



Douglas Partners

Geotechnics | Environment | Groundwater

Report on
Geotechnical Assessment

55 Coonara Avenue
West Pennant Hills

Prepared for
Mirvac Projects Pty Ltd

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Integrated Practical Solutions





Douglas Partners

Geotechnics | Environment | Groundwater

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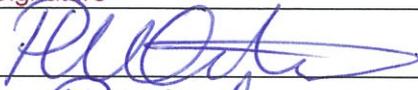
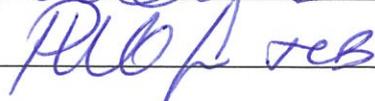
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	Signature	Date
Author		20 November 2017
Reviewer		20 November 2017



Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
96 Hermitage Road
West Ryde NSW 2114
PO Box 472
West Ryde NSW 1685
Phone (02) 9809 0666
Fax (02) 9809 4095

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Report on Geotechnical Assessment

55 Coonara Avenue

West Pennant Hills

1. Introduction

This report presents the results of a geotechnical assessment undertaken at 55 Coonara Avenue, West Pennant Hills. The work was commissioned by Mirvac Projects Pty Ltd, developers of the site.

Redevelopment of the IBM site is proposed which will involve the construction of residential housing and apartments. Planning is currently underway but it is understood that the buildings will vary between 2 storeys and 6 storeys with some basement levels also likely. The development zone is approximately limited to the area in which existing buildings and carpark areas exist; the undeveloped eastern and southern portions of the site will remain as green space.

The purpose of the geotechnical assessment was to investigate whether any instability issues are likely to be present on the site and, if present, to provide commentary on proposed stabilisation measures. Comments on groundwater were also requested.

The assessment comprised a review of our experience in the area and available information (i.e. aerial imagery, landslide risk maps), and a walkover assessment by a Principal Geotechnical Engineer and a Principal Engineering Geologist from Douglas Partners. Comments on the matters outlined above are provided in the following sections.

2. Site Description

The development site is trapezoidal in shape with an approximate area of 26 ha. It is bounded by Coonara Avenue to the north-west, Cumberland State Forest to the east and south, and residential housing to the south-west. The natural topography of the site slopes down to the south with levels varying between about RL 175 m AHD in the northern corner to about RL 105 m AHD near the southern boundary.

The site is currently occupied by a large commercial office complex in the central portion with five adjoining buildings to the east and south of the main structure. A multi-storey concrete and steel framed carpark is located midway along the eastern boundary, and the areas surrounding the buildings contain numerous on-grade parking areas. An open grassed area is present in the south-eastern corner of the site and the remaining area is densely vegetated. Two small dams are located in a natural drainage gully that runs in a southerly direction near the eastern boundary.

The site is shown on Drawing 1 in Appendix B. The site is legally known as Lot 61 in Deposited Plan 737386.

3. Regional Geology and Hydrogeology

The Sydney 1:100 000 Geological Series Sheet indicates that the northern portion of the site is underlain by Ashfield Shale which comprises black to dark-grey shale and laminite. The southern portion of the site is underlain by Hawkesbury Sandstone which comprises medium to coarse-grained quartz sandstone with minor shale and laminite lenses. The intermediate Mittagong Formation is often found between these geological units and comprises interbedded shale, laminite and medium-grained sandstone.

An extract from the geological map is shown in Figure 1.

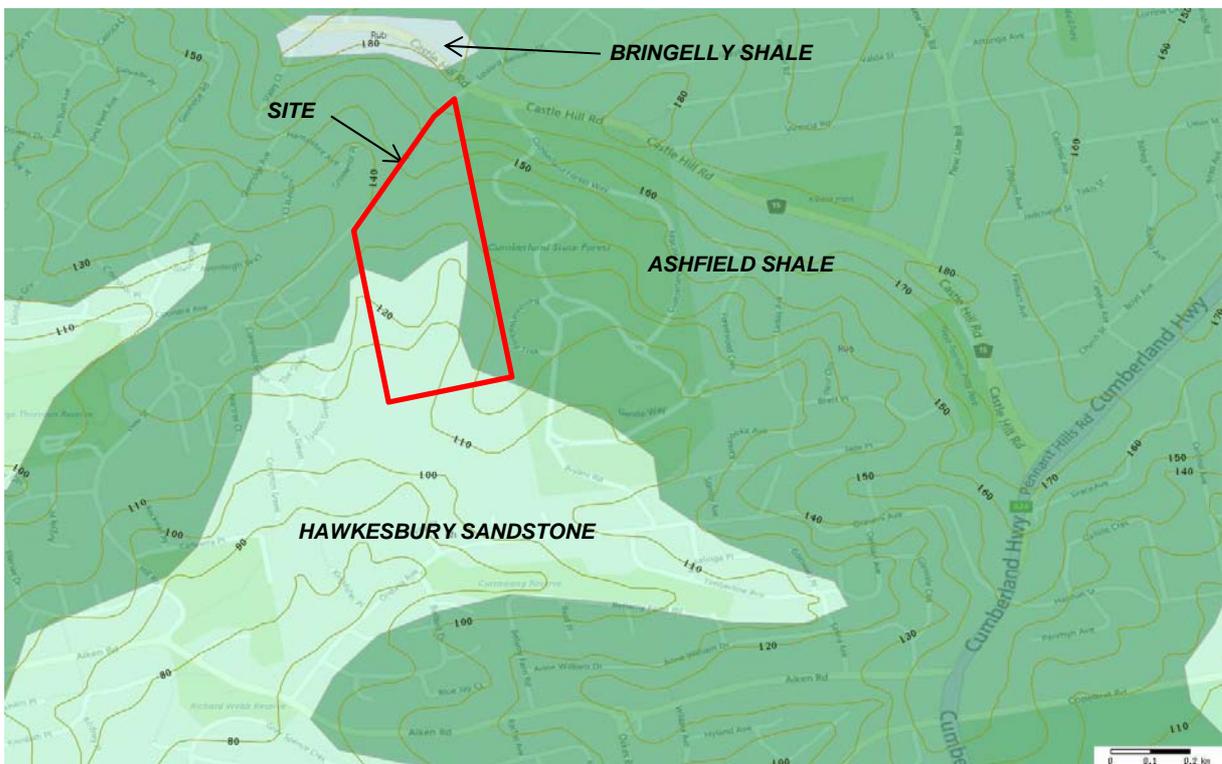


Figure 1: Extract from geological map with surface contours shown at 10 m intervals to AHD

The northern portion of the site is near the top of a ridgeline and therefore the regional groundwater table is expected to be well below the bedrock surface. Seepage would be expected through the shale and sandstone on the site, and may well present as springs along the geological boundary between the shale and sandstone. However, this seepage is likely to be periodic and a result of rainfall within and above the site.

Surface water typically drains towards a gully that runs north-to-south close to the eastern boundary. Two earth-embankment dams are present within this gully and may have historically been constructed in areas where springs were located, although this could not be confirmed during the inspection.

4. Historical Aerial Photographs

Aerial photographs from 1961, 1970, 1982 and 1994 were used to assess historical land-use patterns on the site. Scanned images from the aerial photographs are attached in Appendix C.

The 1961 photograph shows the northern portion of the site only. It suggests that the site had been cleared of vegetation and redeveloped into orchards. The northern tip of the site appears to be steeper than the remaining area and possibly hummocky. Two dams that appear to be in the same location as the current dams can be seen along the eastern boundary and the drainage gully is evident to the west of the lower dam.

The 1970 photograph shows the extent of the orchards in the southern portion of the site. The drainage gully and the southern and south-western portions of the site remain densely vegetated with what is probably virgin forest.

The 1982 photograph shows a similar extent of land development to the 1970 image except that most of the orchard trees have been removed and the site is largely covered by grassed paddocks. The northern tip of the site appears to be slightly more densely vegetated than in the 1961 image.

The 1994 photograph shows the site following development of the IBM facility. The buildings and on-grade parking areas have typically been constructed on the former orchard land and the areas around the new works have been re-vegetated. The on-grade parking area to the south of the multi-storey carpark is not shown in this image and therefore this carpark must have been constructed some time after the remainder of the facility.

5. Landslide Risk Mapping by The Hills Shire Council

The Hills Local Environmental Plan 2012 includes mapping identifying areas of 'Landslide Risk' within the local government area. This mapping was presumably undertaken following a review of topographical maps, aerial photos and possibly limited site inspections. The aim of the mapping was to identify areas that could be at risk of landslide activity so development controls could be put in place to manage this risk.

The mapping indicates that the south-facing slope below the Castle Hill Road ridgeline presents a landslide risk to the west and east of the development site. The map does not show any risks on the subject development site.

An extract from the LEP mapping is provided in Figure 2.

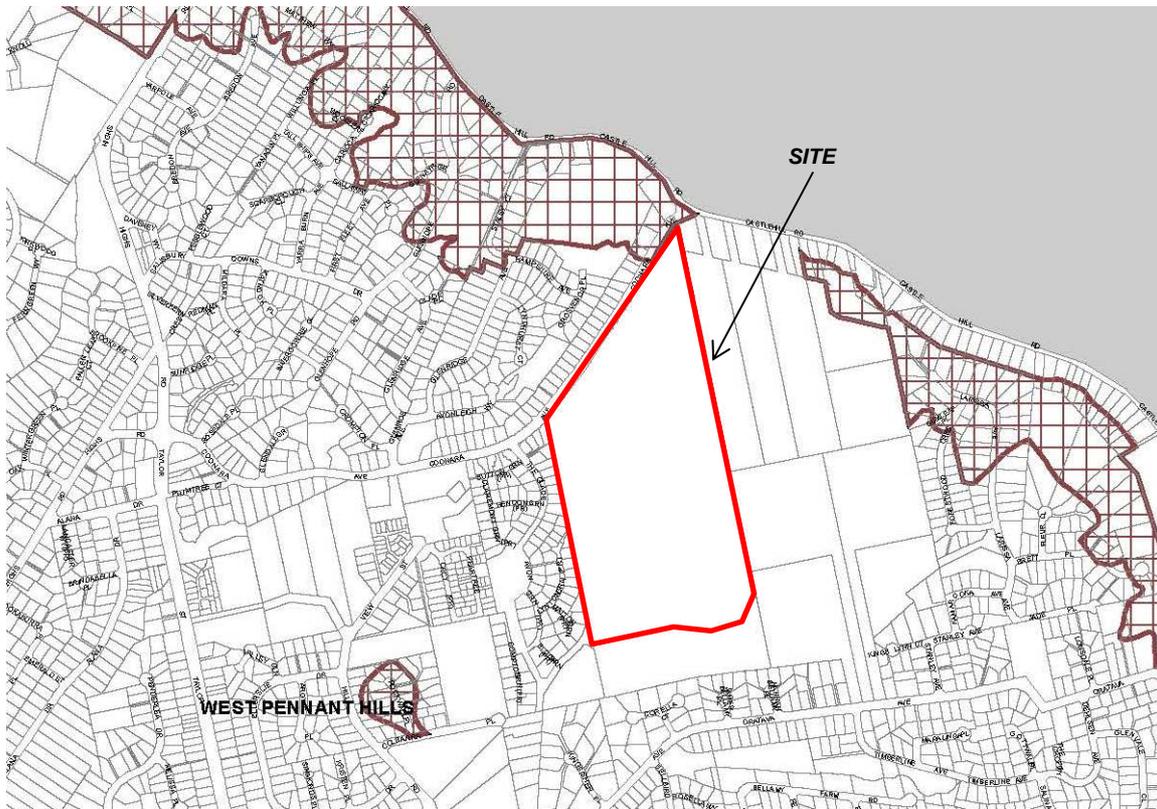


Figure 2: Extract from LEP 2012 (hatched areas show mapped landslide risk)

6. Results of Inspection

A site inspection was undertaken by a Principal Geotechnical Engineer and a Principal Engineering Geologist on 3 August 2017. The following comments are provided in relation to the inspection:

- The northern tip of the site is relatively steep, however no obvious signs of major landslide activity or risk were identified. Several large trees were present and the trunks were relatively vertical which indicates that significant down-slope movement is not occurring;
- The areas of on-grade parking are generally in good condition and damage associated with landslide movements (e.g. displaced kerb-and-gutters, tension cracks in the asphalt etc.) were not observed;
- The upper dam contained water and there were no major stability issues noted in the downstream embankment. A rock-lined spillway was located in the south-eastern corner of the dam suggesting that controlled outflow occurs in times of high flow rather than embankment overtopping;
- The drainage gully has experienced some minor localised erosion which has exposed residual soils and bedrock along its base. Some colluvial soils and/or filling were observed in the sides of the drainage gully; and
- No areas of springs/water seepage were observed during the inspection.

Notes relating to the inspection are provided on Drawing 1 in Appendix B.

7. Preliminary Slope Risk Assessment

The hazards in relation to the slope risks have been assessed for risk to property using the general methodology outlined by the Australian Geomechanics Society (Landslide Risk Management AGS Subcommittee 2007). Identified hazards within and adjacent to the site are summarised in Table 1, together with qualitative assessments of likelihood, consequence and slope instability risk to the existing and proposed structures after completion of construction. We have assumed that appropriate engineering design, inspection and construction methodologies will be undertaken as part of the redevelopment works.

Table 1: Property Slope Instability Risk Assessment for Proposed Development

Hazard	Likelihood	Consequence	Risk
Slow movement of new structures and infrastructure	Barely Credible – if footings are founded on appropriate strata	Medium	Very Low
Rapid movement of new structures and infrastructure	Unlikely – assuming design/construction is adequate	Medium	Low
Deep-seated failure of slopes due to stormwater saturation	Unlikely – if stormwater system is designed to accommodate flows	Medium	Low
Surface erosion/slumping from upslope surface water flows	Unlikely – if design accommodates surface water flows/erosion	Minor	Low

It is noted that the risk assessment summarised in Table 1 is usually undertaken at a more advanced stage in the development approval process and may require updating during/following lodgement of specific development applications.

Loss of life risk assessment is considered inappropriate at this stage of the development because more detailed information on each residence (e.g. proximity to services and infrastructure, upslope conditions etc.) would be needed for such an assessment to be considered representative. This would also best be undertaken during/following lodgement of specific development applications.

8. Conclusions and Recommendations

On the basis of the review of the aerial photographs and observations made during the site inspection, it is considered that the area in which residential development is proposed (i.e. the area bounded by the green line in Drawing 1) has a very low risk of being affected by landslide activity. The only areas on the site which exhibit some slope movement risk appear to be the northern tip of the site and the areas immediately adjacent to the drainage gully; development is not proposed in these areas.

Geotechnical investigation will be required across the site once the layout of the proposed buildings has been confirmed and the depths of basement excavations determined. However, there is nothing presently evident from a geotechnical perspective that would prevent residential development from being undertaken in the proposed redevelopment zone.

Some preliminary considerations when planning the development include:

- Ensuring earthworks are undertaken in a manner that does not induce slope movement risks in both areas of cut and areas of fill;
- Ensuring both temporary and permanent excavations are supported adequately by either stable batter slopes or retaining walls;
- The requirement for drainage around the site and within basements to prevent the build-up of hydrostatic pressures in the soils; and
- Ensuring all new structures are founded on stable foundation material that is capable of supporting the building loads.

Further advice on these issues can be provided during future stages of the project.

9. Limitations

Douglas Partners (DP) has prepared this report for this project at 55 Coonara Avenue, West Pennant Hills, in accordance with DP's proposal dated 28 July 2017 and acceptance received from the client. This report is provided for the use of Mirvac Projects Pty Ltd for this project only and for the purposes as described in the report. It should not be relied upon for other projects or by a third party.

The results provided in the report are based on a review of available documents and a non-intrusive site inspection. Specific sampling and testing has not been carried out. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

Douglas Partners Pty Ltd

Appendix A

About this Report

About this Report

Douglas Partners



Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;

- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawing



Appendix C

Historical Aerial Photographs



Aerial photograph from 1961



Aerial photograph from 1970



Historical Aerial Photographs

55 Coonara Avenue

WEST PENNANT HILLS

CLIENT: Mirvac Developments Pty Ltd

PROJECT: 86072.00

PLATE No: A1

REV: 0

DATE: 9-Aug-17



Aerial photograph from 1982



Aerial photograph from 1994



Historical Aerial Photographs

55 Coonara Avenue

WEST PENNANT HILLS

CLIENT: Mirvac Developments Pty Ltd

PROJECT: 86072.00

PLATE No: A2

REV: 0

DATE: 9-Aug-17

Appendix D

AGS Landslide Risk Documentation

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

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.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

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

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 LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

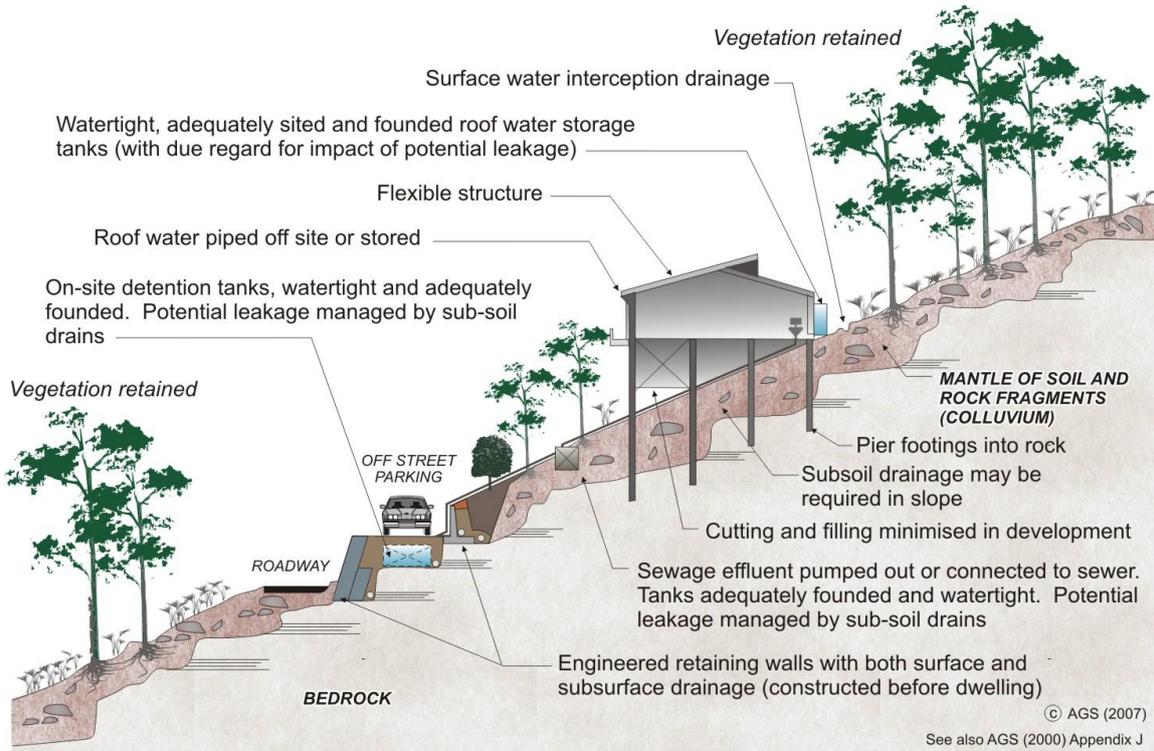
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to 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 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.

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



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.

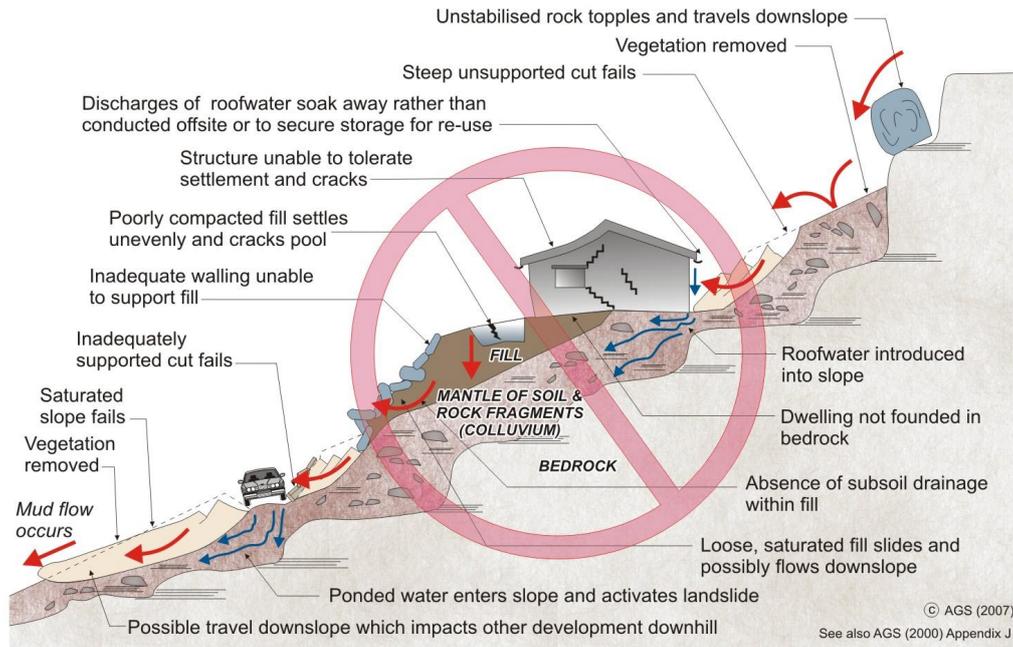
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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)

EXAMPLES OF **POOR** HILLSIDE 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

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 LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- 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.