# APPENDIX D

## Example Schedule to the EMO

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C--

# SCHEDULE TO THE EROSION MANAGEMENT OVERLAY

Shown on the planning scheme map as **EMO**.

## *1.0 Land Susceptible to Landslide*

The City of Moreland contains areas of land which are susceptible to landslide. This land is generally associated with the Moonee Ponds and Merri Creek Valleys. Geotechnical studies have been undertaken to identify those areas within the City of Moreland that may be susceptible to landslide. On the basis of these studies, the City of Moreland has adopted a city wide slope hazard classification system and guidelines for the development of land potentially affected by landslide.

All land included within the Erosion Management Overlay has been identified as having a sufficiently high risk of potential instability to warrant specific review of these risks prior to issuing a planning permit. The control of environmental factors and development such as vegetation cover, drainage and earthworks are important in managing the risk of landslide.

## *2.0 Definitions*

***AGS 2007***

Australian Geomechanics Society (Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group) 'Practice Note Guidelines for Landslide Risk Management 2007' Journal and News of the Australian Geomechanics Society Volume 42 No 1, March 2007 and any subsequent revision of the procedure therein.

***Geotechnical Declaration and Verification***

A declaration form completed by the geotechnical engineer that authored the geotechnical report submitted with the application verifying that it has been prepared in accordance with *AGS 2007c* and that the maximum landslide risk has been calculated at $10^{-5}$ ('Tolerable Risk') or less, taking into account the proposed development and site conditions.

***Landslide***

The movement of a mass of rock, debris or earth down a slope.

***Landslide Hazard***

A Landslide hazard is a site condition with the potential for causing an undesirable consequence (the landslide) – (AGS Journal No 42 Vol 1, March 2007)

***Geotechnical Practitioner***

Is defined as:

- Degree qualified Geotechnical Engineer or Engineering Geologist; and

- has achieved chartered professional status being a Chartered Professional Engineer (CPEng), A Chartered Professional Geologist (CPGeo) or a Registered Professional Geologist (RPGeo); and
- has experience in the identification and management of slope stability problems and landslide as a core competence.

***Tolerable Risk***

For new development or changes to existing development a risk to life and/or property which:

- For loss of life for the person(s) most at risk is taken as having a probability of no greater than $10^{-5}$ (1:100,000) per annum calculated in accordance with AGS Guidelines 2007;
- For property loss is 'Low' or 'Very Low' assessed qualitatively using AGS Guidelines 2007 and specifically Appendix C to that document.

## 3.0 Objectives

- To manage the risk of landslide.
- To ensure that development can be carried out in a manner which will not adversely increase the landslide risk to life or property affecting the subject land or adjoining or nearby land.
- To ensure that on land where a Landslide Risk Assessment is required development is not carried out unless the risk associated with landslide is a Tolerable Risk.
- To ensure that applications for development are supported by adequate site investigation and documentation of geotechnical and related structural matters.
- To ensure that development is only carried out if identified geotechnical and related structural engineering risks to life and property are effectively addressed.
- To ensure that development is appropriate to be carried out either conditionally or unconditionally, having regard to the results of the geotechnical and related structural investigations.
- To ensure that approved development is thereafter appropriately maintained.

## 4.0 No permit required

A permit is not required to construct or carry out any of the following buildings or works:

- A fence provided that:
  - No trench is required for the construction of the fence.
  - No post holes exceed 0.5 metre in depth.
  - The fence is not constructed on, or within one metre of, land with a slope exceeding 50 percent.
- A retaining wall that either:
  - Replaces an existing retaining wall with identical construction specifications and dimensions.
  - Does not exceed one metre in height and does not provide landslip protection for any adjoining land.

- Repairs and routine maintenance to an existing building or works.
- Internal alterations to an existing building provided that, if the land is unsewered, no additional bathrooms, toilets or kitchens are constructed.
- Extensions to the floor area of an existing building, including decks or verandahs, provided that:
  - There is no increase in the ground surface area covered by roofed buildings.
  - No earthworks in the form of cuts or fills are required.
  - No additional bathrooms, toilets or kitchens are constructed.
- Minor structures ancillary to a dwelling provided that:
  - No earthworks (cuts or fills) are required.
  - The ground surface area occupied by structure(s) does not exceed a total maximum of 4 square metres.
- Landscaping and gardening provided that:
  - Any retaining walls comply with the relevant exemptions.
  - No change is made to constructed drainage or fixed irrigation systems.
  - It does not result in the removal of trees or significant vegetation.
- Signs provided that:
  - No trench or post holes or other excavations required for the construction and display of the sign exceed 0.5 metre in depth.
  - The sign is not constructed on, or within one metre of, land with a slope exceeding 50 percent.
- Street furniture.
- A temporary shed or temporary structure required for construction purposes.
- Demolition provided that:
  - No earthworks in the form of cuts or fills are required; and
  - No change is made to constructed drainage or fixed irrigation systems.
- Emergency works undertaken by, or on behalf of, a municipality or public authority or utility service provider in the exercise of any power conferred on them by any Act.

## *5.0 Application requirements*

An application must be accompanied by:

- Development plans showing existing and proposed development.
- A written geotechnical assessment of the proposed development in relation to existing conditions to verify whether it can be carried out in a manner which will not adversely increase the landslide risk to life or property affecting the subject lot or adjoining or nearby land or a landslide risk assessment is required.
- A written Landslide Risk Assessment of the proposed development in relation to existing conditions, if the Geotechnical Assessment or other landform data indicates natural slopes underlying or immediately adjacent to the subject lot which:

- are steeper than 30% (16.7°) and underlain by Tertiary Older Volcanics ($T_{ov}$) or Quaternary Age alluvium and colluvium (Qrt, Qrc and Qra);
- are steeper than 35% (19.3°) and underlain by Tertiary Brighton Group ($T_b$);
- are steeper than 50% (26.5°) in all other areas;
- or where in the opinion of the Responsible Authority, the Geotechnical Assessment is not sufficient to determine that the development can be carried out in a manner which will not adversely increase the risk to life or property affecting the subject lot or adjoining or nearby land.

***Development Plans***

Development plans, must be drawn to scale and dimensioned, showing:

- The proposed development, including a site plan and building elevations, and any proposed cut and fill or retaining wall.
- Any existing development, including buildings and water tanks on both the subject lot and adjacent land, cut and fill, stormwater drainage, subsurface drainage, water supply pipelines, sewerage pipelines and any otherwise identified geotechnical hazard.
- Details and location of existing vegetation, including any vegetation to be removed.

***Geotechnical Assessment***

A Geotechnical Assessment must be prepared or technically verified by a Geotechincal Practitioner and must include, to the satisfaction of the Responsible Authority:

- Details of the Geotechnical Practitioner and his or her qualifications and experience including without limitation experience in the management of slope stability problems and landslide risk management.
- A statement that the assessment is based on field survey measurements which have been undertaken not more than six months prior to the relevant application for development.
- A detailed site description.
- Site assessment plans and cross sections of the subject lot and related land for survey and field measurements with contours and ground slopes as measured shown and drawn to scale and dimensioned.
- A detailed assessment of the subsurface conditions, including the underlying geology.
- A statement indicating whether there are natural slopes on or immediately adjacent to the lot which:
  - Are steeper than 30% (16.7°) and underlain by Tertiary Older Volcanics ($T_{ov}$) or Quaternary Age alluvium and colluvium (Qrt, Qrc and Qra);
  - are steeper than 35% (19.3°) and underlain by Tertiary Brighton Group ($T_b$);
  - are steeper than 50% (26.5°) in all other areas;
  - where evidence for past slope instability has been observed.
- A detailed description of any evidence of slope instability.
- Details of all site investigations and any other information used in the preparation of the geotechnical report.
- Whether the site investigation requires subsurface investigation that may involve boreholes and/or test pits or other methods necessary to adequately assess the geotechnical/geological model for the subject lot and details of all such investigations, boreholes test pits or other methods.
- A conclusion which:
  - Is supported by the data and all stated assumptions contained in the assessment and is capable of being verified by peer review.

- States whether or not a Landslide Risk Assessment is required.
- Where it is considered that a Landslide Risk Assessment is not required, states that, in the opinion of the Geotechnical Practitioner, the development can be carried out in a manner which will not adversely increase the landslide risk to life or property affecting the subject lot or adjoining nearby land.
- Provides justification, including any necessary calculations, for the conclusion.
- States whether or not the development should only be approved subject to conditions, and if so state recommendations of what conditions should be required, including, but without limitation condition relating to:
  - The determination of appropriate footing levels and foundation materials and in any structural works, including all footings and retaining walls;
  - the location/s of and depth/s of earth and rock cut and fill;
  - the construction of any excavations and fill and the method of retention of such works;
  - any details of surface and subsurface drainage;
  - the selection and design of a building structure system to minimise the effects of all identified geotechnical hazards;
  - retention, replanting and new planting of vegetation;
  - any drainage and effluent discharge;
  - any necessary ongoing mitigation and maintenance measures and any recommended periodic inspections, including performance measures;
  - the time within which works must be completed after commencement and the location/s and period in which materials associated with the development can be stockpiled;
  - any requirements for geotechnical inspections and approvals that may need to be incorporated into a construction work plan for building approval purposes.

***Landslide Risk Assessment***

The Landslide Risk Assessment must, to the satisfaction of the Responsible Authority:

- Be prepared by a suitably qualified and experienced geotechnical practitioner (as defined in Section20 of this Schedule) and incorporating an *AGS 2007c Risk Assessment and Checklist* and CV of the author.
- Contain a *Geotechnical Declaration and Verification* by the author verifying their expertise, the contents and report conclusion. Copies of the *Geotechnical Declaration and Verification* form can be obtained by contacting the planning section of the Moreland City Council.
- Contain a copy of or include the Geotechnical Assessment prepared for the subject land and proposal and, if not prepared by the Geotechnical Practitioner preparing the Landslide Risk Assessment, contain a response by the Geotechnical Practitioner preparing the Landslide Risk Assessment that the findings and conclusions of the Geotechnical Assessment are agreed with.
- If the Geotechnical Practitioner preparing the Landslide Risk Assessment does not agree with the findings and conclusions of the Geotechnical Assessment for the subject land and proposal, another Geotechnical Assessment must be prepared by that Geotechnical Practitioner.
- Be based on field survey and measurements which have been undertaken not more than six months prior to lodgement of the application.
- Include a full assessment of the risk posed by all reasonably identified geotechnical hazards which have potential to either individually or cumulatively impact upon people or property on the subject lot or related land. This assessment must be in accordance with AGS 2007c Guidelines.
- Contain a conclusion as to whether the subject lot is suitable for the proposed development. This must be in the form of a specific statement that the subject lot is suitable, or can be made suitable, for the proposed development and that the subject lot

and/or the proposed development can meet the tolerable risk criteria, as defined in this schedule. The report must specify all conditions required to achieve the outcome.

At all times, any decision regarding the degree of investigations and assessment required must be dictated by the consideration of risk to life and property and the recognition by the geotechnical practitioner that the responsible authority will rely on the Geotechnical Assessment and/or Landslide Risk Assessment as the basis for ensuring that the geotechnical risk management aspects of the subject lot and the proposal have been adequately addressed.



## 6.0 Independent Review

The Responsible Authority may require a Geotechnical Assessment and/or a Landlside Risk assessment that has been submitted with an application, to be reviewed by an independent geotechnical practitioner at the applicant's cost.

## 7.0 Decision Guidelines

In deciding on an application, the responsible authority must consider:

- Whether, in the case of land for which natural slopes on or immediately adjacent to the subject lot:
  - are not steeper than 30% (16.7°) and underlain by Tertiary Older Volcanics ($T_{ov}$) or Quaternary Age alluvium and colluvium (Qrt, Qrc and Qra);
  - are not steeper than 35% (19.3°) and underlain by Tertiary Brighton Group ($T_b$);
  - are not steeper than 50% (26.5°) in all other areas;
  - do not exhibit evidence for active slope instability.
- The development can be carried out so that the risk associated with the development is a Tolerable Risk.
- The recommendations of the Geotechnical Assessment, any Landslide Risk Assessment and any other information accompanying the application.
- The advice of any Geotechnical Practitioner who as reviewed the application.
- The risks associated with the development require ongoing monitoring and maintenance of mitigation measures.
- The risks associated non compliance with any conditions placed on the approval of a development.

## 8.0 Conditions and requirements of Permits

Any planning permit issued for development within the EMO must include a condition requiring that:

- Where ongoing maintenance is recommended by the submitted geotechnical report, those obligations are to be included in any planning permit.

## 9.0 Reference Documents

*Risk of Landslide Survey & Recommended Action For the City of Moreland*, USL Group Pty Ltd, March 2009.

*City of Moreland, Landslide Hazard Assessment,* Golder Associates Pty. Ltd. September 2009.

*Journal of the Australian Geomechanics Society, Vol. 42 No 1, March 2007.*

# APPENDIX E

## Australian Geo Guides

Australian Geomechanics Society

Extract from

# Australian Geomechanics

Journal and News of the Australian Geomechanics Society
Volume 42 No 1 March 2007

**Extract containing:**

"The Australian GeoGuides for Slope Management and Maintenance"

Ref: AGS (2007e)

## Landslide Risk Management

ENGINEERS AUSTRALIA

AusIMM

ISSN 0818-9110

# THE AUSTRALIAN GEOGUIDES
# FOR SLOPE MANAGEMENT AND MAINTENANCE

**AGS Landslide Taskforce, Slope Management and Maintenance Working Group**

The Australian Geomechanics Society (AGS) presents on the following pages a guideline on slope management and maintenance, as part of the landslide risk management guidelines developed under the National Disaster Funding Program (NDMP). This Guideline is aimed at home owners, developers and local councils, but also has applicability to a larger audience which includes builders and contractors, consultants, insurers, lawyers, government departments and in fact any person, or organisation, with a responsibility for the management or maintenance of a slope. The objective is to inform those with little or no knowledge of geotechnical engineering about landslides.

Each GeoGuide is a stand-alone document, which is formatted so that it can be printed on two sides of a single A4 sheet. It is expected that the set of GeoGuides will increase with time to cover a range of topics. As things stand:

- **GeoGuide LR1** is an introductory sheet that should be read by all users, since it explains what the LR (landslide risk) series is about and defines terms.
- **GeoGuides LR2, 3 and 4** explain why landslides occur and provide information on different types of landslide.
- **GeoGuide LR5** discusses the critical part that water often plays in relation to landslide occurrence and discusses measures that can be adopted to limit its effect.
- **GeoGuide LR6** refers to retaining walls and their maintenance.
- **GeoGuide LR7** puts the concept of landslide risk into an everyday context, so users can relate a particular landslide risk to other risks that they know they are prepared to take, sometimes on a daily basis.
- **GeoGuide LR8** retains the ideas of good and poor hillside construction practice originally provided by an AGS sub-committee in 1985.
- **GeoGuide LR9** concentrates specifically on effluent and surface water disposal, which is an important topic in some development areas.
- **GeoGuide LR10** is specifically aimed at those who have property on the coast and could be susceptible to coastal erosion processes.
- **GeoGuide LR11** provides information about the benefits of keeping records on inspection and maintenance activities and provides a proforma record sheet for users.

It is recognised that the GeoGuides are likely to be upgraded from time to time. Feedback on use and suggested changes should be sent to the National Chair of the Australian Geomechanics Society. The latest versions of the GeoGuides will be downloadable from the AGS website www.australiangemechanics.org

Through the NDMP, Australian governments (at Commonwealth, State and Local Government levels) are also funding the development of a Landslide Zoning Guideline (AGS 2007a), and a Practice Note Guideline (AGS 2007c) to which interested readers seeking in-depth information should refer.

## ACKNOWLEDGEMENTS

These guidelines have been prepared by The Australian Geomechanics Society with funding from the National Disaster Mitigation Program, the Sydney Coastal Councils Group, and The Australian Geomechanics Society.

The Australian Geomechanics Society established a Working Group within a Landslide Taskforce to develop the guidelines. The development of the guidelines was managed by a Steering Committee. Membership of the Working Group, Taskforce and Steering Committee is listed in the Appendix.

Drafts of these GeoGuides have been subject to review by members of the AGS Landslide Taskforce, members of the geotechnical profession and local government.

## REFERENCES

AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management. Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1.

AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1,

AGS (2007e). The Australian GeoGuides for slope management and maintenance –. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No 1, - this paper.

# INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips

## AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

| | | |
|---|---|---|
| LR1 - Introduction | LR2 - Landslides | LR3 - Landslides in Soil |
| LR4 - Landslides in Rock | LR5 - Water & Drainage | LR6 - Retaining Walls |
| LR7 - Landslide Risk | LR8 - Hillside Construction | LR9 - Effluent & Surface Water Disposal |
| LR10 - Coastal Landslides | LR11 - Record Keeping | |

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

## BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

## STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

## TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

| | |
|---|---|
| Consequence | the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life. |
| Discontinuity | in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground. |
| Equilibrium | the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite. |
| Factor of safety (FOS) | theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one. |
| Failure | when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function. |
| Geotechnical practitioner | when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner. |
| Hazard | a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time. |
| Landslide | the movement, or the potential movement, of a mass of rock, debris, or earth down a slope. |
| Likelihood | a qualitative description of probability, or frequency, of occurrence. |
| Partial saturation | the condition in the ground above the water table where both air and water are present as well as soil, or rock. |
| Perched water table | a water table above the true water table supported by a low permeability stratum. |
| Permeability | a measure of the ability of the ground to allow water to flow through it. |
| Risk | a measure of the probability and severity of an adverse effect to life, health, property or the environment. |
| Slip failure | landslide. |
| Stable | the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure. |
| Retaining structure | anything built by humans which is intended to support the ground and inhibit failure. |
| Structure | in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location. |
| Tension crack | a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent, failure. |
| Water table | the level in the ground below which it is saturated and the voids are filled with water. |

Photograph courtesy of Phil Flentje

## LANDSLIDES

**What is a Landslide?**

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au .

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

**What Causes a Landslide?**

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR 5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

**Does a Landslide Affect You?**

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run- out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

**TABLE 1 - Slope Descriptions**

| Appearance | Slope Angle | Maximum Gradient | Slope Characteristics |
|---|---|---|---|
| Gentle | 0° - 10° | 1 on 6 | Easy walking. |
| Moderate | 10°- 18° | 1 on 3 | Walkable. Can drive and manoeuvre a car on driveway |
| Steep | 18°- 27° | 1 on 2 | Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car. |
| Very Steep | 27°- 45° | 1 on 1 | Can only climb slope by clutching at vegetation, rocks etc. |
| Extreme | 45°- 64° | 1 on 0.5 | Need rope access to climb slope |
| Cliff | 64°- 84° | 1 on 0.1 | Appears vertical. Can abseil down. |
| Vertical or Overhang | 84° - 90±° | Infinite | Appears to overhang. Abseiler likely to lose contact with the face. |

Some typical landslides which could affect residential housing are illustrated below:

# AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

**Rotational or circular slip failures (Figure 1) -** can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

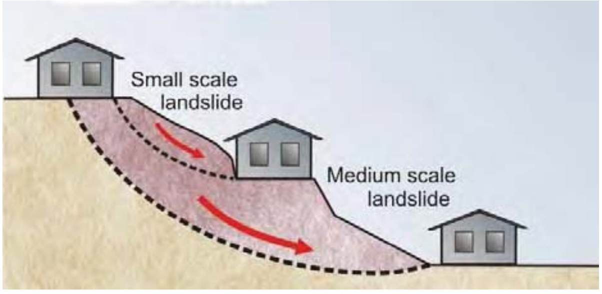


**Figure 1**

**Translational slip failures (Figure 2) -** tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

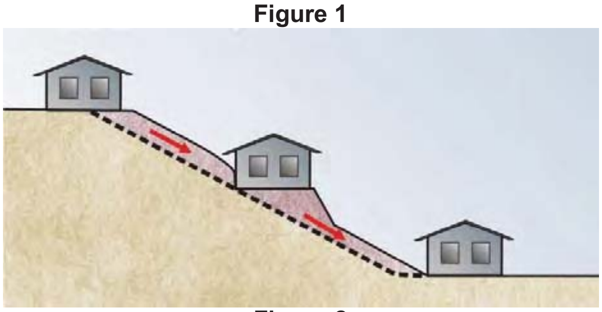

**Figure 2**

**Wedge failures (Figure 3) -** normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

**Rock falls (Figure 3) -** tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

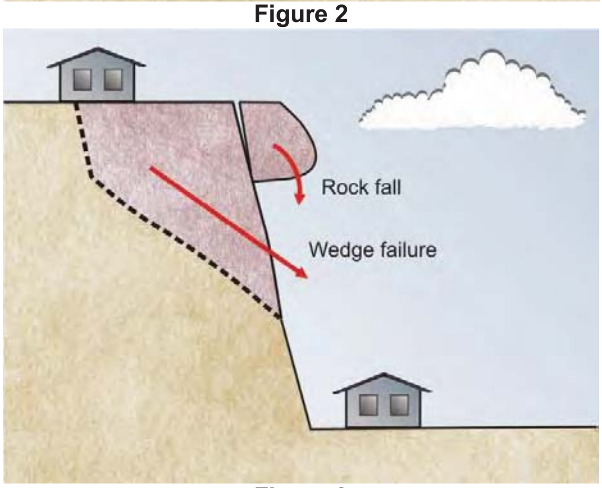


**Figure 3**

**Debris flows and mud slides (Figure 4)** - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

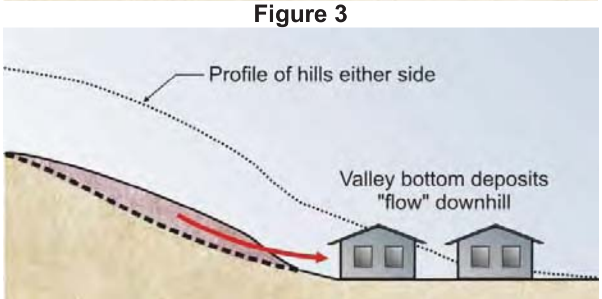


**Figure 4**

**More information relevant to your particular situation may be found in other Australian GeoGuides:**

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
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## LANDSLIDES IN SOIL

Landslides occur on soil slopes and the consequences can include damage to property and loss of life. Soil slopes exist in all parts of Australia and can even occur in places where rock outcrops can be seen on the surface. If you live on, or below, a soil slope it is important to understand why a landslide might occur and what you can do to reduce the risk it presents.

It is always worth asking the question *"why is this slope here?"*, because the answer often leads to an understanding of what might happen in the future. Slopes are usually formed by weathering (breakdown) and erosion (physical movement) of the natural ground - the "parent material". Many factors are involved including rain, wind, chemical change, temperature variation, plant growth, animal activity and our own human enthusiasm for development. The general process is outlined in Figure 1.

The upper levels of the parent material progressively weather over thousands, or millions, of years, losing strength. This can result in a surface layer which looks similar to the parent material (although its colour has probably changed) but has the strength of a soil - this is called "residual soil". At some stage the weathered surface layer is exposed to the elements and fragments are transported down the slope. In this context a fragment could be a single sand grain, a boulder, or a landslide. The time scale could be anything from a few seconds to many thousands of years. The transported fragments often collect on the lower slopes and form a new soil layer that blankets the original slope - "colluvium". If material reaches a river or the sea it is deposited as "alluvium" or as a "marine deposit". With appropriate changes in river and sea level this material can again find itself on the surface to commence another cycle of weathering and erosion. In places often, but not only, near the coast, this can include sand sized fragments which form beaches and are sometimes blown back onto the land to form dunes.

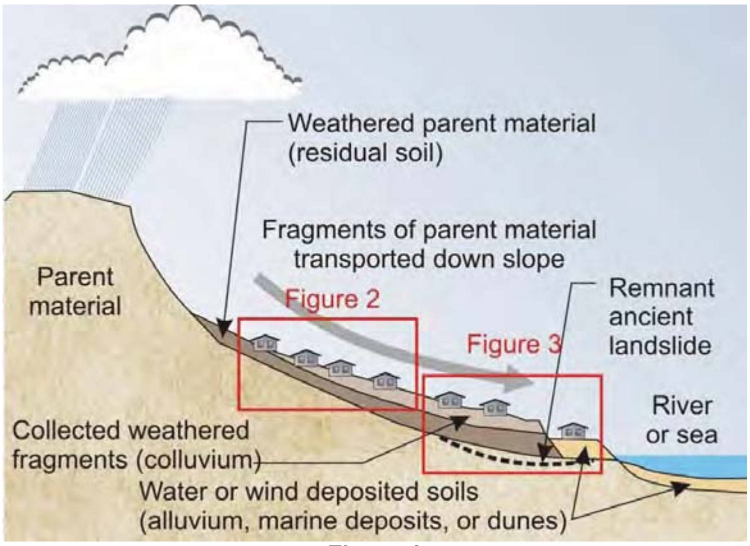


**Figure 1**

Landslides can occur almost anywhere on a soil slope. Slides can be rotational, translational, or debris flows (see GeoGuide LR2) and may have a number of causes.

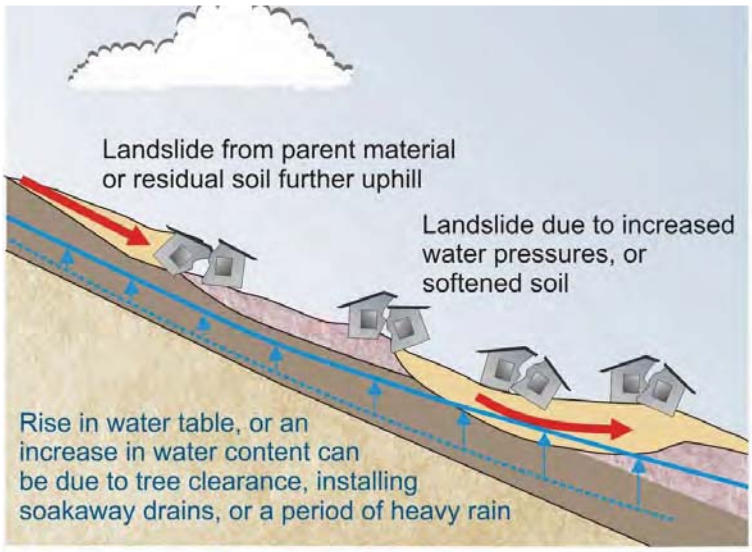


**Figure 2**

# AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

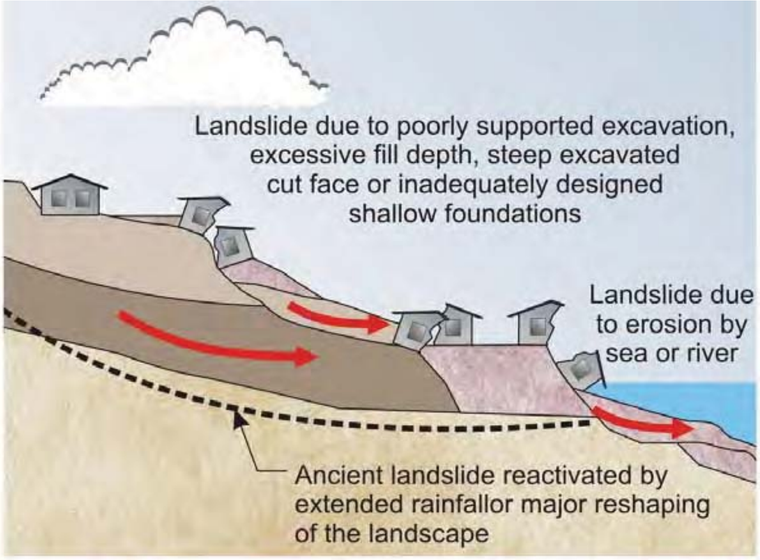


**Figure 3**

Some of the more common causes of landslides in soil are:

1) Falls of the parent material or residual soil from above, due to natural weathering processes (Figure 2).
2) Increased moisture content and consequent softening of the soil, or a rise in the water table. These can be due to excessive tree clearance, ill-considered soak-away drainage or septic systems, or heavy rainfall (Figure 2).
3) Excavation without adequate support, increased surface load from fill placement, or inadequately designed shallow foundations (Figure 3).
4) Natural erosion at the toe of the slope due to scour by a river or the sea (Figure 3).
5) Re-activation of an ancient landslide (Figure 3).

Most soil slopes appear stable, but they all achieved their present shape through a process of weathering and erosion and are often sensitive to minor changes in the factors that affect their stability. As a general rule, human activities only improve the situation if they have been designed to do so. Once this idea is understood, it is probably easy to see why the following basic rules are so important and should not be ignored without seeking site specific advice from a geotechnical practitioner:

- Do not clear trees unnecessarily.
- Do not cut into a slope without supporting the excavated face with an engineer designed structure.
- Do not add weight to a slope by placing earth fill or constructing buildings with inadequately designed shallow foundations (Note: in certain circumstances weight is added to the toe of a slope to inhibit landslide movement, but this must be carried out in accordance with a proper engineering design).
- Do not allow water from storm water drains, or from septic waste or effluent disposal systems to soak into the ground where it could trigger a landslide.

More information in relation to good and poor hillside construction practice is given in GeoGuide LR8. With appropriate engineering input it is often possible to reduce the likelihood, or consequences, of a landslide and so reduce the risk to property and to life. Such measures can include the construction of properly designed storm water and sub-soil drains, surface protection (Geo Guide LR5) and retaining walls (GeoGuide LR6). **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.**

**More information relevant to your particular situation may be found in other Australian GeoGuides:**

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
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## LANDSLIDES IN ROCK

Rocks have been formed by many different geological processes and may have been subjected to intense pressure, large scale distortion, extreme temperature and chemical change. As a result there are many different rock types and their condition varies enormously. Rock strength varies and is often significantly reduced by the presence of discontinuities (GeoGuide LR1). You may think that rock lasts forever, but in reality it weathers under the combined effects of water, wind, chemical change, temperature variation, plant growth and animal activity and erodes with time. Rock is often the parent material that ends up forming soil slopes (GeoGuide LR3). Inevitably different rocks have different physical and chemical characteristics and they weather and erode to form different types of soil.

Weathering can lead to landslides (GeoGuide LR2) on rock slopes. The type of landslide depends on the nature of rock, the way it has weathered and the presence or absence of discontinuities. It is hard to generalise, though normally a specific combination of discontinuities and material types will be the determining factor and these are often underground and out of sight. Typical examples are provided in the figures 1 to 4. A geotechnical practitioner can assess the landslide risk and propose appropriate maintenance measures. This often entails making geological observations over an area significantly larger than the site and a review of available background information, including records of known landslides and aerial photographs. Depending on the amount of information available, geotechnical investigation may or may not be needed. Every site is different and every site has to be assessed individually.

**<u>It is impossible to predict exactly when a landslide will occur on a rock slope, but failure is normally sudden and the consequences can be catastrophic.</u>**

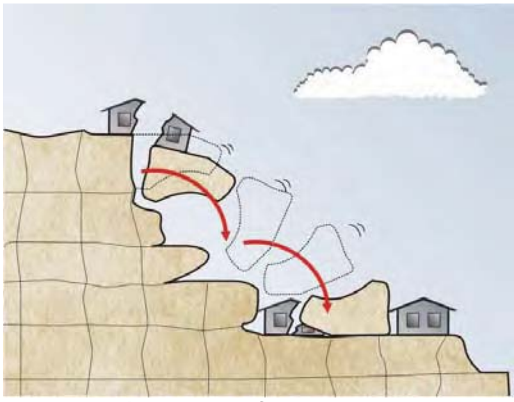

**Figure 1 - Failure of an undercut block**

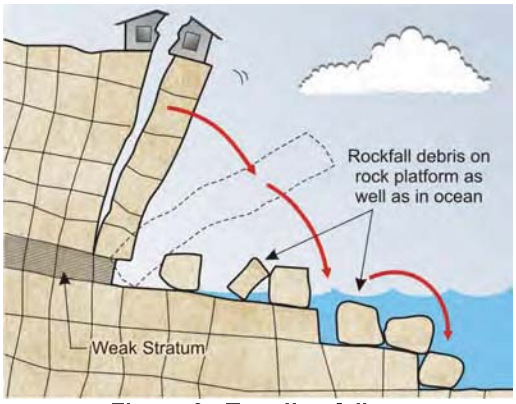


**Figure 2 - Toppling failure**

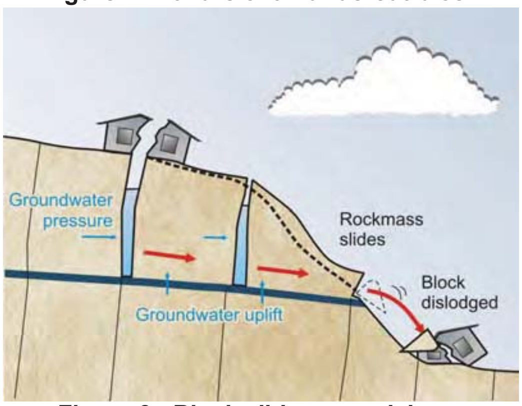


**Figure 3 - Block slide on weak layer**

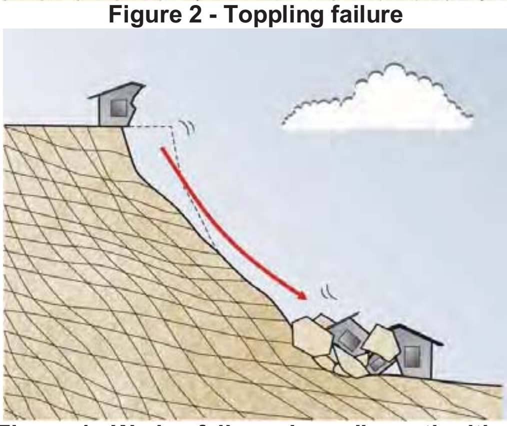

**Figure 4 - Wedge failure along discontinuities**

If the landslide risk is assessed as being anything other that Low, or Very Low, (GeoGuide LR7) it may be possible to carry out work aimed at reducing the level of risk.

The most common options are:

1) Trimming the slope to remove hazardous blocks of rock.
2) Bolting, or anchoring, to fix hazardous blocks in position and prevent movement.
3) Installation of catch fences and other rockfall protection measures to limit the impact of rockfalls.
4) Deep drainage designed to limit changes in the ground water table (GeoGuide LR5).

Although such measures can be effective, they need inspection and on-going maintenance (GeoGuide LR11) if they are to be effective for periods equivalent to the life of a house. **<u>Design should be undertaken by a geotechnical practitioner and will normally require local council approval.</u>** It should be appreciated that it may not be viable to carry out remedial works in all circumstances: for example where the landslide is on someone else's property, where the cost is out of proportion to the value of the property, or where the risk inherent in carrying out the work is actually greater than the risk of leaving things as they are. In situations such as these, development may be considered inappropriate.

# AUSTRALIAN GEOGUIDE LR4 (LANDSLIDES IN ROCK)

## ROCK SLOPE HAZARD REDUCTION MEASURES

**Removal of loose blocks** - may be effective but, depending on rock type, ongoing erosion can result in more blocks becoming unstable within a matter of years. Routine inspection, every 5 or so years, may be required to detect this.

**Rock bolts and rock anchors** (Figure 5) - can be installed in the ground to improve its strength and prevent individual blocks from falling. Rock bolts are usually tightened using a torque wrench, whilst rock anchors carry higher loads and require jacking. Both can be designed to be "permanent" using stainless steel, or sheathing, to inhibit corrosion, but the cost can be up to 10 times that of the "temporary" alternative. You should inspect rock bolts and rock anchors for signs of water seepage, rusting and deterioration around the heads at least once every 5 years. If you notice any of these warning signs, have them checked by a geotechnical practitioner. It is recommended that you keep copies of design drawings and maintenance records (GeoGuide LR11) for the anchors on your site and pass them on to the new owner should you sell.

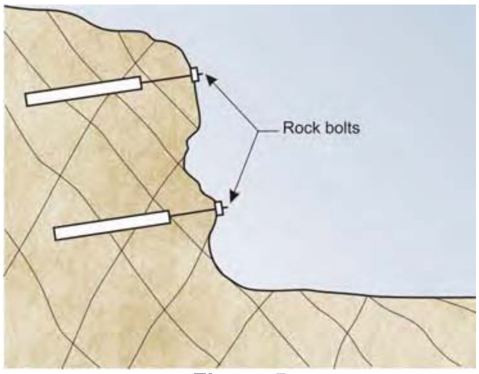

**Figure 5**

**Rock fall netting, catch fences and catch pits** (Figure 6) - are designed to catch or control falling rocks and prevent them from damaging nearby property. You should inspect them at least once every 5 years, and after major falls, and arrange for fallen and trapped rocks to be removed if they appear to be filling up. Check for signs of corrosion and replace steel elements and fixings before they lose significant strength.

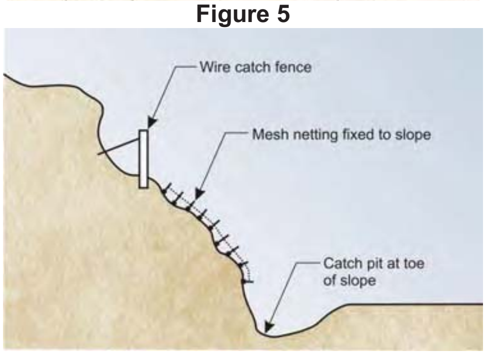

**Figure 6**

**Cut-off drains** (Figure 7) - can be used to intercept surface water run-off and reduce flows down the cliff face. Suitable drains are often excavated into the rock, or constructed from mounds of concrete, or stabilised soil, depending on conditions. Drains must be laid to a fall of at least 1% so they drain adequately. Frequent inspection is needed to ensure they are not blocked and continue to function as intended.

**Clear trees and large bushes** (Figure 7) - from slopes since roots can prize boulders from the face increasing the landslide hazard.

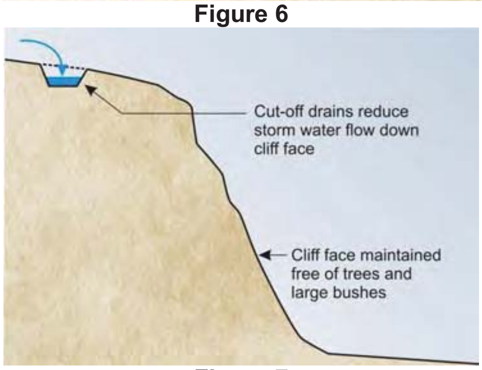

**Figure 7**

**Natural cliffs and bluffs** - often present the greatest hazard and yet are easily overlooked, because they have "been there forever". They can exist above a building, road, or beach, presenting the risk of a rock falling on to whatever is below. They also sometimes support buildings with a fine view to the horizon. Cliffs should be observed frequently to ensure that they are not deteriorating. You may find it convenient to use binoculars to look for signs of exposed "fresh" rock on the face, where a recent fall has occurred, or to go to the foot of the cliff from time to time to see if debris is collecting. A thorough inspection of a cliff face is often a major task requiring the use of rope access methods and should only be undertaken by an appropriately qualified professional. If tension cracks are observed in the ground at the top of a cliff take immediate action, since they could indicate imminent failure. **If you have any concerns at all about the possibility of a rock fall seek advice from a geotechnical practitioner.**

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## WATER, DRAINAGE & SURFACE PROTECTION

One way or another, water usually plays a critical part in initiating a landslide (GeoGuide LR2). For this reason, it is a key factor to be controlled on sites with more than a low landslide risk (GeoGuide LR7).

### Groundwater and Groundwater Flow

The ground is permeable and water flows through it as illustrated in Figure 1. When rain falls on the ground, some of it runs along the surface ("surface water run-off") and some soaks in, becoming groundwater. Groundwater seeps downwards along any path it can find until it meets the water table: the local level below which the ground is saturated. If it reaches the water table, groundwater either comes to a halt in what is effectively underground storage, or it continues to flow downwards, often towards a spring where it can seep out and become surface water again. Above the water table the ground is said to be "partially saturated", because it contains both water and air. Suctions can develop in the partially saturated zone which have the effect of holding the ground together and reducing the risk of a landslide. Vegetation and trees in particular draw large quantities of water out of the ground on a daily basis from the partially saturated zone. This lowers the water table and increases suctions, both of which reduce the likelihood of a landslide occurring.

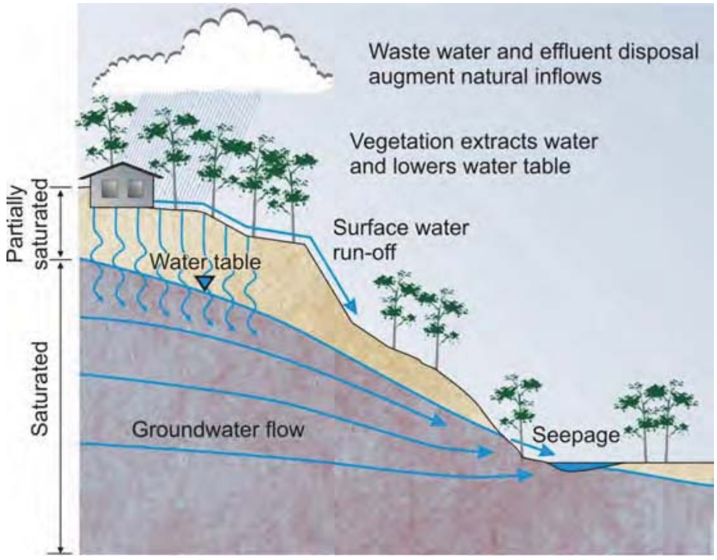


**Figure 1 - Groundwater flow**

### Groundwater Flow and Landslides

The landslide risk in a hillside can be affected by increase in soak-away drainage or the construction of retaining walls which inhibit groundwater flow. The groundwater is likely to rise after heavy rain, but it can also rise when human interference upsets the delicate natural balance. Activities such as felling trees and earthworks can lead to:

- a reduction in the beneficial suctions in the partially saturated zone above the water table.
- increased static water pressures below the water table,
- increased hydraulic pressures due to groundwater flow,
- loss of strength, or softening, of clay rich strata,
- loss of natural cementing in some strata,
- transportation of soil particles.

Any of these effects, or a combination of them, can lead to landslides like those illustrated in GeoGuides LR2, LR3 and LR4.

### Limiting the Effect of Water

Site clearance and construction must be carefully considered if changes in groundwater conditions are to be limited. GeoGuide LR8 considers good and poor development practices. Not surprisingly much of the advice relates to sensible treatment of water and is not repeated here. Adoption of appropriate techniques should make it possible to either maintain the current ground water table, or even cause it to drop, by limiting inflow to the ground.

If drainage measures and surface protection are relied on to keep the risk of a landslide to a tolerable level, it is important that they are inspected routinely and maintained (GeoGuide LR11).

The following techniques may be considered to limit the destabilising effects of rising groundwater due to development and are illustrated in Figure 2.

# AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

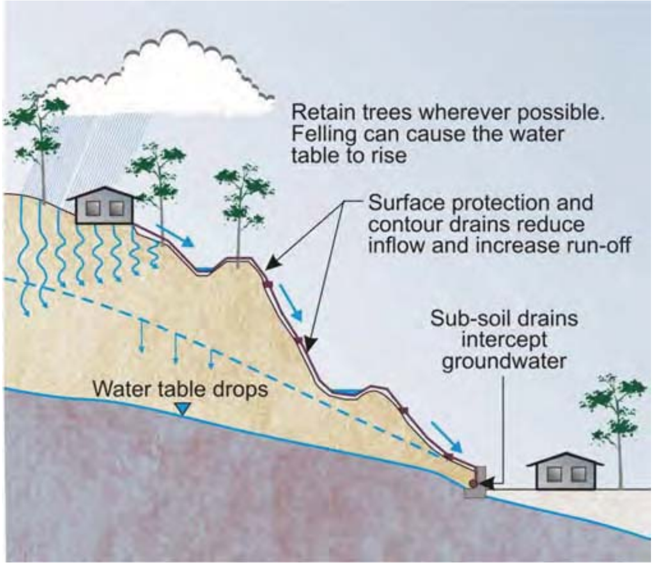


**Figure 2 - Techniques used to control groundwater flow**

**Surface water drains** (dish drains, or table drains) - are often used to prevent scour and limit inflow to a slope. Other than in rock, they are relatively ineffective unless they have an impermeable lining. You should clear them regularly, and as required, and not less than once a year. If you live in an area with seasonal rainfall, it is best to do this near the end of the dry season. If you notice that soil or rock debris is falling from the slope above, determine the source and take appropriate action. This may mean you have to seek advice from a geotechnical practitioner.

**Surface protection** - is sometimes used in addition to surface water drainage to prevent scour and minimise water inflow to a slope. You should inspect concrete, shotcrete or stone pitching for cracking and other signs of deterioration at least once a year. Make sure that weepholes are free of obstructions and able to drain. If the protection is deteriorating, you should seek advice from a geotechnical practitioner.

**Sub-soil drains** - are often constructed behind retaining walls and on hillsides to intercept groundwater. Their function is to remove water from the ground through an appropriate outlet. It is important that subsoil drains are designed to complement other measures being used. They should be laid in a sand, or gravel, bed and protected with a graded stone or geotextile filter to reduce the chance of clogging. Sub-soil drains should always be laid to a fall of at least 1 vertical on 100 horizontal. Ideally the high end should be brought to the surface, so it can be flushed with water from time to time as part of routine maintenance procedures.

**Deep, underground drains** - are usually only used in extreme circumstances, where the landslide risk is assessed as not being tolerable and other stabilisation measures are considered to be impractical. They work by permanently lowering the water table in a slope. They are not often used in domestic scale developments, but if you have any on your site be aware that professional maintenance is essential. If they are not maintained and stop working, the water table will rise and a landslide may even occur during normal weather conditions. Both an increase or a reduction in the normal flow from deep drains could indicate a problem if it appears to be unrelated to recent rainfall. If changes of this sort are observed, you should have the drains and your site checked by a geotechnical practitioner.

**Documentation** - design drawings and specifications for geotechnical measures intended to minimise landslide risk can be of great assistance to a geotechnical specialist, or structural engineer, called in to inspect and report on them. Copies of available documentation should be retained and passed to the new owner when the property is sold (GeoGuide LR11). You should also request details of an appropriate maintenance program for drainage works from the designer and keep that information with other relevant documentation and maintenance records.

**More information relevant to your particular situation may be found in other Australian GeoGuides:**

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- GeoGuide LR4 - Landslides in Rock
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## RETAINING WALLS

Retaining walls are used to support cuts and fills. Some are built in the open and backfill is placed behind them (gravity walls). Others are inserted into the ground (cast *in situ* or driven piles) and the ground is subsequently excavated on one side. Retaining walls, like all man-made structures, have a finite life. Properly engineered walls should last 50 years, or more, without needing significant repairs. However, not all walls fit this category. Some, particularly those built by inexperienced tradesmen without engineering input, can deflect and even fail because they are unable to withstand the pressures that develop in the ground around them or because the materials from which they are built deteriorate with time. **Design of retaining walls more than 900mm high should be undertaken by a geotechnical practitioner or structural engineer and normally require local council approval.**

Retaining walls have to withstand the weight of the ground on the high side, any water pressure forces that develop, any additional load (surcharge) on the ground surface and sometimes swelling pressures from expansive clays. These forces are resisted by the wall itself and the ground on the low side. Engineers calculate the forces that the retained ground, the water, and the surcharge impose on a wall (the disturbing force) as well as the maximum force that the wall and ground on the low side can provide to resist them (the restoring force). The ratio of the restoring force to the disturbing force is called the "factor of safety" (GeoGuide LR1). Permanent retaining walls designed in accordance with accepted engineering standards will normally have a factor of safety in the range 1.5 to 2.

**Never** add surcharge to the high side of a wall (e.g. place fill, erect a structure, stockpile bulk materials, or park vehicles) unless you know the wall has been designed with that purpose in mind.

**Never** more than lightly water plants on the high side of a retaining wall.

**Never** excavate at the toe of a retaining wall.

Any of these actions will reduce the factor of safety of the wall and could lead to failure. If in doubt about any aspect of an existing retaining wall, or changes you would like to make near one, seek advice from a geotechnical practitioner, or a structural engineer. This GeoGuide sets out basic inspection requirements for retaining walls and identifies some common signs that might indicate all is not well. GeoGuide LR 11 provides information about records that should be kept.

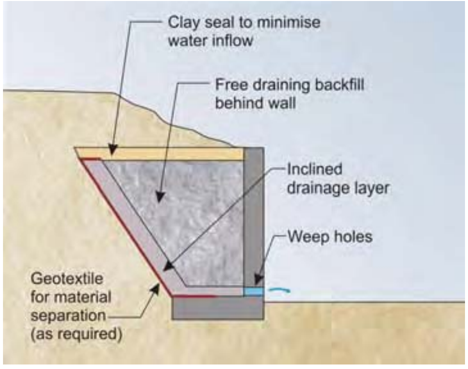


**Figure 1- Typical formed concrete wall**

### GRAVITY WALLS

Gravity walls are so called because they rely on their own weight (the force of gravity) to hold the ground behind in place.

**Formed concrete and reinforced blockwork walls** (Figure 1) **-** should be built so the backfill can drain. They should be inspected at least once a year. Look for signs of tilting, bulging, cracking, or a drop in ground level on the high side, as any of these may indicate that the wall has started to fail. Look for rust staining, which may indicate that the steel reinforcement is deteriorating and the wall is losing structural strength ("concrete cancer"). Ensure that weep holes are clear and that water is able to drain at all times, as high water pressures behind the wall can lead to sudden and catastrophic failure.

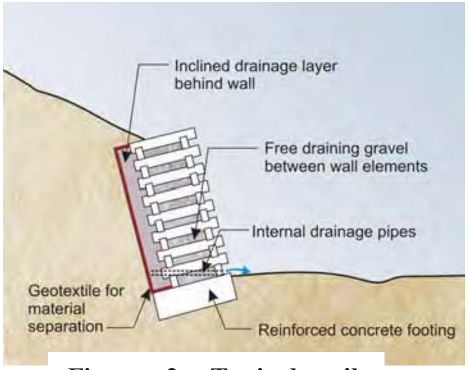


**Figure 2 -Typical crib**

**Concrete "crib" walls** (Figure 2) **-** should be filled with clean gravel, or "blue metal" with a nominated grading. Sometimes soil is used to reduce cost, but this is undesirable, from an engineering perspective, unless internal drainage is incorporated in the wall's construction. Without backfill drainage, a soil filled crib wall is likely to have a lower factor of safety than is required. Crib walls should be inspected as for formed concrete walls. In addition, you should check that material is not being lost through the structure of the wall, which has large gaps through it.

**Timber "crib" walls -** should be checked as for concrete crib walls. In addition, check the condition of the timber. Once individual elements show signs of rotting, it is necessary to have the wall replaced. If you are uncertain seek advice from a geotechnical practitioner, or a structural engineer.

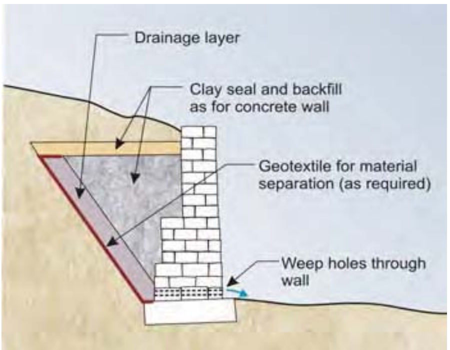


**Figure 3 -Typical masonry wall**

**Masonry walls: natural stone, brick, or interlocking blocks** (Figure 3) - more than about 1m high, should be wider at the bottom than at the top and include specific measures to permit drainage of the backfill. They should be checked as for formed concrete walls. Natural stone walls should be inspected for signs of deterioration of the individual blocks: strength loss, corners becoming rounded, cracks appearing, or debris from the blocks collecting at the foot of the wall.

**Old Masonry walls** (Figure 4) - Many old masonry retaining walls have not been built in accordance with modern design standards and often have a low "factor of safety" (GeoGuide LR1). They may therefore be close to failure and a minor change in their condition, or loading, could initiate collapse. You need to take particular care with such structures and seek professional advice sooner rather than later. Although masonry walls sometimes deflect significantly over long periods of time collapse, when it occurs, is usually sudden and can be catastrophic. Familiarity with a particular situation can instil a false sense of confidence.

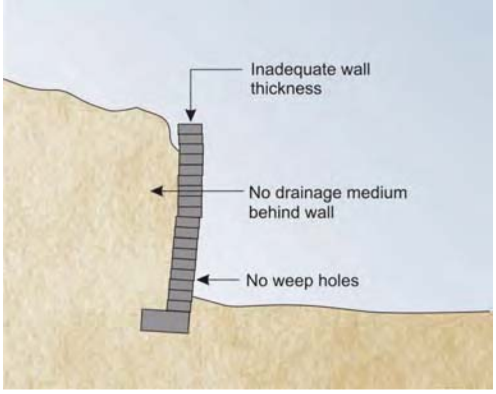


**Figure 4 - Poorly built masonry wall**

**Reinforced soil walls** (Figure 5) **-** are made of compacted select fill in which layers of reinforcement are buried to form a "reinforced soil zone". The reinforcement is all important, because it holds the soil "wall" together. Reinforcement may be steel strip, or mesh, or a variety of geosynthetic ("plastic") products. The facing panels are there to protect the soil "wall" from erosion and give it a finished appearance.

Most reinforced soil walls are proprietary products. Construction should be carried out strictly in accordance with the manufacturer's instructions. Inspection and maintenance should be the same as for formed concrete and concrete block walls. If unusual materials such as timber, or used tyres, are used as a facing it should be checked to see that it is not rotting, or perishing.

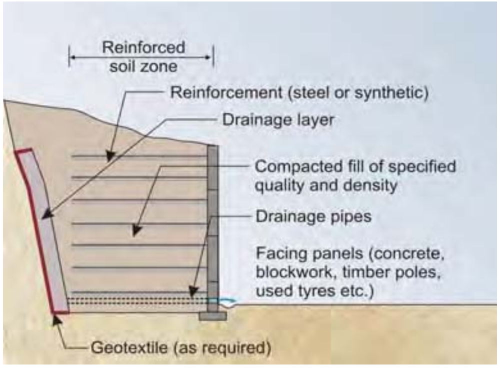


**Figure 5 - Typical reinforced soil wall**

## OTHER WALLS

**Cantilevered and anchored walls** (Figure 6) **-** rely on earth pressure on the low side, rather than self-weight, to provided the restoring force and an adequate factor of safety. These walls may comprise:

- a line of touching bored piers (contiguous bored pile wall) or
- sprayed concrete panels between bored piers (shotcrete wall) or
- horizontal timber or concrete planks spanning between upright timber or steel soldier piles or
- steel sheet piles.

Depending on the form of construction and ground conditions, walls in excess of 3 m height normally require at least one row of permanent ground anchors.

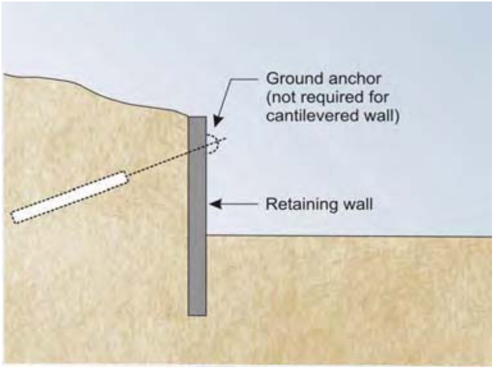


**Figure 6 - Typical cantilevered or anchored wall**

## INSPECTION

All walls should be inspected at least once a year, looking for tilting and other signs of deterioration. Concrete walls should be inspected for cracking and rust stains as for formed concrete gravity walls. Contiguous bored pile walls can have gaps between the piles - look for loss of soil from behind which can become a major difficulty if it is not corrected. Timber walls should be inspected for rot, as for timber crib walls. Steel sheet piles should be inspected for signs of rusting. In addition, you should make sure that ground anchors are maintained as described in GeoGuide LR4 under the heading "Rock bolts and rock anchors".

One of the most important issues for walls is that their internal drainage systems are operational. Frequently verify that internal drainage pipes and surface interception drains around the wall are not blocked nor have become inoperative.

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## LANDSLIDE RISK

### Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

### Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

**Landslide risk assessment must be undertaken by a geotechnical practitioner**. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

### Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

**TABLE 2: LIKELIHOOD**

| Likelihood | Annual Probability |
|---|---|
| Almost Certain | 1:10 |
| Likely | 1:100 |
| Possible | 1:1,000 |
| Unlikely | 1:10,000 |
| Rare | 1:100,000 |
| Barely credible | 1:1,000,000 |

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

**TABLE 1: RISK TO PROPERTY**

| Qualitative Risk | | Significance - Geotechnical engineering requirements |
|---|---|---|
| Very high | VH | **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 the value of the property. |
| High | H | **Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property. |
| Moderate | M | **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 possible. |
| Low | L | **Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required. |
| Very Low | VL | **Acceptable**. Manage by normal slope maintenance procedures. |

## Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

**TABLE 3: RISK TO LIFE**

| **Risk** (deaths per participant per year) | **Activity/Event Leading to Death** (NSW data unless noted) |
|---|---|
| 1:1,000 | Deep sea fishing (UK) |
| 1:1,000 to 1:10,000 | Motor cycling, horse riding, ultra-light flying (Canada) |
| 1:23,000 | Motor vehicle use |
| 1:30,000 | Fall |
| 1:70,000 | Drowning |
| 1:180,000 | Fire/burn |
| 1:660,000 | Choking on food |
| 1:1,000,000 | Scheduled airlines (Canada) |
| 1:2,300,000 | Train travel |
| 1:32,000,000 | Lightning strike |

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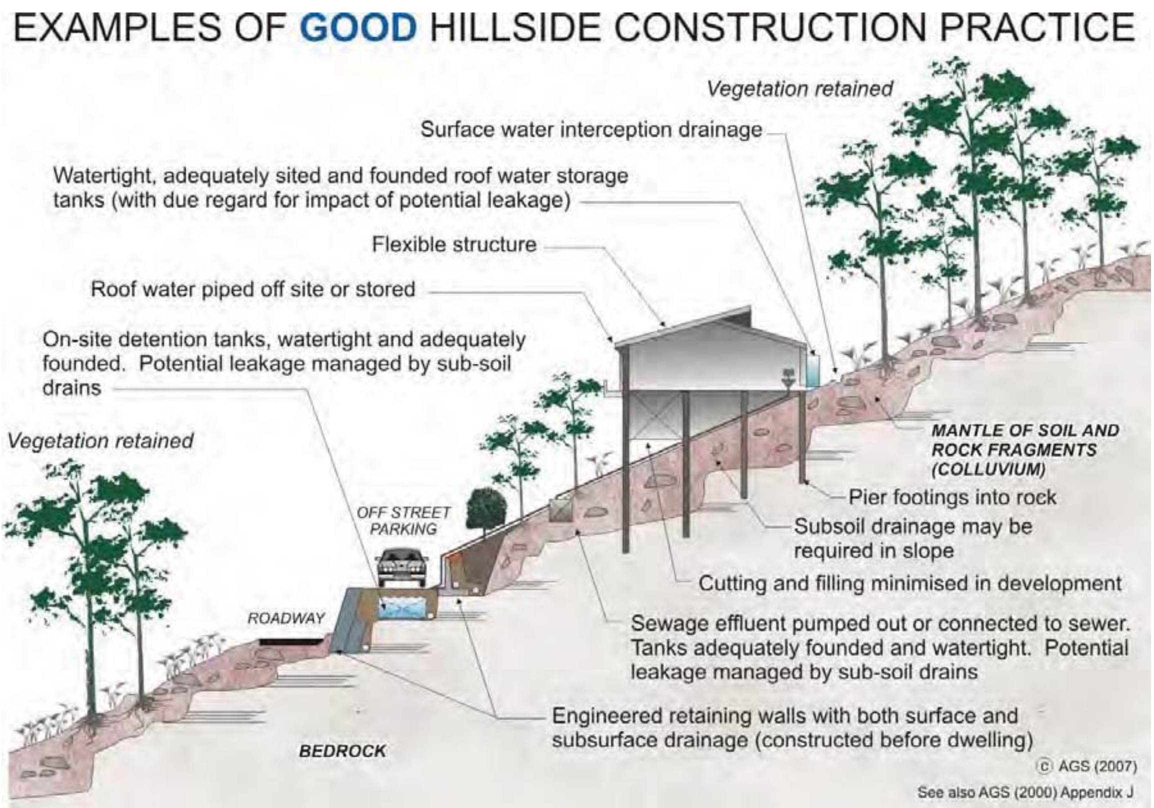
# AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

## HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.




### WHY ARE THESE PRACTICES GOOD?

**Roadways and parking areas -** are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

**Cuttings -** are supported by retaining walls (GeoGuide LR6).

**Retaining walls -** are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

**Sewage -** whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

**Surface water -** from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

**Surface loads** - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

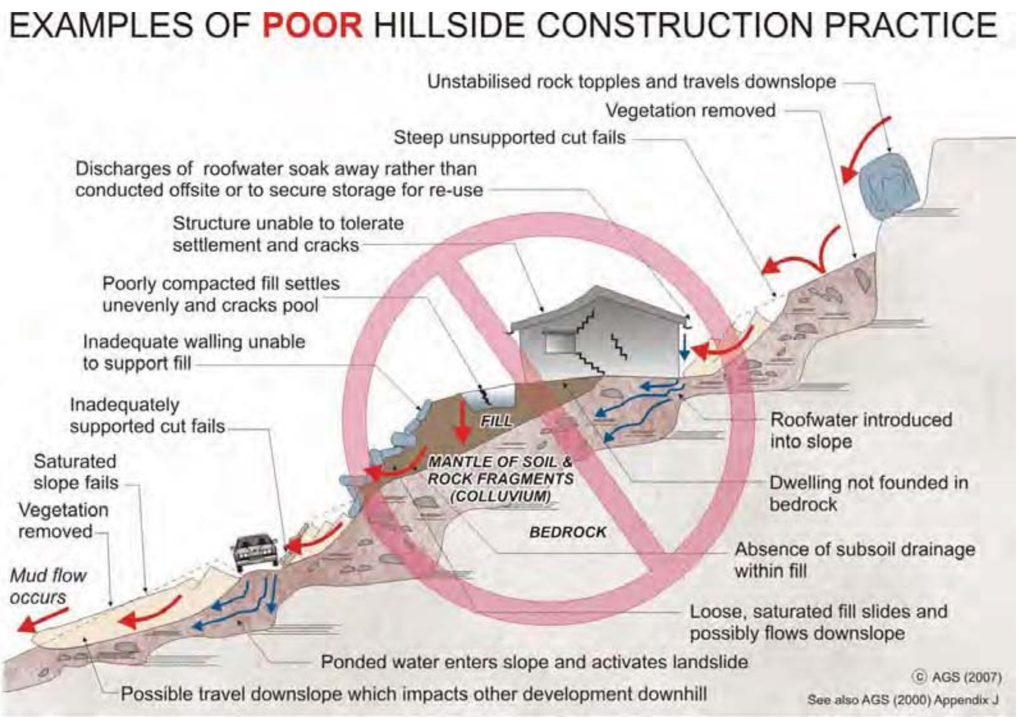
**Flexible structures -** have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

**Vegetation clearance -** on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

**ADOPT GOOD PRACTICE ON HILLSIDE SITES**

# AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)




## WHY ARE THESE PRACTICES POOR?

**Roadways and parking areas -** are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

**Cut and fill -** has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

**Retaining walls -** have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

**A heavy, rigid, house** - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

**Soak-away drainage -** has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

**Rock debris** - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

**Vegetation** - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

**DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER**

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# EFFLUENT AND SURFACE WATER DISPOSAL

## EFFLUENT AND WASTEWATER

All households generate effluent and wastewater. The disposal of these products and their impact on the environment are key considerations in the planning of safe and sustainable communities. Cities and townships generally have reticulated water, sewer and stormwater systems, which are designed to deliver water and dispose of effluent and wastewater with minimal impact on the environment. However, many smaller communities and metropolitan fringe suburbs throughout Australia are un-sewered. Some of these are located in hillside or coastal settings where landslides present a hazard.

### Processes by which wastewater can affect slope stability

As explained in GeoGuides LR3 and LR5, groundwater variations have a significant impact on slope stability. Inappropriate disposal of effluent and wastewater may result in the ground becoming saturated. The result is equivalent to a localised rise of the groundwater table and may have the potential to cause a landslide (GeoGuides LR2, LR5 and LR8).

### On-site effluent disposal

In un-sewered areas disposal of effluent must be achieved through suitable methods. These methods usually involve containment within the boundaries of the site ("on-site disposal"). State environment protection agencies and local government authorities can usually provide advice on suitable disposal systems for your area. Such systems may include:

- *Septic systems,* which involve a storage/digestion tank for solids, with disposal of the liquid effluent via absorption trenches and beds, leach drains, or soak wells. Such systems are best suited to areas not prone to landslides.
- *Aerobic treatment units* which incorporate an individual household treatment plant to aid breakdown of the waste into a higher quality effluent. Such effluent is further treated and disposed of by surface or sub-surface irrigation, sub-soil dripper, or shallow leach drain system.
- *Nutrient retentive leaching systems* which utilise septic tanks to process the solid and liquid wastes in conjunction with discharge of the effluent through sand filters, media filters, mound systems and nutrient retentive leaching systems, which strip the effluent of nutrients.

Toilet (and sometimes kitchen) waste is known as *black water.* Other, less contaminated, wastewater streams from showers, baths and laundries are known as *grey water*. *Grey water re-use systems* allow a household to conserve water from bathrooms, kitchens and laundries, for re-use on gardens and lawns.

### Recommendations for effluent disposal

In areas prone to landslide hazard, it is recommended that whatever effluent disposal system is employed, it should be designed by a qualified professional, familiar with how such a system can impact on the local environment. Local council, and in some instances state environment protection agency, approval is usually required as well. Many local authorities require a site assessment report, which covers all relevant issues. If approved, the report's recommendations must be incorporated in the system design. Reduction in the volume of effluent is beneficial so composting toilets and highly rated (i.e. low consumption) water appliances are recommended. It should be noted that in some state and local government jurisdictions there are restrictions on the alternative measures that can be applied. Consideration should be given to applying treated wastewater to land at low rates and over as large an area as possible. Further guidance can be found in Australian Standard AS/NZS 1547:2000 On-site domestic wastewater management.

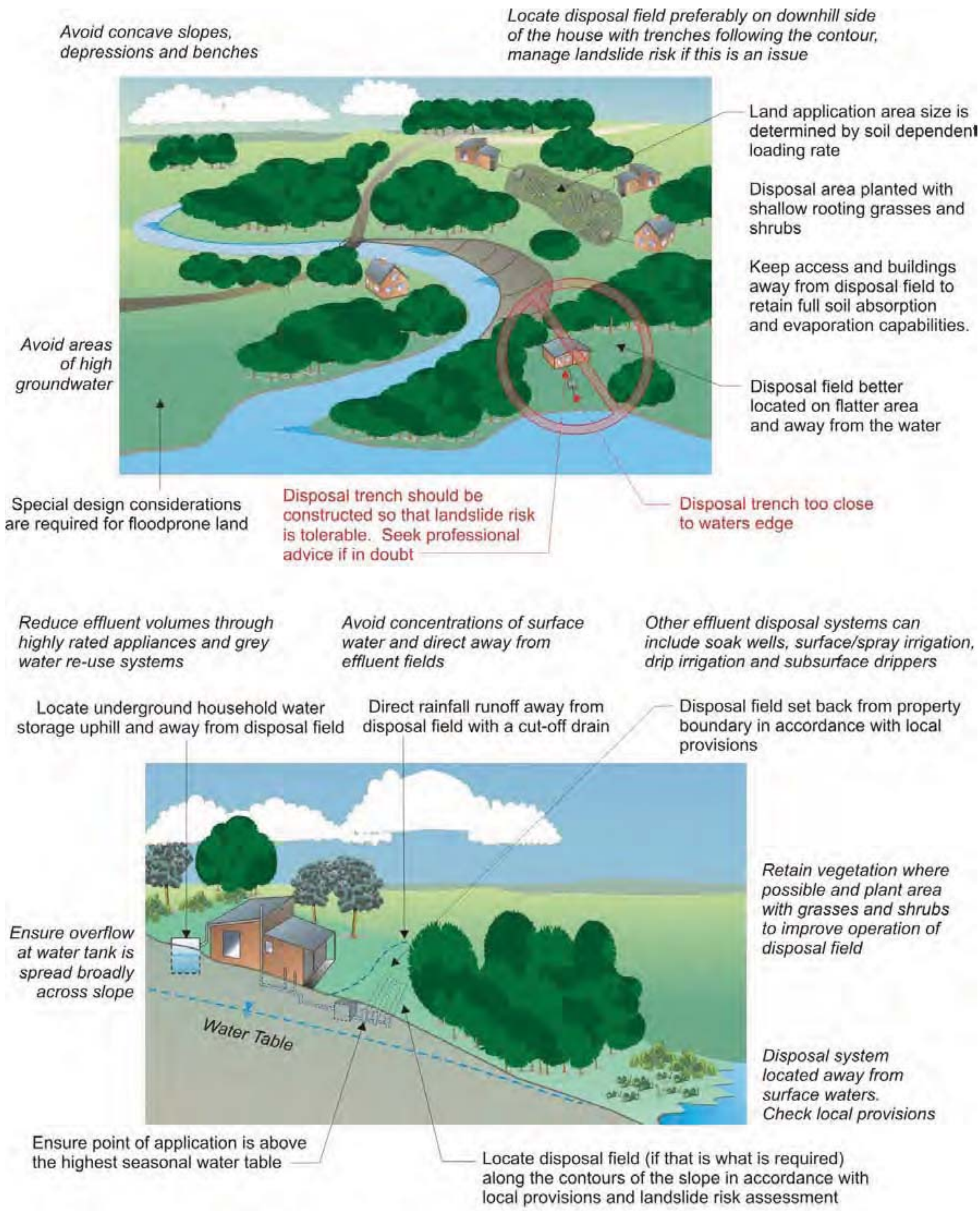
Effluent disposal fields should be sited with due consideration to the overall landscape and the individual characteristics of the property. Some guidance is provided. In particular, effluent fields should be located downslope of the building, away from stormwater, or *grey water*, discharge areas and where there is minimal potential for downstream pollution. Set backs and buffer distances vary from state to state and local requirements should be adhered to. All systems require regular maintenance and inspection. Efficient operation of the system must be a priority for property owners/occupiers to ensure safe and sustainable communities. Responsibility for maintenance rests with owners.

## SURFACE WATER DRAINAGE

Attention to on-site surface water management is also important. Runoff from developments, including buildings, decks, access tracks and hardstand areas should be collected and discharged away from the development and other effluent disposal fields. Particular care must be given to the design of overflows on water tanks, as this is often overlooked. Discharge from any development should be spread out as much as possible, unless it can be directed to an existing natural water course. Ponding of water on hillsides and the concentration of water flows on slopes must be avoided.

It is recommended that a specific drainage plan and strategy should be developed in conjunction with the effluent disposal system for sites with a high potential for slope instability. Maintenance of the surface water drainage system is as important as maintenance of the effluent disposal system and again the responsibility rests with owners.

# AUSTRALIAN GEOGUIDE LR9 (EFFLUENT DISPOSAL)




*Note: Adapted from EPA Vic. Publication 451 (March 1996) "Code of Practice - Septic Tanks", which was sourced from Vic. Department of Planning and Loddon-Campaspe Regional Planning Authority.*

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## LANDSLIDES IN THE COASTAL ENVIRONMENT

### Coastal Instability

The coast presents a particularly dynamic environment where change is often the norm. Hazards exist in relation to both cliffs and sand dunes. The coast is also the most heavily populated part of Australia and always regarded as "prime" real estate, because of the views and access to waterways and beaches.

Photo courtesy Greg Kotze

Waves, wind and salt spray play a significant part, causing dunes to move and cliff-faces to erode well above sea level. Our response is often to try to neutralise these effects by doing such things as dumping rock in the sea, building groynes, dredging, or carrying out dune stabilisation. Such works can be very effective, but ongoing maintenance is usually needed and total reconstruction may be necessary after a relatively short working life.

Of particular significance are extreme events that cause destruction on a scale that ignores our efforts at coastal protection. Records show that cliffs have collapsed, taking with them backyards which had been relied upon as a buffer between a house and the ocean. Sand dunes have also been washed away resulting in the dramatic loss of homes and infrastructure. As with most landslide issues, even though such events may be infrequent, they could happen tomorrow. It is easy to be lulled into a false sense of security on a calm day.

In coastal areas, typical landslide hazards (GeoGuides LR1 to LR4) are compounded by coastal erosion which, over time, undercuts cliffs and eventually results in failure. In the case of sand dunes, dune erosion and dune slumping have equally dramatic effects. Coastal locations are subject to particular processes relating to fluctuating water tables, inundation under storm tides and direct wave attack. Large sections of our more sandy coastline are receding under present sea conditions. The hazards are progressive and likely to be exacerbated through climate change.

### Coastal Development

If you own, or are responsible for, a coastal property it is important that you understand that, where the shore line is receding, there is a greater landslide risk than would be the case on a similar site inland. The view may make the risk worthwhile, but does not reduce it.

### Coastal Landslides

Coastal landslides are little different from other landslides in that the signs of failure (GeoGuides LR2) and the causes (LR3, LR4 & LR5) are largely the same. The main difference relates to the overriding influence of wave impact, tidal movement, salt spray and high winds.

*Cliff failures*

In addition to the processes that produce cliff instability on inland cliffs, coastal cliffs are also subjected to repeated cycles of wetting and drying which can be accompanied by the expansive effect of salt crystal growth in gaps in the rocks. These processes accelerate the deterioration of coastal cliffs. At the base of cliffs, direct wave attack and the impact of boulders moved by wave action causes undercutting and hence instability of the overall face. Figure 2 of GeoGuide LR4 provides an example. Whilst the processes leading to coastal cliff collapse may take years, failure tends to be catastrophic and with little warning. In many cases, waves produced by large oceanic storms are the trigger assisted by rainfall to produce collapse. These are also the conditions in which you are more likely to be inside your home and oblivious to unusual noises or movements associated with imminent failure.

*Sand dune escarpment and slope failures*

An understanding of coastal processes is essential when determining beach erosion potential. Waves produced by large oceanic storms can erode beaches and cut escarpments in to dunes. These may be of relatively short duration, when beach re-building happens after the storm, but can be a permanent feature where long term beach recession is taking place. In many locations, houses and infrastructure are sited on or immediately behind coastal dunes. After an escarpment has eroded, those assets may be lost or damaged by subsequent slumping of the dune. It is important that, on erodible coastal soils, the potential for landward incursion of an erosion escarpment is determined. Having done this, the likelihood of slope instability can be established as part of the landslide risk management process. Injury, death and structural damage have occurred around the Australian coast from collapsing sand escarpments.

Photo courtesy DNR NSW

# AUSTRALIAN GEOGUIDE LR10 (COASTAL LANDSLIDES)

The large scale and potentially high speed of coastal erosion processes means that major civil engineering work and large cost is normally involved in their control. The installation of rock bolts (LR4), drainage (LR5), or retaining walls (LR6) on a single house site may be necessary to provide local stability, but are unlikely to withstand the attack of a large storm on a beach or cliff-line.

## BUILDING NEAR CLIFFS AND HEADLANDS

Coastal cliffs and headlands exist because the rock that they are made from is able to resist erosion. Even so, cliff-faces are not immune and will continue to collapse (Figure 1) by one or other of the mechanisms shown on GeoGuide LR4. If you live on a coastal cliff, you should undertake inspection and maintenance as recommended in LR4 and the other GeoGuides, as appropriate. The top of the cliff, its face, and its base should be inspected frequently for signs of recent rock falls, opening of cracks, and heavy seepage which might indicate imminent failure. Since the sea can remove fallen rocks rapidly, inspections should be made shortly after every major storm as a matter of course. **If collapses are occurring seek advice from an appropriately experienced geotechnical practitioner. Advise you local council if you believe erosion is rapid or accelerating.**

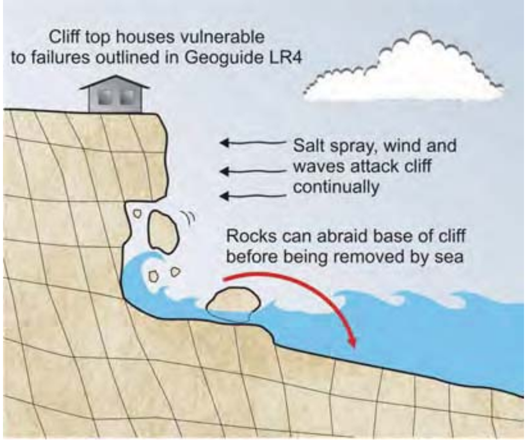


**Figure 1**

### Building on Coastal Dunes

Any excavation in a natural dune slope is inherently unstable and must be supported and maintained (GeoGuide LR6). Dunes are particularly susceptible to ongoing erosion by wind and wave action and extreme changes can occur in a single storm. Whilst vegetation can help to stabilise dunes in the right circumstances, unfortunately a single storm has the potential to cut well into dunes and, in some cases, remove an entire low lying dune system or shift the mouth of a river. **As for cliffs, it is appropriate to observe the effects of major storms on the coastline. If erosion is causing the coastline to recede at an appreciable rate, seek advice from suitably experienced geotechnical and coastal engineering practitioners and bring it to the attention of the local council.**

Photo courtesy DNR NSW

## CLIMATE CHANGE

The coastal zone will experience the most direct physical impacts of climate change. A number of reviews of global data indicate a general trend of sea level rise over the last century of 0.1 - 0.2 metres. Current rates of global average sea level rise, measured from satellite altimeter data over the last decade, exceed 3 mm /year and are accelerating. The most authoritative and recent (at the time of writing) report on climate change (IPCC, 2007) predicts a global average sea level rise of between 0.2 and 0.8 metres by 2100, compared with the 1980 - 1991 levels (the higher value includes the maximum allowance of 0.2 m to account for uncertainty associated with ice sheet dynamics).

In addition to sea level rise, climate change is also likely to result in changes in wave heights and direction, coastal wind strengths and rainfall intensity, all of which have the capacity to impact adversely on coastal dunes and cliff-faces. A Guideline for responding to the effects of climate change in coastal areas was published by Engineers Australia in 2004.

### References


Engineers Australia 2004 'Guidelines for responding to the effects of climate change in coastal and ocean engineering." The National Committee on Coastal and Ocean Engineering, Engineers Australia, updated 2004.

IPCC (2007) *Climate Change 2007: The Physical Science Basis.* Summary for Policy Makers. Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Nielsen, A.F., Lord D.B. and Poulos, H.G. (1992). 'Dune Stability Considerations for Building Foundations', *Aust. Civil Eng. Transactions* CE No.2, 167-174.


More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR11 - Record Keeping


The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

# AUSTRALIAN GEOGUIDE LR11 (RECORD KEEPING)

## RECORD KEEPING

It is strongly recommended that records be kept of all construction, inspection and maintenance activities in relation to developments on sloping blocks. In some local authority jurisdictions, maintenance requirements form part of the building consent conditions, in which case they are mandatory.

### CONSTRUCTION RECORDS

If at all possible, you should keep copies of drawings, specifications and construction (i.e. "as built") records, particularly if these differ from the design drawings. The importance of these documents cannot be over-emphasised. If a geotechnical practitioner comes to a site to carry out a landslide risk assessment and is only able to see the face of a retaining wall, the heads of some ground anchors, or the outlets of a number of sub-soil drains, it may be necessary to determine how these have been built and how they are meant to work before completing the assessment. This could involve drilling through the wall to determine how thick it is, or probing the length of the drains, or even ignoring the anchors altogether, because it is uncertain how long the y are. Such "investigation" of something that may only have been built a few years before is, at best, a waste of time and money and, at worst, capable of coming up with a misleading answer which could affect the outcome of the assessment. Documentary information of this sort often proves to be invaluable later on, so treat it with as much importance as the title deeds to your property.

### INSPECTION AND MAINTENANCE RECORDS

If you follow the recommendations of the Australian GeoGuides it is likely that you will either carry out periodic inspections yourself, or you will engage a geotechnical practitioner to do them for you. The collected records of these inspections will provide a detailed history of changes that might be occurring and will indicate, better than your own memory, whether things are deteriorating and, if so, at what rate. Unfortunately, without some form of written record, all information is usually lost each time a property is sold. It is recommended that a prospective purchaser should have a pre-purchase landslide risk assessment carried out on a hillside site, in much the same way that they would commission a structural assessment, or a pest inspection, of the building. If the vendor has kept good records, then the assessment is likely to be quicker and cheaper, and the outcome more reliable, than if none are available. Each site is different, but noting the following would normally constitute a reasonable record of an inspection/maintenance undertaken:

- date of inspection/maintenance and the name and professional status of the person carrying it out
- description of the specific feature (eg. cliff face, temporary rock bolt, cast *in situ* retaining wall, shallow leach drain system)
- sketch plans, sketches and photographs to indicate location and condition
- activity undertaken (eg. visual inspection; cleared vegetation from drain; removed fallen rock about 500 mm diameter)
- condition of the feature and any matters of concern (e.g. weep holes damp and flowing freely; rust on anchor heads getting worse; shotcrete uncracked and no sign of rust stains; ground saturated around leach field)
- specific outcomes (eg. no action necessary; geotechnical practitioner called in to advise on the state of the anchors; cliff face to be trimmed following the most recent rock fall; leach field to be rebuilt at new location)

A proforma record is provided overleaf for convenience. Photographs and sketches of specific observations can prove to be very useful and should be included whenever possible. Geotechnical practitioners may devise their own site specific inspection/maintenance records.

**More information relevant to your particular situation may be found in other Australian GeoGuides:**

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

**AUSTRALIAN GEOGUIDE LR11 (RECORD KEEPING)**

## INSPECTION/MAINTENANCE RECORD

(Tick boxes as appropriate and add information as required) Date............................................

**Site location** (street address / lot & DP numbers / map reference / latitude and longitude)

..............................................................................................................................................................

# FEATURE

| Feature | Inspected | Maintained | Tested | By Owner | By Professional |
|---|---|---|---|---|---|
| **Slopes & surface protection:** | | | | | |
| ☐ Natural slope/cliff ☐ Cut/fill slope | | | | | |
| ☐ Surface water drains | | | | | |
| ☐ Shotcrete ☐ Stone pitching ☐ Other | | | | | |
| **Retaining walls:** | | | | | |
| ☐ Cast in situ concrete ☐ Concrete block | | | | | |
| ☐ Masonry (natural stone) ☐ Masonry (brick, block) | | | | | |
| ☐ Cribwall (concrete) ☐ Cribwall (timber) | | | | | |
| ☐ Anchored wall ☐ Reinforced soil wall | | | | | |
| ☐ Sub-soil drains ☐ Weep holes | | | | | |
| **Ground improvement:** | | | | | |
| ☐ Rock bolts | | | | | |
| ☐ Ground anchors ☐ Soil nails | | | | | |
| ☐ Deep subsoil drains | | | | | |
| **Effluent and storm water disposal systems:** | | | | | |
| ☐ Effluent treatment system | | | | | |
| ☐ Effluent disposal field | | | | | |
| ☐ Storm water disposal field | | | | | |
| **Other:** | | | | | |
| ☐ Netting ☐ Catch fence ☐ Catch pit | | | | | |
| ☐ ---------------------------------------- | | | | | |
| ☐ ---------------------------------------- | | | | | |
| ☐ ---------------------------------------- | | | | | |

Observations/Notes (Add pages/details as appropriate)

..............................................................................................................................................................

..............................................................................................................................................................

..............................................................................................................................................................

Attachments: ☐ Sketch(es) ☐ Photograph(s) ☐ Other (eg measurements, test results)

Record prepared by ................................................ (name): ........................................(signature)

Contact details: Phone:....................................... E-mail:...........................................................

Professional Status (in relation to landslide risk assessment):......................................................

# APPENDIX

## AUSTRALIAN GEOMECHANICS SOCIETY

**STEERING COMMITTEE**

Andrew Leventhal, GHD Geotechnics, Sydney, Chair
Robin Fell, School of Civil and Environmental Engineering, UNSW, Sydney, Convenor Guidelines on Landslide Susceptibility, Hazard and Risk Working Group
Tony Phillips, Consultant, Sydney, Convenor Slope Management and Maintenance Working Group
Bruce Walker, Jeffery and Katauskas, Sydney, Convenor Practice Note Working Group
Geoff Withycombe, Sydney Coastal Councils Group, Sydney

**WORKING GROUP -** Guidelines on Slope Management and Maintenance
Tony Phillips, Tony Phillips Consulting, Sydney, Convenor
Henk Buys, NSW Roads and traffic Authority, Parramatta
John Braybrooke, Douglas Partners, Sydney
Tony Miner, A.G. Miner Geotechnical, Geelong

**LANDSLIDE TASKFORCE**
Laurie de Ambrosis, GHD Geotechnics, Sydney
Mark Eggers, Pells Sullivan Meynink, Sydney
Max Ervin, Golder Associates, Melbourne
Angus Gordon, retired, Sydney
Greg Kotze, GHD, Sydney
Arthur Love, Coffey Geotechnics, Newcastle
Alex Litwinowicz, GHD Geotechnics, Brisbane
Tony Miner, A.G. Miner Geotechnical, Geelong
Fiona MacGregor, Douglas Partners, Sydney
Garry Mostyn, Pells Sullivan Meynink, Sydney
Grant Murray, Sinclair Knight Merz, Auckland
Garth Powell, Coffey Geotechnics, Brisbane
Ralph Rallings, Pitt and Sherry, Hobart
Ian Stewart, NSW Roads and Traffic Authority, Sydney
Peter Tobin, Wollongong City Council, Wollongong
Graham Whitt, Shire of Yarra Ranges, Lillydale

# APPENDIX F
## Summary of Planning and Development Controls

## DEVELOPMENT CONTROLS – Hazard Level 1 Sites

### ADVICE AND PLANNING

| | |
|---|---|
| OBTAIN ADVICE | Engage a suitably qualified geotechnical practitioner to undertake a site specific geotechnical site assessment and landslide risk assessment in accordance with the Australian Geomechanics Guidelines (AGS 2007). |

### DESIGN AND CONSTRUCTION

| | |
|---|---|
| New Developments | New development will only be permitted in Hazard Level 1 Areas where:<br>• The results of a landslide risk assessment indicate that the risk to life and property from slope instability is tolerable.<br>• Engineering measures are recommended by a suitably qualified geotechnical practitioner which reduce the risk to life and property from slope instability to tolerable levels, and these engineering measures are employed.<br>• Development is in accordance with the development controls for Hazard Level 2 sites. |
| Existing Developments | Where possible, keep additional development outside of areas designated as Hazard Level 1.<br>Obtain a landslide risk assessment from a suitably qualified geotechnical engineer. The assessment should identify slope stability hazards on your property and where appropriate recommend means by which the risk presented by the hazard can be brought to within tolerable levels.<br>It may not always be practical to remediate all slope stability hazards identified on a site. Landowners should be aware of the risks associated with slope instability on their site and discuss with their geotechnical practitioner how to best manage these risks. |

## DEVELOPMENT CONTROLS – Hazard Level 2 Sites

### ADVICE AND PLANNING

| | |
|---|---|
| OBTAIN ADVICE | Engage a suitably qualified geotechnical engineer at an early stage of planning for the development. Obtain a Geotechnical Site Assessment from the Geotechnical Engineer. |

### DESIGN AND CONSTRUCTION

| | |
|---|---|
| HOUSE DESIGN | Use floor plans that minimise the amount of cutting and filling of the site. Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider using split-levels in the house and using decking for recreational areas. |
| SITE CLEARING | Do not indiscriminately clear the site. Retain natural vegetation wherever possible. |
| DRIVEWAYS | Do not excavate and fill for site access without prior permission from the Council. Satisfy all guidelines for cuts, retaining walls and drainage. Driveways and parking areas may need to be supported on piers. |
| EARTHWORKS | Retain natural land contours wherever possible. Do not make large cuts or fills. Do not block any existing watercourse or spring by earthworks. |
| Cuts in Soil | Unsupported cut depths must not exceed 1.0 m and maximum batters should not exceed 1V:2H (V = Vertical; H = Horizontal). Steeper and/or higher fills should be supported with an engineered retaining wall. Provide drainage measures and prevent erosion. |
| Fills | Unsupported fill thickness must not exceed 1.0 m and batters must not exceed 1V:2H (V = Vertical; H = Horizontal). Steeper and/or higher cuts should be supported with an engineer designed retaining wall. Remove vegetation and topsoil before placing fill. Use clean fill materials and compact to appropriate standards. Key the fill into the natural slope. Provide surface and subsurface drainage as appropriate. If seepage from any fill is observed, seek advice. |
| Rocks and Boulders | Remove or stabilise rocks or boulders that are potentially unstable. Support rock faces where necessary. |
| RETAINING WALLS | Obtain an engineer's design. Found in rock or competent natural soil. Provide subsurface drainage behind the base of the wall. Provide surface drainage. Construct wall as soon as possible after excavation. |
| DRAINAGE | |
| Surface | Collect surface run-off and discharge to street drainage or natural watercourses. Provide drains uphill of structures and cuts and fills. Line drains to minimise infiltration and erosion. Provide generous falls to prevent blockage by saltation and incorporate silt traps. Provide energy dissipation structures where fast flow is possible. |
| Subsurface | Provide sand or screenings and filter around subsurface drain. Use flexible pipelines with access to allow blockages to be cleared. Prevent direct inflow of surface water to subsurface drains. (eg. using a capping layer over trench). |
| FOUNDATIONS | Support on rock where practical or on stable ground as identified by qualified geotechnical engineer. Do not found on topsoil, loose fill or unstable ground. Use rows of piers or strip footings oriented up and down slope. Backfill foundation excavations to prevent the entry of surface water. |
| SWIMMING POOLS | Obtain an engineer's design. Support on rock or stable ground. Provide with under |

| | |
|---|---|
| | drainage and gravity drain outlet. Design for appropriate soil pressures. |
| SEPTIC and SULLAGE | Connect to mains sewer where available. Where not available, discuss options with Council's Environment Health Officer. |
| LANDSCAPING | Observe earthworks and drainage recommendations when landscaping. Revegetate cleared areas. |

**DURING AND AFTER CONSTRUCTION**

| | |
|---|---|
| CONSTRUCTION | Review of plans with a qualified geotechnical engineer if uncertain of compliance guidelines. Have the Geotechnical consultant visit the site as appropriate during construction. |
| OWNER'S RESPONSIBILITY | Promptly clean blocked drainage systems, repair broken joins in drains and leaks in supply lines. If seepage is observed, establish the cause and seek advice on consequences and remedial works. Seek advice about any damage observed in structures on your property. |

Table is based on extract from Journal and News of the Australian Geomechanics Society Volume 42 No. 1 March, 2007 – Appendix G of Practice Note Guidelines for Landslide Risk Management 2007.

# APPENDIX G

## Example of Landslide Checklist

Table C12: Example Checklist for LRM Reports

| Items | Check | Response: Yes, No, NA, NK | Comments/ Description (If used by the Regulator, then all except No answers require comment) |
|---|---|---|---|
| Site | Report Reference and date | | |
| | Client's name | | |
| | Site address | | |
| | Date of site visit.<br>Site visit by (name) | | |
| | Weather conditions on date of visit | | |
| | | | |
| Development | Will the proposed development have a degree of use or occupation by humans? | | |
| | Does the development involve significant modification to the landscape, including cut and fill? | | |
| | What is the landslide susceptibility classification for this slope/site? (Assuming the regulator has completed such zoning studies in accordance with AGS 2007a) | | |
| | What is the landslide hazard or risk classification for this? (as above) | | |
| | | | |
| Geology | What is the regional geology according to published maps? | | |
| | Is the site located on surface fill or colluvium? | | |
| | Has the geology been confirmed by inspection or investigation? If not – why not. If Yes – provide basis for confirmation. | | |
| | | | |
| Geomorphology | Are there any indications of possible instability on the site or adjacent to it? | | |
| | Does the site have distinct breaks in slope or benches? | | |
| | Are there terracettes or other signs of creep on the site? | | |
| | Are there signs of tunnel erosion, such as sinkholes or collapse of soils on the site? | | |
| | Are there any tension cracks in the ground surface of the site? | | |
| | | | |
| Adjacent Sites | Do adjacent sites show signs of slope instability as described above? | | |
| | Do adjacent sites have non-retained cuts or fills close to boundaries? | | |
| | Are there steep slopes, different geology or landforms on adjacent sites that may pose a threat to this site? | | |
| | Will the proposed development threaten the stability of adjacent developments via cuts, fill or drainage? | | |
| | | | |
| Slope | What is the overall (natural) slope of the site? | | |
| | Are there changes (breaks) in the slope?<br>Are these man made or natural? | | |
| | What is the maximum slope of the site? | | |
| | Is the slope in an area of development different to elsewhere (large sites)? | | |
| | | | |
| Drainage | Does the site have deeply dissected drainage courses? | | |
| | Is the site likely to receive significant surface water runoff from other sites upslope? | | |
| | Does the site have dams, lakes, ponds, swamps, bogs, seeps or soaks? | | |
| | Does the site receive drainage from road culverts or spoon drains? | | |
| | Will any aspect of the development significantly modify the existing site drainage? | | |

# COMMENTARY ON PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

| Items | Check | Response: Yes, No, NA, NK | Comments/ Description (If used by the Regulator, then all except No answers require comment) |
|---|---|---|---|
| Erosion | Are there any severe forms of erosion including tunnels or gullies on the site? | | |
| | Do any existing cuts and fills show signs of erosion including loss of vegetative cover? | | |
| | Do access tracks show erosion, scouring or signs of uncontrolled runoff? | | |
| | Will the development have the potential to change the current conditions? | | |
| | | | |
| Site Cuts and Fills | Are there existing cuts and/or fill areas on the site? | | *(If Yes, attach site sketch showing location, extent, height and batter angles)* |
| | Are there any existing unsupported cuts or fills that exceed 1.0m in vertical height from toe to crest? | | |
| | Are batter angles steeper than 1V:2H (or 26 degrees or 50%) for any existing cut or fill in soil materials? | | |
| | Are batter angles steeper than 1V:1H (or 45 degrees or 100%) for any existing cut in rock? | | |
| | Do existing cuts and fills have adequate surface or subsurface drainage? Provide details. | | |
| | Were vegetation and topsoil removed prior to filling? If No, provide details. | | |
| | Have suitable fill materials been used and have they been properly compacted (with evidence thereof)? | | |
| | Do any existing cuts and fills show seepage? If Yes, show details on site plan. | | |
| | | | |
| Retaining Walls | Are there any existing retaining walls on the site? | | *(If Yes, attach site sketch showing location, extent, height, type, condition and slope of batter above)* |
| | Are timber or dry rock retaining walls used for any purpose other than minor landscaping of vertical height less than 1.0m? | | |
| | Do existing retaining walls supporting major cuts and fills appear to be unengineered? | | |
| | Do existing retaining walls show signs of distress or movement? If Yes, provide details. | | |
| | Do existing retaining walls have adequate drainage above and below the wall? If No, provide details. | | |
| | | | |
| Groundwater | Are there discharge areas such as springs, seeps, bogs, swamps or constantly wet areas on the site or adjacent to the site? | | *(If Yes, provide site sketch showing location and extent)* |
| | Are there bores intersecting a shallow watertable on the site? | | |
| | Any other evidence of high groundwater levels? | | |
| | | | |
| Rock | Is rock exposed on the site? | | |
| | Do any exposed cuts have rock strata that are dipping out of the slope? | | |
| | Do any exposed rock faces show open joints or loose boulders? If yes, provide site sketch plan and details. | | |
| | | | |
| Soil Profile | Do exposed faces or existing excavations show soil profiles exceeding 1.5m vertical height? | | |
| | Do exposed faces or existing excavations show a mixture of soil and rock, which may be landslide debris or colluvium? | | |
| | Does the soil profile show inconsistent colouring or interbedded layers of differing materials? | | |

| Items | Check | Response: Yes, No, NA, NK | Comments/ Description (If used by the Regulator, then all except No answers require comment) |
|---|---|---|---|
| | Does the exposed profile show imported materials or fill? | | |
| | Is there significant evidence of yabby holes or other burrowings? | | |
| Vegetation | Has the natural vegetation been substantially cleared from the site? | | |
| | Does the proposed development involve significant clearing of the site? | | |
| | Are any of the plants species on site indicators of waterlogging (eg. spiny rush, swamp gums)? | | |
| | Is revegetation work required? | | |
| | Do existing trees and shrubs show signs of slope instability, such as tilting or bent trunks? | | |
| | Does any existing vegetation show signs of isolated dieback or distress? | | |
| | Will the removal of any vegetation cause increased erosion and degradation to the adjacent area? | | |
| | | | |
| Effluent and Stormwater Disposal | What type of effluent disposal system is currently used? If on site disposal, show discharge area on site plan. | | |
| | Provide details of current discharge point for stormwater. Show location on site plan. | | |
| | Does the geology or stability of the site suggest that septic system absorption trenches are unsuitable? | | |
| | Are there any signs of increased waterlogging or impact from effluent of adjacent sites? | | |
| | Is a new point/area for stormwater discharge proposed? If so, give details and show location (and extent if dispersed on site) on site plan. | | |
| | Is a new on site effluent disposal system proposed? If Yes, give details and show proposed disposal area on site plan. | | |
| | | | |
| Slope Classification | Have landslide hazards been identified and shown on relevant plan or section? | | |
| | Has the risk to property been assessed and is the result in accordance with the acceptance criterion? | | |
| | Has the risk to life been assessed and is the result in accordance with the acceptance criterion? | | |
| | What is recommended to maintain or reduce the landslide risk at this site? Are detailed requirements given? | | |
| | | | |
| **OTHER COMMENTS** | | | |
| | | | |

**Assessed by:** ………………………………………………………… **Date:** ………………………………………………..
**Company:** ………………………………………………………………………………………………………………………………………

Note (1) Assessment must be completed by a suitably qualified geotechnical practitioner.

Note (2) Every clear box must be filled in with either Yes (Y), No (N), Not Applicable (NA) or Not Known (NK). Comments could cross reference to specific sections or page of the report.

Note (3) This checklist is intended to document the basic date to facilitate a landslide risk assessment in accordance with the requirements of a regulator's specific policy. The above table may require edits to be suited to local conditions and the requirements of the policy.

Note (4) A comment or full description is required for all Yes responses. Applicant should submit detailed responses in the attached report.

Acknowledgement: This table has been based on the checklist from Yarra Ranges Shire with their kind permission.

# APPENDIX H

## Appendix C to Practice Note Guidelines for Landslide Risk Management

## 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 |
| $10^{-2}$ | $5x10^{-3}$ | 100 years | 200 years | The event will probably occur under adverse conditions over the design life. | LIKELY | B |
| $10^{-3}$ | $5x10^{-4}$ | 1000 years | 2000 years | The event could occur under adverse conditions over the design life. | POSSIBLE | C |
| $10^{-4}$ | $5x10^{-5}$ | 10,000 years | 20,000 years | The event might occur under very adverse circumstances over the design life. | UNLIKELY | D |
| $10^{-5}$ | $5x10^{-6}$ | 100,000 years | 200,000 years | The event is conceivable but only under exceptional circumstances over the design life. | RARE | E |
| $10^{-6}$ | | 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% | 40% | 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% | 10% | 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% | 1% | Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works. | MINOR | 4 |
| 0.5% | | 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

## APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

### *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.

# APPENDIX I

## Limitations

## LIMITATIONS

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