" (quantified where practicable), and "damage potential" (also quantified where practicable). The preference for the term hazard rather than risk is to maintain some link to Varnes (1984) UNESCO definitions. The other option would be to adopt Varnes (1984) definitions, but define limits for very low, low, medium, high, very high, natural hazard and total risk.

b) The AGS classification has been useful for what it was developed for, but it is the author's view (and the author was a joint author of the AGS classification), that the "risk of instability" is an unfortunate mix of the terms hazard and risk. The AGS classification fails to quantify the probability or magnitude of sliding or the damage potential. It also fails to consider the potential for loss of life. It has also been used outside the geological environment for which it was developed.

c) Whichever scheme is used, there are significant implications to the practitioners developing the zoning, the councils who are usually required to implement the zoning, and the public. Classification of a site as a high risk, or very high risk of instability, in the AGS system (or the equivalent terms in other zonings) has an immediate impact on property values, even though landsliding may have a low probability of occurrence, and may not be severly damaging when it occurs. The lack of insurance for landsliding in Australia forces conservative decisions and statements to be made by practitioners, so as to avoid the risk of being sued. Insurance cover is available in some countries, including the United Kingdom and New Zealand, and this allows for more economic zoning to be adopted.

Table 6. Montrose debris flow study, description of debris flow risk zones (adapted from Coffey Parters International, 1991).

Zone Number	Risk Category	Description of Risk Zone
1	High	Steep slopes where landslips may occur, some of which may become debris flows. Initiation and transportation zone for a high risk design debris flood (high risk event).
1X	High X	Subdivision of Zone 1 to include Modern (post European) disturbed ground of 10,000m^3 or greater. Initiation and transportation zone for a High X risk design debris flow (high X risk event).
2	High	Likely extent of deposition area for a High risk event originating in Zone 1.
2X	High X	Subdivision of Zone 2 to indicate likely extent of deposition for a high X risk event originating in Zone 1X.
2C	High	Gullies downstream of Zone 2 where debris may be deposited by the high risk event. Large parts of Zones 2C will also be affected by a high X risk event.
3	High	Gullies where parts of the gully floor are steep (greater than 40% slope) and parts of the immediate catchment are very steep (greater than 50% slope). Debris torrents may affect the sections of gully covered by Zone 3.
4	Medium	Medium risk equivalent of Zone 1.
5	Medium	Medium risk equivalent of Zone 2.
5C	Medium	Medium risk equivalent of Zone 2C and some downslope margins away from gullies.
5M	Medium	Marginal area to Zones 2 and 2C. Medium risk because of difficulty of predicting extent of deposits resulting from high risk events. This difficulty includes the uncertainty associated with assessing the proportion of debris flowing down particular gullies and with assessing the extent of fringe areas. Zone 5M also takes into account the medium risk of larger than design debris flows occurring in the Zone 1 or Zone 1X areas.
6	Low	Low risk equivalent of Zone 1.
7	Low	Low risk equivalent of Zone 2. Extended to include all areas of flatter slopes in which deposits of colluvium or alluvium could occur.
8A	Low	Foothills not included in Zone 7, where steeper slopes occur.
8B	Very low	Foothills or alluvial flats not included in Zone 7 or 8A.
9	Very low	Crestal ridge of the Dandenongs.

Table 7. Montrose debris flow study, assumed recurrence intervals for design debris flows (adapted from Coffey Partners International, 1991).

Risk Category	Assumed Recurrence Interval (years)	Assumed Probability of Occurrence in 50 year period (%)
High X	1 in 100 to 1 in 300	15 to 39
High	1 in 100 to 1 in 1,000	5 to 39
Medium	1 in 1,000 to 1 in 10,000	0.5 to 5
Low	greater than 1 in 10,000	less than 0.5
Very low	greater than 1 in 100,000	less than 0.05

Table 8. Montrose debris flow study, potential damage, injury and death in the flow path of the design debris flows if they occur (adapted from Coffey Partners International, 1991).

Zone Numbers	Damage Potential
1,1X,4,6,8A	Loss of life and serious injury possible. Destruction of buildings could occur.
2,2X,5,5M,7	Loss of life and serious injury possible. Destruction of buildings could occur in or close to gullies and in upper parts of zones. Buildings may survive in fringe areas.
2C,5C,3	Loss of life and serious injury possible. Destruction of buildings could occur in gullies. Buildings on the edge of gullies could deflect flow and survive. Severe flooding could occur at the margins and downstream of these zones.
8B,9	Not assessed as these zones are not likely to be affected by debris flows.

The zoning of the town of Ventnor on the Isle of Wight is an excellent example of what can be done if insurance cover is available. The town of 30,000 persons is virtually all on landslide affected land, but it has been possible to subzone the area to reflect the damage potential. This is described in Hutchinson (1991), Lee et al (1991) and other papers from the same conference.

d) There is a need for strong development controls, and funding for compensation for affected houseowners in areas with a high probability of being affected by death threatening landslides (such as those at Montrose). It is the author's view that Table 8 does not adequately convey the potential to loss of life. Debris slides in zones 1, 1X, 2 and 2X at least, would probably (not possibly) result in loss of life and injury. Whether persons should be allowed to remain living in such areas which have an assessed probability of occurrence of 5% to 39% in the next 50 years is questionable, and influenced by the lack of insurance or compensation funding.

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REFERENCES

Coffey and Partners Pty Ltd (1984). Lake Macquarie City Council. Geotechnical Zoning Study. Report No S7341-1-A3.

Coffey and Partners Pty Ltd (1987). Landslip risk - Mooroolbark. Report M1224/5.

Coffey Partners International Pty Ltd (1990). Slope stability review within the Shire of Lillydale. Report No M2027/1-AD.

Coffey Partners International Pty Ltd (1991). Study of debris flow and other landslips, Montrose, Victoria. Report M2120/1-AJ.

Fell, R. and Flentje, P. (1991). Lake Macquarie City Council. Geotechnical Zoning Study. Unisearch Limited , Report A 14082-01.

Flentje, P. (1991). Geotechnical zoning study of Lake Macquarie City. M.App.Sc. Thesis (in preparation).

Hunt, R.E. (1984). Geotechnical Engineering Investigation Manual. McGraw-Hill.

Hutchinson, J.N. (1991). Keynote paper. The landslides forming the South Wight undercliff of the Isle of Wight , in Slope Stability Engineering Developments and Applications. The Institution of Civil Engineers.

Lee, E.M., Moore, R., Brunsden, D. and Burt, D. (1991). Strategies for managing the landsliding complex at Ventnor, Isle of Wight, in Slope Stability Engineering Developments and Applications. The Institution of Civil Engineers.

MacGregor, J.P. McManus, K.J.. and Fell, R. (1990). Management of protected lands subject to mass movement in the Richmond River catchment. Unisearch Limited Report for Soil Conservation Service of NSW.

MacGregor, J.P. and McManus, K.J. (1992). Management of lands subject to mass movement, in Sixth ISL, Christchurch, New Zealand, February.

Moon, A.T., Olds, R.J. and Wilson, R.A. (1992). Debris flow risk zoning at Montrose, Victoria, Sixth ISL, Christchurch, New Zealand, February.

Olds, R.J. and Wilson, R.A. (1992). Landslip risk zoning and development controls in the Shire of Lillydale, Victoria, in Sixth ISL, Christchurch, New Zealand, February.

Shire of Lillydale (1990). Development in areas of possible slope instability. Resident Information Guide.

Varnes, D.J. (1984). Landslide hazard zonation, a review of principles and practice. UNESCO.

Walker, B.F., Dale, M., Fell, R., Jeffery, R., Leventhal, A., McMahon, M., Mostyn, G. and Phillips, A. (1985). Geotechnical risks associated with hillside development.